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

LOT 2: Distribution and power transformers
Draft task reports
Task 1: Definition

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Important note:
This report contains the updated draft results of research by the authors and is not to be perceived as the opinion of the European Commission.
This is an updated draft document intended for stakeholder communication.

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0 INTRODUCTION

VITO and BIO IS are performing the preparatory study for the new upcoming eco-design directive for Energy Using Products (EuP) related to power and distribution transformers, on behalf of the European Commission (more info http://ec.europa.eu/enterprise/eco_design/index_en.htm).

The EuP Directive (2005/32/EC) provides coherent EU-wide rules for eco-design. The Directive does not introduce directly binding requirements, but defines conditions and criteria for setting requirements regarding environmentally relevant product characteristics and allows them to be improved quickly and efficiently. Products that comply with these requirements may have the CE mark attached, those that do not comply could ultimately be prohibited from being traded within the EC. It contributes to sustainable development by increasing energy efficiency and the level of protection of the environment, taking into account the whole life cycle cost.

The MEEUP methodology (Methodology for the Eco-design of Energy Using Products) allows the evaluation of whether and to which extent various energy-using products fulfil the criteria established by the EuP Directive for which implementing measures might be considered. The MEEUP model translates product specific information, covering all stages of the life of the product, into environmental impacts.

The preparatory phase of this study is to collect data for input in the MEEUP model.

Background colour code is in the draft report:
Requires special attention from stakeholders
Attention because update or verification is needed

1 DEFINITION

Scope: The objective of this task is to discuss definition and scope (from a functional, technical, economic and environmental point of view) for the eco-design preparatory study for the ENTR Lot 2 and to define the product category and the system boundaries of the 'playing field'. It consists of the categorisation of distribution and power transformers according to Prodcom categories (used in Eurostat) and to other schemes (e.g. EN standards), description of relevant definitions and of the overlaps with the Prodcom classification categories, scope definition, and identification of key parameters for the selection of relevant products to perform detailed analysis and assessment during the next steps of the study. Discussion of products definition and scope issues also includes an analysis of product-system interactions in relation to the products' environmental impacts and potential improvements.
Further, harmonised test standards and additional sector-specific procedures for product-testing will be identified and discussed, covering the test protocols for:

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

Finally, this task will identify existing legislations, voluntary agreements, and labelling initiatives at the EU level, in the Member States, and in the countries outside the EU.
This task will also classify Lot 2 equipment into appropriate product groups while providing a first screening of the volume of sales and stock, environmental impacts and improvement potential for these products.

Summary of Task 1:
Transformers were defined for use in the electrical transmission and distribution systems.
These transformers can be segmented according to application. They can be installed by Transmission System Operators (TSO), Distribution System Operators (DSO) or alternatively by the industrial or the tertiary sector end user themselves. Distribution Transformers are installed by a DSO or end user and provide most often connection to the Low Voltage (LV) distribution grid (230/400 VAC). These transformers include those used for connecting Distributed Energy Resources (DER) such as wind turbines. Transformers installed by a TSO are also referred as Power Transformers, they are used in the Medium Voltage (MV) and/or High Voltage (HV) grid. 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). These transformers will be subjected to a first screening in this chapter but more market data is needed. Apart from application transformers can be further segmented according to technology or functionality, see Figure 1-1.
Transformers are rated in kVA or apparent power, the range per application is included in Figure 1-1. Other performance specification parameters are also described in this chapter. The most important efficiency parameters are no-load and load losses. For oil filled distribution

transformers a European standards (EN 50464-1) includes efficiency classes or 'labels' for load losses (Dk, Ck, Bk, Ak) and no-load losses (Do, Co, Bo, A0). For dry transformers there is a harmonised document (HD538) with maximum no-load and load losses. Power transformers (> 5 MVA) used in transmission are efficient for many decades (>99,8 %) and there is no improvement potential reported so far. This tasks also identified some other relevant ecodesign or environmental parameters for transformers they are: noise, electromagnetic fields and hazardous substances (oil filling).

		Technology or functionality														
Name	Application	Oil	Dry	Gas	MV/LV	HV and/or MV	Phase change	LV/LV auto	LV/LV isolation (separation)	LV/SELV (control)	Cu winding	Alu winding	High SC impedance (>5%)	Am-steel core	Min kVA	Max kVA
MV/LV Distribution transformer	Distribution by DSO	99,99%	0,01%		100%						90%	10%		<50	50	2500
line voltage restorers	Distribution by DSO		100%					100%			xx				10	50
DER LV/MV transformers	Connecting DER by producer	20%	80%		100%						80%	20%	90%	0%	50	2500
Industry MV/LV oil transformer	Distribution by non DSO (industry, ..)	50%			100%						85%	15%			50	2500
Industry MV/LV dry transformer	Distribution by non DSO (industry, ..)		50%		100%						15%	85%	95%		50	4000
Power transfomer	Power by TSO (DSO)	100%		0%		99%					xx				5000	>
Phase	Power by TSO (DSO)	100%		0%			1%				xx				5000	>
Seperation/isolation transformer	Distribution by non DSO (industry, ..)		100%						xx		xx				1	63
Control transformer	Distribution by non DSO (industry, ..)		100%							xx	xx				0,04	2,5
Safety transformers	Industry application		100%							xx	xx				1	63
speciality transformers	Industry application	??	??		??	??					??	??	??	??	??	??

Figure 1-1 Summary table of transmission and distribution transformers

1.1 General context and scope

The overall context of this preparatory study is the electricity transmission and distribution (T&D) system (see Figure 1-2 and Figure 1-3). In the alternating current (AC) electrical supply system that is used in all countries for supply to consumers, the transformer is an indispensable component.

The generated electricity goes through various transformations; e.g. stepping up the voltage in order to transmit over large distances and various levels of stepping down the voltage to its final end-user (domestic, commercial, or industrial use). Transformers convert electrical energy from one voltage level to another. They are an essential part of the electricity network. After generation in power stations, electrical energy needs to be transported to the areas where it is consumed. This transport is more efficient at higher voltage, which is why power generated at 10 - 30 kV is converted by transformers into typical voltages of 220 kV up to 400 kV, or even higher. Since the majority of electrical installations operate at lower voltages, the high voltage needs to be converted back close to the point of use. The main reasons to step down voltage is to increase the safety for the end user and insulation material. The first step down is transformation to 33 - 150 kV. It is often the level at which power is supplied to major industrial customers. Distribution companies then transform power further down to the consumer mains voltage.

In this way, electrical energy passes through an average of four transformation stages before being consumed. A large number of transformers of different classes and sizes are needed in the transmission and distribution network, with a wide range of operating voltages. Large transformers for high voltages are called power transformers. The last transformation step into the consumer mains voltage (in Europe 400/230 V) is done by the distribution transformer.

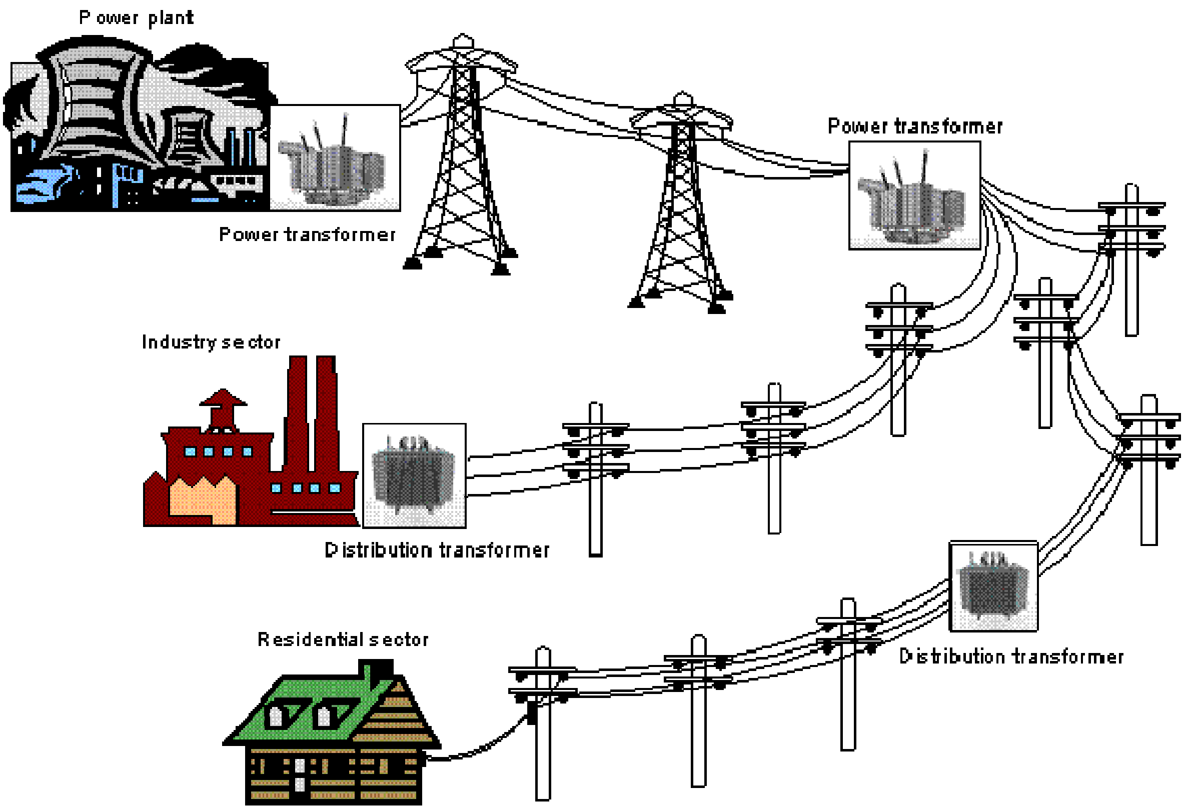

Figure 1-2: Overall context is the electricity and transmission distribution (T&D) system

Transformers are installed at the side of generation and in transmission and distribution (T&D).

The total electrical energy use per annum of the EU-25 is about 2 771.6 TeraWatthours (2005) [TWh] (1 TWh = 10^9 kWh). It is further estimated (Leonardo Energy Transformers, February 2005[1], Eurelectric, 2006[2]) that the losses in all EU's electrical distribution systems are about 200 TWh or 7.2% of the total electrical energy consumed. About 30-35% of these losses are generated in the transformers in the distribution systems, meaning between 60 TWh and 70 TWh, or between 2.4% and 2.8% of total electrical energy consumed (Leonardo Energy Transformers, February 2005[1]).

[1] Leonardo Energy Transformers, 'Potential for global energy savings from high efficiency distribution transformers', February 2005

[2] Eurelectric, Statistics and prospects for the European lectricity sector, December 2006

Transformers can be installed by Transmission System Operators (TSO), Distribution System Operators (DSO) or alternatively by the industrial or the tertiary sector end user themselves. DSO are also called Utilities and they often distributes other commodities such as gas and water. The transmission system is typically operated at higher voltages while the distribution system at lower voltages as schematically represented in Figure 1-3. Industry also frequently uses smaller transformers for isolated electrical grids or 24 VAC power supply for automation equipment.

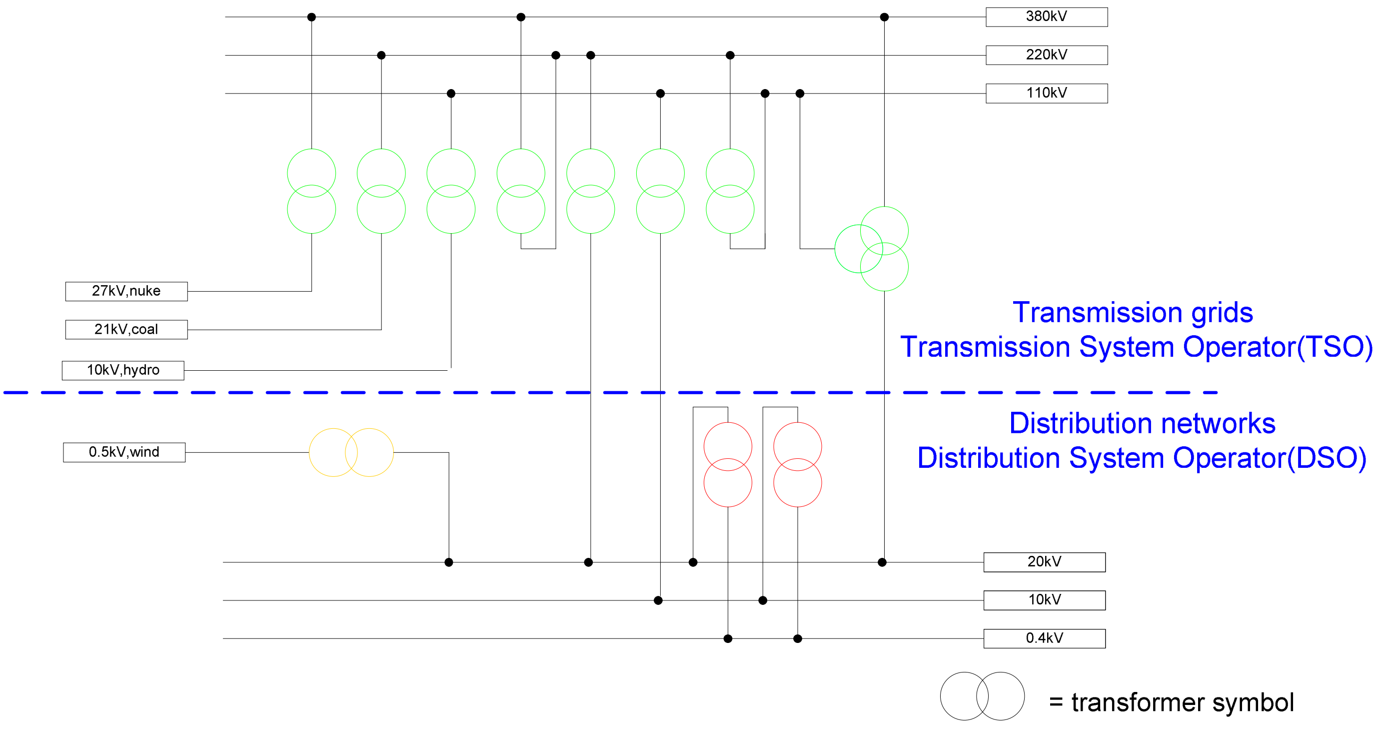

Figure 1-3 Schematic diagram of the electrical Transmission and Distribution (T&D) system

Modern distribution transformers are typically about 98-99% efficient at half load (SEEDT, 2008[3]). This might suggest a low improvement potential to improve their environmental performance. However, due to the very large number of transformers in use in the distribution systems, the total impact of small improvements could provide a significant contribution to reduce environmental impacts, such as global warming and climate change.
Please note that industry sometimes also installes additional transformers in the distrubtion line for safety, lower voltages or special applications.

[3] Strategies for development and diffusion of Energy Efficient Distribution Transformers (SEEDT), Analysis of existing situation of energy efficient transformers – technical and non-technical solutions, 2008)

1.2 Basic concept of a transformer

A transformer is 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 (IEC 60050).

The construction of a transformer (Figure 1-4) comprises two active components: the ferromagnetic core and the windings. Within the transformer industry, the core and windings together are normally referred to as the “active part”. The passive part of a transformer is the cooling system, e.g. consisting of a tank and the cooling liquid. A transformer uses the core's magnetic properties and current in the primary winding (connected to the source of electricity) to induce a current in the secondary winding (connected to the output or load). Alternating current in the primary winding induces a magnetic flux in the core, which in turn induces a voltage in the secondary winding. A voltage step-down results from the exchange of voltage for current, and its magnitude is determined by the ratio of turns in the primary and secondary windings. A transformer with 50 primary turns and five secondary turns would step the voltage down by a factor of 10, for example from 1000 volts to 100 volts. The transformer in Figure 1-4 is an example of a typical distribution transformer in the next sections a broader range of transformers will be covered.

Figure 1-4 Exploded view of a distribution transformer

1.3 Identification of the main ecodesign parameters for energy losses and other environemtal impacts

This study will focus on the whole environmental impact assessment of transformers based on ecodesign parameters.

ANNEX I of the ecodesign Directive 2005/32/EC describes these relevant ecodesign parameters.
For each phase of the life cycle of transformers, the following environmental aspects are to be assessed where relevant:
(a) predicted consumption of materials, of energy and of other resources such as fresh water;
(b) anticipated emissions to air, water or soil;
(c) anticipated pollution through physical effects such as noise, vibration, radiation, electromagnetic fields;
(d) expected generation of waste material;
(e) possibilities for reuse, recycling and recovery of materials and/or of energy.

Note: It is quite common to have Minimum Energy Performance Standards for these transformers globally, see also section 1.8.
Hence, the most prominent focus when analysing the environmental impact of Energy using Products (EuPs) was currently on the use phase and energy use, for transformers being electricity use.

A Life Cycle Assessment (LCA) method will be used based on the MEEuP Methodology report (see project website) which is commonly accepted for these studies.
The MEEuP methodology report summarises environmental impact into 14 environmental indicators (and 2 auxiliary parameters). These environmental indicators are *Energy*, *Water (process & cooling), Waste (hazardous & non-hazardous), Global Warming Potential (GWP), Acidification Potential (AP), Volatile Organic Compounds (VOC), Persistent Organic Pollutants (POP), Heavy Metals (to air & to water) carcinogenic Policyclic Aromatic Hydrocarbons (PAH), Particulate Matter (PM) and the Eutrophication Potential of certain emissions to water (EP)*.
Other environmental parameters are treated on an ad hoc basis or derived from one or more of the indicators that are quantified.
In line with ANNEX 1 the *ad hoc environmental parameters* identified for transformers are:
1. Noise
Transformers can produce a 50 Hz humming noise which might cause nuisance or discomfort, e.g. when installed in the basement of an apartment building.
Please note that transformer noise is regulated in standards
2. Electromagnetic fields (EMF)
Transformers produce extremely low frequency (ELF[4]) fields of 50 Hz.
3. Use of hazardous materials in transformers
Some transformers contain hazardous materials, they are:

- Some products in operation may still comprise polychlorinated biphenyls or *PCBs*, however it is not allowed anymore in new transformers.
- Oil filled distribution transformers mostly contain *Synthetic transformer oil* if released into the environment in the case of a fault, pollutes the ground and will possibly jeopardise the ground water. In this case Biodegradable insulating/coolant liquid may

[4] http://www.who.int/peh-emf/about/WhatisEMF/en/

be used that is biodegradable and not water pollutant and furthermore has a much higher flash point than the mineral oils traditionally used.
- Some power transformers use *Sulphur hexafluoride (SF6) gas* and they are sometimes referred to as a gas-insulated (GIS) transformer. It could be an environmental issue because its strong impact on global warming (1 SF6 = 23.600 CO2).

All above aspects will be discussed in details in the next tasks, especially Tasks 3 and 4. The environmental assessment carried out in Task 4 will allow to identify impacts for 13 environmental indicators during the whole life cycle of transformers.

This Life Cycle Assessment approach would ensure that all relevant environmental impacts will be analysed, and that any tradeoff, when assessing the improvement options in task 6, will be identified.

Stakeholders please report any other environmental impact parameter to be addressed here!

Background info on energy losses in transformers:

Transformer efficiency losses consist of:
- *No load losses (Po)*: these losses occur when the secondary circuit is open and the primary one is at its rated voltage (HV). In that case there is only a small primary current and joule effect losses are negligible. No-load losses are composed of:
  - Hysteresis losses, caused by the frictional movement of magnetic domains in the core laminations being magnetized and demagnetized by alternation of the magnetic field. These losses depend on the type of material used to build a core. Hysteresis losses are usually responsible for more than a half of total no-load losses (50-70%).
  - Eddy current losses, caused by varying magnetic fields inducing eddy currents in the laminations and thus generating heat. These losses can be reduced by building the core from thin laminated sheets insulated from each other by a thin varnish layer to reduce eddy currents.
  - There are also marginal stray and dielectric losses which occur in the transformer core. Stray losses, due to stray magnetic fields, cause eddy currents in the conductors or in surrounding metal. Dielectric losses in the insulating materials - particularly in the oil and the solid insulation of high voltage transformers. They account usually for no more than 1% of total no-load losses.
- *Load losses (Pk)*: these losses occur when the secondary circuit is short-circuited and the primary is supplied at rated current (S/LV). These losses are commonly called copper losses or short circuit losses. Load losses are composed of:
  - Ohmic heat loss in the transformer windings, sometimes referred to as copper loss or Joule effect losses. The magnitude of these losses increases with the square of the load current and is proportional to the resistance of the winding.
  - Conductor eddy current losses. Eddy currents are caused by the magnetic fields of alternating current. They also occur in the windings. Amongst others, stranded conductors are used to lower the eddy current loss.

- *Auxiliary losses (Paux)*: These losses are caused by using energy to run cooling fans or pumps which help to cool larger transformers.

Background information on negative health effects of Electric and magnetic fields (EMF) from power lines and transformers (source EPA[5] (2009):

EMF is commonly associated with power lines. Many people are concerned about potential adverse health effects. Much of the research about power lines and potential health effects is inconclusive. Despite more than two decades of research to determine whether elevated EMF exposure, principally to magnetic fields, is related to an increased risk of childhood leukemia, there is still no definitive answer. The general scientific consensus is that, thus far, the evidence available is weak and is not sufficient to establish a definitive cause-effect relationship.
In 1998, an expert working group, organized by the National Institute of Health's National Institute of Environmental Health Sciences (NIEHS), assessed the health effects of exposure to extremely low frequency EMF, the type found in homes near power lines. Based on studies about the incidence of childhood leukemia involving a large number of households, NIEHS found that power line magnetic fields are a possible cause of cancer. The working group also concluded that the results of EMF animal, cellular, and mechanistic (process) studies do not confirm or refute the finding of the human studies. The International Agency for Research on Cancer (WHO) reached a similar conclusion.

1.4 Methodology of this study

This study will follow a methodology common to all the EuP preparatory studies: Methodology for Eco-design of Energy-using Products (MEEuP). An overview of the 7 task structure of the study is presented in the following Figure 1-5. The results of each task are included in chapters with the same numbering. The methodology used is the same as that approved by the European Commission for all EuP preparatory studies. For further details on the methodology, see the MEEuP final report that is available on the project website (www.ecotransformer.org).

[5] http://www.epa.gov/rpdweb01/power-lines.html

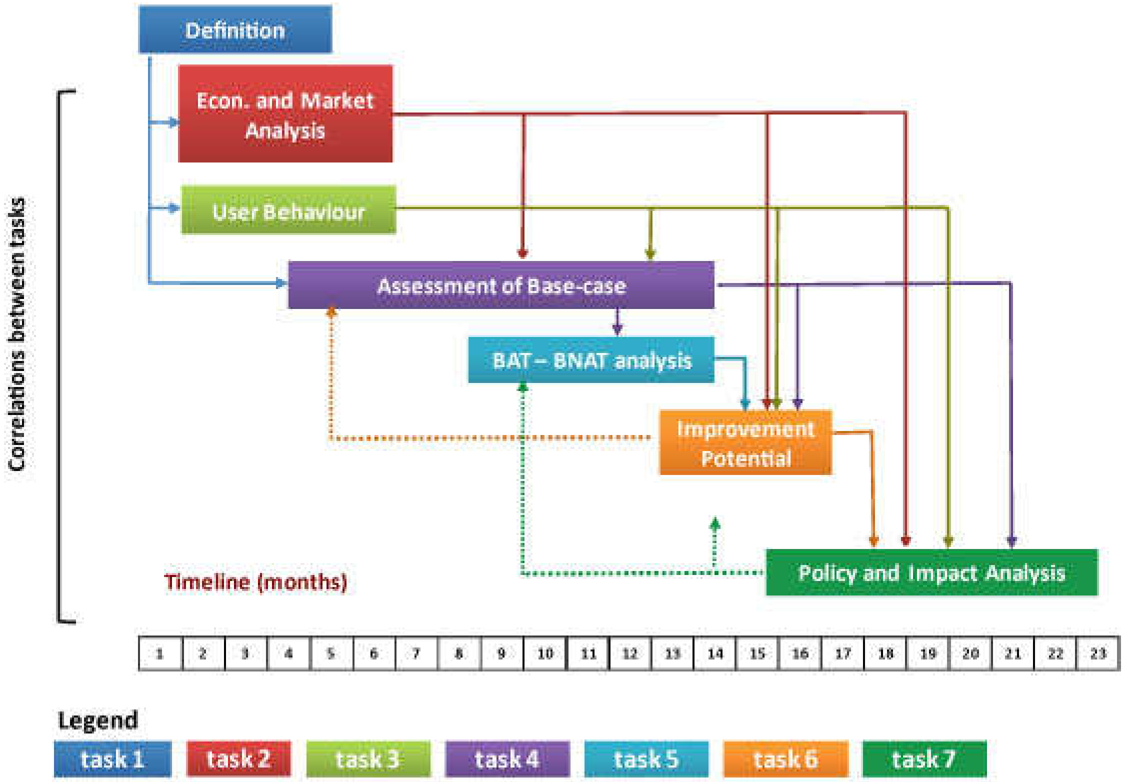

Figure 1-5 MEEuP methodology and planning of this study.

1.5 Product definition

This section defines the categories of products covered by this study and defines the performance parameters.

1.5.1 Key methodological issues related to the product definition

The experience from previous EuP preparatory studies indicates that in order to select a proper product scope and complementary definition from the existing options (e.g. definitions and scopes derived from market statistics, technical standards, and labelling schemes) it is necessary to reflect or match the boundaries of this product with the task requirements of the whole study. This means that the product definition needs to fit:

- Test standards reflecting environmental issues including power consumption measurement procedures (task 1)
- Other performance related standards (task 1)
- Product performance parameters and respective functional unit (task 1)

- Product and technology trends (task 2 and 6)
- Available market data and respective typical market segmentation (task 2 and 4)
- Use environments and respective typical use patterns (task 3 and 4)
- Products design characteristics and respective technical parameters (task 4)
- Environmental impact magnitudes and expected improvements (task 5)

Against this background, the first subtask “product definition” is most critical because it determines to great extent the boundaries of following tasks and the overall result of the study – providing eco-design requirements.

Prodcom will be the first basis for defining the product, since Prodcom allows for precise and reliable calculation of trade and sales volumes in task 2. If the product definition relevant from a technical, economic and environmental point of view does not match directly with one or several Prodcom categories, the study will detail how it is translated into one or several Prodcom categories (or parts of Prodcom categories).

The above existing categorisations are a starting point for defining the product and can be completed by other relevant definition criteria, such as the functionality of the product, its environmental characteristics and the structure of the market where the product is placed (e.g. users, distribution channels or supply chain).

In particular, the definition of the product will also be linked to the assessment of the primary product performance parameter (the "functional unit").

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

The product definition will also take into account whether the product interacts with the installation/ system in which it operates, which may imply:

- that the possible effects of the product being part of a larger system and/ or installation are identified and evaluated regarding environmental impacts and potential for improvement

or

- that the system should be considered as a product, including some parts or incorporating some components, and sub-assemblies as referred to in Article 2 of the Ecodesign Directive.

The suggested product definition will be confirmed by a first screening of the volume of sales and trade, environmental impact and potential for improvement of the product as referred to in Article 15 of the Ecodesign Directive.

Also information on standards, regulations, voluntary agreements and commercial agreements on EU, MS and 3rd country level should be considered when defining the product(s).

1.5.2 Product categories found in PRODCOM

PRODCOM is a system for the collection and dissemination of statistics on production of manufactured goods. It is based on a product classification called the PRODCOM list. It originates from the Europroms[6]-Prodcom[7] statistics database. For distribution transformers it is subdivided according to technology and rated power. Power transformers are subdivided according to their voltage rating.

The PRODCOM classification for transformers is presented in the table below.

Table 1.1: PRODCOM categorisation for transformers

Prodcom Code	Description
31.10.41.30	Liquid dielectric transformers having a power handling capacity ≤ 650 kVA
31.10.41.53	Liquid dielectric transformers having a power handling capacity > 650 kVA but ≤ 1 600 kVA
31.10.41.55	Liquid dielectric transformers having a power handling capacity > 1 600 kVA but ≤ 10 000 kVA
31.10.41.70	Liquid dielectric transformers having a power handling capacity > 10 000 kVA
31.10.42.35	Other transformers, nes, power handling capacity ≤ 1 kVA
31.10.42.55	Other transformers, nes, 1 kVA < power handling capacity ≤ 16 kVA
31.10.43.30	Transformers, nes, 16 kVA < power handling capacity < 500 kVA
31.10.43.50	Transformers, nes, power handling capacity > 500 kVA

Remarks:

- .PRODCOM already subdivide the products according to one performance parameter, its rated power.

- PRODCOM already subdivide the products according to one technological property, liquid or non liquid dielectric transformers.

1.5.3 Subcategories according to the rated power

Transformers are rated based on the apparent power (S) input to the transformer – including its own absorption of active and reactive power (see also definition in section 1.6). Subcategories based on rated power were already defined in PRODCOM, see section 1.5.2.

[6] Europroms is the name given to published Prodcom data. It differs from Prodcom in that it combines production data from Prodcom with import and export data from the Foreign Trade database.
[7] Prodcom originates from the French “PRODuction COMmunautaire”

For any new subcategory defined hereafter new minimum and maximum rated values will have to be derived from related product standards and/or market data. Stakeholders please check minimum and maximum rated power in the concluding Table 1.2.

1.5.4 Subcategories of transformers according to the technology

Transformers can be further subcategorised based on material technological properties. PRODCOM already subdivide the products according to one technological property, liquid or non liquid dielectric transformers. This subcategory is related to the type of cooling medium. Using the product bill of materials, further technological subcategories can be defined by the material used for the coil windings (aluminium, copper) or core (silicon steel, amorphous steel).

Hereafter is a short description of these subcategories. Please note that it is not the purpose to perform a full analysis here in the report nor to enter in the full details of each defined subcategory (e.g. grain oriented vs non grain oriented silicon steel). The detailed technical analysis of the subcategories will be done in tasks 4 and 5. The stakeholders are invited to verify that there are no gaps in between the defined subcategories here.

Short description of liquid dielectric transformers, also called liquid-immersed transformers or liquid transformers or oil cooled transformers

Liquid transformers rely on oil or another liquid circulating around the coils for cooling. Liquid removes heat more effectively than air. Liquid filled transformers are smaller in size than dry-type units for the same power rating capacity and have lower losses due to their better thermal dissipation characteristics. However, many liquids used in transformers are flammable and some older types were toxic. Because of potential fire hazard, these transformers are used in outdoor applications (e.g. distribution transformers).

The identification of the cooling method for oil cooled transformers is expressed by a four-letter code. The first letter expresses the internal cooling medium in contact with the windings. The second letter identifies the circulation mechanism for internal cooling medium. The third letter expresses the external cooling medium. The fourth letter identifies the circulation mechanism for external cooling medium. The following cooling methods exist:

- ONAF: Oil Natural Air Forced
- OFAN: Oil Forced Air Natural
- OFAF: Oil Forced Air Forced
- OFWF: Oil Forced Water Forces

Other combinations are also possible (e.g. ONAN, ..)

Short description of non liquid dielectric transformers

Most common non liquid transformers are *Dry-type transformers*, which use the natural convection of air for insulation and cooling. Dry-type transformers are divided into different temperature classes which are related to maximum permitted temperature increases of the transformer windings (e.g. temperature class H corresponds to a max operating temperature of 180°C). Dry-type transformers are more commonly used in indoor applications, e.g. smaller industrial transformers.

In large power transformers (>25 MVA) gas-filled transformers are also used. It is a transformer whose magnetic circuit and windings are enclosed with an insulating gas. Sulphur hexafluoride (SF6) gas is generally used. Such a transformer is sometimes referred to as a *gas-insulated (GIS) transformer*.

1.5.5 Subcategories according to the type of service

Transformers are also classified in categories depending upon the type of service:

- **MV/LV Distribution transformers installed by DSO** refer to any transformer that takes voltage from a primary distribution circuit and "steps down" or reduces it to a secondary distribution circuit or a consumer's service circuit at e.g. 400 VAC or 230 VAC with an input voltage of at least 1.1 kV. Distribution transformers can vary in size, with the most common ranging from 50 kVA to 2.5 MVA, with an input voltage between 1.1 and 36 kV. (EN 50464-1). Distribution transformers are operated by the DSO (Distribution System Operator) or Utilities. Sometimes these transformers are also referred as *Utility transformers*. Those transformers are three phase transformers. International standards are developed within IEC/TC 14 and CENELEC CLC TC 14..
- **DER LV/MV connecting transformers** are used to connect DER to the distribution grid, e.g. wind turbines, photovoltaic, fuel cells, .. They might be designed with higher rated power than Distribution transformer (especially for wind turbines). Those transformers might also be optimised for a particular load profile and shape for integration (e.g. wind turbine). International standards are developed within IEC/TC 14 and standard IEC 60076-16 is in progress.
- **MV/LV distribution tranformers installed by non DSO (industry, ..)** are used by the industry to purchase electricity at high voltage (HV) or medium voltage (MV) grid and step it down for use on site at Low Voltage (230/400 VAC). The size of industrial transformers are higher compared to distribution transformers. These transformers connect to the DSO. Also the tertiary sector (e.g. large retailer stores, office buildings, ..) frequently installs these transformers. They range from 100 kVA until 4 MVA. Please note that smaller industrial consumers are connected to the distribution grid and transformers. International standards are developed within IEC/TC 14 and CENELEC CLC TC 14. Sometimes these transformers are also referred as *Industry transformers*.
- **LV/LV distribution autotransformers installed by DSO** have a secondary voltage which is higher than the primary voltage. They can be installed as **line voltage restorers** in the 230 VAC distribution grid, typical in rural grids with long distribution lines and few users. These transformers are so-called autotransformer, it is a transformer with primary and secondary windings that have a common part. The size ranges from one single connection (10 kVA) until the minimum distribution transformer (50 kVA). Transformers can be single or three phase. Please note that this is a very different products group because standards are developed within IEC/TC 96 and the products are not made by distribution transformer manufacturers. .
- **Power transformers installed by TSO (DSO)** refer to those transformers used between the generator and the distribution circuits and are usually rated at 5 to 500 MVA or even higher, with an input voltage mostly above 36kV. They are used in the MV and/or HV electrical grid. It ranges from the maximum size of 2 large distribution transformers (i.e. 5 MVA) until the largest power plant (about 500 MVA). Power

transformers are available for step-up operation, primarily used at the generator and referred to as generator step-up (GSU) transformers, and for step-down operation, mainly used to feed distribution circuits. Power transformers are operated by the TSO (Transmission System Operator). International standards are developed within IEC/TC 14. Sometimes these transformers are also referred as *Transmission system transformers*.

- **Phase-shifting power transformers.** Phase-shifting used in the high voltage grid with special vector groups to compensate for long transmission line electrical effects (phase lag) (e.g. those discussed by standard IEC 62032 on 'Guide for the application, specification, and testing of phase-shifting transformers'). They have similar size as power transformers. International standards are developed within IEC/TC 14. Sometimes these transformers are also referred as *Transmission system transformers*.
- **Converter transformers used in HVDC** can be both in the range of power and distribution transformers as far as rated power and rated voltage are concerned. They are used with rectifiers to convert AC to DC or DC to AC with inverters. Converter transformers are typical used in High Voltage DC (HVDC) transmission. They have similar size as power transformers. They are a special category of power transformers. International standards are developed within IEC/TC 14 (IEC 61578-1).
- **Smaller industrial transformers** that do not connect to the DSO:
    a. **Smaller industrial transformers used in 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, 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 electromechanic 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 transformer**s used to supply safety extra low voltage (SELV) circuits (safety voltage ≤ 50 V) with an external power supply. Those are identical to lot 7 and hence should be excluded from the scope. Those are most often single phase transformers from as little as 0.6 VA. Please note that these transformers were already studied in the finalized lot 7 Preparatory Studu on 'External Power Supplies and Battery Chargers[8]'
   ii. **Speciality transformers incorporated in industrial equipment.** In many cases the electrical power is transformed within the industrial equipment simular to many household equipment (TVs, ICT, ..). Some known applications are welding equipment, corona treatment equipment, DC power supplies, .. Stakeholders are welcome to provide us more information on types of applications, volume and impact and improvement. It should also be assessed if the improvement potential is at transformer level or within the system or applicattion.

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 and these products are not made by distribution transformer manufacturers.

1.5.6 Any other functional subcategories of transformers not defined before

Depending on the wiring transformers can be either *three phase* or *single phase* transformers.
One can discriminate *pole* and *non pole mount* distribution transformers.
Oil filled transformers with *biodagradable* or *synthetic oil*.
For energy efficiency please consult the section on standards.

Stakeholders please check of any other category is needed here (please consider especially ecodesign parameters).

1.5.7 Proposed scope of this study and first screening of the results.

When defining the system boundaries, the following elements should be taken into account:

- To define transformers with similar characteristics, e.g. type of technology and apparent power, in order to be able to derive meaningful conclusions regarding design options, improvement potential and finally potential policy options in later tasks or chapters.
- To define and identify product groups, e.g. type of service and application (industry, household,..), suitable for later legislation, the preference is given to product

[8] http://www.ecocharger.org/

boundaries connected to technical performance parameters. The definition of product groups solely on the basis of application without clear verifiable technical parameters might create loopholes if the proper incentives or installation requirements are missing.

Table 1.2 summarises the previously defined product categories.

Table 1.3 contains the first screening of the volume of sales and trade, environmental impact and potential for improvement of the product as referred to in Article 15 of the Ecodesign Directive. In this screening the focus for the fast impact assessment was on electricity related to the use phase (TWh). Please note that a more detailed analysis will be done in the later tasks. The market data was mainly those obtained from contacting ORGALIME members, a more detailed analysis on market data is in Task 2. More details on the improvement options will be discussed in Tasks 5, the first assessment was done based on the best classes included in related standards (see also the related section in this Task report).

Important notice: Discussing the scope is an important item for the kick-off stakeholder meeting. For the cells in grey background we seek urgently more data in order to perform the analysis. Stakeholders are invited to provide input.

Table 1.2 Summary table on product categories

		Technology or functionality														
Name	Application	Oil	Dry	Gas	MV/LV	HV and/or MV	Phase change	LV/LV auto	LV/LV isolation (separation)	LV/SELV (control)	Cu winding	Alu winding	High SC impedance (>5%)	Am-steel core	Min kVA	Max kVA
MV/LV Distribution transformer	Distribution by DSO	99,99%	0,01%		100%						90%	10%		<50	50	2500
line voltage restorers	Distribution by DSO		100%					100%			xx				10	50
DER LV/MV transformers	Connecting DER by producer	20%	80%		100%						80%	20%	90%	0%	50	2500
Industry MV/LV oil transformer	Distribution by non DSO (industry, ..)	50%			100%						85%	15%			50	2500
Industry MV/LV dry transformer	Distribution by non DSO (industry, ..)		50%		100%						15%	85%	95%		50	4000
Power transfomer	Power by TSO (DSO)	100%		0%		99%					xx				5000	>
Phase	Power by TSO (DSO)	100%		0%			1%				xx				5000	>
Seperation/isolation transformer	Distribution by non DSO (industry, ..)		100%						xx		xx				1	63
Control transformer	Distribution by non DSO (industry, ..)		100%							xx	xx				0,04	2,5
Safety transformers	Industry application		100%							xx	xx				1	63
speciality transformers	Industry application	??	??		??	??					??	??	??	??	??	??

Table 1.3 Table with first impact screening on sales and impact per product category

Name	Avg kVA	Stock 2005 (Kunits)	sales (units)	Pk Avg (sales 2005) Watt	PoAvg (sales 2005) Watt	Pk (Avg % load raw estimate)	Estimated TWh	Pk BAT Watt	Po BAT Watt	Pk (Avg % load raw estimate)	Estimated TWh
MV/LV Distribution transformer	250	3600	140400	3250	650	117	24	2350	300	84,835	12
line voltage restorers	25	??	??	??	??	??	??	??	??	??	??
DER LV/MV transformers	2000	20	2900	??	??	??	??	??	??	??	??
Industry MV/LV oil transformer	630	800	43200	6500	1300	1040	16	4600	600	166,06	5
Industry MV/LV dry transformer	800	170	8047	10000	2500	1600	6	6500	1600	234,65	3
Power transfomer	100000	64,4	1803	300000	80000	12000	52	300000	80000	12000	52
Phase	100000	0,65	17	300000	80000	12000	0	300000	80000	12000	1
Seperation/isolation transformer	25	??	??	??	??	??	??	??	??	??	??
Control transformer	1	??	??	??	??	??	??	??	??	??	??
Safety transformers	25	??	??	??	??	??	??	??	??	??	??
speciality transformers	??	??	??	??	??	??	??	??	??	??	??

1.6 Performance specification parameters

The proposed primary transformer performance parameter is ‘Transformer rated power’ (S).

Transformer rated power is defined as a conventional value of apparent power, establishing a basis for the design of a transformer, the manufacturer's guarantees and the tests, determining a value of the rated current that may be carried with rated voltage applied, under specified conditions (IEC 60050).
The interpretation of rated power according to IEC 60076-1 (§4.1) implies that it is a value of apparent **power input** to the transformer, including its own absorption of active and reactive power.

Proposed secondary functional transformer performance parameters related to energy efficiency and connected to *the transformer itself*:

- *No load losses (Po)*: the active power absorbed when a given voltage at rated frequency is applied to the terminals of one of the windings, the other winding(s) being open-circuited (IEC 60076-1)
- *Load losses (Pk)*: the absorbed active power at rated frequency and reference temperature, associated with a pair of windings when rated current is flowing through the line terminals of one of the windings, and the terminals of the other winding are short-circuited. Further windings, if existing, are open-circuited. (IEC 60076-1)
- *Auxiliary losses (Paux)*: the active power needed for the auxiliary components of the transformer (e.g. fans, pumps…).

Proposed secondary functional transformer performance parameters related to energy efficiency and connected to *the transformer application*:

- *Load Factor (α)* (=Pavg/S) the ratio of the energy generated by a unit during a given period of time to the energy it would have generated if it had been running at its maximum capacity for the operation duration within that period of time (IEC 60050)
- *Load form factor (Kf)*: the ratio of the root mean squared (rms) Power to the average Power (=Prms/Pavg)

- *Transformer availability factor (AF)* determines the availability of the transformer on a given instant of time (mostly on a yearly basis).
- *Power factor (PF)*: the ratio of the active power (kWatt) to the apparent power (kVA).
- *K-factor:* this is a derating factor for a standard transformer used to supply non-linear loads, so that the total loss on harmonic load does not exceed the fundamental design loss of the transformer. For these applications, specially constructed or K-rated transformers should be used (EN 50464-3).

Other relevant performance parameters mainly used for *functional transformer selection*:

- *Short-circuit impedance* (of a pair of windings) IEC 60076-1 : the equivalent series impedance (Z=R+jX), in Ohms, at rated frequency and reference temperature, across the terminals of one winding of a pair, when the terminals of the other windings, if existing, are open-circuited. For a three-phase transformer the impedance is expressed as phase impedance (equivalent star connection). This quantity may be expressed in relative, dimensionless form, as a fraction z of the reference impedance Zref, of the same winding of the pair. In percentage notation:

  $z = 100 * Z/Z_{ref}$

  Where $Z_{ref} = U^2/Sr$

  U is the voltage of the winding to which Z and Z_{ref} belong
  Sr is the reference value of rated power

- *Rated voltage of the high-voltage winding (Vrms)*: the rated rms voltage of the high-voltage winding of the transformer (IEC 60076-1)
- *Rated voltage of the low-voltage winding (Vrms)*: the rated rms voltage of the low-voltage winding of the transformer (IEC 60076-1)
- *LwA dB (A)*: Sound power level of the transformer
- *Vector group*: The vector group provides a simple way of indicating how the internal connections of a particular transformer are arranged. The vector group is indicated by a code consisting of two or three letters, followed by one or two digits. In the IEC vector group code, each letter stands for one set of windings. The HV winding is designated with a capital letter, followed by medium or low voltage windings designated with a lowercase letter. The digits following the letter codes indicate the difference in phase angle between the windings, with HV winding taken as a reference. The number is in units of 30 degrees. For example, a transformer with a vector group of Dy1 has a delta-connected HV winding and a wye-connected LV winding. The phase angle of the LV winding lags the HV by 30 degrees.
- *Insulation temperature class*: The insulation temperature classes determines the maximum operating temperature of the transformer. IEC 60085 defines six temperature classes: A (105°C), E (120°C), B (130°C), F (155°C), H (180°C) and C (220°C).
- *Protection class (IP)*: provides a protection rating for the enclosure of the transformer. It is indicated as IP followed by two digits, the first digit (0…6) represents protection against ingress of solid objects, the second digit (0…8) represents protection against ingress of liquids. (EN 60529).

- *Fire behaviour class*: IEC 60076-11 (Dry type transformers) defines three fire behaviour classes: F0 (transformer suitable for being used in an environment without fire risk), F1 (self-extinguishing) and F2 (by means of special provisions, the transformer shall be able to operate for a given time period if subject to an external fire).
- *Environmental class*: with regard to humidity, condensation and pollution, IEC 60076-11 (Dry type transformers) defines three different environmental classes: E0 (clean and dry environment); E1 (presence of occasional condensation and limited pollution); E2 (frequent condensation or heavy pollution or combination of both).
- *Climate class*: with regard to the minimum ambient temperature to witch transformers can be exposed, the following climatic classes are defined (IEC 60076-11): C1 (transformer suitable for being used with ambient temperature up to -5°C, the transformer can be exposed during transport and storage to ambient temperatures down to – 25°C); C2 (transformer suitable for operation, transport and storage at ambient temperatures down to -25°C)

Rated values are conventional values, guaranteed by the manufacturer under specified conditions (eg as specified in an IEC/EN standard). *Nominal values* are suitable approximate values.

The following paragraphs contain a brief explanation and some background information of the energy related performance parameters.

1.6.1 Functional unit for transformers

Knowing the functional product used in this study, we can now further explain what is called the "functional unit" for transformers. In standard 14040 on life cycle assessment (LCA) the functional unit is defined as "the quantified performance of a product system for use as a reference unit in life cycle assessment study". The primary purpose of the functional unit in this study is to provide a calculation reference to which environmental impacts (such as energy use), costs, etc. can be related to, and to allow for comparison between functionally equal products with and without improvement options. Please note that further product segmentations will be introduced in this study in order to allow appropriate equal comparison.

Different functional units have been used in previous studies for such transformers:

- Functional unit used for the LCA[9] of Power transformer TrafoStar 63 MVA was 1 MVA of the system apparent power.
- Functional unit used for the LCA[10] of Distribution transformer 16/20 MVA was 1 kVA of the system apparent power.

[9] Environmental Product Declaration of Power transformer TrafoStar 63 MVA, http://library.abb.com/global/scot/scot292.nsf/veritydisplay/4af3f4e6a43df7aec1256d630042c2fc/$File/ProductDeclarationStarTrafo63.PDF

- An LCA study of current transformers[11] used the functional unit as to deliver 1 kWh electricity for all material and energy flows allocated to 40 years use of a transformer

There is a link between both system apparent power and transformed energy using the transformer load factor (see also Task 3), the transformer load factor is connected to the application.

Proposal for functional unit: ‘Transformer system apparent power’.

Rational: This proposal could provide a product evaluation at the stage of production making different assumptions on the application or putting into service.

1.7 Measurement and test standards or sector procedures related to primary and secondary functional performance parameters and other standards for the product

Scope:
The first aim of this subtask is to give an overview of existing measurement or test standards and associated test methods for power and distribution transformers considered and to identify needs and requirements for new standards to be developed.
These measurement and test standards or procedures are essential for future legislation and this study, because they allow to quantify the product performance.
Finally the second aim is to describe the other standards for the product.

Background information on European and International standardisation bodies:
EN/CENELEC internal regulations define a standard as a document, established by consensus and approved by a recognised body that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context. Standards should be based on consolidated results of science, technology and experience, and aimed at the promotion of optimum community benefits. The European *EN* standards are documents that have been ratified by one of the three European standards organizations, CEN , CENELEC or ETSI .
In addition to “official” standards, there may be other sector specific procedures for product testing, which could be considered as standards when they have been recognised both by the sender and the receiver, that is, when they are using the same parameters or standards. Those procedures are discussed later in this chapter.
Following the EU’s ‘New Approach’, any product-oriented legislation should preferably refer to harmonised (EN) test standards in order to verify the compliance with set measures. The referenced test standard should be accurate, reproducible and cost-effective, and model as well

[10] Environmental Product Declaration Large Distribution Transformer 16/20 MVA, http://www.environdec.com/reg/e_epd56.pdf
[11] LCA study of current transformers, DANTES project co-funded by the EU Life-Environment Program, http://www.dantes.info/Publications/Publication-doc/DANTES%20ABB%20LCA%20study%20of%20instrument%20transformers.pdf

as possible the real-life performance. If no suitable test standard exists, they need to be developed (possibly based on existing sector specific procedures) for the relevant parameters in the view of implementing measures.
In technical use, a standard is a concrete example of an item or a specification against which all others may be measured or tested.
In the context of this study EN standards are equivalent to IEC standards. Nevertheless it is also possible to have CENELEC and EU27 national standards that are not derived from IEC (e.g. EN 50464 described in 1.7.1.1). *IEC* is an acronym for the International Electrotechnical Commission. Power and distribution transformer standards are developed within Technical Committee 14 (IEC/TC14) on ‘Power transformers’. European technical experts are directly delegated directly within IEC/TC 14. In the US and some other countries standards are developed within the IEEE. IEEE is an acronym for the Institute of Electrical and Electronics Engineers. *IEEE* are not de facto equivalent to IEC standards, they are developed in parallel.
Please note that it is also possible to have national standards in Europe as far as they do not conflict with the harmonised standards.

1.7.1 Test Standards on Energy Use and identified ecodesign parameters

Scope:
A “*test or measurement standard*” is a standard that sets out a test method, but that does not indicate what result is required when performing that test. Therefore, strictly speaking, a test standard is different from a “technical standard”. Namely, in technical use, a standard is a concrete example of an item or a specification against which all others may be measured or tested. Often it indicates the required performance.
However, “test standards” are also (but not exclusively) defined in the “technical standard” itself. For example, an IEC standard for a certain product or process gives the detailed technical specifications, which are required in order to conform to this standard. It also defines test standards (or rather methods) to be followed for validating any such conformity. A standard can be either product or sector specific, and it can concern different stages of a product’s life cycle.

1.7.1.1 European (EN) Test Standards on Energy Use

Standards directly related to the environmental performance of transformers are relevant for this preparatory study and especially for power consumption testing.

EN 60076-1 (IEC 60076-1) ‘Power transformers. General’
The ‘IEC 60076-1’ is the general generic standard for power transformers with European equivalent EN 60076-1. This general standard is applicable for power transformers (including auto-transformers) above 1 kVA single phase and 5 kVA polyphase. It contains requirements for transformers having a tapped winding, required information on the rating plate, the required tolerances on certain guaranteed values,….. Paragraph 10 of the standard defines the requirements for routine, type and special tests (e.g. measurement of winding resistance, short-circuit impedance, no-load loss and current etc).

This standard defines the measurement of the primary transformer performance parameter (S) and secondary functional transformer parameters (Po, Pk, Paux) as defined in section 1.6. Tolerances are also specified in this standard (section 9).
Note: This standards covers a broad range of transformers and is not limited to distribution transformers alone.
Industry experts reported that the accuracy of measurements in official laboratories are +/- 2 % and are reproducible. The procedures to carry out the measurements are clearly described without possibility to deviation.

EN 50464 series under the general title "Three-phase oil-immersed distribution transformers 50Hz, from 50 kVA to 2500 kVA with highest voltage for equipment not exceeding 36kV"
Please note that there is no equivalent IEC standard.
EN 50464 Part 1 defines load losses P_k , no load losses P_0 (and sound power levels) for the concerned distribution transformers.
The efficiency of a transformer is given for any load condition by the ratio between the output power (P2) and the input power (P1):

η= 100. P2/P1 (%)

Because the difficulty to determine the efficiency by direct measurements, it can be evaluated conventionally through the measured losses as follows (EN 50464-1):

$$\eta = 100.\left(1 - \frac{\alpha^2.Pk + Po}{\alpha.S + \alpha^2.Pk + Po}\right) \text{ (\%)}$$

The above mentioned formula is applicable for rated frequency; this means, in most cases, for a frequency of 50/60 Hz (Europe). This formula is applicable in the standard loading conditions of the transformer, this means that the load form factor(Kf), the power factor (PF), K-factor are not taken into account. It is also at the reference temperature.

1.7.1.2 European (EN) Test Standards on other ecodesign parameters

Most of current test standards and legislations are related to energy efficiency, and thus to electricity consumption which has impact mainly on the environmental indicator Global Warming Potential. These standards were described in the previous section .However, this study does not focus on a specific environmental impact and on energy efficiency other ecodesign parameters were identified (see section 1.3). There might also be a relationship between energy efficiency and the other identified transformer performance parameters (see section 1.6).
The relationship with the other ecodesign parameter is included in Table 1.4 Relationship between ecodesign parameter and test standards
.
Stakeholders are invited to provide us information on any relevant standards, status and gaps.

Table 1.4 Relationship between ecodesign parameter and test standards

Performance parameter or Ecodesign parameter	Standard	Status/notes	Gap identified
LwA dB (A): Sound power level of the transformer	IEC 600769-10??		?
EMF (electromagnetic field)	To complete		?
Hazardous substances PCB	To complete		?
Hazardous substances PCB	To complete		?
Hazardous substances PCB	To complete		?
ANY OTHER RELEVANT?			?
			?

1.7.1.3 Sector specific Test Standards

No, the IEC standard is used.
(Stakeholders please comment)

1.7.1.4 National Test Standards within EU27

No, the IEC standard is used.
(Stakeholders please comment)

1.7.1.5 Third country Test Standards and comparison

The above EN with IEC numbers are international standards.

As mentioned before the IEEE issues apart from the IEC standards. The equivalent standard for IEC 60076-1 (2000) is the IEEE C57.12.00 (2006) and IEEE C57.12.90.

Important note on 'rated power' (S) definition: The interpretation of rated power according to IEC 60076-1 (§4.1) implies that it is a value of apparent **power input** to the transformer, including its own absorption of active and reactive power. This is different from the method used in transformer standards based on IEEE C57.12.00 where "rated kVA" is "**the output** that can be delivered at….rated secondary voltage …".

1.7.1.6 Conclusion on the Test Standards on Energy Use and other ecodesign parameters

There are no missing test standards or measurement procedures on energy use identified so far in this study.

When interpreting US data or countries data using IEEE standards one should be aware of the difference in definition in rated power (S)(see 1.7.1.5).
Stakeholders please comment.

The standards on other ecodesign parameters still needs to be analysed for gaps or future needs. Stakeholders are invited to provide input.

1.7.2 Other standards related to the product

Scope:
In this section *any other standard* relevant for the product for the product *regarding the technical, economical and evironmental analysis* to be carried out in this study should be indentified and shortly described.

1.7.2.1 Other standards related to performance for energy use and other ecodesign parameters

These standards should be kept in mind when assessing improvement options later in this study (chapter 5), it is not the purpose to start this analysis here on this relationship here.

The relationship of other relevant standards with the identified performance or ecodesign parameter is included in Table 1.5.
Stakeholders are invited to provide us information on any relevant standards, status and gaps.

Table 1.5 R elationship between performance or ecodesign parameter and standards

Performance parameter or Ecodesign parameter	**Standard**	**Status/notes**	**Gap identified**
Short-circuit impedance	IEC 60076-1 (EN)		?
Rated voltage of the high-voltage winding (Vrms)	IEC 60076-1 (EN)		?
Rated voltage of the low-voltage winding (Vrms):	IEC 60076-1 (EN)		?
Insulation temperature class	IEC 60085 (EN)		?
Protection class (IP)	EN 60529		?
Fire behaviour class	IEC 60076-11 (Dry type transformers)		?
Environmental class	IEC 60076-11 (EN)		?
Climate class	IEC 60076-11 (EN)		?
ANY OTHER RELEVANT?			?

			?

1.7.2.2 Other relevant European (EN) Standards or sector procedures

The other identified relevant European Standards are included in Table 1.6

Table 1.6 Identified other relevant standards related to the product

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 standards 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 60726. 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.	No
EN 60726	IEC 60729	See above remarks	No
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.	The minimum losses in this standard does not mean that significant lower losses can’t be achieved with actual technology.
HD 538.1	No	Title “Three-phase dry-type distribution transformers 50 Hz, from 100 to 2500 kVA, with highest voltage for equipment not exceeding 36 kV” See explanation below.	-Currently an equivalent standard EN 50538 is circulated in the CENELEC national committees for remarks. The final document will be probably validated in 2010. -The maximum losses defined in this document does not mean that

			significant lower losses can't be achieved with actual technology.
To be completed (stakeholders are invited to provide input)	To be completed	To be completed	To be completed

More detailed descriptions on selected standards as referred in Table 1.6 are included hereafter:

EN 50464 series under the general title "Three-phase oil-immersed distribution transformers 50Hz, from 50 kVA to 2500 kVA with highest voltage for equipment not exceeding 36kV"

The object of these documents is to lay down requirements related to electrical characteristics and design of three phases distribution transformers immersed in mineral oil, therefore it assist the purchaser by using uniform tender specification.

In this standard distribution transformers are subdivided into four classes according to load (Pk) and no load (Po) losses per subcategory of transformer.

For example, distribution transformers with a rated voltage of the High Voltage (HV) winding of $\leq$ 24kV are divided into four classes for the load losses (A_k to D_k) and five classes for no-load losses (A_0 tot E_0).

The transformers with a rated voltage of the HV winding of 36kV are divided into three classes for load and no-load losses (A_{036} to C_{036} and Ak_{36} to Ck_{36}). Most efficient transformers are labelled as A class.

In the tables below load and no-load losses for oil immersed distribution transformers with rated voltage of the HV-winding $\leq$ 24kV are presented:

Load losses Pk (W) at 75 °C for Um $\leq$ 24 kV

Rated power	Dk	Ck	Bk	Ak	Short circuit impedance
KVA	W	W	W	W	%
50	1 350	1 100	875	750	4
100	2 150	1 750	1 475	1250	
160	3 100	2 350	2 000	1 700	
250	4 200	3 250	2 750	2 350	
315	5 000	3 900	3 250	2800	
400	6 000	4 600	3 850	3 250	
500	7 200	5 500	4 600	3 900	
630	8 400	6 500	5400	4600	
630	8 700	6 750	5 600	4 800	6
800	10 500	8 400	7 000	6 000	
1 000	13 000	10 500	9000	7 600	
1 250	16 000	13 500	11 000	9 500	
1 600	20 000	17 000	14 000	12 000	
2 000	26 000	21 000	18 000	15 000	
2 500	32 000	26 500	22 000	18 500	

No load losses P (W) and sound power level (Lw) for U $\leq$ 24 kV

Rated power	E0		D0		C0		B0		A0		Short circuit impedance
kVA	P0	LwA	P0	LwA	P0	LwA	P0	LwA	P0	LwA	%
	W	dB(A)	W	dB(A)	W	dB(A)	W	dB(A)	W	dB(A)	
50	190	55	145	50	125	47	110	42	90	39	4
100	320	59	260	54	210	49	180	44	145	41	
160	460	62	375	57	300	52	260	47	210	44	
250	650	65	530	60	425	55	360	50	300	47	
315	770	67	630	61	520	57	440	52	360	49	
400	930	68	750	63	610	58	520	53	430	50	
500	1 100	69	880	64	720	59	610	54	510	51	
630	1 300	70	1 030	65	860	60	730	55	600	52	
630	1 200	70	940	65	800	60	680	55	560	52	6
800	1 400	71	1 150	66	930	61	800	56	650	53	
1 000	1 700	73	1 400	68	1 100	63	940	58	770	55	
1 250	2 100	74	1 750	69	1 350	64	1150	59	950	56	
1 600	2 600	76	2 200	71	1 700	66	1450	61	1 200	58	
2 000	3 100	78	2 700	73	2 100	68	1800	63	1 450	60	
2 500	3 500	81	3 200	76	2 500	71	2150	66	1 750	63	

Please note that all combinations of load and no load classes can be found on the market, more detailed information on the market average will be included in chapter 2.

HD 538.1 series under the general title "Three-phase dry-type distribution transformers 50 Hz, from 100 to 2500 kVA, with highest voltage for equipment not exceeding 36 kV"

The object of these documents is to lay down requirements related to electrical characteristics and design of three phases dry-type distribution transformers, therefore it assist the purchaser by using uniform tender specification.

In this standard distribution transformers a maximum load (Pk) and no load (Po) loss is defined according to the subcategory of transformer.

In the table below load and no-load losses for dry-type distribution transformers with rated voltage of the HV-winding of 12 kV are presented:

Table HD538

	Load losses	No Load losses
	12kV HV winding	12kV HV winding
kVA	W	W
100	2000	440
160	2700	610
250	3500	820
400	4900	1150
630 /4%	7300	1500
630 /6%	7600	1370
1000	10000	2000
1600	14000	2800
2500	21000	2200

It consists of three parts:
HD 538.1 S1:1992/A1:1995 -- Part 1: General requirements and requirements for transformers with highest voltage for equipment not exceeding 24 kV
HD 538.2 S1:1995 -- Part 2: Supplementary requirements for transformers with highest voltage for equipment equal to 36 kV
HD 538.3 (1998) -- Part 3: Determination of the power rating of a transformer with non-sinusoidal current

1.7.2.3 Other relevant EU 27 national (EN) Standards or sector procedures

Stakeholders please inform if there are any relevant standards at national level.

1.7.2.4 Other relevant Third country Standards or sector procedures

The equivalent IEC and IEEE standards are included in Table 1.6.
Other countries are welcome to provide information on equivalent standards, it is also possible to report here any missing standard available in Third countries without equivalent European standard.

1.8 Existing legislation and agreements

This section identifies the relevant legislation and agreements for the products within the scope of this study.
It is divided into three parts:

- Legislation and Agreements at European Community level
- Legislation at Member State level
- Third Country Legislation

Please note that MEPS is an acronym for Minimum Energy Performance Standard.

1.8.1 Legislation at European Community level

For the novel reader it is important to know that Europe adopted the so-called ‘New Approach’ to product regulation and the ‘Global Approach’ to conformity assessment. Detailed information on this approach can be found in the ‘Guide to the implementation of directives based on the New Approach and the Global Approach’ (EC, 2000)[12].
The standard elements of the ‘New Approach’ directives are based on the following principles:

- Harmonisation is limited to essential requirements.
- Only products fulfilling the essential requirements may be placed on the market and put into service.
- Harmonised standards, the reference numbers of which have been published in the Official Journal and which have been transposed into national standards, are presumed to conform to the corresponding essential requirements.
- Application of harmonised standards or other technical specifications remains voluntary, and manufacturers are free to choose any technical solution that provides compliance with the essential requirements.
- Manufacturers may choose between different conformity assessment procedures provided for in the applicable directive.

The following European directives are significant for the products within the scope:

- Directive 89/336/EEC 'Electromagnetic compatibility': Power transformers shall be considered as ‘passive elements’ in respect to emission of, and immunity to, electromagnetic disturbances and are as such exempted. Note: Certain accessories may be susceptible to electromagnetic interference ! (IEC 60076-1)
- Directive 73/23/EEC 'Low voltage equipment': For the purposes of this Directive, ‘electrical equipment’ means any equipment designed for use with a voltage rating of between 50 and 1 000 V for alternating current (and between 75 and 1 500 V for direct current, other than the equipment and phenomena listed in Annex II). This means that they are exempted. If any of the primary and/or the secondary voltage falls within LVD limits it is subject to LVD(stakeholders are invited to provide input).

[12] http://ec.europa.eu/enterprise/newapproach/legislation/guide/document/1999_1282_en.pdf

- List relevant ESRs and related standards potentially overlapping with environmental requirements (noise, emissions, etc.) To be completed.
- Directive 98/37/EC on the approximation of the laws of the Member States relating to machinery. The machinery directive is not applicable for transformers as such but may be applicable on certain accessories (e.g. pumps) (stakeholders are invited to provide input).
- Directive 2002/95/EC on Restriction of the use of certain Hazardous Substances in electrical and electronic equipment (RoHS). (stakeholders are invited to provide input).
- Directive 2002/96/EC on 'Waste Electrical and Electronic Equipment' (WEEE) is not applicable as transformers are not falling under the categories set out in Annex IA.
- Directive 2004/40/EC on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields).This Directive lays down minimum requirements for the protection of workers from risks to their health and safety arising or likely to arise from exposure to electromagnetic fields (0 Hz to 300 GHz) during their work. This can be important for the construction of the transformer station, however it is not relevant for the product on its own.
- Directive 89/106/EEC on the approximation of laws, regulations and administrative provisions of the Member States relating to construction products. To be checked is there any measure on transformer products? (stakeholders are invited to provide input).
- Directive 2005/32/EC on Eco-design. This directive establishes a framework for the setting of ecodesign requirements for energy-using products and amending Council Directive 92/42/EEC and Directives 96/57/EC and 2000/55/EC of the European Parliament and of the Council. It should be noted that this study could result in the adoption of a regulation for distribution and/or power transformers.
- Amending Directive 2008/28/EC on Eco-design. This is an amendment on Directive 2005/32/EC related to the implementing powers conferred on the Commission.

  List of related Ecodesign preparatory studies:

  To be completed

  List of related adopted Ecodesign regulation:

  To be completed

Please note that there are currently no specific requirements on energy efficiency, however this could result from this study within the framework of • Directive 2005/32/EC on Eco-design.

1.8.2 Agreements at European Community level

Minimum performance levels or labelling is included in those European standards or agreements:
- EN 60076-1 (IEC 60076-1) series on 'Power transformers. General'(see also section 1.7 for more details);
- EN 50464 series under the general title "Three-phase oil-immersed distribution transformers 50Hz, from 50 kVA to 2500 kVA with highest voltage for equipment not exceeding 36kV" (see also section 1.7 for more details);

- HD 538.1 series under the general title “Three-phase dry-type distribution transformers 50 Hz, from 100 to 2500 kVA, with highest voltage for equipment not exceeding 36 kV” (see also section 1.7 for more details);
- SEEDT a software and selection guide base. In the European IEE FP7 SEEDT project on ‘Strategies for development and diffusion of Energy Efficient Distribution Transformers’ a guide on ‘Selecting Energy Efficient Distribution Transformers’ (see http://seedt.ntua.gr/). It resulted in an on-line transformers losses calculator that compares energy and euro losses of distribution transformers, taking into account the transformer parameters (e.g. those defined in section 1.6);

Any other stakeholders please provide information. Especially green procurement requirements or public tender requirements (e.g. power transformers) adopted by the sector can be reported here.

1.8.3 Legislation at Member State level

Memberstates please indicate any relevant legislation here that is not covered by EU27 legislation.
Also green procurement requirements or public tender requirements (e.g. power transformers) adopted by the sector can be reported here if they have no European dimension.

1.8.4 Third Country legislation

Scope:
This section again deals with the subjects as above, but now for legislation and measures in Third Countries (extra-EU) that have been indicated by stakeholders as being relevant for the product group.

Stakeholders are invited to provide any information here for the sake of simplicity we already included an overview.

IMPORTANT NOTICE ON THE DIFFERENCES IN INTERNATIONAL LINE VOLTAGE STANDARDS:
All European and most African and Asian countries use a supply that is within 10% of 230 V at 50 Hz, whereas Japan, North America and some parts of South America use a voltage between 100 and 127 V at 60 Hz.
Moreover technical standards differ between both groups including the definition on rated power (S), see section 1.7.1.5.
This difference in line voltage and frequency has an influence on the efficiency of the transformer and the sizing of a domestic grid.
In the US and Japan distribution transformer are generally smaller (e.g. 50 kVA) for a smaller group of houses compared to Europe (e.g. 250 kVA). This is because the higher line voltage allows to transport more electricity with the same wire section in Europe.

As a consequence the one-to-one comparison of minimum requirements and benchmarks makes no sense. A comparison is only included hereafter to demonstrate the technical feasibility to have them in place and to show the trends and content.

It should be taken into account that several non European countries are elaborating or have MEPS for transformers (Australia and New Zealand, USA, Canada, etc.) and these ongoing developments will be followed up. Following is a summary of international initiatives targeting distribution transformers:
There is no such information about power transformers (stakeholders are invited to provide input).

USA
The U.S. Department of Energy has published the final rule for the Distribution Transformers Energy Conservation Standard Rulemaking, 72 FR 58190 (October 12, 2007). The Department has determined that energy conservation standards for liquid-immersed and medium-voltage, dry-type distribution transformers will result in significant conservation of energy, are technologically feasible, and are economically justified.
For those who want more detailed information, a full report and the complete regulation can be downloaded in english[13].
Older requirements in the US referred to NEMA TP 1, but this was perceived as not demanding enough. A comparison is included later in this section.

Canada
Canada follows TP-1 strictly but the mandatory levels apply only for dry type transformers. In Canada the Office of Energy Efficiency (OEE) of Natural Resources Canada (NR-Can) has amended Canada's Energy Efficiency Regulations (the Regulations) to require Canadian dealers to comply with minimum energy performance standards for dry-type transformers imported or shipped across state borders for sale or lease in Canada. The standards are harmonized with NEMA TP-1 and TP-2 standards.
Amendment 6 of Canada's Energy Efficiency Regulations was published on April 23, 2003. The regulation of dry-type transformers has been included in this amendment with a completion date of January 1, 2005. This requires all dry-type transformers, as defined in this document, manufactured after this date to meet the minimum efficiency performance standards.
As far as oil transformers are concerned, Canada has conducted analysis of MEPS implementation potential and found that the great majority of Canadian oil distribution transformers already comply with NEMA TP-1 so the standard would almost have no influence on the market. The yearly MEPS standard impact would only be 0.98 GWh for liquid filled transformers compared to saving potential at 132 GWh expected for dry type transformers. Also, Energy Star products are very actively promoted in Canada.

Australia and New Zealand
Australia "recalculated" the American 60 Hz efficiency standard to its 50 Hz frequency and also extrapolated linearly the efficiencies at the size ratings which are different from USA.

[13] http://www1.eere.energy.gov/buildings/appliance_standards/commercial/distribution_transformers.html

The Australian program for energy efficiency in distribution transformers, executed by the National Appliance and Equipment Energy Efficiency Committee (NAEEEC), works on two levels.
First, there is the Minimum Energy Performance Standard (MEPS), a regulation that bans transformers which do not meet minimum efficiency levels. The MEPS are defined for oil-filled distribution transformers between 10 and 2500 kVA and for dry type distribution transformers between 15 and 2500 kVA, both at 50% load. The MEPS are mandated by legislation, effective 1 October 2004. Under the stimulus of the National Greenhouse Strategy and thanks to the strong will of the parties involved, the creation of the MEPS passed smoothly. The field study to define the scope started in 2000 with the minimum standards written in 2002.
The second track, currently under development, is the creation of further energy efficiency performance standards resulting in a scheme for voluntary 'high efficiency' labelling.
New Zealand follows the Australian regulation for distribution transformers.

Japan
Japan has a different type of distribution system, with the last step of voltage transformation much closer to the consumer. The majority of units are pole mounted single phase transformers. The driver for setting up minimum efficiency performance standards was the Kyoto commitment. Transformers, together with other 17 categories of electrical equipment, should meet minimum efficiencies. In case of transformers, the efficiency is defined at 40% load. Target average efficiency has been defined for the year 2006 (oil) or 2007 (dry type), based on the best products on the market in 2003. This Japanese MEPS is currently the most demanding compared to other regulated ones, and is designed in different way than any other ones. Efficiencies for different products are described by equations (see Table XX).

Table 1.7 Types of distribution transformers in Japan

Transformer type	# of phases / frequency Hz	Rating	Formula for calculating efficiency	Class
Oil filled	1 / 50 Hz		$E=15{,}3 * (kVA)^{0{,}696}$	I
	1 / 60 Hz		$E=14{,}4 * (kVA)^{0{,}698}$	II
	3 / 50 Hz	Up to 500 kVA	$E=23{,}8 * (kVA)^{0{,}653}$	III-1
		Over 500 kVA	$E=9{,}84 * (kVA)^{0{,}842}$	III-2
	3 / 60 Hz	Up to 500 kVA	$E=22{,}6 * (kVA)^{0{,}651}$	IV-1
		Over 500 kVA	$E=18{,}6 * (kVA)^{0{,}745}$	IV-2
Dry type	1 / 50 Hz		$E=22{,}9 * (kVA)^{0{,}647}$	V
	1 / 60 Hz		$E=23{,}4 * (kVA)^{0{,}643}$	VI
	3 / 50 Hz	Up to 500 kVA	$E=33{,}6 * (kVA)^{0{,}626}$	VII-1
		Over 500 kVA	$E=24{,}0 * (kVA)^{0{,}727}$	VII-2
	3 / 60 Hz	Up to 500 kVA	$E=32{,}0 * (kVA)^{0{,}641}$	VIII-1
		Over 500 kVA	$E=26{,}1 * (kVA)^{0{,}716}$	VIII-2

Please note that the diffence between Oil filled and Dry type transformers are related to cooling, see also 1.3.

This scheme is a part of the 'Top runner Program' which either defines the efficiency for various categories of a product type, or uses a formula to calculate minimum efficiency. This program, which covers 18 different categories of appliances, has some major differences compared to other minimum efficiency performance programs. For example, it refers to the average particular manufacturer sold populations while manufacturers or importers who ship less than 100 units in total are excluded, but display obligations must be met regardless of the number of units shipped. The minimum standard is not based on the average efficiency level of products currently available, but on the highest efficiency level achievable. However, the program does not impose this level immediately, but sets a target date by which this efficiency level must be reached. A manufacturer's product range must, on average, meet the requirement. It is not applied to individual products. The program shall deliver approximately 30.3% improvement in efficiency compared to 1999 levels by the target year. Labelling of the products is mandatory. A green label signifies a product that meets the minimum standard, while other products receive an orange label.

China

In China, the standards have been regularly upgraded starting from 1999. S7 and the next S9 have been replaced with new standard S11, which has losses slightly below Europe's AC' level. The MEPS defines allowable levels for non-load and load losses. These standards, approved by the State Bureau of Quality and Technology Supervision, are defined for distribution and power transformers covered in China. They stipulate maximum load and no-load losses for oil immersed types ranging from 30 to 31500 kVA and for dry types in the range from 30 to 10000 kVA. This regulation has quickly changed the market to higher efficiency units.

India

The Indian Bureau of Energy Efficiency (BEE) has analysed the feasibility of a distribution transformer minimum efficiency standard. BEE classifies distribution transformers in the range from 25 to 200 kVA up to 200 kVA into 5 categories from 1 Star (high loss) to 5 Stars (low loss). 5 Stars represents world-class performance. 3 Stars is being proposed as a minimum efficiency performance standard, and is being widely followed by utilities. The scheme is a cooperative venture between public and private organisations that issues rules and recommendations under the statutory powers vested with it. The 5-star program stipulates a lower and a higher limit for the total losses in transformers, at 50% load. The scheme recommends replacing transformers with higher star rated units.

The 12th of January 2009, the Indian authorities, Bureau of Energy Efficiency (BEE), published the project of regulation before the final adoption in March 2009.

Since this date, the manufacturers will have 6 months to apply the requirements of the labelling. In comparison to the EU energy labelling program, the Indian one was voluntary since this time.

The label shall be displayed on every product and available at the point of sale.

To qualify the star rating, the manufacturers are invited to use the Indian standards such as the IS 1180: 1989 for testing conditions of distribution transformers.

The scope of the regulation for dtribution transformer is: oil immersed, naturally air cooled, three phase and double wound non sealed type outdoor distribution transformer of standard ratings of 16, 25, 63, 160, 200 kVA of 11k being manufactured and commercially purchased or sold in India.

For labelling criteria, further information are available here:
http://www.bee-india.nic.in/search.php?id=Distribution%20Transformer

Mexico
Mexico sets MEPS at slightly less stringent levels; 0.1% to 0.2% below TP-1 efficiency. As in Australia, the Mexican MEPS includes voluntary and mandatory elements. The Normas Officiales Mexicanas (NOM) defines minimum efficiency performance standards for transformers in the range from 5 to 500 kVA, and a compulsory test procedure for determining this performance. For each power category, maximum load and non-load losses are imposed.

A conclusion on task 1 is missing, in particular on the preliminary proposed product scope to be discussed at the stakeholder meeting.

1.8.5 Summary on legislation and agreements in EU and Third Countries

The European industry uses currently a standard (EN 50464) for oil-filled distribution transformers and harmonised document (HD 538) for dry-type transformers that includes MEPS. This is not included in legislation so far and is used for procurement specifications only.

A comparison of the different MEPS with EN-50464 is included in Figure 1-6, the efficiency is calculated at 50 % load (source: SEEDT (2008)).

Only in China there are MEPS for power transformers up to 31,5 MVA.

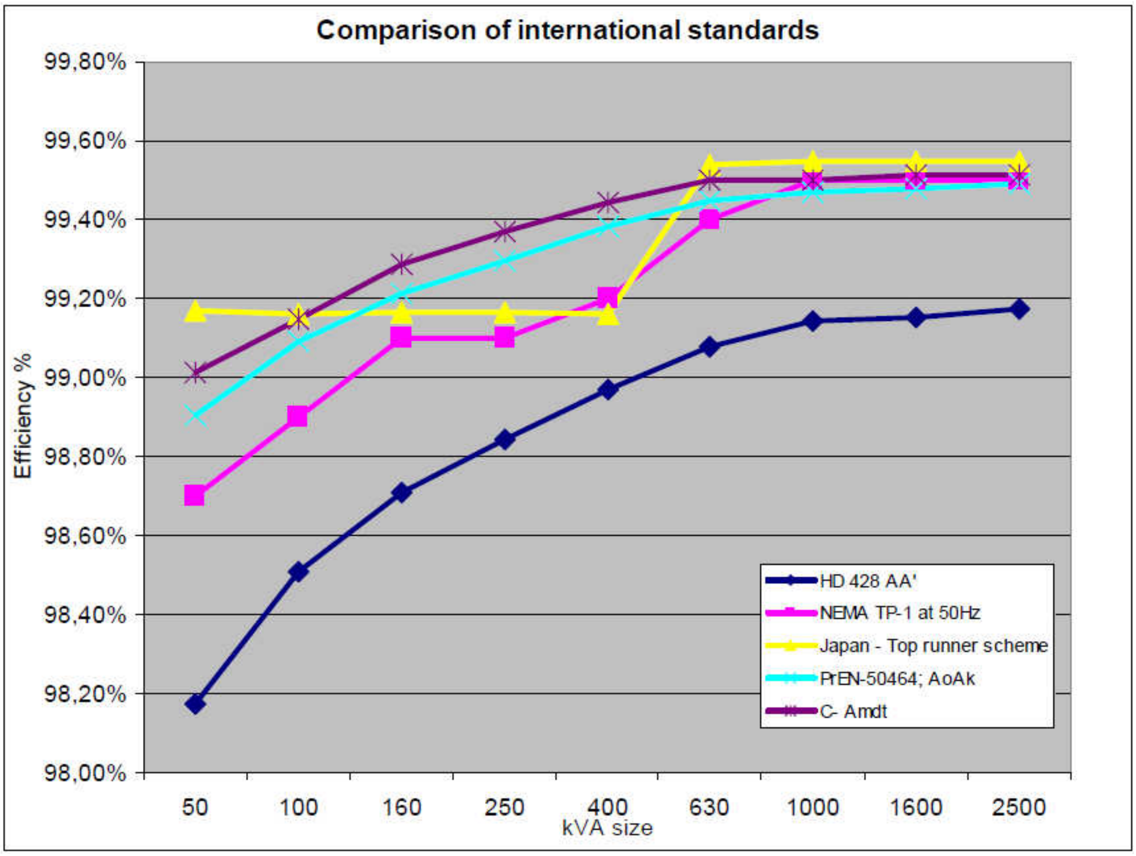

Figure 1-6: Comparison of international transformer standards (Source: SEEDT (2008))

Notes on this comparison:

- These comparison should be handled by care because the definition of rated power (kVA) differs in IEC standards compared to IEEE.
- Moreover, the line frequency and voltage differs in EU compared to US(JP) and this can have an impact on transformer design and efficiency. See notice in the beginning of this section.
- Some MEPS are in efficiency at 50 % load factor, in task 3 it will be shown that it is representative for industry transformers but not for the distribution transformers (20 % load factor). The EN 50464 is more detailed and specifies load (Pk) and no load (Po) losses.
- It is not the purpose to start analysing the performance of transformers here, this will be done in more detail in later Chapters.
- This figure can be updated later, data is changing frequently.