Contract N°. Specific contract 185/PP/ENT/IMA/12/1110333 implementing FC ENTR/29/PP/FC Lot 2

Report

Preparatory Studies for Product Group in the Ecodesign Working Plan 2012-2014:

Lot 8- Power Cables

Task 4 report - Technologies (product supply side, includes both BAT and BNAT)

(2nd version)

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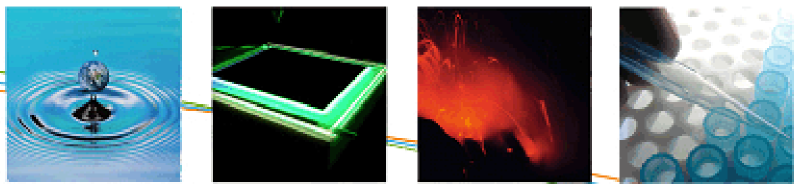

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EXECUTIVE SUMMARY

VITO is performing the preparatory study for the new upcoming eco-design directive for Energy-related Products (ErP) related to power cables, on behalf of the European Commission (more info http://ec.europa.eu/enterprise/policies/sustainable-business/ecodesign/index_en.htm).

In order to improve the efficient use of resources and reduce the environmental impacts of energy-related products the European Parliament and the Council have adopted Directive 2009/125/EC (recast of Directive 2005/32/EC) establishing a framework for the setting Ecodesign requirements (e.g. energy efficiency) for energy-related products in the residential, tertiary, and industrial sectors. 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. This should benefit both businesses and consumers, by enhancing product quality and environmental protection and by facilitating free movement of goods across the EU. It is also possible to introduce binding information requirements for components and sub-assemblies.

The MEErP methodology (Methodology for the Ecodesign of Energy-related Products) allows the evaluation of whether and to which extent various energy-using products fulfill the criteria established by the ErP Directive for which implementing measures might be considered. The MEErP model translates product specific information, covering all stages of the life of the product, into environmental impacts (more info http://ec.europa.eu/enterprise/policies/sustainable-business/ecodesign/methodology/index_en.htm).

The tasks in the MEErP entail:
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, where it is recommended to carry out a first product screening. The objective is to re-group or narrow the product scope, as appropriate from an ecodesign point of view, for the subsequent analysis in tasks 2-7.

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List of Acronyms

BAT	Best Available technology
BNAT	Best Not yet Available Technology
BOM	Bill Of Materials
CSA	conductor Cross Sectional Area
Cu	Copper
CuMg	Copper Magnesium alloy
EC	European Commission
HVAC	Heating, Ventilation, Air-conditioning
ICT	Information and Communication Technology
LED	Light Emitting Diode
PoE	Power-over-Ethernet
PVC	PolyVinyl Chloride
TBC	To Be Confirmed
TBD	To Be Defined
VITO	Flemish institute for Technological Research
XLPE	Cross Linked PolyEthylene

Use of text background colours

Blue: draft text
Yellow: text requires attention to be commented
Green: text changed in the last update

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, there are no improvement options identified related to energy efficiency.
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 analysis, e.g. amount of copper per type of cable.

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 input from stakeholders has been provided.

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[1] Harmonised document FprHD 60364-8-1:2013 “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.

[1] 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[2], 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.
- DC power distribution in commercial buildings, as for instance promoted by the EMerge Alliance[3]. This system will use 380 VDC/24VDC instead of 110 or 230 VAC. Also other initiatives like lighting systems powered via Power- over-Ethernet (PoE)[4] are examples of this trend towards smart DC grids integrating power distribution for lighting, ICT and Building Automation networks. 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. As a consequence an identical cable with identical insulation would need less current in DC (e;g.: 325VDC, 1A, 325 VA) compared to AC (e.g. 230 Vrms, 1.41A, 325 W) and will therefore reduce the cable losses. Such a switch from AC to DC is complex as it requires another concept of power distribution [5] with different converters, protection switches, distribution transformers, etc. Therefore it will not be considered as a viable BAT improvement option.

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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[2] 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

[3] http://www.emergealliance.org/

[4] http://www.ledsmagazine.com/content/leds/en/articles/2014/04/philips-lighting-reveals-ethernet-powered-ssl-project-at-l-b.html?cmpid=EnlLEDsOutdoorLightApril92014 and http://www.xicato.com/xicato®-introduces-xim-—-intelligent-approach-internet-lights

[5] 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*[6]

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.

[6] 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.

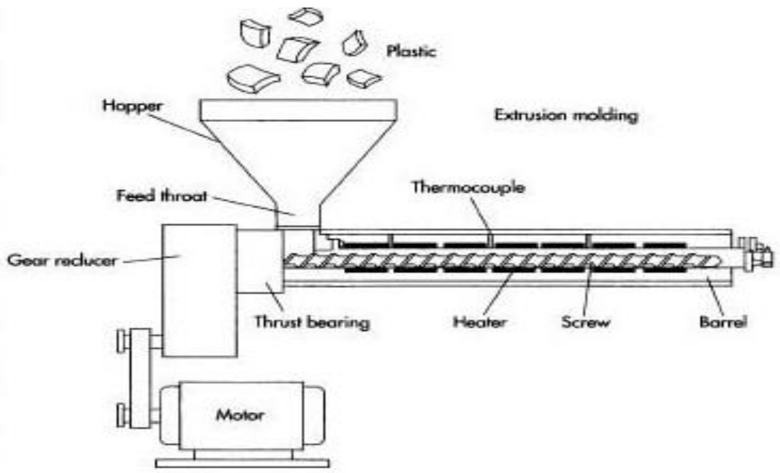


Figure 4-2 The extrusion process

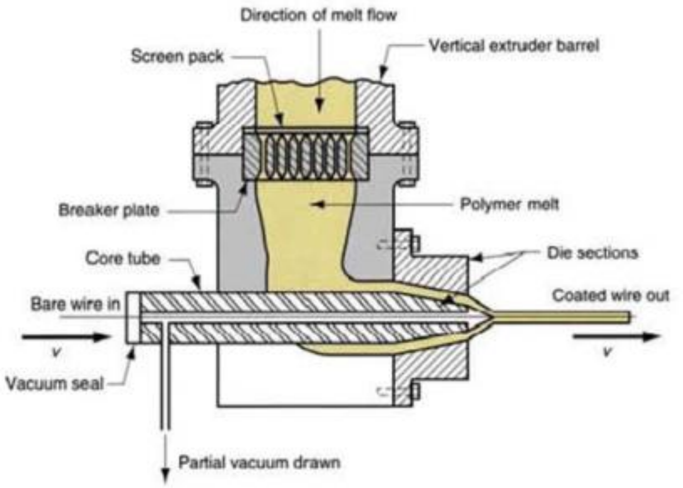


Figure 4-3 The extrusion process (detail)

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.

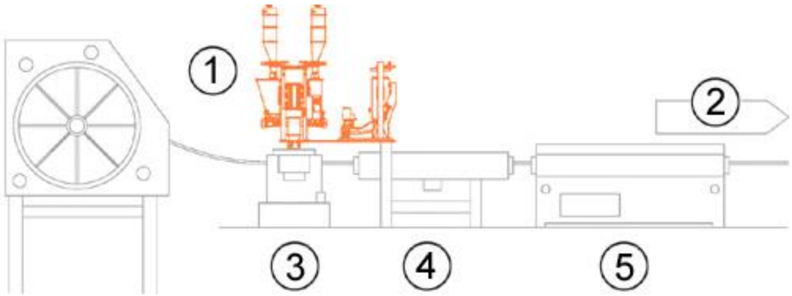


Figure 4-4 cooling and cutting
1. Gravimetric device
2. Cutting and cooling
3. Extruder with crosshead die
4. Cooling unit
5. Haul-off station

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[7], 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[7] 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.

[7] See response of Europacable to second questionnaire

Table 4-2: BOM of typical copper based cable per section

Cable type	5x1,5mm²	5x2,5m²	5x4mm²	5x6mm²	5x10mm²	5x16mm²	5x25mm²	5x35mm²	5x50mm²	5x70mm²	5x95mm²	5x120mm²	5x150mm²	5x185mm²	5x240mm²	4x300mm²	4x400mm²	1x500mm²	1x630mm²
CSA (mm²)	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/cm³)																			
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 (cm³)/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/cm³) - between 0,9 and 0,96 g/cm³ (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 (cm³)	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/cm³) = 1,5 g/cm³	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 €/mm².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	5x35mm^2	5x50mm^2	5x70mm^2	5x95mm^2	5x120mm^2	5x150mm^2	5x185mm^2
CSA (mm^2)	**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/cm^3)							
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 (cm^3)/conductor	24.17	31.10	40.78	46.31	58.06	75.21	95.50
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
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 (cm^3)	164.8	218.7	266.1	321.5	401.3	455.4	540.1
ρ PVC/A (g/cm^3) = 1,5 g/cm^3	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 €/mm^2.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 4-6 in Annex 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[8]

Drum	Flange Diameter	Barrel Diameter	Traverse	Width overall	Drum weight	Volume (cube)	Drum weight per m^3
size	**mm**	**mm**	**mm**	**mm**	**kg**	**m^3**	**kg/m^3**
	F	**B**	**T**	**W**			
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

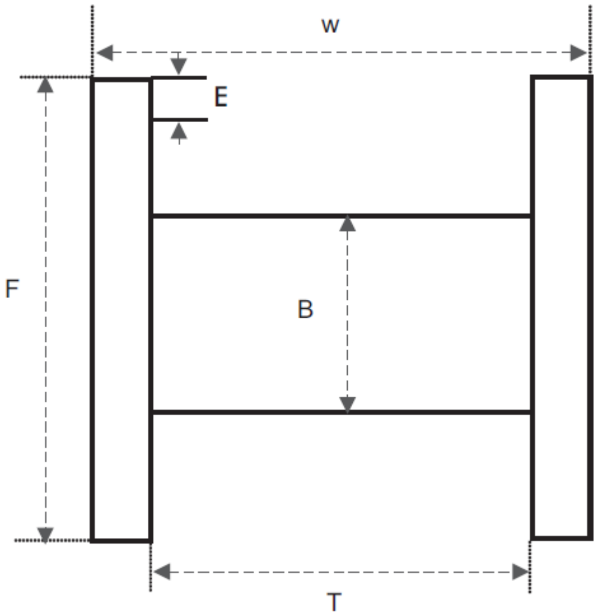


Figure 4-5 Drum dimensions scheme

Table 4-5: maximum cable lengths per CSA and drum size, part 1[8]

[8] Building wire and cables, ABHAR WIRE + CABLE CO., http://www.abharcable.com/Files/Documents/Catalogs/05%20BUILDING%20WIRE%20AND%20CABLES.pdf

Cable Outer Diameter	Max cable length in meters on standard drums											
	Drum sizes											
	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[8]

Cable Outer Diameter	Max cable length in meters on standard drums											
	Drum sizes											
	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	mm^2	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)	m^3	I	0.7
Drum spacing	m^3	C	0.105
Correction factor (spacing)	%	I	0.15
Drum Corrected Volume	m^3	C	0.805
Drum Weight	kg	I	50
Drum corrected volume / meter cable	m^3/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.

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).
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[9].

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.

[9] FprHD 60364-8-1:2013

Annex A

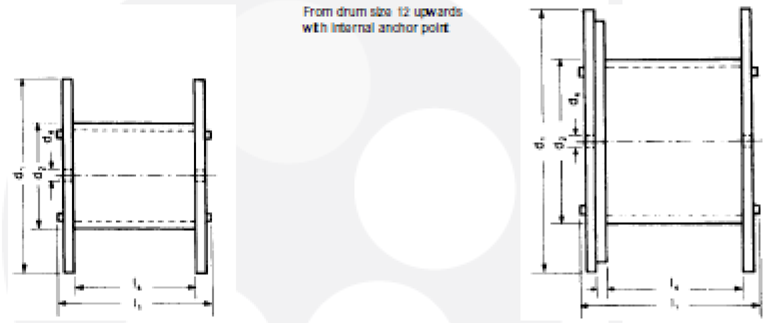
Drum properties

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

Up to drum size 10 with external anchor point

From drum size 12 upwards with internal anchor point



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 4-6 Drum properties (source: www.lappgroup.com/products)