Final version

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Final Report

Preparatory Studies for Product Group in the Ecodesign Working Plan 2012-2014:
Lot 8 - Power Cables
Task 1 -7 report

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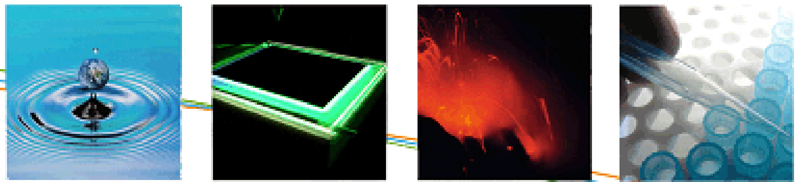

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EXECUTIVE SUMMARY

This study was done for preparing the implementation of the Ecodesign or Energy Related Products (EED) Directive (2009/125/EC) related to power cables on behalf of the European Commission DG ENTR unit B1. The information provided herein can serve to prepare for subsequent phases, including conducting an impact assessment on policy options, to prepare a paper for the Consultation Forum and finally draft regulation for the Regulatory Committee or other policy instruments. Those phases are to be carried out by the European Commission. This study also discusses other policy instruments compared to the EED.
In a multi stakeholder consultation, a number of groups and experts provided comments on a preliminary draft of this report. The report was then revised, benefiting from stakeholder perspectives and input. The views expressed in the report remain those of the authors, and do not necessarily reflect the views of the European Commission or the individuals and organisations that participated in the consultation. A list of stakeholders that participated in this consultation and further information on project meetings and comments can be found in a project report that is published complementary to this report.

The study follows the European Commission's MEErP methodology and consists of seven Tasks:
Task 1 - Scope (definitions, standards and legislation);
Task 2 – Markets (volumes and prices);
Task 3 – Users (product demand side);
Task 4 - Technologies (product supply side, includes both Best Available Technology (BAT) and Best Not Yet Available Technology (BNAT));
Task 5 – Environment & Economics (base case Life Cycle Assessment (LCA) & Life Cycle Costs (LCC));
Task 6 – Design options(improvement potential);
Task 7 – Scenarios (Policy, scenario, impact and sensitivity analysis).
Tasks 1 to 4 can be performed in parallel, whereas 5, 6 and 7 are sequential.
Task 0 or a Quick-scan is optional to Task 1 for the case of large or inhomogeneous product groups to re-group or narrow the product scope, as appropriate from an ecodesign point of view.

Together with this study MEErP EcoReports of task 5 and 6 are provided and an excel tool designed for task 7.

The findings in Task order are the following:

Task 1&0:
The scope of the study is: 'losses in installed power cables in electric circuits in buildings after the meter' taking into account the electrical installation as a system', the power cable being the product put into service by the electrical installer in a circuit of an electrical installation in a building. The electrical installation including loads are taken into account at system level, this is explained in more detail in chapter 3. Amongst others it means that the installation will be analysed at the level needed related to cable losses.
More in detail, the scope defined is losses in installed power cables in buildings that covers low voltage power cables for fixed wiring used in indoor electrical installations in non-residential buildings and initially also in residential buildings. The first screening estimated losses in the services and industry sector about 2% while losses in the residential sector seems to be much lower (<0.3%). This is because circuits in residential buildings are in general much shorter and have relative low loading. The

assessment is about business as usual in new installed circuits according to the current standards. Some stakeholders pointed out that in some member states old residential installation still might have inefficient electric circuits but promoting renovation in residential houses but this cannot be addressed by the EDD. Therefore the focus in the subsequent tasks is on the services and industry sector circuits. Losses in installed power cables in buildings are directly related to the loading.
The primary functional performance parameter of the cable is 'current-carrying capacity' and for electric circuits it is the rated current.

Relevant standards, definitions, regulations, voluntary agreements and commercial agreements on EU, MS and 3rd country level are part of this task report. Important secondary performance parameters are the 'Nominal Cross-Sectional Area (CSA)' and its corresponding 'maximum DC resistance at 20°C (R20)', which are defined in standard IEC/EN 60228. Cable Nominal Cross-Sectional Areas (CSA) are harmonized in this standard and increase stepwise (1-1.5-2-4-6-.. mm²). For the performance electrical installation codes play an important role and they can differ per member state. Important performance standards are IEC 60287-3-2 on the Economic optimization of power cable size and IEC/EN 60364-8-1 on Energy efficiency in Low voltage electrical installation.

Task 2:
Input parameters for a stock and sales model were collected. Therefore the stock or stock growth rate of power cables in buildings is linked to the stock and stock growth rate of buildings respectively. The stock, stock growth rate, replacement, and demolition rates for power cables were deduced from the corresponding building parameters. Absolute stock and sales were estimated based upon these figures and verified with PRODCOM data. The input from stakeholders regarding product lifetime is taken into account.
The results can be found in Table 1-1. These values will be used in the Tasks 5 up to and including 7.

Table 1-1 Summary of cable stock, growth and sales rates

Sector	Product life	Service life	Vacancy	Stock growth rate	Demolition rate	Replace-ment sales rate	New sales rate	Total sales rate	Stock (Reference year: 2010)	
Unit	Year	Year	%	% p.a.	% p.a.	% p.a.	% p.a.	% p.a.	kTon Cu	%
Residential sector	64.00	60.80	5%	0.90%	0.10%	1.18%	0.90%	2.08%	5241	43%
Services sector	25.00	23.75	5%	1.90%	0.20%	3.20%	1.90%	5.10%	3250	26%
Industry sector	25.00	23.75	5%	2.90%	0.20%	2.80%	2.90%	5.70%	3825	31%
Total sector (weighted)	41.60	39.52	5%	1.79%	0.16%	2.22%	1.79%	4.00%	12316	100%

Installation times, cable and connector prices are defined in this chapter along with energy and financial rates. For copper power cables this study uses an average discounted cable price of 0.09434 €/ (mm². m).
The input market stock, sales and growth data was not directly available and as explained in the respective sections the deduced and projected data has a certain degree of uncertainty, therefore a complementary sensitivity analysis and cross checks are performed in Tasks 4 to 7.

Task 3:

The use of the power cable is mainly defined by the characteristics of the circuit, the load distribution in the building and the power consumption profile of the connected loads.
The most important parameters for the circuit characteristics are the average circuit length in meters and minimum and maximum cable cross sectional areas (CSA) in mm² per circuit type.
The most important parameters related to the power consumption profile of the loads are: load factor, load form factor and power factor.
There is a big spreading in these parameters and 'the European average electric circuit' is not directly defined neither existing. This might introduce a large degree of uncertainty in later tasks and therefore ranges of data are included which allow complementary sensitivity analysis in Tasks 6 and 7.

A typical product lifetime in the service and industry sector is about 25 years. Due to the high scrap value of copper, recycling of cables is common business and the MEErP defaults value of 95 % will be used.

On user behaviour the stakeholder questionnaires[1] also revealed that:

- Electro-installers are unaware of the losses in circuits;
- In practice, calculation of losses is not performed when designing an installation. Mostly only voltage drop and safety restrictions are taken into account;
- The responsibility regarding the budget for the investment and the budget for operating expenses is in most cases split and linked to different departments. As a result no economic Life Cycle Cost (LCC) evaluation is performed and the installation with the lowest investment costs is often selected;
- Tenders do not include a requirement to perform LCC calculations in the offer.

Task 4:
At the product level of the power cable itself, there are no improvement options identified related to energy efficiency because every cable cross sectional area (CSA) on the market has a certain load and cable length to fit with.
At circuit level (system level) two improvement options are identified, the first is installing a cable with a larger CSA ('S+x') and the second is installing one or more cables in parallel with the same CSA ('2S'). This task also includes the necessary product data for subsequent life cycle impact modelling which is primarily based on its Bill-of-Material (BOM). A larger CSA will increase the BOM and therefore this environmental impact will be modelled in later Tasks with the MEErP Ecoreport tool.

Task 5:
Previous Task 4 identified improvement options at circuit level. In this Task nine so-called base cases (BC) were selected that represent typical electric circuits in line with the market structure and data described in Task 2. Base Cases according to MEErP are abstractions from reality that serve for modelling purposes. These base cases used the 'median' electric circuit parameters from Task 3, such as load factor and cable length. The nine base cases used are:

- Base case 1: distribution circuit in the services sector;
- Base case 2: lighting circuit in the services sector;
- Base case 3: socket-outlet circuit in the services sector;
- Base case 4: dedicated circuit in the services sector;
- Base case 5: distribution circuit in the industry sector;

[1] This questionnaire was sent to installers on the 30th of September, 2013 in the context of this study. A second questionnaire was sent on the 7th of July, 2014. The results were combined. See "Preparatory Studies for Product Group in the Ecodesign Working Plan 2012-2014:Lot 8 - Power Cables Project report".

- Base case 6: lighting circuit in the industry sector;
- Base case 7: socket-outlet circuit in the industry sector;
- Base case 8: dedicated circuit in the industry sector (BC1 up to and including BC8 are with copper conductors);
- Base case 9: base case 8 but with aluminium instead of copper.

The environmental impact analysis and LCC obtained with the MEErP tool showed that in most cases the use phase, because of electrical cable losses, is dominant. As a consequence, there will be room left for economic energy savings in several of those base cases that will be analysed in detail in Task 6. The data of the nine base cases was also summed using EU-28 circuit level stock data and cross-checked with total EU-28 data on electricity use from Task 2. This showed an overestimation compared to EU-28 data on energy use. This means that the 'median' parameters for the base cases from Task 3 do not reflect 'average reference' parameters that can be used in a stock model in Task 7. Therefore corrections factors on those 'median' parameters were calculated that fit with total EU energy consumption. This also indicates that potentially a lot of circuits in the stock have a relative lower loading and/or longer circuit length and/or higher share of base cases with lower loading.
The annual electricity loss in cables in the service and industry sector at EU-28 level was estimated about 42 TWh which fits with cross checks in the report.

Some cable insulation additives did not match one-to-one with the limited set of materials available in the MEErP Ecoreport tool, therefore alternative materials were chosen and a small sensitivity analysis showed that this has limited impact on the outcomes.

Task 6:
The previous Task 5 identified the use phase as the most important and hence reducing cables losses are the way forward to improve environmental impact. Reducing cable losses in installed cables can easily be done by decreasing the cable resistance and by increasing the copper cross-sectional area (CSA). The methods identified to increase the CSA were installing a cable with a larger CSA ('S+x') and/or installing more cables in parallel with the same CSA ('2S').
Three design options (D1, D2, D3) were calculated with stepwise increased CSA(S+1, S+2, S+3). Another design option (D4) calculated two cables in parallel. These are the four design improvement options that are applied to the nine defined base cases in Task 5.
This task concluded that those design options have a positive impact on almost any of the environment parameters generated with the MEErP EcoReport tool. In summary all the parameters including Global Warming Potential (GWP) improved, except impact from 'water (process)', 'heavy metals (emissions in water and air)' and 'Particulate Matter (PM)'. The defined base cases, representing the so-called lighting and socket-outlet circuits, performed relative less. In particular the parameters Polycyclic Aromatic Hydrocarbons (PAHs), PM and Eutrophication increased in several 'improvement' options. Therefore policy measures from Task 7 are defined carefully not imposing an increased CSA for any circuit disregarding their loading.
Based on input from previous tasks, LCC has also been calculated for all options and the LLCC improvement options were identified. In is important to note that for base cases, representing circuits with a low load, the Least Life Cycle Cost (LLCC) option is 'Business As Usual' (BAU), hence no economic improvement potential is identified. All other defined base cases (1, 3-9) showed economic justified improvement potential. The explanation for these differences is related to the variations in the loading behind the defined base cases.

Finally also a sensitivity analysis has been done on the circuit loading parameters, circuit length, product lifetime and product price. The sensitivity analysis showed that the best design option considering BAT and LCC varies depending on the assumptions made for the parameters.

It should be noted that depending on the local situation shifting to a particular design option may not be technical feasible, because it often requires more space for the cable installation which is not always available. In practice not all improvement options can be realized because the impact of the design options on accessories (ducting systems, trunking systems, junction boxes, etc.) and on the building space that are left out of the quantitative analysis.

Task 7:
The proposed policy options in this task take into account the findings from previous tasks.

From Task 1 it was proposed to focus on 'losses in installed power cables in buildings', the power cable being the product put into service by the electrical installer in a circuit of an electrical installation in a building. As a consequence proposed policy measures focus on the power cables itself and/or the installed power cables in electric circuits in buildings. Therefore, there is also no policy option proposed to set minimum requirements on the cable cross-sectional area (CSA), because they have their economic justified function in circuits with low loading and/or other applications such as machinery. The proposed policy measures at product level are therefore only generic on the provision of information related to cable losses. By consequence most policy measures are formulated at electric circuit or system level, which is not directly in the 'product' scope of the Ecodesign of Energy Related Products Directive (2009/125/EC). The policy options are mostly related to upgraded standardization, labelling and/or electrical installation codes. Task 7 also discusses pros, cons and timing of the proposed policy measures. The task also explains why no other specific ecodesign requirements on the type of cable insulation and/or conductor material are proposed.

This task also calculates different scenarios on energy use and cost with a sensitivity analysis on key parameters like discount rate, inflation rate, energy escalation rate, product lifetime, stock growth rate and product price. In a Business-as-Usual (BAU) scenario the energy losses in power cables in the industry and service sector in 2025 are forecasted at 56.67 TWh, which would be about 2.5 % of the transported electricity in 2025. In an ultimate scenario assuming full impact from 2017 for all proposed policy measures based on the least life cycle cost option these losses could be reduced up to -7.60 TWh in 2025. Various other scenarios are calculated taking into account different policy options, gradual timing of measures and partial impact. Afterwards a sensitivity analysis is done on the key parameters that have an impact on these scenarios. This is useful because the policy scenarios are based on new sales and replacement sales of power cables and this is related to the EU28 economic growth which might be optimistic in this study. For example, the sensitivity analysis showed that a longer product life and lower stock growth has a significant impact on all outcomes. A tool complementary to this study for calculating scenarios with their costs and benefits has been provided to the EC.

It is expected that the proposed measures will have a positive impact on the labour for installers, cable manufacturers and distributors.

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List of Acronyms

A	Ampere
α_c, α_c	Corrected or circuit load factor
AC	Alternating Current
Al	Aluminium
AREI	Algemeen Reglement op de Elektrische Installaties
ASTM	American Society for Testing and Materials
ATEX	ATmosphères EXplosibles
Avg	Average
B2B	Business–to-business
BAT	Best Available Technology
BAU	Business As Usual
BC	Base Case
BNAT	Best Not (yet) Available Technology
BOM	Bill Of Materials
BPIE	Buildings Performance Institute Europe
BS	British Standard
C	Conductor
CE	Conformité Européenne
CEN	European Committee for Normalisation
CENELEC	European Committee for Electro technical Standardization
CPD	Construction Products Directive
CPR	Construction Products Regulation
CSA	Conductor Cross-Sectional Area (symbol: S)
Cu	Copper
Cu-ETP	Copper- Electrolytic Tough Pitch
CuMg	Copper Magnesium alloy
Cu-OF	Copper – Oxygen Free
CO_2	Carbon Dioxide
DALI	Digital Addressable Lighting Interface
DC	Direct Current
DIN	Deutsches Institut für Normung
DF	Decommissioning Fee
E	Energy
EC	European Commission
EEE	Electrical and Electronic Equipment
EMC	Electro Magnetic Compatibility
EMI	Electromagnetic Interference
EMS	Energy Management System
EN	European Norm
EOL	End Of Life
EPBD	Energy Performance of Buildings Directive
EPD	Environmental Product Declaration
EPR	Ethylene Propylene Rubber
ErP	Energy related Products
EU	European Union
EuP	Energy using Products
GER	Gross Energy Requirement
GHG	GreenHouse Gas
GWP	Global Warming Potential
HD	Harmonization Document
HL	High length
HP	High Product price

HPL	High Product Lifetime
HV	High Voltage
HVAC	Heating, Ventilation, Air-conditioning
Hz	Hertz
I	Current
IACS	International Annealed Copper Standard
Iav	Average Current
ICT	Information and Communication Technology
IEC	The International Electro technical Commission
IEV	International Electrotechnical Vocabulary
INDL	INDustry Level
IT	Information Technology
k	kilo (10^3)
kg	Kilogram
Kd	Distribution factor
Kf	Load form factor
Kt	Temperature correction factor
kWh	KiloWatt hour
L	Length
LCA	Life Cycle Assessment
LCC	Life Cost Calculation
LED	Light Emitting Diode
LF	Load Factor
LL	Low length
LLCC	Least Life Cycle Costs
LP	Low Product price
LPL	Low Product Lifetime
LV	Low Voltage
LVD	Low Voltage Directive
MEErP	Methodology for Ecodesign of Energy related Products
MEEuP	Methodology for Ecodesign of Energy using Products
MS	Mega Siemens
MV	Medium Voltage
NACE	Nomenclature statistique des activités économiques dans la Communauté européenne - Statistical classification of economic activities in the European Community
NBN	Bureau voor Normalisatie - Bureau de Normalisation
NEN	NEderlandse Norm
NF	Norm France
NPV	Net Present Value
P	Power
PAHs	Polycyclic Aromatic Hydrocarbons
PE	Polyethylene
PEP	Product Environmental Profile
PF	Power factor
PJ	Peta Joule
PM	Particulate Matter
PoE	Power-over-Ethernet
PP	Polypropylene
PRODCOM	PRODuction COMmunautaire
PV	PhotoVoltaic
PVC	Polyvinylchloride
ρ	conductor resistivity
R	Resistance
R20	Resistance at 20°C
RC	Recycling rate of the conductor

RCD	Residual Current Device
REMODECE	Residential Monitoring to Decrease Energy Use and Carbon Emissions in Europe
RES	Renewable Energy Sources
RF	Residual Factor
r.m.s / RMS	Root Mean Square
RoHS	Restriction of the use of certain Hazardous Substances in electrical and electronic equipment
RV	Residual Value
S’	Apparent power
S	Nominal cross sectional area of a conductor
SERL	SERvices Level
SME	Small and Medium sized Enterprise
SV	Scrap Value
TBC	To Be Completed
TBD	To Be Defined
TC	Technical Committee
TR	Technical Report
TWh	Terra Watthour
UK	United Kingdom
USGS	US Geological Survey
V	Voltage
VA	Volt Ampere
Vac	Voltage Alternate Current
VAT	Value Added Tax
VDE	Verband der Elektrotechnik und Elektronik
VITO	Flemish institute for Technological Research
W	Watt
WEEE	Waste Electrical and Electronic Equipment
XLPE	Cross-linked Polyethene
XLPVC	Cross-linked PVC

CHAPTER 1 TASK 1 - SCOPE

Objective: This task classifies and defines the energy-related product group power cables and sets the scene for the rest of the tasks. The product classification and definition should be relevant from a technical, functional, economic and environmental point of view, so that it can be used as a basis for the whole study.
It is important to define the products as placed on the Community market. This task consists of categorization of power cables according to Prodcom categories (used in Eurostat) and to other schemes (e.g. EN standards), description of relevant definitions and of the overlaps with the Prodcom classification categories, scope definition, and identification of key parameters for the selection of relevant products to perform detailed analysis and assessment during the next steps of the study. This task will also classify power cables into appropriate product categories while providing a first screening or quick-scan of the volume of sales and stock and environmental impact for these products.
Further, harmonized test standards and additional sector-specific procedures for product-testing will be identified and discussed, covering the test protocols for:

- Primary and secondary functional performance parameters (Functional Unit);
- Resource use (energy, etc.) during product-life;
- Safety (electricity, EMC, stability of the product, etc.);
- Other product specific test procedures.

Finally, this task will identify existing legislations, voluntary agreements, and labelling initiatives at the EU level, in the Member States, and in the countries outside the EU.

Summary of Task 1:

The scope of the study is: 'losses in installed power cables in electric circuits in buildings after the meter' taking into account the electrical installation as a system', the power cable being the product put into service by the electrical installer in a circuit of an electrical installation in a building. The electrical installation including loads are taken into account at system level, this is explained in more detail in chapter 3. Amongst others it means that the installation will be analysed at the level needed related to cable losses.
More in detail, the scope defined is losses in installed power cables in buildings that covers low voltage power cables for fixed wiring used in indoor electrical installations in non-residential buildings and initially also in residential buildings. The first screening estimated losses in the services and industry sector about 2% while losses in the residential sector seems to be much lower (<0.3%). This is because circuits in residential buildings are in general much shorter and have relative low loading. The assessment is about business as usual in new installed circuits according to the current standards. Some stakeholders pointed out that in some member states old residential installation still might have inefficient electric circuits but this cannot be addressed by the Ecodesign Directive(EED). Therefore the focus in the subsequent tasks is on the services and industry sector circuits. Losses in installed power cables in buildings are directly related to the loading.

The primary functional performance parameter of the cable is 'current-carrying capacity' and for electric circuits it is the rated current.

Losses in installed power cables in buildings are directly related to the loading. Therefore **nine functional categories** of cable circuits were defined, i.e. 'lighting', 'socket-outlet' and 'dedicated' circuits in the 'residential', the 'services' and the 'industry' **sector.**

A first screening estimated losses in the services and industry sector about 2% while losses in the residential sector seems to be much lower (<0.3%). This is because circuits in residential buildings are in general much shorter and have relative low loading. Therefore it is proposed to focus in the subsequent tasks on the services and industry sector circuits.

Relevant standards, definitions, regulations, voluntary agreements and commercial agreements on EU, MS and 3rd country level are part of this task report. Important secondary performance parameters are the 'Nominal Cross-Sectional Area (CSA)' and its corresponding 'maximum DC resistance at 20°C (R20)', which are defined in standard IEC/EN 60228. Cable Nominal Cross-Sectional Areas(CSA) are harmonized in this standard and increase stepwize(1-1.5-2-4-6-.. mm²). For the performance electrical installation codes play an important role and they can differ per member state. Important performance standards are IEC 60287-3-2 on the Economic optimization of power cable size and IEC/HD 60364-8-1 on Energy efficiency in Low voltage electrical installation.

1.1 Product Scope

1.1.1 Key methodological issues related to the product scope definition

In this task the classification and definition of the products should be based notably on the following categorizations:

- Prodcom category or categories (Eurostat);
- Categories according to EN- or ISO-standard(s);
- Other product-specific categories (e.g. labelling, sector-specific categories), if not defined by the above.

Prodcom should be the first basis for defining the products, since Prodcom allows for precise and reliable calculation of trade and sales volumes (Task 2).
If the proposed product classification and definition relevant from a technical, economic and environmental point of view does not match directly with one or several Prodcom categories, the study should detail how the proposed product categories are mapped to the Prodcom categories or the other categories mentioned above.

In particular customer-made products, business-to-business (B2B) products or systems incorporating several products may not match with Prodcom categories. In these cases, the standalone or packaged products placed on the European internal market, to which a CE mark is/could be affixed, should be defined. This may result in several Prodcom or otherwise categorised products relevant for power cables.

The above existing categorizations are a starting point for classifying and defining the products and can be completed or refined by other relevant criteria, according notably to the functionality of the product, its environmental characteristics and the structure of the market where the product is placed. In particular, the classification and definition of the products should be linked to the assessment of the primary product performance parameter (the "functional unit").

If needed, a further segmentation can be applied on the basis of secondary product performance parameters. This segmentation is based on functional performance characteristics, and not on technology.

Where relevant, a description of the energy systems affected by the energy-related products will be included, as this may influence the definition of the proposed product scope.

The resulting product classification and definition should be confirmed by a first screening of the volume of sales and trade, environmental impact and potential for improvement of the products as referred to in Article 15 of the Ecodesign Directive.
Also information on standards, regulations, voluntary agreements and commercial agreements on EU, MS and 3rd country level should be considered when defining the product(s) (section 1.3.1).

1.1.1.1 Important definitions and terminology in electrical installations

Important definitions and terminology in electrical installations (IEC 60050, IEC Electropedia Area 461) are:

- Low Voltage (IEV 601-01-26 / Fr: basse tension / De: Niederspannung): a set of voltage levels used for the distribution of electricity and whose upper limit is generally accepted to be 1 000 V a.c;

- Electrical installation (IEV 826-10-01 / Fr: installation électrique / De: elektrische Anlage): assembly of associated electric equipment having co-ordinated characteristics to fulfil specific purposes;

- (Electric) circuit (of an electrical installation) (IEV 826-14-01 / Fr: circuit (électrique) (d'installation électrique) / De: Stromkreis (einer elektrischen Anlage)): assembly of electric equipment of the electrical installation protected against overcurrents by the same protective device(s);

- Cable (IEV 151-12-38 / Fr: cable / De: Kabel): assembly of one or more conductors (and/or optical fibres), with a protective covering and possibly filling, insulating and protective material;

- Cord (IEV 461-06-15 / Fr: cordon / De: schnur): flexible cable with a limited number of conductors of small cross-sectional area;

- Core (or insulated conductor) (IEV 461-04-04 / Fr: conducteur (isolé) / De: ader): assembly comprising a conductor with its own insulation (and screens if any);

- Conductor (of a cable) (IEV 461-01-01 / Fr: conducteur (d'un câble) / De: Leiter (eines kabel): conductive part intended to carry a specified electric current;

- Wire (IEV 151-12-28 / Fr: File / De: draht): flexible cylindrical conductor, with or without an insulating covering, the length of which is large with respect to its cross-sectional dimensions
  Note – The cross-section of a wire may have any shape, but the term "wire" is not generally used for ribbons or tapes;

- Socket-outlet (IEV 442-03-02 / Fr: socle de prise de courant/ De: Steckdose): an accessory having socket-contacts designed to engage with the pins of a plug and having terminals for the connection of cables or cords;

- Circuit-breaker (IEV 441-14-20 / Fr: disjoncteur / De: Leistungsschalter): a mechanical switching device, capable of making, carrying and breaking currents under normal circuit conditions and also making, carrying for a specified time and breaking currents under specified abnormal circuit conditions such as those of short circuit;

- Flexible conductor (IEC Electropedia Area: 461): stranded conductor having wires of diameters small enough and so assembled that the conductor is suitable for use in a flexible cable;

- Insulated cable (IEC Electropedia Area: 461): assembly consisting of:
  - one or more cores,
  - their covering(s) (if any),
  - assembly protection (if any),

   - protective covering(s) (if any).

  Note – Additional uninsulated conductor(s) may be included in the cable;

- Insulation of a cable (IEC Electropedia Area: 461): assembly of insulating materials incorporated in a cable with the specific function of withstanding voltage;

- Screen of a cable (IEC Electropedia Area: 461): conducting layer or assembly of conducting layers having the function of control of the electric field within the insulation.
  Note – It may also provide smooth surfaces at the boundaries of the insulation and assist in the elimination of spaces at these boundaries;

- Shaped conductor (IEC Electropedia Area: 461): conductor the cross-section of which is other than circular;

- Armour (IEC Electropedia Area: 461): covering consisting of a metal tape(s) or wires, generally used to protect the cable from external mechanical effects;

- Sheath/jacket (North America) (IEC Electropedia Area: 461): uniform and continuous tubular covering of metallic or non-metallic material, generally extruded
  Note – The term sheath is only used for metallic coverings in North America, whereas the term jacket is used for non-metallic coverings;

- Shielding conductor (IEC Electropedia Area: 461): separate conductor or single-core cable laid parallel to a cable or cable circuit and itself forming part of a closed circuit in which induced currents may flow whose magnetic field will oppose the field caused by the current in the cable(s);

- Shield of a cable (IEC Electropedia Area: 461): surrounding earthed metallic layer which serves to confine the electric field within the cable and/or to protect the cable from external electrical influence
  Note 1 – Metallic sheaths, foils, braids, armours and earthed concentric conductors may also serve as shields.
  Note 2 – In French, the term "blindage" may be used when the main purpose of the screen is the protection from external electrical influence;

- Single-conductor cable or single-core cable (IEC Electropedia Area: 461): cable having only one core;
  Note – The French term «câble unipolaire» is more specifically used to designate the cable constituting one of the phases of a multiphase system;

- Solid conductor (IEC Electropedia Area: 461): conductor consisting of a single wire;
  Note – The solid conductor may be circular or shaped;

- Stranded conductor (IEC Electropedia Area: 461): conductor consisting of a number of individual wires or strands all or some of which generally have a helical form.
  Note 1 – The cross section of a stranded conductor may be circular or otherwise shaped.
  Note 2 – The term “strand” is also used to designate a single wire;

- Wire strand (IEC Electropedia Area: 461): one of the individual wires used in the manufacture of a stranded conductor.

1.1.2 Context of power cables within buildings and their electrical installation

Power cables are used to transport electrical power either inside buildings or in electrical distribution grids outdoor.

This study will focus on electrical installations within buildings and behind the electrical meter. This is in line with the working plan 2012-2014[2] and the Consultation Forum (CF-2012-02-EC) regarding power cables. In the working plan and at the Consultation Forum (CF-2012-02-EC) it was explained that this product group concerns cables within domestic and industrial buildings. A rationale for this is that electrical distribution and transmission networks are another market segment with other functional product requirements and players. Cables in distribution are a product group very close to power transformers who are already advanced within the Ecodesign of Energy Related Products Directive[3] process.

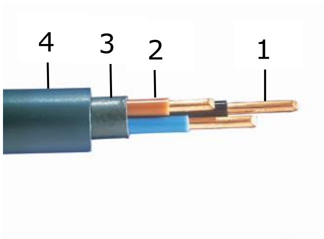
Power cables within buildings can be clearly separated from distribution power cables by product related standards, primarily by its voltage, but also by earthing and electrical armour requirements. Voltage levels used in electrical power cables are:

- High Voltage (HV): voltage whose nominal r.m.s. value lies above 35kV
- Medium Voltage (MV): voltage whose nominal r.m.s. value lies above 1kV and below 35 kV (EN 50160)
- Low Voltage (LV): voltage with a maximum of 1000Vac (IEV 601-01-26 / EN50160).

Low voltage (LV) being the scope of the end application within electrical power installations within buildings and therefore defining the proposed scope of this study.

<u>Different parts of a LV power cable</u>

Basically a cable consists of one or more conductors (a "core" is an insulated conductor), insulation material of the conductors, an inner sheath and an over sheath (Figure 1-1).



1. Solid Copper conductor
2. Insulation of the conductor
3. Inner sheath
4. Over sheath

Figure 1-1: A typical LV cable

Depending on the application (installation method, voltage level, environmental conditions…) an additional mechanical protective cover (armour) and/or an electrical shield can be present (Figure 1-2).

2 http://ec.europa.eu/enterprise/policies/sustainable-business/documents/eco-design/working-plan/

3 http://ec.europa.eu/enterprise/policies/sustainable-business/ecodesign/product-groups/index_en.htm

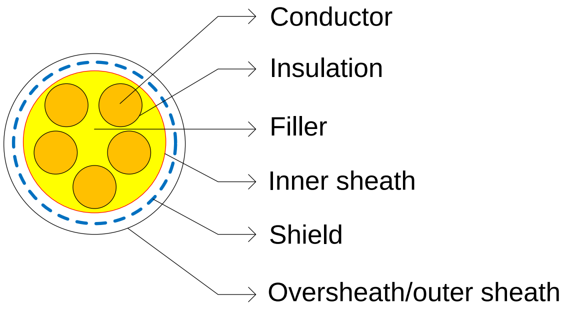


Figure 1-2: Different parts of a LV cable

The different parts of a typical LV cable are:

- Conductor: conductive part intended to carry a specified electric current (IEV 461-01-01). The basic material of the conductor is copper or aluminium. The conductor can be solid or flexible, depending on the application. Copper has a higher electrical conductivity than aluminium, aluminium has a lower weight density (see Table 1). Copper is the most used conductive material in wirings in buildings whereas aluminium is e.g. most used for overhead lines. A LV cables may contain one or more conductors (cores): earthing conductor, phase conductors, neutral conductor). The earthing conductor is sometimes not present in the electrical distribution, for example when TT earthing systems are used.

Table 1-1: Properties of Copper and Aluminium

Property	**Copper (Cu-ETP)**	**Aluminium (1350)**
Electrical conductivity at 20°C [MS/m] / [% IACS[4]]	58 / 100	35 / 61
Thermal conductivity at 20°C [W/mK]	397	230
Density [g/cm³]	8.89	2.7

- Insulation : assembly of insulating materials incorporated in a cable with the specific function of withstanding voltage (IEV 461-02-01). Insulation material can consist of thermoplastic compounds such as PVC (Poly Vinyl Chloride), PE (Polyethylene); thermosetting compounds such as XLPE (Cross-linked Polyethylene), EPR (Ethylene Propylene Rubber) or other synthetic or natural materials. Sometimes also so-called halogen-free insulation is used to avoid harmful smoke from PVC during fire hazards.

[4] IACS: International Annealed Copper Standard

- Filler: This material is used in multi conductor cables to occupy interstices between insulated conductors. The filler material shall be suitable for the operating temperature of the cable and compatible with the insulating material.

- Sheath: Uniform and continuous tubular covering of metallic or non-metallic material, generally extruded (IEV 461-05-03). PVC (Poly Vynil Chloride), PE (Polyethylene); thermosetting compounds such as XLPE (Cross-linked Polyethylene), EPR (Ethylene Propylene Rubber) or commonly used.

- Armour (*Protective cover)*: covering consisting of a metal tape(s) or wires, generally used to protect the cable from external mechanical effects (IEV 461-05-06*)* (see Figure 1-2). This is not often used in electrical power cables within buildings, it is mainly used in outdoor cables and in Low Voltage IT earthing systems e.g. Norway[5].

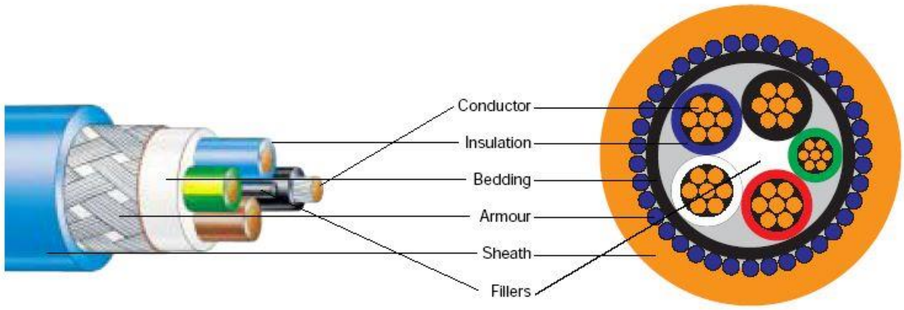
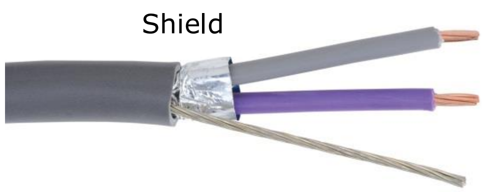


Figure 1-2*: An armoured cable*

Shield (of a cable) (Figure 1-3): surrounding earthed metallic layer which serves to confine the electric field within the cable and/or to protect the cable from external electrical influence (IEV-461-03-04). This is a commonly used cable in industry (e.g. in areas with Electro Magnetic Interferences). Sometimes this cable is also used in residential buildings e.g. Sweden (Europacable)



[5] See comments Europacable – first stakeholder meeting

Figure 1-3: A shielded LV cable

Copper is the most used conductive material in wirings in buildings. Besides the electrical losses, the use of copper, the insulation material and the method of installation are the most significant environmental aspects related to power cables.

Electrical losses in power cables

Cable electrical losses are determined by Ohm's law of physics and are also called Joule losses. The magnitude of these losses increases with the square of the load current and is proportional to the cable electrical resistance. As a consequence without loading there are no cable losses, hence the entire electrical installation system (e.g. way of installation, load of the cable, duration of use, interfaces with a variety of electrical equipment) needs to be considered. For instance there is a relation between the total cable losses in an electrical installation and the topology of the electrical installation.
When designing circuits for lighting three different topologies are commonly used:

- Bus approach (e.g. DALI), where the switching is done near the lighting point by means of a local relay
- Relays (interrupters) located in the distribution board resulting in a star topology
- Traditional wiring, by means of a mechanical switch connected to the lighting point

The amount of cable used in an electrical installation depends among others on the kind of topology that is applied. A star topology, connecting each individual appliance to a central point by a dedicated cable, will increase the total length of cable used in the installation. The average load per cable decreases compared to a traditional or bus topology, therefore cables with a smaller CSA could be used. In practice however, the same cable sections are used as in other topologies, unless the electrical installation design is calculated.

Electrical installations in buildings

Electrical installations in buildings are defined by the international standard IEC 60364 series and fixed wiring products (cables) in the standards IEC 60227 and IEC 60245. Electrical installation rules at EU member state level are in general according to these international and European standards, however there may exist deviations and/or additional requirements at member state level. The above mentioned standards are primarily concerned with safety aspects of the electrical installation. However cables with cross section areas beyond what is required for safe installations could lead to a more economic operation and energy savings.

Cables are part of electrical circuits in electrical installations. The current-carrying capacity is limited by circuit breakers because of safety reasons. Electrical circuits can have socket-outlets or can be directly connected to loads, e.g. for lighting. The power electrical installation system is typically described with a so-called 'One-line diagram'[6]. Examples of one-line diagrams of electrical circuits with typical IEC component symbols are included in Figure 1-4 and Figure 1-5. The latter is a two-level electrical circuit, meaning that there is a main distribution board with circuit breakers and a second-level distribution board(box) with circuit breakers directly connected to the loads.

[6] http://en.wikipedia.org/wiki/One-line_diagram

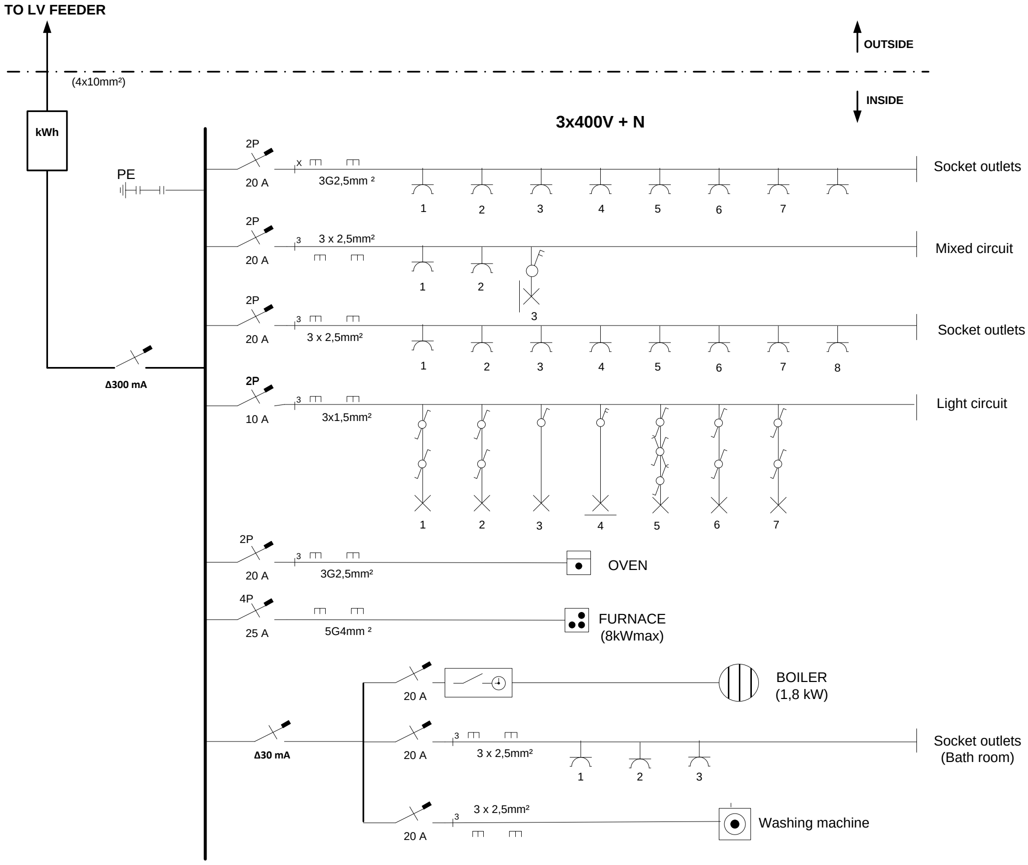


Figure 1-4: Simplified residential electrical diagram

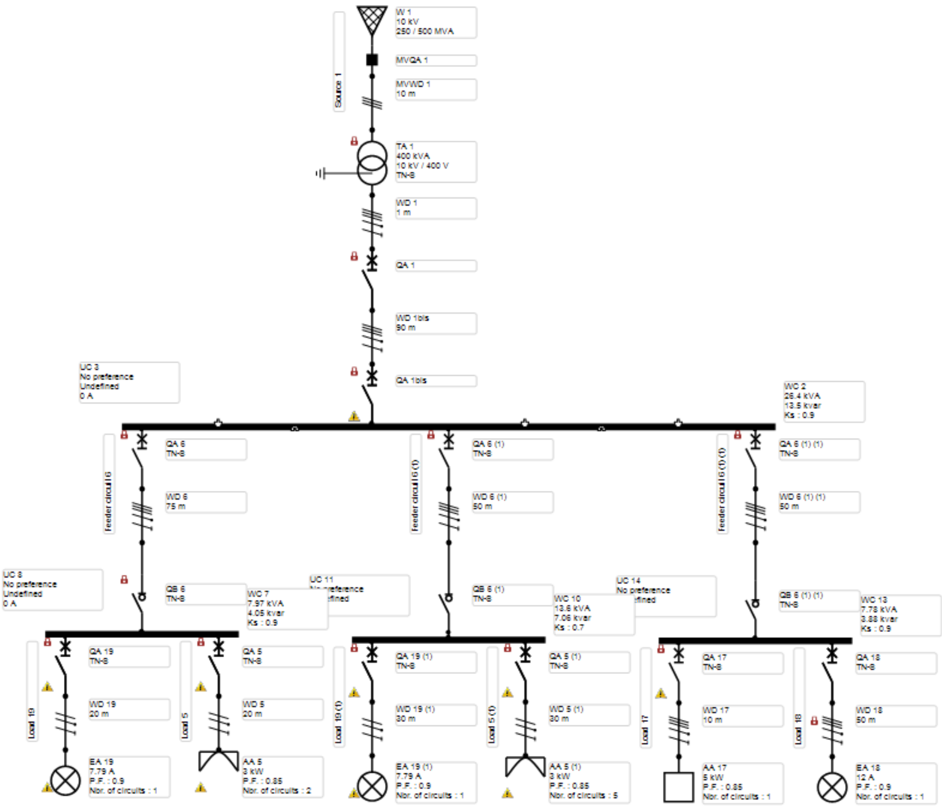


Figure 1-5: Simplified electrical diagram with 2 circuit levels

1.1.3 First proposed scope of this study

As a conclusion from the context discussion in 1.1.2 the first scope proposal is in brief: **'losses in installed power cables in electric circuits in buildings after the meter' taking into account the electrical installation as a system**, the power cable being the product put into service by the electrical installer in a circuit of an electrical installation in a building.
The electrical installation including loads are taken into account at system level, this is explained in more detail in chapter 3 amongst others it means that the installation will be analysed at the level needed related to cable losses.

More in detail, the **scope** of this study "losses in installed power cables in buildings" covers Low Voltage power cables for fixed wiring used in indoor electrical installations in:

- Residential buildings;
- Non-residential buildings:

The non-residential buildings can be further categorised as follow (Ecofys[7]):

- Public/commercial buildings:
    - Trade facilities: Trade, retail, wholesale, mall
    - Gastronomic facilities: Hotels, restaurants, pubs, café's…
    - Health facilities: Hospitals, surgeries,..
    - Educational facilities: Schools, colleges, academies, universities, nurseries,..

[7] Ecofys report, Panorama of the European non-residential construction sector, 9 December 2011

  - Offices
  - Other buildings: Warehouses, recreation facilities…
- Industrial buildings: factories, workshops, distribution centres….

Remarks:
- Industrial buildings can consist of production halls and attached or detached offices. Both are in the scope of this study;
- Process installations which are in general outdoor installations are out of the scope.

Practically, the scope includes low voltage cables on the customer side of the electricity meter (utility cables are out of the scope) inside the above mentioned buildings. These cables can be single core or multicore, shielded…. depending on the application and on the European and National wiring regulations.

Explanation of the terms used in the scope:
- "Low voltage": voltage with a maximum of 1000Vac (IEV 601-01-26). In Europe the standard nominal voltage for public Low Voltage is Un=230Vac r.m.s with a maximum variation of ± 10% (see EN 50160). For four wire LV distributions systems the voltage between phase and neutral is 230Vac r.m.s and 400Vac r.m.s between 2 phases.

- "Fixed wiring": refer to the method of installation of the cable in the building e.g. enclosed in conduit, installed on a cable tray, cable trunking, cable ladder…. (see IEC 60364-5-52, Table A.52.3)

- "Insulated cables": assembly consisting of:
  - one or more cores,
  - their individual covering(s) (if any),
  - assembly protection (if any),
  - protective covering(s) (if any).

  Note – Additional un-insulated conductor(s) may be included in the cable

- "Single core cables": cable having only one core
  - Note – The French term «câble unipolaire» is more specifically used to designate the cable constituting one of the phases of a multiphase system.

Remark: Further in this study the word "power cables" will be used as a general term for single core or multi-core power cables, unless otherwise stated.

Out of the scope in this study:
- Losses in circuit breakers;
- Losses or inefficiency in the loads connected to the circuit;
- Losses due to poor connections ("A recent study found that average electrical distribution system losses accounted for 2% of a plant's annual energy use. Losses due to poor connections represented one-third of these losses and accounted for 40% of the savings after corrective actions were taken. (Source: U.S. Department of Energy")[8];
- Utility cables for transmission (HV) and distribution (MV,LV) of electrical energy;
- Power cables for Nuclear power plants (require higher-quality cables that meet stringent Nuclear Regulatory Commission standards);

[8] ECI Publication No Cu0192: APPLICATION NOTE INFRARED SCANNING FOR ENERGY EFFICIENCY ASSESSMENT -Paul De Potter - January 2014

- Power cables for hazardous locations (in ATEX zones);
- Cables used for power plants such as PV, Wind, ….;
- Outdoor cables: Cables used in process installations (e.g. chemical and petrochemical plants), railway cables,..;
- Cables for mobile applications: (electric) cars, ships, metro, …
- Busbar Trunking systems;

Outside of the scope of Tasks 1-6, but in the scope of Task 7 for a review on potential negative impact related to proposed policy measures (if applicable):

- Some of the installation cables included in the scope of this study are also used in other sectors like machinery construction for wiring inside machines. Measures on product level could as such have an impact on machine construction.
- Socket-outlets, junction boxes, cable installation systems (ducting systems, trunking systems..), cable accessories,…,
- Building design and construction
- LV distribution board

Outside of the scope of Tasks 1-6, but in the scope of Task 7 for review on potential loopholes related to proposed policy measures (if applicable):

- utility cables, be it low Voltage, Medium Voltage and High Voltage utility cables,
- all the cables with a rated voltage above 1000Vac r.m.s,
- extra Low voltage (e.g. 24Vdc/ac; 12Vac…) cables,
- connection of the electrical distribution board of the building to the LV distribution grid (via a buried or overhead cable),
- the electrical distribution boards, internal wiring in the distribution boards, (smart) KWh-meter, RCD… ,
- data cables (Ethernet cable, TV ..), telephone cables, lift cables, safety cables (fire alarm..), , welding cables, instrumentation cable,… In general these are special purpose power cables which are not fixed wired (flexible lift cables) or have very low load currents (cables to fire detectors, data cables..).
- DC cables for PV installations
- power cords of the electrical apparatus and the internal wiring of these apparatus,
- building automation systems, lighting controls, …..

1.1.4 Prodcom category or categories

The only category found in Prodcom, related to the scope of this study, is the category with NACE code 27321380.

Table 1-2 ProdCom data

Prodcom NACE code	Description
27321380	Other electric conductors, for a voltage <= 1000 V, not fitted with connectors

1.1.5 Categories according to IEC, EN- or ISO-standard(s)

Cables can be roughly divided into High voltage cables ($\geq$ 1kVac) & Low voltage cables (<1kVac). These are the topics of respectively Working Group 16 and Working Group 17 of IEC TC 20 (Electric Cables).

The following sections list IEC standards defining subcategories of cables according to the field of application.

1.1.5.1 IEC 60228

IEC 60228: "Conductors of insulated cables" defines 4 classes for conductors:
- Class 1: solid conductor
- Class 2: stranded conductors
- Class 5: flexible conductors
- Class 6: flexible conductors which are more flexible than class 5

Whereas Class 1 and 2 conductors are intended for use in cables for fixed installation. Class 5 and 6 are intended for use in flexible cables and cords but may also be used for fixed installation.
Functional difference is the minimum bending radius which is expressed in x times the outer diameter of the cable.

1.1.5.2 IEC 60227-1

The following classes and types are defined in **IEC 60227-1**: "Polyvinyl chloride cables of rated voltage up to and including 450/750V – general requirements":

0. Non-sheathed cables for fixed wiring.
- **01.** Single-core non-sheathed cable with rigid conductor for general purposes (60227 IEC 01).
- **02.** Single-core non-sheathed cable with flexible conductor for general purposes (60227 IEC 02).
- **05.** Single-core non-sheathed cable with solid conductor for internal wiring for a conductor temperature of 70 °C (60227 IEC 05).
- **06.** Single-core non-sheathed cable with flexible conductor for internal wiring for a conductor temperature of 70 °C (60227 IEC 06).
- **07.** Single-core non-sheathed cable with solid conductor for internal wiring for a conductor temperature of 90 °C (60227 IEC 07).
- **08.** Single-core non-sheathed cable with flexible conductor for internal wiring for a conductor temperature of 90 °C (60227 IEC 08).

1. Sheathed cables for fixed wiring.
- **10.** Light polyvinyl chloride sheathed cable (60227 IEC 10).

1.1.5.3 IEC 60245-1

IEC 60245-1: "Rubber insulated cables – Rated voltages up to and including 450/750 V – Part 1: General requirements" defines the following classes and types:

0 Non-sheathed cables for fixed wiring
- **03** Heat-resistant silicone insulated cable for a conductor temperature of maximum

180 °C (60245 IEC 03).

04 Heat-resistant ethylene-vinyl acetate rubber insulated, single-core non-sheathed 750 V cable with rigid conductor for a maximum conductor temperature of 110 °C (60245 IEC 04).

05 Heat-resistant ethylene-vinyl acetate rubber insulated, single-core non-sheathed 750 V cable with flexible conductor for a maximum conductor temperature of 110 °C (60245 IEC 05).

06 Heat-resistant ethylene-vinyl acetate rubber or other equivalent synthetic elastomer insulated, single-core non-sheathed 500 V cable with rigid conductor for a maximum conductor temperature of 110 °C (60245 IEC 06).

07 Heat-resistant ethylene-vinyl acetate rubber or other equivalent synthetic elastomer insulated, single-core non-sheathed 500 V cable with flexible conductor for a maximum conductor temperature of 110 °C (60245 IEC 07).

1.1.6 Other product-specific categories

In general cables can be categorised according to their field of application or the composition of the cable.

Categories according to the **field of application** (typically found in cable catalogue):

- Energy (or power) cables: Cables for transmission & distribution of electrical energy
  - LV, MV and HV (AC/DC) cables
  - Underground / overhead cables
- Industrial cables
  - LV,MV,(HV) cables
  - Power, control, instrumentation.. cable
- Building wire cable
  - Cables for fixed wiring (e.g. Class 1&2– EN60228)
  - Other (flexible) cables (e.g. Class 5&6 – EN 60228)
- Special purpose cables (automotive, railway, renewables, military…)
- Communication cables (data, telephone..)

Categories according to the **composition of the cable**:

- Conductor material: Copper or Aluminium
- Insulation and sheath material: bare or insulated conductors/cables. Insulation and sheath material depends on:
  - The rated voltage level: LV, MV, HV
  - Mechanical requirements: bending radius, elongation, tensile strength, abrasion, max diameter, ..
  - Chemical requirements: resistance to chemical products (oil, fuels, acids,..) and resistance to fire/heat, halogen free

A further categorisation can be made, based on:

- Nominal Cross sectional area of the conductors (expressed in mm²): value that identifies a particular size of a conductor but is not subject to direct measurement (IEC 60228)
- The construction of the conductor: Solid, stranded, flexible
- The amount of conductors in the cable: single core or multicore

1.1.7 Proposal for primary product performance parameter or 'functional unit'

Knowing the functional product used in this study we now further explain what is called the "functional unit" for installed power cables which form parts of electrical circuits.

In standard 14040 on life cycle assessment (LCA) the functional unit is defined as "the quantified performance of a product system for use as a reference unit in life cycle assessment study". The primary purpose of the functional unit is to provide a calculation reference to which environmental impacts (such as energy use), costs, etc. can be related and to allow for comparison between functionally equal electrical power distribution cables and/or circuits. Further product segmentations will be introduced in this study in order to allow appropriate equal comparison.

The primary functional performance parameter for cables in this study is **"current-carrying capacity".**

The "current-carrying capacity" of a cable or (insulated) conductor is defined as the maximum value of electric current which can be carried continuously by a conductor (a cable), under specified conditions without its steady-state temperature exceeding a specified value (see IEV 826-11-13). The current-carrying capacity is expressed in Amperes [A].

The current-carrying capacity of a cable depends on:

- Conductor material: Cu or Al or alloys;
- Nominal cross sectional area of the conductor (expressed in mm²);
- Insulation material: maximum operating temperature (e.g. PVC=70°C, XLPE= 90°C);
- Ambient temperature at the place where the cable is installed;
- Method of installation: The installation method has an impact on the heat transfer from the conductor to the environment;

The primary functional performance parameter for electrical circuits in this study is **"the rated current".**

In a circuit the current-carrying-capacity is limited by the rated current (In) of the circuit breaker.

IEC 60898-1 and European Standard EN 60898-1 define the rated current (In) of a circuit breaker for low voltage distribution applications as the maximum current that the breaker is designed to carry continuously (at an ambient air temperature of 30 °C).Industrial circuit-breakers must comply with IEC 60947-1 (general rules) and 60947-2 (part 2: circuit-breakers) or other equivalent standards. Domestic-type circuit-breakers must comply with IEC standard 60898, or an equivalent national standard.

Note: in some North-American countries the word "**ampacity**" is used to express the current-carrying capacity.

1.1.8 Secondary product performance parameters

These parameters can be divided in two subcategories:

- secondary product performance parameter related to the construction of the cable;
- secondary product performance parameter related to the use of the cable.

1.1.8.1 Secondary product performance parameters related to the construction of the cable

The secondary product performance parameters related to the construction of the cable are:

- **Nominal Cross-Sectional Area (CSA):** a value that identifies a particular size of conductor but is not subject to direct measurement, expressed in mm² (IEC 60228). The csa of the conductor is standardized: e.g. 0.5 mm², 0.75mm², 1 mm², 1.5 mm², 2.5 mm² ….

  The cross-sectional area of conductors shall be determined for both normal operating conditions and for fault conditions according to (IEC 60364-1):
  - their admissible maximum temperature;
  - the admissible voltage drop;
  - the electromechanical stress likely to occur due to earth fault and short circuit currents;
  - other mechanical stress to which the conductor can be subjected;
  - the maximum impedance with respect to the functioning of the protection against fault currents;
  - the method of installation.

  Note: The items listed above concern primarily the safety of electrical installations. Cross-sectional areas greater than those for safety may be desirable for economic operation.

- **DC resistance (R_{20}):** Direct current resistance of the conductor(s) at 20°C expressed in Ohm/km (IEC 60228 – Annex A). The DC resistance of solid conductors (Class 1) are lower than these of flexible conductors (Class 5,6), e.g. For a Class 1, 1 mm² Cu wire R_{20}= 18.1 Ohm/km; for a class 5, 1 mm² Cu wire R_{20}= 19.5 Ohm/km;

- **Rated voltage Uo/U**: The rated voltage of a cable is the reference voltage for which the cable is designed and which serves to define electrical tests (IEC 60227-1). The rated voltage is expressed by the combination of two values Uo/U expressed in volts:
  - U0 is the r.m.s value between any insulated conductor and "earth" whereas
  - U is the r.m.s value between any two-phase conductor of a multicore cable or of a system of single-core cables.

- **Insulation material:** synthetic insulation materials can be roughly divided into:
  - Thermoplastics (PVC, PE, PP,..);
  - Thermosettings (Neoprene, Silicone Rubber…);
  - Elastomers (XLPE, EPR,…).

  The selection criteria of the insulation material depends on the electrical (rated voltage, ..) and physical (temperature range, flexibility, flammability, chemical resistance…) requirements of the application.

- **Conductor material (Cu, Al):** Copper and aluminium are the most commonly used metals as conductors. The compositions of copper and aluminium wire for the manufacturing of electrical conductors are specified in respectively EN13601/13602 and EN1715.

- **Number of cores in the cable:** In general a distinction is made between single core and multi-core cables. A single core cable consists of only one conductor covered by an insulation material (1 or 2 layers). A multi-core cable consists of

2, 3, 4, 5 or more cores, each individually insulated and globally covered by a sheath. In general conductors in a cable have the same CSA, but there are also cables with other combinations. For instance for balanced three-phase systems the neutral can have a smaller CSA than the phase conductors, sometimes indicated as 3.5 (3 conductors with the same size, 1 conductor with a smaller CSA) or 4.5 (4 conductors with the same size, 1 conductor with a smaller CSA). Also the protective earth conductor can have a smaller CSA.

- **The construction of the conductor**: Solid, stranded, flexible. Solid wire, also called solid-core or single-strand wire, consists of one piece of metal wire. Stranded wire is composed of smaller gauge wire bundled or wrapped together to form a larger conductor. The type of construction mainly has an effect on the flexibility/bending radius, but it has also an effect on the AC resistance of the cable.

1.1.8.2 Secondary product performance parameter related to the use of the cable

Secondary product performance parameters related to the use of the cable in an electrical installation system are the following:

At the level of **the electrical installation system**:

- Supply parameters & topology of the grid:
    - Nominal voltage (U and/or Uo)
    - Maximum and minimum fault currents to earth and between live conductors
    - Maximum supply loop impedance to earth (Z41), given as a minimum fault current
    - AC Grid system (TT, TN, IT) / DC (marginal, see BAT)
    - Single phase or three phase electrical installation. A single phase installation consists of single phase circuits. A three phase installation can consist of any combination of single phase and three phase circuits;

- Design of the electrical distribution system in the building
    - Main and/or sub distribution board (levels). Small installations have just one level, the main distribution board feeding the circuits. Larger installations in general have two levels, the main distribution board serving secondary distribution boards. Exceptionally, very large installations or installations with special design requirements may have a third level.
    - Installation cable length: the total length of all fixed wired power cables used in the total electrical installation of a building;
    - Method of installation: in cable trunk, inside the wall, in open air, grouped, indoor/outdoor. Reference installation methods and their corresponding correction factors are defined in IEC 60364-5-52;

- External influences (see IEC 60364-5-51), such as:
    - Environmental conditions:
        - Ambient temperature: A correction factor for ambient temperatures other than 30°C has to be applied to the current-carrying capacities for cables in the air (IEC 60364-5-52). Higher ambient temperatures have a negative effect on the current-carrying capacity of the cable, e.g. a correction factor of 0.87 has

    - to applied for PVC cables installed in locations with a ambient temperature of 40°C;
    - Presence of corrosive or polluting substances: the sheath material of the cable must be resistant to the substances at which it is exposed to;
  - Utilisation of the building: The utilisation of the building has a significant impact on the choice of the cables, especially on the fire behaviour of the cables. Important building aspects related to this topic are:
    - Condition of evacuation in case of emergency
    - Nature of processed or stored material
  - Construction of the building: cables must be conform to the performance criteria of the Construction Product Directive / Construction Product Regulation (see further on)

At the level of **the circuit**:

- Voltage drop over the cable in a circuit (Volt): an electric current flowing through a resistive material (conductor) creates a voltage drop over the material. The voltage drop depends on the resistance of the conductor (Cu, Al), the amount of current flowing through the conductor (depends on the electrical load) and the length of the cable. The voltage drop can be calculated with the following formula (IEC 60364-5-52):

$$u = b\left(\rho 1 \frac{L}{S} cos\varphi + \lambda L\ sin\varphi\right) Ib$$

  Where
  u= voltage drop in volts;
  b= the coefficient equal to 1 for three-phase circuits and equal to 2 for single-phase circuits;

  ρ1= the resistivity of the conductor in normal service, taken equal to the resistivity at the temperature in normal service, i.e. 1.25 times the resistivity at 20°C, or 0.0225 Ωmm²/m for copper and 0.036 Ωmm²/m for aluminium;

  L= the straight length of the wiring systems in metres;

  S= the cross-sectional area of conductors, in mm2;

  cos φ= the power factor; in the absence of precise details, cos φ is taken as equal to 0,8 ;

  λ= the reactance per unit length of conductors, which is taken to be 0,08 mΩ/m in the absence of other details;

  Ib is the design current (in amps);

- Load current (Ampere): This is the design current of the electric circuit and is determined by the electric load in normal operation connected to the circuit. The load current can be calculated as follow:

  $Ib = P/(Uo.cos\ \varphi)$ for single phase systems
  $Ib = P/(\sqrt{3}.U.cos\ \varphi)$ for three phase systems

  Where P= active power of the load (Watt)
  Uo= nominal voltage between line and neutral

U= nominal voltage between the lines
Cos φ = power factor of the load

- Single phase or three phase circuit;

- Circuit topology: radial, loop, line, tree circuit;

- Load factor (LF) (IEV 691-10-02):
  The ratio, expressed as a numerical value or as a percentage, of the consumption within a specified period (year, month, day, etc.), to the consumption that would result from continuous use of the maximum or other specified demand occurring within the same period

  Note 1 – This term should not be used without specifying the demand and the period to which it relates.
  Note 2 – The load factor for a given demand is also equal to the ratio of the utilization time to the time in hours within the same period.
  As a consequence the load factor is an important parameter for calculating the energy losses in the cable;

- Load form factor (Kf) (derived from IEV 103-06-14): the ratio of the root mean squared (r.m.s) Power to the average Power (=Prms/Pavg);

  - The r.m.s or root mean square value is the value of the equivalent direct (non-varying) voltage, current, power which would provide the same energy to a circuit as the sine wave. That is, if an AC sine wave has a r.m.s value of 240 volts, it will provide the same energy to a circuit as a DC supply of 240 volts. The r.m.s value can be calculated as follow:

$$Prms = \sqrt{\frac{1}{t2-t1}\int_{t1}^{t2}(V(t)\times I(t))^2 dt}$$

For a sine wave (eg. Grid voltage, power): y= $a\sin(2\pi f t)$ with amplitude "a" and frequency "f", the r.m.s value is $rms = a/\sqrt{2}$. or $a \times 0.707$

  - The avg or average value is normally taken to mean the average value of only half a cycle of the wave. If the average of the full cycle was taken it would of course be zero, as in a sine wave symmetrical about zero, there are equal excursions above and below the zero line.
  -

$$P_{avg} = \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} V(t)I(t)\,dt$$

For a sine wave (eg. Grid voltage, power): y=a sin(2πft) with amplitude "a" and frequency "f" , the avg value is $avg = a \times \frac{2}{\pi} = a \times 0.637$

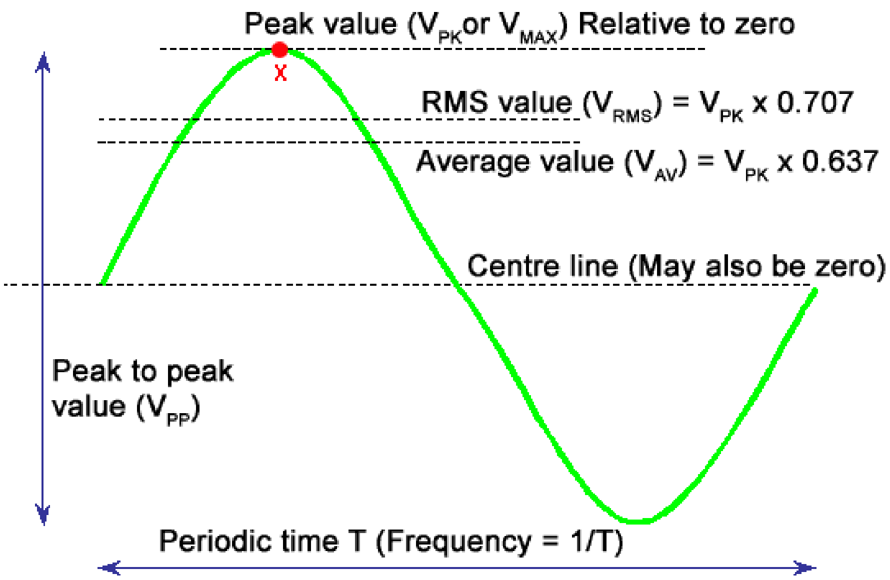


Figure 1-6: Peak-, r.m.s-, avg value of a sine wave

- The equivalent operating time at maximum loss, in h/year; (IEC 60287-3-2) : is the number of hours per year that the maximum current Imax would need to flow in order to produce the same total yearly energy losses as the actual, variable, load current;

$$T = \int_0^{8760} \frac{Ib(t)^2 . dt}{Imax^2}$$

where

- t is the time, in hours;
- Ib(t) the design current in function of time, in A;
- Imax is the maximum load on the cable during the first year, in A;

The energy losses according IEC 60287-3-2 are:

$$energy\ loss\ during\ the\ first\ year\ = \quad I^2max.\ RL\ .L.NP.NC\ .T$$

where

- Imax is the maximum load on the cable during the first year, in A;
- RL is cable resistance per unit length;
- L is the cable length, in m;
- NP is the number of phase conductors per circuit (=*segment in this context*);
- NC is the number of circuits carrying the same type and value of load;
- T is the equivalent operating time, in h/year.

Be aware that the formula used in IEC 60287-3-2 is only used to calculate the cable losses for cable segments. Compared to circuits the load is situated at the end of the cable, having an equal load (current) over the total length of the cable.

- Power factor (IEC 60364-5-52) of the load: is defined as the ratio of active power (P – kWatt) to the apparent power (S' – kVA). The power factor is equal to cos φ for linear loads (i.e. loads with sinusoidal currents).

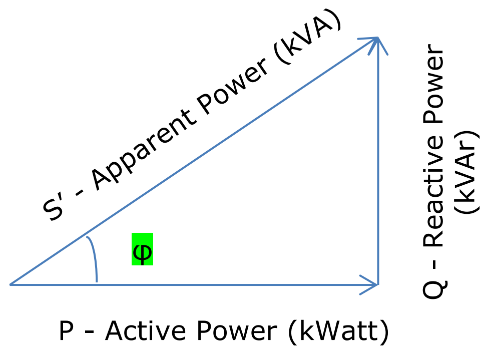


Figure 1-7: Relationship between active-, reactive- and apparent power

Where:

Active Power (P) (IEV 141-03-11): For a three-phase line under symmetric and sinusoidal conditions, the active power is $P = \sqrt{3}\, UI \cos\varphi$, where U is the r.m.s value of any line-to-line voltage, I is the r.m.s value of any line current and φ is the displacement angle between any line-to-neutral voltage and the corresponding line current.

Apparent Power (S') (IEV 131-11-41): product of the r.m.s voltage U between the terminals of a two-terminal element or two-terminal circuit and the r.m.s electric current I in the element or circuit $S' = UI$ expressed in VoltAmpere, VA. For a three-phase system, the apparent power is $S' = \sqrt{3}\, UI$.

- Short-circuit intensity: Short-circuits causes large currents in the conductors which lead to thermal stresses in these conductors. Therefore the breaking time for a short-circuit may not be greater than the time taken for the temperature of the conductors to reach maximum permissible value. The maximum thermal stresses of a cable depends on:
  - Insulation material (PVC, XLPE,..)
  - Conductor material (Cu, Al)
  - Cross sectional area of the conductors

- Harmonic currents (will be defined later in task 3).

- Kd distribution factor (defined for this study): distribution of the load over the cable of a circuit. A circuit can have several connection terminals along the circuit with different loads attached to it. As a result the current passing along the circuit reduces towards the end. This distribution factor compensates this effect by reducing the cable length to an equivalent cable length at peak load. Note this is probably only relevant for small loads, as in general larger loads are fed by dedicated circuits serving one single load;

- Rated Diversity Factor (IEC 61439): the rated current of the circuits will be equal to or higher than the design current (or assumed loading current). The Rated Diversity Factor recognizes that multiple loads are in practice not fully loaded simultaneously or are intermittently loaded.

- Amount of junction boxes per circuit;

- Number of nodes per circuit;

- Circuit levels 1 and 2 (defined for this study) (see also Figure 1-5);

    - Circuit level 1 cables are cables that feed the secondary distribution boards from the main distribution board;
    - Circuit level 2 cables are cables that are connected to the end loads.

- Number of load per circuit;

- Skin effect, skin depth[9]: skin effect is the tendency of an alternating electric current (AC) to become distributed within a conductor such that the current density is largest near the surface of the conductor. It decreases with greater depths in the conductor. The electric current flows mainly at the "skin" of the conductor, between the outer surface and a level called the skin depth δ. The skin effect causes the effective resistance of the conductor to increase at higher frequencies where the skin depth is smaller, thus reducing the effective cross-section of the conductor.

- Lifetime of the cable: the lifetime of a cable depends mainly on the nominal load current and the environmental conditions (temperature, presence of corrosive or polluting substances ...) in which the cable is installed. Short circuits have an negative impact on the lifetime, because of the high conductor temperatures caused by the short circuit currents.

1.1.9 First screening

Objective:
The first product screening is a preliminary analysis that sets out the recommended scope for the subsequent Tasks. As the full study investigates the feasibility and appropriateness of Ecodesign and/or Energy Labelling measures, the first product screening entails an initial assessment of the eligibility and appropriateness of the product group envisaged.

Important note: These are indicative for a first screening only and will be updated in later chapters.

1.1.9.1 Envisaged product application categories

When the classification is performed according the main application of the circuit, 12 categories are defined (see Table 1-3).

[9] http://en.wikipedia.org/wiki/Skin_effect

Table 1-3: Application categories

	Sector	Residential			Services			Industry		
Circuit level 1	Application category id	1			2			3		
Circuit level 2	type of application	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit
	Application category id	4	5	6	7	8	9	10	11	12

At circuit level 1 there is one type of circuit per sector, e. g. Figure 1-5. The main function of a level 1 circuit is to feed the secondary distribution boards. Standalone single family houses in the residential sector generally have one circuit level, but for instance apartment buildings have two circuit levels (secondary distribution board per dwelling).

At circuit level 2 we differentiate between lighting circuits, socket-outlet circuits and dedicated circuits (see for example in Figure 1-4 and Figure 1-5). Each circuit type has one or more typical topologies. For instance lighting circuits can be designed as single line circuit (no branches), as a tree by means of junction boxes (with one branch per node), or as a star. Socket-outlet circuits in general are single line circuits or looped circuits. Dedicated circuits serve mostly just one load. For instance a motor or pump with a dedicated circuit breaker in the distribution board and a cable between circuit breaker and load. The load is thus located at the end of the dedicated circuit. For lighting and socket-outlet circuits the load is distributed along the circuit.

Acronyms for circuit identification based upon the above mentioned application categories in Table 1-3:
RESidential Level1 circuit: RESL1
SERvices Level1 circuit: SERL1
INDustry Level1 circuit: INDL1
RESidential Level2 Lighting circuit: RESL2L
SERvices Level2 Lighting circuit: SERL2L
INDustry Level2 Lighting circuit: INDL2L
RESidential Level2 Socket-outlet circuit: RESL2S
SERvices Level2 Socket-outlet circuit: SERL2S
INDustry Level2 Socket-outlet circuit: INDL2S
RESidential Level2 Dedicated circuit: RESL2D
SERvices Level2 Dedicated circuit: SERL2D
INDustry Level2 Dedicated circuit: INDL2D

1.1.9.2 Parameters determining power loss in cables

This section elaborates the physical parameters of a power cable related to losses in the cable.

As stated in the previous section the power losses are proportional to the cable resistance (R). The resistance of a cable in circuit at a temperature t can be calculated by the formula: $R = \rho_t . l/A$ (Ohm). This means the losses in a circuit can be diminished by:

- reducing the specific electrical resistance (ρ) of the conductor material;
- increasing the cross sectional area (A) of the cable;
- reducing the total length (l) of cable for a circuit.

In annex 1-B a closer look is taken at these physical parameters and at how manipulation of these parameters can contribute to smaller power losses in power cables.

1.1.9.3 Preliminary analysis according to working plan

The preliminary analysis in this section is based upon data from the "Modified Cable Sizing Strategies, Potential Savings" study[10] – Egemin Consulting for European Copper Institute – May 2011. This study is also referred to in the Ecodesign of Energy Related Products Directive Working plan 2012-2014[11]. It focuses on the use of electrical conductors with cross-sections beyond the minimum safety prescriptions, which helps to achieve energy savings and cost-effectiveness.

1.1.9.3.1 Market and stock data for the first screening

Electrical installations in buildings were modelled by their content of conductive material. The analysis was carried out considering the equivalent content of copper of the electrical installation (largely dominated by the electrical conductor).

Buildings can be split into three main categories:

- Residential;
- Non-residential;
    - Industry;
    - Services.

This classification (residential, industry, services) corresponds with available statistical and forecast data on electricity consumption, which allows making estimates of potential energy savings.
Annual sales of wiring, expressed as kilotons equivalent copper, are estimated to be some 760 kTon in 2010, and are expected to increase to 924 kTon in 2030 (see Table 1-4).

Table 1-4: Sales of power cables (kTon Copper)[12]

Annual Sales (kTons eq. Copper)	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**
Industry	226	245	241	253	266	279	293
Services	202	219	216	227	238	250	263
Residential	284	308	303	318	334	351	368
Total	712	772	760	798	838	880	924

The total amount of copper installed in buildings ('stock') is estimated to be some 18788 kTon in 2010, expected to increase to 21583 kTon in 2030 (see Table 1-5).

[10] http://www.leonardo-energy.org/white-paper/economic-cable-sizing-and-potential-savings
[11] http://ec.europa.eu/enterprise/policies/sustainable-business/ecodesign/product-groups/

[12] http://ec.europa.eu/enterprise/policies/sustainable-business/ecodesign/product-groups/

Table 1-5: Stock of power cables (kTon of Copper)[12]

Stock (kTons eq. Copper)	2000	2005	2010	2015	2020	2025	2030
Industry	5991	6102	6538	6951	7395	7453	7511
Services	4338	4419	4734	5033	5355	5397	5439
Residential	6886	7014	7515	7989	8500	8567	8633
Total	17215	17536	18788	19974	21250	21417	21583

The gap between the stock increase and the cumulative 5 years sales is due to refurbishment, maintenance and extension of existing installations as well as dismantling of old buildings.

Information sources were:

- Residential and non-residential new construction and refurbishment activity (Euroconstruct database)
- Demographic statistics, households statistics and projections (Eurostat, European Union portal, European Environmental Agency)
- Copper wire and cable consumption (European Copper Institute)

Assumptions were:

- 30 kg of equivalent copper per electrical installation of a household.
- Stock in non-residential buildings = 1.5 times the stock in residential buildings (based on copper wire and cable consumption statistics).

1.1.9.3.2 Cable loading data for first screening

Losses in electrical cables are related to the loading (see 1.1.9.2). This electric loss is therefore directly related to the overall electricity consumption in the buildings concerned.
Hence, the Reference scenario for the calculations is defined by the projections made by the European Commission[13] regarding electricity consumption in buildings and industrial indoor sites. Note that probably part of the industry electricity consumption (see Table 1-6) can strictly not be seen as cables inside buildings, they could be located outdoor but due to a lack of data this is neglected at this stage.

Table 1-6: Final affected energy demand, related to power cables[14]

FINAL ENERGY DEMAND - Reference Scenario	Unit	2010	2015	2020	2025	2030
Industry	TWh	1073	1152	1207	1279	1329
Services	TWh	775	832	872	924	960
Residential	TWh	950	1021	1069	1133	1177
Total Electricity	TWh	2798	3005	3148	3336	3466
Total Electricity	PJelec	10074	10818	11334	12011	12478
Total energy	PJ prim	25182	27045	28332	30024	31194

1.1.9.3.3 Estimated losses in cables in buildings

[13] http://ec.europa.eu/energy/observatory/trends_2030/doc/trends_to_2030_update_2009.pdf

In the Modified Cable Sizing Strategies, Potential Savings" study – Egemin Consulting for European Copper Institute – May 2011, referred to in the Ecodesign of Energy Related Products Directive Working plan 2012-2014[14], four electrical systems were defined modelling and representing a small office, a large office, a small logistics centre and a large industrial plant.

The calculated averaged energy loss in power cables for the sectors defined in this study was **2.04%.**

Some stakeholders made remarks to the above mentioned study[15]. In the next sections we will re-analyse the assumptions made in the Egemin study.

1.1.9.4 Review of losses

In the following sections the losses in the circuits, classified according the product application categories in 1.1.9.1, have been calculated. Analogue to the study elaborated in 1.1.9.3.3, a residential and non-residential model have been worked out based upon empirical findings. Beware that every individual installation and loading can vary a lot compared to those assumptions.
The parameters used in the models are explained in chapter 3 of this report. The length of the circuits in the models is based upon the answers on the questionnaire for installers[16]. The acronyms used for the circuit identification are listed in 1.1.9.1.

The loss ratio used in the model is defined as:

$$loss\ ratio = \frac{\text{energy losses in the circuit cables}}{energy\ transported\ by\ those\ circuits}$$

Two loss ratios are used:

- Loss ratio on Imax: this is according formula on energy losses in power cables explained in chapter 3;
- Loss ratio on Iavg: this is according the $P= R.I_{avg}^2$ formula. Formula to calculate the average value see xxxxx

1.1.9.4.1 Estimated residential cable losses

Average annual household consumption in Europe is 3500kWh, resulting in an average power usage of 400 W and an average current of 1.74 A at 230 V. According to MEErP[17] the average floor area for existing residential dwellings (year 2010) is 90 m^2 and 110 $m^2$for new residential dwellings.

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[14] http://ec.europa.eu/enterprise/policies/sustainable-business/ecodesign/product-groups/

[15] Ivar GRANHEIM, by mail 20/09/2013,

> *The report motivating the inclusion of power cables in the Working Plan is missing key information to evaluate the effective potential saving of power cables, and assumptions are not robust. A more complete technical study is needed.*

[16] This questionnaire was sent to installers on the 30th of September, 2013 in the context of this study. See "Preparatory Studies for Product Group in the Ecodesign Working Plan 2012-2014:Lot 8 - Power Cables: Project Report".

[17] MEErP 2011 Methodology Part 2 , chapter 6.5, edition 28 November 2011

The assumed residential model consists of one level 1 circuit (RESL1), 2 lighting (RESL2L), 2 socket-outlet (RESL2S) and 2 dedicated circuits (RESL2D). The length of the circuits in the model is about 30 m for the cat 1 circuit and 17 to 20 m for the other circuits. The total amount of conductor material (copper) used in this model is 25 kg/100m^2. It is assumed that the phases are in balance (no current through neutral conductor in case of 3-phase circuit).

Table 1-7: Residential model: parameters and calculated losses (Note: these values are updated in later chapters)

Summary	Circuits					Installation
	RESL1	RESL2L	RESL2S	RESL2D	RESL2D	
Total circuit length (m)	30	34	40	17	17	
CSA (mm²)	10	1.5	2.5	2.5	6	
Loaded cores	3	2	2	2	2	
Kd (distribution factor)	1.00	0.50	0.50	1.00	1.00	
LF (load factor = Pavg/S = Iavg/Imax)	0.03	0.01	0.02	0.01	0.01	
Kf (load form factor)	1.08	1.29	2.83	6.48	4.90	
PF (power factor)	0.90	0.90	0.90	0.90	0.90	
loss ratio on Imax	0.15%	0.02%	0.09%	0.21%	0.06%	0.24%
loss ratio on Iavg	0.12%	0.02%	0.03%	0.03%	0.01%	0.15%

The loads used for the RESL2D circuits are a washing machine and an induction cooker.

Most of the losses are in the level 1 circuit and in the dedicated circuits. Due to the low load factor the losses are rather small (see Table 1-7).

1.1.9.4.2 Estimated service sector cable losses

An average office[18] of 400m² is used with about 33 employees, and an annual energy usage of 166666 kWh. The model consists of one level 1 circuit (SERL1), lighting (SERL2L), socket-outlet (SERL2S) and dedicated (SERL2D) circuits. The length of the circuits in this model is about 30 to 35 m according the results of the enquiry[19]. The total amount of conductor material (copper) used in this model is about 96 kg/100m^2. It is assumed that the phases are in balance (no current through neutral conductor in case of 3-phase circuit).

[18] http://www.entranze.eu/, http://www.leonardo-energy.org/sites/leonardo-energy/files/documents-and-links/Scope%20for%20energy%20and%20CO2%20savings%20in%20EU%20through%20BA_2013-09.pdf The scope for energy and CO2 savings in the EU through the use of building automation technology.

[19] This questionnaire was sent to installers on the 30th of September, 2013 in the context of this study. See "Preparatory Studies for Product Group in the Ecodesign Working Plan 2012-2014:Lot 8 - Power Cables: Project Report".

Table 1-8: Services model: parameters and calculated losses(Note: these values are updated in later chapters)

Summary	Circuits					Installation
	SERL1	SERL2L	SERL2S	SERL2D	SERL2D	
Total circuit length (m)	50	258	155	57	57	
CSA (mm²)	95	1.5	2.5	25	35	
Loaded cores	3	2	2	3	3	
Kd (distribution factor)	1.00	0.50	0.50	1.00	1.00	
LF (load factor = Pavg/S = Iavg/Imax)	0.36	0.12	0.25	0.12	0.10	
Kf (load form factor)	1.08	1.06	1.23	1.06	1.43	
PF (power factor)	0.90	0.90	0.90	0.90	0.90	
loss ratio on Imax	1.67%	0.38%	0.68%	0.63%	0.61%	2.26%
loss ratio on Iavg	1.39%	0.32%	0.50%	0.53%	0.38%	1.83%

The electrical losses in this electrical installation defined by the parameters listed in Table 1-8 are about 2.26% of the total transported electricity consumed by the loads.

1.1.9.4.3 Estimated industry sector cable losses

In the industry sector and in most cases in the services sector the electrical installation network is designed and worked out by means of an integrated calculation software tool. The IEC recommends a maximum voltage drop at the connection terminals of the electric load (the end point of the circuit) of 3% for lighting circuits and 5 %for other circuits, when supplied from public voltage distribution (see Table 1-16). The recommended limits for installations when supplied from private LV power supplies are even higher (6% for lighting circuits, 8% for other circuits). Consider that this is a recommendation (presented in an informative annex of standard IEC 60634-5-52) and only provides some guidance to designers. In some countries the IEC recommendations are in fact legal requirements, while in other countries similar requirements can be included in local legislation.

Based upon the following assumptions:
- designers use the above mentioned recommendation to design the electrical installation;
- in general the loads in the industry have a rather high load factor;
- most of the energy is transported via dedicated circuits with a high distribution factor (limited number of terminals/loads per dedicated circuit);

one can conclude that:
- the losses in cables in the electrical installation in the industry sector will be between 1% and 8%.

A loss ratio of 2% mentioned in 1.1.9.3.3 is plausible. The following tasks will continue to estimate this loss ratio.

1.1.9.4.4 Summary of estimated cable losses

Looking at the results in the previous sections the calculated losses are in line with the average result of about **2% losses** for electrical installations **in the services and**

industry sector, concluded in the EGEMIN study[20]. The calculated losses in the residential sector, however, are much lower (less than 0.3% compared to 2%). This can be explained by the following reasons:

- The circuits in the residential buildings are in general much shorter than the circuits in the services or industry sector. This is also confirmed by the results of the questionnaire to the installers. Only in multi-dwellings the level 1 circuits can be considerably long and can contribute significantly to the losses in the electrical installation in residential dwellings.
- The load profile (load factor and load form factor) in the residential and non-residential sector differ a lot. In the residential sector the load factor is rather low and the load form factor can be rather high. In the non-residential sector the load profile is more evenly, but with a higher average load per circuit. Again, in general the level 1 circuit in the residential sector also has a higher average load.

Most of the installers (75%) that responded to the enquiry[21] estimated that the losses in the electrical installation vary between 1% and 3%. The others (25%) estimated a loss of less than 1%.

1.1.9.5 Improvement potential by increasing the cross sectional area of the cable

The Egemin study[22] estimated that cable losses could be reduced from 2% up to **0.75%** (see Table 1-9) when applying the **economic** strategy. The study formulated four alternative strategies based on increased conductor cross-sections:

- One size up (S+1) strategy: selection of 1 standard calibre size up from the base line;
- Two sizes up (S+2) strategy: selection of 2 standard calibre sizes up from the base line;
- Economic optimum strategy: a cost minimisation algorithm is run balancing the cost represented by the energy losses over a 10 year investment horizon and the cost for initial purchase and installation of the cables;
- Energy loss minimisation (carbon footprint minimisation) strategy: a minimisation algorithm is run balancing the CO_2 equivalent of the energy losses over a 20 year lifetime horizon and the CO_2 equivalent of copper production for the cables copper weight.

[20] http://ec.europa.eu/enterprise/policies/sustainable-business/ecodesign/product-groups/

[21] This questionnaire sent to installers on the 30th of September, 2013 in the context of this study. See "Preparatory Studies for Product Group in the Ecodesign Working Plan 2012-2014:Lot 8 - Power Cables: Project Report".

[22] "Modified Cable Sizing Strategies, Potential Savings" study,Egemin Consulting for European Copper Institute, May 2011)

Table 1-9: Impact on energy losses and copper usage (averaged over all models)[22]

Strategy	Energy loss	Loss reduction	Cu weight	Additional Cu
Base	2.04%	0.00%	100.0%	0.0%
S+1	1.42%	0.62%	141.6%	41.6%
S+2	1.02%	1.02%	197.7%	97.7%
Economic	0.75%	1.30%	274.2%	174.2%
Carbon	0.29%	1.76%	907.3%	807.3%

The averaged energy loss in power cables in this study was estimated at 2.04 % and the losses can be reduced to 0.75% (loss reduction of 1.3%) applying the economic strategy to the design of the electrical installation (see Table 1-9).

The potential savings are calculated on the basis of the building annual renewal rate[23], as indicated in the table below. The older installations maintain the conventional losses pattern.

Table 1-10: Improvement scenario power cables[24]

Potential savings (starting measures in 2013)	Unit	2010	2015	2020	2025	2030
annual rate (refurbishment)		3%				
Stock of buildings - old standard installations		100%	100%	85%	70%	55%
Stock of buildings - new standard installations		0%	0%	15%	30%	45%
Improvement scenario - final energy consumption	PJprim/year	25182	27045	28277	29907	31012
Savings	PJprim/year	0	0	55	117	182
Total electricity savings	TWh/year	0	0	6	13	20

182 PJ/year of primary energy savings are forecasted by 2030 if the 'improved product' is applied in electrical installations in buildings as of 2015, which corresponds to 20 TWh/year of electric energy savings (see Table 1-10).

Review of the improvement potential

In Annex 1-B another approach is used to calculate the improvement potential of a S+x scenario, independent of a specific model. For each CSA the improvement is calculated based upon the physical parameters. Independent of the amount of cable or the CSA used, one can conclude that a S+1 scenario will reduce losses with minimum 17% and maximum 40% (see Table 1-11). The exact savings in between the minimum and maximum are determined by the amount of cable per cross-sectional areas and the cross-sectional areas of the installed cables.

[23] The refurbishment rate has been set at 3% following the rationale applied for thermal insulation products. Stakeholder Eurocopper applied higher refurbishment rates, but these have been amended to better reflect historic refurbishment rates

[24] http://ec.europa.eu/enterprise/policies/sustainable-business/ecodesign/product-groups/

Table 1-11 S+x scenario overview based upon CSA ratio (Note: these values are updated in later chapters)

CSA (S)	resistance reduction based upon CSA ratio (S+x)/S				
mm²	S+1	S+2	S+3	S+4	S+5
Minimum	17%	33%	48%	58%	67%
Maximum	40%	63%	76%	85%	91%
Average	27%	47%	61%	71%	78%
Average for CSA 1,5 till CSA 10	38%	61%	74%	83%	89%
Average for CSA 1,5 till CSA 25	36%	58%	72%	81%	86%

For instance when cables with a cross-area section of 1.5 mm² till 10 mm² are used in an electrical installation, opting for a S+1 upsizing strategy would on average reduce the power losses in the installed cables by 38% and by 61 % for the S+2 strategy, by 74% for the S+3 strategy and so on.

A reduction in losses from 2.04% to 0.75% (reduction of 1,3%) implies a resistance reduction of 63%. A scenario consisting of a combination of S+2 and S+3 strategies corresponds with such a resistance reduction.

1.1.9.6 Other improvement potential options

There are other options for lowering losses in electrical installations, e.g. reducing the load per circuit with parallel cables. These options are briefly touched in Annex 1-B and will be researched in detail in Task 4 of this report.

1.1.9.7 Conclusion from the first screening

Important note: the input data and outcomes of the first screening are used with the sole purpose to narrow the scope, they will be reviewed in later tasks.

There is a significant environmental impact.
The losses in power cables, based upon an average loss ratio of 0.3 % in the residential sector and 2% in the non-residential sector, result in an annual loss in power cables of **3.5 TWh** (0.3 % of 1177 TWh) **in the residential sector** in 2030 and **45.8 TWh** (2% of 1329+960 TWh) **in the non-residential sector in 2030, or a total of 49.3 TWh**. Even when the residential sector would be taken out of the equation, this would still mean a loss of about **46 TWh/year** in 2030.

There is significant potential for improvement.
The calculations above proof that a modified sizing strategy, S+2 will reduce the losses by 33% to 63%. With a penetration of 45 % of buildings with an electrical installation according the S+2 strategy in 2030, this would mean an overall reduction of losses in power cables by 15% to 28%. This is equal to annual savings between 7.3 TWh and 14 TWh in 2030. The maximum estimated potential **savings** with S+2 are **in between 0.5 TWh and 1 TWh in the residential secto**r and **in between 6.8 TWh and 13.0 TWh in the non-residential sector** per year. A S+1 strategy in this case (S+1

strategy not applied in the residential buildings sector and 45% penetration) would result in annual savings between 3.5 TWh and 8.24 TWh in 2030. An overview can be found in Table 1-12.

Table 1-12: Overview annual savings in 2030 (Note: these values are updated in later chapters)

		Unit	Residential sector	Services sector	Industry sector	Total	Total without residential sector
Energy consumption		TWh/y	1177	960	1329	3466.00	2289
Loss ratio		%	0.3%	2.0%	2.0%		
Losses		TWh/y	3,531	19.2	26.58	49.31	45.78
Improvement scenario penetration in 2030		%	45%	45%	45%		
S+1 strategy minimum savings	17%	TWh/y	0.27	1.47	2.03	3.77	3.50
S+1 strategy maximum savings	40%	TWh/y	0.64	3.46	4.78	8.88	8.24
S+2 strategy minimum savings	33%	TWh/y	0.52	2.85	3.95	7.32	6.80
S+2 strategy maximum savings	63%	TWh/y	1.00	5.44	7.54	13.98	12.98

There is a significant trade and sales volume.
An annual sales volume of 924 kTon copper in EU for power cables in 2030 is equal to a volume of 103820 m³ copper or an equivalent of 69213 km single core cable with a conductor CSA of 1.5 mm² or 346 km single core cable with a conductor CSA of 300 mm². At a price of 5.3 Euro/kg cable 924 kTon results in 4897 million Euro annual sales. PRODCOM statistics lists for the NACE code 27321380 "Other electric conductors, for a voltage <= 1000 V, not fitted with connectors" in 2012 for the EU28 a production of 2128 kTon and a production value of 12300 million Euro.

Losses in the residential sector are low and also the potential for environmental is low.
Losses in the residential sector are estimated at 3.351 TWh (Table 1-12) and also the improvement potential (0.27-1 TWh). Also cable loading can vary strongly between installation circuits. Non-residential it is also proposed not to focus in residential installation because the improvement potential is low (<> 2 TWh).

Conclusion on eligibility and scope:
Power cables installed in in the service and industry sector meet the criteria for "eligible" products imposed by article 15 of ecodesign directive 2009/125/EC.
Power cables installed in the residential sector do not meet the criteria for "eligible" products imposed by article 15 of ecodesign directive 2009/125/EC.
Ecodesign requirements will apply to power cables when they are placed on the market. When the cables are placed on the market, it is not known in which sector the power cables will be used and therefore residential cables should be in the scope of Tasks 1, 2

and 7 (partly) but not for Tasks 3-6 on environmental improvement potential.

1.2 Measurements/test standards

1.2.1.1 Relevant standards

Different types of EN documents are available:

- Standards (EN-xxxxx): The EN-50000 to -59999 covers CENELEC activities and the EN-60000 to -69999 series refer to the CENELEC implementation of IEC documents with or without changes.
- Technical Reports (TR): A Technical Report is an informative document on the technical content of standardization work. Only required in one of the three official languages, a TR is approved by the Technical Board or by a Technical Committee by simple majority. No lifetime limit applies.
- Harmonization Documents (HD): Same characteristics as the EN except for the fact that there is no obligation to publish an identical national standard at national level (may be done in different documents/parts), taking into account that the technical content of the HD must be transposed in an equal manner everywhere.

The most relevant standards for this study are explained in the following paragraphs.

1.2.1.1.1 EN 13601:2002 Copper and copper alloys - Copper rod, bar and wire for general electrical purposes

This European Standard specifies the composition, property requirements including electrical properties, and tolerances on dimensions and form for copper rod, bar and wire for general electrical purposes.
Cross-sections and size ranges are:

- round, square and hexagonal rod with diameters or widths across-flats from 2 mm up to and including 80 mm;
- rectangular bar with thicknesses from 2 mm up to and including 40 mm and widths from 3 mm up to and including 200 mm;
- round, square, hexagonal and rectangular wire with diameters or widths across-flats from 2 mm up to and including 25 mm, as well as thicknesses from 0.5 mm up to and including 12 mm with widths from 1 mm up to and including 200 mm.

The sampling procedures, the methods of test for verification of conformity to the requirements of this standard and the delivery conditions are also specified.

Annex A of this standard describes a general grouping of copper into 4 types:

- Tough pitch coppers (i.e. oxygen-containing coppers);
- Oxygen-free coppers;
- Deoxidized coppers;
- Silver-bearing coppers.

The main grade of copper used for electrical applications such as building wire, motor windings, cables and busbars is electrolytic tough pitch copper CW004A (Cu-ETP) which is at least 99.90% pure and has an electrical conductivity of at least 100% IACS minimum. Tough pitch copper contains a small percentage of oxygen (0.02 to 0.04%). If the high conductivity copper is to be welded or brazed or used in a reducing atmosphere, then the more expensive oxygen free high conductivity copper CW008A (Cu-OF) may be used[25].

An important electrical parameter for this study is the electrical conductivity of the copper wire, expressed in [MS/m] or Mega Siemens per meter. A derived unit is the electrical resistivity, expressed in [µΩ/m]. The minimum electric conductivity values for the different copper alloys are defined in Table 3 of the standard.

Notes:

- Copper having an electrical conductivity of 58 MS/m at 20°C (which corresponds to a volume resistivity of 0.01724 µΩ x m at 20°C) is defined as corresponding to a conductivity of 100% IACS (International Annealed Copper Standard);
- Cu-ETP(CW004A) corresponds to E-Cu58 (DIN), Cu-a1 (NF), C101 (BS), C11000 (ASTM)…

1.2.1.1.2 EN 13602:2002 Copper and copper alloys. Drawn, round copper wire for the manufacture of electrical conductors

This European Standard specifies the composition, property requirements including electrical properties, and dimensional tolerances for drawn round copper wire from 0.04 mm up to and including 5.0 mm for the manufacture of electrical conductors intended for the production of bare and insulated cables and flexible cords.
This standard covers plain or tinned, single or multiline, annealed or hard drawn wire. It does not include wire for enamelling (winding wire, magnet wire), for electronic application and for contact wire for electric traction. The sampling procedures, the methods of test for verification of conformity to the requirements of this standard and the delivery conditions are also specified.

1.2.1.1.3 IEC 60502-1: Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1,2 kV) up to 30 kV (Um = 36 kV) - Part 1: Cables for rated voltages of 1 kV (Um = 1,2 kV) and 3 kV (Um = 3,6 kV)

This standard specifies the construction, dimensions and test requirements of power cables with extruded solid insulation for rated voltages of 1 kV (Um = 1,2 kV) and 3 kV (Um = 3,6 kV) for fixed installations such as distribution networks or industrial installations. This standard includes cables which exhibit properties of reduced flame spread, low levels of smoke emission and halogen-free gas emission when exposed to fire.
Cables for special installation and service conditions are not included, for example cables for overhead networks, the mining industry, nuclear power plants (in and around the containment area), submarine use or shipboard application

For this study only the cables with a rated voltage U_0/U (U_m) of 0.6/1 (1.2kV) are considered. Whereas:

- U_0 is the rated voltage between conductor and earth or metallic screen for which the cable is designed;
- U is the rated voltage between conductors for which the cable is designed;
- Um is the maximum value of the "highest system voltage'' for which the equipment may be used (see IEC 60038).

[25] See: http://www.copperinfo.co.uk/alloys/copper/

The conductors in the scope of this standard shall be either of Class 1 or Class 2 of plain or metal-coated annealed copper or of plain aluminium or aluminium alloy, or of Class 5 of plain or metal-coated copper in accordance with IEC 60228.

The types of insulating compounds covered by this standard are listed in table xxx

Table 1-13: Insulating compounds

Insulating compound	Abbreviated designation
a) *Thermoplastic*	
Polyvinyl chloride intended for cables with rated voltages $U_0/U \leq 1{,}8/3$ kV	PVC/A*
b) *Cross-linked:*	
Ethylene propylene rubber or similar (EPM or EPDM)	EPR
High modulus or hard grade ethylene propylene rubber	HEPR
Cross-linked polyethylene	XLPE
* Insulating compound based on polyvinyl chloride intended for cables with rated voltages U_0/U = 3,6/6 kV is designated PVC/B in IEC 60502-2.	

The oversheath material shall consist of a thermoplastic compound (PVC or polyethylene or halogen free) or an elastomeric compound (polychloroprene, chlorosulfonated polyethylene or similar polymers). Halogen free sheathing material shall be used on cables which exhibit properties of reduced flame spread, low levels of smoke emission and halogen free gas emission when exposed to fire.

1.2.1.1.4 EN 60228: Conductors of insulated cables

EN 60228 specifies standardized nominal cross-section areas from 0.5 mm^2 to 2 000 mm^2, numbers and diameters of wires and resistance values of conductors in electric cables and flexible cords.

Conductors are divided into four classes

- Class 1: solid conductors;
- Class 2: stranded conductors;
- Class 5: flexible conductors;
- Class 6: flexible conductors which are more flexible than class 5.

The maximum DC resistance of conductor at 20°C is defined for each Class and each nominal cross sectional area for circular annealed, plain and metal-coated copper conductors and aluminium (alloy) conductors.

A table of temperature correction factors kt for conductor resistance to correct the measured resistance at t °C to 20°C is also included.

The measurement of conductor resistance is explained in Annex A of the standard: The measurement must be done on complete length of cable or on a sample of at least 1 meter in length. The conductor resistance at the reference temperature of 20°C is calculated with the following formula:

$$R20 = (Rt\,.\,Kt\,.1000)/L$$

Where

Kt= temperature correction factor;
R20= conductor resistance at 20°C, in Ω/km;
Rt= measured conductor resistance, in Ω;
L= length of the cable (sample), in m.

Remark:
The maximum resistance of the conductor (Ω/km) is the most important specification related to the energy losses in the power cable. An accurate measurement method to determine this resistance is therefore essential. Nevertheless some important requirements are missing in the measurement method described in Annex A of IEC 60228, such as:

- The maximum allowed uncertainty of the measurement equipment (resistance-, length- and temperature measurement equipment);
- The temperature conditions of the test room;
- The time needed for temperature stabilisation of the test sample.

The above mentioned requirements are defined in IEC 60468:" Method of measurement of resistivity of metallic materials", but this standard is only applicable to solid (non-stranded=Class 1) metallic conductor and resistor material. The maximum allowed over-all uncertainty for the routine measurement method for resistance per unit length is ± 0.4%. IEC 60228 doesn't refer to this standard.

Table 1-14: Maximum resistance of class 1 solid conductors (IEC 60228:2004)

Nominal cross-sectional area (S)	Circular, annealed copper conductors		Aluminium and aluminium alloy conductors, circular or shaped
	Plain	Metal coated	
mm²	Ω/km	Ω/km	Ω/km
0.5	36	36.7	-
0.75	24.5	24.8	-
1	18.1	18.2	-
1.5	12.1	12.2	-
2.5	7.41	7.56	-
4	4.61	4.7	-
6	3.08	3.11	-
10	1.83	1.84	3.08
16	1.15	1.16	1.91
25	0.727	-	1.2
35	0.524	-	0.868
50	0.387	-	0.641
70	0.268	-	0.443
95	0.193	-	0.32
120	0.153	-	0.253
150	0.124	-	0.206
185	0.101	-	0.164
240	0.0775	-	0.125
300	0.062	-	0.1
400	0.0465	-	0.0778
500	-	-	0.0605
630	-	-	0.0469
800	-	-	0.0367
1000	-	-	0.0291
1200	-	-	0.0247

Note: Due to low resistance values for the higher nominal cross-section areas, accurate resistance measuring equipment is needed specially in case of short cable samples (1….5 m). E.g. A 10 mm² class 1 plain annealed copper conductor has a resistance of 1.83 Ω/km, for a sample length of 1 meter this is 0.00183 Ω or 1.83 m Ω.

1.2.1.1.5 EN 50525-1:2011 Electric cables - Low voltage energy cables of rated voltages up to and including 450/750 V (U0/U) - Part 1: General requirements

The EN 50525 (series) standards supersede HD 21.1 S4:2002 and HD 22.1 S4:2002.

This European Standard gives the general requirements for rigid and flexible energy cables of rated voltages U0/U up to and including 450/750 Vac, used in power installations and with domestic and industrial appliances and equipment.

Important NOTE in this standard (Note 3): National regulations may prescribe additional performance requirements for cables that are not given in the particular requirements. For example for buildings with high levels of public access, additional fire performance requirements may be applicable.

The test methods for checking conformity with the requirements are given in other standards, e.g. EN 50395: Electric test methods and EN 50396: Non-electrical test methods.
The particular types of cables are specified in EN 50525-2 (series) and EN 50525-3 (series). The individual parts within those two series are collectively referred to hereafter as "the particular specifications". Only the sizes (conductor class, cross-sectional area), number of cores, other constructional features and rated voltages given in the particular specification apply to the individual cable type. The code designations of these types of cables are in accordance with HD 361.

Notes: National standards conflicting with EN 50525-1 have to be withdrawn on 2014-01-17

1.2.1.1.6 EN HD 21.1 S4: Cables of rated voltages up to and including 450/750V and having thermoplastic insulation – Part1: General requirements - Superseded by EN 50525-1:2011

This harmonized document applies to rigid and flexible cables with insulation and sheath, if any, based on thermoplastic materials, of rated voltages Uo/U up to and including 450/750V, used in power installations.
HD 21.1 S4 specifies the marking of the cable and extension leads, the core identifications, general requirements for the construction of the cables (conductors and insulation) and requirements for the electrical and non-electrical tests for the thermoplastic insulation materials

Note: HD 21.1 S4 is related to IEC 60227-1:1993 "Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 – Part 1: General requirements", but is not directly equivalent.
(Remark: IEC 60227-1993 and the amendment 1 and 2 is replaced by IEC 60227-1: 2007.)

HD 21.1 S4 defines for instance other types of insulation materials in comparison to IEC 60227-1:2007. HD 21.1 S4 defines types TI 1, TI 2, TI 4, TI 5 and TI 6 for conductor insulation material, whereas IEC 60227-1 defines Type PVC/C (fixed installation), PVC/D (flexible cables) and PVC/E (heat resistance cables).

1.2.1.1.7 EN HD 22.1 S4 "Cables of rated voltages up to and including 450/750V and having cross linked insulation – Part1: General requirements" - Superseded by EN 50525-1:2011

Note: HD 22.1 S4 is related to IEC 60245-1:1994 "Rubber insulated cables: Rated voltages up to and including 450/750V – Part 1: General requirements", but is not directly equivalent.

1.2.1.1.8 HD 60364-1:2008 Low-voltage electrical installations - Part 1: Fundamental principles, assessment of general characteristics, definitions

Harmonized Document 60364-1 (IEC 60364-1) gives the rules for the design, erection, and verification of electrical installations. The rules are intended to provide for the safety of persons, livestock and property against dangers and damage which may arise in the reasonable use of electrical installations and to provide for the proper functioning of those installations.

IEC 60364-1 applies to the design, erection and verification of electrical installations such as those of

a) residential premises;
b) commercial premises;
c) public premises;
d) industrial premises;
e) agricultural and horticultural premises;
f) prefabricated buildings;
g) caravans, caravan sites and similar sites;
h) construction sites, exhibitions, fairs and other installations for temporary purposes;
i) marinas;
j) external lighting and similar installations;
k) medical locations;
l) mobile or transportable units;
m) photovoltaic systems;
n) low-voltage generating sets.

IEC 60364-1 covers

a) circuits supplied at nominal voltages up to and including 1 000 Vac or 1 500 V d.c.;
b) circuits, other than the internal wiring of apparatus, operating at voltages exceeding 1 000 V and derived from an installation having a voltage not exceeding 1 000 Vac, for example, discharge lighting, electrostatic precipitators;
c) wiring systems and cables not specifically covered by the standards for appliances;
d) all consumer installations external to buildings;
e) fixed wiring for information and communication technology, signalling, control and the like (excluding internal wiring of apparatus);
f) the extension or alteration of the installation and also parts of the existing installation affected by the extension or alteration.

The different types of system earthing are explained in paragraph 312.2 of the standard. The system earthing configuration is expressed by a 2 letter combination. The first letter gives the relationship of the power system to earth:

- T= direct connection of one point to the earth
- I= all live parts isolated from earth, or one point connected to earth through a high impedance

The second letter gives the relationship of the exposed-conductive parts of the installation to earth:

- T= direct electrical connection of exposed-conductive-parts to earth, independently of the earthing of any point of the power system
- N= direct electrical connection of the exposed-conductive-parts to the earthed point of the power system.

The following system earthing configurations are most common:

1. **TN systems,** with some additional configurations:
    - TN-S (Separated, neutral conductor and earth conductor are separated);
    - TN-C (Common: neutral conductor and earth conductor are common);
    - TN-C-S (Common-Separated: in a first part of the installation the neutral and earth conductor are common in a second part of the installation they are separated. After separation they must remain separated!).

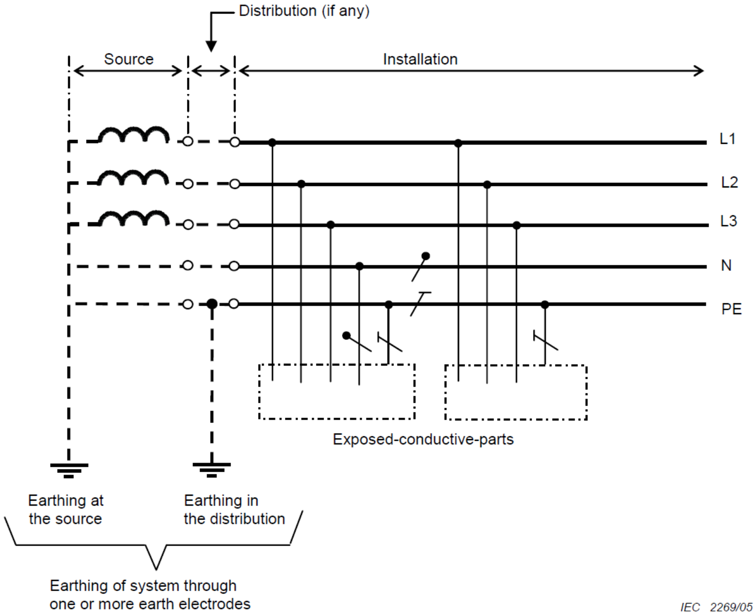


Figure 1-8: TN-S system with separate neutral conductor and protective conductor throughout the system

2. TT systems

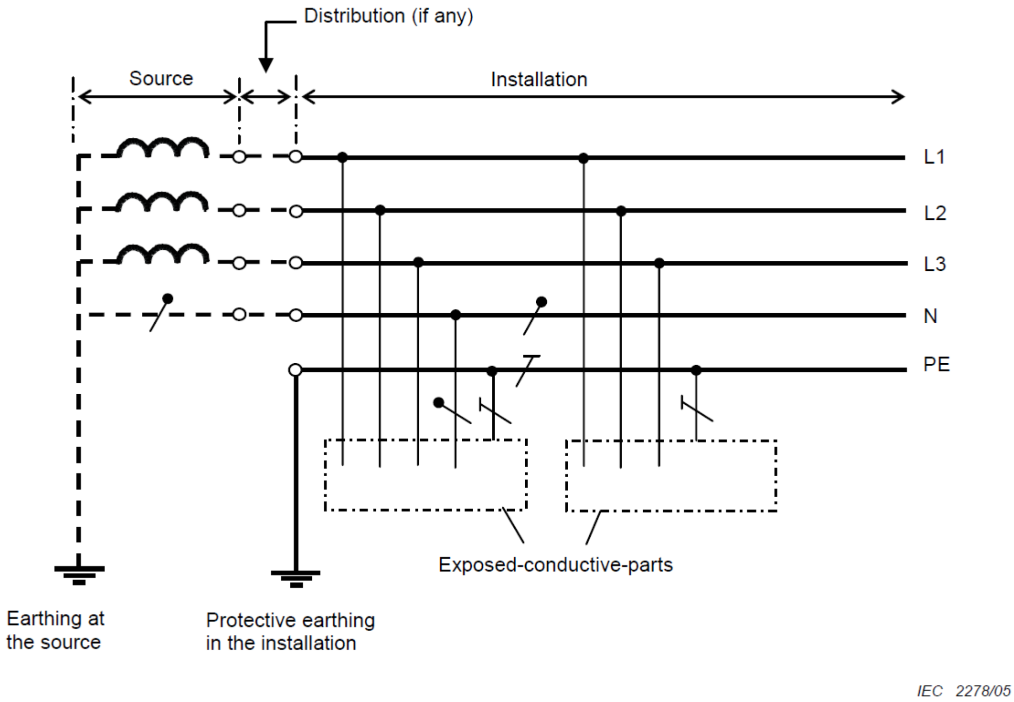


Figure 1-9: TT system with separate neutral conductor and protective conductor throughout the installation

3. IT systems

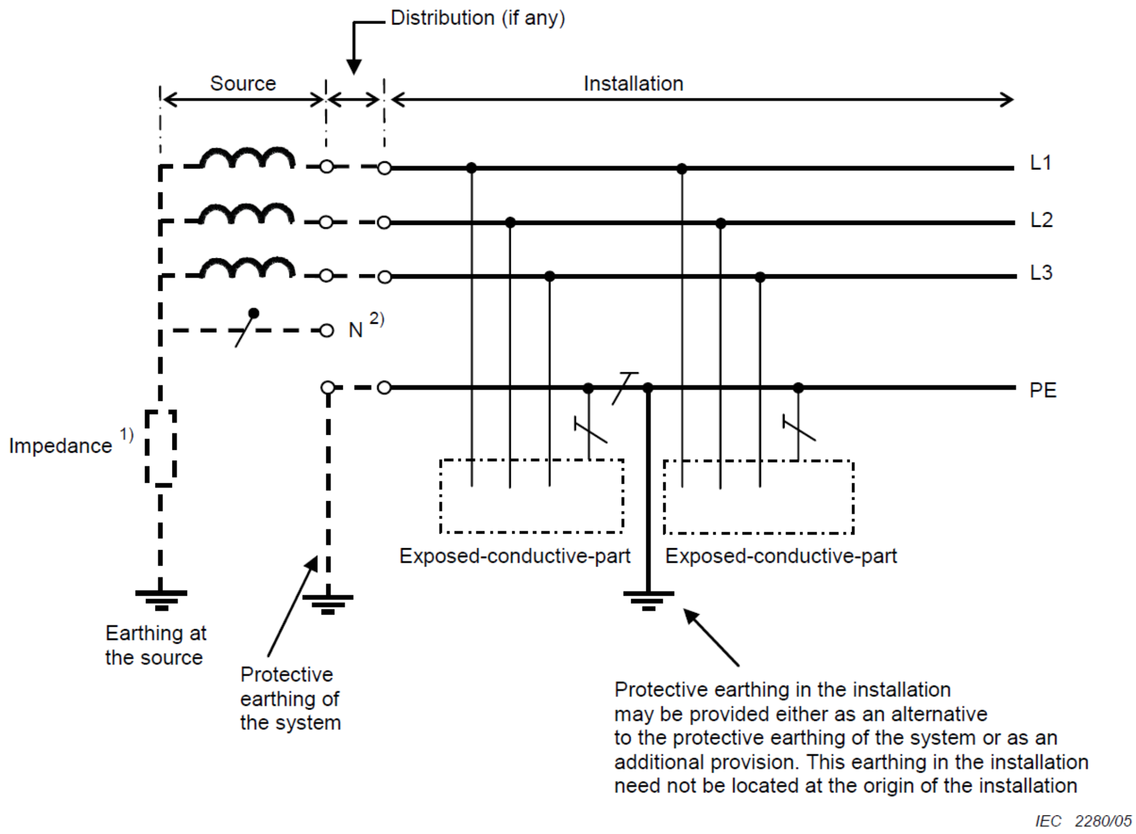


Figure 1-10: IT system with all exposed-conductive-parts interconnected by a protective conductor which is collectively earthed.

1.2.1.1.9 HD 60364-5-52:2011: Low-voltage electrical installations - Part 5-52: Selection and erection of electrical equipment - Wiring systems

IEC 60364-5-52:2009 contains requirements for:

- Selection and erection of wiring systems in relation to external influences, such as:
  - Ambient temperature (AA);
  - Presence of water (AD) or high humidity (AB);
  - Presence of solid foreign bodies (AE);
  - …

- Determination of the current-carrying capacities which depends on:
  - Maximum operating temperature of the insulation material (PVC: 70°C, XLPE: 90°C..);
  - The ambient temperature (Reference temperature is 30°C, the current-carrying capacity decreases with increasing temperatures);
  - The method of installation (examples of methods of installation are defined in the Annex of the standard);
  - The amount of single core or multi core cables grouped (in e.g. a cable tray).

This standard also defines the minimum cross-sectional area of conductors (see Table 1-15)

Table 1-15: HD 60364-5-52:2011 minimum cross-sectional area

Type of wiring system		Use of the circuit	Conductor	
			Material	**Cross-sectional area mm^2**
Fixed Installations	Cables and insulated conductors	Power and lighting circuits	Copper	1,5
			Aluminium	To align with cable standard IEC 60228 (10 mm^2) (see note 1)
		Signalling and control circuits	Copper	0,5 (see note 2)
	Bare conductors	Power circuits	Copper	10
			Aluminium	16
		Signalling and control circuits	Copper	4
Connections with flexible insulated conductors and cables		For a specific appliance	Copper	As specified in the relevant IEC standard
		For any other application		0,75[a]
		Extra-low voltage circuits for special applications		0,75

NOTE 1 Connectors used to terminate aluminium conductors should be tested and approved for this specific use.

NOTE 2 In signalling and control circuits intended for electronic equipment a minimum cross-sectional area of 0,1 mm^2 is permitted.

NOTE 3 For special requirements for ELV lighting see IEC 60364-7-715.

NOTE 4 In the UK, 1,0mm^2 cable is allowed for use in lighting circuits.

NOTE 5 In the UK 1,0 mm^2 copper cable is allowed for fixed installations utilizing cables and insulated conductors for power and lighting circuits.

[a] In multi-core flexible cables containing 7 or more cores, NOTE 2 applies.

The minimum cross-sectional area for conductors used in fixed installations is 1.5 mm² for copper and 10 mm² (!) for aluminium, as mentioned in Table 1-15. In the UK 1.0mm² copper cable is allowed for fixed installations utilizing cables and insulated conductors for power and lighting circuits (see Note 5).
Remark: In IEC 60228 there are no specifications defined for Aluminium conductors smaller than 10mm².

Special attention is needed for dimensioning the cross-sectional area of the neutral conductor (paragraph 524.2). In applications (e.g. IT infrastructure) where the third harmonic and odd multiples of third harmonic currents are higher than 33%, total harmonic distortion, it may be necessary to increase the cross-sectional area of the neutral conductor. In some cases the cross sectional area of the neutral conductor has to be dimensioned on 1.45xIb of the line conductor.

The informative Annex G of the standard determines maximum Voltage drop values for consumers' installations. The voltage drop is defined as the voltage difference between the origin of an electrical installation and any load point (see Table 1-16 for voltage drop values for lighting and other uses)
This annex is informative so in fact not obligatory.

Table 1-16: Voltage drop values for lighting and other uses

Type of installation	Lighting %	Other uses %
A – Low voltage installations supplied directly from a public low voltage distribution system	3	5
B – Low voltage installation supplied from private LV supply[a]	6	8
[a] As far as possible, it is recommended that voltage drop within the final circuits do not exceed those indicated in installation type A. When the main wiring systems of the installations are longer than 100 m, these voltage drops may be increased by 0,005 % per metre of wiring system beyond 100 m, without this supplement being greater than 0,5 %. Voltage drop is determined from the demand by the current-using equipment, applying diversity factors where applicable, or from the values of the design current of the circuits.		

The higher these voltage drop values the higher the energy losses in the cable *(e.g. for a resistive load a voltage drop of 5% is equal to an energy loss of 5%).*

Annex I of the standard contains an overview of deviations and/or additional requirements at member state level.

1.2.1.1.10 HD 361 S3:1999/A1:2006 System for cable designation

This Harmonisation Document details a designation system for harmonized power cables and cords, of rated voltage up to and including 450/750 V. (see Table 1-17)

Table 1-17: Cable designation system

Symbol	Relationship of Cable to Standards
H	Cable conforming with harmonised standards
A	Recognised National Type of cable listed in the relevant Supplement to harmonised standards
Symbol	**Value, Uo/U**
01	=100/100V; (<300/300V)
03	300/300V
05	300/500V
07	450/750V
Part 2 of the Designation	
Symbol	**Insulating Material**
B	Ethylene-propylene rubber
G	Ethylene-vinyl-acetate
J	Glass-fibre braid
M	Mineral
N	Polychloroprene (or equivalent material)

N2	Special polychloroprene compound for covering of welding cables according to HD 22.6
N4	Chlorosulfonated polyethylene or chlorinated polyethylene
N8	Special water resistant polychloroprene compound
Q	Polyurethane
Q4	Polyamide
R	Ordinary ethylene propylene rubber or equivalent synthetic elastomer for a continuous operating temperature of 60ºC
S	Silicone rubber
T	Textile braid, impregnated or not, on assembled cores
T6	Textile braid, impregnated or not, on individual cores of a multi-core cable
V	Ordinary PVC
V2	PVC compound for a continuous operating temperature of 90ºC
V3	PVC compound for cables installed at low temperature
V4	Cross-linked PVC
V5	Special oil resistant PVC compound
Z	Polyolefin-based cross-linked compound having low level of emission of corrosive gases and which is suitable for use in cables which, when burned, have low emission of smoke
Z1	Polyolefin-based thermoplastic compound having low level of emission of corrosive gases and which is suitable for use in cables which, when burned, have low emission of smoke

Symbol	**Sheath, concentric conductors and screens**
C	Concentric copper conductor
C4	Copper screen as braid over the assembled cores

Symbol	**Sheath, concentric conductors and screens**
D	Strain-bearing element consisting of one or more textile components, placed at the centre of a round cable or tributed inside a flat cable
D5	Central heart (non strain-bearing for lift cables only)
D9	Strain-bearing element consisting of one or more metallic components, placed at the centre of a round cable or distributed inside a flat cable

Symbol	**Special construction**
No Symbol	Circular construction of cable
H	Flat construction of “divisible” cables and cores, either sheathed or non-sheathed
H2	Flat construction of “non-divisible” cables and cores
H6	Flat cable having three or more cores, according to DH 359 or EN 50214
H7	Cable having a double layer insulation applied by extrusion
H8	Extensible lead

Symbol	**Conductor material**
No Symbol	Copper
-A	Aluminium

Symbol	Conductor form
-D	Flexible conductor for use in arc welding cables to HD 22Part 6 (flexibility different from Class 5 of HD 383)
-E	Highly flexible conductor for use in arc welding cables to HD22 Part 6 (flexibility different from Class 6 of HD 383)
-F	Flexible conductor of a flexible cable or cord (flexibility according to Class 5 of HD 383)
-H	Highly flexible conductor of a flexible cable or cord (flexibility according to Class 6 of HD 383)
-K	Flexible conductor of a cable for fixed installations (unless otherwise specified, flexibility according to Class 5 of HD 383)
-R	Rigid, round conductor, stranded
-U	Rigid round conductor, solid
-Y	Tinsel conductor

Part 3 of the Designation

Symbol	Number and size of conductors
(number)	Number, n of cores
X	Times, where a green/yellow core is not included
G	Times, when a green/yellow core is included
(number)	Nominal cross-section, s, of conductor in mm^2
Y	For a tinsel conductor where the cross-section is not specified

NOTE The use of the system for Recognised National Types of cable or cord has been withdrawn by CENELEC TC 20. For non-harmonised cables of rated voltage up to and including 450/750 V, National Committees are permitted to use any designation that does not conflict with this HD.

The designation codes of these National normalized cables are defined in national standards, e.g. in Germany according to DIN VDE xxxx, in France according to UTE NF Cxxxx, in Belgium according to NBN xxxx, etc...

1.2.1.1.11 HD 604 S1 1994: 0,6/1 kV and 1,9/3,3 kV power cables with special fire performance for use in power stations

HD 604 applies to rigid and flexible conductor cables for fixed installations having a rated voltage Uo/U of 0.6/1 kV or 1.9/3.3 kV. The insulation and sheaths may be mainly intended for use in power generating plants and sub-stations. All cables have specific fire performance requirements.
Note: The HD 604 cables can also be used in other applications such as residential and industrial electrical installations.

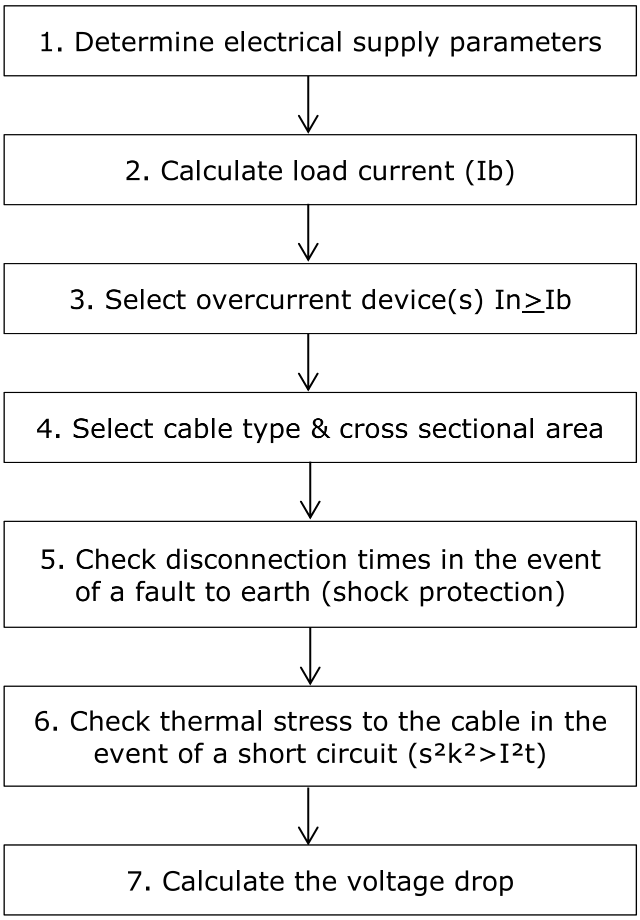
1.2.1.1.12 TR 50480 Determination of cross-sectional area of conductors and selection of protective devices

This Technical Report applies to low-voltage installations with a nominal system frequency of 50 Hz in which the circuits consist of insulated conductors, cables or busbar trunking systems. It defines the different parameters used for the calculation of the characteristics of electrical wiring systems in order to comply with rules of HD 384/HD 60364.

Remarks:

1. This Technical Report is also applicable for checking the compliance of the results of calculations performed by software programs for calculation of cross-sectional area of insulated conductors, cross-sectional area of cables and characteristics for selection of busbar trunking systems with HD 384/HD 60364.
2. Effects of harmonics currents are not covered by this document.
3. The NORMAPME User Guide for European SME's on CENELEC TR 50480 describes the design procedure for an electric circuit. The procedure is summarized in the flow diagram below:

Figure 1-11: Design procedure for an electric circuit



1.2.1.1.13 IEC 60287-1-1 Electric cables – Calculation of the current rating –Part 1-1: Current rating equations (100 % load factor) and calculation of losses – General

Applicable to the conditions of steady-state operation of cables at all alternating voltages, and direct voltages up to 5 kV, buried directly in the ground, in ducts, troughs or in steel pipes, both with and without partial drying-out of the soil, as well as cables in air. The term "steady state" is intended to mean a continuous constant current (100 % load factor) just sufficient to produce asymptotically the maximum conductor temperature, the surrounding ambient conditions being assumed constant. The standard provides formulae for current ratings and losses. The formulae given are essentially literal and designedly leave open the selection of certain important parameters. These may be divided into three groups:

- parameters related to construction of a cable (for example, thermal resistivity of insulating material) for which representative values have been selected based on published work;
- parameters related to the surrounding conditions, which may vary widely, the selection of which depends on the country in which the cables are used or are to be used;
- parameters which result from an agreement between manufacturer and user and which involve a margin for security of service (for example, maximum conductor temperature).

1.2.1.1.14 IEC 60287-3-2 Electric cables - Calculation of the current rating - Part 3-2: Sections on operating conditions - Economic optimization of power cable size

IEC 60287-3-2:2012 sets out a method for the selection of a cable size taking into account the initial investments and the future costs of energy losses during the anticipated operational life of the cable. Matters such as maintenance, energy losses in forced cooling systems and time of day energy costs have not been included in this standard.

For energy efficiency purpose, the most relevant element of the electrical installation is the fixed wiring. The international standard wire sizes are given in the IEC 60228 standard of the International Electro technical Commission.
One important impact on wire size selection for installations comes from the so-called electrical code. In European countries, an attempt has been made to harmonize national wiring standards in an IEC standard, IEC 60364 Electrical Installations for Buildings. Hence national standards follow an identical system of sections and chapters. However, this standard is not written in such language that it can readily be adopted as a national wiring code. As a result many European countries have their own national wiring regulations and/or electrical installation codes, e.g. AREI (Belgium), NFC 15-100 (France), VDE-100 (Germany), BS 7671 (UK), NN1010 (the Netherlands),CEI 64-8 (Italy), etc.

These national regulations can be different from the international and European standards. This means that wiring typology and acronyms are different from country to country as well as the complementary electrical installation code. They have an important impact on cable losses and as requested, an overview of the IEC, European and national standards will be worked out and differences between these standards will briefly be explained in this chapter.

Gap identified:

This calculation method is only elaborated for a single cable segment with one supply source and a single load; it does not describe a circuit with multiple sources and/or loads.
There are no benchmark values or typical reference calculations included that can be used to validate calculation tools. There are no typical load profiles for common building loads included, such as HVAC, lighting, elevator, ..

1.2.1.2 Comparative analysis of existing test standards (if applicable)

EN 50395:2005 Electrical test methods for low voltage energy cables

EN 50395 contains electrical test methods required for the testing of harmonized low voltage energy cables, especially those rated at up to and including 450/750 V.

NOTE 1 A description of the origin of these test methods and the background to this European Standard is given in the Introduction and in Annex B. The particular cable standard dictates the tests which need to be performed on the relevant cable type. It also specifies whether the specific test is a type test (T), a sample test (S) or a routine test (R) for the particular cable type.
NOTE 2 T, S and R are defined in the relevant cable standard. The requirements to be met during or after the test are specified for the particular cable type in the relevant cable standard. However, some test requirements are obvious and universal, such as the fact that no breakdown shall occur during voltage tests, and these are stated in the particular test method. Test methods for use specifically in utility power cables are not covered by this European Standard. They can be found in HD 605. Test methods for use specifically in communications cables are the responsibility of the Technical Committee CENELEC TC 46X, Communication cables. At present such test methods are given in EN 50289 series.

Remarks:

- Reference is made to Annex A of EN 60228 for testing the electrical d.c. resistance of conductor (see paragraph 5).
- IEC 60468: “Method of measurement of resistivity of metallic materials” defines a more detailed approach for determining the resistivity of solid metallic conductors compared to the EN 60228 approach

IEC 60364-6: Low-voltage electrical installations – Verification

IEC 60364-6 provides requirements for initial verification, by inspection and testing, of an electrical installation to determine, as far as reasonably practicable, whether the requirements of the other parts of IEC 60364 have been met, and requirements for the reporting of the results of the initial verification. The initial verification takes place upon completion of a new installation or completion of additions or of alterations to existing installations.
This standard also provides requirements for periodic verification of an electrical installation to determine, as far as reasonably practicable, whether the installation and all its constituent equipment are in a satisfactory condition for use and requirements for the reporting of the results of the periodic verification.

1.2.1.3 New standards under development

IEC 60364-8-1 / HD 60364-8-1: 2015: Low voltage electrical installation - Part 8-1: Energy efficiency

The new HD 60364-8-1:2015 standard provides guidance to optimize the efficiency of the whole electrical installation. This part of IEC 60364 provides additional requirements, measures and recommendations for the design, erection and verification of electrical installations including local production and storage of energy for optimizing the overall efficient use of electricity. It introduces requirements and recommendations for the design of an electrical installation in the frame of an Energy Efficiency management approach in order to get the best permanent like for like service for the lowest electrical energy consumption and the most acceptable energy availability and economic balance. These requirements and recommendations apply for new installations and modification of existing installations. This standard is applicable to the electrical installation of a building or system and does not apply to products.

Cables are a means to carry power and are part of an electrical installation. The standard therefore takes into consideration the usage of the load or application for the whole installation and the design of the installation to maximize the efficiency of the wiring system. It indicates that the implementation of electrical energy efficiency needs to have an integrated approach of the electrical installations as optimization of the electrical energy consumption requires consideration of all types and operations of these installations.

Reduction of energy losses in wiring is one of the many design requirements that are mentioned in this standard. These losses can be reduced by:

- Reducing the voltage drop in the wiring by reducing the losses in the wiring. Reference is made to IEC 60364-5-52 for recommendation on the maximum voltage drop;
- Increasing the cross sectional area of conductors. Reference is made to IEC 60287-3-2 for an Economic optimization of power cable size;
- Power factor correction to improve the power factor of the load circuit. This will decrease the amount of reactive energy consumption in the cable;
- Reduction of harmonic currents at the load level reduces thermal losses in the wiring.
- Introduction of meshes in an electrical installation to optimize the number and allocation of circuits.

Besides the above mentioned recommendations the standards emphasizes that measurement is one of the primary key for electrical energy efficiency. It recommends:

- To audit the energy consumption for having an indication of the situation and the main avenues to pursue saving;
- To optimize through permanent automation or control;
- To monitor, maintain and improve the electrical installation.

The standard mentions a renewal rate of existing electrical installations of around 2% in mature economies and 5% in fast growing economies.
The standard takes into consideration the energy efficiency life cycle of an electrical installation, meaning how the energy efficiency of the installation can be improved and/or maintained. It introduces a performance program and associated energy

efficiency rating for electrical installations. Verification by means of audits or permanent monitoring and periodic maintenance are some of the recommendations in this context.

The standard acknowledges that most of the progress can be made in existing installations due to rather low renewal rate of existing installations. It estimates it will take around 25 years in mature economies and 10 years in fast growing economies to address half of the installations, when only considering new installations. Therefore this standard did not only cover new installations but also existing installations.

For the calculations of cable losses and economic optimization reference is made to IEC 60287-3-2, see section 1.2.1.1.14

Gaps identified:
There are no benchmark values or typical reference calculations included that can be used for setting efficiency targets and serve to validate/verify software tools. There are no typical load profiles for common building loads included, such as HVAC, lighting, elevator, ..

IEC TR 62125 Environmental statement specific to IEC TC 20 – Electric cables
"Annex A.4 Considerations for use and end of life phase [...] 2) Has information been given to the user on the fact that the choice of transmission/distribution voltage and the conductor cross-section will seriously influence the current transmission losses?"
This TR might evolve into a standard in the years to come (Europacable)

1.3 Existing legislation

1.3.1 Key methodological issues related to existing legislation

This task identifies and analyses the relevant legislation for the products. It is subdivided in three parts:

Subtask 1 - Legislation and Agreements at European Union level
This section identifies and shortly describes the relevance for the product scope of any relevant existing EU legislation, such as on resource use and environmental impact, EU voluntary agreements and labels.

Subtask 2 - Legislation at Member State level
This section includes a comparative analysis of any relevant existing legislation at Member State level, such as on resource use and environmental impact, voluntary agreements and labels.

Subtask 3 - Third Country Legislation
This section includes a comparative analysis of any relevant existing legislation in third countries, such as on resource use and environmental impact, voluntary agreements and labels.

1.3.1.1 Legislation and Agreements at European Union level

In the regulation and electrical code for electrical wiring in force worldwide, cable sizing is generally a function of the following factors:

- Maximum voltage drop: this criterion is usually decisive when sizing long cables;

- Maximum current in wiring (to avoid cable overheating): this criterion is generally determinative when sizing short cables;
- Temperature of the conductor;
- Emergency or short circuit current rating capacity of the wire;
- Installation mode.

Most of the above criteria were selected on the basis of safety reasons or proper equipment operation concerns, rather than on the basis of an objective of energy loss reduction. For instance, IEC 60364 has requirements for protection against overcurrent, a minimum cable cross section requirement for mechanical strength and a maximum voltage drop. This maximum voltage drop requirement varies according to the ownership of wiring (private vs. public), the end usage (lighting vs. others) and the length of the wire.

The following European directives might be related to the electrical installation/ energy cables within the scope of this study:

- **Directive 89/336/EEC 'Electromagnetic compatibility'**: Energy cables shall be considered as 'passive elements' in respect to emission of, and immunity to, electromagnetic disturbances and are as such exempted. Note: Certain accessories may be susceptible to electromagnetic interference ! (IEC 60076-1).

- **Directive 2002/95/EC: Restriction of Hazardous Substances in electrical and electronic equipment**: Cables in the scope of RoHS should be compliant either at the due date of the EEE category they fall in, or in 2019 if not dedicated to any EEE specific category. External cables placed on the market separately that are not part of another electrical and electronic equipment (EEE) must meet the material restrictions and will need their own Declaration of Conformity and CE marking from the relevant date.. The directive is restricted to categories for use with a voltage rating not exceeding 1 000 Volt for alternating current. Cable manufacturers adhere to the European RoHS* directive for electrical materials, and participate to recycle for copper and plastics
- **The Construction Products Regulation (EU) No 305/2011 (CPR)** is replacing the Construction Products Directive (EU) No 89/106/EEC (CPD) since July 1, 2013. CE marking of cables regarding fire performance is mandatory within the CPR and will be possible once all the necessary standards are issued and endorsed by the EC. In order to perform CE-marking a so called harmonized product standard is needed in addition to the test a classification standards. The product standard describes the construction of cable families. The current document is termed Fpr EN 50575: "Power, control and communication cables - Cables for general applications in construction works subject to reaction to fire requirements".

  According to CENELEC JWG M/443 an optimistic scenario would be that CE marking can start by early 2015 and will be obligatory by early 2016 (assuming the minimum default one year transition time)[26]

- **Directive 2006/95/EC 'Low voltage equipment'**: For the purposes of this Directive, 'electrical equipment' means any equipment designed for use with a voltage rating of between 50 and 1 000 V for alternating current (and between 75 and 1 500 V for direct current, other than the equipment and phenomena listed in Annex II of the Directive). Please note that LVD is applicable to independent low-voltage equipment placed on EU market which is also used in

[26] Status summary of cable reaction to fire regulations in Europe by SP Technical Research Institute of Sweden & SINTEF NBL Norwegian Fire Research Laboratory

installations, such as control circuits, protection relays, measuring and metering devices, terminal strips, etc. " and thus must carry the CE label.

According to the EU-Commission's guide on the Low Votlage Directive (LVD GUIDELINES ON THE APPLICATION OF DIRECTIVE 2006/95/EC, last modified January 2012); cables (and in general wiring material) is in the scope of the LVD and therefore, must be CE-marked. In addition to the CE-mark, cables will be marked with HAR to increase the tractability. See Annex II of the above mentioned LVD guide.

- **Directive 98/37/EC on the approximation of the laws of the Member States relating to machinery.** The machinery directive is not applicable for power cables as such but may be applicable on certain accessories in the electrical installation.

- **Directive 2002/96/EC on 'Waste Electrical and Electronic Equipment' (WEEE)** is not applicable as power cables are not falling under the categories set out in Annex IA of the directive.

- **Directive 2010/31/EU: Energy Performance of Buildings Directive** and is a revision of Directive 2002/91/EC. Under this Directive, Member States must establish and apply minimum energy performance requirements for new and existing buildings, ensure the certification of building energy performance and require the regular inspection of boilers and air conditioning systems in buildings. Moreover, the Directive requires Member States to ensure that by 2021 all new buildings are so-called 'nearly zero-energy buildings'.

- **Guidelines** accompanying Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012 supplementing Directive 2010/31/EU of the European Parliament and of the Council on the energy performance of buildings by establishing a comparative methodology framework **for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements** (2012/C 115/01). The electrical installation is **not** included in the current guidelines as a cost element to be taken into account for calculating initial investment costs of buildings and building elements.

- REACH is the Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals. It entered into force on 1st June 2007. It streamlines and improves the former legislative framework on chemicals of the European Union (EU). This directive is applicable to all the chemical substances that are manufactured and/or marketed in the EU

1.3.1.2 Legislation at Member State level

In general, the national wiring codes of the European countries (see Table 1-18) are based on the IEC 60364 x-xx standards. Most of the European countries have additional national wiring rules. Table 8-1 in Annex 1-A gives an overview of the supply parameters and domestic installation practices from some European countries (Austria, Belgium, Denmark, Germany, Italy, Norway, Spain and United Kingdom)

Table 1-18: EU 28 National wiring codes

Country	National Wiring code
Austria	ÖVE/ÖNORM E8001
Belgium	A.R.E.I/R.G.I.E
Bulgaria	
Croatia (EU28 2013)	
Cyprus	
Czech Republic	
Denmark	Staerkstrombekendtgorelsen 6
Estonia	
Finland	SFS 6000 (based on IEC 60364)
France	NFC 15-100
Germany	VDE 0100
Greece	ELOT HD384
Italy	IEC EN 64-8
Greece	
Hungary	
Ireland	
Italy	CEI 64-8
Latvia	
Lithuania	
Luxembourg	
Malta	
Netherlands	NEN 1010
Poland	
Portugal	UNE 20460
Romania	
Slovakia	
Slovenia	
Spain	UNE 20460
Sweden	SS4364661/ELSÄK-FS 1999:5
UK	BS7671 16° Edition IEE Wiring Regulations

The designation codes of National normalized cables are defined in national standards, e.g. in Germany according to DIN VDE xxxx, in Belgium according to NBN xxxx, etc.

Legislation on environmental aspects:

Environmental Product Declaration (EPD) (source: Europacable):
French decree (2013-1264): The Order related to environmental product declarations for construction and decoration products intended for use in buildings was published in Official Journal No. 0302 from December 29th 2013. It defines the content of environmental declarations and the LCA methodologies and calculation rules applicable (see http://www.developpement-durable.gouv.fr/-La-declaration-environnementale,7322-.html)

The Norwegian legislation on recycling and treatment of Waste (FOR-2004-06-01-930) has a dedicated section for cables (Amendment 1 on Product groups for EE-products and EE-waste – § 12 on cables and wires)

1.3.1.3 Third Country Legislation

Scope:
This section again looks at legislation and measures in Third Countries (extra-EU) that have been indicated by stakeholders as being relevant for the product group.

IMPORTANT NOTICE ON THE DIFFERENCES IN INTERNATIONAL LINE VOLTAGE STANDARDS:
All European and most African and Asian countries use a supply that is within 10% of 230 V at 50 Hz, whereas Japan, North America and some parts of South America use a voltage between 100 and 127 V at 60 Hz.

A number of building energy guidelines, standards or codes go beyond the existing electrical safety and operational requirements by adopting more stringent maximum voltage drop requirements to limit circuit impedance and thereby wiring energy loss. In North America, the "Energy Standard for Buildings Except Low-Rise Residential Buildings" of the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE/ IESNA 90.1), as well as the National Energy Code for Buildings of Canada (NECB 2011) are two examples.

1.3.1.4 Voluntary initiatives

The **ELEKTRO+ Initiative** in Germany is designed to assist in the planning and installation of electrical systems in flats and houses. It covers the following areas:

- scope and complexity of the electrical installation,
- safety,
- comfort,
- energy efficiency.

Awareness among building owners and renovators for safer and more energy sustainable electrical installation has been in decline for years. Even in new houses electrical systems are often inadequate for the size of the building and fail to meet minimum standards. There is a shortage of switches, sockets, lighting points, communication devices and electrical circuits.

In older buildings the situation is even more critical. There are approximately 10.6 million occupied housing units in Germany built before 1949. The majority of these still use their original electrical systems which fall well below the needs of today's residents.

The demands of modern household appliances push these old electrical installations to their limits. Residents are often unaware of the dangers. This **overloading** is reflected in the high incidence of household fires; 10 – 15% being caused by the smouldering of electrical cables and through the use of defective appliances.

The inadequate provision of electrical power points in houses leads to **the use of multi-socket connectors and extension leads**. This puts a permanent overload onto the electrical circuits, considerably raising the risk of fire. By providing additional socket-outlets and circuits the cables will be less loaded on average.

The service life of an electrical installation is 40 to 45 years, so the decision to fit an up to date system, meeting modern standards, will have a beneficial effect on the quality and value of the building.

For this reason the **HEA** – Fachgemeinschaft für effiziente Energieanwendung e.V. has been working for decades on the standardisation of electrical systems and has developed, on the basis of the **minimum standard (DIN 18015**), its own set of HEA Electrical Installation Values.

In the interests of ensuring better consumer protection the HEA, together with the Zentralverband Elektrotechnik- und Elektronikindustrie e.V. (ZVEI), founded the ELEKTRO+ Iniative to inform building owners and renovators about planning standards.

The ELEKTRO+ Initiative presents the standards and directives on electrical installation in houses and flats as readily accessible information for planners (architects, consultant electrical engineers and electrical contractors). This information is also designed to help building owners and home buyers to better understand and have a greater say in the planning of their electrical systems.

The ELEKTRO+ Initiative provides objective information for these target groups on the planning and installation of electrical systems both for new buildings and for modernisation projects.

The Approved Cables Initiative in the UK was established in March 2010 to address the issue of unsafe, non-approved and counterfeit cable entering the UK marketplace. With industry and regulator support, the ACI is taking a proactive and hard hitting approach to educate the electrical supply chain – from manufacturers to end users through a comprehensive communication schedule of seminars, marketing material and articles to national trade media**.**

The Product Environmental Profile (PEP) Eco passport (http://www.pep-ecopassport.org/p-e-p-association): is an environmental identity card for electrical and HVAC-R products. It allows the results of a Life Cycle Analysis to be presented appropriately and in accordance with international standards (ISO14025, 14040 and 14044).
The PEP association consists of manufacturers, users, institutional and professional associations. It is responsible for implementing the PEP Eco passport ®, which is recognised as the benchmark for good practices in terms of environmental communication

Some cables manufacturers provide **tools to calculate the economic optimum section** based on the use conditions (Europacable):

A number of software tools (see Table 1-19) exist for the design of electrical installations, some of them offering the possibility to run energy efficiency calculations and potential optimization.

Table 1-19 Non exhaustive list of software tools for the design of electrical installations, providing economic sizing feature or not[27]

Software	Manufacturer	Economic sizing			Remarks
		Standard	Optional	External	
Caneco BT	ALPI Software	No	Partly Investment estimation only	Yes, through export and import to and from external processing (proven)	Modular software, features depend on actual licensed configuration
TR-ciel (legacy) Elec Calc	Trace Software	No	Partly Investment estimation only	No clear information on export and import facilities	Features depend on installed options (TR-ciel) Unclear for successor Elec Calc
Kitgoni	Kitgoni SPRL	Yes	/	/	The URE module (Utilisation Rationnelle de l'Energie), is standard included, the user only has to choose to use it.
Simaris design	Siemens	No	No	No	Import & export facilities can be extend through Simaris project software
Ecodial	Schneider Electric	No	No	No	
Solutions Electrical	Solutions Electrical UK	No	Partly Investment estimation only	No	

27 27 http://www.leonardo-energy.org/white-paper/economic-cable-sizing-and-potential-savings

CHAPTER 2 TASK 2: MARKETS

The objective of Task 2 is to present the economic and market analysis related to the products. The aims are:

- to place the product group within the total of EU industry and trade policy (subtask 2.1);
- To provide market and cost inputs for the EU-wide environmental impact of the product group (subtask 2.2);
- To provide insight in the latest market trends so as to indicate the place of possible Ecodesign measures in the context of the market structures and ongoing trends in product design (subtask 2.3, also relevant for the impact analyses in Task 3); And finally,
- To provide a practical data set of prices and rates to be used in a Life Cycle Cost (LCC) calculation (subtask 2.4).

Summary of results:

Input parameters for a stock and sales model were collected. Therefore the stock or stock growth rate of power cables in buildings are linked to the stock and stock growth rate of buildings respectively. The stock, stock growth rate, replacement, and demolition rates for power cables were deduced from the corresponding building parameters. Absolute stock and sales were estimated based upon these figures and verified with PRODCOM data. The input from stakeholders regarding product lifetime is taken into account.

The results can be found in Table 2-1. These values will be used in the Tasks 5 up to and including 7.

Table 2-1: Summary of cable stock, growth and sales rates

Sector	Product life	Service life	Vacancy	Stock growth rate	Demolition rate	Replace-ment sales rate	New sales rate	Total sales rate	Stock (Reference year: 2010)	
Unit	Year	Year	%	% p.a.	% p.a.	% p.a.	% p.a.	% p.a.	kTon Cu	%
Residential sector	64.00	60.80	5%	0.90%	0.10%	1.18%	0.90%	2.08%	5241	43%
Services sector	25.00	23.75	5%	1.90%	0.20%	3.20%	1.90%	5.10%	3250	26%
Industry sector	25.00	23.75	5%	2.90%	0.20%	2.80%	2.90%	5.70%	3825	31%
Total sector (weighted)	41.60	39.52	5%	1.79%	0.16%	2.22%	1.79%	4.00%	12316	100%

Installation times (see Table 2-3 for copper based cables and Table 2-4 for aluminium based cables), cable and connector prices (see Table 2-2) are defined in this chapter along with energy (Table 2-5) and financial rates (Table 2-6). For copper based power cables this study uses an average discounted cable price of 0.09434 €/ (mm². m) (year

2014). The average hourly rate in the EU28 for the year 2010 is 22.4 €/hour. The conductor material is quite valuable and recyclable, so a residual value for the conductor material has been calculated taken into account the amount of copper that can be recycled, the scrap value and a decommissioning fee. This results in a residual value of about 60% of the original conductor cost, and about 30% of the product price of the cable.

Table 2-2 connector prices

Minimum wire size	Maximum wire size	CSA	Connector price	Discounted connector price
mm^2	mm^2	mm^2	€	€
0.14	4	1	0.87	0.54
0.14	4	1.5	0.87	0.54
0.14	4	2.5	0.87	0.54
0.14	4	4	0.87	0.54
0.2	10	6	1.61	0.97
0.2	10	10	1.61	0.97
0.5	16	16	2.11	1.25
1.5	25	25	2.11	1.07
1.5	50	35	4.85	2.84
1.5	50	50	4.85	2.84
16	70	70	11.79	7.31
25	95	95	22.11	13.71
35	150	120	28.96	17.96
35	150	150	28.96	17.96
70	240	185	35.36	21.92
70	240	240	35.36	21.92
		300	44.20	27.40
		400	58.93	36.53
		500	73.67	45.67
		630	92.82	57.54

Table 2-3 installation times for Cu based cables[28]

Cu based cables		
Section	**Installation time per meter**	**Installation time for the cable ends**
mm2	Min	Min
1	1.75	5
1.5	2.45	7
2.5	3.15	9
4	3.85	12
6	5.25	12
10	5.95	15
16	7	17
25	8.75	20.4
35	9.8	25.5
50	10.5	30.6
70	11.9	36
95	12.6	45
120	14	45
150	15.75	60
185	17.5	60
240	21	85
300	24.5	120
400	28	200
500	35	360
630	42	480

[28] EUROPEAN COPPER INSTITUTE, UTILISATION RATIONNELLE DES ENERGIES APPLIQUEE AU DIMENSIONNEMENT DES NOUVELLES INSTALLATIONS ELECTRIQUES

Table 2-4 installation times for Al based cables[77]

Al based cables		
Mono	**Installation time per meter**	**Installation time for the cable ends**
Min	Min/mm2	Min/mm2
1	1.66	4.75
1.5	2.33	6.65
2.5	2.99	8.55
4	3.66	11.4
6	4.99	11.4
10	5.65	14.25
16	6.65	16.15
25	8.31	19.38
35	9.31	24.23
50	9.97	29.07
70	11.3	34.2
95	11.97	42.75
120	13.3	42.75
150	14.96	57
185	16.63	57
240	19.95	80.75
300	23.27	114
400	26.6	190
500	33.25	342
630	39.9	456

Table 2-5 Generic energy rates in EU-27 (1.1.2011)[29]

	Unit	**domestic incl.VAT**	**Long term growth per yr**	**non-domestic excl. VAT**
Electricity	€ / kWh	0.18	5%	0.11
Energy escalation rate*	%		4%	
**= real (inflation-corrected) increase*				

[29] VHK, MEErP 2011 METHODOLOGY PART 1.

Table 2-6 Generic financial rates in EU-27[52]

	Unit	domestic incl.VAT	non-domestic excl. VAT
Interest	%	7.7%	6.5%
Inflation rate	%	2.1%	
Discount rate (EU default)	%	4%	
VAT	%	20%	

The input market stock, sales and growth data was not directly available and as explained in the respective sections the deduced and projected data has a certain degree of uncertainty, therefore a complementary sensitivity analysis and cross checks are performed in Tasks 4 to 7.

2.1 Generic economic data

2.1.1 Definition of 'Generic economic data' and objective

'Generic economic data' gives an overview of production and trade data as reported in the official EU statistics. It places the power cables within the total of EU industry and trade. To investigate the market, Europroms -PRODCOM statistics are screened, and verified with recent data from stakeholders.

2.1.2 PRODCOM data

The PRODCOM statistics (published by Eurostat) have the advantage of being the official EU source. PRODCOM data is based on manufactured goods whose definitions are standardised across the EU thus guaranteeing comparability. Although it is used and referenced in other EU policy documents regarding trade and economic policy, it does have its limitations. Many data points are unknown, estimated, confidential and therefore not available.

Based on the scope defined in Task 1 only one relevant category (see Table 2-7) for this study has been found in the PRODCOM database.

Table 2-7: PRODCOM data relevant NACE code

PRODCOM NACE code	Description
27321380	Other electric conductors, for a voltage <= 1000 V, not fitted with connectors

The market data in quantity of units and monetary value (see Table 2-8) was obtained for the NACE code 27321380 from EUROSTAT for the years 2007 – 2012.

Table 2-8: EU27 PRODCOM data on NACE code 27321380

Year	Quantity in kton				Value in million €			
	Produc-tion	Import	Export	Apparent EU consump-tion	Produc-tion	Import	Export	Apparent EU consump-tion
2007	1550				9300			
2008	2171				11648			
2009	1920				8400			
2010	2200				11100			
2011	2280				12600			
2012	2128				12300			

Table 2-9: Value per kg based on PRODCOM data (NACE code 27321380)

Year	Value in 1000 €	Quantity in ton	€/kg
2007	9300000	1550000	6.00
2008	11647510	2171223	5.36
2009	8400000	1920000	4.38
2010	11100000	2200000	5.05
2011	12600000	2280000	5.53
2012	12300000	2128632	5.78
Average			**5.35**

Table 2-9 shows that the average value per kilo cable is **5.35** EURO/kg for the years 2007 up to and including 2012.

Note: The PRODCOM data include a broad range of electrical wires and cables, such as wires and cables for electrical installations inside and outside the buildings (e.g. LV distribution cables), wires and cables for data communication (coax cables are excluded), flexible cords, wires for internal wiring of control panels, instrumentation cables, elevator cable, and others. Be aware that this category includes cables and wires with conductors made of copper, aluminium or any other material. The values in Table 2-8 and Table 2-9 are expressed in kg product (cable) regardless of the material used.
As such the PRODCOM data can only be used as a reality check, i.e. an upper limit to verify figures from other sources.

2.1.3 Generic economic data

For 2007 the global (world) copper demand was 24.2 million tonnes, of which 48% was used in the manufacturing of electric cables[30], or about 11 million tonnes.

[30] Source: www.eurocopper.eu> marketdata, EGEMIN study 2011 Modified Cable Sizing Strategies

2.2 Market and stock data

2.2.1 Sales data

2.2.1.1 Sales data from EU cable industry associations

To verify the PRODCOM data with recent data from stakeholders a questionnaire was sent to the cable manufacturers[31].

2.2.1.2 Sales of power cables in Europe according to working plan[32]

Table 2-10: Sales of power cables (kton Copper)

Annual Sales (kton eq. Copper)	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**
Industry	226	245	241	253	266	279	293
Services	202	219	216	227	238	250	263
Residential	284	308	303	318	334	351	368
Total	712	772	760	798	838	880	924

Table 2-10 shows that annual sales of wiring, expressed as kilotons equivalent copper, which was estimated to be 760 kton in 2010 and is expected to increase to 924 kton by 2030.

2.2.1.3 CRU Wire and Cable Quarterly report

Table 2-11 and Table 2-12 are extracted from the CRU[33] Wire and Cable Quarterly, Q3 2013 report[34]. Please note that CRU includes Russia and all of East Europe in Europe.

The in Table 2-11 mentioned insulated cables includes the cables used in building and construction, which also includes power distribution cables and diverse industrial cables etc. from low to high voltage. Winding wire is enamelled wire (magnetic wire) used in transformers.

[31] questionnaire for cable manufacturers, sent in context of this study, September 30th, 2013
[32] Study of the Amended Ecodesign Working Plan, Final report Task 3 – version 6 Dec. 2011

[33] http://www.crugroup.com/about-cru/industries_we_cover/wirecable/
[34] http://www.crugroup.com/about-cru/industries_we_cover/wirecable/

Table 2-11: Ktons of conductor for Europe 2013f (source: CRU Wire and Cable Quarterly, Q3 2013)

000 tons conductor content by region (2013f)		
Europe	**Cu**	**Al**
Bare Overhead Conductors	0	306
Insulated Cables	1828	531
Winding Wire	424	38
Subtotal	**2252**	**874**

Table 2-12: European consumption of wire and cable by type (000 ton conductor independent of metal, 2013f) (source: CRU Wire and Cable Quarterly, Q3 2013)

Europe	
LV Energy	1073
Power Cable	1114
External Telecom	68
Internal/Data	218
Winding Wire	465
Sub-Total	**2938**

In the CRU report the following product sectors are used (Table 2-12):

- LV Energy: all cable whose primary function is the transmission of energy and rated at below 1kVac;
- Power Cable: comprises all energy cable rated at 1kVac and above;
- External Telecom: metallic cable used in telecommunication networks installed outside buildings;
- Internal/Data: all other types of cable used for the transmission of voice/data, including internal telephone cable, LAN data cable and all types of co-axials;
- Winding Wire: all types of round and flat enamelled and taped wire used in the windings of motors, transformers etc.;
- Fibre Optic Cable: all types of cable containing optical fibres.

Note: there is a small mismatch between the Table 2-11 and Table 2-12 because some cables that are produced in Europe can be exported or others can be imported to fit the consumption in the second table.

Based upon Table 2-12 one can conclude that about 37 % (= 1073/2938) of wire and cable consumption in Europe is for LV energy cables. This category, however, includes among others the sales of cables for the LV distribution grid, LV cables for industry and original equipment manufacturer (OEM) application, meaning automotive, rolling stock, and so on. As such, these figures can only be used as an upper limit to verify data from other sources.

2.2.1.4 Sales data from annual reports of cable manufacturers

According to Europacable, the two largest European manufacturers of LV indoor power cables are Nexans and Prysmian. Economic market data can be found in some form in

their annual reports[35, 36]. Such data can be useful as an upper limit to cross check with projected annual EU27 cable sales in end user prices.
Some key figures for the annual reports are:

- Nexans reported for 2013 global sales of 6711 Meuro with 57 % European geographic sales and 25 % sales in the distribution and installers business (incl. data cables).
- Prysmian Group reported for 2013 a global sales of 7273 MEuro with 63 % Europe - Middle-East - Africa geographic sales and 26 % sales in the trade and installers business.

Note: these figures also cover products and geographic areas that are outside the proposed scope of the study in Task 1.
For more information on the European manufacturers and production structure, consult also section 2.3.

2.2.2 Stock data

Power cables are used in all type of buildings both residential and non-residential (industry and service). The annual sale depends on the amount of new buildings and building renovations. Especially building renovation is considered to increase in the coming years.

2.2.2.1 Stock data according to working plan

As illustrated in Table 2-13, the total amount of copper installed in buildings ('stock') was estimated to be 18788 kton in 2010 and is expected to increase to 21583 kton by 2030.

Table 2-13: Total amount of copper installed in buildings[37]

Stock (ktons eq. Copper)	***2000***	***2005***	***2010***	***2015***	***2020***	***2025***	***2030***
Industry	*5991*	*6102*	*6538*	*6951*	*7395*	*7453*	*7511*
Services	*4338*	*4419*	*4734*	*5033*	*5355*	*5397*	*5439*
Residential	*6886*	*7014*	*7515*	*7989*	*8500*	*8567*	*8633*
Total	*17215*	*17536*	*18788*	*19974*	*21250*	*21417*	*21583*

2.2.2.2 Building stock

2.2.2.2.1 BPIE

35 http://www.nexans.com/eservice/navigation/NavigationPublication.nx?CZ=Corporate&language=en&publicationId=-3506

36 http://investoren.prysmian.com/phoenix.zhtml?c=211070&p=irol-reportsannual

37 Study of the Amended Ecodesign Working Plan, Final report Task 3 – version 6 Dec. 2011

Buildings Performance Institute Europe (BPIE) estimates that there are **24 billion m²** of useful floor space (industry floor space excluded?) in the EU27 countries[38]. The residential stock is the biggest segment with an EU floor space of **75%** of the building stock. Within the residential sector, different types of single family houses (e.g. detached, semi-detached and terraced houses) and apartment blocks are found. Apartment blocks may accommodate several households typically ranging from 2-15 units or in some cases holding more than 20-30 units (e.g. social housing units or high rise residential buildings).

2.2.2.2.2 Ecofys report

The Ecofys study 'Panorama of the European non-residential construction sector'[39] was conducted by investigating five reference countries (Sweden, Germany, Poland, Hungary and Spain) and extrapolating the results to European scale.
The number of non-residential buildings and the total floor area of these buildings are shown per building group in Table 2-14 up to and including Table 2-16.

[38] BPIE study: Europe's buildings under the microscope – October 2011 http://www.bpie.eu/documents/BPIE/HR_%20CbC_study.pdf

Table 2-14: Extrapolated EU27 non–residential building stock[39] (year 2009?)

	Non-government owned offices	Trade facilities	Gastronomic facilities	Health facilities	Educational facilities	Industrial buildings	Public buildings	Other buildings	Total
Northern Europe EU27									
Buildings	27,134	16,679	6,597	20,288	59,247	194,613	27,134	26,885	**356,547**
Floor area [Mio m²]	47.7	29.3	11.6	35.6	104.1	194.6	9.0	47.2	**479.1**
Western Europe EU27									
Buildings	1,200,354	1,192,100	1,465,150	121,663	144,214	1,180,094	871,799	642,660	**6,818,034**
Floor area [Mio m²]	917.4	1,490.1	596.0	781.1	905.4	1,180.1	871.8	642.7	**7.384.6**
North Eastern Europe EU27									
Buildings	39,860	333,388	85,764	19,043	37,356	275,103	168,553	1,124,362	**2,083,428**
Floor area [Mio m²]	53.1	213.8	35.0	15.5	99.3	349.3	135.0	360.3	**1,261.2**
South Eastern Europe EU27									
Buildings	4,627	734,185	232,186	19,887	56,246	204,413	159,798	103,114	**1,514,456**
Floor area [Mio m²]	36.1	131.7	124.7	46.3	63.7	316.4	92.3	141.2	**952.5**
Southern Europe EU27									
Buildings	86,395	312,650	118,469	52,653	158,694	522,299	25,090	396,655	**1,672,906**
Floor area [Mio m²]	117.7	426.0	161.4	71.7	216.2	711.6	34.2	540.4	**2,279.2**
Total EU27									
Buildings EU27	1,358,370	2,589,001	1,908,167	233,535	455,757	2,376,522	1,230,343	2,293,676	**12,455,371**
Floor area EU27	1,171.9	2,291.0	928.7	950.2	1,388.7	2,752.0	1,142.3	1,731.8	**12,356.6**

Table 2-15: Number of non-residential buildings in the EU27 [1,000 units][40]

Age structure	Private offices	Trade facilities	Gastronomic facilities	Health facilities	Educational facilities	Industrial buildings	Public buildings	Other buildings	Total
Until 1980	594.2	1,566.7	1,291.4	143.9	333.7	1,636.2	687.4	1.841.1	**8.102.7**
1980 -1989	223.1	329.7	373.5	29.9	71.7	329.3	173.5	183.6	**1701.8**
1990 -1999	373.3	459.1	207.2	38.4	56.1	237.1	318.1	505.7	**2,190.9**
2000-2009	197.3	481.3	99.7	35.3	22.2	377.6	177.0	601.0	**1,999.5**
Total	**1,387.8**	**2,836.8**	**1,971.8**	**247.6**	**483.1**	**2,580.2**	**1,356.0**	**3,131.4**	**13,994.8**

[39] Ecofys report, Panorama of the European non-residential construction sector, 9 December 2011

[40] Prepared by a Taskforce of Actors and Stakeholders from the European Construction Sector, 12th July 2010

Table 2-16: Floor area of the non-residential building stock in the EU27 [Mio m²][40]

Age structure	Private offices	Trade facilities	Gastro-nomic facilities	Health facilities	Educa-tional facilities	Industrial buildings	Public buildings	Other buildings	Total
Until 1980	507.6	1,247.5	609.2	611.8	1,124.5	1,867.0	619.3	1,190.3	**7,783.1**
1980 -1989	185.8	272.1	176.0	121.7	152.4	362.5	169.0	205.6	**1,642.2**
1990 -1999	307.4	409.4	97.4	123.1	124.6	219.4	279.0	202.9	**1,757.1**
2000-2009	210.3	520.2	71.7	104.9	60.6	561.5	175.7	400.1	**2,108.2**
Total	**1,211.2**	**2,449.2**	**954.3**	**961.5**	**1.462.1**	**3,010.4**	**1,242.9**	**1,999.0**	**13,290.6**

2.2.2.2.3 Building Research & Information study[41]

This study compares European residential building stocks regarding performance, renovation and policy opportunities.

The study states:

- In most European countries the rate of new construction in the residential sector is around 1% of the total stock.
- The annual demolition rate in the European Union varied between 0.025% and 0.23% of the total stock in 2003.

2.2.2.2.4 The Fundamental Importance of Buildings in Future EU Energy Saving Policies paper

Figure 2-1 displays an extract of the paper 'The Fundamental Importance of Buildings in Future EU Energy Saving Policies'[42].

[41] Comparing European residential building stocks: performance, renovation and policy opportunities. OTB Research Institute for Housing, Urban and Mobility Studies, TU Delft, Department of Architecture, University of Cambridge, 2 December 2010

3.2 It is estimated that there are about 210 million buildings in the European Union providing approximately 53 billion square metres of usable indoor space for our activities. These buildings are divided into the following types[3]:

Type	Number constructed before 1973	Number constructed after 1973	Overall percentage of total stock
Individual Private Residences	42,840,000	28,560,000	34
Private Apartment Buildings	17,640,000	11,760,000	14
Public (Social) Housing	16,800,000	8,400,000	12
Commercial Buildings	18,900,000	44,100,000	30
Public Buildings	5,040,000	11,760,000	8
Other (Leisure, Industrial…)	1,890,000	2,310,000	2
Totals:	**103,110,000**	**106,890,000**	**100**

Note:
The table above seeks to establish a baseline for the quantum of buildings in the European Union. The division into sub-sections of building types follows a generally accepted sub-division of the building stock and it is further broken down to reflect construction before the first major oil crisis in 1973 as the buildings built before that time were built in an era where there was little or no consciousness of the need to design for energy efficient performance.

Figure 2-1 Building stock according paper [42]

This paper also states that it will be necessary to increase the rate of deep energy renovation (of buildings) by a factor of two to three times the current rate of between 1.2% and 1.4% in the decades up to 2050 in order to reach the short and long term EU targets of reducing CO_2 emissions by 80-95% by 2050 as compared to 1990 levels.

2.2.2.2.5 Think study[43]

This study states, referring to DG Energy[44], the following:
"Buildings must be central to the EU's energy efficiency policy, as nearly 40% of final energy consumption (and 36% of greenhouse gas emissions) is in houses, offices, shops and other buildings. Moreover, buildings provide the second largest untapped cost effective potential for energy savings after the energy sector. In this context, it is important to stress that buildings constructed today will be there for the next 50 to 100 years. For example, 92% of the building stock from 2005 will still be there in 2020 and 75% in 2050. This is due to the very low demolition rates (about 0.5% per year) and new built construction rates (about 1.0% per year).Moreover, the current general

[42] The Fundamental Importance of Buildings in Future EU Energy Saving Policies, A Paper Prepared by a Taskforce of Actors and Stakeholders from the European Construction Sector, 12th July 2010, http://www.euroace.org/LinkClick.aspx?fileticket=IYFmSEm7faM%3D&tabid=159

[43] How to Refurbish All Buildings by 2050; Final Report June 2012; http://www.eui.eu/Projects/THINK/Documents/Thinktopic/THINKTopic72012.pdf

[44] European Commission Directorate- General for Energy. Consultation Paper "Financial support for energy efficiency in buildings". European Commission, Directorate-General for Energy, Brussels. February 2012

refurbishment cycles are between 30-40 years but those which lead to energy efficiency improvements are at longer intervals (60-80 years). With approximately 3% of the building stock being renovated per year, this signifies that in only half of the cases energy efficiency improvements are included (i.e. 1.5% energy-related renovation rate per year)."

2.2.2.2.6 Relation between stock and loading

Building stock data and energy consumption can be used to calculate the energy consumption per square meter and per sector. Table 2-17 shows the final consumption of electricity in TWh per year for EU28 according to Eurostat.

Table 2-17 EU28 annual final consumption of electricity by industry and households/services in TWh[45]

	Final annual energy consumption in TWh											
Year	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Industry	1075	1081	1089	1120	1133	1131	1142	1119	966	1030	1037	1008
Households	744	753	787	798	806	818	810	820	820	845	803	828
Services	703	716	741	763	780	822	837	864	867	904	885	898

The origin of the consumption is shown in Figure 2-2.

[45] Eurostat, http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=ten00094

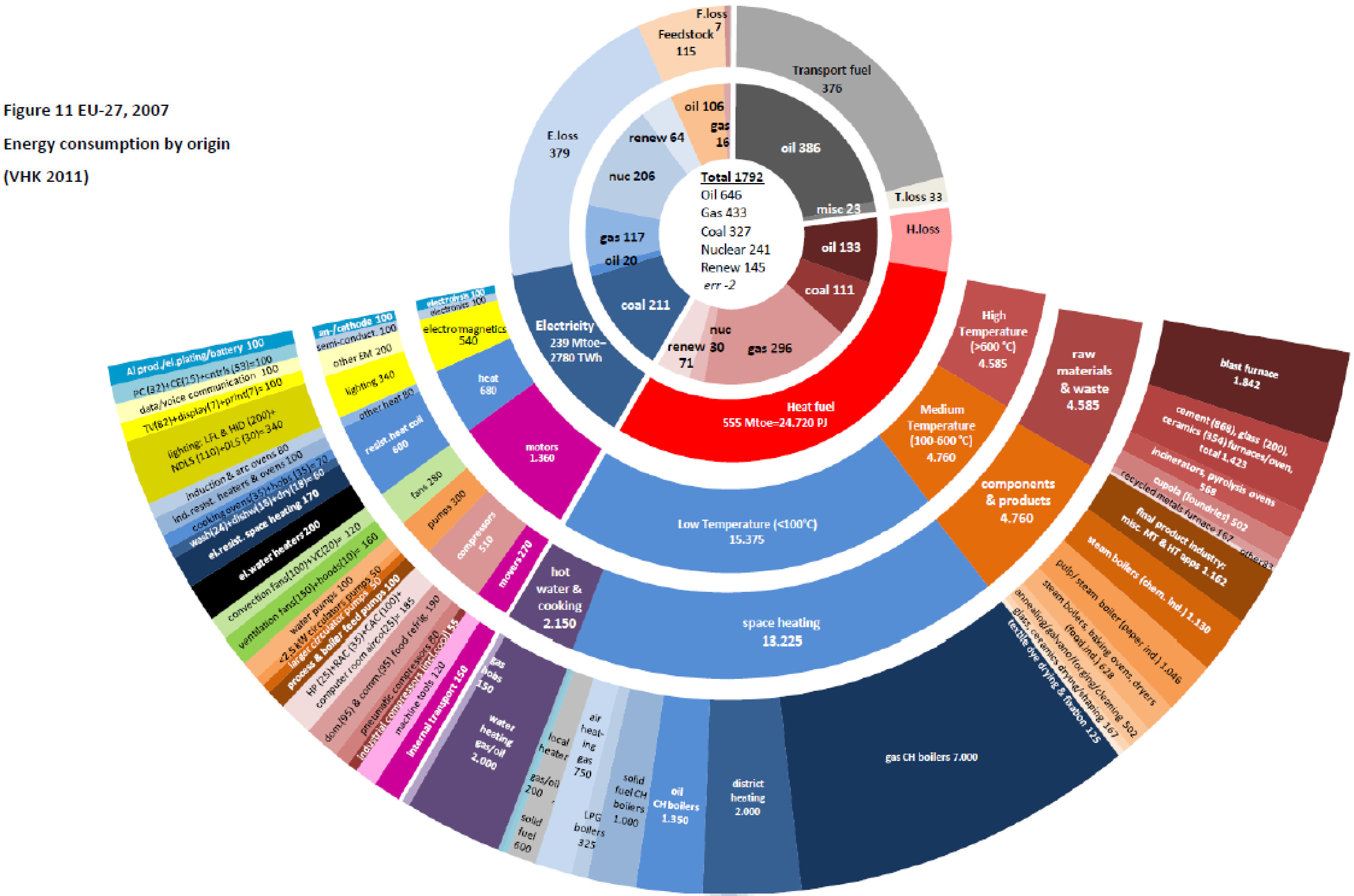


Figure 2-2 Energy consumption by origin, EU27, 2007 (VHK 2011)[81]

2.2.2.3 Power cable stock

The tables in this paragraph shows the stock data, i.e. estimations of the amount of copper of fixed wired conductors and cables in residential and non-residential buildings divided into services and industry sector.

Table 2-18: Stock of LV cables and wires in residential buildings[46]

Avg living area	109	m²
Avg Cu/100m²	**29.1**	kg/100m²
EU27 Building floor space	2,40E+10	m²
Residential Floor space	1,80E+10	m² (75% total building floor space)
Total Cu	**5241**	kton

Remark: In the study of the Amended Ecodesign Working Plan, Final report Task 3 (v. 16 Dec. 2011), the determined stock in residential buildings was: 7515kton (= **41.75** kg/100m²) in 2010.

The diversity in terms of typology within the non-residential sector is vast. Compared to the residential sector, this sector is more complex and heterogeneous. It includes types such as offices, shops, hospitals, hotels, restaurants, supermarkets, schools, universities, and sports centres while in some cases multiple functions exist in the same building. The non-residential stock counts for about 25%[47] of the total EU27 Building floor space.

Table 2-19: Stock of LV cables and wires in non-residential buildings - Services[48]

Avg Cu/100m²	**54**	kg/100m²
EU27 Building floor space	2.40E+10	m²
Floor space	6.00E+09	m² (25% total building floor space)
Total Cu	**3250**	kton

Remark: In the study of the Amended Ecodesign Working Plan, Final report Task 3 (v. 16 Dec. 2011), the determined stock in services buildings was: 4734 kton (= **78.9** kg/100m²) in 2010.

[46] Source: CuIoU survey European Copper Institute, year 2000
[47] Europe's Buildings under the Microscope (2011), http://www.bpie.eu/documents/BPIE/HR_%20CbC_study.pdf
[48] Source: CuIoU survey European Copper Institute, year 2000

Table 2-20: Stock of LV cables and wires in non-residential buildings - Industry[49]

Avg Cu/100m²	**139**	kg/100m²
EU27 Building floor space	2.40E+10	m²
Floor space	2752E+06	m²
Total Cu	**3825**	kton

Remark: In the study of the Amended Ecodesign Working Plan, Final report Task 3 (v. 16 Dec. 2011), the determined stock in industry buildings was: 6538 kton (= 237.6 kg/100m^2) in 2010.

General assumption in Amended Ecodesign Working Plan:
Stock in non-residential buildings is 1.5 times the stock in residential buildings. This means 1.5 x 5241 kton= **7861** kton as a total amount of copper used in non-residential (services + industry) buildings (Amount determined in Working Plan: 11272 kton).

The amount of copper and circuits in a real office building[50] is shown in Table 2-21 as an example. The calculated figure of 93 kg/100m^2 for this this building is about 18% above proposed average (78.9 kg/100m^2).

Table 2-21: Example of a real office building[50]

Amount of Lighting circuits	33
Amount of Socket outlet circuits	62
Amount of Dedicated circuits	34
Amount of Main feeders	1
Amount of Sub feeders	11
Cu total (kg)	2851
Floor space (m²)	3059
Cu (kg/100m²)	**93**

2.2.2.4 Distribution of power cables based upon cross sectional area

Distribution of LV cables in residential buildings shown in Table 2-22 and in non-residential buildings shown in Table 2-23 is based upon a survey of the European Copper Institute[51].

Table 2-22: Distribution of LV cables in the residential buildings[52]

CSA (mm²)	% Weight	% Length
1.5	23.4	27.5
2.5	38.9	40
4	6.6	4.9
6	9.3	5.7
10	6.1	<1

[49] Source: CuIoU survey European Copper Institute, year 2000
[50] EnergyVille building, Waterschei, Belgium
[51] Source: CuIoU survey European Copper Institute, year 2000
[52] Source: CuIoU survey European Copper Institute , year 2000

Wires and cables with a CSA of 1.5 mm² are most common for lighting circuits; whereas 2.5 mm² wires and cables are most common for socket outlet circuits. These circuits count for about 60.9 % of the total copper used in fixed wired electrical installations in residential buildings.

Wires and cables with a CSA above 2.5 mm² are mostly used for dedicated circuits, e.g. electrical circuits for electrical heating, cooking, and washing machine.
In residential buildings cables with a CSA of more than 10 mm² are generally used for:

- Connecting the LV circuit board to the main LV feeder in the street.
- Connection between the LV main circuit board and sub LV circuit boards in the building (e.g. apartment).
- Equipotential and secondary bonding.

Note: In the UK 1 mm² wiring is also used for lighting circuits. In Germany 1.5 mm² wire and cable are also used for socket outlet circuits.

Table 2-23: Distribution of LV cables in non-residential buildings[53]

CSA (mm²)	% Weight	% Length
1.5	2	15
2.5	13	58.6
4	2	4.9
6	3	5.1
10	3	3.2
16	3	2.4
25	4	2
35	6	1.9
50	5	1.2
70	11	1.8
95	12	1.4
120	9	0.9
150	6	0.4
185	13	0.8
240	7	0.4
300	0	0
400	3	0.1
500	0	0
600	0	0

Wires and cables with a CSA of 1.5 mm² are most common for lighting circuits; whereas 2.5 mm² wires and cables are most common for socket outlet circuits. These circuits count for about 15 % of the total Copper used in fixed wired electrical installations in non-residential buildings. The total length of these cables counts for 73.6% of the total length of the installed cables.

[53] Source: CuIoU survey European Copper Institute, year 2000

2.2.3 New sales rate

The new sales are directly related to construction of new buildings. Hence, the new sales of power cables will be equal to the power cable stock of the previous year multiplied by the buildings stock growth rate.

2.2.3.1 BPIE

In terms of growth, annual construction rates in the residential sector are around 1% over the period between 2005 and 2010[55]. Except in The Netherlands (in the case of multi-family houses), all other countries experienced a decrease in the rate of new build in recent years, reflecting the impact of the current financial crisis in the construction sector[54].

2.2.3.2 Ecofys

The Ecofys study[58] estimates the overall new construction rate for the non-residential buildings at **2.1%** and the new construction rate for the industrial buildings at **3.1%** (see Table 2-24).

2.2.4 Replacement sales rate

The replacement sales are directly related to the building renovations. However, renovations do not always include a replacement of the electric wiring. Hence, the replacement sales rate needs to be corrected downwards.

The renovation rates of buildings will have a large impact on future market trends. In the BPIE study[55] three scenarios of renovation rates (in combination with different renovation depths) are considered.

Public buildings are in the limelight at the moment due to policies requiring them to become close to zero energy buildings by the end of 2018 and a sectorial renovation rate of **at least 3%** is recommended.

Most estimates of overall renovation rates (other than those relating to single energy saving measures) are mainly between around 0.5% and 2.5% of the building stock per year.

2.2.4.1 Working Plan

In the Working Plan the refurbishment rate has been set at **3%** following the rationale applied for thermal insulation products.

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[54] http://www.bpie.eu/

[55] BPIE study: Europe's buildings under the microscope – October 2011 http://www.bpie.eu/documents/BPIE/HR_%20CbC_study.pdf

2.2.4.2 BPIE

In the BPIE study[56], it is assumed that the current, at that time 2011, prevailing building renovation rate across Europe was **1%**.

2.2.4.3 Ecofys

The Ecofys study[58] estimates the overall renovation rate for the non-residential building sector at **12.4%** ().

The Heinze [57], [58] study allows a better understanding of the non-residential modernisation market in Germany. The study is based on an extensive architect survey and investigates what kind of modernisation activities are typically realized in building renovations. The study indicates that in **59%** of all renovation activities in Germany the power cables are replaced.

[56] Europe's Buildings under the Microscope (2011), http://www.bpie.eu/documents/BPIE/HR_%20CbC_study.pdf

[57] Modernisierungsmarkt 2008 - Modernisierungsaktivitäten von Bewohnern und privaten Vermietern im Wohnungsbau: Produktbereich Dach. Heinze GmbH. (Unpublished). Germany.

[58] Also referred to in: Ecofys report, Panorama of the European non-residential construction sector, 9 December 2011

Table 2-24: Summary of metabolism rates in representative countries and EU27[59]

	Germany	Hungary	Poland	Spain	Sweden	EU27 (weighted)
New construction rate						
Private offices	0.7 %	4.0%	5.3 %	4.7 %	1.2 %	**2.6 %**
Trade facilities	2.4 %	1.9 %	4.4 %	1.5 %	3.5 %	**2.4 %**
Gastronomic facilities	0.1 %	0.9 %	2.6 %	1.4 %	1.8 %	**0.9 %**
Health facilities	1.4 %	0.8 %	3.1 %	3.1%	0.5 %	**2.0 %**
Educational facilities	1.4 %	0.8 %	1.0 %	0.5%	0.4 %	**1.0 %**
Industrial buildings	3.5 %	1.7 %	1.9 %	3.5 %	1.3 %	**3.1 %**
Public buildings	0.9 %	0.7 %	5.3 %	4.0 %	n.a. %	**2.2 %**
Other buildings	1.0 %	2.7 %	1.6 %	8.4 %	2.5 %	**3.2 %**
Total (weighted)	**1.0 %**	**1.7 %**	**2.3 %**	**4.2 %**	**1.3 %**	**2.1 %**
Demolition rate						
Non-residential sector	0.29 %	n.a.	n.a.	0.1 %	0.6 %*	**0.2 %**
Renovation rate						
Overall renovation rate	**11.0 %**	**6.2 %**	**5.6 %**	**20.1 %**	**14.3 %**	**12.4 %**
Energy related renovation rate	2.3 %	1.7 %	1.2 %	4.1 %	2.8 %	**2.6 %**
Not energy related renovation rate	8.7 %	4.5 %	4.4 %	16.0 %	11.4 %	**9.8 %**

2.2.4.4 Euroconstruct

Euroconstruct [60] is a European research group for research and analysis of the construction industry, which includes 19 European countries (the EC19 countries include Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, Czech Republic, Hungary, Poland and Slovak Republic). GDP and construction output in Euroconstruct countries is shown in Figure 2-3. Construction output per segments is listed in Table 2-25.

[59] Ecofys report, Panorama of the European non-residential construction sector, 9 December 2011
[60] http://www.euroconstruct.org/

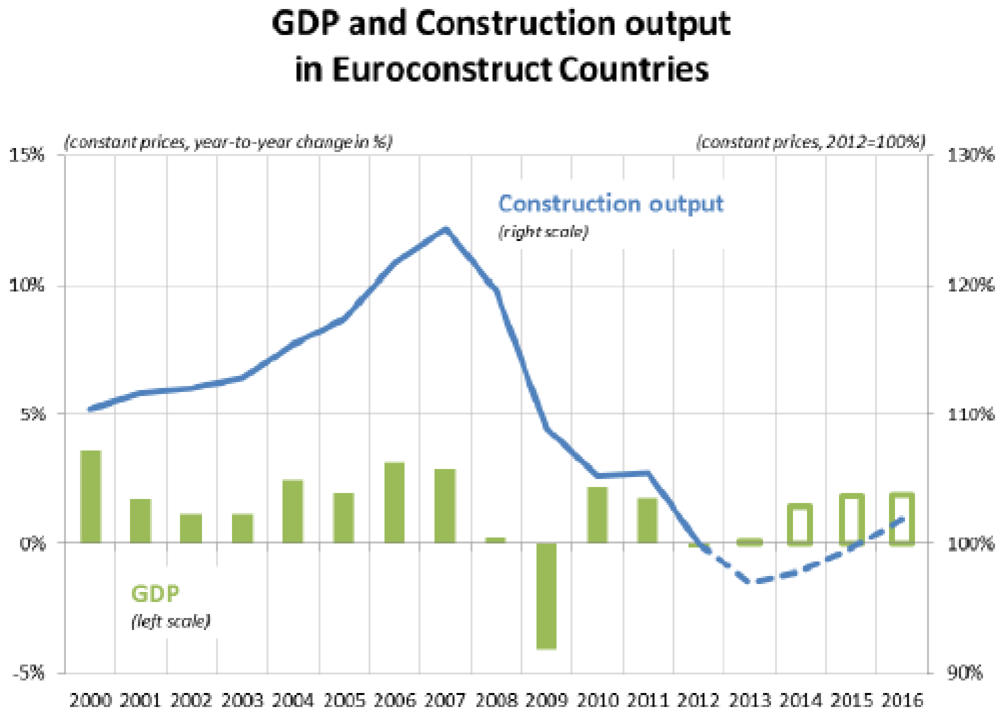

Figure 2-3 GDP and Construction output in Euroconstruct Countries[61]

Table 2-25: Construction output by segments[61]

Construction Output by Segments (EC19)

(% change in real terms)

Country	2010	2011	2012	Estimate 2013	Forecasts 2014	2015	Outlook 2016
Residential	-1,9	1,9	-4,2	-2,2	1,4	2,2	2,3
Non-Residential	-5,3	0,0	-4,6	-3,4	0,0	1,4	2,3
Civil Engineering	-3,6	-2,4	-8,2	-4,0	1,2	1,6	1,7
Total construction output	-3,4	0,3	-5,2	-3,0	0,9	1,8	2,2

2.2.5 Market and stock data summary

The assumed building stock and rates, based upon the previous sections, are shown in Table 2-26.

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61 76th Euroconstruct conference, Prague, 28-29th November 2013, press release, http://www.euroconstruct.org/

Table 2-26: Summary of building stock, growth rates and construction sales

Sector	Building product time	Building service life	Vacancy	New building construction rate	Building demolition rate	Building refurbish-ment rate	Building stock growth rate	Stock Number of buildings	
Unit	Year	Year	%	% p.a.	% p.a.	% p.a.	% p.a.	(1000 units)	%
Residential sector	47.62	45.24	5%	1.00%	0.10%	2.00%	0.90%	200000	93%
Services sector	8.20	7.79	5%	2.10%	0.20%	12.00%	1.90%	11415	5%
Industry sector	8.20	7.79	5%	3.10%	0.20%	12.00%	2.90%	2580	1%
Total sector (weighted)	45.04	42.79	5%	1.08%	0.11%	2.65%	0.98%	213995	100%

Some of the stakeholders remarked [62] that an average building lifetime between renovations of 8 years (12.4%) for the services and industrial sector is rather short. The product lifetime of cables and circuits is explained in Task 3. The stock and sales are calculated based upon reference year 2010 and in accordance with the product lifetime figures described in Task 3.

It is assumed that in **59%** of all building renovation activities the power cables are replaced (cfr. 2.2.4.3).

The assumed cables stock and sales rates, based upon the building construction rates, can be found in Table 2-27. However, the product lifetime is adapted according the comments of the stakeholders.

Table 2-27: Summary of cable stock, growth and sales rates

Sector	Product life	Service life	Vacancy	Stock growth rate	Demolition rate	Replace-ment sales rate	New sales rate	Total sales rate	Stock (Reference year: 2010)	
Unit	Year	Year	%	% p.a.	% p.a.	% p.a.	% p.a.	% p.a.	kTon Cu	%
Residential sector	64.00	60.80	5%	0.90%	0.10%	1.18%	0.90%	2.08%	5241	43%
Services sector	25.00	23.75	5%	1.90%	0.20%	3.20%	1.90%	5.10%	3250	26%
Industry sector	25.00	23.75	5%	2.90%	0.20%	2.80%	2.90%	5.70%	3825	31%
Total sector (weighted)	41.60	39.52	5%	1.79%	0.16%	2.22%	1.79%	4.00%	12316	100%

Table 8-13 the absolute values of stock and sales are calculated based upon the figures in Table 2-27.

[62] Minutes of the second stakeholder meeting. See "Preparatory Studies for Product Group in the Ecodesign Working Plan 2012-2014:Lot 8 - Power Cables: Project Report".

Table 2-28: Summary of stock data per 100m² floor area

Sector	Building floor area	Amount of Cu material per 100m² empirical	Amount of Cu material per 100m² according working plan
Unit	**Million m²**	**kg/100m²**	**kg/100m²**
Residential	18000	29.1	41.75
Services	6000	54	78.9
Industry	2752	139	237

2.3 Market trends

Power cables are a mature product and available in standardized sizes. Power cables are a mature product and available in standardized sizes. As described earlier, the annual sale of power cables depends on the amount of new buildings built and existing buildings renovated. Especially the latter is considered to increase in the coming years.

2.3.1 Market production structures

Most cables in buildings use copper conductors. According to the European Copper Institute[63], the direct copper industry in Europe is made up of around 500 companies, with an estimated turnover of about €45 billion, and employs around 50,000 people.
While the global economic situation remained relatively weak in 2012, the world demand for copper was at a record high of around 25.5 million tonnes, made up of 20.5 million tonnes of refined metal production plus 5 million tonnes of direct-melt scrap. The EU27 demand, impacted by the ongoing malaise in the construction sector, was estimated at around 4 million tonnes.

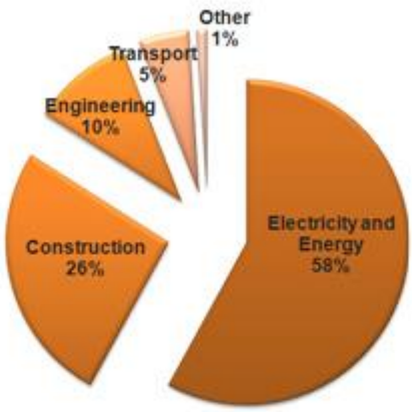

Figure 2-4: Use of refined copper within Europe (ECI, 2012)

To meet the modern world's increasing demand for copper, which has doubled in the last 25 years, it has been important to exploit copper's ability to be 100% recycled, without any loss in performance. Throughout the last ten years, it is estimated that

[63] See comments of European copper institute - second stakeholder meeting
See "Preparatory Studies for Product Group in the Ecodesign Working Plan 2012-2014:Lot 8 - Power Cables: Project Report" and http://www.copperalliance.eu/industry/economy

41% of the EU27's copper demand has been met through the recovery and recycling of value chain offcuts, plus end-of-life products[64] .

In 2011, the copper mine production in Europe was 926,868 tonnes, representing 5.7% of the world. Chile was the largest miner, with a 32% share, followed by China (8%), Peru (8%), USA (7%) and Australia (6%)[63].

China was the world's largest producer of refined copper, with 27% of the world output, followed by Chile (16%), Japan (7%) and USA and Russia (5% each)[65].

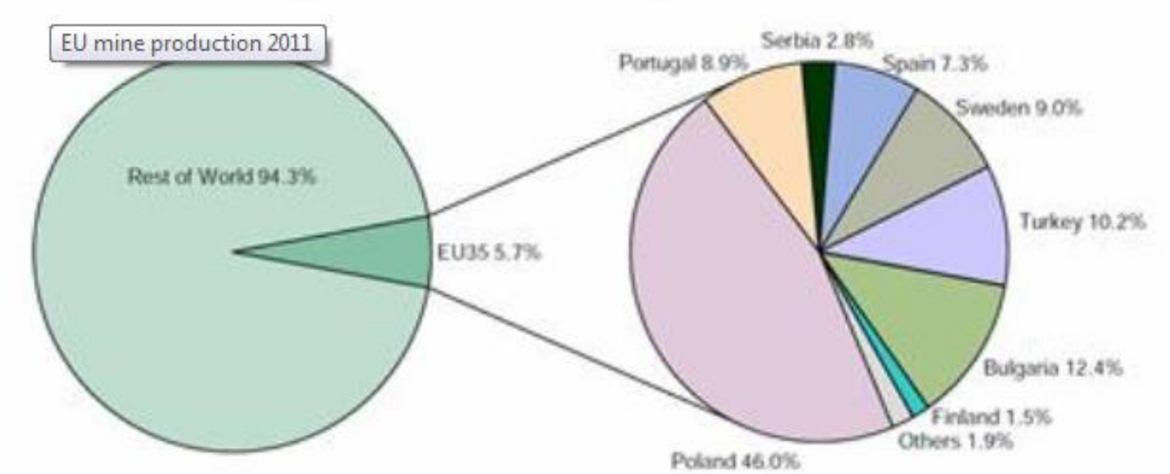

Figure 2-5: EU35 Mine production of copper 2011[65]

Cable manufacturers are grouped in the 'Europacable' association. Some of the main manufacturers of power cables are listed below, by alphabetical order:

- Acome – www.acome.com, France
- Brugg Cables, www.bruggcables.com, Switzerland
- General Cable, www.generalcable.es, Spain
- Hellenic Cables, www.cablel.com, Greece
- Italian Cable Company, www.icc.it, Italy
- Kabelwerk Eupen, www.eupen.com, Belgium
- Leoni, www.leoni.com, Germany
- Nexans, www.nexans.com, France
- Nkt cables, www.nktcables.com, Denmark
- Plastelec - http://www.plastelec.com/, France
- Prysmian Group, www.prysmiangroup.com, Italy
- Reka Cables, www.reka.fi, Finland
- SKB Gruppe, www.skb-gruppe.at, Austria
- TELE-FONIKA Kable, www.tfkable.com, Poland
- TKF, www.tkf.nl, Netherlands
- Tratos Cavi, www.tratos.eu, Italy
- Waskönig+Walter, www.waskoenig.de, Germany

Aluminium conductors are still used for bulk power distribution and large feeder circuits, but not as such in buildings. They are seldom used indoor, because connections are

[64] Glöser, Simon; Soulier, Marcel; Tercero Espinoza, Luis A. (2013): Dynamic Analysis of Global Copper Flows. Global Stocks, Postconsumer Material Flows, Recycling Indicators, and Uncertainty Evaluation. In Environ. Sci. Technol. 47 (12), pp. 6564–6572.

[65] Britisch Geological Survey, 2013, European Mineral Statistics 2007-11 A product of the World Mineral Statistics database

more difficult to avoid cold-flow under pressure which causes screw clamped connections may get loose over time. Also aluminium forms an insulating oxide layer on the surface and therefore needs an antioxidant paste at joints.

Depending on their final application, the power cables are sold to the end user through variety of channels such as directly from manufacturers, via wholesalers, via distributors or via installers. The product distribution channels of power cables are mostly business-to-business, as these products usually need professional installation (mainly due to safety hazards). Cables are installed by electrical contractors, e.g. those represented by European Association of Electrical Contractors (www.aie.org). A fraction of the sales is distributed via retail and is mainly installed in the residential sector.

2.3.2 General trends in product design and product features; feedback from consumer associations

Power cables are a mature product and available in standardized sizes.
There is a trend to use low smoke halogen free cables in buildings.

2.4 Consumer expenditure base data

The cable price is proportional to the copper price and therefore the cable price can be expressed in €/ (CSA [mm²] x l [m] x N) wherein CSA means Cross-Sectional-Area, l means Length and N means number of cores. Hence, the product unit is (CSA [mm²] x l [m] x N).

Factors influencing the Cable price:

The price of cable can be calculated as[66] :

$$NDP = K'_1(\text{cable type}) \times CP \times CM + K'_2(\text{cable type})$$

Where:

- NDP: Not discounted cable sales price
- CP: conductor material price per kg
- CM: amount of conductor material in kg
- K'_1: constant in function of cable type, reflecting the cost of the conductor material
- K'_2: constant, in function of cable type, reflecting the plastics, labour costs and other added values

It is common practice in various sectors to use catalogue prices as an approach to price an installation. Sometimes the price of the equipment at catalogue price (which is higher than the cost paid by the installer to the manufacturer or distributor) allows enough margin to include the labour and auxiliaries costs.
Installers actually buy at discounted prices. Then, on top of that, the labour cost plus the auxiliaries are to be added to the offer.
The "LV Power Cable Market Prices" study[67], based on the analysis of data of 13948 cables from 7 European manufacturers of different sizes, indicates for the category BB

[66] Comments of Europacable – first stakeholder meeting

(=multi or single core cables without any special characteristic) that an average not discounted price of 0.21588 €/ (mm²x m) is applicable.
The prices in this study refer to:

- 1 m cable, per mm² section;
- July 2014;
- standard packages;
- prices for the final professional customer;
- in case of single core cables or wires, the total section is the rated section of the cable. In case of multicore cables the total section has been calculated summing the sections of all the cores;

and do not include:

- the costs of cable installation and cable transportation to the building site;
- discounts (see further on);
- VAT.

Like for many other products also cable and wire prices are subjected to typical discount policies. According the study[67], power cables of category BB are subjected to discount class A (typical discount is 45+8+5) or class B (typical discount is 50+8+5).
Where the discount is A+B+C, the final discounted price is calculated by following formula:

$$DP = NDP \times (1-A/100) \times (1-B/100) \times (1-C/100)$$

Where:

DP: Discounted cable sales price
NDP: Not discounted cable sales price
A, B, C: discounts

The ECD study[67] lists for cables of category BB an average discounted cable price of 0.09434 €/ (mm². m).

[67] "LV power cable market prices" study by ECD (Engineering, Consulting and Design) for European Copper Institute, August 2014

Table 8-14 lists the prices, obtained from 2 sources, for the cables mentioned in the Bill Of Materials table in Task 4. The average discounted cable price of 0.1 €/ (mm². m) for this cable type matches well with the 0.09434 €/ (mm². m) mentioned in the study[67].

The cost of cable can be calculated as[68]:

$$CC = K_1(\text{cable type}) \times CP \times CM + K_2(\text{cable type})$$

Where:

- CC: cable cost
- CP: conductor material price per kg
- CM: amount of conductor material in kg
- K_1: constant in function of cable type, reflecting the cost of the conductor material
- K_2: constant in function of cable type, reflecting the plastics, labour costs and other added values

Note that the values K_1 and K_2 depend on the type of cable.

Table 2-29: conductor cost based upon conductor material price

Conductor material	Price LME 10 October 2013	density ρ	Volume V (1 m at 1 mm²)	Weight of V	Price
Unit	€/100kg	kg/m³	m³	Kg	€/mm².m
Cu core	535	8900	0.000001	0.0089	0.047615
Al core	183	2700	0.000001	0.0027	0.004941

For similar aluminium cables, the price of copper cables is used as a starting point, except that the price of the copper material is subtracted of the product price and the price of aluminium material is added to the product price. In Task 4 this price is verified with some commercial offers.

Conductor prices are very volatile[69], therefore it is common to correct cable prices with a surcharge[70] depending on the market price.

[68] See comments of Europacable – first stakeholder meeting
[69] http://www.ems-power.com/ems-metallkurse/ems-metallkurse.de.shtml
[70] http://www.igus.de/_Product_Files/Download/pdf/copper_en.pdf

Figure 2-6 example of cable connector

In the calculation of the base case product price in later tasks, the connector price will be included, because altering the cable size can have an impact on the price of the used connectors (example see Figure 2-6). The price of connectors is shown in Table 2-30. This price is based upon several offers.

Table 2-30 connector prices

Minimum wire size	Maximum wire size	CSA	Connector price	Discounted connector price
mm^2	mm^2	mm^2	€	€
0.14	4	1	0.87	0.54
0.14	4	1.5	0.87	0.54
0.14	4	2.5	0.87	0.54
0.14	4	4	0.87	0.54
0.2	10	6	1.61	0.97
0.2	10	10	1.61	0.97
0.5	16	16	2.11	1.25
1.5	25	25	2.11	1.07
1.5	50	35	4.85	2.84
1.5	50	50	4.85	2.84
16	70	70	11.79	7.31
25	95	95	22.11	13.71
35	150	120	28.96	17.96
35	150	150	28.96	17.96
70	240	185	35.36	21.92
70	240	240	35.36	21.92
		300	44.20	27.40
		400	58.93	36.53
		500	73.67	45.67
		630	92.82	57.54

Notes on copper long-term availability

Europe studied and defined a list of 'critical raw materials'[71]. Neither copper nor aluminium are included in this list and impact thereof will therefore not be taken into account.

[71] http://ec.europa.eu/enterprise/policies/raw-materials/critical/index_en.htm

According to the European Copper Institute copper is **not** becoming a scarce resource. According to Europacable[72], referring to a JRC study[73], copper is becoming a scarce resource.

Neither copper nor aluminium is listed in the MEErP 2011 critical raw material list. This MEErP 2011 critical raw material list is part of the EcoReport tool.

The future availability of minerals is based on the concept of reserves and resources. Reserves are deposits that have been discovered, evaluated and assessed to be profitable. Resources are far larger and include reserves, discovered and potentially profitable deposits, and undiscovered deposits predicted based on preliminary geological surveys. Copper is naturally present in the Earth’s crust. According to the US Geological Survey (USGS, 2014), the copper reserves amount to 690 million tonnes and the copper resources are estimated to exceed 3500 million tonnes. The number does not include vast copper deposits found in deep sea nodules and submarine massive sulphides. Current and future exploration opportunities will increase both for reserves and known resources. According to USGS data, since 1950 there has always been, on average, 40 years of copper reserves and over 200 years of resources left (see Figure 2-7).[74, 75]

When comparing the global estimated copper resources of 3500 million tonnes with the estimated stock (see 2.2.2.3) of 3,25 million tonnes in non-residential services buildings in the EU it is only about 0,1 %. Therefore increasing over time the stock with 50 to 100 % will not exhaust the global copper resources however it can have an impact on the product price, which will be taken into account in the sensitivity analysis in Tasks 6&7.

[72] Comment 22 of Europacable – second stakeholder meeting. See “Preparatory Studies for Product Group in the Ecodesign Working Plan 2012-2014:Lot 8 - Power Cables: Project Report”.

[73] JRC study “Integration of resource efficiency and waste management criteria in European product policies – Second phase report N°2 (Report EUR 25667 EN)”, http://sa.jrc.ec.europa.eu/uploads/ecodesign-Application-of-the-projects-methods-to-three-product-groups-final.pdf

[74] See comment 2 of ECI comments – second stakeholder meeting. See “Preparatory Studies for Product Group in the Ecodesign Working Plan 2012-2014:Lot 8 - Power Cables: Project Report”.

[75] http://copperalliance.org/core-initiatives/sd/availability/

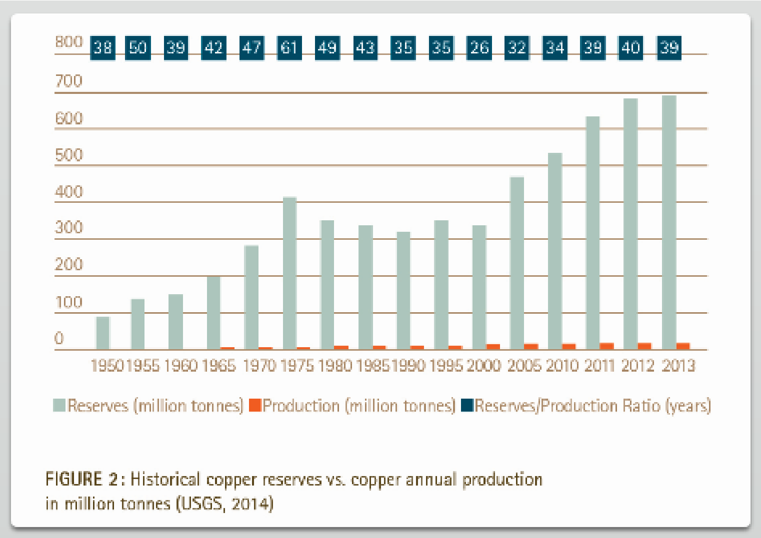

Figure 2-7 Historical copper reserves vs. annual copper production (USGS, 2014)

2.4.1 Installation costs

Cable installation time and installation costs depend on the length of the cable, the CSA of the cable and the difficulty for installation (accessibility). The cable installation time does not take into account the installation of the cable fixing system (cable tray, cable ladder, etc.) to which the cable is mounted. The calculation of the installation time is based on a normal accessibility to the cable fixing system (normal working height, no obstacles, etc.). The installation time of a cable with section CSA, length L is calculated with formula below.

$$T_{CSA} = Tm_{CSA} \cdot L + Te_{CSA}$$

Where

T_{CSA} = time to install a cable with section CSA and length L
Tm_{CSA} = time to install one meter cable with section CSA without connecting it
L = length of the cable to install
Te_{CSA} = time to connect the ends of a cable of section CSA

The average hourly rates in the EU28 are shown in Table 2-31 and are used as the installer's hourly rate. Installation times for copper based cables are listed per cable section in Table 2-32. Installation times for aluminium based cables are listed per cable section in Table 2-33.

Table 2-31 hourly rates in EU-28[76]

	2008	2010	2011	2012	2013	Non-wage costs (% of total), 2013	Change 2013/2008, %
EA17	25.7	26.9	27.5	28	28.4	25.90%	10.40%
EA18	25.5	26.7	27.3	27.8	28.2	25.90%	10.40%
EU28	21.5	22.4	22.9	23.4	23.7	23.70%	10.20%
Belgium	32.9	35.3	36.3	37.2	38	27.40%	15.40%
Bulgaria	2.6	3.1	3.3	3.6	3.7	15.80%	44.10%
Czech Republic	9.2	9.8	10.5	10.5	10.3	26.80%	12.40%
Denmark	34.4	36.7	37.3	38	38.4	12.40%	11.70%
Germany	27.9	28.8	29.6	30.5	31.3	21.80%	12.20%
Estonia	7.8	7.6	7.9	8.4	9	26.70%	15.20%
Ireland	28.9	28.9	28.7	29	29	13.80%	0.50%
Greece	16.7	17	16.2	15	13.6	19.10%	-18.60%
Spain	19.4	20.7	21.2	21	21.1	26.60%	8.70%
France	31.2	32.6	33.6	34.3	34.3	32.40%	9.90%
Croatia	9.2	8.6	8.7	8.7	8.8	15.40%	-4.00%
Italy	25.2	26.8	27.2	27.6	28.1	28.10%	11.40%
Cyprus	16.7	17.7	18	18	17.2	16.60%	2.60%
Latvia	5.9	5.5	5.7	6	6.3	20.60%	7.10%
Lithuania	5.9	5.4	5.5	5.8	6.2	28.50%	5.00%
Luxembourg	31	32.9	33.9	34.7	35.7	13.40%	15.40%
Hungary	7.8	7	7.3	7.5	7.4	24.60%	-5.20%
Malta	11.3	11.9	12.2	12.5	12.8	8.00%	13.90%
Netherlands	29.8	31.1	31.6	32.3	33.2	24.70%	11.70%
Austria	26.4	28	29	30.5	31.4	26.70%	18.90%
Poland	7.6	7.2	7.3	7.4	7.6	16.70%	0.10%
Portugal	12.2	12.6	12.6	11.6	11.6	19.30%	-5.10%
Romania	4.2	4.1	4.2	4.1	4.6	23.20%	10.60%
Slovenia	13.9	14.6	14.9	14.9	14.6	14.70%	4.90%
Slovakia	7.3	7.7	8	8.3	8.5	27.40%	17.00%
Finland	27.1	28.8	29.5	30.8	31.4	22.10%	15.90%
Sweden	31.6	33.6	36.4	39.2	40.1	33.30%	26.90%
United Kingdom	20.9	20	20.1	21.6	20.9	15.30%	-0.30%
Norway	37.8	41.6	44.5	48.5	48.5	18.90%	28.20%

[76] Labour costs in the EU28, Eurostat news release 49/2014, 27 March 2014

Table 2-32 installation times for Cu based cables[77]

Cu based cables		
Section	**Installation time per meter**	**Installation time for the cable ends**
mm2	Min	Min
1	1.75	5
1.5	2.45	7
2.5	3.15	9
4	3.85	12
6	5.25	12
10	5.95	15
16	7	17
25	8.75	20.4
35	9.8	25.5
50	10.5	30.6
70	11.9	36
95	12.6	45
120	14	45
150	15.75	60
185	17.5	60
240	21	85
300	24.5	120
400	28	200
500	35	360
630	42	480

[77] EUROPEAN COPPER INSTITUTE, UTILISATION RATIONNELLE DES ENERGIES APPLIQUEE AU DIMENSIONNEMENT DES NOUVELLES INSTALLATIONS ELECTRIQUES

Table 2-33 installation times for Al based cables[77]

Al based cables		
Mono	**Installation time per meter**	**Installation time for the cable ends**
Min	Min/mm2	Min/mm2
1	1.66	4.75
1.5	2.33	6.65
2.5	2.99	8.55
4	3.66	11.4
6	4.99	11.4
10	5.65	14.25
16	6.65	16.15
25	8.31	19.38
35	9.31	24.23
50	9.97	29.07
70	11.3	34.2
95	11.97	42.75
120	13.3	42.75
150	14.96	57
185	16.63	57
240	19.95	80.75
300	23.27	114
400	26.6	190
500	33.25	342
630	39.9	456

The installation cost is composed of a cost to design (and verify or certify) the circuit plus the cost to install the cable. This is modelled with formula 2.2:

$$C_I = C_E + T_{CSA} \cdot hr \qquad \text{(formula 2.2)}$$

Where

C_I = installation cost (EURO)
C_E= engineering/design/certification cost (EURO)
T_{CSA} = time to install a cable with section CSA and length L
hr = hourly rate (EURO/hour)

Unless impacted by a measure proposed in later tasks C_E will be set tot 0.

2.4.2 Repair and Maintenance costs

Neither repair, nor maintenance costs are applicable to power cables. Once installed, a power cable is unlikely to become faulty, unless inappropriate use or damage by external factors (third party damages the cable) is the cause.

2.4.3 Disposal costs/benefits

For methods on recycling see Task 3.

As power cables have positive scrap value, it is an advantage for a company to send the old power cables for scrap and avoid disposal costs. It is assumed that there is no disposal cost required for the handling of power cables at their end-of-life.

The positive scrap value for the owner of the cable conductor should be about 70% of the copper price (fluctuates). For instance, calculation of the positive scrap value based upon May 2014th figures results in €3500/ton / €5300/ton = 66%.

Copper price – scrap: ~ € 3500/ton[78] (05/2014)
Primary Copper price: ~€ 5300/ton[79] (05/2014)

A decommissioning fee of 10% is assumed for the recovery of the cable, which includes transport to the recycling facility and so on.

The residual value of a cable is calculated by means of the following formula:

RV= C . RC . SV . (1-DF)

Or

RV = C . RF

Where:

RV = residual value in EURO
C = conductor material in EURO (purchase)
RC = recycling rate of the conductor material in % (not all material is recycled)
SV = relative scrap value in %
DF = decommissioning fee in %
RF = residual factor and is equal to RC . SV . (1-DF)

For the values defined in this chapter this means that RF equals to 60 % (=95%.70%.(1-10%)). Based upon the figures in the "LV Power Cable Market Prices" study[80] and the average primary copper price, one can deduct that on average the price of the conductor material in a cable is about half of the discounted cable product price. This means that the residual value is about 30% of the cable product price (not taken into account the discount rate for the product lifetime and fluctuation of the conductor material price).

2.4.4 Energy rates

Table 2-34 presents the average financial rates in the EU27 suggested in the MEErP 2011 Methodology. These rates will be used in this preparatory study according the MEErP methodology[81]. The calculated rates per year (reference year = 2011) are listed in Table 8-12. This table shows the calculated annual electricity rates for the domestic and non-domestic sector, based upon the figures in Table 2 29 (reference year 2011).

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78 http://www.scrapmonster.com/european-scrap-prices
79 http://www.cablebel.be/index-site.php
80 "LV power cable market prices" study by ECD (Engineering, Consulting and Design) for European Copper Institute, August 2014

Table 2-34 Generic energy rates in EU-27 (1.1.2011)[81]

	Unit	domestic incl.VAT	Long term growth per yr	non-domestic excl. VAT
Electricity	€ / kWh	0.18	5%	0.11
Energy escalation rate*	%	4%		
**= real (inflation-corrected) increase*				

For the calculation in this study all non-residential prices are VAT exclusive.

2.4.5 Financial rates

Table 2-35 presents the average financial rates in the EU27 suggested in the MEErP 2011 Methodology.

Table 2-35 Generic financial rates in EU-27[52]

	Unit	domestic incl.VAT	non-domestic excl. VAT
Interest	%	7.7%	6.5%
Inflation rate	%	2.1%	
Discount rate (EU default)	%	4%	
VAT	%	20%	

[81] VHK, MEErP 2011 METHODOLOGY PART 1.

CHAPTER 3 TASK 3: USERS

The objective of this task is to identify the system aspects of the use phase. User requirements can be influenced by product design and product information. Relevant user-parameters are an important input for the assessment of the environmental impact of a product during its use and end-of-life phase, in particular if they are different from the standard measurement conditions as described in subtask 1.2.

With the recast of the Ecodesign Directive to energy-related products in 2009, the discussion on user requirements needs to take into account the indirect impacts of energy-related products (see illustration below).

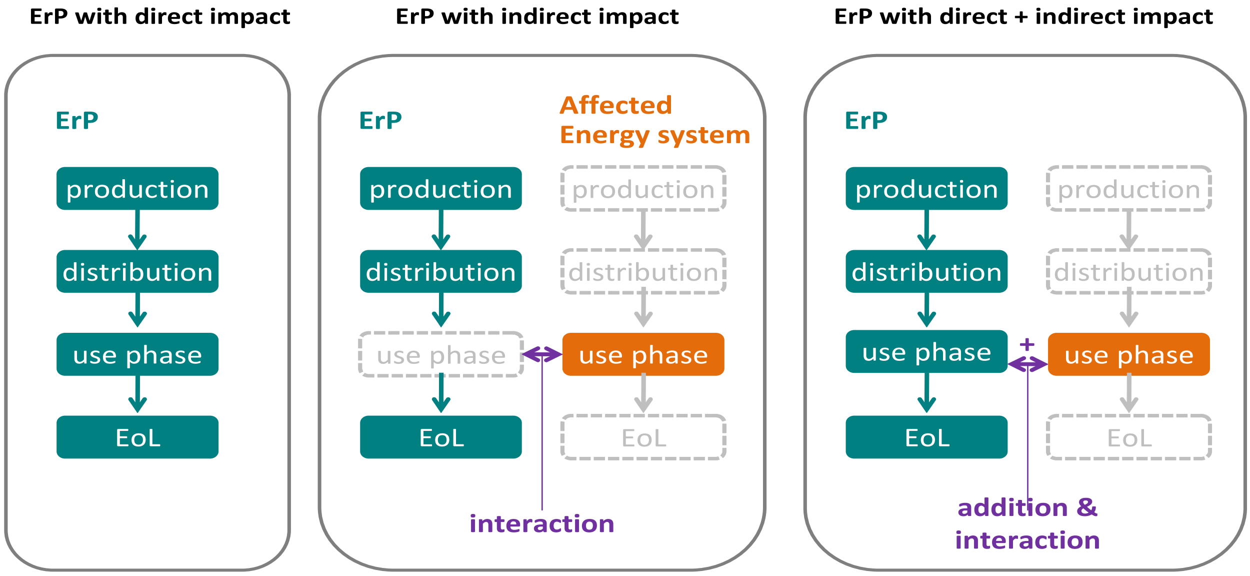

Figure 3-8: Three groups of ErP, distinguished by their impact (source: MEErP 2011 Methodology Part 1).

Summary of Task 3:
The use of the power cable is mainly defined by the characteristics of the circuit, the load distribution in the building and the power consumption profile of the connected loads.
The most important parameters for the circuit characteristics are the average circuit length (l) in meters (see Table 3-4) and minimum and maximum cable cross sectional areas (CSA) in mm² per circuit type (see Table 3-2).
The most important parameters related to the power consumption profile of the loads are:circuit load factor (αc), load form factor (Kf) (see Table 3-13) and power factor (see 3.1.5.2).
There is a big spreading in these parameters and 'the European average electrical circuit' is not directly defined neither existing. This might introduce a large degree of uncertainty in later tasks and therefore ranges of data are included which allow complementary sensitivity analysis in Tasks 6 and 7.

The product lifetime is summarized in Table 3-24. End-of-life parameters are listed in Table 3-17. A typical product lifetime in the service and industry sector is about 25 years. Due to the high scrap value of copper, recycling of cables is common business and the MEErP defaults value of 95 % will be used.

On user behaviour the stakeholder questionnaires[82] also revealed that:

- that electro-installers are unaware of the losses in circuits;
- in practice, calculation of losses is not performed when designing an installation. Mostly only voltage drop and safety restrictions are taken into account;
- The responsibility regarding the budget for the investment and the budget for operating expenses is in most cases split and linked to different departments. As a result no economic Life Cycle Cost (LCC) evaluation is performed and the installation with the lowest investment costs is often selected. Tenders do generally not include a requirement to perform LCC calculations in the offer.

3.1 Systems aspects of the use phase for ErPs with direct impact

The main function of the electrical installation is to transport electricity. The installation consumes energy by fulfilling this function, because the transport experiences electrical resistance in different parts of the installation and part of the energy is dissipated as heat energy. In this study the focus is on the power cable used in the electrical installation. The power cable is part of the electric circuit (see Figure 3-1 and 3-2). The electric circuit consists of different segments using power cables, junction boxes, terminal connections and protection equipment like circuit breakers limiting the maximum current in the power cable. The electrical installation consists of several circuits, distribution boards/system board, and overall protection devices. The electrical installation is an indispensable part of modern buildings.

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[82] this questionnaire was sent to installers on the 30th of September, 2013 in the context of this study. A second questionnaire was sent on the 7th of July, 2014. The results were combined. See "Preparatory Studies for Product Group in the Ecodesign Working Plan 2012-2014:Lot 8 - Power Cables: Project Report".

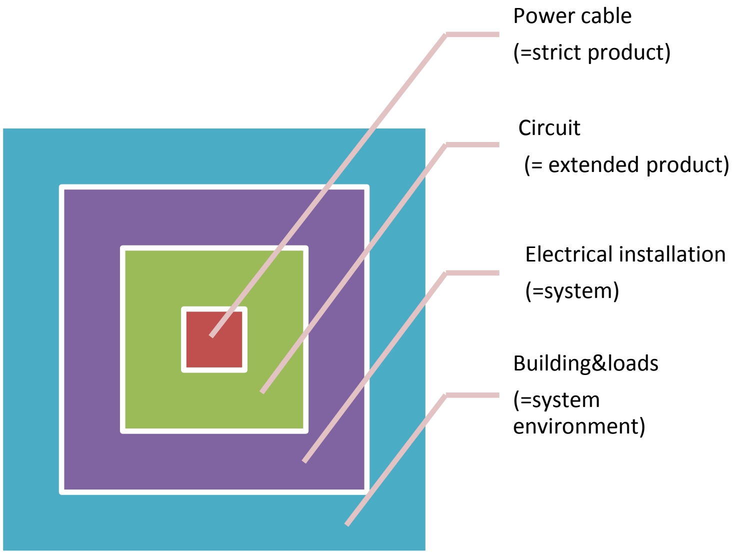

Figure 3-9: From strict product to systems approach

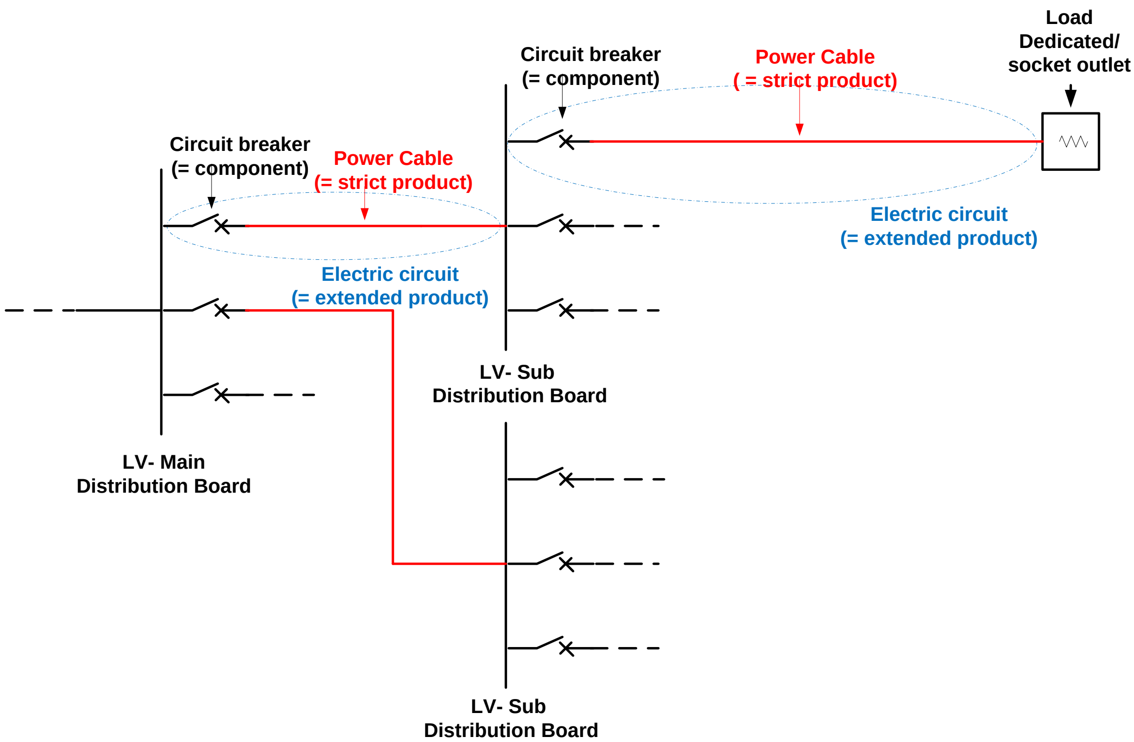

Figure 3-10: Simplified 1-wire diagram of an electric installation

The use of the power cable is mainly defined by the characteristics of the circuit, the load distribution in the building and the profile of the loads (in time).

3.1.1 Definition of the user and context

For electrical installation it is important to discriminate between different types of users who use cables:

1. The engineering company or architect of the electrical installation.
2. The person or organisation performing the actual installation of electrical installation of a new building or renovation of parts of the building, e.g. electrical contractors, interior designers, property developers and installers, hereafter called the *'installers'.* The installer is responsible for putting the electrical installation including the power cables into service.
3. The person or organisation responsible or certifying the electrical installation, hereafter called the *'certifier'.*
4. The end-user who lives or works in the building and makes use of the electrical installation, hereafter called the *'user'*.
5. The owner of the building and thus of the electrical installation, hereafter called the *'owner'*. The owner finances the electrical installation and has the end-responsibility for the electrical installation in the building (certification, safety coordinator, etc.). Depending on the sector and function type of the building the owner and user roles may be unified in one organisation/person.

Depending on the sector and country the installer and user can be the same acting as a Do-It-Yourself (DIY) consumer. In some countries the installer can also perform the certification of a (small) installation. The DIY method however is only applied in the residential building sector.

3.1.2 Loss parameters directly related to the cable itself

As discussed in Task 1, the power losses are proportional to the cable resistance (R). The resistance of a cable in circuit at a temperature t can be calculated by the formula:

$$R = \rho_t . l/A \text{ (Ohm)} \qquad \text{(formula 3.1)}$$

The losses in a power cable are therefore affected by:

- the specific electrical resistance (ρ_t) of the conductor material;
- the cross-sectional area (A) of the cable;
- the total length (l) of cable for a circuit.

In annex 1-B of Task 1, a closer look is taken at these physical parameters and at how manipulation of these parameters can contribute to smaller power losses in power cables.

3.1.2.1 Conductor material electrical resistance

Both aluminium and copper are used as conductors and are available for use in standard wire sizes and foils. Aluminium is less used in cables with small CSAs.

Table 3-1: Properties of Aluminium and Copper

Property	Aluminium	Copper
Electrical Conductivity (relative)	0.61	1
Thermal Conductivity (Cal/s.cm.K)	0.57	0.94
Relative weight for the same conductivity	0.54	1
Cross section for the same conductivity	1.56	1
Tensile Strength (kg/cm^2)	844	2250
Specific weight (kg/dm^2)	2.7	8.9
Electrical Resistivity (mOhm.mm) (20°C)	26.5	16.7
Thermal coefficient of resistance (1e-6/K)	3770	3900

3.1.2.2 Cross-sectional area (CSA)

The available CSAs for power cable are defined by standardisation and are expressed in mm². The following values for CSA are used in IEC 60228:2004: 0.75; 1; 1.5; 2.5; 4; 6; 10; 16; 25; 35; 50; 70; 95; 120; 150; 185; 240; 300; 400; 500; 630; 800; 1000 and 1200 mm².

According IEC 60364-1 the CSA of conductors shall be determined for both normal operating conditions and for fault conditions according to:

- their admissible maximum temperature;
- the admissible voltage drop;
- the electromechanical stresses likely to occur due to earth fault and short-circuit currents;
- other mechanical stresses to which the conductors can be subjected;
- the maximum impedance with respect to the functioning of the protection against fault currents;
- the method of installation.

The selection of the appropriate cable cross sectional area takes into account specific parameters like:

- their maximum admissible intensity;
- requested current-rating capacity by the circuit;
- length of the cable in the circuit;
- maximum allowed voltage drop;
- installation conditions (ambient temperature and installation type);
- maximum operating temperature for cables and the full installation;
- safety fuses, circuit breakers and short circuit time;
- number of cables per circuit.

Table 3-2: Minimum and maximum cable cross-sectional areas per circuit type

Sector	Circuit application type	CSA (mm²) min	CSA (mm²) max
Residential	Distribution circuit	6	16
	Lighting circuit	1	2.5
	Socket-outlet circuit	1.5	6[83]
	Dedicated circuit	2.5	6
Services	Distribution circuit	10	600
	Lighting circuit	1.5	2.5
	Socket-outlet circuit	1.5	6
	Dedicated circuit	2.5	95
Industry	Distribution circuit	25	600
	Lighting circuit	1.5	2.5
	Socket-outlet circuit	1.5	10[84]
	Dedicated circuit	2.5	600

3.1.2.3 Length of cable

The length of cable is primarily determined by the physical topography and design of the building, the building's function type and the placing of the appliances along the building. The length of cable used in the electrical installation is also determined by the topology of the electrical installation. For instance an installation can have one or more distribution levels.

Conclusion:
See data on lengths of cables in electrical circuits in section 3.1.4.5.

3.1.2.4 Number of cores

A power cable contains one or more conductor cores. When the cable is placed in conduits multiple single-core cables can be used. Some products consist of a combination of singe-core or multicore cable and flexible conduits. The number of cores is determined by:

- The AC grid system (TT,TN,IT), see Task 1
- Single phase or three-phase system
- Earthing conductor included or not, neuter conductor included or not
- Also the handling of the cable (multi-core cables with large CSAs are more difficult to handle than multiple single-core cables) and the product availability/existence play a role in cable selection.

The cores in a cable generally have the same CSA, but can also have different CSA. The phase currents in three phase systems tend to cancel out one another, summing to

[83] 5G6 mm² cable at 3-phase 400Vac and max 3% voltage drop results in maximum circuit length of 132m and Imax of 16A or maximum circuit length of 53m and Imax of 40A.
[84] 5G10 cable at 3-phase 400Vac and max 3% voltage drop results in maximum circuit length of 142m and Imax of 25A or maximum circuit length of 56m and Imax of 63A.

zero in the case of a linear balanced load. This makes it possible to reduce the size of the neutral conductor or even to leave it out in the ideal situation.

3.1.2.5 Skin effect

The skin effect is the tendency of an alternating electric current (AC) to become distributed within a conductor such that the current density is largest near the surface of the conductor, and decreases with greater depths in the conductor. It has an effect on the cable resistance and is partly determined by the used conductor material and CSA of the cable. The electric current flows mainly at the 'skin' of the conductor, between the outer surface and a level called the skin depth δ. The skin effect causes the effective resistance of the conductor to increase at higher frequencies where the skin depth is smaller, thus reducing the effective cross-section of the conductor.

$$\delta = \sqrt{2\rho/\omega\mu} \quad \text{(formula 3.2)}$$

Where

ρ = resistivity of the conductor
ω = angular frequency of current = 2π × frequency
μ = absolute magnetic permeability of the conductor

At 50 Hz in copper, the skin depth δ is about 9.2 mm. For aluminium it is about 11.6 mm.

The skin effect is only relevant for cables with a diameter D much larger than the skin depth. Using a material of resistivity ρ we then find the AC resistance of a wire of length L to be:

$$R \approx L\rho/(\pi(D - \delta)) \quad \text{(formula 3.3)}$$

At 50 Hz the skin effect is negligible for cables with a CSA of less than 400 mm². For cables with a very large CSA the skin effect is an important factor. For instance for cables with a CSA of 1000 mm² the AC resistance compared to the DC resistance will increase with almost 30% for copper and 14 % for aluminium. Figure 3-11 shows the increase in resistance for copper and aluminium conductors at 50Hz for CSAs from 400 mm² till 1200 mm².

An S+x strategy for cables with a CSA of more than 400 mm² will therefore be countered by the increasing resistance due to the skin effect. Looking at material use versus savings the strategy will become less efficient for cables with a very large CSA.

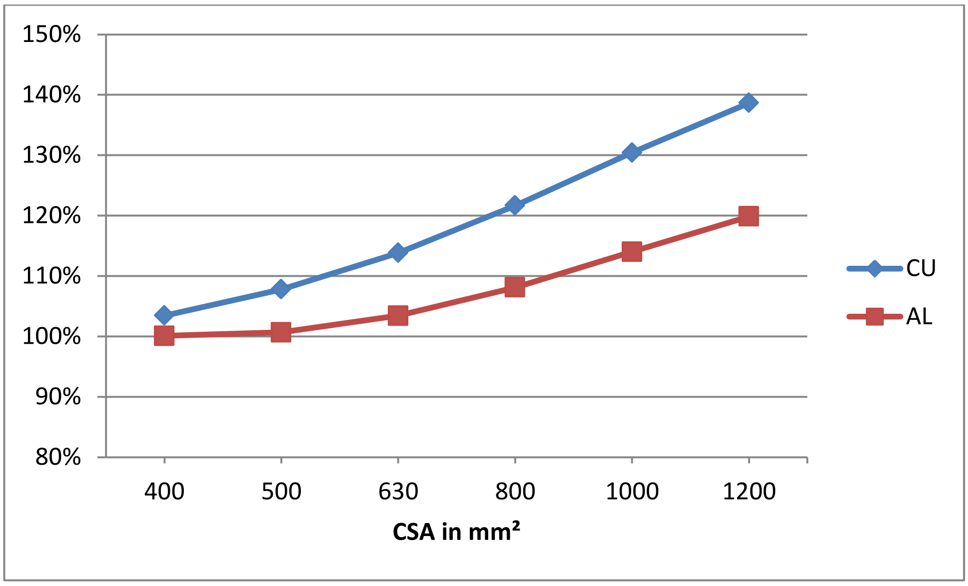

Figure 3-11: Resistance increase due to skin effect at 50Hz for Cu and Al conductors

Conclusion:
The skin effect is only relevant for power cables with very large CSA. From 400 mm² on the effect is noticeable, and becomes relevant for CSAs more than 630 mm². When selecting the appropriate measure for energy savings in power cables with a very large CSA, the skin effect should be taken into consideration. From a certain CSA magnitude on a dual-wiring strategy (with a smaller CSA than the S+x strategy) may be preferred upon an S+x strategy.

3.1.3 Other functional cable parameters not directly related to losses

3.1.3.1 Insulation material

The selection criteria of insulation material depend on electrical (rated voltage) and physical (temperature range, flexibility, flammability, chemical resistance, etc.) requirements of the application.

The selection of insulation material is also influenced by building properties and function of the building (risk of fire, evacuation capability, etc.). For instance, in Belgium the national code AREI imposes requirements on power cables regarding flame resistance. For buildings higher than 25 meter, schools, hospitals and so on the evacuation velocity is one of the factors determining the flame resistance category (elapsed time).

3.1.3.2 Construction of the conductor

The type of construction mainly has an effect on the flexibility/bending radius. The selection of the type of construction is thus largely determined by the flexibility and bending requirements.

The construction type has also a small effect on the AC resistance of the cable. Table 3-3 shows the influence of the construction type on the maximum resistance at 20° C, based upon the resistance values for different CSAs and classes, listed in IEC 60228:2004. ΔR stands for the R_{classx} – R_{class1}. $\Delta R/R_{class1}$ indicates the amount of resistance reduction or increase for class x compared to class1.

Table 3-3: Construction type versus maximum resistance (at 20° C)

	Class 1 solid conductors for single-core and multicore cables	Class 2 stranded conductors for single-core and multi-core cables		Class 5 flexible copper conductors for single-core and multi-core cables		Class 6 flexible copper conductors for single-core and multi-core cables	
CSA	Plain	Plain wires	ΔR/Rclass1	Plain wires	ΔR/Rclass1	Plain wires	ΔR/Rclass1
mm²	Ω/km	Ω/km	%	Ω/km	%	Ω/km	%
0.5	36	36	0.0%	39	8%	39	8%
0.75	24.5	24.5	0.0%	26	6%	26	6%
1	18.1	18.1	0.0%	19.5	8%	19.5	8%
1.5	12.1	12.1	0.0%	13.3	10%	13.3	10%
2.5	7.41	7.41	0.0%	7.98	8%	7.98	8%
4	4.61	4.61	0.0%	4.95	7%	4.95	7%
6	3.08	3.08	0.0%	3.3	7%	3.3	7%
10	1.83	1.83	0.0%	1.91	4%	1.91	4%
16	1.15	1.15	0.0%	1.21	5%	1.21	5%
25	0.727	0.727	0.0%	0.78	7%	0.78	7%
35	0.524	0.524	0.0%	0.554	6%	0.554	6%
50	0. 387	0.387	0.0%	0.386	0%	0.386	0%
70	0.268	0.268	0.0%	0.272	1%	0.272	1%
95	0.193	0.193	0.0%	0.206	7%	0.206	7%
120	0.153	0.153	0.0%	0.161	5%	0.161	5%
150	0.124	0.124	0.0%	0.129	4%	0.129	4%
185	0.101	0.0991	-1.9%	0.106	5%	0.106	5%
240	0.0775	0.0754	-2.7%	0.0801	3%	0.0801	3%
300	0.062	0.0601	-3.1%	0.0641	3%	0.0641	3%
Average			-0.4%		5.6%		5.6%

3.1.4 Loss parameters directly related to the electrical circuit and network topology

Losses are also related to the electrical circuit and network topology.
An electrical circuit starts at a distribution board and consists of a protective device, cable, junction boxes and distribution endpoints all being part of the electrical circuit.
Also the network topology has an impact, which are the relative positions and the interconnections of the circuit elements representing an electric circuit.
In the following sections parameters are defined and reference data is included to model relevant parameters related to cable losses.

3.1.4.1 Single phase or three phase circuit

Being a single or three phase circuit has mainly an effect on the number of cores of the cable (or number of single core cables) used in the circuit. A single phase circuit cable will have two cores (phase and neuter) or three cores (phase, neuter, earthing). A three phase circuit cable canl have three cores (three phases), four cores (phases and earthing, phases and neuter) or five cores (phases, neuter, earthing).

The voltage used in the single phase system is 230V.
The voltage used in the three phase system can be 230VAC or 400VAC, depending the configuration. To transport the same energy in a three phase 400V system as in a single phase 230 V system the current can be reduced and hence losses are lower. High power loads in the service sector and industry, i.e. above 4600 VA (230VAC/20A), are therefore most often connected 400 VAC three phase.

Conclusion:
In this study we will assume that all loads above 4600 VA are connected three-phase, a sensitivity analysis in Task 7 could check for a single phase 230 VAC.
Lighting circuits and socket outlet circuits will be considered single phase.
Three phase socket outlet or connector circuits do exist and will be reconsidered in a sensitivity analysis in Task 7.

3.1.4.2 Maximum voltage drop in a circuit

The maximum voltage drop in a circuit (see Figure 3-12) is determined in standard (IEC 60364-5-52 – informative Annex G), see Task 1. The voltage drop is directly proportional to the power loss.

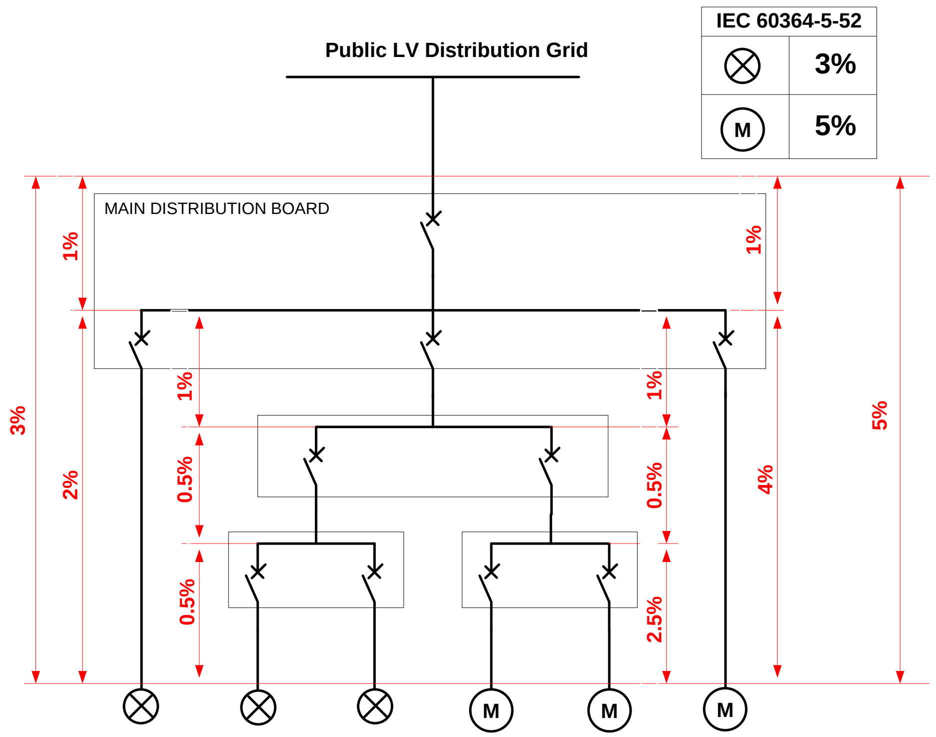

Figure 3-12: Voltage drop in an electrical installation

3.1.4.3 Overcurrent protection in a circuit

Cable losses are limited because the maximum current or overcurrent is limited in an electrical circuit by using circuit breakers or fuses, as discussed in Task 1.
The overcurrent device rating (In) is selected so that In is greater than or equal to the load current (Ib). Ib is the design current of the circuit, i.e. the current intended to be carried by the circuit in normal service (see task 1).

Circuit breakers are installed according to standard IEC 60364-1.

3.1.4.4 Circuit network topology

Electrical circuits can be installed in various network topologies.

In lighting circuits three different topologies are common:

- A 'Bus network topology' approach, e.g. this is most often implemented with a so-called DALI[85] bus where a control signal is distributed together the power cable. This is frequently used in large industrial installations. Typically a five wire cable is used (5G1.5) whereby two wires are used for the control signal.
- 'Two-wire installation' that contains only one wire between switch and lamp. In this system the switch/control product is connected in series with lamp/load and the neutral is not present in the switch (except in some countries). The advantage is the low amount of required copper wire and reduced short circuit risk during installation but the disadvantage is that no direct power supply is available for electronic control switches (e.g. dimmers). In Figure 3-13 an example of a 'two wire installation' of a two wire installation is shown. The neutral wire is directly going to the lamp, without intermediate switch.

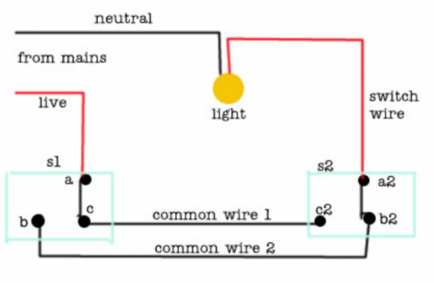

Figure 3-13: Example of a 'two wire installation'

- 'Three wire installation' that contains both the neutral and phase wire between the switch and the lamp. The main advantage is that a power supply for the control switch can easily be obtained but it requires more copper wire for installation.
- A single wire topology with a relays either at the lamp or at a central distribution board.

[85] http://www.dali-ag.org

In most European countries socket-outlets are interconnected with a single line, in the UK a ring circuit topology is used.

Conclusion:
The following topologies will be assumed as typical:

- For lighting in the industry and service sector: a DALI bus cable network topology;
- For socket-outlet: a single line topology;
- For dedicated loads: a point to point connection.

3.1.4.5 Circuit length

Length of circuit stands for the total amount of cable used for the circuit between distribution board (start point of the circuit) and final endpoint of a circuit.

The average length in meters of a circuit, based upon the responses on the questionnaire for installers[86], per circuit type and sector is shown in Table 3-4.

Table 3-4: Average circuit length in meters according questionnaire[86]

Sector	Circuit application type	Average length min (m)	Average length ref (m)	Average length max (m)
Residential	Distribution circuit	15	21	54
	Lighting circuit	10	20	60
	Socket-outlet circuit	5	24	100
	Dedicated circuit	5	18	80
Services	Distribution circuit	20	56	200
	Lighting circuit	12	44	240
	Socket-outlet circuit	10	53	300
	Dedicated circuit	10	51	300
Industry	Distribution circuit	30	83	240
	Lighting circuit	20	68	340
	Socket-outlet circuit	15	72	500
	Dedicated circuit	15	79	400
CorrectionFactor		1	1	2

Conclusion:
Table 3-4 shows the average circuit lengths. The proposal is to use the average reference length values listed in Table 3-4 for the calculation of losses in circuits. Crosschecks in later tasks indicated that the maximum average value should be larger.

[86] This questionnaire was sent to installers on the 30th of September, 2013 in the context of this study. A second questionnaire was sent on the 7th of July, 2014. The results were combined. See "Preparatory Studies for Product Group in the Ecodesign Working Plan 2012-2014:Lot 8 - Power Cables: Project Report".

This correction (results are multiplied with the corresponding correction factor shown in the last row of the table) is already incorporated in the results listed in Table 3-4. The maximum and minimum values are used for sensitivity analysis.

3.1.4.6 Effect of load distribution

In the case of socket-outlets electrical wires are 'branched' to distributed loads and hence losses are not equal within all cable segments. Figure 3-14 shows a typical wiring diagram with branches, the cable loading at the end points or sockets is of course lower compared to the central feeder connection.

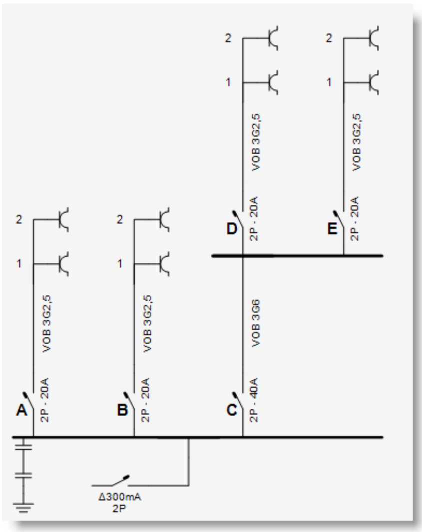

Figure 3-14: Typical wiring diagram

As explained in Task 1, the Kd 'distribution factor' is introduced to compensate the distribution of the loading over the cable of a circuit. A 'distribution factor' of 1 means that all cable segments are loaded with the same load current. The Kd 'distribution factor' is lower than or equal to 1.

Table 3-5: Kd factors for circuits with minimum 1 to maximum 8 socket-outlets with equally distributed loads and cable segment lengths

	Number of socket-outlet							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Kd	1	0.61	0.50	0.45	0.42	0.40	0.39	0.38

Table 3-5 shows the calculated Kd factor for circuits with up to 8 socket outlets, equally distributed loads and cable segment lengths. The calculation results for 8 nodes can be found in Annex 3-A in Table 8-15, Table 8-16, Table 8-17 and Table 8-18.
Table 3-6 and Figure 3-15 show the Kd factor for up to 30 nodes in function of the load branch length factor of respectively 1%, 10%, 50%, 100%, 150% and 200%. One can

conclude that the effect of the number of nodes on the Kd factor beyond 10 nodes is minimal.

Table 3-6: Kd factors for circuits with up to 30 nodes in function of load branch length factor

Load branch length factor	**Number of nodes**														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1%	1	0.624	0.517	0.467	0.438	0.420	0.406	0.397	0.389	0.383	0.378	0.374	0.371	0.368	0.366
10%	1	0.613	0.502	0.451	0.422	0.403	0.390	0.381	0.373	0.367	0.362	0.358	0.355	0.352	0.350
50%	1	0.563	0.437	0.382	0.351	0.332	0.319	0.309	0.302	0.296	0.292	0.288	0.285	0.282	0.280
100%	1	0.500	0.356	0.295	0.262	0.242	0.229	0.220	0.213	0.207	0.203	0.200	0.197	0.194	0.192
150%	1	0.438	0.274	0.208	0.173	0.153	0.140	0.130	0.124	0.119	0.115	0.111	0.109	0.106	0.105
200%	1	0.375	0.193	0.121	0.084	0.064	0.050	0.041	0.035	0.030	0.026	0.023	0.021	0.019	0.017

Load branch length factor	**Number of nodes**														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1%	0.363	0.362	0.360	0.358	0.357	0.356	0.355	0.354	0.353	0.352	0.351	0.350	0.350	0.349	0.348
10%	0.348	0.346	0.344	0.343	0.341	0.340	0.339	0.338	0.337	0.336	0.336	0.335	0.334	0.334	0.333
50%	0.278	0.276	0.275	0.273	0.272	0.271	0.270	0.269	0.268	0.267	0.267	0.266	0.265	0.265	0.264
100%	0.190	0.189	0.187	0.186	0.185	0.184	0.183	0.183	0.182	0.181	0.181	0.180	0.180	0.179	0.179
150%	0.103	0.102	0.100	0.099	0.098	0.098	0.097	0.096	0.096	0.095	0.094	0.094	0.094	0.093	0.093
200%	0.016	0.014	0.013	0.012	0.012	0.011	0.010	0.010	0.009	0.009	0.008	0.008	0.008	0.007	0.007

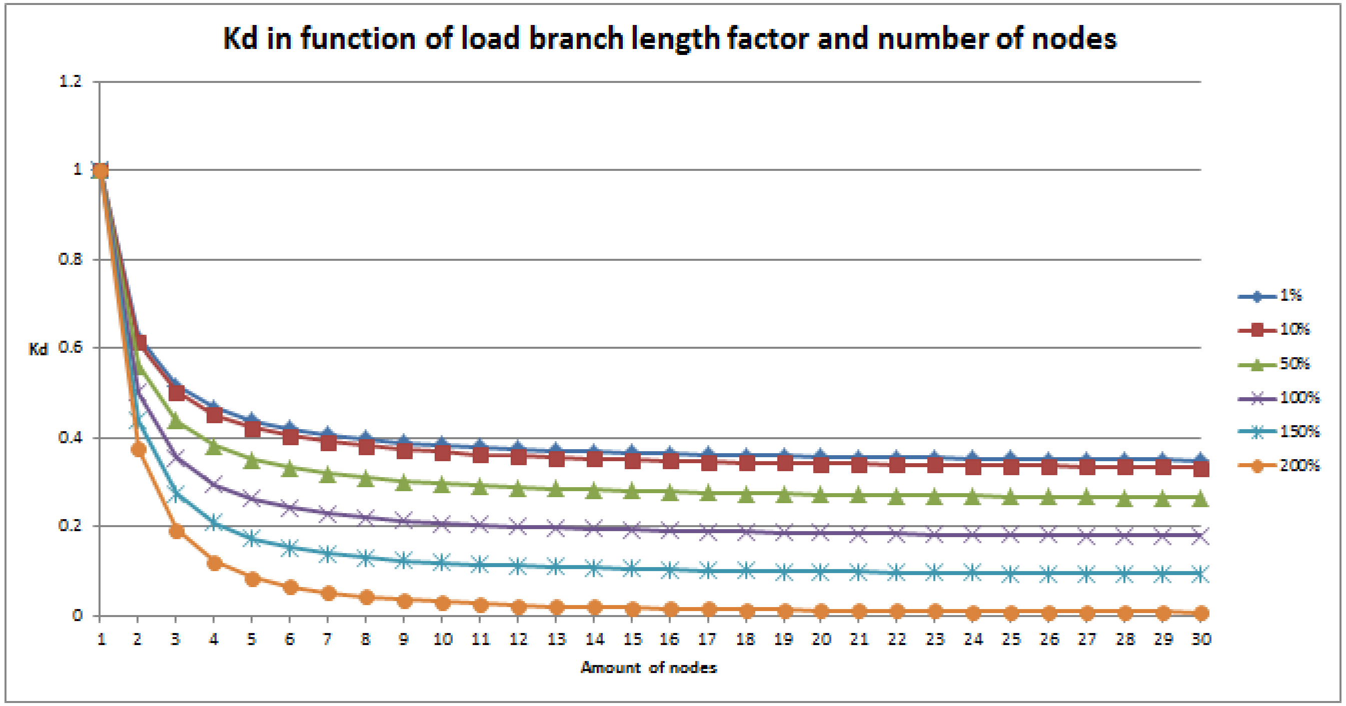

Figure 3-15: Kd in function of load branch length factor and number of nodes

Table 3-7: Average number of nodes per circuit application type according to questionnaire[87]

Sector	Circuit application type	Average number min	Average number ref	Average number max
Residential	Distribution circuit	1	1	1
	Lighting circuit	5	10	30
	Socket-outlet circuit	8	10	20
	Dedicated circuit	1	2	3
Services	Distribution circuit	1	1	1
	Lighting circuit	3	12	25
	Socket-outlet circuit	4	8	15
	Dedicated circuit	1	2	6
Industry	Distribution circuit	1	1	1
	Lighting circuit	3	14	28
	Socket-outlet circuit	2	6	10
	Dedicated circuit	1	2	5

Typical circuits have almost no branches. The cables are wired through at the nodes. Therefor a load branch length factor of 1% is used to calculate the Kd factor based upon the number of nodes in Table 3-7. The values in Table 3-8 are extracted from Table 3-6 based upon the number of nodes in Table 3-7.

[87] This questionnaire was sent to installers on the 30th of September, 2013 in the context of this study. A second questionnaire was sent on the 7th of July, 2014. The results were combined. See "Preparatory Studies for Product Group in the Ecodesign Working Plan 2012-2014:Lot 8 - Power Cables: Project Report".

Table 3-8: Kd factor per circuit type

Sector	Circuit application type	Kd if low number of nodes	Kd avg	Kd if high number of nodes
Residential	Distribution circuit	1.00	1.00	1.00
	Lighting circuit	0.44	0.39	0.35
	Socket-outlet circuit	0.40	0.39	0.36
	Dedicated circuit	1.00	1.00	0.52
Services	Distribution circuit	1.00	1.00	1.00
	Lighting circuit	0.52	0.37	0.35
	Socket-outlet circuit	0.47	0.40	0.37
	Dedicated circuit	1.00	1.00	1.00
Industry	Distribution circuit	1.00	1.00	1.00
	Lighting circuit	0.52	0.37	0.35
	Socket-outlet circuit	0.62	0.44	0.38
	Dedicated circuit	1.00	1.00	1.00

Note: in distributed and in most dedicated circuits the loads are concentrated at the end of the circuit, resulting in a Kd factor of one.

Conclusion:
Table 3-8 summarises the proposal for average values to be used in this study.

3.1.4.7 Effect of not simultaneous functioning of distributed loads

Socket-outlets are connected to multiple loads and when they are not functioning simultaneously this will decrease load current in the circuit. Because losses are proportional to square of the loading current, the losses will be lower. This can be modelled by the so-called 'Rated Diversity Factor'. However, when considering all the loads served by one circuit as one aggregated load, this factor isn't necessary. The diversity factor effect is then incorporated in the load factor and load form factor of the 'circuit load'.

Conclusion:
By using load factor and load form factors associated with a 'circuit load', this factor can be omitted.

3.1.4.8 Ambient temperature

Conductor losses are temperature dependent and therefore higher ambient temperatures have a negative effect on the losses and the current-carrying capacity of the cable. For instance, according IEC 60364-5-52 a correction factor of 0.87 has to be applied for PVC cables installed in locations with a ambient temperature of 40°C.

Conclusion:

An ambient temperature of 20°C will be assumed, because this is the normal indoor temperature.

3.1.4.9 Temperature effect caused by the 'method of installation'

Conductor losses are temperature dependent and therefore also the so-called method of installation influences the losses and hence the current-carrying capacity of the cable. This effect is included in standard IEC 60364-5-52 which defines correction factors according to the installation method. IEC 60364-5-52 describes 73 reference installation methods. For each method different correction factors are defined to calculate the current carrying capacity. Figure 3-16 shows some examples of methods of installation and Figure 3-17 the most typical thermal conditions.

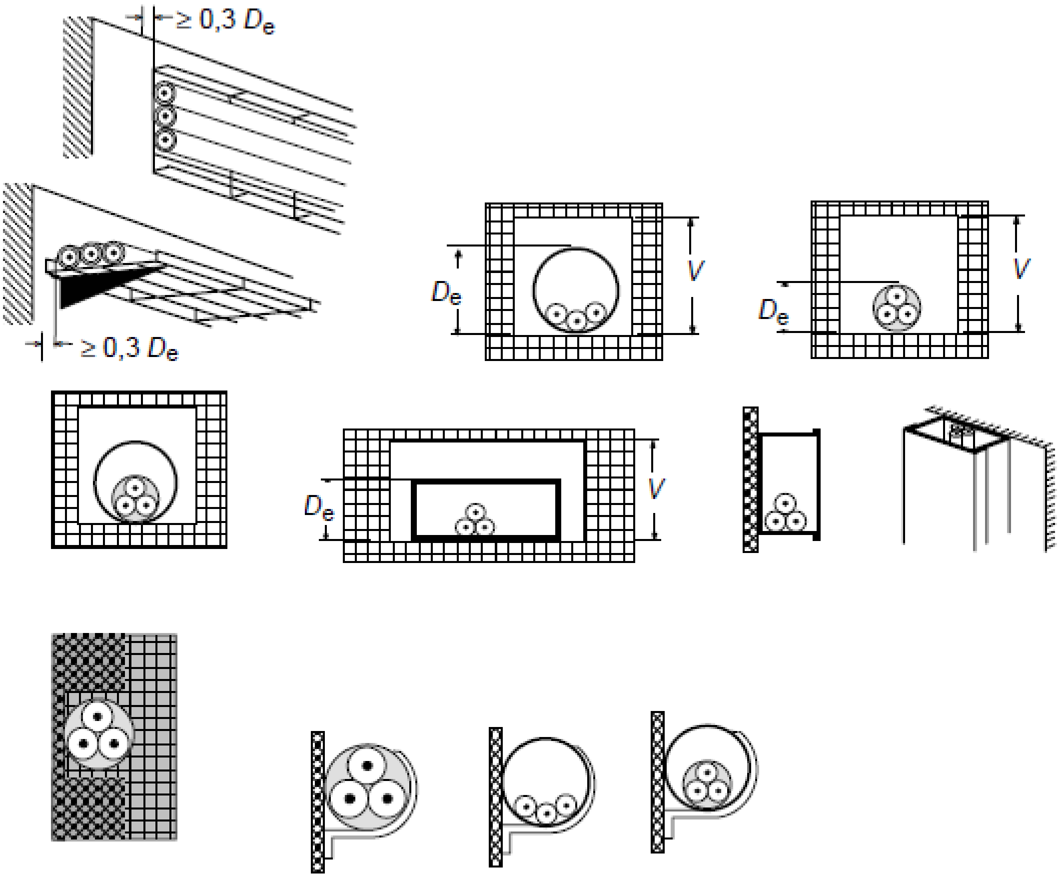

Figure 3-16: Some examples of method of installation (IEC 60364-5-52)

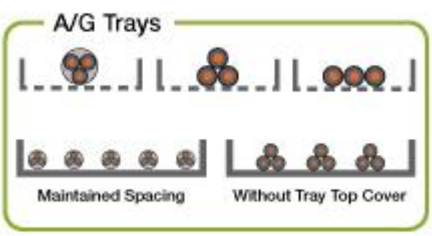

Figure 3-17: Different thermal conditions

Conclusion:
The correction factors in IEC 60364-5-52 related to the method of installation have an impact on the selection of the cross section of a cable (fixed current carrying capacity), or on the current carrying capacity (fixed cross section). The cross section and the current carrying capacity are incorporated in the formulas calculating the losses in a circuit (see formula 3.4 and 3.7).

3.1.4.10 Single or three phase system

See also 3.1.4.1. Of course, in order to have a three phase load connection a three phase grid connection is required.

Conclusion:
See 3.1.4.1.

3.1.4.11 Number of distribution levels

An electrical installation has one or more distribution levels (see definition in Task 1). Small installations have just one level. Larger installations in general have two levels. Exceptionally, very large installations or installations with special design requirements may have a third level.

Conclusion:
No statistics on distribution levels is available. Therefore, two levels will be regarded as a reference design in the industry and service sector.

3.1.4.12 Rated Diversity Factor DF at installation level

The Diversity Factor according IEC 61439-3 recognizes that multiple functional units (in this case outgoing circuits at a distribution board or assembly) are in practice not fully loaded simultaneously or are intermittently loaded. The Diversity Factor should be used when calculation the total load in an distribution board/assembly and higher level based upon the sum of the loads in the outgoing circuits of the distribution board.

Different Rated Diversity Factor may be stated for groups of outgoing circuits or for all the outgoing circuits of the assembly/distribution board. Within each of these groups, including the complete assembly, the sum of the rated currents multiplied by the Rated Diversity Factor shall be equal to or higher than the assumed loading currents.

IEC 61439-3 states that in case of lack of information relating to the actual load currents, the Manufacturer will select and declare appropriate Rated Diversity Factor values, preferably from the conventional values listed in in Table 3-9.

Table 3-9: Diversity factor in function of the number of circuits according IEC 61439-3

Number of outgoing circuits	**Diversity Factor (DF)**
2 and 3	0,8
4 and 5	0,7
6 to 9 inclusive	0,6
10 and above	0,5

Conclusion:
This factor should be used when the total load is calculated in function of the loading of each outgoing circuit at the specific distribution level. However, in task 4 till task 7 the base cases and their associated parameters are specified at circuit level and not at electrical installation level. Consequently, this factor isn't relevant for this study. See also conclusion in 3.1.4.7.

3.1.5 Parameters related to the building and loading

Losses in cables depend on the current loading, the relevant loading parameters are explained hereafter.

3.1.5.1 Load Factor (α_c) and load form factor (Kf)

This section describes the used Load factors (α_c =Pavg/S) and Load Form factors (Kf = Prms/Pavg) as defined in chapter 1. To simplify the calculation the loads served by a circuit is regarded as one single virtual load at the end of the circuit (this the reason why α_c and not α is used; α_c stands for corrected or circuit load factor). The Kd distribution factor will compensate this change in topology. The diversity of the different single loads is incorporated into the virtual load.

The load factor α_c is in between 0 and 1. The Load Form factor is always larger than or equal to 1. The product of the load factor and the load form factor is always less than or equal to 1.

Clearly in real conditions current loading (I) (and temperature) have an important influence. In order to calculate the annual energy loss of cables from data files with an estimation of the current loading, it is convenient to switch to time independent parameters and use the so-called RMS load (Prms) or root-mean-square value of the power load load profile. The RMS load values can be computed from data files, e.g. from the Synthetic Load Profiles. The study will investigate which load form factors are most common and could be used in later tasks for assessment of base cases.

When calculating the losses in a circuit, the load profiles for each load of the circuit have to be known. These statistics are however not available. Synthetic Load Profiles are aggregated averaged load profiles of building units (households), and can differ largely from the load profile of a single circuit, and can therefore not be used.

Therefore some general assumptions are made in the calculation of the load and form factors. For instance office lighting[88] have typical annual operating hours ranging from

[88] Preparatory Studies for Eco-design Requirements of EuPs: 'Final report lot 8 on office lighting' (see www.eup4light.net)

2000-2500 hours per year which should be equivalent to a load factor (Pavg/S) = 2250h/8760h = 26 %. Assuming the lights are all switched on 2250h a year, and all are switched off the rest of the year results in a Kf equal to 1.96. In case of 2 periods with two distinct power usage P1 and P2, Kf is calculated as follows:

$$\text{Kf} = \frac{\sqrt{\dfrac{period1\ x\ P1^2 + period2\ x\ P2^2}{period1 + period\ 2}}}{\dfrac{period1\ x\ P1 + period\ 2\ x\ P2}{period1 + period2}}$$

Table 3-10, Table 3-11 and Table 3-12 show the calculation of the load factors and load form factors and the assumptions made for this calculation. The calculation is performed per circuit type and per sector. For each of these combinations a low, a reference and a high value is provided.
There are two periods in this model: P1 period 1 and P2 period 2. The sum of the 2 periods is 168, which can be seen as 168 hours in one week. There are two load levels represented by P1 and P2. The ratio between the P2 and P1 load level is given by the P2/P1 ratio. In this model P1 was always 100 (high loading), and P2 (low loading) was always lower than P1. The absolute load values in this calculation have no influence on the calculation.

To calculate the load factor based upon periods, an additional use factor is introduced. The load factor is calculated as follows:

$$\alpha_c = \frac{period\ 1 + P2/P1\ x\ period\ 2}{period\ 1 + period\ 2}\ x\ use\ factor$$

The use factor indicates the ratio of the design load and the rated maximum load (current-carrying capacity) of the circuit. For instance when assuming 0.3 for a lighting circuit (circuit breaker 10 A, 230 Vac, i.e S= 2300 W) it means that the design load of the circuit is about 690 W.

The terms P2 period 2, Prms, Pavg, Kf, α_c and Kf.α_c are calculated. The other terms are input values and represent the assumptions.

Table 3-10: Load form factor and load factors in the residential sector

	Residential											
	Lighting circuit			**Socket-outlet circuit**			**Dedicated circuit**			**Distribution circuit**		
	Low	**Ref**	**High**	**Low**	**Ref**	**High**	**Low**	**Ref**	**High**	**Low**	**Ref**	**High**
Use factor	0.2	0.3	0.4	0.1	0.2	0.3	0.3	0.4	0.5	0.05	0.1	0.3
P2/P1 ratio	1%	5%	10%	1%	10%	20%	1%	1%	1%	20%	30%	40%
P1 period 1	100	100	100	100	100	100	100	100	100	100	100	100
Period 1	14	21	28	5	15	25	4	7	14	70	80	90
P2 period 2	1	5	10	1	10	20	1	1	1	20	30	40
Period 2	154	147	140	163	153	143	164	161	154	98	88	78
Period 1 + Period 2	168	168	168	168	168	168	168	168	168	168	168	168
Prms	29	36	42	17	31	43	15	20	29	66	72	78
Pavg	9	17	25	4	18	32	3	5	9	53	63	72
Kf	3.12	2.11	1.67	4.38	1.74	1.34	4.61	3.99	3.12	1.24	1.14	1.08
α_c	0.02	0.05	0.10	0.00	0.04	0.10	0.01	0.02	0.05	0.03	0.06	0.22
Kf . α_c	0.06	0.11	0.17	0.02	0.06	0.13	0.05	0.08	0.14	0.03	0.07	0.23

Table 3-11: Load form factor and load factors in the services sector

Services												
	Lighting circuit			**Socket-outlet circuit**			**Dedicated circuit**			**Distribution circuit**		
	Low	**Ref**	**High**	**Low**	**Ref**	**High**	**Low**	**Ref**	**High**	**Low**	**Ref**	**High**
Use factor	0.4	0.5	0.7	0.2	0.3	0.4	0.6	0.7	0.8	0.6	0.7	0.8
P2/P1 ratio	10%	20%	30%	10%	20%	30%	10%	20%	30%	10%	20%	30%
P1 period 1	100	100	100	100	100	100	100	100	100	100	100	100
Period 1	50	60	70	50	60	70	70	80	90	70	80	90
P2 period 2	10	20	30	10	20	30	10	20	30	10	20	30
Period 2	118	108	98	118	108	98	98	88	78	98	88	78
Period 1 + Period 2	168	168	168	168	168	168	168	168	168	168	168	168
Prms	55	62	68	55	62	68	65	71	76	65	71	76
Pavg	37	49	59	37	49	59	48	58	68	48	58	68
Kf	1.50	1.27	1.16	1.50	1.27	1.16	1.37	1.21	1.13	1.37	1.21	1.13
α_c	0.15	0.24	0.41	0.07	0.15	0.24	0.29	0.41	0.54	0.29	0.41	0.54
Kf . α_c	0.22	0.31	0.48	0.11	0.19	0.27	0.39	0.49	0.61	0.39	0.49	0.61

Table 3-12: Load form factor and load factors in the industry sector

Industry												
	Lighting circuit			**Socket-outlet circuit**			**Dedicated circuit**			**Distribution circuit**		
	Low	**Ref**	**High**	**Low**	**Ref**	**High**	**Low**	**Ref**	**High**	**Low**	**Ref**	**High**
Use factor	0.4	0.5	0.7	0.2	0.4	0.6	0.6	0.7	0.8	0.6	0.7	0.8
P2/P1 ratio	40%	50%	60%	40%	50%	60%	60%	75%	90%	52%	65%	78%
P1 period 1	100	100	100	100	100	100	100	100	100	100	100	100
Period 1	50	60	70	50	60	70	70	80	90	70	80	90
P2 period 2	40	50	60	40	50	60	60	75	90	52	65	78
Period 2	118	108	98	118	108	98	98	88	78	98	88	78
Period 1 + Period 2	168	168	168	168	168	168	168	168	168	168	168	168
Prms	64	72	79	64	72	79	79	88	95	76	84	90
Pavg	58	68	77	58	68	77	77	87	95	72	82	90
Kf	1.11	1.06	1.03	1.11	1.06	1.03	1.03	1.01	1.00	1.05	1.02	1.01
Lf	0.23	0.34	0.54	0.12	0.27	0.46	0.46	0.61	0.76	0.43	0.57	0.72
Kf . α_c	0.26	0.36	0.55	0.13	0.29	0.47	0.47	0.61	0.76	0.45	0.58	0.72

Conclusion:

Table 3-13 contains the summary of the load factors (α_c) and load form factors (Kf) calculated in Table 3-10, Table 3-11 and Table 3-12.

Table 3-13: Load factors (α_c) and load form factors (Kf) to be used in this study

		Lighting circuit			Socket-outlet circuit			Dedicated circuit			Distribution circuit		
		Low	Ref	High	Low	Ref	High	Low	Ref	High	Low	Ref	High
Residential sector	Kf	3.12	2.11	1.67	4.38	1.74	1.34	4.61	3.99	3.12	1.24	1.14	1.08
	αc	0.01	0.05	0.10	0.00	0.04	0.10	0.01	0.02	0.05	0.01	0.06	0.22
	Kf . αc	0.03	0.11	0.17	0.01	0.06	0.13	0.02	0.08	0.14	0.02	0.07	0.23
Services sector	Kf	1.50	1.27	1.16	1.50	1.27	1.16	1.37	1.21	1.13	1.37	1.21	1.13
	αc	0.07	0.24	0.41	0.04	0.15	0.24	0.14	0.41	0.54	0.14	0.41	0.54
	Kf . αc	0.11	0.31	0.48	0.06	0.19	0.27	0.20	0.49	0.61	0.20	0.49	0.61
Industry sector	Kf	1.11	1.06	1.03	1.11	1.06	1.03	1.03	1.01	1.00	1.05	1.02	1.01
	αc	0.12	0.34	0.54	0.06	0.27	0.46	0.23	0.61	0.76	0.22	0.57	0.72
	Kf . αc	0.13	0.36	0.55	0.06	0.29	0.47	0.24	0.61	0.76	0.23	0.58	0.72
αc correction factor		0.5	1	1	0.5	1	1	0.5	1	1	0.5	1	1

Crosschecks in later tasks indicated that the minimum average value is too high. This correction (results are multiplied with the corresponding correction factor shown in the last row of the table) is already incorporated in the results listed in Table 3-13. The maximum and minimum values are used for the sensitivity analysis

3.1.5.2 Power factor

The power factor is the real power used by the load divided by the apparent power required by the load conditions, see definition in Task 1.

Conclusion:
Although the power factor will differ from circuit to circuit depending on the load type, it is proposed to use PF = 0.8 (see IEC 60364-5-52/Annex G) as the default power factor.

3.1.5.3 Impact of harmonics

Current harmonics can cause extra losses due to the skin effect and uneven harmonics can cause overload current in the neutral wire[89]. Current losses depend on the type of load[90].
Harmonic current is limited by standard EN 61000-3-2, especially for lighting equipment.

Conclusion:

[89] Leonardo Energy Power Quality Initiative (2001), 'APPLICATION NOTE HARMONICS: CAUSES AND EFFECTS'
[90] Leonardo Energy Power Quality Initiative (2001), 'APPLICATION NOTE HARMONICS: CAUSES AND EFFECTS'

It is proposed to neglect these losses in further tasks.
Rationale: These losses are neglected because losses are already modelled by the fundamental load current (50 Hz) and more precise data on typical harmonic current of loads is missing.

3.1.5.4 Number of loaded conductors and impact of phase imbalance and harmonics

The number of loaded conductors in a single phase circuit is 2, i.e. the phase conductor and neutral conductor.

IEC 60364-5-52 article 523.6.1 states: ” The number of conductors to be considered in a circuit are those carrying load current. Where it can be assumed that conductors in polyphase circuits carry balanced currents, the associated neutral conductor need not be taken into consideration. Under these conditions, a four-core cable is given the same current-carrying capacity as a three-core cable having the same conductor cross-sectional area for each line conductor. Four- and five-core cables may have higher current-carrying capacities when only three conductors are loaded.
This assumption is not valid in the case of the presence of third harmonic or multiples of 3 presenting a THDi (total harmonic distortion) greater than 15%.”.

IEC 60364-5-52 article 523.6.2 states: “Where the neutral conductor in a multicore cable carries current as a result of an imbalance in the line currents, the temperature rise due to the neutral current is offset by the reduction in the heat generated by one or more of the line conductors. In this case, the neutral conductor size shall be chosen on the basis of the highest line current.”.

IEC 60364-5-52 Annex E states: “Where the neutral current is expected to be higher than the line current then the cable size should be selected on the basis of the neutral current. If the neutral current is more than 135 % of the line current and the cable size is selected on the basis of the neutral current, then the three line conductors will not be fully loaded.”.

Table 3-14 shows the reduction factors that should be applied to the design load to calculate the conductor section. For instance, consider a three-phase circuit with a design load of 39 A to be installed using four-core PVC insulated cable clipped to a wall, installation method C. A 6 mm² cable with copper conductors has a current-carrying capacity of 41 A and hence is suitable if harmonics are not present in the circuit. If 20 % third harmonic is present, then a reduction factor of 0.86 is applied and the design load becomes:39/086 = 45 A. As a result a 10 mm² cable is necessary.

Table 3-14: Reduction factors for harmonic currents in four-core and five-core cables[91]

Third harmonic content of line current %	Reduction factor	
	Size selection is based on line current	Size selection is based on neutral current
0 – 15	1,0	–
15 – 33	0,86	–
33 – 45	–	0,86
> 45	–	1,0

Conclusion:
The number of loaded conductors in a **single phase** circuit is **2**.

By lack of statistics on the imbalance in the line currents and the THDi in electric circuits, it is proposed to use a balanced system with a THdi of less than 15 % in this study. Consequently, the number of loaded cores in a 3-phase circuit is **3.**

3.1.6 Formulas used for power losses in cables

The general formulas for power losses and energy losses are the following:

- Power losses (in a cable) (Watt): the power losses at a certain moment of time t can be calculated by the following formula:

  $P(t) = R.I^2(t)$ (Watt) (formula 3.3)

- The resistance of a cable at temperature t can be calculated by the following formula:

  $R_t = \rho_t.l/A$ (Ω) (formula 3.4)

  where,
  - ρ_t= specific electrical resistance of the conductor at temperature t (Ω.mm²/m)[92]
  - l= length of the cable (meter)
  - A= cross sectional area of the conductor (mm²)

- Energy losses(E) according to the laws of physics:

  $E = \int_0^T R.I^2(t)$ (formula 3.5)

- Energy loss in cables according to IEC 60287-3-2:

  $energy\ loss\ during\ the\ first\ year = I^2max.\ RL\ .L.NP.NC\ .T$ (formula 3.6)

  where,
  - Imax is the maximum load on the cable during the first year, in A;
  - RL is cable resistance per unit length;
  - L is the cable length, in m;

[91] IEC 60364-5-52
[92] ρ_t is the resistivity of conductors in normal service, taken equal to the resistivity at the temperature in normal service, i.e. 1,25 times the resistivity at 20 °C, or 0,0225 Ωmm²/m for copper and 0,036 Ωmm²/m for aluminium; IEC 60364-5-52 annex G

- NP is the number of phase conductors per circuit (=*segment in this context*);
- NC is the number of circuits carrying the same type and value of load;
- T is the equivalent operating time, in h/year.

Note: the formula used in IEC 60287-3-2 is only applicable to calculate the cable losses in a 'single cable segments' of a circuit.

- The formula in this study to calculate the annual energy loss (E (loss)) in a circuit cable based upon the above mentioned factors is:

$E_{circuit,}(y)$ [kVAh] = $Kd \cdot R_t \cdot In^2 \cdot (\alpha_c \cdot Kf)^2 \cdot 8760 / 1000$ (formula 3.7)

where,

- Kd = the distribution factor
- R_t = cable resistance at temperature t (see formula 3.4)
- In = the rated current of the circuit
- α_c = The circuit load factor
- Kf = Load form factor (=Prms/Pavg)

Note: Prms requires the calculation of an integral of the load profile and therefore aligns with formula 3.5.

- The formula in this study to calculate the annual active energy (E (active)) transported via the circuit cable based upon the above mentioned factors is:

$E_{active}(y)$ [kWh] = $V \cdot Imax \cdot \alpha_c \cdot Kf \cdot PF \cdot 8760 / 1000$ (single phase)
or
$E_{active}(y)$ [kWh] = $\sqrt{3} \cdot V \cdot Imax \cdot \alpha_c \cdot Kf \cdot PF \cdot 8760 / 1000$ (three phase)
(formula 3.8)

where,

- V = electrical installation voltage (V =230 for single phase and 400 for three phase)
- Imax = the maximum rated current of the cable
- α_c = The circuit load factor
- Kf = Load form factor (=Prms/Pavg)
- PF = the power factor of the load served by the power cable

- The next formula defines the loss ratio as the losses in the cable (formula 3.7) divided by the active energy transported via the circuit (formula 3.8):

Loss ratio = $E_{circuit}(y) / E_{active}(y)$ (formula 3.9)

3.2 Systems aspects of the use phase for ErPs with indirect impact

The following systems are impacted in the use phase by the ErP.

3.2.1 Building space heating and cooling system

Cable losses are dissipated in the form of heat energy and therefore contribute to so-called 'internal heat gains', this has and impact on the building heating and cooling requirements. The impact can be positive when heating is needed or negative when cooling is needed.

Conclusion: because the impact can be positive or negative and it is not the primary function of the cable to contribute to the heating it is proposed to further neglect this effect in the study.

3.3 End-of-Life behaviour

General
Copper is a valuable material and therefore cables are in general returned for recycling. In 2009 recycled copper met 45.7% of Europe's copper demand[93]. In this process PVC insulation is separated mechanically from copper with shredders and granulators. The main purpose is to recover the valuable copper, but when transport cost are economically viable PVC insulation is also sold for recycling. Recycling of PVC can be done with Vinyloop technology[94]. Figure 3-18 shows the general recycling flow of power cables.

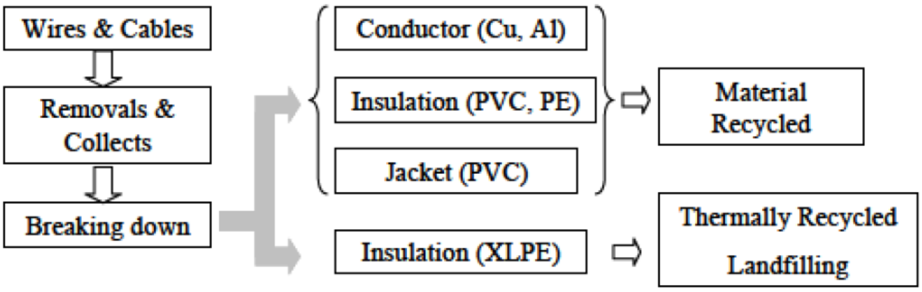

Figure 3-18: Recycling flow of wires and cables[95].

Stripping of the cable
According to a recent study by Flanders PlasticVision[95], metal recyclers with a focus on cables are mostly interested in the metals due to the copper and consider the plastic insulation as waste. Additionally, most of the European recyclers will only treat cables if they contain at least 40 to 45% copper as the shredder and separation costs will be too high to be economically viable in the case of lower copper content. Cable waste containing less copper is shipped towards low cost markets (e.g. China and India)

[93] http://eurocopper.org/copper/copper-information.html
[94] http://www.chemicals-technology.com/projects/ferrara/
[95] Proposal on material criteria for the product group: "Cables in closed circuit", May 2014, commissioned by OVAM.

where it is still economically viable to strip cables manually. An advantage of the manual process is the better separation of the materials and therefor a higher purity can be obtained. The volume of this shipped waste is told to be more than 50% of the collected cable waste.

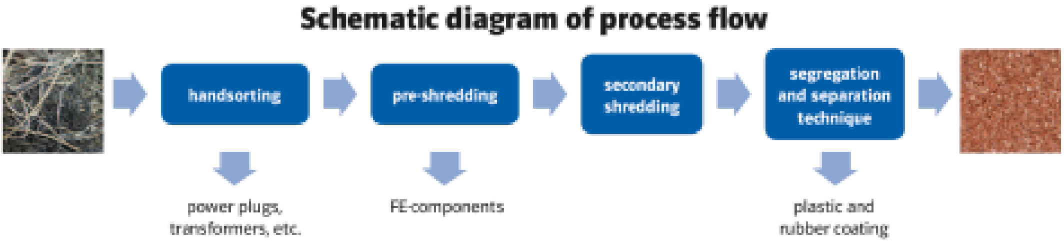

Figure 3-19: Schematic diagram of mechanical recycling process[95], see Figure 3-21 for more details.

The study[95] also mentions that not all cable waste is collected as a mixture of copper and plastic insulation. This is the case when the workload of electric installation companies is low and that those companies will strip cable waste themselves with basic stripping machines (see Figure 3-31) in order to get higher copper prices. Plastic waste that is generated during this process always ends up in the mixed waste. In Figure 3-31: Basic cable stripping machines95.
Table 3-15 the advantages and disadvantages are given between a mechanical or manual separation process of cables.

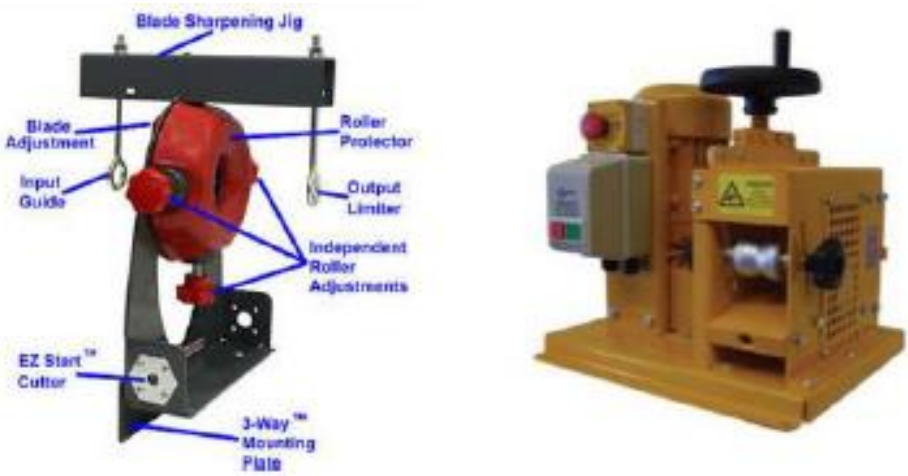

Figure 3-31: Basic cable stripping machines[95].

Table 3-15: Comparison between mechanical and manual separation process[95].

Type of processing	Advantages	Disadvantages
Mechanical shredder	• High throughput (multiple tons/hour) • Cable dimension flexibility	• Need for high copper content • Always residual copper in plastic residue
Manual/basic wire stripper	• High purity both copper and plastic	• Low output (10-15 kg/hour) • Change of settings per cable dimension • Economically barely viable

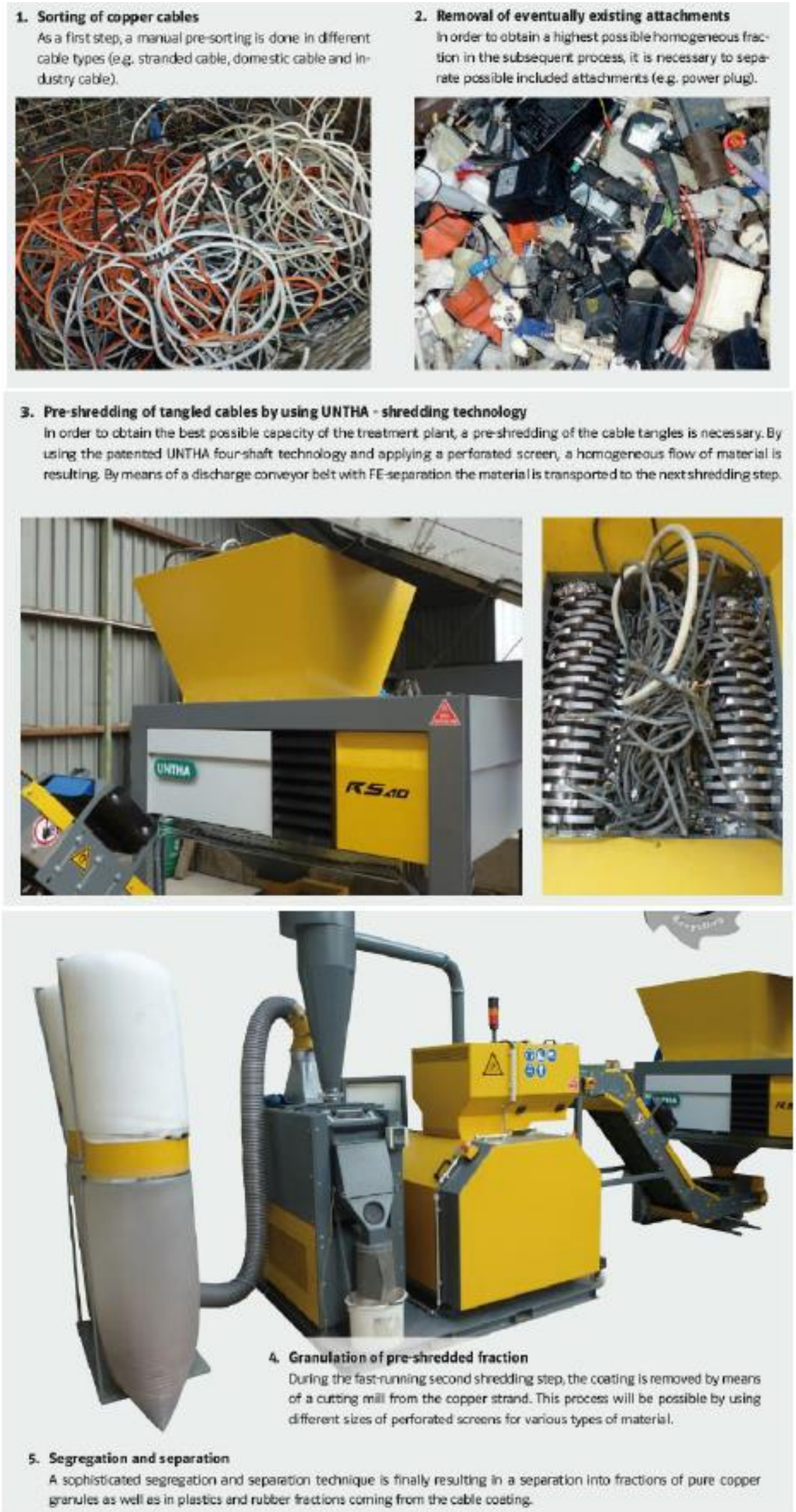

Figure 3-21: Detailed process flow of cable waste shredding[95].

Vinyloop – PVC recycling

In the study of the OVAM[95], another possibility for stripping power cables with softened PVC jacket and insulation was described, which is called Vinyloop®. Vinyloop is a chemical extraction technology developed by Solvay. The solvent-based technology recycles PVC and produces high-quality PVC. In Figure 3-33 the process is illustrated. In the beginning of the process, cable waste is reduced in size and brought into contact with the appropriate solvent, dissolving the softened PVC and separating the non-dissolved (non-ferrous) fraction. The solution, i.e. the solvent and dissolved PVC, is then submitted to a steam distillation process in order to recycle the solvent. At the end, the PVC compound fraction is dried and separated.

Figure 3-34 shows the amounts of recycled PVC since 2012. Recovered PVC material can technically be used for cable applications and coverings (e.g. flooring and tarpaulins), however this is currently not the case due to the price (Vinyloop is an expensive process) and colour.

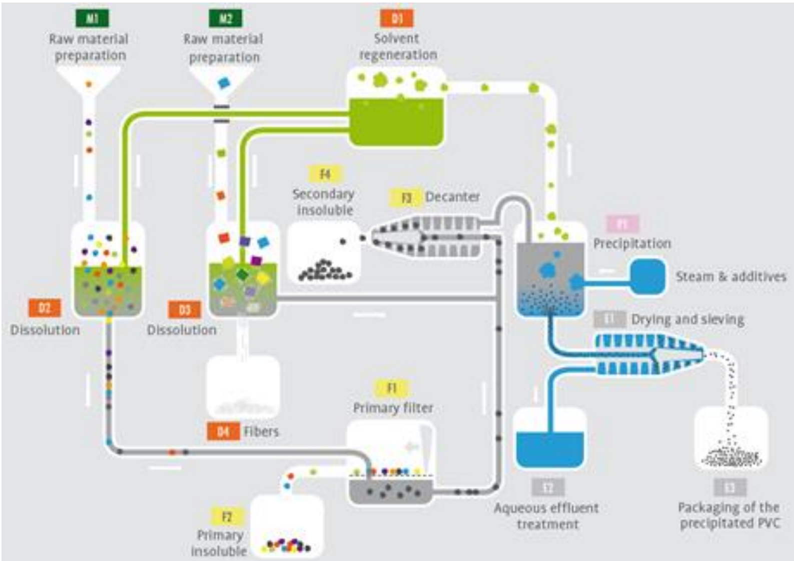

Figure 3-33: The Vinyloop® process.

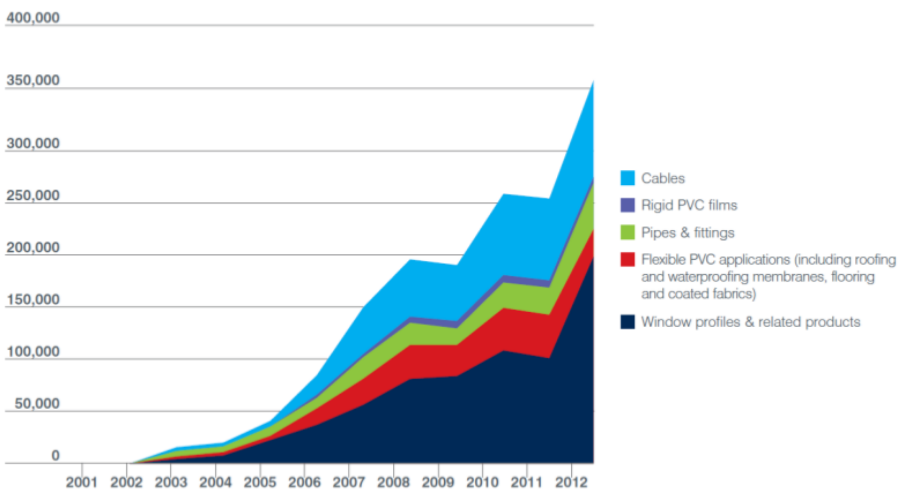

Figure 3-34: Amounts of recycled PVC (in tonnes) within the Vinyl 2010's and VinylPlus' frameworks.

Waste treatment XLPE

Recycling of cross-linked polyethelene (XLPE) is not possible yet due to its chemical cross-linked structure and the difficulty of thermo-plasticizing it. The three-dimensional lattice structure makes it impossible to melt it down again for moulding. As a result, almost all XLPE waste is currently incinerated for energy-recovery or disposed of in landfilles. There is no hope that an effective industrial-scale material recycling technology can be implemented.[95]

Waste of Halogen-free cable insulation

Sometimes Halogen-free cable insulation is used to reduce harmful smoke from PVC during a fire hazard. Therefore thermoplastic polyurethane material is used[96] instead of PVC. Because this is thermoplastic material it can be easily recycled and such material is already available[97] from other applications. For cables it is not yet an issue because the material is only recently introduced compared to the long service life of cables installed in buildings.

Use of recycled materials

According to the study by Flanders PlasticVision[95], there is no problem in using recycled copper and aluminium in new power cables provided it does not include any impurities. Cable material is rather specific due to its inherent properties, such as fire and mechanical properties. Using other sources of post-consumer waste is technically feasible, but will need very specific entry control and reprocessing.

EOL parameters

Note: This study deals with new power cables entering the market and that will have to be recycled when buildings are renovated (>20 years).

The following assumptions are made in this study:

- The End-of-Life (EOL) parameters are shown in Table 3-17. These match the default parameters of the EcoReport tool[98], except that 0% re-use for the non-ferro is used instead of 1%. Cables, removed from buildings, are not re-used. Repair & maintenance practice: not existing
- Second hand use: not existing

Table 3-16: Lifetime parameters per sector

[96] Oliver Muehren, Dr. Oliver Henze(2011): 'Thermoplastic polyurethane solutions for low smoke zero halogen (LSZH) flame retardant cable applications', see: http://iwcs.omnibooksonline.com/data/papers/2011/9-5.pdf

[97] http://about.puma.com/en/sustainability/products/recycled-polyester-and-tpu

[98] EcoReport Tool version 3.06, VHK, MEErP 2011 METHODOLOGY PART 1 and PART 2

Sector	Product life	Service life	Vacancy
Unit	Year	Year	%
Residential sector	64.00	60.80	5%
Services sector	25.00	23.75	5%
Industry sector	25.00	23.75	5%
Total sector (weighted)	41.60	39.52	5%

Table 3-17: End of life parameters

	Bulk Plastics	TecPlastics	Ferro	Non-ferro	Coating	Electronics	Misc., excluding refrigant & Hg	refrigerant	Hg (mercury), **in mg/unit**	Extra	Auxiliaries
EoL mass fraction to re-use, in %	1%	1%	1%	0%	1%	**1%**	1%	1%	1%	1%	**5%**
EoL mass fraction to (materials) recycling, in %	29%	**29%**	94%	95%	94%	**50%**	**64%**	**30%**	**39%**	**60%**	**30%**
EoL mass fraction to (heat) recovery, in %	15%	**15%**		0%		**0%**	**1%**	**0%**	**0%**	**0%**	**10%**
EoL mass fraction to non-recov. incineration, in %	22%	**22%**		0%		**30%**	**5%**	**5%**	**5%**	**10%**	**10%**
EoL mass fraction to landfill/missing/fugitive, in %	33%	**33%**		5%		**19%**	**29%**	**64%**	**55%**	**29%**	**45%**

Note: according to Europacable[99], for plastics the recycling rate of the insulation and sheath are quite unpredictable as it depends on:

- the kind of materials that is used in the insulation (rubber is poorly recyclable, plastic is better recyclable, XLPE is technically recyclable but there are no existing channels today);
- the possibility to separate the plastics between them and from the rest of the cable (which may depend on the cable design and plastics mix);
- the countries, which may have different legislation and collection/treatment capabilities.

As a result it is thus not possible to provide generic information that could be used whatever the cable type for all European countries.

Europacable does not agree on the 95% recycling and 5% landfilling/missing/fugitive for non-ferro, regarding the actual sales price for recycled copper and aluminium. These assumptions might be too pessimistic. However they cannot provide any updated figures and therefore the above mentioned default values (Table 3-17) will be retained.

[99] response of Europacable to second questionnaire. See "Preparatory Studies for Product Group in the Ecodesign Working Plan 2012-2014:Lot 8 - Power Cables: Project Report".

3.4 Local infrastructure (barriers and opportunities)

3.4.1 Opportunities

3.4.1.1 Effect on electrical installation and end-user

Reliability, availability and nature of the energy will not change when the resistance of the electrical system is changed.
Increasing the wiring size will also not influence the users of the buildings because the cables are typically hidden in walls or behind panels. Probably the users do not at all notice whether the wirings are slightly thicker or thinner.

3.4.1.2 Certification

Certification of the electric installation in buildings is in most of the EU countries required by legislation. Measures at the level of the electrical installation could therefore be verified and enforced at the certification stage. For instance in Belgium the electrical installations in houses need to be recertified when a house is sold. In the industrial and services sector in Belgium the local regulation specifies that recertification of the electrical installation by a certification authority has to be performed every 5 years.

3.4.1.3 Refurbishment occasions

Refurbishment occasions, like when houses are sold, provide an opportunity to stimulate the renovation of electrical installations.

In the residential sector financial incentive structures are one of the main instruments in redressing householders' unwillingness or inability to invest in energy efficiency by themselves. Financial incentives for energy efficiency measures, like wall insulation or new windows, may provide an opportunity for house owners to renew the electrical installation. Additional financial incentives for renewal of electrical installation may stimulate house owners to renew the electrical installation.

3.4.2 Barriers

3.4.2.1 Lock-in effect into existing installations

As illustrated in Figure 3-16 the cable can be placed direct in masonry or wooden wall, in conduits, cable ducts, on cable ladder, on brackets, on trays, in building voids, in a channel in the floor and so on. This installation method can create a kind of lock-in effect. In some of the methods the cables cannot be easily replaced unless a thorough renovation is done, for instance when the cables are placed direct in the masonry, making it more costly.

In the residential sector installers will choose more often methods of installation (lower cost) for which the cables are more difficult to replace. In the industry and services sector it often part of the requirements of the electrical installation that the cables have to be placed in ducts, conduits or voids, and are therefore easier to be replaced.

3.4.2.2 *Implication on material use*

Strategies like S+x or 2S will result for the same system in a larger use of material for the conductor and the insulation.

The relative increase in conductor material can be calculated with Formula 3.10.

$$relative\ conductor\ volume\ increase = \frac{V_{S+x} - V_S}{V_S} = \frac{r_{S+x}^2 - r_S^2}{r_S^2} \qquad \text{(formula 3.10)}$$

Where:

$V = (r^2)\pi L$
r = radius of conductor section
L = length of the cable
S and S+x indicate the associated CSA strategy

The additional need of material may have following consequences:

- Additional material use means additional mining and treatment of the raw material, with extra CO_2 emission;
- An effect on the material price. Future commodity prices, however, cannot be predicted. Therefore, a sensitivity analysis will be performed for the product price in Task 6 and Task 7. The amount of extra material needed will be determined by the design option and applied scenario.

Also a strategy like dual wiring would mean significant increase in material use.

Insulation/sheath/inner coverings and filler material increase:

The relative increase in insulation/sheat/inner coverings and filler material can be calculated with Formula 3.11 when cylindrical. For the inner coverings and filler material, when unknown, a ratio factor equal to the insulation/sheath material increase may be used. In case of a dual wire strategy the used material volume doubles.

$$relative\ insulation\ volume\ increase = \frac{V_{S+x} - V_S}{V_S} \qquad \text{(formula 3.11)}$$

Where:

$V = (r_o^2 - r_i^2)\pi L$
r_o = outer radius of insulation cylinder
r_i = inner radius of insulation cylinder = radius of conductor section
L = length of the cable
S and S+x indicate the associated CSA strategy

Conclusion:
The relative increase of conductor and insulation material for an S+x strategy can be calculated with formula 3.10 and formula 3.11 respectively. In case of a dual wire strategy the used conductor and insulation material volume doubles (=100% increase).

3.4.2.3 Handling and space requirements

Strategies like dual wiring and S+x strategies requires more space for the wiring in the building. A higher cable volume could exclude any possible renewal due to lack of space. Wires with larger sizes have also larger bending curves and are more difficult to handle.

3.4.2.4 Cost implications

Strategies like dual wiring and S+x strategies will increase the cost of:
- Cable per circuit,
- Cable transportation,
- Cable installation if more time is needed,
- Electrical installation equipment. Any modification of cables size may require a modification of the other equipment such as socket-outlet and other accessories in the electrical installation.
- building infrastructure. Apart from the space, use of higher cross-section will induce a non-negligible cost increase of the installation due to building infrastructure.

3.4.2.5 Economic product life (=actual time to disposal)

Lifetime is a crucial component of the life cycle cost (LCC) calculation. Power cables are durable and have long working lives.

The following materials[100] (Table 3-18) with lifetime figures for a wide range of products was developed for the US National Association of Home Builders (NAHB) Economics Department based on a survey of manufacturers, trade associations and product researchers.

Table 3-18: Lifetime of wiring according NAHB

Electrical	Life in years
Copper wiring, copper plated, copper clad aluminum, and bare copper	100+
Armored cable (BX)	Lifetime
Conduit	Lifetime
Source: Jesse Aronstein, Engineering Consultant	

International Association of Certified Home Inspectors (NACHI)[101] and NAHB charts agree that copper wiring can last 100 years or more. But the real life expectancy of your wiring is not in the copper. It's dependent on the wiring's insulation, and that lifetime can vary widely.

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[100] http://www.oldhouseweb.com/how-to-advice/life-expectancy.shtml

[101] http://www.improvementcenter.com/electrical/home-electrical-system-how-long-can-it-last.html

The modern formula for thermoplastic NM-B type wiring dates from 1984, when the insulation's heat resistance was increased. The best guess is that it will provide over 100 years of service.

Therefore, it can be concluded that the economic product lifetime of wiring in modern electrical installations is not determined by the technical lifetime of wiring. Power cables are part of the electrical installation and are in general replaced when the complete electrical installation is renovated. An electrical installation will be partially or completely renewed when the building environment served by the electrical installation is changed or gets a new function. Also when new machinery or appliances are added to the installation it might be necessary to replace or upgrade part of the electrical installation. Therefore it's safe to conclude that the lifetime of electrical wiring is determined by the lifetime of the system of which the wiring is a component, thus the electrical installation.

The PEP ecopassport®[102] is an environmental declaration program for electric, electronic and HVAC industries. Some Product Category Rules (PCR) have been developed, in accordance with ISO 14025[103], to carry out life cycle assessments of electrical, electronic and HVAC products in a transparent manner. Some specific rules have been developed for cables and wires and some lifetime of products are used as standard hypothesis and are provided in Annex 1 of PSR-0001-ed1-EN-2012 01 10 (Products Specific Rules for Wires, cables and accessories)[104]. The PEP ecopassport program considers an average lifetime of 30 years for energy cables in residential / tertiary building applications and industrial buildings (see Table 3-19). Those hypotheses have been agreed among cable manufacturers through the French cable Association (Sycabel)[110].

Table 3-19: Lifetime of cables and wires according their application[104]

AREAS APPLICATIONS	Applications	Lifetime (years)
INFRASTRUCTURES	Energy distribution networks	40
	Railway networks	30
	Telecom networks (fixed and mobile phones)	20
INDUSTRIAL APPLICATIONS	Oil, gas and petrochemicals	30
	Handling	10
	Automation	5
	Nuclear	40
	Wind turbines	20
	Photovoltaic power plants	10
	Airports	20
ONBOARD SYSTEMS	Civil aeronautics	15
	Shipbuilding and marine	30
	Rolling stock	30
	Automotives (Cars and trucks)	10
BUILDING	Residential/tertiary/industrial	30
	Data centers	10
	LAN : residential	10
	LAN: tertiary	10
	LAN: industrial (factories, warehouses)	10

102 http://www.pep-ecopassport.org
103 Environmental labels and declarations - Type III environmental declarations - Principles and procedures
104 http://www.pep-ecopassport.org/documents/PSR0001-ed1-FR-20120110-Fils%20Câbles%20et%20Materiels%20de%20Raccordement-.pdf

The JRC report "Development of European Ecolabel and Green Public Procurement for Office buildings - Economical and market analysis"[105] of 2011 provides information on building stocks, renovation rate, construction, building age, etc. In section 4.2.1 "Assumed working life of products and systems", it mentions different sources for the working life of construction product and resulting tables (see Table 3-20, Table 3-21, Table 3-22, and Table 3-22).

Table 3-20: Assumed working life of construction products[106]

Assumed working life of works (years)		Working life of construction products to be assumed in ETAGs, ETAs and HENs (years)		
Category	Years	Category		
		Repairable or easy replaceable	Repairable or replaceable with some more efforts	Lifelong[2]
Short	10	10[1]	10	10
Medium	25	10[1]	25	25
Normal	50	10[1]	25	50
Long	100	10[1]	25	100

[1] In exceptional and justified cases, e.g. for certain repair products, a working life of 3 to 6 years may be envisaged (when agreed by EOTA TB or CEN respectively).
[2] When not repairable or replaceable "easily" or "with some more efforts".

Table 3-21: Minimum design life of components[107]

Design life of building	Inaccessible or structural components	Components where replacement is expensive or difficult	Major replaceable components	Building services
Unlimited	Unlimited	100	40	25
150	150	100	40	25
100	100	100	40	25
60	60	60	40	25
25	25	25	25	25
15	15	15	15	15
10	10	10	10	10

[105] http://susproc.jrc.ec.europa.eu/buildings/docs/market%20and%20economic%20analysis.pdf
[106] European Organisation for Technical Approvals (EOTA) (1999). Assumption of working life of construction products in Guidelines for European Technical Approval, European Technical Approvals and Harmonized Standards. Guidance Document 002.
[107] ISO 15686-1

Table 3-22: Design working life of components[108]

Design working life (years)	Examples
10	Temporary structures
10- 25	Replaceable structural parts
15- 30	Agricultural and similar structures
50	Building structures and other common structures
100	Monumental buildings, bridges, other structures

Table 3-23: Lifetime of cables and wires according their application

Design working life (years)	Examples
1-3	Information technology
5	Interior partition
10	Electrical systems
25	Mechanical systems
50	Skin (exterior)
100	Structure

Taking into account the variation amongst sources this study proposes the following lifetime values for power cables:

- Product life[109]: the product life is equal to the number of years between product purchased and product discarded. The product life is not necessarily the same as the product service life, e.g. because the product can be stocked before disposal. In case of power cables the product life is assumed equal to the life time of the building. Buildings have a not-in-service time part (vacancy) before getting into service, refurbished or discarded. During the not-in-service period the power cables do not transport energy and have thus no losses. The product life parameter is listed per sector in Table 3-24.
  Some of the stakeholders remarked that an average building lifetime between renovations of 8 years (12.4%, see Task 2) for the services and industrial sector is rather short. Europacable experts mentioned lifetimes of 40 to 50 years for cables in the services and industrial sector[110].
  Taking into account the variation amongst sources a short, long and reference cable product lifetime is provided in Table 3-24 per sector. The high and low values for the product lifetime will be applied in the sensitivity analysis in Task 6 and Task 7.

[108] European Commission (2002). EN 1990. Eurocode: Basis of structural design.
[109] Definition according VHK, MEErP 2011 METHODOLOGY PART 1.
[110] Europacable paper as response to the secondary questionnaire. See "Preparatory Studies for Product Group in the Ecodesign Working Plan 2012-2014:Lot 8 - Power Cables: Project Report".

Table 3-24: Cable product lifetime

	short product life		Reference		long product life	
Sector	Replace-ment rate	Product life	Replace-ment rate	Product life	Replace-ment rate	Product life
Unit	%	year	%	year	%	year
Residential sector	2.10%	40	1.18%	64	0.80%	84
Services sector	7.08%	13	3.20%	25	1.70%	40
Industry sector	7.08%	12	2.80%	25	1.37%	40

- Product service life[109]: the product service life is the period in years that the product is in use and operational. The product service life parameter is listed per sector Table 3-24. The product service life of power cables is calculated with following formula:

  $Product\ service\ life = Product\ life - not\_in\_service\_time$ (formula 3.12)

  Where
  - not_in_service_time = Product life * building_vacancy_factor
  - building_vacancy_factor is assumed to be 5%

Conclusion:
The economic product lifetime therefore is determined by the refurbishment rate of the building. This refurbishment rate is related to the function type of the building (see Task 2).

3.4.3 Installers and certifiers of electrical installations

Potential affected:
- Electrical installation engineering companies
- Installers
- Certifiers

Designing taking energy efficiency and economy into account might require installers to invest in extra training, and design tools. These design tools have to be adapted by software development companies.

Installation time and related cost may increase due to extra wiring or more difficult handling of cables with larger sizes.

Installing extra cables or cables with a larger size will have no implications on the required know-how of the installer. Installers in the non-residential sector are used to handle large cable sizes.

Depending on the policy certifiers may have to include extra procedures in the certification process to verify the electrical installation.

Most of the installers (75%) that responded to the enquiry[111] estimated that the losses in the electrical installation vary between 1% and 3%. The others (25%) estimated a

[111] This questionnaire sent to installers on the 30th of September, 2013 in the context of this study. See "Preparatory Studies for Product Group in the Ecodesign Working Plan 2012-2014:Lot 8 - Power Cables: Project Report".

loss of less than 1%. The general impression is that installers are unaware (or not interested in the knowledge) about the losses and that in most cases no economic optimisation is calculated.

3.4.4 Physical environment

As discussed in Task 1 the losses in electrical installations can be reduced by increasing the cable section or by reducing the load per circuit, having additional circuits for the same amount of load.

The building construction and electric installation will be affected by:

- thicker cables are less flexible and need more volume/space for installation
- thicker cables need larger ducts and tubing
- the connectors for thicker cables may be different and larger
- having more circuits will increase the space requirements for the distribution boards
- having more circuits will increase the space requirements for the cables (ducts)

CHAPTER 4 TASK 4: TECHNOLOGIES

The objective of this task is analysing technical aspects related to power cables. Typical products on the market and alternative design options are described including indications on the use of materials, performance and costs. Additionally, information on product manufacturing, distribution, durability and end-of-life is reported. Best Available Technologies (BAT) and Best Not Yet Available technologies (BNAT) are also analysed.

Summary of Task 4:
At the product level of the power cable itself, there are no improvement options identified related to energy efficiency because every cable cross sectional area (CSA) on the market has a certain load and cable length to fit with.
At circuit level (system level) two improvement options are identified, the first is installing a cable with a larger CSA ('S+x') and the second is installing one or more cables in parallel with the same CSA ('2S'). This task also includes the necessary product data for subsequent life cycle impact modelling which is primarily based on its Bill-of-Material (BOM). A larger CSA will increase the BOM and therefore this environmental impact will be modelled in later Tasks with the MEErP Ecoreport tool.

4.1 Technical product description

Power cables are technically described in previous Task 1 section 1.1.2 on 'Context of power cables within buildings and their electrical installation'.
The next subsections will further investigate BAT and BNAT wherein:

- 'Best' shall mean most effective in achieving a high level of environmental performance of the product. 'Available' technology shall mean that developed on a scale which allows implementation for the relevant product, under economically and technically viable conditions, taking into consideration the costs and benefits, whether or not the technology is used or produced inside the Member States in question or the EU-27, as long as they are reasonably accessible to the product manufacturer. Barriers for take-up of BAT should be assessed, such as cost factors or availability outside Europe.
- 'Not yet' available technology shall mean that not developed yet on a scale which allows implementation for the relevant product but that is subject to research and development. Barriers for BNAT should be assessed, such as cost factors or research and development outside Europe.

4.1.1 BAT at product level meaning the power cable itself

BAT to improve Energy losses:

The technology currently applied to power cables in buildings is the best available technology today.

Power cables are a mature product and losses are related to its resistance and loading current (see Task 3).

EN 60228 specifies 'standardized nominal' cross-section areas (CSA) from 0.5 mm² to 2000 mm², numbers and diameters of wires and their maximum resistance values of conductors.

Therefore variations in conductivity should be compensated by modifications in 'real' cross-section areas compared to their 'standardized nominal' cross-section areas' (CSA), under which they are sold. **This means that for so-called 'standardized nominal' cross-section areas' (CSA) under which power cables are brought on the market there is no improvement potential at product level.**

The technology currently applied to power cables in buildings is the best available technology today.

BAT to improve impact from material usage:

No specific improvement options were brought forward by stakeholders and are known.

4.1.2 BAT at system level (electrical installation / electric circuit view)

BAT at system level has to be interpreted as best available electrical installation practices. Considering how an electrical installation can provide the required level of service and safety for the lowest energy consumption (= energy losses in the electrical installation) can improve current installation practices. This is for instance explained in standard draft[112] Harmonised document HD 60364-8-1:2015 "Low voltage electrical installations- energy efficiency". This draft standard provides additional requirements, measures and recommendations for the design, erection and verification of all types of electrical installations including local production and storage of energy for optimizing the overall efficient use of electricity. Examples of recommendations at system level mentioned in this standard related to losses in wires are:

- **Increasing the CSA of the cable used** in the circuit: using a larger CSA will reduce the power losses. The most economical cross section may be several sizes larger than that required for thermal reasons.
- **Power factor correction**: reduction of the reactive energy consumption at the load level reduces the thermal losses in the wiring. A possible solution to improve the power factor could be the installation of a power factor correction system at the respective load circuits.
- **Reduction of the effects of harmonic currents**: reduction of harmonics at the load level, e.g. selection of harmonic-free products, reduces the thermal losses in the wiring. Possible solutions to reduce the effect of the harmonics include the installation of harmonic filters at the respective load circuits, or increasing the cross sectional area of the conductors.

4.1.3 BNAT at product level (power cable view)

No BNAT technologies in accordance with the above mentioned MEErP definition were found nor specified by the stakeholders.

112 http://www.iec.ch/dyn/www/f?p=103:52:0::::FSP_ORG_ID,FSP_DOC_ID,FSP_DOC_PIECE_ID:1249,152113,280396

4.1.4 BNAT at system level (electrical installation / electric circuit view)

At system level some trends can be noted which will have an influence on the losses in the circuits:

- Energy efficiency at appliance level: by reducing the amount of energy needed by appliances (change of load profile/ reduction of current), the losses in the circuit will reduce significant (square of the current), assuming that not a smaller CSA of the cable in the circuit is used. Energy efficiency measures at appliance level will contribute to this power loss reduction. Examples are more efficient lighting (LED use or enhanced control systems for lighting) or more efficient appliances (circulators, compressors, and so on).
- Building and home automation may not only reduce the energy needed by the technical installation (HVAC, elevator, etc.) of the building[113], but may also have an influence on the topology of the electrical installation compared to a traditional electrical installation.
- Control systems to perform peak reduction will change the load profile on the electrical installation and therefore the losses in the electrical installation.
- Increasing the voltage for power distribution may improve the efficiency as it reduces the current flowing in the cables. As an example, 380 VDC instead of 230 VAC power distribution in commercial buildings will reduce current and losses, as promoted by the EMerge Alliance[114]. Moving towards higher voltages will have a major impact on the existing power grid. In principle it could also be done in AC.

Note : changing to DC could have an impact on the required thickness of the insulation of a cable, and thus on the amount of insulation material used in a cable. The rationale is that cable insulation is related to the peak voltage(Vpeak). In AC systems peak voltage is $Vrms.\sqrt{2}$ = 325 Vpeak. In DC systems the peak voltage is equivalent to the VDC. However, a switch from AC to DC is complex as it requires another concept of power distribution [115] with different converters, protection switches, distribution transformers, etc. which may reduce the energy efficiency. Therefore it will not be considered as a viable BAT improvement option in this study.

4.2 Production, distribution and End of Life

4.2.1 Production

Objective: The objective is to discuss environmental impact from the production of Power Cables. Please note that the MEErP methodology uses the EcoReport Tool which models production according to Bill-Of-Material, therefore this will be discussed in detail.

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113 The scope for energy and CO_2 savings in the EU through the use of building automation technology, final report 10 August 2013.
http://www.leonardo-energy.org/sites/leonardo-energy/files/documents-and-links/Scope%20for%20energy%20and%20CO2%20savings%20in%20EU%20through%20BA_2013-09.pdf

114 http://www.emergealliance.org/

115 Edison's Revenge: Could DC Carve Out a Place in Our AC Grids?, http://smartgrid.ieee.org/june-2013/880-edison-s-revenge-could-dc-carve-out-a-place-in-our-ac-grids

4.2.1.1 *Power Cable Manufacturing*[116]

The first manufacturing process of a conductor is the wire-drawing. This consists of reducing the diameter of the copper wire gradually to its final diameter to increase its ductility and conductivity.
The copper is 8 mm in diameter, is technically known as 'wire rod'.
The first stage of the wire-drawing is simply called 'drawing'. The diameter of the wire is reduced to 2 mm during this process. This 2 mm is then drawn further to reduce the diameter of the wire to the size needed for each kind of conductor.
In the last stage of wire-drawing, all the wires undergo a heat treatment called annealing. The aim of this stage is to increase the ductility and conductivity of the copper.

After the wire-drawing, the copper wires are grouped together to make conductors. This process is called wiring (Figure 4-1).
During the wiring process, conductors with different cross-sections are made. For example, a cross-section as small as 0.5 mm² to 240 mm², 400 mm² or even higher for larger current capacities.
The machine used to make the cables depends on the cross-section of each conductor.

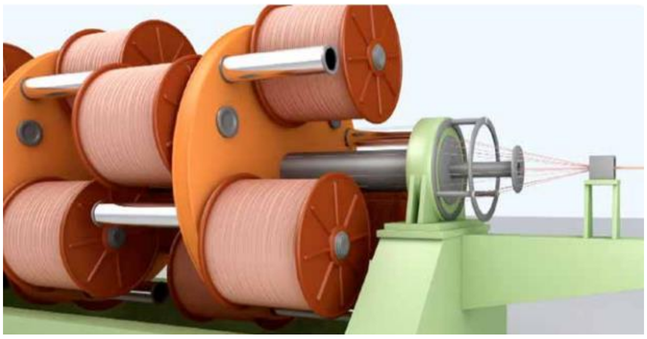

Figure 4-1 The wiring process

The next process in the manufacture of electrical cables is the insulation. This is an insulating cover over the conductor to prevent current leakages. In this process, the insulating material is added by a process of extrusion at high temperature.
Extrusion process (see Figure 4-2 and Figure 4-3) is a high volume manufacturing process in which plastic material is melted and moves towards a screw mechanism. The screw rotates, forcing the plastic material to advance through the extruder cavity and is pushed through the die. After exiting the die, it is cooled, solidifies and wound up.

[116] This section is (with permission) based upon section '2.2 Production of cables' of the study 'proposal on material criteria for the product group: cables in closed circuit' by Flanders PlasticVision commissioned by OVAM.

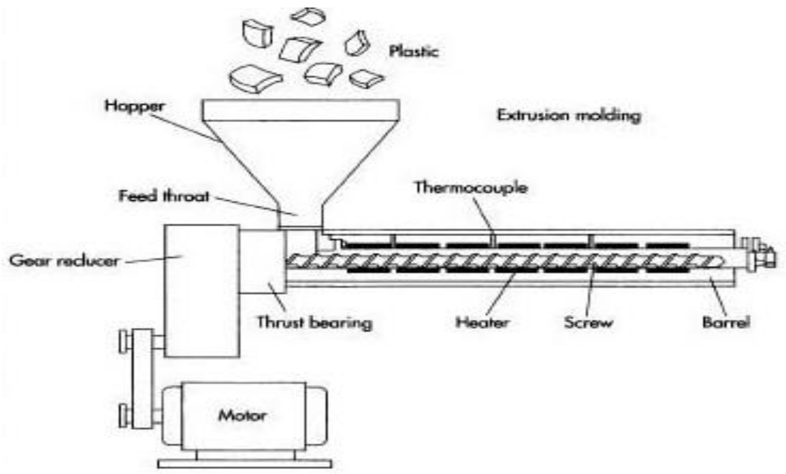

Figure 4-2 The extrusion process

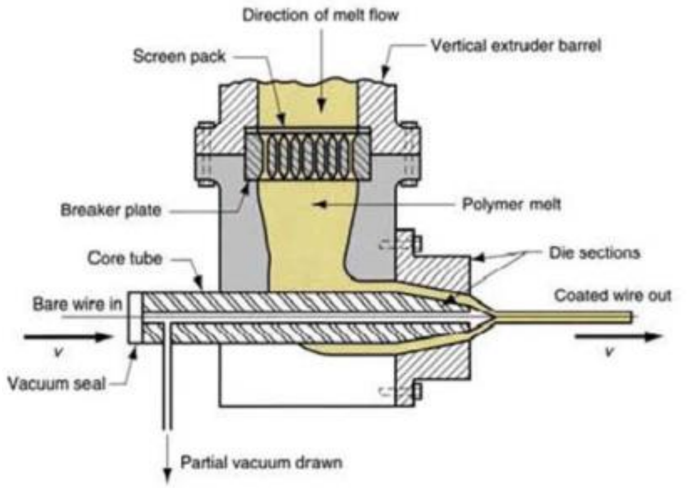

Figure 4-3 The extrusion process (detail)

The insulation/coatings for wires and cables are typically mixed with two or more components at the intake of a single or twin screw extruder. The insulation or coating material is applied via a crosshead die (see Figure 4-3). In this way the cable core or cable is fed through a special pipe. The polymer is entered on the side of this pipe and covers the cable core in a distribution area. A slight vacuum is drawn between wire and polymer to promote adhesion of coating.

After extrusion, the insulated wire or coated cable is cooled by air, sprayed water or a water bath and is then sent to a haul-off and cutting station before being wound up. This is shown in Figure 4-4.

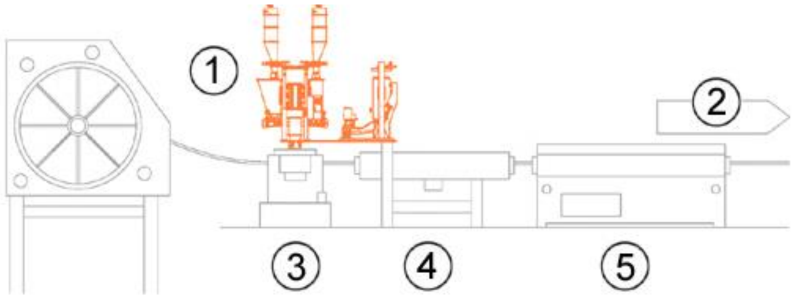

Figure 4-4 cooling and cutting
1. Gravimetric device
2. Cutting and cooling
3. Extruder with crosshead die
4. Cooling unit
5. Haul-off station

In several applications, phase wiring is the next step. Phase wiring is the grouping of different insulated conductors to make a multicore cable. The phases can be identified by colour or by numbering them.

The cable may require additional elements in order to improve its protection or operation.
Electrical coverings, also called 'screens', insulate the signals that circulate in the cable from possible external interference. They also shield the power cables to prevent them from interfering with adjacent signal circuits.
Mechanical coverings, also called 'armour', protect the cable from external damage that may occur from knocks, rodents, and any other potential causes of damage. The armour is made from steel or aluminium and can come in the form of metal strips, wires or braids.

4.2.1.2 Primary scrap production during sheet metal manufacturing

Not applicable to cables.

4.2.1.3 Bill Of Materials of example products

The material composition and weight are based upon product catalogues of several cable manufacturers and input of Europacable (see Table 4-1). Due to the wide range of materials and designs (number of cores, construction type, etc.) the composition information provided may not cover all products on the market, but it is nevertheless considered to be representative for typical products available on the market. The BOM per section for a typical power cable is provided in Table 4-2. These values are used as input for the base cases further on in this study. The dimensions mentioned in the table are according the standards. The composition and amount of filler material is not specified in standards and is different amongst manufacturers. To estimate the amount of filler material in the cable, an average total weight of the cable based upon several manufacturers' catalogues is compared with the calculated total weight of the cable. The difference in weight is assigned to the filler material. Specific details on filler and sheath material are not publically available and cannot be disclosed by cable manufacturers. According to Europacable members[117], the composition listed in Table 4-1 can be used a reference.

Table 4-1: PVC sheath and XLPE insulation composition

Cable Part	Composition	% in weight
PVC sheath	PVC resin	45
	Ca Carbonate filler	25
	Plasticizer (DIDP)	25
	Lubricant, stabilizer and others	5
XLPE insulation	LDPE	97
	Crosslinking compound (Silane based)	3

According to Europacable[117] some other compounds, non-PVC and non-XLPE, whose recyclability have not been tested, are applied in cables. Information about those compounds is however confidential.

The last line in Table 4-2 displays the discounted base case purchase price, excl. VAT. The price is calculated and based upon the average price per €/mm².m as mentioned in Task 2.

[117] See response of Europacable to second questionnaire

Table 4-2: BOM of typical copper based cable per section

Cable type	5x1,5mm^2	5x2,5m^2	5x4mm^2	5x6mm^2	5x10mm^2	5x16mm^2	5x25mm^2	5x35mm^2	5x50mm^2	5x70mm^2	5x95mm^2	5x120mm^2	5x150mm^2	5x185mm^2	5x240mm^2	4x300mm^2	4x400mm^2	1x500mm^2	1x630mm^2
CSA (mm^2)	1.5	2.5	4	6	10	16	25	35	50	70	95	120	150	185	240	300	400	500	630
Conductors	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	4	1	1
Conductor form	Round	Round	Round	Round	Round	Round	Round	Round	Round	Round	Round	Round	Round	Round	Round	Sectorial	Sectorial	Round	Round
Class	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
PE included	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No
Material/Component																			**g/m**
Conductor-Calculated (ρCu= 8,89 g/cm^3)																			
Cu (g/m)	**66.7**	**111.1**	**177.8**	**266.7**	**444.5**	**711.2**	**1111.3**	**1555.8**	**2222.5**	**3111.5**	**4222.8**	**5334.0**	**6667.5**	**8223.3**	**10668.0**	**10668.0**	**14224.0**	**4445.0**	**5600.7**
XLPE Insulation - calculated																			
Thickness (mm) - acc. to IEC 60502-1/Table 6	0.7	0.7	0.7	0.7	0.7	0.7	0.9	0.9	1	1.1	1.1	1.2	1.4	1.6	1.7	1.8	2	2.2	2.4
Diameter conductor (mm) - acc. to IEC 60502-1/Table A.1	1.40	1.8	2.3	2.8	3.6	4.5	5.6	6.7	8	9.4	11	12.4	13.5	15.3	17.5	19.5	22.6	25.2	28.3
Volume (cm^3)/conductor	4.6	5.50	6.60	7.70	9.46	11.44	18.38	21.49	28.27	36.29	41.81	51.27	65.53	84.95	102.54	120.45	154.57	189.38	231.47
ρ XLPE (g/cm^3) - between 0,9 and 0,96 g/cm^3 (Wiki)	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
XLPE (g/m)	**21.5**	**25.6**	**30.7**	**35.8**	**44.0**	**53.2**	**85.5**	**99.9**	**131.5**	**168.7**	**194.4**	**238.4**	**304.7**	**395.0**	**476.8**	**448.1**	**575.0**	**176.1**	**215.3**
PVC Sheath - calculated																			
Thickness (mm) - acc. to IEC 60502-1/Table A1 & A2	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.9	2.1	2.2	2.4	2.6	2.7	3.0	3.0	3.3	2.0	2.2
Dc (mm)- Ficitious diameter - acc. To IEC 60502-1 Annex A.2.2	7.6	8.6	10.0	11.3	13.5	15.9	20.0	23.0	27.0	31.3	35.6	40.0	44.8	50.0	56.4	55.9	64.4	29.6	33.1
Volume (cm^3)	52.9	59.0	66.7	74.3	86.5	100.3	123.2	140.2	176.9	220.1	267.5	319.2	382.4	455.0	555.2	546.7	691.1	202.4	239.1
ρ PVC/A (g/cm^3) = 1,5 g/cm^3	1.5	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
PVC (g/m)	**79.4**	**88.6**	**100.0**	**111.5**	**129.8**	**150.4**	**184.7**	**210.3**	**265.3**	**330.1**	**401.3**	**478.8**	**573.6**	**682.5**	**832.8**	**820.0**	**1036.7**	**303.5**	**358.6**
Inner coverings and fillers - Type & weight ??? TBD (g/m)	41.2	50.3	69.0	93.3	141.2	203.2	301.3	391.0	364.2	635.7	1044.1	1300.8	1561.6	2129.3	2727.3	1933.9	2014.4	0.0	0.0
Total - (g/m) - Without inner coverings and fillers	**167.5**	**225.2**	**308.5**	**413.9**	**618.3**	**914.8**	**1381.5**	**1866.0**	**2619.3**	**3610.3**	**4818.4**	**6051.2**	**7545.9**	**9300.7**	**11977.7**	**11936.1**	**15835.6**	**4924.6**	**6174.6**
Total - (g/m) - Avg value of 4 cable manufacturers	**208.8**	**275.5**	**377.5**	**507.3**	**759.5**	**1118.0**	**1682.8**	**2257.0**	**2983.5**	**4246.0**	**5862.5**	**7352.0**	**9107.5**	**11430.0**	**14705.0**	**13870.0**	**17850.0**	**4930.0**	**6465.0**
Ratio conductor weight/cable weight	80%	82%	82%	82%	81%	82%	82%	69%	74%	73%	72%	73%	73%	72%	73%	77%	80%	90%	87%
Cable manufacturers																			
Manufacturer 1- N2XY cable (Germany)																			
Total estimated (g/m)	**250**	**325**	**415**	**580**	**815**	**1155**	**1780**	**2345**	**na**	**4400**	**5920**	**7380**	**9160**	**11430**	**14705**	**13870**	**17850**	**4930**	**6465**
Manufacturer 2- 2XY-Fl (Germany)																			
Total estimated (g/m)	**180**	**240**	**360**	**470**	**690**	**1080**	**1650**	**2120**	**2840**	**3990**									
Manufacturer 3 - XVB-F2 (Belgium)																			
Total estimated (g/m)	**190**	**255**	**370**	**500**	**780**	**1090**	**1550**												
Manufacturer 4-YMvKmb (The Netherlands)																			
Total estimated (g/m)	**215**	**282**	**365**	**479**	**753**	**1147**	**1751**	**2306**	**3127**	**4348**	**5805**	**7324**	**9055**						
Total AVG (g/m)	**208.75**	**275.5**	**377.5**	**507.25**	**759.5**	**1118**	**1682.75**	**2257**	**2983.5**	**4246**	**5862.5**	**7352**	**9107.5**	**11430**	**14705**	**13870**	**17850**	**4930**	**6465**
Unit price based upon price per €/mm^2.m	0.70755	1.17925	1.8868	2.8302	4.717	7.5472	11.7925	16.5095	23.585	33.019	44.8115	56.604	70.755	87.2645	113.208	113.208	150.944	47.17	59.4342

Table 4-3: BOM of typical aluminium based cable per section

Cable type	5x35mm²	5x50mm²	5x70mm²	5x95mm²	5x120mm²	5x150mm²	5x185mm²
CSA (mm²)	**35**	**50**	**70**	**95**	**120**	**150**	**185**
Conductors	5	5	5	5	5	5	5
Conductor form	Round	Round	Round	Round	Round	Round	Round
Class	2	2	2	2	2	2	2
PE included	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Material/Component							
Conductor-Calculated (ρAl= 2,7 g/cm³)							
Al (g/m)	**472.5**	**675.0**	**945.0**	**1282.5**	**1620.0**	**2025.0**	**2497.5**
XLPE Insulation - calculated							
Thickness (mm) - acc. Manufacturer specs	0.9	1	1.1	1.1	1.2	1.4	1.6
Diameter conductor (mm) - acc. Manufacturer specs	7.65	8.9	10.7	12.3	14.2	15.7	17.4
Volume (cm³)/conductor	24.17	31.10	40.78	46.31	58.06	75.21	95.50
ρ XLPE (g/cm³) - between 0,9 and 0,96 g/cm³ (Wiki)	0.93	0.93	0.93	0.93	0.93	0.93	0.93
XLPE (g/m)	**112.4**	**144.6**	**189.6**	**215.3**	**270.0**	**349.7**	**444.1**
~~PVC~~ Sheath (Thermoplatisch elastomeer) - calculated							
Thickness (mm) - acc. Manufacturer specs	1.8	2.0	2.1	2.3	2.5	2.6	2.8
Outside diameter - acc. Manufacturer specs	30.9	36.8	42.5	46.8	53.6	59.0	64.2
Volume (cm³)	164.8	218.7	266.1	321.5	401.3	455.4	540.1
ρ PVC/A (g/cm³) = 1,5 g/cm³	1.50	1.50	1.50	1.50	1.50	1.50	1.50
PVC (g/m)	**247.3**	**328.0**	**399.1**	**482.3**	**602.0**	**683.1**	**810.2**
Inner coverings and fillers - Type & weight ??? TBD (g/m)	389.8	609.4	843.3	899.9	1307.0	1386.2	1518.3
Total - (g/m) - Without inner coverings and fillers	**832.2**	**1147.6**	**1533.7**	**1980.1**	**2492.0**	**3057.8**	**3751.7**
Total - (g/m) - With inner coverings and fillers	**1222.0**	**1757.0**	**2377.0**	**2880.0**	**3799.0**	**4444.0**	**5270.0**
Ratio conductor weight/cable weight	39%	38%	40%	45%	43%	46%	47%
Cable manufacturers							
Manufacturer 1							
Total estimated (g/m)							
Manufacturer 2							
Total estimated (g/m)							
Manufacturer 3							
Total estimated (g/m)							
Manufacturer 4- YMz1K mbzh (The Netherlands)							
Total estimated (g/m)	**1222**	**1757**	**2377**	**2880**	**3799**	**4444**	**5270**
Total AVG (g/m)	**1222**	**1757**	**2377**	**2880**	**3799**	**4444**	**5270**
Unit price based upon price per €/mm².m	9.40	13.42	18.79	25.50	32.21	40.27	49.66

4.2.2 Distribution

Objective: The objective is to discuss environmental impact from the distribution of Power Cables.

Volume of the packaged product
In the MEErP methodology, impact from transport is modelled according to weight and volume.

The product can be transported:

- In cartons:
  - for cables with small CSA and limited length.
  - some manufacturers indicate in their catalogues that the cartons are made of 100 % recycled paper.
- In plastic:
  - for cables with small CSA and limited length.
- On drums / reels:

- for cables with larger CSA or for large lengths of cable (typical >10 kg). The drum number (size) is marked on the drum. The basic characteristics of wooden drums are given in the table below pursuant to DIN standard 46391.

For this study the assumption is made that most cables are transported by means of drums. Although one-way drums for single trip use exists, assumed is that the drum is recuperated by the manufacturer. The material of the drum is not included in the BOM. The outer diameter and width of the drum are used to calculate the transport volume of the drum as a cube (see formula 4.1). A spacing factor is introduced to cover the spacing needed for handling the drums. An educated guess of 15% is used for the spacing factor.

$$V_{drum} = d.d.w.SF \ (m^3) \qquad \text{(formula 4.1)}$$

Where

d = outer diameter of drum
w = width of drum
SF= spacing factor

The volume of the packaged product (power cable) depends on the length of cable. For a certain cable section the appropriate drum is selected. If multiple drum sizes (drum numbers) are available the average drum size has been selected. The volume of the packaged product is equal to the volume of the drum divided by the maximum length of cable on the drum multiplied by the length of the specific cable.

$$V_{product} = V_{drum} \ / \ l_{max} \ . \ l_{product} (m^3) \qquad \text{(formula 4.2)}$$

Where

V_{drum} = volume of drum (see formula 4.1)
l_{max} = maximum length of cable (with the specific CSA) on this drum size
$l_{product}$ = length of cable (with the specific CSA)

As an example Figure 8-2 in Annex 4-A shows the maximum length of cable in meters for different drum sizes and cable sections.

For calculating the packaged volume, the figures in Table 4-4 (and associated dimension scheme in Figure 4-5) and Table 4-5 are used. As an example, Table 4-7 shows the calculated volume of the packaged product per meter cable.

Table 4-4: properties of different drum sizes[118]

Drum size	Flange Diameter mm F	Barrel Diameter mm B	Traverse mm T	Width overall mm W	Drum weight kg	Volume (cube) m^3	Drum weight per m^3 kg/m^3
6	600	300	400	430	20	0.15	129
8	800	350	520	600	30	0.38	78
10	1000	450	620	700	50	0.70	71
12	1200	600	720	820	70	1.18	59
14	1400	700	790	920	125	1.80	69
16	1600	900	900	1028	175	2.63	66
18	1800	1100	1120	1248	290	4.04	72
20	2000	1200	1120	1248	330	4.99	66
22	2200	1400	1120	1248	450	6.04	74
24	2400	1600	1370	1570	595	9.04	66
26	2600	1600	1700	1900	645	12.84	50
30	3000	2000	1900	2100	770	18.90	41

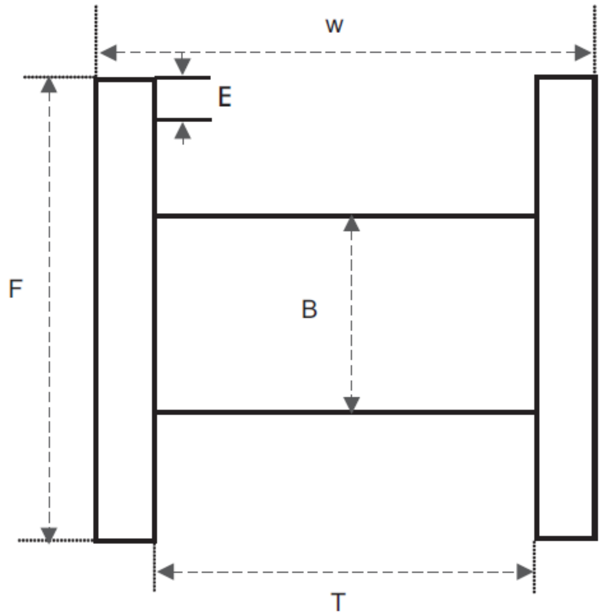

Figure 4-5 Drum dimensions scheme

Table 4-5: maximum cable lengths per CSA and drum size, part 1[118]

[118] Building wire and cables, ABHAR WIRE + CABLE CO., http://www.abharcable.com/Files/Documents/Catalogs/05%20BUILDING%20WIRE%20AND%20CABLES.pdf

Cable	Max cable length in meters on standard drums											
Outer	Drum sizes											
Diameter	6	8	10	12	14	16	18	20	22	24	26	30
6	1326	3961										
7	975	2910										
8	746	2228	4391									
9	590	1760	3470									
10	478	1426	2810	4566								
11	395	1178	2323	3774								
12	332	990	1952	3171	4912							
13	283	844	1663	2702	4185							
14		727	1434	2330	3609	4934						
15		634	1249	2029	3144	4298						
16		557	1098	1784	2763	3777						
17		493	972	1580	2448	3346	4858					
18		440	867	1409	2183	2985	4333	4643				
19		395	778	1265	1959	2679	3889	4167	4722			
20		356	703	1142	1768	2417	3510	3760	4262			
21		323	637	1035	1604	2193	3183	3411	3866			
22		295	581	943	1461	1998	2901	3108	3522	4815		
23		270	531	863	1337	1828	2654	2843	3223	4406		
24			488	793	1228	1679	2437	2611	2960	4046		
25			450	731	1132	1547	2246	2407	2728	3729		
26			416	675	1046	1430	2077	2225	2522	3448		
27			386	626	970	1326	1926	2063	2338	3197		
28			358	582	902	1233	1791	1919	2174	2973		
29			334	543	841	1150	1669	1789	2027	2771	4826	
30			312	507	786	1074	1560	1671	1894	2590	4510	
31			292	475	736	1006	1461	1565	1774	2425	4224	
32			274	446	691	944	1371	1469	1665	2276	3964	
33			258	419	650	888	1289	1381	1565	2140	3727	4999
34				395	612	836	1214	1301	1475	2016	3511	4709
35				373	577	789	1146	1228	1392	1903	3313	4444
36				352	546	746	1083	1161	1315	1798	3132	4200
37				334	517	706	1026	1099	1245	1702	2965	3976
38				316	490	670	972	1042	1181	1614	2811	3770
39				300	465	636	923	989	1121	1532	2669	3579
40				285	442	604	877	940	1065	1457	2537	3402
41				272	421	575	835	895	1014	1386	2415	3238
42				259	401	548	796	853	966	1321	2301	3086
43					383	523	759	814	922	1260	2195	2944
44					365	499	725	777	881	1204	2097	2812
45					349	478	693	743	842	1151	2004	2688
46					334	457	663	711	806	1101	1918	2573
47					320	438	636	681	772	1055	1837	2464
48					307	420	609	653	740	1012	1762	2363
49					295	403	585	626	710	971	1691	2267
50					283	387	562	602	682	932	1624	2178

Table 4-6: maximum cable lengths per CSA and drum size, part 2[118]

Cable	Max cable length in meters on standard drums											
Outer	Drum sizes											
Diameter	6	8	10	12	14	16	18	20	22	24	26	30
51					272	372	540	578	655	896	1561	2093
52					262	358	519	556	630	862	1501	2013
53					252	344	500	535	607	830	1445	1938
54						332	481	516	585	799	1392	1867
55						320	464	497	564	770	1342	1800
56						308	448	480	544	743	1294	1736
57						298	432	463	525	717	1249	1676
58						287	417	447	507	693	1207	1618
59						278	403	432	490	670	1166	1564
60						269	390	418	474	647	1127	1512
61						260	377	404	458	626	1091	1463
62						252	365	391	443	606	1056	1416
63							354	379	430	587	1023	1372
64							343	367	416	569	991	1329
65							332	356	403	552	961	1288
66							322	345	391	535	932	1250
67							313	335	380	519	904	1213
68							304	325	369	504	878	1177
69							295	316	358	490	853	1143
70							287	307	348	476	828	1111
71							278	298	338	462	805	1080
72							271	290	329	450	783	1050
73							263	282	320	437	762	1022
74							256	275	311	426	741	994
75							250	267	303	414	722	968
76								260	295	403	703	942
77								254	288	393	685	918
78									280	383	667	895
79									273	373	650	872
80									266	364	634	851
81									260	355	619	830
82									254	347	604	810
83										338	589	790
84										330	575	772
85										323	562	753
86										315	549	736
87										308	536	719
88										301	524	703
89										294	512	687
90										288	501	672
91										281	490	657
92										275	480	643
93										269	469	629
94										264	459	616
95										258	450	603
96										253	440	591
97											431	579
98											423	567
99											414	555
100											406	544

Table 4-7: package volume calculation example

	Unit	T	Example
CSA	mm²	I	3 x 2.5
Ficitious diameter	mm	I	7.56
PVC sheat tickness	mm	I	1.8
Cable outer diameter	mm	C	11.16
Drum Size		I	10
Max. cable length	m	I	2323
Drum Volume (formula 4.1)	m³	I	0.7
Drum spacing	m³	C	0.105
Correction factor (spacing)	%	I	0.15
Drum Corrected Volume	m³	C	0.805
Drum Weight	kg	I	50
Drum corrected volume / meter cable	m³/m	C	0.0003465
Drum Weigth / meter cable	g/m	C	21.523892

4.2.3 End of Life practices

See Task 3 section 3.3.

4.2.4 Summary of identified improvement options for further tasks

A series of priority improvement options for the assessment of environmental and economic impacts have been identified based on the information gathered along the different tasks and is displayed in Table 4-8. The main driver for the selection of these improvement options is the reduction of energy losses in the electric circuits. At circuit level (system level) two improvement options are identified, the first is installing a cable with a larger CSA ('S+x') and the second is installing one or more cables in parallel with the same CSA ('2S').

Table 4-8: summary of identified improvement options

Option Name	Description
At cable level	
Low loss cable as a product	No BNAT technologies are available at cable level that could reduce the energy losses in an economical feasible manner. Labelling information on the cable about energy losses is not an improvement option and can be implemented by the scenarios mentioned in "at circuit level" part.
At circuit level (system level)	
S+x	Using, for a particular circuit and load, a cable with a larger CSA (S+x) than necessary (according current standards and regulation) will result in a lower cable resistance R, and thus lower energy losses. The CSA increments are conform the current, standardized CSA values (no new CSA values are considered). S+1 means one size up, S+2 two sizes up, S+3 three sizes up, and so on.
2S	By installing, for a particular circuit and load, instead of one cable with a particular CSA_x one or more cables in parallel with the same CSA (or even smaller CSA than the original foreseen CSA_x) the losses in the circuit can be reduced.
Topology	Keeping the topology in mind when designing the electrical system of a building can reduce the energy losses in the circuits. For instance, to keep losses to a minimum, the main distribution transformers and switchboards are to be located to keep the distances (circuit lengths) to main loads to a minimum. The building's use, construction and space availability has to be taken into account to obtain the best position. One such method to determine the best position is the barycentre method[119].

The impacts of the improvement options 'S+x' and '2S' at circuit level will be quantified in Task 6 and Task 7. The 'topology' design option is considered as an improvement at electrical installation level (more particular at the design of the whole electrical installation and even physical placement of loads within a building) and is not retained as an circuit level improvement in Task 6. Task 7 may consider the 'Topology' improvement option in a qualitative manner.

4.3 Recommendations

In the light of the work produced in Task 4, no refinement of the product scope from the technical perspective is proposed. As the Ecodesign Lot 8-Power Cables product is a mature product, the design cycle for this product is not relevant to determine an appropriate timing of measures. It has to be noted that most of the progress can be made at installation level, recommended improvement options for further tasks are defined in section 4.2.4.

[119] HD 60364-8-1:2015

CHAPTER 5 TASK 5: ENVIRONMENT & ECONOMICS

The objective of Task 5 is to define one or two average EU product(s) or to choose a representative product category as the 'Base Case' (BC) for the whole of the EU-28. Throughout the rest of the study, most of the environmental and Life Cycle Cost (LCC) analyses will be built on this BC. The BC is a conscious abstraction of reality, necessary for practical reasons (e.g. budget and time). The question if this abstraction leads to inadmissible conclusions for certain market segments will be addressed in the impact and sensitivity analysis. The description of the BC is the synthesis of the results of Tasks 1 to 4 and the point of reference for Tasks 6 (improvement potential) and 7 (impact analysis).

The aim of this section is to assess environmental and economic impacts of the different base cases. The assessment is based on the updated version 3.06 of the EcoReport Tool[120], as provided with the MEErP 2011 methodology. The Product life cycle impacts are calculated using the Ecoreport tool which is an element of the MEErP.

Remark: Further in this study the word 'power cables' will be used as a general term for single core or multi-core LV power cables in buildings, unless otherwise stated.

Summary of Task 5:

Previous Task 4 identified improvement options at circuit level. In this Task nine so-called base cases (BC) were selected that represent typical electrical circuits in line with the market structure and data described in Task 2. Base Cases according to MEErP are abstractions from reality that serve for modelling purposes. The Product life cycle impacts are calculated using the EcoReport tool which is an element of the MEErP. The base cases used the 'median' electrical circuit parameters from Task 3, such as load factor and cable length. The nine base cases used are:

- Base case 1 (BC1): distribution circuit in the services sector;
- Base case 2 (BC2): lighting circuit in the services sector;
- Base case 3(BC3): socket-outlet circuit in the services sector;
- Base case 4(BC4): dedicated circuit in the services sector;
- Base case 5(BC5): distribution circuit in the industry sector;
- Base case 6(BC6): lighting circuit in the industry sector;
- Base case 7(BC7): socket-outlet circuit in the industry sector;
- Base case 8 (BC8): dedicated circuit in the industry sector (BC1 up to and including BC8 are with copper conductors);
- Base case 9 (BC9): base case 8 but with aluminium instead of copper.

The environmental impact analysis and LCC obtained with the MEErP tool showed that in most cases the use phase, because of electrical cable losses, is dominant. This is due

[120] Legal notice of EcoReport tool
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to the impact of electrical cable losses. As a consequence, there will be room left for economic energy savings in several of those base cases that will be analysed in detail in Task 6. The data of the nine base cases was also summed using EU-28 circuit level stock data and cross-checked with total EU-28 data on electricity use from Task 2. This showed an overestimation compared to EU-28 data on energy use. This means that the 'median' parameters for the base cases from Task 3 do not reflect 'average reference' parameters that can be used in a stock model in Task 7. Therefore corrections factors on those 'median' parameters were calculated that fit with total EU energy consumption. This also indicates that potentially a lot of circuits in the stock have a relative lower loading and/or longer circuit length and/or higher share of base cases with lower loading. This is also something to take into account in the sensitivity analysis (Task 6).

The annual electricity loss in cables in the service and industry sector at EU-28 level was estimated about 42 TWh which fits with cross checks in the report.

The tables in section 5.2 show that the use phase is responsible for the largest part of this electricity consumption.

Some cable insulation additives did not match one-to-one with the limited set of materials available in the MEErP Ecoreport tool, therefore alternative materials were chosen and a small sensitivity analysis showed that this has limited impact on the outcomes.

5.1 Product specific inputs

This section collects all relevant quantitative BC information from previous tasks for the modelling exercise in the rest of Task 5. The input parameters are defined in previous tasks. In these tasks, a parameter may have a low/minimum, average/reference or high/maximum value. For the calculation in Task 5 the average/reference value of each parameter is used as input.

5.1.1 Identification of base cases

According to the MEErP methodology, base cases should reflect average EU products. Different products of similar functionalities, Bill Of Materials (BOM), technologies and efficiency can be compiled into a single BC, thus it does not always represent a real product.
For the identification of the base cases, four application types (power cable for use in distribution circuit, power cable for use in lighting circuit, power cable for use in socket-outlet circuit, and power cable for use in dedicated circuit) and two different application sectors (services sector and industry sector) have been chosen. All base cases use cables with copper conductors, except for base case nine which is based upon cables with aluminium conductors.

The most appropriate base cases have been selected in accordance with the analysis presented in Tasks 2, 3 and 4 concerning the analysis of market and environmental and technical elements associated to products used across the EU.
Nine base cases have been identified to assess the environmental and economic impacts over the life cycle:

- Base case 1: A typical power cable for use in typical distribution circuit in the services sector (see Figure 5-1);

- Base case 2: A typical power cable for use in typical lighting circuit in the services sector;
- Base case 3: A typical power cable for use in typical socket-outlet circuit in the services sector;
- Base case 4: A typical power cable for use in typical dedicated circuit in the services sector (see Figure 5-1);
- Base case 5: A typical power cable for use in typical distribution circuit in the industry sector (see Figure 5-2);
- Base case 6: A typical power cable for use in typical lighting circuit in the industry sector;
- Base case 7: A typical power cable for use in typical socket-outlet circuit in the industry sector;
- Base case 8: A typical power cable for use in typical dedicated circuit in the industry sector (see Figure 5-2);
- Base case 9: The same base case as base case 8, but instead of copper the cable conductors are of aluminium.

The characteristics of each BC are summarised in Table 5-1. These characteristics are relevant because they have an impact on the energy consumption and the BoM. The bases cases are explained more in detail in the next paragraphs.

Table 5-1: Base case identification

	Unit	T				Bases cases definiton					
Base case id			BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
Sector			Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
Application circuit			Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
Transformer/Consumer	kVA	I	400	2.3	4	43	1250	2.3	4	108	108
Voltage	V	I	400	230	230	400	400	230	230	400	400
Load current Ib	A	I	577	10	16	62	1804	10	16	156	156
Cores		I	5	5	5	5	4	5	5	5	5
Conductor material		I	Cu	Cu	Cu	Cu	Cu	Cu	Cu	Cu	Al
CSA	mm²	I	120	1.5	2.5	10	300	1.5	2.5	35	70
Installation Method (IEC 60364-5-52)		I	E	E	E	E	E	E	E	E	E
Current Carying Capacity cable (IEC 60364-5-52 / Table B52.12)	A	I	346	26	30	75	621	26	30	158	158
Cables in parallel //		I	2	1	1	1	4	1	1	1	1
Current-Carrying Capacity - total	A	I	692	26	30	75	2484	26	30	158	158
Reduction Factor (IEC 60364-5-52 / Table B52.17)		I	0.88	1	1	1	0.8	1	1	1	1
Current-Carrying Capacity cable - total - reducted	A	C	609	26	30	75	1987	26	30	158	158
Icircuit= Ir (circuit breaker setting)	A	I	577	10	16	62	1804	10	16	156	156
Single phase or 3-phase		I	3	1	1	3	3	1	1	3	3
In per cable		I	289	10	16	62	451	10	16	156	156
Circuit length	m	I	56.25	43.56	52.78	50.56	82.50	67.50	72.00	78.50	78.50

Remarks:

- The circuits are 100% loaded. For each circuit the required CSA according to IEC 60364-5-52 is determined and checked with a commercial calculation tool.
- Installation Method E means cables arranged in a single layer on a perforated horizontal or vertical cable tray system (IEC 60364-5-52).

- Cable sizing is done according to the circuit breaker setting (Ir) and not according to the circuit breaker rating (In). For instance in base case 2 a 630 A (=In) circuit breaker will be used with Ir set at 609A.
- To make transitions between design options in later chapters possible, the number of conductors/cores of a cable has to be the same for each CSA. Therefore the cables in these base cases have always 5 cores. The BOM mentioned in Task 4 is based upon cables with 5 cores.

Base Case 1: Services sector – Distribution circuit

This base case includes the main distribution circuit - this means the LV power cable and protective device - between the 400 kVA MV/LV power transformer and the main LV distribution board (see Figure 5-1). In services sector smaller transformers are used compared to the industry. A 400 kVA transformer[122] is assumed as a common used transformer in services sector.
Two parallel cables of each 5G120 mm² are needed to transport the maximum power from the 400 kVA transformer to the main distribution board at the given circuit length.

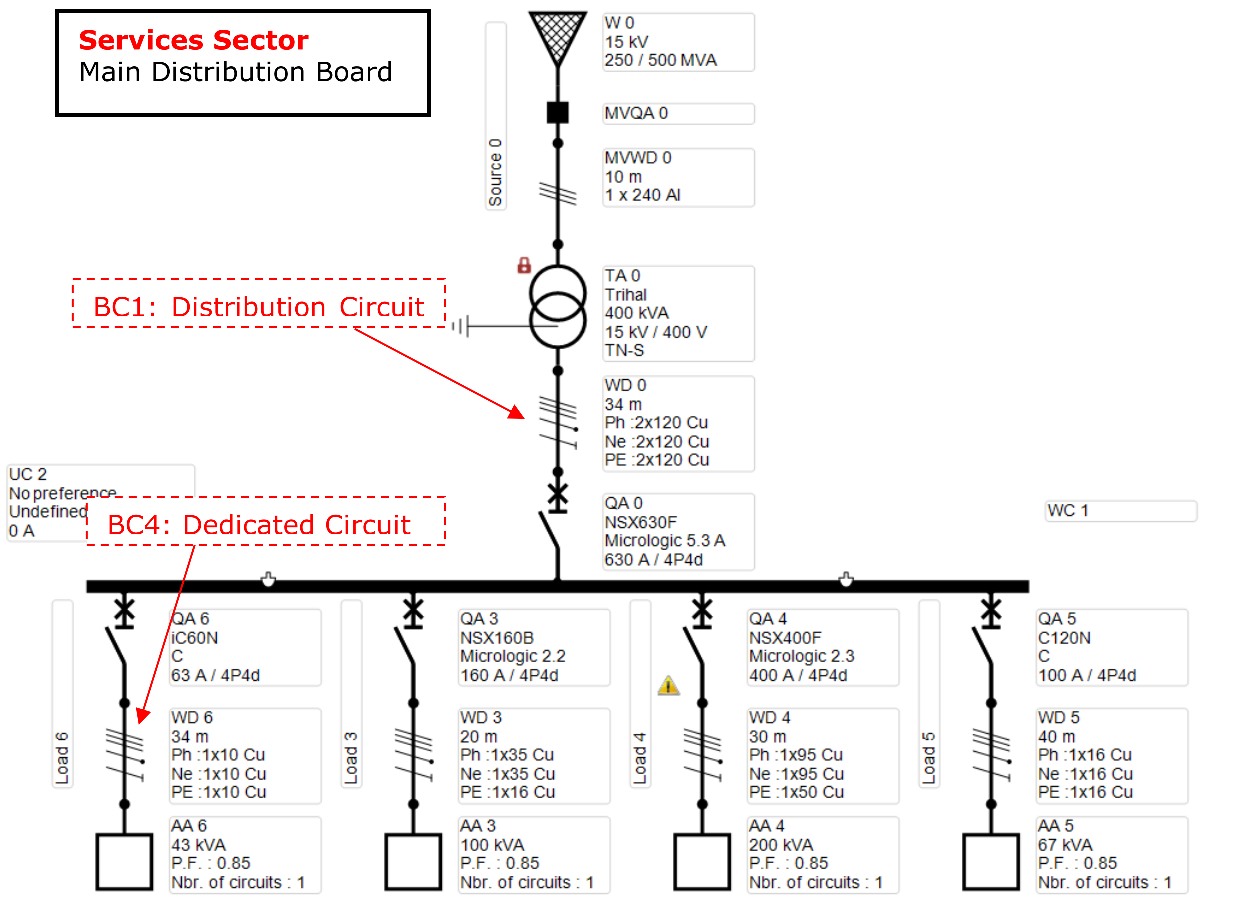


Figure 5-1 Services Sector - Base Cases 1 & 4

Base Case 2: Services sector - Lighting circuit

3G1.5 mm² and 5G1.5 mm² (two extra conductors for DALI protocol[121]) power cables are commonly used in lighting circuits in EU-28 countries. A 5G1.5 mm² is used in this base case. A circuit breaker of 10 A (or 16 A) can be used to protect the cable against overload and short circuit. The maximum power which can be transmitted over the cable is (230V*10A=) 2.3 kVA.

Base Case 3: Services sector – Socket-outlet circuit
A 3G2.5 mm² power cable is commonly used in socket-outlet circuits in EU-28 countries. A 5G2.5 mm² is used in this base case for reasons mentioned in the remarks above. A circuit breaker of 16 A (or 20 A) can be used to protect the cable against overload and short circuit. The maximum power which can be transmitted over the cable is (230V*16A=) 36.8 kVA.

Base Case 4: Services sector – Dedicated circuit

A dedicated circuit forms the connection between a main- or sub-distribution board and a dedicated consumer (see Figure 5-1). A 5G10 mm² cable is selected for the services sector as a dedicated circuit cable. For the given cable length and cable section a load of 43 kVA can be connected to the 63 A circuit breaker in the distribution board.

Base Case 5: Industry sector – Distribution circuit

In general, transformers with a higher power rate are used in industry sector compared to the services sector. A 1250 kVA transformer is used in this BC as a common used transformer in industry[122].
The distribution circuit contains the main distribution circuit - this means the LV power cable and protective device - between the 1250 kVA MV/LV power transformer and the main LV distribution board (see Figure 5-2).

Four parallel cables of each 4 x 300 mm² are needed to transport the maximum power from the 1250 kVA transformer to the main distribution board at the given circuit length.

[121] DALI protocol is an open digital lighting standard: IEC 62386
[122] EU DG ENTR- Lot 2: Distribution and power transformers:
http://www.eceee.org/ecodesign/products/distribution_power_transformers/Final_report_Feb2011

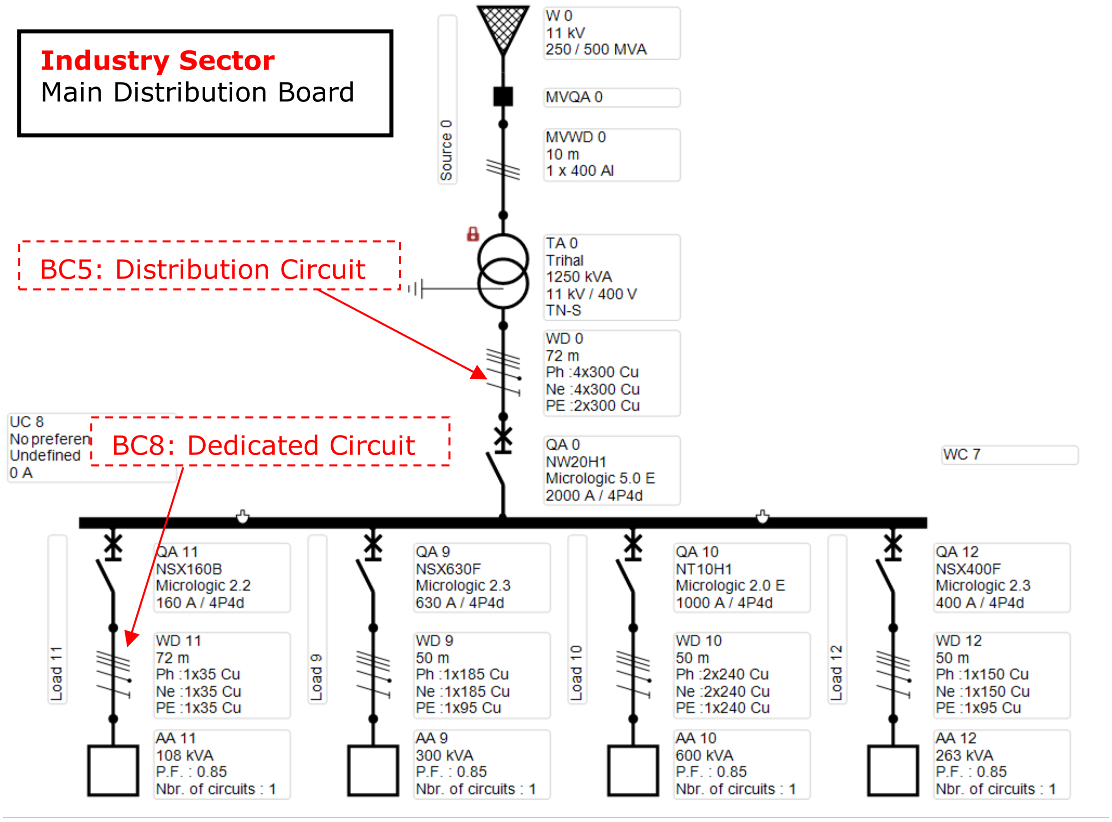


Figure 5-2 Industry Sector – Base Cases 5 & 8

Base Case 6: Industry sector – Lighting circuit
A circuit similar to base case 2, but with characteristics typical for the industry, as defined in Task 3.

Base Case 7: Industry sector – Socket-outlet circuit
A circuit similar to base case 3, but with characteristics typical for the industry as defined in Task 3.

Base Case 8: Industry sector – Dedicated circuit

A 5G35 mm² cable is selected for the industry sector as a dedicated circuit cable. For the given cable length and cable section a load of 108 kVA can be connected to the 160 A circuit breaker in the distribution board (Figure 5-2).

Base Case 9: Industry sector – Dedicated
The same base case as base case 8, but with the difference that the cable conductors are of aluminium instead of copper. The aluminium cable with the smallest CSA complying with the requested current requirements is selected. In this case it means that a 5x35mm² copper based cable is replaced by a 5x70 mm² aluminium based cable. The selection is verified by means of an electrical installation design engineering tool.

5.1.2 Manufacturing of the product: Bill Of Materials

The manufacturing phase includes the extraction and processing of the required materials and the following steps necessary to produce and assembly one product. The MEErP 2011 EcoReport tool contains a fixed list of materials and processes for which materials and energy indicators are provided (see for instance the 'Material Code in EcoReport tool' reported in Table 5-9).

A frequently used LV power cable with the following specifications is selected as the reference cable:

- Conductor:
  - Material: Cu
  - Flexibility: Class 1 and 2
- Insulation material: XLPE (Cross-Linked Polyethylene)
- Sheath material: PVC (Polyvinyl Chloride)
- Voltage rating: 0.6/1 kV
- Single- and multicore
- Armoured: No
- Standard: IEC 60502-1

The BOM of this preparatory study has been selected according to information included in Task 2 and Task 4. An overview of the BOM per BC is shown in Table 5-2.

Table 5-2: Bill Of Materials per base case

	Unit		Bases cases definiton								
Base case id			BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
Sector			Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
Application circuit			Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
BoM per meter cable											
CSA	mm²	I	120.00	1.50	2.50	10.00	300.00	1.50	2.50	35.00	70.00
Conductor material	g/m	I	5,334.00	66.68	111.13	444.50	10,668.00	66.68	111.13	1,555.75	945.00
Insulation material	g/m	I	238.41	21.47	25.56	43.97	448.07	21.47	25.56	99.92	189.62
Sheath material	g/m	I	478.79	79.39	88.56	129.78	820.05	79.39	88.56	210.34	399.11
Filler material	g/m	I	1,300.81	41.21	50.26	141.25	1,933.88	41.21	50.26	390.98	843.27
Total weight material	g/m	C	7,352.00	208.75	275.50	759.50	13,870.00	208.75	275.50	2,257.00	2,377.00
BoM per base case											
Conductor material	kg	C	600.08	2.90	5.86	22.47	3,520.44	4.50	8.00	122.13	74.18
Insulation material	kg	C	26.82	0.94	1.35	2.22	147.86	1.45	1.84	7.84	14.88
Sheath material	kg	C	53.86	3.46	4.67	6.56	270.62	5.36	6.38	16.51	31.33
Filler material	kg	C	146.34	1.79	2.65	7.14	638.18	2.78	3.62	30.69	66.20
Total weight material	kg	C	827.10	9.09	14.54	38.40	4,577.10	14.09	19.84	177.17	186.59

In the EcoReport tool the following material components are selected, based on Table 4-1 of Task 4:

- Conductor material: Cu or Al (depending on the BC);
- Insulation material: 100% LDPE (According to the Europacable members, there is 3% silane based crosslinking compound in the XLPE insulation, however due to the limited list of materials in the EcoReport tool 100% LDPE is used for the calculations, also given the small share of crosslinking compound.) ;
- Sheath material, composed of:
  - 50% of the sheath material weight: PVC (not recycled)[123];

[123] See minutes of second stakeholder meeting. See "Preparatory Studies for Product Group in the Ecodesign Working Plan 2012-2014:Lot 8 - Power Cables: Project Report".

  - 25% of the sheath material weight: talcum filler as filler material in the sheath (According to the Europacable members, calcium carbonate filler is used, however in the EcoReport tool calcium carbonate cannot be chosen. Given that both talcum and calcium carbonate are mineral fillers that are used in plastic, talcum is used as a substitute.);
  - 25% of the sheath material weight: bitumen, as it is the closest to a plasticizer in the EcoReport tool. To analyse the impact of this approximation a small sensitivity analysis on the plasticizer material is carried out. The results are shown in annex in section 8.7. The impact on the total energy consumption and greenhouse gases is less than 0.1%;
- Filler material: 100% talcum filler.

The material resource input for base case 1 in the EcoReport tool is shown in Table 5-3 as an example.

Table 5-3: Material resource input for base case 1

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	Conductor	600075.0	4-Non-ferro	30 - Cu wire
2	Insulation	268210	1-BlkPlastics	1-LDPE
3	Sheath - PVC	269317	1-BlkPlastics	8 - PVC
4	Sheath - Filler	13465.8	2-TecPlastics	18 - Talcum filler
5	Sheath - plasticizer	13465.8	7-Misc.	56 - Bitumen
6	Filler material	146340.7	2-TecPlastics	18 - Talcum filler

5.1.3 Distribution phase: volume of packaged product

This phase includes the distribution of the packaged product. The volume of the packaged product (power cable) depends on the length of cable. For a certain cable section, the appropriate drum is selected. If multiple drum sizes (drum numbers) are available, the average drum size has been selected. The volume of this drum is then multiplied by length of cable of the BC (= circuit length x number of parallel cables) divided by the maximum length of cable on this drum. Drum characteristics are listed in Task 4. The calculation is shown in Table 5-4. An estimated spacing correction factor of 15% has been chosen for the extra space between drums during transport needed for handling. The EcoReport input is shown in Table 5-5.

Table 5-4: Calculation of volume of packaged base case per meter cable

	Unit	T	BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
CSA	mm²	I	120	1.5	2.5	10	300	1.5	2.5	35	70
Ficitious diameter	mm	I	39.96	7.56	8.64	13.50	55.90	7.56	8.64	22.95	31.32
PVC sheat tickness	mm	I	2.40	1.80	1.80	1.80	2.96	1.80	1.80	1.80	2.10
Cable outer diameter	mm	C	44.76	11.16	12.24	17.10	61.82	11.16	12.24	26.56	35.51
Drum Size		I	22	10	10	14	22	10	10	16	20
Max. cable length	m	I	842	2323	1952	2448	443	2323	1952	1326	1161
Drum Volume (formula 4.1)	m³	I	6.04	0.70	0.70	1.80	6.04	0.70	0.70	2.63	4.99
Drum spacing	m³	C	0.91	0.11	0.11	0.27	0.91	0.11	0.11	0.39	0.75
Correction factor (spacing)	%	I	15%	15%	15%	15%	15%	15%	15%	15%	15%
Drum Corrected Volume	m³	C	6.95	0.81	0.81	2.07	6.95	0.81	0.81	3.03	5.74
Drum Weight	kg	I	450.00	50.00	50.00	125.00	450.00	50.00	50.00	175.00	330.00
Drum corrected volume / meter cable	m³/m	C	0.00825	0.00035	0.00041	0.00085	0.01568	0.00035	0.00041	0.00228	0.00494
Drum Weigth / meter cable	g/m	C	534.4	21.5	25.6	51.1	1015.8	21.5	25.6	132.0	284.2

Table 5-5: EcoReport input: volume of packaged base case

	Unit		Bases cases definiton								
Base case id			BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
Sector			Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
Application circuit			Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
Volume package											
Volume package per meter cable	m3	I	0.008250	0.000347	0.000412	0.000847	0.015680	0.000347	0.000412	0.002282	0.004945
Volume package per base case	m3	C	0.92811	0.01509	0.02177	0.04283	5.17450	0.02339	0.02969	0.17917	0.38816

5.1.4 Use phase

The use phase considers the amount of energy resources demanded during the lifetime of power cables. In this study, the amount of energy loss due to the resistance of the power cable is regarded as the energy consumption of the power cable. The calculated result of the energy consumption value per BC and the input parameters for this calculation are listed in Table 5-6. Average consumption of energy per BC has been calculated based on parameters, models and formulas described in Task 2 and Task 3.

Table 5-6: Energy consumption per base case

Parameter	Unit	T				Base cases					
Base case id			BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
Sector			Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
Application circuit			Distributio n circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distributio n circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
Loaded cores		I	6	2	2	3	12	2	2	3	3
Cables in parallel		I	2	1	1	1	4	1	1	1	1
Conductor material		I	Cu	Cu	Cu	Cu	Cu	Cu	Cu	Cu	Al
In per cable	A	I	289	10	16	62	451	10	16	156	156
CSA	mm²	I	120	1.5	2.5	10	300	1.5	2.5	35	70
Length of circuit	m	I	56	44	53	51	83	68	72	79	79
ρ_t	Ω.m m²/m	I	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0265
R (formula 3.2) per wire	Ω	C	0.008	0.485	0.353	0.084	0.005	0.752	0.481	0.037	0.030
Kd		I	1.00	0.37	0.40	1.00	1.00	0.37	0.44	1.00	1.00
Kf		I	1.21	1.27	1.27	1.21	1.02	1.06	1.06	1.01	1.01
αc		I	0.41	0.24	0.15	0.41	0.57	0.34	0.27	0.61	0.61
Pf		I	0.80	1.00	0.80	0.80	0.80	1.00	0.80	0.80	0.80
Annual energy loss (formula 3.5) per loaded core	kWh	C	1392.06	15.22	10.81	694.00	2797.39	31.38	39.16	3011.51	2389.38
Annual energy loss (formula 3.5) per BC	kWh	C	8352.36	30.44	21.61	2082.01	33568.63	62.75	78.33	9034.54	7168.13
Annual energy transported (formula 3.6) per BC	kVAh	C	1,383,543	6,233	4,787	148,731	5,121,230	7,249	7,423	465,153	465,153
Energy loss ratio (formula 3.7)		C	0.60%	0.49%	0.45%	1.40%	0.66%	0.87%	1.06%	1.94%	1.54%

5.1.5 End of Life (EoL)

Recycling of materials can avoid the extraction of raw materials and the production of virgin materials, which is modelled in the EcoReport tool as credits (avoided impacts), i.e. negative impacts. Defaults values of the EcoReport have been used for recycling rates of the materials, except for ferro and non-ferro materials. For instance, default values for the recycling rate of metals and plastics are 94% and 29% respectively. These recycling rates are considered comparable with the outcomes of the previous tasks and thus suitable for the current environmental analysis. Only the re-use of metals is set to 0% instead of 1% and recycling of metals is set to 95% instead of 94% (see section 3.3 in Task 3).

5.1.6 Life Cycle Cost inputs

Average market data and consumer expenditure data have been estimated in Task 2. These have been summarized in Table 5-7 and form the data input for carrying out the economic assessment of the base cases. As mentioned in Task 3, there are no repair and maintenance costs for installed power cables.

Because altering the cable size can have an impact on the price of the used connectors, the connector price is included in the base case product price. Connectors usually serve a range of cable sizes, for instance from 0.14 mm^2 till 4 mm^2, 0.2 mm^2 till 10 mm^2, 0.5 mm^2 till 16 mm^2 and so on. In the base case calculation the smallest connector, able to fit the cable, is selected.

Base case connector price = CP x CC x NC x NEN (formula 5.1)

Where:

CP: connector price for one wire;
CC: cores per cable;
NC: number of cables in the base case;
NEN: number of end-nodes in a base case.

This means that the connector price doubles when the amount of cables in a base case doubles. Also for base cases with a lot of end-nodes like the base cases for lighting circuits or socket circuits, the connector price will be a substantial part of the base case product price.
Larger connectors may also have an impact on the distribution boards. This is however not included in the base case product price, nor is the cost for potential larger ducts and the building space needed for this. The connector prices are listed in Task 2. Discounted prices are used.

A residual value of the cable is calculated according the formula in 2.4.3. Because the EcoReport tool doesn't provide a residual value input field, the residual value is discounted for the lifetime of the cable and subtracted from the product price. This results in what is called the "corrected base case product price" in Table 5-7.
Note: in Task 5 and Task 6 the "corrected base case product price" is used as the value for the "product price" input field in the EcoReport tool.

Table 5-7: LCC input parameter per base case

	Unit					Bases cases definiton					
Base case id			BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
Sector			Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
Application circuit			Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
LCC data											
Year		I	2010	2010	2010	2010	2010	2010	2010	2010	2010
Electricity rate	€/kWh	I	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Product price for 1 meter cable	€/m	I	52.09	0.65	1.09	4.34	104.18	0.65	1.09	15.19	17.29
Price connectors	€	I	330.55	32.75	22.88	14.30	806.86	37.67	16.63	39.80	102.43
Bace case product price	€	C	6190.53	61.11	80.16	233.75	35185.45	81.62	94.76	1232.41	1459.87
Base case installation cost	€	I	655.20	74.33	93.05	130.22	3376.80	101.42	107.18	316.20	370.05
Product life	Year	I	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Product service life	Year	I	23.75	23.75	23.75	23.75	23.75	23.75	23.75	23.75	23.75
Discounted residual value for 1m cable	€/m	C	5.73	0.07	0.12	0.48	11.46	0.07	0.12	1.67	0.39
Discounted residual value	€	C	644.65	3.12	6.30	24.14	3781.94	4.83	8.60	131.20	30.48
Corrected base case product price	€	C	5545.89	57.99	73.86	209.61	31403.51	76.79	86.16	1101.21	1429.39

5.2 Base case environmental impact assessment (using EcoReport)

In this section, the EcoReport tool 2011 version 3.06 is used to calculate the outputs per environmental indicator and 'cradle-to-grave' stages of a product life.
A summary of all input parameters values used in the EcoReport tool is listed in Table 5-8. For parameters not mentioned in Table 5-8, the default parameters of the EcoReport tool are used.

In accordance with the statement in the MEErP guideline " Recycling: 40% credit of all impacts, related to recycled mass per materials category. Exception for ferro and non-ferro metals, where credit is overall 65-80% per metal (fixed), further differentiated per halfproduct." the credit rating for ferro and non-ferro metals is set to 70% instead of the default 40% for all analysis using the EcoReport tool.

Table 5-8: EcoReport tool input parameters per base case

	Unit	Base cases: ecoreport input								
Base case id		**BC1**	**BC2**	**BC3**	**BC4**	**BC5**	**BC6**	**BC7**	**BC8**	**BC9**
CSA	mm²	120	1.5	2.5	10	300	1.5	2.5	35	70
Conductor material	g	600075.0	2904.1	5864.9	22471.9	3520440.0	4500.6	8001.0	122126.4	74182.5
Insulation material	g	26821.0	935.3	1349.2	2223.0	147862.8	1449.5	1840.7	7843.8	14884.9
Sheath material	g	53863.3	3458.1	4673.7	6561.1	270615.7	5359.1	6376.0	16512.0	31330.4
Filler material	g	146340.7	1794.8	2652.4	7140.9	638181.6	2781.4	3618.4	30692.3	66196.7
Annual energy loss (formula 3.5) per BC	kWh	8352.36	30.44	21.61	2082.01	33568.63	62.75	78.33	9034.54	7168.13
Volume	m3	0.93	0.02	0.02	0.04	5.17	0.02	0.03	0.18	0.39
Product life	Year	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Product service life	Year	23.75	23.75	23.75	23.75	23.75	23.75	23.75	23.75	23.75
Corrected base case product price	€	5545.89	57.99	73.86	209.61	31403.51	76.79	86.16	1101.21	1429.39
Annual sales (base case units)	mln. Units	0.13	2.86	3.77	0.98	0.03	1.78	2.00	0.24	0.24
EU Stock (base case units)	mln. Units	3.23	71.43	94.32	24.62	0.71	44.44	49.99	5.94	5.94
Base case installation cost	€	655.20	74.33	93.05	130.22	3376.80	101.42	107.18	316.20	370.05
Electricity rate	€/kWh	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
EoL mass fraction to re-use, non-Ferro material	%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Conductor material		Cu	Cu	Cu	Cu	Cu	Cu	Cu	Cu	Al

5.2.1 Base case 1: distribution circuit in services sector

The environmental impacts related to the use of one BC1 circuit per year, calculated by means of the EcoReport tool, are shown in Table 5-9.

Table 5-9: Environmental impacts related to the use of one BC1 circuit per year

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Stock	
	Materials	**unit**									
1	Bulk Plastics	g			**2,150**		**22**	1,194	977	0	**0**
2	TecPlastics	g			**6,392**		**64**	3,551	2,905	0	**0**
3	Ferro	g			**0**		**0**	0	0	0	**0**
4	Non-ferro	g			**24,003**		**240**	1,212	23,031	0	**0**
5	Coating	g			**0**		**0**	0	0	0	**0**
6	Electronics	g			**0**		**0**	0	0	0	**0**
7	Misc.	g			**539**		**5**	185	359	0	**0**
8	Extra	g			**0**		**0**	0	0	0	**0**
9	Auxiliaries	g			**0**		**0**	0	0	0	**0**
10	Refrigerant	g			**0**		**0**	0	0	0	**0**
	Total weight	g			**33,084**		**331**	6,142	27,272	0	**0**
									see note!		
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	3,033	349	**3,382**	**49**	**71,443**	18	-1,890		**73,002**
12	of which, electricity (in primary MJ)	MJ	26	210	**236**	**0**	**71,413**	0	-2		**71,647**
13	Water (process)	ltr	19	3	**22**	**0**	**0**	0	-2		**20**
14	Water (cooling)	ltr	115	99	214	0	3,175	0	-9		**3,380**
15	Waste, non-haz./ landfill	g	448	1,093	**1,542**	**27**	**36,806**	15	-210		**38,179**
16	Waste, hazardous/ incinerated	g	17	0	**17**	**1**	**1,127**	0	-5		**1,139**
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	157	19	**177**	**3**	**3,050**	0	-100		**3,130**
18	Acidification, emissions	g SO2 eq.	7,057	83	**7,140**	**10**	**13,560**	4	-4,668		**16,045**
19	Volatile Organic Compounds (VOC)	g	5	0	**5**	**1**	**1,595**	0	-1		**1,599**
20	Persistent Organic Pollutants (POP)	ng i-Teq	90	0	**90**	**0**	**168**	0	-60		**198**
21	Heavy Metals	mg Ni eq.	1,327	0	**1,327**	**1**	**735**	1	-880		**1,185**
22	PAHs	mg Ni eq.	133	0	**133**	**2**	**168**	0	-87		**217**
23	Particulate Matter (PM, dust)	g	212	13	**225**	**127**	**288**	5	-83		**562**
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	2,264	0	**2,264**	**0**	**330**	1	-1,503		**1,092**
25	Eutrophication	g PO4	4	0	**4**	**0**	**14**	0	-3		**16**

5.2.2 Base case 2: lighting circuit in services sector

The environmental impacts related to the use of one BC2 circuit per year, calculated by means of the EcoReport tool, are shown in Table 5-10.

Table 5-10: Environmental impacts related to the use of one BC2 circuit per year

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Stock	
	Materials	**unit**									
1	Bulk Plastics	g			**107**		**1**	59	48	0	**0**
2	TecPlastics	g			**106**		**1**	59	48	0	**0**
3	Ferro	g			**0**		**0**	0	0	0	**0**
4	Non-ferro	g			**116**		**1**	6	111	0	**0**
5	Coating	g			**0**		**0**	0	0	0	**0**
6	Electronics	g			**0**		**0**	0	0	0	**0**
7	Misc.	g			**35**		**0**	12	23	0	**0**
8	Extra	g			**0**		**0**	0	0	0	**0**
9	Auxiliaries	g			**0**		**0**	0	0	0	**0**
10	Refrigerant	g			**0**		**0**	0	0	0	**0**
	Total weight	g			**364**		**4**	136	231	0	**0**
								see note!			
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	23	9	**32**	**5**	**261**	0	-10		**288**
12	of which, electricity (in primary MJ)	MJ	1	5	**7**	**0**	**260**	0	0		**267**
13	Water (process)	ltr	1	0	**1**	**0**	**0**	0	0		**1**
14	Water (cooling)	ltr	6	2	8	0	12	0	0		**20**
15	Waste, non-haz./ landfill	g	8	27	**36**	**5**	**134**	1	-2		**173**
16	Waste, hazardous/ incinerated	g	1	0	**1**	**0**	**4**	0	0		**5**
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	1	0	**2**	**0**	**11**	0	-1		**13**
18	Acidification, emissions	g SO2 eq.	36	2	**38**	**1**	**50**	0	-23		**66**
19	Volatile Organic Compounds (VOC)	g	0	0	**0**	**0**	**6**	0	0		**6**
20	Persistent Organic Pollutants (POP)	ng i-Teq	0	0	**0**	**0**	**1**	0	0		**1**
21	Heavy Metals	mg Ni eq.	7	0	**7**	**0**	**3**	0	-4		**5**
22	PAHs	mg Ni eq.	1	0	**1**	**0**	**1**	0	0		**1**
23	Particulate Matter (PM, dust)	g	10	0	**10**	**2**	**1**	0	-3		**11**
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	11	0	**11**	**0**	**1**	0	-7		**5**
25	Eutrophication	g PO4	0	0	**0**	**0**	**0**	0	0		**0**

5.2.3 Base case 3: socket-outlet circuit in services sector

The environmental impacts related to the use of one BC3 circuit per year, calculated by means of the EcoReport tool, are shown in Table 5-11.

Table 5-11: Environmental impacts related to the use of one BC3 circuit per year

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Stock	
	Materials	**unit**									
1	Bulk Plastics	g			**147**		**1**	82	67	0	**0**
2	TecPlastics	g			**153**		**2**	85	69	0	**0**
3	Ferro	g			**0**		**0**	0	0	0	**0**
4	Non-ferro	g			**235**		**2**	12	225	0	**0**
5	Coating	g			**0**		**0**	0	0	0	**0**
6	Electronics	g			**0**		**0**	0	0	0	**0**
7	Misc.	g			**47**		**0**	16	31	0	**0**
8	Extra	g			**0**		**0**	0	0	0	**0**
9	Auxiliaries	g			**0**		**0**	0	0	0	**0**
10	Refrigerant	g			**0**		**0**	0	0	0	**0**
	Total weight	g			**582**		**6**	195	393	0	**0**
								see note!			
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	41	12	**53**	**5**	**185**	1	-20		**224**
12	of which, electricity (in primary MJ)	MJ	2	7	**9**	**0**	**185**	0	0		**194**
13	Water (process)	ltr	1	0	**2**	**0**	**0**	0	0		**1**
14	Water (cooling)	ltr	8	3	12	0	8	0	-1		**19**
15	Waste, non-haz./ landfill	g	12	38	**51**	**5**	**95**	1	-3		**149**
16	Waste, hazardous/ incinerated	g	1	0	**1**	**0**	**3**	0	0		**4**
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	2	1	**3**	**0**	**8**	0	-1		**10**
18	Acidification, emissions	g SO2 eq.	71	3	**74**	**1**	**36**	0	-46		**65**
19	Volatile Organic Compounds (VOC)	g	0	0	**0**	**0**	**4**	0	0		**4**
20	Persistent Organic Pollutants (POP)	ng i-Teq	1	0	**1**	**0**	**0**	0	-1		**1**
21	Heavy Metals	mg Ni eq.	13	0	**13**	**0**	**2**	0	-9		**7**
22	PAHs	mg Ni eq.	1	0	**1**	**0**	**0**	0	-1		**1**
23	Particulate Matter (PM, dust)	g	13	0	**14**	**3**	**1**	0	-4		**14**
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	23	0	**23**	**0**	**1**	0	-15		**9**
25	Eutrophication	g PO4	0	0	**0**	**0**	**0**	0	0		**0**

5.2.4 Base case 4: dedicated circuit in services sector

The environmental impacts related to the use of one BC4 circuit per year, calculated by means of the EcoReport tool, are shown in Table 5-12.

Table 5-12: Environmental impacts related to the use of one BC4 circuit per year

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Stock	
	Materials	**unit**									
1	Bulk Plastics	g			**220**		**2**	122	100	0	**0**
2	TecPlastics	g			**351**		**4**	195	160	0	**0**
3	Ferro	g			**0**		**0**	0	0	0	**0**
4	Non-ferro	g			**899**		**9**	45	862	0	**0**
5	Coating	g			**0**		**0**	0	0	0	**0**
6	Electronics	g			**0**		**0**	0	0	0	**0**
7	Misc.	g			**66**		**1**	23	44	0	**0**
8	Extra	g			**0**		**0**	0	0	0	**0**
9	Auxiliaries	g			**0**		**0**	0	0	0	**0**
10	Refrigerant	g			**0**		**0**	0	0	0	**0**
	Total weight	g			**1,536**		**15**	385	1,166	0	**0**
									see note!		
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	126	23	**149**	**6**	**17,802**	1	-72		**17,887**
12	of which, electricity (in primary MJ)	MJ	3	14	**17**	**0**	**17,801**	0	0		**17,818**
13	Water (process)	ltr	2	0	**2**	**0**	**0**	0	0		**2**
14	Water (cooling)	ltr	12	7	19	0	791	0	-1		**809**
15	Waste, non-haz./ landfill	g	26	73	**99**	**5**	**9,174**	1	-9		**9,271**
16	Waste, hazardous/ incinerated	g	1	0	**1**	**0**	**281**	0	0		**282**
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	6	1	**8**	**0**	**760**	0	-4		**764**
18	Acidification, emissions	g SO2 eq.	266	6	**272**	**1**	**3,365**	0	-175		**3,464**
19	Volatile Organic Compounds (VOC)	g	1	0	**1**	**0**	**398**	0	0		**398**
20	Persistent Organic Pollutants (POP)	ng i-Teq	3	0	**3**	**0**	**42**	0	-2		**43**
21	Heavy Metals	mg Ni eq.	50	0	**50**	**0**	**180**	0	-33		**198**
22	PAHs	mg Ni eq.	5	0	**5**	**0**	**42**	0	-3		**44**
23	Particulate Matter (PM, dust)	g	20	1	**21**	**6**	**71**	1	-6		**92**
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	85	0	**85**	**0**	**77**	0	-56		**106**
25	Eutrophication	g PO4	0	0	**0**	**0**	**3**	0	0		**3**

5.2.5 Base case 5: distribution circuit in industry sector

The environmental impacts related to the use of one BC5 circuit per year, calculated by means of the EcoReport tool, are shown in Table 5-13.

Table 5-13: Environmental impacts related to the use of one BC5 circuit per year

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Stock	
	Materials	**unit**									
1	Bulk Plastics	g			**11,327**		**113**	6,292	5,148	0	**0**
2	TecPlastics	g			**28,233**		**282**	15,684	12,832	0	**0**
3	Ferro	g			**0**		**0**	0	0	0	**0**
4	Non-ferro	g			**140,818**		**1,408**	7,111	##########	0	**0**
5	Coating	g			**0**		**0**	0	0	0	**0**
6	Electronics	g			**0**		**0**	0	0	0	**0**
7	Misc.	g			**2,706**		**27**	929	1,804	0	**0**
8	Extra	g			**0**		**0**	0	0	0	**0**
9	Auxiliaries	g			**0**		**0**	0	0	0	**0**
10	Refrigerant	g			**0**		**0**	0	0	0	**0**
	Total weight	g			**183,084**		**1,831**	30,016	##########	0	**0**
									see note!		
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	17,595	1,616	**19,211**	**253**	**287,188**	98	-11,057		**295,693**
12	of which, electricity (in primary MJ)	MJ	139	973	**1,112**	**1**	**287,013**	0	-11		**288,115**
13	Water (process)	ltr	97	15	**111**	**0**	**1**	0	-11		**101**
14	Water (cooling)	ltr	602	459	1,061	0	12,762	0	-47		**13,775**
15	Waste, non-haz./ landfill	g	2,500	5,064	**7,564**	**128**	**147,932**	78	-1,216		**154,486**
16	Waste, hazardous/ incinerated	g	91	0	**91**	**3**	**4,529**	0	-27		**4,595**
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	915	90	**1,005**	**16**	**12,261**	0	-586		**12,696**
18	Acidification, emissions	g SO2 eq.	41,354	387	**41,741**	**49**	**54,627**	21	-27,381		**69,058**
19	Volatile Organic Compounds (VOC)	g	26	0	**26**	**4**	**6,410**	0	-7		**6,434**
20	Persistent Organic Pollutants (POP)	ng i-Teq	528	0	**528**	**1**	**675**	0	-351		**853**
21	Heavy Metals	mg Ni eq.	7,779	0	**7,779**	**7**	**2,980**	8	-5,163		**5,611**
22	PAHs	mg Ni eq.	777	0	**777**	**9**	**677**	0	-507		**957**
23	Particulate Matter (PM, dust)	g	1,124	60	**1,183**	**708**	**1,159**	24	-455		**2,620**
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	13,278	0	**13,278**	**0**	**1,368**	4	-8,816		**5,834**
25	Eutrophication	g PO4	24	1	**25**	**0**	**54**	1	-15		**66**

5.2.6 Base case 6: lighting circuit in industry sector

The environmental impacts related to the use of one BC6 circuit per year, calculated by means of the EcoReport tool, are shown in Table 5-14.

Table 5-14: Environmental impacts related to the use of one BC6 circuit per year

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Stock	
	Materials	**unit**									
1	Bulk Plastics	g			**165**		**2**	92	75	0	**0**
2	TecPlastics	g			**165**		**2**	92	75	0	**0**
3	Ferro	g			**0**		**0**	0	0	0	**0**
4	Non-ferro	g			**180**		**2**	9	173	0	**0**
5	Coating	g			**0**		**0**	0	0	0	**0**
6	Electronics	g			**0**		**0**	0	0	0	**0**
7	Misc.	g			**54**		**1**	18	36	0	**0**
8	Extra	g			**0**		**0**	0	0	0	**0**
9	Auxiliaries	g			**0**		**0**	0	0	0	**0**
10	Refrigerant	g			**0**		**0**	0	0	0	**0**
	Total weight	g			**564**		**6**	211	358	0	**0**
									see note!		
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	36	13	**49**	**6**	**537**	1	-16		**577**
12	of which, electricity (in primary MJ)	MJ	2	8	**10**	**0**	**537**	0	0		**546**
13	Water (process)	ltr	2	0	**2**	**0**	**0**	0	0		**2**
14	Water (cooling)	ltr	9	4	13	0	24	0	-1		**36**
15	Waste, non-haz./ landfill	g	13	42	**55**	**5**	**277**	1	-2		**335**
16	Waste, hazardous/ incinerated	g	1	0	**1**	**0**	**8**	0	0		**9**
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	2	1	**2**	**0**	**23**	0	-1		**25**
18	Acidification, emissions	g SO2 eq.	55	3	**59**	**1**	**102**	0	-35		**126**
19	Volatile Organic Compounds (VOC)	g	0	0	**0**	**0**	**12**	0	0		**12**
20	Persistent Organic Pollutants (POP)	ng i-Teq	1	0	**1**	**0**	**1**	0	0		**2**
21	Heavy Metals	mg Ni eq.	10	0	**10**	**0**	**6**	0	-7		**9**
22	PAHs	mg Ni eq.	1	0	**1**	**0**	**1**	0	-1		**2**
23	Particulate Matter (PM, dust)	g	15	0	**15**	**3**	**2**	0	-4		**17**
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	17	0	**17**	**0**	**2**	0	-11		**9**
25	Eutrophication	g PO4	0	0	**0**	**0**	**0**	0	0		**0**

5.2.7 Base case 7: socket-outlet circuit in industry sector

The environmental impacts related to the use of one BC7 circuit per year, calculated by means of the EcoReport tool, are shown in Table 5-15.

Table 5-15: Environmental impacts related to the use of one BC7 circuit per year

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	**Total**	BUTION		Disposal	Recycl.	**Stock**	
	Materials	**unit**									
1	Bulk Plastics	g			**201**		**2**	112	91	0	**0**
2	TecPlastics	g			**208**		**2**	116	95	0	**0**
3	Ferro	g			**0**		**0**	0	0	0	**0**
4	Non-ferro	g			**320**		**3**	16	307	0	**0**
5	Coating	g			**0**		**0**	0	0	0	**0**
6	Electronics	g			**0**		**0**	0	0	0	**0**
7	Misc.	g			**64**		**1**	22	43	0	**0**
8	Extra	g			**0**		**0**	0	0	0	**0**
9	Auxiliaries	g			**0**		**0**	0	0	0	**0**
10	Refrigerant	g			**0**		**0**	0	0	0	**0**
	Total weight	g			**793**		**8**	266	536	0	**0**
									see note!		
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	55	17	**72**	**6**	**670**	1	-27		**722**
12	of which, electricity (in primary MJ)	MJ	2	10	**12**	**0**	**670**	0	0		**682**
13	Water (process)	ltr	2	0	**2**	**0**	**0**	0	0		**2**
14	Water (cooling)	ltr	11	5	16	0	30	0	-1		**45**
15	Waste, non-haz./ landfill	g	17	52	**69**	**5**	**345**	1	-4		**417**
16	Waste, hazardous/ incinerated	g	1	0	**1**	**0**	**11**	0	0		**12**
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	3	1	**3**	**0**	**29**	0	-1		**31**
18	Acidification, emissions	g SO2 eq.	97	4	**101**	**1**	**127**	0	-63		**167**
19	Volatile Organic Compounds (VOC)	g	1	0	**1**	**0**	**15**	0	0		**15**
20	Persistent Organic Pollutants (POP)	ng i-Teq	1	0	**1**	**0**	**2**	0	-1		**2**
21	Heavy Metals	mg Ni eq.	18	0	**18**	**0**	**7**	0	-12		**14**
22	PAHs	mg Ni eq.	2	0	**2**	**0**	**2**	0	-1		**2**
23	Particulate Matter (PM, dust)	g	18	1	**18**	**4**	**3**	1	-5		**21**
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	31	0	**31**	**0**	**3**	0	-20		**14**
25	Eutrophication	g PO4	0	0	**0**	**0**	**0**	0	0		**0**

5.2.8 Base case 8: dedicated circuit in industry sector

The environmental impacts related to the use of one BC8 circuit per year, calculated by means of the EcoReport tool, are shown in Table 5-16.

Table 5-16: Environmental impacts related to the use of one BC8 circuit per year

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Stock	
	Materials	**unit**									
1	Bulk Plastics	g			**644**		**6**	358	293	0	**0**
2	TecPlastics	g			**1,393**		**14**	774	633	0	**0**
3	Ferro	g			**0**		**0**	0	0	0	**0**
4	Non-ferro	g			**4,885**		**49**	247	4,687	0	**0**
5	Coating	g			**0**		**0**	0	0	0	**0**
6	Electronics	g			**0**		**0**	0	0	0	**0**
7	Misc.	g			**165**		**2**	57	110	0	**0**
8	Extra	g			**0**		**0**	0	0	0	**0**
9	Auxiliaries	g			**0**		**0**	0	0	0	**0**
10	Refrigerant	g			**0**		**0**	0	0	0	**0**
	Total weight	g			**7,087**		**71**	1,435	5,723	0	**0**
									see note!		
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	635	83	**718**	**13**	**77,252**	4	-386		**77,600**
12	of which, electricity (in primary MJ)	MJ	8	50	**58**	**0**	**77,245**	0	-1		**77,303**
13	Water (process)	ltr	6	1	**6**	**0**	**0**	0	-1		**6**
14	Water (cooling)	ltr	35	24	58	0	3,433	0	-3		**3,489**
15	Waste, non-haz./ landfill	g	103	261	**364**	**9**	**39,808**	4	-44		**40,141**
16	Waste, hazardous/ incinerated	g	4	0	**4**	**0**	**1,219**	0	-1		**1,222**
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	33	5	**37**	**1**	**3,298**	0	-20		**3,315**
18	Acidification, emissions	g SO2 eq.	1,439	20	**1,459**	**3**	**14,605**	1	-950		**15,117**
19	Volatile Organic Compounds (VOC)	g	2	0	**2**	**0**	**1,725**	0	0		**1,726**
20	Persistent Organic Pollutants (POP)	ng i-Teq	18	0	**18**	**0**	**180**	0	-12		**187**
21	Heavy Metals	mg Ni eq.	271	0	**271**	**0**	**784**	0	-179		**876**
22	PAHs	mg Ni eq.	27	0	**27**	**0**	**181**	0	-18		**191**
23	Particulate Matter (PM, dust)	g	58	3	**61**	**25**	**310**	1	-21		**376**
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	461	0	**461**	**0**	**337**	0	-306		**493**
25	Eutrophication	g PO4	1	0	**1**	**0**	**15**	0	-1		**15**

5.2.9 Base case 9: aluminium based dedicated circuit in industry sector

The environmental impacts related to the use of one BC9 circuit per year, calculated by means of the EcoReport tool, are shown in Table 5-17.

Table 5-17: Environmental impacts related to the use of one BC9 circuit per year

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Stock	
	Materials	**unit**									
1	Bulk Plastics	g			**1,222**		**12**	679	555	0	**0**
2	TecPlastics	g			**2,961**		**30**	1,645	1,346	0	**0**
3	Ferro	g			**0**		**0**	0	0	0	**0**
4	Non-ferro	g			**2,967**		**30**	150	2,847	0	**0**
5	Coating	g			**0**		**0**	0	0	0	**0**
6	Electronics	g			**0**		**0**	0	0	0	**0**
7	Misc.	g			**313**		**3**	108	209	0	**0**
8	Extra	g			**0**		**0**	0	0	0	**0**
9	Auxiliaries	g			**0**		**0**	0	0	0	**0**
10	Refrigerant	g			**0**		**0**	0	0	0	**0**
	Total weight	g			**7,464**		**75**	2,581	4,957	0	**0**
									see note!		
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	698	171	**869**	**23**	**61,294**	6	-396		**61,798**
12	of which, electricity (in primary MJ)	MJ	15	103	**118**	**0**	**61,288**	0	-1		**61,404**
13	Water (process)	ltr	11	2	**12**	**0**	**0**	0	-1		**11**
14	Water (cooling)	ltr	66	49	114	0	2,725	0	-5		**2,834**
15	Waste, non-haz./ landfill	g	1,154	535	**1,689**	**14**	**31,595**	18	-719		**32,597**
16	Waste, hazardous/ incinerated	g	6	0	**6**	**0**	**967**	0	-1		**973**
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	35	9	**45**	**2**	**2,617**	0	-21		**2,642**
18	Acidification, emissions	g SO2 eq.	224	41	**265**	**5**	**11,579**	0	-136		**11,712**
19	Volatile Organic Compounds (VOC)	g	3	0	**3**	**0**	**1,369**	0	-1		**1,371**
20	Persistent Organic Pollutants (POP)	ng i-Teq	15	0	**15**	**0**	**143**	0	-10		**148**
21	Heavy Metals	mg Ni eq.	14	0	**14**	**1**	**620**	0	-8		**626**
22	PAHs	mg Ni eq.	288	0	**288**	**1**	**146**	0	-191		**244**
23	Particulate Matter (PM, dust)	g	134	6	**140**	**53**	**246**	3	-55		**387**
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	107	0	**107**	**0**	**265**	0	-70		**302**
25	Eutrophication	g PO4	0	0	**0**	**0**	**12**	0	0		**12**

5.3 Base case Life Cycle Cost for consumer

This section includes a calculation of the LCC for consumers using the new LCC equations available in the MEErP methodology including the escalation rate.

LCC have been calculated using the EcoReport tool based upon the economic input parameters shown in Table 5-7. The results of this calculation are shown in Table 5-18 referred to the lifetime considered for each of the base cases. Product price, installation costs and energy (electricity) costs during the whole life cycle have been considered.

The life cycle costs for consumer are calculated using the LCC equations according to the ecodesign methodology:

$$LCC = PP + PWF * OE + EoL$$

Where

LCC: is Life Cycle Costs to end-users in €,
PP: is the purchase price (including installation costs) in €,
OE: is the annual operating expense in €
EoL: End-of-life costs (disposal cost, recycling charge) or benefit (resale) in €,
PWF: (Present Worth Factor) is {1 – 1/(1+ r) N }/r, in which N is the product life and r is the discount (interest-inflation) rate minus the growth rate of running cost components (e.g. energy, water rates).

Table 5-18: Life Cycle Costs for consumer per base case

	Unit	Life Cycle Costs per base case								
Base case id		BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
Sector		Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
Application circuit		Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
Product price	€	5545.89	57.99	73.86	209.61	31403.51	76.79	86.16	1101.21	1429.39
Installation/ acquisition costs (if any)	€	655.20	74.33	93.05	130.22	3376.80	101.42	107.18	316.20	370.05
Electricity	€	22968.99	83.72	59.43	5725.54	92313.73	172.57	215.40	24845.00	19712.35
Total	€	29170.07	216.05	226.34	6065.36	127094.04	350.77	408.74	26262.41	21511.79
Product price	%	19%	27%	33%	3%	25%	22%	21%	4%	7%
Installation/ acquisition costs (if any)	%	2%	34%	41%	2%	3%	29%	26%	1%	2%
Electricity	%	79%	39%	26%	94%	73%	49%	53%	95%	92%
Total	%	100%	100%	100%	100%	100%	100%	100%	100%	100%

5.4 Base case Life Cycle Costs for society

This section includes a calculation of the LCC for society as described in the MEErP methodology, following the extended LCC equations with CO_2 stock price, societal damage of certain emissions, etc.

LCC for society have been calculated using the EcoReport tool. The results of this calculation are shown in Table 5-19 referred to the lifetime considered for each of the base cases.

Table 5-19: Life Cycle Costs for society per base case

	Unit	Life Cycle Costs per base case								
Base case id		BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
Sector		sector	sector	sector	sector	sector	sector	sector	sector	sector
Application circuit		Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
Product price	€	5545.89	57.99	73.86	209.61	31403.51	76.79	86.16	1101.21	1429.39
Installation/ acquisition costs (if any)	€	655.20	74.33	93.05	130.22	3376.80	101.42	107.18	316.20	370.05
Electricity	€	22968.99	83.72	59.43	5725.54	92313.73	172.57	215.40	24845.00	19712.35
External damages total, of which	€	6898.51	34.79	46.04	1132.05	32794.55	61.35	86.57	5000.26	3729.21
- production PPext	€	6898.51	34.79	46.04	1132.05	32794.55	61.35	86.57	5000.26	3729.21
- lifetime operating expense N*OEext	€	4101.38	15.01	10.78	1018.93	16513.54	30.87	38.59	4421.97	3506.95
- end-of-life OELext	€	1068.38	6.18	11.75	41.44	6252.26	9.58	16.03	219.19	64.81
Total	€	36068.58	250.84	272.38	7197.41	159888.59	412.12	495.31	31262.67	25241.00
Product price	%	15%	23%	27%	3%	20%	19%	17%	4%	6%
Installation/ acquisition costs (if any)	%	2%	30%	34%	2%	2%	25%	22%	1%	1%
Electricity	%	64%	33%	22%	80%	58%	42%	43%	79%	78%
which	%	19%	14%	17%	16%	21%	15%	17%	16%	15%
Total	%	100%	100%	100%	100%	100%	100%	100%	100%	100%

5.5 EU totals

Following the MEErP 2011 methodology, EU Totals have been calculated using the EcoReport tool in which environmental impacts and LCC outcomes have been aggregated according to stock and market data estimated in Task 2.
As explained in section 5.6, three reference parameters had to be corrected to fit EU-28 stock and EU-28 electricity consumption. These correction factors are applied in sections 5.5 and 5.6.

5.5.1 Stock specific inputs

Table 5-20 shows the stock input parameters per BC. The nine base cases are assumed to represent the installed stock in the EU-28.

Table 5-20: Stock input parameters per base case

	Unit					Bases cases definiton					
Base case id			BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
Sector			Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
Application circuit			Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
Stock and sales data (fixed total stock)											
Year			2010	2010	2010	2010	2010	2010	2010	2010	2010
EU Stock per base case cable (Conductor weight)	kg	I	1.94E+09	2.07E+08	5.53E+08	5.53E+08	2.50E+09	2.00E+08	4.00E+08	7.25E+08	4.40E+08
EU Stock (units of 1 cable)	m	C	3.63E+08	3.11E+09	4.98E+09	1.24E+09	2.34E+08	3.00E+09	3.60E+09	4.66E+08	4.66E+08
EU Stock (base case units)	mln. Units	C	1.75	38.82	51.26	13.38	0.39	24.15	27.17	3.23	3.23
Annual sales (base case units)	mln. Units	C	0.07	1.55	2.05	0.54	0.02	0.97	1.09	0.13	0.13
BC weightfactor of total stock		I	14.00%	1.50%	4.00%	4.00%	50.00%	4.00%	8.00%	14.50%	

5.5.2 Environmental impact at EU-28

The total annual impacts from the EU stock of products are presented in Table 5-21.

Table 5-21: EU-28 total annual environmental impacts from the installed stock

	Unit	Environmental									
Base case id		BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9	Total (BC1-BC8)
Sector		Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector	
Application circuit		Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit	
Materials											
Plastics	Mt	0.028	0.015	0.029	0.014	0.028	0.015	0.021	0.012	0.025	0.16
Ferrous metals	Mt	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
Non-ferrous metals	Mt	0.078	0.008	0.022	0.022	0.101	0.008	0.016	0.029	0.018	0.29
Other resources & waste											
Total Energy (GER)	PJ	71.80	7.41	9.94	119.13	67.59	8.64	12.64	125.04	101.07	422.19
of which, electricity	TWh	6.82	0.60	0.61	12.86	6.05	0.75	1.05	13.45	10.72	42.17
Water (process)*	mln.m3	0.07	0.08	0.15	0.06	0.08	0.08	0.11	0.04	0.07	0.68
Waste, non-haz./ landfill*	Mt	0.04	0.01	0.01	0.06	0.03	0.01	0.01	0.06	0.06	0.22
Waste, hazardous/ incinerated*	kton	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Emissions (Air)											
Greenhouse Gases in GWP100	mt CO2eq.	3.17	0.33	0.46	5.12	3.02	0.38	0.57	5.38	4.36	18.44
Acidifying agents (AP)	kt SO2eq.	34.76	3.70	7.98	28.57	40.12	3.85	6.80	31.56	19.69	157.33
Volatile Org. Compounds (VOC)	kt	1.37	0.13	0.14	2.59	1.22	0.16	0.23	2.71	2.16	8.55
Persistent Org. Pollutants (POP)	g i-Teq.	0.44	0.04	0.10	0.35	0.50	0.05	0.08	0.39	0.31	1.95
Heavy Metals (HM)	ton Ni eq.	4.94	0.54	1.33	2.42	6.13	0.54	1.02	2.85	1.05	19.76
PAHs	ton Ni eq.	0.58	0.07	0.15	0.40	0.69	0.07	0.12	0.45	1.96	2.53
Particulate Matter (PM, dust)	kt	1.39	0.88	1.59	1.13	1.57	0.85	1.17	0.99	1.54	9.57
Emissions (Water)											
Heavy Metals (HM)	ton Hg/20	7.64	0.84	2.17	2.62	9.76	0.81	1.59	3.29	1.05	28.72
Eutrophication (EP)	kt PO4	0.03	0.00	0.01	0.03	0.03	0.01	0.01	0.03	0.02	0.14

Note: the total electricity consumption in TWh in the above table includes the electricity consumption during all phases of the life cycle, and must be higher than the energy losses values (energy consumption in use phase) listed in section 5.6.

5.5.3 Economic assessment at EU-28

Table 5-22 shows the total annual expenditure in Europe, due to the stock of products currently installed in the EU-28.

Table 5-22: Total annual expenditure in the EU-28 per base case

	Unit	Total annual expenditure in the EU-28 per base case									Total (BC1-BC8)
Base case id	0	BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9	
Sector	0	Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector	
Application circuit	0	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit	
Product price	mln. €	696.29	122.98	239.24	199.97	881.57	105.92	157.13	257.18	328.32	2660.27
Installation/ acquisition costs (if any)	mln. €	80.60	167.40	297.71	120.17	91.27	148.07	193.79	71.94	83.66	1170.96
Electricity	mln. €	741.11	59.81	56.06	1409.45	655.56	76.69	107.69	1474.92	1170.22	4581.27
Total	mln. €	1517.99	350.19	593.00	1729.59	1628.40	330.69	458.60	1804.04	1582.19	8412.50
Product price	%	26%	5%	9%	8%	33%	4%	6%	10%	12%	100%
Installation/ acquisition costs (if any)	%	7%	14%	25%	10%	8%	13%	17%	6%	7%	100%
Electricity	%	16%	1%	1%	31%	14%	2%	2%	32%	26%	100%
Total	%	18%	4%	7%	21%	19%	4%	5%	21%	19%	100%

5.6 Cross-checks on EU-28 impact

To verify the outcomes of the calculation some cross-checks were added.

There are two possible cross-checking methods with different starting assumptions for the calculation:

1. Fixed total stock/annual sales (figures in Task 2) -> EU-28 annual transported active energy is calculated
2. Fixed EU-28 energy consumption -> total stock/annual sales is calculated

In case of the first method, the amount of energy transported per BC multiplied by the number of BC units must be lower than the amount of electricity consumed in the EU-28 services and industry sector. The results of the first method (comparison between the amounts of energy transported with the total electricity consumption in Europe) are shown in Table 5-23.

In case of the second method the calculated annual replacement sales multiplied by the product life (= stock) should be about the same as the stock/annual sales figures mentioned in Task 2. Table 5-24 shows the results when using the second method (fixed energy consumption).

In both methods the losses in the base cases are calculated and should be equal.

Table 5-23: EU-28 totals check: first method

	Unit	T	Base cases								Total over all BC
Base case id			BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	
Sector			Services	Services	Services	Services	Industry	Industry	Industry	Industry	
Application circuit			Distribution	Lighting	Socket-	Dedicated	Distribution	Lighting	Socket-	Dedicated	
Method 1: fixed stock	**kg**	**I**									**7.08E+09**
Energy distribution factor	%	I	100%	20%	20%	60%	100%	10%	15%	75%	
EU Stock (base case units)	mln. Units	I	1.75	38.82	51.26	13.38	0.39	24.15	27.17	3.23	
Number of buildings per sector (Task 2 Table 2-9)	mln Units	I	11.41	11.41	11.41	11.41	2.58	2.58	2.58	2.58	
Annual energy loss (formula 3.5) per BC	kWh	I	3842.09	14.00	9.94	957.73	15441.57	28.87	36.03	4155.89	
Annual energy transported (formula 3.6) per BC	kVAh	I	691,772	3,117	2,394	74,365	2,560,615	3,625	3,712	232,577	
Checks											
Annual energy loss Eu-28 (=BC loss * #BC units)	TWh	C	6.74	0.54	0.51	12.81	5.96	0.70	0.98	13.41	34.91
Annual energy transported Eu-28 (=BC annual energy transport * #BC units)	TWh	C	1,213	121	123	995	988	88	101	750	
Annual energy transported Eu-28 corrected with energy distribution factor	TWh	C	1,213	605	614	1,658	988	875	672	1,000	
Number of BC units (circuits) per building		C	0.2	3.4	4.5	1.2	0.1	9.4	10.5	1.3	

Table 5-24: EU-28 totals check: second method

	Unit		Base cases								Total over all BC
Base case id			BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	
Sector			Services	Services	Services	Services	Industry	Industry	Industry	Industry	
Application circuit			Distribution	Lighting	Socket-	Dedicated	Distribution	Lighting	Socket-	Dedicated	
Method 2: fixed EU-28 energy consumption	TWh	I	904				1030				1934
Energy distribution factor	%	I	100%	20%	20%	60%	100%	10%	15%	75%	
Number of buildings per sector (Task 2 Table 2-9)	mln Units	I	11.41	11.41	11.41	11.41	2.58	2.58	2.58	2.58	
Annual energy transported (formula 3.6) per BC	kVAh	I	691,772	3,117	2,394	74,365	2,560,615	3,625	3,712	232,577	
EU28 energy consumption (distributed via energy distribution factor)	TWh	C	904.12	180.82	180.82	542.47	1029.62	102.96	154.44	772.21	1933.74
Checks											
Annual energy loss Eu-28 (=BC loss * #BC units)	TWh	C	5.02	0.81	0.75	6.99	6.21	0.82	1.50	13.80	35.90
BC stock (= EU-28 energy consumption / energy transported per BC)	mln Units	C	1.31	58.02	75.54	7.29	0.40	28.41	41.61	3.32	215.90
BC stock (weight)	kTon	C	1443.07	310.02	815.24	301.62	2604.63	235.22	612.56	746.10	7068.48

NOTE: The EU-28 totals mentioned in the previous sections are based upon a fixed Cu stock for the reference year.

The cross-checks at EU level indicated that the outcome for the losses were too high. The bases cases as such, although abstract cases, are not representative for the average total stock and losses in Europe. Therefore corrections factors on those 'median' parameters were calculated that fit with total EU energy consumption. With the fitted parameters the total energy transported by the base cases equals the energy consumed at EU level, and the stock equals the stock figures in Task 3. To accomplish this, the following three reference parameters are corrected:

- The reference circuit length (Task 3) is multiplied by 1.84;
- The reference load factor (Task 3) is multiplied by 0.5;
- The weight distribution towards the circuits (Task 2) is altered (see Table 5-20).

This also indicates that potentially a lot of circuits in the stock have a relative lower loading and/or longer circuit length and/or higher share of bases case with lower loading. This is also something to take into account in the sensitivity analysis (Task 6).

CHAPTER 6 TASK 6: DESIGN OPTIONS

The objective of this task is to identify design options, their monetary consequences in terms of Life Cycle Cost (LCC) for the user, their economic and possible social impacts, and pinpointing the solution with the Least Life Cycle Costs (LLCC) and the Best Available Technology (BAT).

The assessment of monetary LCC is relevant to indicate whether design solutions might impact the total user's expenditure over the total product life (purchase, operating, end-of-life costs, etc.). The distance between the LLCC and the BAT indicates —in a case an LLCC solution is set as a minimum target— the remaining space for product-differentiation (competition).

The BAT indicates a target in the shorter term that would probably be more subject to promotion measures than to restrictive action. The BNAT indicates possibilities in the longer term and helps to define the exact scope and definition of possible measures. Any intermediate options between the LLCC and the BAT have to be described, and their impacts assessed.

Remark: Further in this study the word "power cables" will be used as a general term for single core or multi-core LV power cables in buildings, unless otherwise stated.

Summary of Task 6:
The previous Task 5 identified the use phase as the most important and hence reducing cables losses are the way forward to improve environmental impact. Reducing cable losses in installed cables can easily be done by decreasing the cable resistance and by increasing the copper cross-sectional area(CSA). The methods identified to increase the CSA were installing a cable with a larger CSA ('S+x') and/or installing more cables in parallel with the same CSA ('2S').
Three design options(D1, D2, D3) were calculated with stepwise increased CSA(S+1, S+2, S+3). Another design option (D4) stands for the '2S scenario', meaning two cables with section S are installed in parallel, and calculated two cables in parallel. These are the four design improvement options that are applied to the nine defined base cases in Task 5.
Section 6.2 concludes that those design options have a positive impact on almost any of the environment parameters generated with the MEErP EcoReport tool. In summary all the parameters including Global Warming Potential (GWP) improved, except impact from 'water (process)', 'heavy metals (emissions in water and air)' and 'Particulate Matter (PM)'. The defined base cases BC2, BC3, BC6 and BC7, representing the so-called lighting and socket-outlet circuits, performed relative less. In particular the parameters Polycyclic Aromatic Hydrocarbons (PAHs), PM and Eutrophication increased in several 'improvement' options. It was also found that the so-called base cases with a high load need only a few years to compensate the increase of greenhouse gas in the production and distribution. This period can be seen as a kind of 'environmental payback time'. For base cases representing circuits with a low load this 'environmental payback time' increased significantly up to almost the circuit life time. Therefore policy measures from Task 7 should be defined carefully not imposing an increased CSA for any circuit disregarding their loading. Looking at GWP alone, the BAT is in almost all base cases design option D3. Only for base case (BC) 3, it is design option D2.

The design options have a considerable impact on the material usage, up to 197% for BC4 and design option D3. The increase in resource material is dependent on the base case characteristics (CSA of used cable) and the design option. D2 and D1 have a lesser increase in resource material, design option D4 has an 100% increase independent of the base case characteristics. Although the design options have a large impact on the amount of resource material used in the product, it has to be noted that a considerable amount of the material will be recycled at the end of the product life (see EoL in task 3).
Likewise the design options have an impact on the volume of the cable, up to +189% for BC4 and design option D3. Design option D4 results in a 100% increase of volume usage. The extra space needed by a cable in case of a design option compared to the BAU can result in an increase of building space and larger cable ducts (see also task 3).

Based on input from previous tasks, LCC has also been calculated in section 6.4 for all options and the LLCC improvement options were identified. For the so-called base cases BC2 (lighting circuits) and BC3 (socket circuits) in the services sector, the LLCC is 'Business As Usual' (BAU), hence no economic improvement is identified. All other defined base cases (1, 3-9) showed economic justified improvement potential that will be addressed in the proposed policy options in Task 7. The explanation for these differences is related to the variations in the loading behind the defined base cases.

Finally also a sensitivity analysis has been done in section 6.6 on the circuit loading parameters, circuit length, product lifetime and product price. This can be useful information for the impact analysis in Task 7.
The sensitivity analysis shows that the best design option considering BAT and LCC varies depending on the assumptions made for the parameters. Trends are indicated. The fact that there isn't much data available on electric circuit characterization and electric circuit use in the field, and the fact that each circuit in the field is unique implicates that tipping points (best design option) can change easily and are highly specific per circuit implementation.

It should be noted that depending on the local situation shifting to a particular design option may not be technical feasible, because it often requires more space for the cable installation which is not always available. In practice not all improvement options can be realized because the impact of the design options on accessories (ducting systems, trunking systems, junction boxes, etc.) and on the building space that are left out of the quantitative analysis. In this task it is assumed that shifting to D1,D2,D3 or D4 is always technical feasible and has no impact on the building construction cost.

6.1 Identification of design options and assessment of their impacts

Available design options are identified by investigating and assessing the environmental impact and LCC of each suggested design option against each BC using the MEErP EcoReport tool 2011, and have to comply with the following rules:

- The design option should not have a significant variation in functionality, quality of the produced products, primary or secondary performance parameters compared to the BC, and in product-specific inputs.
- The design option should have a significant potential for improvement regarding at least one of the following ecodesign parameters without deteriorating others:
    - consumption of energy, water and other resources,
    - use of hazardous substances,
    - emissions to air, water or soil,

  - weight and volume of the product,
  - use of recycled material,
  - quantity and nature of consumables needed for proper use and maintenance,
  - ease for reuse and recycling,
  - extension of lifetime, or
  - amounts of waste generated.
- The design option should not entail excessive costs. Impacts on the manufacturer should be investigated regarding redesign, testing, investment and/or production costs, including economy of scale, sector-specific margins and market structure, and required time periods for market entrance of the design option and market decline of the current product. The assessment of the monetary impact for categories of users includes the estimation of the possible price increase due to implementation of the design option, either by looking at prices of the product on the market and/ or by applying a production cost model with sector-specific margins.

The previous Task 5 identified the use phase as the most important and hence reducing cables losses are the way forward to improve environmental impact. Reducing cable losses in installed cables can easily be done by decreasing the cable resistance, see formulas in section 3.1.6. Cable resistance can be reduced by increasing the copper cross-sectional area(CSA) and/or changing the conductor material. The method to increase the cross sectional was explained in section 4.2.4. The first is installing a cable with a larger CSA ('S+x') and the second is installing one or more cables in parallel with the same CSA ('2S'). The increase of CSA has an impact on the production volume which is modelled with data from section 5.1.2 and 5.1.3. As a consequence, the entire life cycle(LCA) impact of this option is taken into account with the MEErP tool which is discussed in more detail in this task.

The identified design options are listed in Table 6-1. Design options D1, D2 and D3 stand respectively for the S+1, S+2 and S+3 scenario as described in Task 4 in section 4.2.4. Design option D4 stands for the 2S scenario, meaning instead of installing a cable with section S, two cables with section S in parallel are installed. These design options are applied to the different base cases. BAU describes the Business As Usual option, not changing anything to the existing business.

In task 5, 6 and 7 design options D3 (S+3) and D4 (2S) are considered to be the most performant design options to reduce the energy losses in an electric circuit. More performant design options like S+4, S+5, 3S, 4S or more are not included in the analysis due to the following reasons:

- Because in most cases these options are not considered to be technical feasible. For instance, changing the cable section of $1.5mm^2$ according S+4 to $10mm^2$ will have a substantial impact on: the needed space and building construction, connectors, distribution boards, fuses, light fixtures and so on.
- The resource use will increase up to 967% (see Table 8-10 in annex). Hence a positive environmental impact becomes unlikely.

These four design options have been selected for each of the base cases identified in Task 5. The formulas defined in Task 2 and Task 3 are used to calculate the effect on the input parameters for the EcoReport tool. For instance, a cable with a larger section will have an impact on the material use, product cost but also on the installation cost. For each BC – design option combination, these input parameters are fed into the EcoReport tool, resulting in an environmental impact assessment and LCC analysis. The next sections present these results, including the variation of the respective parameter due to the design option compared to the BAU option. This relative variation is defined as ((design option value – BAU value)/BAU value) expressed in percentile.

Table 6-1: Design options

			Unit	T	Base cases definiton								
		Base case id			BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
		Sector			Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
		Application circuit			Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
Design option	Description	Parameter											
BAU	Business As Usual	CSA	mm²	I	120	1.5	2.5	10	300	1.5	2.5	35	70
D1	S+1	CSA	mm²	I	150	2.5	4	16	400	2.5	4	50	95
D2	S+2	CSA	mm²	I	185	4	6	25	500	4	6	70	120
D3	S+3	CSA	mm²	I	240	6	10	35	630	6	10	95	150
D4	2S	Cables in parallel multiplicator		I	2	2	2	2	2	2	2	2	2

Because this MEErP method takes into account the entire life cycle, one could also consider changing materials as improvement options such as copper vs aluminum conductor and/or PVC vs thermoplastic polyurethane insulation. However, Task 5 identified the use phase as most significant one. Moreover, insulation and conductor materials can and are recycled in the Business-as-Usual scenario, see section 3.3. Finally it is hard to compare accurately the underlying MEErP data one-to-one from copper vs aluminum and PVC vs polyurethane production and recycling, this would lead to out of scope discussions on the production methods and plants. As a conclusion, there is no rationale to consider switching from conductor and/or insulation material to another material. Therefore they will not be considered as improvement options in this task 6.

Depending on the local situation shifting to a particular design option may not be technical feasible. For instance shifting from BAU to D3 requires more space for the cable installation which may not be available in an existing installation, or it may result in additional space requirements for the building construction. In this task it is assumed that shifting is always technical feasible and has no impact on the building construction cost.

6.2 Improvement of Ecoreport Impact indicators

Table 6-2 up to and including Table 6-15 show the LCA impact, calculated with the EcoReport tool, of the different design options on the respective parameters. These parameter tables show the life cycle impact per base case over the product lifetime for the reference case (BAU) and for the different design options. When comparing the BAU value in these tables with value in the tables section 5.2 (showing the impact per year) in task 5 one has to multiply the values with the product lifetime.
In every table the impact is calculated in absolute values and in relative values versus the BAU design option. Table 6-26 summarizes for each of the parameters the design option with the lowest value. Table 6-16, Table 6-17 and Table 6-18 provide insight in the impact on Global Warming Potential (GWP) in more detail by giving the GWP value spread over its life cycle phases.

6.2.1 Impact per parameter

Table 6-2: Total Energy (Gross Energy Requirement, GER)

		Unit	Total Energy (GER)								
	Base case id		BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
	Sector		Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
	Application circuit		Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
BAU	Total Energy (GER)	MJ	1825051	7192	5608	447175	7392317	14414	18050	1940005	1544943
D1	Total Energy (GER)	MJ	1477409	4739	4152	281138	5660006	9281	12149	1363358	1144533
D2	Total Energy (GER)	MJ	1219803	3503	3523	182422	4605397	6617	9115	981885	914050
D3	Total Energy (GER)	MJ	971634	2965	3388	132904	3791321	5366	7192	733658	739090
D4	Total Energy (GER)	MJ	972016	4513	4176	226693	4021582	8597	10877	983199	791495
D1	Versus BAU	%	-19%	-34%	-26%	-37%	-23%	-36%	-33%	-30%	-26%
D2		%	-33%	-51%	-37%	-59%	-38%	-54%	-49%	-49%	-41%
D3		%	-47%	-59%	-40%	-70%	-49%	-63%	-60%	-62%	-52%
D4		%	-47%	-37%	-26%	-49%	-46%	-40%	-40%	-49%	-49%

Table 6-3: Electricity

		Unit	of which, electricity (in primary MJ)								
	Base case id		BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
	Sector		Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
	Application circuit		Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
BAU	of which, electricity (in primary MJ)	MJ	1791182	6668	4845	445443	7202865	13662	17050	1932569	1535107
D1	of which, electricity (in primary MJ)	MJ	1435369	4091	3161	278676	5412938	8336	10838	1353371	1132238
D2	of which, electricity (in primary MJ)	MJ	1167395	2667	2255	178767	4323256	5381	7426	967897	898201
D3	of which, electricity (in primary MJ)	MJ	904406	1899	1586	128076	3438519	3775	4774	714796	719981
D4	of which, electricity (in primary MJ)	MJ	904390	3575	2761	223341	3642788	7204	8987	968438	771933
D1	Versus BAU	%	-20%	-39%	-35%	-37%	-25%	-39%	-36%	-30%	-26%
D2		%	-35%	-60%	-53%	-60%	-40%	-61%	-56%	-50%	-41%
D3		%	-50%	-72%	-67%	-71%	-52%	-72%	-72%	-63%	-53%
D4		%	-50%	-46%	-43%	-50%	-49%	-47%	-47%	-50%	-50%

Table 6-4: Water (Process)

		Unit	Water (process)								
	Base case id		BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
	Sector		Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
	Application circuit		Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
BAU	Water (process)	ltr	506	26	36	53	2537	41	49	147	283
D1	Water (process)	ltr	613	30	41	63	3150	46	56	182	334
D2	Water (process)	ltr	755	34	47	82	3356	53	64	235	424
D3	Water (process)	ltr	926	39	56	95	3996	60	76	293	489
D4	Water (process)	ltr	1012	53	72	107	5074	82	98	294	566
D1	Versus BAU	%	21%	13%	15%	18%	24%	13%	15%	24%	18%
D2		%	49%	29%	30%	54%	32%	29%	30%	59%	50%
D3		%	83%	46%	54%	78%	57%	46%	54%	99%	73%
D4		%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 6-5: Waste, non-hazardous / landfill

		Unit	Waste, non-haz./ landfill								
	Base case id		BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
	Sector		Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
	Application circuit		Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
BAU	Waste, non-haz./ landfill	g	954482	4335	3724	231763	3862145	8375	10422	1003527	814934
D1	Waste, non-haz./ landfill	g	777851	3139	3109	146464	2964298	5836	7566	705956	612397
D2	Waste, non-haz./ landfill	g	651371	2614	2933	96139	2340250	4636	6204	511316	500917
D3	Waste, non-haz./ landfill	g	528798	2459	3121	70940	1908149	4181	5564	386156	415710
D4	Waste, non-haz./ landfill	g	528808	3533	3771	119411	2177681	6275	7795	514182	445382
D1	Versus BAU	%	-19%	-28%	-16%	-37%	-23%	-30%	-27%	-30%	-25%
D2		%	-32%	-40%	-21%	-59%	-39%	-45%	-40%	-49%	-39%
D3		%	-45%	-43%	-16%	-69%	-51%	-50%	-47%	-62%	-49%
D4		%	-45%	-18%	1%	-48%	-44%	-25%	-25%	-49%	-45%

Table 6-6: Waste, hazardous / incinerated

		Unit	Waste, hazardous/ incinerated								
	Base case id		BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
	Sector		Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
	Application circuit		Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
BAU	Waste, hazardous/ incinerated	g	28483	117	93	7051	114878	233	290	30558	24323
D1	Waste, hazardous/ incinerated	g	22924	78	68	4424	87045	152	195	21442	17986
D2	Waste, hazardous/ incinerated	g	18755	58	56	2858	70393	108	145	15382	14320
D3	Waste, hazardous/ incinerated	g	14680	47	49	2064	56902	85	108	11406	11543
D4	Waste, hazardous/ incinerated	g	14712	79	74	3568	59939	147	182	15410	12382
D1	Versus BAU	%	-20%	-33%	-26%	-37%	-24%	-35%	-33%	-30%	-26%
D2		%	-34%	-51%	-39%	-59%	-39%	-54%	-50%	-50%	-41%
D3		%	-48%	-60%	-47%	-71%	-50%	-63%	-63%	-63%	-53%
D4		%	-48%	-33%	-20%	-49%	-48%	-37%	-37%	-50%	-49%

Table 6-7: Greenhouse Gases in GWP100

		Unit	Greenhouse Gases in GWP100								
	Base case id		**BC1**	**BC2**	**BC3**	**BC4**	**BC5**	**BC6**	**BC7**	**BC8**	**BC9**
	Sector		**Services sector**	**Services sector**	**Services sector**	**Services sector**	**Industry sector**	**Industry sector**	**Industry sector**	**Industry sector**	**Industry sector**
	Application circuit		**Distribution circuit**	**Lighting circuit**	**Socket-outlet circuit**	**Dedicated circuit**	**Distribution circuit**	**Lighting circuit**	**Socket-outlet circuit**	**Dedicated circuit**	**Dedicated circuit**
BAU	**Greenhouse Gases in GWP100**	**kg CO2 eq.**	78246	313	246	19105	317395	622	779	82883	66043
D1	**Greenhouse Gases in GWP100**	**kg CO2 eq.**	63485	209	186	12025	243960	404	530	58287	48973
D2	**Greenhouse Gases in GWP100**	**kg CO2 eq.**	52598	158	162	7822	198905	293	404	42046	39174
D3	**Greenhouse Gases in GWP100**	**kg CO2 eq.**	42162	137	162	5720	164755	243	329	31507	31730
D4	**Greenhouse Gases in GWP100**	**kg CO2 eq.**	42170	200	189	9706	175348	376	477	42106	33971
D1	**Versus BAU**	**%**	-19%	-33%	-24%	-37%	-23%	-35%	-32%	-30%	-26%
D2		**%**	-33%	-50%	-34%	-59%	-37%	-53%	-48%	-49%	-41%
D3		**%**	-46%	-56%	-34%	-70%	-48%	-61%	-58%	-62%	-52%
D4		**%**	-46%	-36%	-23%	-49%	-45%	-39%	-39%	-49%	-49%

Table 6-8: Acidification emissions

		Unit	Acidification, emissions								
	Base case id		**BC1**	**BC2**	**BC3**	**BC4**	**BC5**	**BC6**	**BC7**	**BC8**	**BC9**
	Sector		**Services sector**	**Services sector**	**Services sector**	**Services sector**	**Industry sector**	**Industry sector**	**Industry sector**	**Industry sector**	**Industry sector**
	Application circuit		**Distribution circuit**	**Lighting circuit**	**Socket-outlet circuit**	**Dedicated circuit**	**Distribution circuit**	**Lighting circuit**	**Socket-outlet circuit**	**Dedicated circuit**	**Dedicated circuit**
BAU	**Acidification, emissions**	**g SO2 eq.**	401129	1643	1623	86592	1726446	3161	4177	377931	292812
D1	**Acidification, emissions**	**g SO2 eq.**	349529	1361	1679	56497	1508712	2473	3514	273881	217479
D2	**Acidification, emissions**	**g SO2 eq.**	317359	1401	2002	39747	1416868	2393	3543	208394	174321
D3	**Acidification, emissions**	**g SO2 eq.**	296326	1664	2859	32502	1405270	2722	4385	169741	141612
D4	**Acidification, emissions**	**g SO2 eq.**	296392	1417	1912	47068	1419867	2496	3586	208682	151479
D1	**Versus BAU**	**%**	-13%	-17%	3%	-35%	-13%	-22%	-16%	-28%	-26%
D2		**%**	-21%	-15%	23%	-54%	-18%	-24%	-15%	-45%	-40%
D3		**%**	-26%	1%	76%	-62%	-19%	-14%	5%	-55%	-52%
D4		**%**	-26%	-14%	18%	-46%	-18%	-21%	-14%	-45%	-48%

Table 6-9: Volatile Organic Compounds (VOC)

		Unit	Volatile Organic Compounds (VOC)								
	Base case id		**BC1**	**BC2**	**BC3**	**BC4**	**BC5**	**BC6**	**BC7**	**BC8**	**BC9**
	Sector		**Services sector**	**Services sector**	**Services sector**	**Services sector**	**Industry sector**	**Industry sector**	**Industry sector**	**Industry sector**	**Industry sector**
	Application circuit		**Distribution circuit**	**Lighting circuit**	**Socket-outlet circuit**	**Dedicated circuit**	**Distribution circuit**	**Lighting circuit**	**Socket-outlet circuit**	**Dedicated circuit**	**Dedicated circuit**
BAU	**Volatile Organic Compounds (VOC)**	**g**	39986	151	111	9951	160840	309	385	43161	34282
D1	**Volatile Organic Compounds (VOC)**	**g**	32036	94	74	6226	120955	190	246	30232	25291
D2	**Volatile Organic Compounds (VOC)**	**g**	26030	62	53	3994	96992	124	170	21618	20058
D3	**Volatile Organic Compounds (VOC)**	**g**	20142	45	38	2861	77310	88	110	15955	16082
D4	**Volatile Organic Compounds (VOC)**	**g**	20165	85	68	4993	81308	168	209	21629	17236
D1	**Versus BAU**	**%**	-20%	-38%	-34%	-37%	-25%	-38%	-36%	-30%	-26%
D2		**%**	-35%	-59%	-52%	-60%	-40%	-60%	-56%	-50%	-41%
D3		**%**	-50%	-70%	-66%	-71%	-52%	-71%	-71%	-63%	-53%
D4		**%**	-50%	-44%	-39%	-50%	-49%	-46%	-46%	-50%	-50%

Table 6-10: Persistent Organic Pollutants (POP)

		Unit	Persistent Organic Pollutants (POP)								
	Base case id		**BC1**	**BC2**	**BC3**	**BC4**	**BC5**	**BC6**	**BC7**	**BC8**	**BC9**
	Sector		**Services sector**	**Services sector**	**Services sector**	**Services sector**	**Industry sector**	**Industry sector**	**Industry sector**	**Industry sector**	**Industry sector**
	Application circuit		**Distribution circuit**	**Lighting circuit**	**Socket-outlet circuit**	**Dedicated circuit**	**Distribution circuit**	**Lighting circuit**	**Socket-outlet circuit**	**Dedicated circuit**	**Dedicated circuit**
BAU	**Persistent Organic Pollutants (POP)**	**ng i-Teq**	4950	20	19	1068	21333	38	50	4666	3707
D1	**Persistent Organic Pollutants (POP)**	**ng i-Teq**	4313	16	20	697	18674	29	42	3382	2812
D2	**Persistent Organic Pollutants (POP)**	**ng i-Teq**	3911	17	24	489	17658	28	42	2572	2311
D3	**Persistent Organic Pollutants (POP)**	**ng i-Teq**	3651	20	34	400	17562	32	52	2094	1949
D4	**Persistent Organic Pollutants (POP)**	**ng i-Teq**	3651	16	22	579	17553	28	41	2573	2051
D1	**Versus BAU**	**%**	-13%	-18%	3%	-35%	-12%	-23%	-17%	-28%	-24%
D2		**%**	-21%	-16%	23%	-54%	-17%	-26%	-16%	-45%	-38%
D3		**%**	-26%	0%	78%	-63%	-18%	-15%	4%	-55%	-47%
D4		**%**	-26%	-19%	12%	-46%	-18%	-25%	-18%	-45%	-45%

Table 6-11: Heavy Metals to air

		Unit	Heavy Metals								
	Base case id		**BC1**	**BC2**	**BC3**	**BC4**	**BC5**	**BC6**	**BC7**	**BC8**	**BC9**
	Sector		**Services sector**	**Services sector**	**Services sector**	**Services sector**	**Industry sector**	**Industry sector**	**Industry sector**	**Industry sector**	**Industry sector**
	Application circuit		**Distribution circuit**	**Lighting circuit**	**Socket-outlet circuit**	**Dedicated circuit**	**Distribution circuit**	**Lighting circuit**	**Socket-outlet circuit**	**Dedicated circuit**	**Dedicated circuit**
BAU	**Heavy Metals**	**mg Ni eq.**	29617	133	172	4946	140274	237	339	21893	15659
D1	**Heavy Metals**	**mg Ni eq.**	28891	144	223	3518	144681	241	369	17041	11630
D2	**Heavy Metals**	**mg Ni eq.**	29525	186	304	2895	156154	298	457	14480	9308
D3	**Heavy Metals**	**mg Ni eq.**	32126	252	477	2812	176387	397	676	13587	7556
D4	**Heavy Metals**	**mg Ni eq.**	32151	162	269	3137	171717	264	418	14492	8075
D1	**Versus BAU**	**%**	-2%	9%	29%	-29%	3%	2%	9%	-22%	-26%
D2		**%**	0%	40%	76%	-41%	11%	26%	35%	-34%	-41%
D3		**%**	8%	90%	177%	-43%	26%	68%	99%	-38%	-52%
D4		**%**	9%	22%	56%	-37%	22%	12%	23%	-34%	-48%

Table 6-12: Polycyclic Aromatic Hydrocarbons (PAHs)

		Unit	PAHs								
	Base case id		BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
	Sector		Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
	Application circuit		Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
BAU	**PAHs**	**mg Ni eq.**	5415	26	28	1090	23920	46	61	4764	6109
D1	**PAHs**	**mg Ni eq.**	4889	24	31	728	22045	40	57	3512	6058
D2	**PAHs**	**mg Ni eq.**	4632	26	39	537	21299	42	62	2759	6419
D3	**PAHs**	**mg Ni eq.**	4580	33	56	464	22125	51	82	2351	7073
D4	**PAHs**	**mg Ni eq.**	4579	26	37	620	22724	42	61	2766	6852
D1	**Versus BAU**	**%**	-10%	-8%	13%	-33%	-8%	-14%	-7%	-26%	-1%
D2		**%**	-14%	3%	40%	-51%	-11%	-8%	1%	-42%	5%
D3		**%**	-15%	27%	103%	-57%	-8%	11%	34%	-51%	16%
D4		**%**	-15%	1%	32%	-43%	-5%	-8%	0%	-42%	12%

Table 6-13: Particulate Matter (PM, dust)

		Unit	Particulate Matter (PM, dust)								
	Base case id		**BC1**	**BC2**	**BC3**	**BC4**	**BC5**	**BC6**	**BC7**	**BC8**	**BC9**
	Sector		**Services sector**	**Services sector**	**Services sector**	**Services sector**	**Industry sector**	**Industry sector**	**Industry sector**	**Industry sector**	**Industry sector**
	Application circuit		**Distribution circuit**	**Lighting circuit**	**Socket-outlet circuit**	**Dedicated circuit**	**Distribution circuit**	**Lighting circuit**	**Socket-outlet circuit**	**Dedicated circuit**	**Dedicated circuit**
BAU	**Particulate Matter (PM, dust)**	**g**	14040	268	353	2311	65489	429	523	9395	9684
D1	**Particulate Matter (PM, dust)**	**g**	14131	292	414	1774	71090	460	591	7601	8895
D2	**Particulate Matter (PM, dust)**	**g**	14812	342	465	1606	64613	535	651	6907	9241
D3	**Particulate Matter (PM, dust)**	**g**	16335	384	559	1585	70189	598	773	6638	9593
D4	**Particulate Matter (PM, dust)**	**g**	17367	497	677	1952	87926	776	945	7203	10174
D1	**Versus BAU**	**%**	1%	9%	17%	-23%	9%	7%	13%	-19%	-8%
D2		**%**	6%	28%	32%	-31%	-1%	25%	25%	-26%	-5%
D3		**%**	16%	43%	59%	-31%	7%	40%	48%	-29%	-1%
D4		**%**	24%	85%	92%	-16%	34%	81%	81%	-23%	5%

Table 6-14: Heavy Metals to water

		Unit	Heavy Metals								
	Base case id		BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
	Sector		Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
	Application circuit		Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
BAU	Heavy Metals	mg Hg/20	27301	130	221	2660	145861	216	346	12317	7561
D1	Heavy Metals	mg Hg/20	30661	183	329	2382	176420	291	477	11533	6160
D2	Heavy Metals	mg Hg/20	35212	272	478	2612	210018	426	671	12149	5489
D3	Heavy Metals	mg Hg/20	43044	395	782	3126	255913	616	1078	13902	5118
D4	Heavy Metals	mg Hg/20	43074	218	411	2447	245392	344	583	12164	5230
D1	Versus BAU	%	12%	40%	49%	-10%	21%	35%	38%	-6%	-19%
D2		%	29%	109%	117%	-2%	44%	98%	94%	-1%	-27%
D3		%	58%	204%	254%	18%	75%	186%	212%	13%	-32%
D4		%	58%	68%	86%	-8%	68%	60%	69%	-1%	-31%

Table 6-15: Euthropication

		Unit	Eutrophication								
	Base case id		BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
	Sector		Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
	Application circuit		Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
BAU	Eutrophication	g PO4	389.4	2.4	2.5	87.3	1644.0	4.3	5.4	377.0	299.9
D1	Eutrophication	g PO4	334.2	2.1	2.6	56.9	1391.8	3.6	4.8	271.6	225.7
D2	Eutrophication	g PO4	298.1	2.1	2.9	39.7	1255.2	3.6	4.7	204.5	184.7
D3	Eutrophication	g PO4	269.7	2.4	3.6	31.9	1193.9	3.8	5.4	163.7	153.1
D4	Eutrophication	g PO4	273.0	2.9	3.7	48.5	1255.1	4.8	6.1	206.7	165.7
D1	Versus BAU	%	-14%	-11%	2%	-35%	-15%	-15%	-12%	-28%	-25%
D2		%	-23%	-9%	13%	-54%	-24%	-17%	-13%	-46%	-38%
D3		%	-31%	0%	41%	-63%	-27%	-11%	-1%	-57%	-49%
D4		%	-30%	22%	48%	-44%	-24%	11%	12%	-45%	-45%

6.2.2 Impact on Greenhouse gas in more detail (per lifecycle phase)

Table 6-16: Greenhouse Gases (in detail, absolute values) in GWP100

		Unit	Greenhouse Gases in GWP100								
	Base case id		**BC1**	**BC2**	**BC3**	**BC4**	**BC5**	**BC6**	**BC7**	**BC8**	**BC9**
	Sector		**Services sector**	**Services sector**	**Services sector**	**Services sector**	**Industry sector**	**Industry sector**	**Industry sector**	**Industry sector**	**Industry sector**
	Application circuit		**Distribution circuit**	**Lighting circuit**	**Socket-outlet circuit**	**Dedicated circuit**	**Distribution circuit**	**Lighting circuit**	**Socket-outlet circuit**	**Dedicated circuit**	**Dedicated circuit**
BAU	**Production**	**kg CO2 eq.**	4419	38	64	189	25116	58	87	929	1116
	Distribution	**kg CO2 eq.**	79	10	10	12	402	10	11	22	38
	Use	**kg CO2 eq.**	76248	278	198	18998	306518	573	715	82442	65413
	End of live	**kg CO2 eq.**	-2501	-13	-25	-95	-14641	-20	-35	-510	-524
	Total	**kg CO2 eq.**	78246	313	246	19105	317395	622	779	82883	66043
D1	**Production**	**kg CO2 eq.**	5498	53	92	287	32865	82	125	1271	1431
	Distribution	**kg CO2 eq.**	96	10	11	13	573	11	12	28	45
	Use	**kg CO2 eq.**	61016	167	124	11875	230020	344	448	57715	48204
	End of live	**kg CO2 eq.**	-3125	-21	-40	-151	-19498	-32	-55	-727	-707
	Total	**kg CO2 eq.**	63485	209	186	12025	243960	404	530	58287	48973
D2	**Production**	**kg CO2 eq.**	6847	76	127	439	38592	117	174	1793	1844
	Distribution	**kg CO2 eq.**	114	10	11	15	451	12	12	38	58
	Use	**kg CO2 eq.**	49494	105	83	7603	184147	216	299	41233	38167
	End of live	**kg CO2 eq.**	-3856	-33	-60	-235	-24285	-51	-81	-1018	-895
	Total	**kg CO2 eq.**	52598	158	162	7822	198905	293	404	42046	39174
D3	**Production**	**kg CO2 eq.**	8837	105	198	598	48494	163	270	2452	2236
	Distribution	**kg CO2 eq.**	143	11	12	17	532	12	13	45	69
	Use	**kg CO2 eq.**	38183	70	51	5433	146322	144	181	30392	30540
	End of live	**kg CO2 eq.**	-5001	-49	-99	-329	-30594	-76	-135	-1382	-1116
	Total	**kg CO2 eq.**	42162	137	162	5720	164755	243	329	31507	31730
D4	**Production**	**kg CO2 eq.**	8839	75	128	379	50232	117	174	1858	2231
	Distribution	**kg CO2 eq.**	150	11	12	15	795	12	13	36	68
	Use	**kg CO2 eq.**	38183	139	100	9502	153602	287	359	41233	32719
	End of live	**kg CO2 eq.**	-5001	-26	-51	-189	-29281	-40	-69	-1020	-1047
	Total	**kg CO2 eq.**	42170	200	189	9706	175348	376	477	42106	33971

Table 6-17: Greenhouse Gases (in detail, each phase relative to total) in GWP100

			BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC8
BAU	**Production**	%	6%	12%	26%	1%	8%	9%	11%	1%	1.7%
	Distribution	%	0%	3%	4%	0%	0%	2%	1%	0%	0%
	Use	%	97%	89%	80%	99%	97%	92%	92%	99%	99.0%
	End of live	%	-3%	-4%	-10%	0%	-5%	-3%	-4%	-1%	-0.8%
	Total	%	100%	100%	100%	100%	100%	100%	100%	100%	100%
D1	**Production**	%	9%	25%	49%	2%	13%	20%	24%	2%	3%
	Distribution	%	0%	5%	6%	0%	0%	3%	2%	0%	0%
	Use	%	96%	80%	67%	99%	94%	85%	85%	99%	98%
	End of live	%	-5%	-10%	-21%	-1%	-8%	-8%	-10%	-1%	-1%
	Total	%	100%	100%	100%	100%	100%	100%	100%	100%	100%
D2	**Production**	%	13%	48%	79%	6%	19%	40%	43%	4%	5%
	Distribution	%	0%	7%	7%	0%	0%	4%	3%	0%	0%
	Use	%	94%	66%	51%	97%	93%	74%	74%	98%	97%
	End of live	%	-7%	-21%	-37%	-3%	-12%	-17%	-20%	-2%	-2%
	Total	%	100%	100%	100%	100%	100%	100%	100%	100%	100%
D3	**Production**	%	21%	77%	122%	10%	29%	67%	82%	8%	7%
	Distribution	%	0%	8%	7%	0%	0%	5%	4%	0%	0%
	Use	%	91%	51%	32%	95%	89%	59%	55%	96%	96%
	End of live	%	-12%	-36%	-61%	-6%	-19%	-31%	-41%	-4%	-4%
	Total	%	100%	100%	100%	100%	100%	100%	100%	100%	100%
D4	**Production**	%	21%	38%	68%	4%	29%	31%	37%	4%	7%
	Distribution	%	0%	5%	6%	0%	0%	3%	3%	0%	0%
	Use	%	91%	70%	53%	98%	88%	76%	75%	98%	96%
	End of live	%	-12%	-13%	-27%	-2%	-17%	-11%	-14%	-2%	-3%
	Total	%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 6-18: Greenhouse Gases (in detail, relative to BAU) in GWP100

			BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC8
D1/BAU	**Production**	**%**	124%	140%	143%	152%	131%	140%	143%	137%	128%
	Distribution	**%**	121%	102%	107%	111%	143%	103%	109%	124%	118%
	Use	**%**	80%	60%	63%	63%	75%	60%	63%	70%	74%
	End of live	**%**	125%	163%	158%	159%	133%	163%	158%	142%	135%
	Total	**%**	81%	67%	76%	63%	77%	65%	68%	70%	74%
D2/BAU	**Production**	**%**	155%	201%	199%	232%	154%	201%	199%	193%	165%
	Distribution	**%**	144%	108%	110%	131%	112%	112%	113%	172%	152%
	Use	**%**	65%	38%	42%	40%	60%	38%	42%	50%	58%
	End of live	**%**	154%	259%	236%	248%	166%	259%	236%	200%	171%
	Total	**%**	67%	50%	66%	41%	63%	47%	52%	51%	59%
D3/BAU	**Production**	**%**	200%	279%	309%	316%	193%	279%	309%	264%	200%
	Distribution	**%**	180%	111%	117%	147%	133%	116%	122%	203%	182%
	Use	**%**	50%	25%	26%	29%	48%	25%	25%	37%	47%
	End of live	**%**	200%	385%	390%	347%	209%	385%	390%	271%	213%
	Total	**%**	54%	44%	66%	30%	52%	39%	42%	38%	48%
D4/BAU	**Production**	**%**	200%	200%	200%	200%	200%	200%	200%	200%	200%
	Distribution	**%**	189%	112%	116%	128%	198%	117%	121%	161%	178%
	Use	**%**	50%	50%	50%	50%	50%	50%	50%	50%	50%
	End of live	**%**	200%	200%	200%	200%	200%	200%	200%	200%	200%
	Total	**%**	54%	64%	77%	51%	55%	61%	61%	51%	51%

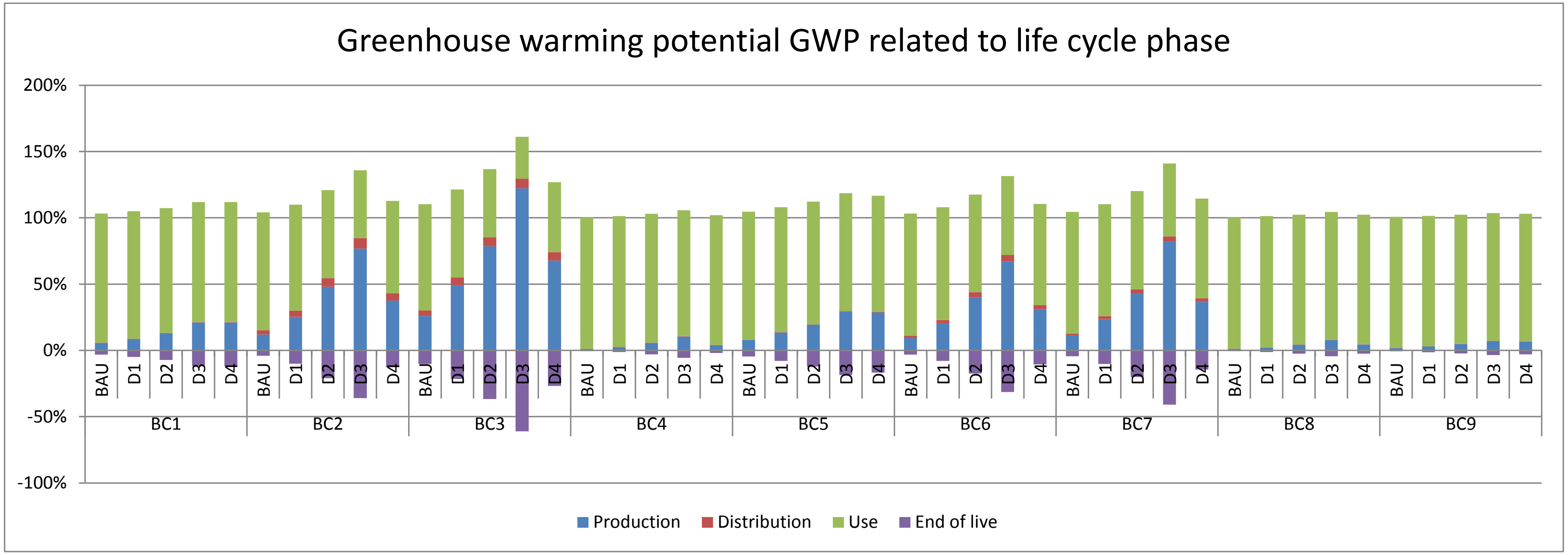


Figure 6-1 Greenhouse Gases (in detail, each phase relative to total) in GWP100

Figure 6-1 shows that for the design options compared to the BAU case, the emission of greenhouse gas shifts from the use phase towards the production (and distribution) phase. Figure 6-2 displays the absolute GWP values per life cycle phase. A shift of greenhouse gas emissions towards the production phase can be noticed in absolute terms, but one can also notice the significant reduction on greenhouse gas emissions during the use phase.

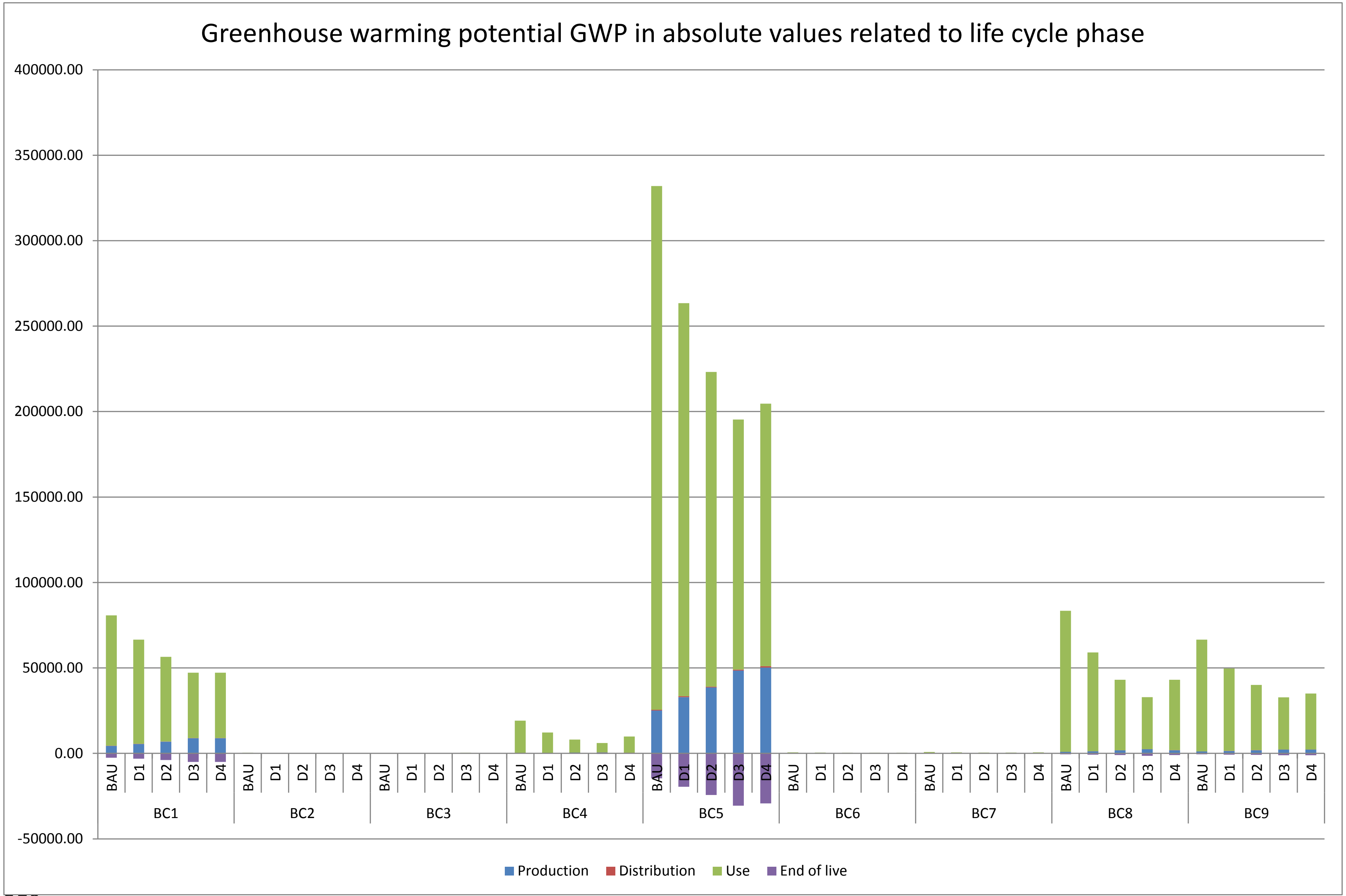

Greenhouse warming potential GWP in absolute values related to life cycle phase
400000.00
350000.00
300000.00
250000.00
200000.00
150000.00
100000.00
50000.00
0.00
-50000.00
BAU D1 D2 D3 D4
BC1
BC2
BC3
BC4
BC5
BC6
BC7
BC8
BC9
Production
Distribution
Use
End of live

Figure 6-2 Greenhouse Gases in absolute values (in detail, each phase relative to total) in GWP100

Table 6-19 shows how many years it takes to match the increase of greenhouse gas in the production and distribution phase with the reduction of greenhouse gas in the use phase. The environmental payback period is calculated by means of formula 6.1.

$$EPP_{\text{design option x - BAU}} = dPD_{\text{design option x - BAU}} / (dU_{\text{design option x - BAU}} / \text{product lifetime}) \quad \text{(formula 6.1)}$$

Where

$EPP_{\text{design option x - BAU}}$ = Environmental Payback Period, in years
$dPD_{\text{design option x – BAU}}$ = Difference (increase) in production and distribution phase emission
$dU_{\text{design option x - BAU}}$ = Difference (decrease) in use phase emission

Table 6-19: Greenhouse Gases: environmental payback period in years

	Unit	Greenhouse Gases: payback period								
Base case id		**BC1**	**BC2**	**BC3**	**BC4**	**BC5**	**BC6**	**BC7**	**BC8**	**BC9**
Sector		**Services sector**	**Services sector**	**Services sector**	**Services sector**	**Industry sector**	**Industry sector**	**Industry sector**	**Industry sector**	**Industry sector**
Application circuit		**Distribution circuit**	**Lighting circuit**	**Socket-outlet circuit**	**Dedicated circuit**	**Distribution circuit**	**Lighting circuit**	**Socket-outlet circuit**	**Dedicated circuit**	**Dedicated circuit**
Product lifetime	years	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
D1	years	1.80	3.45	9.61	0.35	2.59	2.59	3.61	0.35	0.47
D2	years	2.30	5.58	14.07	0.56	2.76	4.20	5.28	0.53	0.69
D3	years	2.94	8.24	23.07	0.76	3.67	6.19	8.64	0.74	0.83
D4	years	2.95	7.00	16.71	0.51	4.17	5.26	6.27	0.57	0.88

6.2.3 Impact on material resource usage

Table 6-20 shows the material usage in case of BAU. Table 6-20 Table 6-22, Table 6-23 and Table 6-24 show the impact of the design option on the material usage for respectively design option D1, D2, D3 and D4. Although the design options have a considerable impact on the material usage, it has to be mentioned that a considerable amount of the material, like the conductor metal, will be recycled at the end of the product life.

Table 6-20: Resource usage BAU

	Unit	material resource usage								
Base case id		BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
Sector		Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
Application circuit		Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
Conductor	g	600075	2904.06667	5864.93056	22471.9444	3520440	4500.5625	8001	122126.375	74182.5
Insulation	g	26821	935	1349	2223	147863	1450	1841	7844	14885
Sheath - PVC	g	26932	1729	2337	3281	135308	2680	3188	8256	15665
Sheath - Filler	g	13466	865	1168	1640	67654	1340	1594	4128	7833
Sheath - plasticizer	g	13466	865	1168	1640	67654	1340	1594	4128	7833
Filler material	g	146341	1795	2652	7141	638182	2781	3618	30692	66197
Total	g	827100	9092	14540	38397	4577100	14091	19836	177175	186595

Table 6-21: Resource usage in case of design option D1

	Unit	material resource usage for design option D1								
Base case id		BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
Sector		Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
Application circuit		Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
Absolute values										
Conductor	g	750094	4840	9384	35955	4693920	7501	12802	174466	100676
Insulation	g	34282	1113	1619	2688	189746	1726	2209	10321	16903
Sheath - PVC	g	32266	1929	2639	3802	171048	2989	3600	10413	18931
Sheath - Filler	g	16133	964	1320	1901	85524	1494	1800	5206	9465
Sheath - plasticizer	g	16133	964	1320	1901	85524	1494	1800	5206	9465
Filler material	g	175685	2189	3643	10275	664737	3392	4969	28592	70639
Total	g	1024594	12000	19924	56521	5890500	18596	27180	234205	226080
Relative values compared to BAU										
Conductor	%	+25%	+67%	+60%	+60%	+33%	+67%	+60%	+43%	+36%
Insulation	%	+28%	+19%	+20%	+21%	+28%	+19%	+20%	+32%	+14%
Sheath - PVC	%	+20%	+12%	+13%	+16%	+26%	+12%	+13%	+26%	+21%
Sheath - Filler	%	+20%	+12%	+13%	+16%	+26%	+12%	+13%	+26%	+21%
Sheath - plasticizer	%	+20%	+12%	+13%	+16%	+26%	+12%	+13%	+26%	+21%
Filler material	%	+20%	+22%	+37%	+44%	+4%	+22%	+37%	-7%	+7%
Total	%	+24%	+32%	+37%	+47%	+29%	+32%	+37%	+32%	+21%

Table 6-22: Resource usage in case of design option D2

	Unit	material resource usage for design option D2								
Base case id		BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
Sector		Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
Application circuit		Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
Absolute values										
Conductor	g	925116	7744	14076	56180	5867400	12002	19202	244253	127170
Insulation	g	44439	1336	1889	4320	232477	2071	2577	13245	21192
Sheath - PVC	g	38390	2178	2941	4670	200329	3375	4012	12956	23629
Sheath - Filler	g	19195	1089	1471	2335	100165	1688	2006	6478	11814
Sheath - plasticizer	g	19195	1089	1471	2335	100165	1688	2006	6478	11814
Filler material	g	239541	3006	4924	15232	0	4659	6718	49901	102602
Total	g	1285875	16442	26772	85072	6500536	25481	36522	333311	298222
Relative values compared to BAU										
Conductor	%	+54%	+167%	+140%	+150%	+67%	+167%	+140%	+100%	+71%
Insulation	%	+66%	+43%	+40%	+94%	+57%	+43%	+40%	+69%	+42%
Sheath - PVC	%	+43%	+26%	+26%	+42%	+48%	+26%	+26%	+57%	+51%
Sheath - Filler	%	+43%	+26%	+26%	+42%	+48%	+26%	+26%	+57%	+51%
Sheath - plasticizer	%	+43%	+26%	+26%	+42%	+48%	+26%	+26%	+57%	+51%
Filler material	%	+64%	+67%	+86%	+113%	-100%	+67%	+86%	+63%	+55%
Total	%	+55%	+81%	+84%	+122%	+42%	+81%	+84%	+88%	+60%

Table 6-23: Resource usage in case of design option D3

	Unit	material resource usage for design option D3								
Base case id		BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
Sector		Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
Application circuit		Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
Absolute values										
Conductor	g	1200150	11616	23460	78652	7392924	18002	32004	331486	158963
Insulation	g	53642	1559	2321	5052	284156	2416	3166	15263	27453
Sheath - PVC	g	46847	2427	3425	5317	236701	3762	4672	15749	26811
Sheath - Filler	g	23423	1214	1712	2659	118351	1881	2336	7875	13406
Sheath - plasticizer	g	23423	1214	1712	2659	118351	1881	2336	7875	13406
Filler material	g	306827	4064	7455	19766	0	6298	10170	81959	108816
Total	g	1654313	22094	40085	114104	8150483	34239	54684	460206	348854
Relative values compared to BAU										
Conductor	%	+100%	+300%	+300%	+250%	+110%	+300%	+300%	+171%	+114%
Insulation	%	+100%	+67%	+72%	+127%	+92%	+67%	+72%	+95%	+84%
Sheath - PVC	%	+74%	+40%	+47%	+62%	+75%	+40%	+47%	+91%	+71%
Sheath - Filler	%	+74%	+40%	+47%	+62%	+75%	+40%	+47%	+91%	+71%
Sheath - plasticizer	%	+74%	+40%	+47%	+62%	+75%	+40%	+47%	+91%	+71%
Filler material	%	+110%	+126%	+181%	+177%	-100%	+126%	+181%	+167%	+64%
Total	%	+100%	+143%	+176%	+197%	+78%	+143%	+176%	+160%	+87%

Table 6-24: Resource usage in case of design option D4

	Unit	material resource usage for design option D4								
Base case id		BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
Sector		Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
Application circuit		Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
Absolute values										
Conductor	g	1200150	5808	11730	44944	7040880	9001	16002	244253	148365
Insulation	g	53642	1871	2698	4446	295726	2899	3681	15688	29770
Sheath - PVC	g	53863	3458	4674	6561	270616	5359	6376	16512	31330
Sheath - Filler	g	26932	1729	2337	3281	135308	2680	3188	8256	15665
Sheath - plasticizer	g	26932	1729	2337	3281	135308	2680	3188	8256	15665
Filler material	g	292681	3590	5305	14282	1276363	5563	7237	61385	132393
Total	g	1654200	18184	29081	76794	9154200	28181	39672	354349	373189
Relative values compared to BAU										
Conductor	%	+100%	+100%	+100%	+100%	+100%	+100%	+100%	+100%	+100%
Insulation	%	+100%	+100%	+100%	+100%	+100%	+100%	+100%	+100%	+100%
Sheath - PVC	%	+100%	+100%	+100%	+100%	+100%	+100%	+100%	+100%	+100%
Sheath - Filler	%	+100%	+100%	+100%	+100%	+100%	+100%	+100%	+100%	+100%
Sheath - plasticizer	%	+100%	+100%	+100%	+100%	+100%	+100%	+100%	+100%	+100%
Filler material	%	+100%	+100%	+100%	+100%	+100%	+100%	+100%	+100%	+100%
Total	%	+100%	+100%	+100%	+100%	+100%	+100%	+100%	+100%	+100%

Table 6-25 shows the impact of the design option on the cylindrical cable volume. In case of BC5 the relative cylindrical volume increase for option D2 and D3 is less than for design option D1 because instead of using a multicore cable, as used in the BAU and design option D1, four single core cables are used in parallel.

Table 6-25: Design option impact on cable volume

		Unit	Base cases definiton								
	Base case id		BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
	Sector		Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
	Application circuit		Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
Design option	Parameter										
BAU	outer diameter	mm	39.96	7.56	8.64	13.5	55.902	7.56	8.64	22.95	31.32
D1	outer diameter	mm	44.82	8.64	9.99	15.93	64.372	8.64	9.99	27	35.64
D2	outer diameter	mm	49.95	9.99	11.34	19.98	29.6	9.99	11.34	31.32	39.96
D3	outer diameter	mm	56.43	11.34	13.5	22.95	33.1	11.34	13.5	35.64	44.82
D4	outer diameter	mm	39.96	7.56	8.64	13.5	55.902	7.56	8.64	22.95	31.32
D1 vs BAU	cable volume	%	+26%	+31%	+34%	+39%	+33%	+31%	+34%	+38%	+29%
D2 vs BAU	cable volume	%	+56%	+75%	+72%	+119%	+12%	+75%	+72%	+86%	+63%
D3 vs BAU	cable volume	%	+99%	+125%	+144%	+189%	+40%	+125%	+144%	+141%	+105%
D4 vs BAU	cable volume	%	+100%	+100%	+100%	+100%	+100%	+100%	+100%	+100%	+100%

6.2.4 Conclusion on EcoReport tool impact parameters

Table 6-26 shows that for all the parameters, except for the parameters 'water (process)', 'heavy metals (emissions in water and air)' and 'Particulate Matter (PM)', the design options for almost all base cases have a lower value than the BAU scenario.

Looking vertically at Table 6-26 in function of base case, the design options for the base cases 2, 3, 6 and 7 representing the lighting and socket-outlet circuits perform less compared to the other base cases, in particular for the parameters PAHs, PM and Eutrophication. In terms of resource efficiency, the best performing design option is always the BAU case.

Table 6-26: best performing design option per parameter and base case

	Best performing design option per parameter and base case								
Base case id	BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
Sector	Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
Application circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
Other resources and waiste									
Total Energy (GER)	D3	D3	D3	D3	D3	D3	D3	D3	D3
of which, electricity (in primary MJ)	D4	D3	D3	D3	D3	D3	D3	D3	D3
Water (process)	BAU	BAU	BAU	BAU	BAU	BAU	BAU	BAU	BAU
Waste, non-haz./ landfill	D3	D3	D2	D3	D3	D3	D3	D3	D3
Emissions (air)									
Waste, hazardous/ incinerated	D3	D3	D3	D3	D3	D3	D3	D3	D3
Greenhouse Gases in GWP100	D3	D3	D3	D3	D3	D3	D3	D3	D3
Acidification, emissions	D3	D1	BAU	D3	D3	D2	D1	D3	D3
Volatile Organic Compounds (VOC)	D3	D3	D3	D3	D3	D3	D3	D3	D3
Persistent Organic Pollutants (POP)	D3	D4	BAU	D3	D4	D2	D4	D3	D3
Heavy Metals	D1	BAU	BAU	D3	BAU	BAU	BAU	D3	D3
PAHs	D4	D1	BAU	D3	D2	D1	D1	D3	D1
Particulate Matter (PM, dust)	BAU	BAU	BAU	D3	D2	BAU	BAU	D3	D1
Emissions (water)									
Heavy Metals	BAU	BAU	BAU	D1	BAU	BAU	BAU	D1	D3
Eutrophication	D3	D1	BAU	D3	D3	D2	D2	D3	D3

6.3 Impact on Life Cycle Cost

Per base case and design option the product price, installation cost, and the electricity cost during the products' lifetime are calculated according the formulas in Task 2, Task 3 and Task 4. Besides the variation of the total cost per design option compared to the BAU case ((Design option value – BAU value)/BAU value expressed in percentile) also the payback period is calculated. This is the time period it takes for an investor to recuperate the extra investment in purchase price dPP through reduction in annual operating expense dOE. The simple payback period approach can be used due to the fact that the product life of the circuit regardless of the applied design option or BAU option does not change.

When assuming that the discount and escalation rate are equal the Simple Payback Period SPP can be used. The formula, as defined by the MEErP 2011 methodology[124], for comparing the alternatives is:

$$SPP_{design\ option\ x\ -\ BAU} = dPP_{design\ option\ x\ -\ BAU} / dOE_{design\ option\ x\ -\ BAU} \quad \text{(formula 6.2)}$$

Where

$SPP_{design\ option\ x\ -\ BAU}$ = simple payback period, in years
$dPP_{design\ option\ x\ -\ BAU}$ = difference (increase) in purchase price
$dOE_{design\ option\ x\ -\ BAU}$ = difference (decrease) in operating expenses

[124] VHK, MEErP 2011 METHODOLOGY PART 1.

Table 6-27 shows that when applying a design option for the base cases representing lighting circuits and socket-outlet circuits (BC2, BC3, BC6 and BC7) the simple payback period is almost for all cases greater than the product lifetime. This can be explained by the increase in product and installation cost for these small cable sections but especially by the low load on these circuits in these base cases. A low load means low energy cost and thus a longer payback period. BC1 and BC5 perform better, but still have long periods. BC4, BC8 and BC9 have really small payback periods.

Table 6-27: LCC of design options referred to a unit of product over its lifetime and compared to base cases

		Unit	Life Cycle Costs per base case per year								
	Base case id		BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
	Sector		Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
	Application circuit		Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distribution circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
BAU	Product price	€	5545.89	57.99	73.86	209.61	31403.51	76.79	86.16	1101.21	1429.39
	Installation cost	€	655.20	74.33	93.05	130.22	3376.80	101.42	107.18	316.20	370.05
	Electricity cost	€	22968.99	83.72	59.43	5725.54	92313.73	172.57	215.40	24845.00	19712.35
	Total	€	29170.07	216.05	226.34	6065.36	127094.04	350.77	408.74	26262.41	21511.79
D1	Product price	€	6849.72	74.82	104.44	330.90	41871.35	102.86	127.89	1556.11	1992.99
	Installation cost	€	751.10	95.57	117.17	152.43	4046.93	130.39	133.50	342.51	399.41
	Electricity cost	€	18375.19	50.23	37.15	3578.46	69235.30	103.54	134.62	17391.50	14524.89
	Total	€	25976.01	220.63	258.76	4061.79	115153.58	336.80	396.01	19290.12	16917.28
	Purchase price compared to BAU		+23%	+29%	+33%	+42%	+32%	+31%	+35%	+34%	+33%
	Total cost compared to BAU		-11%	+2%	+14%	-33%	-9%	-4%	-3%	-27%	-21%
	SPP	years	7.62	28.42	61.36	1.67	12.07	19.94	21.06	1.61	2.86
D2	Product price	€	8443.74	100.06	163.54	504.02	52339.18	141.98	196.83	2225.27	2526.46
	Installation cost	€	824.60	121.74	144.76	189.52	5883.73	165.03	171.14	389.68	438.38
	Electricity cost	€	14898.80	31.40	24.76	2290.22	55388.24	64.71	89.75	12422.50	11498.87
	Total	€	24167.14	253.20	333.07	2983.76	113611.15	371.73	457.71	15037.45	14463.71
	Purchase price compared to BAU		+49%	+68%	+85%	+104%	+67%	+72%	+90%	+84%	+65%
	Total cost compared to BAU		-17%	+17%	+47%	-51%	-11%	+6%	+12%	-43%	-33%
	SPP	years	9.50	42.75	101.96	2.57	15.87	29.86	34.74	2.41	3.55
D3	Product price	€	10834.11	159.94	245.10	725.39	65947.37	224.30	308.09	3073.10	3095.15
	Installation cost	€	1008.93	144.50	168.88	215.43	7347.20	200.31	197.46	420.43	503.24
	Electricity cost	€	11484.49	20.93	14.86	1635.87	43958.92	43.14	53.85	9153.42	9199.10
	Total	€	23327.53	325.37	428.84	2576.69	117253.49	467.75	559.39	12646.95	12797.49
	Purchase price compared to BAU		+91%	+130%	+148%	+177%	+111%	+138%	+161%	+146%	+100%
	Total cost compared to BAU		-20%	+51%	+89%	-58%	-8%	+33%	+37%	-52%	-41%
	SPP	years	12.28	68.53	138.57	3.67	19.91	47.60	48.31	3.31	4.28
D4	Product price	€	11091.77	115.99	147.71	419.21	62807.02	153.57	172.33	2202.43	2858.79
	Installation cost	€	1310.40	148.67	186.11	260.44	6753.60	202.83	214.37	632.40	740.10
	Electricity cost	€	11484.49	41.86	29.72	2862.77	46156.87	86.28	107.70	12422.50	9856.17
	Total	€	23886.66	306.52	363.54	3542.42	115717.48	442.69	494.39	15257.32	13455.06
	Purchase price compared to BAU		+100%	+100%	+100%	+100%	+100%	+100%	+100%	+100%	+100%
	Total cost compared to BAU		-18%	+42%	+61%	-42%	-9%	+26%	+21%	-42%	-37%
	SPP	years	13.50	79.03	140.42	2.97	18.84	51.63	44.88	2.85	4.56

6.4 Analysis of BAT and LLCC

The total energy (Gross Energy Requirement, GER) and LCC are calculated by means of the EcoReport tool for each BC and design option, including BAU. Table 6-28 summarizes the results of this calculation. Per BC the Least (minimum) Life Cycle Costs (LLCC) and Best Available Technology (BAT) are identified. The BAT design option for a base case indicates the design option (including BAU as an option) that results in the smallest amount of energy losses for this base case during its lifetime. The LLCC design option indicates the design option that results in the smallest LLC for this base case. The figures Figure 6-3 up to and including Figure 6-11 display these results graphically. In Figure 6-12, the results of BC8 and BC9 (similar circuits but with Copper and Aluminium cable conductors respectively) are shown for comparison.

Looking at the total energy usage, the BAT is in all base cases design option D3.

Looking at the LCC, the results are more dispersed. For the base cases BC2 and BC3 the LLCC is the BAU option. This can be explained by the low load on these circuits (less gain in use phase) while having a large increase in material when opting for one of the design options D1, D2, D3 or D4. The same can be said for the base cases BC6 and BC7, except that the D1 design option is the LLCC, owing to a higher load on these circuits in the industry. This reinforces the decision to leave out residential circuits, because the residential circuits are similar to BC2 and BC3, except that the loading is even lower.

For the base cases with a high load and a large CSA (BC1, BC4 and BC8) the design option D3 is the LLCC, owing to the lesser energy expenses during the use phase. Although BC5 is a base case with a high load and a very large CSA, design option D2, and not D3, is the best solution. The BAT and LLCC design options for BC9 (with Aluminium based cables) are equal to BC8.

Table 6-28: LLCC and BAT per base case

		Unit	Base cases								
	Base case id		BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
	Sector		Services sector	Services sector	Services sector	Services sector	Industry sector	Industry sector	Industry sector	Industry sector	Industry sector
	Application circuit		Distributio n circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Distributio n circuit	Lighting circuit	Socket-outlet circuit	Dedicated circuit	Dedicated circuit
BAU	Total Energy (GER)	MJ	1825051	7192	5608	447175	7392317	14414	18050	1940005	1544943
D1	Total Energy (GER)	MJ	1477409	4739	4152	281138	5660006	9281	12149	1363358	1144533
D2	Total Energy (GER)	MJ	1219803	3503	3523	182422	4605397	6617	9115	981885	914050
D3	Total Energy (GER)	MJ	971634	2965	3388	132904	3791321	5366	7192	733658	739090
D4	Total Energy (GER)	MJ	972016	4513	4176	226693	4021582	8597	10877	983199	791495
BAU	LCC	€	29170.07	216.05	226.34	6065.36	127094.04	350.77	408.74	26262.41	21511.79
D1	LCC	€	25976.01	220.63	258.76	4061.79	115153.58	336.80	396.01	19290.12	16917.28
D2	LCC	€	24167.14	253.20	333.07	2983.76	113611.15	371.73	457.71	15037.45	14463.71
D3	LCC	€	23327.53	325.37	428.84	2576.69	117253.49	467.75	559.39	12646.95	12797.49
D4	LCC	€	23886.66	306.52	363.54	3542.42	115717.48	442.69	494.39	15257.32	13455.06
BAT			D3	D3	D3	D3	D3	D3	D3	D3	D3
LLCC			D3	BAU	BAU	D3	D2	D1	D1	D3	D3

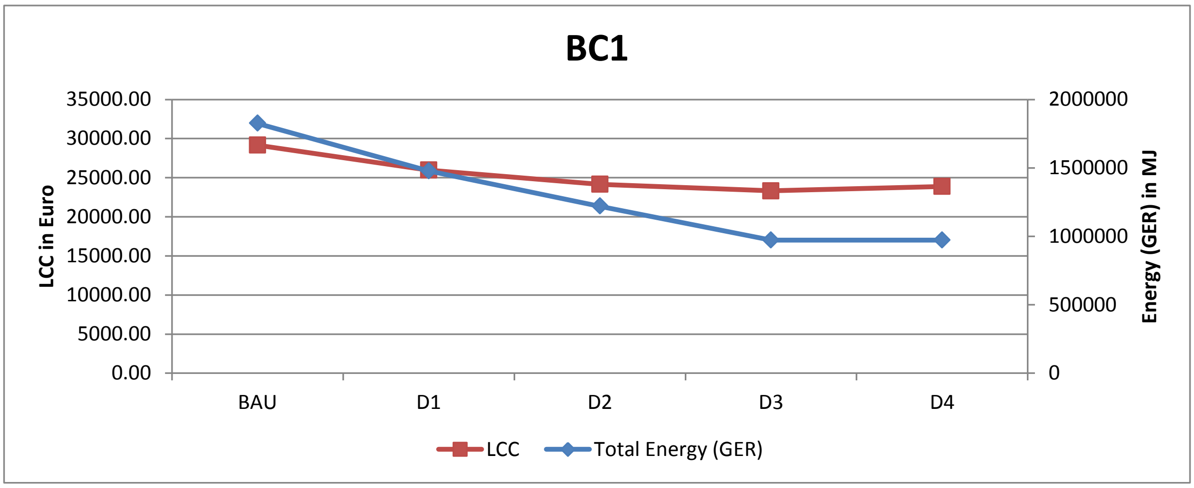


Figure 6-3 BAT and LLCC for BC1

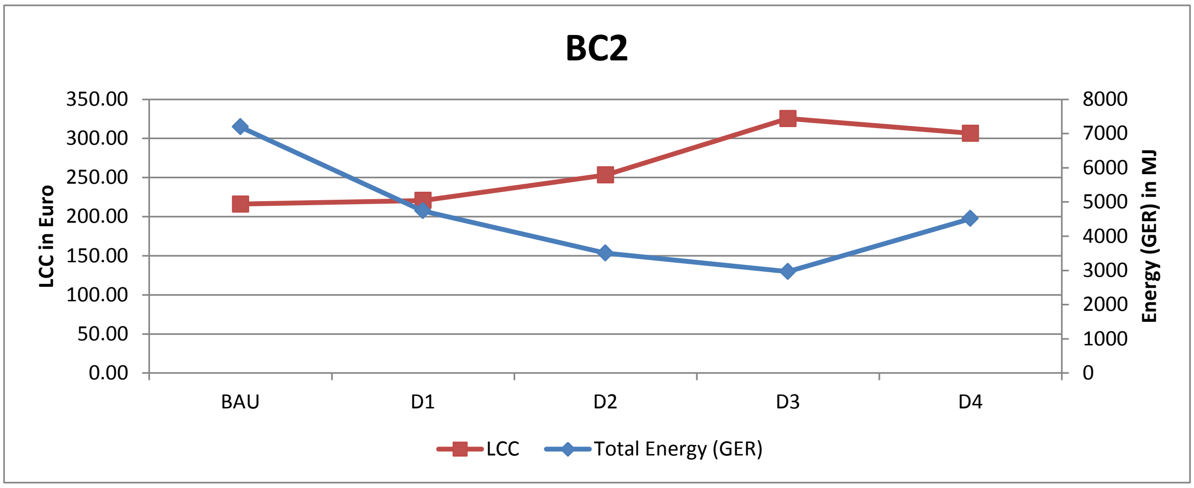


Figure 6-4 BAT and LLCC for BC2

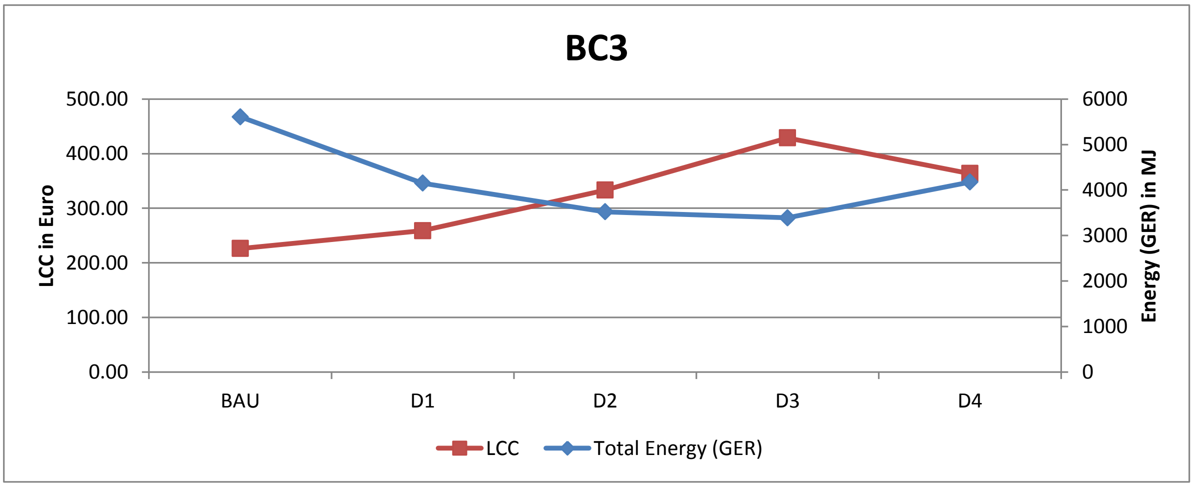


Figure 6-5 BAT and LLCC for BC3

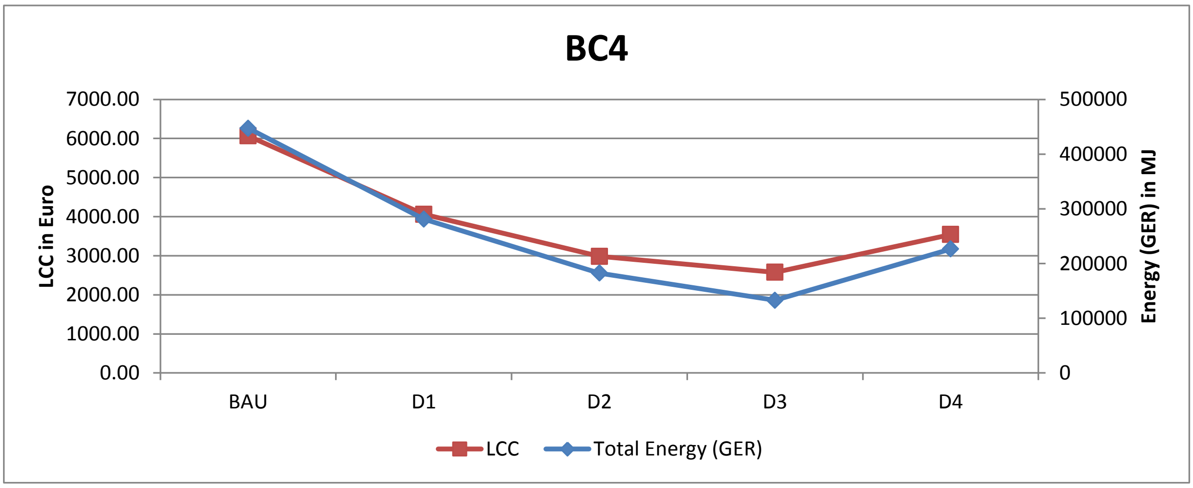


Figure 6-6 BAT and LLCC for BC4

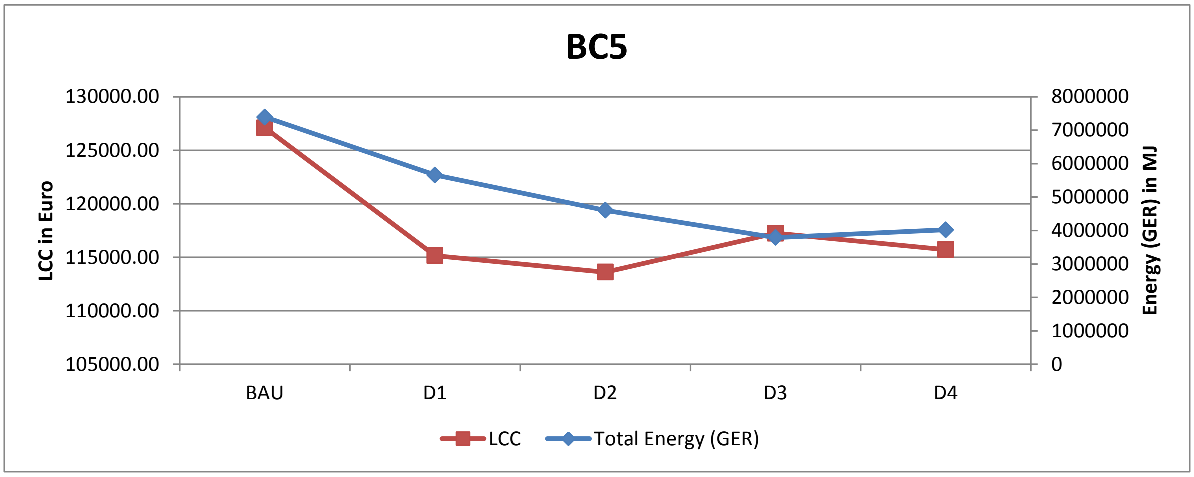


Figure 6-7 BAT and LLCC for BC5

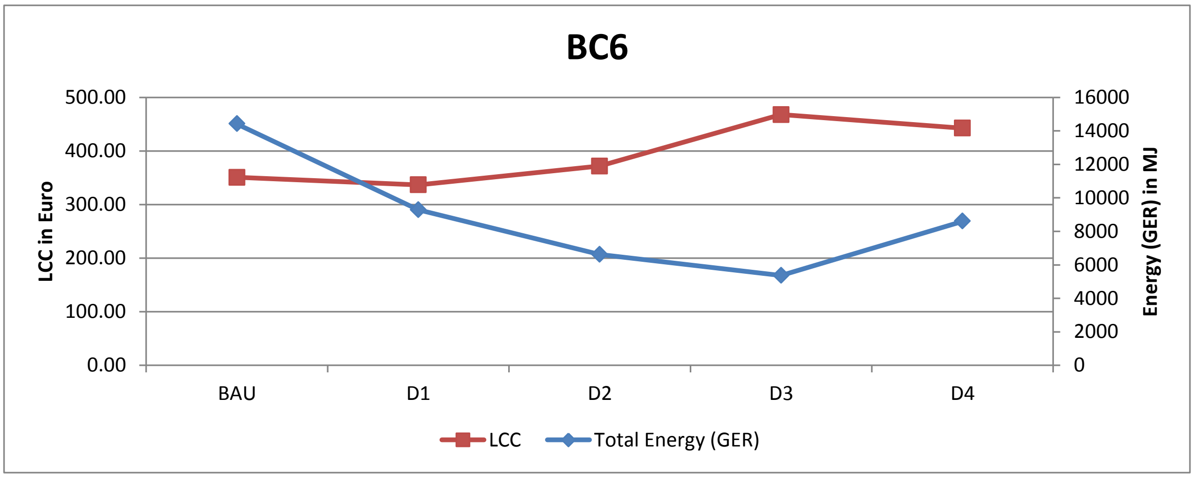


Figure 6-8 BAT and LLCC for BC6

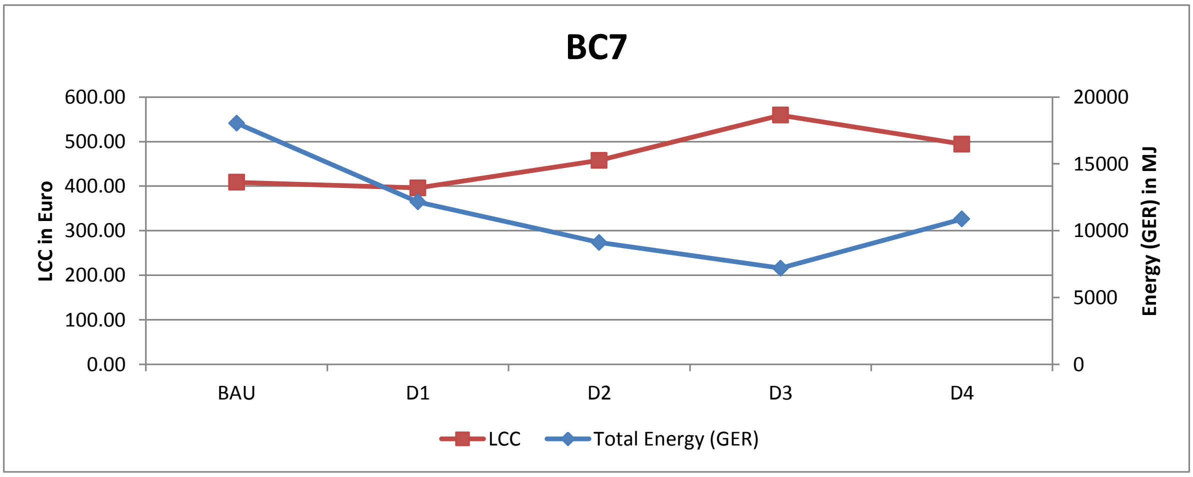


Figure 6-9 BAT and LLCC for BC7

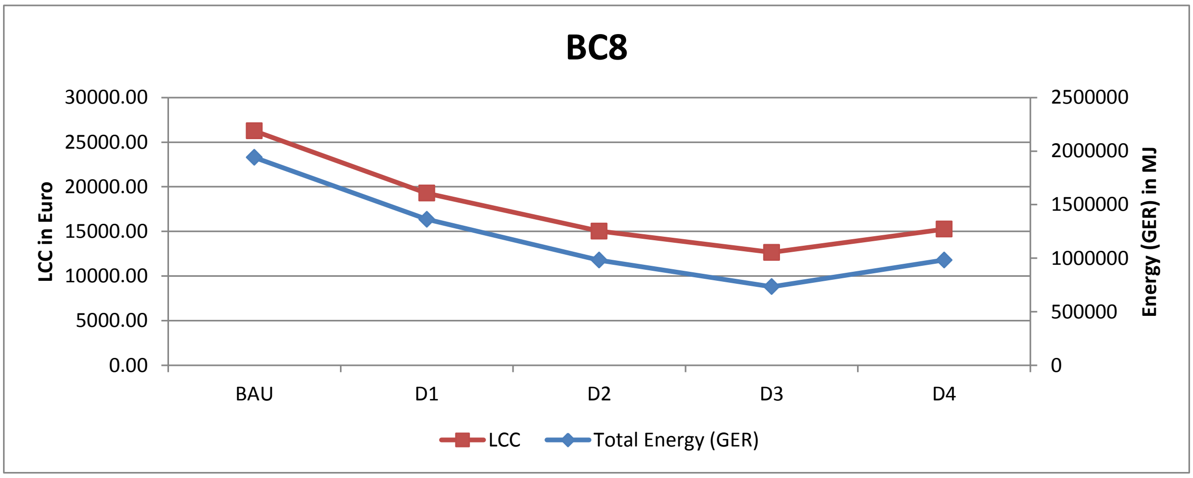


Figure 6-10 BAT and LLCC for BC8

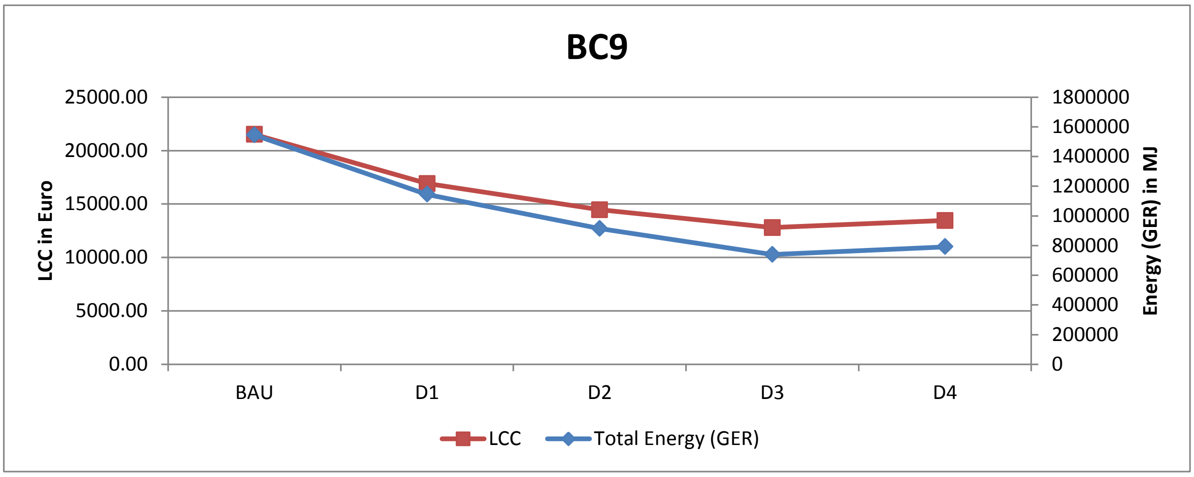


Figure 6-11 BAT and LLCC for BC9

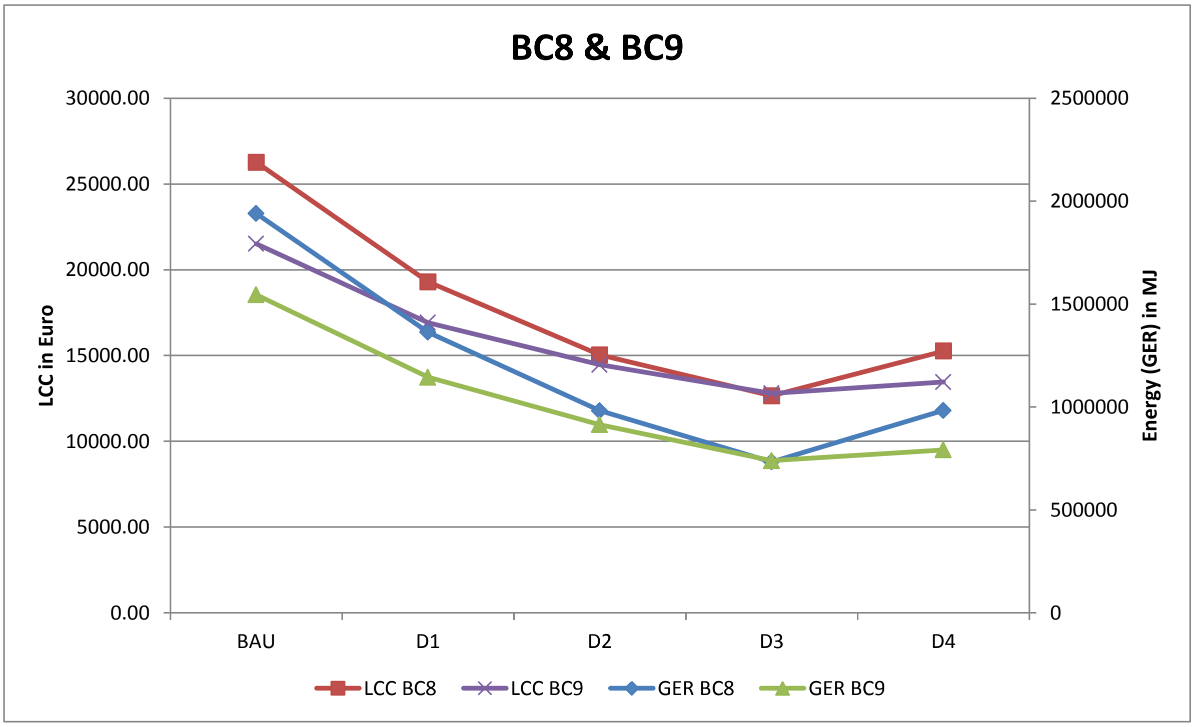


Figure 6-12 BAT and LLCC BC8 & BC9

Figure 6-12 shows that in case of circuit and loading characteristics of BC8/BC9, the solution based upon aluminium conductors has a lower LCC and BAT value in almost every option (except for D3) than the solution based upon copper.

6.5 Long term potential (BNAT) & systems analysis

Regarding BNAT options for power cables, nothing was identified in Task 4, as a consequence that there is also no further analysis.

6.6 Sensitivity analysis

The basic calculation in the previous section is based upon the reference values of the parameters defined in Task 2 and Task 3. In this section the LCC and GER are recalculated per BC with the parameters (i.e. circuit loading, length of the circuits, product lifetime and product price) set to their low value and to their high value. The low, reference and high values are listed in the tables in Task 2 and Task 3.

6.6.1 Sensitivity to circuit loading

In this section, the following parameters are taken into account:

- the load factor;
- load form factor;
- Kd factor;
- number of nodes per circuit.

The load, load form and Kd factors have an impact on the energy losses in the use phase. The number of nodes influences the Kd factor and thus the energy used in the use phase.

The load, load form and Kd factor have not impact on the production cost, but on the use phase cost. The number of nodes per circuit will have an impact on the production cost, meaning needing more or less connectors, and the use phase cost, by means of the Kd factor.

Table 6-29: Sensitivity data BC1

	Base Case Id		BC1		
		Unit	Low	Ref	High
BAU	Total Energy (GER)	Unit	318415	1825051	2748490
D1	Total Energy (GER)	0	272101	1477409	2216161
D2	Total Energy (GER)	0	242526	1219803	1818791
D3	Total Energy (GER)	0	218316	971634	1433354
D4	Total Energy (GER)	MJ	218698	972016	1433736
BAU	LCC	€	9786	29170	41051
D1	LCC	€	10469	25976	35480
D2	LCC	€	11594	24167	31873
D3	LCC	€	13636	23328	29268
D4	LCC	0	14195	23887	29827

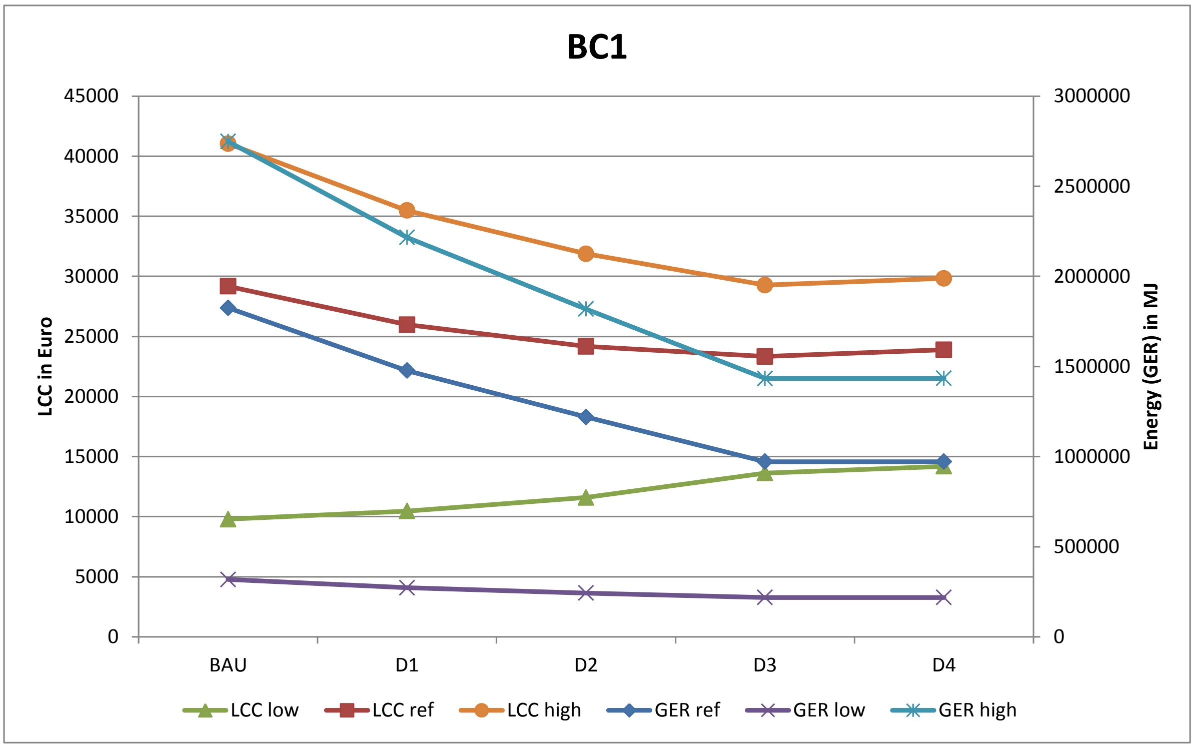


Figure 6-13 BC1 sensitivity to low, reference and high values

Table 6-30: Sensitivity data BC2

	Base Case Id		BC2		
		Unit	Low	Ref	High
BAU	Total Energy (GER)	Unit	1829	7192	15375
D1	Total Energy (GER)	0	1521	4739	9649
D2	Total Energy (GER)	0	1492	3503	6572
D3	Total Energy (GER)	0	1624	2965	5010
D4	Total Energy (GER)	MJ	1831	4513	8604
BAU	LCC	€	100	216	387
D1	LCC	€	125	221	359
D2	LCC	€	163	253	382
D3	LCC	€	226	325	466
D4	LCC	0	178	307	490

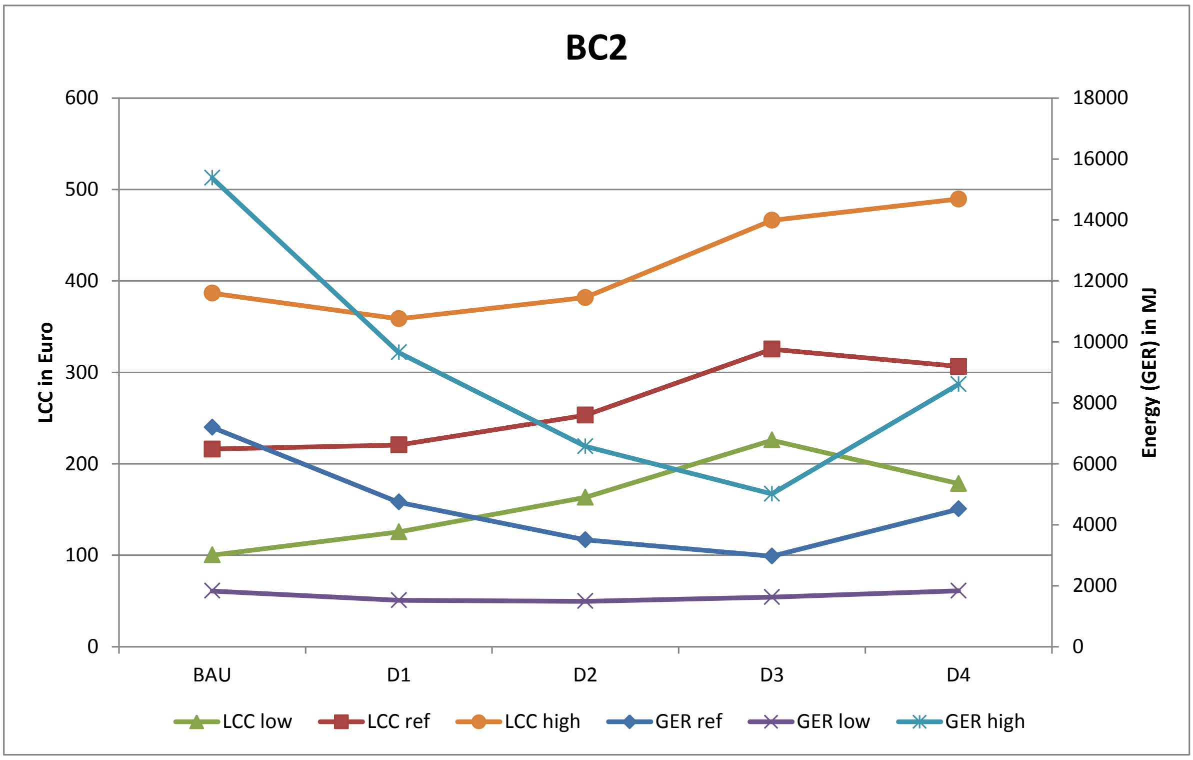


Figure 6-14 BC2 sensitivity to low, reference and high values

Table 6-31: Sensitivity data BC3

	Base Case Id		BC3		
		Unit	Low	Ref	High
BAU	Total Energy (GER)	Unit	1469	5608	10266
D1	Total Energy (GER)	0	1565	4152	7063
D2	Total Energy (GER)	0	1798	3523	5463
D3	Total Energy (GER)	0	2354	3388	4553
D4	Total Energy (GER)	MJ	2107	4176	6505
BAU	LCC	€	148	226	326
D1	LCC	€	196	259	343
D2	LCC	€	273	333	419
D3	LCC	€	373	429	512
D4	LCC	0	288	364	473

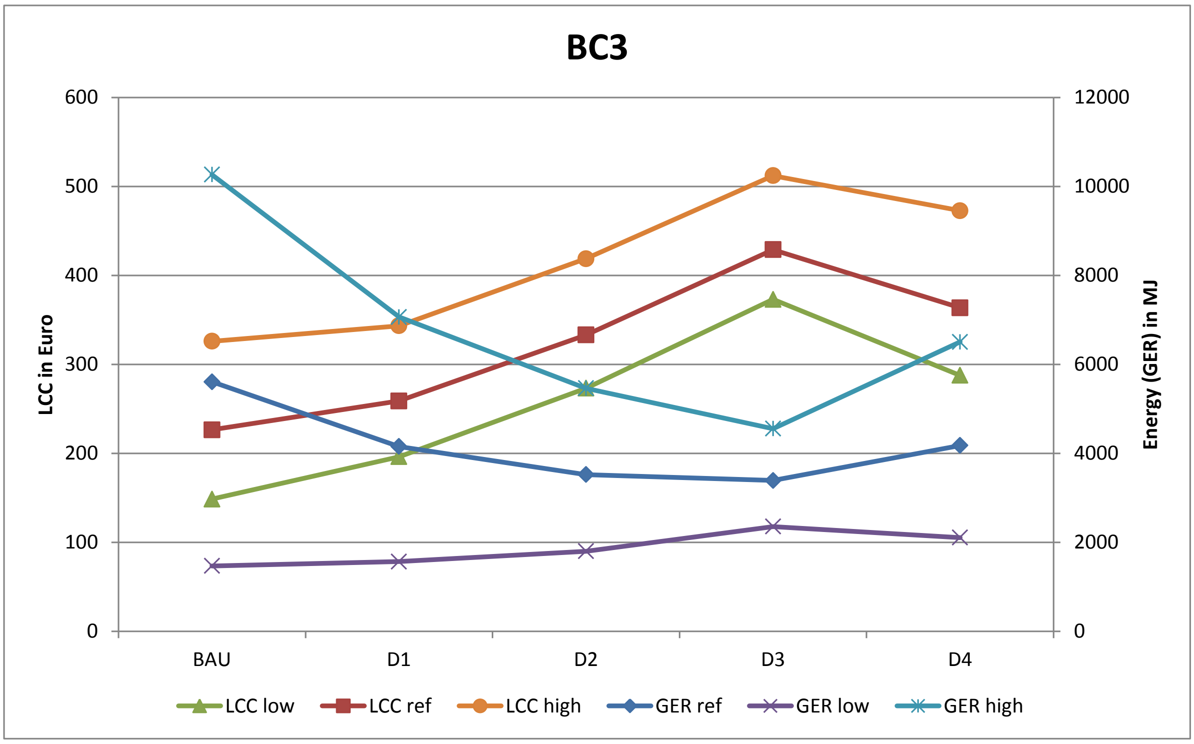


Figure 6-15 BC3 sensitivity to low, reference and high values

Table 6-32: Sensitivity data BC4

	Base Case Id		BC4		
		Unit	Low	Ref	High
BAU	Total Energy (GER)	Unit	71612	447175	677363
D1	Total Energy (GER)	0	46411	281138	425005
D2	Total Energy (GER)	0	32197	182422	274498
D3	Total Energy (GER)	0	25600	132904	198672
D4	Total Energy (GER)	MJ	38911	226693	341787
BAU	LCC	€	1221	6065	9065
D1	LCC	€	1027	4062	5959
D2	LCC	€	1036	2984	4216
D3	LCC	€	1169	2577	3509
D4	LCC	0	1102	3542	5100

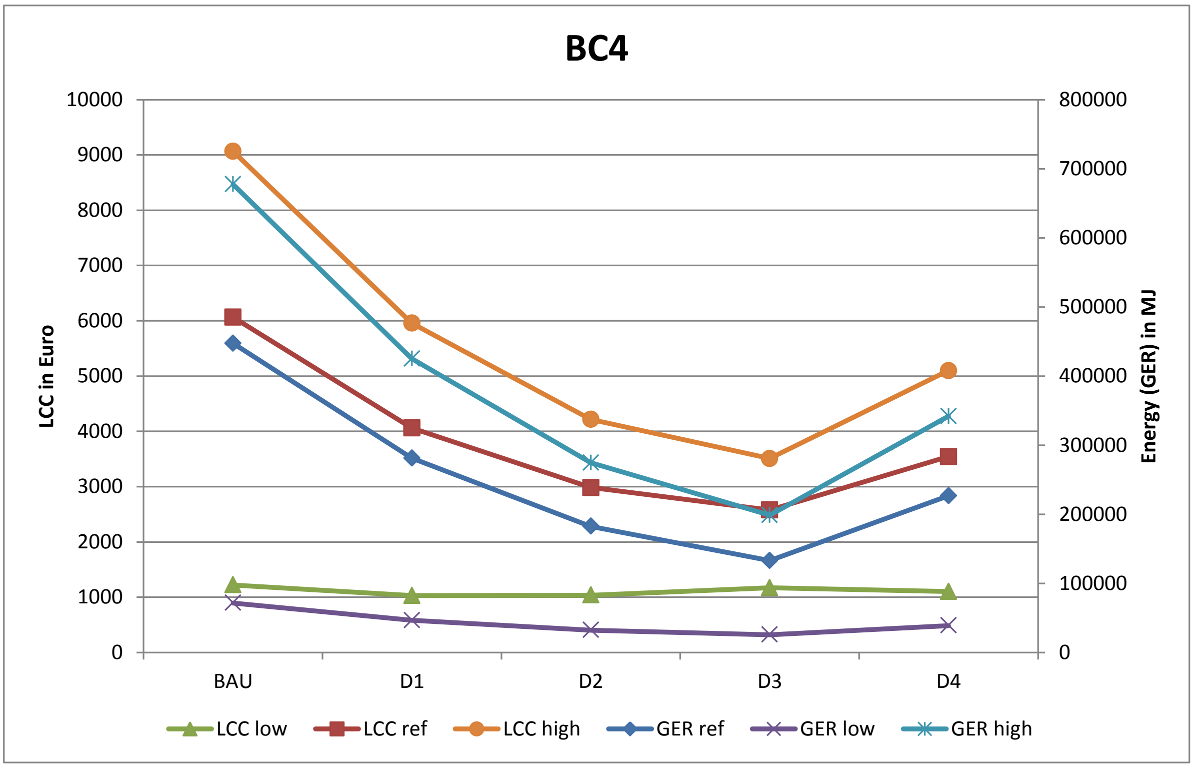


Figure 6-16 BC4 sensitivity to low, reference and high values

Table 6-33: Sensitivity data BC5

	Base Case Id		BC5		
		Unit	Low	Ref	High
BAU	Total Energy (GER)	Unit	1302339	7392317	11210405
D1	Total Energy (GER)	0	1092523	5660006	8523572
D2	Total Energy (GER)	0	951410	4605397	6896250
D3	Total Energy (GER)	0	891332	3791321	5609458
D4	Total Energy (GER)	MJ	976593	4021582	5930626
BAU	LCC	€	48743	127094	176216
D1	LCC	€	56391	115154	151995
D2	LCC	€	66601	113611	143084
D3	LCC	€	79944	117253	140645
D4	LCC	0	76542	115717	140278

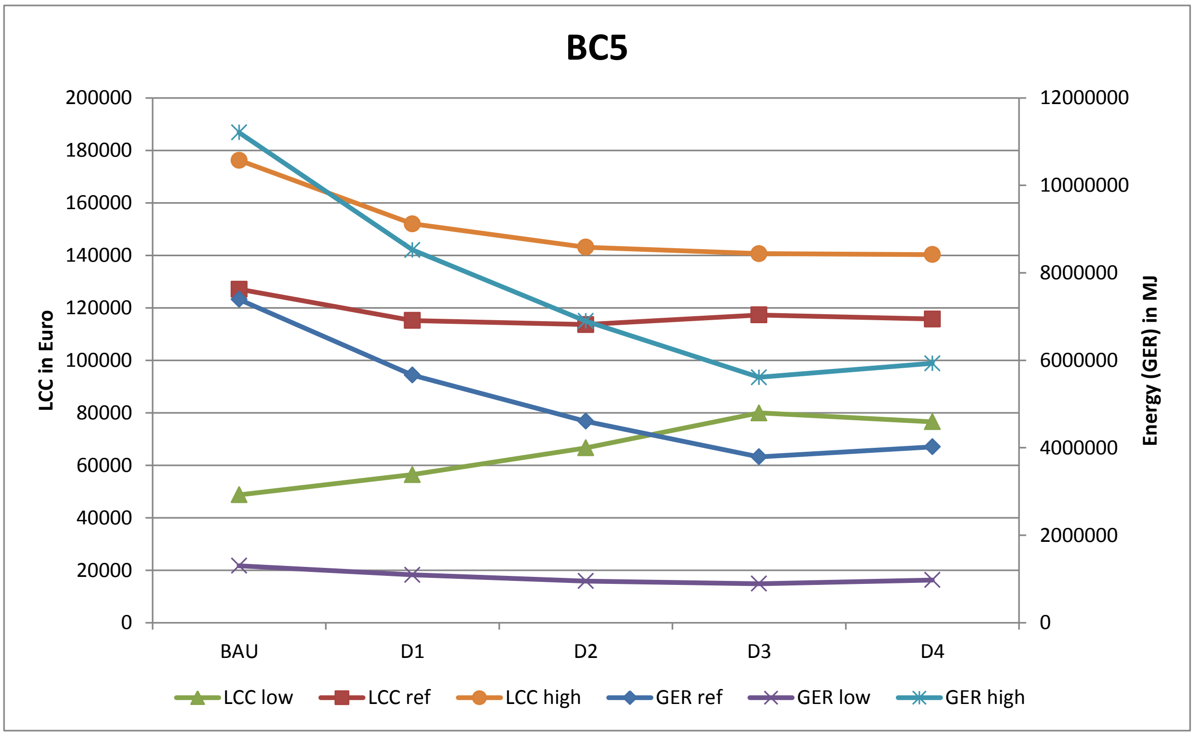


Figure 6-17 BC5 sensitivity to low, reference and high values

Table 6-34: Sensitivity data BC6

	Base Case Id		BC6		
		Unit	Low	Ref	High
BAU	Total Energy (GER)	Unit	1302339	14414	31219
D1	Total Energy (GER)	0	1092523	9281	19364
D2	Total Energy (GER)	0	951410	6617	12919
D3	Total Energy (GER)	0	891332	5366	9567
D4	Total Energy (GER)	MJ	976593	8597	17000
BAU	LCC	€	48743	351	637
D1	LCC	€	56391	337	547
D2	LCC	€	66601	372	549
D3	LCC	€	79944	468	645
D4	LCC	0	76542	443	692

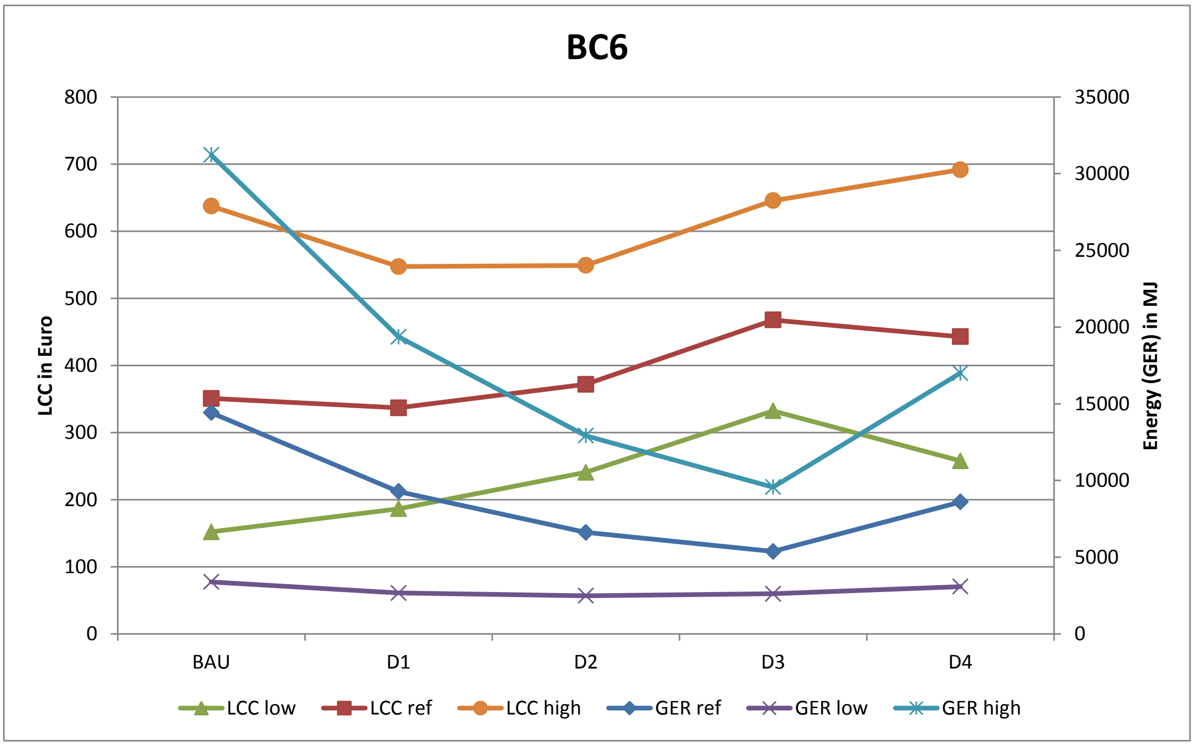


Figure 6-18 BC6 sensitivity to low, reference and high values

Table 6-35: Sensitivity data BC7

	Base Case Id		BC7		
		Unit	Low	Ref	High
BAU	Total Energy (GER)	Unit	2487	18050	41172
D1	Total Energy (GER)	0	2422	12149	26600
D2	Total Energy (GER)	0	2631	9115	18749
D3	Total Energy (GER)	0	3301	7192	12973
D4	Total Energy (GER)	MJ	3095	10877	22438
BAU	LCC	€	187	409	731
D1	LCC	€	245	396	612
D2	LCC	€	341	458	620
D3	LCC	€	472	559	677
D4	LCC	0	351	494	693

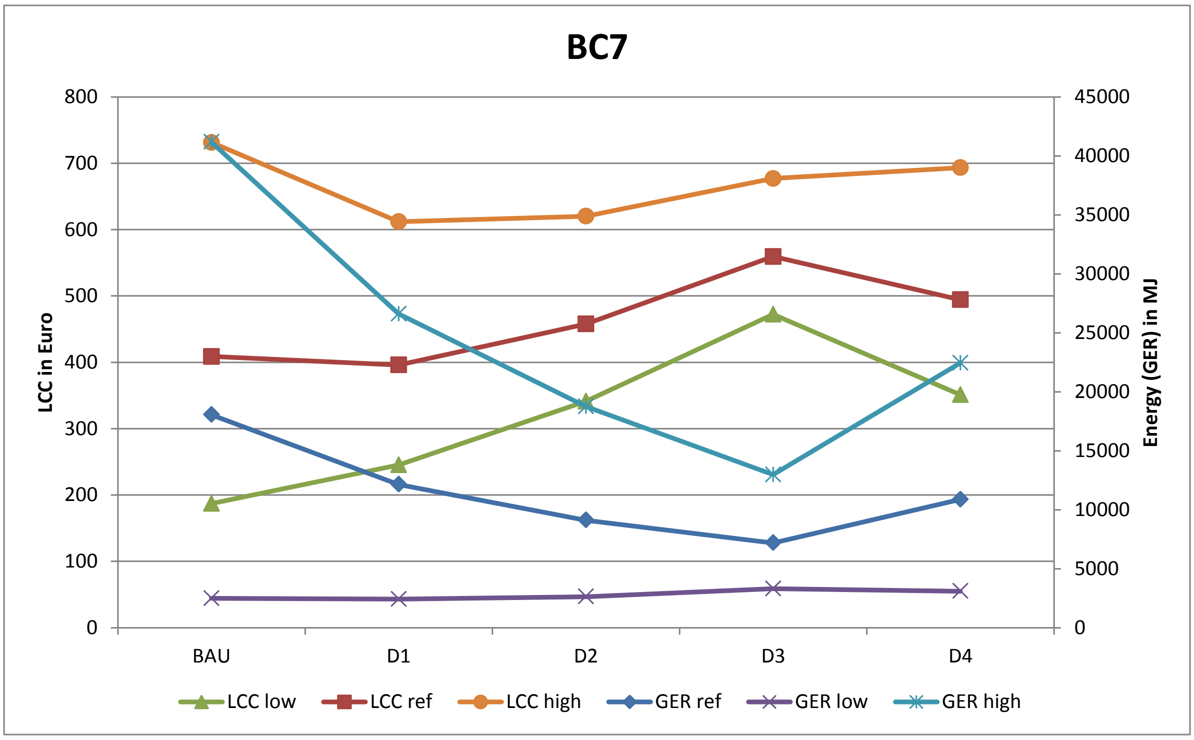


Figure 6-19 BC7 sensitivity to low, reference and high values

Table 6-36: Sensitivity data BC8

	Base Case Id		BC8		
		Unit	Low	Ref	High
BAU	Total Energy (GER)	Unit	297231	1940005	2992389
D1	Total Energy (GER)	0	213416	1363358	2100027
D2	Total Energy (GER)	0	160498	981885	1508077
D3	Total Energy (GER)	0	128426	733658	1121378
D4	Total Energy (GER)	MJ	161812	983199	1509390
BAU	LCC	€	5104	26262	39869
D1	LCC	€	4470	19290	28840
D2	LCC	€	4421	15037	21946
D3	LCC	€	4777	12647	17871
D4	LCC	0	4643	15257	22161

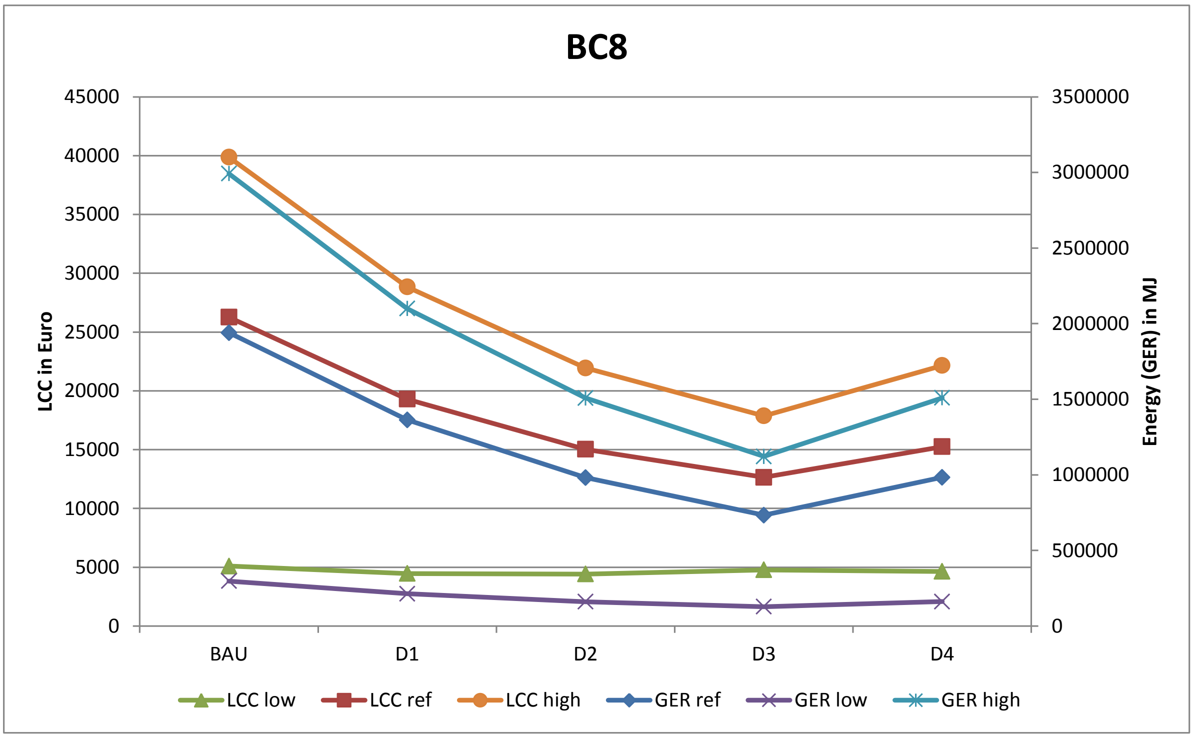


Figure 6-20 BC8 sensitivity to low, reference and high values

Table 6-37: Sensitivity data BC9

	Base Case Id		BC9		
		Unit	Low	Ref	High
BAU	Total Energy (GER)	Unit	241544	1544943	2379918
D1	Total Energy (GER)	0	184134	1144533	1759778
D2	Total Energy (GER)	0	153735	914050	1401119
D3	Total Energy (GER)	0	130838	739090	1128745
D4	Total Energy (GER)	MJ	139796	791495	1208982
BAU	LCC	€	4694	21512	32391
D1	LCC	€	4479	16917	25066
D2	LCC	€	4579	14464	21021
D3	LCC	€	4863	12797	18118
D4	LCC	0	4974	13455	19100

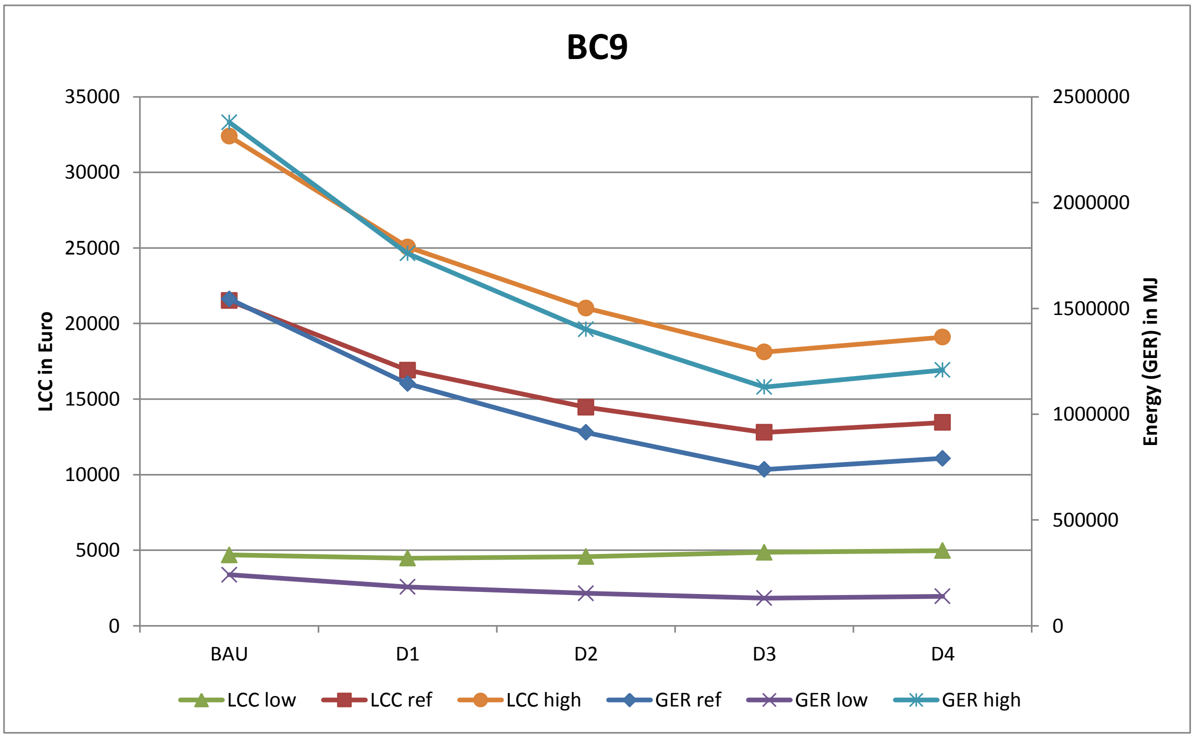


Figure 6-21 BC9 sensitivity to low, reference and high values

Conclusion:

Table 6-38 summarizes the BAT and LLCC sensitivity to the loading of the circuit in terms of design options shifts. In case of BAT there is no shift in design option for BC1, BC4, BC5, BC8 and BC9. However for BC2, BC3, BC6 and BC7 being the lighting and socket-outlet circuits and having a lower overall load, it is more difficult to compensate the extra energy needed at production by the energy gains during the use phase.

A lower load means it is more difficult to compensate the investment costs by the gains made during the use phase due to the lesser electricity consumption. A higher load is favourable for the LCC of more costly design options, as to be expected.
One can notice also that for circuits having a low load in general, the BAU solution is the best option.
Even for circuits having a high load, like BC1, a lower load can cause the LLCC to shift from D3 to BAU.

Table 6-38: design option sensitivity to circuit use (load)

	BAT - load sensitivity			LLCC - load sensitivity		
	low	ref	high	low	ref	high
BC1	D3	D3	D3	BAU	D3	D3
BC2	D2	D3	D3	BAU	BAU	D1
BC3	BAU	D3	D3	BAU	BAU	BAU
BC4	D3	D3	D3	D1	D3	D3
BC5	D3	D3	D3	BAU	D2	D4
BC6	D2	D3	D3	BAU	D1	D1
BC7	D1	D3	D3	BAU	D1	D1
BC8	D3	D3	D3	D2	D3	D3
BC9	D3	D3	D3	D1	D3	D3

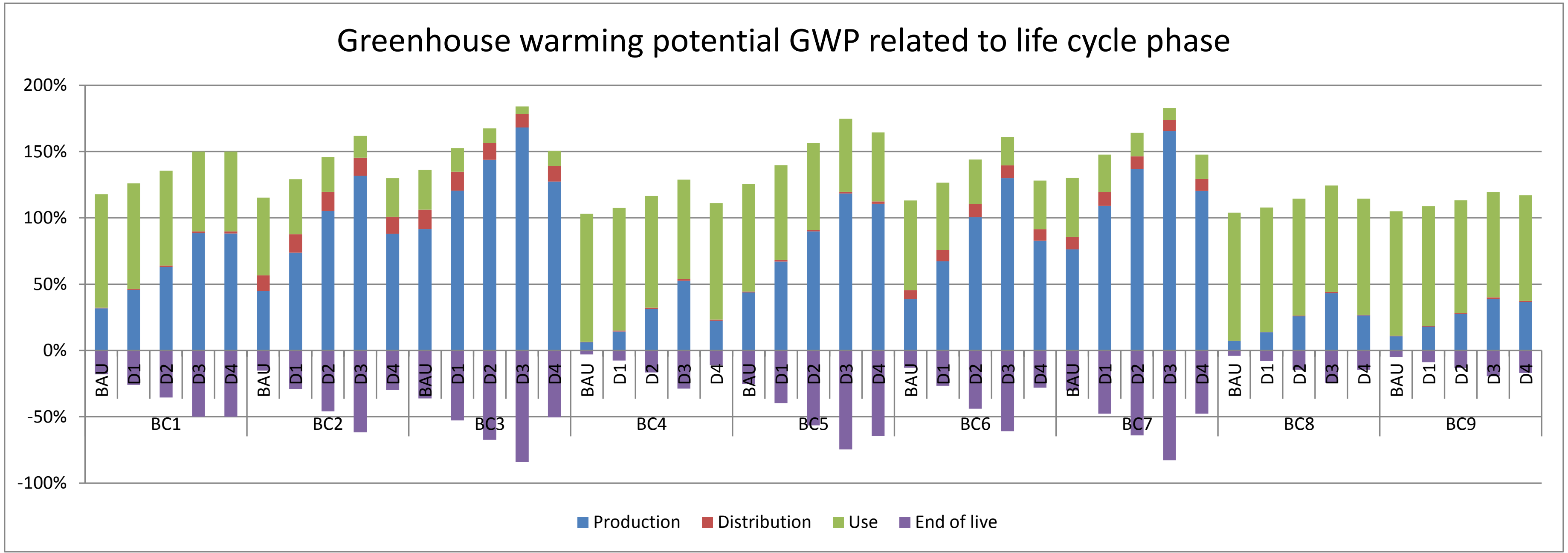


Figure 6-22 Greenhouse Gases (in detail, relative of each phase to total) in GWP100 for the 'low values'

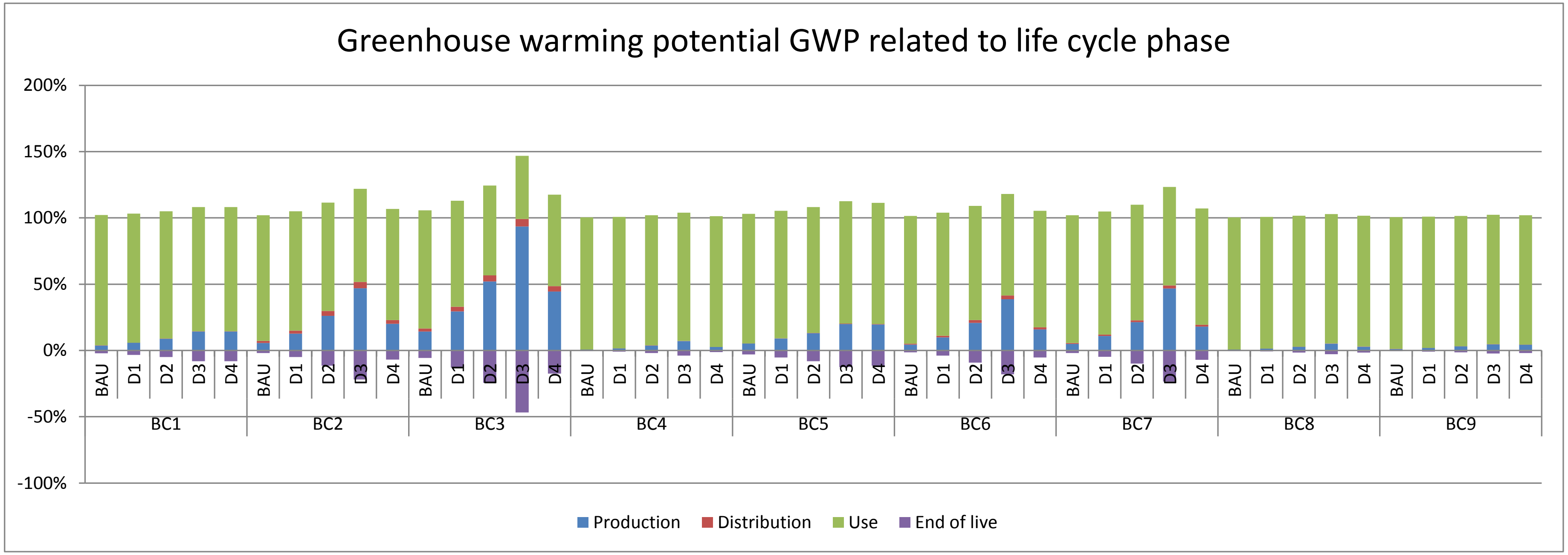


Figure 6-23 Greenhouse Gases (in detail, relative of each phase to total) in GWP100 for the 'high values'

6.6.2 Sensitivity to length of the circuits

This section analyses the impact from the circuit length parameter. Longer circuits mean more energy needed for production and transport.

The circuit length will have an impact on the LCC during all phase of the product life.

Table 6-39: Sensitivity data BC1

	Base Case Id		BC1				
		Unit	Low length (LL)	Ref	High length (HL)	Low length compared to ref	High length compared to ref
BAU	Total Energy (GER)	Unit	648978	1825051	6488787	-64%	+256%
D1	Total Energy (GER)	0.00	525372	1477409	5252729	-64%	+256%
D2	Total Energy (GER)	0.00	433779	1219803	4336795	-64%	+256%
D3	Total Energy (GER)	0.00	345541	971634	3454417	-64%	+256%
D4	Total Energy (GER)	MJ	345677	972016	3455774	-64%	+256%
BAU	LCC	€	10628	29170	102699	-64%	+252%
D1	LCC	€	9507	25976	91285	-63%	+251%
D2	LCC	€	8910	24167	84668	-63%	+250%
D3	LCC	€	8636	23328	81587	-63%	+250%
D4	LCC	€	9006	23887	82897	-62%	+247%
GER	D1 compared to BAU		-19%	-19%	-19%		
	D2 compared to BAU		-33%	-33%	-33%		
	D3 compared to BAU		-47%	-47%	-47%		
	D4 compared to BAU		-47%	-47%	-47%		
LCC	D1 compared to BAU		-11%	-11%	-11%		
	D2 compared to BAU		-16%	-17%	-18%		
	D3 compared to BAU		-19%	-20%	-21%		
	D4 compared to BAU		-15%	-18%	-19%		

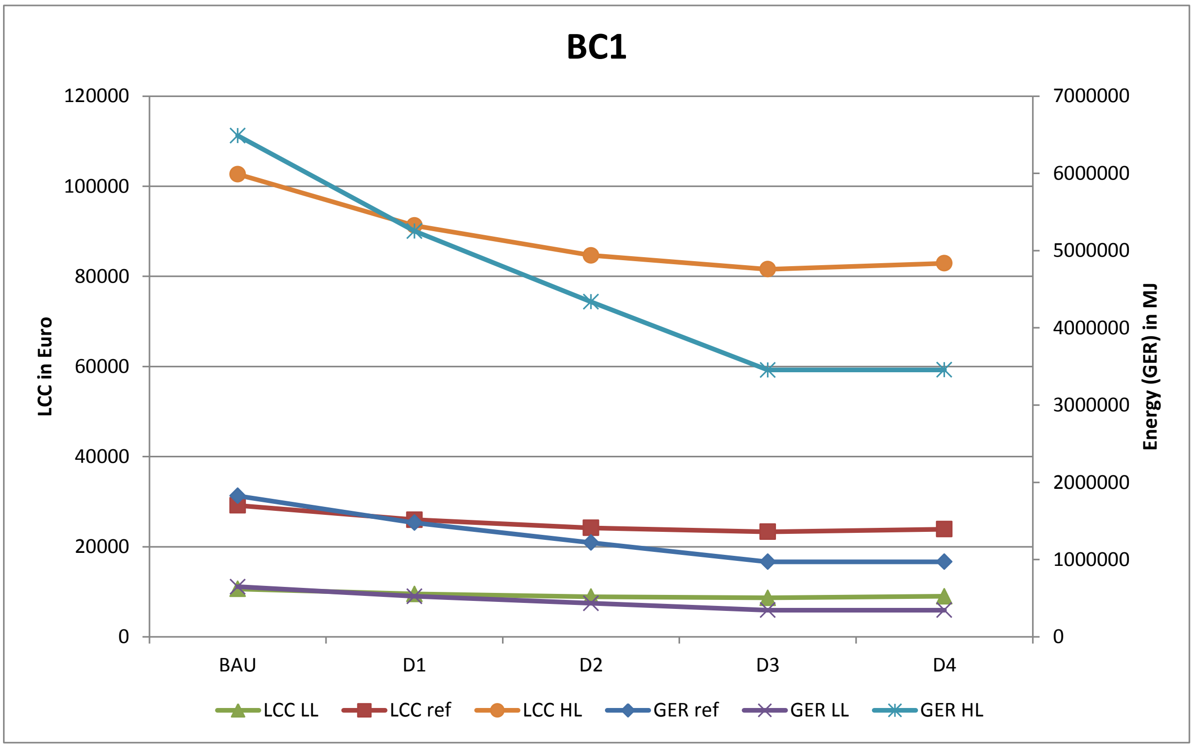


Figure 6-24 BC1 sensitivity to length of circuit

Table 6-40: Sensitivity data BC2

	Base Case Id		BC2				
		Unit	Low length (LL)	Ref	High length (HL)	Low length compared to ref	High length compared to ref
BAU	Total Energy (GER)	Unit	2062	7192	39133	-71%	+444%
D1	Total Energy (GER)	0	1386	4739	25617	-71%	+441%
D2	Total Energy (GER)	0	1045	3503	18805	-70%	+437%
D3	Total Energy (GER)	0	897	2965	15838	-70%	+434%
D4	Total Energy (GER)	MJ	1323	4513	24369	-71%	+440%
BAU	LCC	€	108	216	887	-50%	+311%
D1	LCC	€	117	221	868	-47%	+293%
D2	LCC	€	136	253	981	-46%	+287%
D3	LCC	€	175	325	1260	-46%	+287%
D4	LCC	€	182	307	1082	-41%	+253%
GER	D1 compared to BAU		-33%	-34%	-35%		
	D2 compared to BAU		-49%	-51%	-52%		
	D3 compared to BAU		-56%	-59%	-60%		
	D4 compared to BAU		-36%	-37%	-38%		
LCC	D1 compared to BAU		+8%	+2%	-2%		
	D2 compared to BAU		+26%	+17%	+11%		
	D3 compared to BAU		+62%	+51%	+42%		
	D4 compared to BAU		+68%	+42%	+22%		

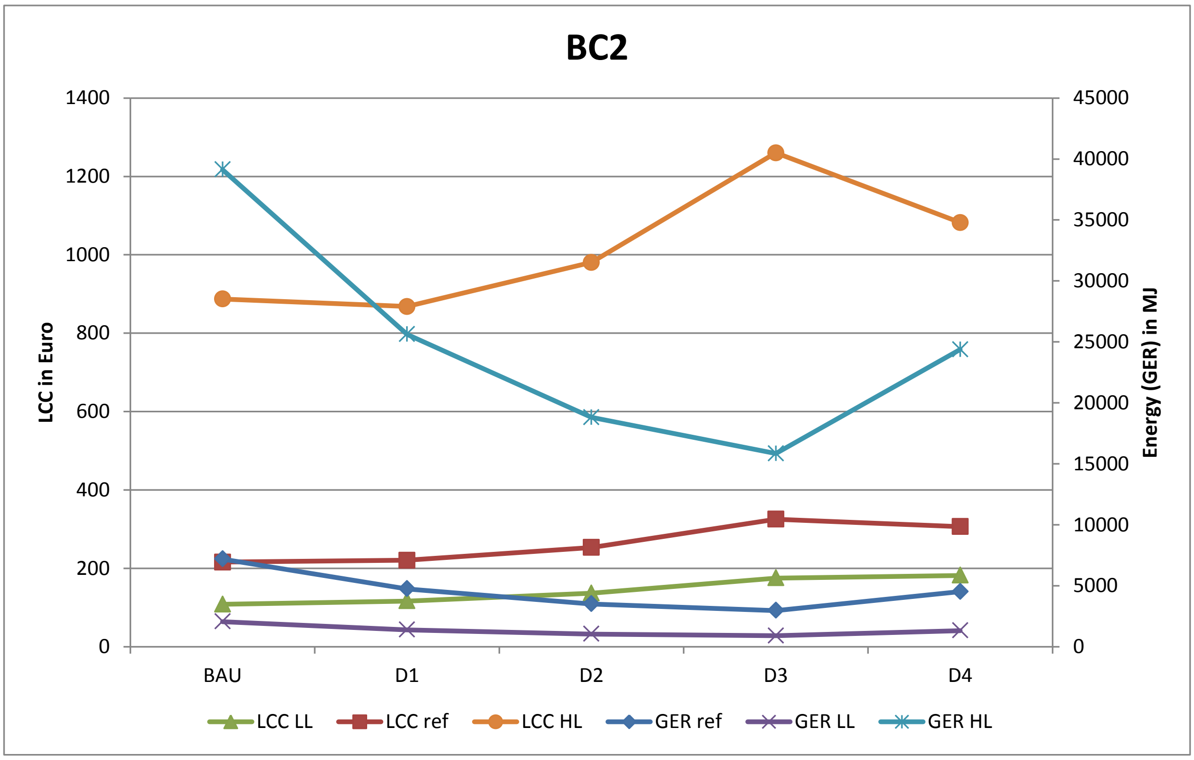


Figure 6-25 BC2 sensitivity to length of circuit

Table 6-41: Sensitivity data BC3

	Base Case Id		BC3				
		Unit	Low length (LL)	Ref	High length (HL)	Low length compared to ref	High length compared to ref
BAU	Total Energy (GER)	Unit	1152	5608	31359	-79%	+459%
D1	Total Energy (GER)	0	876	4152	23082	-79%	+456%
D2	Total Energy (GER)	0	757	3523	19506	-79%	+454%
D3	Total Energy (GER)	0	732	3388	18742	-78%	+453%
D4	Total Energy (GER)	MJ	881	4176	23219	-79%	+456%
BAU	LCC	€	87	226	1034	-62%	+357%
D1	LCC	€	101	259	1170	-61%	+352%
D2	LCC	€	130	333	1507	-61%	+352%
D3	LCC	€	157	429	2003	-64%	+367%
D4	LCC	€	156	364	1562	-57%	+330%
GER	D1 compared to BAU		-24%	-26%	-26%		
	D2 compared to BAU		-34%	-37%	-38%		
	D3 compared to BAU		-37%	-40%	-40%		
	D4 compared to BAU		-24%	-26%	-26%		
LCC	D1 compared to BAU		+17%	+14%	+13%		
	D2 compared to BAU		+50%	+47%	+46%		
	D3 compared to BAU		+81%	+89%	+94%		
	D4 compared to BAU		+80%	+61%	+51%		

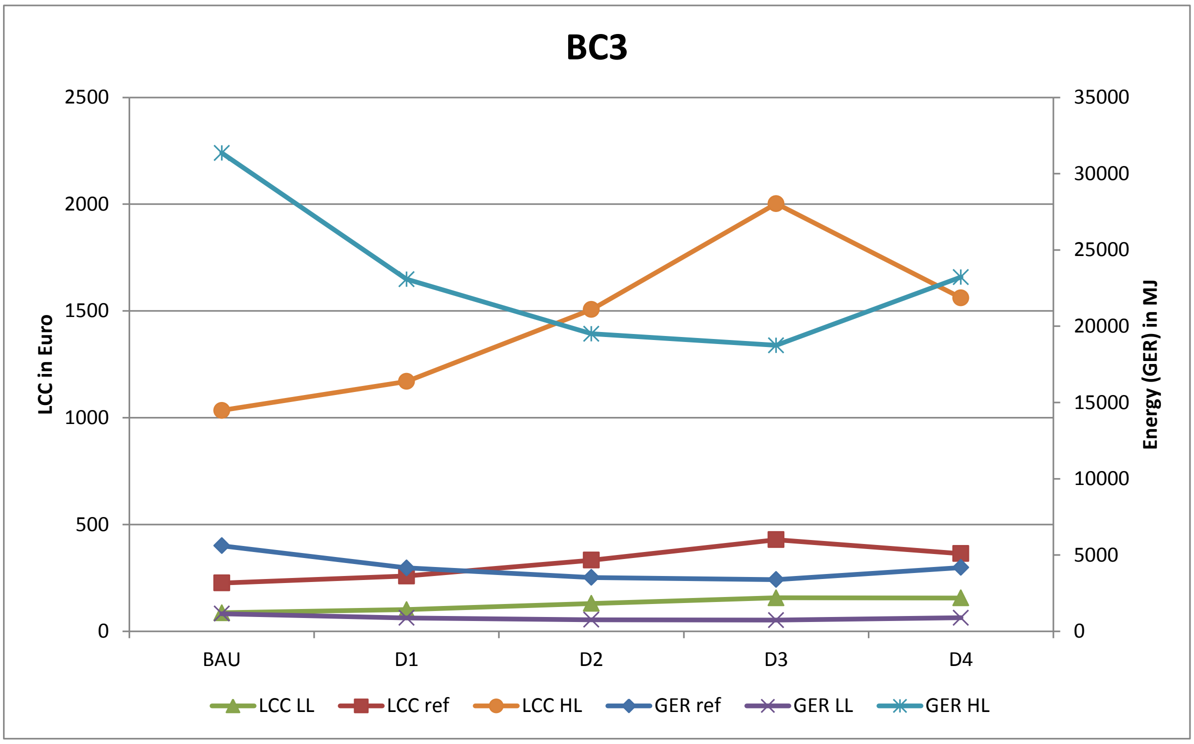


Figure 6-26 BC3 sensitivity to length of circuit

Table 6-42: Sensitivity data BC4

	Base Case Id		BC4				
		Unit	Low length (LL)	Ref	High length (HL)	Low length compared to ref	High length compared to ref
BAU	Total Energy (GER)	Unit	88541	447175	2653018	-80%	+493%
D1	Total Energy (GER)	0	55698	281138	1667745	-80%	+493%
D2	Total Energy (GER)	0	36172	182422	1081962	-80%	+493%
D3	Total Energy (GER)	0	26377	132904	788116	-80%	+493%
D4	Total Energy (GER)	MJ	44929	226693	1344665	-80%	+493%
BAU	LCC	€	1226	6065	35833	-80%	+491%
D1	LCC	€	834	4062	23912	-79%	+489%
D2	LCC	€	622	2984	17508	-79%	+487%
D3	LCC	€	568	2577	14934	-78%	+480%
D4	LCC	€	752	3542	20703	-79%	+484%
GER	D1 compared to BAU		-37%	-37%	-37%		
	D2 compared to BAU		-59%	-59%	-59%		
	D3 compared to BAU		-70%	-70%	-70%		
	D4 compared to BAU		-49%	-49%	-49%		
LCC	D1 compared to BAU		-32%	-33%	-33%		
	D2 compared to BAU		-49%	-51%	-51%		
	D3 compared to BAU		-54%	-58%	-58%		
	D4 compared to BAU		-39%	-42%	-42%		

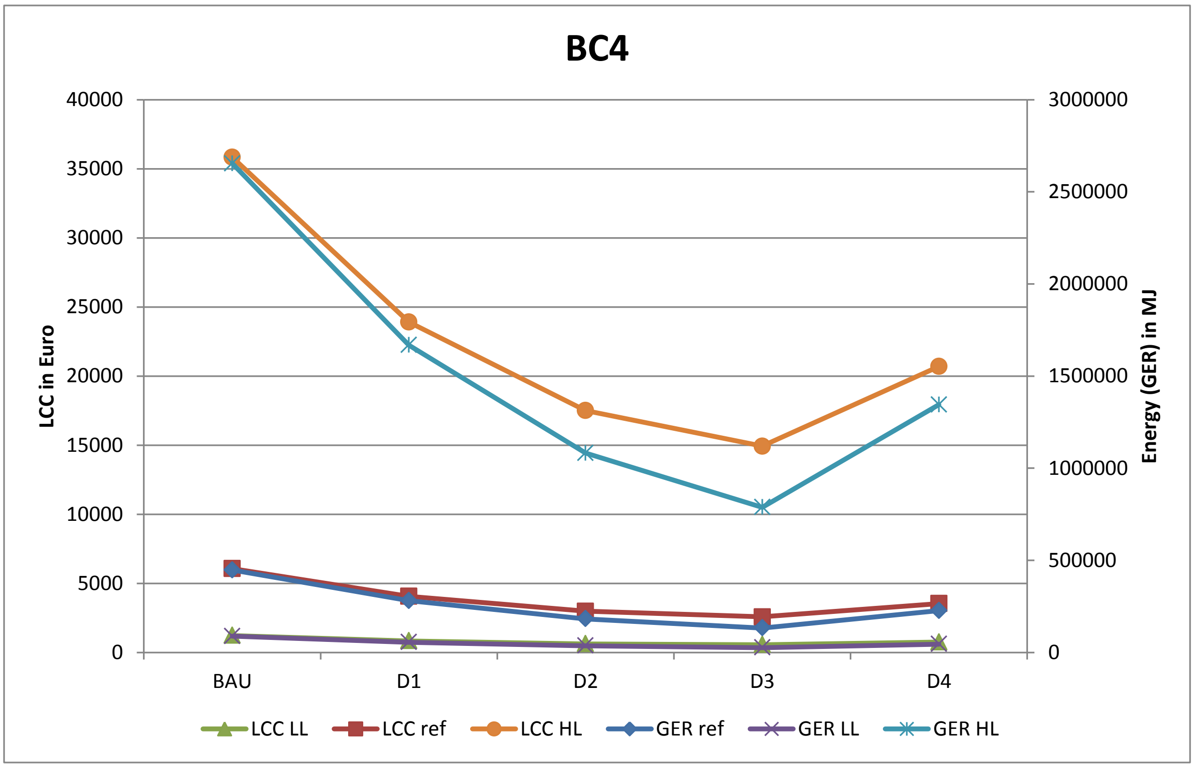


Figure 6-27 BC4 sensitivity to length of circuit

Table 6-43: Sensitivity data BC5

	Base Case Id		BC5				
		Unit	Low length (LL)	Ref	High length (HL)	Low length compared to ref	High length compared to ref
BAU	Total Energy (GER)	Unit	2688186	7392317	21504712	-64%	+191%
D1	Total Energy (GER)	0	2058254	5660006	16465262	-64%	+191%
D2	Total Energy (GER)	0	1674760	4605397	13397309	-64%	+191%
D3	Total Energy (GER)	0	1378733	3791321	11029087	-64%	+191%
D4	Total Energy (GER)	MJ	1462464	4021582	11698937	-64%	+191%
BAU	LCC	€	46958	127094	367504	-63%	+189%
D1	LCC	€	42939	115154	331798	-63%	+188%
D2	LCC	€	42777	113611	326113	-62%	+187%
D3	LCC	€	44628	117253	335129	-62%	+186%
D4	LCC	€	43562	115717	332184	-62%	+187%
GER	D1 compared to BAU		-23%	-23%	-23%		
	D2 compared to BAU		-38%	-38%	-38%		
	D3 compared to BAU		-49%	-49%	-49%		
	D4 compared to BAU		-46%	-46%	-46%		
LCC	D1 compared to BAU		-9%	-9%	-10%		
	D2 compared to BAU		-9%	-11%	-11%		
	D3 compared to BAU		-5%	-8%	-9%		
	D4 compared to BAU		-7%	-9%	-10%		

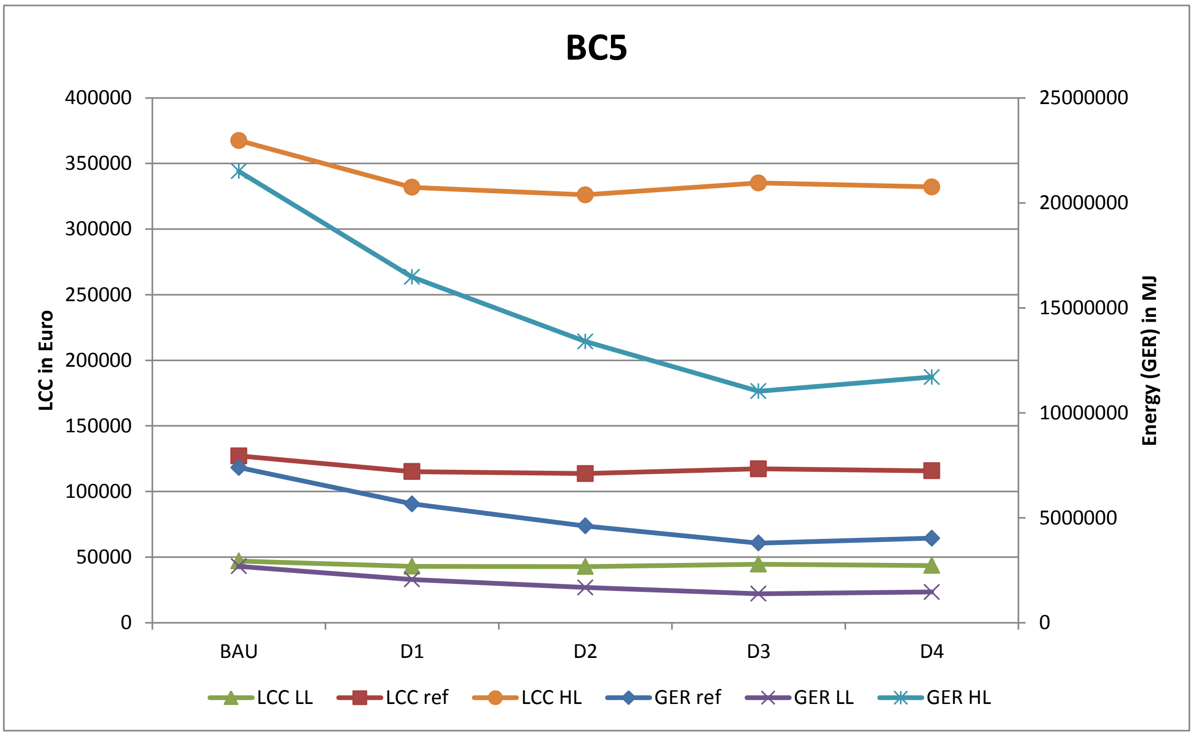


Figure 6-28 BC5 sensitivity to length of circuit

Table 6-44: Sensitivity data BC6

	Base Case Id		BC6				
		Unit	Low length (LL)	Ref	High length (HL)	Low length compared to ref	High length compared to ref
BAU	Total Energy (GER)	Unit	2688186	14414	72157	18550%	+401%
D1	Total Energy (GER)	0	2058254	9281	46303	22077%	+399%
D2	Total Energy (GER)	0	1674760	6617	32882	25212%	+397%
D3	Total Energy (GER)	0	1378733	5366	26583	25594%	+395%
D4	Total Energy (GER)	MJ	1462464	8597	42859	16911%	+399%
BAU	LCC	€	46958	351	1455	13287%	+315%
D1	LCC	€	42939	337	1338	12649%	+297%
D2	LCC	€	42777	372	1446	11408%	+289%
D3	LCC	€	44628	468	1808	9441%	+286%
D4	LCC	€	43562	443	1605	9740%	+263%
GER	D1 compared to BAU		-23%	-36%	-36%		
	D2 compared to BAU		-38%	-54%	-54%		
	D3 compared to BAU		-49%	-63%	-63%		
	D4 compared to BAU		-46%	-40%	-41%		
LCC	D1 compared to BAU		-9%	-4%	-8%		
	D2 compared to BAU		-9%	+6%	-1%		
	D3 compared to BAU		-5%	+33%	+24%		
	D4 compared to BAU		-7%	+26%	+10%		

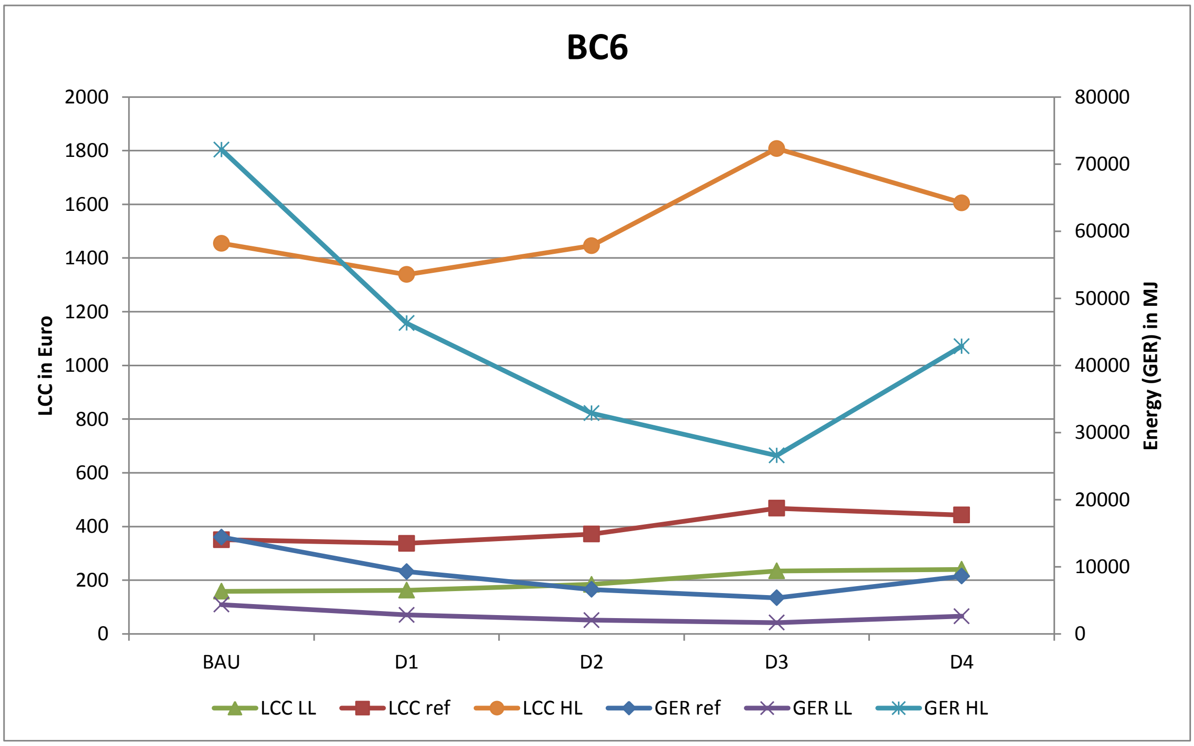


Figure 6-29 BC6 sensitivity to length of circuit

Table 6-45: Sensitivity data BC7

	Base Case Id		BC7				
		Unit	Low length (LL)	Ref	High length (HL)	Low length compared to ref	High length compared to ref
BAU	Total Energy (GER)	Unit	3848	18050	124692	-79%	+591%
D1	Total Energy (GER)	0	2618	12149	83711	-78%	+589%
D2	Total Energy (GER)	0	1986	9115	62645	-78%	+587%
D3	Total Energy (GER)	0	1586	7192	49289	-78%	+585%
D4	Total Energy (GER)	MJ	2353	10877	74876	-78%	+588%
BAU	LCC	€	116	409	2606	-72%	+538%
D1	LCC	€	119	396	2473	-70%	+524%
D2	LCC	€	143	458	2822	-69%	+517%
D3	LCC	€	170	559	3484	-70%	+523%
D4	LCC	€	165	494	2968	-67%	+500%
GER	D1 compared to BAU		-32%	-33%	-33%		
	D2 compared to BAU		-48%	-49%	-50%		
	D3 compared to BAU		-59%	-60%	-60%		
	D4 compared to BAU		-39%	-40%	-40%		
LCC	D1 compared to BAU		+3%	-3%	-5%		
	D2 compared to BAU		+23%	+12%	+8%		
	D3 compared to BAU		+46%	+37%	+34%		
	D4 compared to BAU		+42%	+21%	+14%		

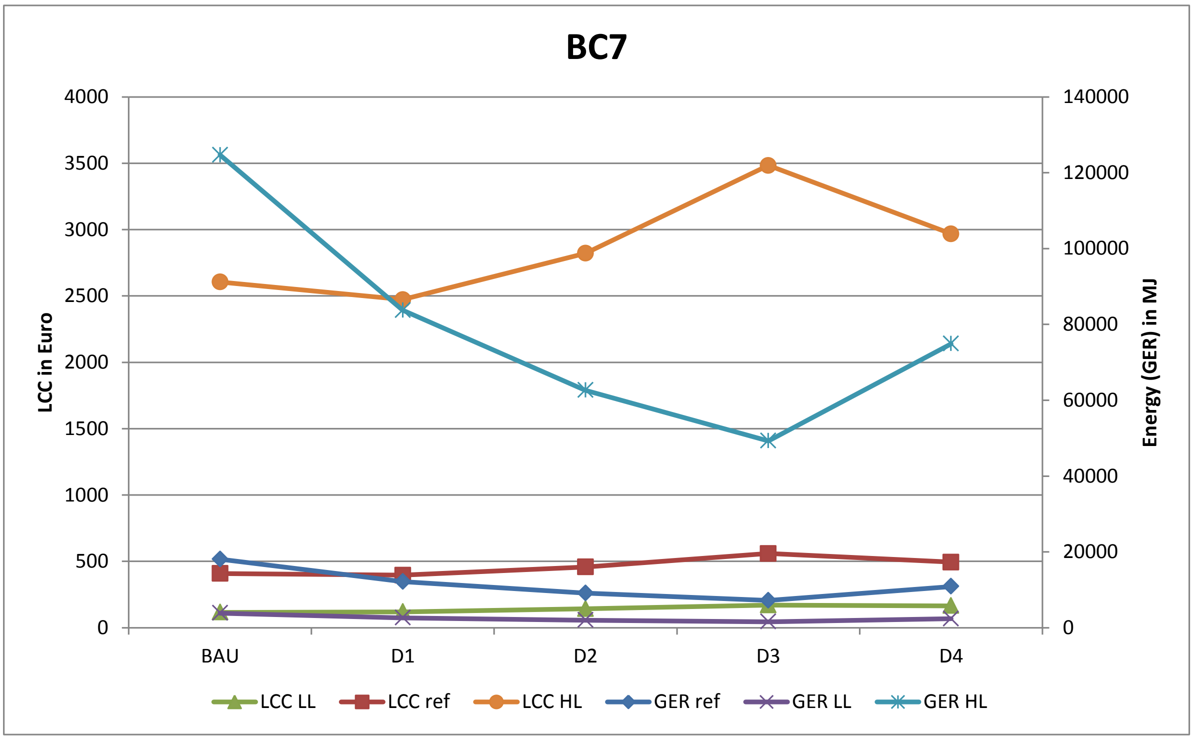


Figure 6-30 BC7 sensitivity to length of circuit

Table 6-46: Sensitivity data BC8

	Base Case Id		BC8				
		Unit	Low length (LL)	Ref	High length (HL)	Low length compared to ref	High length compared to ref
BAU	Total Energy (GER)	Unit	370791	1940005	9884923	-81%	+410%
D1	Total Energy (GER)	0	260604	1363358	6946595	-81%	+410%
D2	Total Energy (GER)	0	187711	981885	5002782	-81%	+410%
D3	Total Energy (GER)	0	140279	733658	3737933	-81%	+409%
D4	Total Energy (GER)	MJ	187962	983199	5009477	-81%	+410%
BAU	LCC	€	5074	26262	133539	-81%	+408%
D1	LCC	€	3746	19290	97988	-81%	+408%
D2	LCC	€	2989	15037	76037	-80%	+406%
D3	LCC	€	2613	12647	63447	-79%	+402%
D4	LCC	€	3027	15257	77181	-80%	+406%
GER	D1 compared to BAU		-30%	-30%	-30%		
	D2 compared to BAU		-49%	-49%	-49%		
	D3 compared to BAU		-62%	-62%	-62%		
	D4 compared to BAU		-49%	-49%	-49%		
LCC	D1 compared to BAU		-26%	-27%	-27%		
	D2 compared to BAU		-41%	-43%	-43%		
	D3 compared to BAU		-48%	-52%	-52%		
	D4 compared to BAU		-40%	-42%	-42%		

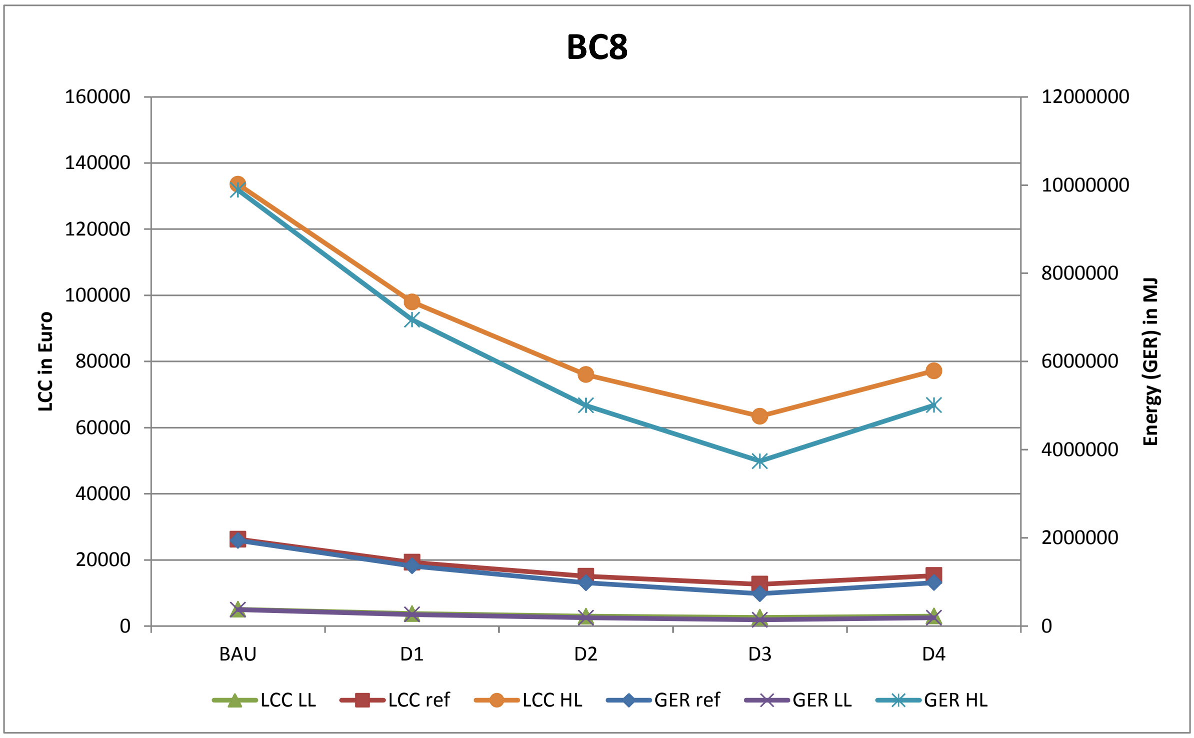


Figure 6-31 BC8 sensitivity to length of circuit

Table 6-47: Sensitivity data BC9

	Base Case Id		BC9				
		Unit	Low length (LL)	Ref	High length (HL)	Low length compared to ref	High length compared to ref
BAU	Total Energy (GER)	Unit	295301	1544943	7871869	-81%	+410%
D1	Total Energy (GER)	0	218790	1144533	5831562	-81%	+410%
D2	Total Energy (GER)	0	174749	914050	4657130	-81%	+410%
D3	Total Energy (GER)	0	141317	739090	3765614	-81%	+409%
D4	Total Energy (GER)	MJ	151330	791495	4032642	-81%	+409%
BAU	LCC	€	4225	21512	109035	-80%	+407%
D1	LCC	€	3427	16917	85217	-80%	+404%
D2	LCC	€	3007	14464	72471	-79%	+401%
D3	LCC	€	2701	12797	63914	-79%	+399%
D4	LCC	€	2800	13455	67403	-79%	+401%
GER	D1 compared to BAU		-26%	-26%	-26%		
	D2 compared to BAU		-41%	-41%	-41%		
	D3 compared to BAU		-52%	-52%	-52%		
	D4 compared to BAU		-49%	-49%	-49%		
LCC	D1 compared to BAU		-19%	-21%	-22%		
	D2 compared to BAU		-29%	-33%	-34%		
	D3 compared to BAU		-36%	-41%	-41%		
	D4 compared to BAU		-34%	-37%	-38%		

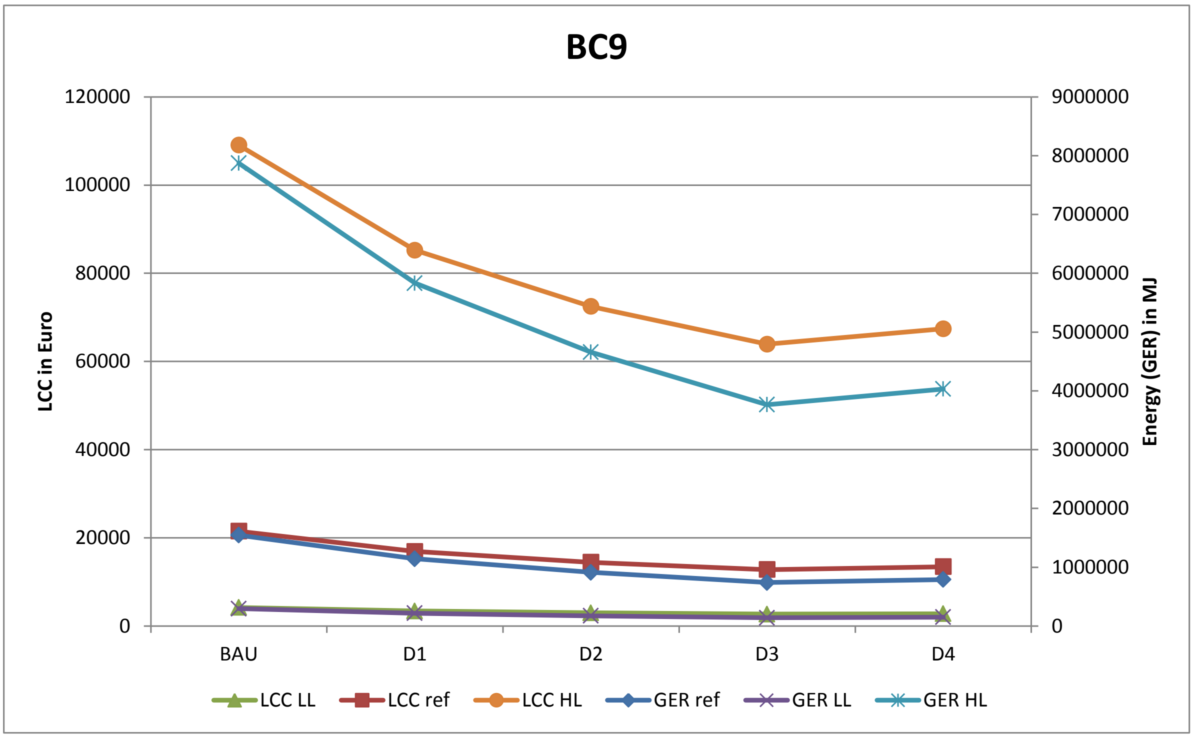


Figure 6-32 BC9 sensitivity to length of circuit

Conclusion:
Table 6-48 summarizes the sensitivity to length of the circuit in terms of design options shifts. In case of BAT, there is no shift in design option to be noticed for all nine base cases. In the graphics in section 6.6.2 one can notice that in absolute terms the energy usage increments when increasing the length of the circuits, but also that the differences between the design options get more pronounced.

Regarding the LLCC, one can notice that in case of BC6 and BC7 a higher length justifies a shift from design option BAU to D1. For the other base cases no shift can be justified.

Table 6-48: design option sensitivity to circuit length

	BAT - length sensitivity			LLCC - length sensitivity		
	low	ref	high	low	ref	high
BC1	D3	D3	D3	D3	D3	D3
BC2	D3	D3	D3	BAU	BAU	D1
BC3	D3	D3	D3	BAU	BAU	BAU
BC4	D3	D3	D3	D3	D3	D3
BC5	D3	D3	D3	D2	D2	D2
BC6	D3	D3	D3	BAU	D1	D1
BC7	D3	D3	D3	BAU	D1	D1
BC8	D3	D3	D3	D3	D3	D3
BC9	D3	D3	D3	D3	D3	D3

6.6.3 Sensitivity to product lifetime

The basic calculation assumes a circuit product life according the reference values for product life per sector mentioned in Task 3. In order to assess the sensitivity of results compared to circuits with a lower or higher lifetime, the calculations are repeated for a low product lifetime and high product lifetime (see Table 3-16, copied from Task 3).

Table 6-49: Life time parameters per sector

	short product life		Reference		long product life	
Sector	Replace-ment rate	Product life	Replace-ment rate	Product life	Replace-ment rate	Product life
Unit	%	year	%	year	%	year
Residential sector	2.10%	40	1.18%	64	0.80%	84
Services sector	7.08%	13	3.20%	25	1.70%	40
Industry sector	7.08%	12	2.80%	25	1.37%	40

Table 6-50: Sensitivity data BC1

	Base Case Id		BC1				
		Unit	Low product lifetime (LPL)	Ref	High product lifetime	LPL compared to ref	HPL compared to ref
BAU	Total Energy (GER)	Unit	932392	1825051	2896241	-49%	+59%
D1	Total Energy (GER)	0.00	763283	1477409	2334361	-48%	+58%
D2	Total Energy (GER)	0.00	640781	1219803	1914629	-47%	+57%
D3	Total Energy (GER)	0.00	525305	971634	1507229	-46%	+55%
D4	Total Energy (GER)	MJ	525687	972016	1507611	-46%	+55%
BAU	LCC	€	17278	29170	43238	-41%	+48%
D1	LCC	€	16279	25976	37359	-37%	+44%
D2	LCC	€	16089	24167	33548	-33%	+39%
D3	LCC	€	16769	23328	30792	-28%	+32%
D4	LCC	€	17329	23887	31351	-27%	+31%
GER	D1 compared to BAU		-18%	-19%	-19%		
	D2 compared to BAU		-31%	-33%	-34%		
	D3 compared to BAU		-44%	-47%	-48%		
	D4 compared to BAU		-44%	-47%	-48%		
LCC	D1 compared to BAU		-6%	-11%	-14%		
	D2 compared to BAU		-7%	-17%	-22%		
	D3 compared to BAU		-3%	-20%	-29%		
	D4 compared to BAU		+0%	-18%	-27%		

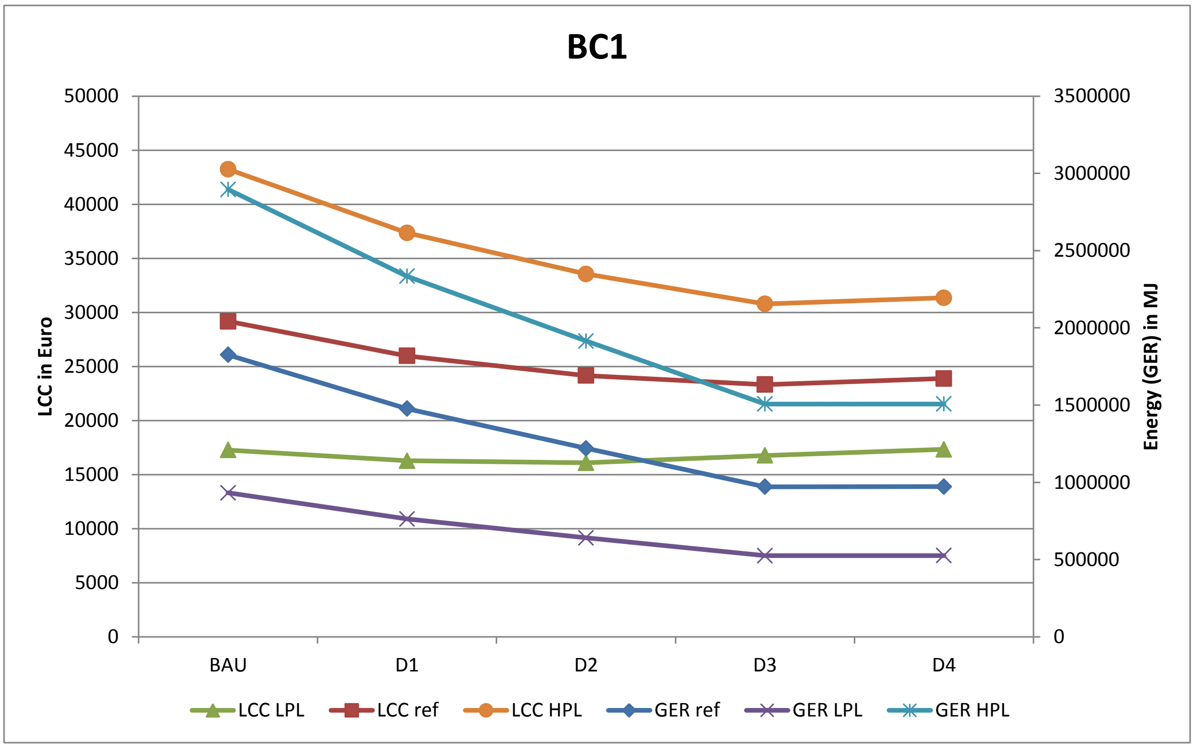


Figure 6-33 BC1 sensitivity to low, reference and high product lifetime

Table 6-51: Sensitivity data BC2

	Base Case Id		BC2				
		Unit	Low product lifetime (LPL)	Ref	High product lifetime	LPL compared to ref	HPL compared to ref
BAU	Total Energy (GER)	Unit	3939	7192	11097	-45%	+54%
D1	Total Energy (GER)	0	2787	4739	7082	-41%	+49%
D2	Total Energy (GER)	0	2283	3503	4967	-35%	+42%
D3	Total Energy (GER)	0	2151	2965	3941	-27%	+33%
D4	Total Energy (GER)	MJ	2886	4513	6465	-36%	+43%
BAU	LCC	€	172	216	268	-20%	+24%
D1	LCC	€	192	221	253	-13%	+15%
D2	LCC	€	232	253	276	-8%	+9%
D3	LCC	€	307	325	343	-6%	+6%
D4	LCC	€	282	307	334	-8%	+9%
GER	D1 compared to BAU		-29%	-34%	-36%		
	D2 compared to BAU		-42%	-51%	-55%		
	D3 compared to BAU		-45%	-59%	-64%		
	D4 compared to BAU		-27%	-37%	-42%		
LCC	D1 compared to BAU		+12%	+2%	-5%		
	D2 compared to BAU		+35%	+17%	+3%		
	D3 compared to BAU		+78%	+51%	+28%		
	D4 compared to BAU		+64%	+42%	+25%		

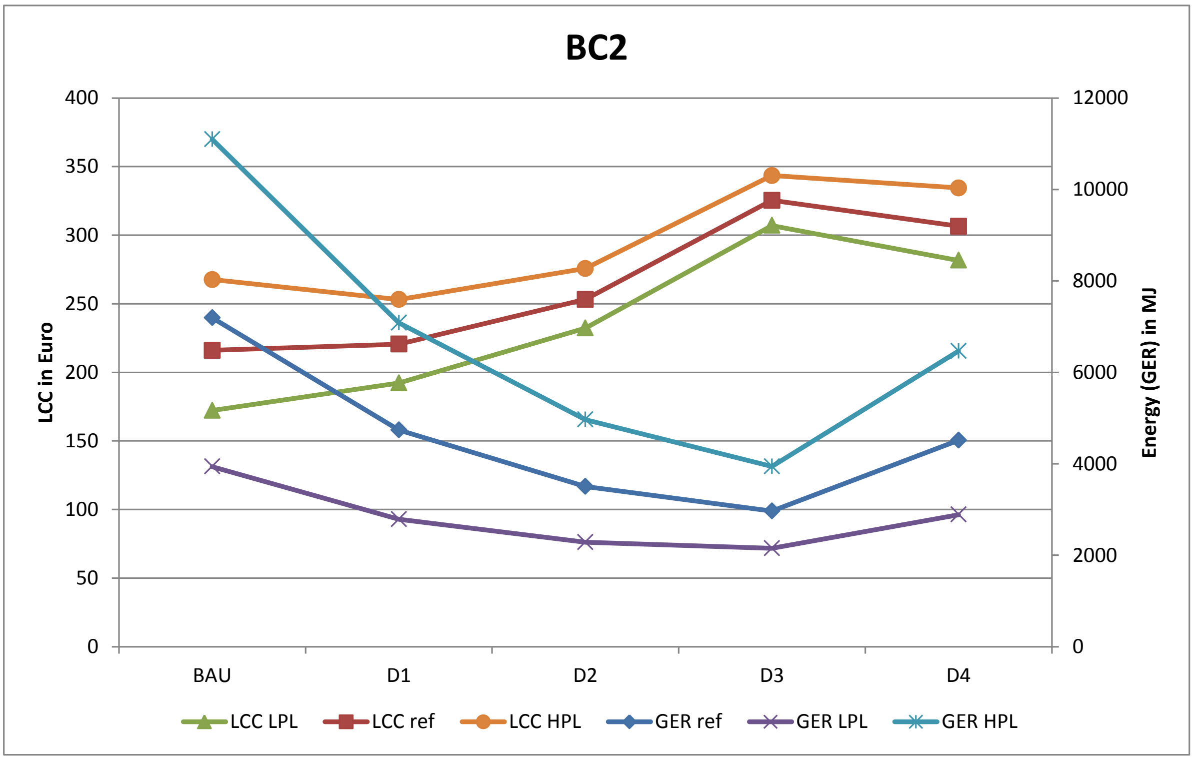


Figure 6-34 BC2 sensitivity to low, reference and high product lifetime

Table 6-52: Sensitivity data BC3

	Base Case Id		BC3				
		Unit	Low product lifetime (LPL)	Ref	High product lifetime (HPL)	LPL compared to ref	HPL compared to ref
BAU	Total Energy (GER)	Unit	3298	5608	8380	-41%	+49%
D1	Total Energy (GER)	0	2708	4152	5884	-35%	+42%
D2	Total Energy (GER)	0	2560	3523	4677	-27%	+33%
D3	Total Energy (GER)	0	2811	3388	4081	-17%	+20%
D4	Total Energy (GER)	MJ	3021	4176	5562	-28%	+33%
BAU	LCC	€	193	226	265	-15%	+17%
D1	LCC	€	234	259	286	-10%	+10%
D2	LCC	€	311	333	355	-7%	+6%
D3	LCC	€	405	429	449	-5%	+5%
D4	LCC	€	341	364	387	-6%	+6%
GER	D1 compared to BAU		-18%	-26%	-30%		
	D2 compared to BAU		-22%	-37%	-44%		
	D3 compared to BAU		-15%	-40%	-51%		
	D4 compared to BAU		-8%	-26%	-34%		
LCC	D1 compared to BAU		+21%	+14%	+8%		
	D2 compared to BAU		+62%	+47%	+34%		
	D3 compared to BAU		+110%	+89%	+70%		
	D4 compared to BAU		+77%	+61%	+46%		

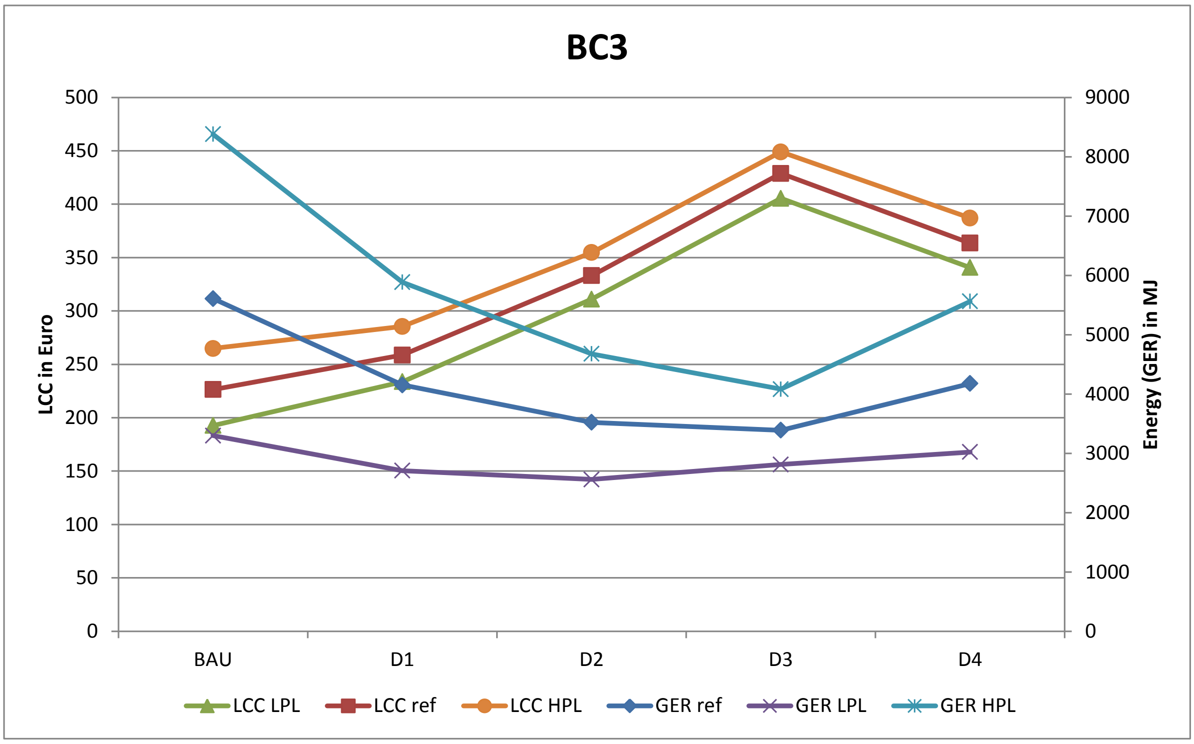


Figure 6-35 BC3 sensitivity to low, reference and high product lifetime

Table 6-53: Sensitivity data BC4

	Base Case Id		BC4				
		Unit	Low product lifetime (LPL)	Ref	High product lifetime (HPL)	LPL compared to ref	HPL compared to ref
BAU	Total Energy (GER)	Unit	224659	447175	714193	-50%	+60%
D1	Total Energy (GER)	0	142066	281138	448024	-49%	+59%
D2	Total Energy (GER)	0	93416	182422	289230	-49%	+59%
D3	Total Energy (GER)	0	69328	132904	209195	-48%	+57%
D4	Total Energy (GER)	MJ	115435	226693	360202	-49%	+59%
BAU	LCC	€	3187	6065	9511	-47%	+57%
D1	LCC	€	2248	4062	6226	-45%	+53%
D2	LCC	€	1800	2984	4385	-40%	+47%
D3	LCC	€	1705	2577	3596	-34%	+40%
D4	LCC	€	2080	3542	5282	-41%	+49%
GER	D1 compared to BAU		-37%	-37%	-37%		
	D2 compared to BAU		-58%	-59%	-60%		
	D3 compared to BAU		-69%	-70%	-71%		
	D4 compared to BAU		-49%	-49%	-50%		
LCC	D1 compared to BAU		-29%	-33%	-35%		
	D2 compared to BAU		-44%	-51%	-54%		
	D3 compared to BAU		-46%	-58%	-62%		
	D4 compared to BAU		-35%	-42%	-44%		

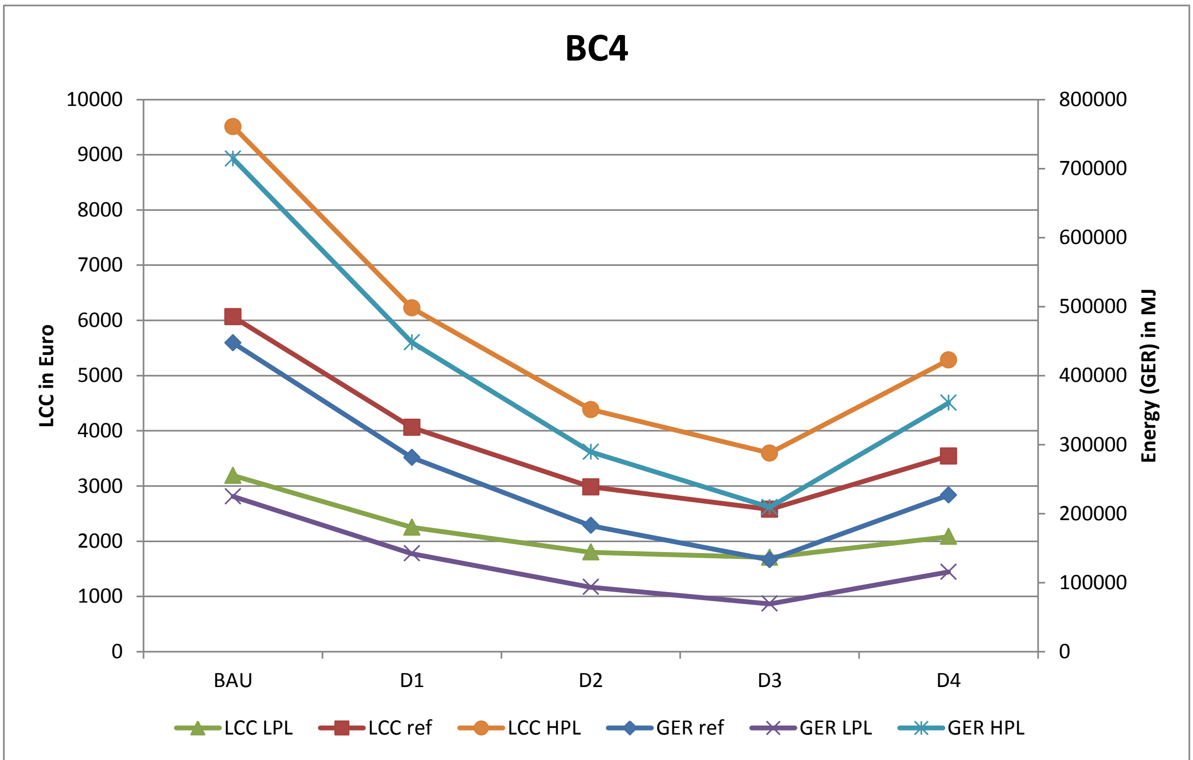


Figure 6-36 BC4 sensitivity to low, reference and high product lifetime

Table 6-54: Sensitivity data BC5

	Base Case Id		BC5				
		Unit	Low product lifetime (LPL)	Ref	High product lifetime (HPL)	LPL compared to ref	HPL compared to ref
BAU	Total Energy (GER)	Unit	3804670	7392317	11697494	-49%	+58%
D1	Total Energy (GER)	0	2969271	5660006	8888889	-48%	+57%
D2	Total Energy (GER)	0	2452809	4605397	7188503	-47%	+56%
D3	Total Energy (GER)	0	2082918	3791321	5841405	-45%	+54%
D4	Total Energy (GER)	MJ	2227759	4021582	6174171	-45%	+54%
BAU	LCC	€	78544	127094	184164	-38%	+45%
D1	LCC	€	77345	115154	158937	-33%	+38%
D2	LCC	€	81929	113611	149647	-28%	+32%
D3	LCC	€	90249	117253	147161	-23%	+26%
D4	LCC	€	87853	115717	146776	-24%	+27%
GER	D1 compared to BAU		-22%	-23%	-24%		
	D2 compared to BAU		-36%	-38%	-39%		
	D3 compared to BAU		-45%	-49%	-50%		
	D4 compared to BAU		-41%	-46%	-47%		
LCC	D1 compared to BAU		-2%	-9%	-14%		
	D2 compared to BAU		+4%	-11%	-19%		
	D3 compared to BAU		+15%	-8%	-20%		
	D4 compared to BAU		+12%	-9%	-20%		

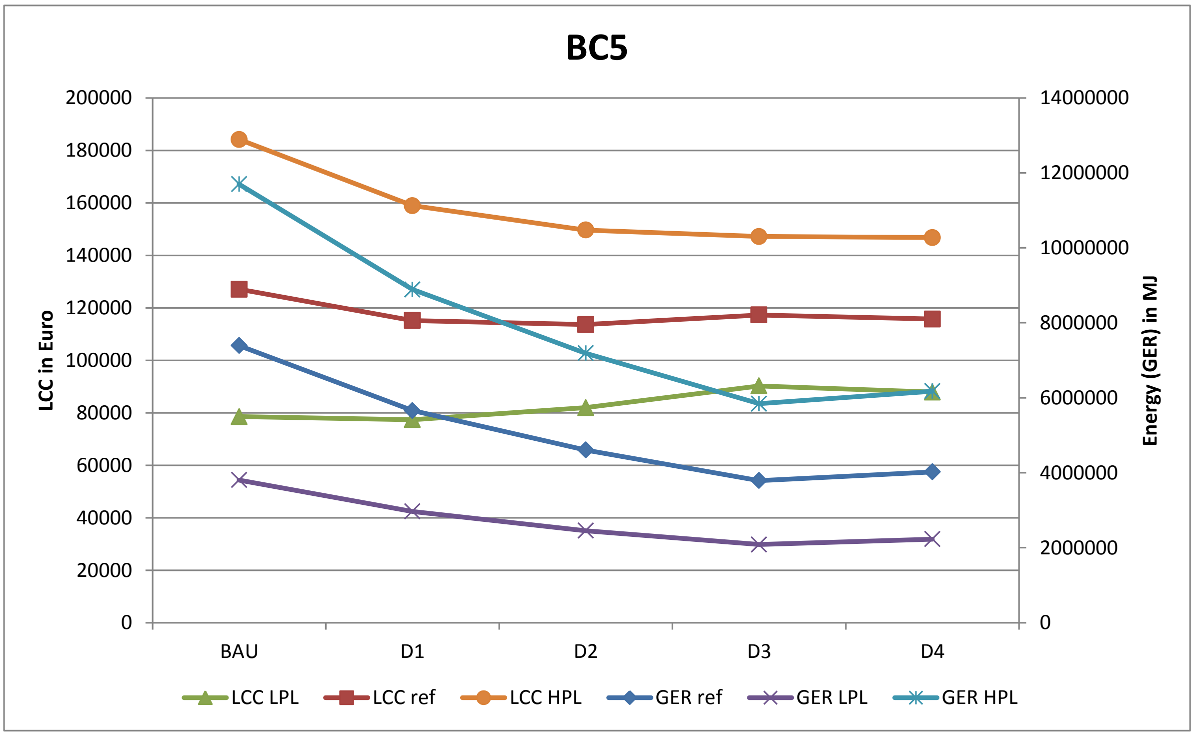


Figure 6-37 BC5 sensitivity to low, reference and high product lifetime

Table 6-55: Sensitivity data BC6

	Base Case Id		BC6				
		Unit	Low product lifetime (LPL)	Ref	High product lifetime (HPL)	LPL compared to ref	HPL compared to ref
BAU	Total Energy (GER)	Unit	3804670	14414	22462	26296%	+56%
D1	Total Energy (GER)	0	2969271	9281	14110	31893%	+52%
D2	Total Energy (GER)	0	2452809	6617	9635	36971%	+46%
D3	Total Energy (GER)	0	2082918	5366	7378	38717%	+37%
D4	Total Energy (GER)	MJ	2227759	8597	12621	25812%	+47%
BAU	LCC	€	78544	351	456	22292%	+30%
D1	LCC	€	77345	337	403	22865%	+20%
D2	LCC	€	81929	372	416	21940%	+12%
D3	LCC	€	90249	468	502	19194%	+7%
D4	LCC	€	87853	443	499	19745%	+13%
GER	D1 compared to BAU		-22%	-36%	-37%		
	D2 compared to BAU		-36%	-54%	-57%		
	D3 compared to BAU		-45%	-63%	-67%		
	D4 compared to BAU		-41%	-40%	-44%		
LCC	D1 compared to BAU		-2%	-4%	-12%		
	D2 compared to BAU		+4%	+6%	-9%		
	D3 compared to BAU		+15%	+33%	+10%		
	D4 compared to BAU		+12%	+26%	+9%		

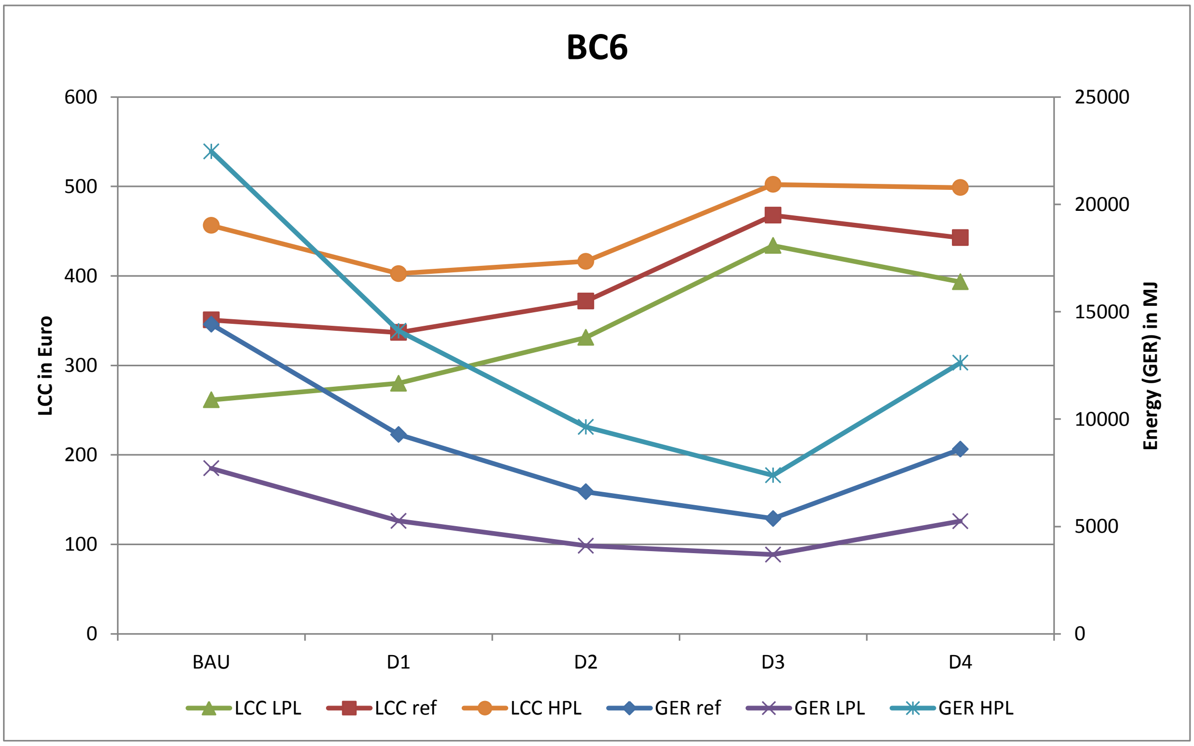


Figure 6-38 BC6 sensitivity to low, reference and high product lifetime

Table 6-56: Sensitivity data BC7

Base Case Id			BC7				
		Unit	Low product lifetime (LPL)	Ref	High product lifetime (HPL)	LPL compared to ref	HPL compared to ref
BAU	Total Energy (GER)	Unit	9679	18050	28096	-46%	+56%
D1	Total Energy (GER)	0	6917	12149	18427	-43%	+52%
D2	Total Energy (GER)	0	5627	9115	13301	-38%	+46%
D3	Total Energy (GER)	0	5099	7192	9703	-29%	+35%
D4	Total Energy (GER)	MJ	6691	10877	15899	-38%	+46%
BAU	LCC	€	296	409	542	-28%	+33%
D1	LCC	€	320	396	483	-19%	+22%
D2	LCC	€	400	458	521	-13%	+14%
D3	LCC	€	511	559	607	-9%	+9%
D4	LCC	€	430	494	567	-13%	+15%
GER	D1 compared to BAU		-29%	-33%	-34%		
	D2 compared to BAU		-42%	-49%	-53%		
	D3 compared to BAU		-47%	-60%	-65%		
	D4 compared to BAU		-31%	-40%	-43%		
LCC	D1 compared to BAU		+8%	-3%	-11%		
	D2 compared to BAU		+35%	+12%	-4%		
	D3 compared to BAU		+73%	+37%	+12%		
	D4 compared to BAU		+45%	+21%	+5%		

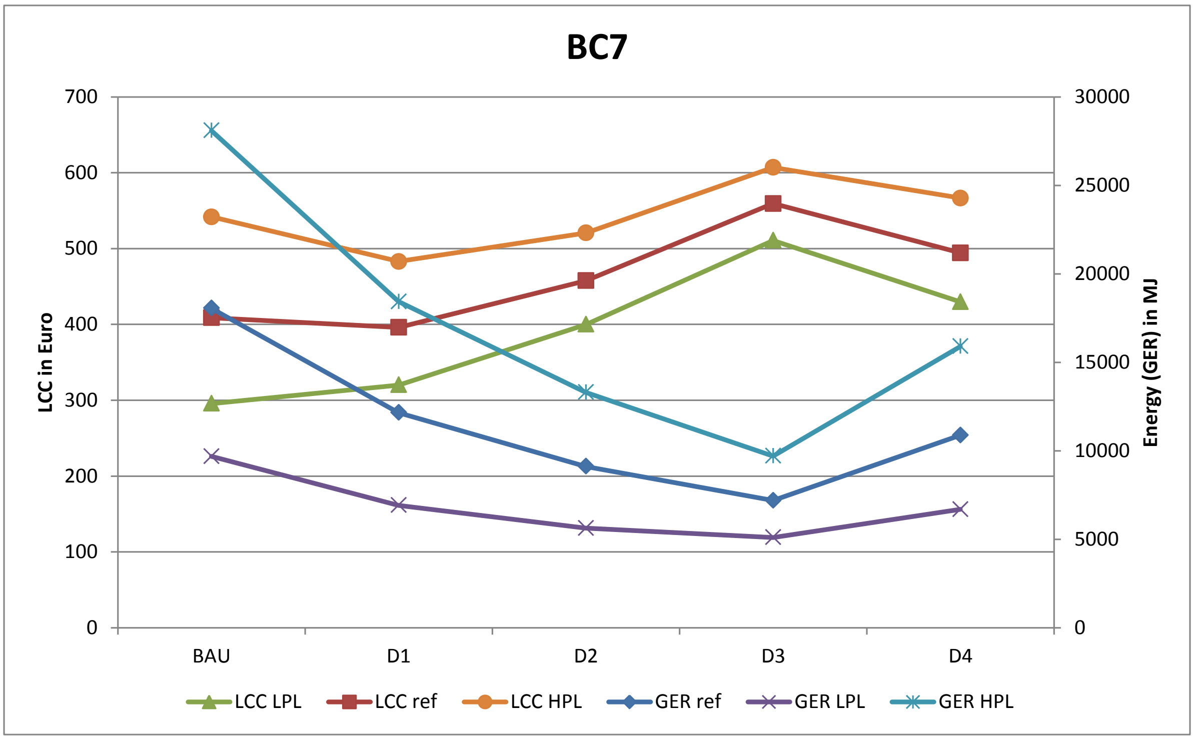


Figure 6-39 BC7 sensitivity to low, reference and high product lifetime

Table 6-57: Sensitivity data BC8

	Base Case Id		BC8				
		Unit	Low product lifetime (LPL)	Ref	High product lifetime (HPL)	LPL compared to ref	HPL compared to ref
BAU	Total Energy (GER)	Unit	974438	1940005	3098685	-50%	+60%
D1	Total Energy (GER)	0	687461	1363358	2174434	-50%	+59%
D2	Total Energy (GER)	0	499101	981885	1561225	-49%	+59%
D3	Total Energy (GER)	0	377923	733658	1160540	-48%	+58%
D4	Total Energy (GER)	MJ	500415	983199	1562539	-49%	+59%
BAU	LCC	€	13757	26262	41228	-48%	+57%
D1	LCC	€	10476	19290	29808	-46%	+55%
D2	LCC	€	8660	15037	22608	-42%	+50%
D3	LCC	€	7845	12647	18297	-38%	+45%
D4	LCC	€	8880	15257	22828	-42%	+50%
GER	D1 compared to BAU		-29%	-30%	-30%		
	D2 compared to BAU		-49%	-49%	-50%		
	D3 compared to BAU		-61%	-62%	-63%		
	D4 compared to BAU		-49%	-49%	-50%		
LCC	D1 compared to BAU		-24%	-27%	-28%		
	D2 compared to BAU		-37%	-43%	-45%		
	D3 compared to BAU		-43%	-52%	-56%		
	D4 compared to BAU		-35%	-42%	-45%		

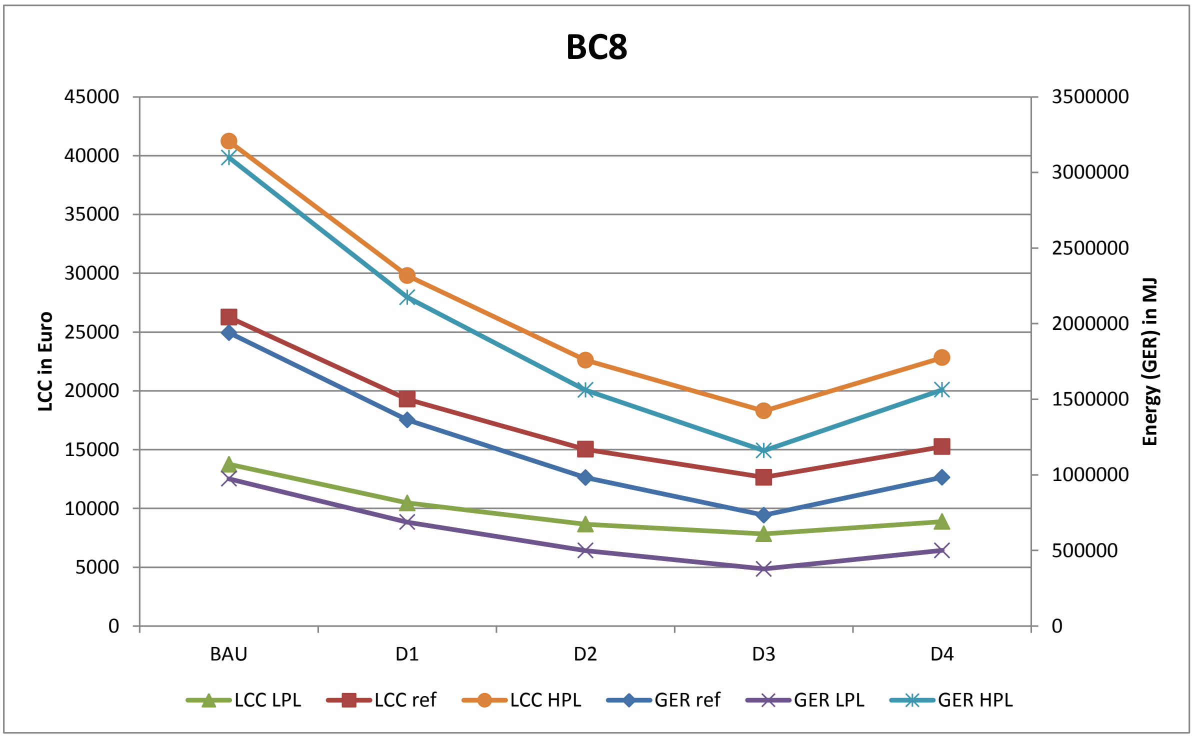


Figure 6-40 BC8 sensitivity to low, reference and high product lifetime

Table 6-58: Sensitivity data BC9

	Base Case Id		BC9				
		Unit	Low product lifetime (LPL)	Ref	High product lifetime (HPL)	LPL compared to ref	HPL compared to ref
BAU	Total Energy (GER)	Unit	778849	1544943	2464255	-50%	+60%
D1	Total Energy (GER)	0	580043	1144533	1821921	-49%	+59%
D2	Total Energy (GER)	0	467163	914050	1450316	-49%	+59%
D3	Total Energy (GER)	0	381580	739090	1168103	-48%	+58%
D4	Total Energy (GER)	MJ	408448	791495	1251151	-48%	+58%
BAU	LCC	€	11636	21512	33353	-46%	+55%
D1	LCC	€	9629	16917	25651	-43%	+52%
D2	LCC	€	8681	14464	21386	-40%	+48%
D3	LCC	€	8157	12797	18346	-36%	+43%
D4	LCC	€	8488	13455	19396	-37%	+44%
GER	D1 compared to BAU		-26%	-26%	-26%		
	D2 compared to BAU		-40%	-41%	-41%		
	D3 compared to BAU		-51%	-52%	-53%		
	D4 compared to BAU		-48%	-49%	-49%		
LCC	D1 compared to BAU		-17%	-21%	-23%		
	D2 compared to BAU		-25%	-33%	-36%		
	D3 compared to BAU		-30%	-41%	-45%		
	D4 compared to BAU		-27%	-37%	-42%		

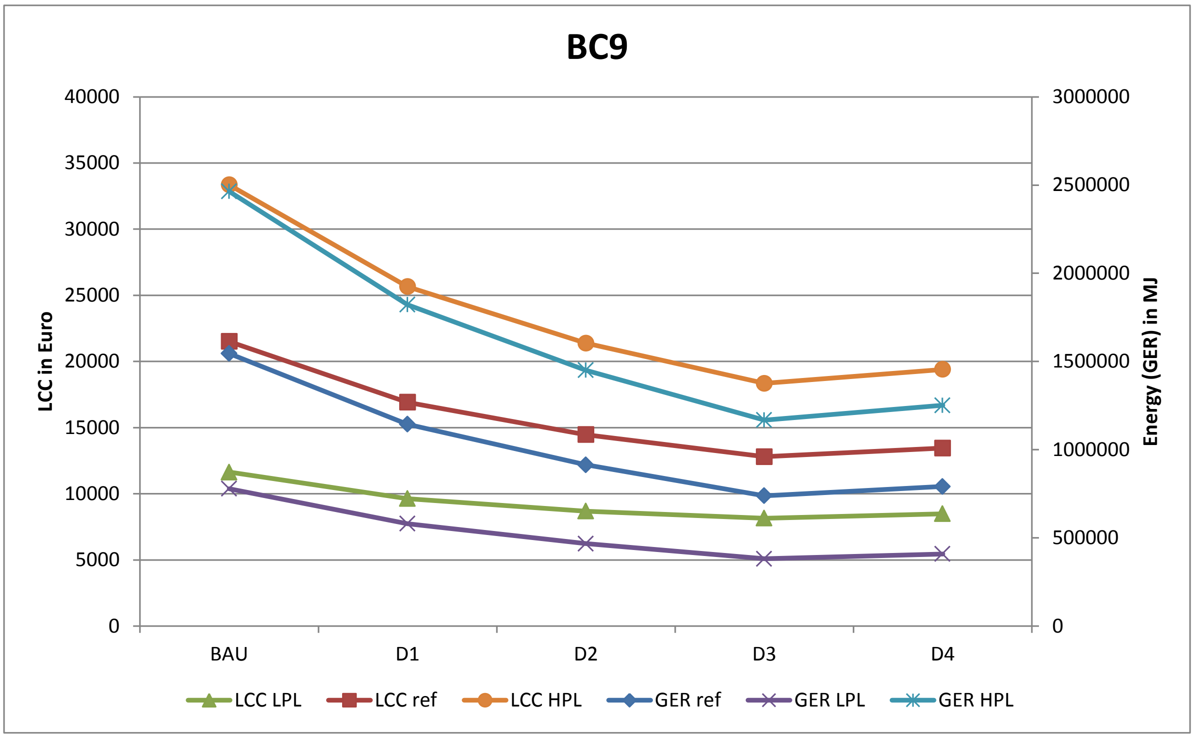


Figure 6-41 BC9 sensitivity to low, reference and high product lifetime

Conclusion:
Table 6-59 summarizes the sensitivity to product lifetime in terms of design options shifts. In case of BAT design option D3 stays the best option for low, ref and high values, except for BC3. In case of BC3, a shorter product life will justify a shift from D3 to D2 design option, meaning the lesser electricity consumption in the use phase can compensate the higher energy usage at the production and distribution.

Having a smaller lifetime will make it more difficult to compensate the investment costs by the gains made during the use phase due to the lesser electricity consumption. Overall it appears that lengthening the product lifetime is favourable for the LCC of more costly design options, as to be expected.

Table 6-59: Design option sensitivity to product lifetime

	BAT - lifetime sensitivity			LLCC - lifetime sensitivity		
	low	ref	high	low	ref	high
BC1	D3	D3	D3	D2	D3	D3
BC2	D3	D3	D3	BAU	BAU	D1
BC3	D2	D3	D3	BAU	BAU	BAU
BC4	D3	D3	D3	D3	D3	D3
BC5	D3	D3	D3	D1	D2	D4
BC6	D3	D3	D3	BAU	D1	D1
BC7	D3	D3	D3	BAU	D1	D1
BC8	D3	D3	D3	D3	D3	D3
BC9	D3	D3	D3	D3	D3	D3

6.6.4 Sensitivity to product price

The basic calculation uses product prices of 2010 according the reference values for product price mentioned in Task 3. The conductor material price can fluctuate considerably depending on global market factors and has substantial impact upon the product price. In order to assess the sensitivity of results compared to circuits with a lower or higher product price, the calculations are repeated for a low product price equal to 50% of the reference product price and high product price equal to 150% of the reference product price.

Table 6-60: Product price sensitivity data BC1

	Base Case Id		BC1				
		Unit	Low product price (LP)	Ref	High product price (HP)	LP compared to ref	HP compared to ref
BAU	Total Energy (GER)	Unit	1825051	1825051	1825051	0%	+0%
D1	Total Energy (GER)	0.00	1477409	1477409	1477409	0%	+0%
D2	Total Energy (GER)	0.00	1219803	1219803	1219803	0%	+0%
D3	Total Energy (GER)	0.00	971634	971634	971634	0%	+0%
D4	Total Energy (GER)	MJ	972016	972016	972016	0%	+0%
BAU	LCC	€	28057	29170	31397	-4%	+8%
D1	LCC	€	24584	25976	28759	-5%	+11%
D2	LCC	€	22451	24167	27600	-7%	+14%
D3	LCC	€	21101	23328	27781	-10%	+19%
D4	LCC	€	21660	23887	28340	-9%	+19%
GER	D1 compared to BAU		-19%	-19%	-19%		
	D2 compared to BAU		-33%	-33%	-33%		
	D3 compared to BAU		-47%	-47%	-47%		
	D4 compared to BAU		-47%	-47%	-47%		
LCC	D1 compared to BAU		-12%	-11%	-8%		
	D2 compared to BAU		-20%	-17%	-12%		
	D3 compared to BAU		-25%	-20%	-12%		
	D4 compared to BAU		-23%	-18%	-10%		

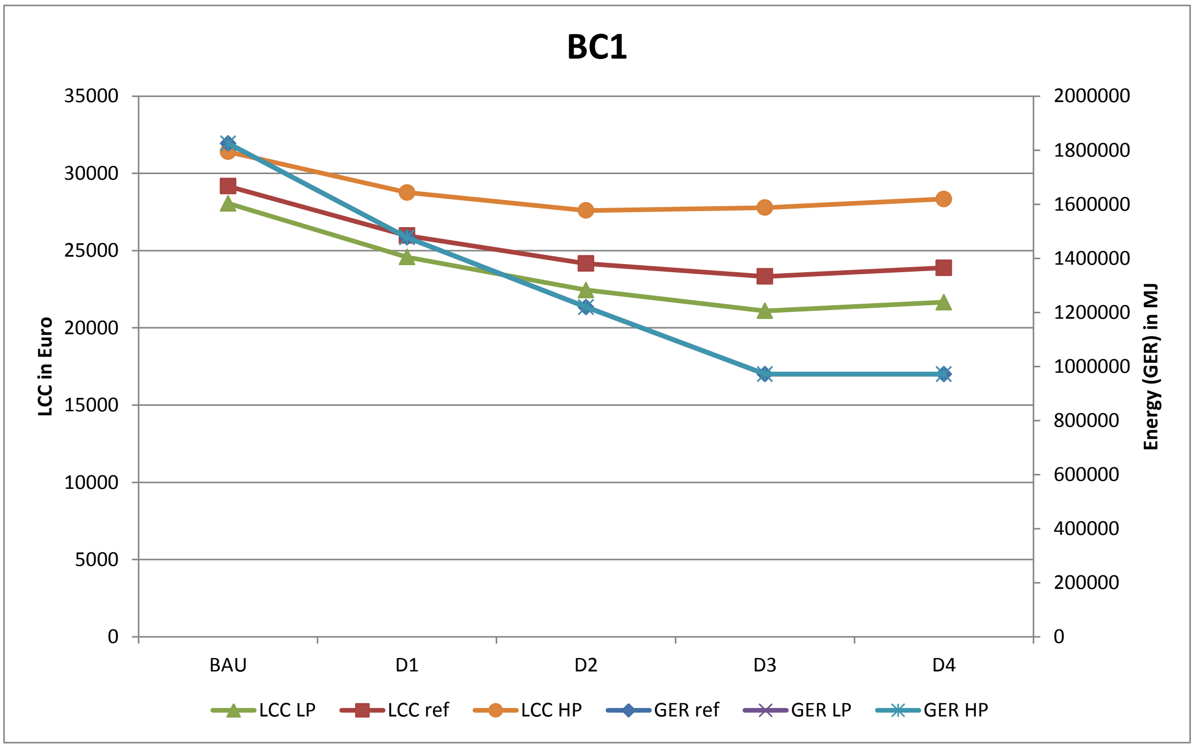


Figure 6-42 BC1 sensitivity to low, reference and high product price

Table 6-61: Product price sensitivity data BC2

	Base Case Id		BC2				
		Unit	Low product price (LP)	Ref	High product price (HP)	LP compared to ref	HP compared to ref
BAU	Total Energy (GER)	Unit	7192	7192	7192	0%	+0%
D1	Total Energy (GER)	0	4739	4739	4739	0%	+0%
D2	Total Energy (GER)	0	3503	3503	3503	0%	+0%
D3	Total Energy (GER)	0	2965	2965	2965	0%	+0%
D4	Total Energy (GER)	MJ	4513	4513	4513	0%	+0%
BAU	LCC	€	211	216	227	-2%	+5%
D1	LCC	€	212	221	239	-4%	+8%
D2	LCC	€	239	253	282	-6%	+11%
D3	LCC	€	304	325	368	-7%	+13%
D4	LCC	€	296	307	328	-4%	+7%
GER	D1 compared to BAU		-34%	-34%	-34%		
	D2 compared to BAU		-51%	-51%	-51%		
	D3 compared to BAU		-59%	-59%	-59%		
	D4 compared to BAU		-37%	-37%	-37%		
LCC	D1 compared to BAU		+0%	+2%	+5%		
	D2 compared to BAU		+13%	+17%	+24%		
	D3 compared to BAU		+44%	+51%	+62%		
	D4 compared to BAU		+40%	+42%	+45%		

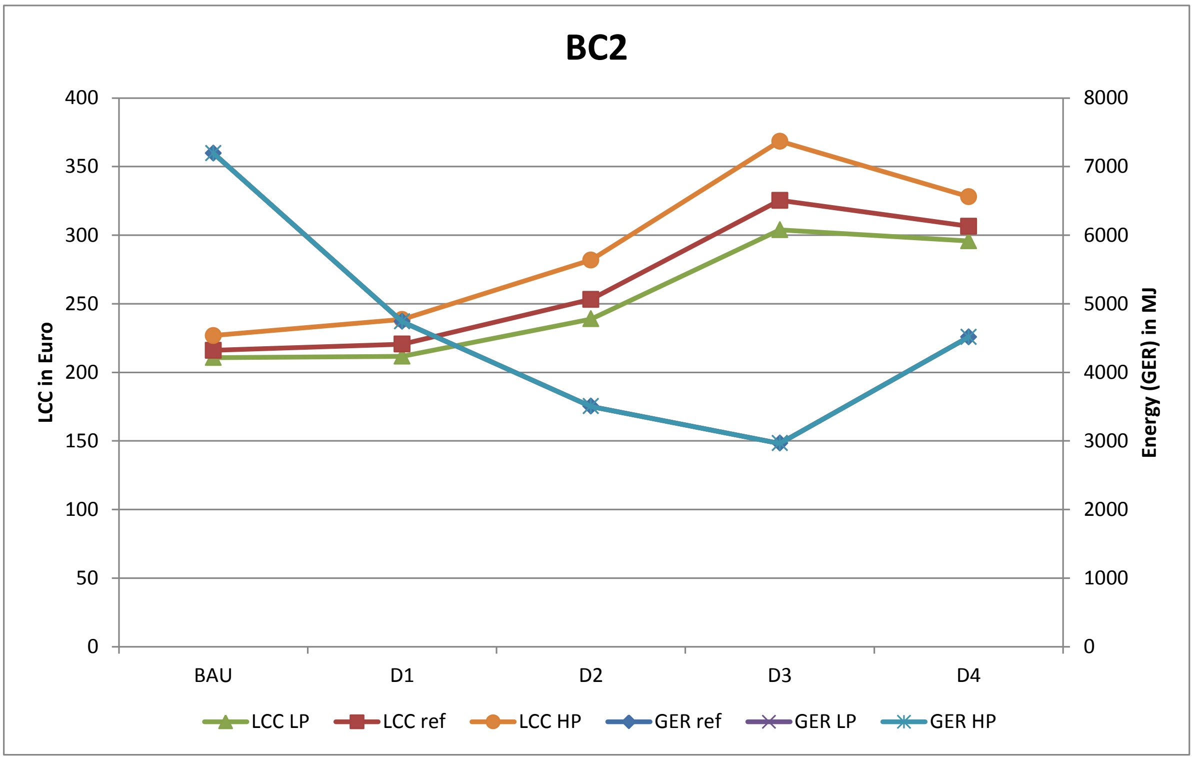


Figure 6-43 BC2 sensitivity to low, reference and high product price

Table 6-62: Product price sensitivity data BC3

	Base Case Id		BC3				
		Unit	Low product price (LP)	Ref	High product price (HP)	LP compared to ref	HP compared to ref
BAU	Total Energy (GER)	Unit	5608	5608	5608	0%	+0%
D1	Total Energy (GER)	0	4152	4152	4152	0%	+0%
D2	Total Energy (GER)	0	3523	3523	3523	0%	+0%
D3	Total Energy (GER)	0	3388	3388	3388	0%	+0%
D4	Total Energy (GER)	MJ	4176	4176	4176	0%	+0%
BAU	LCC	€	215	226	248	-5%	+10%
D1	LCC	€	241	259	294	-7%	+13%
D2	LCC	€	307	333	385	-8%	+16%
D3	LCC	€	385	429	516	-10%	+20%
D4	LCC	€	342	364	407	-6%	+12%
GER	D1 compared to BAU		-26%	-26%	-26%		
	D2 compared to BAU		-37%	-37%	-37%		
	D3 compared to BAU		-40%	-40%	-40%		
	D4 compared to BAU		-26%	-26%	-26%		
LCC	D1 compared to BAU		+12%	+14%	+18%		
	D2 compared to BAU		+42%	+47%	+55%		
	D3 compared to BAU		+79%	+89%	+108%		
	D4 compared to BAU		+59%	+61%	+64%		

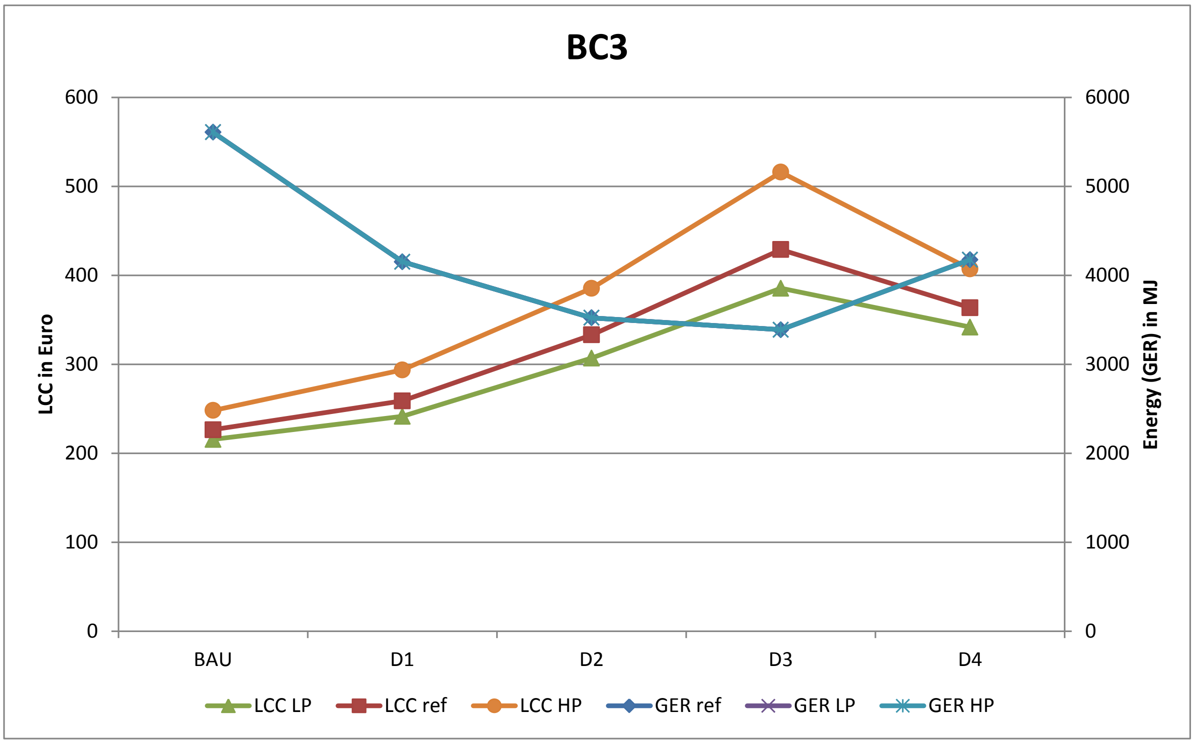


Figure 6-44 BC3 sensitivity to low, reference and high product price

Table 6-63: Product price sensitivity data BC4

	Base Case Id		BC4				
		Unit	Low product price (LP)	Ref	High product price (HP)	LP compared to ref	HP compared to ref
BAU	Total Energy (GER)	Unit	447175	447175	447175	0%	+0%
D1	Total Energy (GER)	0	281138	281138	281138	0%	+0%
D2	Total Energy (GER)	0	182422	182422	182422	0%	+0%
D3	Total Energy (GER)	0	132904	132904	132904	0%	+0%
D4	Total Energy (GER)	MJ	226693	226693	226693	0%	+0%
BAU	LCC	€	6024	6065	6149	-1%	+1%
D1	LCC	€	3995	4062	4195	-2%	+3%
D2	LCC	€	2880	2984	3192	-3%	+7%
D3	LCC	€	2431	2577	2869	-6%	+11%
D4	LCC	€	3459	3542	3709	-2%	+5%
GER	D1 compared to BAU		-37%	-37%	-37%		
	D2 compared to BAU		-59%	-59%	-59%		
	D3 compared to BAU		-70%	-70%	-70%		
	D4 compared to BAU		-49%	-49%	-49%		
LCC	D1 compared to BAU		-34%	-33%	-32%		
	D2 compared to BAU		-52%	-51%	-48%		
	D3 compared to BAU		-60%	-58%	-53%		
	D4 compared to BAU		-43%	-42%	-40%		

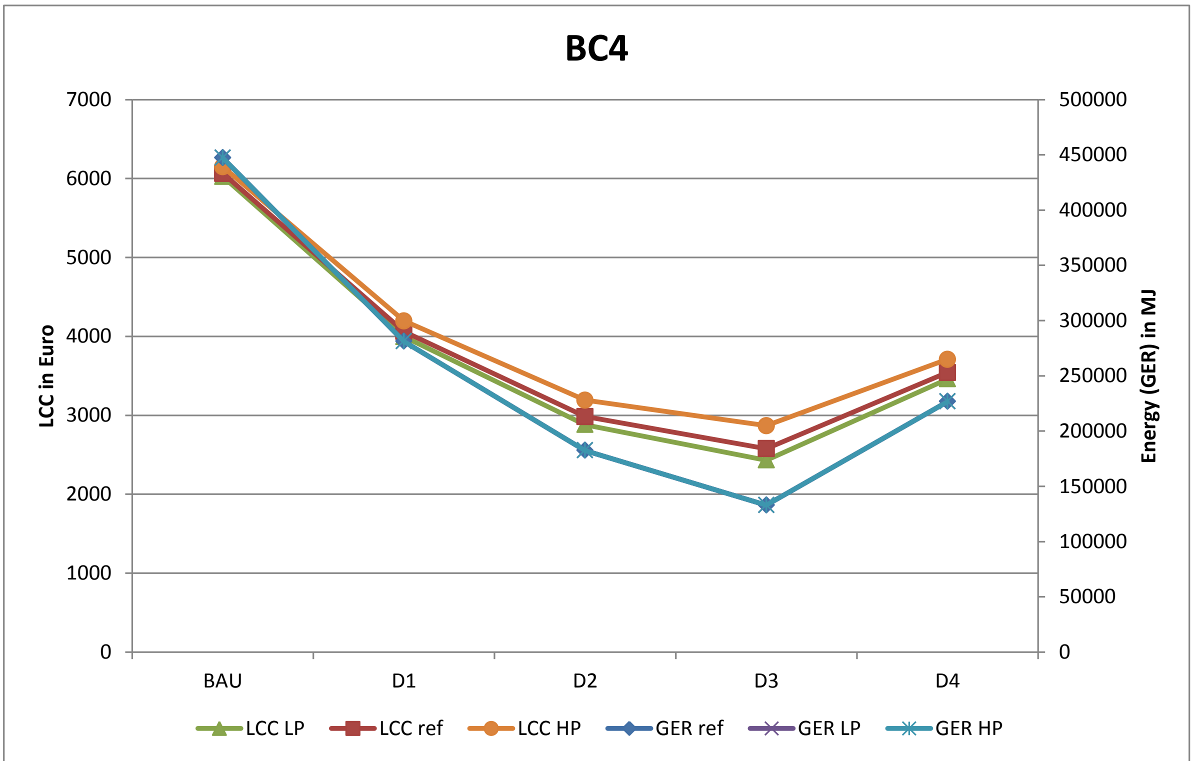


Figure 6-45 BC4 sensitivity to low, reference and high product price

Table 6-64: Product price sensitivity data BC5

	Base Case Id		BC5				
		Unit	Low product price (LP)	Ref	High product price (HP)	LP compared to ref	HP compared to ref
BAU	Total Energy (GER)	Unit	7392317	7392317	7392317	0%	+0%
D1	Total Energy (GER)	0	5660006	5660006	5660006	0%	+0%
D2	Total Energy (GER)	0	4605397	4605397	4605397	0%	+0%
D3	Total Energy (GER)	0	3791321	3791321	3791321	0%	+0%
D4	Total Energy (GER)	MJ	4021582	4021582	4021582	0%	+0%
BAU	LCC	€	120562	127094	140158	-5%	+10%
D1	LCC	€	106445	115154	132572	-8%	+15%
D2	LCC	€	102725	113611	135384	-10%	+19%
D3	LCC	€	103537	117253	144687	-12%	+23%
D4	LCC	€	102654	115717	141845	-11%	+23%
GER	D1 compared to BAU		-23%	-23%	-23%		
	D2 compared to BAU		-38%	-38%	-38%		
	D3 compared to BAU		-49%	-49%	-49%		
	D4 compared to BAU		-46%	-46%	-46%		
LCC	D1 compared to BAU		-12%	-9%	-5%		
	D2 compared to BAU		-15%	-11%	-3%		
	D3 compared to BAU		-14%	-8%	+3%		
	D4 compared to BAU		-15%	-9%	+1%		

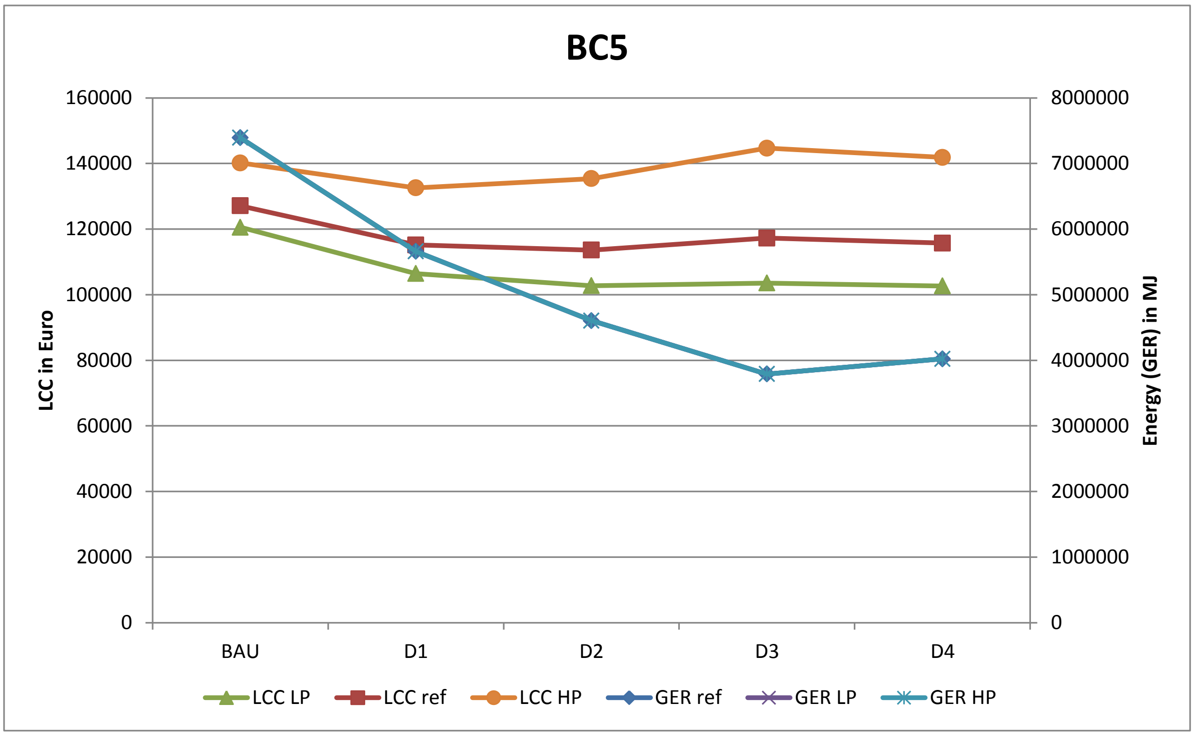


Figure 6-46 BC5 sensitivity to low, reference and high product price

Table 6-65: Product price sensitivity data BC6

	Base Case Id		BC6				
		Unit	Low product price (LP)	Ref	High product price (HP)	LP compared to ref	HP compared to ref
BAU	Total Energy (GER)	Unit	7392317	14414	14414	51186%	+0%
D1	Total Energy (GER)	0	5660006	9281	9281	60884%	+0%
D2	Total Energy (GER)	0	4605397	6617	6617	69504%	+0%
D3	Total Energy (GER)	0	3791321	5366	5366	70555%	+0%
D4	Total Energy (GER)	MJ	4021582	8597	8597	46677%	+0%
BAU	LCC	€	120562	351	367	34271%	+5%
D1	LCC	€	106445	337	365	31505%	+8%
D2	LCC	€	102725	372	416	27535%	+12%
D3	LCC	€	103537	468	535	22035%	+14%
D4	LCC	€	102654	443	476	23089%	+8%
GER	D1 compared to BAU		-23%	-36%	-36%		
	D2 compared to BAU		-38%	-54%	-54%		
	D3 compared to BAU		-49%	-63%	-63%		
	D4 compared to BAU		-46%	-40%	-40%		
LCC	D1 compared to BAU		-12%	-4%	-1%		
	D2 compared to BAU		-15%	+6%	+13%		
	D3 compared to BAU		-14%	+33%	+45%		
	D4 compared to BAU		-15%	+26%	+30%		

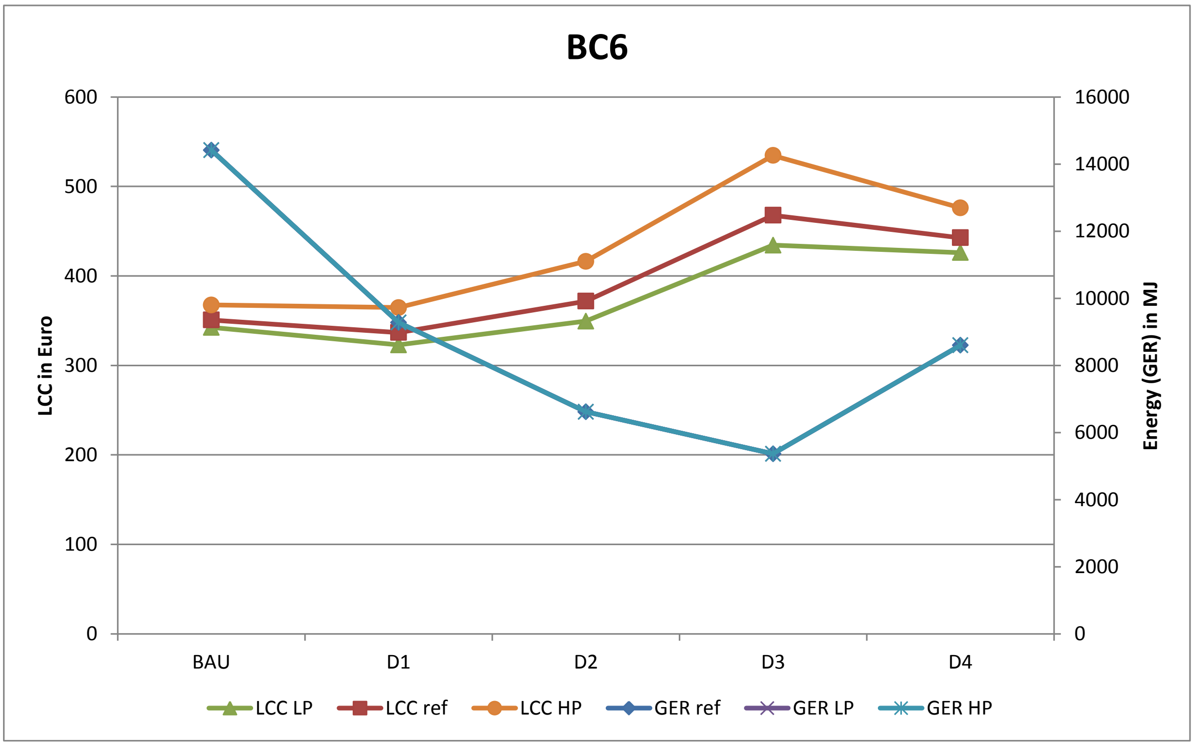


Figure 6-47 BC6 sensitivity to low, reference and high product price

Table 6-66: Product price sensitivity data BC7

	Base Case Id		BC7				
		Unit	Low product price (LP)	Ref	High product price (HP)	LP compared to ref	HP compared to ref
BAU	Total Energy (GER)	Unit	18050	18050	18050	0%	+0%
D1	Total Energy (GER)	0	12149	12149	12149	0%	+0%
D2	Total Energy (GER)	0	9115	9115	9115	0%	+0%
D3	Total Energy (GER)	0	7192	7192	7192	0%	+0%
D4	Total Energy (GER)	MJ	10877	10877	10877	0%	+0%
BAU	LCC	€	394	409	438	-4%	+7%
D1	LCC	€	372	396	444	-6%	+12%
D2	LCC	€	422	458	529	-8%	+16%
D3	LCC	€	500	559	678	-11%	+21%
D4	LCC	€	465	494	554	-6%	+12%
GER	D1 compared to BAU		-33%	-33%	-33%		
	D2 compared to BAU		-49%	-49%	-49%		
	D3 compared to BAU		-60%	-60%	-60%		
	D4 compared to BAU		-40%	-40%	-40%		
LCC	D1 compared to BAU		-5%	-3%	+1%		
	D2 compared to BAU		+7%	+12%	+21%		
	D3 compared to BAU		+27%	+37%	+55%		
	D4 compared to BAU		+18%	+21%	+26%		

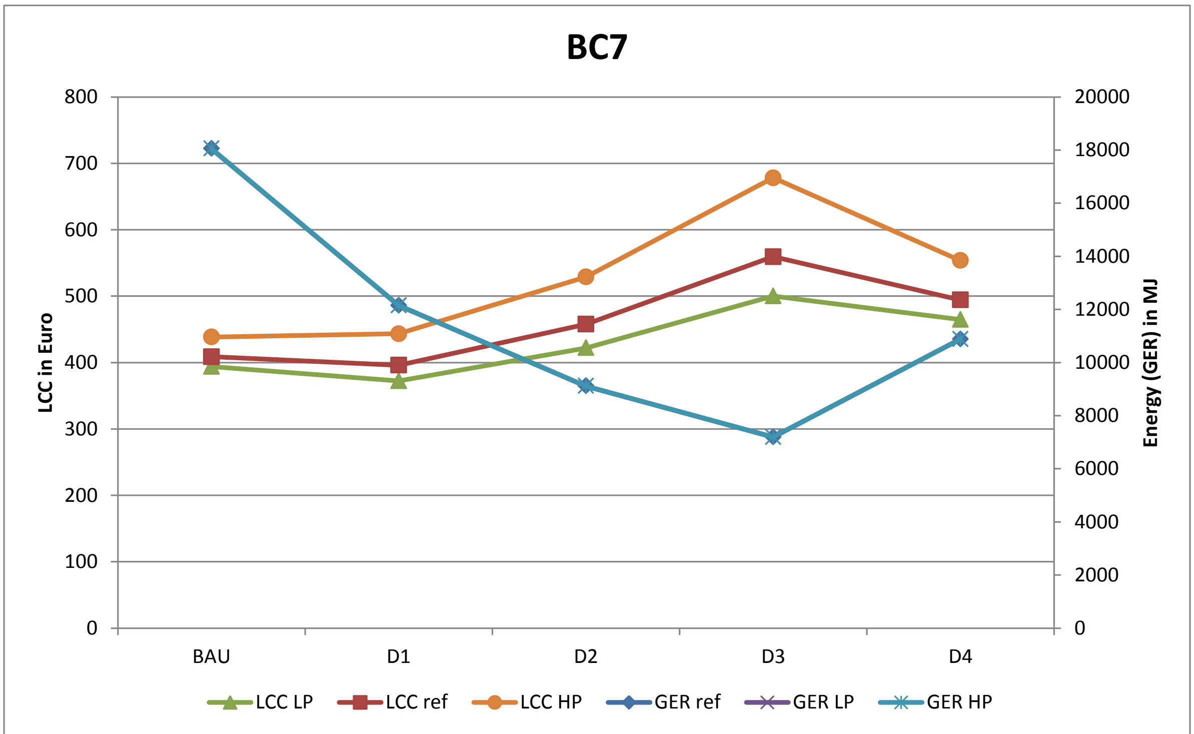


Figure 6-48 BC7 sensitivity to low, reference and high product price

Table 6-67: Product price sensitivity data BC8

	Base Case Id		BC8				
		Unit	Low product price (LP)	Ref	High product price (HP)	LP compared to ref	HP compared to ref
BAU	Total Energy (GER)	Unit	1940005	1940005	1940005	0%	+0%
D1	Total Energy (GER)	0	1363358	1363358	1363358	0%	+0%
D2	Total Energy (GER)	0	981885	981885	981885	0%	+0%
D3	Total Energy (GER)	0	733658	733658	733658	0%	+0%
D4	Total Energy (GER)	MJ	983199	983199	983199	0%	+0%
BAU	LCC	€	26036	26262	26716	-1%	+2%
D1	LCC	€	18966	19290	19938	-2%	+3%
D2	LCC	€	14584	15037	15944	-3%	+6%
D3	LCC	€	12032	12647	13877	-5%	+10%
D4	LCC	€	14804	15257	16164	-3%	+6%
GER	D1 compared to BAU		-30%	-30%	-30%		
	D2 compared to BAU		-49%	-49%	-49%		
	D3 compared to BAU		-62%	-62%	-62%		
	D4 compared to BAU		-49%	-49%	-49%		
LCC	D1 compared to BAU		-27%	-27%	-25%		
	D2 compared to BAU		-44%	-43%	-40%		
	D3 compared to BAU		-54%	-52%	-48%		
	D4 compared to BAU		-43%	-42%	-39%		

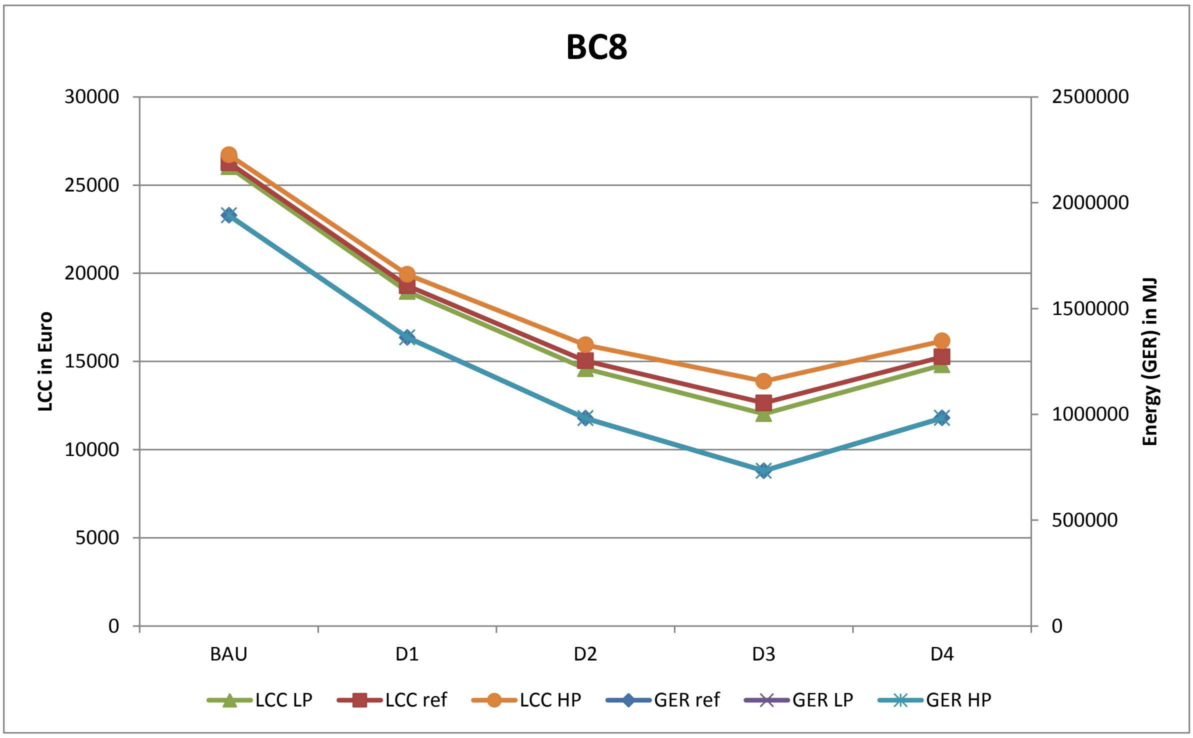


Figure 6-49 BC8 sensitivity to low, reference and high product price

Table 6-68: Product price sensitivity data BC9

	Base Case Id		BC9				
		Unit	Low product price (LP)	Ref	High product price (HP)	LP compared to ref	HP compared to ref
BAU	Total Energy (GER)	Unit	1544943	1544943	1544943	0%	+0%
D1	Total Energy (GER)	0	1144533	1144533	1144533	0%	+0%
D2	Total Energy (GER)	0	914050	914050	914050	0%	+0%
D3	Total Energy (GER)	0	739090	739090	739090	0%	+0%
D4	Total Energy (GER)	MJ	791495	791495	791495	0%	+0%
BAU	LCC	€	21459	21512	21617	0%	+0%
D1	LCC	€	16846	16917	17060	0%	+1%
D2	LCC	€	14373	14464	14644	-1%	+1%
D3	LCC	€	12685	12797	13023	-1%	+2%
D4	LCC	€	13350	13455	13666	-1%	+2%
GER	D1 compared to BAU		-26%	-26%	-26%		
	D2 compared to BAU		-41%	-41%	-41%		
	D3 compared to BAU		-52%	-52%	-52%		
	D4 compared to BAU		-49%	-49%	-49%		
LCC	D1 compared to BAU		-21%	-21%	-21%		
	D2 compared to BAU		-33%	-33%	-32%		
	D3 compared to BAU		-41%	-41%	-40%		
	D4 compared to BAU		-38%	-37%	-37%		

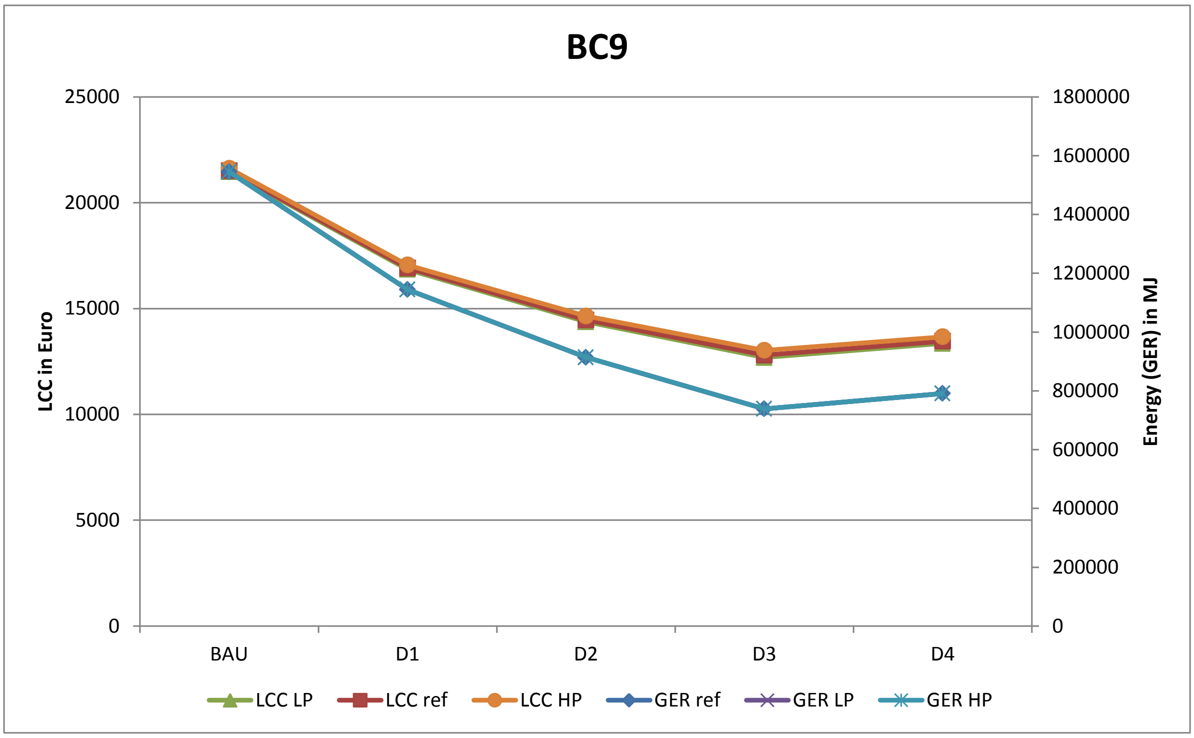


Figure 6-50 BC9 sensitivity to low, reference and high product price

Conclusion:
Table 6-69 summarizes the sensitivity to product price in terms of design options shifts. As expected a lower or higher product price will have no impact on the BAT design option. In terms of LCC a lower product price will improve the conditions to shift to a design option with a higher investment cost. And vice-versa a higher product price will improve the conditions to shift to a design option with a lower investment cost. In case of the formulated base cases a lower product price has no impact on the LCC design option except for BC5 which shifts from D2 to D4. A higher product price results in a shift from D3 towards D2 in case of BC1, from D2 to D1 in case of BC5 and from D1 to BAU in case of BC7.

Table 6-69: Design option sensitivity to product price

	BAT - product price sensitivity			LLCC - product price sensitivity		
	low	ref	high	low	ref	high
BC1	D3	D3	D3	D3	D3	D2
BC2	D3	D3	D3	BAU	BAU	BAU
BC3	D3	D3	D3	BAU	BAU	BAU
BC4	D3	D3	D3	D3	D3	D3
BC5	D3	D3	D3	D4	D2	D1
BC6	D3	D3	D3	D1	D1	D1
BC7	D3	D3	D3	D1	D1	BAU
BC8	D3	D3	D3	D3	D3	D3
BC9	D3	D3	D3	D3	D3	D3

CHAPTER 7 TASK 7: SCENARIOS

The objective of this task is to look at suitable policy means to achieve the potential improvement, e.g. implementing Least Life Cycle Cost (LLCC) as a minimum requirement, the environmental performance of Best Available Technology (BAT) or Best Not (Yet) Available Technology (BNAT) as a benchmark, using dynamic aspects, legislative or voluntary agreements, standards, labelling or incentives, relating to public procurement or direct and indirect fiscal instruments. It draws up scenarios quantifying the improvements that can be achieved versus a Business As Usual (BAU) scenario and compares the outcomes with EU environmental targets, the societal costs if the environmental impact reduction would have to be achieved in another way, etc.

It makes an estimate of the impact on users (purchasing power, societal costs) and industry (employment, profitability, competitiveness, investment level, etc.), explicitly describing and taking into account the typical design cycle (platform change) in a product sector.

In addition, this final task provides an analysis of which significant impacts should be measured under possible implementation of measures, and which measurement methods are needed to be developed or adapted for that purpose.

Summary of Task 7:

The proposed policy options in this task take into account the findings from previous tasks.

From Task 1 it was proposed to focus on 'losses in installed power cables in buildings', the power cable being the product put into service by the electrical installer in a circuit of an electrical installation in a building. As a consequence proposed policy measures focus on the power cables itself and/or the installed power cables in electrical circuits in buildings. Therefore, there is also no policy option proposed that would phase out all power cables with small cross-sectional areas (CSA) considered as products brought on the market, because they have their economic justified function in circuits with low loading and/or other applications such as machinery. By consequence most policy measures are formulated at electrical circuit or the system level, which is not directly in the 'product' scope of the Ecodesign of Energy Related Products Directive (2009/125/EC). The policy options are mostly related to upgraded standardization, labelling and/or electrical installation codes. Task 7 also discusses pros, cons and timing of the proposed policy measures. The task also explains why no other specific ecodesign requirements on the type of cable insulation and/or conductor material are proposed.

By cross-checking the available data in Task 5, it was concluded that many circuits in the stock potentially have a low average load and/or load form factor or equivalent time of peak load. Therefore proposed policy options focuses on typical circuits with high load.

From Task 6 it was concluded that there is improvement potential in several of the design options that increase the CSA. For base cases representing circuits with a low load, the 'environmental payback time' increased significantly up to almost the defined circuit lifetime. Therefore policy measures in this task are carefully chosen, not imposing an increased CSA for any circuit disregarding their loading and use. For some base cases the LLCC is the BAU, hence this is also taken into account for the proposed policy options.

This task also calculates five different scenarios on energy use and cost with a sensitivity analysis on key parameters like discount rate, inflation rate, energy escalation rate, product lifetime , stock growth rate and product price. Scenario BAU is the baseline scenario acting as the reference for the other scenarios. Scenario I and II reflect respectively the BAT and LLCC design option selection with a 100% impact from the introduction of the measure on. This is useful to estimate the impact in the assumption that all proposed policy measures achieve their maximum impact. Scenario III and IV simulate a well-considered design option selection inspired by Task 6 and the HD 60364-8-1:2015 standard. A the same time these scenarios assume a more gradual impact in time of the proposed measure. The introduction start time of these measures for all scenarios is the year 2017.

In a Business-as-Usual (BAU) scenario the energy losses in power cables in the industry and service sector in 2025 are forecasted at 56.67 TWh, which would be about 2.5 % of the transported electricity in 2025.

For scenario I, this results in a reduction of annual electricity losses **up to -13.61 TWh** in 2025. For scenario II, this equates to a reduction of annual electricity losses **up to -7.60 TWh**, for scenario III about **-2.93 TWh** and for scenario IV about **-1.93 TWh**, in 2025.

Sensitivity case 1 looks at the case the stock growth rate is much lower. It assumes a stock growth rate of 1% for the services and industry sector compared to 1.9% and 2.9% for respectively the services and industry sector, along with a corresponding lower replacement sales rate. With these figures, this equates to a reduction of annual electricity losses **up to -5.70 TWh** for scenario I, **up to -3.21 TWh** for scenario II, about **-1.23 TWh** for scenario III and about **-0.80 TWh** for scenario IV in 2025.

Besides the above mentioned sensitivity case, three more sensitivity cases were carried out:

- Sensitivity case 2, simulating a lower inflation and discount rate;
- Sensitivity case 3, simulating a lower energy (price) escalation rate;
- Sensitivity case 4, simulating a higher product price.

The analysis shows that:

- A longer product life and lower stock growth (sensitivity case 1) has an significant impact on all outcomes (electricity losses, greenhouse gases emission and expenditure).
- In terms of financial factors the lower energy escalation rate has the largest impact on the expenditure outcomes, taken into account the used figures.

The study focusses on power cables. The impact of the design options on the cost of the connectors is included. However, due to the uniqueness of each circuit and the absence of relevant field data, the impact of the design options on accessories (ducting systems, trunking systems, distribution boards, junction boxes, socket outlets, etc.) and on the building space have been left out of the quantitative analysis. This means for instance that design options may require more space, which will have an impact on the building construction. As a result the above figures have to be considered as maximum values.

It is expected that the proposed measures will have a positive impact on the labour for installers, cable manufacturers and distributors.

7.1 Policy analysis

7.1.1 Summary of stakeholders position

In the subsequent sections is an overview and summary of the stakeholders position that was collected after the last stakeholder meeting. Please note also that stakeholders have been consulted on regularly basis and have contributed to the elaboration of this report; more information including their comments is contained in the project report that is published complimentary to this report.

7.1.1.1 Peronnet – Schneider/ member of the Standardisation Organisation: Cenelec TC64 WG29

"It is important to understand that cables are not a product but a means to carry power. It is therefore important to take into consideration the usage of the load or application for the whole installation to maximize the efficiency of the wiring system. The brand new HD 60364-8-1:2015 standard gives guidance to optimize the efficiency of the whole electrical installation where the wiring system is part of it.
To maximize the efficiency of the wiring system during the life time of the electrical installation, it is key that the HD 60364-8-1:2015 shall be implemented by each Cenelec country as soon as possible. As it will be implemented in the design software as it is based on the other part of HD 60364, it should be quickly implemented at the European level in a transparent and efficient way."

7.1.1.2 Europacable/ cable manufactuters

Europacable did not provided a new position paper.

Europacable provided the following comments on the Revision of the 2012 – 2014 Working Plan under the EcoDesign Directive (2009/125/EC) before this study on 18 September 2012.'Europacable believes that the inclusion of 'power cables' in the recently adopted priority list of the 2012-2014 Working Plan under the EcoDesign Directive is based on incomplete and incorrect information. While we strongly support Europe's ambition to reduce carbon emissions and increase energy efficiency, we take the view that low voltage power cables installed in buildings only offer a marginal contribution to achieving the overall objectives.'
The full position paper of September 2012 can be found in annex in 8.8.1.

7.1.1.3 European Copper Institute/ material supplier

Given the substantial energy savings potential, the numerous additional benefits and the market failure, so far, to secure these benefits through voluntary initiatives,

European Copper Institute (ECI) advocates for a cable-sizing regulation and supports the European Commission's efforts to formulate the best regulatory approach.
The full position paper can be found in annex in 8.8.2.

7.1.2 Opportunities for policy measures and barriers

As background for the selected policy options please also read the Task 7 summary section that discusses the findings of previous tasks and the consequences on proposed policy options. Hereafter policy options are discussed with pros and cons. The objective is to support the identified improvement options from Task 6 with appropriate policy measures.

7.1.2.1 Opportunities for policy measures and barriers at product level

These 'product' related policay measures fit within the Ecodesign Directive (Ecodesign Directive 2009/125/EC) (see Task 1). Alternatively the Energy labelling Directive 2010/31/EC and/or Construction Products Regulation 305/2011 could be considered (see Task 1).

7.1.2.1.1 Policy measures at product level by a generic ecodesign requirements on information implementing the Ecodesign Directive (2009/125/EC)

A proposal for generic cable product information requirements:

Rationale: Installers and users are generally unaware of cable losses. The current information provided, such as CSA, expressed in mm², and the maximum current-carrying capacity in open air, expressed in Amperes [A], is therefore insufficient.

A technical solution for this is to set a generic ecodesign requirement on the provision of cable loss information, for example:

- Indication of the maximum DC ohmic resistance per kilometer at 20°C (R_{20} expressed in Ω/km) on the cable complementary to CSA;
- On the package and sales websites:
    - Cable losses per kilometer (W/kilometer) at 50 % and 100% of the maximum current-carrying capacity of the cable in open air;
- One stakeholder suggested in introduce an new Cable Performance Index, see annex in section 8.9);
- Together with resistance, it would be welcome to give a figure of annual energy losses for a limited number of predefined load profiles (see Task 3). Such information could also be presented in the design software commercially available and tools offered by the cable manufacturers.

Notes:

- The real measurement and indication on the package of DC ohmic resistance of all cables according to the compliance check as described in paragraph 7 of IEC 60228 and Annex A of the standard isn't feasible according the cable manufacturers. The DC ohmic resistance is measured on a cable sample of at least 1 meter at a given room temperature and corrected to 20°C and a length of 1 km (R_{20} expressed in Ω/km). All cables have to comply with the standard imposing and guaranteeing a maximum ohmic resistance of the product consumers buy. This maximum DC resistance is already indicated in all technical cable datasheets;

- The measurement of the DC ohmic resistance of a sample of a cable must be carried out according to the requirements of the ISO 9001 (or ISO 17025) Quality Management System. This means that the measurement equipment has to be calibrated according to an (international) standard. Also the required accuracy of the measurement equipment shall be determined to guaranty an accurate measurement result;
- Information about the quality assurance of the production process including the technical procedures for testing of cable samples could/should be mentioned on the manufactures websites.

A complementary proposal for cable sizing tools to be provided with placing on the market of cables:

Rationale: As discussed in section 7.1.2.2 the proposed policy is to address cable losses at installation level, however for this standards and tools are needed that can be supplied by the manufacturers.

A technical solution for this is to require manufacturers that are placing cables on the market to provide or ensure that such a tool and standard is available free of charge. It is also recommended that reference is made to this tool together with product information such as cable prices and quotes. Such a method should be harmonized and include some reference calculations that enable to verify the tool. The reference calculations could be similar to the base cases of this study. Such a set of limited number of predefined load profiles (dedicated circuit high load, dedicated circuit low load, distribution circuit,…) is also useful for the previous measure.
When considering such a tool standard IEC 60287-3-2 and IEC 60228/IEC 60227 should be considered, but it is recommended that they are updated and refined for this purpose taking gaps identified in Task 1 into account. Apart from the method it will be important to include reference calculations that can serve as independent validation for such a tool. The rationale and requirements for such a tool are also discussed in section 7.1.2.2.

Proposal for an exact definition of the cables within the scope of such a measure:

The above mentioned measures can be applied to single core and multi core Low Voltage (LV) cables that meet the following standards:

- IEC 60502-1: Power cables with extruded insulation and their accessories for rated voltages from 1kV up to 30 kV;
  Remark: restricted to cables with a rated voltage U0/U (Um) of 0.6/1 (1.2kV);
- EN 50525-1 Electric cables: LV energy cables of rated voltages up to and including 450/750 (U0/u).
  Remark: restricted to EN50525 cables for fixed wiring.

Pros, cons and of such an Ecodesign implementing measure:

Contra: Elaborating and putting into force an Ecodesign implementing measure related to information requirements alone could be weak compared to the complexity of entire legislative procedure behind Ecodesign Legislation. An alternative option is to support and accelerate the standardisation process with a similar aim first and reassess its impact afterwards.
Pro: The voting procedure behind Ecodesign legislation could accelerate the putting into force of such a system, even when not all stakeholders agree on the exact procedure and/or standard.

Timing:

Elaborating such a standard and/or drafting an implementing measure should start ASAP. Afterwards a generic ecodesign requirement could be considered if there is no satisfactory standard and/or free tool made available in a voluntary initiative supported by the manufacturers.

7.1.2.1.2 Why no other product related improvement options related to the impact of production and end-of life were proposed in this study?

In theory this is possible because the used MEErP tool takes into account the entire life cycle. Therefore changing materials as improvement options such as copper vs aluminum conductor and/or PVC vs thermoplastic polyurethane insulation could be considered. The rationale for not considering such policy options was provided in section 6.1. First, Task 5 identified the use phase as most significant one. Moreover insulation and conductor materials can and are recycled in the Business-as-Usual scenario as explained in section 3.3. Finally it is hard to compare accurately the underlying MEErP data from copper vs aluminum and PVC vs polyurethane production and this would lead to out of scope discussions on the comparison of their production methods and plants. As a conclusion, there was no rationale and possibility during the study for power cables in buildings to consider policy options that would phase out one material vs another. Nevertheless, some green NGOs and recycling companies showed interest for this topic and it could be reconsidered on the long term when more accurate production data comes available and is thoroughly verified. In this context it should be noted that similar cables are used in appliances and equipment with a shorter life compared to installed power cables in buildings. In this case the impact from the production phase could be dominant and such improvement options could make sense. If such a study would take place it is also recommended to check how accurate manufacturing data could be obtained for such modelling, e.g. it might require an obligation for manufacturers & recyclers to disclose detailed production information and allow on site verification for market surveillance.

7.1.2.1.2 Are electric circuits in buildings products?

This study does not consider electric circuits installed in buildings as products brought on the market nor their buildings. The rationale behind this is explained hereafter. Electric circuits are elements or components of a building and so far were not considered as 'products' in European legislation. As a consequence, buildings and/or installed power circuits currently do not carry a CE label. So far, installers are therefore also not seen as product manufacturers as specified in EC Decision (768/2008/EC) on a common framework for the marketing of products in the EEA. Therefore 'installers' seen as 'power circuit manufacturers' also have no administrative work resulting from Article R2 neither on Annex II in Decision (768/2008/EC) that specify the obligations related to technical documentation and conformity assessment. Buildings and their electrical installations cannot be moved or relocated and the 'free movement of goods' is irrelevant issue in this context. For this reason, it is also unlikely that they would ever belong to the product categories of the CE product marking directive (93/68/EEC).
Even if they were considered as new 'products' brought on the market, one might argue the minimum volume of sales (200000 'units') requirement of article 15 (5) of the Ecodesign Directive (2009/125/EC) based on the argument that each power circuit is a 'unique product' that would need individual documentation. In total volume however there are more than 200000 building permits[1] and therefore new power circuits brought on the market per year which could provide an argument pro.
Despite the above arguments it should be noted that in principle nothing has been found to preclude as such to consider 'installed electric power circuits' as products and installers as their manufacturers, therefore it remains a policy option to be decided by

the EC. The consequence is also that the buildings with their circuits would become 'products' with a CE label.
As a conclusion the EC should decide whether or not an installed power circuit is a 'product'. Therefore new policy approaches might be needed to address the identified improvement options in Task 6 and they are discussed in separate sections in this report.

7.1.2.1.3 Other policy measures at product level

Neither technical improvement options nor policy measures were identified at product level in task 6. There is no rationale for setting specific requirements for the implementation of the Ecodesign of Energy Related Products Directive regulation (2009/125/EC) Article 15 item 6 because every cable section (CSA) on the market has a certain load and cable length to fit with.

7.1.2.2 Policy measures at installation level to reduce cable losses

Improvement options at installation level are discussed in the next sections. As explained before(see 7.1.2.1.2) installed circuits are not considered as a product in the meaning of the Ecodesign of Energy Related Products Directive (2009/125/EC). As a consequence alternative policy instruments are discussed hereafter. They can be considered for a revision of the Energy Performance of Buildings Directive(2010/31/EU). Alternatively they can be implemented in local installation codes. In any case in order to maintain the free trade of products and facilitate fair comparison and competition a harmonized and standardized method and requirements are highly recommended.

Rationale: Task 6 identified significant improvement potential in cables installed in buildings (in the services and industry sector). In many cases, cables with a larger CSA will reduce cable losses economically for electric circuits of low voltage installations in buildings. It was also identified that installers and building owners are unaware of this and therefore even do not consider cables as a potential source for improvement. In the subsequent section specific and generic information requirements are proposed.

Specific ecodesign requirements to increase CSA and lower cable losses *during design* of the installation:

Requiring minimum CSA above standard CSA levels for the above mentioned electric circuits, by means of:

- Requiring an economic analysis (Life Cycle Cost) for circuits that use the minimum CSA:
    - Similar to IEC 60287-3-2 Electric cables – Calculation of the current – part 3-2: sections on operating conditions – Economic optimization of power cable size. As indicated in Task 1 this standard contains elements but is not complete for this purpose and at least should be updated. The standard does only calculate individual cable segments point-to-point and not circuits with distributed loads and sources. Apart from the method it will be important to include reference calculations that can serve as validation for such a tool;
    - Using economic optimization tool (e.g. Ecocalculator Nexans, Simaris Energy Efficiency optimization tool, etc.);
    - Mentioning a reference to this economic optimization tool on the cable package. This reference can be in the form of a textual URL and/or a QR-

code. The reference could link to a web based tool on the sales website, to a commercial tool or to an app running on a smartphone or tablet. The QR-code should contain, besides the URL, the characteristics of the cable, which are automatically provided as input to the tool. For this, the installer has to provide additional information like circuit length and load (load factor and load form factor or equivalent operating time at maximum loss) of the circuit;

  - Require the installer to provide additional information like assumed circuit length and load (load factor and load form factor or equivalent operating time at maximum loss) of the circuit. Load factor and load form factor have a decisive impact on the results. Too much freedom on its selection could lead to gaming behaviour by designer or installer to minimize investment cost at the expense of a higher life cycle cost. Therefore, defining a number of predefined load profiles could be useful.

- Introduction of an extra correction factor based on the load factor of the electric consumer. HD 60364-5-52:2011 (IEC 60364-5-52:2009) defines two correction factors to determine the maximum allowable current-carrying capacity of an electric circuit; these are the method of installation and the ambient temperature. A third correction factor based on the load factor of the electrical load could be applied. Electrical loads with a high load factor (high amount of operating hours per year) would need cables with a higher CSA compared to the loads with a lower load factor. The choice of the load factor could be limited to a number of predefined profiles (see Task 3), so as to avoid gaming behaviour by designer or installer to minimize investment cost. An alternative approach is to introduce more stringent voltage drop limitations in the standard;
- Inclusion of cable losses in the standards for implementing the EPB Directive (2010/31/EU), especially taking into account dedicated building loads such HVAC components. In the framework of EPB it is also possible to add the electrical installation as one of the items of the building system in the guidelines[125] on cost optimal level calculations.

Note: it is proposed to include this in an updated HD 60364-8-1:2015. To include cable losses in the EPB Directive related standards needs to be updated, e.g. EN15603, and a new standard EN15XXX on the calculation of cable losses needs to be elaborated.

Generic information requirements on the provision of information to decrease cable losses *before commissioning* of the electric circuit:

It is recommended that the following information is provided for each circuit when commissioning the installation to the end-user and/or building owner:

- The unique reference number of the electric circuit;
- Denomination of the load (e.g. pump, server, socket outlets, etc.);
- The design current (Ib);
- The rated current of the circuit (In);
- The cable type and cable length;
- The (estimated) load factor of the electrical load of the circuit (amount of operating hours per year).

Based on this information, the cable losses (kWh per year) in each circuit can be calculated and optimized for circuits with a high load factor and/or long cable lengths.

[125] Guidelines accompanying Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012 supplementing Directive 2010/31/EU of the European Parliament and of the Council on the energy performance of buildings by establishing a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements (2012/C 115/01).

An economic analysis for circuits with a high load factor should be provided as part of the technical file of the electrical installation to be approved by the building owner. Therefore the section on economic optimization of power cable size (part 3-23 2) in standard IEC 60287-3-2 on 'Electric cables - Calculation of the current rating' could be used.

Note: it is proposed to include this in an updated HD 60364-8-1:2015. This could be aligned with the standard IEC 60287-3-2 that describes an economic optimization method.

Generic information requirements on the provision of information to decrease cable losses after commissioning of the electric circuit

This generic information may contain the following elements:

- Measure and indicate the loop impedance of electric circuits according to EN 61557-3 (Electrical safety in low voltage distribution systems up to 1000 V a.c. and 1500 V d.c. - Equipment for testing, measuring or monitoring of protective measures - Part 3: Loop impedance). Fault loop impedances meters[126] can be used for this purpose and are already used to verify the Prospective Short Circuit Current (PSCCC);
- Indicate circuit breakers of electric circuits with a label reflecting the loss in function of % of rated current of the circuit (In);
- The estimated loss (kWh) and assumed load (average load factor (LF)), load form factor (Kf) and/or equivalent time of peak load (h/y) for the electric circuit;
- A cable loss reduction indicator can be assigned to the intended circuits. This indicator is the ratio of the cable losses for the 'standard' electric circuit to the 'economically optimized' one;
- Also a performance indicator of the complete installation, i.e. multiple circuits, could also be considered, e.g. taking into account the cables loss reduction indicators of each circuit and the ratio of circuits which are economically.

Note: it is proposed to include this in an updated HD 60364-8-1:2015.

Specific requirements for monitoring of cable losses with BACS during operation of the building (Building Automation and Control Systems)

It is possible to promote and/or mandate the monitoring of power cable losses.

This would require sub-metering and monitoring of the targeted electric circuits. The monitoring system should calculate the load factor (LF) and load form factor (Kf) and/or equivalent or equivalent time of peak load and implement alarms when estimated values at commissioning are exceeded. It is recommended to include these cable loss monitoring functions in standard EN 15232 (2007) on 'Impact of Building Automation'. More specific it should therefore be defined as a building automation function and assigned to a certain efficiency class in Table 1 of the standard.

For consideration: monitor cable temperature instead of measuring the loading current, it is less accurate but could be less expensive.

Support for the standard IEC 60634-8-1 / HD 60634-8-1:2015 – Low voltage electrical installations energy efficiency

[126] http://www.fluke.com/fluke/m3en/Installation-Testers/Fluke-1653B-Multifunction-Installation-Tester.htm?PID=72323

The scope of this standard are electrical installations related to losses, cables, accessories and the building. For a description of the standard and identified gaps, see section 1.2.1.3. Please note that the standard also refers to standard IEC 60287-3-2 for economic optimization of cables but does not include the method itself, see section 1.2.1.1.14.
To maximize the efficiency of the wiring system during the life time of the electrical installation, it is key that the HD 60364-8-1:2015 shall be implemented by each Cenelec country as soon as possible. As it will be implemented in the design software as it is based on the other part of HD 60364, it should be quickly implemented at the European level in a transparent and efficient way. It is recommended that future revisions of this standard will be more specific and provide quantifiable objectives, see also gaps identified in section 1.2.1.3.
To accelerate the impact of the standard it is also recommended to impose a mandatory recurring certification of an electrical installation in non-residential buildings at least every 10 years (the cycle period can be different per sector). Such a requirement could be included in an update of the EPB Directive (2010/31/EU). In some member states (e.g. Belgium) industrial installations need already a recertification of the electrical installation to verify with the safety requirments of the electrical code. Hence such a requirement could also be implemented in local regulations. This certification could therefore combine the actual safety regulation as well as the energy efficiency performance requirements. In case the energy efficiency performance requirement aren't mandatory, the certification process could include an energy efficiency performance audit of the electrical installation providing the building occupant insights in the energy efficiency performance of its electrical installation.

Proposal for an exact definition of the electric circuits within the scope of such installation measures:

The scope of this study is "installed Low Voltage power cables in buildings after the meter" (see Task 1, paragraph 1.1.3).

The focus for the policy measures will be on the electric circuits which transport the highest amount of electrical energy in the building. In general these are:

- Electric circuits between the transformer(s) and the main distribution board of the building, after the meter;
- Electric circuits between the main distribution board and the secondary distribution boards;
- Dedicated electric circuits from the main and secondary distribution boards to electrical consumers with a high load factor (large number of operating hours per year) (e.g. HVAC components and servers).

Pros, cons and of such an Ecodesign implementing measure:

Pro:
As mentioned it will create awareness of cable losses.
Installations implemented according to this standard (and data from the verification process) will provide detailed energy consumption information which will provide a solid data source for future (ecodesign) studies on energy efficiency of electrical installations.

Cons:
There is a risk for increased paperwork to be done by installers, therefore it is highly recommended to support these measures with standardized methods and free available software tools.
The impact of some of the proposed measures could be weakened because they leave much freedom on its selection of load profiles which could result in gaming behaviour by the designer or installer to minimize investment cost.

Timing:

As discussed previously for such purpose several standards would be needed to have the economic optimization tool in place. It can be done by updating or extending existing ones and/or creating a new standard. Existing standards in the scope are IEC 60287-3-2 and IEC/HD 60634-8-1, see previous discussions.

When the method is available it is possible to require manufactures to provide this tool free of charge, as discussed in section 7.1.2.1.1. Afterwards the different proposed policy options for implementation can be considered: local regulation, inclusion in an update of the EPB Directive (2010/31/EU),

It Is also recommended to ask member states ASAP to integrate the recommendations in the section on 'Generic information requirements on the provision of information to decrease cable losses after commissioning of the electric circuit'' and to collect statistics' and on 'Requirements for monitoring of cable losses with BACS during operation of the building (Building Automation and Control Systems)'. This would provide data for a follow up study to reevaluate and update the proposed policy measures, as recommended for 2020. Therefore member states should also collect and report statistics.

7.1.3 Opportunities for policy impact on losses for installed cables in residential buildings

In section 1.1.9.7 it was concluded that there is no significant improvement potential for 'new' installed cables in residential buildings in line with state of art European installation codes.
However, this does not exclude that there is no improvement potential in some 'existing' old installations. It was mentioned that in cases residential installations are overloaded and not in line with the current installation codes. Hence verification and recertification of existing installations (>30 years) should continue, not only for energy savings but also for safety.

7.2 Scenario analysis (unit stock/sale & environmental)

The objective of this section is to set up a stock-model, 1990-2030 (2050) with MEErP guidance and calculate a baseline scenario ('BaU', 'Base Case') for resources use and emissions (in physical units). It should then go on to calculate scenarios for policy options identified in the previous section 7.1.

Many of the proposed policy options did not set strict minimum performance requirements and the assumed positive impact is an indirect consequence of the proposed methods and practices. Therefore this study will calculate the baseline scenario(BAU) and some most optimistic borderline scenarios related to the improvement options of task 6 (e.g. LLCC, BAT). These borderline scenarios will be indicative for what is achievable with the proposed policy measures when they have full impact. Because the policy measures still allow the user to work around the real impact will be lower, but this is hard to quantify and we assume in large extend a positive attitude and impact caused by increasing awareness.

In task 5 nine base cases were defined and the environmental and LCC impact has been calculated per base case by means of the EcoReport tool. Also the impact at EU-

28 has been calculated in this task for the defined base cases. These base cases represent the BAU scenario.
In task 6 the design options were identified. By means of the EcoReport tool the environmental and LCC impact of each design option on each base case has been analysed.
In this task the environmental and LCC impact of different scenarios has been analysed based upon parameters and values defined in previous tasks. These scenarios describe the roll-out timing, the involved base cases, and opted design options. The impact calculation is at EU-28 level.

7.2.1 Scenario definition

In order to assess the effects of possible ecodesign requirements a calculation model has been developed. This spreadsheet-based model allows the calculation of impacts (on resource use, such as primary energy consumption, overall EU expenditure and GHG emissions) depending on inputs on the level and timing of energy efficiency requirements. For the assessment five scenarios have been designed.

Baseline / business as usual scenario:
BAU means 'do not change the regulatory framework' and is used as the baseline to compare all other scenarios. All impacts and savings calculated will be referenced to this baseline scenario, which describes the resource consumption and impacts assuming no new legislation is introduced, nor will have upcoming voluntary standards any effect. For each base case circuit the BAU option is selected (see Table 7-1).

	Selected design options per scenario							
	BC1	**BC2**	**BC3**	**BC4**	**BC5**	**BC6**	**BC7**	**BC8**
Scenario BAU design options	BAU	BAU	BAU	BAU	BAU	BAU	BAU	BAU
Scenario I design options	D3	D2	D1	D3	D3	D2	D2	D3
Scenario II design options	BAU	BAU	BAU	D2	BAU	BAU	BAU	D2
Scenario III design options	D1	BAU	BAU	D1	D1	BAU	BAU	D1
Scenario IV design options	D1	BAU	BAU	D1	D1	BAU	BAU	D1

Table 7-1: scenario design options selection

In the previous section it has been explained that it is extremely difficult to introduce ecodesign requirements at power cable level. Even at circuit level it is difficult as electric circuits cannot be defined as products.
Therefore the scenarios, described further on, are selected based upon a mix of ecodesign regulatory options and the improvement options defined in Task 6.

The ecodesign scenarios differ from the baseline scenario with regard to the efficiency of the installed circuits. The change in efficiency is reflected in a change of the average electricity losses input used to calculate energy consumption. The other factors like annual sales volume and product life (and thus stock) remain the same. In Scenario IV an additional decrease of 10% is assumed to reflect the impact of other recommendations in the HD 60634-8-1 which could have for instance an impact on the load factor.

The efficiency of the installation circuits in the ecodesign scenarios are defined in terms of design option selections per base case. The figures in this section do not show the base case level detail, but only the totals (sum of) for all base cases. Although the efficiency of an installation is automatically calculated by the design option selection, this can be overruled in the tool by filling in (overwriting) the electricity losses manually.

To distinguish a BAU electric circuit with an electric circuit designed according to a design option mentioned in Task 6, these latter circuits are called 'improved circuits' in this document.

As regards timing of measures: the assumed start date for introducing 'improved' circuits is 2017 and is the same for all scenarios. Three tiers are foreseen in the scenario model to simulate the introduction of the measures. Each tier has an associated introduction date, which is kept the same for all scenarios. The dates and assumed effectiveness of the measures are shown in Table 7-2. By effectiveness of a measure is meant the amount of circuits that are designed according the measure compared to the amount of potential circuits that qualify for the measure. In all scenarios we assume that only new circuits and circuits that are replaced along the BAU scenario qualify for the measure. No measure includes a forced introduction.

Table 7-2: Timing of the measures

	Scenario				
Impact rate and introduction dates	**BAU**	**I**	**II**	**III**	**IV**
Start date	2017	2017	2017	2017	2017
Tier 1 date	2020	2020	2020	2020	2020
Tier 2 date	2025	2025	2025	2025	2025
Tier 3 date	2030	2030	2030	2030	2030
Start impact rate	0%	100%	100%	25%	10%
Tier 1 impact rate	0%	100%	100%	50%	25%
Tier 2 impact rate	0%	100%	100%	75%	50%
Tier 3 impact rate	0%	100%	100%	100%	80%

Scenarios I and II:
Scenarios I and II have to be regarded as ideal "up to" scenarios. In scenario I the BAT improvement option is selected for each base case circuit. For scenario II, the LLCC improvement option is selected for each base case circuit. This selection of the design options for each scenario is listed in Table 7-1. The calculated BAT and LLCC design options may differ from the results in Task 6, due to the fact that this task looks at the total impact at EU28 level.
The assumption for scenario I and II is that the measures (in this case the implementation of the suggested design options) enter into force immediately at the start date of the scenario. Tiers 1, 2 and 3 are irrelevant in this case. The effectiveness is assumed to be 100%, meaning that all new and replaced circuits will be designed according the corresponding design options.

Scenarios III and IV:
Scenario III and IV model the case there are no compulsory measures, but only voluntary standards on the energy efficiency of cable installations (see 0). Scenario III is inspired by the recommendation of increasing the cross sectional area conductors to reduce the power losses as stated in HD 60634-8-1. As it is a voluntary standard the industry will look for a cost effective implementation and it will take the necessary time to be implemented in the field. As such, scenario III is based upon the assumption that only the distribution and dedicated circuits in the services and industry sectors are improved by means of the least impacting design option, it is the D1 design option (i.e.

S+1). Scenario IV adds to this scenario an assumed, educated guess of 10% additional reduction of the energy losses in the wiring due to additional requirements and recommendations like power factor correction, reduction of effects of harmonic currents, introduction of meshes, determination of the transformers and switchboard location, etcetera as stated in HD 60634-8-1. The selection of design options for both scenarios is listed in Table 7-1. Regarding the timing we assume that it will take some time before this voluntary standard has an effect on the implementation in the field. The assumed effectiveness is listed per tier in Table 7-2.

The input for the scenarios is based upon parameters and values defined in previous tasks. Due to the fact that this task looks at the total impact at EU28 level, the correction factors mentioned in section 5.5 of Task 5 are applied to the input data.

7.2.2 Scenario analysis

Later on in this task this scenario analysis will be referenced as the 'default scenario analysis', to distinguish it from the sensitivity scenario analysis cases.

7.2.2.1 Main input parameters for the analysis

The main input parameters are the parameters that will be altered in the sensitivity analysis. The parameters for this scenario analysis are listed in Table 7-3.

Table 7-3: Main input parameters

Discount rate	+4.0%
Inflation rate	+2.1%
Energy Escalation rate	+4.0%
Electricity rate (€/kWh)	0.11
Stock growth rate services sector	+1.9%
Stock growth rate industry sector	+2.9%
Replacement sales rate services sector	+3.2%
Replacement sales rate industry sector	+2.8%
Product lifetime services sector (years)	25
Product lifetime industry sector (years)	25
Product price factor	1
Growth / sales rate type	onalFrom1

7.2.2.2 Stock

Figure 6-1 and Table 7-4 show the increase of circuit stock in units of circuits due to the building stock increase. Of course the increase of the amount of circuits stays the same for each scenario. Figure 7-2 and Table 7-5 shows that this is not the case for the quantity of conductor material used in each scenario. Scenario I, opting for the best design options in terms of electricity loss reduction, needs the largest quantity of conductor material, more than 2 times the quantity needed in BAU scenario, in 2050.

The surplus of needed conductor material compared to the BAU scenario in case of scenario II is about +21.6%, in case of scenario III +27.9% and in case of scenario IV +25.9%, in 2050.

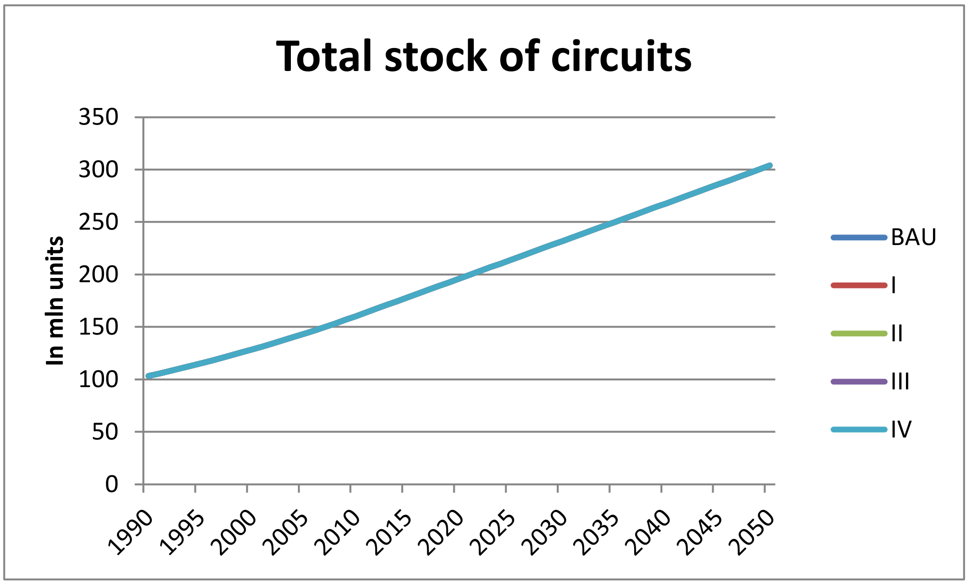


Figure 7-1: Total stock of circuits (in circuit units)

Table 7-4: Total stock of circuits (in circuit units)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	103.22	115.11	128.44	143.38	160.15	178.11	196.07	214.03	232.00	249.96	267.92	285.88	303.84
I	103.22	115.11	128.44	143.38	160.15	178.11	196.07	214.03	232.00	249.96	267.92	285.88	303.84
II	103.22	115.11	128.44	143.38	160.15	178.11	196.07	214.03	232.00	249.96	267.92	285.88	303.84
III	103.22	115.11	128.44	143.38	160.15	178.11	196.07	214.03	232.00	249.96	267.92	285.88	303.84
IV	103.22	115.11	128.44	143.38	160.15	178.11	196.07	214.03	232.00	249.96	267.92	285.88	303.84
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
III	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%

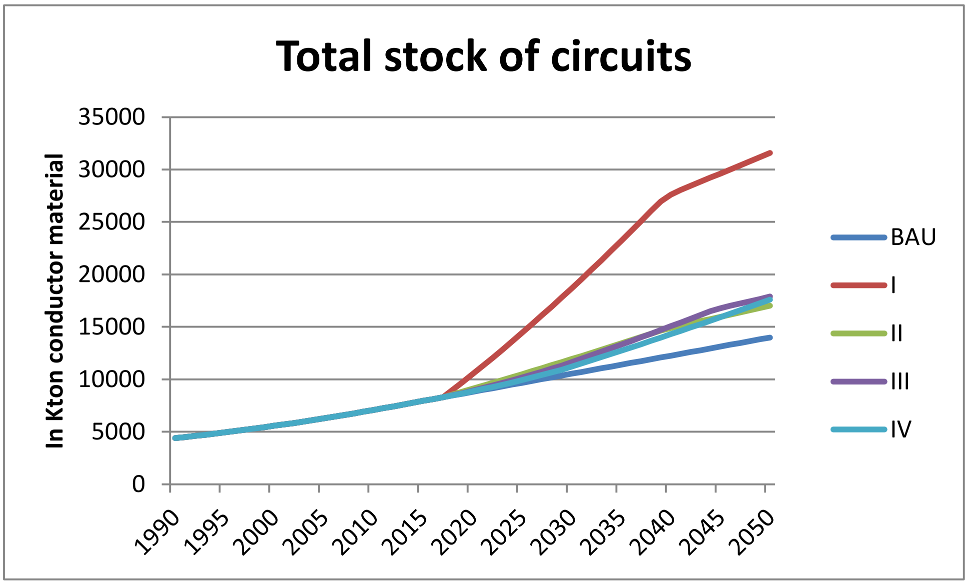


Figure 7-2: Total stock of circuits (in Kton conductor material)

Table 7-5: Total stock of circuits (in Kton conductor material)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	4389.84	4941.75	5566.35	6273.64	7075.00	7938.38	8801.75	9665.13	10528.50	11391.88	12255.25	13118.63	13982.00
I	4389.84	4941.75	5566.35	6273.64	7075.00	7938.38	10499.75	14432.11	18663.22	23193.07	27594.99	29618.98	31570.55
II	4389.84	4941.75	5566.35	6273.64	7075.00	7938.38	9094.73	10486.47	11928.26	13420.12	14898.73	15961.10	17008.43
III	4389.84	4941.75	5566.35	6273.64	7075.00	7938.38	8928.02	10167.62	11631.27	13310.36	15056.48	16760.00	17889.23
IV	4389.84	4941.75	5566.35	6273.64	7075.00	7938.38	8858.67	9927.87	11212.11	12728.05	14297.63	15920.84	17597.69
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	1698.00	4766.98	8134.72	11801.19	15339.74	16500.36	17588.55
II	0.00	0.00	0.00	0.00	0.00	0.00	292.98	821.34	1399.76	2028.24	2643.48	2842.47	3026.43
III	0.00	0.00	0.00	0.00	0.00	0.00	126.27	502.50	1102.77	1918.48	2801.23	3641.37	3907.23
IV	0.00	0.00	0.00	0.00	0.00	0.00	56.92	262.75	683.61	1336.18	2042.38	2802.22	3615.69
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+19.3%	+49.3%	+77.3%	+103.6%	+125.2%	+125.8%	+125.8%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+3.3%	+8.5%	+13.3%	+17.8%	+21.6%	+21.7%	+21.6%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+1.4%	+5.2%	+10.5%	+16.8%	+22.9%	+27.8%	+27.9%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.6%	+2.7%	+6.5%	+11.7%	+16.7%	+21.4%	+25.9%

Figure 7-3, Figure 7-4, Table 7-6 and Table 7-7 show that the number of BAU circuits decreases when they are replaced by improved circuits. The decrease is the same in circuit numbers as in conductor material for all scenarios.

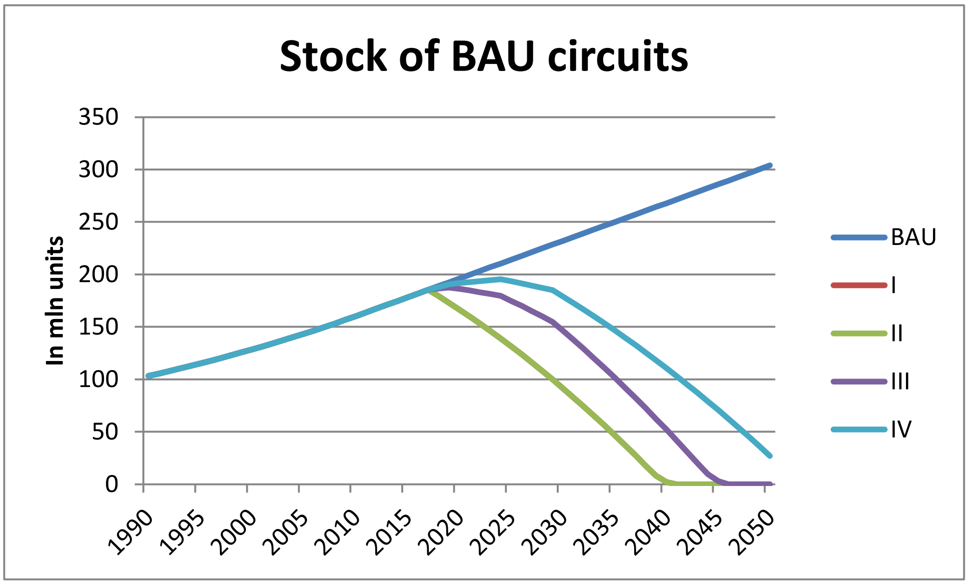


Figure 7-3: Stock of BAU circuits (in circuit units)

Table 7-6: Stock of BAU circuits (in circuit units)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	103.22	115.11	128.44	143.38	160.15	178.11	196.07	214.03	232.00	249.96	267.92	285.88	303.84
I	103.22	115.11	128.44	143.38	160.15	178.11	166.53	131.41	91.46	46.69	1.91	0.00	0.00
II	103.22	115.11	128.44	143.38	160.15	178.11	166.53	131.41	91.46	46.69	1.91	0.00	0.00
III	103.22	115.11	128.44	143.38	160.15	178.11	186.18	174.84	146.38	101.62	52.03	2.90	0.00
IV	103.22	115.11	128.44	143.38	160.15	178.11	191.61	193.55	178.97	146.75	110.67	70.74	26.96
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	-29.54	-82.63	-140.54	-203.26	-266.01	-285.88	-303.84
II	0.00	0.00	0.00	0.00	0.00	0.00	-29.54	-82.63	-140.54	-203.26	-266.01	-285.88	-303.84
III	0.00	0.00	0.00	0.00	0.00	0.00	-9.89	-39.19	-85.61	-148.34	-215.88	-282.98	-303.84
IV	0.00	0.00	0.00	0.00	0.00	0.00	-4.46	-20.48	-53.03	-103.21	-157.24	-215.14	-276.88
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-15.1%	-38.6%	-60.6%	-81.3%	-99.3%	-100.0%	-100.0%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-15.1%	-38.6%	-60.6%	-81.3%	-99.3%	-100.0%	-100.0%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-5.0%	-18.3%	-36.9%	-59.3%	-80.6%	-99.0%	-100.0%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-2.3%	-9.6%	-22.9%	-41.3%	-58.7%	-75.3%	-91.1%

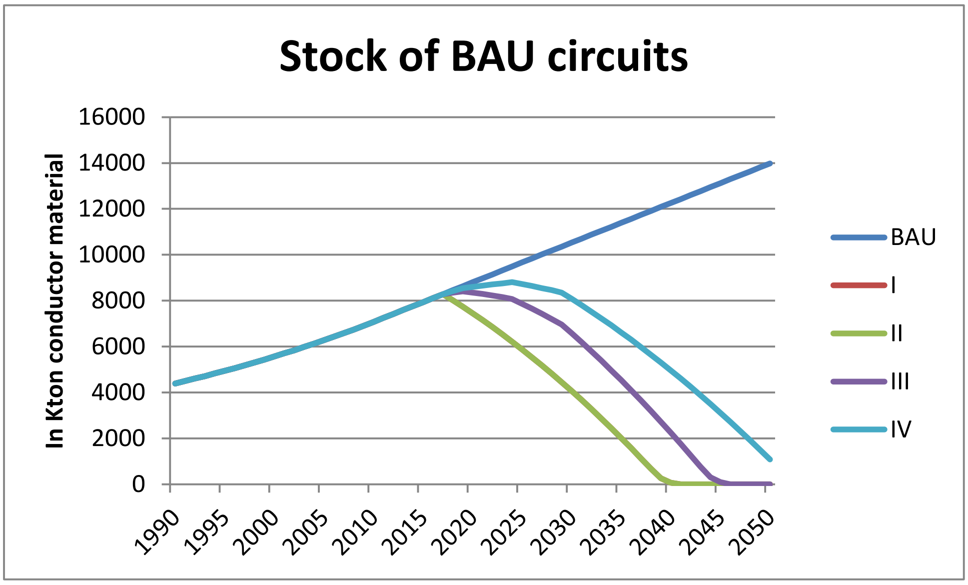


Figure 7-4: Stock of BAU circuits (in Kton conductor material)

Table 7-7: Stock of BAU circuits (in Kton conductor material)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	4389.84	4941.75	5566.35	6273.64	7075.00	7938.38	8801.75	9665.13	10528.50	11391.88	12255.25	13118.63	13982.00
I	4389.84	4941.75	5566.35	6273.64	7075.00	7938.38	7451.51	5875.05	4061.80	2011.74	58.89	0.00	0.00
II	4389.84	4941.75	5566.35	6273.64	7075.00	7938.38	7451.51	5875.05	4061.80	2011.74	58.89	0.00	0.00
III	4389.84	4941.75	5566.35	6273.64	7075.00	7938.38	8349.30	7866.03	6583.37	4533.31	2246.45	89.43	0.00
IV	4389.84	4941.75	5566.35	6273.64	7075.00	7938.38	8597.79	8724.48	8083.26	6615.89	4959.08	3112.83	1077.14
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	-1350.24	-3790.07	-6466.70	-9380.14	-12196.36	-13118.63	-13982.00
II	0.00	0.00	0.00	0.00	0.00	0.00	-1350.24	-3790.07	-6466.70	-9380.14	-12196.36	-13118.63	-13982.00
III	0.00	0.00	0.00	0.00	0.00	0.00	-452.45	-1799.09	-3945.13	-6858.57	-10008.80	-13029.19	-13982.00
IV	0.00	0.00	0.00	0.00	0.00	0.00	-203.96	-940.64	-2445.24	-4775.99	-7296.17	-10005.80	-12904.86
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-15.3%	-39.2%	-61.4%	-82.3%	-99.5%	-100.0%	-100.0%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-15.3%	-39.2%	-61.4%	-82.3%	-99.5%	-100.0%	-100.0%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-5.1%	-18.6%	-37.5%	-60.2%	-81.7%	-99.3%	-100.0%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-2.3%	-9.7%	-23.2%	-41.9%	-59.5%	-76.3%	-92.3%

Figure 7-5 and Table 7-8 show the number of circuits replaced by the 'improved' circuits. Figure 7-6 and Table 7-9 show the consequences for the amount of conductor material needed, as explained before for the total stock.

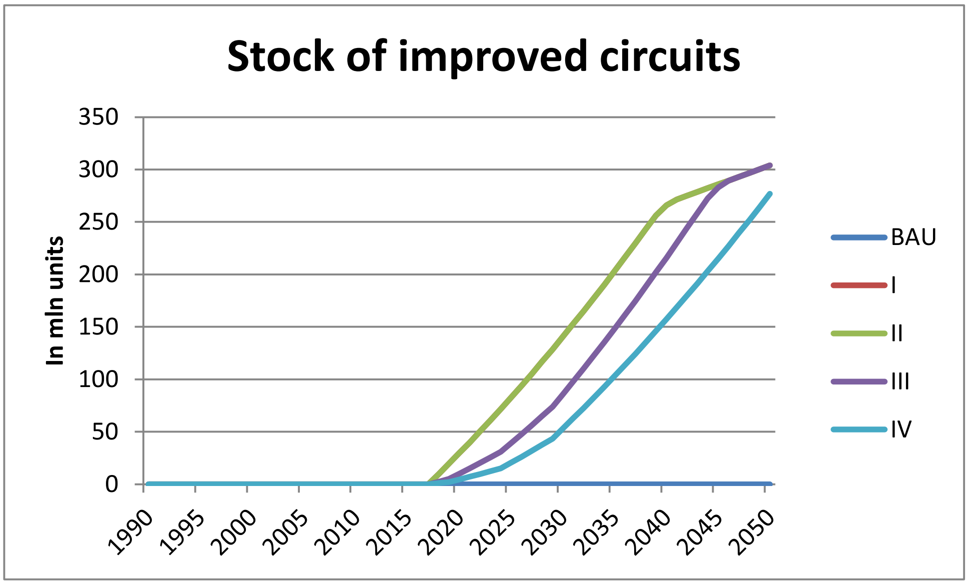


Figure 7-5: Stock of improved circuits (in circuit units)

Table 7-8: Stock of improved circuits (in circuit units)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I	0.00	0.00	0.00	0.00	0.00	0.00	29.54	82.63	140.54	203.26	266.01	285.88	303.84
II	0.00	0.00	0.00	0.00	0.00	0.00	29.54	82.63	140.54	203.26	266.01	285.88	303.84
III	0.00	0.00	0.00	0.00	0.00	0.00	9.89	39.19	85.61	148.34	215.88	282.98	303.84
IV	0.00	0.00	0.00	0.00	0.00	0.00	4.46	20.48	53.03	103.21	157.24	215.14	276.88
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	29.54	82.63	140.54	203.26	266.01	285.88	303.84
II	0.00	0.00	0.00	0.00	0.00	0.00	29.54	82.63	140.54	203.26	266.01	285.88	303.84
III	0.00	0.00	0.00	0.00	0.00	0.00	9.89	39.19	85.61	148.34	215.88	282.98	303.84
IV	0.00	0.00	0.00	0.00	0.00	0.00	4.46	20.48	53.03	103.21	157.24	215.14	276.88
Relative difference to BAU													
I	-	-	-	-	-	-	-	-	-	-	-	-	-
II	-	-	-	-	-	-	-	-	-	-	-	-	-
III	-	-	-	-	-	-	-	-	-	-	-	-	-
IV	-	-	-	-	-	-	-	-	-	-	-	-	-

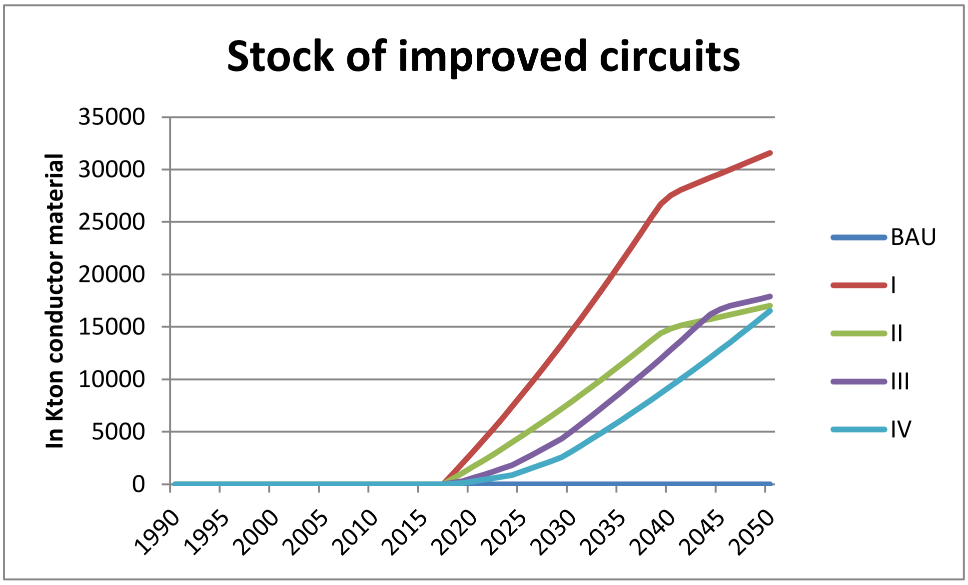


Figure 7-6: Stock of improved circuits (in Kton conductor material)

Table 7-9: Stock of improved circuits (in Kton conductor material)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I	0.00	0.00	0.00	0.00	0.00	0.00	3048.23	8557.05	14601.42	21181.33	27536.10	29618.98	31570.55
II	0.00	0.00	0.00	0.00	0.00	0.00	1643.22	4611.41	7866.47	11408.38	14839.84	15961.10	17008.43
III	0.00	0.00	0.00	0.00	0.00	0.00	578.71	2301.59	5047.91	8777.05	12810.03	16670.57	17889.23
IV	0.00	0.00	0.00	0.00	0.00	0.00	260.88	1203.39	3128.85	6112.16	9338.55	12808.01	16520.55
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	3048.23	8557.05	14601.42	21181.33	27536.10	29618.98	31570.55
II	0.00	0.00	0.00	0.00	0.00	0.00	1643.22	4611.41	7866.47	11408.38	14839.84	15961.10	17008.43
III	0.00	0.00	0.00	0.00	0.00	0.00	578.71	2301.59	5047.91	8777.05	12810.03	16670.57	17889.23
IV	0.00	0.00	0.00	0.00	0.00	0.00	260.88	1203.39	3128.85	6112.16	9338.55	12808.01	16520.55
Relative difference to BAU													
I	-	-	-	-	-	-	-	-	-	-	-	-	-
II	-	-	-	-	-	-	-	-	-	-	-	-	-
III	-	-	-	-	-	-	-	-	-	-	-	-	-
IV	-	-	-	-	-	-	-	-	-	-	-	-	-

7.2.2.3 Annual sales of circuits

The amount of sales in terms of number of circuits is displayed in Figure 7-7 and Table 7-10. There is no difference between the scenarios. The amount of sales in terms of conductor material differs between the scenarios starting at the introduction of the improved circuits in the stock, shown in Figure 7-8 and Table 7-11.

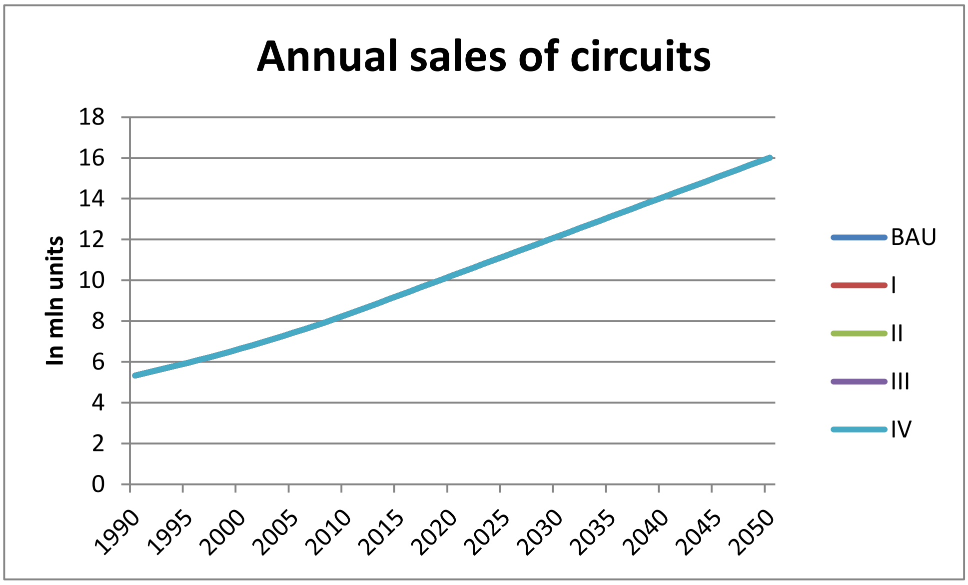


Figure 7-7: Annual sales of circuits (in circuit units)

Table 7-10: Annual sales of circuits (in circuit units)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	5.33	5.95	6.65	7.43	8.31	9.27	10.23	11.20	12.16	13.12	14.09	15.05	16.02
I	5.33	5.95	6.65	7.43	8.31	9.27	10.23	11.20	12.16	13.12	14.09	15.05	16.02
II	5.33	5.95	6.65	7.43	8.31	9.27	10.23	11.20	12.16	13.12	14.09	15.05	16.02
III	5.33	5.95	6.65	7.43	8.31	9.27	10.23	11.20	12.16	13.12	14.09	15.05	16.02
IV	5.33	5.95	6.65	7.43	8.31	9.27	10.23	11.20	12.16	13.12	14.09	15.05	16.02
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
III	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%

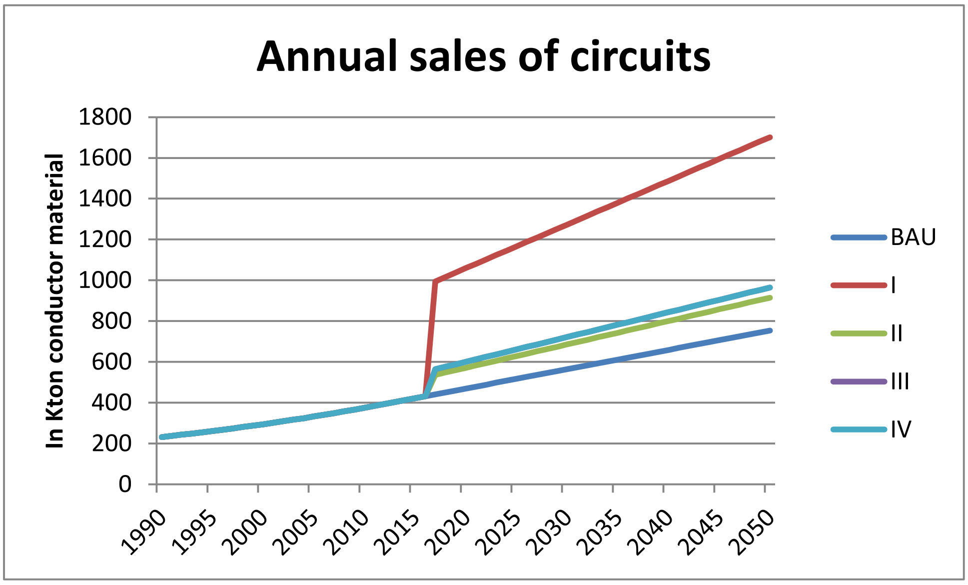


Figure 7-8: Annual sales of circuits (in Kton conductor material)

Table 7-11: Annual sales of circuits (in Kton conductor material)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	231.25	260.64	293.95	331.71	374.54	421.66	469.02	516.38	563.74	611.10	658.46	705.82	753.18
I	231.25	260.64	293.95	331.71	374.54	421.66	1058.92	1166.03	1273.14	1380.25	1487.36	1594.46	1701.57
II	231.25	260.64	293.95	331.71	374.54	421.66	570.69	628.06	685.43	742.81	800.18	857.55	914.92
III	231.25	260.64	293.95	331.71	374.54	421.66	599.98	660.75	721.52	782.29	843.06	903.83	964.60
IV	231.25	260.64	293.95	331.71	374.54	421.66	599.98	660.75	721.52	782.29	843.06	903.83	964.60
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	589.90	649.65	709.40	769.14	828.89	888.64	948.39
II	0.00	0.00	0.00	0.00	0.00	0.00	101.67	111.68	121.69	131.70	141.72	151.73	161.74
III	0.00	0.00	0.00	0.00	0.00	0.00	130.96	144.37	157.78	171.19	184.60	198.00	211.41
IV	0.00	0.00	0.00	0.00	0.00	0.00	130.96	144.37	157.78	171.19	184.60	198.00	211.41
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+125.8%	+125.8%	+125.8%	+125.9%	+125.9%	+125.9%	+125.9%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+21.7%	+21.6%	+21.6%	+21.6%	+21.5%	+21.5%	+21.5%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+27.9%	+28.0%	+28.0%	+28.0%	+28.0%	+28.1%	+28.1%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+27.9%	+28.0%	+28.0%	+28.0%	+28.0%	+28.1%	+28.1%

Table 7-12 and Figure 7-9 show the sales due to circuit replacement, in number of circuits. Table 7-13 and Figure 7-10 display the same replacement sales but expressed in amount of conductor material needed here for.

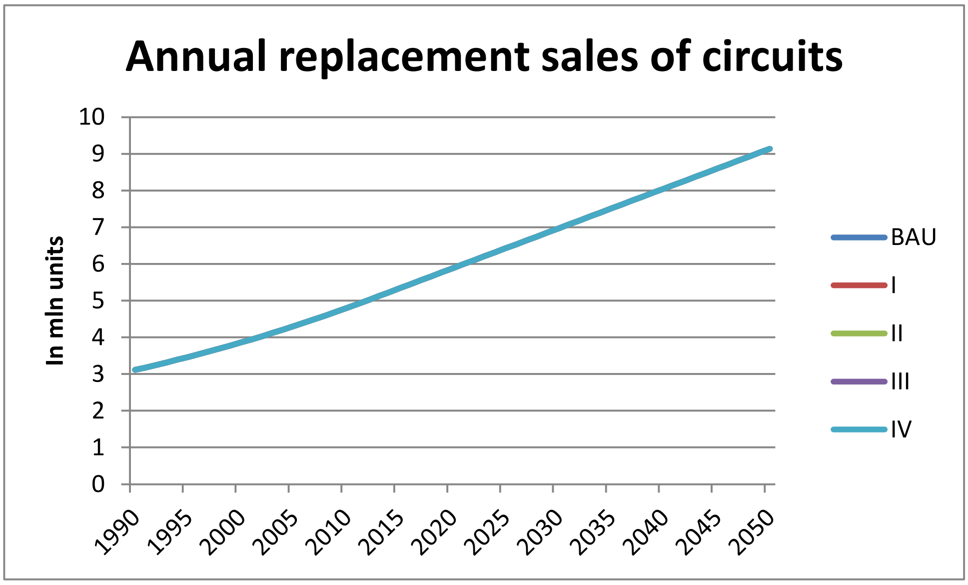


Figure 7-9: Annual replacement sales of circuits (in circuit units)

Table 7-12: Annual replacement sales of circuits (in circuit units)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	3.11	3.46	3.86	4.30	4.80	5.34	5.88	6.43	6.97	7.51	8.05	8.60	9.14
I	3.11	3.46	3.86	4.30	4.80	5.34	5.88	6.43	6.97	7.51	8.05	8.60	9.14
II	3.11	3.46	3.86	4.30	4.80	5.34	5.88	6.43	6.97	7.51	8.05	8.60	9.14
III	3.11	3.46	3.86	4.30	4.80	5.34	5.88	6.43	6.97	7.51	8.05	8.60	9.14
IV	3.11	3.46	3.86	4.30	4.80	5.34	5.88	6.43	6.97	7.51	8.05	8.60	9.14
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
III	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%

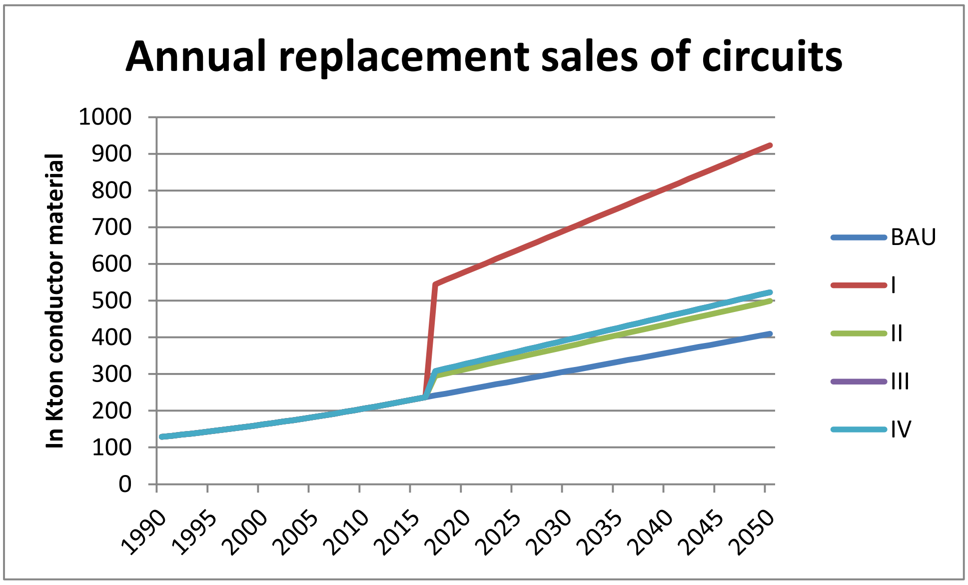


Figure 7-10: Annual replacement sales of circuits (in Kton conductor material)

Table 7-13: Annual replacement sales of circuits (in Kton conductor material)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	128.80	144.74	162.75	183.11	206.14	231.43	256.84	282.25	307.66	333.07	358.48	383.88	409.29
I	128.80	144.74	162.75	183.11	206.14	231.43	579.13	636.52	693.92	751.32	808.72	866.12	923.51
II	128.80	144.74	162.75	183.11	206.14	231.43	313.53	344.40	375.28	406.16	437.03	467.91	498.78
III	128.80	144.74	162.75	183.11	206.14	231.43	327.81	360.34	392.88	425.41	457.95	490.48	523.02
IV	128.80	144.74	162.75	183.11	206.14	231.43	327.81	360.34	392.88	425.41	457.95	490.48	523.02
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	322.29	354.28	386.27	418.25	450.24	482.23	514.22
II	0.00	0.00	0.00	0.00	0.00	0.00	56.69	62.16	67.62	73.09	78.56	84.02	89.49
III	0.00	0.00	0.00	0.00	0.00	0.00	70.97	78.09	85.22	92.35	99.47	106.60	113.72
IV	0.00	0.00	0.00	0.00	0.00	0.00	70.97	78.09	85.22	92.35	99.47	106.60	113.72
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+125.5%	+125.5%	+125.6%	+125.6%	+125.6%	+125.6%	+125.6%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+22.1%	+22.0%	+22.0%	+21.9%	+21.9%	+21.9%	+21.9%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+27.6%	+27.7%	+27.7%	+27.7%	+27.7%	+27.8%	+27.8%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+27.6%	+27.7%	+27.7%	+27.7%	+27.7%	+27.8%	+27.8%

7.2.2.4 Annual demand of electricity due to losses in circuits

Table 7-14 and Figure 7-11 show for the design option scenarios a significant diminution of electricity losses in the total stock of circuits thanks to the introduction of improved circuits compared to the BAU scenario. The decrease will take place for all design option scenarios although at a different pace. Compared to the BAU scenario the decrease starts at the introduction of the improved circuits and will carry on till all BAU circuits are replaced by improved circuits. This will take more time in case of scenario III and IV compared to scenario I or II. In scenario I, II and III the nod in the figure is showing the turning point where all BAU circuits are replaced by improved circuits. In scenario IV this point is not reached before 2050, meaning that part of the installed circuits are still BAU circuits.

For scenario I, this equates to a reduction of annual electricity losses up to -13.61 TWh in 2025. For scenario II, this equates to a reduction of annual electricity losses up to -

7.60 TWh, for scenario III a reduction of about -2.93 TWh and for scenario IV a reduction of about -1.93 TWh, in 2025.

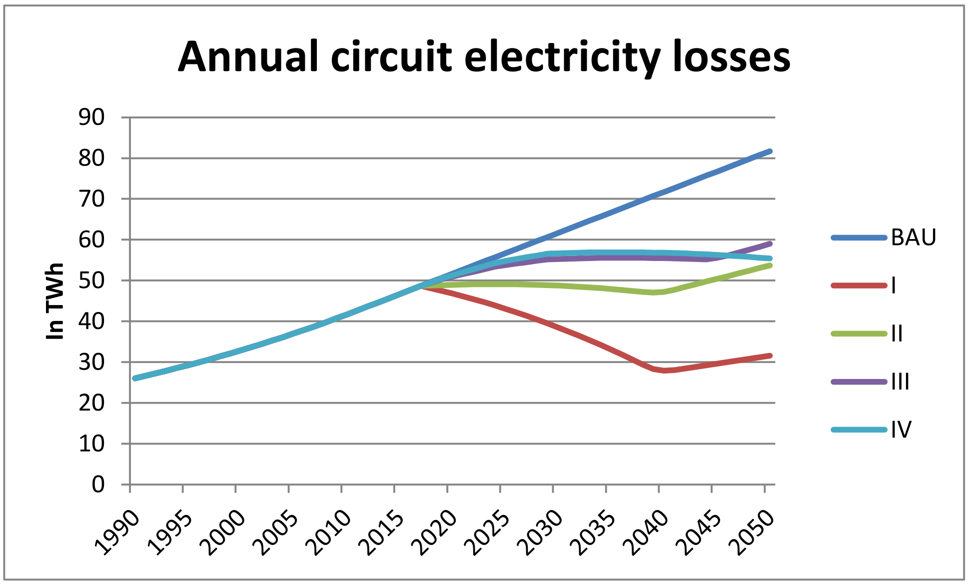


Figure 7-11: Annual circuit electricity losses (in TWh/yr)

Table 7-14: Annual circuit electricity losses (in TWh/yr)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	26.02	29.24	32.88	36.99	41.65	46.66	51.67	56.67	61.68	66.69	71.70	76.71	81.72
I	26.02	29.24	32.88	36.99	41.65	46.66	46.81	43.06	38.47	33.05	27.89	29.60	31.54
II	26.02	29.24	32.88	36.99	41.65	46.66	48.95	49.07	48.73	47.92	47.23	50.40	53.71
III	26.02	29.24	32.88	36.99	41.65	46.66	50.93	53.75	55.27	55.56	55.47	55.53	58.98
IV	26.02	29.24	32.88	36.99	41.65	46.66	51.25	54.75	56.68	56.93	56.79	56.28	55.39
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	-4.85	-13.61	-23.21	-33.64	-43.81	-47.11	-50.18
II	0.00	0.00	0.00	0.00	0.00	0.00	-2.71	-7.60	-12.96	-18.77	-24.47	-26.31	-28.01
III	0.00	0.00	0.00	0.00	0.00	0.00	-0.74	-2.93	-6.41	-11.13	-16.23	-21.18	-22.74
IV	0.00	0.00	0.00	0.00	0.00	0.00	-0.42	-1.93	-5.00	-9.76	-14.91	-20.43	-26.33
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-9.4%	-24.0%	-37.6%	-50.4%	-61.1%	-61.4%	-61.4%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-5.2%	-13.4%	-21.0%	-28.1%	-34.1%	-34.3%	-34.3%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-1.4%	-5.2%	-10.4%	-16.7%	-22.6%	-27.6%	-27.8%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-0.8%	-3.4%	-8.1%	-14.6%	-20.8%	-26.6%	-32.2%

7.2.2.5 Annual emissions of CO_2 eq.

Figure 7-12 and Table 7-15 show a considerable increase of GHG emissions for the design option scenarios starting at the introduction of the improved circuits in the stock. For the scenario I it means that the emissions due to production and distribution more than double.

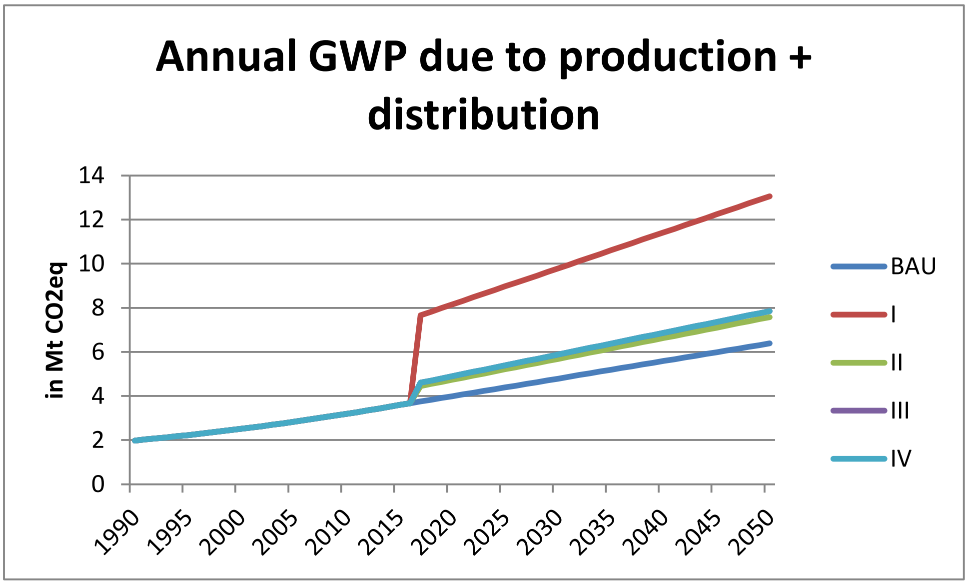


Figure 7-12: Annual GWP due to production + distribution (in Mt CO_2 eq.)

Table 7-15: Annual GWP due to production + distribution (in Mt CO_2 eq.)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	1.98	2.23	2.51	2.83	3.19	3.59	3.99	4.39	4.79	5.19	5.59	5.99	6.39
I	1.98	2.23	2.51	2.83	3.19	3.59	8.15	8.97	9.79	10.61	11.42	12.24	13.06
II	1.98	2.23	2.51	2.83	3.19	3.59	4.74	5.21	5.68	6.16	6.63	7.10	7.58
III	1.98	2.23	2.51	2.83	3.19	3.59	4.90	5.39	5.88	6.37	6.87	7.36	7.85
IV	1.98	2.23	2.51	2.83	3.19	3.59	4.90	5.39	5.88	6.37	6.87	7.36	7.85
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	4.16	4.58	5.00	5.42	5.84	6.25	6.67
II	0.00	0.00	0.00	0.00	0.00	0.00	0.75	0.82	0.89	0.97	1.04	1.11	1.19
III	0.00	0.00	0.00	0.00	0.00	0.00	0.91	1.00	1.09	1.19	1.28	1.37	1.46
IV	0.00	0.00	0.00	0.00	0.00	0.00	0.91	1.00	1.09	1.19	1.28	1.37	1.46
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+104.4%	+104.4%	+104.4%	+104.4%	+104.5%	+104.5%	+104.5%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+18.7%	+18.7%	+18.7%	+18.7%	+18.6%	+18.6%	+18.6%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+22.8%	+22.8%	+22.9%	+22.9%	+22.9%	+22.9%	+22.9%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+22.8%	+22.8%	+22.9%	+22.9%	+22.9%	+22.9%	+22.9%

As expected, Figure 7-13 and Table 7-16 show the diminution of GHG emissions due to the lower electricity losses of the improved circuits. Compared to the BAU scenario, the decrease starts at the introduction of the improved circuits and will carry on till all BAU circuits are replaced by improved circuits, thus until introduction date plus product lifetime. From then on the emissions of GHG due to electricity losses will again increase, due to stock increase, although at a slower pace as for the BAU scenario.

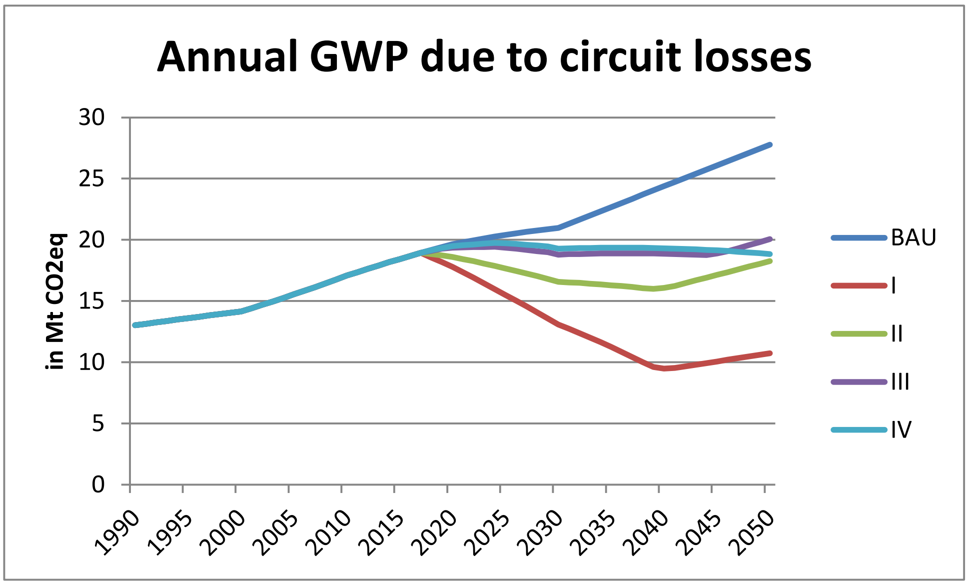


Figure 7-13: Annual GWP (total stock) due to circuit losses (in Mt CO_2 eq.)

Table 7-16: Annual GWP (total stock) due to circuit losses (in Mt CO_2 eq.)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	13.01	13.60	14.14	15.54	17.08	18.43	19.63	20.40	20.97	22.68	24.38	26.08	27.78
I	13.01	13.60	14.14	15.54	17.08	18.43	17.79	15.50	13.08	11.24	9.48	10.06	10.72
II	13.01	13.60	14.14	15.54	17.08	18.43	18.60	17.67	16.57	16.29	16.06	17.14	18.26
III	13.01	13.60	14.14	15.54	17.08	18.43	19.35	19.35	18.79	18.89	18.86	18.88	20.05
IV	13.01	13.60	14.14	15.54	17.08	18.43	19.47	19.71	19.27	19.36	19.31	19.14	18.83
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	-1.84	-4.90	-7.89	-11.44	-14.90	-16.02	-17.06
II	0.00	0.00	0.00	0.00	0.00	0.00	-1.03	-2.74	-4.40	-6.38	-8.32	-8.95	-9.52
III	0.00	0.00	0.00	0.00	0.00	0.00	-0.28	-1.05	-2.18	-3.79	-5.52	-7.20	-7.73
IV	0.00	0.00	0.00	0.00	0.00	0.00	-0.16	-0.69	-1.70	-3.32	-5.07	-6.95	-8.95
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-9.4%	-24.0%	-37.6%	-50.4%	-61.1%	-61.4%	-61.4%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-5.2%	-13.4%	-21.0%	-28.1%	-34.1%	-34.3%	-34.3%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-1.4%	-5.2%	-10.4%	-16.7%	-22.6%	-27.6%	-27.8%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-0.8%	-3.4%	-8.1%	-14.6%	-20.8%	-26.6%	-32.2%

Figure 7-14 and Table 7-17 show that 25 years, which equals the product lifetime, after the introduction of the improved circuits a considerable gain in emissions can be noted due to the recycling of the improved circuits, compared to the BAU scenario.

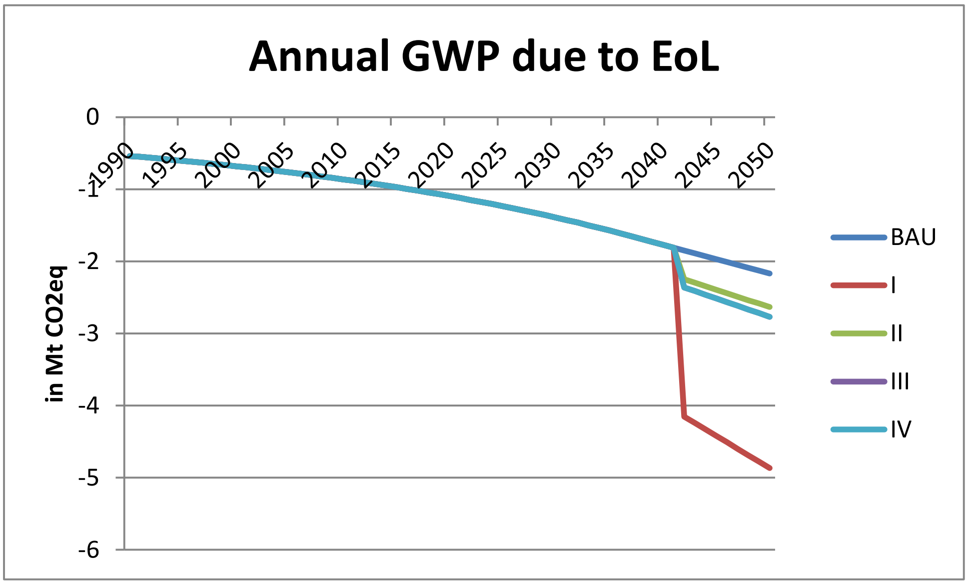


Figure 7-14: Annual GWP due to EoL (in Mt CO_2 eq.)

Table 7-17: Annual GWP due to EoL (in Mt CO_2 eq.)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	-0.54	-0.61	-0.68	-0.77	-0.86	-0.97	-1.10	-1.24	-1.39	-1.57	-1.77	-1.97	-2.17
I	-0.54	-0.61	-0.68	-0.77	-0.86	-0.97	-1.10	-1.24	-1.39	-1.57	-1.77	-4.42	-4.87
II	-0.54	-0.61	-0.68	-0.77	-0.86	-0.97	-1.10	-1.24	-1.39	-1.57	-1.77	-2.39	-2.63
III	-0.54	-0.61	-0.68	-0.77	-0.86	-0.97	-1.10	-1.24	-1.39	-1.57	-1.77	-2.51	-2.77
IV	-0.54	-0.61	-0.68	-0.77	-0.86	-0.97	-1.10	-1.24	-1.39	-1.57	-1.77	-2.51	-2.77
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-2.45	-2.70
II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.42	-0.46
III	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.54	-0.60
IV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.54	-0.60
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+124.3%	+124.4%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+21.5%	+21.4%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+27.6%	+27.6%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+27.6%	+27.6%

Figure 7-15 and Table 7-18 show at the start of the introduction of the improved circuits a considerable increase of GHG emissions due to the production and distribution of these circuits, compared to the BAU circuits. In case of scenario I, it will take less than 8 years before the total GHG emissions drop below emissions level of the BAU scenario. In case of scenario II, it will take less than 3 years, in case of scenario III it will take less than 8 years, and in case of scenario IV it will take less than 13 years before the total GHG emissions drop below emissions level of the BAU scenario.

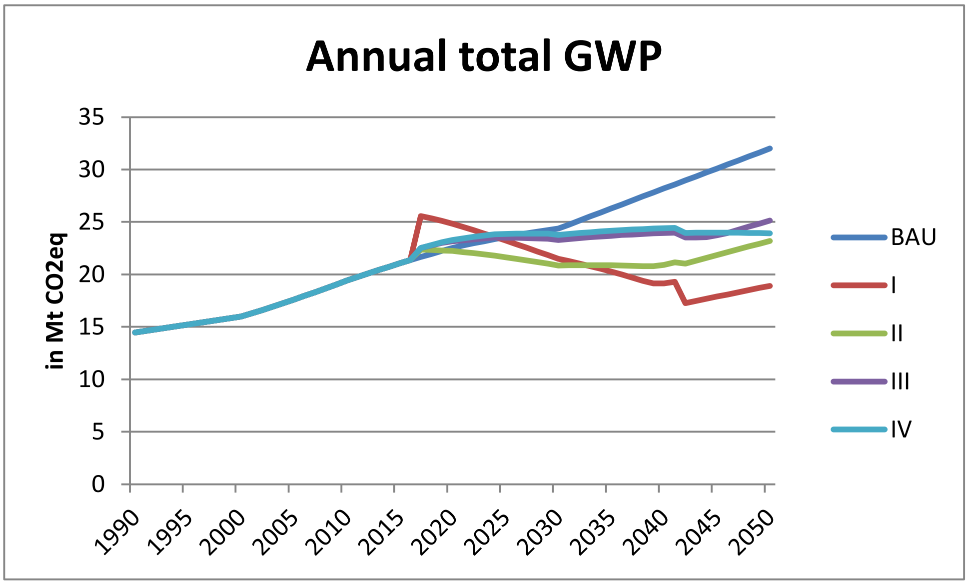
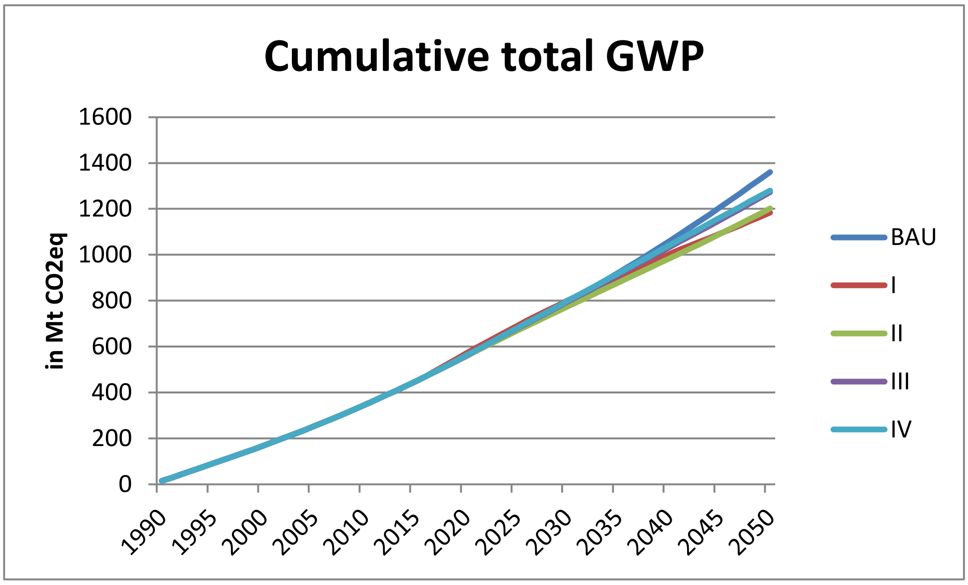


Figure 7-15: Annual total GWP (in Mt CO_2 eq.)

Table 7-18: Annual total GWP (in Mt CO_2 eq.)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	14.45	15.22	15.97	17.60	19.40	21.05	22.53	23.56	24.37	26.29	28.19	30.10	32.00
I	14.45	15.22	15.97	17.60	19.40	21.05	24.85	23.24	21.48	20.27	19.14	17.88	18.92
II	14.45	15.22	15.97	17.60	19.40	21.05	22.24	21.64	20.86	20.87	20.92	21.84	23.20
III	14.45	15.22	15.97	17.60	19.40	21.05	23.16	23.50	23.28	23.69	23.95	23.72	25.14
IV	14.45	15.22	15.97	17.60	19.40	21.05	23.28	23.86	23.76	24.16	24.41	23.98	23.92
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	2.32	-0.32	-2.89	-6.02	-9.06	-12.21	-13.09
II	0.00	0.00	0.00	0.00	0.00	0.00	-0.28	-1.92	-3.51	-5.41	-7.28	-8.25	-8.80
III	0.00	0.00	0.00	0.00	0.00	0.00	0.63	-0.05	-1.09	-2.60	-4.24	-6.37	-6.86
IV	0.00	0.00	0.00	0.00	0.00	0.00	0.75	0.31	-0.61	-2.13	-3.79	-6.12	-8.09
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+10.3%	-1.4%	-11.9%	-22.9%	-32.1%	-40.6%	-40.9%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-1.3%	-8.1%	-14.4%	-20.6%	-25.8%	-27.4%	-27.5%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+2.8%	-0.2%	-4.5%	-9.9%	-15.0%	-21.2%	-21.5%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+3.3%	+1.3%	-2.5%	-8.1%	-13.4%	-20.3%	-25.3%

The figures in Table 7-19, illustrated by Figure 7-16, show that in case of scenario I it will take about 15 years to level out the increase of GHG emission due to the increase of GHG caused by production and distribution of the improved circuits. In case of the scenario I, it will take about 5 years, in case of scenario III about 14 years and in case of scenario IV about 17 years.



(in Mt CO_2 eq.)

Figure 7-16: Cumulative GWP (in Mt CO_2 eq.)

Table 7-19: Cumulative GWP (in Mt CO_2 eq.)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	14.45	89.01	167.36	252.03	345.37	447.38	557.12	672.92	793.22	920.83	1058.00	1204.68	1360.89
I	14.45	89.01	167.36	252.03	345.37	447.38	569.59	689.07	800.02	903.90	1001.27	1090.88	1183.40
II	14.45	89.01	167.36	252.03	345.37	447.38	557.96	667.45	773.36	877.77	981.97	1088.87	1202.16
III	14.45	89.01	167.36	252.03	345.37	447.38	560.15	677.21	794.28	911.98	1031.27	1149.60	1272.34
IV	14.45	89.01	167.36	252.03	345.37	447.38	560.38	678.79	798.11	918.15	1039.74	1160.07	1279.83
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	12.47	16.14	6.80	-16.93	-56.73	-113.80	-177.49
II	0.00	0.00	0.00	0.00	0.00	0.00	0.85	-5.48	-19.86	-43.06	-76.03	-115.81	-158.72
III	0.00	0.00	0.00	0.00	0.00	0.00	3.04	4.28	1.06	-8.86	-26.73	-55.09	-88.54
IV	0.00	0.00	0.00	0.00	0.00	0.00	3.26	5.87	4.88	-2.68	-18.26	-44.62	-81.06
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+2.2%	+2.4%	+0.9%	-1.8%	-5.4%	-9.4%	-13.0%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.2%	-0.8%	-2.5%	-4.7%	-7.2%	-9.6%	-11.7%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.5%	+0.6%	+0.1%	-1.0%	-2.5%	-4.6%	-6.5%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.6%	+0.9%	+0.6%	-0.3%	-1.7%	-3.7%	-6.0%

7.3 Socio-economic impact analysis

7.3.1 Annual expenditure

The next figures illustrate that initial investment costs for building owners will be higher but there is a return on investment. Building owners might need higher loans and therefore dedicated bank support might be needed and could be considered as a policy option.
In Figure 7-17 and Table 7-20 one can notice that after the introduction of improved circuits the sales at EU-28 level in terms of EURO (year 2010) increases with about +100.5% for scenario I, about +16.1% for scenario II, +20.1% for scenario III and about +20.1% in case of scenario IV. In case of scenario IV there is a decrease in annual expenditure. In case of scenario IV no costs related to the additional HD 60364-8-1:2015 measures are foreseen in the simulation model. Amongst others, measures

mentioned in the standard are a better design of the electrical installation (placement of distribution boards, determination of meshes, etc.), power factor correction and so on.
The increase in terms of EUROs does not only reflect the cable purchase cost increase, but also the installation cost (and connector cost) increase.

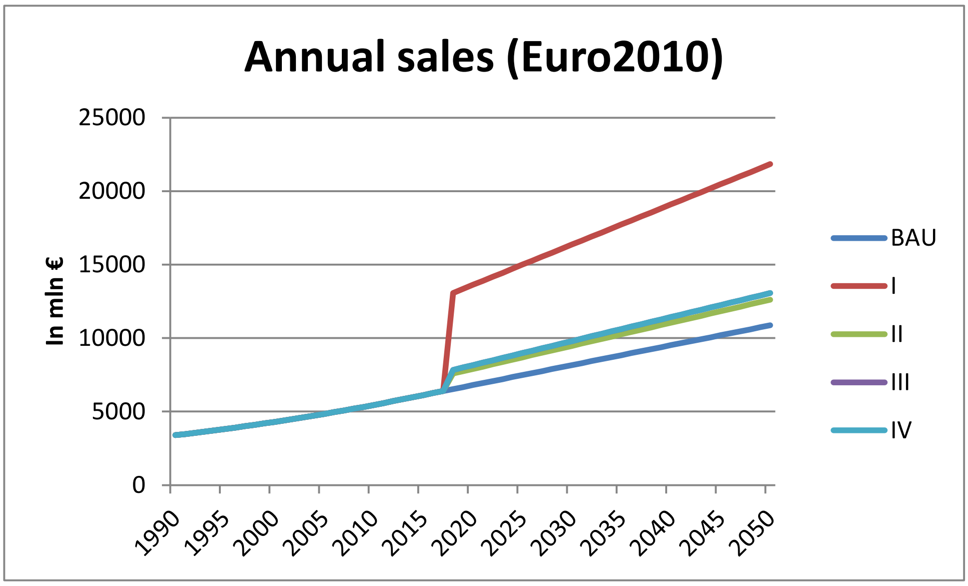


Figure 7-17: Annual sales (in mln. euro)

Table 7-20: Annual sales (in mln. euro)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	3391.69	3815.41	4294.61	4836.89	5450.88	6125.51	6803.49	7481.46	8159.43	8837.41	9515.38	10193.35	10871.33
I	3391.69	3815.41	4294.61	4836.89	5450.88	6125.51	13622.15	14991.11	16360.06	17729.02	19097.98	20466.93	21835.89
II	3391.69	3815.41	4294.61	4836.89	5450.88	6125.51	7899.86	8685.19	9470.51	10255.83	11041.15	11826.47	12611.79
III	3391.69	3815.41	4294.61	4836.89	5450.88	6125.51	8163.53	8980.34	9797.15	10613.96	11430.77	12247.58	13064.39
IV	3391.69	3815.41	4294.61	4836.89	5450.88	6125.51	8163.53	8980.34	9797.15	10613.96	11430.77	12247.58	13064.39
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	6818.66	7509.65	8200.63	8891.61	9582.60	10273.58	10964.56
II	0.00	0.00	0.00	0.00	0.00	0.00	1096.38	1203.73	1311.07	1418.42	1525.77	1633.12	1740.46
III	0.00	0.00	0.00	0.00	0.00	0.00	1360.04	1498.88	1637.72	1776.55	1915.39	2054.23	2193.06
IV	0.00	0.00	0.00	0.00	0.00	0.00	1360.04	1498.88	1637.72	1776.55	1915.39	2054.23	2193.06
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+100.2%	+100.4%	+100.5%	+100.6%	+100.7%	+100.8%	+100.9%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+16.1%	+16.1%	+16.1%	+16.1%	+16.0%	+16.0%	+16.0%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+20.0%	+20.0%	+20.1%	+20.1%	+20.1%	+20.2%	+20.2%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+20.0%	+20.0%	+20.1%	+20.1%	+20.1%	+20.2%	+20.2%

Figure 7-18 and Table 7-21 show the stock value in terms of EURO (year 1020). The stock value at year N equals the summation of all precedent sales up to the year N minus the product lifetime period.

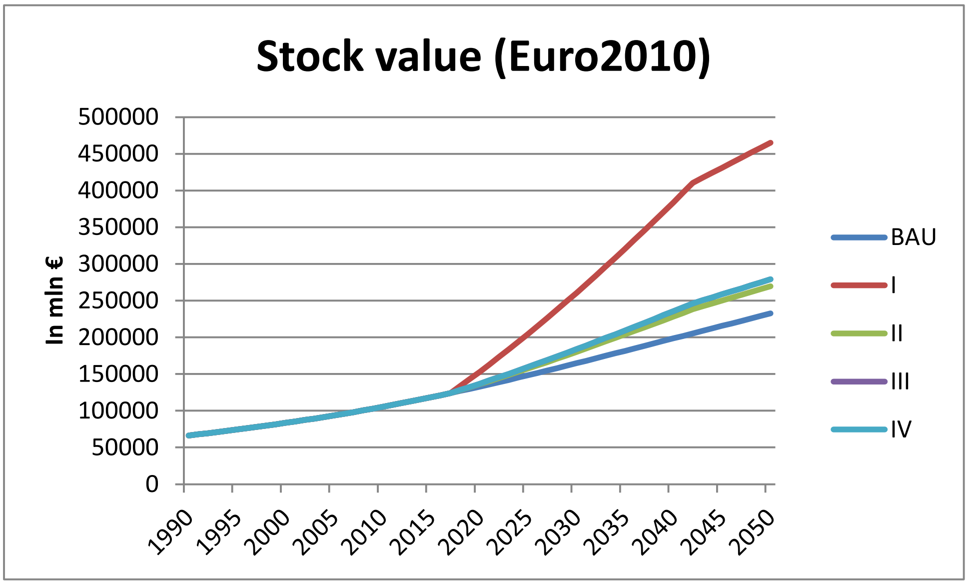


Figure 7-18: Stock value (in mln. euro)

Table 7-21: Stock value (in mln. euro)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	66369.91	74399.02	83468.31	93718.49	105310.04	118391.24	132843.91	148404.24	164772.43	181607.65	198556.99	215506.34	232455.68
I	66369.91	74399.02	83468.31	93718.49	105310.04	118391.24	152885.31	204611.91	260601.29	320512.61	383992.97	430886.85	465110.77
II	66369.91	74399.02	83468.31	93718.49	105310.04	118391.24	136068.63	157432.89	180141.76	203854.39	228217.88	249893.39	269526.42
III	66369.91	74399.02	83468.31	93718.49	105310.04	118391.24	136840.74	159617.80	183896.90	209337.22	235585.84	258531.81	278952.06
IV	66369.91	74399.02	83468.31	93718.49	105310.04	118391.24	136840.74	159617.80	183896.90	209337.22	235585.84	258531.81	278952.06
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	20041.40	56207.67	95828.86	138904.96	185435.98	215380.51	232655.09
II	0.00	0.00	0.00	0.00	0.00	0.00	3224.72	9028.66	15369.33	22246.74	29660.89	34387.05	37070.75
III	0.00	0.00	0.00	0.00	0.00	0.00	3996.83	11213.56	19124.47	27729.56	37028.84	43025.47	46496.38
IV	0.00	0.00	0.00	0.00	0.00	0.00	3996.83	11213.56	19124.47	27729.56	37028.84	43025.47	46496.38
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+15.1%	+37.9%	+58.2%	+76.5%	+93.4%	+99.9%	+100.1%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+2.4%	+6.1%	+9.3%	+12.2%	+14.9%	+16.0%	+15.9%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+3.0%	+7.6%	+11.6%	+15.3%	+18.6%	+20.0%	+20.0%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+3.0%	+7.6%	+11.6%	+15.3%	+18.6%	+20.0%	+20.0%

At the benefit side Figure 7-19 and Table 7-22 show the gains due to lower electricity losses in case of improved circuits in net present value terms for the year 2010. From the introduction of the improved circuits, the end-user will have to spend less on electricity due to the higher energy efficiency of the improved circuits. In 2025 the total EU28 expenditure caused by energy losses in electric circuits will diminish by about -24.0% in case of scenario I, by about -13.4% in case of scenario II, -5.2% in case of scenario III, and by about -3.4% in case of scenario IV.

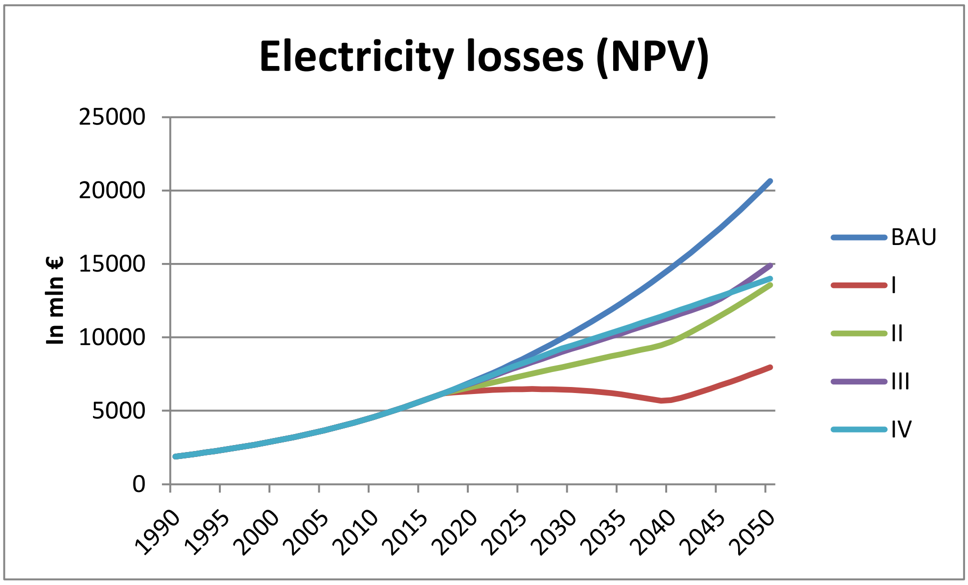


Figure 7-19: Annual expenditure due to electricity losses (in mln. euro)

Table 7-22: Annual expenditure due to electricity losses (in mln. euro)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	1888.84	2355.08	2938.15	3667.76	4581.27	5694.23	6996.00	8514.59	10281.87	12334.11	14712.50	17463.88	20641.42
I	1888.84	2355.08	2938.15	3667.76	4581.27	5694.23	6338.74	6469.40	6413.18	6112.34	5722.72	6737.71	7966.12
II	1888.84	2355.08	2938.15	3667.76	4581.27	5694.23	6628.79	7372.46	8122.28	8862.23	9691.91	11474.21	13565.83
III	1888.84	2355.08	2938.15	3667.76	4581.27	5694.23	6896.17	8074.74	9213.08	10274.86	11381.37	12641.52	14898.69
IV	1888.84	2355.08	2938.15	3667.76	4581.27	5694.23	6939.34	8225.01	9447.67	10528.17	11653.87	12813.17	13990.42
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	-657.26	-2045.19	-3868.69	-6221.77	-8989.79	-10726.17	-12675.30
II	0.00	0.00	0.00	0.00	0.00	0.00	-367.21	-1142.13	-2159.60	-3471.88	-5020.60	-5989.67	-7075.59
III	0.00	0.00	0.00	0.00	0.00	0.00	-99.83	-439.85	-1068.79	-2059.25	-3331.13	-4822.36	-5742.73
IV	0.00	0.00	0.00	0.00	0.00	0.00	-56.66	-289.58	-834.20	-1805.94	-3058.63	-4650.72	-6651.00
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-9.4%	-24.0%	-37.6%	-50.4%	-61.1%	-61.4%	-61.4%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-5.2%	-13.4%	-21.0%	-28.1%	-34.1%	-34.3%	-34.3%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-1.4%	-5.2%	-10.4%	-16.7%	-22.6%	-27.6%	-27.8%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-0.8%	-3.4%	-8.1%	-14.6%	-20.8%	-26.6%	-32.2%

Figure 7-20 and Table 7-23 show the residual value in mln. euro due to the recycling of the conductor material.

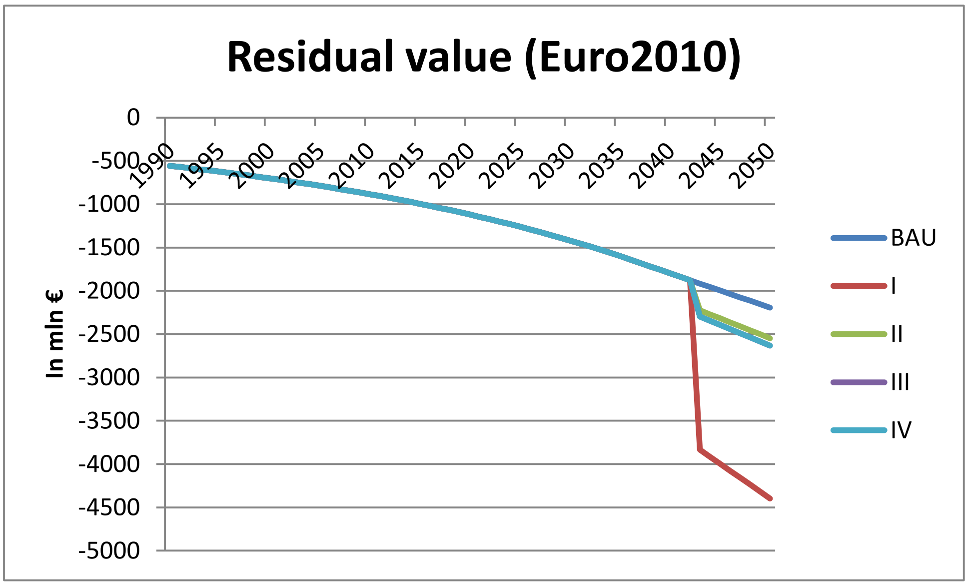


Figure 7-20: Residual value (in mln. euro)

Table 7-23: Residual value (in mln. euro)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	-557.07	-624.82	-701.21	-787.41	-884.73	-994.67	-1118.93	-1259.46	-1418.49	-1598.55	-1796.40	-1995.22	-2194.05
I	-557.07	-624.82	-701.21	-787.41	-884.73	-994.67	-1118.93	-1259.46	-1418.49	-1598.55	-1796.40	-3994.90	-4396.37
II	-557.07	-624.82	-701.21	-787.41	-884.73	-994.67	-1118.93	-1259.46	-1418.49	-1598.55	-1796.40	-2316.75	-2547.06
III	-557.07	-624.82	-701.21	-787.41	-884.73	-994.67	-1118.93	-1259.46	-1418.49	-1598.55	-1796.40	-2394.08	-2633.62
IV	-557.07	-624.82	-701.21	-787.41	-884.73	-994.67	-1118.93	-1259.46	-1418.49	-1598.55	-1796.40	-2394.08	-2633.62
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1999.68	-2202.32
II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-321.53	-353.01
III	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-398.85	-439.57
IV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-398.85	-439.57
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+100.2%	+100.4%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+16.1%	+16.1%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+20.0%	+20.0%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+20.0%	+20.0%

Figure 7-21 and Table 7-24: Total costs (annual sales + losses) (in mln. euro)Table 7-24 show the total annual expenditure at EU-28 level, summing the annual sales, annual expenditure due to electricity losses and residual value.

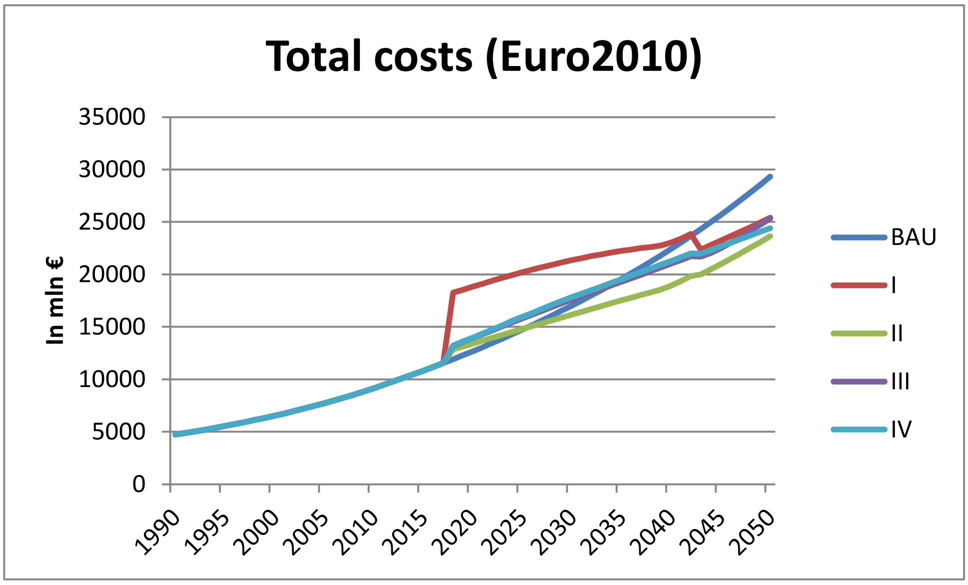


Figure 7-21: Total costs (annual sales + losses) (in mln. euro)

Table 7-24: Total costs (annual sales + losses) (in mln. euro)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	4723.47	5545.67	6531.55	7717.23	9147.42	10825.08	12680.56	14736.59	17022.82	19572.96	22431.48	25662.01	29318.70
I	4723.47	5545.67	6531.55	7717.23	9147.42	10825.08	18841.96	20201.04	21354.76	22242.80	23024.30	23209.75	25405.65
II	4723.47	5545.67	6531.55	7717.23	9147.42	10825.08	13409.73	14798.18	16174.29	17519.51	18936.66	20983.93	23630.56
III	4723.47	5545.67	6531.55	7717.23	9147.42	10825.08	13940.77	15795.62	17591.74	19290.27	21015.75	22495.02	25329.46
IV	4723.47	5545.67	6531.55	7717.23	9147.42	10825.08	13983.94	15945.89	17826.33	19543.58	21288.24	22666.67	24421.19
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	6161.40	5464.45	4331.94	2669.84	592.81	-2452.26	-3913.05
II	0.00	0.00	0.00	0.00	0.00	0.00	729.17	61.59	-848.52	-2053.45	-3494.83	-4678.09	-5688.14
III	0.00	0.00	0.00	0.00	0.00	0.00	1260.21	1059.03	568.92	-282.69	-1415.74	-3166.99	-3989.23
IV	0.00	0.00	0.00	0.00	0.00	0.00	1303.38	1209.30	803.52	-29.38	-1143.24	-2995.34	-4897.50
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+48.6%	+37.1%	+25.4%	+13.6%	+2.6%	-9.6%	-13.3%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+5.8%	+0.4%	-5.0%	-10.5%	-15.6%	-18.2%	-19.4%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+9.9%	+7.2%	+3.3%	-1.4%	-6.3%	-12.3%	-13.6%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+10.3%	+8.2%	+4.7%	-0.2%	-5.1%	-11.7%	-16.7%

7.3.2 Impact on workforce

The proposed policy option will lead to an increase in the need for human resources, and thus can lead to significant job creation within EU28 in the sector of local electrical contracting, local engineering.
More specific, the most important increase is expected in manual labour jobs at electrical contractors.

7.4 Sensitivity analysis

The analysis in this section investigates the sensitivity of the main outcomes for changes in the main calculation parameters. This sensitivity analysis is performed at scenario level. The sensitivity analysis in Task 6 is performed at base case level.

This sensitivity analysis should also serve to complement for weaknesses in the robustness of the reference scenarios and policy options due to uncertainties in the underlying data and assumptions.

Selected sensitivity analysis cases are:

- Sensitivity case 1: the stock growth, replacement rate and product life are set according to the long product life value, listed in Task 3.
- Sensitivity case 2: the inflation and discount parameters are set to their low value, indicated by the MEErP guidelines.
- Sensitivity case 3: the energy escalation rate is set to a low value.
- Sensitivity case 4: the product price is set to a substantial higher value.

Per sensitivity analysis case only these parameters are changed. All other parameters values remain the same. It has to be noted that changing the value of a certain parameter can have an impact on the definition of the scenario. As scenario I and II are based upon a design option selection according the BAT or LLCC criteria, changing the value of the parameter might result in a different set of design options. Because this would result in an altered definition of a scenario, it is opted **not** to change the base case design option selection for the scenarios in the sensitivity analysis. For instance, in case of sensitivity case 4 (higher product price) this could mean that scenario II isn't actually showing the LLCC case.

7.4.1 Sensitivity case 1: scenario analysis

In this sensitivity case, the stock growth, replacement rate and product life for the services and industry sector are set according to the long product life value, listed in Task 3.
The main calculation parameters for this analysis are listed in Table 7-25.

Table 7-25: Sensitivity case 1 - Main input parameters

Discount rate	+4.0%
Inflation rate	+2.1%
Energy Escalation rate	+4.0%
Electricity rate (€/kWh)	0.11
Stock growth rate services sector	+1.0%
Stock growth rate industry sector	+1.0%
Replacement sales rate services sector	+1.7%
Replacement sales rate industry sector	+1.4%
Product lifetime services sector (years)	40
Product lifetime industry sector (years)	40
Product price factor	1
Growth / sales rate type	onalFrom1

One should notice that the product life of improved circuits, being introduced in 2017, extends beyond 2050. This means the full potential of savings is not visible yet in 2050.

Sales (Figure 7-28 up to and including Figure 7-31, Table 7-32 up to and including Table 7-35) and stock (Figure 7-22 up to and including Figure 7-27, Table 7-26 up to and including Table 7-31), and associated economic figures (Figure 7-38, Table 7-42,

Figure 7-39 and Table 7-43) are directly impacted by changing these parameters. As a result circuit losses will be lower, so the gains will also be lower (see Table 7-36 and Figure 7-32).
Although the amounts of GHG emissions are lower, it takes about the same period as for the default scenario analysis case to level out the increased GHG emission in production and distribution by the decreased GHG emission during the use phase (Figure 7-33 up to Figure 7-37, Table 7-37 up to Table 7-41).

A lower stock means lower electricity losses, and thus also a lower annual expenditure due to electricity losses (Figure 7-40, Table 7-44).

7.4.1.1 Stock

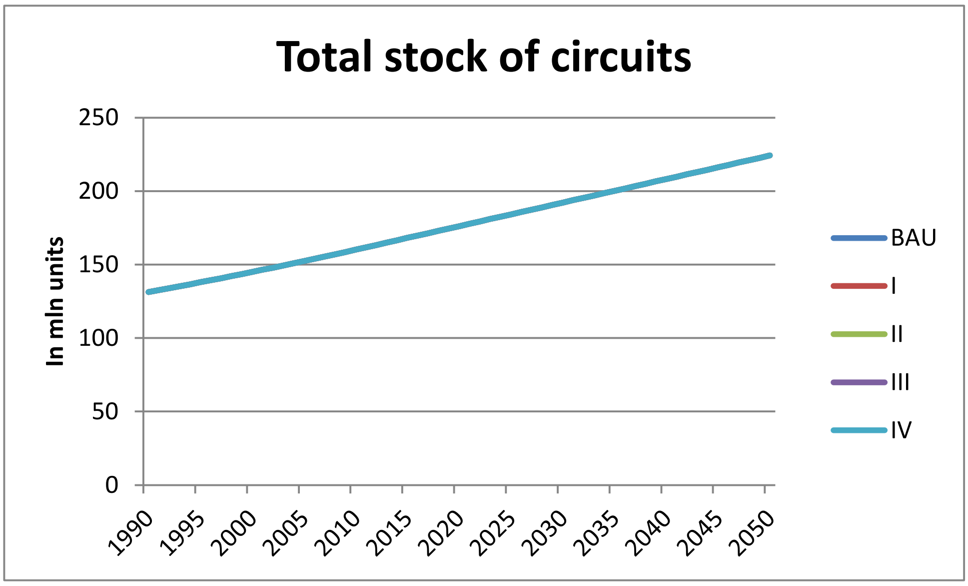


Figure 7-22: Sensitivity case 1 - Total stock of circuits (in circuit units)

Table 7-26: Sensitivity case 1 - Total stock of circuits (in circuit units)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	131.25	137.95	144.98	152.38	160.15	168.16	176.17	184.17	192.18	200.19	208.20	216.20	224.21
I	131.25	137.95	144.98	152.38	160.15	168.16	176.17	184.17	192.18	200.19	208.20	216.20	224.21
II	131.25	137.95	144.98	152.38	160.15	168.16	176.17	184.17	192.18	200.19	208.20	216.20	224.21
III	131.25	137.95	144.98	152.38	160.15	168.16	176.17	184.17	192.18	200.19	208.20	216.20	224.21
IV	131.25	137.95	144.98	152.38	160.15	168.16	176.17	184.17	192.18	200.19	208.20	216.20	224.21
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
III	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%

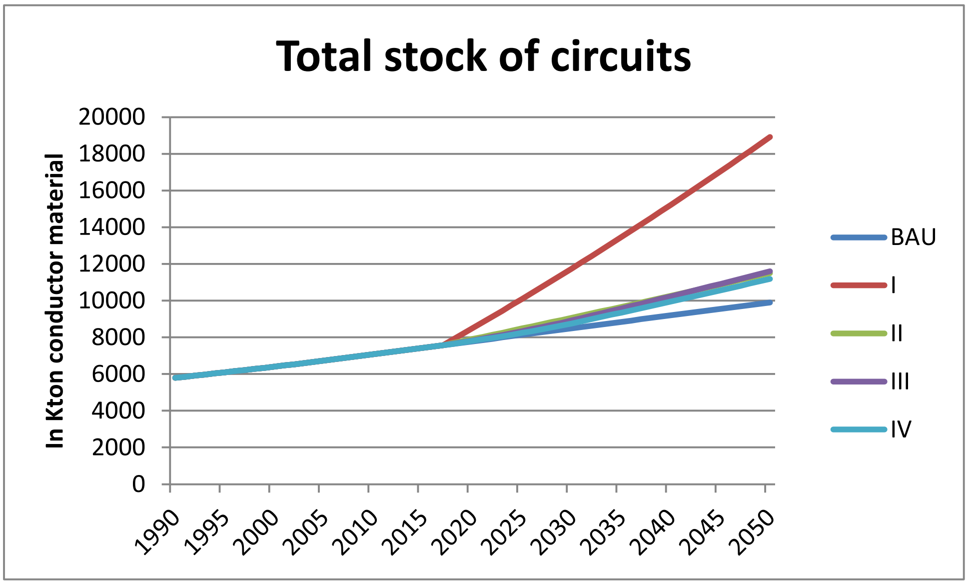


Figure 7-23: Sensitivity case 1 - Total stock of circuits (in Kton conductor material)

Table 7-27: Sensitivity case 1 - Total stock of circuits (in Kton conductor material)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	5798.28	6094.05	6404.91	6731.62	7075.00	7428.75	7782.50	8136.25	8490.00	8843.75	9197.50	9551.25	9905.00
I	5798.28	6094.05	6404.91	6731.62	7075.00	7428.75	8500.63	10096.01	11747.31	13454.55	15217.71	17036.81	18911.83
II	5798.28	6094.05	6404.91	6731.62	7075.00	7428.75	7909.57	8483.03	9066.38	9659.63	10262.78	10875.82	11498.76
III	5798.28	6094.05	6404.91	6731.62	7075.00	7428.75	7835.21	8339.22	8921.25	9572.32	10235.68	10911.33	11599.27
IV	5798.28	6094.05	6404.91	6731.62	7075.00	7428.75	7806.24	8242.06	8755.73	9347.34	9948.78	10560.04	11181.14
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	718.13	1959.76	3257.31	4610.80	6020.21	7485.56	9006.83
II	0.00	0.00	0.00	0.00	0.00	0.00	127.07	346.78	576.38	815.88	1065.28	1324.57	1593.76
III	0.00	0.00	0.00	0.00	0.00	0.00	52.71	202.97	431.25	728.57	1038.18	1360.08	1694.27
IV	0.00	0.00	0.00	0.00	0.00	0.00	23.74	105.81	265.73	503.59	751.28	1008.79	1276.14
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+9.2%	+24.1%	+38.4%	+52.1%	+65.5%	+78.4%	+90.9%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+1.6%	+4.3%	+6.8%	+9.2%	+11.6%	+13.9%	+16.1%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.7%	+2.5%	+5.1%	+8.2%	+11.3%	+14.2%	+17.1%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.3%	+1.3%	+3.1%	+5.7%	+8.2%	+10.6%	+12.9%

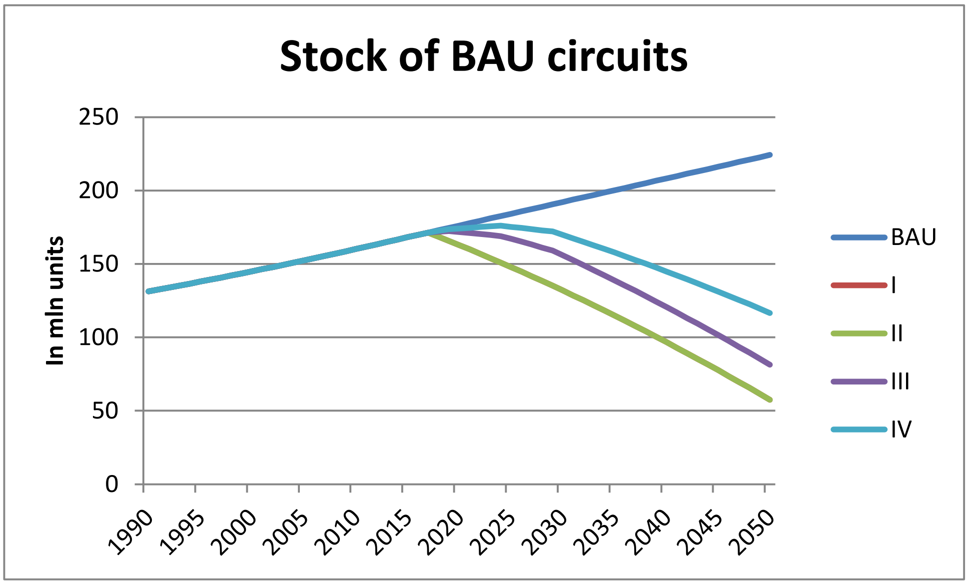


Figure 7-24: Sensitivity case 1 - Stock of BAU circuits (in circuit units)

Table 7-28: Sensitivity case 1 - Stock of BAU circuits (in circuit units)

1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
131.25	137.95	144.98	152.38	160.15	168.16	176.17	184.17	192.18	200.19	208.20	216.20	224.21
131.25	137.95	144.98	152.38	160.15	168.16	162.87	147.88	131.86	114.81	96.71	77.59	57.42
131.25	137.95	144.98	152.38	160.15	168.16	162.87	147.88	131.86	114.81	96.71	77.59	57.42
131.25	137.95	144.98	152.38	160.15	168.16	171.72	167.06	155.83	138.77	120.68	101.55	81.39
131.25	137.95	144.98	152.38	160.15	168.16	174.17	175.25	169.78	157.74	144.87	131.16	116.64
difference to BAU												
0.00	0.00	0.00	0.00	0.00	0.00	-13.30	-36.29	-60.32	-85.38	-111.48	-138.62	-166.79
0.00	0.00	0.00	0.00	0.00	0.00	-13.30	-36.29	-60.32	-85.38	-111.48	-138.62	-166.79
0.00	0.00	0.00	0.00	0.00	0.00	-4.44	-17.11	-36.35	-61.42	-87.52	-114.65	-142.82
0.00	0.00	0.00	0.00	0.00	0.00	-2.00	-8.92	-22.40	-42.45	-63.33	-85.04	-107.58
ifference to BAU												
+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-7.5%	-19.7%	-31.4%	-42.7%	-53.5%	-64.1%	-74.4%
+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-7.5%	-19.7%	-31.4%	-42.7%	-53.5%	-64.1%	-74.4%
+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-2.5%	-9.3%	-18.9%	-30.7%	-42.0%	-53.0%	-63.7%
+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-1.1%	-4.8%	-11.7%	-21.2%	-30.4%	-39.3%	-48.0%

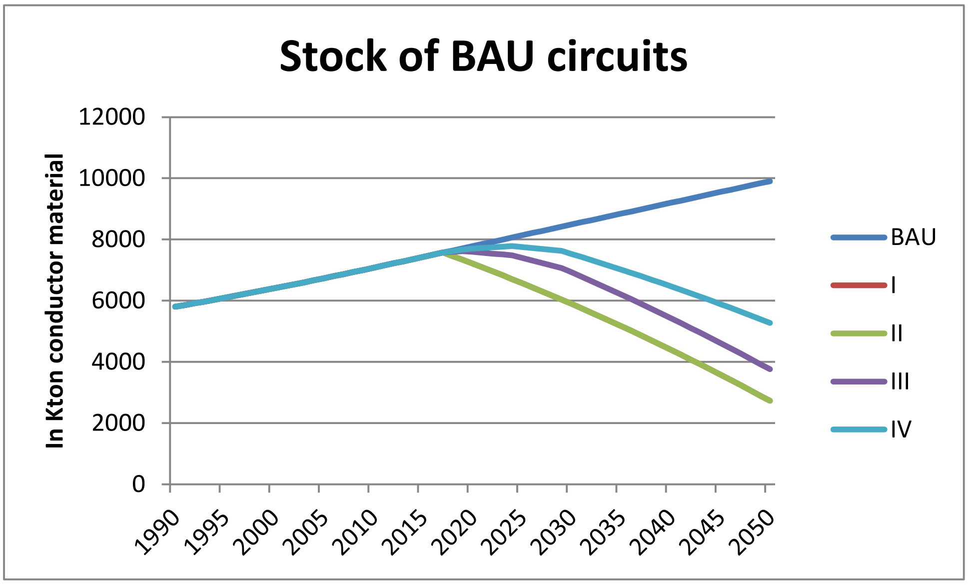


Figure 7-25: Sensitivity case 1 - Stock of BAU circuits (in Kton conductor material)

Table 7-29: Sensitivity case 1 - Stock of BAU circuits (in Kton conductor material)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	5798.28	6094.05	6404.91	6731.62	7075.00	7428.75	7782.50	8136.25	8490.00	8843.75	9197.50	9551.25	9905.00
I	5798.28	6094.05	6404.91	6731.62	7075.00	7428.75	7209.83	6573.44	5892.46	5166.87	4396.69	3581.90	2722.52
II	5798.28	6094.05	6404.91	6731.62	7075.00	7428.75	7209.83	6573.44	5892.46	5166.87	4396.69	3581.90	2722.52
III	5798.28	6094.05	6404.91	6731.62	7075.00	7428.75	7591.16	7399.45	6924.52	6198.93	5428.75	4613.96	3754.57
IV	5798.28	6094.05	6404.91	6731.62	7075.00	7428.75	7696.33	7752.15	7525.38	7015.66	6470.26	5889.18	5272.42
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	-572.67	-1562.81	-2597.54	-3676.88	-4800.81	-5969.35	-7182.48
II	0.00	0.00	0.00	0.00	0.00	0.00	-572.67	-1562.81	-2597.54	-3676.88	-4800.81	-5969.35	-7182.48
III	0.00	0.00	0.00	0.00	0.00	0.00	-191.34	-736.80	-1565.48	-2644.82	-3768.75	-4937.29	-6150.43
IV	0.00	0.00	0.00	0.00	0.00	0.00	-86.17	-384.10	-964.62	-1828.09	-2727.24	-3662.07	-4632.58
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-7.4%	-19.2%	-30.6%	-41.6%	-52.2%	-62.5%	-72.5%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-7.4%	-19.2%	-30.6%	-41.6%	-52.2%	-62.5%	-72.5%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-2.5%	-9.1%	-18.4%	-29.9%	-41.0%	-51.7%	-62.1%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-1.1%	-4.7%	-11.4%	-20.7%	-29.7%	-38.3%	-46.8%

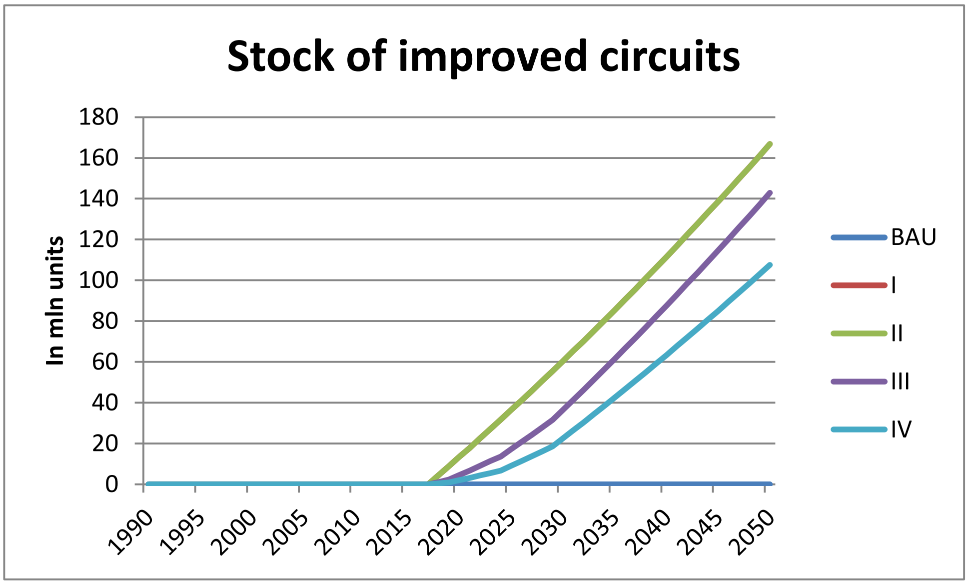


Figure 7-26: Sensitivity case 1 - Stock of improved circuits (in circuit units)

Table 7-30: Sensitivity case 1 - Stock of improved circuits (in circuit units)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I	0.00	0.00	0.00	0.00	0.00	0.00	13.30	36.29	60.32	85.38	111.48	138.62	166.79
II	0.00	0.00	0.00	0.00	0.00	0.00	13.30	36.29	60.32	85.38	111.48	138.62	166.79
III	0.00	0.00	0.00	0.00	0.00	0.00	4.44	17.11	36.35	61.42	87.52	114.65	142.82
IV	0.00	0.00	0.00	0.00	0.00	0.00	2.00	8.92	22.40	42.45	63.33	85.04	107.58
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	13.30	36.29	60.32	85.38	111.48	138.62	166.79
II	0.00	0.00	0.00	0.00	0.00	0.00	13.30	36.29	60.32	85.38	111.48	138.62	166.79
III	0.00	0.00	0.00	0.00	0.00	0.00	4.44	17.11	36.35	61.42	87.52	114.65	142.82
IV	0.00	0.00	0.00	0.00	0.00	0.00	2.00	8.92	22.40	42.45	63.33	85.04	107.58
Relative difference to BAU													
I	-	-	-	-	-	-	-	-	-	-	-	-	-
II	-	-	-	-	-	-	-	-	-	-	-	-	-
III	-	-	-	-	-	-	-	-	-	-	-	-	-
IV	-	-	-	-	-	-	-	-	-	-	-	-	-

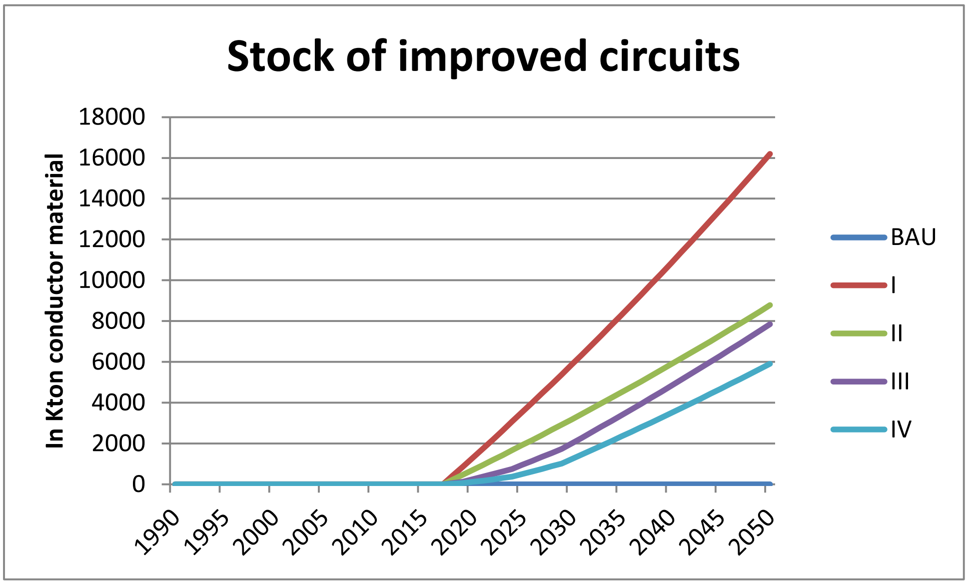


Figure 7-27: Sensitivity case 1 - Stock of improved circuits (in Kton conductor material)

Table 7-31: Sensitivity case 1 - Stock of improved circuits (in Kton conductor material)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I	0.00	0.00	0.00	0.00	0.00	0.00	1290.80	3522.56	5854.85	8287.67	10821.02	13454.90	16189.31
II	0.00	0.00	0.00	0.00	0.00	0.00	699.75	1909.59	3173.92	4492.76	5866.09	7293.92	8776.25
III	0.00	0.00	0.00	0.00	0.00	0.00	244.04	939.77	1996.73	3373.39	4806.94	6297.37	7844.69
IV	0.00	0.00	0.00	0.00	0.00	0.00	109.91	489.91	1230.35	2331.68	3478.52	4670.86	5908.72
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	1290.80	3522.56	5854.85	8287.67	10821.02	13454.90	16189.31
II	0.00	0.00	0.00	0.00	0.00	0.00	699.75	1909.59	3173.92	4492.76	5866.09	7293.92	8776.25
III	0.00	0.00	0.00	0.00	0.00	0.00	244.04	939.77	1996.73	3373.39	4806.94	6297.37	7844.69
IV	0.00	0.00	0.00	0.00	0.00	0.00	109.91	489.91	1230.35	2331.68	3478.52	4670.86	5908.72
Relative difference to BAU													
I	-	-	-	-	-	-	-	-	-	-	-	-	-
II	-	-	-	-	-	-	-	-	-	-	-	-	-
III	-	-	-	-	-	-	-	-	-	-	-	-	-
IV	-	-	-	-	-	-	-	-	-	-	-	-	-

7.4.1.2 Annual sales of circuits

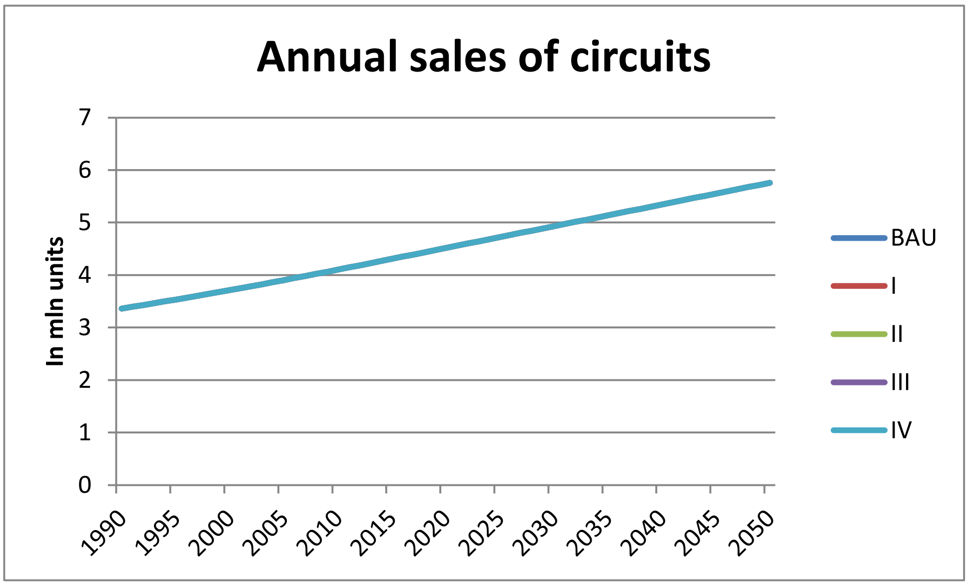


Figure 7-28: Sensitivity case 1 - Annual sales of circuits (in circuit units)

Table 7-32: Sensitivity case 1 - Annual sales of circuits (in circuit units)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	3.36	3.53	3.71	3.90	4.10	4.31	4.52	4.72	4.93	5.14	5.34	5.55	5.76
I	3.36	3.53	3.71	3.90	4.10	4.31	4.52	4.72	4.93	5.14	5.34	5.55	5.76
II	3.36	3.53	3.71	3.90	4.10	4.31	4.52	4.72	4.93	5.14	5.34	5.55	5.76
III	3.36	3.53	3.71	3.90	4.10	4.31	4.52	4.72	4.93	5.14	5.34	5.55	5.76
IV	3.36	3.53	3.71	3.90	4.10	4.31	4.52	4.72	4.93	5.14	5.34	5.55	5.76
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
III	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%

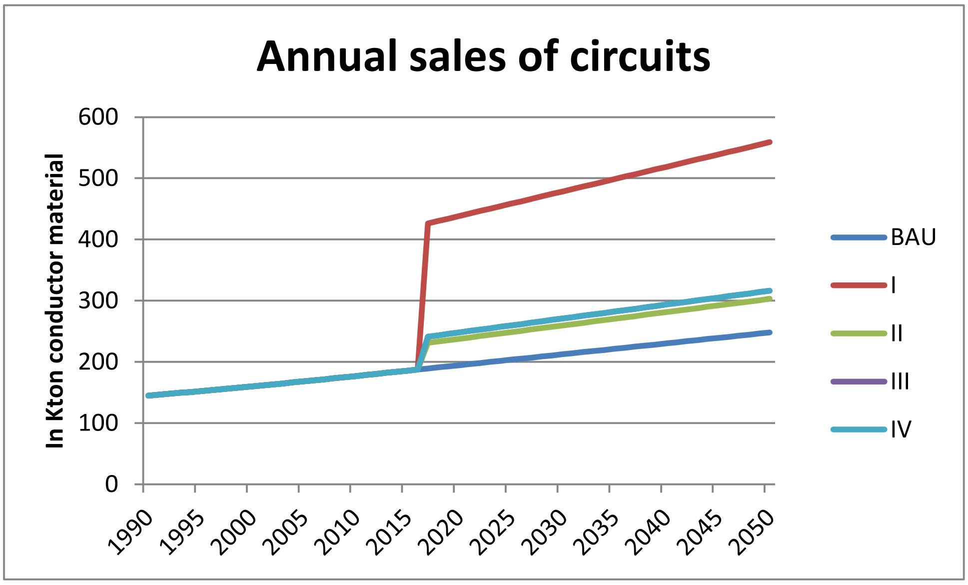


Figure 7-29: Sensitivity case 1 - Annual sales of circuits (in Kton conductor material)

Table 7-33: Sensitivity case 1 - Annual sales of circuits (in Kton conductor material)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	144.76	152.15	159.91	168.06	176.64	185.54	194.46	203.38	212.30	221.22	230.14	239.06	247.98
I	144.76	152.15	159.91	168.06	176.64	185.54	438.31	458.42	478.52	498.63	518.73	538.84	558.95
II	144.76	152.15	159.91	168.06	176.64	185.54	237.61	248.51	259.41	270.31	281.21	292.11	303.01
III	144.76	152.15	159.91	168.06	176.64	185.54	248.03	259.40	270.78	282.16	293.54	304.91	316.29
IV	144.76	152.15	159.91	168.06	176.64	185.54	248.03	259.40	270.78	282.16	293.54	304.91	316.29
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	243.85	255.04	266.22	277.41	288.59	299.78	310.97
II	0.00	0.00	0.00	0.00	0.00	0.00	43.15	45.13	47.11	49.09	51.07	53.05	55.03
III	0.00	0.00	0.00	0.00	0.00	0.00	53.57	56.03	58.48	60.94	63.40	65.85	68.31
IV	0.00	0.00	0.00	0.00	0.00	0.00	53.57	56.03	58.48	60.94	63.40	65.85	68.31
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+125.4%	+125.4%	+125.4%	+125.4%	+125.4%	+125.4%	+125.4%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+22.2%	+22.2%	+22.2%	+22.2%	+22.2%	+22.2%	+22.2%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+27.5%	+27.5%	+27.5%	+27.5%	+27.5%	+27.5%	+27.5%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+27.5%	+27.5%	+27.5%	+27.5%	+27.5%	+27.5%	+27.5%

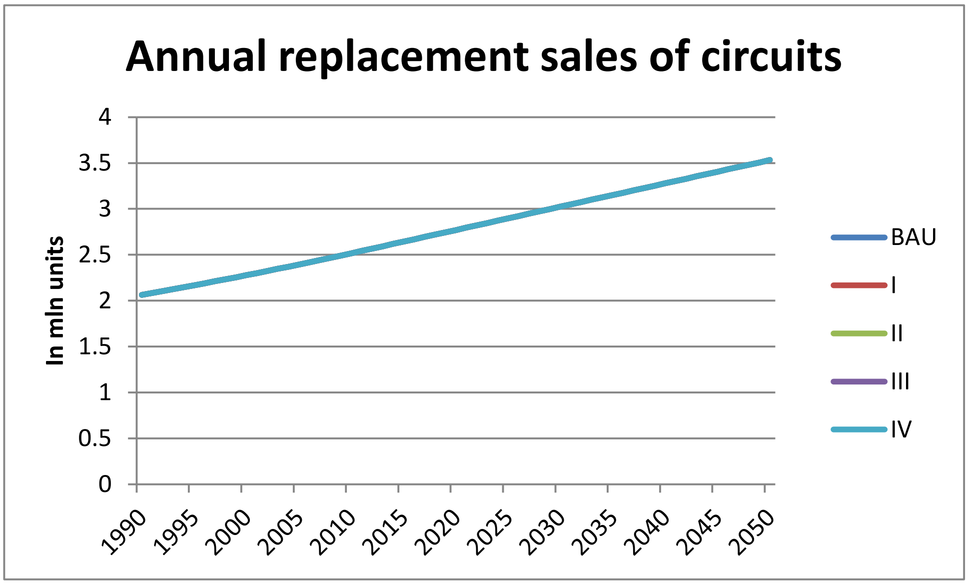


Figure 7-30: Sensitivity case 1 - Annual replacement sales of circuits (in circuit units)

Table 7-34: Sensitivity case 1 - Annual replacement sales of circuits (in circuit units)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	2.06	2.17	2.28	2.39	2.52	2.64	2.77	2.90	3.02	3.15	3.28	3.41	3.53
I	2.06	2.17	2.28	2.39	2.52	2.64	2.77	2.90	3.02	3.15	3.28	3.41	3.53
II	2.06	2.17	2.28	2.39	2.52	2.64	2.77	2.90	3.02	3.15	3.28	3.41	3.53
III	2.06	2.17	2.28	2.39	2.52	2.64	2.77	2.90	3.02	3.15	3.28	3.41	3.53
IV	2.06	2.17	2.28	2.39	2.52	2.64	2.77	2.90	3.02	3.15	3.28	3.41	3.53
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
III	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%

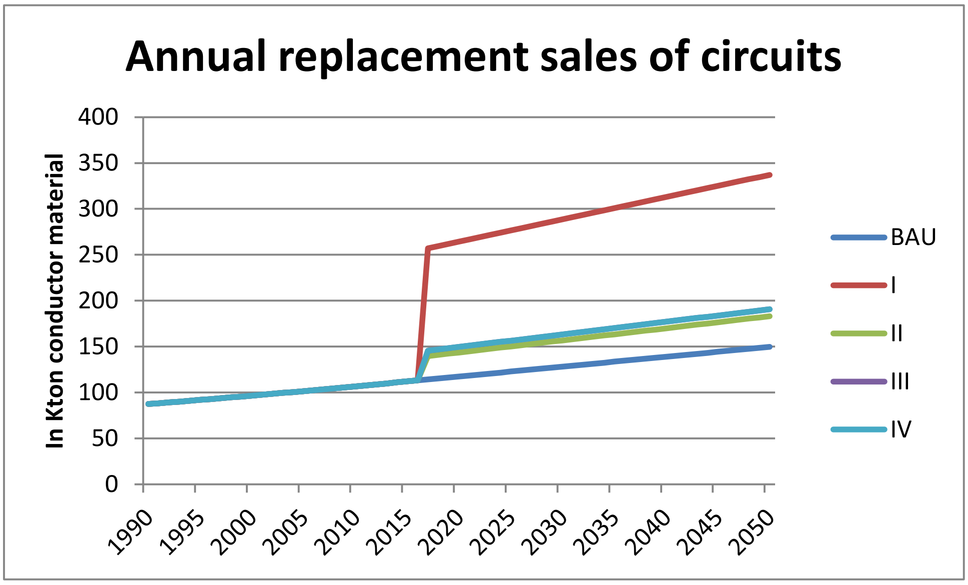


Figure 7-31: Sensitivity case 1 - Annual replacement sales of circuits (in Kton conductor material)

Table 7-35: Sensitivity case 1 - Annual replacement sales of circuits (in Kton conductor material)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	87.35	91.81	96.49	101.41	106.59	111.96	117.34	122.72	128.11	133.49	138.87	144.25	149.64
I	87.35	91.81	96.49	101.41	106.59	111.96	264.37	276.49	288.62	300.75	312.88	325.00	337.13
II	87.35	91.81	96.49	101.41	106.59	111.96	143.54	150.13	156.71	163.30	169.88	176.47	183.05
III	87.35	91.81	96.49	101.41	106.59	111.96	149.54	156.40	163.26	170.12	176.98	183.84	190.70
IV	87.35	91.81	96.49	101.41	106.59	111.96	149.54	156.40	163.26	170.12	176.98	183.84	190.70
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	147.03	153.77	160.51	167.26	174.00	180.75	187.49
II	0.00	0.00	0.00	0.00	0.00	0.00	26.20	27.40	28.61	29.81	31.01	32.21	33.41
III	0.00	0.00	0.00	0.00	0.00	0.00	32.20	33.68	35.16	36.64	38.11	39.59	41.07
IV	0.00	0.00	0.00	0.00	0.00	0.00	32.20	33.68	35.16	36.64	38.11	39.59	41.07
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+125.3%	+125.3%	+125.3%	+125.3%	+125.3%	+125.3%	+125.3%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+22.3%	+22.3%	+22.3%	+22.3%	+22.3%	+22.3%	+22.3%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+27.4%	+27.4%	+27.4%	+27.4%	+27.4%	+27.4%	+27.4%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+27.4%	+27.4%	+27.4%	+27.4%	+27.4%	+27.4%	+27.4%

7.4.1.3 Annual demand of electricity due to losses in circuits

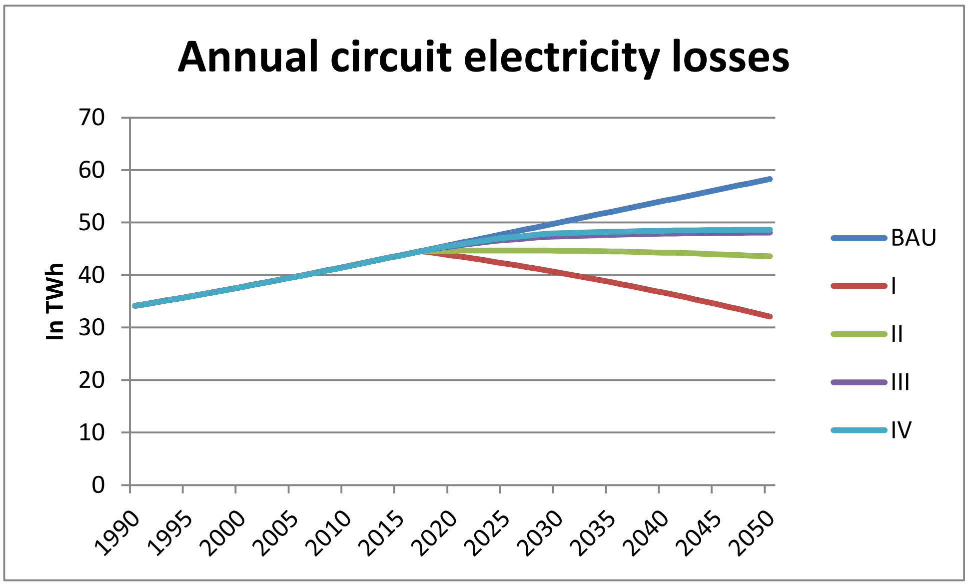


Figure 7-32: Sensitivity case 1 - Annual circuit electricity losses (in TWh/yr)

Table 7-36: Sensitivity case 1 - Annual circuit electricity losses (in TWh/yr)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	34.13	35.87	37.70	39.63	41.65	43.73	45.81	47.90	49.98	52.06	54.14	56.22	58.31
I	34.13	35.87	37.70	39.63	41.65	43.73	43.72	42.19	40.50	38.64	36.63	34.44	32.10
II	34.13	35.87	37.70	39.63	41.65	43.73	44.64	44.68	44.64	44.51	44.28	43.96	43.55
III	34.13	35.87	37.70	39.63	41.65	43.73	45.49	46.67	47.37	47.66	47.87	48.01	48.08
IV	34.13	35.87	37.70	39.63	41.65	43.73	45.63	47.09	47.96	48.24	48.45	48.58	48.63
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	-2.09	-5.70	-9.48	-13.42	-17.52	-21.78	-26.21
II	0.00	0.00	0.00	0.00	0.00	0.00	-1.18	-3.21	-5.34	-7.55	-9.86	-12.26	-14.75
III	0.00	0.00	0.00	0.00	0.00	0.00	-0.32	-1.23	-2.60	-4.40	-6.27	-8.21	-10.23
IV	0.00	0.00	0.00	0.00	0.00	0.00	-0.18	-0.80	-2.01	-3.82	-5.70	-7.65	-9.67
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-4.6%	-11.9%	-19.0%	-25.8%	-32.4%	-38.7%	-44.9%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-2.6%	-6.7%	-10.7%	-14.5%	-18.2%	-21.8%	-25.3%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-0.7%	-2.6%	-5.2%	-8.5%	-11.6%	-14.6%	-17.5%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-0.4%	-1.7%	-4.0%	-7.3%	-10.5%	-13.6%	-16.6%

For scenario I, this equates to a reduction of annual electricity losses of about -5.70 TWh in 2025. For scenario II, this equates to a reduction of annual electricity losses of about -3.21 TWh, for scenario III, -1.23 TWh and for scenario IV, -0.80 TWh, in 2025.

7.4.1.4 Annual emissions of CO_2 eq.

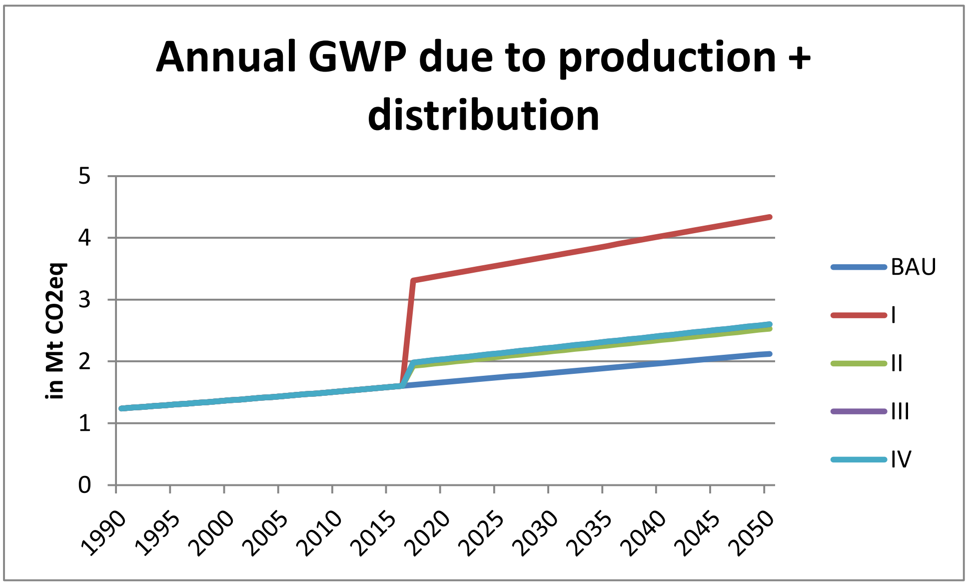


Figure 7-33: Sensitivity case 1 - Annual GWP due to production + distribution (in Mt CO_2 eq.)

Table 7-37: Sensitivity case 1 - Annual GWP due to production + distribution (in Mt CO_2 eq.)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	1.24	1.30	1.37	1.44	1.51	1.59	1.67	1.74	1.82	1.89	1.97	2.05	2.12
I	1.24	1.30	1.37	1.44	1.51	1.59	3.40	3.56	3.71	3.87	4.03	4.18	4.34
II	1.24	1.30	1.37	1.44	1.51	1.59	1.98	2.07	2.17	2.26	2.35	2.44	2.53
III	1.24	1.30	1.37	1.44	1.51	1.59	2.04	2.13	2.23	2.32	2.41	2.51	2.60
IV	1.24	1.30	1.37	1.44	1.51	1.59	2.04	2.13	2.23	2.32	2.41	2.51	2.60
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	1.74	1.82	1.90	1.98	2.06	2.13	2.21
II	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.33	0.35	0.36	0.38	0.39	0.41
III	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.39	0.41	0.43	0.44	0.46	0.48
IV	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.39	0.41	0.43	0.44	0.46	0.48
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+104.3%	+104.3%	+104.3%	+104.3%	+104.3%	+104.3%	+104.3%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+19.1%	+19.1%	+19.1%	+19.1%	+19.1%	+19.1%	+19.1%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+22.5%	+22.5%	+22.5%	+22.5%	+22.5%	+22.5%	+22.5%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+22.5%	+22.5%	+22.5%	+22.5%	+22.5%	+22.5%	+22.5%

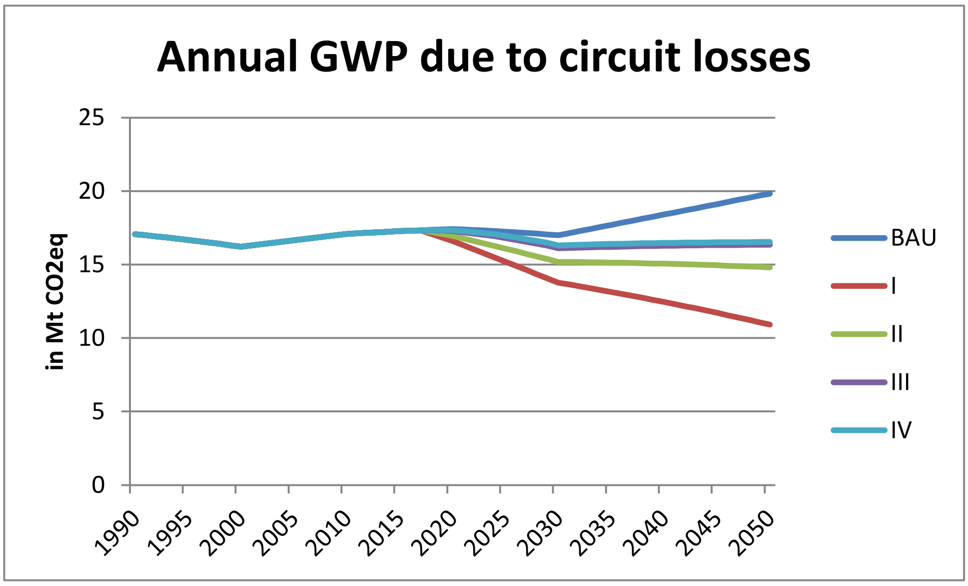


Figure 7-34: Sensitivity case 1 - Annual GWP (total stock) due to circuit losses (in Mt CO_2 eq.)

Table 7-38: Sensitivity case 1 - Annual GWP (total stock) due to circuit losses (in Mt CO_2 eq.)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	17.07	16.68	16.21	16.64	17.08	17.27	17.41	17.24	16.99	17.70	18.41	19.12	19.82
I	17.07	16.68	16.21	16.64	17.08	17.27	16.61	15.19	13.77	13.14	12.45	11.71	10.91
II	17.07	16.68	16.21	16.64	17.08	17.27	16.96	16.09	15.18	15.13	15.06	14.95	14.81
III	17.07	16.68	16.21	16.64	17.08	17.27	17.29	16.80	16.11	16.20	16.28	16.32	16.35
IV	17.07	16.68	16.21	16.64	17.08	17.27	17.34	16.95	16.31	16.40	16.47	16.52	16.53
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	-0.79	-2.05	-3.22	-4.56	-5.96	-7.41	-8.91
II	0.00	0.00	0.00	0.00	0.00	0.00	-0.45	-1.16	-1.81	-2.57	-3.35	-4.17	-5.02
III	0.00	0.00	0.00	0.00	0.00	0.00	-0.12	-0.44	-0.89	-1.50	-2.13	-2.79	-3.48
IV	0.00	0.00	0.00	0.00	0.00	0.00	-0.07	-0.29	-0.68	-1.30	-1.94	-2.60	-3.29
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-4.6%	-11.9%	-19.0%	-25.8%	-32.4%	-38.7%	-44.9%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-2.6%	-6.7%	-10.7%	-14.5%	-18.2%	-21.8%	-25.3%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-0.7%	-2.6%	-5.2%	-8.5%	-11.6%	-14.6%	-17.5%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-0.4%	-1.7%	-4.0%	-7.3%	-10.5%	-13.6%	-16.6%

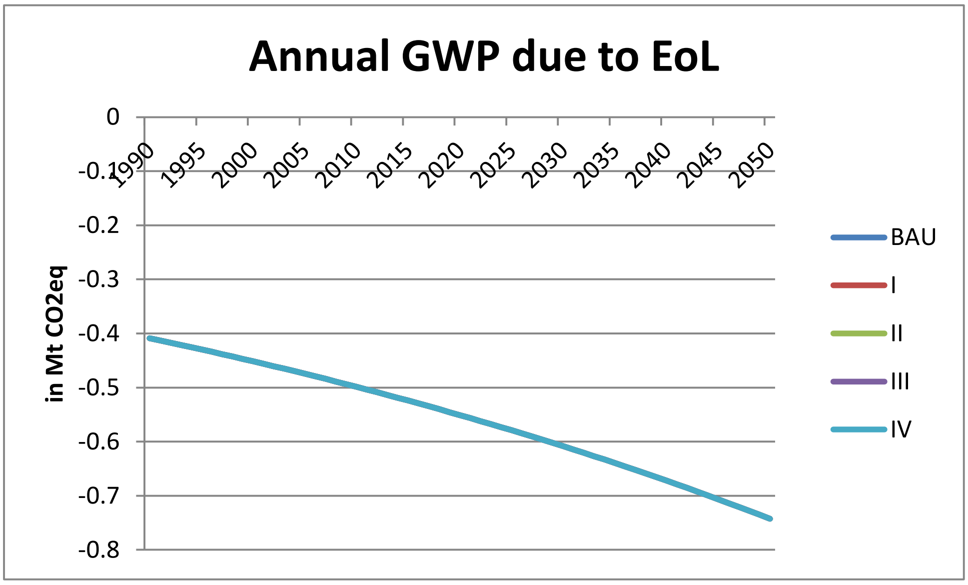


Figure 7-35: Sensitivity case 1 - Annual GWP due to EoL (in Mt CO_2 eq.)

Table 7-39: Sensitivity case 1 - Annual GWP due to EoL (in Mt CO_2 eq.)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	-0.41	-0.43	-0.45	-0.47	-0.50	-0.52	-0.55	-0.58	-0.61	-0.64	-0.67	-0.71	-0.74
I	-0.41	-0.43	-0.45	-0.47	-0.50	-0.52	-0.55	-0.58	-0.61	-0.64	-0.67	-0.71	-0.74
II	-0.41	-0.43	-0.45	-0.47	-0.50	-0.52	-0.55	-0.58	-0.61	-0.64	-0.67	-0.71	-0.74
III	-0.41	-0.43	-0.45	-0.47	-0.50	-0.52	-0.55	-0.58	-0.61	-0.64	-0.67	-0.71	-0.74
IV	-0.41	-0.43	-0.45	-0.47	-0.50	-0.52	-0.55	-0.58	-0.61	-0.64	-0.67	-0.71	-0.74
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
III	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%

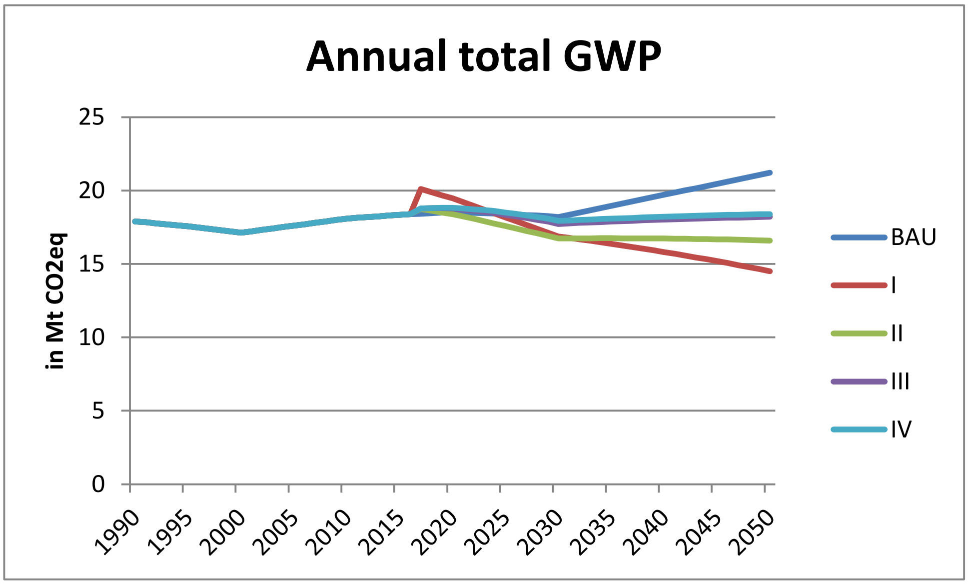
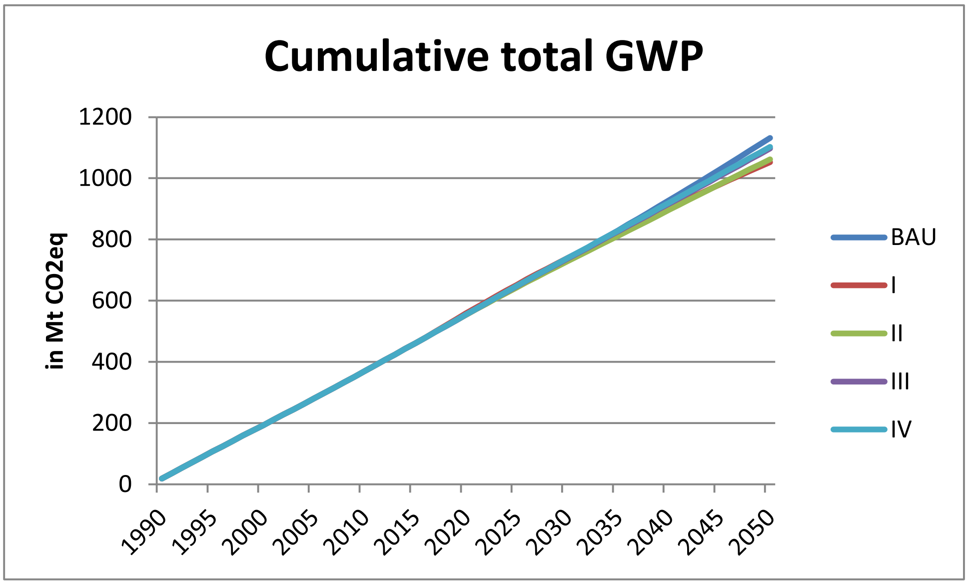


Figure 7-36: Sensitivity case 1 - Annual total GWP (in Mt CO_2 eq.)

Table 7-40: Sensitivity case 1 - Annual total GWP (in Mt CO_2 eq.)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	17.90	17.55	17.13	17.61	18.09	18.34	18.52	18.40	18.20	18.96	19.71	20.46	21.21
I	17.90	17.55	17.13	17.61	18.09	18.34	19.47	18.17	16.88	16.37	15.81	15.19	14.51
II	17.90	17.55	17.13	17.61	18.09	18.34	18.39	17.58	16.74	16.75	16.73	16.68	16.60
III	17.90	17.55	17.13	17.61	18.09	18.34	18.78	18.36	17.73	17.89	18.02	18.12	18.20
IV	17.90	17.55	17.13	17.61	18.09	18.34	18.83	18.51	17.93	18.08	18.21	18.32	18.39
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	0.94	-0.24	-1.33	-2.59	-3.90	-5.27	-6.70
II	0.00	0.00	0.00	0.00	0.00	0.00	-0.13	-0.82	-1.47	-2.21	-2.98	-3.78	-4.61
III	0.00	0.00	0.00	0.00	0.00	0.00	0.25	-0.05	-0.48	-1.07	-1.69	-2.33	-3.00
IV	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.10	-0.28	-0.87	-1.49	-2.14	-2.81
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+5.1%	-1.3%	-7.3%	-13.6%	-19.8%	-25.8%	-31.6%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-0.7%	-4.5%	-8.1%	-11.6%	-15.1%	-18.5%	-21.7%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+1.4%	-0.3%	-2.6%	-5.6%	-8.6%	-11.4%	-14.2%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+1.7%	+0.6%	-1.5%	-4.6%	-7.6%	-10.5%	-13.3%



(in Mt CO_2 eq.)

Figure 7-37: Sensitivity case 1 - Cumulative GWP (in Mt CO_2 eq.)

Table 7-41: Sensitivity case 1 - Cumulative GWP (in Mt CO_2 eq.)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	17.90	106.39	192.92	280.00	369.49	460.70	552.98	645.27	736.72	829.99	927.02	1027.81	1132.34
I	17.90	106.39	192.92	280.00	369.49	460.70	558.23	651.67	738.63	821.51	901.69	978.89	1052.81
II	17.90	106.39	192.92	280.00	369.49	460.70	553.34	642.89	728.27	812.00	895.71	979.22	1062.38
III	17.90	106.39	192.92	280.00	369.49	460.70	554.24	646.95	736.91	826.03	915.87	1006.29	1097.16
IV	17.90	106.39	192.92	280.00	369.49	460.70	554.34	647.62	738.53	828.64	919.46	1010.85	1102.67
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	5.26	6.40	1.91	-8.48	-25.33	-48.92	-79.53
II	0.00	0.00	0.00	0.00	0.00	0.00	0.36	-2.38	-8.45	-17.99	-31.31	-48.59	-69.96
III	0.00	0.00	0.00	0.00	0.00	0.00	1.26	1.68	0.19	-3.96	-11.16	-21.52	-35.18
IV	0.00	0.00	0.00	0.00	0.00	0.00	1.36	2.35	1.81	-1.35	-7.56	-16.96	-29.67
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+1.0%	+1.0%	+0.3%	-1.0%	-2.7%	-4.8%	-7.0%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.1%	-0.4%	-1.1%	-2.2%	-3.4%	-4.7%	-6.2%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.2%	+0.3%	+0.0%	-0.5%	-1.2%	-2.1%	-3.1%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.2%	+0.4%	+0.2%	-0.2%	-0.8%	-1.7%	-2.6%

7.4.1.5 Annual expenditure

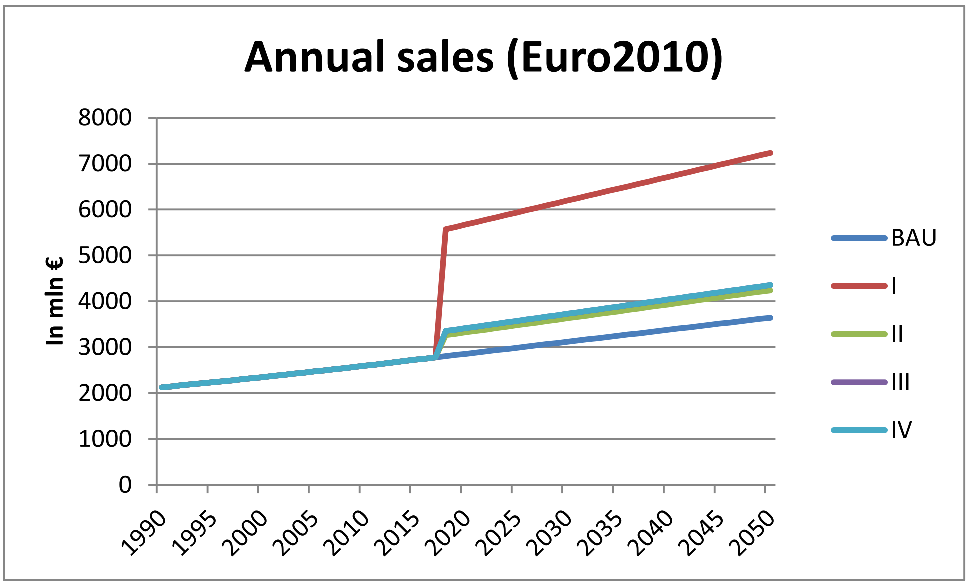


Figure 7-38: Sensitivity case 1 - Annual sales (in mln. euro)

Table 7-42: Sensitivity case 1 - Annual sales (in mln. euro)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	2126.29	2234.75	2348.74	2468.55	2594.47	2725.23	2856.26	2987.28	3118.30	3249.32	3380.34	3511.36	3642.38
I	2126.29	2234.75	2348.74	2468.55	2594.47	2725.23	5673.59	5933.85	6194.11	6454.36	6714.62	6974.88	7235.13
II	2126.29	2234.75	2348.74	2468.55	2594.47	2725.23	3324.05	3476.53	3629.01	3781.49	3933.97	4086.45	4238.93
III	2126.29	2234.75	2348.74	2468.55	2594.47	2725.23	3414.21	3570.82	3727.44	3884.05	4040.67	4197.28	4353.90
IV	2126.29	2234.75	2348.74	2468.55	2594.47	2725.23	3414.21	3570.82	3727.44	3884.05	4040.67	4197.28	4353.90
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	2817.34	2946.57	3075.81	3205.05	3334.28	3463.52	3592.75
II	0.00	0.00	0.00	0.00	0.00	0.00	467.80	489.26	510.71	532.17	553.63	575.09	596.55
III	0.00	0.00	0.00	0.00	0.00	0.00	557.95	583.54	609.14	634.73	660.33	685.92	711.51
IV	0.00	0.00	0.00	0.00	0.00	0.00	557.95	583.54	609.14	634.73	660.33	685.92	711.51
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+98.6%	+98.6%	+98.6%	+98.6%	+98.6%	+98.6%	+98.6%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+16.4%	+16.4%	+16.4%	+16.4%	+16.4%	+16.4%	+16.4%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+19.5%	+19.5%	+19.5%	+19.5%	+19.5%	+19.5%	+19.5%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+19.5%	+19.5%	+19.5%	+19.5%	+19.5%	+19.5%	+19.5%

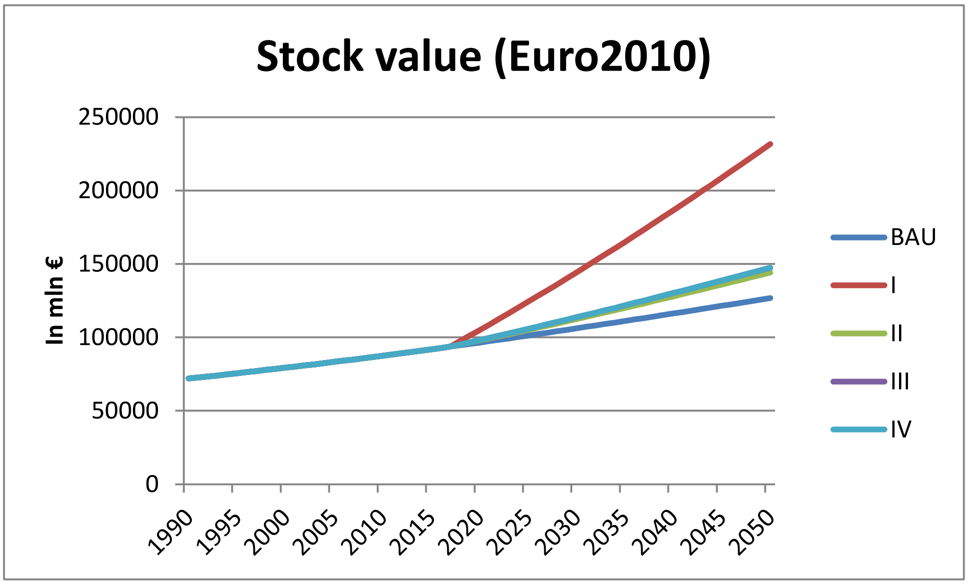


Figure 7-39: Sensitivity case 1 - Stock value (in mln. euro)

Table 7-43: Sensitivity case 1 - Stock value (in mln. euro)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	71942.23	75539.16	79319.56	83292.81	87468.73	91855.03	96438.48	101195.71	106102.18	111132.07	116258.26	121452.27	126684.11
I	71942.23	75539.16	79319.56	83292.81	87468.73	91855.03	104812.95	124044.58	144071.62	164868.27	186407.40	208660.51	231597.64
II	71942.23	75539.16	79319.56	83292.81	87468.73	91855.03	97829.00	104989.59	112406.70	120054.54	127905.98	135932.51	144104.18
III	71942.23	75539.16	79319.56	83292.81	87468.73	91855.03	98096.97	105720.74	113621.71	121774.07	130150.71	138723.13	147461.36
IV	71942.23	75539.16	79319.56	83292.81	87468.73	91855.03	98096.97	105720.74	113621.71	121774.07	130150.71	138723.13	147461.36
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	8374.47	22848.87	37969.45	53736.20	70149.13	87208.24	104913.53
II	0.00	0.00	0.00	0.00	0.00	0.00	1390.52	3793.88	6304.53	8922.47	11647.71	14480.24	17420.07
III	0.00	0.00	0.00	0.00	0.00	0.00	1658.49	4525.03	7519.53	10642.00	13892.45	17270.86	20777.25
IV	0.00	0.00	0.00	0.00	0.00	0.00	1658.49	4525.03	7519.53	10642.00	13892.45	17270.86	20777.25
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+8.7%	+22.6%	+35.8%	+48.4%	+60.3%	+71.8%	+82.8%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+1.4%	+3.7%	+5.9%	+8.0%	+10.0%	+11.9%	+13.8%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+1.7%	+4.5%	+7.1%	+9.6%	+11.9%	+14.2%	+16.4%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+1.7%	+4.5%	+7.1%	+9.6%	+11.9%	+14.2%	+16.4%

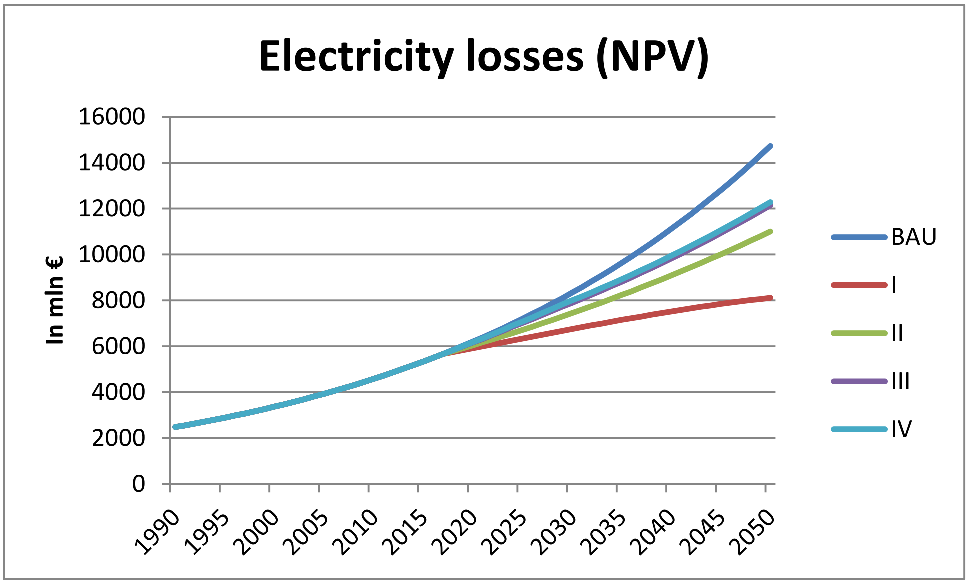


Figure 7-40: Sensitivity case 1 - Annual expenditure due to electricity losses (in mln. euro)

Table 7-44: Sensitivity case 1 - Annual expenditure due to electricity losses (in mln. euro)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	2477.67	2889.21	3369.10	3928.71	4581.27	5337.08	6203.49	7195.64	8330.70	9628.07	11109.67	12800.31	14727.99
I	2477.67	2889.21	3369.10	3928.71	4581.27	5337.08	5920.54	6338.94	6750.86	7146.88	7515.29	7841.64	8108.23
II	2477.67	2889.21	3369.10	3928.71	4581.27	5337.08	6044.20	6713.35	7441.30	8231.24	9086.15	10008.73	11001.27
III	2477.67	2889.21	3369.10	3928.71	4581.27	5337.08	6160.39	7011.51	7896.64	8814.42	9823.30	10930.55	12143.76
IV	2477.67	2889.21	3369.10	3928.71	4581.27	5337.08	6179.12	7075.13	7994.90	8921.98	9940.94	11059.11	12284.14
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	-282.94	-856.70	-1579.85	-2481.19	-3594.38	-4958.67	-6619.75
II	0.00	0.00	0.00	0.00	0.00	0.00	-159.29	-482.30	-889.40	-1396.83	-2023.53	-2791.58	-3726.72
III	0.00	0.00	0.00	0.00	0.00	0.00	-43.10	-184.13	-434.07	-813.65	-1286.37	-1869.76	-2584.23
IV	0.00	0.00	0.00	0.00	0.00	0.00	-24.37	-120.52	-335.81	-706.09	-1168.74	-1741.20	-2443.84
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-4.6%	-11.9%	-19.0%	-25.8%	-32.4%	-38.7%	-44.9%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-2.6%	-6.7%	-10.7%	-14.5%	-18.2%	-21.8%	-25.3%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-0.7%	-2.6%	-5.2%	-8.5%	-11.6%	-14.6%	-17.5%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-0.4%	-1.7%	-4.0%	-7.3%	-10.5%	-13.6%	-16.6%

Figure 7-41 and Table 7-45 show the residual value in mln. euro due to the recycling of the conductor material.

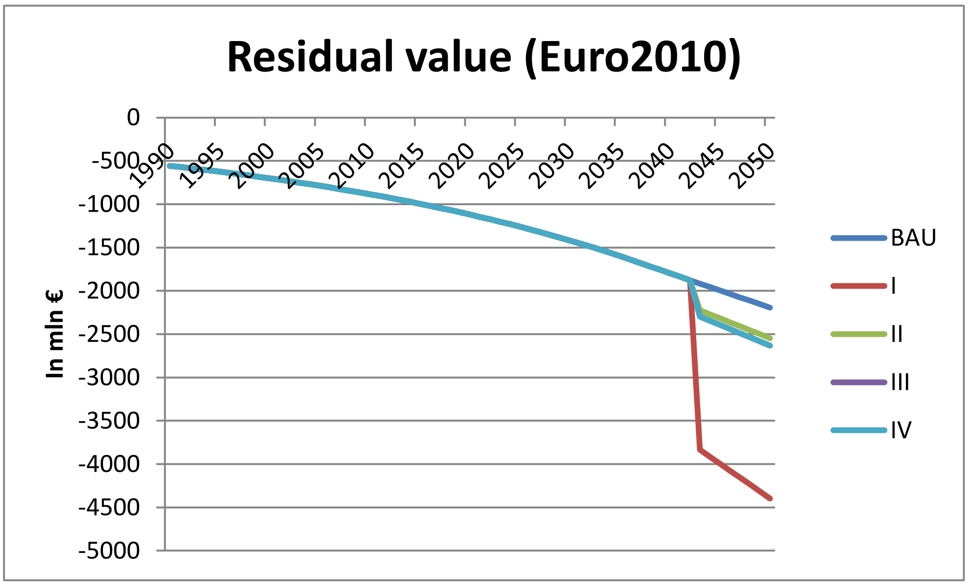


Figure 7-41: Sensitivity case 1 - Residual value (in mln. euro)

Table 7-45: Sensitivity case 1 - Residual value (in mln. euro)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	-557.07	-624.82	-701.21	-787.41	-884.73	-994.67	-1118.93	-1259.46	-1418.49	-1598.55	-1796.40	-1995.22	-2194.05
I	-557.07	-624.82	-701.21	-787.41	-884.73	-994.67	-1118.93	-1259.46	-1418.49	-1598.55	-1796.40	-3994.90	-4396.37
II	-557.07	-624.82	-701.21	-787.41	-884.73	-994.67	-1118.93	-1259.46	-1418.49	-1598.55	-1796.40	-2316.75	-2547.06
III	-557.07	-624.82	-701.21	-787.41	-884.73	-994.67	-1118.93	-1259.46	-1418.49	-1598.55	-1796.40	-2394.08	-2633.62
IV	-557.07	-624.82	-701.21	-787.41	-884.73	-994.67	-1118.93	-1259.46	-1418.49	-1598.55	-1796.40	-2394.08	-2633.62
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1999.68	-2202.32
II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-321.53	-353.01
III	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-398.85	-439.57
IV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-398.85	-439.57
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+100.2%	+100.4%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+16.1%	+16.1%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+20.0%	+20.0%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+20.0%	+20.0%

Figure 7-44 and Table 7-46 show the total annual expenditure at EU-28 level, summing the annual sales, annual expenditure due to electricity losses and residual value.

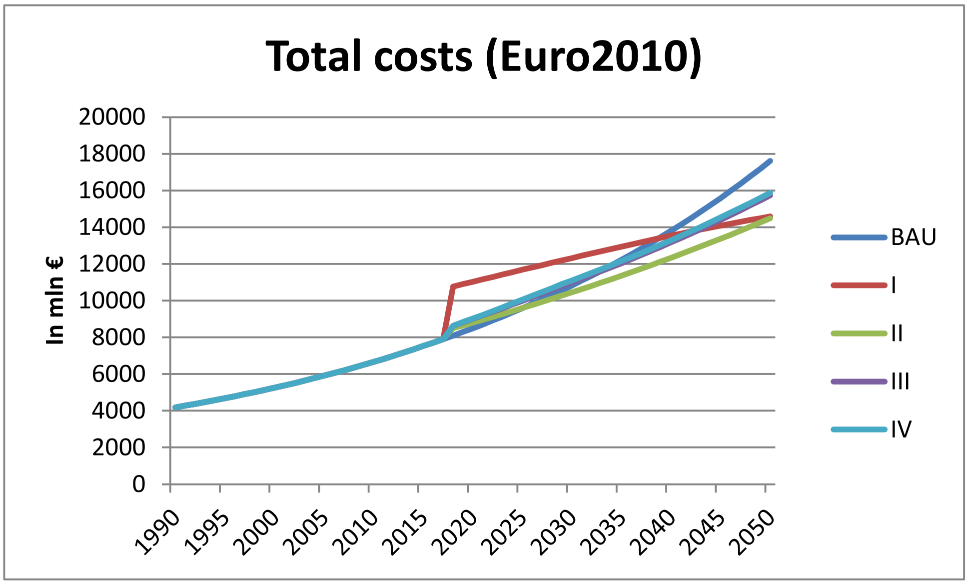


Figure 7-42: Sensitivity case 1 - Total costs (annual sales + losses) (in mln. euro)

Table 7-46: Sensitivity case 1 - Total costs (annual sales + losses) (in mln. euro)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	4185.14	4683.77	5255.21	5911.03	6664.70	7525.21	8495.24	9589.62	10825.44	12222.01	13801.21	15587.73	17609.50
I	4185.14	4683.77	5255.21	5911.03	6664.70	7525.21	11029.63	11679.49	12321.40	12945.87	13541.11	14092.57	14582.50
II	4185.14	4683.77	5255.21	5911.03	6664.70	7525.21	8803.74	9596.58	10446.75	11357.35	12331.31	13371.24	14479.33
III	4185.14	4683.77	5255.21	5911.03	6664.70	7525.21	9010.09	9989.03	11000.51	12043.10	13175.16	14403.89	15736.78
IV	4185.14	4683.77	5255.21	5911.03	6664.70	7525.21	9028.82	10052.65	11098.77	12150.65	13292.80	14532.45	15877.17
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	2534.39	2089.87	1495.96	723.86	-260.10	-1495.15	-3027.00
II	0.00	0.00	0.00	0.00	0.00	0.00	308.51	6.96	-378.69	-864.66	-1469.90	-2216.49	-3130.17
III	0.00	0.00	0.00	0.00	0.00	0.00	514.85	399.41	175.07	-178.91	-626.04	-1183.84	-1872.71
IV	0.00	0.00	0.00	0.00	0.00	0.00	533.58	463.03	273.33	-71.36	-508.41	-1055.28	-1732.33
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+29.8%	+21.8%	+13.8%	+5.9%	-1.9%	-9.6%	-17.2%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+3.6%	+0.1%	-3.5%	-7.1%	-10.7%	-14.2%	-17.8%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+6.1%	+4.2%	+1.6%	-1.5%	-4.5%	-7.6%	-10.6%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+6.3%	+4.8%	+2.5%	-0.6%	-3.7%	-6.8%	-9.8%

7.4.2 Sensitivity case 2: scenario analysis

In this sensitivity analysis, the inflation and discount rate are set to their lowest value defined by the MEErP guidelines. Changing these parameters has only impact on the economic results, therefore only the economic charts and tables are shown in the next section.
The parameters for this analysis are listed in Table 7-47.

Table 7-47: Sensitivity case 2 - Main input parameters

Discount rate	+2.5%
Inflation rate	+1.0%
Energy Escalation rate	+4.0%
Electricity rate (€/kWh)	0.11
Stock growth rate services sector	+1.9%
Stock growth rate industry sector	+2.9%
Replacement sales rate services sector	+3.2%
Replacement sales rate industry sector	+2.8%
Product lifetime services sector (years)	25
Product lifetime industry sector (years)	25
Product price factor	1
Growth / sales rate type	onalFrom1

7.4.2.1 Annual expenditure

The sales and stock value are expressed in euro2010 value; as a result these values will not alter.

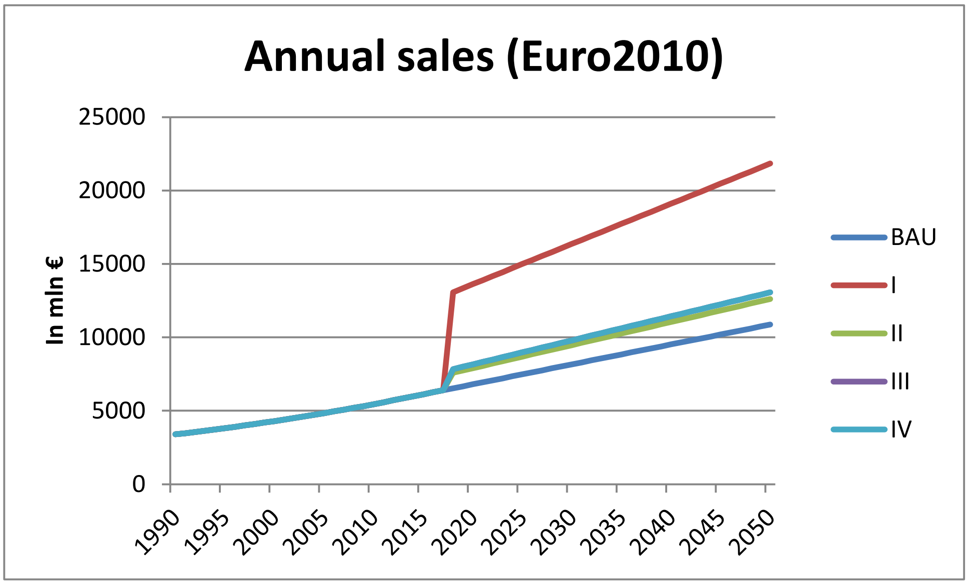


Figure 7-43: Sensitivity case 2 - Annual sales (in mln. euro)

Table 7-48: Sensitivity case 2 - Annual sales (in mln. euro)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	3391.69	3815.41	4294.61	4836.89	5450.88	6125.51	6803.49	7481.46	8159.43	8837.41	9515.38	10193.35	10871.33
I	3391.69	3815.41	4294.61	4836.89	5450.88	6125.51	13622.15	14991.11	16360.06	17729.02	19097.98	20466.93	21835.89
II	3391.69	3815.41	4294.61	4836.89	5450.88	6125.51	7899.86	8685.19	9470.51	10255.83	11041.15	11826.47	12611.79
III	3391.69	3815.41	4294.61	4836.89	5450.88	6125.51	8163.53	8980.34	9797.15	10613.96	11430.77	12247.58	13064.39
IV	3391.69	3815.41	4294.61	4836.89	5450.88	6125.51	8163.53	8980.34	9797.15	10613.96	11430.77	12247.58	13064.39
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	6818.66	7509.65	8200.63	8891.61	9582.60	10273.58	10964.56
II	0.00	0.00	0.00	0.00	0.00	0.00	1096.38	1203.73	1311.07	1418.42	1525.77	1633.12	1740.46
III	0.00	0.00	0.00	0.00	0.00	0.00	1360.04	1498.88	1637.72	1776.55	1915.39	2054.23	2193.06
IV	0.00	0.00	0.00	0.00	0.00	0.00	1360.04	1498.88	1637.72	1776.55	1915.39	2054.23	2193.06
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+100.2%	+100.4%	+100.5%	+100.6%	+100.7%	+100.8%	+100.9%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+16.1%	+16.1%	+16.1%	+16.1%	+16.0%	+16.0%	+16.0%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+20.0%	+20.0%	+20.1%	+20.1%	+20.1%	+20.2%	+20.2%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+20.0%	+20.0%	+20.1%	+20.1%	+20.1%	+20.2%	+20.2%

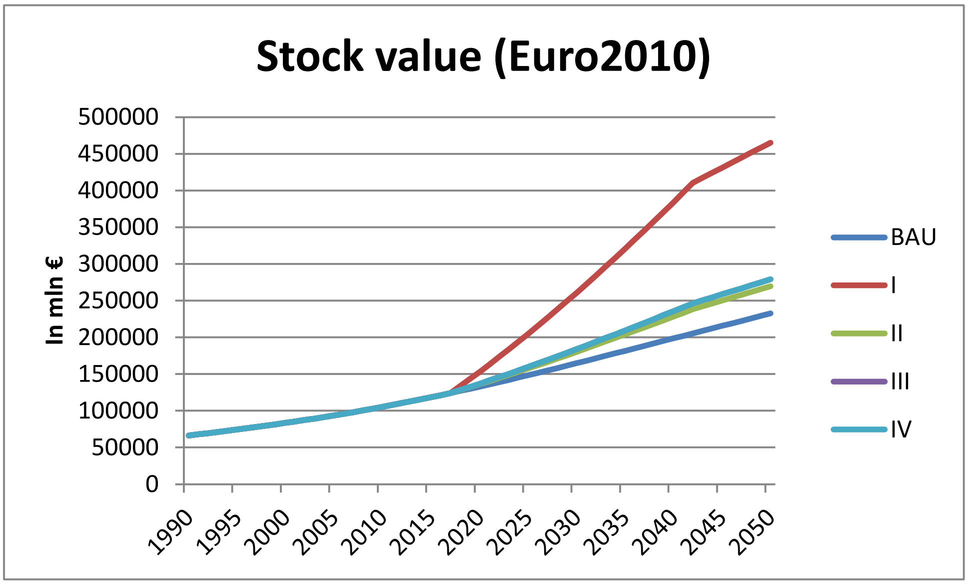


Figure 7-44: Sensitivity case 2 - Stock value (in mln. euro)

Table 7-49: Sensitivity case 2 - Stock value (in mln. euro)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	66369.91	74399.02	83468.31	93718.49	105310.04	118391.24	132843.91	148404.24	164772.43	181607.65	198556.99	215506.34	232455.68
I	66369.91	74399.02	83468.31	93718.49	105310.04	118391.24	152885.31	204611.91	260601.29	320512.61	383992.97	430886.85	465110.77
II	66369.91	74399.02	83468.31	93718.49	105310.04	118391.24	136068.63	157432.89	180141.76	203854.39	228217.88	249893.39	269526.42
III	66369.91	74399.02	83468.31	93718.49	105310.04	118391.24	136840.74	159617.80	183896.90	209337.22	235585.84	258531.81	278952.06
IV	66369.91	74399.02	83468.31	93718.49	105310.04	118391.24	136840.74	159617.80	183896.90	209337.22	235585.84	258531.81	278952.06
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	20041.40	56207.67	95828.86	138904.96	185435.98	215380.51	232655.09
II	0.00	0.00	0.00	0.00	0.00	0.00	3224.72	9028.66	15369.33	22246.74	29660.89	34387.05	37070.75
III	0.00	0.00	0.00	0.00	0.00	0.00	3996.83	11213.56	19124.47	27729.56	37028.84	43025.47	46496.38
IV	0.00	0.00	0.00	0.00	0.00	0.00	3996.83	11213.56	19124.47	27729.56	37028.84	43025.47	46496.38
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+15.1%	+37.9%	+58.2%	+76.5%	+93.4%	+99.9%	+100.1%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+2.4%	+6.1%	+9.3%	+12.2%	+14.9%	+16.0%	+15.9%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+3.0%	+7.6%	+11.6%	+15.3%	+18.6%	+20.0%	+20.0%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+3.0%	+7.6%	+11.6%	+15.3%	+18.6%	+20.0%	+20.0%

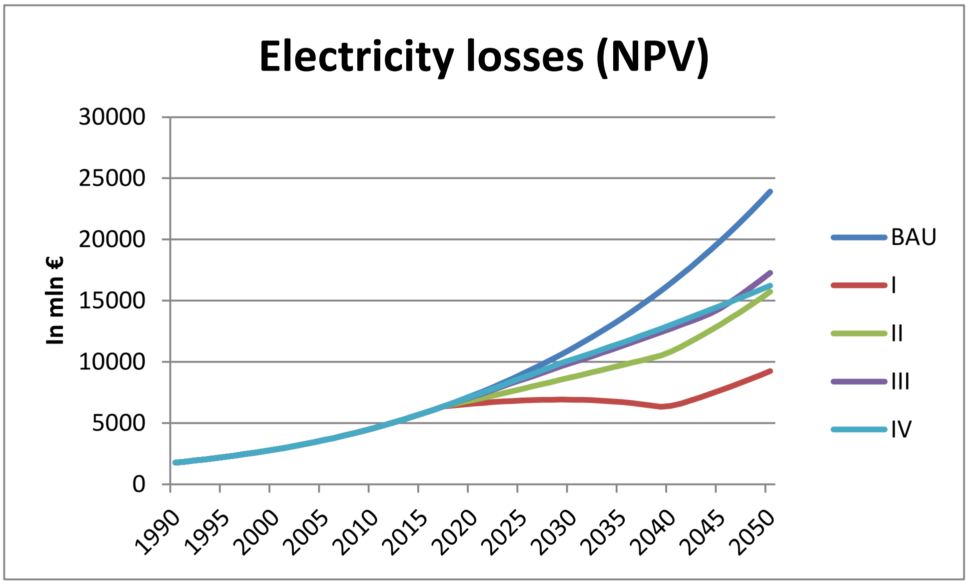


Figure 7-45: Sensitivity case 2 - Annual expenditure due to electricity losses (in mln. euro)

Table 7-50: Sensitivity case 2 - Annual expenditure due to electricity losses (in mln. euro)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	1754.26	2228.07	2831.54	3600.60	4581.27	5800.43	7259.40	8999.96	11070.68	13528.05	16437.65	19875.57	23930.06
I	1754.26	2228.07	2831.54	3600.60	4581.27	5800.43	6577.39	6838.18	6905.19	6704.01	6393.75	7668.16	9235.30
II	1754.26	2228.07	2831.54	3600.60	4581.27	5800.43	6878.37	7792.72	8745.41	9720.10	10828.35	13058.75	15727.17
III	1754.26	2228.07	2831.54	3600.60	4581.27	5800.43	7155.81	8535.03	9919.89	11269.47	12715.92	14387.26	17272.39
IV	1754.26	2228.07	2831.54	3600.60	4581.27	5800.43	7200.61	8693.87	10172.48	11547.30	13020.37	14582.61	16219.41
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	-682.01	-2161.78	-4165.49	-6824.04	-10043.90	-12207.41	-14694.75
II	0.00	0.00	0.00	0.00	0.00	0.00	-381.03	-1207.24	-2325.28	-3807.95	-5609.30	-6816.82	-8202.89
III	0.00	0.00	0.00	0.00	0.00	0.00	-103.59	-464.93	-1150.79	-2258.58	-3721.73	-5488.31	-6657.67
IV	0.00	0.00	0.00	0.00	0.00	0.00	-58.79	-306.08	-898.20	-1980.75	-3417.27	-5292.96	-7710.65
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-9.4%	-24.0%	-37.6%	-50.4%	-61.1%	-61.4%	-61.4%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-5.2%	-13.4%	-21.0%	-28.1%	-34.1%	-34.3%	-34.3%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-1.4%	-5.2%	-10.4%	-16.7%	-22.6%	-27.6%	-27.8%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-0.8%	-3.4%	-8.1%	-14.6%	-20.8%	-26.6%	-32.2%

Figure 7-46 and Table 7-51 show the residual value in mln. euro due to the recycling of the conductor material.

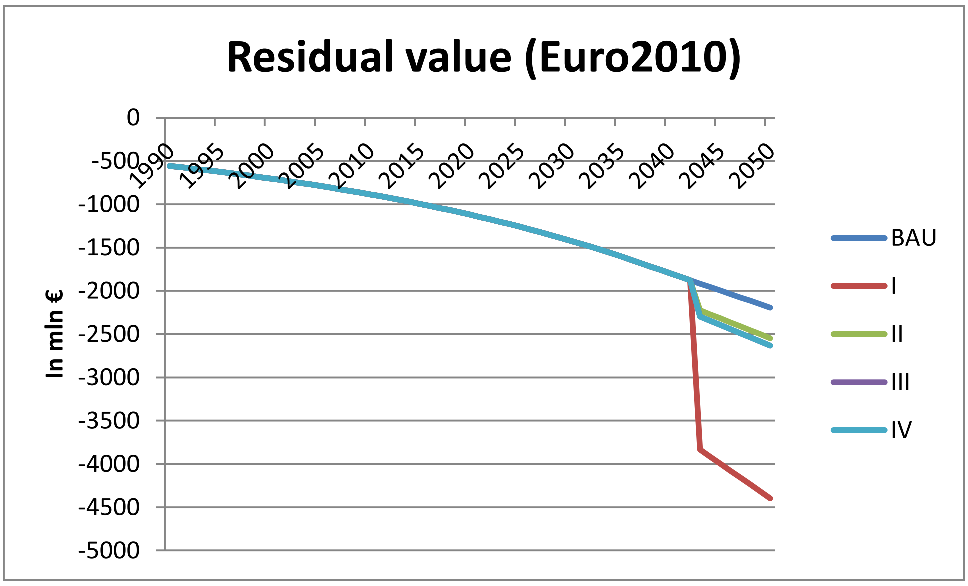


Figure 7-46: Sensitivity case 2 - Residual value (in mln. euro)

Table 7-51: Sensitivity case 2 - Residual value (in mln. euro)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	-557.07	-624.82	-701.21	-787.41	-884.73	-994.67	-1118.93	-1259.46	-1418.49	-1598.55	-1796.40	-1995.22	-2194.05
I	-557.07	-624.82	-701.21	-787.41	-884.73	-994.67	-1118.93	-1259.46	-1418.49	-1598.55	-1796.40	-3994.90	-4396.37
II	-557.07	-624.82	-701.21	-787.41	-884.73	-994.67	-1118.93	-1259.46	-1418.49	-1598.55	-1796.40	-2316.75	-2547.06
III	-557.07	-624.82	-701.21	-787.41	-884.73	-994.67	-1118.93	-1259.46	-1418.49	-1598.55	-1796.40	-2394.08	-2633.62
IV	-557.07	-624.82	-701.21	-787.41	-884.73	-994.67	-1118.93	-1259.46	-1418.49	-1598.55	-1796.40	-2394.08	-2633.62
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1999.68	-2202.32
II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-321.53	-353.01
III	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-398.85	-439.57
IV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-398.85	-439.57
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+100.2%	+100.4%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+16.1%	+16.1%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+20.0%	+20.0%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+20.0%	+20.0%

Figure 7-47 and Table 7-52 show the total annual expenditure at EU-28 level, summing the annual sales,annual expenditure due to electricity losses and residual value.

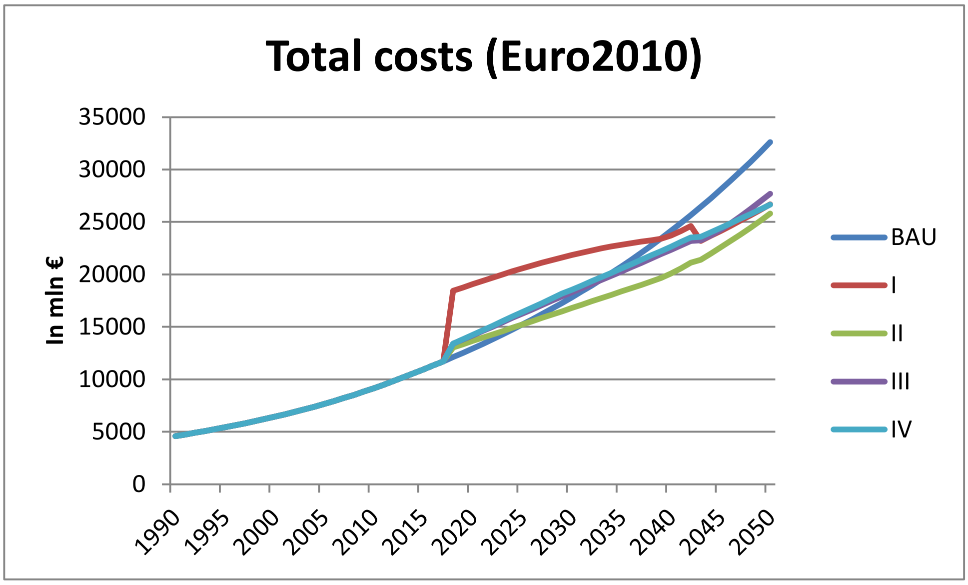


Figure 7-47: Sensitivity case 2 - Total costs (annual sales + losses) (in mln. euro)

Table 7-52: Sensitivity case 2 - Total costs (annual sales + losses) (in mln. euro)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	4588.88	5418.66	6424.94	7650.08	9147.42	10931.28	12943.96	15221.95	17811.62	20766.91	24156.63	28073.70	32607.34
I	4588.88	5418.66	6424.94	7650.08	9147.42	10931.28	19080.62	20569.82	21846.77	22834.48	23695.32	24140.20	26674.83
II	4588.88	5418.66	6424.94	7650.08	9147.42	10931.28	13659.31	15218.44	16797.42	18377.37	20073.10	22568.46	25791.90
III	4588.88	5418.66	6424.94	7650.08	9147.42	10931.28	14200.41	16255.91	18298.55	20284.88	22350.29	24240.76	27703.16
IV	4588.88	5418.66	6424.94	7650.08	9147.42	10931.28	14245.21	16414.75	18551.14	20562.71	22654.75	24436.11	26650.18
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	6136.66	5347.87	4035.14	2067.57	-461.31	-3933.50	-5932.51
II	0.00	0.00	0.00	0.00	0.00	0.00	715.34	-3.51	-1014.20	-2389.53	-4083.53	-5505.23	-6815.44
III	0.00	0.00	0.00	0.00	0.00	0.00	1256.45	1033.95	486.93	-482.03	-1806.34	-3832.94	-4904.18
IV	0.00	0.00	0.00	0.00	0.00	0.00	1301.25	1192.80	739.52	-204.20	-1501.88	-3637.58	-5957.16
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+47.4%	+35.1%	+22.7%	+10.0%	-1.9%	-14.0%	-18.2%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+5.5%	-0.0%	-5.7%	-11.5%	-16.9%	-19.6%	-20.9%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+9.7%	+6.8%	+2.7%	-2.3%	-7.5%	-13.7%	-15.0%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+10.1%	+7.8%	+4.2%	-1.0%	-6.2%	-13.0%	-18.3%

7.4.3 Sensitivity case 3: scenario analysis

The parameters for this analysis are listed in Table 7-53. Compared to the default scenario analysis only the energy escalation rate has been altered. The impact of this parameter is limited to the electricity cost. As a result only the charts and tables showing the annual expenditure due to electricity losses and the total costs are listed in this section.

Table 7-53: Sensitivity case 3 - Main input parameters

Discount rate	+4.0%
Inflation rate	+2.1%
Energy Escalation rate	+1.0%
Electricity rate (€/kWh)	0.11
Stock growth rate services sector	+1.9%
Stock growth rate industry sector	+2.9%
Replacement sales rate services sector	+3.2%
Replacement sales rate industry sector	+2.8%
Product lifetime services sector (years)	25
Product lifetime industry sector (years)	25
Product price factor	1
Growth / sales rate type	onalFrom1

7.4.3.1 Annual expenditure due to electricity losses

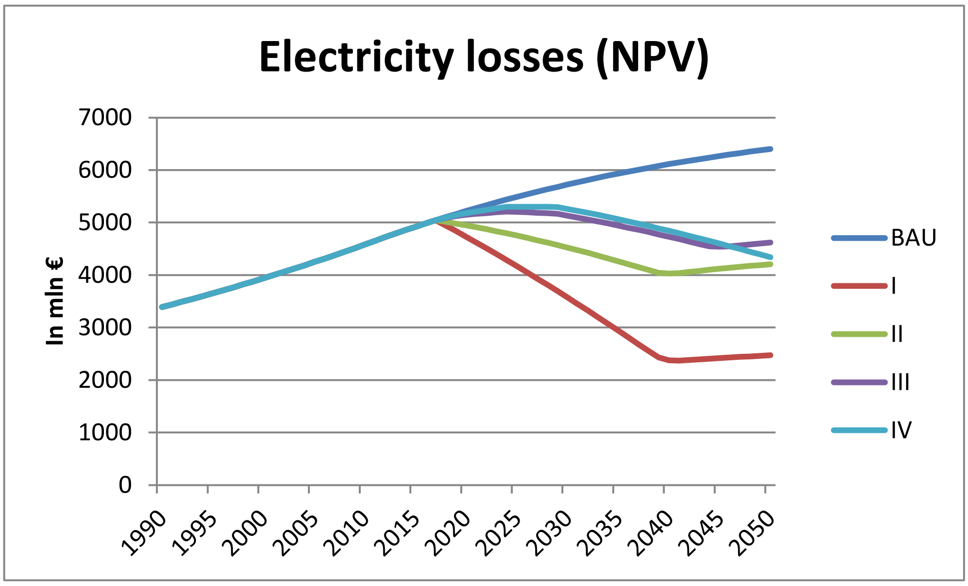


Figure 7-48: Sensitivity case 3 - Annual expenditure due to electricity losses (in mln. euro)

Table 7-54: Sensitivity case 3 - Annual expenditure due to electricity losses (in mln. euro)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	3391.84	3653.30	3937.26	4245.81	4581.27	4918.98	5220.72	5488.89	5725.76	5933.47	6114.03	6269.34	6401.19
I	3391.84	3653.30	3937.26	4245.81	4581.27	4918.98	4730.24	4170.46	3571.37	2940.41	2378.17	2418.77	2470.41
II	3391.84	3653.30	3937.26	4245.81	4581.27	4918.98	4946.69	4752.62	4523.12	4263.28	4027.64	4119.12	4206.95
III	3391.84	3653.30	3937.26	4245.81	4581.27	4918.98	5146.22	5205.34	5130.57	4942.84	4729.72	4538.17	4620.29
IV	3391.84	3653.30	3937.26	4245.81	4581.27	4918.98	5178.44	5302.21	5261.21	5064.70	4842.96	4599.79	4338.63
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	-490.48	-1318.42	-2154.39	-2993.06	-3735.86	-3850.58	-3930.79
II	0.00	0.00	0.00	0.00	0.00	0.00	-274.03	-736.27	-1202.63	-1670.19	-2086.39	-2150.23	-2194.24
III	0.00	0.00	0.00	0.00	0.00	0.00	-74.50	-283.55	-595.19	-990.63	-1384.31	-1731.18	-1780.90
IV	0.00	0.00	0.00	0.00	0.00	0.00	-42.28	-186.67	-464.55	-868.77	-1271.07	-1669.56	-2062.57
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-9.4%	-24.0%	-37.6%	-50.4%	-61.1%	-61.4%	-61.4%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-5.2%	-13.4%	-21.0%	-28.1%	-34.1%	-34.3%	-34.3%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-1.4%	-5.2%	-10.4%	-16.7%	-22.6%	-27.6%	-27.8%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-0.8%	-3.4%	-8.1%	-14.6%	-20.8%	-26.6%	-32.2%

Figure 7-49 and Table 7-55 show the residual value in mln. euro due to the recycling of the conductor material.

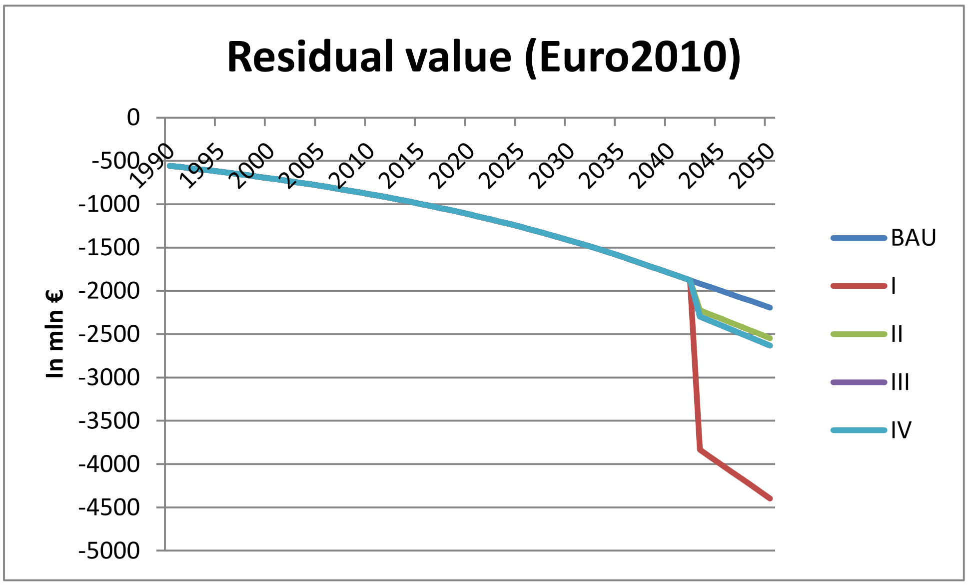


Figure 7-49: Sensitivity case 3 - Residual value (in mln. euro)

Table 7-55: Sensitivity case 3 - Residual value (in mln. euro)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	-557.07	-624.82	-701.21	-787.41	-884.73	-994.67	-1118.93	-1259.46	-1418.49	-1598.55	-1796.40	-1995.22	-2194.05
I	-557.07	-624.82	-701.21	-787.41	-884.73	-994.67	-1118.93	-1259.46	-1418.49	-1598.55	-1796.40	-3994.90	-4396.37
II	-557.07	-624.82	-701.21	-787.41	-884.73	-994.67	-1118.93	-1259.46	-1418.49	-1598.55	-1796.40	-2316.75	-2547.06
III	-557.07	-624.82	-701.21	-787.41	-884.73	-994.67	-1118.93	-1259.46	-1418.49	-1598.55	-1796.40	-2394.08	-2633.62
IV	-557.07	-624.82	-701.21	-787.41	-884.73	-994.67	-1118.93	-1259.46	-1418.49	-1598.55	-1796.40	-2394.08	-2633.62
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1999.68	-2202.32
II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-321.53	-353.01
III	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-398.85	-439.57
IV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-398.85	-439.57
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+100.2%	+100.4%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+16.1%	+16.1%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+20.0%	+20.0%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+20.0%	+20.0%

Figure 7-50 and Table 7-56 show the total annual expenditure at EU-28 level, summing the annual sales, annual expenditure due to electricity losses and residual value.

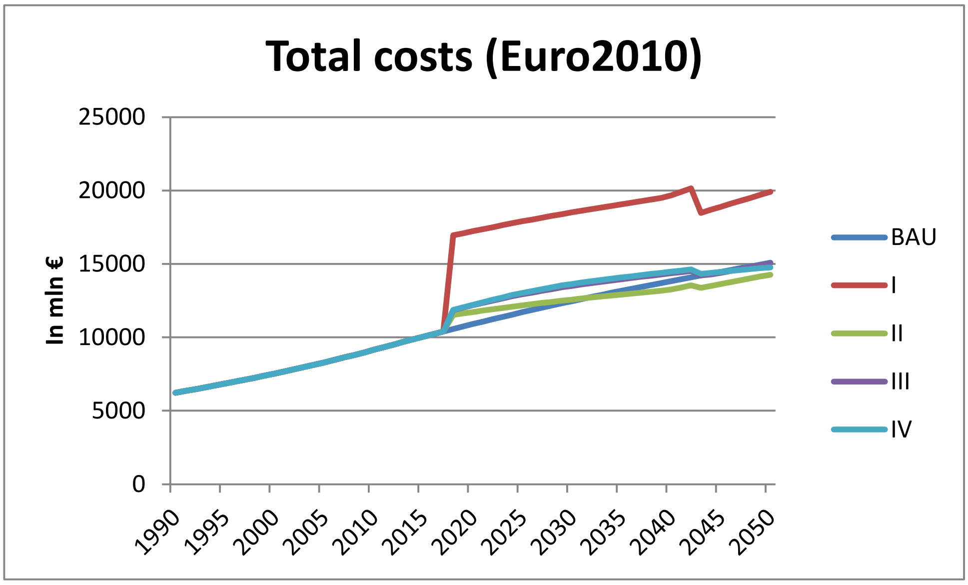


Figure 7-50: Sensitivity case 3 - Total costs (annual sales + losses) (in mln. euro)

Table 7-56: Sensitivity case 3 - Total costs (annual sales + losses) (in mln. euro)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	6226.46	6843.89	7530.66	8295.28	9147.42	10049.83	10905.28	11710.89	12466.70	13172.32	13833.01	14467.47	15078.47
I	6226.46	6843.89	7530.66	8295.28	9147.42	10049.83	17233.46	17902.11	18512.94	19070.88	19679.75	18890.80	19909.93
II	6226.46	6843.89	7530.66	8295.28	9147.42	10049.83	11727.63	12178.34	12575.14	12920.56	13272.39	13628.83	14271.68
III	6226.46	6843.89	7530.66	8295.28	9147.42	10049.83	12190.82	12926.22	13509.23	13958.25	14364.10	14391.67	15051.06
IV	6226.46	6843.89	7530.66	8295.28	9147.42	10049.83	12223.04	13023.09	13639.87	14080.11	14477.34	14453.29	14769.40
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	6328.19	6191.22	6046.24	5898.56	5846.74	4423.33	4831.46
II	0.00	0.00	0.00	0.00	0.00	0.00	822.35	467.45	108.44	-251.77	-560.62	-838.64	-806.79
III	0.00	0.00	0.00	0.00	0.00	0.00	1285.54	1215.33	1042.53	785.93	531.08	-75.80	-27.41
IV	0.00	0.00	0.00	0.00	0.00	0.00	1317.76	1312.21	1173.17	907.79	644.32	-14.18	-309.07
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+58.0%	+52.9%	+48.5%	+44.8%	+42.3%	+30.6%	+32.0%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+7.5%	+4.0%	+0.9%	-1.9%	-4.1%	-5.8%	-5.4%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+11.8%	+10.4%	+8.4%	+6.0%	+3.8%	-0.5%	-0.2%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+12.1%	+11.2%	+9.4%	+6.9%	+4.7%	-0.1%	-2.0%

7.4.4 Sensitivity case 4: scenario analysis

The fact is that a large part of the product price is determined by the price of the conductor material. Future commodity prices, however, cannot be predicted. This analysis investigates the impact of a substantial higher product price.

The parameters for this analysis are listed in Table 7-57. Compared to the default scenario analysis only the product price has been altered. The product price[127] has been multiplied by 1.5 which approximately correlates with a 100% increase of the conductor material price (see sensitivity analysis in Task 6). Changing this parameter has only impact on the economic results, therefore only the economic charts and tables are shown in this section.

[127] The product price includes also the connector cost. The connector cost is therefore also multiplied by the same factor.

Table 7-57: Sensitivity case 4 - Main input parameters

Discount rate	+4.0%
Inflation rate	+2.1%
Energy Escalation rate	+4.0%
Electricity rate (€/kWh)	0.11
Stock growth rate services sector	+1.9%
Stock growth rate industry sector	+2.9%
Replacement sales rate services sector	+3.2%
Replacement sales rate industry sector	+2.8%
Product lifetime services sector (years)	25
Product lifetime industry sector (years)	25
Product price factor	1.5
Growth / sales rate type	onalFrom1

7.4.4.1 Annual expenditure

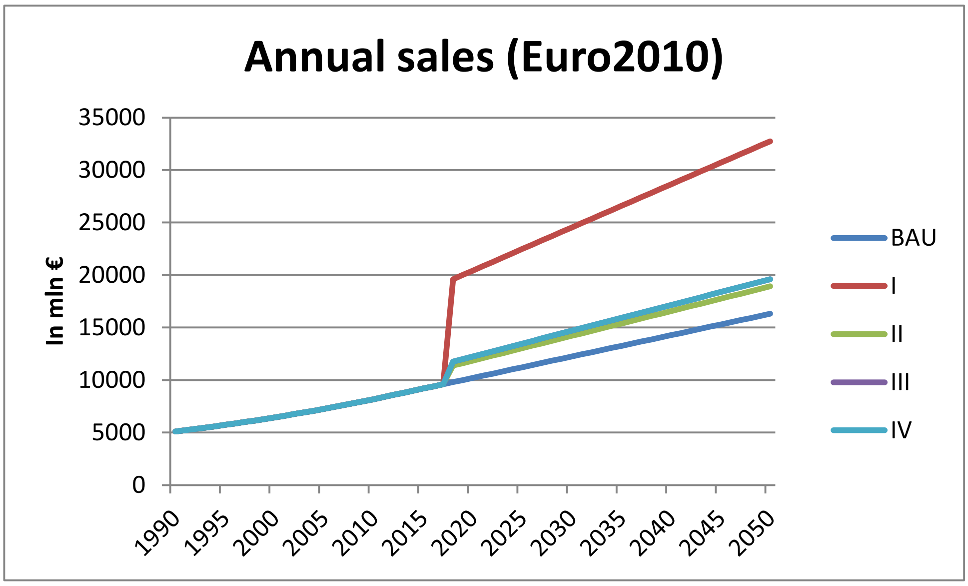


Figure 7-51: Sensitivity case 4 - Annual sales (in mln. euro)

Table 7-58: Sensitivity case 4 - Annual sales (in mln. euro)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	5087.54	5723.11	6441.92	7255.34	8176.32	9188.27	10205.23	11222.19	12239.15	13256.11	14273.07	15290.03	16306.99
I	5087.54	5723.11	6441.92	7255.34	8176.32	9188.27	20433.23	22486.66	24540.10	26593.53	28646.97	30700.40	32753.84
II	5087.54	5723.11	6441.92	7255.34	8176.32	9188.27	11849.80	13027.78	14205.76	15383.74	16561.72	17739.71	18917.69
III	5087.54	5723.11	6441.92	7255.34	8176.32	9188.27	12245.29	13470.51	14695.73	15920.94	17146.16	18371.37	19596.59
IV	5087.54	5723.11	6441.92	7255.34	8176.32	9188.27	12245.29	13470.51	14695.73	15920.94	17146.16	18371.37	19596.59
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	10228.00	11264.47	12300.95	13337.42	14373.90	15410.37	16446.85
II	0.00	0.00	0.00	0.00	0.00	0.00	1644.57	1805.59	1966.61	2127.63	2288.65	2449.68	2610.70
III	0.00	0.00	0.00	0.00	0.00	0.00	2040.07	2248.32	2456.58	2664.83	2873.08	3081.34	3289.59
IV	0.00	0.00	0.00	0.00	0.00	0.00	2040.07	2248.32	2456.58	2664.83	2873.08	3081.34	3289.59
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+100.2%	+100.4%	+100.5%	+100.6%	+100.7%	+100.8%	+100.9%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+16.1%	+16.1%	+16.1%	+16.1%	+16.0%	+16.0%	+16.0%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+20.0%	+20.0%	+20.1%	+20.1%	+20.1%	+20.2%	+20.2%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+20.0%	+20.0%	+20.1%	+20.1%	+20.1%	+20.2%	+20.2%

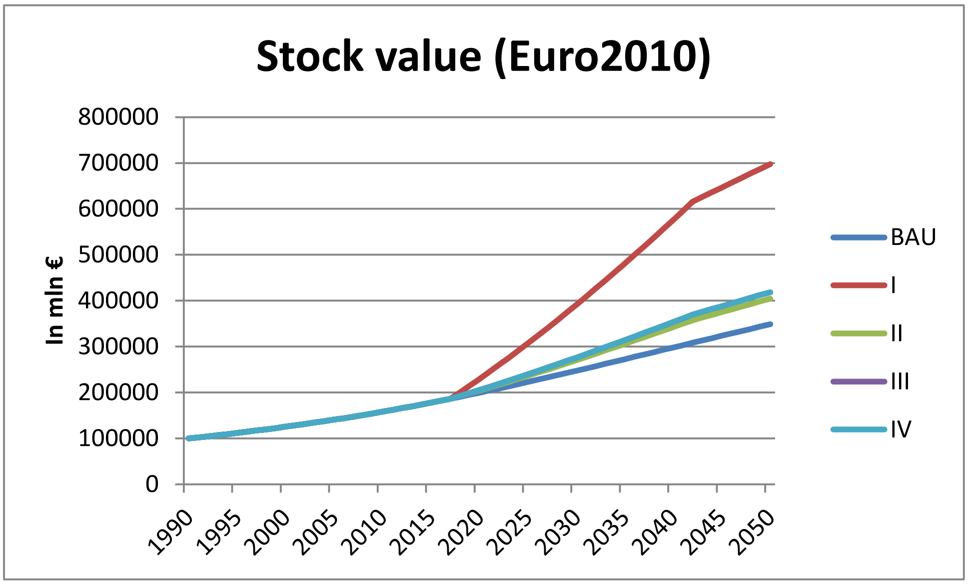


Figure 7-52: Sensitivity case 4 - Stock value (in mln. euro)

Table 7-59: Sensitivity case 4 - Stock value (in mln. euro)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	99554.86	111598.53	125202.46	140577.73	157965.06	177586.85	199265.87	222606.36	247158.64	272411.48	297835.49	323259.51	348683.52
I	99554.86	111598.53	125202.46	140577.73	157965.06	177586.85	229327.97	306917.86	390901.93	480768.92	575989.46	646330.27	697666.16
II	99554.86	111598.53	125202.46	140577.73	157965.06	177586.85	204102.95	236149.34	270212.64	305781.58	342326.82	374840.08	404289.64
III	99554.86	111598.53	125202.46	140577.73	157965.06	177586.85	205261.11	239426.70	275845.35	314005.83	353378.75	387797.71	418428.09
IV	99554.86	111598.53	125202.46	140577.73	157965.06	177586.85	205261.11	239426.70	275845.35	314005.83	353378.75	387797.71	418428.09
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	30062.10	84311.51	143743.29	208357.44	278153.97	323070.77	348982.64
II	0.00	0.00	0.00	0.00	0.00	0.00	4837.09	13542.98	23053.99	33370.11	44491.33	51580.57	55606.12
III	0.00	0.00	0.00	0.00	0.00	0.00	5995.24	16820.34	28686.71	41594.35	55543.26	64538.21	69744.58
IV	0.00	0.00	0.00	0.00	0.00	0.00	5995.24	16820.34	28686.71	41594.35	55543.26	64538.21	69744.58
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+15.1%	+37.9%	+58.2%	+76.5%	+93.4%	+99.9%	+100.1%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+2.4%	+6.1%	+9.3%	+12.2%	+14.9%	+16.0%	+15.9%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+3.0%	+7.6%	+11.6%	+15.3%	+18.6%	+20.0%	+20.0%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+3.0%	+7.6%	+11.6%	+15.3%	+18.6%	+20.0%	+20.0%

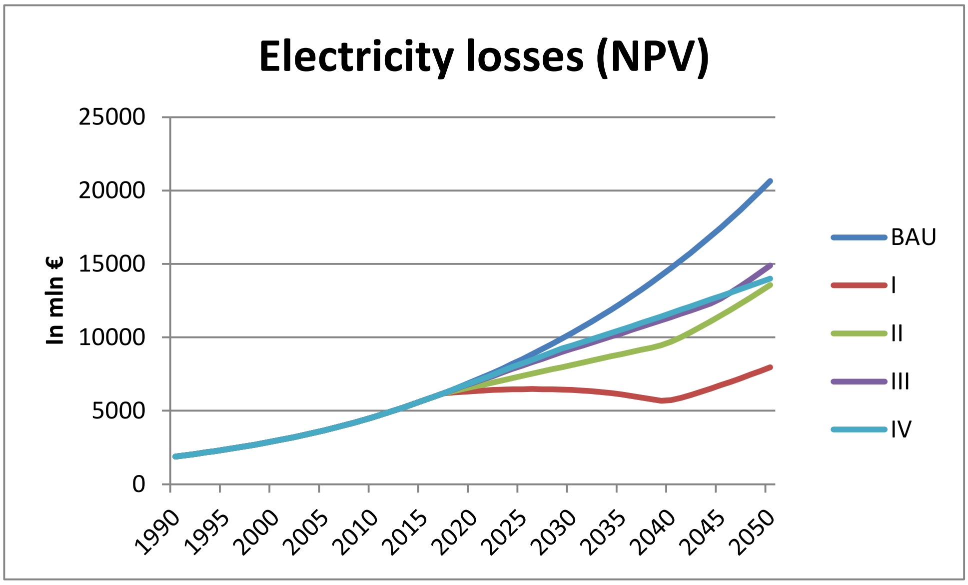


Figure 7-53: Sensitivity case 4 - Annual expenditure due to electricity losses (in mln. euro)

Table 7-60: Sensitivity case 4 - Annual expenditure due to electricity losses (in mln. euro)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	1888.84	2355.08	2938.15	3667.76	4581.27	5694.23	6996.00	8514.59	10281.87	12334.11	14712.50	17463.88	20641.42
I	1888.84	2355.08	2938.15	3667.76	4581.27	5694.23	6338.74	6469.40	6413.18	6112.34	5722.72	6737.71	7966.12
II	1888.84	2355.08	2938.15	3667.76	4581.27	5694.23	6628.79	7372.46	8122.28	8862.23	9691.91	11474.21	13565.83
III	1888.84	2355.08	2938.15	3667.76	4581.27	5694.23	6896.17	8074.74	9213.08	10274.86	11381.37	12641.52	14898.69
IV	1888.84	2355.08	2938.15	3667.76	4581.27	5694.23	6939.34	8225.01	9447.67	10528.17	11653.87	12813.17	13990.42
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	-657.26	-2045.19	-3868.69	-6221.77	-8989.79	-10726.17	-12675.30
II	0.00	0.00	0.00	0.00	0.00	0.00	-367.21	-1142.13	-2159.60	-3471.88	-5020.60	-5989.67	-7075.59
III	0.00	0.00	0.00	0.00	0.00	0.00	-99.83	-439.85	-1068.79	-2059.25	-3331.13	-4822.36	-5742.73
IV	0.00	0.00	0.00	0.00	0.00	0.00	-56.66	-289.58	-834.20	-1805.94	-3058.63	-4650.72	-6651.00
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-9.4%	-24.0%	-37.6%	-50.4%	-61.1%	-61.4%	-61.4%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-5.2%	-13.4%	-21.0%	-28.1%	-34.1%	-34.3%	-34.3%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-1.4%	-5.2%	-10.4%	-16.7%	-22.6%	-27.6%	-27.8%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	-0.8%	-3.4%	-8.1%	-14.6%	-20.8%	-26.6%	-32.2%

Figure 7-54 and Table 7-61 show the residual value in mln. euro due to the recycling of the conductor material.

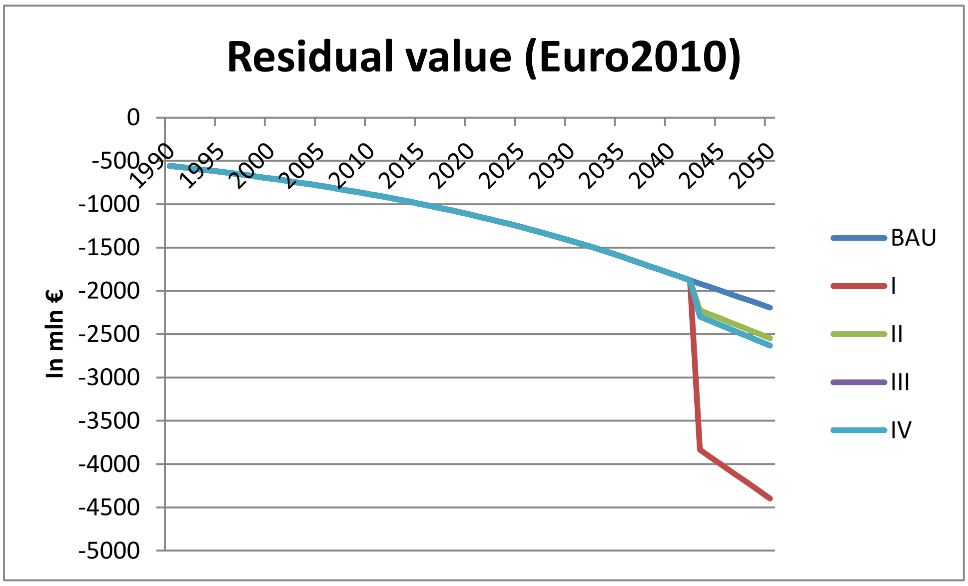


Figure 7-54: Sensitivity case 4 - Residual value (in mln. euro)

Table 7-61: Sensitivity case 4 - Residual value (in mln. euro)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	-557.07	-624.82	-701.21	-787.41	-884.73	-994.67	-1118.93	-1259.46	-1418.49	-1598.55	-1796.40	-1995.22	-2194.05
I	-557.07	-624.82	-701.21	-787.41	-884.73	-994.67	-1118.93	-1259.46	-1418.49	-1598.55	-1796.40	-3994.90	-4396.37
II	-557.07	-624.82	-701.21	-787.41	-884.73	-994.67	-1118.93	-1259.46	-1418.49	-1598.55	-1796.40	-2316.75	-2547.06
III	-557.07	-624.82	-701.21	-787.41	-884.73	-994.67	-1118.93	-1259.46	-1418.49	-1598.55	-1796.40	-2394.08	-2633.62
IV	-557.07	-624.82	-701.21	-787.41	-884.73	-994.67	-1118.93	-1259.46	-1418.49	-1598.55	-1796.40	-2394.08	-2633.62
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1999.68	-2202.32
II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-321.53	-353.01
III	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-398.85	-439.57
IV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-398.85	-439.57
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+100.2%	+100.4%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+16.1%	+16.1%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+20.0%	+20.0%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+20.0%	+20.0%

Figure 7-47Figure 7-55 and Table 7-62 show the total annual expenditure at EU-28 level, summing the annual sales, annual expenditure due to electricity losses and residual value.

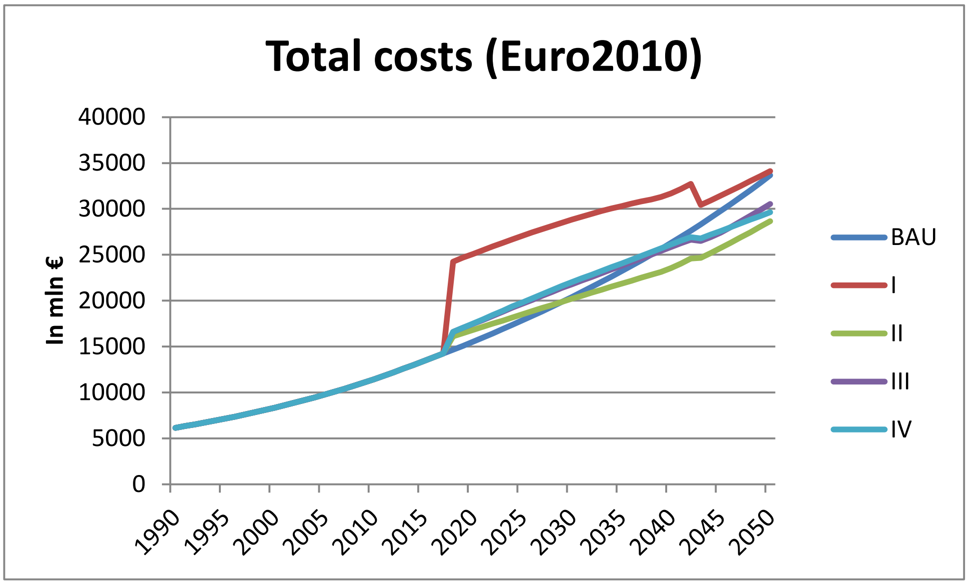


Figure 7-55: Sensitivity case 4 - Total costs (annual sales + losses) (in mln. euro)

Table 7-62: Sensitivity case 4 - Total costs (annual sales + losses) (in mln. euro)

	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
BAU	6140.78	7140.97	8328.25	9741.97	11430.50	13390.50	15522.84	17847.59	20393.29	23192.39	26290.97	29761.08	33657.34
I	6140.78	7140.97	8328.25	9741.97	11430.50	13390.50	25093.57	27066.87	28825.54	30308.04	31675.08	31445.77	34125.41
II	6140.78	7140.97	8328.25	9741.97	11430.50	13390.50	16800.20	18511.04	20200.30	21848.14	23559.03	25738.79	28662.92
III	6140.78	7140.97	8328.25	9741.97	11430.50	13390.50	17463.07	19656.06	21781.07	23797.97	25832.93	27421.77	30544.85
IV	6140.78	7140.97	8328.25	9741.97	11430.50	13390.50	17506.25	19806.33	22015.66	24051.28	26105.43	27593.42	29636.58
Absolute difference to BAU													
I	0.00	0.00	0.00	0.00	0.00	0.00	9570.73	9219.28	8432.26	7115.65	5384.11	1684.69	468.07
II	0.00	0.00	0.00	0.00	0.00	0.00	1277.36	663.45	-192.99	-1344.24	-2731.94	-4022.29	-4994.41
III	0.00	0.00	0.00	0.00	0.00	0.00	1940.23	1808.47	1387.78	605.58	-458.04	-2339.30	-3112.49
IV	0.00	0.00	0.00	0.00	0.00	0.00	1983.41	1958.74	1622.37	858.89	-185.54	-2167.66	-4020.76
Relative difference to BAU													
I	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+61.7%	+51.7%	+41.3%	+30.7%	+20.5%	+5.7%	+1.4%
II	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+8.2%	+3.7%	-0.9%	-5.8%	-10.4%	-13.5%	-14.8%
III	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+12.5%	+10.1%	+6.8%	+2.6%	-1.7%	-7.9%	-9.2%
IV	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+0.0%	+12.8%	+11.0%	+8.0%	+3.7%	-0.7%	-7.3%	-11.9%

7.4.5 Main conclusions from the sensitivity analysis

The tables below summarize the impact of the sensitivity analysis on the outcomes compared to the reference case, for the five scenarios. Because of the long product lifetime (25 to 40 years) the figures are presented for the year 2025 and 2050.

In case of annual circuit electricity losses and annual total GWP only sensitivity case 1 matters. Compared to the reference case the reduction in the electricity losses and GWP is reduced to about 1/2 to 1/3 of the reference case reduction depending on the selected scenario. Because the policy measures depend on the “natural” replacement cycle to introduce improved circuits, having a much longer product lifetime and a lower stock growth will have a considerable impact on the reduction in the annual electricity losses and annual GWP. This is reflected in Table 7-63, Table 7-64, Table 7-65 and Table 7-66.

Table 7-63: Annual circuit electricity losses in TWh in 2025

	Annual circuit electricity losses in TWh in 2025				
	Reference case	**Sensitivity case 1**	**Sensitivity case 2**	**Sensitivity case 3**	**Sensitivity case 4**
BAU scenario (absolute values)	56.67	47.90	56.67	56.67	56.67
Difference to BAU					
Scenario I	-13.61	-5.70	-13.61	-13.61	-13.61
Scenario II	-7.60	-3.21	-7.60	-7.60	-7.60
Scenario III	-2.93	-1.23	-2.93	-2.93	-2.93
Scenario IV	-1.93	-0.80	-1.93	-1.93	-1.93

Table 7-64: Annual circuit electricity losses in TWh in 2050

	Annual circuit electricity losses in TWh in 2050				
	Reference case	**Sensitivity case 1**	**Sensitivity case 2**	**Sensitivity case 3**	**Sensitivity case 4**
BAU scenario (absolute values)	81.72	58.31	81.72	81.72	81.72
Difference to BAU					
Scenario I	-50.18	-26.21	-50.18	-50.18	-50.18
Scenario II	-28.01	-14.75	-28.01	-28.01	-28.01
Scenario III	-22.74	-10.23	-22.74	-22.74	-22.74
Scenario IV	-26.33	-9.67	-26.33	-26.33	-26.33

Table 7-65: Annual total GWP in Mt CO2eq in 2025

	Annual total GWP in Mt CO2eq in 2025				
	Reference case	**Sensitivity case 1**	**Sensitivity case 2**	**Sensitivity case 3**	**Sensitivity case 4**
BAU (absolute values)	23.56	18.40	23.56	23.56	23.56
Difference to BAU					
Scenario I	-0.32	-0.24	-0.32	-0.32	-0.32
Scenario II	-1.92	-0.82	-1.92	-1.92	-1.92
Scenario III	-0.05	-0.05	-0.05	-0.05	-0.05
Scenario IV	+0.31	+0.10	+0.31	+0.31	+0.31

Table 7-66: Annual total GWP in Mt CO2eq in 2050

	Annual total GWP in Mt CO2eq in 2050				
	Reference case	Sensitivity case 1	Sensitivity case 2	Sensitivity case 3	Sensitivity case 4
BAU (absolute values)	32.00	21.21	32.00	32.00	32.00
Difference to BAU					
Scenario I	-13.09	-6.70	-13.09	-13.09	-13.09
Scenario II	-8.80	-4.61	-8.80	-8.80	-8.80
Scenario III	-6.86	-3.00	-6.86	-6.86	-6.86
Scenario IV	-8.09	-2.81	-8.09	-8.09	-8.09

Table 7-67 shows that in 2025 the total expenditure for all policy measure scenarios will be higher than for the BAU scenario.

Table 7-68 shows that in 2050:

- in case of sensitivity case 1 (longer product life and lower stock growth) the annual expenditure will be considerably smaller than for the reference case. The relative reduction in expenditure for scenario III and IV however is smaller than for the reference case.
- In case of the lower energy escalation rate (sensitivity case 3) the annual expenditure will be much lower compared to the reference case. However, scenario I will still result in an annual expenditure surplus (no reduction of the costs, meaning the extra investment costs for these scenarios are not compensated by the reduction in annual electricity costs).
- A higher product price (sensitivity case 4) will cause an annual expenditure surplus for scenario I. For the other scenarios there is a reduction in the annual total expenditure, but the relative reduction is less compared to the reduction in case of the reference case.
- Sensitivity case 3 (energy escalation rate) has the largest impact on the figures.

Table 7-67: Annual total costs in mln. € in 2025

	Annual total costs in mln € in 2025				
	Reference case	Sensitivity case 1	Sensitivity case 2	Sensitivity case 3	Sensitivity case 4
BAU (absolute values)	14736.59	9589.62	15221.95	11710.89	17847.59
Difference to BAU					
Scenario I	+5464.45	+2089.87	+5347.87	+6191.22	+9219.28
Scenario II	+61.59	+6.96	-3.51	+467.45	+663.45
Scenario III	+1059.03	+399.41	+1033.95	+1215.33	+1808.47
Scenario IV	+1209.30	+463.03	+1192.80	+1312.21	+1958.74

Table 7-68: Annual total costs in mln. € in 2050

	Annual total costs in mln € in 2050				
	Reference case	**Sensitivity case 1**	**Sensitivity case 2**	**Sensitivity case 3**	**Sensitivity case 4**
BAU (absolute values)	29318.70	17609.50	32607.34	15078.47	33657.34
Difference to BAU					
Scenario I	-3913.05	-3027.00	-5932.51	+4831.46	+468.07
Scenario II	-5688.14	-3130.17	-6815.44	-806.79	-4994.41
Scenario III	-3989.23	-1872.71	-4904.18	-27.41	-3112.49
Scenario IV	-4897.50	-1732.33	-5957.16	-309.07	-4020.76

CHAPTER 8 ANNEX

8.1 ANNEX 1-A

Table 8-1 is informational only and based upon the NORMAPME user guide[128].

Table 8-1: Supply parameters and domestic installation practices per country[128]

Country	Austria	Belgium	Denmark	Italy	Norway	Spain	United Kingdom
1. Distribution system (of the supplier)	TN-C-S 3% TT	TN-C-S (earth not made available) A little IT, being replaced by TN	The most common system is TT Except for Copenhagen- TN-C-S For large industrial TN-S	Mainly TT (domestic) TN-C-S TN-S for large industrial IT hospitals	Most common: IT without distributed neutral, New residential areas: TN-C-S Some parts of the country: TT without distributed neutral	90% TT	Generally TN-C-S with a little TT
2. Provision of earth by supplier	Yes for TN-C-S (In addition the installation must have its own earthing system)	No Installer must provide, less than 30 (300mA RCD) If greater than 30 100mA RCD	Not for domestic	No for TT	Yes for TN-C-S and most IT and TT (In addition the installer must set up an earthing system)	Not for domestic or small commercial	Legislation requires the supplier to provide an earth terminal unless it is considered inappropriate e.g. Building supplies, farms, domestic swimming pools

[128] NORMAPME User Guide on CENELEC TR 50480

Country	Austria	Belgium	Denmark	Italy	Norway	Spain	United Kingdom
3. Installation system	Most TN-S TT	TT	TT for domestic TN-C-S for commercial/ind ustrial TN-S for large industrial, where they own their transformer-station	TT for domestic TN-C-S for commercial/industri al TN-S for large industrial	Most common: IT (without N) In some parts of the country: TT (without N) Where a new supply transformer is established: TN-C-S	Most common TT (90%)	TN-C-S with a little TN-S and a little TT
4. Demand limits (supply capacity)	Domestic max 60 A Every supply must be able to deliver 18kW	Own transformer for loads greater than 125A	Domestic up to 80A fuse	Domestic 3kW,4,5kW,6kW or 10kW 1Phase+N 230V or 10kW 3Phase 400V Can go to 15kW for 3Phase+N 400V ; increasing in 1kW steps to 30kW with increasing demand charges	Domestic: Most common: 63 A circuit breaker, but this is no absolute limit.	level 1 -3.3kW, level 2 - 5.5kW, level 3 - 12kW min 15A max 63A	Domestic up to 100A
5. Supply Voltage	3 phase and neutral 400/230V , Tolerance +10% -6%	3Phase 230V 3Phase+N 230V 3Phase+N 400V (new installations 3P+N 400V)	3Phase +N 400/230 V Tolerance +/- 10%	3 phase and neutral 400/230V , Legislation requires Tolerance +/-10% Note: Italy the Voltage supply is still 220 /380V for effect of the law 105/1949	IT and TT 230 V TN-C-S 230/400 V Supplier declares limits e.g.= ± 10% No legislation	3 Phase+N 230/400V Tolerance +/- 10%	3 phase and neutral 400/230V , Legislation requires Tolerance +10% -6%

Country	Austria	Belgium	Denmark	Italy	Norway	Spain	United Kingdom
6. Allowed voltage drop	legislation1% before meter, 3% in installation (4% for domestic installations) but recommended 1.5%	Proper functioning	4% for all installations	Proper functioning 4%; 1,5% *Mounting column* 2,5%	Legislation: Proper functioning Standard: 3 % for lighting 5 % for others	Domestic 3% lighting 5% power Can be exceeded if total voltage drop	No legislation that is specific Proper functioning For domestic installations
				Internal circuit of flat		from Xfmer less than 9.5%	
7. Legislation	Building regulations have electrical –specific IEC 60364 Not retrospective	Reg Gen for elec installations Royal decree of 1981-specific req for domestic	Building regulations have electrical –specific IEC 60364 Not retrospective	CEI 64-8 ; 700 page doc CEI 0-21 90 page doc	Legislation for electrical installations is general. The Standard is one way of complying. The Standard includes a specific section for dwellings.	Yes specific ref to standard see Electrical rules for low voltage RD 842/2002	General requirement in the Building regulations for domestic electrical installations to be safe.
8. Registration of electrical installer				Chamber of Commerce, DM37/08	Yes		Yes for domestic work

Country	Austria	Belgium	Denmark	Italy	Norway	Spain	United Kingdom
9. Fault level Maximum at supply	Max 16kA assumed Assumed to be 10kA max at distribution board. In practice fault levels less than 6kA	6kA at supply Predicted to be 3000A	Ik,max = 16 kA cos = 0,3 Assumed to be 6kA max at distribution board (It applies only to household)	Max 6kA for single phase 10kA three phase. 15kA three phase when there is no main-switch on the power supplier	Most common less than 10 kA at the distribution board. The supplier often declares maximum 16 kA and minimum 0.5 kA. No max/min described in the legislation	Max 6kA for single phase 10kA three phase	Supply authorities declare 16kA In practice fault levels less than 6kA
10.Loop impedance Max at supply, (or min fault level)	Max domestic Loop impedance at supply = 0,6Ω Typically 0.3 For TT Ra+Rb less than 100	All TT	and Ik,min = 5 x In cos = 1.	No limits $R_E\ I_{dn}$≤50V 30mA RCD protection	No limits	TT, limit 20+R	Assumed to be 0.35Ω for TN-C-S supplies 0.8 Ω for TN-S $20\Omega+R_A$ for TT
11. Sockets	Schuko Sockets DIN 49440 30mA RCD protection	Except SELV and luminaries, must have earth contact Max 8 per circuit 30mA RCD protection	Sockets must comply with Regulation 107-2-D1 Schuko sockets are not allowed. Only the Danish and French/Belgian systems are allowed	Italian standard 16/10A, Schuko in offices , in kitchen and washing machine	Schuko	Schuko	Must comply with BS 1363 (13A shuttered) or EN 60309-2 Rings are commonly used in all domestic and commercial properties, but radial circuits are allowed and often used. 30mA RCD protection

12. Lighting circuits	Separate Lighting Circuits (2 required) Separate Socket Outlet circuits	Two circuits required Class I luminaires not required to be connected with earth	not separated	New Standard 64-8-V3 September 2011, Level 1,2,3,: Level 1 Separate Lightning Circuits Separate Socket Outlet circuits Level 2 Separate Lightning Circuits (3 required) Separate Socket Outlet circuits Level 3 Separate Lightning Circuits (more than 3 required with automatic control) Separate Socket Outlet circuits	Not separated	Separate required, up to 30 per circuit	It is practice to have separate lighting, socket outlet and heating circuits, but is not a requirement of the standard.
13. Mixed power and lighting circuits	Separated	Allowed, outlets limited to 8	Allowed	Not Allowed	Allowed		Allowed, but generally separated
14. Installation standard used	HD 60364 series Austrian special: ÖVE/ÖNORM E8001		IEC 60- 364 series or “Danish special rules”	Italian standard CEI	IEC 60364 series supplemented by HD 60364/384		IEC 60364 series supplemented by HD 60364/384, published as BS 7671
Country	Austria	Belgium	Denmark	Italy	Norway	Spain	United Kingdom

15. Earthing requirements	Earth electrode required even for TN systems TN: 4.5m vertically 10m horizontal TT: $R_A \leq 100\Omega$.	i) Earth electrode $R_A \leq 100\Omega$ ii) 35 mm^2Cu electrode installed In foundations as a loop ii) If $R_A \geq 30\Omega$ separate RCD ($I_{\Delta n}$ 30mA) for lighting and for Each group of 16 sockets	Earth electrode is a requirement for TT incl. protection by RCD in all installations. ($I_{\Delta n}$ 30mA)	TT system No limits $R_E\ I_{dn} \leq 50V$ With RCD ($I_{\Delta n}$ 30mA)	Separate earth electrode required for all systems. Dwellings supplied from IT and TT:		Mainly TT (domestic) Industrial TN
16. Design(circuit calculations		Not required	Table for Ze: $Ze \quad \frac{U_0}{I_a}$ Ia is interrupted for the time there are set in table 3.	The project required more power to 6kW, size of more 400m2 and Special Environments	Has to verify and document protection against: Overload Short circuit Fault		Simple tables are used for domestic installations specifying cable csa, protective device and cable length (to meet voltage drop, shock and short circuit requirements.
17. Singular National Characteristi cs				For domestic $I_2 \leq I_z$	For dwellings: $I_2 \leq I_z$		Ringed socket circuits are commonly used in all domestic and commercial properties, but radial circuits are allowed and often used.
Country	Austria	Belgium	Denmark	Italy	Norway	Spain	United Kingdom

18. Lighting circuit polarised				yes			Yes
19. Socket circuit polarised				Yes for wiring Yes for socket terminals			Yes for wiring Yes for socket terminals

8.2 Annex 1-B

Table 1-14 shows the maximum resistance of conductor at 20 °C according IEC 60228:2004 Table 1 Class 1 solid conductors for single-core and multicore cables.

Based on the values in Table 1-14 the losses in Watt per meter cables (at 20 °C) for current rating of 0,5A till 100A are shown in Table 8-2, Table 8-3 and Table 8-4 respectively for plain circular annealed copper conductors, metal coated circular annealed copper conductors and circular or shaped aluminium and aluminium alloy conductors.

Notes:

- the calculation of the losses ($R.I^2$) in Table 8-2, Table 8-3 and Table 8-4 is made for each section and current rating in the table based upon the values in Table 1-14.The maximum current-carrying capacities are based on Table C.52.1 of IEC 60364-5-52 (Installation method E, XLPE insulation) for copper conductors and on Table B.52.13 of the same standard (Installation method E, XLPE insulation) for aluminium conductors.
- in the calculation of losses in this paragraph the skin effect isn’t taken into account. However, when applying a S+x strategy to cables with large diameters (above 400 mm^2 CSA) this gradually becomes important.
- The resistance of a cable increases with the temperature. This is not included in the calculation of losses here. A S+x strategy will result in a lower conductor temperature.

Table 8-2: Losses in W/m for LV cables of class 1: circular, annealed copper conductors: plain

	Circular, annealed copper conductors: plain									
Current (A)	**0.5**	**1**	**2**	**4**	**10**	**16**	**20**	**40**	**64**	**100**
CSA (mm²)										
0.5	0.009	0.036	0.144	0.576	-	-	-	-	-	-
0.75	0.006125	0.0245	0.098	0.392	2.45	-	-	-	-	-
1	0.004525	0.0181	0.0724	0.2896	1.81	4.6336	-	-	-	-
1.5	0.003025	0.0121	0.0484	0.1936	1.21	3.0976	4.84	-	-	-
2.5	0.001853	0.00741	0.02964	0.11856	0.741	1.89696	2.964	-	-	-
4	0.001153	0.00461	0.01844	0.07376	0.461	1.18016	1.844	7.376	-	-
6	0.00077	0.00308	0.01232	0.04928	0.308	0.78848	1.232	4.928	-	-
10	0.000458	0.00183	0.00732	0.02928	0.183	0.46848	0.732	2.928	7.49568	-
16	0.000288	0.00115	0.0046	0.0184	0.115	0.2944	0.46	1.84	4.7104	11.5
25	0.000182	0.000727	0.002908	0.011632	0.0727	0.186112	0.2908	1.1632	2.977792	7.27
35	0.000131	0.000524	0.002096	0.008384	0.0524	0.134144	0.2096	0.8384	2.146304	5.24
50	9.68E-05	0.000387	0.001548	0.006192	0.0387	0.099072	0.1548	0.6192	1.585152	3.87
70	0.000067	0.000268	0.001072	0.004288	0.0268	0.068608	0.1072	0.4288	1.097728	2.68
95	4.83E-05	0.000193	0.000772	0.003088	0.0193	0.049408	0.0772	0.3088	0.790528	1.93
120	3.83E-05	0.000153	0.000612	0.002448	0.0153	0.039168	0.0612	0.2448	0.626688	1.53
150	0.000031	0.000124	0.000496	0.001984	0.0124	0.031744	0.0496	0.1984	0.507904	1.24
185	2.53E-05	0.000101	0.000404	0.001616	0.0101	0.025856	0.0404	0.1616	0.413696	1.01
240	1.94E-05	7.75E-05	0.00031	0.00124	0.00775	0.01984	0.031	0.124	0.31744	0.775
300	1.55E-05	0.000062	0.000248	0.000992	0.0062	0.015872	0.0248	0.0992	0.253952	0.62
400	1.16E-05	4.65E-05	0.000186	0.000744	0.00465	0.011904	0.0186	0.0744	0.190464	0.465
500	-	-	-	-	-	-	-	-	-	-
630	-	-	-	-	-	-	-	-	-	-
800	-	-	-	-	-	-	-	-	-	-
1000	-	-	-	-	-	-	-	-	-	-
1200	-	-	-	-	-	-	-	-	-	-

Table 8-3: Losses in W/m for LV cables of class 1: circular, annealed copper conductors: metal-coated

	Circular, annealed copper conductors: Metal-coated									
Current (A)	**0.5**	**1**	**2**	**4**	**10**	**16**	**20**	**40**	**64**	**100**
CSA (mm²)										
0.5	0.009175	0.0367	0.1468	0.5872	-	-	-	-	-	-
0.75	0.0062	0.0248	0.0992	0.3968	2.48	-	-	-	-	-
1	0.00455	0.0182	0.0728	0.2912	1.82	4.6592	-	-	-	-
1.5	0.00305	0.0122	0.0488	0.1952	1.22	3.1232	4.88	-	-	-
2.5	0.00189	0.00756	0.03024	0.12096	0.756	1.93536	3.024	-	-	-
4	0.001175	0.0047	0.0188	0.0752	0.47	1.2032	1.88	7.52	-	-
6	0.000778	0.00311	0.01244	0.04976	0.311	0.79616	1.244	4.976	-	-
10	0.00046	0.00184	0.00736	0.02944	0.184	0.47104	0.736	2.944	7.53664	-
16	0.00029	0.00116	0.00464	0.01856	0.116	0.29696	0.464	1.856	4.75136	11.6
25	-	-	-	-	-	-	-	-	-	-
35	-	-	-	-	-	-	-	-	-	-
50	-	-	-	-	-	-	-	-	-	-
70	-	-	-	-	-	-	-	-	-	-
95	-	-	-	-	-	-	-	-	-	-
120	-	-	-	-	-	-	-	-	-	-
150	-	-	-	-	-	-	-	-	-	-
185	-	-	-	-	-	-	-	-	-	-
240	-	-	-	-	-	-	-	-	-	-
300	-	-	-	-	-	-	-	-	-	-
400	-	-	-	-	-	-	-	-	-	-
500	-	-	-	-	-	-	-	-	-	-
630	-	-	-	-	-	-	-	-	-	-
800	-	-	-	-	-	-	-	-	-	-
1000	-	-	-	-	-	-	-	-	-	-
1200	-	-	-	-	-	-	-	-	-	-

Table 8-4: Losses in W/m for LV cables of class 1: Aluminium and aluminium alloy conductors, circular or shaped

	Aluminium and aluminium alloy conductors, circular or shaped									
Current (A)	**0.5**	**1**	**2**	**4**	**10**	**16**	**20**	**40**	**64**	**100**
CSA (mm^2)										
0.5	-	-	-	-	-	-	-	-	-	-
0.75	-	-	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-	-	-
1.5	-	-	-	-	-	-	-	-	-	-
2.5	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-
10	0.00077	0.00308	0.01232	0.04928	0.308	0.78848	1.232	4.928	12.61568	-
16	0.000478	0.00191	0.00764	0.03056	0.191	0.48896	0.764	3.056	7.82336	-
25	0.0003	0.0012	0.0048	0.0192	0.12	0.3072	0.48	1.92	4.9152	12
35	0.000217	0.000868	0.003472	0.013888	0.0868	0.222208	0.3472	1.3888	3.555328	8.68
50	0.00016	0.000641	0.002564	0.010256	0.0641	0.164096	0.2564	1.0256	2.625536	6.41
70	0.000111	0.000443	0.001772	0.007088	0.0443	0.113408	0.1772	0.7088	1.814528	4.43
95	0.00008	0.00032	0.00128	0.00512	0.032	0.08192	0.128	0.512	1.31072	3.2
120	6.33E-05	0.000253	0.001012	0.004048	0.0253	0.064768	0.1012	0.4048	1.036288	2.53
150	5.15E-05	0.000206	0.000824	0.003296	0.0206	0.052736	0.0824	0.3296	0.843776	2.06
185	0.000041	0.000164	0.000656	0.002624	0.0164	0.041984	0.0656	0.2624	0.671744	1.64
240	3.13E-05	0.000125	0.0005	0.002	0.0125	0.032	0.05	0.2	0.512	1.25
300	0.000025	0.0001	0.0004	0.0016	0.01	0.0256	0.04	0.16	0.4096	1
400	1.95E-05	7.78E-05	0.000311	0.001245	0.00778	0.019917	0.03112	0.12448	0.318669	0.778
500	1.51E-05	6.05E-05	0.000242	0.000968	0.00605	0.015488	0.0242	0.0968	0.247808	0.605
630	1.17E-05	4.69E-05	0.000188	0.00075	0.00469	0.012006	0.01876	0.07504	0.192102	0.469
800	9.18E-06	3.67E-05	0.000147	0.000587	0.00367	0.009395	0.01468	0.05872	0.150323	0.367
1000	7.28E-06	2.91E-05	0.000116	0.000466	0.00291	0.00745	0.01164	0.04656	0.119194	0.291
1200	6.18E-06	2.47E-05	9.88E-05	0.000395	0.00247	0.006323	0.00988	0.03952	0.101171	0.247

The resistance of the cable and thus the losses in a circuit can be reduced by using cables with a larger CSA. Table 8-5 shows the reduction in cable resistance when replacing a cable with CSA S by a cable with CSA S+1. S+1 is one size up, S+2 two sizes up and S+3 three sizes up. Table 8-6 shows the reduction in cable resistance when replacing a cable with CSA S by a cable with CSA S+2. Table 8-7 shows the reduction in cable resistance when replacing a cable with CSA S by a cable with CSA S+3.

The resistance of the cable and thus the losses in a circuit can be reduced by using cables with a larger CSA. Table 8-5 shows the reduction in cable resistance when replacing a cable with CSA S by a cable with CSA S+1. S+1 is one size up, S+2 two sizes up and S+3 three sizes up. Table shows the reduction in cable resistance when replacing a cable with CSA S by a cable with CSA S+2. Table 8-7 shows the reduction in cable resistance when replacing a cable with CSA S by a cable with CSA S+3.

Table 8-5: S+1 scenario

Nominal cross-sectional area (S)	S+1 resistance reduction		
	Circular. annealed copper conductors		Aluminium and aluminium alloy conductors. circular or shaped
	Plain	Metal coated	
mm²			
0.5	32%	32%	-
0.75	26%	27%	-
1	33%	33%	-
1.5	39%	38%	-
2.5	38%	38%	-
4	33%	34%	-
6	41%	41%	-
10	37%	37%	-
16	37%	-	38%
25	28%	-	37%
35	26%	-	28%
50	31%	-	26%
70	28%	-	31%
95	21%	-	28%
120	19%	-	21%
150	19%	-	19%
185	23%	-	20%
240	20%	-	24%
300	25%	-	20%
400	-	-	22%
500	-	-	22%
630	-	-	22%
800	-	-	22%
1000	-	-	21%
1200	-	-	15%

Table 8-6: S+2 scenario

Nominal cross-sectional area (S)	S+2 resistance reduction		
	Circular. annealed copper conductors		Aluminium and aluminium alloy conductors. circular or shaped
	Plain	Metal coated	
mm²			
0.5	50%	50%	-
0.75	51%	51%	-
1	59%	58%	-
1.5	62%	61%	-
2.5	58%	59%	-
4	60%	61%	-
6	63%	63%	-
10	60%	-	61%
16	54%	-	55%
25	47%	-	47%
35	49%	-	49%
50	50%	-	50%
70	43%	-	43%
95	36%	-	36%
120	34%	-	35%
150	38%	-	39%
185	39%	-	39%
240	40%	-	38%
300	-	-	40%
400	-	-	40%
500	-	-	39%
630	-	-	38%
800	-	-	33%
1000	-	-	-
1200	-	-	-

Table 8-7: S+3 scenario

Nominal cross-sectional area (S)	S+3 resistance reduction: Circular, annealed copper conductors – Plain	S+3 resistance reduction: Circular, annealed copper conductors – Metal coated	S+3 resistance reduction: Aluminium and aluminium alloy conductors, circular or shaped
mm²			
0.5	66%	67%	-
0.75	70%	70%	-
1	75%	74%	-
1.5	75%	75%	-
2.5	75%	76%	-
4	75%	75%	-
6	76%	-	-
10	71%	-	72%
16	66%	-	66%
25	63%	-	63%
35	63%	-	63%
50	60%	-	61%
70	54%	-	53%
95	48%	-	49%
120	49%	-	51%
150	50%	-	51%
185	54%	-	53%
240	-	-	52%
300	-	-	53%
400	-	-	53%
500	-	-	52%
630	-	-	47%
800	-	-	-
1000	-	-	-
1200	-	-	-

Table 8-8 shows the minimum and maximum resistance reduction for the above mentioned cables. For instance when all class 1 plain copper cables are replaced by plain copper cables with one size up the cables losses will reduce by minimum 19% and maximum 41%.

Table 8-8: S+x scenario overview

	Circular, annealed copper conductors				Aluminium and aluminium alloy conductors, circular or shaped	
	Plain		Metal coated			
Upsizing strategy	Minimum resistance reduction	Maximum resistance reduction	Minimum resistance reduction	Maximum resistance reduction	Minimum resistance reduction	Maximum resistance reduction
S+1	19%	41%	27%	41%	15%	38%
S+2	34%	62%	50%	63%	33%	61%
S+3	48%	76%	67%	76%	47%	72%

Table 8-9: S+x scenario overview based upon CSA ratio

CSA (S)	resistance reduction based upon CSA ratio (S+x)/S				
mm²	S+1	S+2	S+3	S+4	S+5
0.5	33%	50%	67%	80%	88%
0.75	25%	50%	70%	81%	88%
1	33%	60%	75%	83%	90%
1.5	40%	63%	75%	85%	91%
2.5	38%	58%	75%	84%	90%
4	33%	60%	75%	84%	89%
6	40%	63%	76%	83%	88%
10	38%	60%	71%	80%	86%
16	36%	54%	68%	77%	83%
25	29%	50%	64%	74%	79%
35	30%	50%	63%	71%	77%
50	29%	47%	58%	67%	73%
70	26%	42%	53%	62%	71%
95	21%	37%	49%	60%	68%
120	20%	35%	50%	60%	70%
150	19%	38%	50%	63%	70%
185	23%	38%	54%	63%	71%
240	20%	40%	52%	62%	70%
300	25%	40%	52%	63%	70%
400	20%	37%	50%	60%	67%
500	21%	38%	50%	58%	
630	21%	37%	48%		
800	20%	33%			
1000	17%				
1200					
Minimum	17%	33%	48%	58%	67%
Maximum	40%	63%	76%	85%	91%
Average	27%	47%	61%	71%	78%
Average for CSA 1,5 till CSA 10	38%	61%	74%	83%	89%
Average for CSA 1,5 till CSA 25	36%	58%	72%	81%	86%

Assuming cables of section 1.5 mm² till 10 mm² are used in residential houses, opting for a S+1 upsizing strategy would on average reduce the power losses in the installed cables by 38% and by 61 % for the S+2 strategy, by 74% for the S+3 strategy and so on.

Table 8-10: Conductor volume increase based upon CSA ratio

CSA (S)	volume increase based upon CSA ratio				
mm²	S+1	S+2	S+3	S+4	S+5
0.5	50%	100%	200%	400%	700%
0.75	33%	100%	233%	433%	700%
1	50%	150%	300%	500%	900%
1.5	67%	167%	300%	567%	967%
2.5	60%	140%	300%	540%	900%
4	50%	150%	300%	525%	775%
6	67%	167%	317%	483%	733%
10	60%	150%	250%	400%	600%
16	56%	119%	213%	338%	494%
25	40%	100%	180%	280%	380%
35	43%	100%	171%	243%	329%
50	40%	90%	140%	200%	270%
70	36%	71%	114%	164%	243%
95	26%	58%	95%	153%	216%
120	25%	54%	100%	150%	233%
150	23%	60%	100%	167%	233%
185	30%	62%	116%	170%	241%
240	25%	67%	108%	163%	233%
300	33%	67%	110%	167%	233%
400	25%	58%	100%	150%	200%
500	26%	60%	100%	140%	
630	27%	59%	90%		
800	25%	50%			
1000	20%				
1200					
Minimum	20%	50%	90%	140%	200%
Maximum	67%	167%	317%	567%	967%
Average	39%	95%	178%	297%	467%
Average for CSA 1,5 till CSA 6	61%	156%	304%	529%	844%
Average for CSA 1,5 till CSA 25	57%	142%	266%	448%	693%
Average for CSA 10 till CSA 70	46%	105%	178%	271%	386%

Table 8-11: Loss reduction per conductor volume increase

CSA (S)	loss reduction per volume increase				
mm²	S+1	S+2	S+3	S+4	S+5
0.5	67%	50%	33%	20%	13%
0.75	75%	50%	30%	19%	13%
1	67%	40%	25%	17%	10%
1.5	60%	38%	25%	15%	9%
2.5	63%	42%	25%	16%	10%
4	67%	40%	25%	16%	11%
6	60%	38%	24%	17%	12%
10	63%	40%	29%	20%	14%
16	64%	46%	32%	23%	17%
25	71%	50%	36%	26%	21%
35	70%	50%	37%	29%	23%
50	71%	53%	42%	33%	27%
70	74%	58%	47%	38%	29%
95	79%	63%	51%	40%	32%
120	80%	65%	50%	40%	30%
150	81%	63%	50%	38%	30%
185	77%	62%	46%	37%	29%
240	80%	60%	48%	38%	30%
300	75%	60%	48%	38%	30%
400	80%	63%	50%	40%	33%
500	79%	63%	50%	42%	
630	79%	63%	53%		
800	80%	67%			
1000	83%				
1200					
Minimum	60%	38%	24%	15%	9%
Maximum	83%	67%	53%	42%	33%
Average	73%	53%	39%	29%	22%
Average for CSA 1,5 till CSA 6	62%	39%	25%	16%	11%
Average for CSA 1,5 till CSA 25	64%	42%	28%	19%	14%
Average for CSA 10 till CSA 70	69%	49%	37%	28%	22%

Reducing the total length of cable for a circuit
Because the physical location of appliances/loads for a particular installation is fixed, the total length of cable needed in the electrical installation cannot be changed, unless other installation techniques or topologies are used. For instance adding an extra circuit level with additional circuit boards could reduce the total length of cable used in the electrical installation and even shorten the average circuit length of the electrical installation.
The goal is to keep the distances between the main loads and the switch boards (and transformers) as close as possible to minimize energy losses in the electrical wiring. This can be achieved with the "barycentre method": The objective of this method is to set up the transformer and switchboard at a location based on a relative weighting due to the energy consumption of the loads so that the distance to a higher energy consumption load is less than the distance of a lower energy consumption load (see Informative Annex A of HD 60364-8-1:2015).
Using a size up strategy combined with a higher circuit load (less circuits) could reduce the total length of the cable in the circuit and the resistance per meter cable, but the load (I) will increase.

Reducing the load per circuit
Peak current load profile – secondary PFP

The power losses are determined by the I^2 factor. Reducing the average current per circuit will reduce the loss exponential. However, reducing the loss per circuit by diminishing the average current per circuit will in fact reduce the average load per circuit. As a result extra circuits have to be added to the installation to serve the same load as before, resulting in larger installed cable lengths.

For instance all the loads of one circuit could be fed over two circuits instead of one. The load (I) per circuit will be lower, but the total length of cable will increase.

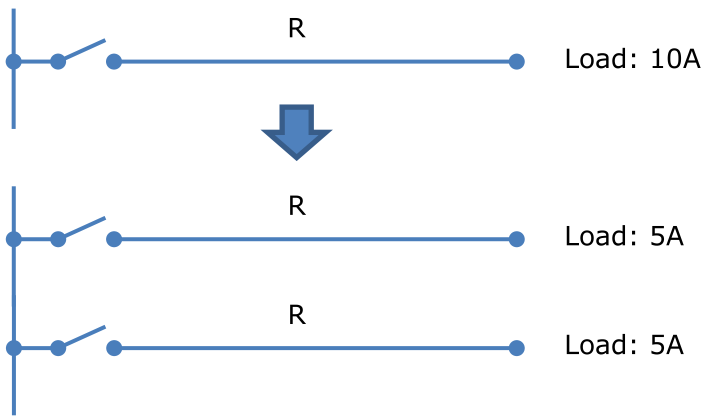


Figure 8-1 example: two parallel circuits instead of one circuit

For instance the losses ($R.I^2$) in Figure 8-1 for scenario with one circuit are $10^2.R$ = 100.R, where R is the resistance of the cable in the circuit. For the same load the losses in the second scenario with two parallel circuits of the same length is $5^2.R + 5^2.R$ = 50.R. However, when splitting the load (multiple appliances) over two circuits the load should be divided in such a way that appliances consuming simultaneously are split over different circuits; otherwise the losses will remain the same. However, it is not trivial to split loads over different circuits when the load profiles are complex or unknown. Energy management systems in combination with smart plugs or smart appliances (BNAT) could overcome this problem and reduce the peaks in a circuit.

Looking at the installation level this means that losses in an installation can be reduced by balancing loads over different circuits based upon the degree of simultaneity of these loads.

Note: jagged load profiles with a lot of temporary peak (accumulated) currents cause higher losses than more peak shaved load profiles demanding the same amount of energy. Adequate design of circuits and load distribution over the circuits or control mechanisms in energy management systems (or energy management functions in building management systems) in buildings reducing the total energy usage and the peak currents (peak clipping) will therefore diminish the losses in the circuits.

8.3 Annex 2-A

Table 8-12 shows the calculated annual electricity rates for the domestic and non-domestic sector, based upon the figures in Table 2-34 (reference year 2011).

Table 8-12 Annual electricity rates per year for domestic and non-domestic sector

year	Electricity rate domestic incl. VAT (€/kWh)	Electricity rate non-domestic incl. VAT (€/kWh)
1990	0.08	0.05
1991	0.08	0.05
1992	0.09	0.05
1993	0.09	0.05
1994	0.09	0.06
1995	0.10	0.06
1996	0.10	0.06
1997	0.10	0.06
1998	0.11	0.07
1999	0.11	0.07
2000	0.12	0.07
2001	0.12	0.07
2002	0.13	0.08
2003	0.13	0.08
2004	0.14	0.08
2005	0.14	0.09
2006	0.15	0.09
2007	0.15	0.09
2008	0.16	0.10
2009	0.17	0.10
2010	0.17	0.11
2011	0.18	0.11
2012	0.19	0.11
2013	0.19	0.12
2014	0.20	0.12
2015	0.21	0.13
2016	0.22	0.13
2017	0.23	0.14
2018	0.24	0.14
2019	0.25	0.15
2020	0.26	0.16
2021	0.27	0.16
2022	0.28	0.17
2023	0.29	0.18
2024	0.30	0.18
2025	0.31	0.19
2026	0.32	0.20
2027	0.34	0.21
2028	0.35	0.21
2029	0.36	0.22
2030	0.38	0.23

Table 8-13 shows the calculated stock and sales in absolute values based upon the rates figures in Table 2-27.

Table 8-13 Stock and sales per year and sector

	Residential					Services					Industry				
	Stock	Stock growth	Replacement sales	New sales	Total sales	Stock	Stock growth	Replacement sales	New sales	Total sales	Stock	Stock growth	Replacement sales	New sales	Total sales
Year	kTon Cu	kTon Cu	kTon Cu	kTon Cu	kTon Cu	kTon Cu	kTon Cu	kTon Cu	kTon Cu	kTon Cu	kTon Cu	kTon Cu	kTon Cu	kTon Cu	kTon Cu
1990	4381	39	51	39	90	2230	42	70	42	112	2159	61	59	61	120
1991	4421	39	52	39	91	2273	42	71	42	114	2222	63	60	63	123
1992	4460	40	52	40	92	2316	43	73	43	116	2286	64	62	64	127
1993	4501	40	53	40	93	2360	44	74	44	118	2353	66	64	66	130
1994	4541	41	53	41	94	2405	45	76	45	120	2421	68	66	68	134
1995	4582	41	54	41	94	2451	46	77	46	123	2491	70	68	70	138
1996	4623	41	54	41	95	2497	47	78	47	125	2563	72	70	72	142
1997	4665	42	55	42	96	2545	47	80	47	127	2638	74	72	74	146
1998	4707	42	55	42	97	2593	48	81	48	130	2714	76	74	76	150
1999	4749	42	56	42	98	2642	49	83	49	132	2793	79	76	79	155
2000	4792	43	56	43	99	2692	50	85	50	135	2874	81	78	81	159
2001	4835	43	57	43	100	2744	51	86	51	137	2957	83	80	83	164
2002	4878	44	57	44	101	2796	52	88	52	140	3043	86	83	86	169
2003	4922	44	58	44	101	2849	53	89	53	143	3131	88	85	88	173
2004	4967	44	58	44	102	2903	54	91	54	145	3222	91	88	91	178
2005	5011	45	59	45	103	2958	55	93	55	148	3316	93	90	93	184
2006	5056	45	59	45	104	3014	56	95	56	151	3412	96	93	96	189
2007	5102	46	60	46	105	3072	57	96	57	154	3511	99	96	99	194
2008	5148	46	60	46	106	3130	58	98	58	157	3612	102	98	102	200
2009	5194	46	61	46	107	3189	59	100	59	160	3717	105	101	105	206
2010	**5241**	**47**	**61**	**47**	**108**	**3250**	**61**	**102**	**61**	**163**	**3825**	**108**	**104**	**108**	**212**
2011	5288	47	62	47	109	3312	62	104	62	166	3936	111	107	111	218
2012	5336	48	62	48	110	3375	63	106	63	169	4050	114	110	114	224
2013	5384	48	63	48	111	3439	64	108	64	172	4168	117	113	117	231
2014	5432	48	64	48	112	3504	65	110	65	175	4288	121	117	121	238
2015	5481	49	64	49	113	3571	67	112	67	179	4413	124	120	124	244
2016	5530	49	65	49	114	3639	68	114	68	182	4541	128	124	128	252
2017	5580	50	65	50	115	3708	69	116	69	186	4672	132	127	132	259
2018	5630	50	66	50	116	3778	70	119	70	189	4808	135	131	135	266
2019	5681	51	66	51	117	3850	72	121	72	193	4947	139	135	139	274
2020	5732	51	67	51	118	3923	73	123	73	196	5091	143	139	143	282
2021	5784	52	68	52	119	3998	75	126	75	200	5238	148	143	148	290
2022	5836	52	68	52	120	4074	76	128	76	204	5390	152	147	152	299
2023	5888	53	69	53	121	4151	77	130	77	208	5547	156	151	156	307
2024	5941	53	69	53	122	4230	79	133	79	212	5708	161	155	161	316
2025	5995	53	70	53	124	4310	80	135	80	216	5873	166	160	166	325
2026	6049	54	71	54	125	4392	82	138	82	220	6043	170	164	170	335
2027	6103	54	71	54	126	4476	83	141	83	224	6219	175	169	175	344
2028	6158	55	72	55	127	4561	85	143	85	228	6399	180	174	180	354
2029	6214	55	73	55	128	4647	87	146	87	233	6585	186	179	186	365
2030	6270	56	73	56	129	4736	88	149	88	237	6775	191	184	191	375

Table 8-14 shows some prices (2 sources) for copper cables (cable type is specified in detail in Bill Of Material in Task 4). It is only used to verify the average cable price mentioned in this document. The discounted price mentioned in this table is a little bit higher than the average price mentioned in this document (5% to 15% depending on the section).

Table 8-14 Prices of copper cable per section (based upon Bill Of Materials in Task 4)

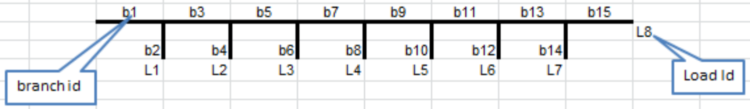
Cable type	**5x1,5mm^2**	**5x2,5m^2**	**5x4mm^2**	**5x6mm^2**	**5x10mm^2**	**5x16mm^2**	**5x25mm^2**	**5x35mm^2**	**5x50mm^2**	**5x70mm^2**	**5x95mm^2**	**5x120mm^2**	**5x150mm^2**	**5x185mm^2**	**5x240mm^2**	**4x300mm^2**	**4x400mm^2**	**1x500mm^2**	**1x630mm^2**
CSA (mm^2)	1.5	2.5	4	6	10	16	25	35	50	70	95	120	150	185	240	300	400	500	630
Conductors	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	4	1	1
Conductor form	Round	Round	Round	Round	Round	Round	Round	Round	Round	Round	Round	Round	Round	Round	Round	Sectorial	Sectorial	Round	Round
Class	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
PE included	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No
Sales Price - DM light (€/m)	0.99	1.44	2.71	3.77	6.11	10.11	14.86	18.1				58.225				116.45			
Discounted Sales Price - Rexel (06/2014)(€/m)	0.8332	1.22	2.12	3.24	5.26	7.96	12.8	17.7	25.575	34.6	46.5875	58.9	73.95	92.9375	119.5625	119.5625	159.4167	49.46667	62.328
Sales Price - Rexel (06/2014)(€/m)	1.4	2.05	3.52	4.92	8	13.22	19.46	25.8	37.2875	50.425	67.9125	85.8625	107.8	135.475	174.2875	174.2875	232.3833	72.10807	90.85617
Cu (€/kg) - avg 06/2014 (www.cablebel.be)	5.1876																		
Cu cost (€/m)	0.346	0.576	0.922	1.384	2.306	3.689	5.765	8.071	11.529	16.141	21.906	27.671	34.588	42.659	55.341	55.341	73.788	23.059	29.054
Sales Price - DM light (€/mm^2.m)	0.132	0.115	0.136	0.126	0.122	0.126	0.119	0.103				0.097				0.097			
Discounted Sales Price - Rexel (06/2014)(€/mm^2.m)	0.111	0.098	0.106	0.108	0.105	0.100	0.102	0.101	0.102	0.099	0.098	0.098	0.099	0.100	0.100	0.100	0.100	0.099	0.099
Sales Price - Rexel (06/2014)(€/mm^2.m)	0.187	0.164	0.176	0.164	0.160	0.165	0.156	0.147	0.149	0.144	0.143	0.143	0.144	0.146	0.145	0.145	0.145	0.144	0.144
Cu cost/Sales Price - DM light	35%	40%	34%	37%	38%	36%	39%	45%				48%				48%			
Cu cost/Discounted Sales Price - Rexel (06/2014)	16%	47%	44%	43%	44%	46%	45%	46%	45%	47%	47%	47%	47%	46%	46%	46%	46%	47%	47%
Cu cost/ Sales Price - Rexel (06/2014)	8%	28%	26%	28%	29%	28%	30%	31%	31%	32%	32%	32%	32%	31%	32%	32%	32%	32%	32%

8.4 Annex 3-A

The tables in this section illustrate the calculation of the Kd factor for a load branch length factor of respectively 10%, 50%, 100% and 200%. The load branch length factor is a factor to reduce the ratio between the even (b2, b4, etc.) and odd (b1, b3, etc.) branches. A factor of 100% means that the branches all have the same length. A factor lower than 100% means that the even branches are shorter than the odd branches. A factor more than 100% means that the even branches are longer than the odd branches. For instance for a load branch factor of 200% the odd branches are getting very small, so the topology of the circuit is moving towards a star point topology where every node has a dedicated branch towards the begin point of the circuit (circuit breaker). The used lengths for the branches are shown in each table.

Table 8-15: Kd factors: load branch length factor equal to 10%

CSA circuit	2,5	mm^2
Cable resistivity per m	0,00672	Ω/m
Number of relevant cores	2	
I_{max} (circuit breaker)	16	A
Voltage	230	V
Pmax	3680	W
Circuit (total cable) length	30	m
Circuit loss at Imax	103,2192	W
Load branch length factor	10%	%



Number of branches with loa	1		2		3		4	
Load Id	Power usage W	Current A	Power usage W	Current A	Power usage W	Current A	Power usage W	Current A
1	3680	16	1840	8	1226,67	5,33333	920	4
2	0	0	1840	8	1226,67	5,33333	920	4
3	0	0	0	0	1226,67	5,33333	920	4
4	0	0	0	0	0	0	920	4
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0

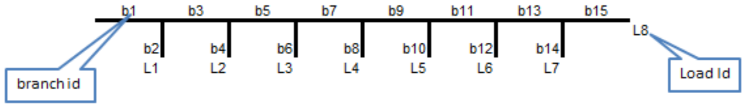
Number of branches with loa	5		6		7		8	
Load Id	Power usage W	Current A	Power usage W	Current A	Power usage W	Current A	Power usage W	Current A
1	736	3,2	613,333	2,66667	525,714	2,28571	460	2
2	736	3,2	613,333	2,66667	525,714	2,28571	460	2
3	736	3,2	613,333	2,66667	525,714	2,28571	460	2
4	736	3,2	613,333	2,66667	525,714	2,28571	460	2
5	736	3,2	613,333	2,66667	525,714	2,28571	460	2
6	0	0	613,333	2,66667	525,714	2,28571	460	2
7	0	0	0	0	525,714	2,28571	460	2
8	0	0	0	0	0	0	460	2

Number of branches with loa	1			2			3			4		
Branch id	Current A	Length m	loss ($R.I^2$) W	Current A	Length m	loss ($R.I^2$) W	Current A	Length m	loss ($R.I^2$) W	Current A	Length m	loss ($R.I^2$) W
1	16,00	30,00	103,22	16,00	14,50	49,89	16,00	9,60	33,03	16,00	7,18	24,70
2	0,00	0,00	0,00	8,00	1,00	0,86	5,33	0,60	0,23	4,00	0,43	0,09
3	0,00	0,00	0,00	8,00	14,50	12,47	10,67	9,60	14,68	12,00	7,18	13,89
4	0,00	0,00	0,00	0,00	0,00	0,00	5,33	0,60	0,23	4,00	0,43	0,09
5	0,00	0,00	0,00	0,00	0,00	0,00	5,33	9,60	3,67	8,00	7,18	6,17
6	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	4,00	0,43	0,09
7	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	4,00	7,18	1,54
8	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
9	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
10	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
11	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
12	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
13	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
14	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
15	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total		30,00	103,22		30,00	63,22		30,00	51,84		30,00	46,59
Kd			1,00			0,61			0,50			0,45

Number of branches with loa	5			6			7			8		
Branch id	Current A	Length m	loss ($R.I^2$) W	Current A	Length m	loss ($R.I^2$) W	Current A	Length m	loss ($R.I^2$) W	Current A	Length m	loss ($R.I^2$) W
1	16,00	5,73	19,73	16,00	4,77	16,42	16,00	4,09	14,07	16,00	3,58	12,30
2	3,20	0,33	0,05	2,67	0,27	0,03	2,29	0,23	0,02	2,00	0,20	0,01
3	12,80	5,73	12,62	13,33	4,77	11,40	13,71	4,09	10,33	14,00	3,58	9,42
4	3,20	0,33	0,05	2,67	0,27	0,03	2,29	0,23	0,02	2,00	0,20	0,01
5	9,60	5,73	7,10	10,67	4,77	7,30	11,43	4,09	7,18	12,00	3,58	6,92
6	3,20	0,33	0,05	2,67	0,27	0,03	2,29	0,23	0,02	2,00	0,20	0,01
7	6,40	5,73	3,16	8,00	4,77	4,11	9,14	4,09	4,59	10,00	3,58	4,80
8	3,20	0,33	0,05	2,67	0,27	0,03	2,29	0,23	0,02	2,00	0,20	0,01
9	3,20	5,73	0,79	5,33	4,77	1,82	6,86	4,09	2,58	8,00	3,58	3,08
10	0,00	0,00	0,00	2,67	0,27	0,03	2,29	0,23	0,02	2,00	0,20	0,01
11	0,00	0,00	0,00	2,67	4,77	0,46	4,57	4,09	1,15	6,00	3,58	1,73
12	0,00	0,00	0,00	0,00	0,00	0,00	2,29	0,23	0,02	2,00	0,20	0,01
13	0,00	0,00	0,00	0,00	0,00	0,00	2,29	4,09	0,29	4,00	3,58	0,77
14	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	2,00	0,20	0,01
15	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	2,00	3,58	0,19
Total		30,00	43,58		30,00	41,64		30,00	40,28		30,00	39,28
Kd			0,42			0,40			0,39			0,38

Table 8-16: Kd factors: load branch length factor equal to 50%

CSA circuit	2,5	mm²
Cable resistivity per m	0,00672	Ω/m
Number of relevant cores	2	
I_{max} (circuit breaker)	16	A
Voltage	230	V
Pmax	3680	W
Circuit (total cable) length	30	m
Circuit loss at Imax	103,2192	W
Load branch length factor	50%	%



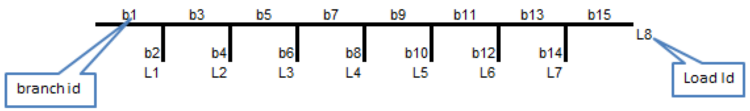
Number of branches with loa	1		2		3		4		5		6		7		8	
Load Id	Power usage W	Current A	Power usage W	Current A	Power usage W	Current A	Power usage W	Current A	Power usage W	Current A	Power usage W	Current A	Power usage W	Current A	Power usage W	Current A
1	3680	16	1840	8	1226,67	5,33333	920	4	736	3,2	613,333	2,66667	525,714	2,28571	460	2
2	0	0	1840	8	1226,67	5,33333	920	4	736	3,2	613,333	2,66667	525,714	2,28571	460	2
3	0	0	0	0	1226,67	5,33333	920	4	736	3,2	613,333	2,66667	525,714	2,28571	460	2
4	0	0	0	0	0	0	920	4	736	3,2	613,333	2,66667	525,714	2,28571	460	2
5	0	0	0	0	0	0	0	0	736	3,2	613,333	2,66667	525,714	2,28571	460	2
6	0	0	0	0	0	0	0	0	0	0	613,333	2,66667	525,714	2,28571	460	2
7	0	0	0	0	0	0	0	0	0	0	0	0	525,714	2,28571	460	2
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	460	2

Branch id	1: Current A	1: Length m	1: loss (R.I^2) W	2: Current A	2: Length m	2: loss (R.I^2) W	3: Current A	3: Length m	3: loss (R.I^2) W	4: Current A	4: Length m	4: loss (R.I^2) W
1	16,00	30,00	103,22	16,00	12,50	43,01	16,00	8,00	27,53	16,00	5,89	20,28
2	0,00	0,00	0,00	8,00	5,00	4,30	5,33	3,00	1,15	4,00	2,14	0,46
3	0,00	0,00	0,00	8,00	12,50	10,75	10,67	8,00	12,23	12,00	5,89	11,40
4	0,00	0,00	0,00	0,00	0,00	0,00	5,33	3,00	1,15	4,00	2,14	0,46
5	0,00	0,00	0,00	0,00	0,00	0,00	5,33	8,00	3,06	8,00	5,89	5,07
6	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	4,00	2,14	0,46
7	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	4,00	5,89	1,27
8	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
9	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
10	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
11	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
12	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
13	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
14	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
15	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total		30,00	103,22		30,00	58,06		30,00	45,11		30,00	39,40
Kd			1,00			0,56			0,44			0,38

Branch id	5: Current A	5: Length m	5: loss (R.I^2) W	6: Current A	6: Length m	6: loss (R.I^2) W	7: Current A	7: Length m	7: loss (R.I^2) W	8: Current A	8: Length m	8: loss (R.I^2) W
1	16,00	4,67	16,06	16,00	3,86	13,29	16,00	3,30	11,34	16,00	2,88	9,89
2	3,20	1,67	0,23	2,67	1,36	0,13	2,29	1,15	0,08	2,00	1,00	0,05
3	12,80	4,67	10,28	13,33	3,86	9,23	13,71	3,30	8,33	14,00	2,88	7,57
4	3,20	1,67	0,23	2,67	1,36	0,13	2,29	1,15	0,08	2,00	1,00	0,05
5	9,60	4,67	5,78	10,67	3,86	5,91	11,43	3,30	5,79	12,00	2,88	5,56
6	3,20	1,67	0,23	2,67	1,36	0,13	2,29	1,15	0,08	2,00	1,00	0,05
7	6,40	4,67	2,57	8,00	3,86	3,32	9,14	3,30	3,70	10,00	2,88	3,86
8	3,20	1,67	0,23	2,67	1,36	0,13	2,29	1,15	0,08	2,00	1,00	0,05
9	3,20	4,67	0,64	5,33	3,86	1,48	6,86	3,30	2,08	8,00	2,88	2,47
10	0,00	0,00	0,00	2,67	1,36	0,13	2,29	1,15	0,08	2,00	1,00	0,05
11	0,00	0,00	0,00	2,67	3,86	0,37	4,57	3,30	0,93	6,00	2,88	1,39
12	0,00	0,00	0,00	0,00	0,00	0,00	2,29	1,15	0,08	2,00	1,00	0,05
13	0,00	0,00	0,00	0,00	0,00	0,00	2,29	3,30	0,23	4,00	2,88	0,62
14	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	2,00	1,00	0,05
15	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	2,00	2,88	0,15
Total		30,00	36,24		30,00	34,25		30,00	32,89		30,00	31,91
Kd			0,35			0,33			0,32			0,31

Table 8-17: Kd factors: load branch length factor equal to 100%

CSA circuit	2,5	mm²
Cable resistivity per m	0,00672	Ω/m
Number of relevant cores	2	
I_{max} (circuit breaker)	16	A
Voltage	230	V
Pmax	3680	W
Circuit (total cable) length	30	m
Circuit loss at Imax	103,2192	W
Load branch length factor	100%	%



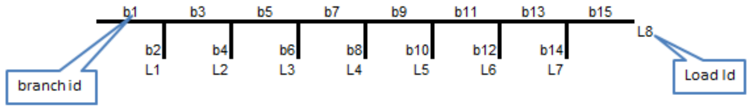
Number of branches with loa	1		2		3		4		5		6		7		8	
Load Id	Power usage	Current	Power usage	Current	Power usage	Current	Power usage	Current	Power usage	Current	Power usage	Current	Power usage	Current	Power usage	Current
	W	A	W	A	W	A	W	A	W	A	W	A	W	A	W	A
1	3680	16	1840	8	1226,67	5,33333	920	4	736	3,2	613,333	2,66667	525,714	2,28571	460	2
2	0	0	1840	8	1226,67	5,33333	920	4	736	3,2	613,333	2,66667	525,714	2,28571	460	2
3	0	0	0	0	1226,67	5,33333	920	4	736	3,2	613,333	2,66667	525,714	2,28571	460	2
4	0	0	0	0	0	0	920	4	736	3,2	613,333	2,66667	525,714	2,28571	460	2
5	0	0	0	0	0	0	0	0	736	3,2	613,333	2,66667	525,714	2,28571	460	2
6	0	0	0	0	0	0	0	0	0	0	613,333	2,66667	525,714	2,28571	460	2
7	0	0	0	0	0	0	0	0	0	0	0	0	525,714	2,28571	460	2
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	460	2

Branch id	Current	Length	loss (R.I²)	Current	Length	loss (R.I²)	Current	Length	loss (R.I²)	Current	Length	loss (R.I²)
	A	m	W	A	m	W	A	m	W	A	m	W
1	16,00	30,00	103,22	16,00	10,00	34,41	16,00	6,00	20,64	16,00	4,29	14,75
2	0,00	0,00	0,00	8,00	10,00	8,60	5,33	6,00	2,29	4,00	4,29	0,92
3	0,00	0,00	0,00	8,00	10,00	8,60	10,67	6,00	9,18	12,00	4,29	8,29
4	0,00	0,00	0,00	0,00	0,00	0,00	5,33	6,00	2,29	4,00	4,29	0,92
5	0,00	0,00	0,00	0,00	0,00	0,00	5,33	6,00	2,29	8,00	4,29	3,69
6	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	4,00	4,29	0,92
7	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	4,00	4,29	0,92
8	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
9	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
10	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
11	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
12	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
13	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
14	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
15	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total		30,00	103,22		30,00	51,61		30,00	36,70		30,00	30,41
Kd			1,00			0,50			0,36			0,29

Branch id	Current	Length	loss (R.I²)	Current	Length	loss (R.I²)	Current	Length	loss (R.I²)	Current	Length	loss (R.I²)
	A	m	W	A	m	W	A	m	W	A	m	W
1	16,00	3,33	11,47	16,00	2,73	9,38	16,00	2,31	7,94	16,00	2,00	6,88
2	3,20	3,33	0,46	2,67	2,73	0,26	2,29	2,31	0,16	2,00	2,00	0,11
3	12,80	3,33	7,34	13,33	2,73	6,52	13,71	2,31	5,83	14,00	2,00	5,27
4	3,20	3,33	0,46	2,67	2,73	0,26	2,29	2,31	0,16	2,00	2,00	0,11
5	9,60	3,33	4,13	10,67	2,73	4,17	11,43	2,31	4,05	12,00	2,00	3,87
6	3,20	3,33	0,46	2,67	2,73	0,26	2,29	2,31	0,16	2,00	2,00	0,11
7	6,40	3,33	1,84	8,00	2,73	2,35	9,14	2,31	2,59	10,00	2,00	2,69
8	3,20	3,33	0,46	2,67	2,73	0,26	2,29	2,31	0,16	2,00	2,00	0,11
9	3,20	3,33	0,46	5,33	2,73	1,04	6,86	2,31	1,46	8,00	2,00	1,72
10	0,00	0,00	0,00	2,67	2,73	0,26	2,29	2,31	0,16	2,00	2,00	0,11
11	0,00	0,00	0,00	2,67	2,73	0,26	4,57	2,31	0,65	6,00	2,00	0,97
12	0,00	0,00	0,00	0,00	0,00	0,00	2,29	2,31	0,16	2,00	2,00	0,11
13	0,00	0,00	0,00	0,00	0,00	0,00	2,29	2,31	0,16	4,00	2,00	0,43
14	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	2,00	2,00	0,11
15	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	2,00	2,00	0,11
Total		30,00	27,07		30,00	25,02		30,00	23,66		30,00	22,69
Kd			0,26			0,24			0,23			0,22

Table 8-18: Kd factors: load branch length factor equal to 200%

CSA circuit	2,5	mm^2
Cable resistivity per m	0,00672	Ω/m
Number of relevant cores	2	
I_{max} (circuit breaker)	16	A
Voltage	230	V
Pmax	3680	W
Circuit (total cable) length	30	m
Circuit loss at Imax	103,2192	W
Load branch length factor	200%	%



Number of branches with loa	1		2		3		4		5		6		7		8	
Load Id	Power usage W	Current A	Power usage W	Current A	Power usage W	Current A	Power usage W	Current A	Power usage W	Current A	Power usage W	Current A	Power usage W	Current A	Power usage W	Current A
1	3680	16	1840	8	1226,67	5,33333	920	4	736	3,2	613,333	2,66667	525,714	2,28571	460	2
2	0	0	1840	8	1226,67	5,33333	920	4	736	3,2	613,333	2,66667	525,714	2,28571	460	2
3	0	0	0	0	1226,67	5,33333	920	4	736	3,2	613,333	2,66667	525,714	2,28571	460	2
4	0	0	0	0	0	0	920	4	736	3,2	613,333	2,66667	525,714	2,28571	460	2
5	0	0	0	0	0	0	0	0	736	3,2	613,333	2,66667	525,714	2,28571	460	2
6	0	0	0	0	0	0	0	0	0	0	613,333	2,66667	525,714	2,28571	460	2
7	0	0	0	0	0	0	0	0	0	0	0	0	525,714	2,28571	460	2
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	460	2

Branch id	1 Current A	1 Length m	1 loss ($R.I^2$) W	2 Current A	2 Length m	2 loss ($R.I^2$) W	3 Current A	3 Length m	3 loss ($R.I^2$) W	4 Current A	4 Length m	4 loss ($R.I^2$) W
1	16,00	30,00	103,22	16,00	5,00	17,20	16,00	2,00	6,88	16,00	1,07	3,69
2	0,00	0,00	0,00	8,00	20,00	17,20	5,33	12,00	4,59	4,00	8,57	1,84
3	0,00	0,00	0,00	8,00	5,00	4,30	10,67	2,00	3,06	12,00	1,07	2,07
4	0,00	0,00	0,00	0,00	0,00	0,00	5,33	12,00	4,59	4,00	8,57	1,84
5	0,00	0,00	0,00	0,00	0,00	0,00	5,33	2,00	0,76	8,00	1,07	0,92
6	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	4,00	8,57	1,84
7	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	4,00	1,07	0,23
8	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
9	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
10	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
11	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
12	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
13	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
14	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
15	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total		30,00	103,22		30,00	38,71		30,00	19,88		30,00	12,44
Kd			1,00			0,38			0,19			0,12

Branch id	5 Current A	5 Length m	5 loss ($R.I^2$) W	6 Current A	6 Length m	6 loss ($R.I^2$) W	7 Current A	7 Length m	7 loss ($R.I^2$) W	8 Current A	8 Length m	8 loss ($R.I^2$) W
1	16,00	0,67	2,29	16,00	0,45	1,56	16,00	0,33	1,13	16,00	0,25	0,86
2	3,20	6,67	0,92	2,67	5,45	0,52	2,29	4,62	0,32	2,00	4,00	0,22
3	12,80	0,67	1,47	13,33	0,45	1,09	13,71	0,33	0,83	14,00	0,25	0,66
4	3,20	6,67	0,92	2,67	5,45	0,52	2,29	4,62	0,32	2,00	4,00	0,22
5	9,60	0,67	0,83	10,67	0,45	0,70	11,43	0,33	0,58	12,00	0,25	0,48
6	3,20	6,67	0,92	2,67	5,45	0,52	2,29	4,62	0,32	2,00	4,00	0,22
7	6,40	0,67	0,37	8,00	0,45	0,39	9,14	0,33	0,37	10,00	0,25	0,34
8	3,20	6,67	0,92	2,67	5,45	0,52	2,29	4,62	0,32	2,00	4,00	0,22
9	3,20	0,67	0,09	5,33	0,45	0,17	6,86	0,33	0,21	8,00	0,25	0,22
10	0,00	0,00	0,00	2,67	5,45	0,52	2,29	4,62	0,32	2,00	4,00	0,22
11	0,00	0,00	0,00	2,67	0,45	0,04	4,57	0,33	0,09	6,00	0,25	0,12
12	0,00	0,00	0,00	0,00	0,00	0,00	2,29	4,62	0,32	2,00	4,00	0,22
13	0,00	0,00	0,00	0,00	0,00	0,00	2,29	0,33	0,02	4,00	0,25	0,05
14	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	2,00	4,00	0,22
15	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	2,00	0,25	0,01
Total		30,00	8,72		30,00	6,56		30,00	5,19		30,00	4,25
Kd			0,08			0,06			0,05			0,04

8.5 Annex 3-B

8.5.1 September 2013 questionnaire towards the electrical installers and engineering companies

1. On average how many nodes/points (socket-outlet, light fixture, fixed connection,…) are there on an electric circuit (circuit after a circuit breaker) ?

	Average number of nodes/points per circuit		
	Residential	Services	Industry
Light circuit			
Socket-outlet circuit			
Permanent connected devices (fixed) circuit			

Remarks:

2. Please estimate the average length of an electric circuit per sector?

	Average length of an electric circuit in meter (m)		
	Residential	Services	Industry
Light circuit			
Socket-outlet circuit			
Permanent connected devices (fixed) circuit			

Remarks:

3. Do you use aluminium power cables for electrical installations inside buildings?

No☐ Yes☐

Remarks:

4. How many electrical installations, performed by your company, are designed by means of a maximum voltage drop and safety requirement calculation. Please indicate roughly in percentage (0 %, 25% , 50 %, 75% or 100 %).

	Residenti al	**Services**	**Industry**
No calculation	%	%	%

Design based on rules of thumb or predefined tables	%	%	%
Design calculated by means of software tool, taking into account voltage drop and safety requirements	%	%	%

Remarks:

5. Do you think there are significant energy losses in low voltage power cables in indoor electrical installations?

Less than 1% ☐ Between 1% and 3% ☐ More than 3% ☐ No idea ☐

Remarks:

6. Who may perform an electrical installation in your country

    a. In the residential sector?

Anyone (no qualification) ☐ Qualified person/organisation ☐ No idea ☐

    b. In the non-residential sector?

Anyone (no qualification) ☐ Qualified person/ organisation ☐ No idea ☐

Remarks:

7. Must an electrical installation be certified in your country

    a. In the residential sector?

    No☐ Yes☐ No idea ☐

    b. In the non-residential sector?

    No☐ Yes☐ No idea ☐

    Remarks:

8. Who may certify an electrical installation in your country? Only to be filled in when certification is obligatory.

    Anyone ☐ Qualified installer☐ Independent (accredited) company☐

    Remarks:

9. Please indicate the installation/national wiring code or standard used for electrical installations in your country?

10. Please indicate relatively (in percentage) per sector how many installations performed by your company include a home/building management system (BMS) or building automations and control system (BACS)?

	Residential	**Services**	**Industry**
Percentage of installations having a BMS or BACS	%	%	%

Remarks:

If you have any remark or additional clarification to any of the questions or answers above, feel free to use the next field to do so:

Remarks:

8.5.2 September 2013 questionnaire towards the cable manufactures

1. Indicate the annual EU27 (27 member states of European union in 2010) of sales for the year 2010 of power cables per cross cable section (CSA) and per number of cores. Please express in **kilometer** cable.
(If you have this information available in another format, please feel free to enclose it as an attachment.)

	EU27 cable sales (year 2010) amount in km				
CSA mm²	Single core cable	2-core cable	3-core cable	4-core cable	5-core cable
0,75					
1					
1.5					
2.5					
4					
6					
10 till 35					
50 till 120					
150 till 300					
More than 300					

Remarks:

8.5.3 July 2014 questionnaire towards the electrical installers and engineering companies

1. On average how many nodes/points (socket-outlet, light fixture, fixed connection,…) are there on an electric circuit ?

	Average number of nodes/points per circuit		
	Residential	Services	Industry
Distribution circuit[129]			
Lighting circuit			
Socket-outlet circuit			
Dedicated circuit[130]			

Remarks:

2. Please estimate the average length of an electric circuit per sector?

	Average length of an electric circuit in meter (m)		
	Residential	Services	Industry
Distribution circuit[129]			
Lighting circuit			
Socket-outlet circuit			
Dedicated circuit[130]			

Remarks:

3. If you do not have the information requested in above questions, could you provide one representative electrical installation plan per sector?

No☐ Yes☐

4. Do you use aluminium power cables for electrical installations inside buildings? If so, please provide more information on the use of aluminium power cables inside buildings (circumstances, reason,…).

No☐ Yes☐

Aluminium use information:

[129] Distribution circuit: electric circuit between meter and main distribution board, or between main distribution board and secondary distribution boards.
[130] Dedicated circuit: electric circuit serving one or more dedicated loads (pump, ventilation, machine,etc.)

5. When designing an electrical installation by means of an integrated design software tool, do you perform an economic optimization? This optimization could result in a higher investment cost, but lower life cycle cost overall. In other words, are your clients interested in long term savings or do they only consider the investment costs. Please explain.

   Explanation:

If you have any remark or additional clarification to any of the questions or answers above, feel free to use the next field to do so:

Remarks:

8.5.4 Questionnaire results

The response to the questionnaire was very low. 8 installers / engineering companies responded to the questionnaire of September 2013 for the installers. 2 cable manufacturers answered the questionnaire of September 2013 for the cable manufacturers. Only 3 installers / engineering companies responded to the questionnaire of July 2014 for the installers.

The results of the installers questionnaires have been summarized in Task 3, and are taken into account when defining the base cases in Tasks 5.

The collected results of the sales data of the cable manufacturers questionnaires was too limited to be used in the study. Instead general available data (PROCOMM, EUROSTAT, building construction data) was used to estimate the sales and stock data. Europacable indicated that they are limited by strict EU competition requirements that need to be duly respected.

Some qualitative remarks on the questionnaires indicate that:

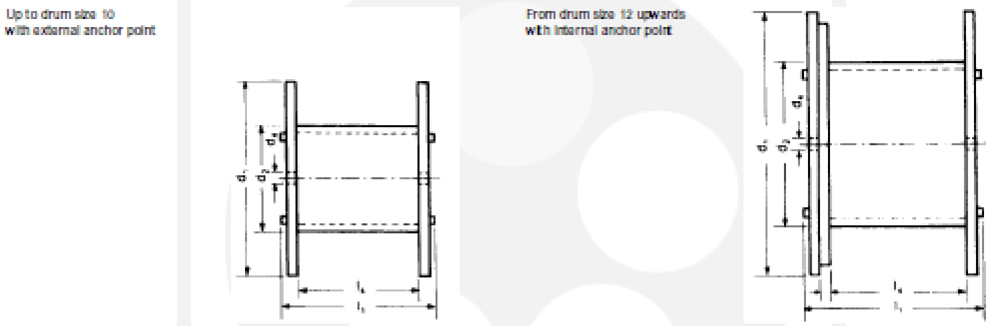
- electro-installers are unaware of the losses in circuits;
- calculation of the losses is not performed when designing an installation. Mostly only voltage drop and safety restrictions are taken into account;
- In the vast majority of investment projects the supplier for the electrical system is selected according to the lowest cost of investment. As a consequence electrical contractors offer the cheapest legal solution as a response to quotation requests.

8.6 Annex 4-A

Drum properties

T19: Drum capacities for polymer-insulated cables in m according to DIN 46391

Drum number	Cable-Ø mm										
	6	9	12	15	20	25	30	40	50	60	80
71	2024	892	468	297	165	–	–	–	–	–	–
81	2755	1152	643	430	219	151	–	–	–	–	–
91	–	2202	1206	749	402	285	162	–	–	–	–
101	–	–	1540	1000	576	365	220	–	–	–	–
121	–	–	–	1991	1139	688	450	249	–	–	–
141	–	–	–	2479	1352	839	564	327	–	–	–
161	–	–	–	–	2435	1608	1028	549	319	–	–
181	–	–	–	–	–	1867	1197	640	373	256	–
201	–	–	–	–	–	2522	1583	812	558	296	163
221	–	–	–	–	–	–	2383	1328	678	566	278
250	–	–	–	–	–	–	–	1892	1107	699	363



TK 61.2 Wooden drum

Drum number	Drum size	Diameter in mm			Width in mm		Max. load kg	Weight kg
		d_1	d_2	d_4	l_1	l_4		
071	07	710	355	80	520	400	250	25
081	08	800	400	80	520	400	400	31
091	09	900	450	80	690	560	750	47
101	10	1000	500	80	710	560	900	71
121	12	1250	630	80	890	670	1700	144
141	14	1400	710	80	890	670	2000	175
161	16/8	1600	800	80	1100	850	3000	280
181	18/ 10	1800	1000	100	1100	840	4000	380
201	20/ 12	2000	1250	100	1340	1045	5000	550
221	22/ 14	2240	1400	125	1450	1140	6000	710
250	25/ 14	2500	1400	125	1450	1140	7500	875
251	25/ 16	2500	1600	125	1450	1130	7500	900
281	28/ 18	2800	1800	140	1635	1280	10000	1175

Figure 8-2 Drum properties (source: www.lappgroup.com/products)

8.7 Annex 5-A

The cable manufacturers could not disclose the composition of the plasticizer used in the cables. In this study bitumen is used in the EcoReport tool to represent the plasticizer in a cable. To address this approximation, a small sensitivity analysis has been carried out.
The impact is analyzed by changing the plasticizer material in the input sheet of the EcoReport tool from bitumen to polyurethane and to PVC for base case 1. The results of the analysis are shown in Table 8-19. The parameters Water (process), Particulate Matter (PM, Dust) and Eutrophication are impacted the most (more than 5 %). The Total Energy (GER) and Greenhouse Gases in GWP100 parameters are impacted less than 0.1 %.

Table 8-19 Results of sensitivity analysis on plasticizer material

			Absolute life cycle Impact per product			Relative difference compared to bitumen	
		Unit	**PU**	**PVC**	**Bitumen**	**PU/Bitumen-1**	**PVC/Bitumen-1**
11	**Total Energy (GER)**	MJ	1,826,339	1,825,844	1,825,051	0.07%	0.04%
12	**of which, electricity (in primary MJ)**	MJ	1,791,712	1,791,653	1,791,182	0.03%	0.03%
13	**Water (process)**	ltr	1,131	589	506	**123.53%**	**16.39%**
14	**Water (cooling)**	ltr	88,071	85,438	84,504	4.22%	1.11%
15	**Waste, non-haz./ landfill**	g	961,475	957,114	954,482	0.73%	0.28%
16	**Waste, hazardous/ incinerated**	g	28,705	28,546	28,483	0.78%	0.22%
	Emissions (Air)						
17	**Greenhouse Gases in GWP100**	kg CO2 eq	78,319	78,299	78,246	0.09%	0.07%
18	**Acidification, emissions**	g SO2 eq.	401,579	401,415	401,129	0.11%	0.07%
19	**Volatile Organic Compounds (VOC)**	g	39,907	39,907	39,986	-0.20%	-0.20%
20	**Persistent Organic Pollutants (POP)**	ng i-Teq	4,950	4,950	4,950	0.00%	0.00%
21	**Heavy Metals**	mg Ni eq.	29,528	29,528	29,617	-0.30%	-0.30%
22	**PAHs**	mg Ni eq.	5,643	5,415	5,415	4.21%	-0.01%
23	**Particulate Matter (PM, dust)**	g	11,450	11,401	14,040	**-18.44%**	**-18.80%**
	Emissions (Water)						
24	**Heavy Metals**	mg Hg/20	27,749	27,293	27,301	1.64%	-0.03%
25	**Eutrophication**	g PO4	430	391	389	**10.46%**	0.43%

phthalate

8.8 Position papers of stakeholders

8.8.1 Past Position paper Europacable from September 2012

Europacable comments on the Revision of the 2012 – 2014 Working Plan under the EcoDesign Directive (2009/125/EC)

Brussels, 18 September 2012

Europacable believes that the inclusion of 'power cables' in the recently adopted priority list of the 2012-2014 Working Plan under the EcoDesign Directive is based on incomplete and incorrect information. While we strongly support Europe's ambition to reduce carbon emissions and increase energy efficiency, we take the view that low voltage power cables installed in buildings only offer a marginal contribution to achieving the overall objectives.
Europacable therefore calls for a revision of the data provided for the Study for the Amended EcoDesign Working Plan by involving key stakeholders and collecting additional environmental and economic impact information for a balanced decision.

Europacable welcomes the work currently under way regarding a revision of the working plan of the EcoDesign Directive (EDD) as we believe that the reduction of environmental impacts of energy related products are critical for a sustainable economy. Three product categories of the European Wire and Cable Industry can contribute to achieving these objectives:

1. Medium, High and Extra high voltage power transmission cables deployed in electricity distribution and transmission grids;
2. Low voltage power cables installed in buildings, either residential or non-residential;
3. Data- and telecommunication cables for infrastructure as well as building applications.

Europacable takes the view the largest energy efficiency improvements and carbon dioxide reductions for copper and aluminum cable systems are mainly depending on:

- intelligent management of central and de-central electricity generation,
- increasing the share of renewable energy sources in the energy mix, and
- installing energy saving equipment and management devices in buildings.

This said, in our view low voltage power cables installed in the buildings only offer marginal contribution to achieving the overall European objectives.
After reviewing the reports, which motivated the inclusion of power cables in the working program of the EDD for 2012 - 2014, Europacable concludes that EDD goals will not be achieved by focusing on conductor size. Essential information about a major part of power cable applications is missing for a complete evaluation of a "significant environmental impact and savings potential". Furthermore, the scope and assumptions in the report are inconsistent and not robust:

- The technical hypotheses used for the calculations of carbon savings and intensity rates are not accurate;
- The impact of cable size modification on the entire electrical installation has not been taken into account;
- Country differences in installation specifications and energy mix have significant impact on results and are not included.

Europacable therefore calls for a revision of the data provided for the Study for the Amended EcoDesign Working Plan by involving key stakeholders and collecting additional environmental and economic impact information for a balanced decision.

Europacable is committed to supporting the upcoming consultation process to ensure the optimal effectiveness of the envisaged Directive.

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8.8.2 Position paper European Copper Institute

Position Paper on Ecodesign for Power Cables in Indoor Electrical Installations

Given the substantial energy savings potential, the numerous additional benefits and the market failure, so far, to secure these benefits through voluntary initiatives, European Copper Institute (ECI) advocates for a cable-sizing regulation and supports the European Commission's efforts to formulate the best regulatory approach.

Brussels, December 15th, 2014: Electrical energy is lost not only in end-use devices (being addressed by Ecodesign regulations) but also in the electricity supply cables. Today's cable losses, which amount to approximately 2% of the EU's total electricity consumption (60 TWh/year), could be halved by increasing the cross section of the conductor up to its economical optimum. In the large majority of cases, minimising the Total Cost of Ownership (TCO) results in a cross section that is substantially greater than prescribed in today's technical standards.
The current standards for cable sizing take safety aspects (thermal impact, short circuit current) and voltage drop into account, but not energy efficiency. A new standard that includes energy efficiency (IEC 60364-8-1) has recently been published, but its scope is much broader than cables and therefore the adoption rate of economically optimum cable sizing is expected to be low. Another standard explicitly dedicated to the economic optimisation of power cable sizing (IEC 60287-3-2) was published several years ago, but, since its application is voluntary, it has had practically no impact on the market.
While the vast majority of electrical installations in tertiary sector buildings or industrial premises are designed using specialised software, economically optimum cable sizing is not common market practice. A survey, conducted as part of the Preparatory Study, shows that engineering companies and installers are often unaware of the many benefits, or miss the incentives to adopt an improved scenario.

The main reason given for the lack of adoption of best practice is split incentives – e.g. between the building owner and the user/occupier, or between the purchasing and operations departments. During a recent interview program by ECI, contractors stated that the lowest investment cost usually wins the bid. This acts as a disincentive to design for minimum total cost of ownership, which would be done relatively easily by modifying current design software. This market failure, due to split incentives, is similar to that of other product categories which have been regulated recently, such as electric motor systems and transformers.

The benefits of improved cable sizing stand out. The Preparatory Study points to savings of about 1% of the electricity consumed which, for the tertiary and industry sectors, currently represents 20 TWh/year. This figure significantly exceeds the estimated annual savings of some Ecodesign measures that have already been adopted, such as domestic refrigerators (4 TWh/year) or air conditioners and comfort fans (11 TWh/year). Consequently, the adoption of mandatory regulatory measures for improved cable sizing would be a logical step to address such a significant savings potential.

The savings in electricity are accompanied by important reductions in Greenhouse Gas Emissions (in the range of 8-10 million tonnes per year). These more than compensate for the increased emissions from the manufacturing phase of the cables (environmental paybacks are generally around one year, as stated in the Preparatory Study).

In addition to these more quantifiable savings, more robust electrical installations will deliver an improved quality of supply (mitigation of harmonics, voltage distortions and flicker), higher electrical and fire safety, and increased operational flexibility (greater tolerance to overloads).

From an economic perspective, the improved scenarios are attractive. The incremental investment remains reasonable, typically less than a fraction of the entire building investment cost, and is generally recovered in less than 4 years. After this time, the ongoing, lower energy costs will benefit entirely the customer until the end of life of the installation (assumed to be 25 years as per the Preparatory Study).

Lastly, when the electrical installation is finally dismantled, the cables can be recycled allowing the building owner to recover an important part of the initial cost (clean copper scrap recovered from cables is valued at +/- 90% of the new copper market price). As at November 2014, this aspect has not been considered in the economic analysis of the Preparatory Study.

These efficient investments will support directly the electrical engineering and manufacturing sectors (electrical installers, cable vendors, cable manufacturers, cable material manufacturers, electrical software developers…). ECI has estimated an employment impact of 22,000 additional jobs, largely local due to the nature of the activity.

A regulation on cable sizing will increase conductor demand. The Preparatory Study estimates a few hundred thousand tonnes per year. Considering that copper is a commodity, traded globally, and that the annual demand for copper exceeds 20 million tonnes, the potential increment would represent a small percentage. The Copper Alliance’s statement on long-term copper availability can be downloaded from here.

About the European Copper Institute:

ECI, founded in 1996, represents the copper industry in Europe. ECI is also part of the Copper Alliance™, an international network of trade associations funded by the copper industry, whose common mission is to defend and grow markets for copper, based on its superior technical performance and contributions to a higher quality of life. Read more about us on copperalliance.eu.

8.9 Annex 7-A: PROPOSAL FOR THE DEFINITION OF POTENTIAL APPROACHES TO BE ADOPTED IN A POTENTIAL REGULATION ON CABLE SIZING as proposed by Prof. Angelo Baggini, Univ. Bergamo

1. INTRODUCTION

The scope of this document is to present a couple of original potential approaches useful to regulate the energy performance of power cables in the context of the Ecodesign Directive 2009/125/EC.
At the end of the document some minor comments to the current revision of the preparatory study are also provided.

2. BACKGROUND

The Ecodesign Directive 2009/125/EC establishes a framework for the setting of ecodesign requirements for energy-related products with the aims

- of developing a policy to foster environmental and energy efficient products in the European market
- of ensuring the free movement of those products within the internal market.

It prevents disparate national legislations on the environmental performance of these products from becoming obstacles to the intra-EU trade and contributes to sustainable development by increasing energy efficiency and the level of protection of the environment, taking into account the whole life cycle cost.
The Ecodesign directive does not set binding requirements on products by itself but it provides the framework (rules and criteria) for setting such binding requirements through 'Implementing Measures'. It is also possible to introduce information requirements for components and sub-assemblies.
Power cables are listed among the product groups identified in the Working Plan 2012-14 Ecodesign Directive 2009/125/EC but they need to be defined exactly.
Product grouping, i.e. the exact definition of products to be included in a study or a measure, plays a very important role in the whole of the preparatory studies during the design of legislation.
The spirit of the Directive is to regulate products manufacturers side, however, the energy saving potential is in the installation for its intended use, not in the products used (cables) themselves.
The possibility to define a conventional index representing on the energy performance of the product should be useful to the need to regulate the market acting at manufacturer side[1] and could be also a transitional approach to move in the direction of more strict regulatory mechanism in the future.
Alternatively the adoption at least of a meaningful informative but synthetic data set accompanying the product seems to be a good compromise to start to approach power cables in the context under examination.

1 To face the complexity introduced by functional performance approach, the document MEErP 2011 Methodology, among the others, mention that in the case of integrated and modular products (in the case under examination cables
and lines) representing almost all the market, the requirements can be set for the modules only.
Regulation of the complete "product" (the line in the case under examination), built from individual modules placed on
the market, should then take place through (non-Ecodesign) legislation that regulates the products
- at the level of combinations offered by the installer/retailer (the so-called installer label),
- at the level of (building) permits (e.g. EPBD),
- after installation (e.g. EPBD certification, operating permits).

3. PRODUCT VS INSTALLATION APPROACHES

In the field under examination and in the perspective of cable energy performance there is an underlying issue on the product vs installation regulatory approach. A definition and a number of principles apply to each category.
The dualism is between:

- a product, i.e. the cable with a given section and number of cores but without any given length
- an electrical line made with one or more cables to carry a given current over a given length for a given time in a given place. A line is an electrical installation[2] and is not a product or a part of a product.

Obviously for a given cable, at a given voltage and in given conditions, losses in a cable line depend on the length of the line i.e. a parameter of the electrical installation and not at all in the end of the cable manufacturer.

3.1. Installation approach

The installation approach seems to be the simplest way to face the energy performance issue of power cables (i.e. of electrical lines manufactured using power cables) but:

- Installation characteristics are managed by users while cable characteristics are managed by manufactures
- European Regulations related to ErP have to regulate the market acting at manufacturer side
- Market regulation acting at user side for example by way of EPBD could be much less effective than ErP Regulations as its application remains at national level and is often transposed in a very mild way that prevent savings happening.

3.2. Product approach

The product approach is closer to the need to regulate the market acting at manufacturer side[3] but shows some difficulties of definitions.

4. PROPOSALS OF POSSIBILE ORIGINAL APPROACHES FOR CABLE REGULATION WITHIN THE ECODESIGN FRAMEWORK

This paragraph presents two original basic concepts potentially useful to regulate energy performances of power cable within the Ecodesign framework.
Both approaches are intended to avoid shifting the regulation of cable energy performances to user side:

- The first one consists in suggesting an original index representing conventionally the cable energy performance without any reference to the length of the line and the size of the cable (cross-section);
- The second approach allows to take into account the length of the cable (i.e. of the line) working on the concept of the product.

[2] Let's neglect for the moment on board electrical lines for mobile application (like on board electrical installations on product like cars, trains, ships, electrical appliances in general).

[3] To face the complexity introduced by functional performance approach, the document MEErP 2011 Methodology, among the others, mention that in the case of integrated and modular products (in the case under examination cables
and lines) representing almost all the market, the requirements can be set for the modules only.
Regulation of the complete "product" (the line in the case under examination), built from individual modules placed on
the market, should then take place through (non-Ecodesign) legislation that regulates the products
- at the level of combinations offered by the installer/retailer (the so-called installer label),
- at the level of (building) permits (e.g. EPBD),
- after installation (e.g. EPBD certification, operating permits)

4.1. Cable energy performance index

The direct definition of the power cable energy performance as a product is difficult because
the manufacturer has no knowledge about:

- The length
- The voltage or the power of the line that will use it (the power cable) for the intended use.

An option to solve this issue could be to express the energy performance of the cable by an index (here referred as EPI - Energy Performance Index) based on the ratio between the losses per unit of length and the rated current at given conditions:

$$EPI= LI=RI\ (WAm)$$

Where:

- L are the losses per unit of length
- I is the rated current of the cable in the reference condition
- R is the electrical resistance of the cable in the same reference condition

The basic reference condition should consist in:

- a basic* temperature
- a basic* installation method

i.e. a temperature and an installation method allowed by all types of cables, for example 40°C, free air.

Losses per unit of length of each cable could be calculated using the actual existing method and equations available in the standards:

- IEC 60287-1-1, Electric cables – Calculation of the current rating – Part 1-1: Current rating equations (100 % load factor) and calculation of losses – General;
- IEC 60287-2-1, Electric cables – Calculation of the current rating – Part 2-1: Thermal resistance – Calculation of thermal resistance;
- IEC 60853 (all parts), Calculation of the cyclic and emergency current rating of cables;
- 4th new criteria : energy loss limitation. Current rating limited depending on intended use. There would be pre-defined values per installation type (industry, hotels, offices, etc) and per use (lighting, power, other).

As well as any other method also referred to other unknown technology.

With such approach:

- the energy performance of the cable at reference installation conditions[131] would be based only on the data available to the cable manufacturer at product design stage and could be managed in the way already standardized for managing deviations in the environmental temperature, solar radiation, proximity etc.;
- once defined the maximum allowable value of the losses per unit length (W/(Am)) in the standard conditions, any future mandatory MEPS for power cables could be expressed re-defining maximum EPI;

[131] According to the method prescribed in the current standards.

- the rating currents for cyclic currents could be defined and declared by the cable manufacturer for given standard and unified working cycles;
- having standardized and unified working cycle, if needed the eventual future MEPS could also be expressed in terms of energy losses per ampere and unit of length (Wh/(Am));
- cables with enhanced technological insulating materials would not be penalized.

Allowing a direct comparison among cables of different sections and technologies, such index seems more meaningful than simple DC resistance.

[4] According to the method prescribed in the current standards

4.2. Sized cable approach

In this proposed approach the regulated product is nor the electrical installation (because definitely the installed circuit is not a product) nor the cable in the package of the original manufacturer but the cable already cut ready to be installed, or in other terms the electrical circuit floating in the air just before being installed (i.e. the cut piece of cable or in other terms the sized cable)[5].

Practically this approach introduce two levels of manufacturers:

- The original one i.e. the company manufacturing cables in standard lengths (the companies actually classified as cable manufactures) – not regulated
- The manufactures of the sized cables i.e. typically the installers (not in the act of installation but in the act of cutting/sizing the cable) – regulated

An analogy could help in understanding this approach:

- Let’s imagine we want to regulate thermal insulation performances of a piece of clothing
- Cables are like tissues, installers are like tailors
- Cut pieces of cable (sized cables) are equivalent to suits
- Tissues as well as suits are products, but the regulated product is not the tissue, the regulated products are the tissues cut and put together into a suit
- Obligations are set on tailors (installers) and not on tissues manufactures (cable makers)
- The installer, as well as the tailor, is the manufacturer of the final product

5. MINOR COMMENTS ON THE CURRENT RELEASE OF THE PREPARATORY STUDY

Ref. 7.1.2.1.1 Policy measures at product level by a generic ecodesign requirements on information

[...] On the package and sales websites:

- Cable losses per kilometer (VA/kilometer) at 50 % and 100% of the maximum current-carrying capacity of the cable in open air;
- Indication of the real measured DC ohmic resistance according to the compliance check as described in paragraph 7 of IEC 60228 and Annex A of the standard. The DC ohmic resistance is measured on a cable sample of at least 1 meter at a given room temperature and corrected to 20°C and a length of 1 km (R20 expressed in Ω/km).

Comments

- losses should be expressed in terms of W/km and not VA/km
- another communicative way to express/represent the DC resistance could be (W/(A km)) instead of ohm. Performing dimensional analysis it's easy to demonstrate that resistance is a loss per unit of length and per carried ampere (W/(A km)). The value is the same but it should be more meaningful for general users

[5] The installer indeed will remain responsible also of the installation (and therefore the installed circuit) but this is not argument of interest for the potential Regulation under exam.

8.10 Annex 7-B

Table 8-20 shows the assumed kWh electrical energy to kg CO_2 ratio per year.
These ratio values are used in Task 7 to calculate the GWP of the use phase. From 2030 on 0.34 is used as ratio value.

Table 8-20 GWP conversion ratios

Year	GWP Electric
	kg/kWh electric
1990	0.5
1991	0.493
1992	0.486
1993	0.479
1994	0.472
1995	0.465
1996	0.458
1997	0.451
1998	0.444
1999	0.437
2000	0.43
2001	0.428
2002	0.426
2003	0.424
2004	0.422
2005	0.42
2006	0.418
2007	0.416
2008	0.414
2009	0.412
2010	0.41
2011	0.407
2012	0.404
2013	0.401
2014	0.398
2015	0.395
2016	0.392
2017	0.389
2018	0.386
2019	0.383
2020	0.38
2021	0.376
2022	0.372
2023	0.368
2024	0.364
2025	0.36
2026	0.356
2027	0.352
2028	0.348
2029	0.344
2030	0.34