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Review of Ecodesign of small, medium and large Power Transformers: Phase 1 qualitative questionnaire

A Eurelectric response

September 2023

Eurelectric represents the interests of the electricity industry in Europe. Our work covers all major issues affecting our sector. Our members represent the electricity industry in over 30 European countries.

We cover the entire industry from electricity generation and markets to distribution networks and customer issues. We also have affiliates active on several other continents and business associates from a wide variety of sectors with a direct interest in the electricity industry.

We stand for

The vision of the European power sector is to enable and sustain:
- A vibrant competitive European economy, reliably powered by clean, carbon-neutral energy
- A smart, energy efficient and truly sustainable society for all citizens of Europe

We are committed to lead a cost-effective energy transition by:

investing in clean power generation and transition-enabling solutions, to reduce emissions and actively pursue efforts to become carbon-neutral well before mid-century, taking into account different starting points and commercial availability of key transition technologies;

transforming the energy system to make it more responsive, resilient and efficient. This includes increased use of renewable energy, digitalisation, demand side response and reinforcement of grids so they can function as platforms and enablers for customers, cities and communities;

accelerating the energy transition in other economic sectors by offering competitive electricity as a transformation tool for transport, heating and industry;

embedding sustainability in all parts of our value chain and take measures to support the transformation of existing assets towards a zero carbon society;

innovating to discover the cutting-edge business models and develop the breakthrough technologies that are indispensable to allow our industry to lead this transition.

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WG Technology

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Eurelectric values and welcomes the opportunity to respond to the questionnaire as part of the review study performed on behalf of DG GROW on Commission Regulation 2019/1783 on the Ecodesign of small, medium and large power transformers.

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Response to questionnaire

Eurelectric's comments are provided in blue writing.

1. Regulation definitions and scope

f) the appropriateness of the exemptions for transformers in offshore applications;
g) the appropriateness of the concessions for pole-mounted transformers and for special combinations of winding voltages for medium power transformers:
p) functional categorisation of power transformers (including conventional transformers, overload transformers and fire performant transformers and any others that the contractor may suggest).

1) Do you have any views or concerns with regards to the definitions and scope set out in the regulation?

   a. *The regulation applies to power transformers with a minimum power rating of 1kVA used in 50Hz electricity transmission and distribution networks or for industrial applications. What are your views on this scope?*

In practice 1 kVA is very small and the load factor, utilization and the high intermittency of loads that would be fed with a 1kVA transformer would likely result in low energy usage, so the absolute level of losses available to be saved is low.

A somewhat higher value of 5 kVA might aid simplicity and compliance, however this would also require that the CENELC/IEC Definitions were also changed, so is perhaps a change best considered for the future.

   b. *The regulation defines "Small power transformers" as: a power transformer with a highest voltage for equipment not exceeding 1,1kV. What are your views on this scope?*

This is fine as it clearly designates transformers that are Low Voltage/Low Voltage, which is what is intended.

   c. *The regulation defines "medium power transformers" as: a power transformer with all windings having rated power lower than or equal to 3 150 kVA, and highest voltage for equipment greater than 1,1 kV and lower or equal to 36kV. What are your views on this scope?*

This is reasonable and was agreed at CENELEC level between manufacturers, utilities, and academic experts. There would be little value in changing it at this stage.[1]

   d. The regulation defines "large power transformers" as: a power transformer with at least one winding having either rated power greater than 3150kVA or highest voltage for equipment greater than 36kV. What are your views on this scope?

Again, this was agreed at CENELEC level, is in place and little value changing at this stage. (See also Footnote 1 above.)

[1] Note: In EU, those nominal 36 kV networks which are based on rated voltages of 40.5 kV can already use PEI.

2) What are your views on the appropriateness of the exemptions for transformers in offshore applications? Can you provide an estimate of the market share these represent? What sort of rated power kVA values can we expect for these transformers? How are these transformers different from the mainstream?

Exemptions for offshore applications, which are nearly entirely associated with Renewable generation, are completely justified on the following grounds:

(a) Value of Energy Efficiency vs Cost:
The renewable generator produces energy with no associated carbon emissions, and at virtually zero marginal cost, so the value to society in investing more CAPEX in extremely efficient low loss transformers to increase savings in such energy is negative – money is being wasted.

However, as money is fungible, any money saved could instead be invested in other areas of energy efficiency which would actually produce a greater return for society.

In fact, given the very high levels of transformer efficiency already existing it is likely that investment in any other part of the offshore energy infrastructure would produce higher energy saving e.g.. Cables connecting the Transformer.

(b) Savings in CO2:
The kWh saved using energy efficient transformers are entirely free of fossil fuel as they are supplied from Wind, so there is no increase in CO2 arising from extra losses in the Transformer.

However, as the energy efficient transformer has more Magnetic Steel, Copper and Mineral Oil than a less efficient unit, there are much higher value of embedded carbon in the transformer, arising from the extra materials used in manufacture e.g., the Steel may well be smelted using energy from coal fired plants in China.

However, the embedded carbon debt associated with the extra materials will never be repaid from any savings in kWh free losses.

(c) Extra Costs:
EcoDesign was to be cost neutral as the extra Capex in the transformer was to be repaid from the value of Losses saved and CO2 emissions avoided. However, as shown above, there are no savings from these areas when the transformer is being used on a renewable energy generation site. Yet the amount of CAPEX is even higher with offshore transformers as the extra weight and size has to be supported on the offshore platform, which is yet another burden of embedded carbon and cost.

3) The regulation defines "medium power, pole mounted transformers" as a power transformer with a rated power of up to 400 kVA suitable for outdoor service and designed to be mounted on the support structures of overhead power lines. These devices are subject to a separate table of allowable maximum load and no-load losses. What are your views on the appropriateness of having a separate table for medium power pole-mounted transformers? The kVA Rating of a Transformer which can fit on a pole is determined mainly by the weight and to a second degree by the wind loading (proportional to area.). Reduced losses for the same kVA rating require more material so that the weight of the Pole Mounted Transformer increases by an appreciable amount tand is likely to require a reinforced supporting structure.

The intention of EcnDesign was that the savings in losses and CO2 emissions would be economic and would fund the extra costs of the transformers.

In the case of Pole Mounted Transformers, the level of losses appropriate to fund the loss levels in Ground Mounted Units would by definition not fund the extra costs which would be incurred if the same level of losses were required from a Pole Transformer, due to the extra installation costs involved in the supporting structures.

At minimum a more elaborate platform would be required using two poles, a platform and a much greater land areas in the farmer's field. It would be more visually obtrusive and possibly need Planning Permission, which would delay installation. If too heavy to allow a Pole Mounted Transformer, then the Transformer would need to be ground mounted, which would require a concrete plinth, MV Switchgear, LV Fuses, cables and more elaborate routing of circuits back to the overhead network. The site for the substation would need to be purchased and title established. Typically, costs would jump from about €4,000 to €25,000 plus Site costs and civil works.

In reality, it would then be cheaper to use several Pole Mounted Transformers with higher losses (as all the Iron Losses are incurred each time a transformer is put online) than one Larger Ground Mounted unit with lower losses.

Pole Mounted Transformer typically supply low load rural areas, but load in such areas is expected to increase dramatically as each customer installs an Electric Vehicle and Heat Pump. Such extra load will drive increases in Transformer capcity, and if additional transformers become difficult/expensive to install this may delay electrification.

It is for these reasons that Pole Mounted Transformers have lower loss requirements.

4) The regulation sets out correction factors for the applied regulatory maximum load and no-load losses to medium power transformers with special combinations of voltages in one or both windings. What are your views on the appropriateness of the correction factors for special combinations of winding voltages for medium transformers?

Transformers with special combinations of voltages cannot economically be manufactured to the same efficiency levels as normal transformers, and hence are given extra loss allowances.

The number of Transformers with special combinations is few, their use is necessary, and the use of the correction factor with such units does not make a material difference to overall loss levels. e.g., Dual winding 20/10kV /LV Transformers are used to prepare for voltage conversion of networks from 10kV to 20kV. The saving in circuit losses produced is 75%, so in this context any change in transformer losses is immaterial. The same logic applies to transformers with dual secondary windings which facilitate the transition from 230 V to 400 V.

Hence correction factors are entirely justifiable.

Note: There is currently an inconsistency present in the second part of the note associated with Table 1.3b in the current version of the Regulation which is inconsistent with the main text in the Table and requires correction.

5) Transformers can be categorised in line with their functionality, such as for conventional transformers, overload transformers, for fire performant transformers, distribution transformers, safe extra low voltage transformers and Ultra High Voltage transformers.

a. What are your thoughts on the categories mentioned here? Should specific definitions be clarified for them in the regulation?

The regulations apply to all transformers other than where some category is specially excluded. 'Conventional Transformers' ,'Distribution Transformers' and 'Fire Performant' transformers are all catered for in the Regulations.

'Safe Extra Low Voltage Transformers' are usually < 1 kVA and used on building sites for small power tools, and 'Ultra High Voltage transformers' (usually > 800kV) are rare in the EU.

b. Are there other functional categories that you suggest for inclusion?

No.

2. Ecodesign energy efficiency requirements

a) the extent to which requirements set out for Tier 2 have been cost-effective and the appropriateness to introduce stricter Tier 3 requirements.
e) the appropriateness of setting minimum performance requirements for small power transformers.
n) impact of rising electricity prices on current and potentially stricter Ecodesign requirements.

6) Tier 2 energy efficiency requirements on transformers came into force in 2021.
   a. In your view, has Tier 2 been cost-effective?

Unfortunately not, because circumstances have radically changed and the original assumptions on which cost-benefit assessments (CBA) were made have also changed.

The CBA was based on the lifetime:
i. Expected cost of extra Material for Transformers
ii. Expected levels of savings in CO_2 emissions.
iii. Expected savings in cost of energy saved

Note: However, there may have been some unanticipated benefits which are positive, in that lower losses leave more scope to increase transformer loading rather than constrain renewables.

Distribution Transformers:

i. Expected cost of extra Material for Transformers

Whilst there has been an expected increase in the cost of material generally, one of the critical assumptions in EcoDesign2 was that there would be high availability of High Efficiency (Low Loss) GOES Transformer steel.

This was appreciated by EU and attempts were made to encourage the establishment EU production facilities to secure availability, but these were not successful.

The war in Ukraine and the loss of Mariupol Steel plant, plus the greater attractiveness of alternative markets for steel such as in Electric Vehicle production, has meant that such low loss steel has not been readily available.

The lack of availability of Low Loss Transformer magnetic steel means that in order to meet Tier 2 targets, greater volumes of lower grade steel are required, resulting in larger steel cores and consequently greater volumes of copper for the windings which surround the magnetic core, and in turn this larger volume now requires to be accommodated by a greater tank volume, consequently with a greater volume of Mineral oil.

All these issues have meant that the cost of the transformer has increased substantially from what would have been expected, ignoring any other cost increases produced by outside economic conditions. (See Appendix 1)

ii. Expected levels of savings in CO_2 emissions.

Savings in CO_2 arise from:
- Reduction in kWh usage of fossil fuelled grid electricity
- Net of the payback for embedded carbon in the extra Transformer material used to produce low loss design

Reduction in kWh usage of fossil fuelled grid electricity

As the percentage of fossil fuelled electricity on the Grid reduces, the kWh actually saved are increasingly arising from Renewable sources, which are CO2 free, and which have zero marginal cost.

But the value predicted from saving losses was based on the costs of Fossil Fuel saved, and the reduction in fossil fuel CO 2 emissions , which are now only occurring at a dwindling rate, and which are expected to be zero by 2050 within EU, and are already down to less than 50% in many EU countries.

Less payback for embedded carbon in Extra Transformer material used to produce low losses

The reduction in kWh losses by the transformer is less than expected and will decrease further in future because the Load Factor for which efficiency has been optimised is now increasingly mismatched to the actual load behaviour.

This is mainly because, for Distribution Transformers, minimum fixed values of Iron and Copper losses were used, and these optimised values were based on an expected Load Factor. If the actual load is above or below this load factor, then the transformer is less efficient

Intuitively, transformers with heavy loads and high load factors should be designed to minimise Copper losses, and those with light loads should be designed to minimise constant Iron Losses which will be predominant, as a lightly loaded transformer seldom works at high loading, hence copper losses are minimal.

The use of one Load Factor for all Distribution Transformers for all loads mean that the transformers are no longer aligned to their loads, and so operate sub-optimally at lower performance than expected.

Accordingly, Transformers feeding areas with high Electric Vehicle and Heat Pump usage (High Load Factor) should have been designed for low Copper losses, and those feeding sparsely loaded rural areas (Low Load Factor) should have been designed to minimise Iron losses.

Instead, with Fixed Losses, all transformers are designed for c. 32% Load Factors, a Load Factor that is too low for urban areas (which increasingly feature the electrification of Transport and Heat), yet too high for sparsely loaded rural areas.

As these Fixed Loss figures for Distribution Transformers are applied EU wide, they also mean that colder areas such as Sweden (with high kWh usage) will use the same Transformer designs as Ireland (with much lower kWh usage).

Due to the above, the expected level of transformer efficiency has not been achieved and so the savings in kWh losses expected are unlikely to have been produced.

Note: If the use of Fixed losses were to be maintained to facilitate simpler Transformer design, then multiple values of Fixed losses would be required to correspond to different load factors e.g. a High, Medium and Low

iii. Expected savings in cost of energy saved

A reduction in losses corresponds to a saving in the energy component cost of the kWh – the remaining costs of the retail kWh are composed of an allocation of Fixed Costs (such as Network Costs, Public Levies, Taxes etc) which will not reduce as losses decrease.

This means that when Gas or Oil is at a high price, and forms a significant part of kWh cost, that energy loss savings are more significant.

In contrast, when fossil fuel generation is replaced by Renewables, then the energy component of the electricity (which is what will be saved by reducing losses), goes to zero, as the initial commitment to build the wind/solar farm locks in the investment cost and all electricity produced is then already determined, so that this electricity will be produced at zero marginal cost – if it is not used it will be lost.

Conclusion:
Given the above factors the societal benefits of using more expensive low loss transformers to ineffectively save grid electricity which has a decreasing energy cost and is becoming CO2 free, is unlikely to be cost effective. for Distribution Transformers.

However, any extra loading capacity available from Low Losse transformer may have a future value in allowing greater use of renewable electricity when Wind/Solar is high, by facilitating a higher peak load to match the renewables available

Power Transformers:

Power Transformers use PEI so that they can be optimised for efficiency around the load factor required, and as PEI is relatively flat over a range of load factors, the Power Transformer will remain efficient even if the Load Factor varies.

PEI should also be used in conjunction with Loss Capitalisation figures for Iron and Copper Losses, as this provides information on the Load factor for which the transformer is to be optimised, but also about the cost trade-offs between Iron and Coper losses during the optimisation of the design process.

In theory only capitalisation is required to optimise the transformer design, but as this would be very difficult process to regulate, PEI was introduced as a standard index of required efficiency.

Additionally, as PEI allows Iron and Copper losses to be varied once PEI is achieved, the lack of High-Quality steel can also be compensated for to some extent.
Note: As Power Transformers are somewhat bespoke and ordered in small numbers, they have been more able to secure access to Low Loss Core Steel. than have Distribution Transformers.

Having said the above, the same issues which arise from the grid decarbonising, and hence reducing the value of losses saved, are still applicable.

b. What are your views on the introduction of stricter Tier 3 requirements?

The increasing efficiency levels introduced in Tier 1 and Toer 2 are now at a stage where any further increases will produce rapidly decreasing returns to scale – some manufactures have privately indicated a figure of an increase of up to 50% in cost for a further 10% in efficiency, or for a 5% increase in efficiency Iron and copper Losses would need to be reduced by 10% each from Tier 2 levels, resulting in an increase in weight of up to 30%.

Additionally, any increase in efficiency will result in a very significant increase in material usage on each transformer and given the Critical Raw Materials and Circularity Initiatives by EU, further increases in efficiency would be sub-optimal and regressive.

However, the drive to Net Zero has produced some significant new issues involving transformers:

A. Renewable Electricity should be used as it is produced as the additional use of electrolysers and storage is costly and inefficient.

This means that customer loads should be turned on and using electricity when renewables are available e.g., EV Charging should be matched to when the Wind/Solar is available.

If Load cannot be turned on when renewables are available (e.g., due to limits on the Grid), then any surplus wind/solar will have to be spilled, as it will be too expensive to store.

Consequently, it could be more cost effective to increase Grid capacity where economic and practical in order to avoid wasting renewable energy.

So the choice could be between running a Transformer at no more than 100% loading, with losses of say 2%, or running at 20% overload and losses of 5% but saving an extra 17% of renewable electricity!

This would mean that the best approach to any Transformer design issues in the context of Net Zero could be to concentrate on increasing Transformer 'load ability' so that renewable resources are not wasted, and in turn this would probably mean making more use of Ester Transformers which have high overload capabilities but low levels of Iron Losses at normal loads as they require less transformer steel. Additionally, the focus on losses would then be to avoid unnecessary heat production which would limit loading.

In general, it can be expected that with the electrification of heat and transport loads on the network (particularly at LV) will significantly increase, will often have high peak loadings and hence high losses at times, but as the electricity used is renewable this is both economic and environmentally acceptable.

What would be counterproductive would be to attempt to have low grid losses, as this would indicate that renewables were likely being wasted rather than used, or that overinvestment had occurred on the grid!
Furthermore, to ensure that the high demands from the electrification of heat and transport can be met, utilities are increasing the sizes of the transformers which are being installed and ensuring that these can be further uprated in the future if required.

Using transformers in this way is optimal, as Circuits can be split between Substations so that large amounts of capacity can be added to the circuit without requiring to rebuild it e.g., in an LV Cabled network with say 300m of LV Cable between MV/LV Substations, it is far less expensive, and much simpler, to add a new substation in the middle to reduce circuit loads than dig of 300m of street!

Similarly, on new estates instead of using 400 KVA transformer the minimum size used is (say) a 630 kVA is used instead, as it is very economic to provide capacity at the design stage-less than 10% in additional overall costs allows average household demand to be increased from 2kW to 5.5kW, with an option to later increase further to 8,7 kW per household simply by uprating the transformer.

7) The Ecodesign regulation defines small power transformers as being transformers with a voltage for equipment under 1.1kV. These are currently excluded from energy efficiency requirements under Ecodesign.

a. What are the use cases for small power transformers? What would you estimate their market Instead are to be? What quantities of small transformers are traded annually within the EU?

There are only small numbers of Transformers of close to 1 kVA because most LV Loads connect directly to the LV Supply directly e.g. cookers, electric vehicles, heat pumps, water heating.

The main Transformers of around 1kVA rating would be isolating transformer used for safety on building sites (e.g. to feed small tools with intermittent use.).

Below these levels are small transformers used on electronic equipment, which are very small in capacity (say 50 – 100W) and feed loads with variable load and intermittent use.

In fact, most low load electronic equipment no longer uses a transformer.

The quantities of such small transformers is very large and proportional to the amount of electronic equipment traded, but the capacity of each will be tiny, and the scope for efficiency gains small.

Additionally, there are special applications for LV to LV transformers in LV Grids. These are required for grid transition from 230 V insulated 3-wire network to 400 V earthed 4-wire network.
Furthermore, there are autotransformers or network compensators now required In certain networks due to the energy transition. These transformers are now seeing a resurgence in use due to the increased loading in the network due to photovoltaics or electric vehicles which lead to complaints on over- or undervoltage, which these niche transformers help address.

b. What value would you state as the current average efficiency for small transformers? Do you believe this average efficiency rate can be improved?

The level of efficiency required will depend on the load factor, and the utilization of the transformer, and with electronic equipment the load factor and utilization can be expected to be low as the units are intermittently used.

So, if any level of general efficiency were set, it is likely not to be capable of being economically justified as the use-cases will be very varied, and the ancillary cost, such as a larger casing or a re-layout of circuitry to accommodate changed transformer dimensions, would outweigh any potential savings.

As the transformers will likely be produced outside the EU for a worldwide market as generic components, and then embedded as part of another generic product, it will be impossible to use the current legislation to impose sanctions on the transformer manufacturers involved.

Furthermore, the issues of grid decarbonisation will also apply.

c. What are your views on setting minimum performance requirements for small power transformers? What performance level would you suggest is applied to small transformers?

Not worthwhile to attempt to set performance requirements for such a diverse market.

If energy efficiency is justified it should be set on the product itself, not on an individual component which accounts for probably the smallest energy wastage within the appliance.

In short, it is Inappropriate to attempt to set a performance level for an individual component within an appliance. A better approach is to set an efficiency level for that class of appliance.

8) Have the recent high electricity prices affected purchasing, operation and replacements of power transformers? If so, in what way?

Capitalisation of losses assesses the value of losses over 25 – 40 years and is not influenced by price patterns over a few years. In fact, the longer-term pattern with Net Zero is for the energy cost within the kWh to fall to zero.

The main trends have been to move to bigger transformer ratings in anticipation of larger loads and to have the capability for the transformer to cope with higher peak loads rather than constrain the use of renewables. Higher capacity units also provide scope for future load growth and insurance against unexpectedly large increases in load due to electrification.

Copper losses are reducing not because of loss capitalisation but because more copper means better voltage regulation at higher loads, and greater capability of the transformer to cope with unexpectedly high loading peaks due to tariff changes or demand control which attempts to match load to availability of renewables.

Interestingly, due to the very high levels of efficiency produced by Tier 2 requirements, the use of capitalized losses to derive further increases in efficiency which may be economic is indicating that further increases in losses are uneconomic. This is because of disproportionate increase In Transformer costs produced by severe diseconomies of scale in attempting to increase efficiency further.

3. Existing Standards and Regulations

j) an analysis of the standards, and of their relevance for regulatory purposes.
l) Ecodesign (or similar) requirements for power transformers in other jurisdictions, in particular the US and Japan and in comparison, to current Eco-design requirements for Tier 2.

9) IEC 60076 is the main standard for single and three-phase power transformers. It is in 21 parts and covers many aspects of the product, including energy performance testing. The IEC 60076-20 specification proposes two methods of defining an energy efficiency index and three methods of evaluating the energy performance of a transformer:

- The Peak Efficiency Index (PEI) including a Total Cost of Ownership approach.
- The no-load and load losses at rated power for rationalisation of transformer cores
- The efficiency at a defined power factor and particular load factor (typically 50%)

a. What are your views on this standard and the energy performance metrics presented above?

i. The Peak Efficiency Index (PEI) including a Total Cost of Ownership approach.

It has always been clear that PEI and Loss capitalisation give the optimal level of energy efficiency at the lowest cost.

This is simply because PEI provides the option to interchange iron and copper losses in order to produce a transformer which has optimum performance at the expected load factor. However, PEI has a relatively flat curve, so that even if the load factor varies over a certain range the PEI will still be optimal, whereas with Fixed Losses there is a peak at which efficiency is maximised, but if the load factor is above or below that Load Factor efficiency decreases sharply.

The use of Capitalisation with PEI means that the manufacturer can use different combinations of Iron and Copper in the transformer design to produce the required level of PEI, but taking into account the associated costs of such combinations on the overall initial cost of the transformer i.e. the sum of Initial Cost plus NPV of future losses can be minimised.

As a practical illustration of one benefit from use of PEI, the unavailability of Low Loss Steel could be compensated for by using more copper to reduce the overall losses and meet required PEI value in a more flexible way. This would then avoid the need to produce larger and heavier transformers with bigger tanks, more mineral oil and higher weight simply to accommodate the larger core required when only poor-quality magnetic steel is available – as is the case when Fixed Losses are used instead of PEI.

ii. The no-load and load losses at rated power for rationalisation of transformer cores

Using Fixed Values of Load (Copper) and No Load (Iron) losses has the benefit simpler design requirements which necessitate less skill and engineering expertise, as the same design is used regardless of load factor.

Furthermore, as the design is only optimised at one load factor, then the steel core is standard for each rating and this allows less variation in the width of the magnetic steel used to make the core, and following from that other aspects such as tank size are also standardised.
However, the above benefits for the manufacturer do not result in benefits to the customer.
The transformer is not optimised for it's expected use, so that losses are not optimal. The requirement to use fixed levels of Iron and Copper Losses regardless of the availability of low loss

Magnetic steel, or the relative costs of Iron and Copper, can consequently result in unnecessarily high costs which create no value for society.
The volumes of material required are unnecessarily high, which also contradicts the principles of Circularity and requires greater use of Critical Raw Materials.

The efficiency at a defined power factor and particular load factor (typically 50%)

This produces a transformer which is sub-optimally efficient at every load factor above or below 50%.

It is probably slightly worse for efficiency than fixed losses, because at least with fixed losses the expected level of load factor is used e.g., 32%, whereas when 50% is used it is unlikely to be near whatever the likely load factor may be, simply because just one point - 50% - has been chosen, regardless of what the actual load factor may be.

Similar issues arise on the inflexibility to choose different combinations of Iron and Copper also arise.

b. Should other standards be considered when reviewing the transformers Ecodesign regulation?

In terms of setting and measuring efficiency levels the PEI approach with capitalisation is near optimal and has a sound theoretical basis from Cenelec.

Initial Cost plus Loss Capitalisation, and without PEI, would actually produce a more optimal result as it would look to optimise the overall economic cost and this would give the best outcome for society where it was correctly applied but without any restriction imposed by a PEI value (which limits the degrees of freedom in optimising the design).

However, such an approach could not easily be regulated, hence the reason PEI was introduced.
Using PEI to provide a minimum standard, with either:

- load factor then used to provide information on the expected load factor for which PEI was to be calculated,
- or with the capitalised costs of Iron and Copper losses (which provides both Load Factor and Marginal costs of Iron and Copper Loss)

then used to optimise the initial cost of the transformer itself, so that the overall total of Initial Costs + Capitalised losses was at a minimum.

10) What are your views on minimum performance requirements in other jurisdictions, in particular the US and Japan?

a. How do these requirements compare to the current Ecodesign requirements for Tier 2?

Where comparisons were previously done by VITO in the last round of EcoDesign they showed the EU approach to give higher levels of efficiency, but they were all quite similar overall.

The EU approach is probably simpler and more transparent whilst also having a better engineering justification, and certainly PEI (originally developed by CENELEC as part of ECODESIGN) as a concept is superior to the cruder approaches used in the US and Japan.

b. *Are there any areas or considerations of these requirements which could be used to further improve the Eco-design requirements?*

In the derivation of the value of efficiency which is justified there could be useful information found from examining the economic basis used to determine the efficiency level chosen in other countries, but this would be a major exercise e.g. in New Zealand consideration of the appropriate discount rate alone involved over a hundred pages of analysis by a professor of economics.

4. Implementation of Ecodesign Requirements and Methodologies

b) the appropriateness of the concessions introduced for medium and large power transformers in cases where installation costs would have been disproportionate. In particular, the analysis should investigate concessions in concrete cases (e.g., manufacturers, electricity companies, market surveillance authorities) and determine their
appropriateness.

c) the possibility of utilising the PEI calculation for losses alongside the losses in absolute values for medium power transformers.

d) the possibility to adopt a technology-neutral approach to the minimum requirements set out for liquid-immersed, dry-type and, possibly, electronic transformers.

o) existing methodologies for assessing technoeconomic aspects of Ecodesign for power transformers (especially in terms of technology neutrality, circularity, MEPS and MMPS), as well as for the assessment of the costs for replacement/installation of transformers, based on the principles laid down in Regulation 2019/1783.

q) a techno-economic analysis on the relevance and feasibility of requirements (in particular for low-to-medium and medium-to-high voltage transformers) related to design features aimed to increase the efficiency and lifetime of transformers when working with reversed power flows (due, for instance, to electricity from renewable energy sources injected in the grid at lower voltage levels).

11) The regulation 2019/1783 introduced concessions for the Tier 2 requirements such that: "when the one-to-one replacement of an existing medium power transformer entails disproportionate costs associated with their installation, the replacement transformer is, exceptionally, only required to meet Tier 1 requirements for the given rated power."

> a. *Did you find these concessions useful for your operations? If so, what is the proportion of replacement cases where this concession was applied?*

The number of occasions when such concessions require to be applied depends strongly on where reinforcement work is being carried out. In new installations any larger facilities can be provided by the customer at their costs, and in some existing installations the use of more expensive Ester Transformers can be deployed to the space actually available.

For uprating transformers in packaged substations which were designed for 630kVA transformers with low losses means that aby replacement 1000kVA transformers must be designed for the same level of losses as the 630kVA, as this is what the overall substation has been designed for.

Where the extra costs are less than 20% of the transformer cost and are not common no concessions are normally requested as the administrative costs would be excessive.

However, in locations where space is limited the extra costs involved will likely involve many multiples of the transformer costs and considerable delays where civil works are required – this could extend to delays of years where Planning Permission was required.

Most utility transformers are currently installed in new substations, but as electrification of heat and transport rolls out, older stations will require larger capacity transformers or the replacement of existing ones, and if lower loss units with larger dimensions do not fit then the cost and delay arising form civil works will be enormous, and it is in such areas that concessions will be required:

The photo above shows existing under street transformer vault with limited dimensions for replacement transformers. If a transformer were not readily available which could fit into the existing space available then the customer would remain without power for a considerable period should a fault occur, and this would be unacceptable.

For Power Transformers the main issues were size and weight for transport and installation, as above certain dimensions the very large Power Transformer will not fit through tunnels or onto trains. Additionally, if being installed in existing substations there may not be space.

Such issues are extensively covered in CNEELEC Standards.

Additionally, the issue of 'disproportionate costs' issue was extensively covered in the last Tier 2 discussions and VITO Reports.

To date very few (if any) derogations have been requested, which may mean extra costs have been unnecessarily incurred by customers.

b. What was the magnitude of the disproportionate costs quoted? How were these justified?

The overall increases in costs of energy efficient transformers which were to be compensated by the value of losses saved was about 20% of the value of the Transformer.

Accordingly, costs would certainly be 'disproportionate' where the additional costs incurred as a result of the requirement to use larger and heavier low loss transformers was in excess of the full lifetime savings in losses would certainly be justifiable.

So, on that basis additional costs in excess of 20% of the transformer would be a conservative guide.

If such costs are incurred, it means that the customer has paid an extra 20% for no extra benefit.

(See Appendix 3 for further analysis)

c. What are your views on the technical and/or economic justifications quoted to justify the exemption?

Justifications will usually be related to particular sites or transport requirements are easily explained, justified and verified.

Typically, the increases in costs arising from a requirement to use the EcoDesign unit is very high and self-evident.

If such concessions are not available then the work will still be carried out regardless of cost, but ultimately this is at the customers expense e.g., on Power Transformer would not fit through a tunnel so the Transformer parts were made in the factory and then an assembly building erected on site and the transformer manufactured on site prior to installation nearby.

Costs of transport for Power Transformers are now a significant portion of their cost, so further increases in size or weight can be egregious.

d. Do you consider this concession appropriate? what Improvements should be considered for inclusion?

Use of 20% of the transformer cost as a guideline to demarcate excessive costs in specific situations and arising from factors external to the transformer should be included in the EcoDesign legislation.

12) For medium transformers, the regulation currently sets requirements for load and no-load losses separately, whereas these are brought together with the PEI calculation for large transformers. What are your views of utilising the PEI calculation for energy efficiency requirements on medium power transformers? The PEI would be used as a compliment to the absolute values requirements.

As explained in the answer to Q9, PEI is superior to the use of Fixed Losses for Load and No-Load losses, as such fixed losses are based on optimizing efficiency at one load factor, and at any other are sub-optimal.

Furthermore, where it is known that the Load Factor will be radically different e.g. a night storage heating load in an apartment block with EV Charging and Commercial premises on the ground floor, and an overall load factor of (say) 75%, the transformer currently used will still be one which has been optimized for a 32% load factor.

With PEI, high load factor buildings such as this would be designed for a load factor in the appropriate range.

Moreover, as PEI allows trade-off between copper and Iron losses it is better placed to produce an economic design for the transformer when there are restrictions on raw materials or other factors.

It is not clear what is meant by the statement ‘PEI would be used as a complement to the absolute value requirements’; but if it meant that there would be a range of (say) four PEI values corresponding to four sets of Fixed Losses, this would be inappropriate – instead of optimizing using PEI alone, there would instead be a choice between four sub-optimal approaches!

One approach is that PEI should simply be used alone – this is simple and more likely to produce an optimal result.

However, if there are particular benefits to using a restricted set of Fixed Losses, then the utility can simply use the value of PEI to itself calculate the Fixed Loss Levels it favours (and which meet PEI required), and Tender for these Fixed Loses directly. The particular benefits for certain DSOs can be:

- Maintaining consistency with Utility Management of data
- Rationalising product ranges to optimize manufacturing processes and guarantee mass production
- To have a tool for controlling cost changes in raw materials, which have an impact on unit costs
- To control the quality and reliability of mass-produced products
- To facilitate the management of losses at national level between manufacturers

13) What are your views on the possibility of adopting a technology-neutral approach to the minimum requirements set out for liquid-immersed, dry-type and, possibly, electronic transformers?

a. Would a technology-neutral approach be an appropriate way to harmonise regulations and standards across transformer types?

The technologies are different for a purpose and attempts to harmonize regulations are driven by commercial requirements between manufacturers rather than by a need to harmonize energy efficiency.

Due to the specificities of particular technologies, it is unlikely to be possible to harmonize without effectively banning certain technologies e.g. transformer for use in area that requires very high fire performance cannot be substituted for another with lower fire performance, even if losses are less.

The key issue arises because Technologies such as Dry Type which are used in areas of Higher Fire Risk are allowed to have higher levels of losses than say Mineral oil or Ester Transformers.

Dry Type Transformers have higher initial costs and higher losses than liquid type but are required where high fire resilience and no bunding are needed. Consequently, the choice of such a transformer is independent of its level of losses compared to other types of transformers.

They are not the same technologies and should not be compared.

In contrast, Ester and Mineral oil transformers are close substitutes for each other with Ester having somewhat higher costs but greater fire resilience and a higher power density and greater scope to run at higher load for longer periods.

Where high loading is intermittent then the lower required levels of magnetic steel required in Ester transformers will mean that Iron losses will be lower than with mineral oil transformers, so Esters could be considered more energy efficient.

The difficulty lies in the copper losses, where a 630kVA Mineral oil transformer could be replaced with a 400kVA Ester Transformer, as the losses on the 630kVA Mineral oil unit would be fixed at one set of values, but the 400kVA would have only to meet a lower set of values yet could be run at 630kVA for a peak loading produced by an unexpected confluence of EV and HP loads, albeit with higher copper losses. Accordingly, the initial costs of the 400kVA Ester would be lower than with the 630kVA Mineral oil unit.

The Eco-design Directive does require that the nominal losses are based on the expected normal usage but this is difficult to enforce when an ester can be run at a higher sustained loading near permanently.

So, in a choice between a cheaper 400KVA which, if run at 630kVA will have high losses, and a 630kVA which if run at 630kVA will have lower losses, the 400kVA will have lower initial costs, and this is perceived as unfair by mineral oil manufacturers.

However, if the peak load is high, but only occurs for a short period than a 400KVA with less Iron losses which occasionally gets overloaded to 630kVA will likely have less losses overall than a lightly loaded 630kVA with higher Iron losses (depending on the duration of the higher loading levels).

It is not possible, or worthwhile, to remover the possibility that some customers may use smaller Ester Transformers and overload them to the competitive disadvantage of Mineral Oil Manufacturers, whose transformers will be larger for the same level of loading.

In practice the regulation volt drops and higher heating (from internal losses) associated with the Ester Transformers will prevent them being excessively overloaded.

Additionally, for intermittent high loadings they are more efficient and cheaper than the alternative Mineral oil transformers.

In some utilities Ester Transformers are used instead of Mineral Oil transformers as they are considered more environmentally friendly and with less risk of fire and greater scope to cope safely with higher loads.

So perhaps this is an area where the market should make its own choices give the specificities of the particular requirements from the transformer?

b. What approach would you consider be most useful for a technology-neutral regulation? What are your thoughts on using a measurement of minimum efficiency at a specific load?

The minimum efficiency at a specific load is what is currently in the Eco-design Directive where the load is the Transformer rating.

It would be possible to measure the efficiency of a 400kVA Ester Transformer at 630kVA and then require that the Ester Transformer had the same efficiency at 630KVA as a Mineral Oil Unit, but this would effectively mean that a 400KVA ester transformer could not be used economically at 400kVA but only at 630kVA.

For Tier 2 VITO specially advised in their final report to the EU that Ester Transformers would be used where space was limited, and higher power densities were required.

The possible choice between using a 630kVA Ester in a packaged Substation which might need to cope with a peak of 1 MVA, instead of two packaged substations each with a 500kAV Mineral Oil Transformer is clear – it is far more economic to use on ester transformer and one Substation to cope with this possibility, and furthermore the overall losses are likely to be less as the Iron losses from two transformers would exceed those of one transformer with intermittent overload.

14) Are there any existing methodologies you would recommend for assessing technoeconomic aspects of Ecodesign for power transformers (especially in terms of technology neutrality, circularity, MEPS and MMPS)?

No – going further makes a complex subject yet more complex and increases likelihood that the changes proposed will not be as coherent as is required.

15) Alternatively, do you foresee the need to develop new methodologies for any particular technoeconomic aspects of Ecodesign?

Yes – the Discount rate that underpins the justification for energy efficiency is too low- it is a societal discount rate which is the risk free rate used by Govts for inter-generational investments, whereas the costs of increased efficiency are actually met by utilities which have higher discount rates as they raise funds on the market rather than by taxes and have to incorporate financial risk in their assessments.

Additionally, the decarbonisation of the grid has meant that the value of electricity saved from losses is vastly reduced, so that the efficiency levels currently used are likely excessive in the longer term and offer diminishing value to society.

16) What are the technical and economic costs to consider when setting requirements on transformers with a reversed power flow?

Probably none.

The Transformer with reversed power flows will typically be one feeding a load with significant embedded generation, and during some periods the embedded generation may exceed the load and back feed through the transformer.

In older Transformers with outdated tap-changers ('flag' type) this could pose a problem for the tap changer, but for more modern tap changers this is not an issue.

The losses either on forward or reverse feed within the transformer will be based on the overall current regardless of the direction in which it flows, and on the internal resistance within the transformer.

17) What requirements would you suggest including to increase the efficiency and lifetime of transformers when working with reversed power flows?
None!

If the transformer is being reverse fed it is due to excessive generation, nearly invariably from renewables.

So, from a societal point of view any losses within the transformer will not create extra CO_2 emissions nor will they have an energy cost, as their marginal cost of production will be zero.

From a Commercial perspective, if the Renewable Generators have been paid for their export at their terminals and now this export is passing up through the system, with part of it being absorbed in losses along the way, then the Distribution Loss Adjustment Factor applied to the Generator will act to deduct the cost of these losses from the price paid to such generators,

5. Material Efficiency

i) material efficiency aspects;

m) strengthening potential of the existing MEPS and the potential of introducing material efficiency requirements (MMPS).

18) Are there specific measures to be considered to increase the commercial lifetime of transformers?

From a customer (utility) perspective the following changes would increase commercial lifetime:

1. Transformer Capacity:

Transformers seldom fail but instead are changed out when their capacity becomes inadequate. However, there are high costs in changing a transformer, so that if the replaced transformer is old there is a fear that if installed in another substation it may not have a long enough life before it needs to be replaced on fault. Hence such transformers are likely to be scrapped, as the cost of installation coupled with early failure will be excessive.

So having Transformers which can tolerate occasional high overloads (such as esters) would greatly reduce early replacement. Also, larger capacity units can be more easily used in alternative locations, whereas smaller units may be inadequate for use elsewhere.

For replaced Distribution transformers, rust on fins which could result in an oil leak will be the greatest risk and is difficult to repair.

Requirements in the Eco-design Directive which require uprating the loss levels to current values are likely to be uneconomic and result in the transformer being scrapped rather and repaired.

So from Circularity and Critical Materials perspective, repair/refurbishment of the transformer should not be a requirement in the Eco-design regulations.

19) Are there specific materials that should be tracked for transformers due to their potential impact if released into the environment? If so, what measures would you recommend to limit these impacts?

The requirement to bund ester filled transformers when the ester is organic, does not penetrate into the soil and deteriorates naturally is a waste of resources and requires the use of a lot of material and concrete. Any requirement to bund esters transformers should be removed.

In older transformers tests for PCB are routine on scrapping regardless of the transformers declared status.

20) What materials within transformers should be targeted for recycling operations? What sort of quantities can be expected in each transformer? Are there specific critical raw materials that should be tracked?

Copper, Aluminium, Steel – magnetic steel is more difficult to recycle as magnetic steel unless it goes to a dedicated facility specialising in in this area.

21) What is the rate of materials recovered and recycled from power transformers?

High as the material is valuable and are easily recovered. In general Power Transformers can be repaired /refurbished and continue in use for up to a 60+ years, but if any major work is required then if this triggers losses upgrade then the transformer may be scrapped as the lifetime of the other parts of the transformer would not match that of the uprated parts.

22) Material efficiency goals include improving product durability, reusability and recyclability, tracking substances of concern and increasing information requirements. Beyond what was detailed in the questions above, are there any other material efficiency considerations to be had for transformers?

Main issue would be deferral of any recycling as the transformer should be capable of 60+ years lfe, albeit not in some critical usage locations, but possibly at less onerous installations in another country.

From a global perspective having a transformer in use elsewhere is better for the planet than scrapping and attempting to recycle.

6. Environmental considerations

h) the possibility and appropriateness of covering environmental impacts other than energy in the use phase, such as noise and material efficiency.

k) technological, market and regulatory evolutions affecting environmental performance;

23) What are your views on the inclusion of an Ecodesign criteria with regards to noise emissions?

Noise emissions should not be included in Eco-design as noise can be reduced according to how the transformer is installed (e.g., within a building). It is not a requirement to have the transformer itself with low noise emissions.

In any case all EU Countries have quite detailed Noise regulations which are already in place and are adequate.

The proposed inclusion of 'noise emission' in the Eco-design Review list arose from consideration that low loss transformer also tend to have lower noise emissions, but this is just as a by-product of low losses.

It would be dysfunctional to set low noise emissions and then design the transformer Iron and Copper losses to meet the allowed noise levels, possibly contradicting what was required for efficiency.

24) Are the temperature operation range considerations for transformers that should be considered as requirements under Ecodesign? Should the respective cooling systems be considered in this process, notably relating to the cooling mediums and mechanisms employed?
Possibly the range of ambient temperatures for which the transformer can operate should be reviewed in light of more extreme temperatures arising from Climate Change.

In general, if technical changes to transformer design are merited they should be considered in Cenelec standards rather than in Eco-design legislation, as the issues are complex e.g. active cooling in distribution transformers would be uneconomic as maintenance would be required to ensure availability and with tens of thousands of times more Distribution than Transmission transformers it is unlikely to be practical On the other hand designing the transformer for higher temp operation and maintenance costs and will work indefinitely, but has to be considered In conjunction with other alternatives.

To prevent increased viscosity of transformer oil in cold weather, a less viscous oil could be used but this might exclude esters; using an auxiliary heater is also an option but normal Iron losses may also be sufficient.

In short there are multiple alternative options that would need to be considered but these evaluations should be done in a standardization forum such as Cenelec rather than in legislation.

25) What are the climate adaptation considerations with regards to the design and installation of transformers?
Ensure that the Transformer capacity can be increased on site if load requirements increase.
This may require increased power density from the new unit being installed.

26) What are the considerations for Ecodesign with regards to the use of SF6 in gas-insulated transformers?
May be affected by new F-Gas Directive.

SF6 is excellent for use in high rise buildings where fire and explosion proof installations are required, or in underground stations where apartment blocks may be built on top..

Many (<<100) examples in Japan, Hong Kong, Singapore and Australia with one or two in UK.

Very High Land Prices. are required to justify costs.

27) Are there other environmental considerations to be had for transformers?

The requirement to bund ester filled transformers is probably wasteful of concrete and other materials and provides little benefit to society – should be removed.

Excessively high efficiency standards in light of a decarbonized grid means that current Eco-design Regulations will drive further cost increases and material usage and costs for decreasing benefit to society, so that the funds being invested would give a better environmental return if invested elsewhere.

The key environmental issue for transformers in the future is to what extent they restrict the load fed from them, as this may restrict the level of load that can be fed when peak renewable generation is available e.g. if 120% of renewables available to be fed to load but transformer restricts load to 100%, then 20% of renewables is then wasted.

7. Other topics

r) other topics, as emerged from consultations with stakeholders.

28) Are there any other topics not raised in this questionnaire that this regulation review should consider?

Yes.

(a) the application of Eco-design requirements to Transformers used to connect Renewable Generations such as wind and solar farms to the system is inappropriate.

Such Generators produce electricity which is free from carbon emissions, and which has a zero marginal cost of production – this means that there are no benefits to the society or to the Renewable Generator form compliance with Eco-design, and any costs which might arise would be at their expense anyway.

At the time Eco-design was initially being introduced this issue also arose but no representatives from renewable Generators were present and it was decided that to simplify administration they would be required to install energy efficient Transformers complying with Eco Design.

However as large Transformers used to connect Renewable generation are individually produced there were in fact no administrative issues in practice.

(b) the ability to overload transformers too allow connected loads to absorb more renewable energy at peak

Overloading increases losses which was unacceptable when such losses were produced by fossil fuelled generation, but when produced by Renewable Generation and where the inability to overload the transformer means the renewable generation will be lost, that is another matter.

Appendix 1: Impact of a lack of High-Grade Transformer steel

Summary:

High grade steel produces low losses of electricity and is used to produce transformers compliant with higher (so called Tier 2) efficiency requirements mandated by the Eco-design regulation. Currently, such steel is not readily available in Europe and is in short supply, at high prices, from Asia, where it is being diverted for use in Electric Vehicles. Consequently, manufacturers are using higher quantity of low grade, high loss steel instead. However, to meet Tier 2 targets this requires use of a higher quantity of steel in a larger transformer volume, which then requires use of a greater quantity of mineral oil for this same usage. This causes higher CO2 emissions elsewhere and contradicts EU's sustainability objectives. Hence, this is negating the benefits that were foreseen to be achieved from implementation of the higher efficiency requirements as the steel is produced in countries using fossil fired generation and high CO2/kWh, yet the savings in kWh within EU will be in terms of reduced kWh losses but where each kWh saved has a low CO2 content.

This approach will actually result in increased levels of CO2 emissions!

Explanation of the impact of unavailability of low loss Grain Oriented Electrical Steel (GOES) and why it is negating the benefits of the Tier 2 transformers

<u>Impact 1:</u> Substitution of High Grade LOW Loss Steel with HIGHER Loss steel causing increased levels of embedded CO2 during production

Using High Loss Steel to produce Tier 2 Transformers is required when Low Loss steel is unavailable. Furthermore, this requires the use of higher volumes of steel and mineral oil to reach Tier 2 Targets.

The incremental amounts of extra steel and oil for common sizes of Medium Voltage transformers are as follows:

400kVA: +125kg Steel + 24 Litres Mineral oil   Extra Weight for Transport: 146kg

630kVA: + 153kg Steel + 27 Litres Mineral oil   Extra Weight for Transport: 176kg

This extra steel is produced in steel plants which use fossil fuels and grid electricity which, depending on the country of production, could be mainly from coal/oil burning power plant.

This means that the embedded CO2 use in the production of the extra material is very high, yet the savings in CO2 from lower kWh losses will come from a future EU grid which is largely run on renewables.

In short, transformer uses 15- 20% more core steel and is about 10-15% larger in size so that more oil and paper is used, with higher embedded carbon footprint.

Additionally, the higher transport weights result in extra use of fuel during transportation.

So, using this approach the Carbon Emissions from Tier 2 adaptation will actually increase CO2 emissions over those which would have been produced had Tier 1 been used pending the availability of Low Loss Steel.

Additionally at end of life there will be more material which requires to be disposed.

<u>Impact 2:</u> Increased Cost to Customers as Cost/Benefit are no longer in balance with due to the higher lifecycle costs created by the shortage of steel.

The Tier 2 Loss levels were justified on the basis that over the Transformer lifecycle the extra costs of a more efficient transformer would be balanced by the value of the energy savings made.

An increase in transformer costs was expected but was to be in the region of 10-15%, yet figures from ENEL below show that the actual market costs are significantly in excess of these levels (by over 40%) due to the shortage of Low Loss Transformer steel.

During 2021, transformers' prices increased by 40%, mainly due to lack of raw materials and consequently wholesale market prices surged. These price increases affected both existing and new contracts because transformer contracts are generally made on the basis of pass-through costs for raw material prices (- as utilities better able to absorb risk of price increases than manufacturers, this approach reduces tender prices as manufacturers would price in risk at higher cost than utilities).

Those market trends can be easily represented through the 2021 LME (London Metal Exchange) data: dramatic increases for Grain Oriented Electrical Steel (GOES), Aluminium, Copper and Hot Rolled Coil Steel.

	Δ vs Avg. 2020	Δ YTD
GOES	+69%	+64%
Aluminum	+72%	+46%
Copper	+59%	+23%
Steel HRC	+82%	+57%

Having said this, following benefits were envisaged when the Tier 2 efficiency requirement for medium and large power transformers was introduced in the Eco-design directive.

(a) Societal benefits of reduced CO2 emissions from kWh saved plus the lifetime savings in the cost of associated fuel, justified the extra initial capital costs of the transformers
(b) Significant environmental benefits in terms of reduced CO2 emissions

These benefits outweighed the extra initial capital costs for more efficient transformers. Moreover, the low loss steel was expected to become readily available in the EU by 2021 and no supply chain disruption was expected. All these factors had motivated the implementation of Tier 2 requirements for transformers. However, the current shortage not only negates these benefits foreseen but also places the Tier 2 requirement to increase the environmental and economic costs to the society.

Appendix 2 Small Transformers:

			Main Type of Technology used or Functionality												
Study scope	Major subcategory name	Type of Service and Sector	Oil cooled	Dry-type	Gas-filled	MV/LV	HV and/or MV	Phase change	LV/LV	Copper winding	Aluminium winding	Amorphous steel core	S Min (kVA)	S Max (kVA)	S Avg (kVA)
y	MV/LV Distribution transformer	Distribution by DSO	99.99%	0.01%		100%				90%	10%	<100	50	2500	250
y	line voltage restorers	Distribution by DSO		100%					yes	100%			10	50	25
y	DER LV/MV transformers	Connecting DER by producer	20%	80%		100%				80%	20%	0%	50	2500	2000
y	Industry MV/LV oil transformer	Distribution by non DSO (industry, ..)	50%			100%				85%	15%		50	2500	630
y	Industry MV/LV dry transformer	Distribution by non DSO (industry, ..)		50%		100%				15%	85%		50	4000	800
y	Power transformer	Power by TSO (DSO)	100%		0%		99%			100%			5000	>	1E+05
y	Phase	Power by TSO (DSO)	100%		0%			1%		100%			5000	>	1E+05
y	Seperation/isolation transformer	Distribution by non DSO (industry, ..)		100%						100%			1	63	16
y/n	Control transformer	Distribution by non DSO (industry, ..)		100%					yes	100%			0.04	2.5	1.6
n	Safety transformers	Specific ext. applications industry/domestic		100%					yes	100%			0.04	0.25	0.06
n	speciality/consumer transformers	Specific int. application industry/domestic	NA	NA		NA	NA		yes	NA	NA	NA	NA	NA	NA
n	magnetic halogen transformers	Lighting all sectors		100%					yes	100%			0.04	0.63	0.06

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Sustainable Industrial Policy – Building on the Ecodesign Directive – Energy-Using Product Group Analysis/1

Report

LOT 2: Distribution and power transformers
Draft Tasks 1 – 5 Report

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P24:

Another category of smaller industrial transformers are Isolation (Separation) Transformers or Safe Extra Low Voltage (SELV) (control) external power supply transformers (e.g. 24 VAC). The first screening indicated that the smaller industrial transformers cause very low impact (<0.4 TWh) and this is also confirmed by other studies (Australia). The smaller industrial transformers are constructed according to other standards and are not connected to the medium voltage system.

See p39 – 40 below:

a. **Smaller industrial transformers used in industrial LV electricity distribution.** Please note that although the technical similarities this is a very different products group because the standards are developed within IEC/TC 96 and these products are not made by distribution transformer manufacturers**.** Identified categories are:

   i. **Separating transformer**: Is a transformer that has primary and secondary windings electrically isolated by means of basic insulation (Figure 1-8), 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 not that this is not common practice in industry and they are only used in cases of strong safety and availability requirements.

   ii. **Isolating transformer:** 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 not that this is not 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.

b. **Smaller industrial transformers used with industrial applications:**

   i. **Safety transformers** used to supply safety extra low voltage (SELV) circuits (safety voltage ≤ 50 V) with an external power supply. Those are most often single phase transformers from as little as 0.6 VA. Please note that such transformers with a power supply up to 250 W were already studied in the finalized lot 7 Preparatory Study on 'External Power Supplies and Battery Chargers[10]'

   ii. **Special transformers incorporated in industrial equipment.** In many cases the electrical power is transformed within the industrial equipment similar to much household equipment (TVs, ICT, ..). Some known applications are welding equipment, corona treatment equipment, DC power supplies, ..It should also be assessed if the improvement potential is at transformer level or within the system or application. US NAICS (North American Industry Classification System) Code 335311 (Power, Distribution, and Speciality Transformer Manufacturing) which names fluorescent lamp ballasts, machine tools, high-intensity light transformers, electric furnaces, rectifiers, and ignition systems as other examples of specialty transformers.

c. **Smaller transformers used in or with consumer products: (LV-LV AC to AC or LV-LV AC to DC).** They are mentioned here for the sake of completeness. Many small transformers are used for power supply units of appliances, electronic devices and UPS. They are addressed in the Ecodesign Directive context together with the related products. For more information the product related Ecodesign studies should be consulted.

Please note that although the technical similarities these smaller industrial transformers are a very different products group because the standards are developed within IEC/TC 96 or other product or application standards. These products are not made by distribution transformer manufacturers. The smaller transformers themselves are all technical very similar, the difference is often only in the insulation layer between the primary and secondary winding and the output voltage in the case of a control transformer.

Appendix 3 Use of Disproportionate cost in the application of EcoDesign Legislation:

If a decision is clearly uneconomic then it would clearly not be the intention of Eco-design legislation to support it, as the purpose of Eco-design legislation is to increase societal benefits overall.

However, in practice it can be very difficult to create legislation that is perfect in all cases and unusual cases can occur. Even then it may not be economic or worthwhile to treat these cases differently – in fact treating the exception could be more costly due to extra administration involved.

In the establishment of appropriate losses levels, the societal benefits from reduced losses (less Cos2 emissions, savings in fossil fuel costs) from better designed transformers are matched against the extra costs involved, and an appropriate balance is then struck in the legislation.

However unusual levels of extra costs can occur in particular situations where extra installation costs can be incurred due to increased size or weight which can be difficult to accommodate.

In such situations the extra costs of installation can greatly outweigh any savings from losses, and it would be inappropriate to impose such disproportionate excess costs on customers.

However, there is currently no simple definition of 'disproportionate cost'.

As the expected level of extra material costs in Tier 2 were initially expected by VITO to be about 20% and then reduce somewhat over time, one approximation could be that 20% of the transformer purchase cost is an upper limit of the extra costs that could be justified from a loss reducing transformer, on the basis that at worst this transformer would then impose an extra cost of no more than 20% on customer i.e. The overall cost of the transformer installation including excess costs would then be up to be 140% of the Transpower price but of the extra 40%, 20 % would be paid back from loss savings and up to a further 20% would be carried by society as an unavoidable by-product of reducing losses and which was generally not worth attempting to avoid.

Accordingly, if the extra installation costs) which could not be considered by VITO as they are particular to each class of installations, and do not form part of the product itself), were in excess of 20% then this could acts as a simple indicator or excess costs.

Such instances could arise where the transformer would not fit though the existing door into the substation and civil works and new door needed to be put in place, where the ope into the Underground substation or the basement itself was not large enough to accommodate the transformer, or where the weight on the pole was excessive and required a new platform, and were costs of these works was > 20% of the transformer cost, then a transformer with higher loss levels could be used e.g. Tier 1 if possible.

Currently there is no simple test for 'disproportionate' costs but adaptation of 20% extra cost would be a clear method, easily verified and justified.

It would then be up to the utility to decided what they wanted to do where costs were in excess of 20% of transformer costs – the instances could be ignored as not material overall and not worth the administrative costs of pursuing, or alternatively a derogation could be requested where it was economic to implement e.g. for a particular class of transformer used ina particular type of installation.

The 20% figure is a clear point of demarcation for disproportionate costs and makes justification for a derogation simple to assess and justify to the local Regulatory authority.

Currently there is no figure for what ‘disproportionate costs’ means.

Eurelectric pursues in all its activities the application of the following sustainable development values:

Economic Development

- Growth, added-value, efficiency

Environmental Leadership

- Commitment, innovation, pro-activeness

Social Responsibility

- Transparency, ethics, accountability

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