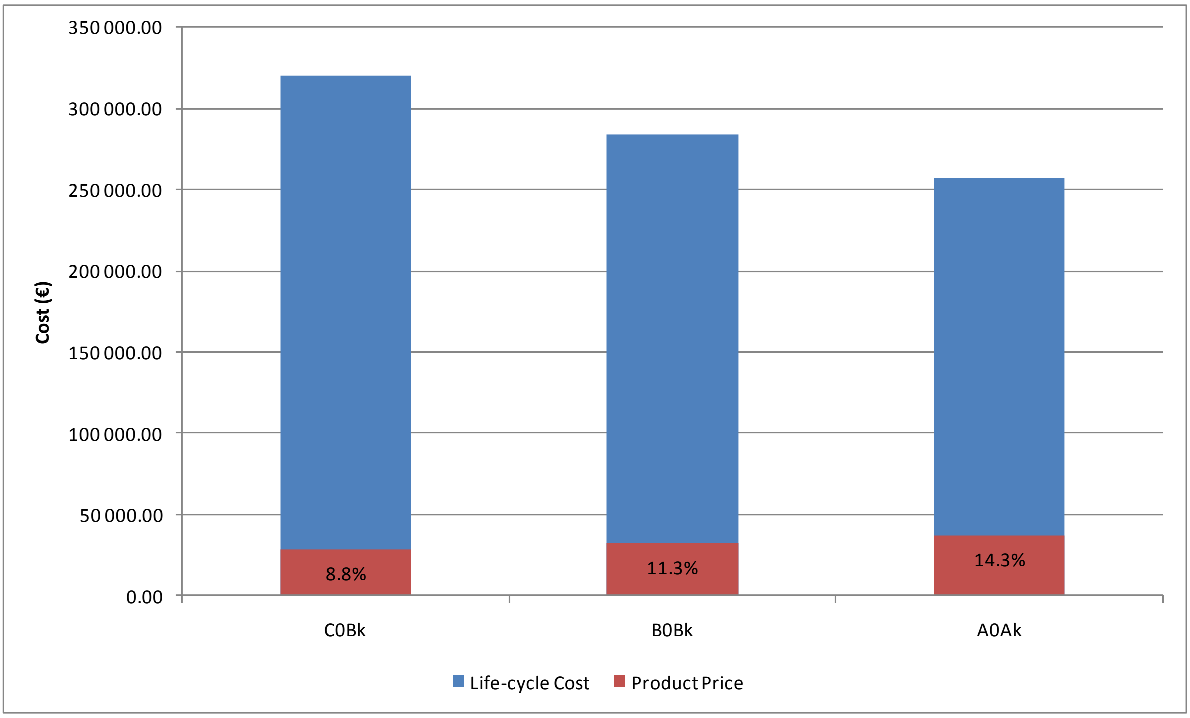


Figure 6-17: BC 6 Option 1 - Life-cycle cost and product price

Figure 6-18 compares total energy consumption with life-cycle cost in order to obtain a picture of how cost relates to general environmental performance. As the figure shows, the least life-cycle cost of A0Ak is also the lowest energy consumption option.

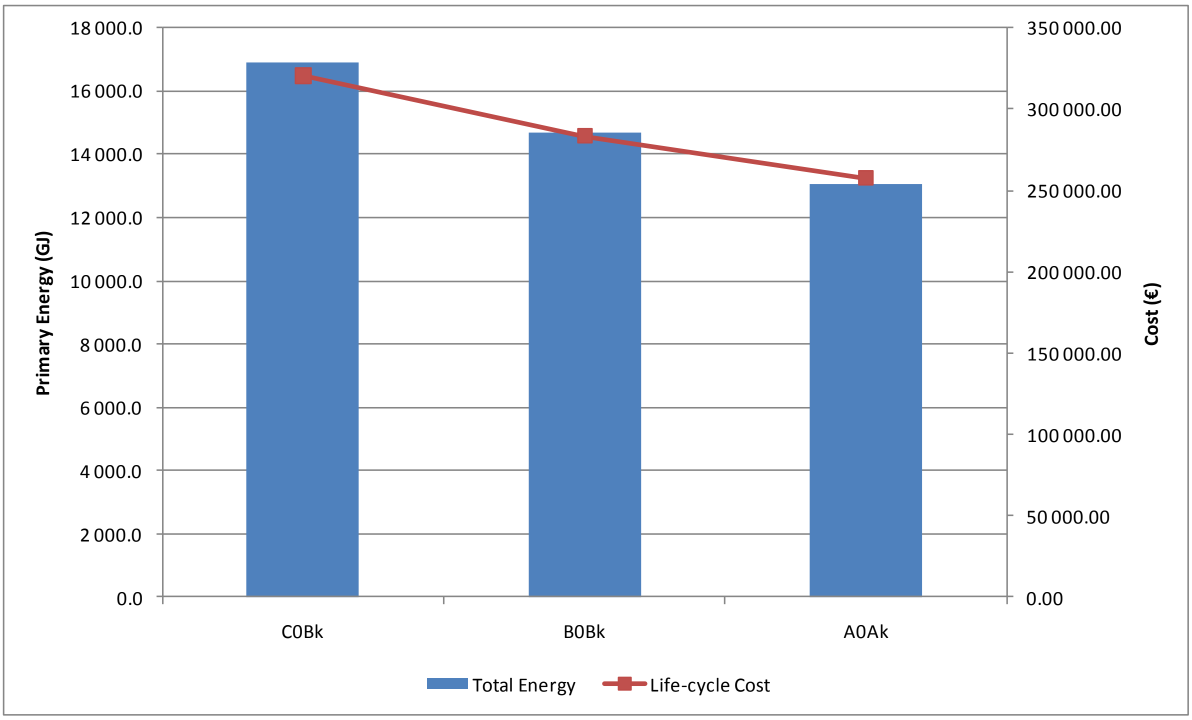


Figure 6-18: BC 6 Option 1 - Total energy consumption and life-cycle cost

Alternative option: switching to DER liquid-immersed transformer

No amorphous design(s) was modelled for this base-case. However, having an amorphous liquid-immersed transformer (filled with biodegradable oil, and not mineral oil, to cope with the same constraints requiring a dry-type transformer) appears as an additional improvement option for BC 6.

Assuming that the quantity of biodegradable liquid[147] that is necessary is similar to the amount of mineral oil but that the price is approximately six times higher (6 €/kg, see Annex E), the design to consider would be exactly the same as the BC 5 A0+Ak* option with biodegradable oil instead of mineral oil. The environmental analysis would give approximately the same total electricity consumption (same losses levels, thus exactly the same electricity losses during the use phase, possibly slightly different consumption for the other phases of the life cycle because of the two oils difference): the total primary energy consumption would be around 7 000 GJ, of which 6 250 GJ in electricity (see Table 6-21), compared to 12 445 GJ of electricity for the BC 6 A0Ak design (see Table 6-22). The electricity consumption is therefore roughly divided by a factor two. The other environmental impacts would be similar (the current indicators present in EcoReport would not allow a fair comparison between mineral oil and biodegradable oil, see section 6.2.2 for more details on this comparison). Regarding the LCC, it can directly be obtained by just adding the addidional purchase price of the biodegradable oil: 1 862 kg of biodegradable oil at 6€/kg, instead of the same quantity of mineral oil at 1.5 €/kg results in an additional cost of 8 379 €. The total LCC of this option would be 159 000 €, which represent a reduction of 38%, compared to BC 6 A0Ak LCC

[147] For instance MIDEL® 7131. More information available: http://www.midel.com/uploads/midel/documents/technical/MIDEL7131%20TDS2%20ProductOverview.pdf

(257 715 €). In short, this option would score better than A0Ak[148] option, both on the environmental and economic approaches. Given the substantial differences in the outcomes, this conclusion is clearly not expected to vary, should the price of biodegradable liquid or the quantity of liquid required be slightly different than the ones considered. This result is also in line with the fact that immersed transformers are normally more efficient than dry-type ones, which are only used when safety requirements impose this solution.

This alternative option is not modelled in the current policy scenario analysis (see Task 7), as it deals with a transfer from the stock and sales quantities from the BC 6 category to the BC 5 that is not straightforward to forecast, should it happen. The additional electric and economic savings that could be achieved with this option as BAT and LLCC for BC 6 will nonetheless be briefly presented aside in the text.

6.2.1.7 Improvement options for BC 7: Separation/isolation transformer 16 kVA

The results of the analysis of the improvement options for base-case 7 are seen below. As Table 6-23 shows, 110-400 provides the greatest improvement in terms of energy consumption (-20%), while the base-case of 110-750 remains the least life-cycle cost. Environmental performance indicators are more or less split between the base-case and improvement option.

Table 6-23: BC 7 Option 1 - Indicators

life-cycle indicators per unit	unit	110-750	110-400
	Other resources and waste		
Total Energy (GER)	GJ	63.1	51.1
	% change with BC	0%	-19%
of which, electricity	primary GJ	53.6	38.3
	TWh	0.4	0.3
	% change with BC	0%	-28%
Water (process)	kL	3.5	2.5
	% change with BC	0%	-29%
Water (cooling)	kL	141.5	100.8
	% change with BC	0%	-29%
Waste, non-haz./ landfill	kg	860.7	1 256.1
	% change with BC	0%	46%
Waste, hazardous/ incinerated	kg	1.3	0.9
	% change with BC	0%	-27%
	Emissions (Air)		
Greenhouse Gases in GWP100	t CO2 eq.	2.9	2.4
	% change with BC	0%	-17%
Ozone Depletion, emissions	mg R-11 eq.	0.0	0.0
	% change with BC	0%	0%

[148] Be aware that A0Ak levels are not the same for oil-immersed transformers and dry-type transformers.

life-cycle indicators per unit	unit	110-750	110-400
Acidification, emissions	kg SO2 eq.	25.1	27.3
	% change with BC	0%	9%
Volatile Organic Compounds (VOC)	kg	0.0	0.0
	% change with BC	0%	-8%
Persistent Organic Pollutants (POP)	mg i-Teq	1.8	2.0
	% change with BC	0%	6%
Heavy Metals	g Ni eq.	3.4	4.3
	% change with BC	0%	26%
PAHs	g Ni eq.	0.6	0.7
	% change with BC	0%	14%
Particulate Matter (PM, dust)	kg	5.2	5.3
	% change with BC	0%	1%
	Emissions (Water)		
Heavy Metals	g Hg/20	0.8	0.8
	% change with BC	0%	7%
Eutrophication	kg PO4	0.0	0.0
	% change with BC	0%	28%
Persistent Organic Pollutants (POP)	ng i-Teq	0.0	0.0
	% change with BC	0%	0%
	Economic indicators		
Electricity cost	€	319.17	227.12
	% change with BC	0%	-29%
Life-cycle cost	€	1 667.17	2 141.28
	% change with BC	0%	28%

Figure 6-19 below displays total energy, with total electricity consumption as a percentage of total energy consumption. As the results clearly show, electricity consumption and thus the use phase dominates energy consumption, however not as much so as in other base-cases. Electricity consumption represents greater than 77% for both options.

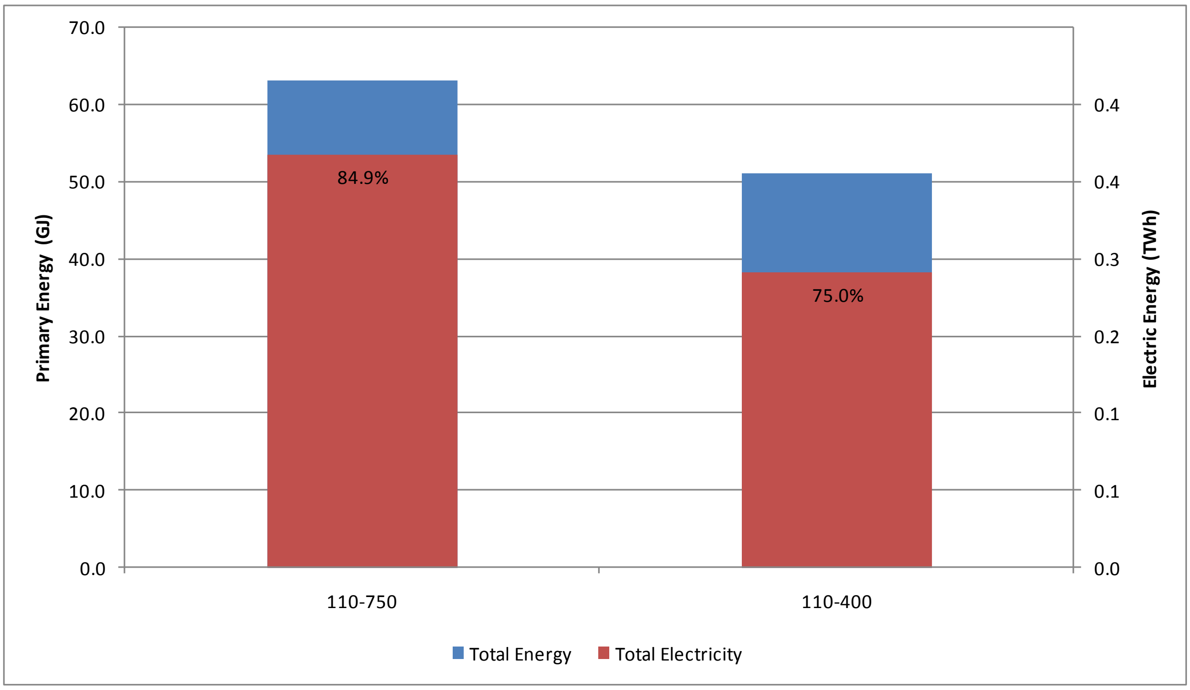


Figure 6-19: BC 7 Option 1 - Total energy and electricity consumption

Figure 6-20 shows product prices as a percentage of life-cycle costs. The part in blue represents electricity costs over the lifetime of the transformer. Product price represents 81-89% of life-cycle cost for these options. As the figure shows, the base-case achieves least life-cycle cost of € 1 667.

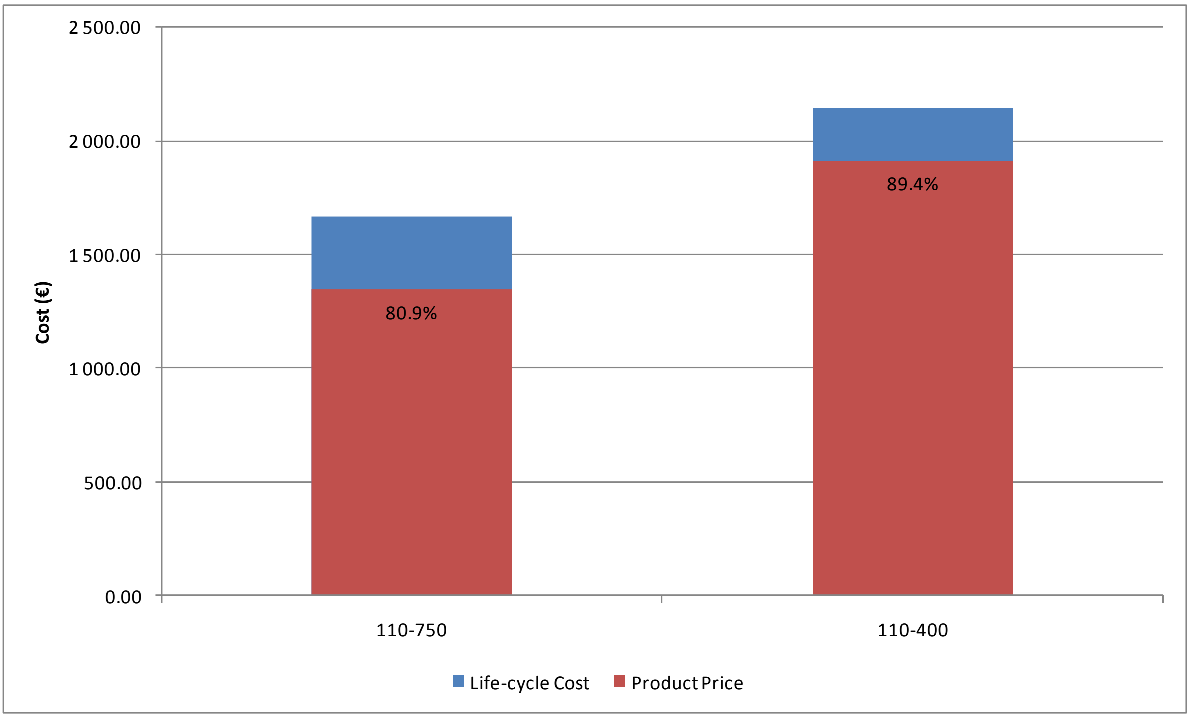


Figure 6-20: BC 7 Option 1 - Life-cycle cost and product price

Figure 6-21 compares total energy consumption with life-cycle cost in order to obtain a picture of how cost relates to general environmental performance. As the figure shows, the least life-cycle cost of 110-750 does not match with the lowest energy consumption option of 110-400. This is the only base-case for which an improvement option is not also the least life-cycle cost option.

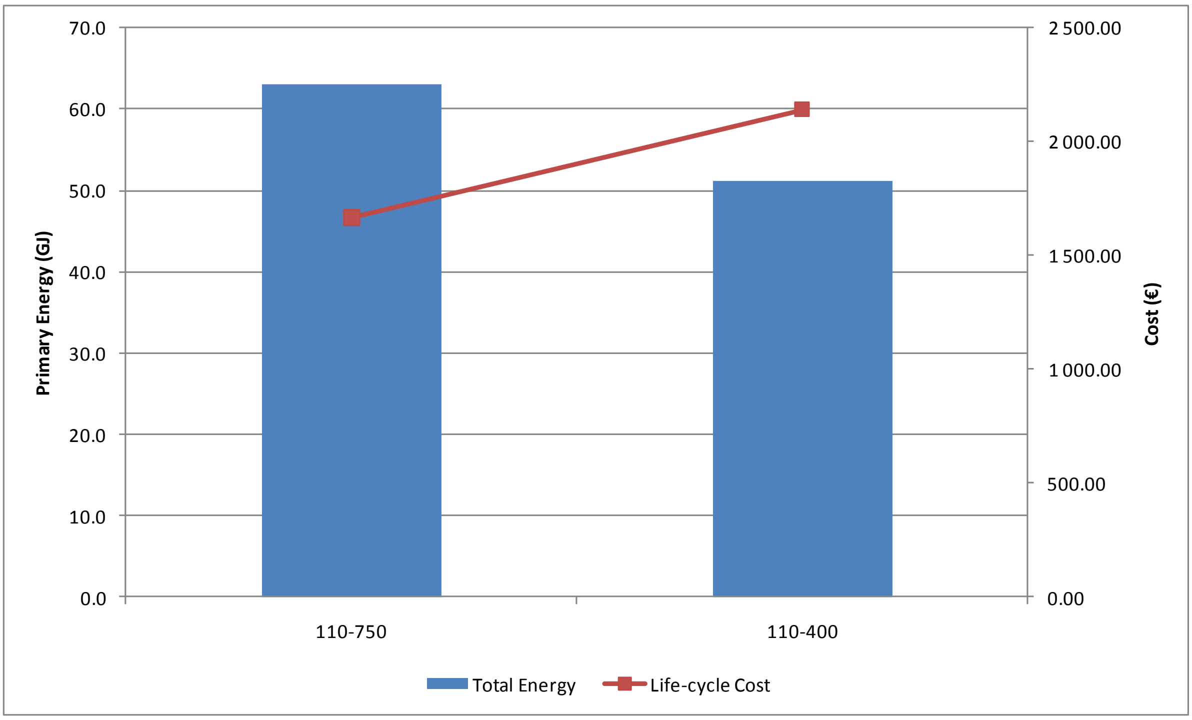


Figure 6-21: BC 7 Option 1 - Total energy consumption and life-cycle cost

6.2.2 Option 2: Replace mineral oil with natural esters

As the production cycle for rapeseed oil and other natural esters is not included in the standard EcoReport specified by the MEEuP methodology, the life-cycle analysis team at the JRC Institute for Environment and Sustainability provided expert input to complement publicly available data that originates mainly from the petroleum industry[149].

Because of the production chain of rapeseed, including significant quantities of chemical-based fertilizers and pesticides, the environmental impact of natural esters is significant and comparable to that of mineral oil. Simply evaluating the production stage of life, results from Nynas AB show that mineral oil consumes more crude oil and emits more sulphur dioxide. In contrast, natural esters are calculated to emit more carbon dioxide, nitrous oxide, phosphor and nitrogen[150]. The JRC IES notes that natural esters have an equally relevant environmental impact as mineral oil, including land use which needs further investigation. Additionally, as the fluids are recycled or incinerated after use, the net impacts are quite small and perhaps negligible considering the lifetime of transformers as a system. However, for cases in which leakages are frequent or used fluids are not properly disposed of, natural esters would have a distinctive environmental advantage.

To complement this external analysis, a simplified Life Cycle Analysis was carried out to compare mineral oil and rape seed oil. Because impacts such as land occupation or ecotoxicity are not included in the EcoReport and are expected to play a major role in

[149] Two reports relevant to the life-cycle analysis of natural esters compared to mineral oil were found, both supported by Nynas AB, a petroleum refining company. As these studies potentially were biased towards mineral oil, JRC experts provided an expert quality check in order to ensure a fair evaluation.

[150] Harryson, Björn. "Vegetable oil versus mineral oil". Nynas AB. Accessed 13 July 2010. http://www2.nynas.com/naph/start/article.cfm?Art_ID=627&Sec_ID=55

the comparison between mineral oil and natural esters, the study was carried out on a one-to-one comparison basis without trying to implement the rape seed oil option to the base-cases. Indeed, the overall impacts of transformers are not known for all relevant categories and assessing this product with the EcoReport would not make sense.

Two different methods were used to check the consistency of the results: *IMPACT 2002+_CIRAIG 09-07-2008 V2.04* and *CML 2 baseline 2000 V2.04*. The latter method was slightly modified: the biogenic carbon contributions were considered null instead of the default values in order to consider a full life cycle of the rape seed oil with incineration at the end of life, or at least release of the carbon contained in the product in the environment[151]. In the *IMPACT* method, this question is already addressed by the default values.

The two products compared are "Mineral oil" (same as defined in chapter 4[152]) and "Rape oil", included in the EcoInvent 2.0 Life Cycle Inventory (LCI). In order to calculate the impacts over the whole life cycle, a few assumptions were made:

- Mineral oil and rape seed oil are assumed to have similar thermal and dielectric properties so that the functional unit can be defined as one kilogramme of material. This might not be exactly true in practice but is assumed so that 1 kg of mineral oil can be considered equivalent to 1 kg of natural ester in terms of usage (i.e. the two liquids would be present in similar quantities in a given transformer). Thus, if a transformer requires specific properties of the cooling liquid, the choice might not exist, in which case there is no need to compare environmental impacts of mineral oil and natural ester.
- The environmental impacts occurring during the distribution phase are similar between the two oils as similar quantities are required for a same transformer. Besides, these impacts are expected to be small regarding the overall impacts. They are neglected.
- The environmental impacts during the use phase are not taken into account. These impacts should be null as the role of the oil is only cooling and insulation. However, in case of leakage, these oils can make important damage to the environment but this is not expected to be a regular phenomenon and it is hardly quantifiable.
- For the end-of-life management, both oils were considered under an incineration scenario, but with different impacts. The process "Disposal, biowaste, 60% H_2O, to municipal incineration" was used for rape oil while "Disposal, used mineral oil, 10% water, to hazardous waste incineration" was used for mineral oil. Both processes were found in the EcoInvent LCI. The energy recovery was not taken into account as the benefits from this process are expected to be very similar for the two oils.

These assumptions are justified by the fact that the objective of this Life Cycle Assessment is only to compare these two products. If most accurate figures for environmental impacts were required, a detailed analysis would be required and would take much more time.

Table 6-24 presents the results of these calculations for the production and the end-of-life phases. The two methods give similar results: during the production phase, the mineral oil has higher impacts only for the ozone layer depletion (274% of the rape seed oil impacts), the non-renewable energy/abiotic depletion (around 235%), and

151 If default values are kept, the Global Warming impact gives negative values because of the absorption of carbon by the growing plants. However, this is not representative of a full life cycle of rape seed oil.

152 70% by weight of light fuel oil and 30% by weight of heavy fuel oil.

marine aquatic ecotoxicity (107%). For all other impacts, mineral oil does not account for more than 50% of the rape seed oil values: around 20% for Global Warming Potential (GWP), and only 0.1% of land use. For the end-of-life phase, the results are quite different: for GWP (around 6 000%), aquatic eutrophication and ecotoxicity (for IMPACT method), the incineration of mineral oil has much more influence than the incineration of rape oil.

Table 6-24: Environmental impacts of mineral oil and rape seed oil during the production and end-of-life phase (for 1 kg of material)

		Production phase			End-of-life phase		
Impact category	Unit	Rape seed oil	Mineral Oil	Ratio	Rape seed oil	Mineral Oil	Ratio
IMPACT 2002+_CIRAIG 09-07-2008 V2.04 / IMPACT 2002+							
Carcinogens	*kg C2H3Cl eq*	1.4E-02	6.0E-03	41.2%	1.0E-02	6.8E-03	67.0%
Non-carcinogens	*kg C2H3Cl eq*	4.5E-01	6.7E-03	1.5%	5.4E-02	3.9E-02	72.3%
Respiratory inorganics	*kg PM2.5 eq*	2.4E-03	6.9E-04	28.7%	7.1E-05	7.9E-05	111.1%
Ionizing radiation	*Bq C-14 eq*	3.0E+01	6.3E+00	21.2%	4.4E-01	4.3E-01	96.5%
Ozone layer depletion	*kg CFC-11 eq*	1.7E-07	4.6E-07	274.2%	3.2E-09	3.7E-09	115.4%
Respiratory organics	*kg C2H4 eq*	1.5E-03	8.2E-04	52.9%	5.2E-05	7.0E-06	13.6%
Aquatic ecotoxicity	*kg TEG water*	4.4E+02	1.4E+02	31.0%	9.8E+00	1.0E+02	1069.7%
Terrestrial ecotoxicity	*kg TEG soil*	9.5E+02	3.0E+01	3.1%	1.7E+00	9.0E-01	51.5%
Terrestrial acid/nutri	*kg SO2 eq*	1.2E-01	1.3E-02	10.6%	2.5E-03	1.5E-03	60.5%
Land occupation	*m2org.arable*	5.5E+00	3.1E-03	0.1%	2.4E-04	2.0E-04	83.9%
Aquatic acidification	*kg SO2 eq*	1.9E-02	5.3E-03	28.3%	3.5E-04	2.3E-04	65.8%
Aquatic eutrophication	*kg PO4 P-lim*	2.9E-03	3.4E-04	11.6%	3.8E-06	3.9E-05	1038.9%
Global warming	*kg CO2 eq*	2.0E+00	4.3E-01	21.8%	2.9E-02	1.8E+00	6405.4%
Non-renewable energy	*MJ primary*	2.3E+01	5.4E+01	231.5%	4.1E-01	4.7E-01	115.5%
Mineral extraction	*MJ surplus*	4.2E-02	2.3E-03	5.4%	4.2E-04	8.7E-04	205.3%
CML 2 baseline 2000 V2.04 / West Europe, 1995 (without biogenic carbon)							
Abiotic depletion	*kg Sb eq*	9.8E-03	2.4E-02	239.8%	1.8E-04	2.2E-04	122.8%
Acidification	*kg SO2 eq*	1.6E-02	5.7E-03	35.2%	2.7E-04	1.8E-04	67.5%
Eutrophication	*kg PO4--- eq*	1.2E-02	5.7E-04	4.6%	2.4E-04	8.6E-04	364.7%
Global warming	*kg CO2 eq*	2.7E+00	4.6E-01	17.0%	3.1E-02	1.8E+00	5910.2%
Ozone layer depletion	*kg CFC-11 eq*	1.6E-07	4.6E-07	292.3%	3.1E-09	3.8E-09	120.3%
Human toxicity	*kg 1,4-DB eq*	1.2E+00	3.4E-01	28.4%	4.8E-02	6.9E-02	143.9%
Fresh water aqu. ecotox.	*kg 1,4-DB eq*	9.4E+00	3.4E-02	0.4%	4.4E-02	2.4E-02	54.9%
Marine aquatic ecotox.	*kg 1,4-DB eq*	2.5E+02	2.6E+02	106.9%	4.3E+01	1.9E+01	43.4%
Terrestrial ecotoxicity	*kg 1,4-DB eq*	4.2E+00	2.0E-03	0.0%	1.4E-04	1.6E-04	116.2%
Photochemical oxidation	*kg C2H4*	1.3E-03	3.3E-04	25.6%	9.4E-06	5.1E-06	53.8%

Table 6-25 shows the sum of these production and end-of-life impacts. The results are similar to the impacts of the production phase only: mineral oil has higher impacts in terms of the ozone layer depletion (around 280% for both methods) and the non-renewable energy/abiotic depletion (around 233%). In terms of GWP, IMPACT gives a result of 112.3% while CML indicates 83% which tends to signify that mineral oil and rape seed oil have similar greenhouse gases emissions over their life cycle. Mineral oil has much lower impacts in the following impact categories: acidification (around 30%), eutrophication (around 12%), ecotoxicity (especially in fresh water and terrestrial, in CML). Finally, the land use impacts of mineral oil only represent 0.1% of the rape seed value.

Table 6-25: Environmental impacts of mineral oil and rape seed oil over their lifecycle (for 1 kg of material)

		LifeCycle		
Impact category	Unit	Rape seed oil	Mineral Oil	Ratio
IMPACT 2002+_CIRAIG 09-07-2008 V2.04 / IMPACT 2002+				
Carcinogens	*kg C2H3Cl eq*	2.5E-02	1.3E-02	51.9%
Non-carcinogens	*kg C2H3Cl eq*	5.1E-01	4.6E-02	9.1%
Respiratory inorganics	*kg PM2.5 eq*	2.5E-03	7.6E-04	31.1%
Ionizing radiation	*Bq C-14 eq*	3.0E+01	6.7E+00	22.3%
Ozone layer depletion	*kg CFC-11 eq*	1.7E-07	4.6E-07	271.2%
Respiratory organics	*kg C2H4 eq*	1.6E-03	8.2E-04	51.7%
Aquatic ecotoxicity	*kg TEG water*	4.5E+02	2.4E+02	53.5%
Terrestrial ecotoxicity	*kg TEG soil*	9.5E+02	3.1E+01	3.2%
Terrestrial acid/nutri	*kg SO2 eq*	1.3E-01	1.5E-02	11.6%
Land occupation	*m2org.arable*	5.5E+00	3.3E-03	0.1%
Aquatic acidification	*kg SO2 eq*	1.9E-02	5.5E-03	29.0%
Aquatic eutrophication	*kg PO4 P-lim*	2.9E-03	3.8E-04	12.9%
Global warming	*kg CO2 eq*	2.0E+00	2.3E+00	112.3%
Non-renewable energy	*MJ primary*	2.4E+01	5.4E+01	229.5%
Mineral extraction	*MJ surplus*	4.2E-02	3.1E-03	7.4%
CML 2 baseline 2000 V2.04 / West Europe, 1995 (without biogenic carbon)				
Abiotic depletion	*kg Sb eq*	1.0E-02	2.4E-02	237.7%
Acidification	*kg SO2 eq*	1.7E-02	5.9E-03	35.7%
Eutrophication	*kg PO4--- eq*	1.3E-02	1.4E-03	11.3%
Global warming	*kg CO2 eq*	2.8E+00	2.3E+00	83.0%
Ozone layer depletion	*kg CFC-11 eq*	1.6E-07	4.6E-07	288.9%
Human toxicity	*kg 1,4-DB eq*	1.2E+00	4.1E-01	32.9%
Fresh water aqu. ecotox.	*kg 1,4-DB eq*	9.4E+00	5.8E-02	0.6%
Marine aquatic ecotox.	*kg 1,4-DB eq*	2.9E+02	2.8E+02	97.5%
Terrestrial ecotoxicity	*kg 1,4-DB eq*	4.2E+00	2.2E-03	0.1%
Photochemical oxidation	*kg C2H4*	1.3E-03	3.4E-04	25.8%

These results are thus in line with the preliminary analysis from JRC, as mineral oil and rape seed oil can be considered as having similar environmental impacts. However, their impact varies across the different impact categories so that a clear choice cannot be made if the focus is not put on certain product categories. Table 6-26 shows the normalised impacts: for instance, even if mineral oil scores higher for the ozone layer depletion impact (289%), the normalised value of this impact is low in comparison with other impact categories (in the range of 10^{-15}). On the contrary, the abiotic depletion (237%), the marine and freshwater aquatic ecotoxicity (97.5% and 0.6%) and the terrestrial ecotoxicity (0.1%) have higher normalised values and may have the priority over other impact categories

Table 6-26: Normalised environmental impacts mineral oil and rape seed oil over their life cycle (for 1 kg of material)

		LifeCycle (normalised)		
Impact category	Unit	Rape seed oil	Mineral Oil	Ratio
CML 2 baseline 2000 V2.04 / West Europe, 1995 (without biogenic carbon)				
Abiotic depletion	*kg Sb eq*	6.7E-13	1.6E-12	237.7%
Acidification	*kg SO2 eq*	6.1E-13	2.2E-13	35.7%
Eutrophication	*kg PO4--- eq*	1.0E-12	1.1E-13	11.3%
Global warming	*kg CO2 eq*	5.7E-13	4.8E-13	83.0%
Ozone layer depletion	*kg CFC-11 eq*	1.9E-15	5.5E-15	288.9%
Human toxicity	*kg 1,4-DB eq*	1.6E-13	5.4E-14	32.9%
Fresh water aqu. ecotox.	*kg 1,4-DB eq*	1.9E-11	1.1E-13	0.6%
Marine aquatic ecotox.	*kg 1,4-DB eq*	2.5E-12	2.5E-12	97.5%
Terrestrial ecotoxicity	*kg 1,4-DB eq*	8.8E-11	4.6E-14	0.1%
Photochemical oxidation	*kg C2H4*	1.6E-13	4.1E-14	25.8%

In conclusion, determining the lowest impacting product between mineral oil and rape seed oil is almost impossible without prioritising the environmental impacts to consider, and will remain difficult if this is done. According to this simplified Life Cycle analysis, mineral oil has higher impacts in terms of ozone layer depletion and abiotic depletion, similar impacts for GWP, and lower impacts regarding acidification, eutrophication, ecotoxicity or land use. The choice of the cooling fluid should consequently be made regarding the functional properties of the possible options (e.g. fire-resistance properties, risks of leakage, sensitive location of the transformer).

From an economical point of view, mineral oil remains the cheapest cooling fluid that can be used in transformers to date. Alternatives fluids and natural esters may benefit from cost reduction by volume production in the future.

6.2.3 Rebound effects

Rebound effects are not relevant as the end-user receives no direct service from the transformer, and thus will not overcompensate in their energy usages because of the economies made with more efficient transformers.

6.3 BNAT and long-term systems analysis

Scope: The design option(s) should be discussed against long-term targets, including the appropriateness to use the environmental performance of BNAT as benchmark:

- Discussion of long-term technical potential on the basis of outcomes of applied and fundamental research and development (BNAT = Best Not yet Available Technologies), but still in the context of the present product archetype;
- Discussion of long-term potential on the basis of changes of the total system to which the present archetype product belongs: societal transitions, product-services substitution, dematerialisation, etc.

6.3.1 Expected impact for new material development on amorphous metals, silicon steel and microcrystalline steel

As explained in section 5.2.1, this is an ongoing development and the key expected impact from this is that the more efficient transformers (e.g. A0Ak class) will have a lower purchase price in the coming years.

A further price reduction can be expected for amorphous metals that reach saturation at induction levels closer to those typically reached by magnetic steel, such as for alloy 2605HB1 recently introduced on the market (see 5.1.2.4). This would allow more compact cores and smaller-lighter transformers than the current amorphous designs with consequently a lower material and transformer cost.

6.3.2 Expected impact from using superconducting technology

As explained in section 5.2.4, it remains very speculative if this technology will ever appear in economic viable power or distribution transformers as they rely on exotic materials and vulnerable high tech peripheral equipment to maintain system integrity and superconductivity over time. It is clear that this technology will nullify load losses, which account for about 13 TWh per year in 2005 for distribution and power transformers. Despite this very significant savings potential, the likelihood of implementing such a technology is very low before 2050.

6.3.3 Expected impact from using smart grid technology and an increased share of Distributed Energy Resources (DER) and/or new loads such as electric vehicles on the grid

The key expected benefit from smart grid technology on transformers comes from matching the loading profile of the distribution grid to the irregular production profile Distributed Energy Resources (DER).

The main differences are reflected in the load form factor (Kf), as seen in Table 3-1. While residential and industrial distribution grids have nowadays typically load form factors of 1.08 (e.g. Figure 3-3) a single wind turbine has a load form factor 1.5 (Table 3-2). Therefore it is realistic to expect that the load form factor (Kf) may increase over time, e.g. towards 1.25, as more renewable energy is integrated into the electric grid. The impact is modelled by the sensitivity analysis on Kf in section 6.4.2. The load form factor has a direct impact on the load losses, as specified in formula 3.2 in section 3.2.1.1.3. In other words, with the same energy transported but a more peaked transformer loading profile, the load losses will increase.

It is also expected that more applications such as electric cars and heat pumps will be connected to the electrical grid to benefit from Distributed Energy Resources and renewable energy. This would of course increase the transformer load factor (α) and increase losses as well. Nevertheless, it can be expected that more energy efficient equipment can be used in the future as well, which will compensate the transformer load factor (α) increase from an increased share of electric cars and heat pumps. The impact is modelled by the sensitivity analysis on load factor in section 6.4.1.

6.3.4 Expected impact from improvement options at system level by increasing the MV voltage and having dual or triple windings

As explained in section 5.1.2.9 part of the transmission losses are in the MV cables. By increasing the voltage for the same cable cross sectional area (CSA) one can reduce cable losses.

It is estimated that about 113 Watt per transformer can be saved by increasing the voltage. Assuming that these savings could be applied to about half of the EU stock of distribution transformers in 2020 (4 459 000/2) annual savings are about 2.2 TWh. Stakeholders estimated that this would increase the BC1 (400 kVA) transformer price by about 20 %. The impact on the Life Cycle Cost of this improvement option can therefore also easily be assessed in the assumption that the product price increased by 20% and that 39595 kWh energy is saved per transformer over its 40 years life time. The life cycle cost is then estimated at 16 391 € if all the other parameters remain the same, which represents a reduction of 10% compared with base-case 1 life cycle cost (18 255 €). The environmental impact is proportional to the energy saving because the impact of the Bill of Material was already low in the base case and would not change substantially for this system related improvement option.

6.3.5 Expected impact from any other societal or business model transition

There is no expected change of societal or business model. All technologies examined are available to all manufacturers, and consumers of transformers already apply energy efficienct requirements to their transformer purchases.

6.4 Sensitivity analysis of the main parameters

Scope: A sensitivity analysis, covering the relevant factors (such as the price of energy or other resources, production costs, discount rates, base-case simplifications) and, where appropriate, external environmental costs, should be carried out and discussed for the identified design option(s).

- Load factor
- Load form factor (for DER transformers)
- Lifetime
- Electricity price
- Transformer price
- Discount rate
- Installed stock

The robustness of the outcomes of the study depends on the underlying assumptions. These assumptions have been explicitly mentioned at the relevant steps of the study. In this section, the sensitivity of the results to the most critical parameters and assumptions is tested, related namely to:

- The load factors and lifetimes that has a direct influence on the environmental impacts and LCC of the base-cases and their improvement options
- The economic data, such as the electricity tariff, the discount rate, and the purchase price of transformers, which have an influence on the LCC when implementing improvement options,
- The stock of transformers (for each type) that has an impact of the overall environmental impacts, and especially electricity consumption, at EU level

6.4.1 Assumptions related to the load factors

As stated in Task 3, average load factors were defined for each type of transformer. However, some factors can be lower or higher (see Table 6-27), as mentioned in some studies or by stakeholders. Therefore, a sensitivity analysis is carried out for each base-case and their improvement options to see the impact of the load factor on the electricity consumption.

Table 6-27: Load factors (α) used in this study

Application	Base	Min	Max
Distribution	0.15	0.10	0.25
Industry	0.30	0.10	0.60
Power	0.20	0.20	0.50
DER (wind)	0.25	0.20	0.30
Small industry	0.40	0.10	0.60

Figure 6-22 to Figure 6-35 present the results of the sensitivity analysis on this parameter (all numbers are presented in Annex F). The order of improvement options with the use of minimum or maximum load factors is similarly compared with the base. Whatever the transformer type and whatever the value of the load factor, the base-case is always the product consuming the most electricity during the use phase. As load factor increases, the more efficient options become more cost-effective as the electrical losses become more significant.

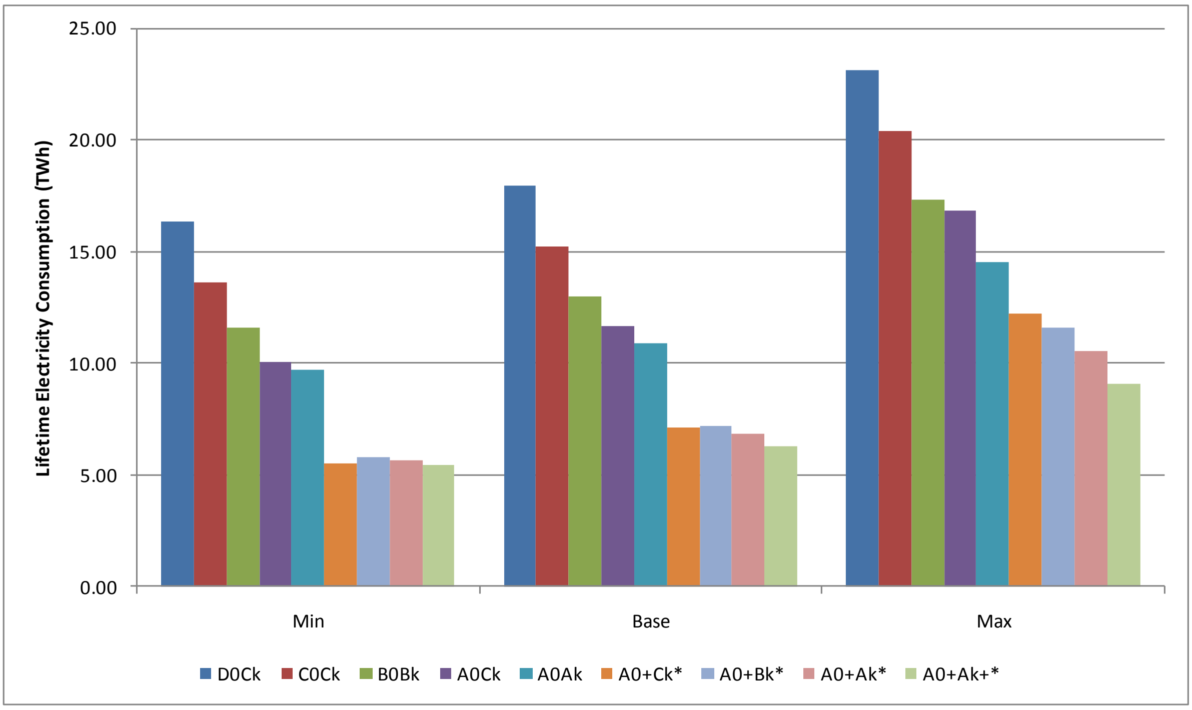


Figure 6-22: Base-case 1 and its improvement options – Impact of the load factor on the electricity consumption (in TWh)

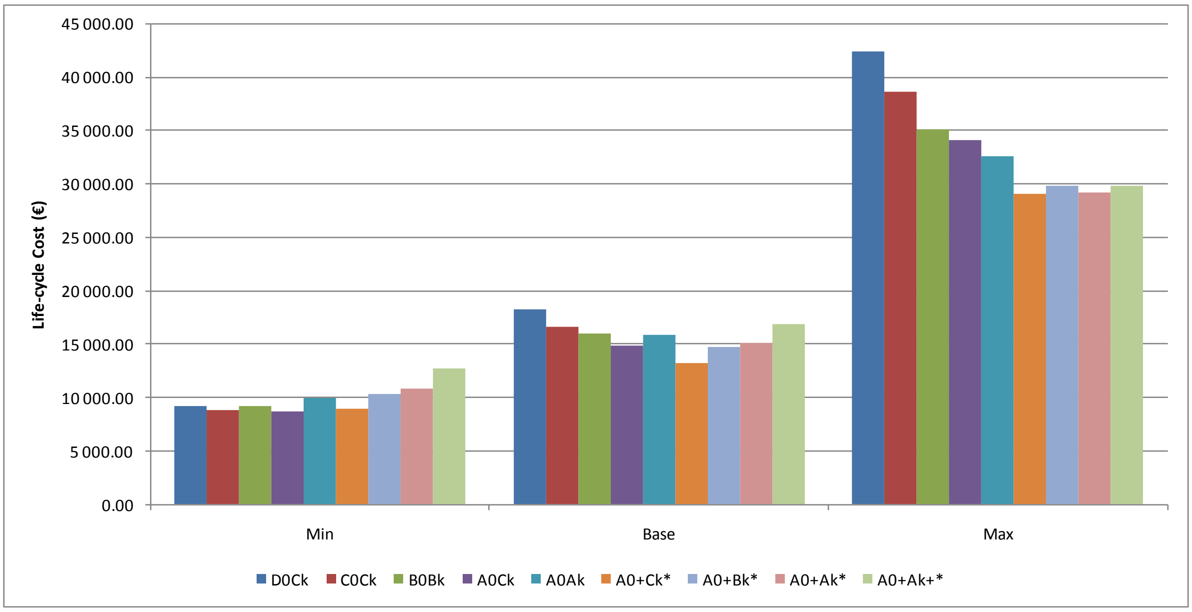


Figure 6-23: Base-case 1 and its improvement options – Impact of the load factor on the LCC

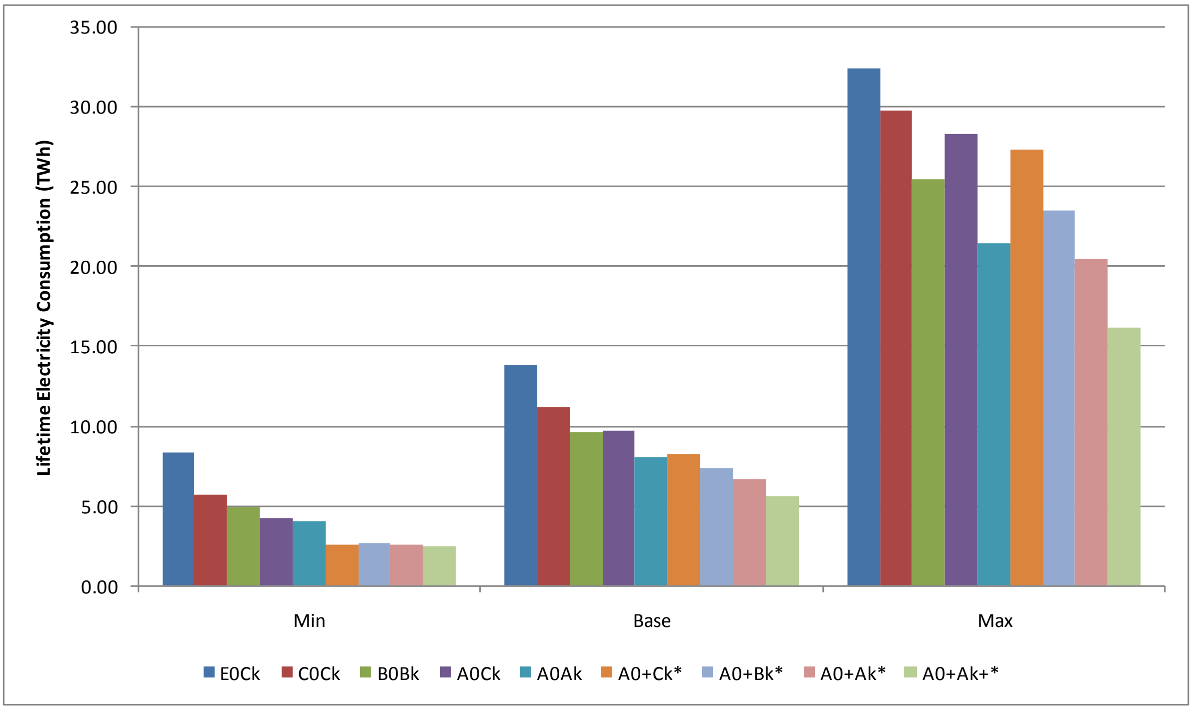


Figure 6-24: Base-case 2 and its improvement options – Impact of the load factor on the electricity consumption (in TWh)

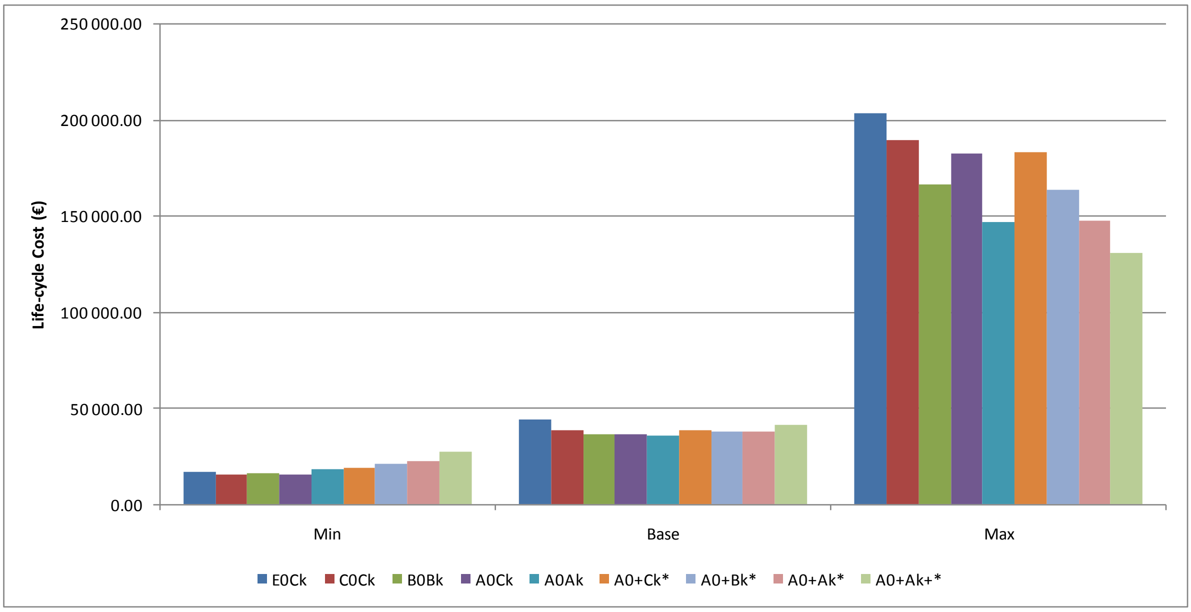


Figure 6-25: Base-case 2 and its improvement options – Impact of the load factor on the LCC

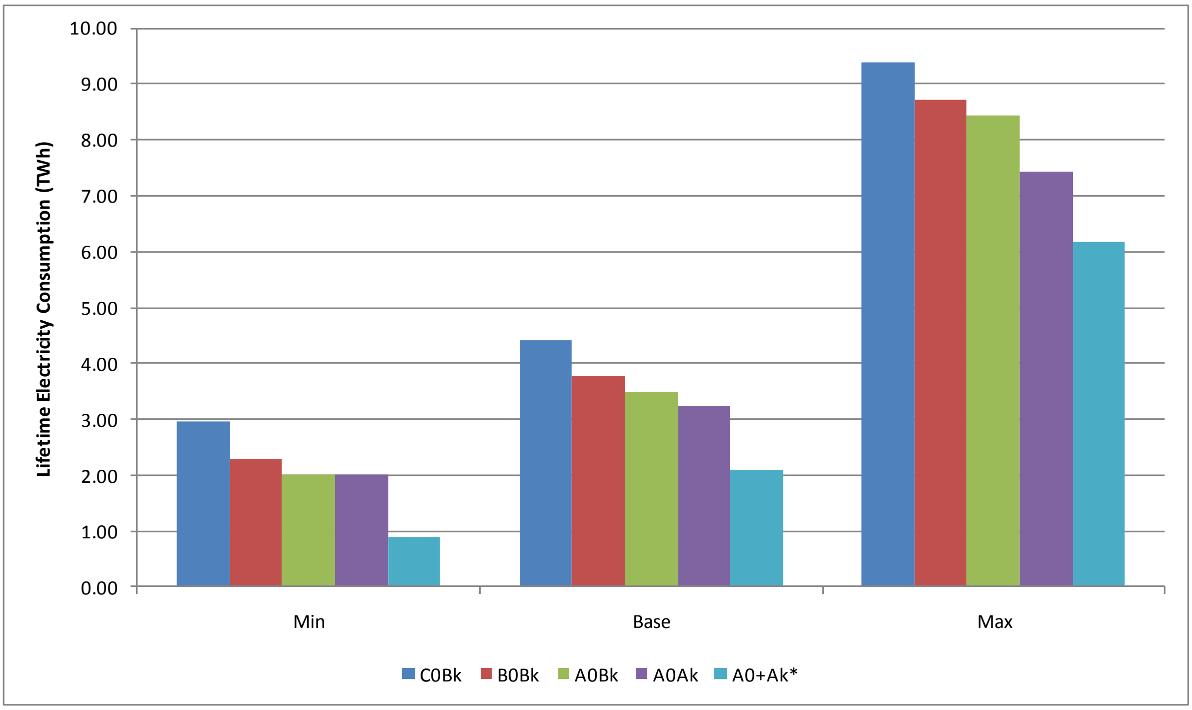


Figure 6-26: Base-case 3 and its improvement options – Impact of the load factor on the electricity consumption (in TWh)

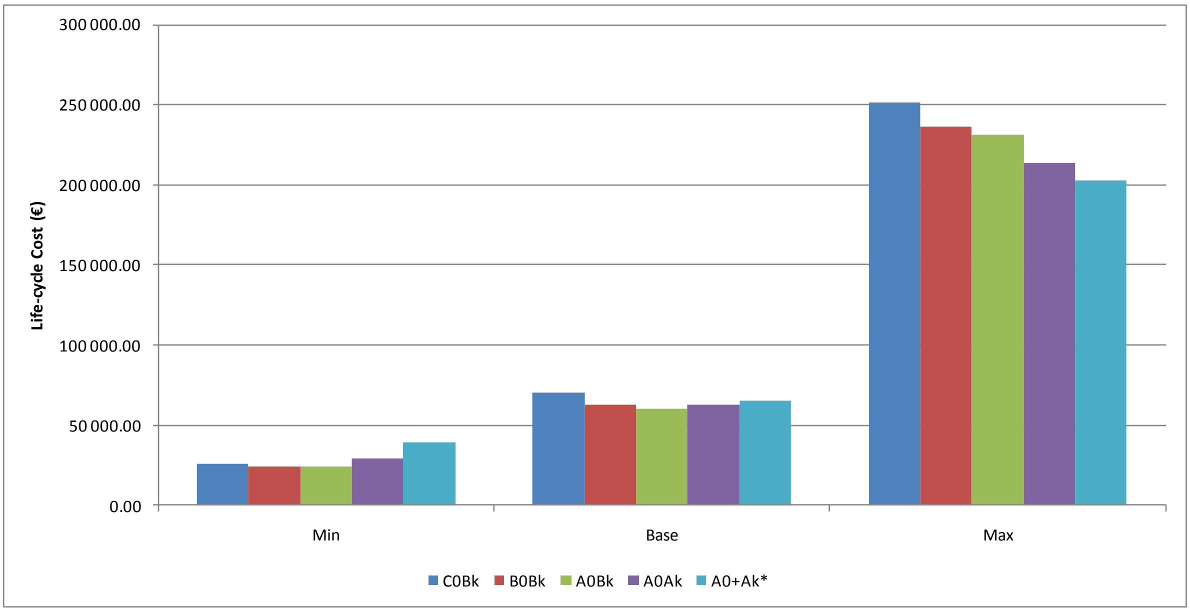


Figure 6-27: Base-case 3 and its improvement options – Impact of the load factor on the LCC

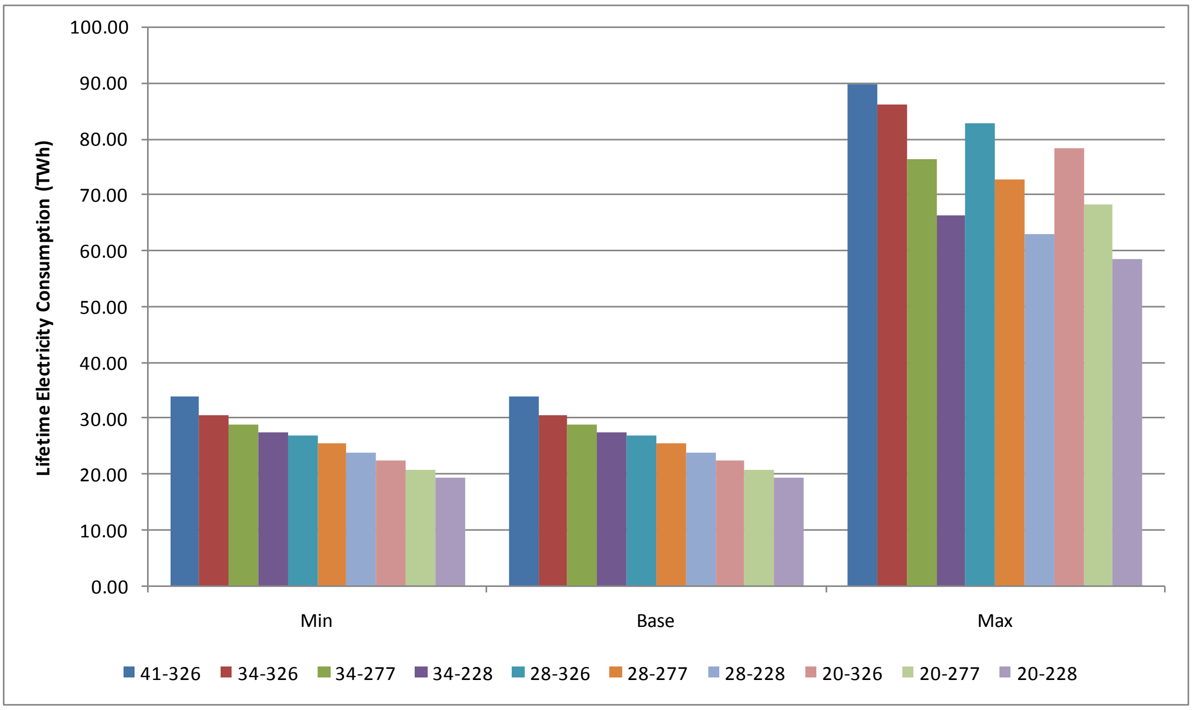


Figure 6-28: Base-case 4 and its improvement options – Impact of the load factor on the electricity consumption (in TWh)

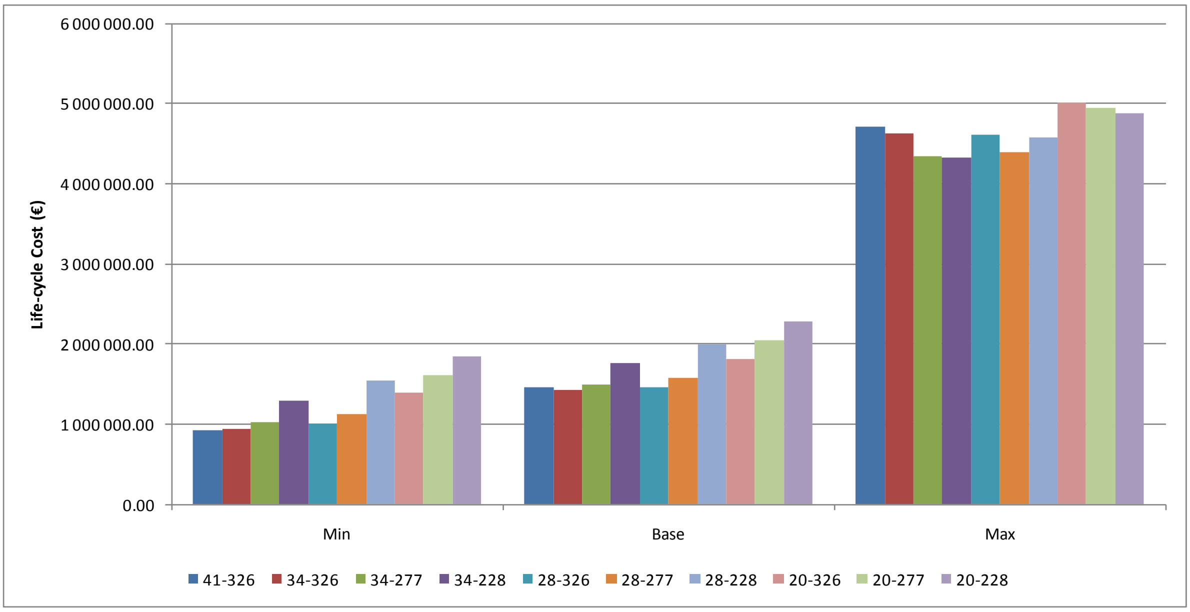


Figure 6-29: Base-case 4 and its improvement options – Impact of the load factor on the LCC

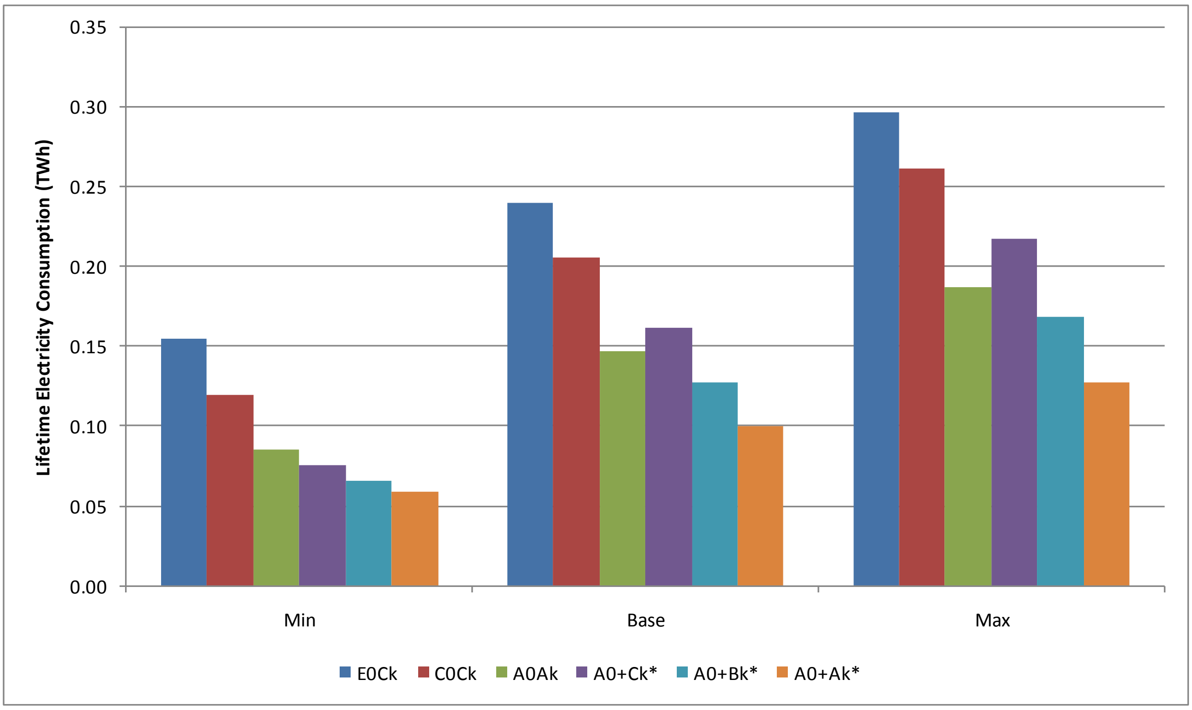


Figure 6-30: Base-case 5 and its improvement options – Impact of the load factor on the electricity consumption (in TWh)

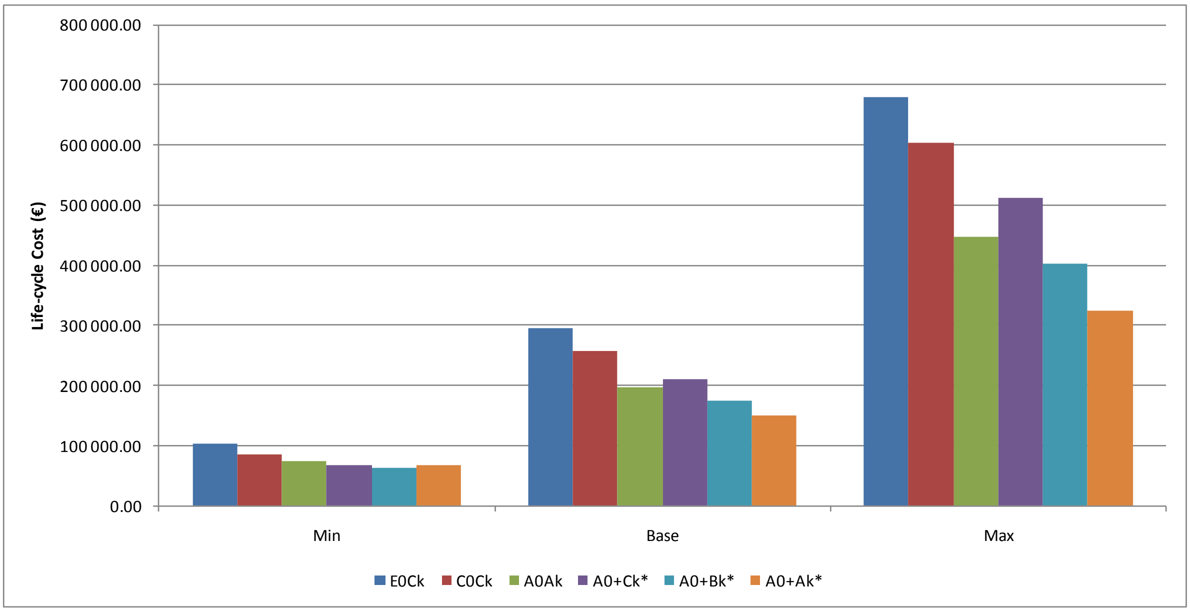


Figure 6-31: Base-case 5 and its improvement options – Impact of the load factor on the LCC

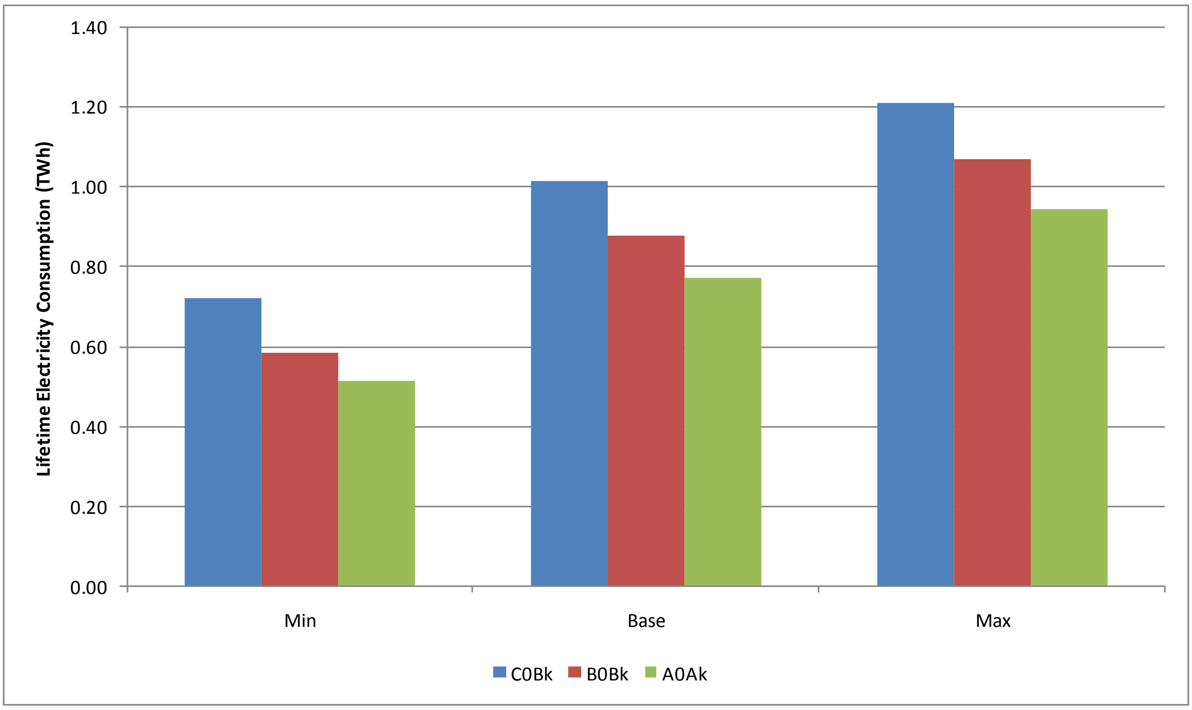


Figure 6-32: Base-case 6 and its improvement options – Impact of the load factor on the electricity consumption (in TWh)

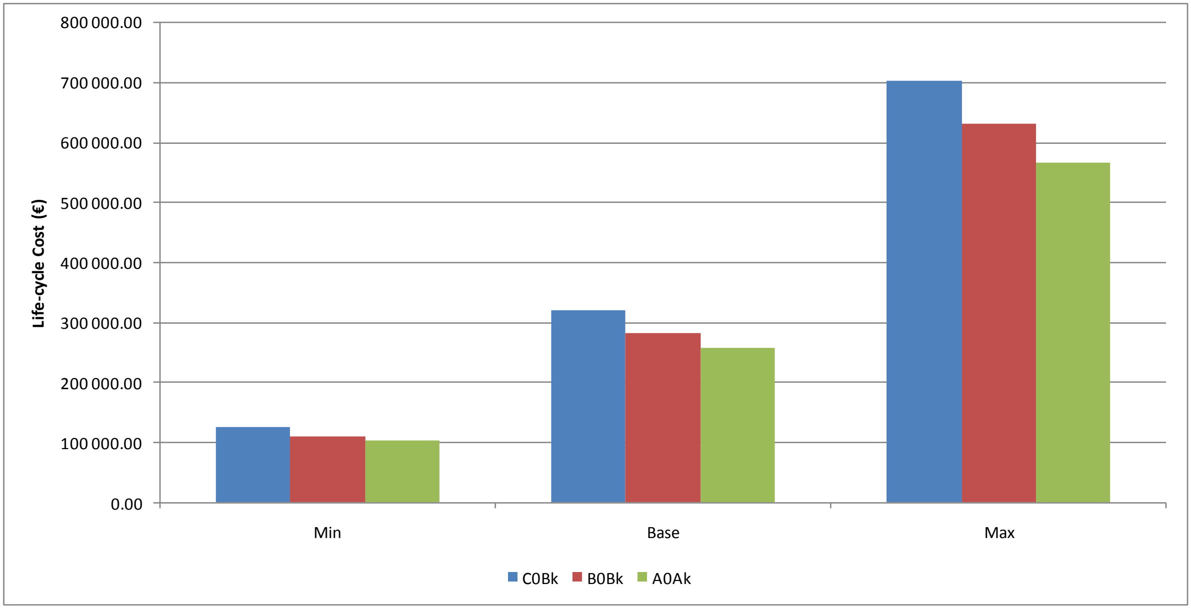


Figure 6-33: Base-case 6 and its improvement options – Impact of the load factor on the LCC

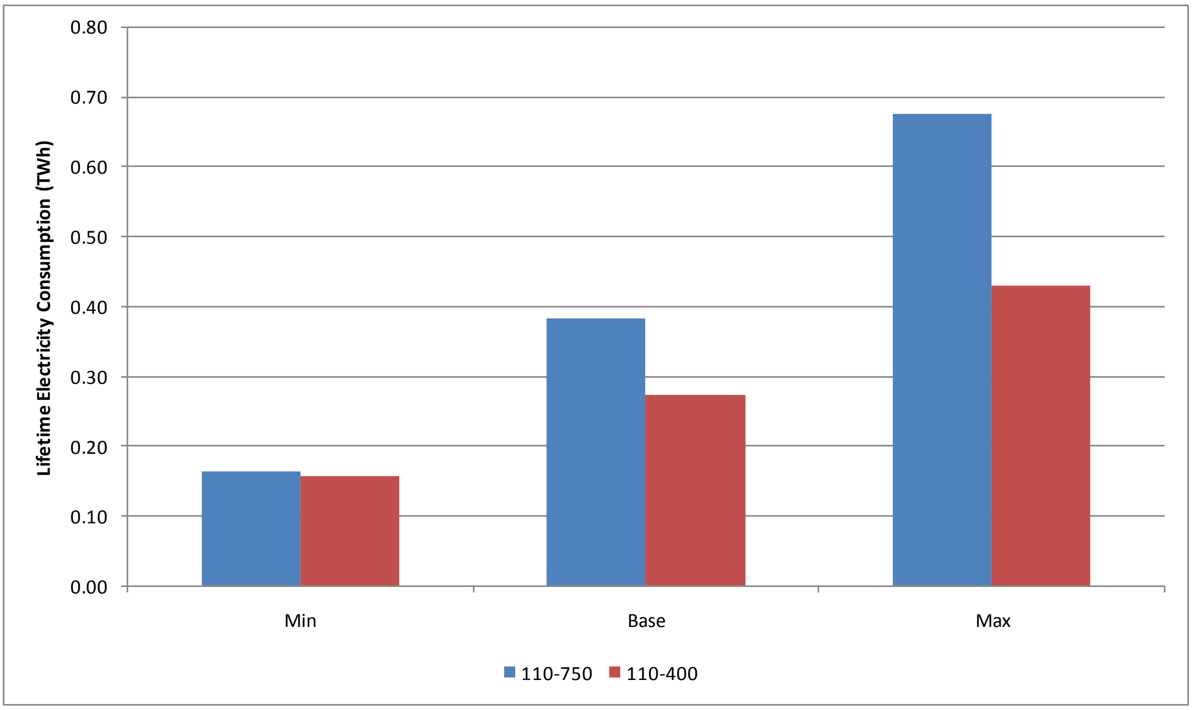


Figure 6-34: Base-case 7 and its improvement options – Impact of the load factor on the electricity consumption (in TWh)

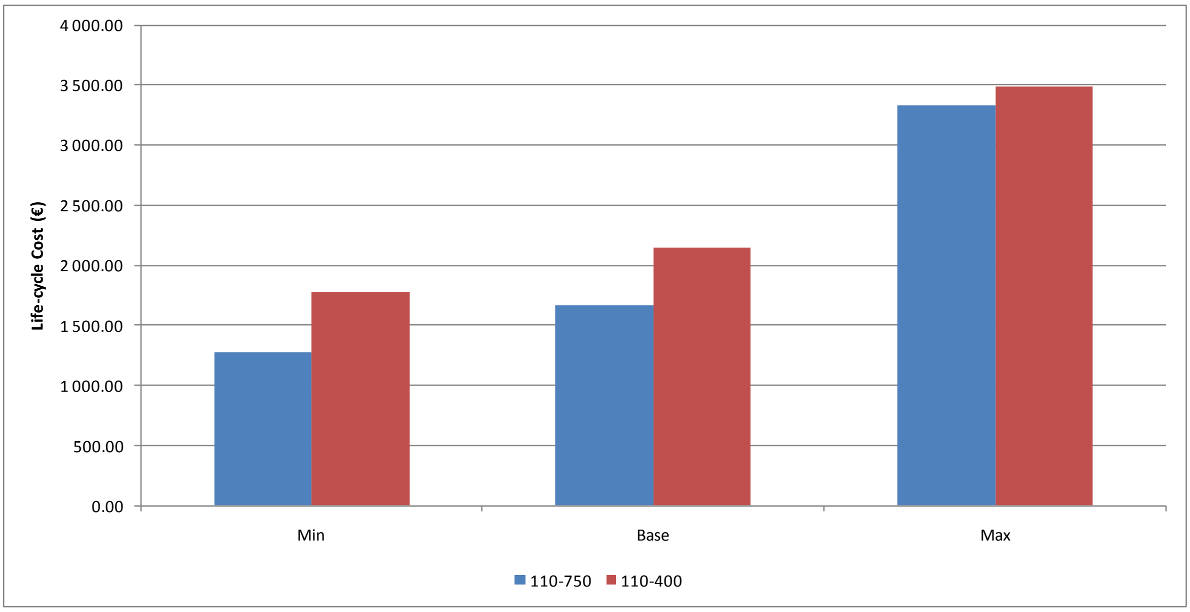


Figure 6-35: Base-case 7 and its improvement options – Impact of the load factor on the LCC

6.4.2 Assumptions related to the load form factor for DER transformers

For DER transformers, i.e. base-cases 5 (DER oil transformer) and 6 (DER dry transformer), the load form factor used for the environmental and economic assessment is 1.5. Figure 6-36 and Figure 6-39 present the electricity consumption of these two base-cases and their improvement options with other Kf values: 1.08 which corresponds to the load form factor for residential and industrial distribution grids, and 1.25 which is an intermediate value that could be reached for DER transformers in the coming years (all numbers are presented in Annex F). As the figures show, as load form factor increases, so too does electricity consumption. Despite this, the trends of the results of the improvement options are maintained.

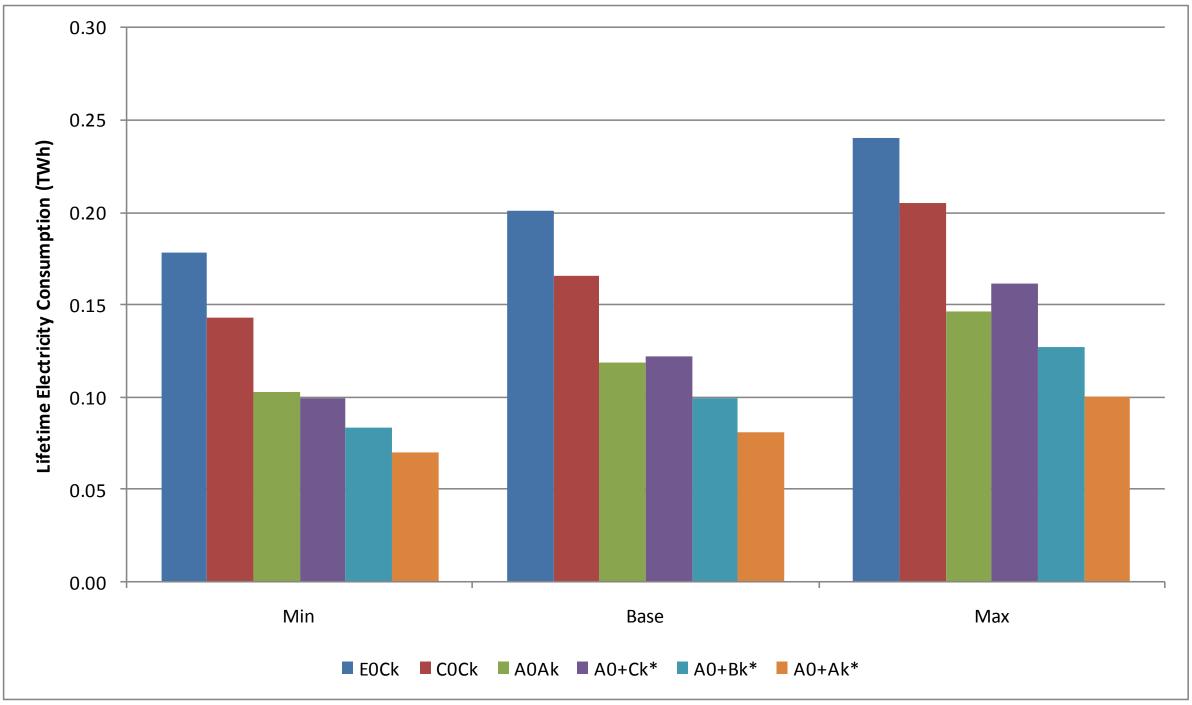


Figure 6-36: Base-case 5 and its improvement options – Impact of the load form factor on the electricity consumption (in TWh)

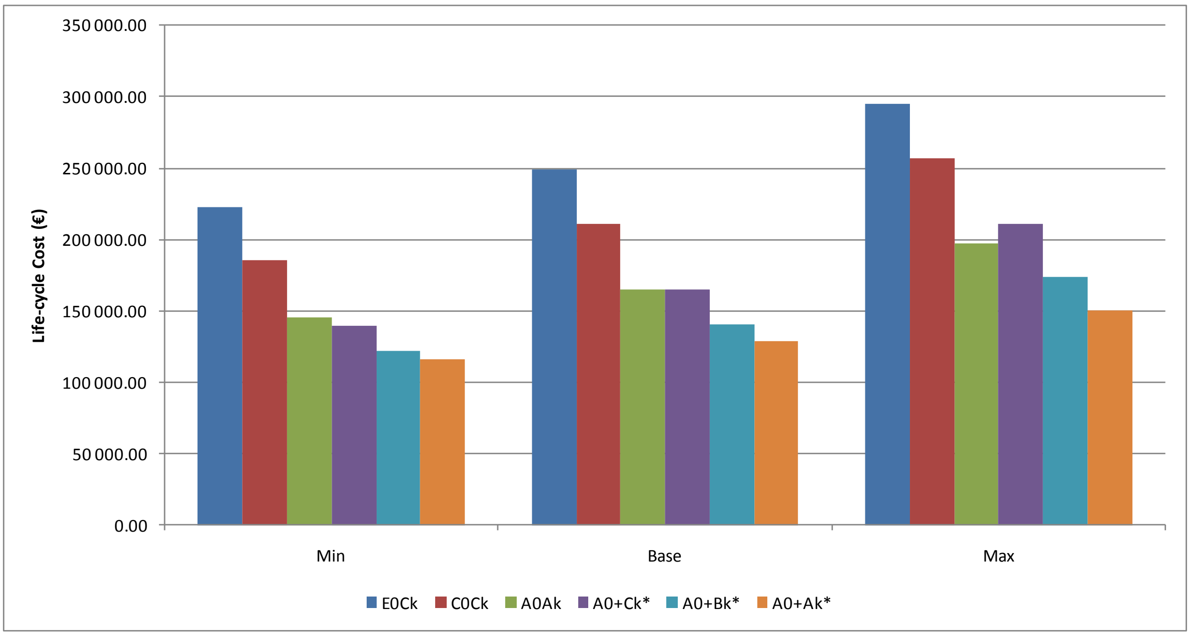


Figure 6-37: Base-case 5 and its improvement options – Impact of the load form factor on the LCC

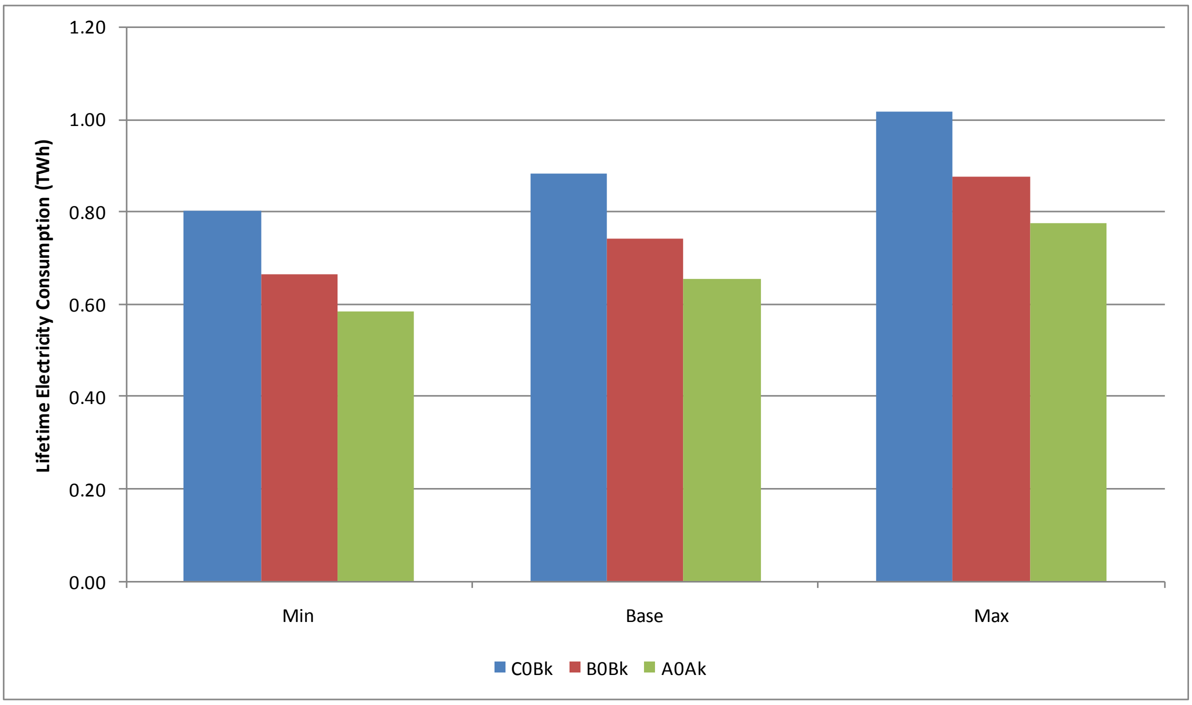


Figure 6-38: Base-case 6 and its improvement options – Impact of the load form factor on the electricity consumption (in TWh)

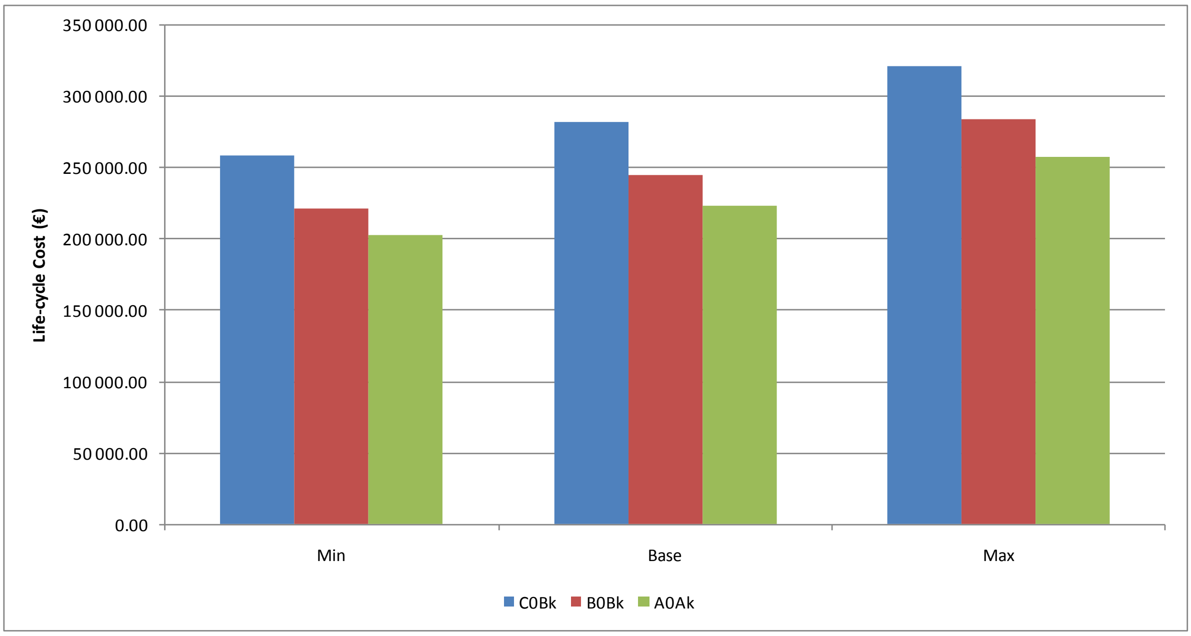


Figure 6-39: Base-case 6 and its improvement options – Impact of the load form factor on the LCC

6.4.3 Assumptions related to the lifetimes

Average lifetimes are used in the EcoReport tool to assess environmental and life cycle costs over the whole life cycle of transformers. As mentioned in Task 2, some products can have a shorter or a longer lifetime. These extreme values are presented in Table 6-

28 and used in this sensitivity analysis to analyse the impact of this parameter on the LCC of the base-cases and their electricity consumption during the use phase.

Table 6-28: Transformer lifetimes used in this study

Application	Base	Min	Max
Distribution	40	30	50
Industry oil	25	20	40
Industry dry	30	20	35
Power	30	25	35
DER (wind)	25	20	30
Small industry	10	10	20

Figure 6-40 to Figure 6-46 present for each base-case and its improvement options, the life cycle cost depending on the lifetimes specified in Table 6-28.

As lifetime increases, the economic advantage of more efficient becomes apparent. Despite this, the results of the improvement option analysis are maintained, with the LLCC option remaining the same for all base-cases.

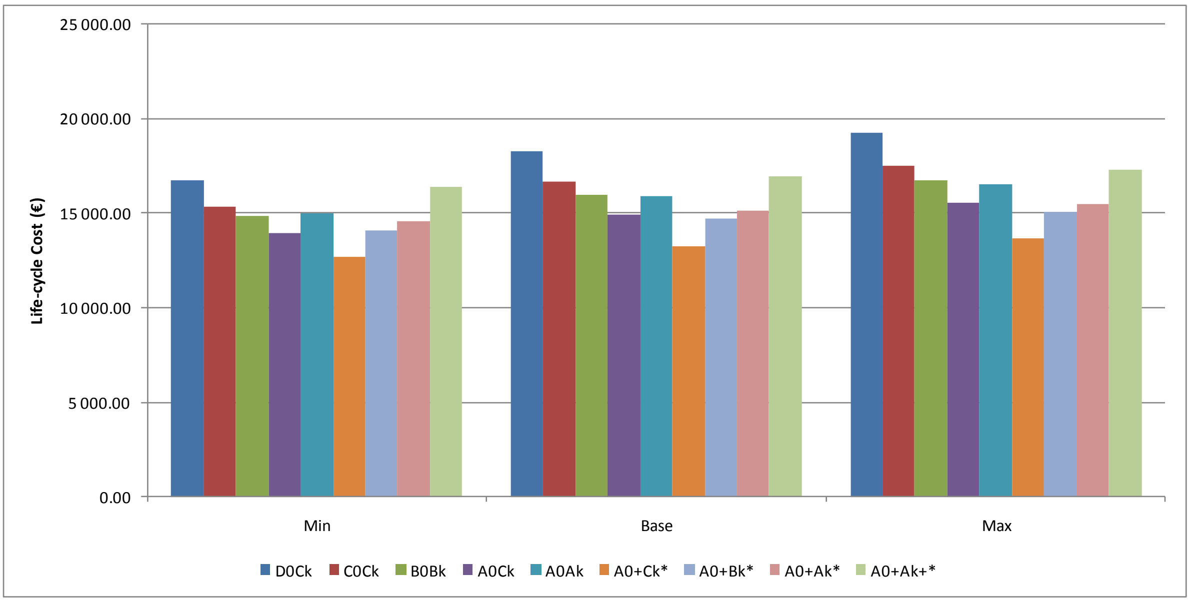


Figure 6-40: Base-case 1 and its improvement options – Impact of lifetime on the LCC

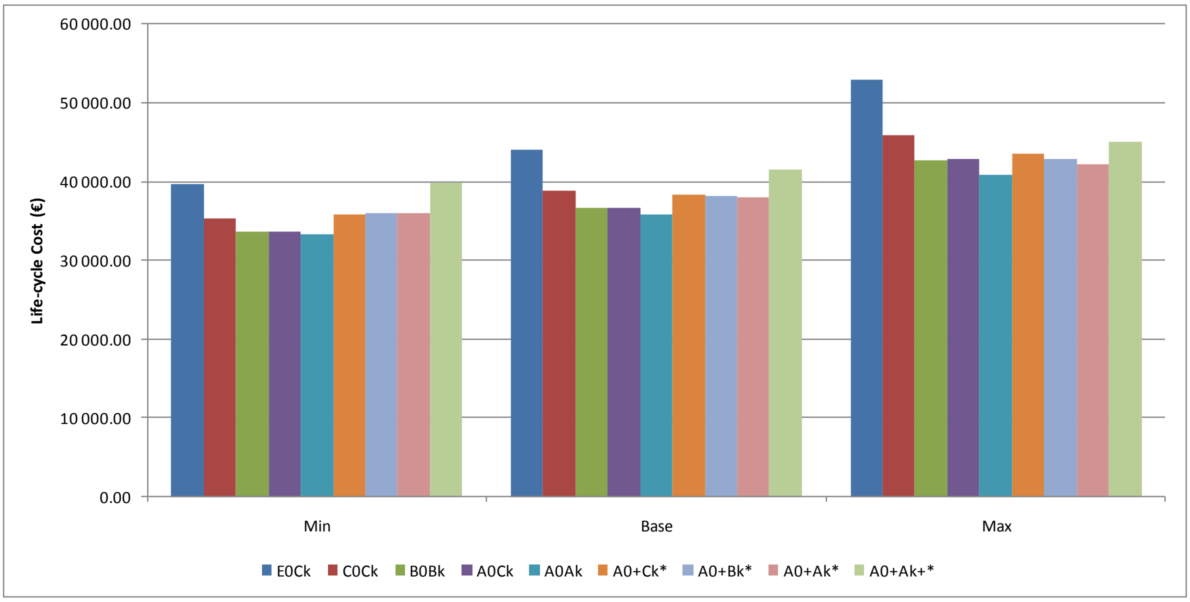


Figure 6-41: Base-case 2 and its improvement options – Impact of lifetime on the LCC

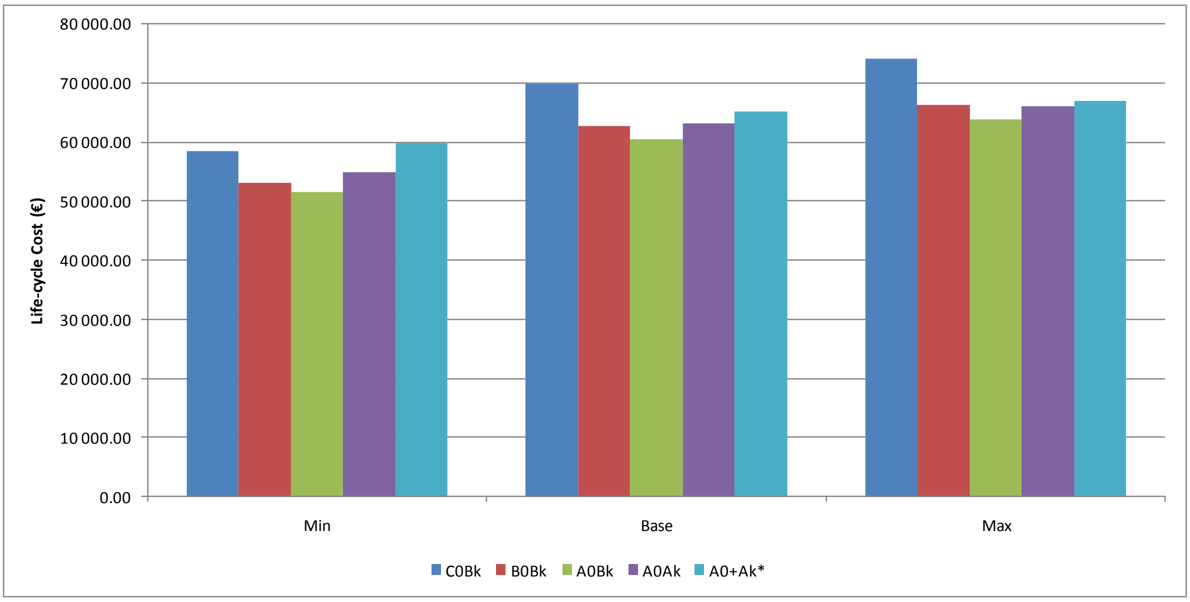


Figure 6-42: Base-case 3 and its improvement options – Impact of lifetime on the LCC

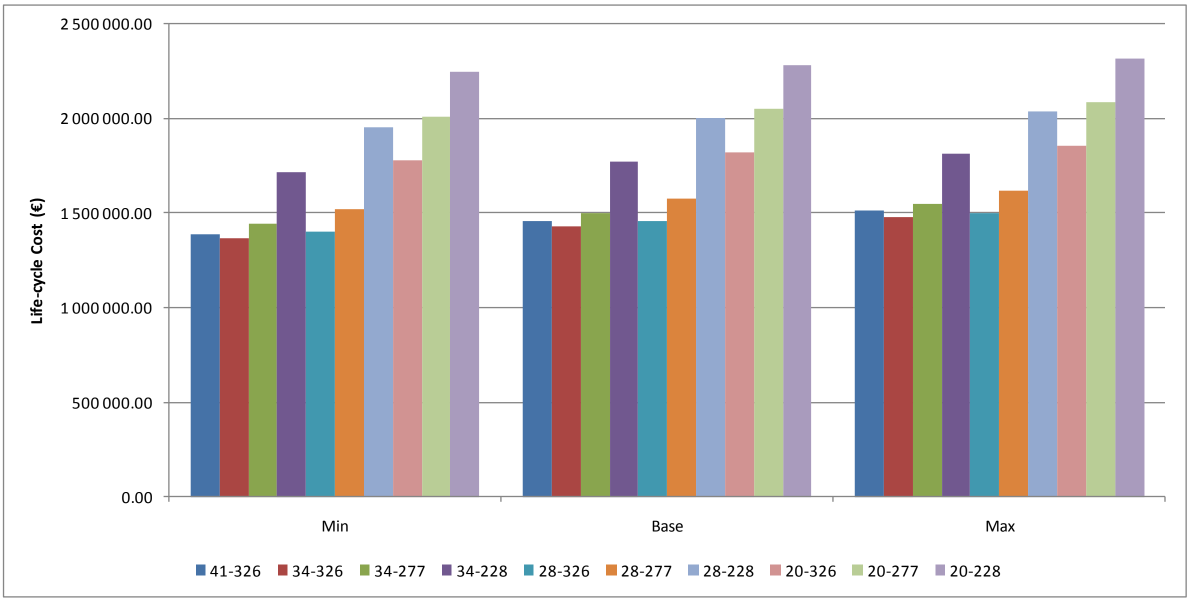


Figure 6-43: Base-case 4 and its improvement options – Impact of lifetime on the LCC

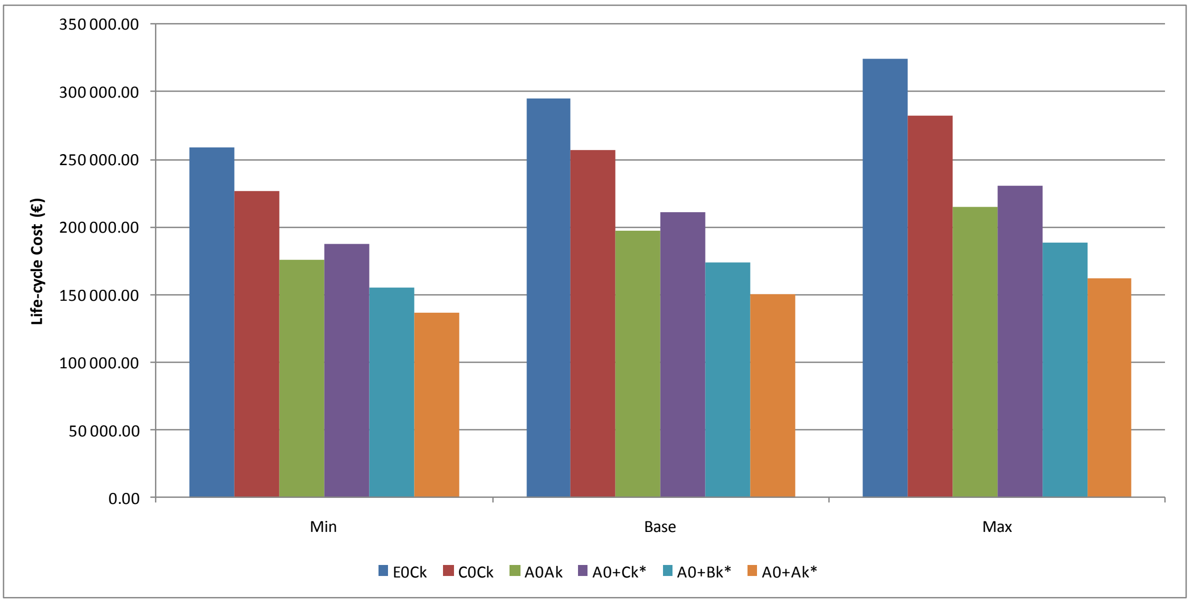


Figure 6-44: Base-case 5 and its improvement options – Impact of lifetime on the LCC

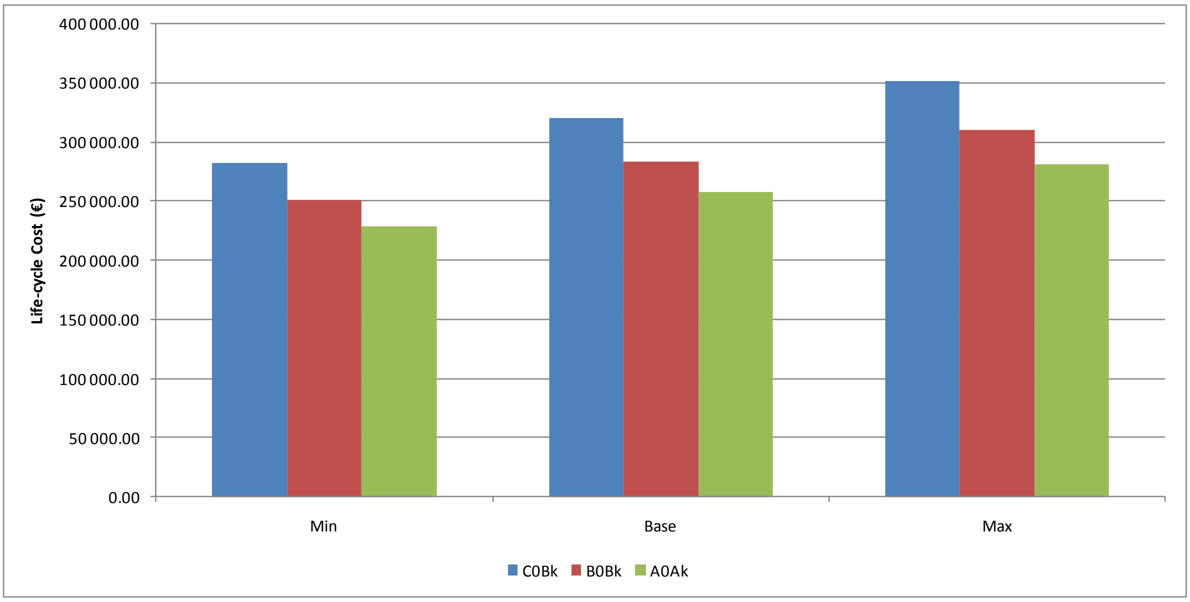


Figure 6-45: Base-case 6 and its improvement options – Impact of lifetime on the LCC

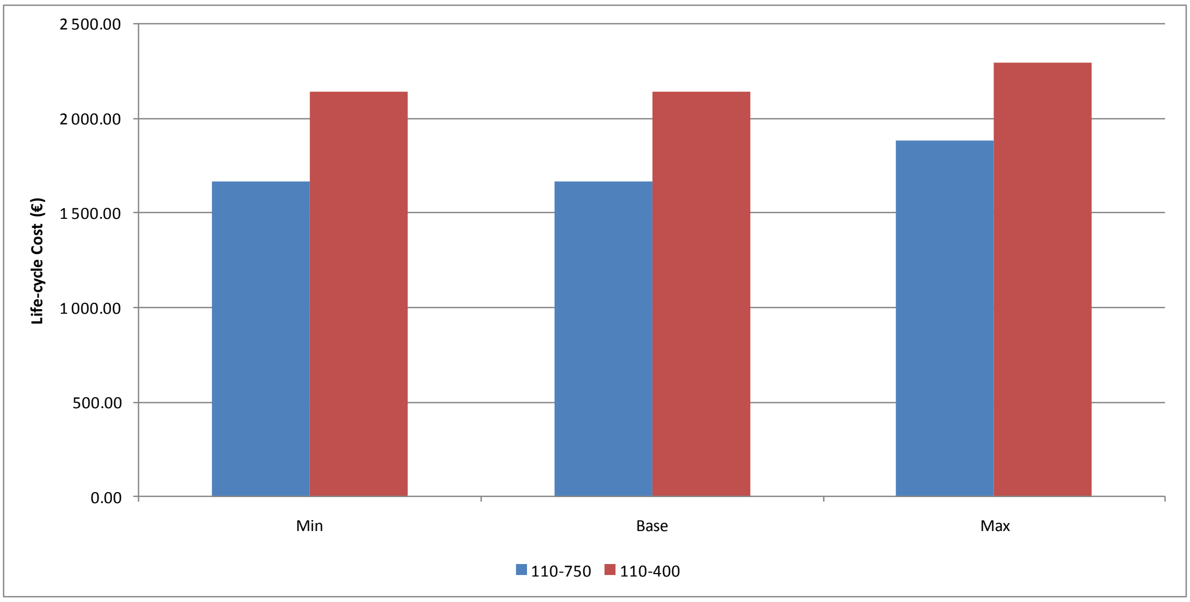


Figure 6-46: Base-case 7 and its improvement options – Impact of lifetime on the LCC

6.4.4 Assumptions related to the electricity tariff and the discount rate

For the non-DER transformers, an average EU-27 electricity tariff of 0.078 €/kWh was used, based on the data from Eurostat. However, if the lowest electricity tariff (i.e. 0.038 €/kWh in Estonia) and the highest electricity tariff (i.e. 0.108 €/kWh in Ireland) are applied, this could lead to different LCC for the base-cases and their improvement options. The same reasoning is applicable for DER transformers (base-cases 5 and 6) when an electricity tariff of 0.4 or 0.2 €/kWh is used (see Table 6-29).

In the same way, the discount rate (interest minus inflation rate) influences the life cycle cost calculation. The services of the European Commission proposed to use a 4%

discount rate for the economic assessment of the base-cases and their improvement options. An increase/decrease by 2% of this parameter is applied for the sensitivity analysis.

Table 6-29: Assumptions related to electricity tariff and discount rate

	Average (used in Task 4 and 6)	**MIN**	**MAX**
Electricity tariff, except for DER transformers (€/kWh)	0.078	0.038 (Estonia)	0.108 (Ireland)
Electricity tariff for DER transformers (€/kWh)	0.3	0.2	0.4
Discount rate (%)	4	2	6

Figure 6-47 to Figure 6-60 present the LCC of each base-case and its improvement options with the basic assumptions and with the extreme values of electricity tariff and discount rate (all numbers are presented in Annex F).

As electricity rate increases, more efficient transformers become more economical, reducing their LCC relative to less efficient models. An increase in discount rate has the opposite effect, as a low discount rate provides little incentive to invest in expensive efficient transformers. The trends of the analysis of the base-case improvement options hold, though in the cases of base-cases 2 and 4, the LLCC option changes very slightly with the variation in input parameters.

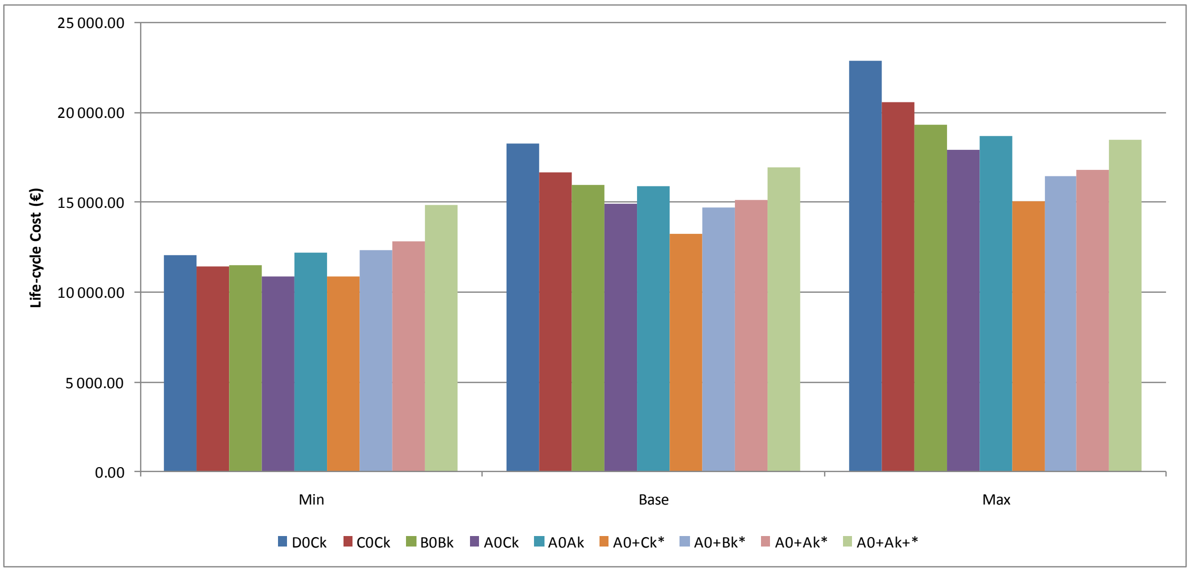


Figure 6-47: Base-case 1 and its improvement options – Impact of the electricity tariff on the LCC

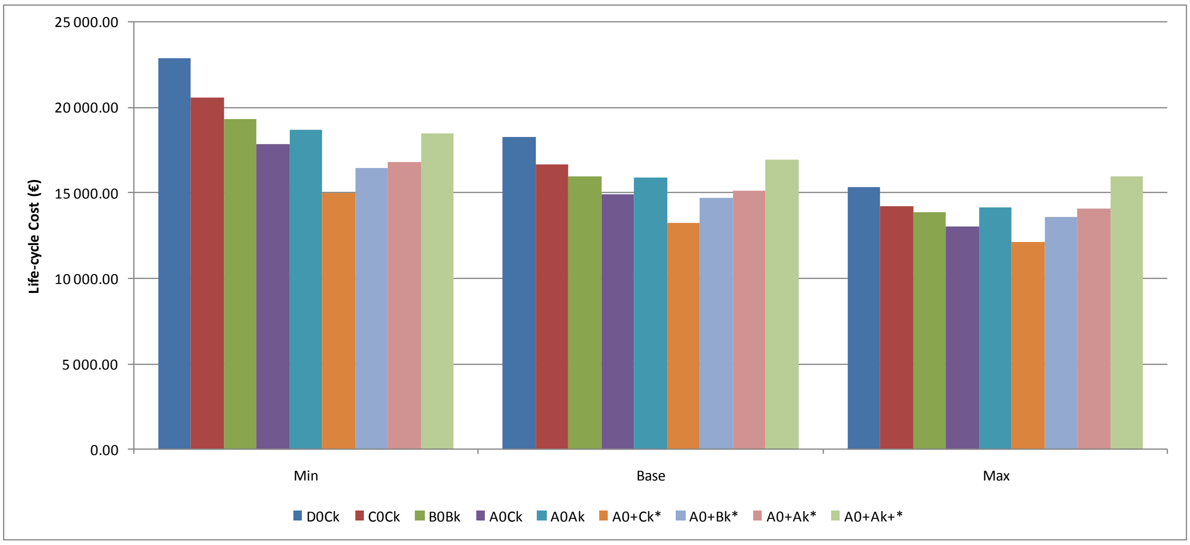


Figure 6-48: Base-case 1 and its improvement options – Impact of the discount rate on the LCC

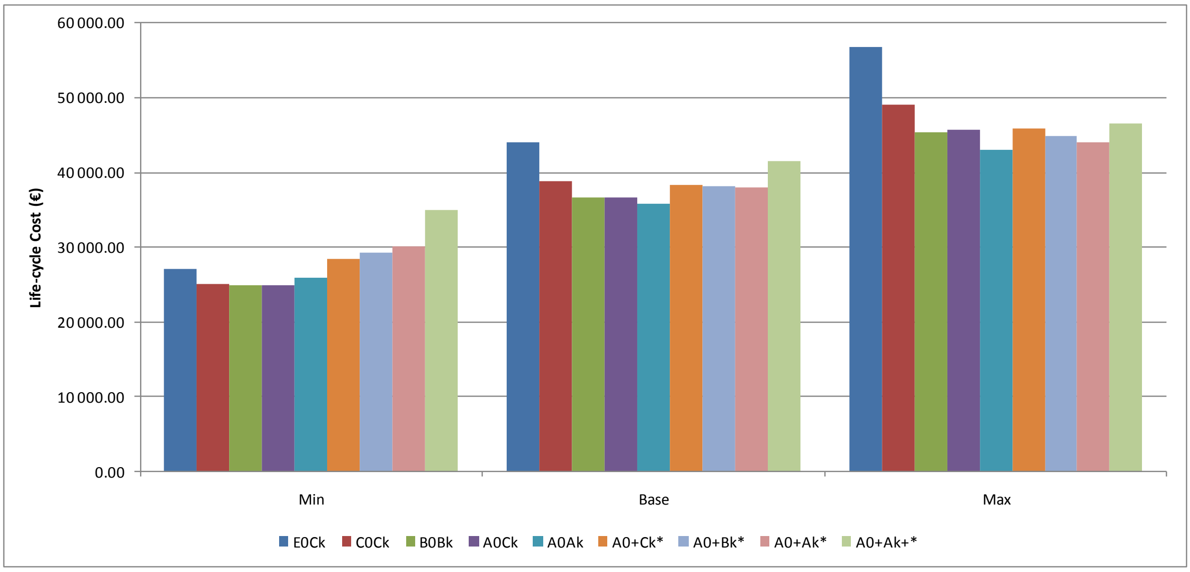


Figure 6-49: Base-case 2 and its improvement options – Impact of the electricity tariff on the LCC

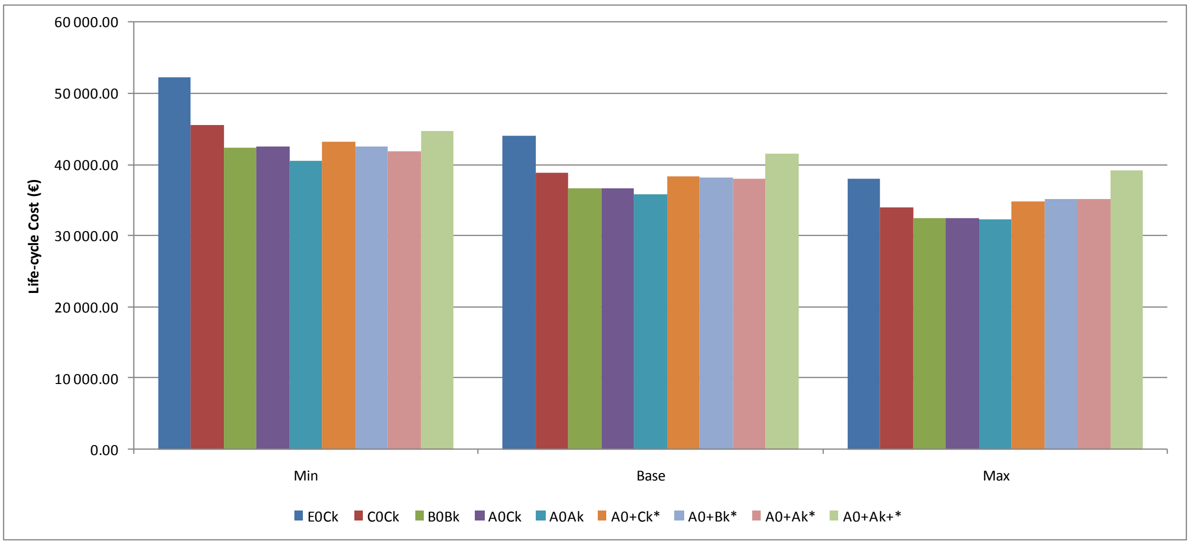


Figure 6-50: Base-case 2 and its improvement options – Impact of the discount rate on the LCC

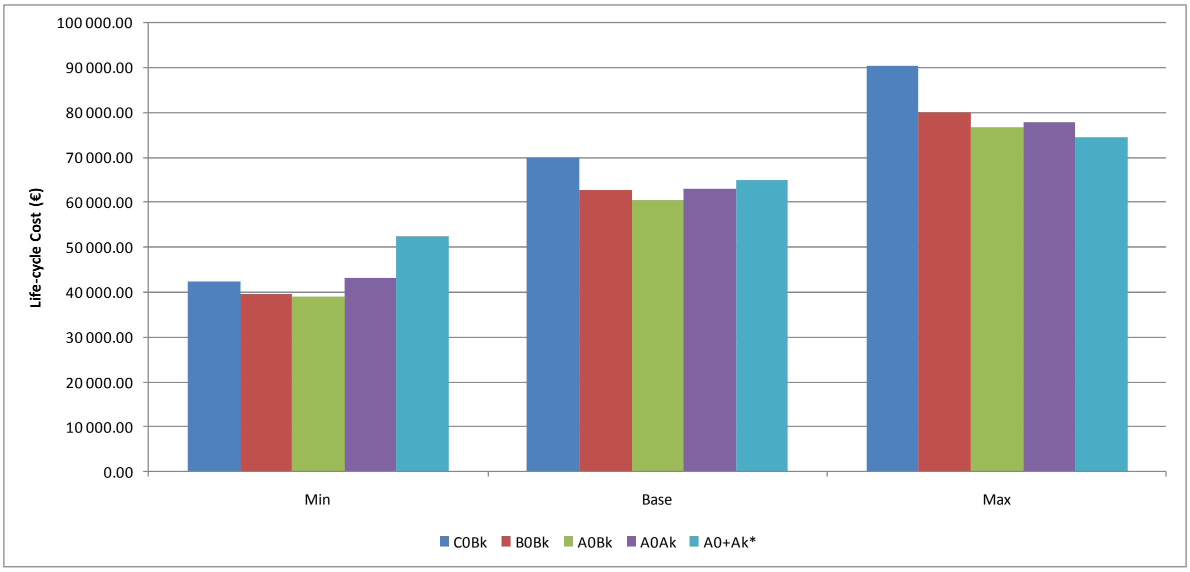


Figure 6-51: Base-case 3 and its improvement options – Impact of the electricity tariff on the LCC

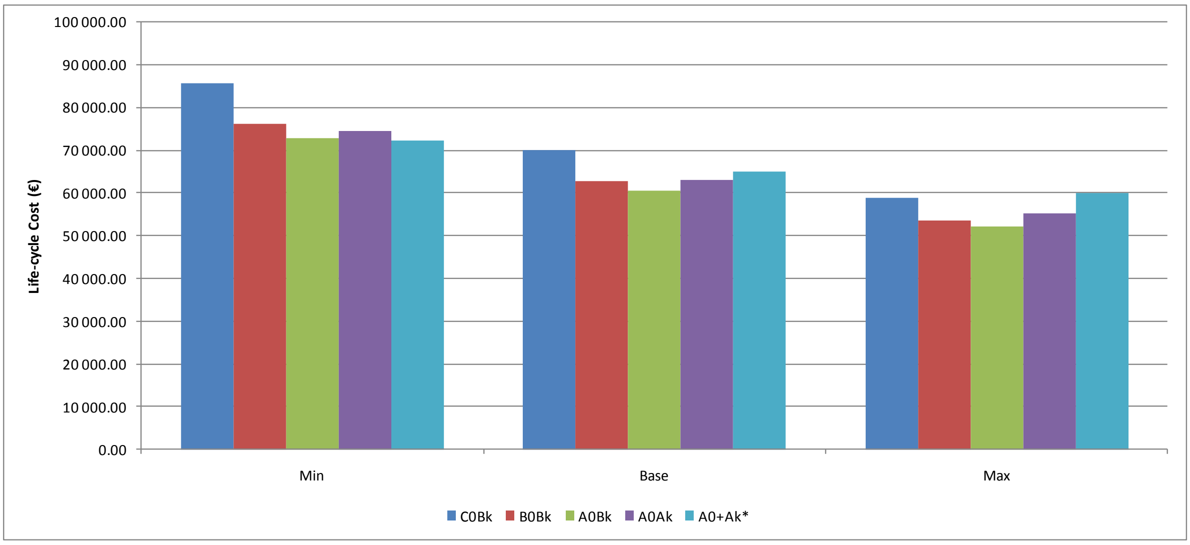


Figure 6-52: Base-case 3 and its improvement options – Impact of the discount rate on the LCC

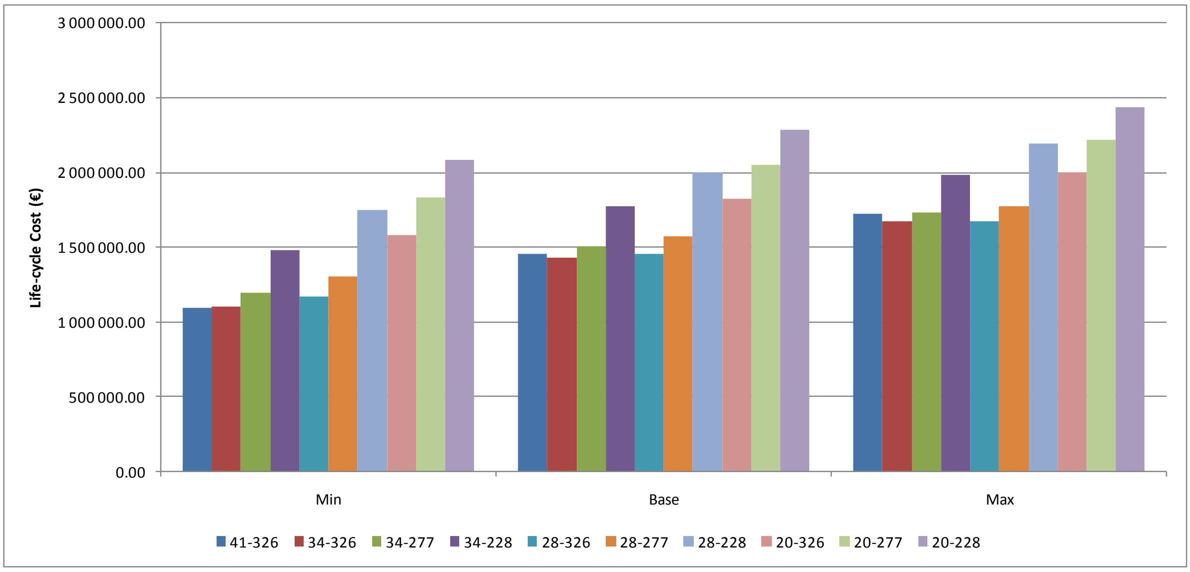


Figure 6-53: Base-case 4 and its improvement options – Impact of the electricity tariff on the LCC

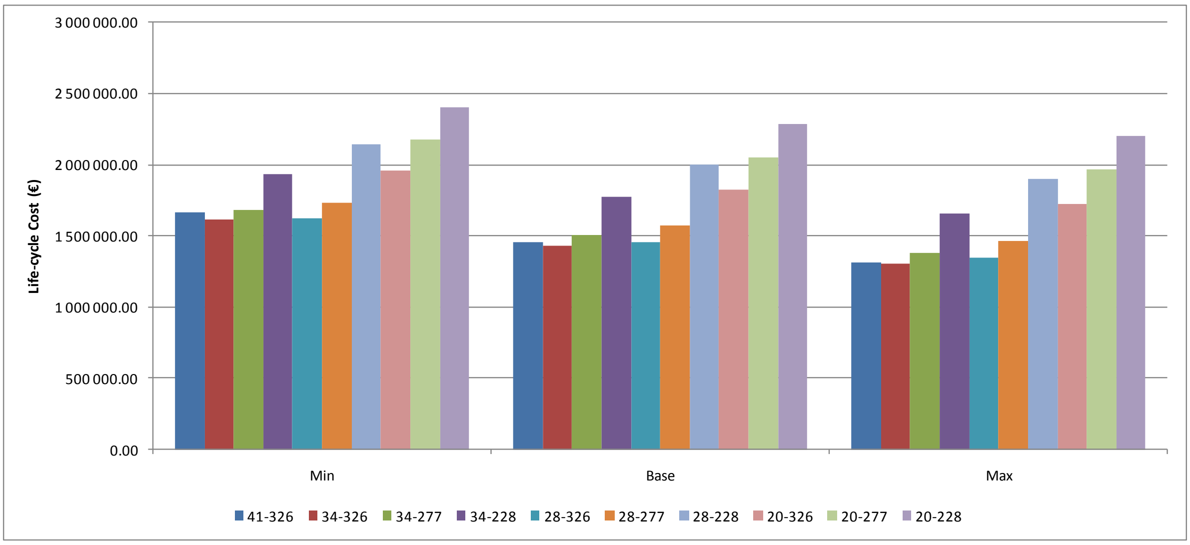


Figure 6-54: Base-case 4 and its improvement options – Impact of the discount rate on the LCC

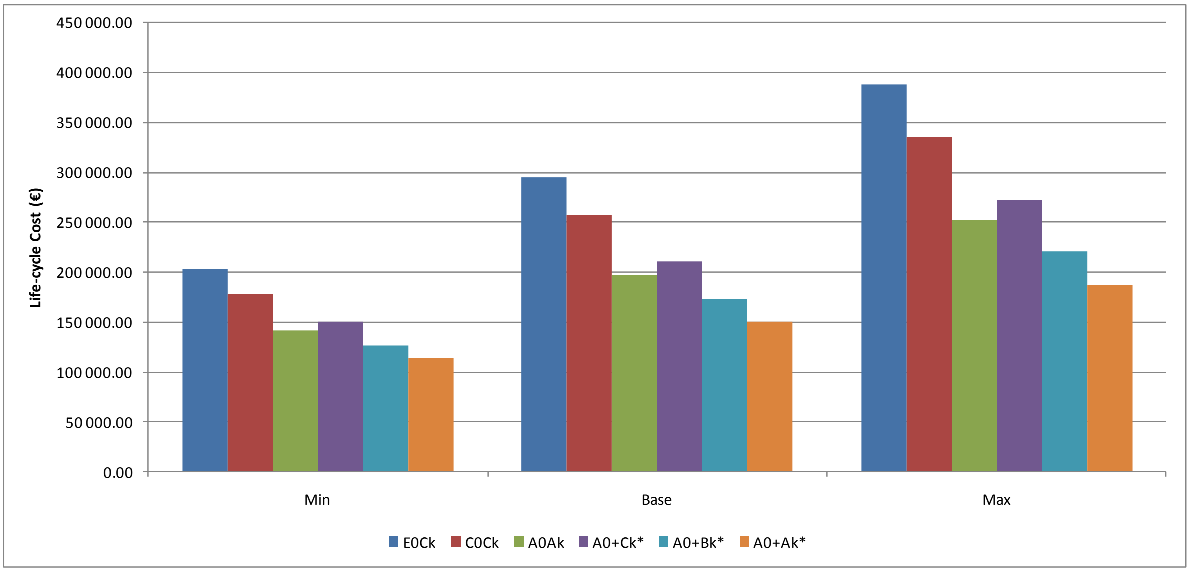


Figure 6-55: Base-case 5 and its improvement options – Impact of the electricity tariff on the LCC

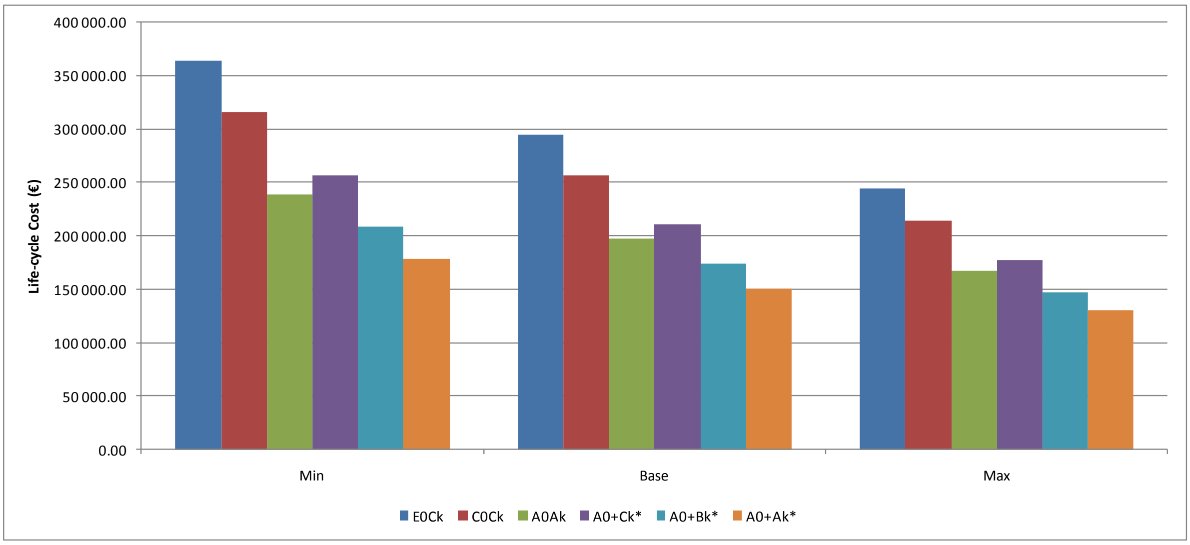


Figure 6-56: Base-case 5 and its improvement options – Impact of the discount rate on the LCC

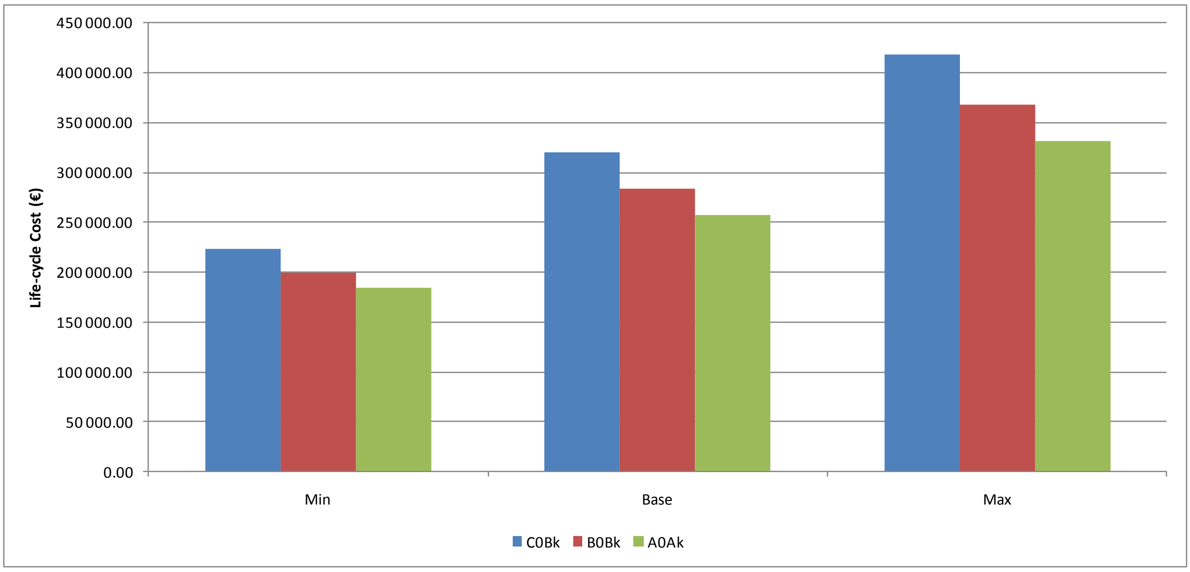


Figure 6-57: Base-case 6 and its improvement options – Impact of the electricity tariff on the LCC

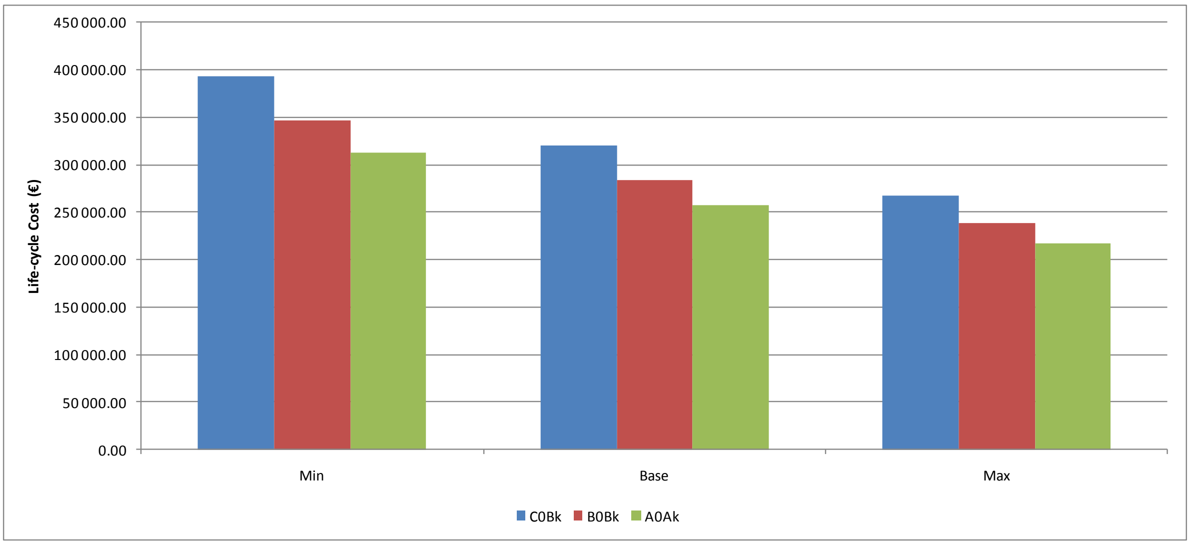


Figure 6-58: Base-case 6 and its improvement options – Impact of the discount rate on the LCC

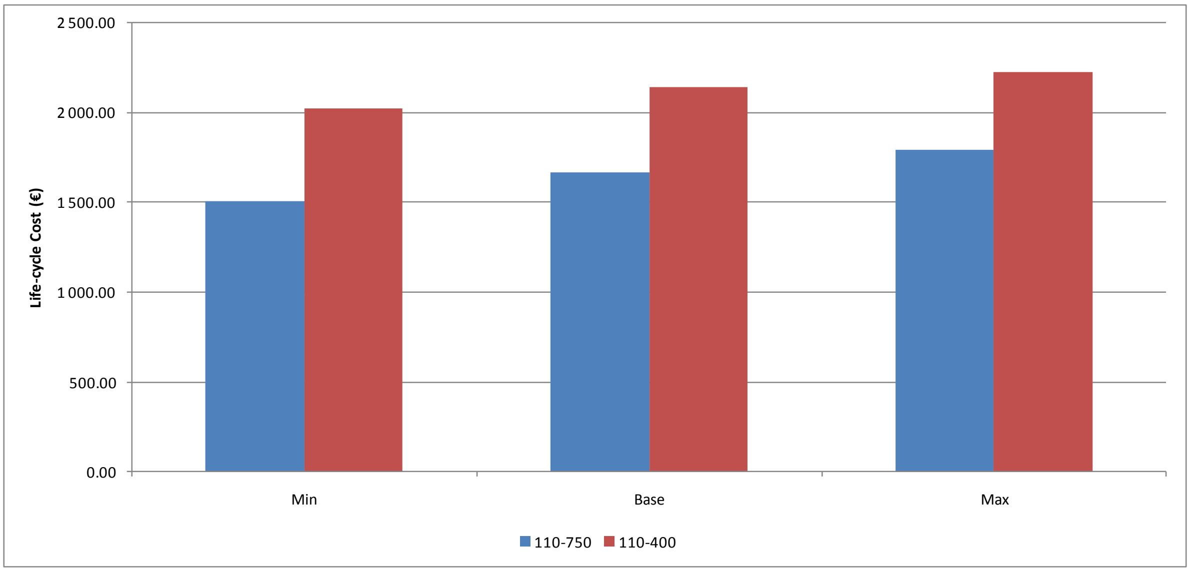


Figure 6-59: Base-case 7 and its improvement options – Impact of the electricity tariff on the LCC

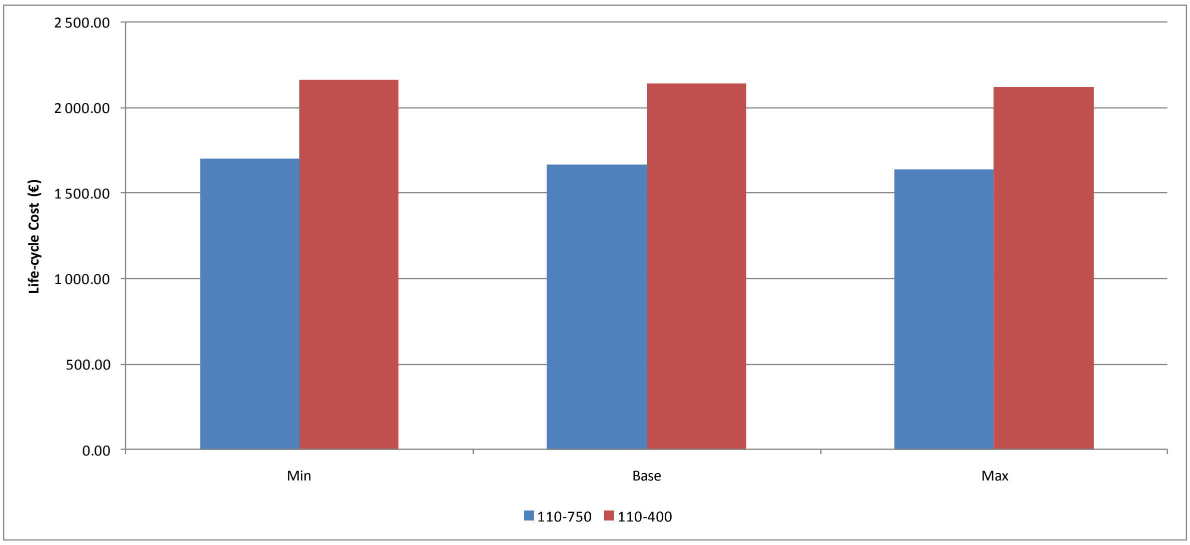


Figure 6-60: Base-case 7 and its improvement options – Impact of the discount rate on the LCC

6.4.5 Assumptions related to the price of base-cases

The price of a transformer mainly depends on the price of the raw materials. As the market and the price of raw materials are dynamic, a sensitivity analysis on the transformer price is required.

Compared to the product price defined for base-cases, 3 scenarios where defined:

- An increase of 10%
- A decrease of 10%
- An increase of 30%

Figure 6-61 to Figure 6-67 present the LCC of the base-cases and their improvement options with different base-case product prices. As product price increases, naturally LCC increases as well. The trends of the base-case improvement option analysis remain despite the variation of input.

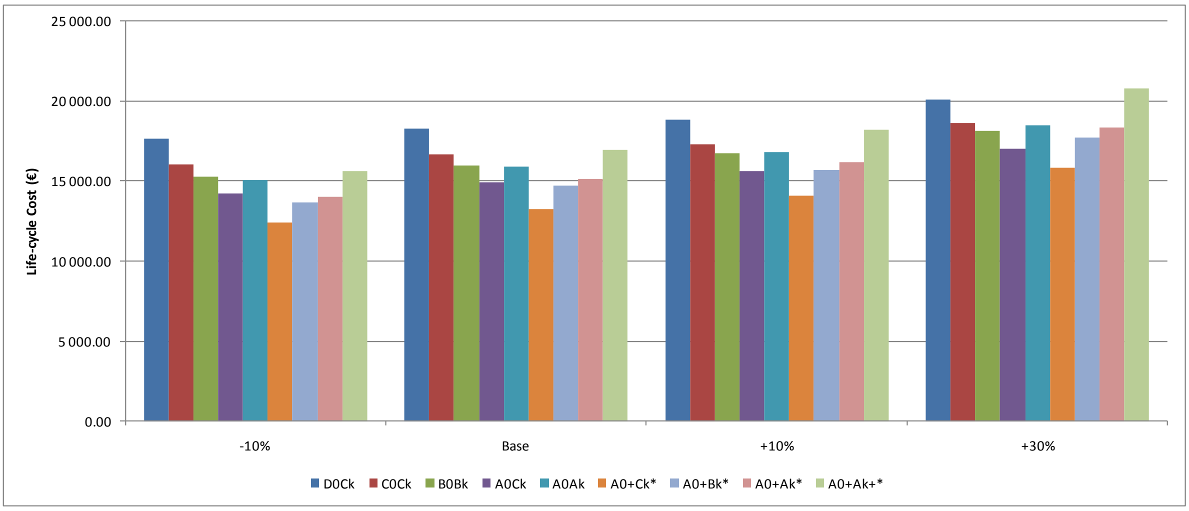


Figure 6-61: Base-case 1 and its improvement options – Impact of product price of the base-case on the LCC

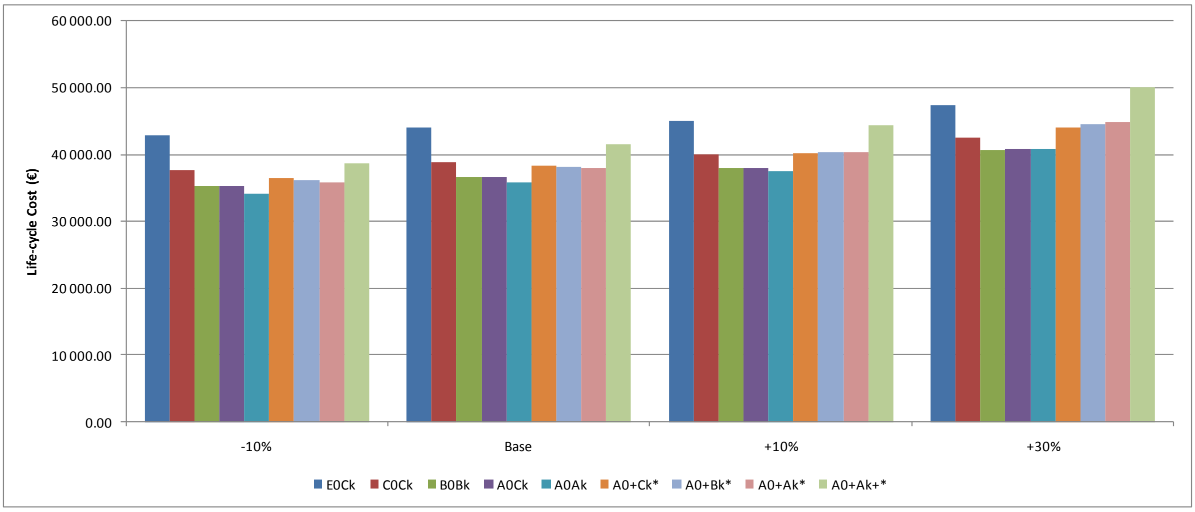


Figure 6-62: Base-case 2 and its improvement options – Impact of product price of the base-case on the LCC

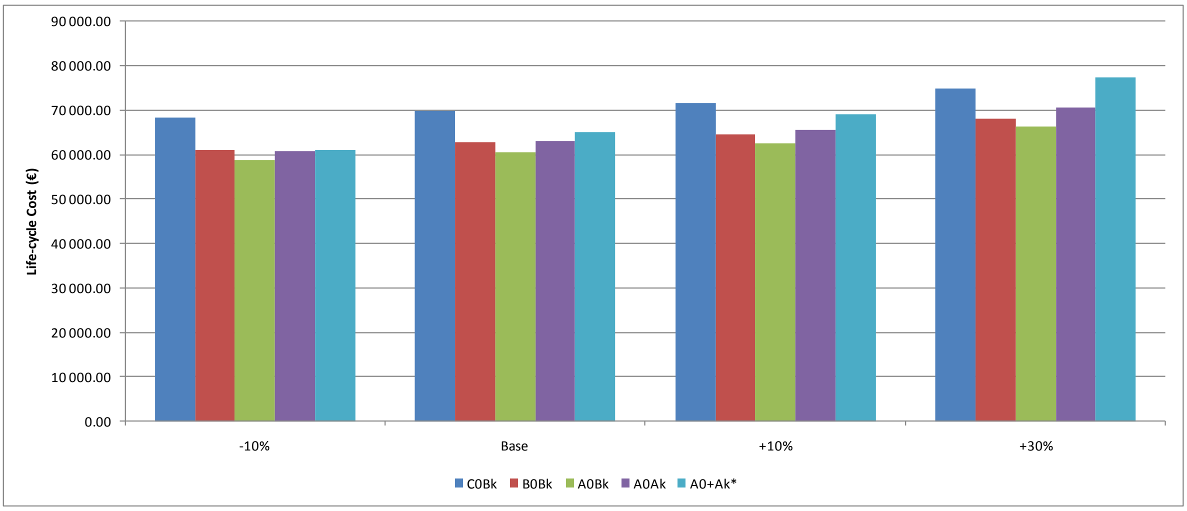


Figure 6-63: Base-case 3 and its improvement options – Impact of product price of the base-case on the LCC

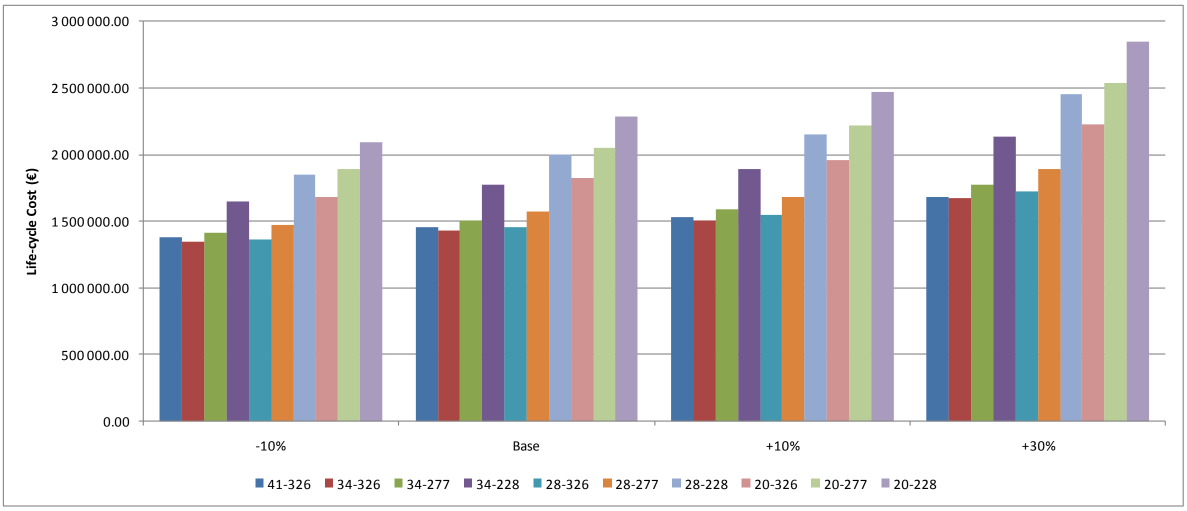


Figure 6-64: Base-case 4 and its improvement options – Impact of product price of the base-case on the LCC

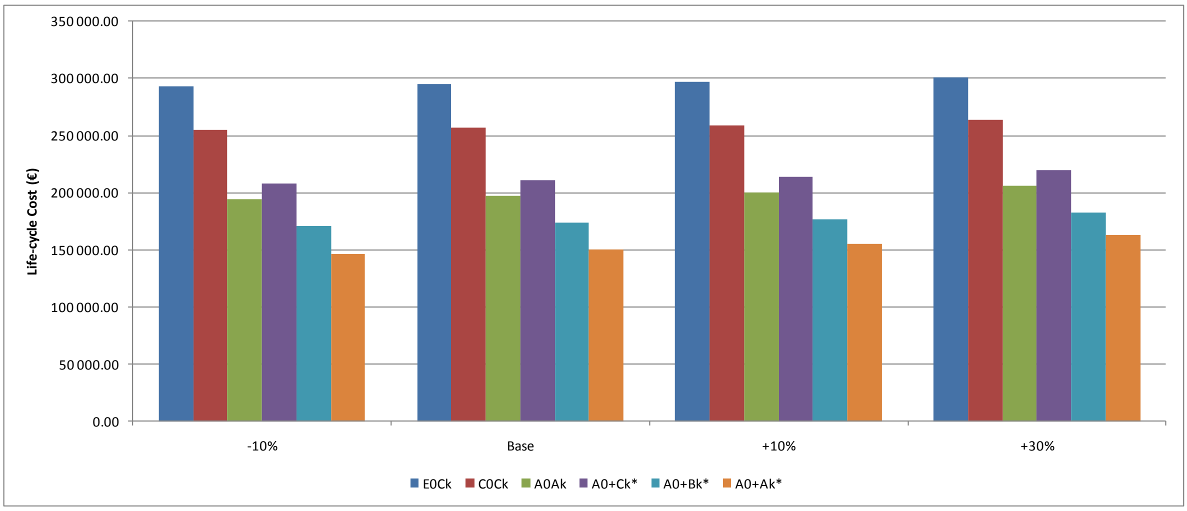


Figure 6-65: Base-case 5 and its improvement options – Impact of product price of the base-case on the LCC

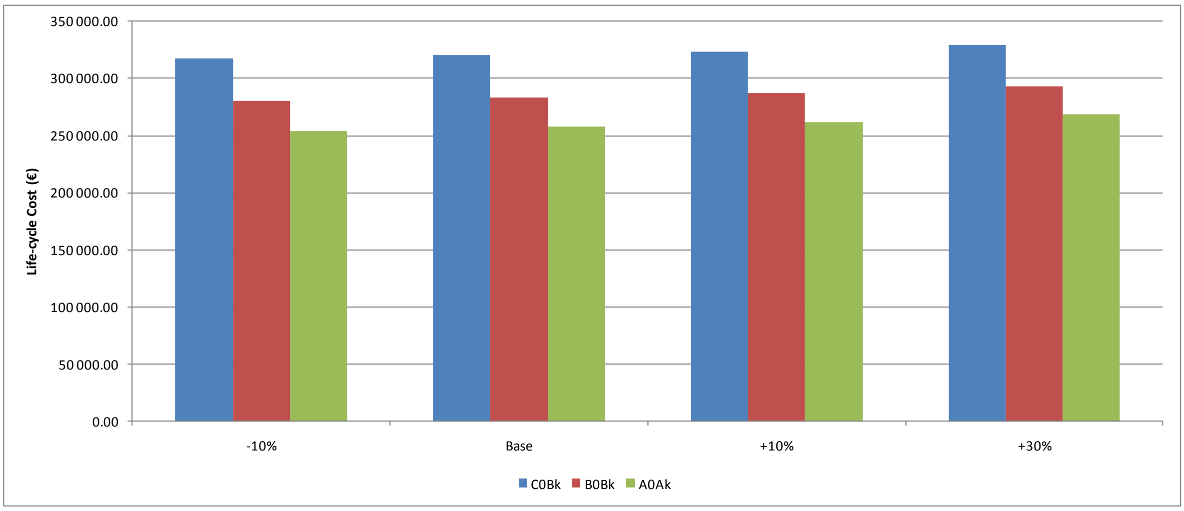


Figure 6-66: Base-case 6 and its improvement options – Impact of product price of the base-case on the LCC

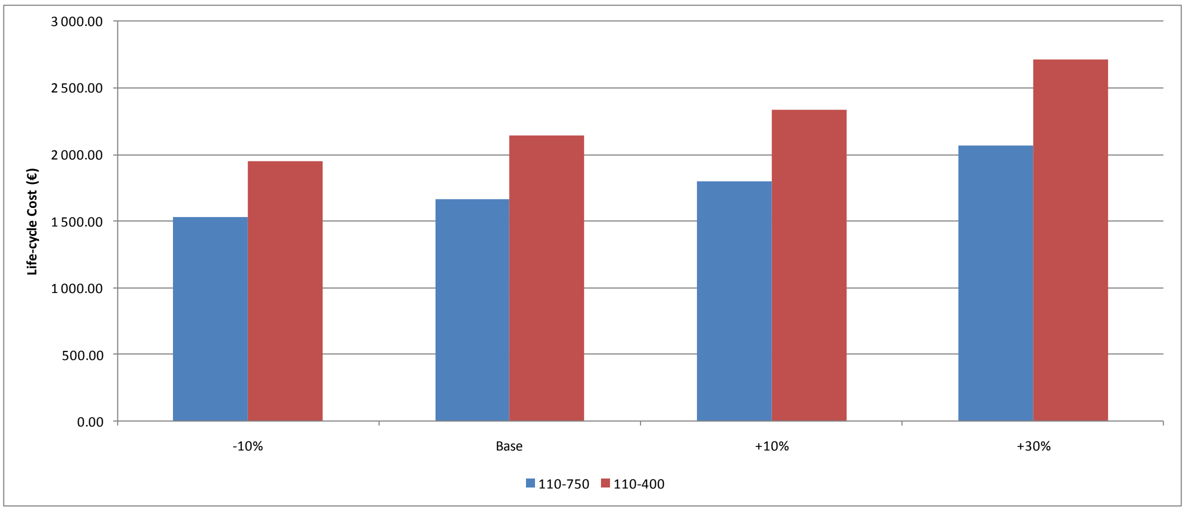


Figure 6-67: Base-case 7 and its improvement options – Impact of product price of the base-case on the LCC

6.4.6 Assumptions related to the installed stocks

Estimating the stock of transformers is not an easy task as there is no market study available, and that the market is quite fragmented.

In a draft of Task 2, first estimates were proposed as presented in Table 6-30 ("Initial data"). Then, based on stakeholders' comments and trends in electricity consumption, stock data for base-cases BC1, BC2, and BC3 were normalised. Therefore, if the initial stock values were used, the electricity consumption of transformers included in the scope of this study would have been 30% higher (93 TWh vs. 72 TWh).

Table 6-30: EU stock of some transformers types

EU stock (units)	***BC1 Distribution***	***BC2 Industry oil***	***BC3 Industry dry***
Updated data	2 250 000	504 000	108 800
Initial data	3 600 000	800 000	170 000

6.4.7 Extreme scenarii for the sensitivity analysis

Previous sections present an individual sensitivity analysis for various parameters. In this section, a combined sensitivity analysis is carrying out for all parameters previously assessed (except stock data which does not have an influence of the LCC of the base-cases and their improvement options).

For each parameter, two values were chosen:

- One leading to the lowest reduction of the LCC compared to the base-case (scenario called Min in Table 6-31)

- One leading to the highest reduction of the LCC compared to the base-case (scenario called Max in Table 6-31)

Note that for the parameter of discount rate, the max value of discount rate actually leads to a lower LCC. Thus, the max value of discount rate is used for the min output scenario, and likewise the min value of discount rate is used for the max output scenario.

Table 6-31: Parameters used for the extreme scenarii of the sensitivity analysis

		BC1	BC2	BC3	BC4	BC5	BC6	BC7
Load factor	**Min**	0.1	0.1	0.1	0.2	0.2	0.2	0.1
	Base	0.15	0.3	0.3	0.2	0.25	0.25	0.4
	Max	0.25	0.6	0.6	0.5	0.3	0.3	0.6
Load form factor	**Min**	1.5	1.5	1.5	1.5	1.08	1.08	1.5
	Base	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	Max	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Lifetime	**Min**	30	20	20	25	20	20	10
	Base	40	25	30	30	25	25	10
	Max	50	40	35	35	30	30	20
Electricity tariff	**Min**	0.038	0.038	0.038	0.038	0.2	0.2	0.038
	Base	0.078	0.078	0.078	0.078	0.3	0.3	0.078
	Max	0.108	0.108	0.108	0.108	0.4	0.4	0.108
Discount rate	**Min**	6%	6%	6%	6%	6%	6%	6%
	Base	4%	4%	4%	4%	4%	4%	4%
	Max	2%	2%	2%	2%	2%	2%	2%
Price	**Min**	90%	90%	90%	90%	90%	90%	90%
	Base	100%	100%	100%	100%	100%	100%	100%
	Max	130%	130%	130%	130%	130%	130%	130%

These extreme scenarii are presented in Figure 6-68 to Figure 6-74 for each base-case (all values are included in Annex F). The results indicate large variation depending upon the specific characteristics of the options being compared. In most cases, the LLCC changes depending upon the extremes.

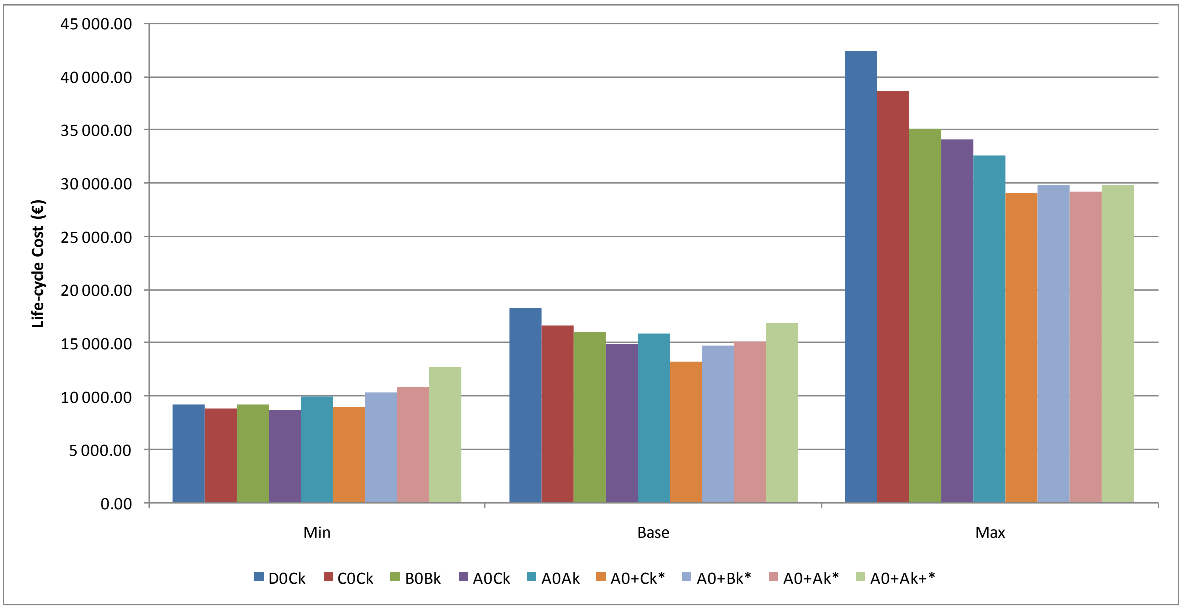


Figure 6-68: Base-case 1 and its improvement options – Impact of extreme scenarii on the LCC

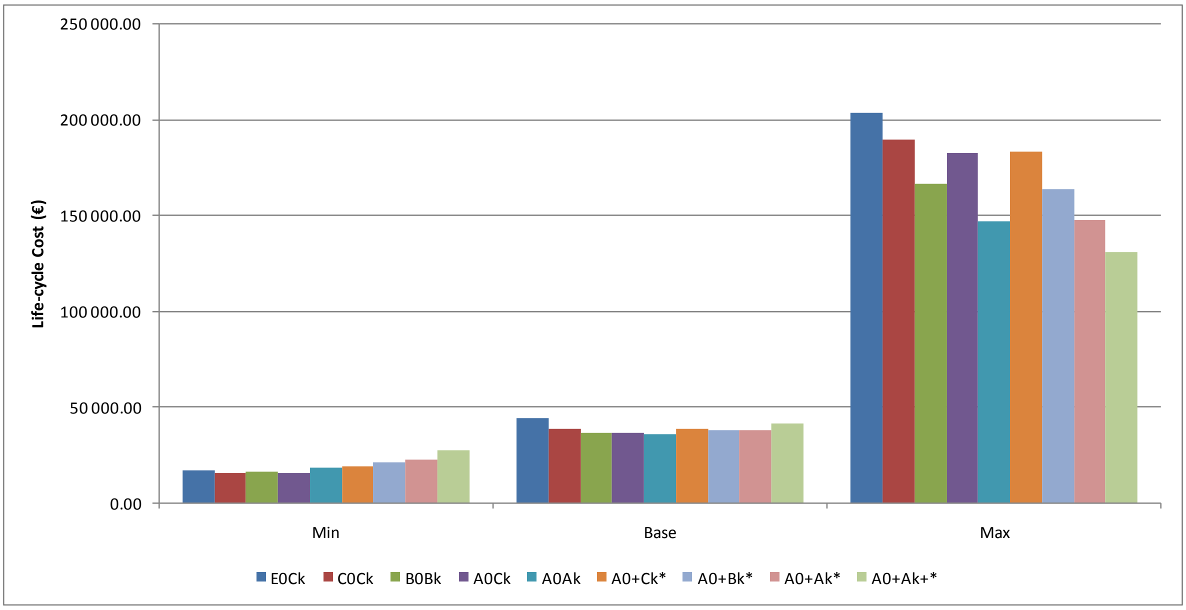


Figure 6-69: Base-case 2 and its improvement options – Impact of extreme scenarii on the LCC

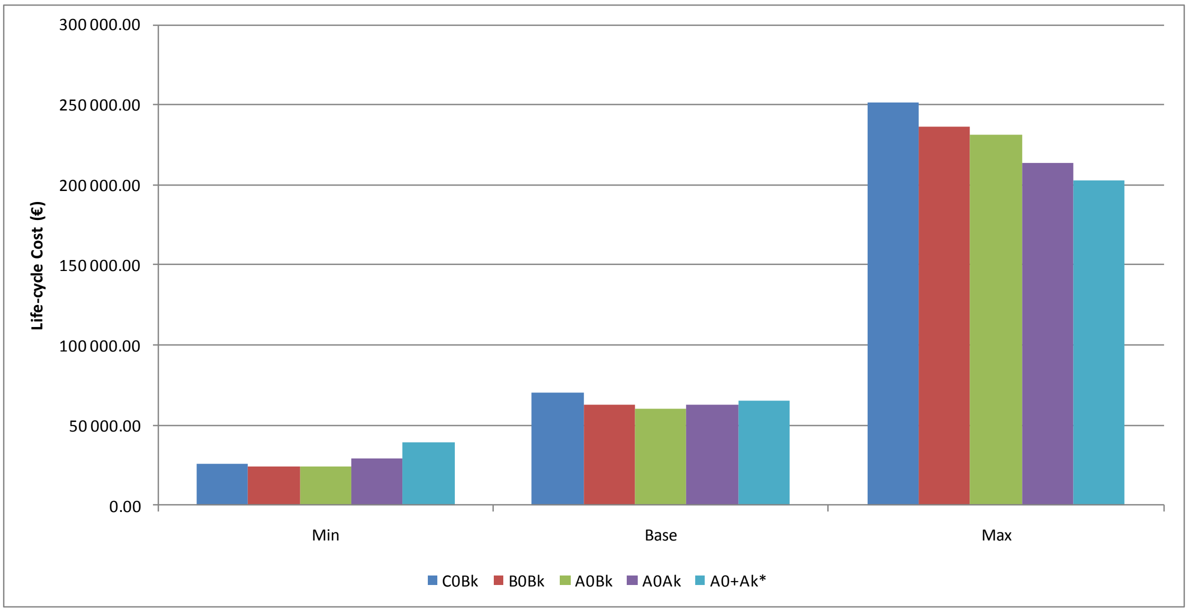


Figure 6-70: Base-case 3 and its improvement options – Impact of extreme scenarii on the LCC

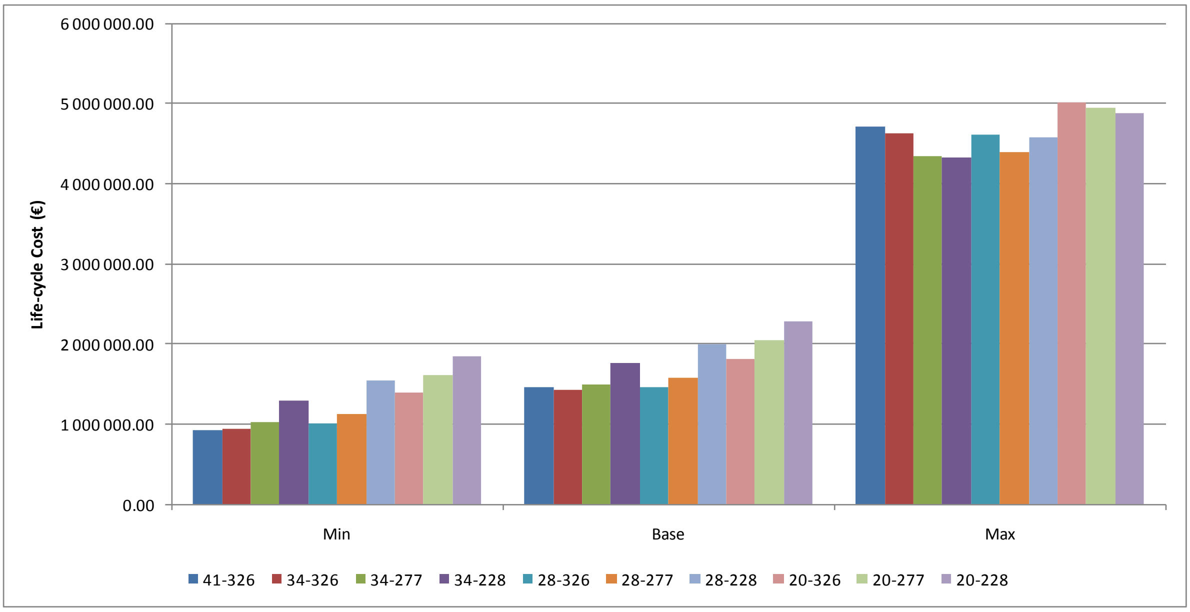


Figure 6-71: Base-case 4 and its improvement options – Impact of extreme scenarii on the LCC

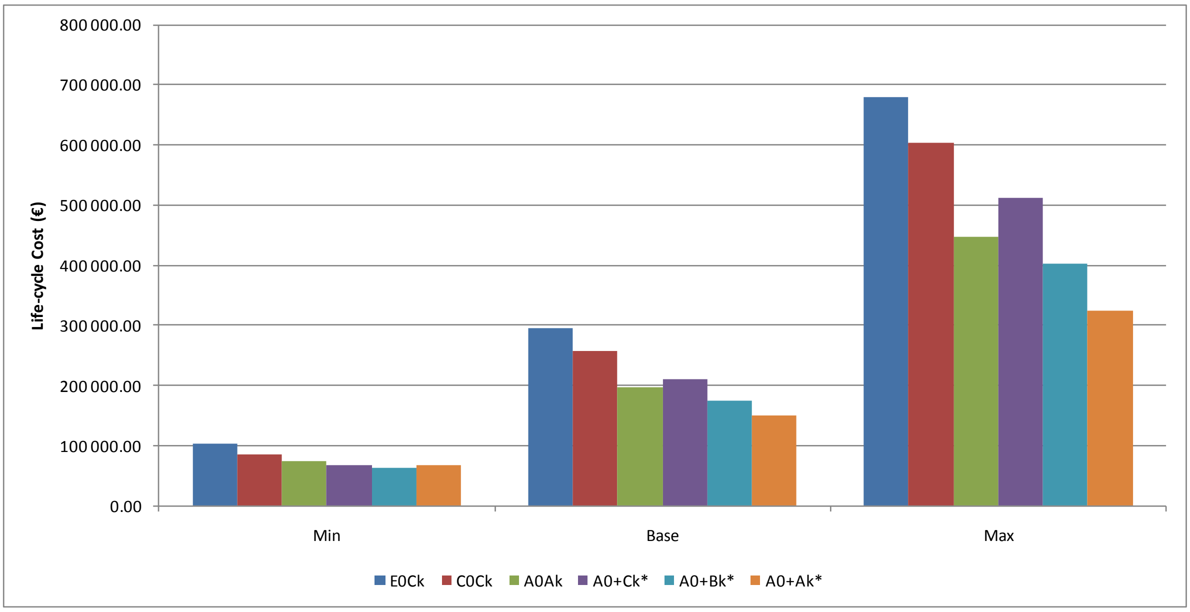


Figure 6-72: Base-case 5 and its improvement options – Impact of extreme scenarii on the LCC

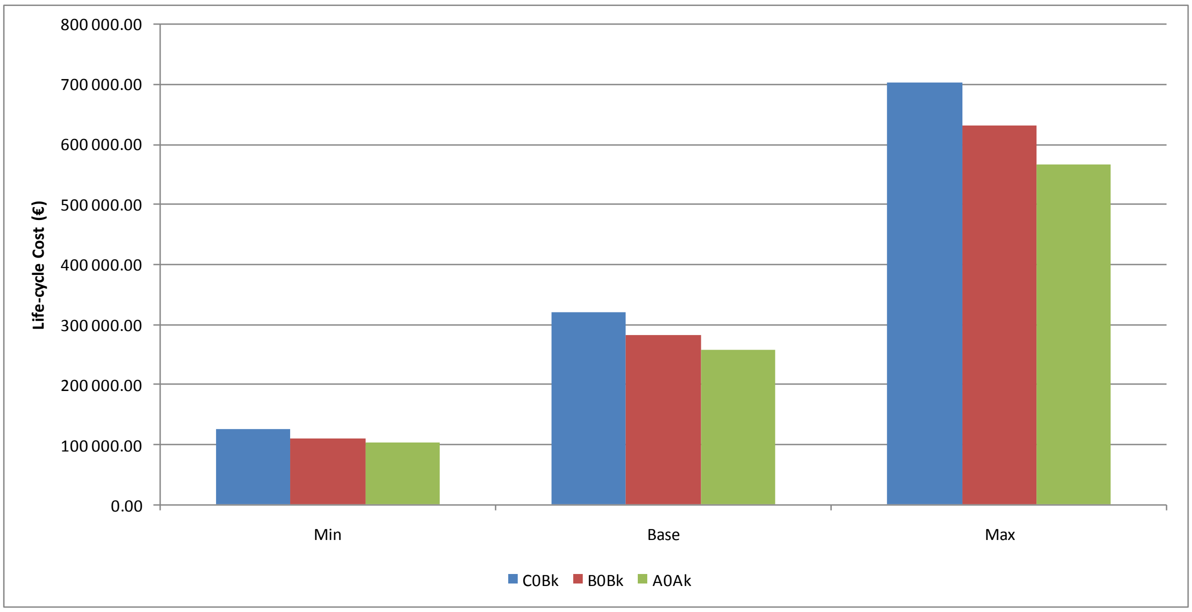


Figure 6-73: Base-case 6 and its improvement options – Impact of extreme scenarii on the LCC

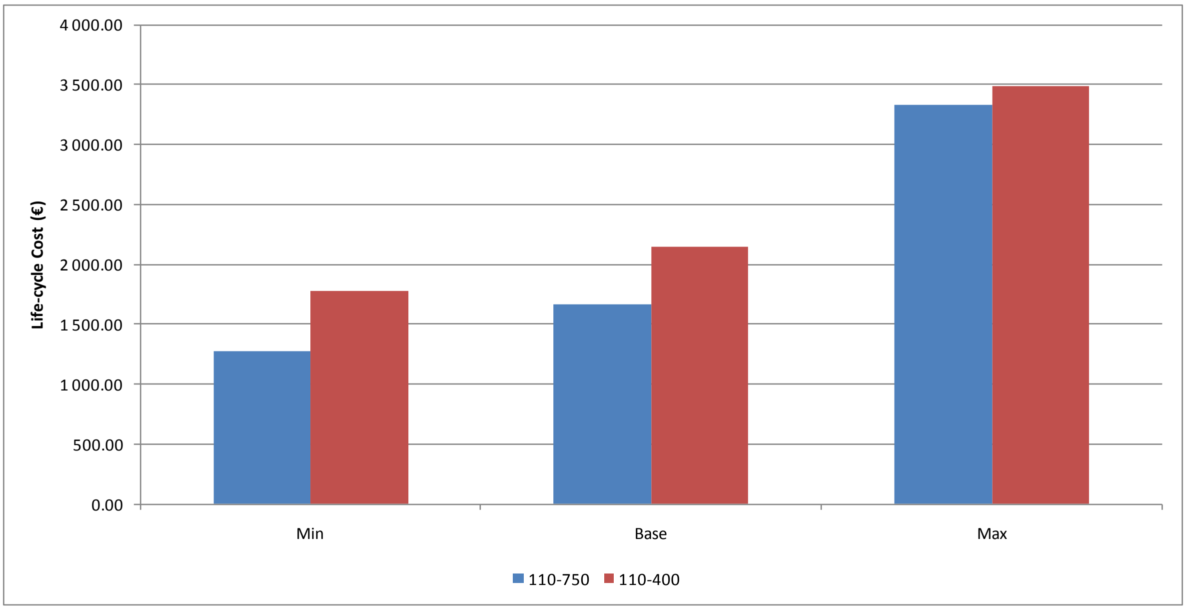


Figure 6-74: Base-case 7 and its improvement options – Impact of extreme scenarii on the LCC

6.5 Conclusions

The results of the BAT and LLCC analysis show that reductions in energy consumption often, but not always, correlate with lower life-cycle costs. In many instances the least life-cycle option is of middle efficiency. This is due to significant cost increases for the most efficient models, which despite their efficiency cannot close the gap throughout the limited lifetime. In addition, energetic and economic improvement comes at a trade-off with increased environmental impacts in some cases, such as waste, particulate matter, and eutrophication. Further, regarding mineral oil replacement by natural ester, the conclusions of the simplified LCA are not obvious as the “best” oil depends on the environmental impact considered.

The sensitivity analysis shows that the results are not significantly dependent upon the assumptions made throughout the text. In general, the relative order of base-cases and their improvement options remains the same or similar (according to the LCC) despite the variation of load factor, load form factor (for DER transformers), lifetime, electricity price, transformer price, and discount rate, except when all these parameters are modified simultaneously in extreme scenarios.

CHAPTER 7 POLICY AND IMPACT ANALYSIS

Scope:
This task looks at suitable policy means to achieve the potential improvement, e.g. implementing LLCC as a minimum requirement, the environmental performance of BAT or 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 2005–2025 quantifying the improvements that can be achieved versus a Business-as-Usual 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.

It has to be kept in mind that the conclusions represent solely the point of view of the consortium and they do not reflect the opinion of the European Commission in any way. Unlike chapters 1-6, which will serve as the baseline data for the future work (impact assessment, further discussions in the Consultation Forum, and development of implementing measures, if any) conducted by the European Commission, chapter 7 simply serves as a summary of policy implications as seen by the consortium. Further, some elements of this chapter may be analysed again in a greater depth during the impact assessment.

Summary:

Several policy options are proposed in this chapter, with a strong focus on the decrease of transformer load and no load losses compared to Business as Usual (BAU). The chapter also includes recommendations on product definitions and the scope of the proposed measures. The table below summarises the Minimum Energy Performance Standard proposals for the distribution and power transformers.

Product category	***Base-cases included***	***MEPS Tier 1 (2013)***	***MEPS Tier 2 (2018)***	***Comment***
Oil-immersed distribution transformers	BC 1, BC 2, BC 5	For ≤630 kVA: A0Ck For >630 kVA: A0Ak	Harmonisation to avoid having a subcategory	MEPS in line with LLCC options (amorphous options excluded)
Subcategory: pole mounted transformers	none	low loss core material (≤0,95 W per kg at 1,7 T at 50 Hz) if not possible to meet generic MEPS		-
Dry-type distribution Transformers	BC 3, BC 6	A0Ak	-	MEPS in line with LLCC options (slightly more ambitious for BC 3 to have a consistent regulation between oil-immersed and dry-type transformers)
Large Power Transformers	BC 4	See Table 7-3	-	MEPS more ambitious than LLCC (see text for justification) but less ambitious than the BAT
Smaller Power Transformers	BC 7	-	See Table 7-4	MEPS in line with LLCC option (Business as Usual(BAU)) for Tier 1, more ambitious target kept for Tier 2

Because of weight limitations, it might be that some pole mounted transformers can technically not satisfy the proposed maximum loss requirements of the category 'oil-immersed distribution transformers'. For these transformers, an alternative requirement on core loss alone (W/kg) is proposed. These transformers could also benefit from strict installation requirements in Member States. There are also generic eco-design requirements proposals on the supply of product information. The reasons why the authors believe that strictly implementing identified LLCC (A0+Ck, ≤630 kVA) for oil-immersed distribution transformers cannot be done in the medium term (Tiers 1 and 2) are related to the uncertainty on the availability of amorphous material, transformer production in the EU, copper price, maintaining transformer price competition and some small functional differences of amorphous transformers (compactness, etc.). However on the long term (Tier 3) such a target can be considered.

There is a need for updated harmonized standards to measure smaller transformer and large power transformers losses and proposals to fill these gaps are formulated. For several standards, updates are recommended, especially to add extra no load losses categories in standards EN50464-1 and prEN 50541-1 to cover Best Available Technology developments.

There are policy recommendations such as benchmarking or incentives or Green Public Procurement (GPP) to promote efficient power and distribution transformers. Several TSO/DSOs currently use a Total Cost of Ownership (TCO) that takes into account load and no load losses. Therefore the TCO is also a suitable tool to drive the market towards more efficient transformers. The TCO should not replace exclusively the MEPS but should only be used as a complementary tool to go beyond the MEPS in terms of energy efficiency if it is economically justified. Recommendations are made on the current TCO approach to increase consistency with an energy efficiency policy and the EU 20/20/20 targets.

This chapter also includes proposals for policy actions related to Best Not Yet Available Technology (BNAT). Amongst others, more research is needed on fire behaviour of liquid filled transformers with silicon liquid or biodegradable natural esters and the creation of a standard could be considered.

The scenario analysis shows that significant energy savings are possible from a LLCC or BAT scenario over BAU, achieving up to 16 % and 28% electric savings in 2025 from 102 TWh (BAU, annually in 2025), respectively. A MEPS scenario is also described and would reduce by 17.2% the electricity losses in 2025, saving 17.8 TWh. In addition, the LLCC scenario is economically advantageous and saves 1.5% of expenditures in 2025, while providing overall economic savings since 2011 starting in 2032. The MEPS scenario is expected to provide overall economic savings in 2048 (assuming that the electricity tariff will not increase).

There is also a section related to impact of policy measures. Most important is the lack (anno 2010) of amorphous material and transformer production capacity within Europe.

7.1 Policy analysis

Scope:
The policy analysis should identify policy option(s) considering the outcomes of all previous tasks, notably the option(s) should:

- Be based on the exact definition of the product, according to chapter 1 and modified/ confirmed by the other tasks;
- Provide ecodesign requirements, such as minimum (or maximum) requirements, considering the sensitivity analysis carried out in chapter 6;
- Be complemented, where appropriate, with (dynamic) labelling and benchmark categories linked to possible incentives, relating to public procurement or direct and indirect fiscal instruments;
- Where appropriate, apply existing standards or propose needs/generic requirements for harmonized standards to be developed;
- Provide measurement requirements, including test standards and/or methods;
- Consider possible self-regulation, such as voluntary agreement or sectoral benchmarks initiatives;
- Provide requirements on installation of the product or on user information.
- This task also provides a simple tool (e.g. in Excel), allowing estimates of the impacts on different scenarios and, to the extent possible, the estimation of Member State specific impacts.

7.1.1 Proposed exact product definitions and scope for policy measures

7.1.1.1 Three-phase oil-immersed distribution transformers 50 Hz

These transformers can easily be defined as transformers designed according to EN 50464-1 series: 2007 'Three-phase oil-immersed distribution transformers 50 Hz, from 50 kVA to 2500 kVA with highest voltage for equipment not exceeding 36 kV'.
This scope should be extended to transformers from 25 kVA to 3150 kVA as the same extension takes place during the revision of EN 50464-1 (2007). These transformers are also referred hereafter simply as 'Oil-immersed distribution transformers'.

Rationale and remarks:

- 25 kVA should be sufficient to prevent loopholes by underrating a transformer that is not compliant with the proposed loss limits. Power ratings below 25 kVA are very because of the typical rating of house connection (see chapter 2), e.g. in Germany the minimum household connection is 3x63A equivalent to 40 kVA. Further, in Europe, normally 230 VAC is used in residential areas. Taking into account realistic cable sections and fusing, ratings below 25 kVA are therefore very unlikely for MV/LV transformers.
- This definition covers also the so-called oil-immersed industry or DER transformers which are technically similar.
- Sometimes 'smaller industrial transformers' are used for particular applications such as isolation or lower voltages (see chapter 1 for background and section 7.1.1.4 for definition). The key difference is that they have a 230 VAC primary voltage instead of MV.
- For larger ratings (> 2500 kVA) please consult section 7.1.1.3 on 'power transformers'.

Proposal for a subcategory needed for MEPS (Minimum Energy Performance Standards) for Tier 1:
Because of functional limitations in weight the following subcategory needs to be adopted: 'Light weight pole mounted transformers with rating between 150 - 200 kVA with a maximum weight of 690 kg'. These transformers might need different and less stringent losses requirements proposed with functional requirements (see section 7.1.2). These transformers are also referred hereafter simply as 'Light weight pole mounted transformers'.

Rationale and remarks:

- Small pole mounted transformers are not an expected future trend as overhead lines are becoming less popular compared to underground lines, this reduces the risk for loopholes created by introducing this subcategory.
- Obviously, pole mounted transformers between 150 - 200 kVA (smaller ones) can technically also achieve class A0Ck, which is the proposed MEPS in section 7.1.2. Nevertheless, weight might be a problem to mount them on some poles as currently specified by some DSOs. Heavier weight means that the specifications for poles and installers (cranes and transport) need to be modified, which can take some time to implement in tender specifications. Therefore, this subcategory is proposed for this range of ratings.
- There are also < 150 kVA pole mounted transformers but it is not proposed to include them in this special subcategory. Those transformers are de facto lighter by their rating and should not have installation problems. Therefore, it is not proposed to include them in a special subcategory as they do not need an exception.
- Larger (>200 kVA) pole mounted transformers exist, but as far as known they are always mounted on a four poles construction which is very stable. Therefore,

it is not proposed to include them in a special subcategory as they also do not need an exception.
- Mobile construction cranes for 1 ton are not exceptional, as this is equivalent to only 0.45 m³ concrete. Therefore cranes capacity should not be a limitation.
- During the final stakeholder meeting it was concluded that there is no need to extend this category for ratings above 160 kVA. However, after the stakeholder meeting it was communicated that some utilities install 200 kVA pole mounted transformers (comment from Eurelectric) and the range was accordingly amended.
- Finally, when the size or the weight can cause logistic limitations, it is sometimes possible to install two smaller transformers on two different poles.

As a conclusion:
This pole-mounted transformers category is a category that can be considered for an intermediate period but should be outfaced after a transition period of five years needed for DSOs to adapt their requirements for pole mounted transformers (see section 7.1.2.1 on Tier 2).

There is no need for a special subcategory for DER transformers:
The particular technical differences of DER transformers do not conflict with efficiency as concluded during the final stakeholder meeting (24/08/2010). During this meeting it was also concluded that there is no need for any other subcategory for compact or light weight transformers (above 200 kVA).

7.1.1.2 Three-phase dry-type distribution transformers 50 Hz

Those transformers can easily be defined as transformers designed according to prEN 50541-1 series: 'Three-phase dry-type distribution transformers 50 Hz, from 100 to 3150 kVA, with highest voltage for equipment not exceeding 36 kV'. These transformers are also referred hereafter simply as 'Dry-type distribution Transformers'.

Rationale and remarks:
- It is assumed that the draft standard prEN 50541-1 will be voted in the upcoming months.
- This definition also covers so-called dry-type DER transformers which are technically identical to transformers installed by Distribution System Operators, e.g. base-case 6 in previous chapters.

During the final stakeholder meeting (24/08/2010) it was also concluded that there is no need for other new particular subcategories.

7.1.1.3 Medium and Large power transformers (≥ 3150 MVA) used in 50 Hz electricity transmission with highest voltage for equipment exceeding 36 kV

A 'Medium or Large power transformers (≥3150 MVA) used in 50 Hz electricity transmission' can be defined as 'a static piece of apparatus with two or more windings which, by electromagnetic induction, transforms a system of alternating voltage and current into another system of voltage and current usually of different values and at the same frequency for the purpose of transmitting electrical power' (IEV definition) designed for use in a 50 Hz frequency system and with highest voltage for equipment exceeding 36 kV. These transformers are also referred hereafter simply as 'Large Power Transformers'.

To the knowledge of the project team, no exception is needed and no stakeholder request has been received so far (1/2011).

7.1.1.4 Smaller power transformers (≥ 1kVA and ≤ 100 kVA) designed for use in electricity 50 Hz distribution with highest-voltage for equipment not exceeding 1 kV

A smaller power transformer (≥ 1kVA and ≤ 100 kVA) designed for use in electricity 50 Hz distribution grid can be defined as 'a static piece of apparatus with two or more windings which, by electromagnetic induction, transforms a system of alternating voltage and current into another system of voltage and current usually of different values and at the same frequency for the purpose of transmitting electrical power' (IEV definition) designed for use in a 50 Hz frequency system and with highest voltage for equipment not exceeding 1 kV. These transformers are also referred hereafter as 'Smaller Power Transformers'.

If minimum efficiency requirements are requested, it is needed not to mix the product with various transformers that are used in or with special equipment (welding, guitar amplifiers, machine tools, etc.) (see chapter 1). Therefore, it is suggested to limit the scope to well defined smaller power transformers in electricity distribution.

These smaller power transformer subcategories were clearly defined in the scope of this study and analysed in detail in chapters 1-6 as the so-called smaller power transformers:

i. Separating transformer: it is a transformer that has primary and secondary windings electrically isolated by means of basic insulation, so as to limit, in the circuit fed by the secondary winding, the risks in the event of accidental simultaneous contact with earth and live parts. Typical size for three phase transformers is from 1 kVA up to 63 kVA. Please note that this is not a common practice in industry and they are only used in cases of strong safety and availability requirements.
ii. Isolating transformer: it is a separating transformer that has primary and secondary windings electrically isolated by means of double or reinforced insulation. Frequent applications are a change of earthing system or a critical load protection in distorted systems. Typical size for three phase transformers is from 1 kVA up to 63 kVA. Please note that this is not a common practice in industry and they are only used in cases of severe electromagnetic compatibility requirements (e.g. also in medical equipment).
iii. Control transformer: these transformers have at least a basic isolation between primary and secondary windings and are required for power supplies in machine control circuits (cf. EN 60 204 – 1), e.g. for powering small motors or instrumentation equipment. The typical secondary voltage is 24 VAC. Those are most often single phase transformers from 40 VA until 2.5 kVA. Please note that these transformers are nowadays being replaced by electronic power supplies as a consequence of using PLC (programmable logic control) instead of formerly electro-mechanic relays in industrial control applications. Nevertheless, those transformers might still be available on the market.

Note on 'voltage restorers or autotransformers':
They were excluded from the scope of the detailed analysis from Task 2 due to the low number of sales on the EU market and the first screening showed low environmental impacts.
The above definition does not exclude them and it is recommended to broaden the scope of smaller power transformers for further legislation in order to avoid any

loophole. From a technical point of view, the authors currently see no argument why they would be unable to satisfy the proposed ecodesign requirements in this study. From the efficiency point of view there might be no conflict as the autotransformer construction is de facto more efficient, because less insulation and conductor is needed.

A proposal for two subdivisions of smaller power transformers needed when MEPS are considered is:

- 'General purpose smaller power transformers (50 Hz)' marketed for distribution (≤ 1 kV)';
- 'Special purpose smaller power transformers (50 Hz) (≤ 1 kV)'.

Rationale and remarks:

- Manufacturers are free to choose one type depending on the targeted and most relevant application and performance.
- The rationale for these subcategories is that it cannot be avoided that special transformers complying with the above 'general purpose' definition are designed for being integrated in a special application (e.g. a guitar amplifier with valves or portable machine tools) as illustrated hereafter.

For instance, in the case of guitar amplifier audio transformer, the audio transformer is also able to operate at 50 Hz within audible sound and might work as well in the defined low voltage range, therefore it could be considered within the scope of smaller power transformers. However, the special non linear characteristics create a particular sound but those transformers are inefficient. To avoid this negative impact on the functionality, they might be exempted which justifies the need for the subcategory 'special purpose with well defined target application'.
Another example is the case of special form factor transformer in portable machine tools. There is a broad range of portable machine tools on the market (e.g. plasma surface treatment, laser sources, arc welding equipment, water purifiers). They often have customized transformers inside. They have low operational hours and are so rare that it is impossible to review them all before continuing with legislation for other categories.

As calculated in Table 7-7, the impact of these 'smaller power transformers' (0.4 TWh in 2025) is very low compared to distribution and power transformers.

7.1.2 Maximum transformer load and no-load losses requirements

As a general remark, only recommendations for Tier 1 and/or Tier 2 are made in the following section, for reasons also explained below. To keep encouraging effort in energy efficiency of transformers, it is suggested that the possible Regulation be revised by the EC in a 6 years time after its effective implementation. Experience from the evolution of the EU transformer market during this period will be very valuable to make new and adapted recommendations.

Table 7-1: Summary of proposed MEPS for various types of distribution and power transformers

Product category	Base-cases included	MEPS Tier 1 (2013)	MEPS Tier 2 (2018)	Comment
Oil-immersed distribution transformers	BC 1, BC 2, BC 5	For ≤630 kVA: A0Ck For >630 kVA: A0Ak	Harmonisation to avoid having a subcategory	MEPS in line with LLCC options (amorphous options excluded)
Subcategory: pole mounted transformers	none	low loss core material (≤0,95 W per kg at 1,7 T at 50 Hz)		-
Dry-type distribution Transformers	BC 3, BC 6	A0Ak	-	MEPS in line with LLCC options (slightly more ambitious for BC 3 to have a consistent regulation between oil-immersed and dry-type transformers)
Large Power Transformers	BC 4	See Table 7-3	-	MEPS more ambitious than LLCC (see text for justification) but less ambitious than the BAT
Smaller Power Transformers	BC 7	-	See Table 7-4	MEPS in line with LLCC option (Business as Usual(BAU)) for Tier 1, more ambitious target kept for Tier 2

7.1.2.1 Proposed maximum load and no-load losses requirements for Oil-immersed distribution transformers

It is proposed to agree on maximum load and no-load losses requirements for oil-immersed distribution transformers. Based on the analysis made in Chapter 6, the following MEPS are proposed:

- For ≤630 kVA, A0Ck in Tier 1 (2013)
- For >630 kVA, A0Ak in Tier 1 (2013)

Loss limits for ratings that fall in between ratings defined in the standard should be obtained by linear interpolation and so should the ratings outside the standard boundaries.
In Tier 2 one can extend the particular requirement to use low loss core material to all transformers (this requirement is currently proposed for Tier 1 for particular pole mounted transformers, see below).

The MEPS for 'Light weight pole mounted transformers with rating between 150 – 200 kVA with a maximum of 690 kg' as defined in section in section 7.1.11 and that could not meet the MEPS defined above for 'oil-immersed distribution transformers' due to limits in design, are:

- These transformers shall only use low loss core material with quality of magnetic steel giving losses inferior or equal to M095-27P levels defined by EN10107 (≤0,95 W per kg at 1,7 T at 50 Hz) (see Table 5-3) in Tier 1.
- A0Ck in Tier 2 (2018).

Table 7-2: Losses levels corresponding to the different options identified

Option	Losses level
MEPS	A0Ck
LLCC	A0+Ck*
BAT	A0+Ak+*

Rationale and remarks:

- The above MEPS include what the authors of this study think can be implemented in the near future (Tiers 1 and 2). They do not strictly implement the LLCC option but are consistent with the analysis that was made in Chapter 6. In the case of distribution transformers (base-case 1), the level A0Ck corresponds to the LLCC option, in case the amorphous improvement options were not taken into account. The reasons why the authors believe that strictly implementing LLCC (amorphous level A0+Ck*) cannot be done in the medium term (Tiers 1 and 2) are related to the uncertainty on the availability at short term of amorphous material and transformer production in the EU, maintaining transformer price competition and some small functional differences of amorphous transformers (compactness, etc.). Currently amorphous transformers are not a mainstream product and prices used were estimated prices, therefore they should be handled with care (see section 7.2 on impact). In the case of industry oil-immersed transformers (base-case 2), the level suggested (A0Ak as the power rating of this base-case is larger than 630 kVA) matches with the option identified as the LLCC option in Chapter 6. Finally, in the case of DER oil-immersed transformers (base-case 5), the situation is the same than for base-case 1: the level proposed (A0Ak as the power rating of the base-case is larger than 630 kVA) represents the LLCC option in case the amorphous improvement options were not taken into account which has already been justified.
- The difference between the LLCC and the MEPS scenario is quite important in the case of base-case 1 as the LLCC option saves 16.8 additional TWh on the period 2011-2025 in comparison with the MEPS scenario (see section 7.1.11.5.). This highlights the higher improvement potential still remaining, that could be achieved thanks to the use of amorphous technology. Therefore, there is still potential for a Tier 3 target but the current uncertainty on the future of the amorphous technology in EU (especially on prices) impose more time and information on the market evolution before more ambitious targets can be set.
- The financial impact of this measure on a 'Light weight pole mounted transformers with rating between 150 - 200 kVA with a maximum of 690 kg' is low. For such a transformer the core weight is maximum 350 kg (200 kVA) and the extra material cost only 1 €/kg (see chapter 2, M3 compared to domain refined material) hence 350 € in total. This is little for a transformer that will cost about 4450 € (half the price of BC1). This amount is negligible and there is no need to replace the pole with a stronger one. This is also applicable for the smaller ratings, because the transformer weight is proportionally lower.

- Extending the requirement to all transformers to use only low loss core material with quality of magnetic steel giving losses inferior or equal to M095-27P levels defined by EN10107 (≤0,95 W per kg at 1,7 T at 50 Hz) (see Table 5-3) in Tier 2 will seal safe the market for more efficient magnetic steel. It is expected that this will most often result in transformer well below A0 by design, closer to BAT levels. Moreover, this will make these steels a mainstream product with benefits for other products outside the scope of this study (e.g. relays, inductors, motors, etc.).

7.1.2.2 Proposed maximum load and no-load losses requirements for Dry-type distribution Transformers

The proposed MEPS requirements for Dry-type distribution transformers are the A0Ak losses level in Tier 1 (2013).
A second Tier should be considered when more evidence is available about the availability and cost of the identified improvement options related to amorphous transformers.

Rationale and remarks:

- When drafting the dry-type distribution transformer requirements, the risk of dry-type transformers being substituted for oil-immersed transformers needs to be considered. The no-load and load losses classes 'A0Ak' defined in prEN 50541-1 (dry type) and EN464-1 (oil-immersed) are very different. For example, a 400 kVA oil-immersed has 430 W no-load and 2 800 W load losses while a dry-type has 700 W and 4 500 W losses (see chapter 1 for details). The risk of substitution might be relatively low as these transformers are about 10% more expensive and occupy a larger volume (see Annex C chapter 5).
- This risk can also be reduced by requiring additional installation requirements as proposed in later sections. Therefore, it is also recommended to require A0Ak from Tier 1 (2013) to avoid any loopholes.
- The above MEPS include what the authors of this study think can be implemented in the near future (Tier 1, 2013). Similarly to the oil-immersed transformers, no differentiation is made between industry and DER transformers as they are technically alike. In case of industry transformers (base-case 3), the level suggested (A0Ak) is slightly more ambitious than the LLCC option identified in Chapter 6 (A0Bk). The reason for this proposal is to have the same required levels for oil-immersed and dry-type transformers in order to avoid any substitution of one type by another. In the case of DER dry-types transformers (base-case 6), the level suggested matches with the LLCC option identified in the Chapter 6 analysis.

7.1.2.3 Proposed maximum load and no-load losses requirements for Large Power Transformers (3150 kVA and above)

It is proposed to agree on maximum load and no-load losses for different ratings and voltage levels of the HV winding for power transformers. The current proposals are presented in Table 7-3.

The table was elaborated based on the enquiry results (see Annex G) and extrapolated with the German DIN 42508 standard (see section 1.7.1.4) (range up to 80 MVA). Values above 80 MVA were completed in line with the manufacturers' enquiry.

Rationale and remarks:

- The LLCC option corresponding to the base-case 4 in Chapter 6 puts the levels at 34 kW for no load losses and 326 kW for load losses. In comparison with the base-case losses levels, only the no load losses are thus reduced. However, many stakeholders commented that it makes sense to also reduce the load losses of large power transformers, in particular because their load factor is normally higher than for the other transformers. In Table 7-2, the MEPS proposal corresponding to the base-case 4 (100 MVA with HVmax < 150 kV) impose load losses at 293.4 kW, i.e. a 10% reduction compared to the LLCC (supported by T&D Europe, see project report Annex U comment 18); the previous justification explains why this level is slightly more ambitious than the LLCC option regarding load losses.
- Concerning no load losses, the proposal also includes a column with -30% no load losses (Po-30%) to be implemented as MEPS, because the improvement option 28-326 was identified as a very close option to the LLCC in chapter 6 (see Figure 6-12). Indeed, the LLCC option has no load losses of 34 kW; the option 28-326 has a LCC slightly higher and enables to achieve substantial electricity savings. Therefore, the 'P0-30%' MEPS suggested in the case of base-case 4 corresponds to no load losses of 28.7 kW, which is in line with the previous explanation.
- Losses (Po, Pk) for ratings (S) not included in Table 7-3 should be obtained with linear inter- and extrapolation.

S	HVmin >	HVmax ≤	Po	Pk	Po-30%	Scope of DIN
kVA	kV	kV	kW	kW	kW	y/n
3150		**36**	**2**	**20**	1.4	y
5000		36	2.7	37.0	1.9	y
10000		36	3.6	48.1	2.5	y
25000		36	11.6	92.5	8.1	y
40000		36	17.0	134.1	11.9	y
10000	36	150	6.3	57.4	4.4	y
25000	36	150	13.4	101.8	9.4	y
50000	36	150	25	166.5	17.5	y
80000	36	150	41	250	28.7	y
100000	36	150	41	293.4	28.7	n
100000	150	300	55	306	38.5	n
170000	150	300	78.8	511.2	55.2	n
350000	300	400	137	690.3	95.9	n
350000	400		146	841.5	102.2	n

Table 7-3: Proposed target no load (P0) and load losses values (Pk) for different ratings (S) and voltage levels (HV) of power transformers

7.1.2.4 Proposed maximum load and no-load losses requirements for Smaller Power Transformers (all LV/LV (50Hz, ≤ 1kV) types except the Special purpose smaller power transformers)

It is not recommended to implement maximum load and no-load losses for smaller power transformers on the short term (Tier 1 – 2013).

The main reasons are:

- The identified BAT was not the LLCC option in chapter 6.
- Stakeholders also commented in final stakeholder meeting (24/08/2010) that there is a very broad range of small transformers produced depending on voltage and ambient temperatures and complementary losses. According to them, it does not look realistic to specify one level of load losses for all of them.
- As mentioned in previous chapters, many smaller power transformers do not have efficiency data in their catalogue and there is no harmonized standard yet (see also section 7.1.6). This gap should be covered in a first Tier 1 (2013).
- One should keep in mind that the estimated EU-27 impact of the product category in this study (see chapter 4) is low compared to the other types of transformers.

Nevertheless, MEPS could be considered in a Tier 2 (2018) and Tier 3 (2020), when more information is available.
Hereafter is a proposal that could be used as a target for those later Tiers (Table 7-4). Tier 3 could be equivalent to identified BAT and Tier 2 could be an intermediate level (e.g. x2).

Rating (S) (kVA)	Maximum load loss (W)	Maximum no load loss (W)
1	100 (x2 in Tier 2)	25 (x2 in Tier 2)
4	200 (x2 in Tier 2)	55 (x2 in Tier 2)
16	400 (x2 in Tier 2)	110 (x2 in Tier 2)
32	600 (x2 in Tier 2)	165 (x2 in Tier 2)
64	800 (x2 in Tier 2)	220 (x2 in Tier 2)

Table 7-4: Proposed Tier 3 maximum load and no-load losses for smaller LV/LV 50 Hz transformers (except special purpose smaller power transformers).

Note:

- By lack of interest in efficiency for these transformers, the ultimate energy efficient transformer is not yet available on the market (e.g. with low core loss material as described in chapter 5). Hence, it is also very likely that future developments enable to go beyond identified BAT levels.

7.1.3 Proposed Generic Eco-design requirements on the supply of information

7.1.3.1 Information related to transformer efficiency

It is proposed to request load and no-load losses to be mandatory information for products within the scope of any future regulation (see also recommendation in section 7.1.7).

7.1.3.2 Information related to recycling

It is recommended to include the weight of the conductor and core material in the product information.
Rationale for this proposal: This is also beneficial for more efficient transformers because they most often rely on more conductor and core material (see chapter 5) and the end user can account the residual value of transformer scrap material in its assets.

7.1.3.3 Information for 'special purposes smaller power transformers (50 Hz) (≤ 1kV)'

To avoid loopholes, additional information requirements to facilitate market surveillance are recommended, e.g.:

1. 'Special purpose transformers with well defined target application' need their application to be mentioned in any related product documentation.
2. 'Special purpose transformers with well defined target application' need the ISO caution mark to read documentation (Figure 7-1).

Figure 7-1: Caution mark to read documentation proposed to be placed on exempted 'special purpose transformers with well defined target application'

7.1.3.4 Information for 'Light weight pole mounted transformers with rating between 150 - 200 kVA with a maximum of 690 kg', and not meeting the generic MEPS for 'oil-immersed distribution transformers'

To avoid loopholes, additional information requirements facilitating market surveillance are recommended, e.g.:

1. 'Special purpose pole mounted distribution transformers with well defined target application' need the applications to be mentioned in any related product documentation.
2. 'Special purpose pole mounted distribution transformers with well defined target application' need the ISO caution mark to read documentation (see Figure 7-1).
3. The normative reference to the core loss to be clearly marked on the product name plate and in the product documentation.

Reminder:
There are also 50 kVA pole mounted transformers but they are light weight due to their low rating (S) and can be constructed with class A0Ck, hence they do not need this extra requirement.
This requirement is also optional for pole mounted transformers that meet the proposed class A0Ck and do not rely on this exception.

7.1.4 Policy recommendations to promote efficient power and distribution transformers

The policy recommendation sections hereafter are organised per transformer user group as different recommendations apply per user group. These are recommendations that are outside the scope of the Ecodesign Directive (2009/125/EC), hence they should be considered as suggestions that will need further elaboration and investigation in the context of other legislation.

For all transformers types that will be covered by a Regulation, it is propose to indicate in Annex of the Regulation benchmarking values corresponding to the current best available products. Such an approach was already used in various Regulations adopted in the context of the Ecodesign Directive (e.g. on non-directional households lamps[153]) and allows costumers and policy makers to have an idea of what is technically feasible, and it can be expected that it can drive the market towards more energy efficient transformers.

[153] Regulation No 244/2009

7.1.4.1 Power transformers operated by Transmission Asset Owners (TAO) and Total Cost of Ownership (TCO) implementation

Most Transmission System Operators (TSO) or Transmission Asset Owners (TAO) already use a Total Cost of Ownership (TCO) approach in their (public) procurement procedures (see sections 3.1.4 and 4.4.2).
This procedure relies on communicating cost per watt of no-load losses (A) and load losses (B). These factors do not disclose the electricity prices used and the assumption on the load profile. When properly used, such a method is a suitable tool to drive the market to more efficient transformers. Therefore it is recommended to maintain this practice but it should not supersede the MEPS possibly implemented, but only be considered as a complementary tool to go beyond the MEPS if relevant.

Some shortcomings of the current TCO method were identified:
The electricity price used can sometimes be lower compared to chapter 2 assumptions as a result of: purchasing large quantities, moderate assumptions on the future electricity price and neglecting or underestimating internal transmission costs for losses. The consequence is that unique energy saving opportunities exists in the electrical grid itself but is overlooked due to this business model with low electricity prices (often lower compared to chapter 4). For example installing renewables might cost 0.07 to 0.4 euro/kWh compared to energy savings overlooked on a 0.04 euro/kWh cost assessment. Note that there is nothing wrong with the TCO method itself neither with the mathematics behind it of the various methods (see chapter 3).

Therefore the following recommendations are made to extend and harmonize the TCO method, for example:

1. To ask to disclose the load profile parameters used for the TCO analysis. This could be the load profile parameters used in this study (Kf, α, PF), but many other methods exist (see chapter 3).
2. To disclose also the price used for the TCO analysis. Prices used should be in between the projected average market price (euro/kWh) and the average EU-27 cost of renewables (euro/kWh) (e.g. 0.08 euro/kWh). In any case, underestimation of the future electricity cost for this analysis should be prevented.

As a result, A and B can be calculated from the above parameters (see chapter 3).

Rationale:

- TSO/DSOs might insist on confidentiality for the real prices obtained in their contract, and this method does not disclose this information.
- EU-27 has set its 20/20/20 targets on lower greenhouse gasses, increased renewables and energy efficiency. Therefore it makes sense to economically balance investments in grid loss reduction or efficiency with the high cost of renewable energy. The above harmonized virtual price can do so. Such a method would provide fairer opportunities for more energy efficient T&D equipment providers compared to renewable equipment providers (e.g. wind turbines).

Currently TSO/DSOs report on grid losses as a whole; it is also recommended to ask them detailed information. An incentive might be that EU-27 regulators benchmark grid losses and require DSO/TSOs to procure above benchmark grid losses with renewable energy. This is also useful to reduce load losses in power lines.

Notes:

- This recommendation is also valid for load losses in power lines.
- TSOs and DSOs are regulated monopolies and can pass on investment costs to the end user after agreement with the regulator, which might not offer the

proper incentive. All incentives or disincentives are handled by the Regulator in the Price Control Structure. This is a much specialised area and basically outside the scope of this study, however only brief suggestions are given for further study. An option is that regulators explicitly incorporate an incentive by limiting the amount of grid losses that can be accounted. In order to seek investment capital for transformers, TSO/DSOs can emit bonds to finance such operations. The government could back up these bonds.

- In some Member States, the situation currently is as follows: while there is bidding for the electricity price for grid losses, there is no incentive for distribution and transmission companies to reduce the quantity of grid losses. Costs of grid losses are always fully paid by the electricity end-users in these countries. If now an implementing measure requires lower losses, the end-user will have to pay less. But lower losses can only be achieved by higher investment costs, which need to be accepted by the regulator as eligible costs.
- Grid losses are not limited to transformer losses but also consist of load losses of the cables and so-called economic losses (theft or unbilled electricity).

7.1.4.2 Distribution transformers operated by Distribution Asset Owner (DAO)

Suggestions made for incentives to avoid focusing on achieving the minimum efficiency requirements alone are:

1. Implement and harmonize the Total Cost of Ownership (TCO) approach as already explained in section 7.1.4.1.
2. Tax incentives could be granted to the most efficient classes (BAT), e.g. accelerated depreciation, in case the most efficient product is not the results of the TCO approach.

To illustrate bullet point 2 for the base-case 1, the TCO approach for a situation similar to the EU average that has been studied throughout this study would suggest the A0+Ck* losses level as being the most economic. However, the BAT option remains more ambitious from an energy perspective (A0+Ak+* losses level). Thus, a DAO using the harmonised TCO and willing to benefit from a tax incentive could decide to purchase the BAT appliance, instead of the LLCC suggested by the TCO approach. Assuming that around 25% of the purchasers decide to buy a BAT transformer and that the tax incentive represents approximately 29% of the purchase price, such a policy option would cost the EU Member States around 578 m€ for a programme over the period 2013-2018 (for 154 000 products sold) and additional electric savings of 2.46 TWh would be achieved over the life cycle of the products (1 126 ktonnes of CO_2 emissions avoided).

Table 7-5 presents similar results by base-cases. The tax incentive amount (in percentage of the purchase price) has been set so that the end user receives a slight economical benefit over the life cycle of the transformer. BC 5 and BC 6 results are not presented as the LLCC option is also the BAT option for these products so that there would theorically be no need to implement tax incentives.

Table 7-5: Economic and environmental results of a tax incentive simulation

		BC 1	BC 2	BC 3	BC 4	BC 7	Total
Product advised by a TCO analysis (Most efficient option between LLCC and MEPS)		A0+Ck*	A0Ak	A0Ak	28-277	110-750	
Product resulting in a tax incentive (BAT option)		A0+Ak+*	A0+Ak+*	A0+Ak+*	20-228	110-400	
Assumptions	Percentage of people choosing BAT product and benefiting from the incentive	**25%**	**25%**	**25%**	**25%**	**25%**	
	Tax benefit, in % of the purchase price	**29%**	**22%**	**10%**	**38%**	**26%**	
Inputs	Date of start	**2013**	**2013**	**2013**	**2013**	**2013**	
	Date of end	**2018**	**2018**	**2018**	**2018**	**2018**	
	Number of BAT products sold	154 385	47 769	8 944	5 392	112 500	328 990
Economic Outputs	Costs for authorities in m€	578.3	300.8	36.4	3 871.8	56.0	4 843.3
	Additional purchase costs by user in €	539	5 612	12 103	120 935	68	
	Additional purchase costs for all users in m€	83.3	268.1	108.2	652.1	7.7	1 119.4
	Total electricity costs by user in €	4 006	12 924	24 424	394 564	227	
	Total electricity costs for all users, in m€	618.5	617.4	218.5	2 127.5	25.6	3 607.3
	Electricity costs savings by user in €	614	6 123	14 190	128 983	92	
	Electricity costs savings for all users in m€	94.9	292.5	126.9	695.5	10.4	1 220.1
	Additional LCC by user in €	-75	-511	-2 087	-8 049	-24	
Environmental Outputs	Electricity savings, by user in kWh	15 920	125 622	315 616	2 868 893	1 455	
	Electricity savings, for all users in TWh	2.46	6.00	2.82	15.47	0.16	26.91
	CO_2 emissions avoided (ktonnes)	1 125.7	2 748.4	1 292.9	7 085.0	75.0	12 326.9

Beyond the variation in cost efficiency of such a policy, it should be kept in mind that the final purpose of such a policy would be to drive the market to the most efficient existing products. Besides, the level of success/failure of this initiative could be a relevant indicator to define next steps in ways to promote further efficiency targets.

Notes:
DSOs or DAOs are already subjected to other legislation, in particular the Energy Service Directive (2006/32/EC) in which those recommendations could be incorporated. As mentioned in chapter 1 some Member States have incorporated distribution transformers in the National Energy Efficiency Action Plan (NEEAP) to be developed by Member States in the framework of the Energy Service Directive (2006/32/EC). The identified BAT should be a target and at least the LLCC level should be implemented.
Smaller DSOs often do not have the personnel available to forecast the proper parameters for a TCO analysis therefore MEPS remain useful (see also the TCO recommendations in the previous section for TSOs).

7.1.4.3 Distribution and power transformers operated by Distributed Energy Resources (DER) plants

In some cases, DER (wind, solar, etc.) investors are also owners of distribution and power transformers (see section 3.1.3.1).
There are two potential reasons why these DER investors might have little interest in efficient transformers:

1. DER investors have often very short payback time targets (see 3.1.3.1) (e.g. 5-7 years) which is not in line with the Life Cycle Cost analysis performed in chapters 4 and 6 (>20 years). These short pay back times were made possible by an increased electricity price reflected in so-called Renewable Energy Certificate Systems (see 2.4.3) and the market created by introducing local obligations or targets for DSO/TSO/local service provider to buy them.
2. It has been reported that in some cases the electricity meter is placed at the low voltage winding, hence neglecting the transformer losses. In this case, it is recommended to include the calculated losses and charge them to the DER owner. It is normal practice at voltages above about 50kV to meter on the LV side of the transformer, as the cost and accuracy of the Voltage Transformers for voltages above 50kV is high. Such metering normally allows the loss levels on the transformers to be inputted, and the actual transformer losses are then calculated and added or subtracted from the power measurements on the LV side as appropriate. In Ireland the actual increase or decrease in losses on the network caused by the presence of the DER unit is assessed and added or subtracted from the DER unit’s output.

Therefore it is recommended:

1. Either to install the meter at the high or medium voltage and provide only Renewable Energy Certificates for this energy.
2. Or install the meter at the low voltage but correct for the energy lost above BAT levels (see chapter 6).

7.1.4.4 Distribution transformers operated by private or public users on incentives and Green Public Procurement

Large industrial site owners or building owners are often also owners of their distribution transformer (see chapter 3). It is important to target this group as well because they often have short return on investment requirements or simply lack knowledge (see chapter 3).

For large public buildings (hospitals, schools, administration, etc.), BAT level could easily be incorporated in Green Public Procurement (GPP) specifications. Note that certain load classes (e.g. A0Ak) should not serve as an alternative for the proposed regulation neither prevent that more ambitious targets could be set in future for products not yet currently available on the market, e.g. the target could be A0-50 % and Ak-90%.

For example, considered base-case 2 transformers and assuming that the proportion of public buildings under possible GPP is around 25% of the transformer stock [154], promoting the BAT option as GPP (beyond the MEPS level) would cost the EU Member States additional 276 m€ for a programme over the period 2013-2018 (for 47 800 products sold, it represents the difference between the LCC of the BAT and the MEPS options) and would result in 6.0 TWh electricity additionally saved over the life cycle of these transformers.

Table 7-6 presents similar results by base-cases. For BC 6, the MEPS option is the BAT option (if the switch alternative to BC 5 category presented in 6.2.1.6 is excluded) so that there would theorically be no need to implement GPP.

[154] Estimation from table 2-17: share of services in total consumption.

Table 7-6: Economic and environmental results of a GPP simulation

		BC 1	BC 2	BC 3	BC 4	BC 5	BC 7	Total
MEPS Product		A0Ck	A0Ak	A0Ak	28-277	A0Ak	110-750	
GPP level (BAT option)		A0+Ak+*	A0+Ak+*	A0+Ak+*	20-228	A0+Ak+*	110-400	
Assumptions	Percentage of public procurement transformers	**25%**	**25%**	**25%**	**25%**	**25%**	**25%**	
Inputs	Date of start	**2013**	**2013**	**2013**	**2013**	**2013**	**2013**	
	Date of end	**2018**	**2018**	**2018**	**2018**	**2018**	**2018**	
	Number of BAT products sold	154 385	47 769	8 944	5 392	2 538	112 500	331 528
Economic Outputs	Additional purchase costs by transformer in €	5 816	11 909	16 170	838 986	10 402	566	
	Additional purchase costs for all GPP transformers in m€	897.9	568.9	144.6	4 523.9	26.4	63.7	6 225.4
	Total electricity costs by transformer in €	4 006	12 924	24 424	394 564	109 563	227	
	Total electricity costs for all GPP transformers, in m€	618.5	617.4	218.5	2 127.5	278.1	25.6	3 885.4
	Electricity costs savings by transformer in €	3 799	6 123	14 190	128 983	56 881	92	
	Electricity costs savings for all GPP transformers in m€	586.5	292.5	126.9	695.5	144.4	10.4	1 856.1
	Additional LCC by transformer in €	2 017	5 786	1 980	710 002	-46 479	474	
	Additional LCC for all GPP transformers in m€	311.4	276.4	17.7	3 828.4	-118.0	53.3	4 369.3
Environmental Outputs	Electricity savings, by transformer in kWh	98 429	125 622	315 616	2 868 893	303 420	1 455	
	Electricity savings, for all GPP transformers in TWh	15.20	6.00	2.82	15.47	0.77	0.16	40.42
	CO_2 emissions avoided (ktonnes)	6 959.7	2 748.4	1 292.9	7 085.0	352.7	75.0	18 513.6

Again, the goal of such a policy option is to drive the market towards the very most efficiency products, therefore it may not look as the most cost effective measure but can play an important role for the future transformers type on the market. GPP recommendations could be adapted to the market evolution.

For private users, local authorities are recommended to provide financial incentives to stimulate accelerated replacement of existing transformers and/or to procure BAT transformers. As a guideline the incentive could be up to about half the extra price as found in chapter 5 Annex C for BAT compared to BAU or LLCC. For retrofitting existing installations the extra price of LLCC compared to BAU could be used, which is about 20% of the transformer purchase price. For new installations the extra price of LLCC compared to BAT could be used, which is about 12% of the transformer purchase price.
This financial incentive could be returned as a direct pay-back or as a fiscal stimulus by granting a reduced fiscal depreciation to reduce companies profit and taxes (e.g. 2 years instead of the usual minimum of 5 years).
The illustration of an example of financial incentive for private users has already been made in section 7.1.4.2.

A TCO is also valuable for industrial users, however they often do not have the personnel available to accurately forecast the proper parameters (future electricity price, transformer loading, life time, etc.) for such an analysis hence MEPS and GPP remain useful.
Also the information and motivation activities such as developed and proposed by the EU SEEDT IEE project can provide support for these users. The SEEDT IEE project provided a web based tool to perform a TCO analysis[155].

7.1.5 Proposed policy actions related to Best Not yet Available Technology (BNAT)

Hereafter is a discussion of potential policy actions related to the BNAT as identified in chapter 5.

Recommended policy actions related to R&D on amorphous metal transformers and material:
It is recommended to support R&D programmes to continue the development of its application in transformers (e.g. on short circuit behaviour and noise). More R&D is needed in particular on the short circuit behaviour of large (>1 MVA) amorphous metal distribution metal transformers. Amorphous material itself is for about 30 years on the market, hence the further material development should be driven by the market demand.

Recommended policy actions related to R&D on silicon steel:
Further technical development is ongoing and should be driven by the market demand.
Potential technical improvement options are:

- Thinner steel laminations in transformer core steel processing machines. Presently, 0.23 mm is the thinnest lamination used, but thinner steels such as 0.18 mm are manufactured and could further reduce core losses.
- Improved coatings between steel laminations that will reduce sound while enhancing electrical performance (i.e. reducing losses).
- Improved machine tools for domain refined material.

[155] http://seedt.ntua.gr/tool/

Recommended policy actions R&D on microcrystalline steel:
No further policy actions are recommended apart from a demonstration project, this could be driven by market demand as well.

Recommended policy actions R&D on superconducting technology:
Due to the weak market potential (see chapter 5) no further policy actions are needed.

Recommended policy actions related to using smart grid technology:
It is strongly recommended to focus a European FP 7 smart grid R&D project on grid losses and smart grid optimization strategies.
This project should model grid losses in cables and transformers and explore grid losses optimization strategies including active switching of transformers, active load management, reduction of transformation steps, increase of the MV system voltage level, and precise monitoring and prediction of grid losses. DSOs and TSOs are currently focused on availability with standards on availability and it is connected benchmarking. This has potentially led to excessive use of no-load loss consumption in redundant idling transformers and generator plant. This is also reflected in the low load factors found (chapter 3). As most of the LV grids are interconnected it is theoretically possible to disable some transformers when the loading is low (e.g. after midnight) with smart grid technology.

7.1.6 Needs and requirements for new standards

Need for a formal standard to measure the load and no load losses for smaller industrial transformers with the high-voltage winding below 1 kV:
It is proposed to use a similar method as distribution transformers (EN 60076-x series). Hereafter is a proposal on how to correct load losses for temperature effects:

1. Load losses should be measured as explained in standard EN 60076-x series with the transformer in the cold state at room temperature (25 °C).
2. Then, load losses should be corrected in the assumption of the insulation temperature class (IEC 60085) temperature minus 50 Celsius degrees.

Hence, the proposed formula is:

$$\mathit{correction\ factor\ load\ loss} = \frac{\text{Thermal coeff.of resistance at insulation class temperature minus 50°C}}{\text{Thermal coeff.of resistance at 25°C}}$$

Rationale for this proposed method: this means that the transformer could be operated safely in a temperature range up to 75 °C, which is a common range for industrial equipment. Temperature distribution effects are neglected in this method, this also justifies the minus 50 °C downward correction.
Note: The high-voltage winding is defined according to the IEV 421-03-03 vocabulary as the winding having the highest rated voltage.

Need to define and include fire behaviour of distribution transformers filled with silicon liquid or biodegradable natural esters:
The fire behaviour is only included in the standard on dry type transformers in IEC 60076-11. The behaviour of silicon liquid transformer under fire had never been tested under standardization condition and pressure in the tank could lead to special results. Therefore, an update of the IEC 60076-11 standard to include oil filled transformers is needed or a new one dedicated to dry type transformers can be developed.
The interest of dry type transformers is not only fire behaviour but also the fact there is no possibility of cold and hot pollution. The behaviour of silicon transformer during fire scenario could degenerate into spreading of liquid and extend the fire outside the transformer. This should also be studied.

Need for an EN equivalent of DIN 42508 standard on - oil-immersed power transformers from 3150 kVA up to 80000 kVA and HV up to 123 kV
This standard includes the reference series for load and no load losses that were used in the MEPS proposal in section 7.1.2.3 and Table 7-1 but there is neither a translation available from German nor an EN equivalent.

7.1.7 Needs for standards to be updated

Add extra no-load classes in standard EN 50464-1:
Additional findings related to EN 50464-1 were made in chapter 5 (see section 5.1.2.4): the most ambitious no-load requirement included herein class 'A0' is not ambitious enough taking into account recent developments with amorphous distribution transformers.
A simple approach to overcome the issue of missing more ambitious classes above A0 and Ak is to indicate A0-XX % and Ak-XX% upon 5 % accuracy. This is already applied in other continents (e.g. China). It is therefore recommended to extend the classes up to A0-50% and also include an intermediate class.

Extend the range and add the inter- and extrapolation method in standard EN 50464-1:
The rated power should be extended from 32kVA to 3 150 kVA and clear inter- and extrapolation methods for unlisted ratings should be included.

Add extra no-load and load classes in draft standard prEN50541-1 standard EN 50464-1:
Although these products were not found on the European market it could be interesting to introduce more ambitious no-load and load classes to avoid mitigation from oil-immersed to dry-type transformers.

Recommendation to reconsider the maximum allowable tolerance of the total losses in IEC 60076-1:
The maximum allowable tolerance on the total losses (sum of the load and no-load losses) is +10% of the total losses (IEC 60076-1). This was discussed in the final stakeholder meeting (24/08/2010) and the best option is to allow a +0% or zero tolerance for exceeding no load losses and load losses separately. The new version of IEC 60076-1 is scheduled for publication towards the end of 2010 and will not be due for revision until around 2015.

Recommendation to include the values of the load and no load losses of the transformer on the rating plate of the transformer in IEC 60076-1/ 7.1:
The values of the load and no load losses of the transformer are not mandatory information on the rating plate of the transformer (IEC 60076-1/ 7.1). This document is about to be re-issued with a new version. Future changers would need to be incorporated in the next review scheduled most likely for 2015 or 2016.

Need for an extended scope of DIN 42508 standard on - oil-immersed power transformers from 3 150 kVA up to 80 000 kVA and HV up to 123 kV to ratings above 80 000 kVA and voltage levels above 123 kV
This standard includes the reference series for load and no load losses that were used in the MEPS proposal in section 7.1.2.3 and Table 7-1 but the scope is limited and should be extended to ratings above 80000 kVA and voltage levels above 123 kV in line with Table 7-1.

7.1.8 Suggestion to add a requirement to consider dual winding for 10 kV or lower voltage transformers

In order to facilitate the MV grid to mitigate to a higher voltage over time and reduce cable losses it might be considered to require a dual or triple primary winding as explained in section 5.1.2.9 in chapter 5. This has no impact on losses: it is only a matter of providing means to switch dual MV windings from series to parallel configuration.
However, requiring dual ratio transformers when such conversion plans are not in sight is a waste of money. Such a conversion also requires more investment in cables and T&D equipment.
Migrating a system from 10 kV operation to 20 kV can be one of the most cost effective investments that any utility can make on Overhead network – ESB Networks have spent about 3 b€ in carrying out such a conversion whilst doing MV refurbishment, and this expenditure was analysed and cost justified to the Irish regulator (CER) and their consultants in exhaustive detail to ensure that it was economically justified. However in the absence of firm plans for such conversion adding in extra windings will only increase cost due to complexity, with possibly a minor increase in losses due to restrictions on the shape of the core.
It is important to keep this improvement option in sight and DSOs could require industry to procure those transformers.

7.1.9 Suggestions for additional installation requirements

Due to the mitigation to less efficient so-called 'Light weight pole mounted transformers with rating between 150-200 kVA with a maximum of 690 kg'', it might be needed that Member States limit the use of them to transformers installed on existing poles.
Due to the potential shift from oil-immersed to less efficient dry type transformers as explained in sections 7.1.2.1 and 7.1.2.2, additional installation for dry-type transformers are also advisable. It is recommended to limit the use of dry type transformers only to industrial sites with a high risk of fire hazard and where the risk of cold pollution and hot pollution is not acceptable. This second approval should be granted by an independent competent body e.g. the competent fire station or an independent organisation (depending on the country and its implementation of industrial fire safety). Currently the risk for this shift should not be overstated because the initial costs of dry type as well as the logistics are significantly higher than for oil types, as they are larger and heavier. The room that the dry type goes into is considerably larger than the substation used by oil-immersed, and furthermore, as dry types run hotter, more HVAC is needed.

7.1.10 Explanation on the spreadsheet impact estimation tool for Member States

The tool used to create the policy scenarios discussed in section 7.1.11 is available on the project website (www.ecotransformer.org). Stakeholders are encouraged to design their own scenarios with preferred timing and ambitious levels.
An important parameter to consider in real life is that the oldest transformers should be replaced first in order to achieve the highest level of electricity savings. This is not modelled in the tool as efficiency classes are defined with average values.

7.1.11 Policy scenario analysis

The scenarios described hereafter provide a global idea of the effects that various scenarios and policy options could have in terms of energy consumption and expenditure. It is therefore possible to calculate different scenarios with a spreadsheet tool provided within this study (see section 7.1.10).
In subsections, a Best Available Technology (BAT), a LLCC (Least Life Cycle Cost) and a MEPS scenario are included. This gives a preview on what is estimated as ultimately achievable. For a realistic implementation, one should take into account some items as discussed in section 7.1.11.5 and a mixture of policy options can be implemented (MEPS, GPP, Regulators requirements, new or updated standards, etc.).
Please note that the scenarios are built upon the assumptions described in the previous chapters and a simplified mathematic model, which results in a certain uncertainty in the outcomes. Amongst others, one of the simplifications is that the model works with discrete values (ratings, life time, losses). The advantage is a spreadsheet model that easily can be understood (see section 7.1.10).
Modifying the data located in Table 2-10 of section 2.2.5 and Table 4-27 from section 4.4.2 in order to estimate future demand with the base-cases, the following inputs are used in all scenarios:

Table 7-7: Policy analysis market inputs

	stock 2005	stock 2020	growth %/year	lifetime (years)
BC1 - Distribution	2 250 000	2 786 875	1.4%	40
BC2 - Industry oil	504 000	624 330	1.4%	25
BC3 - Industry dry	108 800	134 047	1.4%	30
BC4 - Power	64 350	80 000	1.5%	30
BC5 - DER oil	4 000	18 000	10.5%	25
BC6 - DER dry	16 000	72 000	10.5%	25
BC7 - Small	750 000	750 000	0.0%	10

In addition, each base-case has a replacement rate which is inversely proportional to the lifetime of the transformer. For example, 2.5% of the stock of base-case 1 is replaced each year within the model. Table 7-8 uses the market inputs and extrapolates linearly to 2025.

Table 7-8: Detailed market trends 2005-2025

		BC1	BC2	BC3	BC4	BC5	BC6	BC7
2005	**Stock**	2 250 000	504 000	108 800	64 350	4 000	16 000	750 000
	Sales	88 579	27 405	5 151	3 086	582	2 328	75 000
	Replaced	56 250	20 160	3 627	2 145	160	640	75 000
2006	**Stock**	2 282 329	511 245	110 324	65 291	4 422	17 688	750 000
	Sales	89 851	27 799	5 223	3 131	643	2 573	75 000
	Replaced	57 058	20 450	3 677	2 176	177	708	75 000
2007	**Stock**	2 315 122	518 595	111 870	66 245	4 888	19 553	750 000
	Sales	91 142	28 199	5 296	3 177	711	2 844	75 000
	Replaced	57 878	20 744	3 729	2 208	196	782	75 000
2008	**Stock**	2 348 386	526 050	113 437	67 214	5 404	21 615	750 000
	Sales	92 452	28 604	5 370	3 223	786	3 144	75 000
	Replaced	58 710	21 042	3 781	2 240	216	865	75 000
2009	**Stock**	2 382 128	533 613	115 026	68 196	5 974	23 895	750 000

		BC1	BC2	BC3	BC4	BC5	BC6	BC7
	Sales	93 780	29 016	5 446	3 270	869	3 476	75 000
	Replaced	59 553	21 345	3 834	2 273	239	956	75 000
2010	**Stock**	2 416 356	541 284	116 638	69 193	6 604	26 415	750 000
	Sales	95 128	29 433	5 522	3 318	961	3 843	75 000
	Replaced	60 409	21 651	3 888	2 306	264	1 057	75 000
2011	**Stock**	2 451 074	549 065	118 272	70 205	7 300	29 201	750 000
	Sales	96 495	29 856	5 599	3 366	1 062	4 248	75 000
	Replaced	61 277	21 963	3 942	2 340	292	1 168	75 000
2012	**Stock**	2 486 292	556 959	119 928	71 231	8 070	32 281	750 000
	Sales	97 881	30 285	5 678	3 416	1 174	4 696	75 000
	Replaced	62 157	22 278	3 998	2 374	323	1 291	75 000
2013	**Stock**	2 522 016	564 965	121 609	72 272	8 922	35 686	750 000
	Sales	99 287	30 720	5 757	3 466	1 298	5 191	75 000
	Replaced	63 050	22 599	4 054	2 409	357	1 427	75 000
2014	**Stock**	2 558 253	573 087	123 312	73 329	9 863	39 450	750 000
	Sales	100 714	31 162	5 838	3 516	1 435	5 739	75 000
	Replaced	63 956	22 923	4 110	2 444	395	1 578	75 000
2015	**Stock**	2 595 011	581 326	125 040	74 401	10 903	43 611	750 000
	Sales	102 161	31 610	5 920	3 568	1 586	6 344	75 000
	Replaced	64 875	23 253	4 168	2 480	436	1 744	75 000
2016	**Stock**	2 632 297	589 683	126 791	75 488	12 053	48 211	750 000
	Sales	103 629	32 065	6 003	3 620	1 753	7 013	75 000
	Replaced	65 807	23 587	4 226	2 516	482	1 928	75 000
2017	**Stock**	2 670 118	598 160	128 568	76 592	13 324	53 295	750 000
	Sales	105 118	32 525	6 087	3 673	1 938	7 753	75 000
	Replaced	66 753	23 926	4 286	2 553	533	2 132	75 000
2018	**Stock**	2 708 483	606 759	130 369	77 711	14 729	58 917	750 000
	Sales	106 628	32 993	6 172	3 726	2 143	8 571	75 000
	Replaced	67 712	24 270	4 346	2 590	589	2 357	75 000
2019	**Stock**	2 747 400	615 482	132 195	78 847	16 283	65 131	750 000
	Sales	108 160	33 467	6 258	3 781	2 369	9 475	75 000
	Replaced	68 685	24 619	4 407	2 628	651	2 605	75 000
2020	**Stock**	2 786 875	624 330	134 047	80 000	18 000	72 000	750 000
	Sales	109 715	33 948	6 346	3 836	2 618	10 474	75 000
	Replaced	69 672	24 973	4 468	2 667	720	2 880	75 000
2021	**Stock**	2 826 918	633 305	135 925	81 169	19 898	79 594	750 000
	Sales	111 291	34 437	6 435	3 892	2 895	11 579	75 000
	Replaced	70 673	25 332	4 531	2 706	796	3 184	75 000
2022	**Stock**	2 867 536	642 410	137 829	82 356	21 997	87 989	750 000
	Sales	112 890	34 932	6 525	3 949	3 200	12 800	75 000
	Replaced	71 688	25 696	4 594	2 745	880	3 520	75 000
2023	**Stock**	2 908 737	651 645	139 760	83 560	24 317	97 269	750 000
	Sales	114 512	35 434	6 617	4 007	3 537	14 150	75 000
	Replaced	72 718	26 066	4 659	2 785	973	3 891	75 000

		BC1	BC2	BC3	BC4	BC5	BC6	BC7
2024	Stock	2 950 531	661 013	141 718	84 781	26 882	107 528	750 000
	Sales	116 157	35 943	6 709	4 065	3 911	15 642	75 000
	Replaced	73 763	26 441	4 724	2 826	1 075	4 301	75 000
2025	Stock	2 992 925	670 515	143 703	86 021	29 717	118 869	750 000
	Sales	117 826	36 460	6 803	4 125	4 323	17 292	75 000
	Replaced	74 823	26 821	4 790	2 867	1 189	4 755	75 000

7.1.11.1 BAU scenario

The business as usual scenario assumes that the base-cases remain in use for the entire scope of the analysis. As Table 7-9 shows, the transformer market is estimated to consume 101.7 TWh of electricity in 2025. Total electricity consumption from 2011-2025 is expected to be 1 332 TWh. Using the EcoReport conversion factor of 0.458 kg CO_2eq/kWh, greenhouse gas emissions for 2025 amount to 46.6 Mt CO_2eq, and 610.2 Mt CO_2eq for the period of 2011-2025.

Expenditures measures the yearly costs associated with the entire transformer market, and is comprised of two components. The first, product price, is taken into account when the transformer is sold. The second component, electricity cost, is taken as the lifetime electricity cost from losses divided by the transformer lifetime. The table shows that expenditures are expected to be 10.8 b€[156] in 2025, with 135 b€ in the period 2011-2025.

As explained in section 6.2.1.1, other environmental impact indicators are insignificant compared to electricity consumption. Therefore, they are not included in this policy analysis.

As Figure 7-2 shows, base-case 4 (power transformers) uses the most significant portion of electricity, during the period 2011-2025, with 45%, while distribution and industry oil follow with 24% and 19%, respectively. Figure 7-2 shows a similar trend with expenditures, with power transformers dominating with 52% of the total.

[156] Billion Euros in the short scale (10E+9 Euros)

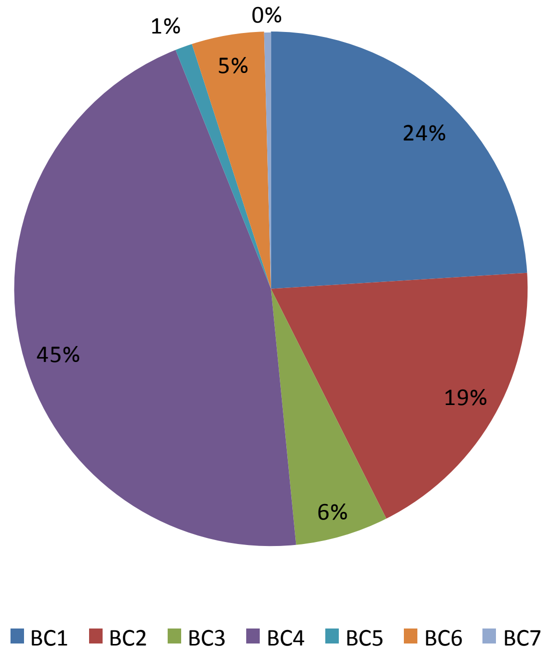


Figure 7-2: BAU electricity consumption 2011-2025 of each base-case

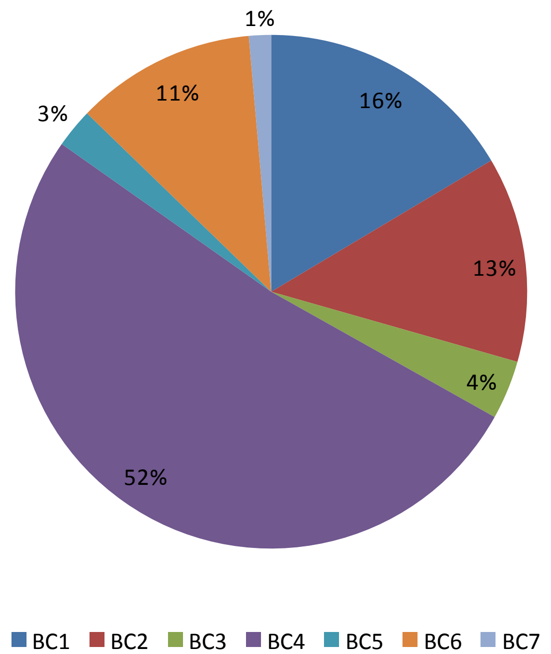


Figure 7-3: BAU expenditure 2011-2025 of each base-case

Table 7-9: Business as usual market trends, electricity consumption, and expenditure

		BC1	BC2	BC3	BC4	BC5	BC6	BC7	Total
		D0Ck	E0Ck	C0Bk	41-326	E0Ck	C0Bk	110-750	
	Electricity (kWh/unit/year)	**7 859**	**27 168**	**39 727**	**519 272**	**59 094**	**62 415**	**505**	
	Product price (€/unit)	**6 122**	**10 926**	**16 333**	**755 843**	**18 248**	**28 192**	**1 348**	
2005	**Stock (units)**	2 250 000	504 000	108 800	64 350	4 000	16 000	750 000	3 697 150
	Sales (units)	88 579	27 405	5 151	3 086	582	2 328	75 000	202 130
	Electricity (TWh)	17.7	13.7	4.3	33.4	0.2	1.0	0.4	70.7
	Expenditure (m€)	1 224.7	966.8	278.5	3 834.6	54.9	252.8	125.0	6 737.5
2006	**Stock (units)**	2 282 329	511 245	110 324	65 291	4 422	17 688	750 000	3 741 298
	Sales (units)	89 851	27 799	5 223	3 131	643	2 573	75 000	204 221
	Electricity (TWh)	17.9	13.9	4.4	33.9	0.3	1.1	0.4	71.9
	Expenditure (m€)	1 242.3	980.7	282.4	3 890.7	60.7	279.5	125.0	6 861.4
2007	**Stock (units)**	2 315 122	518 595	111 870	66 245	4 888	19 553	750 000	3 786 273
	Sales (units)	91 142	28 199	5 296	3 177	711	2 844	75 000	206 370
	Electricity (TWh)	18.2	14.1	4.4	34.4	0.3	1.2	0.4	73.0
	Expenditure (m€)	1 260.2	994.8	286.3	3 947.6	67.1	309.0	125.0	6 990.0
2008	**Stock (units)**	2 348 386	526 050	113 437	67 214	5 404	21 615	750 000	3 832 106
	Sales (units)	92 452	28 604	5 370	3 223	786	3 144	75 000	208 580
	Electricity (TWh)	18.5	14.3	4.5	34.9	0.3	1.3	0.4	74.2
	Expenditure (m€)	1 278.3	1 009.1	290.3	4 005.3	74.2	341.6	125.0	7 123.8
2009	**Stock (units)**	2 382 128	533 613	115 026	68 196	5 974	23 895	750 000	3 878 832
	Sales (units)	93 780	29 016	5 446	3 270	869	3 476	75 000	210 857
	Electricity (TWh)	18.7	14.5	4.6	35.4	0.4	1.5	0.4	75.4
	Expenditure (m€)	1 296.7	1 023.6	294.4	4 063.8	82.0	377.6	125.0	7 263.2
2010	**Stock (units)**	2 416 356	541 284	116 638	69 193	6 604	26 415	750 000	3 926 489
	Sales (units)	95 128	29 433	5 522	3 318	961	3 843	75 000	213 204
	Electricity (TWh)	19.0	14.7	4.6	35.9	0.4	1.6	0.4	76.7
	Expenditure (m€)	1 315.3	1 038.4	298.5	4 123.2	90.7	417.4	125.0	7 408.5

		BC1 D0Ck	BC2 E0Ck	BC3 C0Bk	BC4 41-326	BC5 E0Ck	BC6 C0Bk	BC7 110-750	Total
2011	Stock (units)	2 451 074	549 065	118 272	70 205	7 300	29 201	750 000	3 975 118
	Sales (units)	96 495	29 856	5 599	3 366	1 062	4 248	75 000	215 626
	Electricity (TWh)	19.3	14.9	4.7	36.5	0.4	1.8	0.4	78.0
	Expenditure (m€)	1 334.2	1 053.3	302.7	4 183.5	100.3	461.4	125.0	7 560.4
2012	Stock (units)	2 486 292	556 959	119 928	71 231	8 070	32 281	750 000	4 024 762
	Sales (units)	97 881	30 285	5 678	3 416	1 174	4 696	75 000	218 130
	Electricity (TWh)	19.5	15.1	4.8	37.0	0.5	2.0	0.4	79.3
	Expenditure (m€)	1 353.4	1 068.4	306.9	4 244.7	110.8	510.1	125.0	7 719.3
2013	Stock (units)	2 522 016	564 965	121 609	72 272	8 922	35 686	750 000	4 075 470
	Sales (units)	99 287	30 720	5 757	3 466	1 298	5 191	75 000	220 720
	Electricity (TWh)	19.8	15.3	4.8	37.5	0.5	2.2	0.4	80.7
	Expenditure (m€)	1 372.8	1 083.8	311.2	4 306.7	122.5	563.9	125.0	7 886.0
2014	Stock (units)	2 558 253	573 087	123 312	73 329	9 863	39 450	750 000	4 127 294
	Sales (units)	100 714	31 162	5 838	3 516	1 435	5 739	75 000	223 404
	Electricity (TWh)	20.1	15.6	4.9	38.1	0.6	2.5	0.4	82.1
	Expenditure (m€)	1 392.5	1 099.4	315.6	4 369.7	135.4	623.4	125.0	8 061.0
2015	Stock (units)	2 595 011	581 326	125 040	74 401	10 903	43 611	750 000	4 180 290
	Sales (units)	102 161	31 610	5 920	3 568	1 586	6 344	75 000	226 189
	Electricity (TWh)	20.4	15.8	5.0	38.6	0.6	2.7	0.4	83.5
	Expenditure (m€)	1 412.5	1 115.2	320.0	4 433.5	149.7	689.1	125.0	8 245.2
2016	Stock (units)	2 632 297	589 683	126 791	75 488	12 053	48 211	750 000	4 234 522
	Sales (units)	103 629	32 065	6 003	3 620	1 753	7 013	75 000	229 083
	Electricity (TWh)	20.7	16.0	5.0	39.2	0.7	3.0	0.4	85.0
	Expenditure (m€)	1 432.8	1 131.2	324.5	4 498.3	165.5	761.8	125.0	8 439.3
2017	Stock (units)	2 670 118	598 160	128 568	76 592	13 324	53 295	750 000	4 290 057
	Sales (units)	105 118	32 525	6 087	3 673	1 938	7 753	75 000	232 094
	Electricity (TWh)	21.0	16.3	5.1	39.8	0.8	3.3	0.4	86.6

		BC1 D0Ck	BC2 E0Ck	BC3 C0Bk	BC4 41-326	BC5 E0Ck	BC6 C0Bk	BC7 110-750	Total
	Expenditure (m€)	1 453.4	1 147.5	329.1	4 564.1	183.0	842.2	125.0	8 644.2
2018	Stock (units)	2 708 483	606 759	130 369	77 711	14 729	58 917	750 000	4 346 968
	Sales (units)	106 628	32 993	6 172	3 726	2 143	8 571	75 000	235 233
	Electricity (TWh)	21.3	16.5	5.2	40.4	0.9	3.7	0.4	88.2
	Expenditure (m€)	1 474.3	1 164.0	333.7	4 630.8	202.3	931.0	125.0	8 861.0
2019	Stock (units)	2 747 400	615 482	132 195	78 847	16 283	65 131	750 000	4 405 337
	Sales (units)	108 160	33 467	6 258	3 781	2 369	9 475	75 000	238 510
	Electricity (TWh)	21.6	16.7	5.3	40.9	1.0	4.1	0.4	89.9
	Expenditure (m€)	1 495.5	1 180.7	338.3	4 698.5	223.6	1 029.2	125.0	9 090.9
2020	Stock (units)	2 786 875	624 330	134 047	80 000	18 000	72 000	750 000	4 465 252
	Sales (units)	109 715	33 948	6 346	3 836	2 618	10 474	75 000	241 938
	Electricity (TWh)	21.9	17.0	5.3	41.5	1.1	4.5	0.4	91.7
	Expenditure (m€)	1 517.0	1 197.7	343.1	4 767.2	247.2	1 137.7	125.0	9 334.9
2021	Stock (units)	2 826 918	633 305	135 925	81 169	19 898	79 594	750 000	4 526 810
	Sales (units)	111 291	34 437	6 435	3 892	2 895	11 579	75 000	245 528
	Electricity (TWh)	22.2	17.2	5.4	42.1	1.2	5.0	0.4	93.5
	Expenditure (m€)	1 538.8	1 214.9	347.9	4 836.9	273.3	1 257.7	125.0	9 594.5
2022	Stock (units)	2 867 536	642 410	137 829	82 356	21 997	87 989	750 000	4 590 116
	Sales (units)	112 890	34 932	6 525	3 949	3 200	12 800	75 000	249 296
	Electricity (TWh)	22.5	17.5	5.5	42.8	1.3	5.5	0.4	95.4
	Expenditure (m€)	1 560.9	1 232.3	352.8	4 907.6	302.1	1 390.4	125.0	9 871.1
2023	Stock (units)	2 908 737	651 645	139 760	83 560	24 317	97 269	750 000	4 655 288
	Sales (units)	114 512	35 434	6 617	4 007	3 537	14 150	75 000	253 257
	Electricity (TWh)	22.9	17.7	5.6	43.4	1.4	6.1	0.4	97.4
	Expenditure (m€)	1 583.3	1 250.1	357.7	4 979.3	333.9	1 537.0	125.0	10 166.4
2024	Stock (units)	2 950 531	661 013	141 718	84 781	26 882	107 528	750 000	4 722 453
	Sales (units)	116 157	35 943	6 709	4 065	3 911	15 642	75 000	257 428

		BC1 D0Ck	BC2 E0Ck	BC3 C0Bk	BC4 41-326	BC5 E0Ck	BC6 C0Bk	BC7 110-750	Total
	Electricity (TWh)	23.2	18.0	5.6	44.0	1.6	6.7	0.4	99.5
	Expenditure (m€)	1 606.1	1 268.0	362.7	5 052.1	369.2	1 699.1	125.0	10 482.3
2025	**Stock (units)**	2 992 925	670 515	143 703	86 021	29 717	118 869	750 000	4 791 751
	Sales (units)	117 826	36 460	6 803	4 125	4 323	17 292	75 000	261 829
	Electricity (TWh)	23.5	18.2	5.7	44.7	1.8	7.4	0.4	101.7
	Expenditure (m€)	1 629.1	1 286.3	367.8	5 126.0	408.1	1 878.3	125.0	10 820.7
2011-2025	**Electricity (TWh)**	**319.9**	**247.7**	**77.8**	**606.5**	**14.3**	**60.5**	**5.7**	**1 332.4**
2011-2025	**Expenditure (m€)**	**22 156.6**	**17 492.6**	**5 014.0**	**69 599.1**	**3 326.8**	**15 312.4**	**1 875.6**	**134 777.1**

7.1.11.2 LLCC scenario

The LLCC scenario assumes that minimum performance requirements implement all LLCC options, as calculated in Task 6. The requirements are implemented in one phase in 2013, as shown in Table 7-10.

Table 7-10: LLCC minimum performance requirements (denotes AMT)*

	2010	2013
BC1	D0Ck	A0+Ck*
BC2	E0Ck	A0Ak
BC3	C0Bk	A0Bk
BC4	41-326	34-326
BC5	E0Ck	A0+Ak*
BC6	C0Bk	A0Ak
BC7	110-750	-

Using the minimum performance requirements to dictate market trends, Table 7-11 shows that the transformer market would consume 84.9 TWh of electricity in 2025 (-16.4% BAU), and expenditure for this year would be 10.7 b€ (-1.5% BAU). Total electricity consumption from 2011-2025 is expected to be 1 229 TWh, 7.7% less than BAU, while expenditures are estimated at 139 b€, 2.8% greater than BAU. Using the EcoReport conversion factor of 0.458 kg CO2eq/kWh, greenhouse gas emissions for 2025 amount to 38.9 Mt CO_2 eq, and 563.0 Mt CO_2 eq for the period of 2011-2025. These numbers are 7.7 and 47.2 Mt CO_2eq less than BAU, respectively.

Please note that for other LLCC scenarios, e.g. BC1 with A0Ck a spreadsheet tool is provided (see section 7.1.10 and project website).
Alternative LLCC option for BC 6:

As previously discussed (see section 6.2.1.6), a better improvement option for BC 6 than the A0Ak improvement option could be the implementation of BC 5 A0+Ak* design with biodegradable oil, which would then represent the LLCC option for BC 6.
Assuming this configuration is adopted as LLCC instead of the A0Ak, the transformer market would consume 82.2 TWh of electricity in 2025 (-19.1% BAU) (further reduction of 2.7 TWh electricity in 2025 compared to the LLCC scenario, only due to the adoption of A0+Ak* with biodegradable oil, instead of A0Ak for BC 6) and expenditure for this year would be 10.4 b€ (-4.2% BAU) (similarly, further reduction of 0.3 b€ compared to the LLCC scenario).

Total electricity consumption from 2011-2025 is expected to be 1 215 TWh, 8.8% less than BAU and 1% less than LLCC scenario, while expenditures are estimated at 137.5 b€, 2.0% greater than BAU and 1% less than LLCC scenario.

Table 7-11: LLCC market trends, electricity consumption, and expenditures

		BC1		BC2		BC3		BC4		BC5		BC6		BC7	Total	Difference with BAU	
		2010	2013	2010	2013	2010	2013	2010	2013	2010	2013	2010	2013	2010		absolute	relative
		D0Ck	A0+Ck*	E0Ck	A0Ak	C0Bk	A0Bk	41-326	34-326	E0Ck	A0+Ak*	C0Bk	A0Ak	110-750			
	Electricity (kWh/unit/year)	**7 859**	**2 993**	**27 168**	**15 631**	**39 727**	**30 967**	**519 272**	**466 055**	**59 094**	**23 378**	**62 415**	**47 109**	**505**			
	Product price (€/unit)	**6 122**	**8 632**	**10 926**	**16 717**	**16 333**	**18 783**	**755 843**	**801 194**	**18 248**	**41 059**	**28 192**	**36 931**	**1 348**			
2005	**Stock (units)**	2 250 000	0	504 000	0	108 800	0	64 350	0	4 000	0	16 000	0	750 000	3 697 150	**0.0**	**0.0%**
	Sales (units)	88 579	0	27 405	0	5 151	0	3 086	0	582	0	2 328	0	75 000	202 130	**0.0**	**0.0%**
	Electricity (TWh)	17.7	0.0	13.7	0.0	4.3	0.0	33.4	0.0	0.2	0.0	1.0	0.0	0.4	70.7	**0.0**	**0.0%**
	Expenditure (m€)	1 224.7	0.0	966.8	0.0	278.5	0.0	3 834.6	0.0	54.9	0.0	252.8	0.0	125.0	6 737.5	**0.0**	**0.0%**
2006	**Stock (units)**	2 282 329	0	511 245	0	110 324	0	65 291	0	4 422	0	17 688	0	750 000	3 741 298	**0.0**	**0.0%**
	Sales (units)	89 851	0	27 799	0	5 223	0	3 131	0	643	0	2 573	0	75 000	204 221	**0.0**	**0.0%**
	Electricity (TWh)	17.9	0.0	13.9	0.0	4.4	0.0	33.9	0.0	0.3	0.0	1.1	0.0	0.4	71.9	**0.0**	**0.0%**
	Expenditure (m€)	1 242.3	0.0	980.7	0.0	282.4	0.0	3 890.7	0.0	60.7	0.0	279.5	0.0	125.0	6 861.4	**0.0**	**0.0%**
2007	**Stock (units)**	2 315 122	0	518 595	0	111 870	0	66 245	0	4 888	0	19 553	0	750 000	3 786 273	**0.0**	**0.0%**
	Sales (units)	91 142	0	28 199	0	5 296	0	3 177	0	711	0	2 844	0	75 000	206 370	**0.0**	**0.0%**
	Electricity (TWh)	18.2	0.0	14.1	0.0	4.4	0.0	34.4	0.0	0.3	0.0	1.2	0.0	0.4	73.0	**0.0**	**0.0%**
	Expenditure (m€)	1 260.2	0.0	994.8	0.0	286.3	0.0	3 947.6	0.0	67.1	0.0	309.0	0.0	125.0	6 990.0	**0.0**	**0.0%**
2008	**Stock (units)**	2 348 386	0	526 050	0	113 437	0	67 214	0	5 404	0	21 615	0	750 000	3 832 106	**0.0**	**0.0%**
	Sales (units)	92 452	0	28 604	0	5 370	0	3 223	0	786	0	3 144	0	75 000	208 580	**0.0**	**0.0%**
	Electricity (TWh)	18.5	0.0	14.3	0.0	4.5	0.0	34.9	0.0	0.3	0.0	1.3	0.0	0.4	74.2	**0.0**	**0.0%**
	Expenditure (m€)	1 278.3	0.0	1 009.1	0.0	290.3	0.0	4 005.3	0.0	74.2	0.0	341.6	0.0	125.0	7 123.8	**0.0**	**0.0%**
2009	**Stock (units)**	2 382 128	0	533 613	0	115 026	0	68 196	0	5 974	0	23 895	0	750 000	3 878 832	**0.0**	**0.0%**
	Sales (units)	93 780	0	29 016	0	5 446	0	3 270	0	869	0	3 476	0	75 000	210 857	**0.0**	**0.0%**
	Electricity (TWh)	18.7	0.0	14.5	0.0	4.6	0.0	35.4	0.0	0.4	0.0	1.5	0.0	0.4	75.4	**0.0**	**0.0%**
	Expenditure (m€)	1 296.7	0.0	1 023.6	0.0	294.4	0.0	4 063.8	0.0	82.0	0.0	377.6	0.0	125.0	7 263.2	**0.0**	**0.0%**
2010	**Stock (units)**	2 416 356	0	541 284	0	116 638	0	69 193	0	6 604	0	26 415	0	750 000	3 926 489	**0.0**	**0.0%**
	Sales (units)	95 128	0	29 433	0	5 522	0	3 318	0	961	0	3 843	0	75 000	213 204	**0.0**	**0.0%**
	Electricity (TWh)	19.0	0.0	14.7	0.0	4.6	0.0	35.9	0.0	0.4	0.0	1.6	0.0	0.4	76.7	**0.0**	**0.0%**

		BC1		BC2		BC3		BC4		BC5		BC6		BC7	Total	Difference with BAU	
		2010	2013	2010	2013	2010	2013	2010	2013	2010	2013	2010	2013	2010		absolute	relative
		D0Ck	A0+Ck*	E0Ck	A0Ak	C0Bk	A0Bk	41-326	34-326	E0Ck	A0+Ak*	C0Bk	A0Ak	110-750			
	Expenditure (m€)	1 315.3	0.0	1 038.4	0.0	298.5	0.0	4 123.2	0.0	90.7	0.0	417.4	0.0	125.0	7 408.5	**0.0**	**0.0%**
2011	**Stock (units)**	2 451 074	0	549 065	0	118 272	0	70 205	0	7 300	0	29 201	0	750 000	3 975 118	**0.0**	**0.0%**
	Sales (units)	96 495	0	29 856	0	5 599	0	3 366	0	1 062	0	4 248	0	75 000	215 626	**0.0**	**0.0%**
	Electricity (TWh)	19.3	0.0	14.9	0.0	4.7	0.0	36.5	0.0	0.4	0.0	1.8	0.0	0.4	78.0	**0.0**	**0.0%**
	Expenditure (m€)	1 334.2	0.0	1 053.3	0.0	302.7	0.0	4 183.5	0.0	100.3	0.0	461.4	0.0	125.0	7 560.4	**0.0**	**0.0%**
2012	**Stock (units)**	2 486 292	0	556 959	0	119 928	0	71 231	0	8 070	0	32 281	0	750 000	4 024 762	**0.0**	**0.0%**
	Sales (units)	97 881	0	30 285	0	5 678	0	3 416	0	1 174	0	4 696	0	75 000	218 130	**0.0**	**0.0%**
	Electricity (TWh)	19.5	0.0	15.1	0.0	4.8	0.0	37.0	0.0	0.5	0.0	2.0	0.0	0.4	79.3	**0.0**	**0.0%**
	Expenditure (m€)	1 353.4	0.0	1 068.4	0.0	306.9	0.0	4 244.7	0.0	110.8	0.0	510.1	0.0	125.0	7 719.3	**0.0**	**0.0%**
2013	**Stock (units)**	2 522 016	0	564 965	0	121 609	0	72 272	0	8 922	0	35 686	0	750 000	4 075 470	**0.0**	**0.0%**
	Sales (units)	0	99 287	0	30 720	0	5 757	0	3 466	0	1 298	0	5 191	75 000	220 720	**0.0**	**0.0%**
	Electricity (TWh)	19.8	0.0	15.3	0.0	4.8	0.0	37.5	0.0	0.5	0.0	2.2	0.0	0.4	80.7	**0.0**	**0.0%**
	Expenditure (m€)	765.0	857.1	748.1	513.5	217.2	108.1	1 687.3	2 776.6	98.8	53.3	417.6	191.7	125.0	8 559.3	**673.4**	**8.5%**
2014	**Stock (units)**	2 458 966	99 287	542 367	30 720	117 555	5 757	69 863	3 466	8 565	1 298	34 259	5 191	750 000	4 127 294	**0.0**	**0.0%**
	Sales (units)	0	100 714	0	31 162	0	5 838	0	3 516	0	1 435	0	5 739	75 000	223 404	**0.0**	**0.0%**
	Electricity (TWh)	19.3	0.3	14.7	0.5	4.7	0.2	36.3	1.6	0.5	0.0	2.1	0.2	0.4	80.9	**-1.2**	**-1.5%**
	Expenditure (m€)	745.8	880.8	718.2	544.3	210.0	117.7	1 631.0	2 889.8	94.9	64.6	400.8	257.8	125.0	8 680.8	**619.8**	**7.7%**
2015	**Stock (units)**	2 395 009	200 002	519 443	61 883	113 444	11 595	67 419	6 982	8 170	2 733	32 681	10 930	750 000	4 180 290	**0.0**	**0.0%**
	Sales (units)	0	102 161	0	31 610	0	5 920	0	3 568	0	1 586	0	6 344	75 000	226 189	**0.0**	**0.0%**
	Electricity (TWh)	18.8	0.6	14.1	1.0	4.5	0.4	35.0	3.3	0.5	0.1	2.0	0.5	0.4	81.1	**-2.4**	**-2.9%**
	Expenditure (m€)	726.4	905.0	687.9	575.6	202.6	127.3	1 574.0	3 004.7	90.5	77.1	382.4	330.8	125.0	8 809.3	**564.1**	**6.8%**
2016	**Stock (units)**	2 330 134	302 163	496 190	93 493	109 276	17 515	64 939	10 549	7 734	4 319	30 936	17 274	750 000	4 234 522	**0.0**	**0.0%**
	Sales (units)	0	103 629	0	32 065	0	6 003	0	3 620	0	1 753	0	7 013	75 000	229 083	**0.0**	**0.0%**
	Electricity (TWh)	18.3	0.9	13.5	1.5	4.3	0.5	33.7	4.9	0.5	0.1	1.9	0.8	0.4	81.4	**-3.7**	**-4.3%**
	Expenditure (m€)	706.8	929.4	657.1	607.2	195.2	137.1	1 516.1	3 121.2	85.7	90.9	362.0	411.6	125.0	8 945.3	**506.0**	**6.0%**
2017	**Stock (units)**	2 264 327	405 792	472 603	125 557	105 050	23 517	62 422	14 169	7 252	6 072	29 008	24 288	750 000	4 290 057	**0.0**	**0.0%**

		BC1		BC2		BC3		BC4		BC5		BC6		BC7	Total	Difference with BAU	
		2010	2013	2010	2013	2010	2013	2010	2013	2010	2013	2010	2013	2010		absolute	relative
		D0Ck	A0+Ck*	E0Ck	A0Ak	C0Bk	A0Bk	41-326	34-326	E0Ck	A0+Ak*	C0Bk	A0Ak	110-750			
	Sales (units)	0	105 118	0	32 525	0	6 087	0	3 673	0	1 938	0	7 753	75 000	232 094	**0.0**	**0.0%**
	Electricity (TWh)	17.8	1.2	12.8	2.0	4.2	0.7	32.4	6.6	0.4	0.1	1.8	1.1	0.4	81.6	**-5.0**	**-5.7%**
	Expenditure (m€)	686.8	954.3	625.8	639.4	187.6	147.1	1 457.3	3 239.4	80.3	106.2	339.4	500.8	125.0	9 089.5	**445.3**	**5.2%**
2018	**Stock (units)**	2 197 574	510 910	448 677	158 083	100 765	29 604	59 869	17 842	6 719	8 010	26 876	32 041	750 000	4 346 968	**0.0**	**0.0%**
	Sales (units)	0	106 628	0	32 993	0	6 172	0	3 726	0	2 143	0	8 571	75 000	235 233	**0.0**	**0.0%**
	Electricity (TWh)	17.3	1.5	12.2	2.5	4.0	0.9	31.1	8.3	0.4	0.2	1.7	1.5	0.4	81.9	**-6.3**	**-7.1%**
	Expenditure (m€)	666.6	979.4	594.1	672.0	180.0	157.1	1 397.7	3 359.4	74.4	123.1	314.5	599.5	125.0	9 242.9	**381.8**	**4.3%**
2019	**Stock (units)**	2 129 862	617 538	424 406	191 076	96 419	35 776	57 279	21 568	6 130	10 153	24 519	40 611	750 000	4 405 337	**0.0**	**0.0%**
	Sales (units)	0	108 160	0	33 467	0	6 258	0	3 781	0	2 369	0	9 475	75 000	238 510	**0.0**	**0.0%**
	Electricity (TWh)	16.7	1.8	11.5	3.0	3.8	1.1	29.7	10.1	0.4	0.2	1.5	1.9	0.4	82.3	**-7.7**	**-8.5%**
	Expenditure (m€)	646.0	1 005.0	562.0	705.0	172.2	167.4	1 337.2	3 481.1	67.9	141.7	286.9	708.6	125.0	9 406.2	**315.3**	**3.5%**
2020	**Stock (units)**	2 061 177	725 698	399 787	224 543	92 012	42 035	54 651	25 349	5 479	12 521	21 914	50 086	750 000	4 465 252	**0.0**	**0.0%**
	Sales (units)	0	109 715	0	33 948	0	6 346	0	3 836	0	2 618	0	10 474	75 000	241 938	**0.0**	**0.0%**
	Electricity (TWh)	16.2	2.2	10.9	3.5	3.7	1.3	28.4	11.8	0.3	0.3	1.4	2.4	0.4	82.6	**-9.1**	**-9.9%**
	Expenditure (m€)	625.2	1 030.9	529.4	738.6	164.3	177.7	1 275.9	3 604.6	60.7	162.4	256.4	829.1	125.0	9 580.3	**245.4**	**2.6%**
2021	**Stock (units)**	1 991 505	835 413	374 814	258 492	87 544	48 381	51 984	29 185	4 759	15 140	19 034	60 560	750 000	4 526 810	**0.0**	**0.0%**
	Sales (units)	0	111 291	0	34 437	0	6 435	0	3 892	0	2 895	0	11 579	75 000	245 528	**0.0**	**0.0%**
	Electricity (TWh)	15.7	2.5	10.2	4.0	3.5	1.5	27.0	13.6	0.3	0.4	1.2	2.9	0.4	83.0	**-10.5**	**-11.2%**
	Expenditure (m€)	604.1	1 057.2	496.3	772.6	156.4	188.2	1 213.6	3 730.0	52.7	185.2	222.7	962.4	125.0	9 766.4	**172.0**	**1.8%**
2022	**Stock (units)**	1 920 832	946 704	349 481	292 928	83 013	54 816	49 278	33 078	3 963	18 035	15 850	72 138	750 000	4 590 116	**0.0**	**0.0%**
	Sales (units)	0	112 890	0	34 932	0	6 525	0	3 949	0	3 200	0	12 800	75 000	249 296	**0.0**	**0.0%**
	Electricity (TWh)	15.1	2.8	9.5	4.6	3.3	1.7	25.6	15.4	0.2	0.4	1.0	3.4	0.4	83.4	**-12.0**	**-12.6%**
	Expenditure (m€)	582.6	1 083.8	462.8	807.1	148.3	198.9	1 150.5	3 857.1	43.9	210.4	185.5	1 109.8	125.0	9 965.7	**94.6**	**1.0%**
2023	**Stock (units)**	1 849 143	1 059 594	323 785	327 860	78 419	61 341	46 533	37 027	3 083	21 235	12 331	84 938	750 000	4 655 288	**0.0**	**0.0%**
	Sales (units)	0	114 512	0	35 434	0	6 617	0	4 007	0	3 537	0	14 150	75 000	253 257	**0.0**	**0.0%**
	Electricity (TWh)	14.5	3.2	8.8	5.1	3.1	1.9	24.2	17.3	0.2	0.5	0.8	4.0	0.4	83.9	**-13.5**	**-13.9%**

		BC1		BC2		BC3		BC4		BC5		BC6		BC7	Total	Difference with BAU	
		2010	2013	2010	2013	2010	2013	2010	2013	2010	2013	2010	2013	2010		absolute	relative
		D0Ck	A0+Ck*	E0Ck	A0Ak	C0Bk	A0Bk	41-326	34-326	E0Ck	A0+Ak*	C0Bk	A0Ak	110-750			
	Expenditure (m€)	560.9	1 110.9	428.8	842.1	140.1	209.7	1 086.4	3 986.1	34.2	238.3	144.3	1 272.7	125.0	10 179.3	**12.9**	**0.1%**
2024	**Stock (units)**	1 776 425	1 174 106	297 719	363 293	73 760	67 957	43 748	41 034	2 110	24 772	8 440	99 088	750 000	4 722 453	**0.0**	**0.0%**
	Sales (units)	0	116 157	0	35 943	0	6 709	0	4 065	0	3 911	0	15 642	75 000	257 428	**0.0**	**0.0%**
	Electricity (TWh)	14.0	3.5	8.1	5.7	2.9	2.1	22.7	19.1	0.1	0.6	0.5	4.7	0.4	84.4	**-15.1**	**-15.2%**
	Expenditure (m€)	538.8	1 138.3	394.2	877.6	131.7	220.6	1 021.3	4 117.0	23.4	269.1	98.8	1 452.8	125.0	10 408.8	**-73.5**	**-0.7%**
2025	**Stock (units)**	1 702 662	1 290 263	271 279	399 237	69 036	74 667	40 922	45 099	1 035	28 683	4 139	114 730	750 000	4 791 751	**0.0**	**0.0%**
	Sales (units)	0	117 826	0	36 460	0	6 803	0	4 125	0	4 323	0	17 292	75 000	261 829	**0.0**	**0.0%**
	Electricity (TWh)	13.4	3.9	7.4	6.2	2.7	2.3	21.2	21.0	0.1	0.7	0.3	5.4	0.4	84.9	**-16.7**	**-16.4%**
	Expenditure (m€)	516.4	1 166.1	359.2	913.7	123.3	231.7	955.4	4 249.8	11.5	303.2	48.4	1 651.8	125.0	10 655.6	**-165.0**	**-1.5%**
2011-2025	**Electricity (TWh)**	**255.7**	**24.4**	**179.1**	**39.5**	**59.0**	**14.6**	**458.3**	**133.0**	**5.3**	**3.6**	**22.3**	**28.8**	**5.7**	**1 229.4**	**-103.1**	**-7.7%**
2011-2025	**Expenditure (m€)**	**11 058.9**	**13 098.2**	**9 385.7**	**9 208.8**	**2 838.5**	**2 188.7**	**25 731.8**	**45 416.9**	**1 029.9**	**2 025.6**	**4 431.1**	**10 279.4**	**1 875.6**	**138 569.2**	**3 792.1**	**2.8%**

7.1.11.3 BAT scenario

The BAT scenario assumes that minimum performance requirements implement all BAT options, as calculated in Task 6. The requirements are implemented in one phase the first in 2013 as shown in Table 7-12.

Table 7-12: BAT minimum performance requirements (denotes AMT)*

	2010	2013
BC1	D0Ck	A0+Ak+*
BC2	E0Ck	A0+Ak+*
BC3	C0Bk	A0+Ak*
BC4	41-326	20-228
BC5	E0Ck	A0+Ak*
BC6	C0Bk	A0Ak
BC7	110-750	110-400

Using the minimum performance requirements to dictate market trends, Table 7-13 shows that the transformer market would consume 73.5 TWh of electricity in 2025 (-27.7% BAU), and expenditure for this year would be 15.8 b€ (+45.6% BAU). Total electricity consumption from 2011-2025 is expected to be 1 157 TWh, 13.2% less than BAU, while expenditures are estimated at 202 b€, 50.2% greater than BAU. Using the EcoReport conversion factor of 0.458 kg CO_2 eq/kWh, greenhouse gas emissions for 2025 amount to 33.7 Mt CO_2 eq, and 529.9 Mt CO_2 eq for the period of 2011-2025. These numbers are 12.9 and 80.3 Mt CO2eq less than BAU, respectively.

Alternative BAT option for BC 6:

As previously discussed (see section 6.2.1.6), a better improvement option for BC 6 than the A0Ak improvement option could be the implementation of BC 5 A0+Ak* design with biodegradable oil, which would then represent the BAT option for BC 6.
Assuming this configuration is adopted as BAT instead of the A0Ak, the transformer market would consume 70.8 TWh of electricity in 2025 (-30.3% BAU) (further reduction of 2.7 TWh electricity in 2025 compared to the BAT scenario, only due to the adoption of A0+Ak* with biodegradable oil, instead of A0Ak for BC 6) and expenditure for this year would be 15.5 b€ (+42.9% BAU) (similarly, further reduction of 0.3 b€ compared to the BAT scenario).

Total electricity consumption from 2011-2025 is expected to be 1 142 TWh, 14.3% less than BAU and 1.3% less than BAT scenario, while expenditures are estimated at 201 b€, 49.4% greater than BAU and 1% less than BAT scenario.

Table 7-13: BAT market trends and electricity consumption

		BC1		BC2		BC3		BC4		BC5		BC6		BC7		Total	Difference with BAU	
		2010	2013	2010	2013	2010	2013	2010	2013	2010	2013	2010	2013	2010	2013		absolute	relative
		D0Ck	A0+Ak+*	E0Ck	A0+Ak+*	C0Bk	A0+Ak*	41-326	20-228	E0Ck	A0+Ak*	C0Bk	A0Ak	110-750	110-400			
	Electricity (kWh/unit/year)	7 859	2 595	27 168	10 606	39 727	18 108	519 272	292 534	59 094	23 378	62 415	47 109	505	359			
	Product price (€/unit)	6 122	12 918	10 926	28 626	16 333	40 669	755 843	1 889 608	18 248	41 059	28 192	36 931	1 348	1 914			
2005	Stock (units)	2 250 000	0	504 000	0	108 800	0	64 350	0	4 000	0	16 000	0	750 000	0	3 697 150	0.0	0.0%
	Sales (units)	88 579	0	27 405	0	5 151	0	3 086	0	582	0	2 328	0	75 000	0	202 130	0.0	0.0%
	Electricity (TWh)	17.7	0.0	13.7	0.0	4.3	0.0	33.4	0.0	0.2	0.0	1.0	0.0	0.4	0.0	70.7	0.0	0.0%
	Expenditure (m€)	1 224.7	0.0	966.8	0.0	278.5	0.0	3 834.6	0.0	54.9	0.0	252.8	0.0	125.0	0.0	6 737.5	0.0	0.0%
2006	Stock (units)	2 282 329	0	511 245	0	110 324	0	65 291	0	4 422	0	17 688	0	750 000	0	3 741 298	0.0	0.0%
	Sales (units)	89 851	0	27 799	0	5 223	0	3 131	0	643	0	2 573	0	75 000	0	204 221	0.0	0.0%
	Electricity (TWh)	17.9	0.0	13.9	0.0	4.4	0.0	33.9	0.0	0.3	0.0	1.1	0.0	0.4	0.0	71.9	0.0	0.0%
	Expenditure (m€)	1 242.3	0.0	980.7	0.0	282.4	0.0	3 890.7	0.0	60.7	0.0	279.5	0.0	125.0	0.0	6 861.4	0.0	0.0%
2007	Stock (units)	2 315 122	0	518 595	0	111 870	0	66 245	0	4 888	0	19 553	0	750 000	0	3 786 273	0.0	0.0%
	Sales (units)	91 142	0	28 199	0	5 296	0	3 177	0	711	0	2 844	0	75 000	0	206 370	0.0	0.0%
	Electricity (TWh)	18.2	0.0	14.1	0.0	4.4	0.0	34.4	0.0	0.3	0.0	1.2	0.0	0.4	0.0	73.0	0.0	0.0%
	Expenditure (m€)	1 260.2	0.0	994.8	0.0	286.3	0.0	3 947.6	0.0	67.1	0.0	309.0	0.0	125.0	0.0	6 990.0	0.0	0.0%
2008	Stock (units)	2 348 386	0	526 050	0	113 437	0	67 214	0	5 404	0	21 615	0	750 000	0	3 832 106	0.0	0.0%
	Sales (units)	92 452	0	28 604	0	5 370	0	3 223	0	786	0	3 144	0	75 000	0	208 580	0.0	0.0%
	Electricity (TWh)	18.5	0.0	14.3	0.0	4.5	0.0	34.9	0.0	0.3	0.0	1.3	0.0	0.4	0.0	74.2	0.0	0.0%
	Expenditure (m€)	1 278.3	0.0	1 009.1	0.0	290.3	0.0	4 005.3	0.0	74.2	0.0	341.6	0.0	125.0	0.0	7 123.8	0.0	0.0%
2009	Stock (units)	2 382 128	0	533 613	0	115 026	0	68 196	0	5 974	0	23 895	0	750 000	0	3 878 832	0.0	0.0%
	Sales (units)	93 780	0	29 016	0	5 446	0	3 270	0	869	0	3 476	0	75 000	0	210 857	0.0	0.0%
	Electricity (TWh)	18.7	0.0	14.5	0.0	4.6	0.0	35.4	0.0	0.4	0.0	1.5	0.0	0.4	0.0	75.4	0.0	0.0%
	Expenditure (m€)	1 296.7	0.0	1 023.6	0.0	294.4	0.0	4 063.8	0.0	82.0	0.0	377.6	0.0	125.0	0.0	7 263.2	0.0	0.0%
2010	Stock (units)	2 416 356	0	541 284	0	116 638	0	69 193	0	6 604	0	26 415	0	750 000	0	3 926 489	0.0	0.0%
	Sales (units)	95 128	0	29 433	0	5 522	0	3 318	0	961	0	3 843	0	75 000	0	213 204	0.0	0.0%
	Electricity (TWh)	19.0	0.0	14.7	0.0	4.6	0.0	35.9	0.0	0.4	0.0	1.6	0.0	0.4	0.0	76.7	0.0	0.0%

		BC1		BC2		BC3		BC4		BC5		BC6		BC7		Total	Difference with BAU	
		2010	2013	2010	2013	2010	2013	2010	2013	2010	2013	2010	2013	2010	2013		absolute	relative
		D0Ck	A0+Ak+*	E0Ck	A0+Ak+*	C0Bk	A0+Ak*	41-326	20-228	E0Ck	A0+Ak*	C0Bk	A0Ak	110-750	110-400			
	Expenditure (m€)	1 315.3	0.0	1 038.4	0.0	298.5	0.0	4 123.2	0.0	90.7	0.0	417.4	0.0	125.0	0.0	7 408.5	0.0	0.0%
2011	Stock (units)	2 451 074	0	549 065	0	118 272	0	70 205	0	7 300	0	29 201	0	750 000	0	3 975 118	0.0	0.0%
	Sales (units)	96 495	0	29 856	0	5 599	0	3 366	0	1 062	0	4 248	0	75 000	0	215 626	0.0	0.0%
	Electricity (TWh)	19.3	0.0	14.9	0.0	4.7	0.0	36.5	0.0	0.4	0.0	1.8	0.0	0.4	0.0	78.0	0.0	0.0%
	Expenditure (m€)	1 334.2	0.0	1 053.3	0.0	302.7	0.0	4 183.5	0.0	100.3	0.0	461.4	0.0	125.0	0.0	7 560.4	0.0	0.0%
2012	Stock (units)	2 486 292	0	556 959	0	119 928	0	71 231	0	8 070	0	32 281	0	750 000	0	4 024 762	0.0	0.0%
	Sales (units)	97 881	0	30 285	0	5 678	0	3 416	0	1 174	0	4 696	0	75 000	0	218 130	0.0	0.0%
	Electricity (TWh)	19.5	0.0	15.1	0.0	4.8	0.0	37.0	0.0	0.5	0.0	2.0	0.0	0.4	0.0	79.3	0.0	0.0%
	Expenditure (m€)	1 353.4	0.0	1 068.4	0.0	306.9	0.0	4 244.7	0.0	110.8	0.0	510.1	0.0	125.0	0.0	7 719.3	0.0	0.0%
2013	Stock (units)	2 522 016	0	564 965	0	121 609	0	72 272	0	8 922	0	35 686	0	750 000	0	4 075 470	0.0	0.0%
	Sales (units)	0	99 287	0	30 720	0	5 757	0	3 466	0	1 298	0	5 191	0	75 000	220 720	0.0	0.0%
	Electricity (TWh)	19.8	0.0	15.3	0.0	4.8	0.0	37.5	0.0	0.5	0.0	2.2	0.0	0.4	0.0	80.7	0.0	0.0%
	Expenditure (m€)	765.0	1 282.5	748.1	879.4	217.2	234.1	1 687.3	6 548.6	98.8	53.3	417.6	191.7	23.9	143.6	13 291.1	5 405.2	68.5%
2014	Stock (units)	2 458 966	99 287	542 367	30 720	117 555	5 757	69 863	3 466	8 565	1 298	34 259	5 191	675 000	75 000	4 127 294	0.0	0.0%
	Sales (units)	0	100 714	0	31 162	0	5 838	0	3 516	0	1 435	0	5 739	0	75 000	223 404	0.0	0.0%
	Electricity (TWh)	19.3	0.3	14.7	0.3	4.7	0.1	36.3	1.0	0.5	0.0	2.1	0.2	0.3	0.0	80.0	-2.1	-2.5%
	Expenditure (m€)	745.8	1 310.9	718.2	907.9	210.0	242.1	1 631.0	6 689.9	94.9	64.6	400.8	257.8	21.5	145.3	13 440.8	5 379.8	66.7%
2015	Stock (units)	2 395 009	200 002	519 443	61 883	113 444	11 595	67 419	6 982	8 170	2 733	32 681	10 930	600 000	150 000	4 180 290	0.0	0.0%
	Sales (units)	0	102 161	0	31 610	0	5 920	0	3 568	0	1 586	0	6 344	0	75 000	226 189	0.0	0.0%
	Electricity (TWh)	18.8	0.5	14.1	0.7	4.5	0.2	35.0	2.0	0.5	0.1	2.0	0.5	0.3	0.1	79.3	-4.2	-5.0%
	Expenditure (m€)	726.4	1 339.7	687.9	936.9	202.6	250.2	1 574.0	6 833.3	90.5	77.1	382.4	330.8	19.2	147.0	13 597.8	5 352.7	64.9%
2016	Stock (units)	2 330 134	302 163	496 190	93 493	109 276	17 515	64 939	10 549	7 734	4 319	30 936	17 274	525 000	225 000	4 234 522	0.0	0.0%
	Sales (units)	0	103 629	0	32 065	0	6 003	0	3 620	0	1 753	0	7 013	0	75 000	229 083	0.0	0.0%
	Electricity (TWh)	18.3	0.8	13.5	1.0	4.3	0.3	33.7	3.1	0.5	0.1	1.9	0.8	0.3	0.1	78.7	-6.4	-7.5%
	Expenditure (m€)	706.8	1 368.9	657.1	966.2	195.2	258.4	1 516.1	6 978.7	85.7	90.9	362.0	411.6	16.8	148.7	13 762.9	5 323.6	63.1%
2017	Stock (units)	2 264 327	405 792	472 603	125 557	105 050	23 517	62 422	14 169	7 252	6 072	29 008	24 288	450 000	300 000	4 290 057	0.0	0.0%

		BC1		BC2		BC3		BC4		BC5		BC6		BC7		Total	Difference with BAU	
		2010	2013	2010	2013	2010	2013	2010	2013	2010	2013	2010	2013	2010	2013		absolute	relative
		D0Ck	A0+Ak+*	E0Ck	A0+Ak+*	C0Bk	A0+Ak*	41-326	20-228	E0Ck	A0+Ak*	C0Bk	A0Ak	110-750	110-400			
	Sales (units)	0	105 118	0	32 525	0	6 087	0	3 673	0	1 938	0	7 753	0	75 000	232 094	**0.0**	**0.0%**
	Electricity (TWh)	17.8	1.1	12.8	1.3	4.2	0.4	32.4	4.1	0.4	0.1	1.8	1.1	0.2	0.1	78.0	**-8.6**	**-9.9%**
	Expenditure (m€)	686.8	1 398.5	625.8	996.0	187.6	266.7	1 457.3	7 126.3	80.3	106.2	339.4	500.8	14.4	150.4	13 936.6	**5 292.4**	**61.2%**
2018	**Stock (units)**	2 197 574	510 910	448 677	158 083	100 765	29 604	59 869	17 842	6 719	8 010	26 876	32 041	375 000	375 000	4 346 968	**0.0**	**0.0%**
	Sales (units)	0	106 628	0	32 993	0	6 172	0	3 726	0	2 143	0	8 571	0	75 000	235 233	**0.0**	**0.0%**
	Electricity (TWh)	17.3	1.3	12.2	1.7	4.0	0.5	31.1	5.2	0.4	0.2	1.7	1.5	0.2	0.1	77.4	**-10.8**	**-12.3%**
	Expenditure (m€)	666.6	1 428.5	594.1	1 026.2	180.0	275.1	1 397.7	7 276.1	74.4	123.1	314.5	599.5	12.0	152.1	14 119.8	**5 258.8**	**59.3%**
2019	**Stock (units)**	2 129 862	617 538	424 406	191 076	96 419	35 776	57 279	21 568	6 130	10 153	24 519	40 611	300 000	450 000	4 405 337	**0.0**	**0.0%**
	Sales (units)	0	108 160	0	33 467	0	6 258	0	3 781	0	2 369	0	9 475	0	75 000	238 510	**0.0**	**0.0%**
	Electricity (TWh)	16.7	1.6	11.5	2.0	3.8	0.6	29.7	6.3	0.4	0.2	1.5	1.9	0.2	0.2	76.8	**-13.1**	**-14.6%**
	Expenditure (m€)	646.0	1 459.0	562.0	1 056.8	172.2	283.7	1 337.2	7 428.0	67.9	141.7	286.9	708.6	9.6	153.8	14 313.5	**5 222.6**	**57.4%**
2020	**Stock (units)**	2 061 177	725 698	399 787	224 543	92 012	42 035	54 651	25 349	5 479	12 521	21 914	50 086	225 000	525 000	4 465 252	**0.0**	**0.0%**
	Sales (units)	0	109 715	0	33 948	0	6 346	0	3 836	0	2 618	0	10 474	0	75 000	241 938	**0.0**	**0.0%**
	Electricity (TWh)	16.2	1.9	10.9	2.4	3.7	0.8	28.4	7.4	0.3	0.3	1.4	2.4	0.1	0.2	76.2	**-15.5**	**-16.9%**
	Expenditure (m€)	625.2	1 489.9	529.4	1 087.9	164.3	292.3	1 275.9	7 582.2	60.7	162.4	256.4	829.1	7.2	155.5	14 518.4	**5 183.6**	**55.5%**
2021	**Stock (units)**	1 991 505	835 413	374 814	258 492	87 544	48 381	51 984	29 185	4 759	15 140	19 034	60 560	150 000	600 000	4 526 810	**0.0**	**0.0%**
	Sales (units)	0	111 291	0	34 437	0	6 435	0	3 892	0	2 895	0	11 579	0	75 000	245 528	**0.0**	**0.0%**
	Electricity (TWh)	15.7	2.2	10.2	2.7	3.5	0.9	27.0	8.5	0.3	0.4	1.2	2.9	0.1	0.2	75.6	**-17.9**	**-19.1%**
	Expenditure (m€)	604.1	1 521.3	496.3	1 119.4	156.4	301.1	1 213.6	7 738.6	52.7	185.2	222.7	962.4	4.8	157.2	14 735.8	**5 141.4**	**53.6%**
2022	**Stock (units)**	1 920 832	946 704	349 481	292 928	83 013	54 816	49 278	33 078	3 963	18 035	15 850	72 138	75 000	675 000	4 590 116	**0.0**	**0.0%**
	Sales (units)	0	112 890	0	34 932	0	6 525	0	3 949	0	3 200	0	12 800	0	75 000	249 296	**0.0**	**0.0%**
	Electricity (TWh)	15.1	2.5	9.5	3.1	3.3	1.0	25.6	9.7	0.2	0.4	1.0	3.4	0.0	0.2	75.0	**-20.4**	**-21.3%**
	Expenditure (m€)	582.6	1 553.1	462.8	1 151.4	148.3	310.0	1 150.5	7 897.3	43.9	210.4	185.5	1 109.8	2.4	158.9	14 966.8	**5 095.7**	**51.6%**
2023	**Stock (units)**	1 849 143	1 059 594	323 785	327 860	78 419	61 341	46 533	37 027	3 083	21 235	12 331	84 938	0	750 000	4 655 288	**0.0**	**0.0%**
	Sales (units)	0	114 512	0	35 434	0	6 617	0	4 007	0	3 537	0	14 150	0	75 000	253 257	**0.0**	**0.0%**
	Electricity (TWh)	14.5	2.7	8.8	3.5	3.1	1.1	24.2	10.8	0.2	0.5	0.8	4.0	0.0	0.3	74.5	**-22.9**	**-23.5%**

		BC1		BC2		BC3		BC4		BC5		BC6		BC7		Total	Difference with BAU	
		2010	2013	2010	2013	2010	2013	2010	2013	2010	2013	2010	2013	2010	2013		absolute	relative
		D0Ck	A0+Ak+*	E0Ck	A0+Ak+*	C0Bk	A0+Ak*	41-326	20-228	E0Ck	A0+Ak*	C0Bk	A0Ak	110-750	110-400			
	Expenditure (m€)	560.9	1 585.3	428.8	1 183.8	140.1	319.0	1 086.4	8 058.4	34.2	238.3	144.3	1 272.7	0.0	160.6	15 212.6	**5 046.2**	**49.6%**
2024	**Stock (units)**	1 776 425	1 174 106	297 719	363 293	73 760	67 957	43 748	41 034	2 110	24 772	8 440	99 088	0	750 000	4 722 453	**0.0**	**0.0%**
	Sales (units)	0	116 157	0	35 943	0	6 709	0	4 065	0	3 911	0	15 642	0	75 000	257 428	**0.0**	**0.0%**
	Electricity (TWh)	14.0	3.0	8.1	3.9	2.9	1.2	22.7	12.0	0.1	0.6	0.5	4.7	0.0	0.3	74.0	**-25.5**	**-25.6%**
	Expenditure (m€)	538.8	1 618.1	394.2	1 216.7	131.7	328.2	1 021.3	8 221.7	23.4	269.1	98.8	1 452.8	0.0	160.6	15 475.5	**4 993.2**	**47.6%**
2025	**Stock (units)**	1 702 662	1 290 263	271 279	399 237	69 036	74 667	40 922	45 099	1 035	28 683	4 139	114 730	0	750 000	4 791 751	**0.0**	**0.0%**
	Sales (units)	0	117 826	0	36 460	0	6 803	0	4 125	0	4 323	0	17 292	0	75 000	261 829	**0.0**	**0.0%**
	Electricity (TWh)	13.4	3.3	7.4	4.2	2.7	1.4	21.2	13.2	0.1	0.7	0.3	5.4	0.0	0.3	73.5	**-28.1**	**-27.7%**
	Expenditure (m€)	516.4	1 651.2	359.2	1 250.1	123.3	337.5	955.4	8 387.5	11.5	303.2	48.4	1 651.8	0.0	160.6	15 756.2	**4 935.5**	**45.6%**
2011-2025	**Electricity (TWh)**	**255.7**	**21.2**	**179.1**	**26.8**	**59.0**	**8.6**	**458.3**	**83.5**	**5.3**	**3.6**	**22.3**	**28.8**	**2.8**	**2.0**	**1 157.0**	**-175.4**	**-13.2%**
2011-2025	**Expenditure (m€)**	**11 058.9**	**19 007.0**	**9 385.7**	**13 778.7**	**2 838.5**	**3 698.4**	**25 731.8**	**96 766.7**	**1 029.9**	**2 025.6**	**4 431.1**	**10 279.4**	**381.7**	**1 994.1**	**202 407.6**	**67 630.6**	**50.2%**

7.1.11.4 MEPS Scenario

The MEPS scenario assumes that minimum performance requirements implement all MEPS proposed in section 7.1.2 as policy options. The requirements are implemented in one phase the first in 2013, for all base-cases, except for BC 7 where the implementation of more efficient transformers begins in 2018 (see Table 7-14).

Table 7-14: MEPS requirements

	2010	2013	2018
BC1	D0Ck	A0Ck	-
BC2	E0Ck	A0Ak	-
BC3	C0Bk	A0Ak	-
BC4	41-326	28-277[157]	-
BC5	E0Ck	A0Ak	-
BC6	C0Bk	A0Ak	-
BC7	110-750	-	110-400

Using the minimum performance requirements to dictate market trends, Table 7-15 shows that the transformer market would consume 84.2 TWh of electricity in 2025 (-17.2% BAU), and expenditure for this year would be 11.5 b€ (+6.6% BAU). Total electricity consumption from 2011-2025 is expected to be 1 224 TWh, 8.1% less than BAU, while expenditures are estimated at 149 b€, 10.6% greater than BAU. Using the EcoReport conversion factor of 0.458 kg CO_2 eq/kWh, greenhouse gas emissions for 2025 amount to 38.6 Mt CO_2 eq, and 560.6 Mt CO_2 eq for the period of 2011-2025. These numbers are 8.0 and 49.6 Mt CO_2eq less than BAU, respectively.

[157] The losses levels do not match exactly the MEPS in this case but the closest product available was selected in the scenario tool.

Table 7-15: MEPS market trends and electricity consumption

		BC1		BC2		BC3		BC4		BC5		BC6		BC7		Total	Difference with BAU	
		2010	2013	2010	2013	2010	2013	2010	2013	2010	2013	2010	2013	2010	2018		absolute	relative
		D0Ck	A0Ck	E0Ck	A0Ak	C0Bk	A0Ak	41-326	28-277	E0Ck	A0Ak	C0Bk	A0Ak	110-750	110-400			
	Electricity (kWh/unit/year)	**7 859**	**5 056**	**27 168**	**15 631**	**39 727**	**28 629**	**519 272**	**388 164**	**59 094**	**35 515**	**62 415**	**47 109**	**505**	**359**			
	Product price (€/unit)	**6 122**	**7 102**	**10 926**	**16 717**	**16 333**	**24 500**	**755 843**	**1 050 622**	**18 248**	**30 657**	**28 192**	**36 931**	**1 348**	**1 914**			
2005	**Stock (units)**	2 250 000	0	504 000	0	108 800	0	64 350	0	4 000	0	16 000	0	750 000	0	3 697 150	**0.0**	**0.0%**
	Sales (units)	88 579	0	27 405	0	5 151	0	3 086	0	582	0	2 328	0	75 000	0	202 130	**0.0**	**0.0%**
	Electricity (TWh)	17.7	0.0	13.7	0.0	4.3	0.0	33.4	0.0	0.2	0.0	1.0	0.0	0.4	0.0	70.7	**0.0**	**0.0%**
	Expenditure (m€)	1 224.7	0.0	966.8	0.0	278.5	0.0	3 834.6	0.0	54.9	0.0	252.8	0.0	125.0	0.0	6 737.5	**0.0**	**0.0%**
2006	**Stock (units)**	2 282 329	0	511 245	0	110 324	0	65 291	0	4 422	0	17 688	0	750 000	0	3 741 298	**0.0**	**0.0%**
	Sales (units)	89 851	0	27 799	0	5 223	0	3 131	0	643	0	2 573	0	75 000	0	204 221	**0.0**	**0.0%**
	Electricity (TWh)	17.9	0.0	13.9	0.0	4.4	0.0	33.9	0.0	0.3	0.0	1.1	0.0	0.4	0.0	71.9	**0.0**	**0.0%**
	Expenditure (m€)	1 242.3	0.0	980.7	0.0	282.4	0.0	3 890.7	0.0	60.7	0.0	279.5	0.0	125.0	0.0	6 861.4	**0.0**	**0.0%**
2007	**Stock (units)**	2 315 122	0	518 595	0	111 870	0	66 245	0	4 888	0	19 553	0	750 000	0	3 786 273	**0.0**	**0.0%**
	Sales (units)	91 142	0	28 199	0	5 296	0	3 177	0	711	0	2 844	0	75 000	0	206 370	**0.0**	**0.0%**
	Electricity (TWh)	18.2	0.0	14.1	0.0	4.4	0.0	34.4	0.0	0.3	0.0	1.2	0.0	0.4	0.0	73.0	**0.0**	**0.0%**
	Expenditure (m€)	1 260.2	0.0	994.8	0.0	286.3	0.0	3 947.6	0.0	67.1	0.0	309.0	0.0	125.0	0.0	6 990.0	**0.0**	**0.0%**
2008	**Stock (units)**	2 348 386	0	526 050	0	113 437	0	67 214	0	5 404	0	21 615	0	750 000	0	3 832 106	**0.0**	**0.0%**
	Sales (units)	92 452	0	28 604	0	5 370	0	3 223	0	786	0	3 144	0	75 000	0	208 580	**0.0**	**0.0%**
	Electricity (TWh)	18.5	0.0	14.3	0.0	4.5	0.0	34.9	0.0	0.3	0.0	1.3	0.0	0.4	0.0	74.2	**0.0**	**0.0%**
	Expenditure (m€)	1 278.3	0.0	1 009.1	0.0	290.3	0.0	4 005.3	0.0	74.2	0.0	341.6	0.0	125.0	0.0	7 123.8	**0.0**	**0.0%**
2009	**Stock (units)**	2 382 128	0	533 613	0	115 026	0	68 196	0	5 974	0	23 895	0	750 000	0	3 878 832	**0.0**	**0.0%**
	Sales (units)	93 780	0	29 016	0	5 446	0	3 270	0	869	0	3 476	0	75 000	0	210 857	**0.0**	**0.0%**
	Electricity (TWh)	18.7	0.0	14.5	0.0	4.6	0.0	35.4	0.0	0.4	0.0	1.5	0.0	0.4	0.0	75.4	**0.0**	**0.0%**
	Expenditure (m€)	1 296.7	0.0	1 023.6	0.0	294.4	0.0	4 063.8	0.0	82.0	0.0	377.6	0.0	125.0	0.0	7 263.2	**0.0**	**0.0%**
2010	**Stock (units)**	2 416 356	0	541 284	0	116 638	0	69 193	0	6 604	0	26 415	0	750 000	0	3 926 489	**0.0**	**0.0%**
	Sales (units)	95 128	0	29 433	0	5 522	0	3 318	0	961	0	3 843	0	75 000	0	213 204	**0.0**	**0.0%**

		BC1		BC2		BC3		BC4		BC5		BC6		BC7		Total	Difference with BAU	
		2010	2013	2010	2013	2010	2013	2010	2013	2010	2013	2010	2013	2010	2018		absolute	relative
		D0Ck	A0Ck	E0Ck	A0Ak	C0Bk	A0Ak	41-326	28-277	E0Ck	A0Ak	C0Bk	A0Ak	110-750	110-400			
	Electricity (TWh)	19.0	0.0	14.7	0.0	4.6	0.0	35.9	0.0	0.4	0.0	1.6	0.0	0.4	0.0	76.7	**0.0**	**0.0%**
	Expenditure (m€)	1 315.3	0.0	1 038.4	0.0	298.5	0.0	4 123.2	0.0	90.7	0.0	417.4	0.0	125.0	0.0	7 408.5	**0.0**	**0.0%**
2011	**Stock (units)**	2 451 074	0	549 065	0	118 272	0	70 205	0	7 300	0	29 201	0	750 000	0	3 975 118	**0.0**	**0.0%**
	Sales (units)	96 495	0	29 856	0	5 599	0	3 366	0	1 062	0	4 248	0	75 000	0	215 626	**0.0**	**0.0%**
	Electricity (TWh)	19.3	0.0	14.9	0.0	4.7	0.0	36.5	0.0	0.4	0.0	1.8	0.0	0.4	0.0	78.0	**0.0**	**0.0%**
	Expenditure (m€)	1 334.2	0.0	1 053.3	0.0	302.7	0.0	4 183.5	0.0	100.3	0.0	461.4	0.0	125.0	0.0	7 560.4	**0.0**	**0.0%**
2012	**Stock (units)**	2 486 292	0	556 959	0	119 928	0	71 231	0	8 070	0	32 281	0	750 000	0	4 024 762	**0.0**	**0.0%**
	Sales (units)	97 881	0	30 285	0	5 678	0	3 416	0	1 174	0	4 696	0	75 000	0	218 130	**0.0**	**0.0%**
	Electricity (TWh)	19.5	0.0	15.1	0.0	4.8	0.0	37.0	0.0	0.5	0.0	2.0	0.0	0.4	0.0	79.3	**0.0**	**0.0%**
	Expenditure (m€)	1 353.4	0.0	1 068.4	0.0	306.9	0.0	4 244.7	0.0	110.8	0.0	510.1	0.0	125.0	0.0	7 719.3	**0.0**	**0.0%**
2013	**Stock (units)**	2 522 016	0	564 965	0	121 609	0	72 272	0	8 922	0	35 686	0	750 000	0	4 075 470	**0.0**	**0.0%**
	Sales (units)	0	99 287	0	30 720	0	5 757	0	3 466	0	1 298	0	5 191	75 000	0	220 720	**0.0**	**0.0%**
	Electricity (TWh)	19.8	0.0	15.3	0.0	4.8	0.0	37.5	0.0	0.5	0.0	2.2	0.0	0.4	0.0	80.7	**0.0**	**0.0%**
	Expenditure (m€)	765.0	705.1	748.1	513.5	217.2	141.1	1 687.3	3 641.0	98.8	39.8	417.6	191.7	125.0	0.0	9 291.2	**1 405.2**	**17.8%**
2014	**Stock (units)**	2 458 966	99 287	542 367	30 720	117 555	5 757	69 863	3 466	8 565	1 298	34 259	5 191	750 000	0	4 127 294	**0.0**	**0.0%**
	Sales (units)	0	100 714	0	31 162	0	5 838	0	3 516	0	1 435	0	5 739	75 000	0	223 404	**0.0**	**0.0%**
	Electricity (TWh)	19.3	0.5	14.7	0.5	4.7	0.2	36.3	1.3	0.5	0.0	2.1	0.2	0.4	0.0	80.8	**-1.3**	**-1.5%**
	Expenditure (m€)	745.8	734.6	718.2	544.3	210.0	150.4	1 631.0	3 754.7	94.9	52.6	400.8	257.8	125.0	0.0	9 420.3	**1 359.3**	**16.9%**
2015	**Stock (units)**	2 395 009	200 002	519 443	61 883	113 444	11 595	67 419	6 982	8 170	2 733	32 681	10 930	750 000	0	4 180 290	**0.0**	**0.0%**
	Sales (units)	0	102 161	0	31 610	0	5 920	0	3 568	0	1 586	0	6 344	75 000	0	226 189	**0.0**	**0.0%**
	Electricity (TWh)	18.8	1.0	14.1	1.0	4.5	0.3	35.0	2.7	0.5	0.1	2.0	0.5	0.4	0.0	81.0	**-2.6**	**-3.1%**
	Expenditure (m€)	726.4	764.5	687.9	575.6	202.6	160.0	1 574.0	3 870.1	90.5	66.8	382.4	330.8	125.0	0.0	9 556.6	**1 311.4**	**15.9%**
2016	**Stock (units)**	2 330 134	302 163	496 190	93 493	109 276	17 515	64 939	10 549	7 734	4 319	30 936	17 274	750 000	0	4 234 522	**0.0**	**0.0%**
	Sales (units)	0	103 629	0	32 065	0	6 003	0	3 620	0	1 753	0	7 013	75 000	0	229 083	**0.0**	**0.0%**
	Electricity (TWh)	18.3	1.5	13.5	1.5	4.3	0.5	33.7	4.1	0.5	0.2	1.9	0.8	0.4	0.0	81.2	**-3.9**	**-4.5%**
	Expenditure (m€)	706.8	794.9	657.1	607.2	195.2	169.6	1 516.1	3 987.1	85.7	82.5	362.0	411.6	125.0	0.0	9 700.7	**1 261.4**	**14.9%**

		BC1		BC2		BC3		BC4		BC5		BC6		BC7		Total	Difference with BAU	
		2010	2013	2010	2013	2010	2013	2010	2013	2010	2013	2010	2013	2010	2018		absolute	relative
		D0Ck	A0Ck	E0Ck	A0Ak	C0Bk	A0Ak	41-326	28-277	E0Ck	A0Ak	C0Bk	A0Ak	110-750	110-400			
2017	**Stock (units)**	2 264 327	405 792	472 603	125 557	105 050	23 517	62 422	14 169	7 252	6 072	29 008	24 288	750 000	0	4 290 057	**0.0**	**0.0%**
	Sales (units)	0	105 118	0	32 525	0	6 087	0	3 673	0	1 938	0	7 753	75 000	0	232 094	**0.0**	**0.0%**
	Electricity (TWh)	17.8	2.1	12.8	2.0	4.2	0.7	32.4	5.5	0.4	0.2	1.8	1.1	0.4	0.0	81.4	**-5.2**	**-6.0%**
	Expenditure (m€)	686.8	825.7	625.8	639.4	187.6	179.4	1 457.3	4 105.9	80.3	99.8	339.4	500.8	125.0	0.0	9 853.4	**1 209.2**	**14.0%**
2018	**Stock (units)**	2 197 574	510 910	448 677	158 083	100 765	29 604	59 869	17 842	6 719	8 010	26 876	32 041	750 000	0	4 346 968	**0.0**	**0.0%**
	Sales (units)	0	106 628	0	32 993	0	6 172	0	3 726	0	2 143	0	8 571	0	75 000	235 233	**0.0**	**0.0%**
	Electricity (TWh)	17.3	2.6	12.2	2.5	4.0	0.8	31.1	6.9	0.4	0.3	1.7	1.5	0.4	0.0	81.6	**-6.6**	**-7.5%**
	Expenditure (m€)	666.6	856.9	594.1	672.0	180.0	189.3	1 397.7	4 226.4	74.4	119.0	314.5	599.5	23.9	143.6	10 057.9	**1 196.9**	**13.5%**
2019	**Stock (units)**	2 129 862	617 538	424 406	191 076	96 419	35 776	57 279	21 568	6 130	10 153	24 519	40 611	675 000	75 000	4 405 337	**0.0**	**0.0%**
	Sales (units)	0	108 160	0	33 467	0	6 258	0	3 781	0	2 369	0	9 475	0	75 000	238 510	**0.0**	**0.0%**
	Electricity (TWh)	16.7	3.1	11.5	3.0	3.8	1.0	29.7	8.4	0.4	0.4	1.5	1.9	0.3	0.0	81.9	**-8.0**	**-8.9%**
	Expenditure (m€)	646.0	888.6	562.0	705.0	172.2	199.4	1 337.2	4 348.7	67.9	140.2	286.9	708.6	21.5	145.3	10 229.6	**1 138.7**	**12.5%**
2020	**Stock (units)**	2 061 177	725 698	399 787	224 543	92 012	42 035	54 651	25 349	5 479	12 521	21 914	50 086	600 000	150 000	4 465 252	**0.0**	**0.0%**
	Sales (units)	0	109 715	0	33 948	0	6 346	0	3 836	0	2 618	0	10 474	0	75 000	241 938	**0.0**	**0.0%**
	Electricity (TWh)	16.2	3.7	10.9	3.5	3.7	1.2	28.4	9.8	0.3	0.4	1.4	2.4	0.3	0.1	82.2	**-9.5**	**-10.4%**
	Expenditure (m€)	625.2	920.7	529.4	738.6	164.3	209.6	1 275.9	4 472.7	60.7	163.6	256.4	829.1	19.2	147.0	10 412.4	**1 077.6**	**11.5%**
2021	**Stock (units)**	1 991 505	835 413	374 814	258 492	87 544	48 381	51 984	29 185	4 759	15 140	19 034	60 560	525 000	225 000	4 526 810	**0.0**	**0.0%**
	Sales (units)	0	111 291	0	34 437	0	6 435	0	3 892	0	2 895	0	11 579	0	75 000	245 528	**0.0**	**0.0%**
	Electricity (TWh)	15.7	4.2	10.2	4.0	3.5	1.4	27.0	11.3	0.3	0.5	1.2	2.9	0.3	0.1	82.5	**-11.0**	**-11.8%**
	Expenditure (m€)	604.1	953.3	496.3	772.6	156.4	219.9	1 213.6	4 598.6	52.7	189.5	222.7	962.4	16.8	148.7	10 607.7	**1 013.2**	**10.6%**
2022	**Stock (units)**	1 920 832	946 704	349 481	292 928	83 013	54 816	49 278	33 078	3 963	18 035	15 850	72 138	450 000	300 000	4 590 116	**0.0**	**0.0%**
	Sales (units)	0	112 890	0	34 932	0	6 525	0	3 949	0	3 200	0	12 800	0	75 000	249 296	**0.0**	**0.0%**
	Electricity (TWh)	15.1	4.8	9.5	4.6	3.3	1.6	25.6	12.8	0.2	0.6	1.0	3.4	0.2	0.1	82.8	**-12.6**	**-13.2%**
	Expenditure (m€)	582.6	986.4	462.8	807.1	148.3	230.4	1 150.5	4 726.3	43.9	218.2	185.5	1 109.8	14.4	150.4	10 816.4	**945.4**	**9.6%**
2023	**Stock (units)**	1 849 143	1 059 594	323 785	327 860	78 419	61 341	46 533	37 027	3 083	21 235	12 331	84 938	375 000	375 000	4 655 288	**0.0**	**0.0%**
	Sales (units)	0	114 512	0	35 434	0	6 617	0	4 007	0	3 537	0	14 150	0	75 000	253 257	**0.0**	**0.0%**

		BC1		BC2		BC3		BC4		BC5		BC6		BC7		Total	Difference with BAU	
		2010	2013	2010	2013	2010	2013	2010	2013	2010	2013	2010	2013	2010	2018		absolute	relative
		D0Ck	A0Ck	E0Ck	A0Ak	C0Bk	A0Ak	41-326	28-277	E0Ck	A0Ak	C0Bk	A0Ak	110-750	110-400			
	Electricity (TWh)	14.5	5.4	8.8	5.1	3.1	1.8	24.2	14.4	0.2	0.8	0.8	4.0	0.2	0.1	83.2	**-14.1**	**-14.5%**
	Expenditure (m€)	560.9	1 020.0	428.8	842.1	140.1	241.1	1 086.4	4 855.9	34.2	249.8	144.3	1 272.7	12.0	152.1	11 040.1	**873.6**	**8.6%**
2024	**Stock (units)**	1 776 425	1 174 106	297 719	363 293	73 760	67 957	43 748	41 034	2 110	24 772	8 440	99 088	300 000	450 000	4 722 453	**0.0**	**0.0%**
	Sales (units)	0	116 157	0	35 943	0	6 709	0	4 065	0	3 911	0	15 642	0	75 000	257 428	**0.0**	**0.0%**
	Electricity (TWh)	14.0	5.9	8.1	5.7	2.9	1.9	22.7	15.9	0.1	0.9	0.5	4.7	0.2	0.2	83.7	**-15.8**	**-15.9%**
	Expenditure (m€)	538.8	1 054.0	394.2	877.6	131.7	251.8	1 021.3	4 987.3	23.4	284.8	98.8	1 452.8	9.6	153.8	11 280.0	**797.7**	**7.6%**
2025	**Stock (units)**	1 702 662	1 290 263	271 279	399 237	69 036	74 667	40 922	45 099	1 035	28 683	4 139	114 730	225 000	525 000	4 791 751	**0.0**	**0.0%**
	Sales (units)	0	117 826	0	36 460	0	6 803	0	4 125	0	4 323	0	17 292	0	75 000	261 829	**0.0**	**0.0%**
	Electricity (TWh)	13.4	6.5	7.4	6.2	2.7	2.1	21.2	17.5	0.1	1.0	0.3	5.4	0.1	0.2	84.2	**-17.5**	**-17.2%**
	Expenditure (m€)	516.4	1 088.5	359.2	913.7	123.3	262.8	955.4	5 120.7	11.5	323.5	48.4	1 651.8	7.2	155.5	11 537.9	**717.2**	**6.6%**
2011-2025	**Electricity (TWh)**	**255.7**	**41.3**	**179.1**	**39.5**	**59.0**	**13.5**	**458.3**	**110.8**	**5.3**	**5.4**	**22.3**	**28.8**	**4.6**	**0.8**	**1 224.4**	**-108.0**	**-8.1%**
2011-2025	**Expenditure (m€)**	**11 058.9**	**11 593.3**	**9 385.7**	**9 208.8**	**2 838.5**	**2 604.8**	**25 731.8**	**56 695.4**	**1 029.9**	**2 030.3**	**4 431.1**	**10 279.4**	**999.7**	**1 196.2**	**149 084.0**	**14 306.9**	**10.6%**

7.1.11.5 Comparison of scenarios

Table 7-16 lists the losses levels corresponding to the different scenarios presented above (BAU, LLCC, BAT, MEPS).

Table 7-16: Minimum performance requirements from 2013 (denotes AMT)*

	BAU	LLCC	BAT	MEPS
BC1	D0Ck	A0+Ck*	A0+Ak+*	A0Ck
BC2	E0Ck	A0Ak	A0+Ak+*	A0Ak
BC3	C0Bk	A0Bk	A0+Ak*	A0Ak
BC4	41-326	34-326	20-228	28-277
BC5	E0Ck	A0+Ak*	A0+Ak*	A0Ak
BC6	C0Bk	A0Ak	A0Ak	A0Ak
BC7	110-750	110-750	110-400	110-400[158]

[158] From 2018 only.

Table 7-17 through Table 7-20 show the detailed comparison between the BAU, LLCC BAT and MEPS scenarios, per year and per base-case. In addition, Figure 7-4 to Figure 7-21 show a graphical representation of the results.

With electricity consumption reductions of 7.7% and 13.2% 2011-2025 for the LLCC and BAT scenarios, respectively, it is apparent that significant energy savings are possible by improving minimum energy performance scenarios. Due to the way MEPS were defined (based on the LLCC options most of the time), the MEPS scenario gives electricity savings close to the LLCC scenario with a reduction of 8.1% in comparison with BAU.

Examining the expenditure analysis, there is in fact an overall increase for the period 2011-2025 of 2.8% and 50.2% for the LLCC and BAT scenarios, respectively. The MEPS scenario shows an increase in expenditure of 10.6%. However, looking at the yearly trends, it is apparent that in 2024 the initial investment in energy efficient transformers begins yielding economic benefits, with savings of 0.7% and 1.5% for the LLCC scenario in 2024 and 2025.

Figure 7-22 extrapolates the total expenditure results to 2050. Rather than charting yearly expenditure, this chart shows the total expenditure since 2011. The extrapolation is done with a polynomial trend line that is accurate during the 2013-2025 period within 0.2%. As the figure shows, the LLCC scenario becomes economical in 2032 while the MEPS one becomes economical in 2048. Thus, for the period 2011-2050, the LLCC scenario is expected to save 39 b€ over the BAU scenario, a savings of 7% and the MEPS scenario is expected to save 4 b€ over the BAU scenario.

Table 7-17: Comparison of total electricity consumption between the scenarios

		BAU	LLCC	BAT	MEPS
2013	**absolute (TWh)**	80.7	80.7	80.7	80.7
	relative (TWh)	0.0	0.0	0.0	0.0
	% change	0.0%	0.0%	0.0%	0.0%
2014	**absolute (TWh)**	82.1	80.9	80.0	80.8
	relative (TWh)	0.0	-1.2	-2.1	-1.3
	% change	0.0%	-1.5%	-2.5%	-1.5%
2015	**absolute (TWh)**	83.5	81.1	79.3	81.0
	relative (TWh)	0.0	-2.4	-4.2	-2.6
	% change	0.0%	-2.9%	-5.0%	-3.1%
2016	**absolute (TWh)**	85.0	81.4	78.7	81.2
	relative (TWh)	0.0	-3.7	-6.4	-3.9
	% change	0.0%	-4.3%	-7.5%	-4.5%
2017	**absolute (TWh)**	86.6	81.6	78.0	81.4
	relative (TWh)	0.0	-5.0	-8.6	-5.2
	% change	0.0%	-5.7%	-9.9%	-6.0%
2018	**absolute (TWh)**	88.2	81.9	77.4	81.6
	relative (TWh)	0.0	-6.3	-10.8	-6.6
	% change	0.0%	-7.1%	-12.3%	-7.5%
2019	**absolute (TWh)**	89.9	82.3	76.8	81.9
	relative (TWh)	0.0	-7.7	-13.1	-8.0
	% change	0.0%	-8.5%	-14.6%	-8.9%
2020	**absolute (TWh)**	91.7	82.6	76.2	82.2
	relative (TWh)	0.0	-9.1	-15.5	-9.5
	% change	0.0%	-9.9%	-16.9%	-10.4%
2021	**absolute (TWh)**	93.5	83.0	75.6	82.5
	relative (TWh)	0.0	-10.5	-17.9	-11.0
	% change	0.0%	-11.2%	-19.1%	-11.8%
2022	**absolute (TWh)**	95.4	83.4	75.0	82.8
	relative (TWh)	0.0	-12.0	-20.4	-12.6
	% change	0.0%	-12.6%	-21.3%	-13.2%
2023	**absolute (TWh)**	97.4	83.9	74.5	83.2
	relative (TWh)	0.0	-13.5	-22.9	-14.1
	% change	0.0%	-13.9%	-23.5%	-14.5%
2024	**absolute (TWh)**	99.5	84.4	74.0	83.7
	relative (TWh)	0.0	-15.1	-25.5	-15.8
	% change	0.0%	-15.2%	-25.6%	-15.9%
2025	**absolute (TWh)**	101.7	84.9	73.5	84.2
	relative (TWh)	0.0	-16.7	-28.1	-17.5
	% change	0.0%	-16.4%	-27.7%	-17.2%
2011-2025	**absolute (TWh)**	**1 332.4**	**1 229.4**	**1 157.0**	**1 224.4**
	relative (TWh)	**0.0**	**-103.1**	**-175.4**	**-108.0**
	% change	**0.0%**	**-7.7%**	**-13.2%**	**-8.1%**

Table 7-18: Comparison of total expenditure between the scenarios

		BAU	LLCC	BAT	MEPS
2013	absolute (m€)	7 886.0	8 559.3	13 291.1	9 291.2
	relative (m€)	0.0	673.4	5 405.2	1 405.2
	% change	0.0%	8.5%	68.5%	17.8%
2014	absolute (m€)	8 061.0	8 680.8	13 440.8	9 420.3
	relative (m€)	0.0	619.8	5 379.8	1 359.3
	% change	0.0%	7.7%	66.7%	16.9%
2015	absolute (m€)	8 245.2	8 809.3	13 597.8	9 556.6
	relative (m€)	0.0	564.1	5 352.7	1 311.4
	% change	0.0%	6.8%	64.9%	15.9%
2016	absolute (m€)	8 439.3	8 945.3	13 762.9	9 700.7
	relative (m€)	0.0	506.0	5 323.6	1 261.4
	% change	0.0%	6.0%	63.1%	14.9%
2017	absolute (m€)	8 644.2	9 089.5	13 936.6	9 853.4
	relative (m€)	0.0	445.3	5 292.4	1 209.2
	% change	0.0%	5.2%	61.2%	14.0%
2018	absolute (m€)	8 861.0	9 242.9	14 119.8	10 057.9
	relative (m€)	0.0	381.8	5 258.8	1 196.9
	% change	0.0%	4.3%	59.3%	13.5%
2019	absolute (m€)	9 090.9	9 406.2	14 313.5	10 229.6
	relative (m€)	0.0	315.3	5 222.6	1 138.7
	% change	0.0%	3.5%	57.4%	12.5%
2020	absolute (m€)	9 334.9	9 580.3	14 518.4	10 412.4
	relative (m€)	0.0	245.4	5 183.6	1 077.6
	% change	0.0%	2.6%	55.5%	11.5%
2021	absolute (m€)	9 594.5	9 766.4	14 735.8	10 607.7
	relative (m€)	0.0	172.0	5 141.4	1 013.2
	% change	0.0%	1.8%	53.6%	10.6%
2022	absolute (m€)	9 871.1	9 965.7	14 966.8	10 816.4
	relative (m€)	0.0	94.6	5 095.7	945.4
	% change	0.0%	1.0%	51.6%	9.6%
2023	absolute (m€)	10 166.4	10 179.3	15 212.6	11 040.1
	relative (m€)	0.0	12.9	5 046.2	873.6
	% change	0.0%	0.1%	49.6%	8.6%
2024	absolute (m€)	10 482.3	10 408.8	15 475.5	11 280.0
	relative (m€)	0.0	-73.5	4 993.2	797.7
	% change	0.0%	-0.7%	47.6%	7.6%
2025	absolute (m€)	10 820.7	10 655.6	15 756.2	11 537.9
	relative (m€)	0.0	-165.0	4 935.5	717.2
	% change	0.0%	-1.5%	45.6%	6.6%
2011-2025	absolute (m€)	**134 777.1**	**138 569.2**	**202 407.6**	**149 084.0**
	relative (m€)	**0.0**	**3 792.1**	**67 630.6**	**14 306.9**
	% change	**0.0%**	**2.8%**	**50.2%**	**10.6%**

Table 7-19: Comparison of electricity consumption of base-cases between BAU, LLCC, BAT and MEPS scenarios

		BC 1				BC 2				BC 3				BC 4			
	TWh	**BAU**	**LLCC**	**BAT**	**MEPS**	**BAU**	**LLCC**	**BAT**	**MEPS**	**BAU**	**LLCC**	**BAT**	**MEPS**	**BAU**	**LLCC**	**BAT**	**MEPS**
2013	**absolute (TWh)**	19.8	19.8	19.8	19.8	15.3	15.3	15.3	15.3	4.8	4.8	4.8	4.8	37.5	37.5	37.5	37.5
	relative (TWh)	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	0.0	0.0	0.0
	% change	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%	0.0%	0.0%	0.0%
2014	**absolute (TWh)**	20.1	19.6	19.6	19.8	15.6	15.2	15.1	15.2	4.9	4.8	4.8	4.8	38.1	37.9	37.3	37.6
	relative (TWh)	0.0	-0.5	-0.5	-0.3	0.0	-0.4	-0.5	-0.4	0.0	-0.1	-0.1	-0.1	0.0	-0.2	-0.8	-0.5
	% change	0.0%	-2.4%	-2.6%	-1.4%	0.0%	-2.3%	-3.3%	-2.3%	0.0%	-1.0%	-2.5%	-1.3%	0.0%	-0.5%	-2.1%	-1.2%
2015	**absolute (TWh)**	20.4	19.4	19.3	19.8	15.8	15.1	14.8	15.1	5.0	4.9	4.7	4.8	38.6	38.3	37.1	37.7
	relative (TWh)	0.0	-1.0	-1.1	-0.6	0.0	-0.7	-1.0	-0.7	0.0	-0.1	-0.3	-0.1	0.0	-0.4	-1.6	-0.9
	% change	0.0%	-4.8%	-5.2%	-2.7%	0.0%	-4.5%	-6.5%	-4.5%	0.0%	-2.0%	-5.0%	-2.6%	0.0%	-1.0%	-4.1%	-2.4%
2016	**absolute (TWh)**	20.7	19.2	19.1	19.8	16.0	14.9	14.5	14.9	5.0	4.9	4.7	4.8	39.2	38.6	36.8	37.8
	relative (TWh)	0.0	-1.5	-1.6	-0.8	0.0	-1.1	-1.5	-1.1	0.0	-0.2	-0.4	-0.2	0.0	-0.6	-2.4	-1.4
	% change	0.0%	-7.1%	-7.7%	-4.1%	0.0%	-6.7%	-9.7%	-6.7%	0.0%	-3.0%	-7.5%	-3.9%	0.0%	-1.4%	-6.1%	-3.5%
2017	**absolute (TWh)**	21.0	19.0	18.8	19.8	16.3	14.8	14.2	14.8	5.1	4.9	4.6	4.8	39.8	39.0	36.6	37.9
	relative (TWh)	0.0	-2.0	-2.1	-1.1	0.0	-1.4	-2.1	-1.4	0.0	-0.2	-0.5	-0.3	0.0	-0.8	-3.2	-1.9
	% change	0.0%	-9.4%	-10.2%	-5.4%	0.0%	-8.9%	-12.8%	-8.9%	0.0%	-4.0%	-10.0%	-5.1%	0.0%	-1.9%	-8.1%	-4.7%
2018	**absolute (TWh)**	21.3	18.8	18.6	19.9	16.5	14.7	13.9	14.7	5.2	4.9	4.5	4.9	40.4	39.4	36.3	38.0
	relative (TWh)	0.0	-2.5	-2.7	-1.4	0.0	-1.8	-2.6	-1.8	0.0	-0.3	-0.6	-0.3	0.0	-0.9	-4.0	-2.3
	% change	0.0%	-11.7%	-12.6%	-6.7%	0.0%	-11.1%	-15.9%	-11.1%	0.0%	-5.0%	-12.4%	-6.3%	0.0%	-2.4%	-10.0%	-5.8%
2019	**absolute (TWh)**	21.6	18.6	18.3	19.9	16.7	14.5	13.6	14.5	5.3	4.9	4.5	4.9	40.9	39.8	36.1	38.1
	relative (TWh)	0.0	-3.0	-3.3	-1.7	0.0	-2.2	-3.2	-2.2	0.0	-0.3	-0.8	-0.4	0.0	-1.1	-4.9	-2.8
	% change	0.0%	-13.9%	-15.1%	-8.0%	0.0%	-13.2%	-18.9%	-13.2%	0.0%	-6.0%	-14.7%	-7.6%	0.0%	-2.8%	-11.9%	-6.9%
2020	**absolute (TWh)**	21.9	18.4	18.1	19.9	17.0	14.4	13.2	14.4	5.3	5.0	4.4	4.9	41.5	40.2	35.8	38.2
	relative (TWh)	0.0	-3.5	-3.8	-2.0	0.0	-2.6	-3.7	-2.6	0.0	-0.4	-0.9	-0.5	0.0	-1.3	-5.7	-3.3
	% change	0.0%	-16.1%	-17.4%	-9.3%	0.0%	-15.3%	-21.9%	-15.3%	0.0%	-6.9%	-17.1%	-8.8%	0.0%	-3.2%	-13.8%	-8.0%
2021	**absolute (TWh)**	22.2	18.2	17.8	19.9	17.2	14.2	12.9	14.2	5.4	5.0	4.4	4.9	42.1	40.6	35.5	38.3

	TWh	BC 1 BAU	BC 1 LLCC	BC 1 BAT	BC 1 MEPS	BC 2 BAU	BC 2 LLCC	BC 2 BAT	BC 2 MEPS	BC 3 BAU	BC 3 LLCC	BC 3 BAT	BC 3 MEPS	BC 4 BAU	BC 4 LLCC	BC 4 BAT	BC 4 MEPS
	relative (TWh)	0.0	-4.1	-4.4	-2.3	0.0	-3.0	-4.3	-3.0	0.0	-0.4	-1.0	-0.5	0.0	-1.6	-6.6	-3.8
	% change	0.0%	-18.3%	-19.8%	-10.5%	0.0%	-17.3%	-24.9%	-17.3%	0.0%	-7.8%	-19.4%	-9.9%	0.0%	-3.7%	-15.7%	-9.1%
2022	absolute (TWh)	22.5	17.9	17.6	19.9	17.5	14.1	12.6	14.1	5.5	5.0	4.3	4.9	42.8	41.0	35.3	38.4
	relative (TWh)	0.0	-4.6	-5.0	-2.7	0.0	-3.4	-4.9	-3.4	0.0	-0.5	-1.2	-0.6	0.0	-1.8	-7.5	-4.3
	% change	0.0%	-20.4%	-22.1%	-11.8%	0.0%	-19.4%	-27.8%	-19.4%	0.0%	-8.8%	-21.6%	-11.1%	0.0%	-4.1%	-17.5%	-10.1%
2023	absolute (TWh)	22.9	17.7	17.3	19.9	17.7	13.9	12.3	13.9	5.6	5.0	4.2	4.9	43.4	41.4	35.0	38.5
	relative (TWh)	0.0	-5.2	-5.6	-3.0	0.0	-3.8	-5.4	-3.8	0.0	-0.5	-1.3	-0.7	0.0	-2.0	-8.4	-4.9
	% change	0.0%	-22.6%	-24.4%	-13.0%	0.0%	-21.4%	-30.7%	-21.4%	0.0%	-9.7%	-23.9%	-12.3%	0.0%	-4.5%	-19.3%	-11.2%
2024	absolute (TWh)	23.2	17.5	17.0	19.9	18.0	13.8	11.9	13.8	5.6	5.0	4.2	4.9	44.0	41.8	34.7	38.6
	relative (TWh)	0.0	-5.7	-6.2	-3.3	0.0	-4.2	-6.0	-4.2	0.0	-0.6	-1.5	-0.8	0.0	-2.2	-9.3	-5.4
	% change	0.0%	-24.6%	-26.7%	-14.2%	0.0%	-23.3%	-33.5%	-23.3%	0.0%	-10.6%	-26.1%	-13.4%	0.0%	-5.0%	-21.1%	-12.2%
2025	absolute (TWh)	23.5	17.2	16.7	19.9	18.2	13.6	11.6	13.6	5.7	5.1	4.1	4.9	44.7	42.3	34.4	38.8
	relative (TWh)	0.0	-6.3	-6.8	-3.6	0.0	-4.6	-6.6	-4.6	0.0	-0.7	-1.6	-0.8	0.0	-2.4	-10.2	-5.9
	% change	0.0%	-26.7%	-28.9%	-15.4%	0.0%	-25.3%	-36.3%	-25.3%	0.0%	-11.5%	-28.3%	-14.5%	0.0%	-5.4%	-22.9%	-13.2%
2011-2025	absolute (TWh)	319.9	280.1	276.9	297.0	247.7	218.6	205.9	218.6	77.8	73.7	67.6	72.6	606.5	591.3	541.8	569.1
	relative (TWh)	0.0	-39.7	-43.0	-22.9	0.0	-29.2	-41.9	-29.2	0.0	-4.1	-10.2	-5.2	0.0	-15.2	-64.7	-37.4
	% change	0.0%	-12.4%	-13.4%	-7.2%	0.0%	-11.8%	-16.9%	-11.8%	0.0%	-5.3%	-13.1%	-6.7%	0.0%	-2.5%	-10.7%	-6.2%

	TWh	BC5 BAU	BC5 LLCC	BC5 BAT	BC5 MEPS	BC6 BAU	BC6 LLCC	BC6 BAT	BC6 MEPS	BC7 BAU	BC7 LLCC	BC7 BAT	BC7 MEPS
2013	absolute (TWh)	0.5	0.5	0.5	0.5	2.2	2.2	2.2	2.2	0.4	0.4	0.4	0.4
	relative (TWh)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	% change	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2014	absolute (TWh)	0.6	0.5	0.5	0.6	2.5	2.4	2.4	2.4	0.4	0.4	0.4	0.4
	relative (TWh)	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0
	% change	0.0%	-8.0%	-8.0%	-5.3%	0.0%	-3.2%	-3.2%	-3.2%	0.0%	0.0%	-2.9%	0.0%

	TWh	BC5 BAU	BC5 LLCC	BC5 BAT	BC5 MEPS	BC6 BAU	BC6 LLCC	BC6 BAT	BC6 MEPS	BC7 BAU	BC7 LLCC	BC7 BAT	BC7 MEPS
2015	absolute (TWh)	0.6	0.5	0.5	0.6	2.7	2.6	2.6	2.6	0.4	0.4	0.4	0.4
	relative (TWh)	0.0	-0.1	-0.1	-0.1	0.0	-0.2	-0.2	-0.2	0.0	0.0	0.0	0.0
	% change	0.0%	-15.1%	-15.1%	-10.0%	0.0%	-6.1%	-6.1%	-6.1%	0.0%	0.0%	-5.8%	0.0%
2016	absolute (TWh)	0.7	0.6	0.6	0.6	3.0	2.7	2.7	2.7	0.4	0.4	0.3	0.4
	relative (TWh)	0.0	-0.2	-0.2	-0.1	0.0	-0.3	-0.3	-0.3	0.0	0.0	0.0	0.0
	% change	0.0%	-21.7%	-21.7%	-14.3%	0.0%	-8.8%	-8.8%	-8.8%	0.0%	0.0%	-8.7%	0.0%
2017	absolute (TWh)	0.8	0.6	0.6	0.6	3.3	3.0	3.0	3.0	0.4	0.4	0.3	0.4
	relative (TWh)	0.0	-0.2	-0.2	-0.1	0.0	-0.4	-0.4	-0.4	0.0	0.0	0.0	0.0
	% change	0.0%	-27.5%	-27.5%	-18.2%	0.0%	-11.2%	-11.2%	-11.2%	0.0%	0.0%	-11.5%	0.0%
2018	absolute (TWh)	0.9	0.6	0.6	0.7	3.7	3.2	3.2	3.2	0.4	0.4	0.3	0.4
	relative (TWh)	0.0	-0.3	-0.3	-0.2	0.0	-0.5	-0.5	-0.5	0.0	0.0	-0.1	0.0
	% change	0.0%	-32.9%	-32.9%	-21.7%	0.0%	-13.3%	-13.3%	-13.3%	0.0%	0.0%	-14.4%	0.0%
2019	absolute (TWh)	1.0	0.6	0.6	0.7	4.1	3.4	3.4	3.4	0.4	0.4	0.3	0.4
	relative (TWh)	0.0	-0.4	-0.4	-0.2	0.0	-0.6	-0.6	-0.6	0.0	0.0	-0.1	0.0
	% change	0.0%	-37.7%	-37.7%	-24.9%	0.0%	-15.3%	-15.3%	-15.3%	0.0%	0.0%	-17.3%	-2.9%
2020	absolute (TWh)	1.1	0.6	0.6	0.8	4.5	3.7	3.7	3.7	0.4	0.4	0.3	0.4
	relative (TWh)	0.0	-0.4	-0.4	-0.3	0.0	-0.8	-0.8	-0.8	0.0	0.0	-0.1	0.0
	% change	0.0%	-42.0%	-42.0%	-27.8%	0.0%	-17.1%	-17.1%	-17.1%	0.0%	0.0%	-20.2%	-5.8%
2021	absolute (TWh)	1.2	0.6	0.6	0.8	5.0	4.0	4.0	4.0	0.4	0.4	0.3	0.3
	relative (TWh)	0.0	-0.5	-0.5	-0.4	0.0	-0.9	-0.9	-0.9	0.0	0.0	-0.1	0.0
	% change	0.0%	-46.0%	-46.0%	-30.4%	0.0%	-18.7%	-18.7%	-18.7%	0.0%	0.0%	-23.1%	-8.7%
2022	absolute (TWh)	1.3	0.7	0.7	0.9	5.5	4.4	4.4	4.4	0.4	0.4	0.3	0.3
	relative (TWh)	0.0	-0.6	-0.6	-0.4	0.0	-1.1	-1.1	-1.1	0.0	0.0	-0.1	0.0
	% change	0.0%	-49.6%	-49.6%	-32.7%	0.0%	-20.1%	-20.1%	-20.1%	0.0%	0.0%	-26.0%	-11.5%
2023	absolute (TWh)	1.4	0.7	0.7	0.9	6.1	4.8	4.8	4.8	0.4	0.4	0.3	0.3
	relative (TWh)	0.0	-0.8	-0.8	-0.5	0.0	-1.3	-1.3	-1.3	0.0	0.0	-0.1	-0.1
	% change	0.0%	-52.8%	-52.8%	-34.8%	0.0%	-21.4%	-21.4%	-21.4%	0.0%	0.0%	-28.8%	-14.4%

	TWh	BC5				BC6				BC7			
		BAU	LLCC	BAT	MEPS	BAU	LLCC	BAT	MEPS	BAU	LLCC	BAT	MEPS
2024	absolute (TWh)	1.6	0.7	0.7	1.0	6.7	5.2	5.2	5.2	0.4	0.4	0.3	0.3
	relative (TWh)	0.0	-0.9	-0.9	-0.6	0.0	-1.5	-1.5	-1.5	0.0	0.0	-0.1	-0.1
	% change	0.0%	-55.7%	-55.7%	-36.8%	0.0%	-22.6%	-22.6%	-22.6%	0.0%	0.0%	-28.8%	-17.3%
2025	absolute (TWh)	1.8	0.7	0.7	1.1	7.4	5.7	5.7	5.7	0.4	0.4	0.3	0.3
	relative (TWh)	0.0	-1.0	-1.0	-0.7	0.0	-1.8	-1.8	-1.8	0.0	0.0	-0.1	-0.1
	% change	0.0%	-58.3%	-58.3%	-38.5%	0.0%	-23.7%	-23.7%	-23.7%	0.0%	0.0%	-28.8%	-20.2%
2011-2025	absolute (TWh)	14.3	8.9	8.9	10.7	60.5	51.1	51.1	51.1	5.7	5.7	4.9	5.4
	relative (TWh)	0.0	-5.5	-5.5	-3.6	0.0	-9.4	-9.4	-9.4	0.0	0.0	-0.8	-0.3
	% change	0.0%	-38.2%	-38.2%	-25.2%	0.0%	-15.5%	-15.5%	-15.5%	0.0%	0.0%	-14.4%	-5.4%

Table 7-20: Comparison of expenditure of base-cases between BAU, LLCC, BAT and MEPS scenarios

	m€	BC 1				BC 2				BC 3				BC 4			
		BAU	LLCC	BAT	MEPS	BAU	LLCC	BAT	MEPS	BAU	LLCC	BAT	MEPS	BAU	LLCC	BAT	MEPS
2013	absolute (m€)	1 372.8	1 622.0	2 047.5	1 470.1	1 083.8	1 261.7	1 627.5	1 261.7	311.2	325.3	451.4	358.3	4 306.7	4 463.9	8 235.9	5 328.3
	relative (m€)	0.0	249.2	674.7	97.3	0.0	177.9	543.8	177.9	0.0	14.1	140.1	47.0	0.0	157.2	3 929.1	1 021.6
	% change	0.0%	18.2%	49.1%	7.1%	0.0%	16.4%	50.2%	16.4%	0.0%	4.5%	45.0%	15.1%	0.0%	3.6%	91.2%	23.7%
2014	absolute (m€)	1 392.5	1 626.7	2 056.8	1 480.4	1 099.4	1 262.5	1 626.1	1 262.5	315.6	327.6	452.1	360.4	4 369.7	4 520.8	8 320.9	5 385.7
	relative (m€)	0.0	234.1	664.2	87.9	0.0	163.2	526.8	163.2	0.0	12.0	136.5	44.8	0.0	151.2	3 951.3	1 016.1
	% change	0.0%	16.8%	47.7%	6.3%	0.0%	14.8%	47.9%	14.8%	0.0%	3.8%	43.2%	14.2%	0.0%	3.5%	90.4%	23.3%
2015	absolute (m€)	1 412.5	1 631.4	2 066.1	1 491.0	1 115.2	1 263.4	1 624.7	1 263.4	320.0	330.0	452.8	362.6	4 433.5	4 578.6	8 407.2	5 444.0
	relative (m€)	0.0	218.9	653.6	78.4	0.0	148.2	509.5	148.2	0.0	9.9	132.8	42.6	0.0	145.1	3 973.7	1 010.5
	% change	0.0%	15.5%	46.3%	5.6%	0.0%	13.3%	45.7%	13.3%	0.0%	3.1%	41.5%	13.3%	0.0%	3.3%	89.6%	22.8%
2016	absolute (m€)	1 432.8	1 636.2	2 075.7	1 501.7	1 131.2	1 264.3	1 623.3	1 264.3	324.5	332.3	453.6	364.8	4 498.3	4 637.3	8 494.8	5 503.2
	relative (m€)	0.0	203.4	642.8	68.8	0.0	133.1	492.1	133.1	0.0	7.8	129.1	40.3	0.0	138.9	3 996.5	1 004.9
	% change	0.0%	14.2%	44.9%	4.8%	0.0%	11.8%	43.5%	11.8%	0.0%	2.4%	39.8%	12.4%	0.0%	3.1%	88.8%	22.3%
2017	absolute (m€)	1 453.4	1 641.1	2 085.3	1 512.5	1 147.5	1 265.2	1 621.8	1 265.2	329.1	334.7	454.3	367.0	4 564.1	4 696.8	8 583.7	5 563.2
	relative (m€)	0.0	187.6	631.9	59.1	0.0	117.7	474.3	117.7	0.0	5.7	125.3	38.0	0.0	132.7	4 019.5	999.1

	m€	BC 1 BAU	BC 1 LLCC	BC 1 BAT	BC 1 MEPS	BC 2 BAU	BC 2 LLCC	BC 2 BAT	BC 2 MEPS	BC 3 BAU	BC 3 LLCC	BC 3 BAT	BC 3 MEPS	BC 4 BAU	BC 4 LLCC	BC 4 BAT	BC 4 MEPS
	% change	0.0%	12.9%	43.5%	4.1%	0.0%	10.3%	41.3%	10.3%	0.0%	1.7%	38.1%	11.5%	0.0%	2.9%	88.1%	21.9%
2018	absolute (m€)	1 474.3	1 646.0	2 095.1	1 523.5	1 164.0	1 266.1	1 620.3	1 266.1	333.7	337.1	455.1	369.3	4 630.8	4 757.1	8 673.8	5 624.1
	relative (m€)	0.0	171.7	620.8	49.2	0.0	102.2	456.4	102.2	0.0	3.5	121.4	35.6	0.0	126.3	4 043.0	993.3
	% change	0.0%	11.6%	42.1%	3.3%	0.0%	8.8%	39.2%	8.8%	0.0%	1.0%	36.4%	10.7%	0.0%	2.7%	87.3%	21.4%
2019	absolute (m€)	1 495.5	1 651.0	2 105.0	1 534.6	1 180.7	1 267.0	1 618.8	1 267.0	338.3	339.6	455.9	371.6	4 698.5	4 818.4	8 765.3	5 685.9
	relative (m€)	0.0	155.5	609.5	39.1	0.0	86.4	438.1	86.4	0.0	1.2	117.5	33.3	0.0	119.9	4 066.8	987.4
	% change	0.0%	10.4%	40.8%	2.6%	0.0%	7.3%	37.1%	7.3%	0.0%	0.4%	34.7%	9.8%	0.0%	2.6%	86.6%	21.0%
2020	absolute (m€)	1 517.0	1 656.1	2 115.1	1 545.9	1 197.7	1 268.0	1 617.3	1 268.0	343.1	342.1	456.7	373.9	4 767.2	4 880.5	8 858.1	5 748.6
	relative (m€)	0.0	139.1	598.1	29.0	0.0	70.3	419.6	70.3	0.0	-1.0	113.6	30.9	0.0	113.3	4 090.9	981.4
	% change	0.0%	9.2%	39.4%	1.9%	0.0%	5.9%	35.0%	5.9%	0.0%	-0.3%	33.1%	9.0%	0.0%	2.4%	85.8%	20.6%
2021	absolute (m€)	1 538.8	1 661.2	2 125.3	1 557.4	1 214.9	1 268.9	1 615.7	1 268.9	347.9	344.6	457.5	376.3	4 836.9	4 943.6	8 952.2	5 812.2
	relative (m€)	0.0	122.5	586.5	18.6	0.0	54.1	400.9	54.1	0.0	-3.3	109.6	28.4	0.0	106.7	4 115.3	975.3
	% change	0.0%	8.0%	38.1%	1.2%	0.0%	4.4%	33.0%	4.4%	0.0%	-0.9%	31.5%	8.2%	0.0%	2.2%	85.1%	20.2%
2022	absolute (m€)	1 560.9	1 666.4	2 135.7	1 569.0	1 232.3	1 269.9	1 614.2	1 269.9	352.8	347.2	458.3	378.7	4 907.6	5 007.6	9 047.8	5 876.7
	relative (m€)	0.0	105.6	574.8	8.2	0.0	37.6	381.8	37.6	0.0	-5.6	105.5	25.9	0.0	100.0	4 140.2	969.1
	% change	0.0%	6.8%	36.8%	0.5%	0.0%	3.0%	31.0%	3.0%	0.0%	-1.6%	29.9%	7.4%	0.0%	2.0%	84.4%	19.7%
2023	absolute (m€)	1 583.3	1 671.7	2 146.2	1 580.8	1 250.1	1 270.9	1 612.6	1 270.9	357.7	349.7	459.1	381.1	4 979.3	5 072.5	9 144.7	5 942.2
	relative (m€)	0.0	88.4	562.9	-2.5	0.0	20.8	362.5	20.8	0.0	-7.9	101.4	23.4	0.0	93.1	4 165.4	962.9
	% change	0.0%	5.6%	35.6%	-0.2%	0.0%	1.7%	29.0%	1.7%	0.0%	-2.2%	28.3%	6.5%	0.0%	1.9%	83.7%	19.3%
2024	absolute (m€)	1 606.1	1 677.1	2 156.9	1 592.8	1 268.0	1 271.9	1 611.0	1 271.9	362.7	352.4	459.9	383.6	5 052.1	5 138.3	9 243.1	6 008.7
	relative (m€)	0.0	71.1	550.8	-13.2	0.0	3.8	342.9	3.8	0.0	-10.3	97.2	20.9	0.0	86.2	4 190.9	956.5
	% change	0.0%	4.4%	34.3%	-0.8%	0.0%	0.3%	27.0%	0.3%	0.0%	-2.8%	26.8%	5.8%	0.0%	1.7%	83.0%	18.9%
2025	absolute (m€)	1 629.1	1 682.6	2 167.7	1 605.0	1 286.3	1 272.9	1 609.3	1 272.9	367.8	355.0	460.8	386.1	5 126.0	5 205.2	9 342.9	6 076.1
	relative (m€)	0.0	53.4	538.5	-24.2	0.0	-13.4	323.1	-13.4	0.0	-12.7	93.0	18.3	0.0	79.2	4 216.9	950.1
	% change	0.0%	3.3%	33.1%	-1.5%	0.0%	-1.0%	25.1%	-1.0%	0.0%	-3.5%	25.3%	5.0%	0.0%	1.5%	82.3%	18.5%
2011-2025	absolute (m€)	22 156.6	24 157.1	30 065.9	22 652.2	17 492.6	18 594.5	23 164.4	18 594.5	5 014.0	5 027.3	6 536.9	5 443.3	69 599.1	71 148.7	122 498.5	82 427.2
	relative (m€)	0.0	2 000.5	7 909.3	495.6	0.0	1 101.9	5 671.8	1 101.9	0.0	13.3	1 523.0	429.3	0.0	1 549.6	52 899.4	12 828.2

m€	BC 1 BAU	BC 1 LLCC	BC 1 BAT	BC 1 MEPS	BC 2 BAU	BC 2 LLCC	BC 2 BAT	BC 2 MEPS	BC 3 BAU	BC 3 LLCC	BC 3 BAT	BC 3 MEPS	BC 4 BAU	BC 4 LLCC	BC 4 BAT	BC 4 MEPS
% change	0.0%	9.0%	35.7%	2.2%	0.0%	6.3%	32.4%	6.3%	0.0%	0.3%	30.4%	8.6%	0.0%	2.2%	76.0%	18.4%

	m€	BC5 BAU	BC5 LLCC	BC5 BAT	BC5 MEPS	BC6 BAU	BC6 LLCC	BC6 BAT	BC6 MEPS	BC7 BAU	BC7 LLCC	BC7 BAT	BC7 MEPS
2013	absolute (m€)	122.5	152.1	152.1	138.6	563.9	609.3	609.3	609.3	125.0	125.0	167.5	125.0
	relative (m€)	0.0	29.6	29.6	16.1	0.0	45.4	45.4	45.4	0.0	0.0	42.5	0.0
	% change	0.0%	24.2%	24.2%	13.1%	0.0%	8.0%	8.0%	8.0%	0.0%	0.0%	34.0%	0.0%
2014	absolute (m€)	135.4	159.5	159.5	147.5	623.4	658.6	658.6	658.6	125.0	125.0	166.8	125.0
	relative (m€)	0.0	24.0	24.0	12.1	0.0	35.3	35.3	35.3	0.0	0.0	41.8	0.0
	% change	0.0%	17.7%	17.7%	8.9%	0.0%	5.7%	5.7%	5.7%	0.0%	0.0%	33.4%	0.0%
2015	absolute (m€)	149.7	167.6	167.6	157.3	689.1	713.2	713.2	713.2	125.0	125.0	166.1	125.0
	relative (m€)	0.0	17.9	17.9	7.6	0.0	24.1	24.1	24.1	0.0	0.0	41.1	0.0
	% change	0.0%	11.9%	11.9%	5.1%	0.0%	3.5%	3.5%	3.5%	0.0%	0.0%	32.9%	0.0%
2016	absolute (m€)	165.5	176.6	176.6	168.2	761.8	773.5	773.5	773.5	125.0	125.0	165.4	125.0
	relative (m€)	0.0	11.1	11.1	2.7	0.0	11.7	11.7	11.7	0.0	0.0	40.4	0.0
	% change	0.0%	6.7%	6.7%	1.6%	0.0%	1.5%	1.5%	1.5%	0.0%	0.0%	32.3%	0.0%
2017	absolute (m€)	183.0	186.5	186.5	180.2	842.2	840.2	840.2	840.2	125.0	125.0	164.7	125.0
	relative (m€)	0.0	3.6	3.6	-2.8	0.0	-1.9	-1.9	-1.9	0.0	0.0	39.7	0.0
	% change	0.0%	1.9%	1.9%	-1.5%	0.0%	-0.2%	-0.2%	-0.2%	0.0%	0.0%	31.8%	0.0%
2018	absolute (m€)	202.3	197.5	197.5	193.5	931.0	914.0	914.0	914.0	125.0	125.0	164.0	167.5
	relative (m€)	0.0	-4.8	-4.8	-8.8	0.0	-17.0	-17.0	-17.0	0.0	0.0	39.0	42.5
	% change	0.0%	-2.4%	-2.4%	-4.4%	0.0%	-1.8%	-1.8%	-1.8%	0.0%	0.0%	31.2%	34.0%
2019	absolute (m€)	223.6	209.7	209.7	208.1	1 029.2	995.5	995.5	995.5	125.0	125.0	163.4	166.8
	relative (m€)	0.0	-13.9	-13.9	-15.5	0.0	-33.7	-33.7	-33.7	0.0	0.0	38.3	41.8
	% change	0.0%	-6.2%	-6.2%	-6.9%	0.0%	-3.3%	-3.3%	-3.3%	0.0%	0.0%	30.6%	33.4%
2020	absolute (m€)	247.2	223.1	223.1	224.3	1 137.7	1 085.5	1 085.5	1 085.5	125.0	125.0	162.7	166.1
	relative (m€)	0.0	-24.1	-24.1	-22.9	0.0	-52.2	-52.2	-52.2	0.0	0.0	37.6	41.1

	m€	BC5 BAU	BC5 LLCC	BC5 BAT	BC5 MEPS	BC6 BAU	BC6 LLCC	BC6 BAT	BC6 MEPS	BC7 BAU	BC7 LLCC	BC7 BAT	BC7 MEPS
	% change	0.0%	-9.8%	-9.8%	-9.2%	0.0%	-4.6%	-4.6%	-4.6%	0.0%	0.0%	30.1%	32.9%
2021	absolute (m€)	273.3	237.9	237.9	242.3	1 257.7	1 185.1	1 185.1	1 185.1	125.0	125.0	162.0	165.4
	relative (m€)	0.0	-35.3	-35.3	-31.0	0.0	-72.6	-72.6	-72.6	0.0	0.0	36.9	40.4
	% change	0.0%	-12.9%	-12.9%	-11.3%	0.0%	-5.8%	-5.8%	-5.8%	0.0%	0.0%	29.5%	32.3%
2022	absolute (m€)	302.1	254.3	254.3	262.1	1 390.4	1 295.3	1 295.3	1 295.3	125.0	125.0	161.3	164.7
	relative (m€)	0.0	-47.8	-47.8	-40.0	0.0	-95.1	-95.1	-95.1	0.0	0.0	36.2	39.7
	% change	0.0%	-15.8%	-15.8%	-13.2%	0.0%	-6.8%	-6.8%	-6.8%	0.0%	0.0%	29.0%	31.8%
2023	absolute (m€)	333.9	272.5	272.5	284.0	1 537.0	1 417.0	1 417.0	1 417.0	125.0	125.0	160.6	164.0
	relative (m€)	0.0	-61.5	-61.5	-50.0	0.0	-120.0	-120.0	-120.0	0.0	0.0	35.6	39.0
	% change	0.0%	-18.4%	-18.4%	-15.0%	0.0%	-7.8%	-7.8%	-7.8%	0.0%	0.0%	28.4%	31.2%
2024	absolute (m€)	369.2	292.5	292.5	308.2	1 699.1	1 551.5	1 551.5	1 551.5	125.0	125.0	160.6	163.4
	relative (m€)	0.0	-76.7	-76.7	-61.0	0.0	-147.6	-147.6	-147.6	0.0	0.0	35.6	38.3
	% change	0.0%	-20.8%	-20.8%	-16.5%	0.0%	-8.7%	-8.7%	-8.7%	0.0%	0.0%	28.4%	30.6%
2025	absolute (m€)	408.1	314.7	314.7	335.0	1 878.3	1 700.3	1 700.3	1 700.3	125.0	125.0	160.6	162.7
	relative (m€)	0.0	-93.4	-93.4	-73.1	0.0	-178.1	-178.1	-178.1	0.0	0.0	35.6	37.6
	% change	0.0%	-22.9%	-22.9%	-17.9%	0.0%	-9.5%	-9.5%	-9.5%	0.0%	0.0%	28.4%	30.1%
2011-2025	absolute (m€)	3 326.8	3 055.5	3 055.5	3 060.2	15 312.4	14 710.5	14 710.5	14 710.5	1 875.6	1 875.6	2 375.8	2 195.9
	relative (m€)	0.0	-271.3	-271.3	-266.6	0.0	-601.8	-601.8	-601.8	0.0	0.0	500.2	320.4
	% change	0.0%	-8.2%	-8.2%	-8.0%	0.0%	-3.9%	-3.9%	-3.9%	0.0%	0.0%	26.7%	17.1%

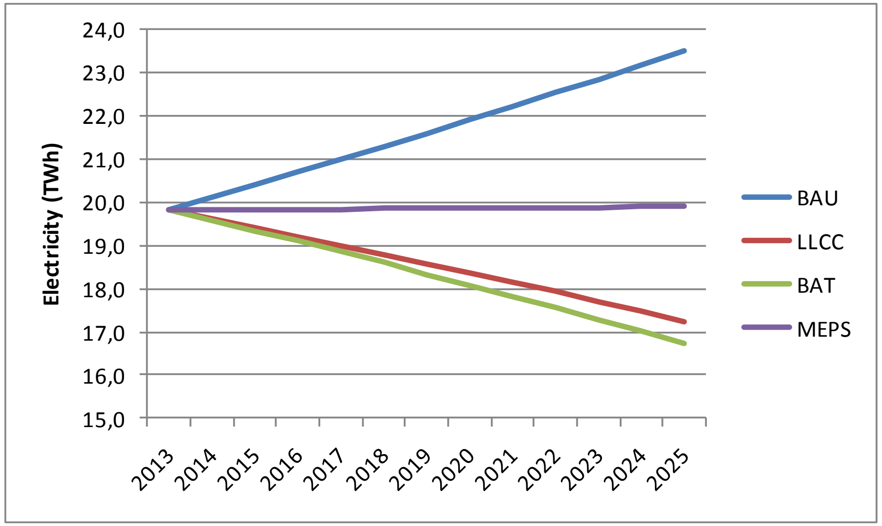


Figure 7-4: Base-case 1 electricity consumption by scenario

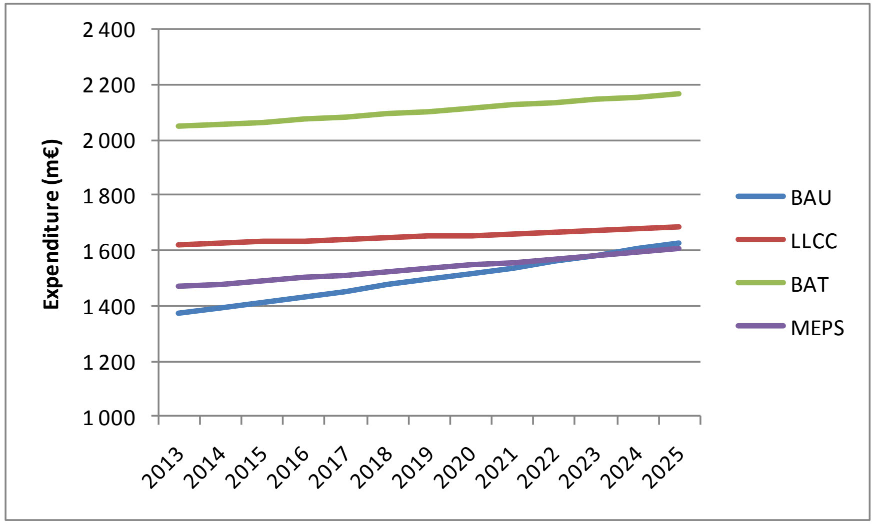


Figure 7-5: Base-case 1 expenditure by scenario

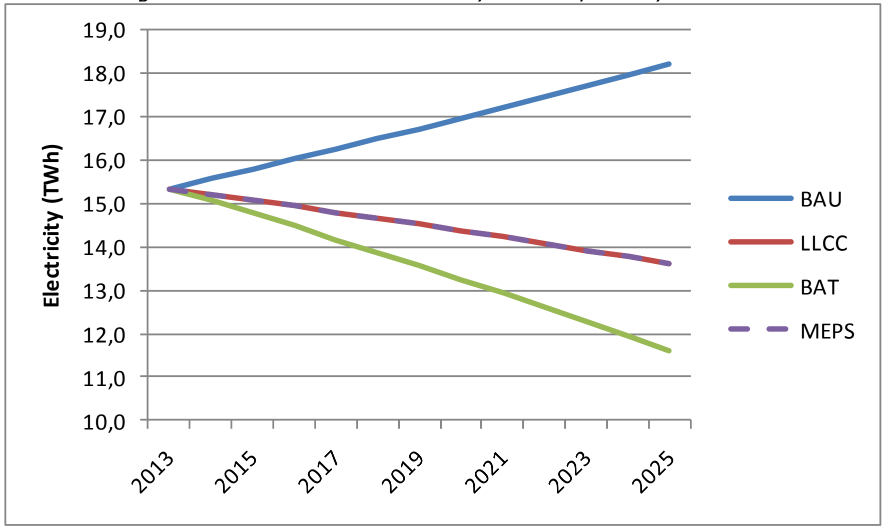


Figure 7-6: Base-case 2 electricity consumption by scenario

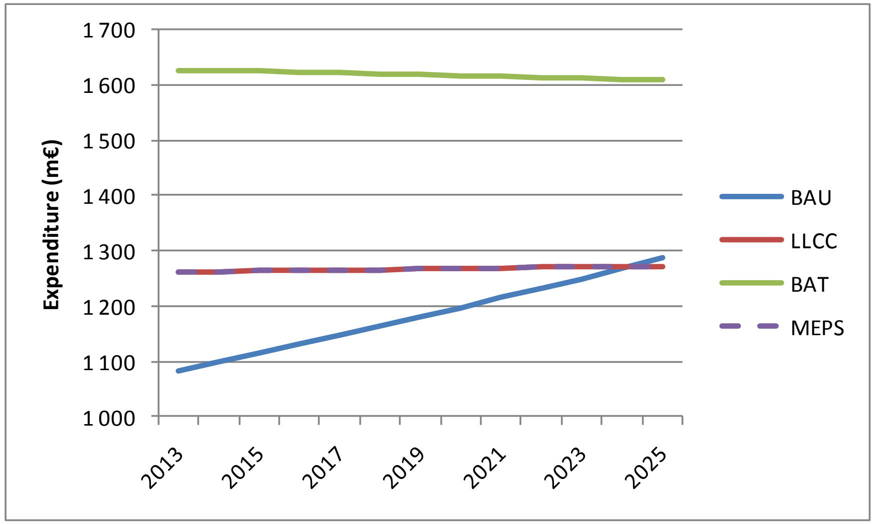


Figure 7-7: Base-case 2 expenditure by scenario

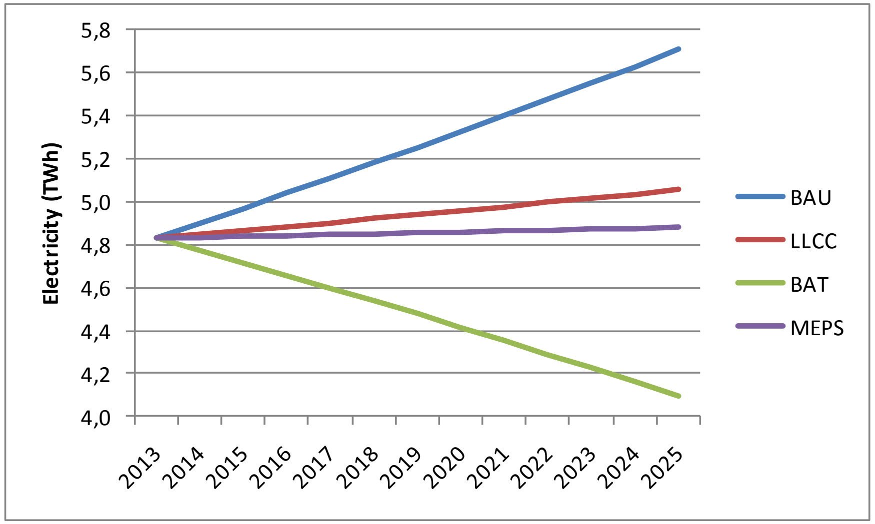


Figure 7-8: Base-case 3 electricity consumption by scenario

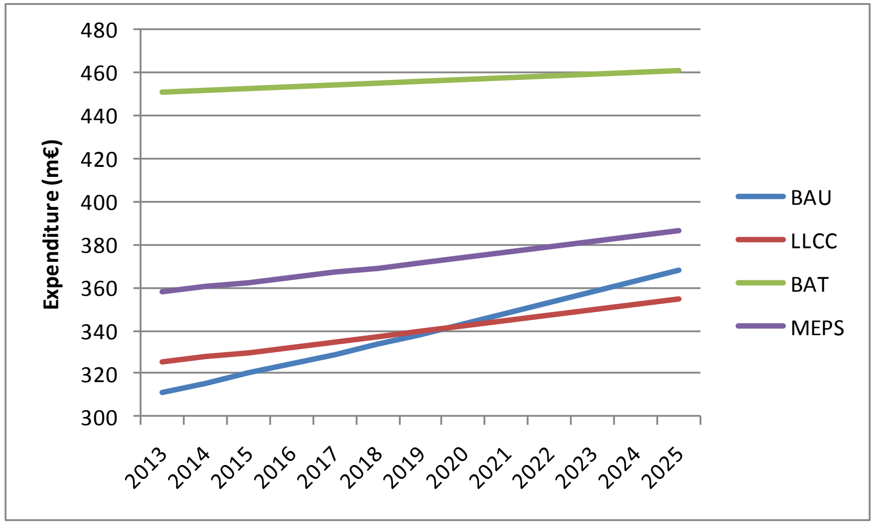


Figure 7-9: Base-case 3 expenditure by scenario

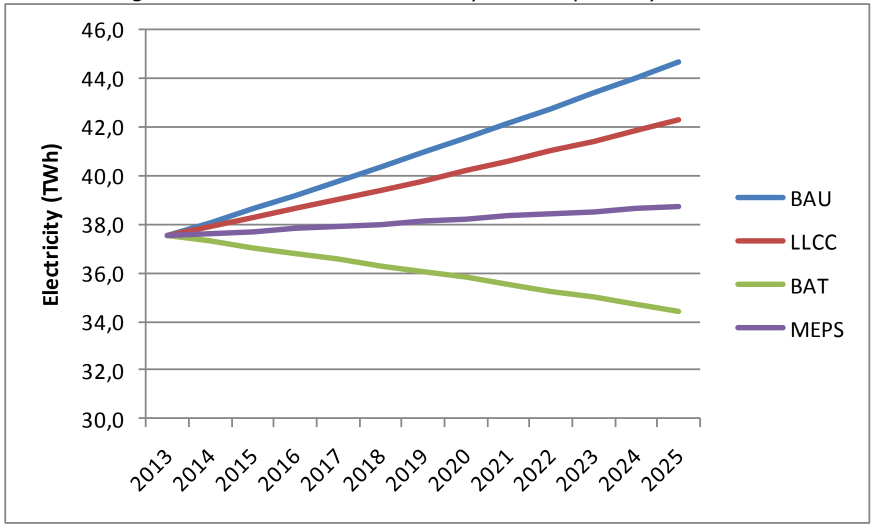


Figure 7-10: Base-case 4 electricity consumption by scenario

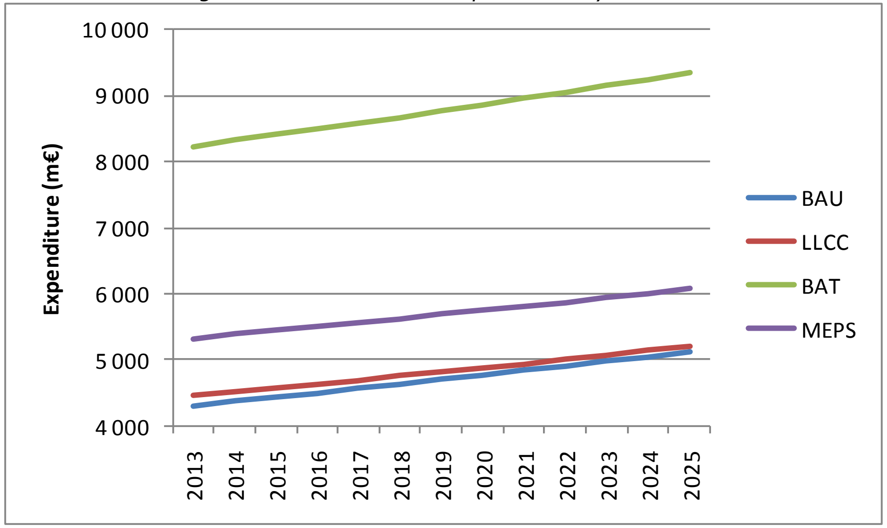


Figure 7-11: Base-case 4 expenditure by scenario

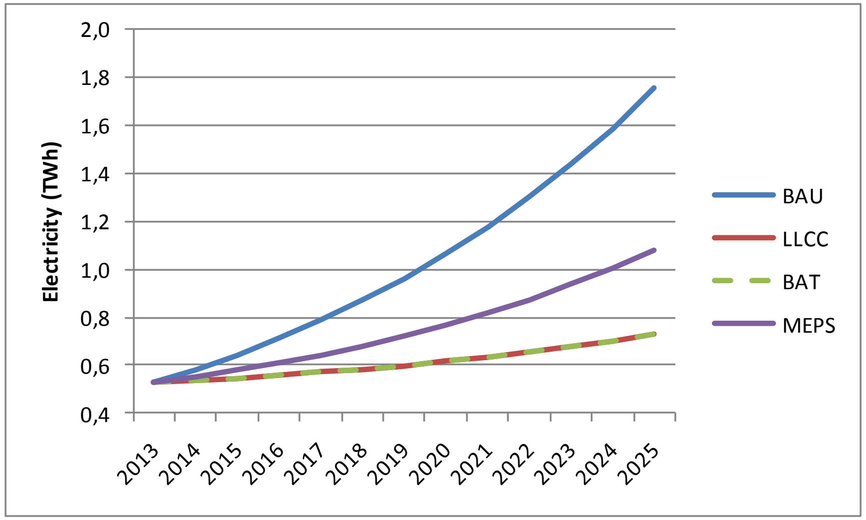


Figure 7-12: Base-case 5 electricity consumption by scenario

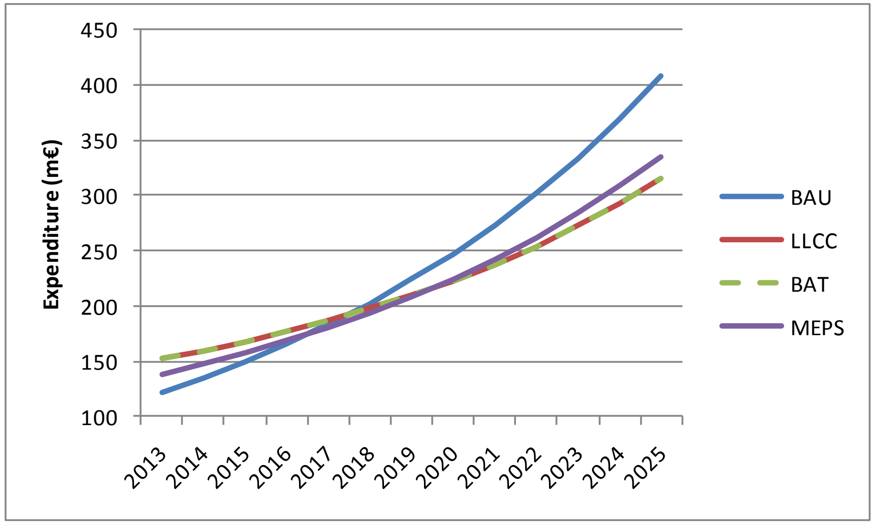


Figure 7-13: Base-case 5 expenditure by scenario

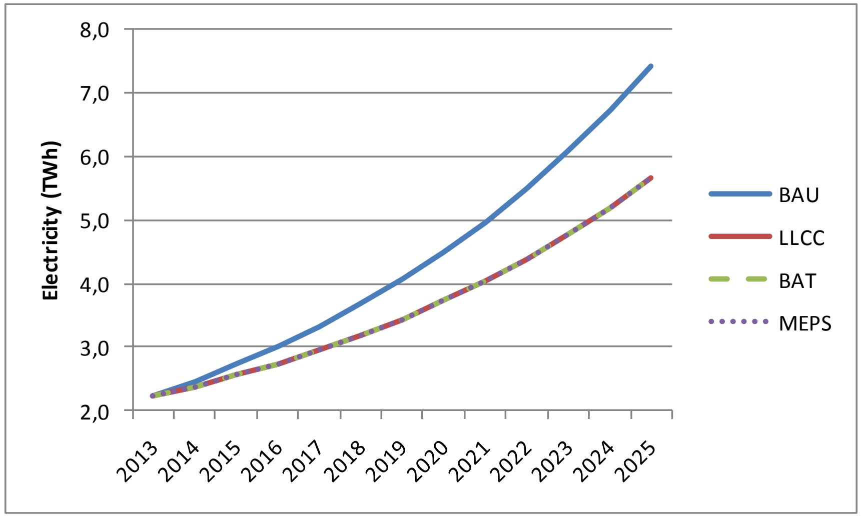


Figure 7-14: Base-case 6 electricity consumption by scenario

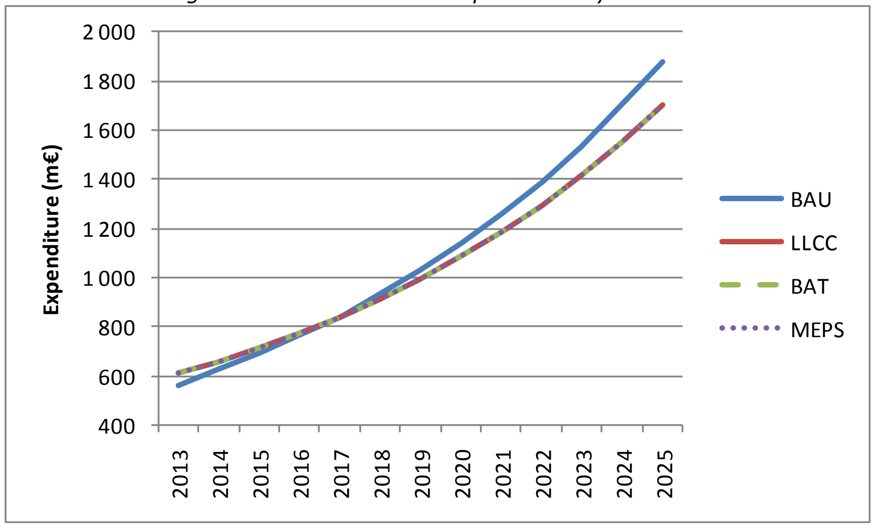


Figure 7-15: Base-case 6 expenditure by scenario

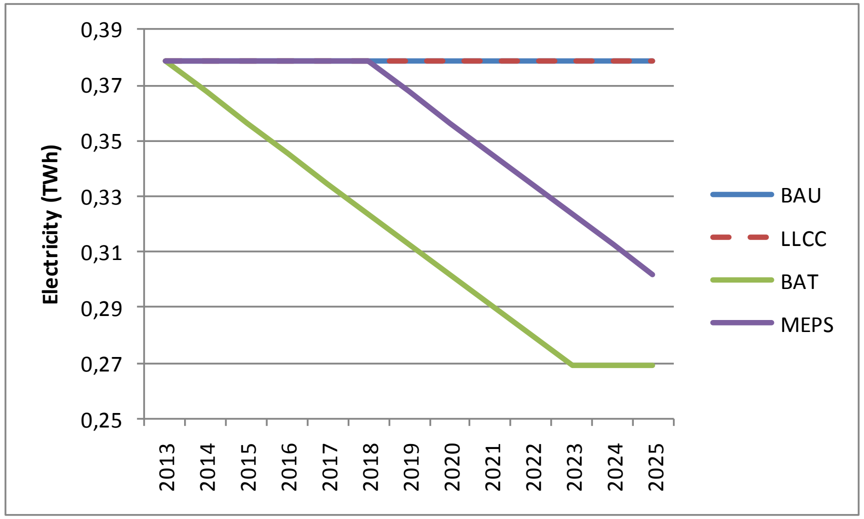


Figure 7-16: Base-case 7 electricity consumption by scenario

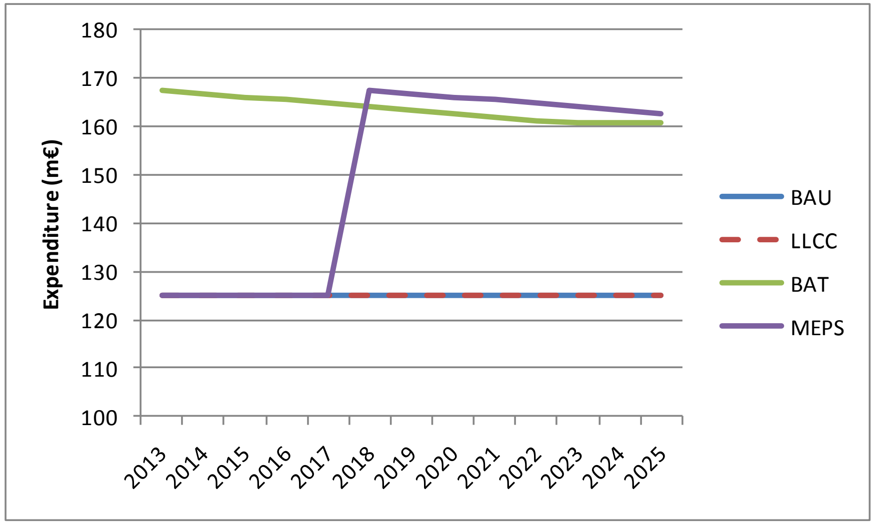


Figure 7-17: Base-case 7 expenditure by scenario

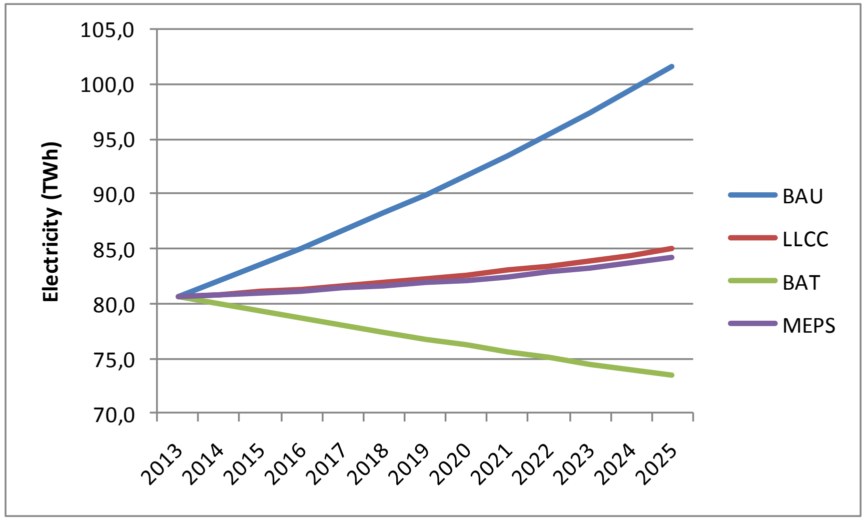


Figure 7-18: Total electricity consumption by scenario

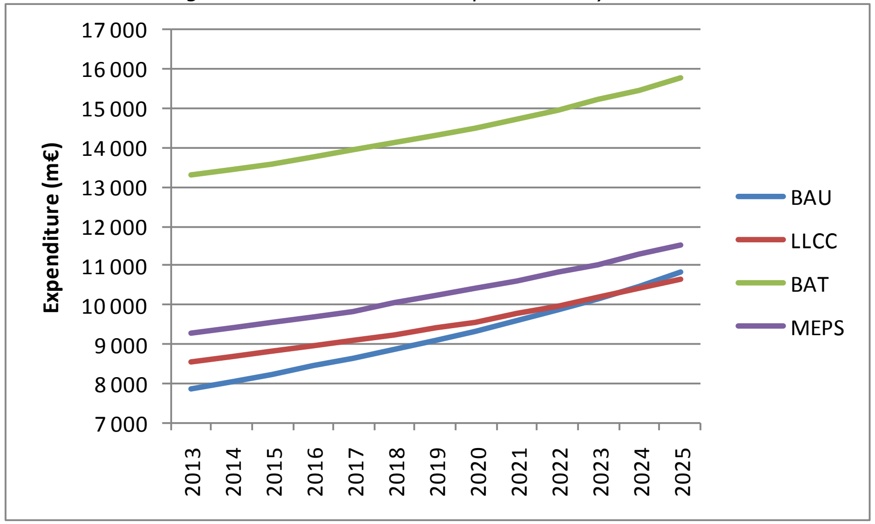


Figure 7-19: Total expenditure by scenario

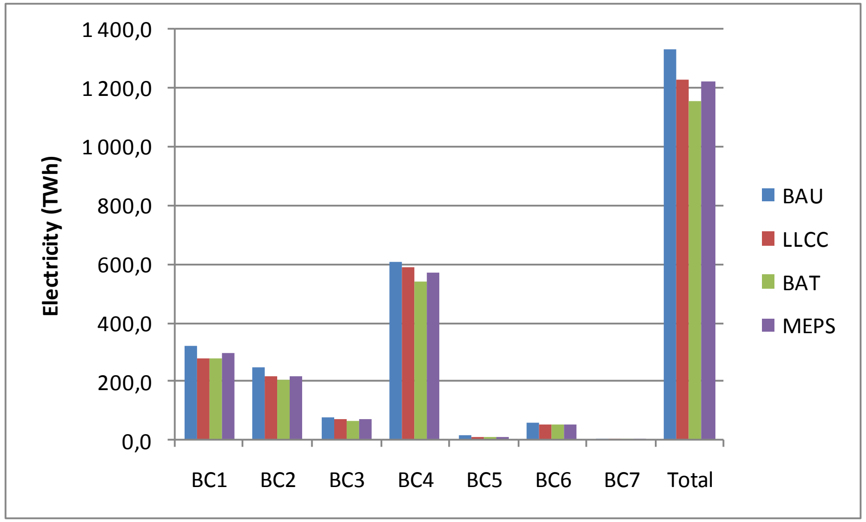


Figure 7-20: Electricity consumption 2011-2025 by scenario and base-case

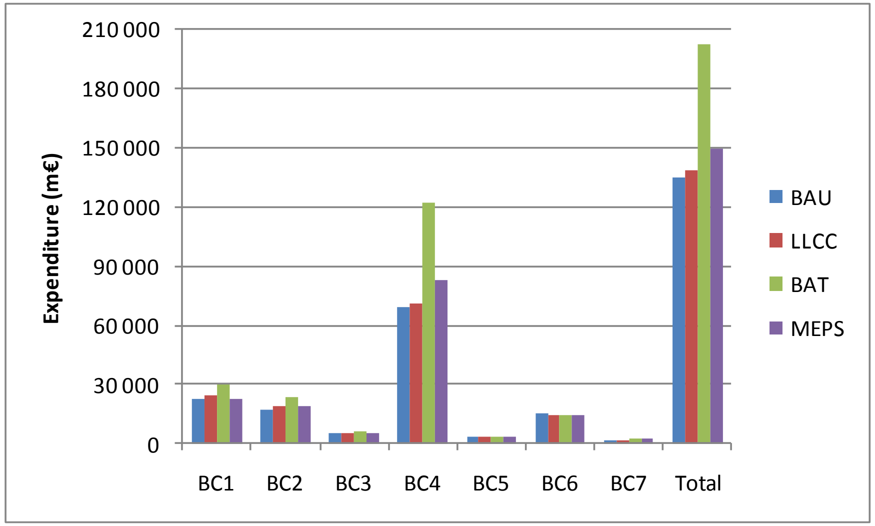


Figure 7-21: Expenditure 2011-2025 by scenario and base-case

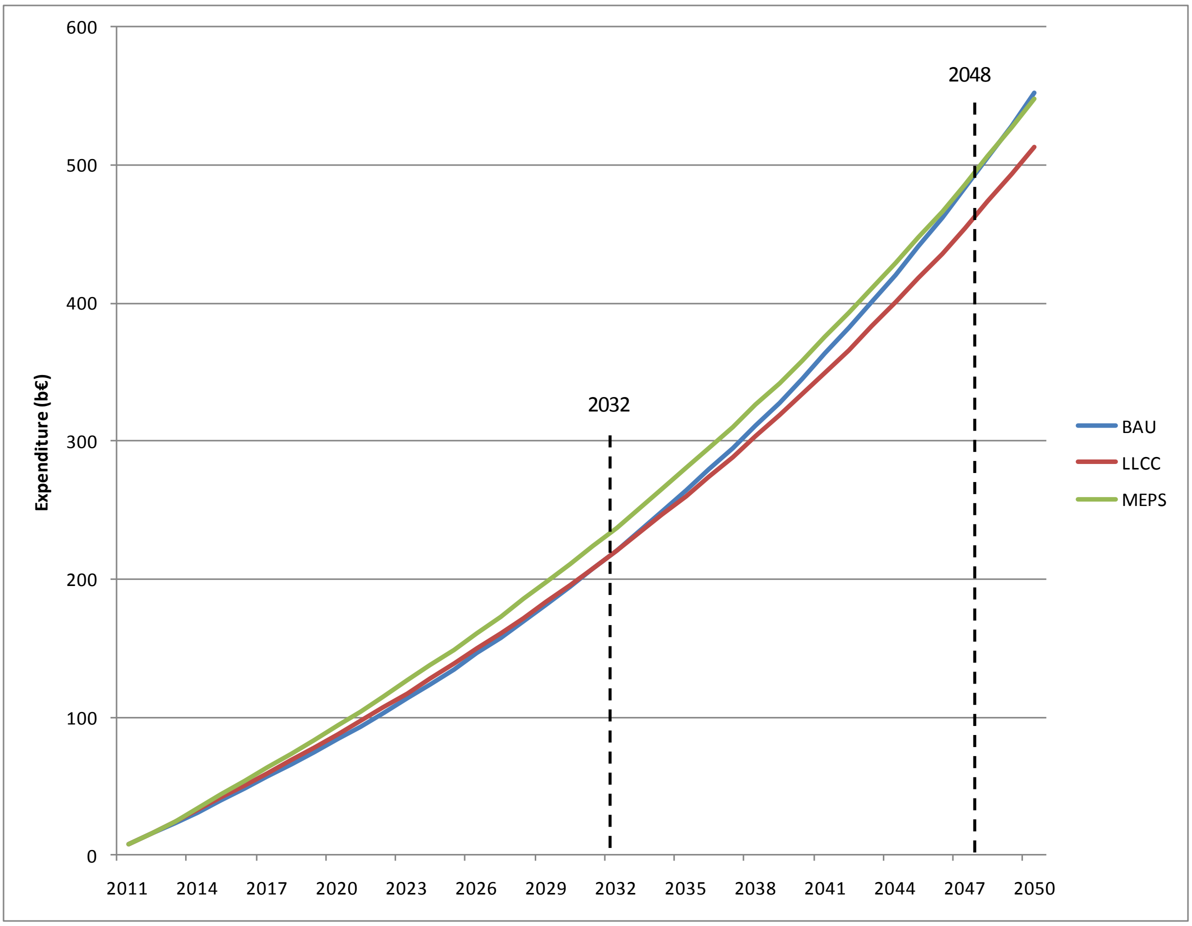


Figure 7-22: Extrapolation of total expenditure since 2011

7.2 Impact Analysis

Scope:

For each of the policy option(s) defined in subtask 7.1, the costs and benefits should be assessed. In particular, the ecodesign requirements should not entail excessive costs nor undermine the competitiveness of European enterprises and should not have a significant negative impact on consumers or other users. This encompasses the assessment of the following impacts:

Monetary impacts for categories of users in particular as regards affordability and life cycle cost of the product (confirming or modifying the results obtained in subtask 6.1);

- Impacts on the functionality of the product, from the perspective of the user;
- Monetary impacts on the manufacturer regarding redesign, testing, investment and/or
- production costs (confirming or modifying the results obtained in subtask 6.1);
- Further impacts on manufacturers, such as imposed proprietary technology or administrative burdens;
- Impact on the competitive situation of the market; such as market share of products already complying with the envisaged minimum requirement, market shares of remaining models after the minimum requirement is introduced, competitive advantage or negative impacts on the competitive situation of some market players (e.g. SMEs, regional players) or reduction in consumer choice;
- Impacts on EU firms' competitiveness outside the EU and on importers;
- Impact on innovation or research and development;

- Any significant social impact, such as impacts on employment and labour conditions, health and safety or equality of treatment and opportunities.

7.2.1 Discussion on potential negative impact on the functionality of the product from increased volume and weight

As pointed out in chapter 5, section 5.1.2.8, optimizing the transformer efficiency often coincides with increased weight of the transformers. This could be unacceptable for oil-immersed distribution transformers that have to be mounted on existing poles. However this is arguable, as it might be easy in many cases to install two more efficient transformers instead.
It should also be mentioned that volume and weight are not a functional requirement or a function as such of the transformer. The problem is that a maximum value could in some cases be unacceptable. Moreover through the use of premium conventional core steels, including domain-refined and mechanically scribed grain-oriented electrical steels with very thin laminations and improved coatings between the laminations, lower losses can be achieved in a smaller volume. These new technologies can result in more efficient transformers that are as compact as older types used on the market for many decades.

As long as the proposed minima in sections 7.1.2.1 and 7.1.2.2 are not exceeded, no negative impact of excessive noise is expected. In the case the minimum no-load loss is raised above A0 level, only amorphous transformers could be used and more research and evidence might be needed that those transformers could satisfy extreme low noise requirements.

7.2.2 Monetary impact on total market

Monetary impact is assessed by the expenditure analysis in the scenarios. As shown in Figure 7-22, the LLCC scenario already begins providing benefits in 2024, and is expected to provide total savings starting in 2032. The MEPS scenario is expected to provide total savings starting in 2048.

Regarding the monetary impact on manufacturers of the implementation of a maximum loss levels policy, it is expected that investments will need to be made to accommodate new techniques in high-efficiency transformer manufacturing. However, it is not expected that these investments would provide a significant burden or barrier to implementation. Investment costs will be returned with slightly higher product prices for more efficient models.

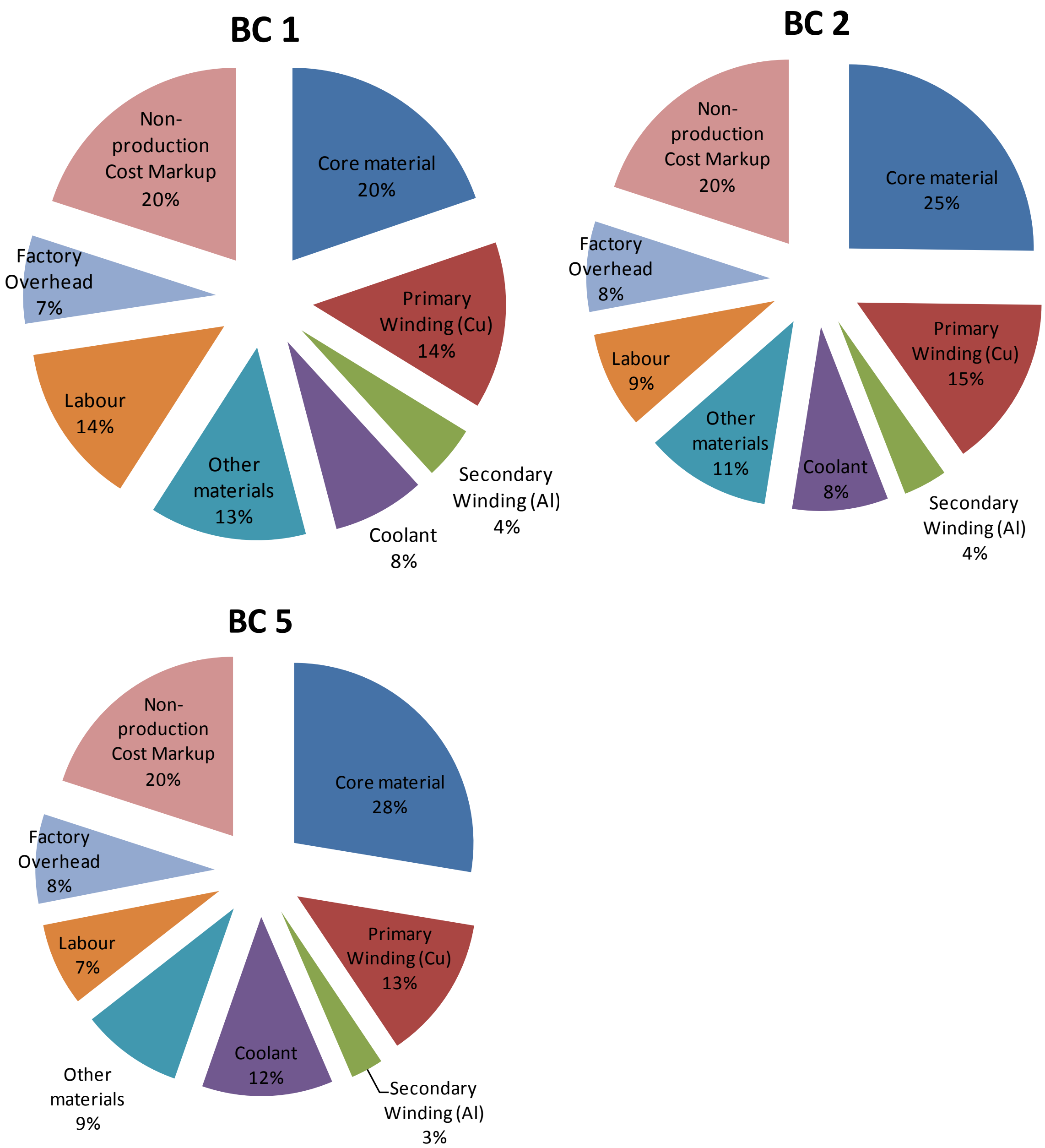
The impact on cost for proposed for MEPS on so-called light weight pole mounted transformers is low as explained in section 7.1.2.1.

7.2.3 Impact from the transformer commodity price on the product LCC

An important share of the transformer cost and purchase price is dependent of the commodities costs. CLASP carried out a complementary cost and design analysis (see 5.1.2.4 and Annex E) for some transformer types[159] and Figure 7-23 shows the breakdown of selling prices for some of these types, according to this data.

[159] The report was provided to the EC, the project team and stakeholders during the final stakeholder meeting.

Figure 7-23: Breakdown of selling prices for BC 1, BC 2 and BC 5



In the CLASP price model, the factory overhead represents a 12.5% mark-up. It includes all the indirect costs associated with production, indirect materials and energy use, taxes and insurance. It only applies to the direct material production costs.
The non-production mark-up represents 25% and includes general and administrative costs, R&D, interest payments and profit factor.

The figure clearly shows that the material costs represent an important share of the total purchase price (around 60-65%), the most costly materials being the core and the primary winding. The primary winding being made out of copper, the copper costs which have been increasing rapidly recently have in particular an important influence on the final purchase price of the product. Transformer commodity prices can strongly vary over time, see Figure 2-18. This is one particular reason why the project team does not estimate relevant to suggest targets at long term, but rather advice a revision of the regulation in the future, which will be able to take into account all the market evolutions of the coming years.

7.2.4 Impact from transformer loading on total energy consumption

The loadings of the transformers have a direct influence on the electricity losses during the use of the products. Losses are indeed separated between no-load and load losses. As Figure 4-8 illustrates it, the load losses share for BC 1 is very low (11% of the LCC), in comparison with for example BC 5 (51% of the LCC). This means that the loading parameters have a direct influence on the LCC. This study used a broad variety of base cases that were estimated EU average for the sake of the methodology (see chapter 4). A detailed LCC sensitivity analysis can be found in section 6.4. From this, it can be concluded that the TCO to specific situation may give different results in terms of option comparison.

7.2.5 Impact on the manufacturers and competitive situation of the market

With respect to the EU market the following elements can be taken into account:

- The European manufacturers need time to adapt their production plants to amorphous core transformer construction (see chapter 5 for technical details). According to T&D Europe manufacturers need several years because all machines for core must be changed and winding machines should be modified. Investments to achieve such modification are important and difficult for smaller manufacturers.
- When deciding on MEPS, T&D Europe insists on one Tier to avoid excessive administrative work (e.g. reprinting catalogues, etc.). Nevertheless, some stakeholders argued that this should not prevent the EC from going to an ambitious Tier 1 MEPS or else introduce a second more ambitious Tier 2.
- The European steel manufacturers need time to add additional equipment to produce high amounts of Domain Refined High-permeability steel (see chapter 5 for technical details).
- There is currently no significant European production of amorphous core steel and suppliers need time to increase quantities manufactured [160] . Needed quantities must be imported from ASIA or USA. Detailed market data of amorphous steel is included in section 2.2.6.9.
- See also recommendations to BNAT in section 7.1.5.
- Currently the 2010 AMT production volumes in China and India nearly equal the EU27 demand (see chapter 2). Over 100 manufacturers are active in China alone and a quarter of them are able to produce amorphous strips and cores. Therefore it is likely that much of this equipment (core and/or transformer) will be imported from Asia instead of produced within EU, especially as there is also hand labour involved in transformer manufacturing (see chapter 5). According to Eurelectric the EU could seek to protect European manufacturers under the GATT agreement[161].

Therefore, the following elements could be taken into account when deciding on maximum transformer losses:

160 There is one manufacturer producing for niche other applications (about 10 000 tons/year only)

161 http://www.wto.org/

- Raising the no-load requirements far above class A0 (EN 50464-1) would phase out Domain Refined High-permeability steel production and associated production of steel and transformers.
- A rapid rise to class A0 (EN 50464-1) will stimulate the market for higher-quality domain refined high-permeability silicon steels, and may require steel suppliers to invest in their production capabilities.

The key patents on amorphous core transformers are expired because the technology is more than 20 years available (see section 2.2.6.9). As indicated in section 2.2.6.9, many new manufacturers already came on the Asian market. Therefore, the authors of this study did not see a barrier related to intellectual property.

Finally there is a typical 'the chicken or the egg' causality dilemma in the transformer market: on the one hand, without any visible increase in demand for energy-efficient transformers, European manufacturers will not invest into HGO or amorphous transformer production plants; on the other hand, if an implementing measure creates this demand, the existing production capacity will not be sufficient to satisfy demand.
Therefore, what is recommended is a clear strategic plan for an implementing measure and further policies and measures in this context, with visible tiers for the European manufacturers clearly showing what will happen, so that investment into production facilities can be better planned and an increase in energy efficiency can be achieved.

7.2.6 Impact on innovation or research and development

Several needs for additional R&D are identified, see section 7.1.5. As Europe has a large engineering base and tradition, this will create several opportunities.

7.2.7 Social impact

Of concern among stakeholders is the use of amorphous technology in production, of which there is currently no production capacity within Europe. However, expected performance requirements are not expected to mandate efficiency levels that are attainable only with amorphous technology, thus still allowing for manufacturers of traditional steel to compete.

7.2.8 Procuring higher cost transformers might reduce capital available for other investments (cables, etc.).

When TSO and/or DSO need to procure more expensive transformers, less capital might be available for other projects reducing losses (e.g. cables).

7.2.9 Focus on loss limits should not replace TCO but complement MEPS

As mentioned before, when implementing MEPS, there should be no conflict from targeting more ambitious levels with TCO (Total Cost of Ownership) analysis.
Unfortunately not all industrial users or smaller DSOs have personnel or resources available to accurately forecast the proper parameters for a TCO analysis. Moreover, TCO will face similar challenges as those found in the study to calculate LCC (Life Cycle Cost) related to electricity price, interest, life time and transformer loading uncertainty. Hence, TCO should be seen as complementary but not as a replacement of MEPS.

As a conclusion, it can also be expected that the price for higher class products drops after implementing MEPS. This will lower the price for more ambitious products and have a positive impact on those who apply TCO.

ANNEX A COMPARISON OF EN, IEC AND IEEE STANDARDS

EN Standard	Equivalent IEC or IEEE	Short description	Note status or gap
EN 60076 series	IEC 60076 series C57.12.00 series	Title "Power transformers-series". This standard was also discussed in section 1.7 on test standards and covers all types of transformers. It gives detailed requirements for transformers for use under the following conditions: a) Altitude: A height above sea-level not exceeding 1000 meter. b) Temperature of ambient air and cooling medium: A temperature of ambient air not below –25 °C and not above +40 °C. For water-cooled transformers, a temperature of cooling water at the inlet not exceeding +25 °C. Further limitations, with regard to cooling are given for: – oil-immersed transformers in IEC 60076-2; – dry-type transformers in IEC 60076-11. .IEC (EN) 60076 series consists of the following parts, under the general title: Power transformers. Part 1: 1993, General Part 2: 1993, Temperature rise Part 3: 1980, Insulation levels and dielectric tests Part 5: 1976, Ability to withstand short circuit Part 7: 2005, Loading guide for oil-immersed power transformers. This part provides recommendations for the specification and loading of power transformers complying with IEC 60076, from the point of view of operating temperatures and thermal ageing. Gives recommendations for loading above the name-plate rating and guidance for the planner to choose rated quantities for new installations. The use of life time is based on the hot spot temperature in the winding. An increase of the hot spot temperature with 6K is a reduction of the life time by 50%. Part 8: 1997, Application guide	No gaps are reported Could be considered: -The maximum allowable tolerance on the total losses (sum of the load and no-load losses) is + 10% of the total losses (IEC 60076-1). This could be reduced to a lower value (+ 7.5 % or even lower) as suggested during the second stakeholder meeting. - The values of the losses or the efficiency class of the transformer is not a mandatory information on the rating plate of the transformer (IEC 60076-1/ 7.1). - Note the fire behaviour is only included in the standard on dry type transformers in IEC 60076-11. The behaviour of silicon transformer under fire had never been tested under standardisation condition and pressure in the tank could lead to special results. Therefore on update of the IEC 60076-11 standard for oil filled transformers might be needed taking new developments and test results into account
EN 50464 series	None	Title "Three-phase oil-immersed distribution transformers 50Hz, from 50 kVA to 2500 kVA with highest voltage for equipment not exceeding 36kV". See explanation below. EN 50464 Part 3 is dedicated on the Determination of the power rating of a transformer loaded with non-sinusoidal currents, see K-Factor as explained in section 1.6	The minimum losses in this standard do not mean that significant lower losses can't be achieved with actual technology.
HD 538.1	None	Title "Three-phase dry-type distribution transformers 50 Hz, from 100 to 2500 kVA, with highest voltage for equipment not exceeding	-Currently an equivalent standard EN 50538 is circulated in the CENELEC

		36 kV” See explanation below.	national committees for remarks. The final document will be probably validated in 2010. -The maximum losses defined in this document do not mean that significant lower losses can’t be achieved with actual technology.

ANNEX B MANUFACTURER ENQUIRY AS LAUNCHED IN THIS STUDY (MID JUNE 2010)

Guidance

The primary objective of the enquiry is to obtain the price differences between the base-cases defined in the report and these base-cases with improvement options (reducing the losses levels).
It would also be very helpful to us to obtain the evolution of the core and conductor weights (section 3 of the enquiry). As we are aware that filling this enquiry may represent a substantial amount of work, please fill in sections 1 and 2 first if your time and resources are not sufficient to fill in the whole spreadsheet.

This enquiry contains information request on all the base-cases. Please provide information for as many as you can, depending on the products manufactured by your company.

None of the information you will provide will be published as such. The data will be aggregated and averaged to be representative of the EU market. If you wish, a Non-Disclosure Agreement can be signed between Vito/BIO Intelligence Service and your company.

Definition of the base-cases:
BC 1: Distribution transformer (400 kVA, P0=750 W, Pk=4 600 W)
BC 2: Oil-immersed industry transfromer (1 MVA, P0=1 700 W, Pk=10 500 W)
BC 3: Dry-type industry transformer (1.25 MVA, P0=2 800 W, Pk=13 100 W)
BC 4: Power transformer (100 MVA, P0=80 000 W, Pk=300 000 W)
BC 5: DER transformer oil-immersed (2 MVA, P0=3 100 W, Pk= 21 000 W)
BC 6: DER transformer dry-type (2 MVA, P0=4 000 W, Pk= 18 000 W)
BC 7: Separation/isolation transfomer (16 kVA, P0=110 W, Pk=750 W)

Please contact Paul Van Tichelen or Thibault Faninger in the event of any question at:
paul.vantichelen@vito.be
thibault.faninger@biois.com

1. Reference price of the base-cases

Note: absolute prices hereafter are those as launched in the enquiry

	BC1	BC2	BC3	BC4	BC5	BC6	BC7
Do you agree with the curent Base-Cases price?	*8.888 €*	*14.751 €*	*19.623 €*	*1.036.720 €*	*30.068 €*	*37.958 €*	*1.348 €*
Answer (select in drop-down menu):	-	-	-	-	-	-	-
If no, please provide a reference price you would suggest:							

Reminder of the base-cases enquiry:
BC 1: Distribution transformer (400 kVA, P0=750 W, Pk=4 600 W)
BC 2: Oil-immersed industry transfromer (1 MVA, P0=1 700 W, Pk=10 500 W)
BC 3: Dry-type industry transformer (1.25 MVA, P0=2 800 W, Pk=13 100 W)
BC 4: Power transformer (100 MVA, P0=80 000 W, Pk=300 000 W)
BC 5: DER transformer oil-immersed (2 MVA, P0=3 100 W, Pk= 21 000 W)
(losses increased in comparison with the base case enquiry chapter 4)
BC 6: DER transformer dry-type (2 MVA, P0=4 000 W, Pk= 18 000 W)
(losses increased in comparison with the base case equiry chapter 4)
BC 7: Separation/isolation transfomer (16 kVA, P0=110 W, Pk=750 W)

2. Evolution of the prices

In the following section, please provide information on the evolution of the prices within the tables, in % (for instance, a 400 kVA C0Ck distribution transformer has a price of 115% of the reference price of the base-case), **assuming the price of the base-case represents 100%**. If you have suggested another price for the base-case than the current one given in the report, **please give this evolution based on your suggested price**. The green cells correspond to the base-cases transformers. Please do not fill in the grey cells. If you are able to fill in the amorphous column, please also precise the level of no-load losses and noise.

BC 1 - Distribution transformer 400 kVA		E0	D0	C0	B0	A0	Amorphous
		930 W	750 W	610 W	520 W	430 W	?
		68 dB	63 dB	58 dB	53 dB	50 dB	?
Dk	6000 W						
Ck	4600 W		100%	?	?	?	?
Bk	3850 W				?	?	?
Ak	3250 W					?	?

BC 2 - Industry oil-immersed transformer 1 MVA		E0	D0	C0	B0	A0	Amorphous
		1700 W	1400 W	1100 W	940 W	770 W	?
		73 dB	68 dB	63 dB	58 dB	55 dB	?
Dk	13000 W						
Ck	10500 W	100%		?	?	?	?
Bk	9000 W				?	?	?
Ak	7600 W					?	?

BC 3 - Industry dry-type transformer 1.25 MVA	C0	B0	A0	Amorphous
	2800 W	2100 W	1800 W	?
	75 dB	67 dB	67 dB	?

Bk	13000 W	100%	?	?	?
Ak	11000 W			?	?

BC 4 - Power transformers 100 MVA (132/33kV) (double winding)		Po(kW)	Po(kW)	Po(kW)	Po(kW)	Po(kW)
		80	70	60	40	30
Pk(kW)(75°C)	390	?				
Pk(kW)(75°C)	300	100%		?	?	?
Pk(kW)(75°C)	275				?	?
Pk(kW)(75°C)	250					?

BC 5 - DER oil-immersed transformer 2 MVA		E0	D0	C0	B0	A0	Amorphous
		3100 W	2700 W	2100 W	1800 W	1450 W	?
		78 dB	73 dB	68 dB	63 dB	60 dB	?
Dk	26000 W						
Ck	21000 W	100%		?			?
Bk	18000 W						
Ak	15000 W					?	?

BC 6 - DER dry-type transformer 2 MVA		C0	B0	A0	Amorphous
		4000 W	3000 W	2600 W	?
		78 dB	70 dB	70 dB	?
Bk	18000 W	100%	?		?
Ak	16000 W			?	?

3. Evolution of the core and conductor weights

In the following section, please indicate the evolution of core and conductor weights, similarly to section 2, but in the format X%/Y%, where X refers to the core material and Y to the conductor material. The green cells correspond to the base-cases transformers. Please do not fill in the grey cells. If you are able to fill in the amorphous column, please also precise the level of no-load losses and noise.

BC 1 - Distribution transformer 400 kVA		E0	D0	C0	B0	A0	Amorphous
		930 W	750 W	610 W	520 W	430 W	?
		68 dB	63 dB	58 dB	53 dB	50 dB	?
Dk	6000 W						
Ck	4600 W		100%/100%	?		?	?
Bk	3850 W				?		
Ak	3250 W					?	?

BC 2 - Industry oil-immersed transformer 1 MVA		E0	D0	C0	B0	A0	Amorphous
		1700 W	1400 W	1100 W	940 W	770 W	?
		73 dB	68 dB	63 dB	58 dB	55 dB	?
Dk	13000 W						
Ck	10500 W	100%/100%		?		?	?
Bk	9000 W				?		
Ak	7600 W					?	?

BC 3 - Industry dry-type transformer 1.25 MVA	C0	B0	A0	Amorphous
	2800 W	2100 W	1800 W	?

		75 dB	67 dB	67 dB	?
Bk	13000 W	100%/100%	?	?	?
Ak	11000 W			?	?

BC 4 - Power transformers 100 MVA (132/33kV)		Po(kW)	Po(kW)	Po(kW)	Po(kW)	Po(kW)
		80	70	60	40	30
Pk(kW)(75°C)	390					
Pk(kW)(75°C)	300	100%/100%		?		?
Pk(kW)(75°C)	275				?	
Pk(kW)(75°C)	250					?

BC 5 - DER oil-immersed transformer 2 MVA		E0	D0	C0	B0	A0	Amorphous
		3100 W	2700 W	2100 W	1800 W	1450 W	?
		78 dB	73 dB	68 dB	63 dB	60 dB	?
Dk	26000 W						
Ck	21000 W	100%/100%		?			?
Bk	18000 W						
Ak	15000 W					?	?

BC 6 - DER dry-type transformer 2 MVA		C0	B0	A0	Amorphous
		4000 W	3000 W	2600 W	?
		78 dB	70 dB	70 dB	?
Bk	18000 W	100%/100%	?		?
Ak	16000 W			?	?

ANNEX C AGGREGATED RESULTS OF MANUFACTURER ENQUIRY AS LAUNCHED IN THIS STUDY (MID JUNE 2010)

Type	***BC1 Distribution***	***BC2 Industry oil***	***BC3 Industry dry***	***BC4 Power***	***BC5 DER oil***	***BC6 DER dry***	***BC7 Separation /isolation***
Product price *(€)*	6 122	10 926	16 333	719 851	18 248	28 192	1 348

Improvement options for BC 1: Distribution transformer 400 kVA

Relative price data:

BC 1 - Distribution transformer 400 kVA		E0	D0	C0	B0	A0
		930 W	750 W	610 W	520 W	430 W
		68 dB	63 dB	58 dB	53 dB	50 dB
Dk	6000 W					
Ck	4600 W		100%	105% ±1%	108% ±1%	116% ±4%
Bk	3850 W				119% ±3%	130% ±8%
Ak	3250 W					142% ±9%

Relative core mass % (top) and conductor mass % (bottom) data:

BC 1 - Distribution transformer 400 kVA		E0	D0	C0	B0	A0
		930 W	750 W	610 W	520 W	430 W
		68 dB	63 dB	58 dB	53 dB	50 dB
Dk	6000 W					
Ck	4600 W		100% 100%	112% ±6% 106% ±4%		135% ±13% 137% ±9%
Bk	3850 W				122% ±17% 144% ±14%	
Ak	3250 W					145% ±34% 207% ±53%

Improvement options for BC 2: Oil-immersed industry transfromer 1 MVA

Relative price data:

BC 2 - Industry oil-immersed transformer 1 MVA		E0	D0	C0	B0	A0
		1700 W	1400 W	1100 W	940 W	770 W
		73 dB	68 dB	63 dB	58 dB	55 dB
Dk	13000 W					
Ck	10500 W	100%		111% ±1%	115% ±1%	124% ±4%
Bk	9000 W				126% ±3%	136% ±8%
Ak	7600 W					153% ±9%

Relative core mass % (top) and conductor mass % (bottom) data:

BC 2 - Industry oil-immersed transformer 1 MVA	E0	D0	C0	B0	A0
	1700 W	1400 W	1100 W	940 W	770 W

		73 dB	68 dB	63 dB	58 dB	55 dB
Dk	13000 W					
Ck	10500 W	100% 100%		114% ±6% 116% ±4%		127% ±13% 154% ±9%
Bk	9000 W				121% ±17% 163% ±14%	
Ak	7600 W					148% ±34% 223% ±53%

Improvement options for BC 3: Dry-type industry transformer 1.25 MVA (17.5 to 24 kV)

Relative price data:

BC 3 - Industry dry-type transformer 1.25 MVA		C0	B0	A0
		2800 W	2100 W	1800 W
		75 dB	67 dB	67 dB
Bk	13000 W	100%	107% ±3%	115% ±5%
Ak	11000 W			150% ±16%

Relative core mass % (top) and conductor mass % (bottom) data:

BC 3 - Industry dry-type transformer 1.25 MVA		C0	B0	A0
		2800 W	2100 W	1800 W
		75 dB	67 dB	67 dB
Bk	13000 W	100% 100%	111%±4% 105%±1%	123% ±14% 115% ±7%
Ak	11000 W			136% ±17% 147% ±30%

Improvement options for BC 4: Power transformer 100 MVA

Relative price data:

BC 4 - Power transformers 100 MVA (132/33kV) (double winding)		Po(kW)	Po(kW)	Po(kW)	Po(kW)	Po(kW)
		80	70	60	40	30
Pk(kW)(75°C)	390	n.a.				
Pk(kW)(75°C)	300	100%		104% ±5%	110% ±5%	117% ±4%
Pk(kW)(75°C)	275				119% ±10%	128% ±11%
Pk(kW)(75°C)	250					141% ±18%

Relative core mass % (top) and conductor mass % (bottom) data:

BC 4 - Power transformers 100 MVA (132/33kV)		Po(kW)	Po(kW)	Po(kW)	Po(kW)	Po(kW)
		80	70	60	40	30
Pk(kW)(75°C)	390					
Pk(kW)(75°C)	300	100% 100%		97% ±20% 114% ±17%		99% ±21% 126% ±32%

Pk(kW)(75°C)	275				99% ±21% 144% ±37%	
Pk(kW)(75°C)	250					101% ±17% 185% ±51%

Improvement options for BC 5: DER transformer oil-immersed 2 MVA

Relative price data:

BC 5 - DER oil-immersed transformer 2 MVA		E0	D0	C0	B0	A0
		3100 W	2700 W	2100 W	1800 W	1450 W
		78 dB	73 dB	68 dB	63 dB	60 dB
Dk	26000 W					
Ck	21000 W	100%		116% ±1%		
Bk	18000 W					
Ak	15000 W					168% ±9%

Relative core mass % (top) and conductor mass % (bottom) data:

BC 5 - DER oil-immersed transformer 2 MVA		E0	D0	C0	B0	A0
		3100 W	2700 W	2100 W	1800 W	1450 W
		78 dB	73 dB	68 dB	63 dB	60 dB
Dk	26000 W					
Ck	21000 W	100% 100%		106% ±6% 111% ±4%		
Bk	18000 W					
Ak	15000 W					118% ±34% 221% ±53%

Improvement options for BC 6: DER transformer dry-type 2 MVA(17.5 to 24 kV)

Relative price data:

BC 6 - DER dry-type transformer 2 MVA		C0	B0	A0
		4000 W	3000 W	2600 W
		78 dB	70 dB	70 dB
Bk	18000 W	100%	114% ±3%	
Ak	16000 W			131% ±16%

Relative core mass % (top) and conductor mass % (bottom) data:

BC 6 - DER dry-type transformer 2 MVA		C0	B0	A0
		4000 W	3000 W	2600 W
		78 dB	70 dB	70 dB
Bk	18000 W	100% 100%	124% ±4% 103% ±1%	
Ak	16000 W			134% ±17% 127% ±30%

ANNEX D AGGREGATED RESULTS OF POWER TRANSFORMERS MANUFACTURER ENQUIRY AS LAUNCHED IN THIS STUDY (BEGIN AUGUST 2010)

Table 1 breaks down the power transformer market by primary and secondary voltage. Please fill in the missing data marked by a ? with data for the most common types -- it is acceptable to use estimations if you do not have concrete data. There is a line for an additional transformer should you wish to add one. Note that these are not auto-transformers.

Table 1: Market segmentation for typical transformers and typical reference prices

Notes	Primary voltage (kV)	Secondary voltage (kV)	Rated power (MVA)	% market share	Typical No load losses (kW)	Typical Load losses (75°C, kW)	Price (€)
	70	15,6	50	NA	21 ±8	180 ±40	60% ±25%
	132	22	50	NA	25	185 ±70	67,1% ±30%
	132	22	100	NA	40 ±10	315 ±70	105,8% ±15%
	132	11	100	NA	40 ±10	315 ±70	105,8% ±15%
new base-case 4	**132**	**33**	**100**	NA	***40,5 ±18***	***326 ±70***	***105% ±15%***
old base-case 4	**132**	**33**	**100**	NA	**80**	**300**	**100%**
	170	22	100	NA	55 ±35	340 ±110	114,8% ±15%
	220	22	170	NA	78,8 ±37	568 ±220	146,7% ±47%
	345	132	350	NA	137 ±110	767 ±100	281,2% ±88%
	425	132	350	NA	146 ±68	935 ±335	328,9% ±125%
Most common type in your company	?	?	?	?	?	?	?

Table 2 asks for relative price data for more efficient transformers. Please fill in the cells marked with a ? with a percentage representing the relative cost of efficient transformers compared to the base. There is an additional block for an additional transformer should you wish to add one.

Table 2: Price evolution compared to typical no load and load losses as defined in table 1

50 MVA (70/15.6 kV) (no autotransformers - double winding)		Po(kW)	Po(kW)	Po(kW)	Po(kW)	Notes
		100%	85%	70%	50%	
Pk(kW)(75°C)	100%	100%	110%	119% ±3%	NA	only 2 enquiries
Pk(kW)(75°C)	85%		118% ±4%	135%	NA	only 2 enquiries
Pk(kW)(75°C)	70%					
Pk(kW)(75°C)	50%					

100 MVA (132/22 kV) ((no autotransformers -double winding)		Po(kW)	Po(kW)	Po(kW)	Po(kW)	Notes
		100%	85%	70%	50%	
Pk(kW)(75°C)	100%	100%	109% ±2%	117% ±3%	NA	only 2 enquiries
Pk(kW)(75°C)	85%		119% ±2%	130%	NA	only 2 enquiries
Pk(kW)(75°C)	70%					
Pk(kW)(75°C)	50%					

100 MVA (132/33 kV) ((no autotransformers -double winding)		Po(kW)	Po(kW)	Po(kW)	Po(kW)	Notes
		100%	85%	70%	50%	
Pk(kW)(75°C)	100%	100%	106% ±6%	119% ±17%	*180%*	
Pk(kW)(75°C)	85%		120% ±22%	139% ±35%	*215%*	
Pk(kW)(75°C)	70%		*160%*	*200%*	*250%*	only 1 enquiry
Pk(kW)(75°C)	50%					

170 MVA (220/22kV) ((no autotransformers -double winding)		Po(kW)	Po(kW)	Po(kW)	Po(kW)	Notes
		100%	85%	70%	50%	
Pk(kW)(75°C)	100%	100%	106% ±7%	115% ±11%	144% ±33%	

Pk(kW)(75°C)	**85%**		122% ±12%	140% ±30%	200%	
Pk(kW)(75°C)	**70%**		*140%*	*200%*	*240%*	only 1 enquiry
Pk(kW)(75°C)	50%					

350 MVA (425/132 kV) ((no autotransformers -double winding)		**Po(kW)**	**Po(kW)**	**Po(kW)**	**Po(kW)**	**Notes**
		100%	**85%**	**70%**	**50%**	
Pk(kW)(75°C)	**100%**	100%	107% ±10%	112% ±16%	133% ±14%	
Pk(kW)(75°C)	**85%**		118% ±10%	141% ±13%	180%	
Pk(kW)(75°C)	**70%**		*130%*	*180%*	*220%*	only 1 enquiry
Pk(kW)(75°C)	**50%**					

Most common type in your company		**Po(kW)**	**Po(kW)**	**Po(kW)**	**Po(kW)**	**Notes**
		100%	**85%**	**70%**	**50%**	
Pk(kW)(75°C)	**100%**	100%	110%	125%	NA	
Pk(kW)(75°C)	**85%**		116%	140%	NA	
Pk(kW)(75°C)	**70%**					
Pk(kW)(75°C)	**50%**					

Note: For values in italic few entries were received. Hence these are not common designs and data should be handled with care.

ANNEX E CLASP[162] RESULTS OF DESIGN REPORT LOT 2: DISTRIBUTION AND POWER TRANSFORMERS (RECEIVED STAKEHOLDER MEETING AUGUST 24TH 2010)

Design	CLASP	CLASP	CLASP	CLASP	CLASP	CLASP	CLASP	CLASP	CLASP	CLASP	CLASP	BC 1-enquiry	BC 1 CLASP price
Power rating:	400 kVA	400 kVA	400 kVA	400 kVA	400 kVA	400 kVA	400 kVA	400 kVA	400 kVA	400 kVA	400 kVA	400 kVA	400 kVA
Core material(AISI)	M6	M4	M3	M3	HO	HO	HO	SA1	SA1	SA1	SA1	-	-
Mass core (kg):	662	698	695	695	683	691	717	747	910	865	851	469	469
Bmax(T):	1.48	1.50	1.50	1.50	1.46	1.46	1.42	1.32	1.31	1.34	1.34	-	-
Afe(cm²):	275	272	271	271	258	258	243	325	360	322	322	-	-
HV material:	CU	CU	CU	CU	CU	CU	CU	CU	CU	CU	CU	Cu and Al	CU
Mass HV winding (kg):	209	193	193	209	183	231	376	206	255	336	423	214.3 (HV + LV)	193
HV current density (A/mm2):	2.31	2.50	2.50	2.31	2.71	2.14	1.40	2.31	1.85	1.52	1.17		
LV material:	AL	AL	AL	CU	CU	CU	CU	AL	AL	AL	CU		AL
Mass LV winding (kg):	87	94	94	310	303	266	260	82	88	123	300	in HV winding	21
J (A/mm²):	1.26	1.14	1.14	1.14	1.23	1.39	1.50	1.26	1.18	0.89	1.19	-	
Core Losses (W):	D0	C0	B0	B0	A0	A0	A0	A0-50%	A0-50%	A0-50%	A0-50%	D0	D0
Coil Losses (W):	Ck	Ck	Ck	Bk	Ck	Bk	Ak	Ck	Bk	Ak	Ak-20%	Ck	Ck
Selling Price:	€ 5.825	€ 6.079	€ 6.146	€ 8.312	€ 7.711	€ 7.821	€ 8.891	€ 7.576	€ 8.812	€ 9.372	€ 11.319	€ 6.122	€ 5.360
CLASP data was fitted to load classes within 2% tolerance.													1.72
						price % of BC		141%	164%	175%	211%		

Design	CLASP	CLASP	CLASP	CLASP	CLASP	CLASP	CLASP	CLASP	CLASP	CLASP	CLASP	BC 2 enquiry	BC 2 CLASP price
Power rating:	1000 kVA	1000 kVA	1000 kVA	1000 kVA	1000 kVA	1000 kVA	1000 kVA	1000 kVA	1000 kVA	1000 kVA	1000 kVA	1000 kVA	1000 kVA
Core material(AISI)	M6	M3	M2	M2	M2	HO	HO	SA1	SA1	SA1	SA1	-	-
Mass core (kg):	1453	1355	1437	1400	1470	1517	1529	1519	1683	1693	1665	882	882
Bmax(T):	1.46	1.51	1.46	1.46	1.31	1.31	1.31	1.35	1.35	1.35	1.35	-	-
Afe(cm²):	507	428	428	422	407	407	407	454	489	489	489	-	-
HV material:	CU	CU	CU	CU	CU	CU	CU	CU	CU	CU	CU	Cu and Al	CU
Mass HV winding (kg):	324	341	381	396	455	518	662	585	664	809	1120	428.8 (HV + LV)	364
HV current density (A/mm2):	2.56	2.65	2.60	2.48	2.48	2.21	1.73	2.05	1.78	1.49	1.04		
LV material:	AL	AL	AL	CU	CU	CU	CU	AL	AL	AL	CU		AL
Mass LV winding (kg):	91	123	150	422	553	646	741	217	260	324	668	cluded in HV windir	65
J (A/mm²):	2.05	1.61	1.44	1.66	1.52	1.32	1.15	1.22	1.00	0.82	1.25	-	
Core Losses (W):	E0	C0	B0	B0	A0	A0	A0	A0-50%	A0-45%	A0-45%	A0-45%	1700	1700
Coil Losses (W):	Ck	Ck	Ck	Bk	Ck	Bk	Ak	Ck	Bk	Ak	Ak-20%	10500	10500
Selling Price:	€ 9.270	€ 9.827	€ 11.177	€ 13.396	€ 15.066	€ 16.716	€ 18.398	€ 15.658	€ 17.300	€ 18.618	€ 23.701	€ 10.926	€ 9.054
CLASP data was fitted to load classes within 2% tolerance.													
						price % of BC		173%	191%	206%	262%		

162 www.CLASPonline.org

Design	CLASP	CLASP	CLASP	CLASP	CLASP	CLASP	BC 5 Enquiry	BC 5 CLASP price
Power rating:	2000 kVA	2000 kVA	2000 kVA	2000 kVA	2000 kVA	2000 kVA	2000 kVA	2000 kVA
Core material(AISI)	M6	M4	HO	SA1	SA1	SA1	-	-
Mass core (kg):	2682	3007	3287	3298	3469	3698	1715	1715
Bmax(T):	1.52	1.35	1.25	1.34	1.34	1.34	-	-
Afe(cm²):	641	710	733	899	899	899	-	-
HV material:	CU	CU	CU	CU	CU	CU	Cu and Al	CU
Mass HV winding (kg):	535	551	805	574	813	1049	952.2 (HV + LV)	762
HV current density (A/mm2):	2.97	2.97	2.18	2.68	1.94	1.53		
LV material:	AL	AL	CU	AL	AL	CU		AL
Mass LV winding (kg):	183	191	772	161	236	954	ncluded in HV winding	190
J (A/mm²):	1.81	1.81	1.59	2.12	1.45	1.19	-	
Core Losses (W):	E0	C0	B0	B0	A0-40%	A0-35%	E0	E0
Coil Losses (W):	Ck	Ck	Ak	Ck	Ak	Ak-20%	Ck	Ck
Selling Price:	€ 16.938	€ 18.729	€ 28.537	€ 26.779	€ 29.178	€ 38.513	€ 18.248	€ 17.134
CLASP data was fitted to load classes within 2% tolerance.								
			price % of BC		156%	170%	225%	

INPUT FOR IMPROVEMENT OPTIONS ON BC 6 BY REPLACING DRY TYPE WITH LIQUID FILLED TRANSFORMER WITH BIODEGRADABLE ESTER

Design	CLASP	CLASP	CLASP	CLASP	CLASP	CLASP
Power rating:	2000 kVA	2000 kVA	2000 kVA	2000 kVA	2000 kVA	2000 kVA
Core Losses (W):	E0	C0	B0	B0	A0-40%	A0-35%
Coil Losses (W):	Ck	Ck	Ak	Ck	Ak	Ak-20%
Liquid volume (l):	2128	2210	2316	2555	2353	2708

FOR A PRICE FOR MARK UP PER LITER SEE SECTION 6.2.1.6.

ANNEXE F SENSITIVITY ANALYSIS

Sensitivity to load factor

		Min		Base		Max	
		Total Electricity (TWh)	LCC (€)	Total Electricity (TWh)	LCC (€)	Total Electricity (TWh)	LCC (€)
BC1	D0Ck	16.32	17 149.31	17.94	18 254.63	23.12	21 791.65
	C0Ck	13.58	15 562.05	15.20	16 667.37	20.37	20 204.39
	B0Bk	11.62	15 057.81	12.97	15 982.91	17.30	18 943.25
	A0Ck	10.07	13 801.16	11.68	14 906.48	16.86	18 443.50
	A0Ak	9.73	15 133.38	10.87	15 914.31	14.53	18 413.30
	A0+Ck*	5.48	12 158.21	7.08	13 252.48	12.20	16 754.13
	A0+Bk*	5.82	13 751.23	7.19	14 687.87	11.57	17 685.11
	A0+Ak*	5.66	14 314.32	6.83	15 113.03	10.57	17 668.91
	A0+Ak+*	5.40	16 320.83	6.28	16 923.47	9.11	18 851.91
BC2	E0Ck	8.30	30 734.36	13.80	44 031.33	32.37	88 908.63
	C0Ck	5.67	25 531.66	11.17	38 828.64	29.73	83 705.94
	B0Bk	4.88	25 225.24	9.60	36 622.65	25.51	75 088.90
	A0Ck	4.23	23 429.54	9.73	36 726.52	28.30	81 603.82
	A0Ak	4.08	26 139.02	8.06	35 763.50	21.49	68 246.11
	A0+Ck*	2.59	24 696.51	8.24	38 346.80	27.30	84 416.56
	A0+Bk*	2.64	26 717.00	7.40	38 235.98	23.48	77 112.55
	A0+Ak*	2.58	28 191.70	6.66	38 055.53	20.43	71 345.94
	A0+Ak+*	2.46	33 961.76	5.59	41 549.90	16.19	67 159.88
BC3	C0Bk	2.95	51 693.76	4.42	69 916.52	9.38	131 418.34
	B0Bk	2.29	44 566.36	3.76	62 789.12	8.72	124 290.94
	A0Bk	2.02	42 328.42	3.49	60 551.18	8.45	122 053.00
	A0Ak	2.00	47 694.55	3.25	63 113.81	7.45	115 153.81
	A0+Ak*	0.89	50 083.75	2.10	65 093.70	6.19	115 752.27
BC4	41-326	33.90	1 456 225.66	33.90	1 456 225.66	89.69	2 621 006.34
	34-326	30.46	1 429 798.29	30.46	1 429 798.29	86.25	2 594 578.97
	34-277	28.89	1 502 336.86	28.89	1 502 336.86	76.31	2 492 400.44
	34-228	27.33	1 771 394.61	27.33	1 771 394.61	66.38	2 586 741.09
	28-326	27.02	1 456 279.93	27.02	1 456 279.93	82.81	2 621 060.61
	28-277	25.45	1 574 169.08	25.45	1 574 169.08	72.87	2 564 232.66
	28-228	23.90	2 001 953.86	23.90	2 001 953.86	62.95	2 817 300.34
	20-326	22.44	1 821 640.22	22.44	1 821 640.22	78.23	2 986 420.90
	20-277	20.88	2 052 905.82	20.88	2 052 905.82	68.30	3 042 969.40
	20-228	19.38	2 284 171.43	19.38	2 284 171.43	58.43	3 099 517.90
BC5	E0Ck	0.19	241 312.93	0.24	295 197.39	0.30	361 056.18
	C0Ck	0.16	203 177.85	0.21	257 062.31	0.26	322 921.09

		Min		Base		Max	
		Total Electricity (TWh)	LCC (€)	Total Electricity (TWh)	LCC (€)	Total Electricity (TWh)	LCC (€)
	A0Ak	0.11	158 611.49	0.15	197 100.39	0.19	244 142.37
	A0+Ck*	0.12	157 265.59	0.16	210 962.73	0.22	276 592.58
	A0+Bk*	0.09	134 890.96	0.13	173 526.11	0.17	220 746.86
	A0+Ak*	0.08	124 687.54	0.10	150 621.36	0.13	182 318.25
BC6	C0Bk	0.86	274 520.69	1.02	320 707.37	1.21	377 157.76
	B0Bk	0.72	237 412.71	0.88	283 599.39	1.07	340 049.78
	A0Ak	0.63	216 660.08	0.77	257 714.91	0.95	307 893.03
BC7	110-750	0.16	1 482.25	0.38	1 667.17	0.67	1 913.73
	110-400	0.16	2 042.66	0.27	2 141.28	0.43	2 272.78

Sensitivity to load form factor (only for DER transformers)

		Min		Mid		Base	
		Total Electricity (TWh)	LCC (€)	Total Electricity (TWh)	LCC (€)	Total Electricity (TWh)	LCC (€)
BC5	E0Ck	0.18	223 111.96	0.20	249 462.13	0.24	295 197.39
	C0Ck	0.14	184 976.88	0.17	211 327.04	0.21	257 062.31
	A0Ak	0.10	145 610.79	0.12	164 432.34	0.15	197 100.39
	A0+Ck*	0.10	139 127.88	0.12	165 386.45	0.16	210 962.73
	A0+Bk*	0.08	121 840.86	0.10	140 733.93	0.13	173 526.11
	A0+Ak*	0.07	115 927.67	0.08	128 609.63	0.10	150 621.36
BC6	C0Bk	0.80	258 919.86	0.88	281 505.72	1.02	320 707.37
	B0Bk	0.67	221 811.88	0.74	244 397.73	0.88	283 599.39
	A0Ak	0.59	202 792.67	0.65	222 868.99	0.77	257 714.91

Sensitivity to lifetime

		Min	Base	Max
		LCC (€)	LCC (€)	LCC (€)
BC1	D0Ck	16 721.73	18 254.63	19 290.21
	C0Ck	15 373.69	16 667.37	17 541.34
	B0Bk	14 884.00	15 982.91	16 725.30
	A0Ck	13 920.36	14 906.48	15 572.66
	A0Ak	15 001.97	15 914.31	16 530.66
	A0+Ck*	12 668.71	13 252.48	13 646.85
	A0+Bk*	14 100.65	14 687.87	15 084.58
	A0+Ak*	14 557.18	15 113.03	15 488.55
	A0+Ak+*	16 417.33	16 923.47	17 265.39
BC2	E0Ck	39 725.77	44 031.33	52 869.61
	C0Ck	35 356.03	38 828.64	45 957.06
	B0Bk	33 650.09	36 622.65	42 724.58
	A0Ck	33 712.03	36 726.52	42 914.52
	A0Ak	33 286.35	35 763.50	40 848.48
	A0+Ck*	35 817.88	38 346.80	43 538.07

		Min LCC (€)	Base LCC (€)	Max LCC (€)
	A0+Bk*	35 977.25	38 235.98	42 872.61
	A0+Ak*	36 033.41	38 055.53	42 206.43
	A0+Ak+*	39 869.08	41 549.90	45 000.22
BC3	C0Bk	58 445.90	69 916.52	74 169.78
	B0Bk	53 089.02	62 789.12	66 385.89
	A0Bk	51 609.87	60 551.18	63 866.58
	A0Ak	54 847.67	63 113.81	66 178.87
	A0+Ak*	59 865.17	65 093.70	67 032.41
BC4	41-326	1 388 587.21	1 456 225.66	1 511 819.54
	34-326	1 369 091.69	1 429 798.29	1 479 694.69
	34-277	1 444 844.17	1 502 336.86	1 549 591.65
	34-228	1 717 115.84	1 771 394.61	1 816 007.80
	28-326	1 402 505.18	1 456 279.93	1 500 478.85
	28-277	1 523 608.25	1 574 169.08	1 615 726.40
	28-228	1 954 606.94	2 001 953.86	2 040 869.57
	20-326	1 777 107.95	1 821 640.22	1 858 242.51
	20-277	2 011 587.46	2 052 905.82	2 086 866.51
	20-228	2 246 066.98	2 284 171.43	2 315 490.50
BC5	E0Ck	259 178.36	295 197.39	324 802.41
	C0Ck	226 382.73	257 062.31	282 278.69
	A0Ak	175 453.37	197 100.39	214 892.65
	A0+Ck*	187 228.03	210 962.73	230 470.93
	A0+Bk*	154 992.55	173 526.11	188 759.35
	A0+Ak*	136 372.04	150 621.36	162 333.26
BC6	C0Bk	282 663.80	320 707.37	351 976.42
	B0Bk	250 895.27	283 599.39	310 479.79
	A0Ak	229 000.54	257 714.91	281 316.02
BC7	110-750	1 667.17	1 667.17	1 882.80
	110-400	2 141.28	2 141.28	2 294.72

Sensitivity to electricity tariff

		Min LCC (€)	Base LCC (€)	Max LCC (€)
BC1	D0Ck	12 032.80	18 254.63	22 921.01
	C0Ck	11 416.49	16 667.37	20 605.53
	B0Bk	11 522.57	15 982.91	19 328.17
	A0Ck	10 903.97	14 906.48	17 908.36
	A0Ak	12 211.24	15 914.31	18 691.62
	A0+Ck*	10 883.05	13 252.48	15 029.55
	A0+Bk*	12 304.43	14 687.87	16 475.45
	A0+Ak*	12 856.91	15 113.03	16 805.13
	A0+Ak+*	14 869.14	16 923.47	18 464.21

		Min LCC (€)	Base LCC (€)	Max LCC (€)
BC2	**E0Ck**	27 054.24	44 031.33	56 764.15
	C0Ck	25 135.93	38 828.64	49 098.17
	B0Bk	24 901.68	36 622.65	45 413.37
	A0Ck	24 840.22	36 726.52	45 641.24
	A0Ak	25 995.95	35 763.50	43 089.15
	A0+Ck*	28 375.10	38 346.80	45 825.58
	A0+Bk*	29 329.66	38 235.98	44 915.72
	A0+Ak*	30 082.21	38 055.53	44 035.51
	A0+Ak+*	34 922.32	41 549.90	46 520.58
BC3	**C0Bk**	42 437.83	69 916.52	90 525.54
	B0Bk	39 551.82	62 789.12	80 217.10
	A0Bk	39 131.61	60 551.18	76 615.85
	A0Ak	43 311.65	63 113.81	77 965.43
	A0+Ak*	52 568.39	65 093.70	74 487.68
BC4	**41-326**	1 097 055.06	1 456 225.66	1 725 603.60
	34-326	1 107 436.90	1 429 798.29	1 671 569.33
	34-277	1 197 041.85	1 502 336.86	1 731 308.11
	34-228	1 483 165.99	1 771 394.61	1 987 566.08
	28-326	1 170 727.74	1 456 279.93	1 670 444.06
	28-277	1 305 683.28	1 574 169.08	1 775 533.43
	28-228	1 750 534.44	2 001 953.86	2 190 518.42
	20-326	1 585 166.98	1 821 640.22	1 998 995.15
	20-277	1 833 498.97	2 052 905.82	2 217 460.97
	20-228	2 081 830.95	2 284 171.43	2 435 926.78
BC5	**E0Ck**	202 881.06	295 197.39	387 513.73
	C0Ck	178 430.91	257 062.31	335 693.70
	A0Ak	141 619.35	197 100.39	252 581.42
	A0+Ck*	150 130.98	210 962.73	271 794.48
	A0+Bk*	126 024.82	173 526.11	221 027.40
	A0+Ak*	114 100.52	150 621.36	187 142.19
BC6	**C0Bk**	223 202.16	320 707.37	418 212.59
	B0Bk	199 779.12	283 599.39	367 419.66
	A0Ak	184 120.33	257 714.91	331 309.48
BC7	**110-750**	1 503.49	1 667.17	1 789.93
	110-400	2 024.81	2 141.28	2 228.64

Sensitivity to discount rate

		Min LCC (€)	Base LCC (€)	Max LCC (€)
BC1	**D0Ck**	22 890.42	18 254.63	15 345.13
	C0Ck	20 579.72	16 667.37	14 211.92
	B0Bk	19 306.24	15 982.91	13 897.14

		Min LCC (€)	Base LCC (€)	Max LCC (€)
	A0Ck	17 888.68	14 906.48	13 034.80
	A0Ak	18 673.42	15 914.31	14 182.66
	A0+Ck*	15 017.90	13 252.48	12 144.47
	A0+Bk*	16 463.73	14 687.87	13 573.31
	A0+Ak*	16 794.03	15 113.03	14 058.01
	A0+Ak+*	18 454.11	16 923.47	15 962.81
BC2	E0Ck	52 298.89	44 031.33	38 015.69
	C0Ck	45 496.75	38 828.64	33 976.78
	B0Bk	42 330.55	36 622.65	32 469.45
	A0Ck	42 514.94	36 726.52	32 514.74
	A0Ak	40 520.12	35 763.50	32 302.47
	A0+Ck*	43 202.85	38 346.80	34 813.44
	A0+Bk*	42 573.21	38 235.98	35 080.13
	A0+Ak*	41 938.39	38 055.53	35 230.27
	A0+Ak+*	44 777.42	41 549.90	39 201.49
BC3	C0Bk	85 733.78	69 916.52	58 986.65
	B0Bk	76 164.96	62 789.12	53 546.30
	A0Bk	72 880.69	60 551.18	52 031.38
	A0Ak	74 512.31	63 113.81	55 237.35
	A0+Ak*	72 303.50	65 093.70	60 111.65
BC4	41-326	1 662 971.09	1 456 225.66	1 313 362.69
	34-326	1 615 355.64	1 429 798.29	1 301 576.47
	34-277	1 678 070.47	1 502 336.86	1 380 903.34
	34-228	1 937 304.49	1 771 394.61	1 656 749.38
	28-326	1 620 649.20	1 456 279.93	1 342 699.27
	28-277	1 728 714.61	1 574 169.08	1 467 376.71
	28-228	2 146 675.66	2 001 953.86	1 901 949.78
	20-326	1 957 758.72	1 821 640.22	1 727 581.10
	20-277	2 179 200.59	2 052 905.82	1 965 635.00
	20-228	2 400 642.45	2 284 171.43	2 203 688.89
BC5	E0Ck	364 361.19	295 197.39	244 872.36
	C0Ck	315 973.29	257 062.31	214 197.44
	A0Ak	238 667.02	197 100.39	166 855.63
	A0+Ck*	256 538.14	210 962.73	177 801.10
	A0+Bk*	209 114.28	173 526.11	147 631.41
	A0+Ak*	177 982.92	150 621.36	130 712.50
BC6	C0Bk	393 758.70	320 707.37	267 553.69
	B0Bk	346 397.90	283 599.39	237 905.87
	A0Ak	312 852.28	257 714.91	217 595.79
BC7	110-750	1 701.48	1 667.17	1 637.63
	110-400	2 165.69	2 141.28	2 120.26

Sensitivity to purchase price

		-10% LCC (€)	Base LCC (€)	+10% LCC (€)	+30% LCC (€)
BC1	**D0Ck**	17 642.43	18 254.63	18 866.84	20 091.25
	C0Ck	16 024.56	16 667.37	17 310.19	18 595.82
	B0Bk	15 254.39	15 982.91	16 711.44	18 168.49
	A0Ck	14 196.32	14 906.48	15 616.64	17 036.95
	A0Ak	15 044.98	15 914.31	16 783.65	18 522.31
	A0+Ck*	12 389.27	13 252.48	14 115.69	15 842.11
	A0+Bk*	13 683.85	14 687.87	15 691.89	17 699.92
	A0+Ak*	14 041.67	15 113.03	16 184.39	18 327.11
	A0+Ak+*	15 631.71	16 923.47	18 215.22	20 798.73
BC2	**E0Ck**	42 938.73	44 031.33	45 123.93	47 309.13
	C0Ck	37 615.85	38 828.64	40 041.43	42 467.00
	B0Bk	35 245.97	36 622.65	37 999.32	40 752.67
	A0Ck	35 371.69	36 726.52	38 081.34	40 790.99
	A0Ak	34 091.82	35 763.50	37 435.17	40 778.53
	A0+Ck*	36 456.61	38 346.80	40 237.00	44 017.40
	A0+Bk*	36 149.12	38 235.98	40 322.85	44 496.58
	A0+Ak*	35 804.77	38 055.53	40 306.28	44 807.80
	A0+Ak+*	38 687.29	41 549.90	44 412.51	50 137.73
BC3	**C0Bk**	68 283.21	69 916.52	71 549.82	74 816.44
	B0Bk	61 041.48	62 789.12	64 536.76	68 032.04
	A0Bk	58 672.87	60 551.18	62 429.48	66 186.09
	A0Ak	60 663.85	63 113.81	65 563.77	70 463.69
	A0+Ak*	61 026.76	65 093.70	69 160.63	77 294.50
BC4	**41-326**	1 380 641.36	1 456 225.66	1 531 809.96	1 682 978.56
	34-326	1 349 678.93	1 429 798.29	1 509 917.65	1 670 156.36
	34-277	1 411 635.70	1 502 336.86	1 593 038.02	1 774 440.34
	34-228	1 650 459.73	1 771 394.61	1 892 329.49	2 134 199.25
	28-326	1 366 334.61	1 456 279.93	1 546 225.24	1 726 115.88
	28-277	1 469 106.90	1 574 169.08	1 679 231.26	1 889 355.61
	28-228	1 850 785.26	2 001 953.86	2 153 122.46	2 455 459.66
	20-326	1 685 588.48	1 821 640.22	1 957 691.96	2 229 795.44
	20-277	1 890 399.58	2 052 905.82	2 215 412.07	2 540 424.56
	20-228	2 095 210.68	2 284 171.43	2 473 132.18	2 851 053.68
BC5	**E0Ck**	293 372.56	295 197.39	297 022.23	300 671.91
	C0Ck	254 945.50	257 062.31	259 179.12	263 412.74
	A0Ak	194 034.66	197 100.39	200 166.11	206 297.57
	A0+Ck*	208 115.98	210 962.73	213 809.48	219 502.97
	A0+Bk*	170 423.89	173 526.11	176 628.34	182 832.79
	A0+Ak*	146 515.47	150 621.36	154 727.24	162 939.01
BC6	**C0Bk**	317 888.20	320 707.37	323 526.55	329 164.89
	B0Bk	280 385.53	283 599.39	286 813.25	293 240.96

		-10% LCC (€)	Base LCC (€)	+10% LCC (€)	+30% LCC (€)
	A0Ak	254 021.79	257 714.91	261 408.03	268 794.26
BC7	110-750	1 532.37	1 667.17	1 801.97	2 071.57
	110-400	1 949.87	2 141.28	2 332.70	2 715.53

Sensitivity to stock

		Original Total Electricity (TWh)	Corrected Total Electricity (TWh)
BC1	D0Ck	28.59	17.94
	C0Ck	24.19	15.20
	B0Bk	20.61	12.97
	A0Ck	18.53	11.68
	A0Ak	17.21	10.87
	A0+Ck*	11.14	7.08
	A0+Bk*	11.27	7.19
	A0+Ak*	10.70	6.83
	A0+Ak+*	9.80	6.28
BC2	E0Ck	21.85	13.80
	C0Ck	17.66	11.17
	B0Bk	15.15	9.60
	A0Ck	15.36	9.73
	A0Ak	12.69	8.06
	A0+Ck*	12.96	8.24
	A0+Bk*	11.62	7.40
	A0+Ak*	10.44	6.66
	A0+Ak+*	8.74	5.59
BC3	C0Bk	6.85	4.42
	B0Bk	5.82	3.76
	A0Bk	5.38	3.49
	A0Ak	5.00	3.25
	A0+Ak*	3.21	2.10

Sensitivity to combined parameters

		Min		Base		Max	
		Total Electricity (TWh)	LCC (€)	Total Electricity (TWh)	LCC (€)	Total Electricity (TWh)	LCC (€)
BC1	D0Ck	16.32	9 245.97	17.94	18 254.63	23.12	42 404.48
	C0Ck	13.58	8 879.97	15.20	16 667.37	20.37	38 640.32
	B0Bk	11.62	9 190.12	12.97	15 982.91	17.30	35 098.10
	A0Ck	10.07	8 661.29	11.68	14 906.48	16.86	34 164.51
	A0Ak	9.73	10 005.93	10.87	15 914.31	14.53	32 668.33
	A0+Ck*	5.48	8 963.56	7.08	13 252.48	12.20	29 076.04
	A0+Bk*	5.82	10 293.49	7.19	14 687.87	11.57	29 857.77
	A0+Ak*	5.66	10 862.19	6.83	15 113.03	10.57	29 217.26

		Min		Base		Max	
		Total Electricity (TWh)	LCC (€)	Total Electricity (TWh)	LCC (€)	Total Electricity (TWh)	LCC (€)
	A0+Ak+*	5.40	12 778.84	6.28	16 923.47	9.10	29 838.09
BC2	**E0Ck**	8.30	16 918.71	13.80	44 031.33	32.37	203 278.11
	C0Ck	5.67	15 709.52	11.17	38 828.64	29.73	189 312.24
	B0Bk	4.88	16 488.70	9.60	36 622.65	25.51	166 576.58
	A0Ck	4.23	15 727.89	9.73	36 726.52	28.30	182 618.18
	A0Ak	4.08	18 415.37	8.06	35 763.50	21.49	146 668.26
	A0+Ck*	2.59	19 084.44	8.24	38 346.80	27.30	183 417.22
	A0+Bk*	2.64	20 873.70	7.40	38 235.98	23.48	163 496.46
	A0+Ak*	2.58	22 289.98	6.66	38 055.53	20.43	147 671.86
	A0+Ak+*	2.46	27 672.03	5.59	41 549.90	16.19	130 641.73
BC3	**C0Bk**	2.95	26 126.55	4.42	69 916.52	9.38	251 599.24
	B0Bk	2.29	24 482.86	3.76	62 789.12	8.72	236 530.06
	A0Bk	2.02	24 513.40	3.49	60 551.18	8.45	231 133.50
	A0Ak	2.00	29 545.08	3.25	63 113.81	7.45	213 312.07
	A0+Ak*	0.89	39 644.67	2.10	65 093.70	6.19	203 163.69
BC4	**41-326**	33.90	932 504.07	33.90	1 456 225.66	89.69	4 716 094.42
					7.2.10 1 42 9 79 8.2 9	7.2.11 86.24	7.2.12 4 63 1 37 2.2 1
	34-326	30.46	947 468.50	30.46			
	34-277	28.89	1 030 719.00	28.89	1 502 336.86	76.31	4 352 588.82
	34-228	27.33	1 290 836.77	27.33	1 771 394.61	66.38	4 329 280.37
	28-326	27.02	1 010 051.04	27.02	1 456 279.93	82.81	4 615 431.71
	28-277	25.46	1 134 117.07	25.45	1 574 169.08	72.87	4 395 604.08
	28-228	23.90	1 537 089.16	23.90	2 001 953.86	62.95	4 578 640.76
	20-326	22.44	1 390 540.73	22.44	1 821 640.22	78.23	5 023 244.59
	20-277	20.88	1 616 645.56	20.88	2 052 905.82	68.30	4 950 806.34
	20-228	19.38	1 842 750.39	19.38	2 284 171.43	58.43	4 878 368.09
BC5	**E0Ck**	0.15	103 026.26	0.24	295 197.39	0.30	679 007.35
	C0Ck	0.12	85 558.72	0.21	257 062.31	0.26	604 325.83
	A0Ak	0.09	74 092.08	0.15	197 100.39	0.19	447 935.80
	A0+Ck*	0.08	66 160.89	0.16	210 962.73	0.22	511 304.17
	A0+Bk*	0.07	62 570.01	0.13	173 526.11	0.17	402 991.59
	A0+Ak*	0.06	67 018.82	0.10	150 621.36	0.13	323 396.87
BC6	**C0Bk**	0.72	126 588.58	1.02	320 707.37	1.21	703 705.29
	B0Bk	0.58	110 045.44	0.88	283 599.39	1.07	630 359.01
	A0Ak	0.51	104 005.67	0.77	257 714.91	0.95	565 959.92
BC7	**110-750**	0.16	1 272.55	0.38	1 667.17	0.67	3 331.57
	110-400	0.16	1 779.55	0.27	2 141.28	0.43	3 489.45

ANNEX G TARGET LOAD AND NO LOAD LOSS VALUES FOR POWER TRANSFORMERS

Target values as included in DIN 42508:2009-08 Table 2 that were used to extrapolate the target values of this study:

S (kVA)	3150	4000	5000	6300	8000	10000	12500	16000	20000	25000	31500	40000	50000	63000	80000
Po(≤36kV)	2.0	3.0	3.0	4.0	4.0	4.0	6.0	8.0	10.0	13.0	15.0	19.0	–	–	–
Po(>36kV)	–	–	–	6.0	6.0	7.0	8.0	10.0	12.0	15.0	19.0	23.0	28.0	34.0	41.0
Pk(≤36kV)	20.0	30.0	40.0	45.0	50.0	52.0	55.0	70.0	85.0	100.0	120.0	145.0	–	–	–
Pk(>36kV)	–	–	–	55.0	60.0	62.0	65.0	75.0	90.0	110.0	125.0	150.0	180.0	210.0	250.0

Target values calculated by linear extrapolation of DIN 42508:2009-08, the Annex D results and format (power transformer enquiry) with Pk corrected (-10%) after T&D comments:

S	HVmin >	HVmax ≤	Po	Pk	Po-30%
kVA	kV	kV	kW	kW	kW
5000		36	2.7	37.0	1.9
10000		36	3.6	48.1	2.5
25000		36	11.6	92.5	8.1
40000		36	17.0	134.1	11.9
10000	36	150	6.3	57.4	4.4
25000	36	150	13.4	101.8	9.4
50000	36	150	25	166.5	17.5
100000	36	150	40.5	293.4	28.4
100000	150	300	55	306	38.5
170000	150	300	78.8	511.2	55.2
350000	300	400	137	690.3	95.9
350000	400		146	841.5	102.2

Note: ratings not included in the table should be obtained by linear inter- and extrapolation.