Policies and Measures Fostering Energy-Efficient Distribution Transformers

Report (Final version of Deliverable No. 6) from the EU-IEE project „Strategies for development and diffusion of energy-efficient distribution transformers – SEEDT"

Project No. EIE/05/056/SI2.419632

Wuppertal
June 2008

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Executive Summary

Using energy in an efficient manner is regarded as the most effective and economic contribution to the EU's key drivers of energy policy: Reduction in EU's dependency on foreign primary energy sources, development of a sustainable energy supply and economic growth. As the negative impact of current energy production, transport and distribution and consumption on climate change are reaching critical levels, **technology that is commercially available to increase energy efficiency** should be implemented as fast as possible.

European electricity distribution networks include about **4.5 mln distribution transformers owned by electricity distribution companies, industry and commerce**. They convert electrical energy supplied at medium voltage level (typically from 10 kV to maximum 36 kV) to electrical energy at voltage levels most appropriate for residential, commercial and partly industrial loads. The European distribution transformer fleet is still dominated by traditional technology, avaraging an operating efficiency in Europe of 98.38% and totalling **electricity losses equal to 33.4 TWh/year in EU-27** in 2004. If all existing distribution transformers in EU-27 were replaced by the most energy-efficient ones available today, **55.5%** of these electricity losses (i.e., about 18.5 TWh/year) could be reduced. If current replacement rates are taken into account, **up to 11.6 TWh electricity per year could be saved compared to BAU market behaviour within 15 years**. A large part of these electricity saving potentials is **economical** from the perspective of the whole economy and from the perspective of industry and commerce.

Since the **different market actors face different barriers and obstacles**, these economic potentials have not been realised yet. A **differentiated policy-mix** is needed to adequately address the different barriers and obstacles. Even if the EU has produced an impressive number of energy policy measures on energy efficiency and CO_2 reductions over the last ten years, an integrated framework to accelerate the use of energy-efficient distribution transformers and to support a respective high quality European industry sector does not exist. In contrast, electricity distribution grid losses are often neglected when talking about increasing energy efficiency. The SEEDT project team proposes the following **main elements** of an appropriate policy-mix:

- Changes in the **regulatory schemes** (introducing incentives and removing existing disincentives) to increase energy-efficiency of distribution transformers in **electricity distribution companies**.
  Due to the current regulatory framework in most of the EU-27 countries, only part of the electricity savings potential of energy-efficient distribution transformers is econimically attractive for an electricity distribution company. Therefore, existing disincentives in regulatory schemes should be removed, reporting on transformers and distribution losses should be strengthened, and additional incentives should be introduced.
  For a transition period, as long as regulation schemes are not improved respectively, or as an additional incentive to invest into energy-efficient distribution

transformers, energy-efficient distribution transformers might be included into existing white certificate schemes or should receive separate financial or fiscal support.

- A **bundle of "soft" measures** to particularly address those market actors who lack of information and knowledge or who tend to follow traditional purchasing routines which do not lead to least-cost solutions. These market actors are particularly **small and medium industry and commerce**, but also some **smaller electricity distribution companies, engineering firms, ESCOs, energy consultants and planners**. The bundle of „soft" measures should consist of:
  - The SEEDT project team proposes a **labelling scheme** in order to harmonise and visualise the information to electricity distribution companies, industry and engineering firms (ESCO's) on energy efficiency specifications of distribution transformers, thereby further developing the EN50464 and HD538 loss classes schemes. SEEDT thereby prefers a simplified combined no-load and load losses label. Until a unified European label is introduced, SEEDT recommends that current **nameplates** on transformers include a clear and consistent indication of the loss category according to the current norm, as well as the specific losses as measured during the testing procedure.
  - **Information campaigns** and **training of buyers** are especially needed in small and medium sized industries. In addition, national, regional and local **energy advice programmes** should include energy-efficient distribution transformers as cross-sectoral technology.
  - In order to allow transfomer users to compare financial, electrical and environmental parameters of different distribution transformers, the SEEDT project developed an interactive tool kit, the **Transformer Losses Calculator**, **TLCalc**. The Calculator is available for download and interactive online use at the SEEDT website (http://seedt.ntua.gr).
  - Stimulation of **co-operative procurement** of energy-efficient transformers by electricity distribution companies or other buyers is another instrument to facilitate increased use of energy-efficient transformers. Joint purchase could reduce investment costs and introduce new transformer technology into the European market.
- A European **mandatory standard** would effectively contribute to realising the saving potentials by addressing the same market actors as the bundle of "soft" measures. However, a mandatory standard makes it necessary that the regulation of electricity distribution acknowledges the higher investment costs needed for the more efficient distribution transformers. Standards and labels for energy-efficient distribution transformers are succesfully used in other parts of the world as Australia, Canada, China, Japan, Mexico, and – from 2010 onwards – the USA. A European mandatory standard would help Europe to catch up with the developments in North America and in Asia. The framework of the **Ecodesign Directive** allows to take transformers as a product group for which implementing

measures setting a mandatory standard and a labelling scheme could be designed during the working period 2009-2011 as proposed by the European Commission.

- All market actors can implement **demonstration or pilot projects** together with manufacturers (and their suppliers), but probably larger companies will particularly be prepared to make use of respective **R&D support** provided. The Strategic Energy Technology Plan could ensure that energy-efficient distribution transformer manufacturers and larger buyers could become part of the European Industrial Initiatives that address grid issues.

Up to about **10 TWh electricity savings** could be realised per year by 2025 and compared to BAU market behaviour, if the policies and measures proposed by the SEEDT project were broadly implemented from 2010 onwards using transformer technology that is already available today and at current replacement rates. A **balanced policy-mix** of „hard“ and „soft“ measures, in which adaptation of national regulatory frameworks is the most crucial element, could make a cost-effective contribution to EU’s key policy objectives. **Further analysis** of the full life cycle and environmental impact of the used materials combined with improved data collection and consideration of system integration into „smart grids“ could enhance insight in the contribution of the use of energy-efficient transformers to an efficient European electricity distribution system.

1 Introduction and overview

This report will give an overview on existing and proposed future **policies and measures promoting improvements in energy efficiency of distribution transformers**. Distribution transformers are devices which transform electrical energy supplied at medium voltage level (typically from 10 kV to maximum 36 kV) to electrical energy at voltage levels most appropriate for residential, commercial and partly industrial loads. The European electricity distribution networks include about **4.5 mln distribution transformers**. About 3.6 mln of these units are owned by electricity distribution companies.

Figure 1: Examples of distribution transformers

Source: ABB 2006

On average, in recent years, about 137,000 distribution transformers have been sold annually in Europe. Together with small transformers below 25 kVA and power transformers > 20 MVA, the number of transformers sold in Europe per year exceeds the threshold of 200,000 pieces set by the **Ecodesign Directive**.

Most of the distribution transformers are liquid-filled ones; about 16,000 are dry-type transformers mainly used for specific applications in industry. More than two thirds are units of rated power below 400 kVA (practically up to 250 kVA and few percent 315 kVA units). The newly purchased units are bigger in size. The low power rated category accounts for less than 50% of newly installed transformers. New transformers are either purchased to replace old ones, to take into account of an increase in electricity distributed, or to connect distributed generation.

The European distribution transformer fleet and **market is still dominated by traditional technology**. To date, on average, distribution transformers' operating efficiency in Europe is 98.38%. **Total losses** of conventional distribution transformers are substantial and sum up to **33.4 TWh/year in EU-27**. Energy losses of distribution transformers can be mainly divided into **non-load losses**, which probably account for about 63% of total losses, and **load losses**, which sum up to about 24% of total losses. Furthermore, there are additional losses (harmonic losses, reactive power losses), which are neglected here due to the lower share in total losses (about 13%), and due to the fact that they can hardly be addressed by specific policies and measures. The tables of the European norms (e.g., the EN 50464-1 of 2007) categorising transformers according to their losses also only differentiate between non-load and load losses.

Table 1: European distribution transformer population and market sales in 2004

Transformer type and size		**Fleet EU-25**		**Market EU-25**	
		pcs	**MVA**	**pcs**	**MVA**
Electricity distribution companies liquid-filled*	< 400 kVA	2,639,129	307,230	55,099	6,886
	≥ 400 kVA & ≤ 630 kVA	845,107	432,793	22,944	12,129
	> 630 kVA	125,047	153,891	5,884	7,823
	Subtotal	3,609,283	893,913	83,927	26,837
Industry liquid-filled	< 400 kVA	480,596	64,540	22,887	3,062
	≥ 400 kVA & ≤ 630 kVA	176,119	88,119	8,237	4,140
	> 630 kVA	124,164	168,295	5,893	7,847
	Subtotal	780,879	320,954	37,017	15,049
Industry dry-type	< 400 kVA	38,416	12,419	2,559	519
	≥ 400 kVA & ≤ 630 kVA	67,084	39,906	5,333	2,863
	> 630 kVA	63,968	87,817	7,818	10,718
	Subtotal	169,468	140,142	15,710	14,100
Total		**4,559,630**	**1,355,010**	**136,654**	**55,985**

* Dry-type transformer population in electricity distribution companies is estimated at marginally low level (~ 1% of electricity distribution companies' fleet)

The share of non-load, load and additional losses in total losses of distribution transformers differs depending on the type of transformer and its application in practice. In general, policies and measures should not address one part of the losses (e. g., non-load losses only), because this could lead to sub-optimal solutions. However, identifying and addressing first-best optimum choices is partly difficult. Therefore, while most of the policies and measures address both, non-load and load losses, some of the policies and measures discussed in this report concentrate on the most important non-load losses only.

Technical options to reduce losses of single transformers are the following:

- Applying improved cold grain oriented (CGO) steel, with improved cutting technology, and decreased lamination thickness, with CGO sheets minimum thickness of 0.23 mm
- Optimisation of (aluminium or copper) windings
- Optimisation of core design

- Change from CGO steel technologies (with a crystalline atomic structure) to distribution transformers with amorphous cores (AMDT) (with a non-crystalline, anisotropic atomic structure) (cf. Frau/Gutierrez 2007 for a comparison of both technologies)
- Using superconducting technology.

A detailed description of these possibilities can be found in the respective SEEDT report on technical solutions (Deliverable No. 1) (cf. also Frau/Guitierrez 2007).

Another possibility to reduce losses is on the system level by reducing redundancies within the grid system (i.e. reducing the number of transformers in the grid and increasing capacity utilisation of remaining transformers like it is done by electricity distribution companies in Germany).

If all existing distribution transformers in EU-27 were replaced at once by the most energy-efficient ones available today, **55.5% of energy losses** (i.e., about 18.5 TWh/year) **could be reduced**. However, of course, this is not a feasible solution.

If every time a distribution transformers is bought the most energy-efficient technical option available today was chosen (but leaving out the superconductivity option), **after 15 years** of such replacement and taking expected trend development of the electricity consumption into account, **up to 11.6 TWh electricity per year** could be saved. This is in comparision to the scenario that 2004 market behaviour remains unchanged. Nearly half of these savings could be realised by electricity distribution companies and the other half by industry and tertiary sector. This is equivalent to the output of more than one of the largest nuclear power plants, or the consumption of three to four mln average homes. **If all distribution transformers were replaced by the most energy-efficient ones until 2025, and if every additional transformer bought was the most energy-efficient one available today, up to 17.9 TWh elecricity per year could be saved compared to 2004 market behaviour.** A detailed analysis of technical and economic savings potentials and possible scenarios of realising them can be found in a separate SEEDT report (Deliverable No. 9).

From the perspective of the whole economy or society, and according to assumptions on prices, costs and discount rates set in the SEEDT project (cf. Deliverable No. 9 for details on these assumptions), **most of these electricity savings potentials are economical**, too. However, sensitivity analysis shows that this result strongly depends on the development of prices for energy-efficient transformers and electricity in the future, and on the transformer lifetime assumed. The transformer prices, in turn, are strongly influenced by world market price development for steel, aluminium and copper. Furthermore, the discount rate chosen for the calculations has an important influence on the economics of distribution transformers due to their long lifetime.

Only part of the electricity savings potential is currently profitable from the perspective of an electricity distribution company. This is largely due to the current regulatory framework in most of the EU-27 countries. Therefore, in this report, suggestions for **changes in the regulatory framework** will be the most important element of the policy-mix proposed by the SEEDT project team to overcome existing barriers and obstacles that hinder the realisation of the existing savings potential. As long as the regulatory framework does not support investment into energy-efficient, least-cost solutions, supplementary measures are needed in the transition phase.

Before developing these and further specific policy proposals in detail, the following **Chapter 2** will describe already existing European or national targets, strategies, policies and measures in the field of energy efficiency, and energy efficiency in transmission and distribution in particular, and analyse their relevance for increasing energy efficiency of distribution transformers in Europe. Specific policies and measures supporting the development and dissemination of energy-efficient distribution transformers in Europe do not exist. However, such specific policies and measures exist in countries outside Europe. They are briefly described in order to give an orientation for the development of a proposal for a policy-mix for the EU and the EU Member States.

As a starting-point for developing this policy-mix, and following recommendations for identifying a ‚good' policy mix, a policy model is laid out in **Chapter 3**, which sets overall policy targets and timeframes, analyses the barriers and obstacles of the different market actors and possible starting-points for overcoming them.

Afterwards, in **Chapter 4**, the policy mix and its elements will be developed in detail. After different policy instruments are analysed one by one, policy packages will be proposed for the different market actors. These policy packages will then be evaluated with regard to their expected impact on energy savings and cost savings.

The report ends with final conclusions and recommendations in **Chapter 5** and an outlook on further possible research and data monitoring in **Chapter 6**.

2 Existing targets, strategies, policies and measures

2.1 General policy-mix in the field of energy efficiency

Before starting to look into details of barriers and obstacles and possible policies and measures to overcome them in the field of energy-efficient distribution transformers, this chapter gives an overview on the general energy efficiency policy-mix available.

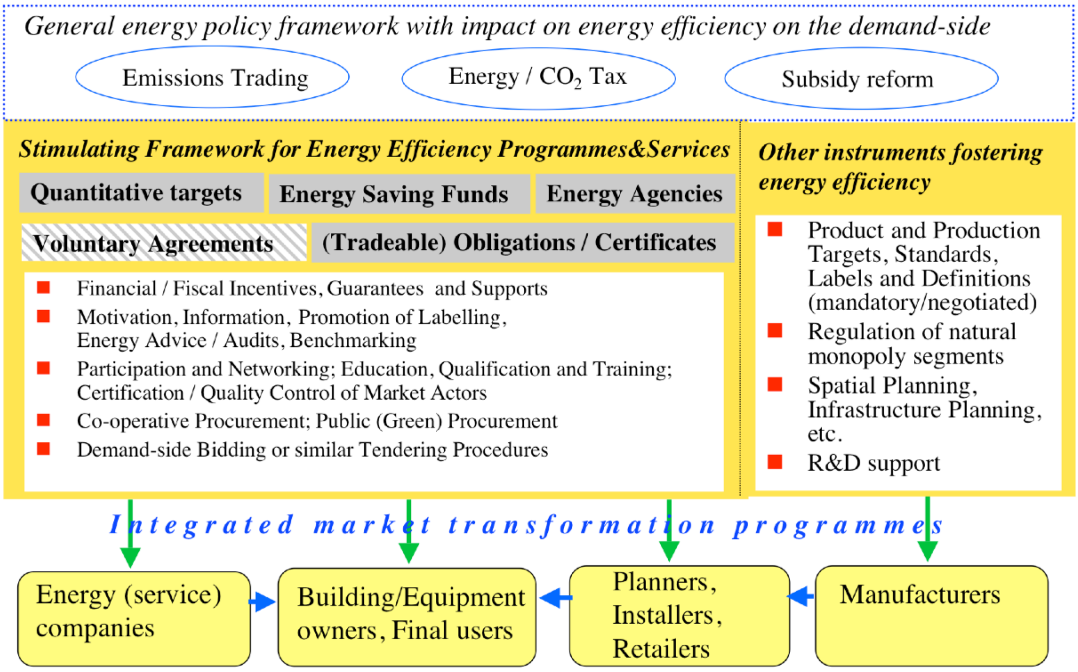
There are different possibilities how to categorise policy instruments. The UNFCCC guidelines for reporting (FCCC/CP/1999/7) distinguish between the following types of policies and measures (cf. also Markewitz/Ziesing 2004, 40):

- economic
- fiscal
- voluntary/negotiated agreements
- regulatory
- information
- education
- research
- other

Another possibility to differentiate between policies and measures is the following used, e. g., in the EU-IEE project AID-EE (cf. www.aid-ee.org) and in the EU project MURE (cf. http://www.isis-it.com/mure):

- legislative / normative
- legislative / informative
- financial
- fiscal/tariffs
- information, education, training
- co-operative measures
- infrastructure
- social planning / organisational
- cross-cutting (with or without sector-specific characteristics; e. g., market-based instruments, general energy efficiency or climate change programmes)
- non-classified policies and measures.

Figure 2: Types of policies and measures in the field of energy efficiency



Source: Wuppertal Institute, based - among others - on Wuppertal Institute et al. 2003 and Irrek/Thomas/et al. 2006

Figure 2 describes the policy-mix in the field of energy efficiency by using a slightly different approach. It stresses that a comprehensive approach will be needed to bundle different policies and measures into target group- and sector-specific market transformation programmes adequately addressing the different actors in the market chain: energy companies, energy service companies, building and equipment owners, final users (in the case of distribution transformers, final users are electricity distribution and industrial or commercial companies), planners, installer, retailers, manufacturers. These target group-oriented packages of policies and measures are usually specific, depending on the energy efficiency technology or field of application. The package has to be tailored in order to strengthen incentives and overcome barriers for all actors in the market chain regarding energy efficiency.

In general, the approach distinguishes between three groups of policies and measures:

- general cross-cutting policies and measures having an impact on energy efficiency on the demand-side by generally altering price ratios: energy/CO_2 tax, emissions trading, sustainable subsidy reform;
- energy efficiency programmes and services specifically targeting relevant market actors, a field of application or an energy-efficient technology (e.g., financial incentive programmes, information campaigns, energy audits, training measures, co-operative procurement, demand-side bidding programmes), that can be further stimulated by framework conditions consisting of

  - an agreed or mandated, quantified target for energy savings as part of an overall energy efficiency strategy,
  - special dedicated institutions like energy agencies contributing to reaching the target by either carrying out energy efficiency activities by themselves and/or supporting market actors in implementing energy efficiency activities (cf. IEA 2006, 26: "Setting up special institution, or giving responsibility for implementation and support of energy efficiency to an existing body which is independent from central government budgetary constraints, could be instrumental in achieving successful policies."),
  - a way how to fund energy efficiency activities (energy saving fund; integrating costs of energy efficiency activities into market prices in a way neutral to competition, e. g., by obligations imposed on market actors, maybe made tradable, e. g. in a white certificate scheme); and
- further instruments fostering energy efficiency like product or production standards and labels, regulation of natural monopoly segments (which will probably be particularly important in the case of increasing energy efficiency of distribution transformers of electricity distribution companies), spatial planning and other planning instruments like infrastructure planning, R&D support.

There are often several barriers and obstacles working together in impeding the implementation of a technical, behavioural or organisational energy efficiency measure within a country. Furthermore, barriers and obstacles differ between market actors, fields of application or technology. Therefore, in most cases, a bundle of policy instruments and measures is needed to overcome the different barriers and obstacles and to address the different actors in the market chain, from production to consumption. For example, push and pull strategies address different parts of the market at the same time. Examples of packages of policy instruments are shown in the following table.

Table 2: Examples of policy packages

Instrument category	Regulation	Information	Economic incentives	Voluntary agreements
Regulation	Building code + energy performance standard	Building code + training tools	Building code + subsidies for demonstration or for achieving higher standard	not applicable
Information	Labelling + energy performance standard	Labelling, audit	Labelling / audit + subsidy	Labelling + voluntary standard
Economic incentives	Subsidy + energy performance standard	Subsidy + energy information centre	Subsidies + tax	Subsidy + voluntary agreement
Voluntary agreements	not applicable	voluntary agreement + audit	VA + tax exemptions	not applicable

Source: AID-EE 2006

In such a policy package, different types of interactions between policy instruments can be observed. The result of an interaction can either be that the effectiveness and/or costs of a combination of two policy instruments are higher, lower or equal to the sum of the effectiveness and/or costs of the separate policy instruments (cf. Boonekamp 2005, Sorrell 2003 and Michelsen 2005 for this and further possibilities to differentiate between the different types of interactions):

- Reinforcement: the combination of at least two policy instruments is more effective and/or less costly than the sum of the separate policy instruments,
- Mitigation: the combination of at least two policy instruments is less effective and/or costly than the sum of the separate policy instruments,
- Neutral: the combination of at least two policy instruments is as effective and/or costly as the sum of the separate policy instruments.

Analysing interactions between policy instruments is still an emerging and immature field of research. Most of the work in this field is focusing on identifying the occurrence of interactions between certain policy instruments and to what degree these interactions will affect the objectives of the respective policies. However, research on the understanding of the mechanisms of interactions and developing methodological approaches are very rare (Simões et al., 2005). There are only a few examples of methodological approaches for analysing interactions between policy instruments in a systematic way (Boonekamp, 2005; Simões, 2005; Sorrell, 2003; Michelsen, 2005; cf. the box for an example from Michelsen 2005).

These approaches are all of a qualitative nature, i.e. a quantification of the effects of the interactions is not taking place. Therefore, while they contribute to the understanding of policy packages and interactions between policy instruments in such a package, for the quantitative assessment of the overall net impact of a policy package they are not useful if not transferred into a quantitative approach.

After having described the general policy-mix available in the field of energy efficiency, the following chapter will give an overview of the existing European framework for implementing such policies and measures.

2.2 Overview of European framework on energy-efficiency

2.2.1 Flexible mechanisms of the Kyoto protocol (ETS, JI, CDM)

In 2002 the EU15 ratified the Kyoto protocol and agreed to an emission reduction target of 8% by 2012, compared to 1990, with separate targets to meet for each Member State. The ten new Member States have also ratified the Kyoto protocol and hence have their own reduction targets (-6% to 8%), except Cyprus and Malta. In order to meet its obligations under the Kyoto protocol the EU has launched the European Climate Change Programme (ECCP) with the purpose of analysing GHG mitigation potentials and proposing actions for GHG mitigation from energy combustion as well as mitigation of emissions from non-energy and non-combustion sources such as industrial processes, production and use of fluorinated gases, waste management, and agriculture and forestry. Energy efficiency measures are an important element of the EU's strategy to reduce GHG emissions and to achieve the emission reduction target set by the Kyoto protocol.

The most important so-called "flexible mechanisms" of the Kyoto protocol is the Emission Trading Scheme (ETS) implemented in Europe following Directive 2003/87/EC. It is designed as a cap and trade system and focuses on the CO_2 emissions of large CO_2 emitting installations. Each Member State has to set up national allocation plans for each trading period, allocating emission allowances to participating companies.

With the so-called 'Linking Directive' (2004/101/EC), the project-based mechanisms CDM (Clean Development Mechanism) and JI (Joint Implementation) of the Kyoto Scheme are linked to the EU ETS. In principle, it is possible to run JI or CDM projects with energy-efficient distribution transformers.

All in all, 15,000 installations (mainly power and heat production, as well as most energy intensive manufacturing industries, with emissions from chemical processes and from non-ferrous metal production as notable exceptions) are covered today by the

ETS, which accounts for about 45% of the EU's total CO_2 emissions and 30% of its total GHG emissions. One problem is that emission trading concerns (directly) only about 40% of the required emission reductions by 2010. A further 45% of the emission reductions are to be achieved by other sectors outside ETS, whereas about 15% are left for non-energy related CO_2 and other gases to reduce emissions (Lechtenböhmer/Perrels/et al. 2006).

2.2.2 EU green paper and action plan on energy efficiency

Increasing energy efficiency has recently become a top priority topic of European energy policy.

In 2000, the EU intensified its activities in the field of energy efficiency with the Action Plan to improve Energy Efficiency in the European Community (COM(2000) 247 final) (EC 2000). The Action Plan estimated a saving potential of 18% by the year 2010 (160 Mtoe or 1 900 TWh) and outlines policies and measures for the realisation of two thirds of this target by 2010 (100 Mtoe or 200 Mt CO_2/year). Furthermore, a doubling of the use of cogeneration by 2010 was proposed, which would lead to additional avoided CO_2 emissions of 65 Mt/year in 2010.

The Green Paper on Energy Efficiency, released in June 2005 by the EU Commission, envisaged launching the debate on how the EU could achieve a reduction in its energy consumption by 20% (190 Mtoe) compared to the BAU projections for 2020 on a cost effective basis and, by doing this, limit energy consumption growth to a level of 1520 Mtoe/year in 2020.

On 19th October 2006, the Commission adopted an Energy Efficiency Action Plan, that shall help to realise the saving targets set in the Green Paper. It contains a list of measures proposed to put the EU well on the path to achieving a key goal of reducing its global primary energy use by 20% by 2020. If successful, this would mean that by 2020 the EU would use approximately 13% less energy than today, saving €100 billion and around 780 millions tonnes of CO_2 each year. However, this would require significant efforts both in terms of behavioural change and additional investment. An important basis for the development of the action plan were different analyses on energy efficiency potentials and energy system scenario analyses carried out, e. g., by [Lechtenböhmer et al. 2005], [Mantzos/Capros 2006] and [Lechtenböhmer/Perrels/et al. 2006] (cf. also further scenario analyses and analysis of energy efficiency potentials by [Matthes et al. 2006], [Thomas et al. 2006] and [EEA 2005]. Key measures proposed within the Energy Efficiency Action Plan include:

- Accelerating the use of fuel efficient vehicles for transport, making better use of public transport; and ensuring that the true costs of transport are faced by consumers;
- Tougher standards and better labelling on appliances;
- Rapidly improving the energy performance of the EU's existing buildings and taking the lead to make very low energy houses the norm for new buildings;

- Coherent use of taxation to achieve more efficient use of energy
- Improving the efficiency of heat and electricity generation, transmission and distribution;
- A new international agreement on energy efficiency to promote a common effort.

These targets and measures proposed by the European Commission have become part of the Commission's comprehensive energy action plan for an Energy Policy for Europe, published on 10 January 2007. The EU energy ministers have adopted the target to improve energy efficiency by 20% at their meeting on 20 February 2007. During its summit on 8/9 March 2007, the European Council adopted a comprehensive Action Plan for the period 2007 – 2009 based on the Commission's Communication "An Energy Policy for Europe". In particular, it stressed the need to increase energy efficiency in the EU so as to achieve the objective of saving 20% of the EU's energy consumption compared to projections for 2020, as estimated by the Commission in its Green Paper on Energy Efficiency, and to make good use of their National Energy Efficiency Action Plans for this purpose.

2.2.3 End-use energy efficiency and energy service directive (ESD)

The Directive on Energy end-use Efficiency and Energy Services (2006/32/EC), adopted in April 2006 by the European Parliament and the Council, sets an indicative target for the EU Member States to achieve overall energy savings of 9% for the ninth year of application of the Directive. Each member state will draw up programmes and measures ("Action Plans") to improve energy efficiency by June 2007 and progress will be measured as from 1 January 2008.

2.2.4 Eco-design directive

The Directive on Eco-design requirements (2005/32/EC), which was adopted in 2005, provides a comprehensive legislative framework for setting eco-design requirements including energy performance standards for energy using products. It aims at improving the environmental performance and energy efficiency during the life cycle of a product. Currently, studies are being undertaken in order to determine the standards based on the concept of lowest possible life cycle costs of the appliance.

2.2.5 Other European framework on energy efficiency

In addition to those Directives and action plans already mentioned, the EU focuses on strategies in specific energy policy fields to enhance energy efficiency. Important fields for action are heating and cooling of buildings, electricity use of machines and appliances, energy efficiency of industrial installations, transport efficiency and conversion efficiency with a focus on combined heat and power production (CHP). A few selected elements in these fields are shortly described in the following.

One of the first elements of the EU policy to improve energy efficiency was the Directive on the indication by labelling and standard product information of the consumption of energy and other resources by household appliances (92/75/EEC).

In the 1995 white paper “An Energy Policy for the European Union” (COM(95) 682final), the European Commission stated that energy efficiency could make a valuable contribution to the reduction of the Community’s energy dependency on external sources. As one consequence, in 1997 the EU emphasised another important field: the use of combined heat and power (CHP), which offers substantial potential for increased energy efficiency. In December 1997 the European Council adopted a resolution on a Community strategy to promote combined heat and power (98/C 4/01), which sets an overall indicative target of doubling the share of electricity production from CHP to 18% by 2010.

The Directive on Energy Performance of Buildings (EPBD) (2002/91/EC) acknowledges the fact that the building sector is responsible for about 40% of the EU’s total primary energy consumption. What is more, huge savings can be achieved in a cost-effective way, particularly when regular retrofits are combined with energy-saving measures. The buildings directive focuses on the energy efficiency of large existing buildings (larger than 1,000 m^2). It requests that Member States establish minimum efficiency standards for existing buildings that undergo significant renovation. For the EU15 the Directive assumes that the reduction potential of emissions would be 34 Mt/a by the year 2010.

With regard to heating systems, the European Commission determined the efficiency requirements for new hot water boilers which are fired by liquid or gaseous fuels with an output of no less than 4 kW and no more than 400 kWth with the Council Directive 92/42/EEC. However, these standards have not been updated since the early 1990s and no longer reflect the state of technology. The Building Directive focuses on the inspection and the potential replacement of “boilers fired by non-renewable liquid or solid fuel of an effective rated output of 20 kW to 100 kW”.

Electric appliances are responsible for a significant and increasing share of the EU’s electricity consumption. One of the first actions to improve energy efficiency in this field was the Directive on the indication by labelling and standard product information of the consumption of energy and other resources by household appliances (92/75/EEC), which made energy labelling mandatory for an increasing number of appliances. However, since the adoption of the Directive standards have improved significantly for many appliances, which led to the need to (regularly) update the efficiency classes.

2.3 Relevance of existing European-wide mechanisms and directive frameworks for increasing energy efficiency of distribution transformers

In the whole European energy efficiency policy-mix described in the previous subchapter, distribution transformers are not addressed yet. There are also no European standards or labels for distribution transformers yet. However, in principle,

- While the flexible instruments of the Kyoto protocol cannot be directly used for increasing energy efficiency of distribution transformers in Europe yet, they might be part of so-called ‘cross-JI’ projects between different European Member States in the future, or of other (unilateral) domestic offset projects that might be allowed to offset emissions of installations obliged by the ETS. Furthermore, energy-efficient distribution transformer investments can be subject of CDM projects. A basic way to certify the carbon credits associated to a new efficient transformer instead of the standard/reference one could be:
  - to calculate the energy savings as difference between the efficient and the reference transformer according to the rated power of the transformer
  - for the NLL (Non-Load Losses) it could be assumed that transformer will be connected for the whole year (8760 hours)
  - for the LL (Load Losses) some reference load curves could be standardised for each one of the markets (e.g., urban, rural, industrial, tourism areas).
  - to calculate the CO_2 emissions avoided based on the European or national generation mix (kg CO_2 emitted/kWh generated).
  - The CO_2 emissions avoided from NLL and LL could be certified every year (for at least 10 years), for each efficient transformer. The amount of individual CO_2 emissions avoided from all the efficient distribution transformers connected could be added and offered to the CO_2 market.
- Energy losses in transmission and distribution are generally mentioned as a problem in the European Commission’s proposal for a European Action Plan on Energy Efficiency. Furthermore, Priority Action 3 of the Action Plan includes the Commission’s objective to reduce transmission and distribution losses, and the Annex of the Action Plan expresses the Commission’s willingness to “agree guidelines in co-operation with CEER through ERGEG on good regulatory practices to reduce transmission and distribution losses” in 2008.
- The Ecodesign Directive does not include distribution transformers yet. They might be included in a later stage, but this would require a higher number of market sales (> 200,000 pieces / year). However, it could be thought about grouping distribution transformers together with other transformers in order to exceed the necessary minimum market volume. A proposal by EPTA/PE International/NTUA (2007) on behalf of the European Commission suggest to include transformers into the next working programme for the implementation of the Ecodesign Directive. If all

transformers in the range of ≤ 1kVA up to >100 MVA are seen as one product group, the threshold of 200,000 pieces sold per year will be exceeded. However, T&D Europe (2008), while welcoming in general the European Commission in its action of achieving higher efficiency of energy consuming products, points to the importance of differentiating policies and measures by the following transformer categories: small transformers up to 25 kVA, distribution transformers between 25 kVA and 20 MVA, and power transformers above 20 MVA.

- Energy savings achieved by additional promotion measures leading to an increase in energy efficiency of distribution transformers in industry and commerce might count for the 9% target of ESD.
- In principle, it would be possible to develop minimum energy efficiency standards and labels for distribution transformers based on the existing CENELEC standards HD428 and HD538, and on the new norm EN 54464 which supersedes HD428.

While specific policies and measures supporting the development and dissemination of energy-efficient distribution transformers in Europe do not exist, it might be useful to look to other countries where such specific policies and measures are in place. Therefore, in the following chapter, policies and measures applied in other countries are shortly described with regard to the question what can be learnt from them for supporting energy-efficient distribution transformers in Europe.

2.4 Excursus: Policies and Measures supporting energy efficiency of distribution transformers in non-EU countries

2.4.1 International standards addressing energy efficiency of distribution transformers

Unlike in many countries around the World, there is no mandatory European standard on energy efficiency of distribution transformers. Still the two main documents which describe losses in transformers are Harmonised Documents; HD428 for oil cooled transformers and HD538 for dry type transformers (or their different country equivalents, e.g. DIN).

CENELEC Technical Committee 14 (Work Group 21) “Power Transformers” has prepared and concluded on a norm which supersedes the HD428 document. This standard has already become the status of a European Standard EN50464-1 in 2007 and has been reviewed and accepted by member countries committees. Also IEC 60076 – Power Transformers - Application Guide is widely referred to in the context of losses measurement.

The table below presents an overview of international standards which address directly or indirectly the issue of losses and efficiency. Standards are not limited to efficiency, or loss levels, but may also include total cost of ownership or cost capitalisation formulae. Separate documents define testing procedures and conditions. Reference standards on testing are NEMA TP-2 and IEC 60076, acting as the basis for national equivalents.

Table 3: International standards addressing energy efficiency in distribution transformers

Country / region	Standard	Subject
USA	Guide for Determining Energy Efficiency for Distribution Transformers (TP1-1996). National Electrical Manufacturers Association. 1996.	Efficiency standards and TOC formula
	Standard Test Method for Measuring the Energy Consumption of Distribution Transformers (TP2-1998). National Electrical Manufacturers Association. 1998.	Efficiency testing methodology
International	Power transformers – Application guide, 60076-8, IEC:1997	Design, calculation aspects including measurement of losses
European	Cenelec 1992, Harmonisation documents HD428, HD 538 oil and dry type transformers EN 50464-1 for oil-filled transformers (supersedes HD428)	Efficiency standards and cost capitalisation formula
Variety of country standards defining efficiency levels; MEPS in Australia, Canada, China, Japan, Mexico, proposed in India and New Zeland, non mandatory in Europe		

Efficiency standards can be expressed in terms of electrical efficiency, at a certain load level, or in terms of maximum values for no load and load loss. Most standards are voluntary. Below the overview of international standards is presented.

2.4.2 Australia and New Zealand

Australia "recalculated" the American 60 Hz efficiency standard to its 50 Hz frequency and also interpolated linearly the efficiencies at the size ratings which are different from USA. 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 standards are defined for oil-filled distribution transformers between 10 and 2 500 kVA and for dry-type distribution transformers between 15 and 2 500 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 was 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' labeling.

New Zealand follows the Australian regulation for distribution transformers.

2.4.3 China

In China, the standards are 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 standard 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. They stipulate maximum load and non-load losses for oil immersed types ranging from 30 to 31 500 kVA and for dry types in the range from 30 to 10 000 kVA. This regulation has quickly changed the market to higher efficiency units.

2.4.4 Europe

As already mentioned there are no mandatory standards in Europe. However there are some patterns or procurement procedures (internal standards of electricity distribution companies) which are highly demanding in Benelux, Germany, Austria and Switzerland and Scandinavia. Most of electricity distribution companies in these countries buy transformers at C[C' minus 30%] (HD428) or AoBk (new 50464) standards. Endesa in Spain purchases HD428 CC' for 400 kVA units. EdF has introduced certain purchasing policy which specifies no load losses between Co and Eo and load losses between Dk and Bk. Mix of losses is focused on low no load losses for small ratings and low load losses for higher ratings. Also tolerance of losses has changed lately. More and more often utilities narrow losses tolerance e.g. to 0% instead of 15%.

2.4.5 India

The Indian Bureau of Energy Efficiency (BEE), acting under a mandate from the Indian Ministry of Power, has analyzed the feasibility of a distribution transformer minimum efficiency standard. BEE classiffies 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 standard, and is being widely followed by utilities. The scheme is a cooperative venture between public and private organizations 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. India historically has a rather poor performance in transformer energy efficiency, but the 5-star program became an important driver for change.

2.4.6 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 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 standard is currently the most demanding compared to other regulated standards.

The standard is designed in different way than any other standards. Efficiencies for different products are described by equations (cf. the table below).

Table 4: Japanese standard (‚Toprunner Programme')

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

Source: Research Committee 2002

This scheme is a part of the 'Toprunner 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.

Labeling of the products is mandatory. A green label signifies a product that meets the minimum standard, while other products receive an orange label.

2.4.7 Mexico

Mexico sets the minimum efficiencies at slightly less stringent levels; 0,1% to 0,2% below TP-1 efficiency. As in Australia, the Mexican standard 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.

2.4.8 USA

In 1997, Oak Ridge National Laboratory performed extensive studies to determine whether energy conservation standards for distribution transformers would offer significant energy savings, be technically achievable and economically justified. This has led to the definition of the NEMA TP-1 standard, which became the basis for the rule making process on minimum standards. NEMA TP-1 has been used as a guideline by Canada, Australia, New Zealand and (partially) Mexico.

The energy savings potential in the USA from switching to high efficient transformers is high. In 1997, the National Laboratory of Oak Ridge estimated it to be 141 TWh. One of the reasons for this high figure is the high number of distribution transformers in the utility networks in the US.

To reduce these losses, the National Electrical Manufacturers Association (NEMA) created the TP1 standard. TP1 defines a minimum efficiency for dry and oil-filled type transformers in the range from 10 to 2500 kVA. After the following states, Massachusets, Minnesota, Wisconsin, New York, Vermont, California and Oregon, have adopted NEMA TP-1 requirements, the discussion initated by utilities, started. This standard was perceived as not demanding enough. In 2006, the US Department of Energy proposed a new standard. It was a compromise between less stringent TP-1 and level of losses which in average represent minimum life cycle cost. The proposed standard would be in one third of difference between TP-1 and minimum LCC.

Now, a new standard has been introduced, which is close to the DOE proposal. It practically means that all transformers manufactured for sale in the USA and imported to USA on or after January 1, 2010 will have minimum efficiency set by this rule, which is very close to CC' -30% or >AoBk.

Next to this standard, transformers also are part of the broader EnergyStar labelling program. EnergyStar is a voluntary program that encourages the participating utilities to calculate the total cost of ownership of their transformers and to buy the type if it is cost-effective to do. EnergyStar is based on TP1 because EPA (Environment Protection Agency) was looking to set an easy standard that did not cause protracted arguments, so it may be tightened in the future.

The third program in the US, set up by the Consortium for Energy Efficiency (CEE), aims to increase the awareness of the potential of efficient transformers in industry. It consists of a campaign to measure the efficiency of industrial transformers and to stimulate companies to upgrade their transformer park to the best available in the market.

2.4.9 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 accress state borders for sale or lease in Canada. The standards are harmonized with NEMA TP-1 and TP-2 standards.

Amendment 6 to 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.

2.4.10 Summary of policies and measures in place internationally

The table below summarises existing international policy instruments supporting energy efficiency of distribution transformers.

Table 5: Policies and measures supporting energy efficiency of distribution transformers in the world

Country	**Labeling**	**BAT**	**Efficiency standard**		**Test standard**
			Mandatory	Voluntary	
Australia			x		
Canada	x		X (dry-type)	x	
China			x		
EU				x (single companies)	
India				x	x
Japan	x	x		x	
Mexico			x		x
Taiwan	x	x			
USA	x	x	x		x

BAT = orientation towards Best Available Technology

The table below presents international standards comparison based on calculation of efficiency at 50% load (40% for Japan). Most of them apply for 50 Hz frequency while these which are originally set at 60 Hz have remained unchanged. For better comparison of these standards with existing EU25 situation, the EU25 fleet and market losses have been computed to efficiency at 50% loading and presented. For EU 25 fleet and market some ratings are not ideally representing the real ratings. In some cases the closest rating has been used.

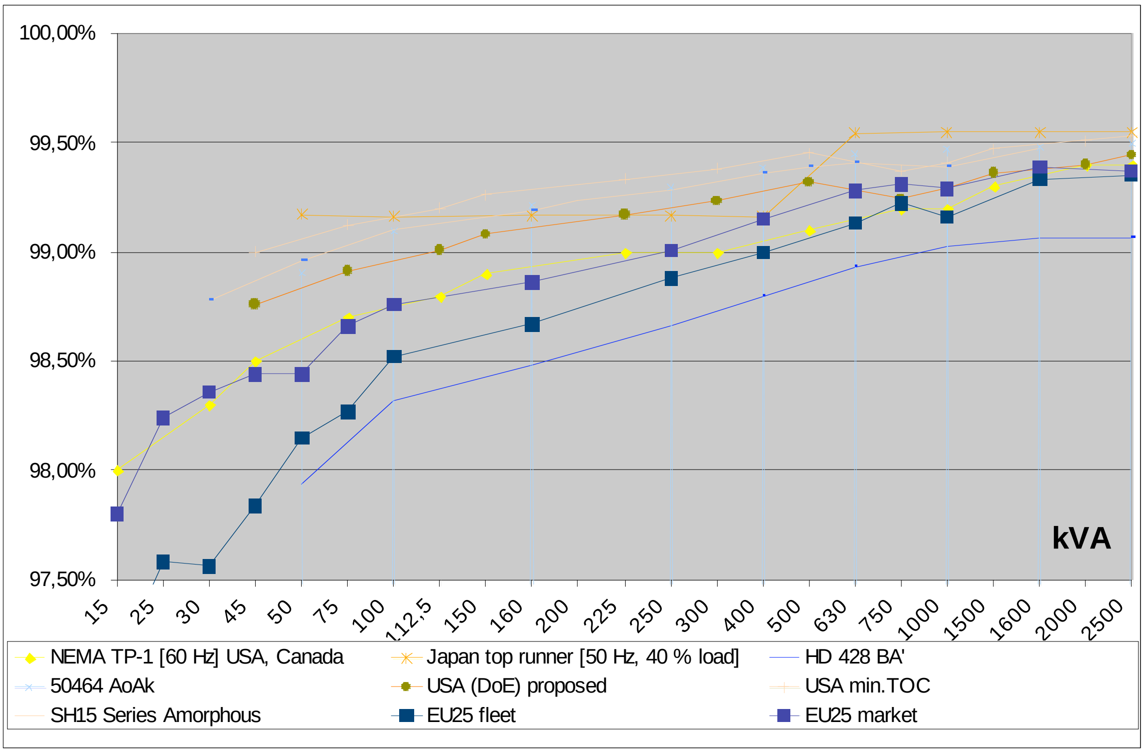
In conclusion, it can be stated that standards and labels seem to be appropriate options used in other countries, that might be developed for Europe, too, in order to foster the development and dissemination of energy-efficient distribution transformers.

Table 6: Comparison of international efficiency standards and levels

Rating kVA	NEMA TP-1 [60 Hz] USA, Canada	Canada Australia sizes [60 Hz]	NEMA freq. cor. [50 Hz] Australia	Mexico [60 Hz]	Japan top runner [50 Hz, 40 % load]	China S9	China S11	HD428 BA'	HD428 AA'	HD428 CC''	HD428 CAmdt	India pro-posed MEPS (3 star)	50464 AoAk	50464 BoAk	USA (DoE) proposed	USA min.TOC	SH15 Series AMDT	EU25 fleet	EU25 market
15	98,00%			97,90%														97,12%	97,80%
25		98,20%	98,40%									98,32%						97,58%	98,24%
30	98,30%			98,25%													98,78%	97,56%	98,36%
45	98,50%			98,35%											98,76%	99,00%		97,84%	98,44%
50		98,50%	98,70%		99,17%	98,47%	98,67%	97,93%	98,17%	98,64%	99,01%	98,79%	98,90%	98,82%			98,96%	98,15%	98,44%
75	98,70%			98,50%											98,91%	99,12%		98,27%	98,66%
100		98,80%	98,90%		99,16%	98,69%	98,86%	98,31%	98,51%	98,86%	99,15%	98,96%	99,09%	99,02%			99,10%	98,52%	98,76%
112,5	98,80%			98,60%											99,01%	99,20%			
150	98,90%			98,70%											99,08%	99,26%			
160					99,16%	98,83%	98,96%	98,48%	98,71%	99,01%	99,29%	99,04%	99,21%	99,15%			99,19%	98,67%	98,86%
200		99,00%	99,10%									99,11%					99,23%		
225	99,00%			98,75%											99,17%	99,33%			
250					99,16%	98,95%	99,08%	98,66%	98,84%	99,12%	99,37%		99,30%	99,25%			99,28%	98,88%	99,01%
300	99,00%	99,00%	99,10%	98,80%											99,23%	99,38%			
400					99,16%	99,07%	99,17%	98,80%	98,97%	99,22%	99,44%		99,38%	99,34%			99,36%	99,00%	99,15%
500	99,10%	99,10%	99,20%	98,90%											99,32%	99,45%	99,39%		
630					99,54%	99,13%	99,24%	98,93%	99,08%	99,30%	99,50%		99,45%	99,41%			99,41%	99,13%	99,28%
750	99,20%	99,20%	99,30%												99,24%	99,37%		99,22%	99,31%
1000	99,20%	99,30%	99,40%		99,55%	99,15%	99,25%	99,02%	99,14%	99,31%	99,50%		99,47%	99,44%	99,29%	99,41%	99,39%	99,16%	99,29%
1500	99,30%	99,40%	99,50%												99,36%	99,47%			
1600					99,55%	99,25%	99,34%	99,06%	99,15%	99,35%	99,51%		99,48%	99,45%			99,47%	99,33%	99,39%
2000	99,40%	99,40%	99,50%												99,40%	99,51%			
2500	99,40%	99,40%	99,50%		99,55%			99,06%	99,17%	99,36%	99,51%		99,49%	99,46%	99,44%	99,53%		99,35%	99,37%

Some selected standards efficiency comparison is also presented in the figure below.

Figure 3: Comparison of selected standards and efficiency levels



3 Starting-points for overcoming barriers and obstacles of the different market actors

3.1 Identifying a ‘good’ policy-mix

Before going into a detailed analysis and design of the different policies and measures that might be suggested as part of an effective and efficient policy-mix for increasing energy efficiency of distribution transformers, this subchapter describes some principles for identifying a ‘good’ policy-mix.

In practice, policy making is often not based on ‘scientific’ rationality but on other kinds of rationality (e.g., electional etc.), and decision makers often trust their feeling in which direction s.th. should go more than ‘objective’ evaluations. However, if policy makers like to base their decisions on inter-subjective rationality, then they should at least follow some general rules for the identification (and ex-ante estimate of the overall impact) of an adequate, effective and efficient policy-mix. Besides taking into account results from ex-post bottom-up evaluations of existing successful single policy instruments and policy packages in the respective or comparable fields of application (maybe, by analogy, if there are no evaluations within the respective field of application), in the end, expert judgement by experienced policy-makers and/or evaluators is needed. In order to come to such a judgement, these experts should (cf. the results of the EU-IEE project AID-EE on www.aid-ee.org):

1. Set targets to be achieved within specified time frames based on thorough analysis of energy efficiency potentials.
2. Roughly estimate the possible impact of a feasible package of policy instruments to achieve the targets set.
3. Decide on elements of the package:
   - Start from the analysis of the market chain: Who are the relevant market actors? What is the decision window they possess?
   - Identify incentives and disincentives, existing support, barriers and obstacles for each type of actor in the market chain: What are the incentives and disincentives, barriers and obstacles the different actors face?
   - Develop solutions how to further strengthen or stabilise the incentives, to abolish disincentives and to overcome barriers and obstacles: Which policy instruments would be suitable to set further incentives and to overcome disincentives, barriers and obstacles? How relevant will the action be compared to the savings potential and the degree of complexity of the policy instrument?
   - Thereby taking interactions between policy instruments and expected changes in framework conditions into account as far as this is possible: To what extent are the different policy instruments in the package needed to set incentives to overcome the specific barriers and obstacles, and to mitigate or abolish the specific disincentives the different market actors / target groups face at the

current/coming stage of the market? What instruments are particularly effective / efficient?

4. Thereby make their policy model explicit, i.e. their ‘theory’ how they think or guess the policy-mix and the different policy instruments within the mix will function and lead to energy savings.
5. Re-evaluate the impact (energy savings; benefit-cost ratios from the different perspectives; etc.) of the policy package after having decided on the different elements.
6. Check consistency and completeness of the design of policy package, the targets and indicators set, and the monitoring requirements.

Furthermore, based on Michelsen (2005), the following rules for identifying the optimal mix of policy instruments could be stated:

- All relevant conditions for realising a certain energy saving option should be covered by a set of policy instruments;
- Policy instruments should be complementary, i.e. not overlapping in the detailed conditions addressed for realising an energy saving option for one type of actor;
- A policy instrument should influence more than one condition in order to limit the number of policy instruments needed;
- Policy instruments should be introduced in the right chronological sequence;
- All relevant actors for realising an energy saving option should be regarded.

Further conclusions and recommendations with regard to the design of new policies and typical circumstances, in which to apply different types of policy instruments, can be found in guidelines developed by the EU-IEE project “AID-EE” (2006).

However, it should be noted that a specific policy-mix identified as adequate or ‘good practice’ might not be appropriate in every country at the same time and to the same extent, and that how a policy instrument is implemented might be even more important than the fact that the specific policy instrument is applied.

3.2 Overall policy targets and timeframes

Following the recommendations for identifying a ‚good’ policy mix, general and policy-oriented targets and timeframes should be roughly set. Afterwards, the policy mix should be designed in detail and evaluated (ex-ante) with regard to the possible contribution to these targets.

For example, following the estimates of electricity saving potentials mentioned in the introduction to this report and that can be found in more detail in the respective SEEDT report Deliverable No. 9, an ambitious target would be to realise most part of the calculated saving potentials, for example, 10 TWh/year in 2025.

3.3 Barriers and obstacles of the different market actors

The next step of developing a ‚good' policy mix is the decision on elements of the mix, which should start with the analysis of the market chain and the market actors involved. The main types of market actors in the field of distribution transformers are:

- Electricity distribution companies as the main owners of distribution transformers, which can be further differentiated between smaller and larger companies, and between distribution companies with urban and those with rural grids. As analysed in Deliverable 1 of the SEEDT project, most of their transformers are liquid-filled ones.
- Large industry, which often needs transformers that are specifically adequate for the relevant industrial processes (often dry-type transformers with specific requirements with regard to fire protection and noise to be integrated into the plant).
- Small and medium industry and commerce.
- Engineering firms; ESCOs; Consultants.
- Manufacturers of the different transformer types and their suppliers (e.g., producers of electrical steel and copper).

The following table gives an overview on the main barriers and obstacles the different market actors face.

Table 7: Barriers and obstacles towards increase energy efficiency of distribution transformers in the EU

<table>
<tr><th>Market actor</th><th colspan="2">Most important market barriers and obstacles</th></tr>
<tr><td>Larger electricity distribution companies</td><td>Disincentives or no incentives from regulation of distribution tariffs; degree of disincentive depending on national regulation scheme
No incentives from emissions trading scheme, Directive on energy end-use efficiency and energy services, or from other policy instruments</td><td rowspan="5">Insufficient competition among amorphous metal manufacturers; no producer of amorphous transformers in Europe

Lack of competences in economic calculation of investment in energy-efficient distribution transformers, particularly with regard to the estimate of the load profile (assumed, e.g., in „A“ and „B“ price factors given by electricity distribution companies to transformer manufacturers in the course of a tender as an input to the capitalisation formula)</td></tr>
<tr><td>Large industry</td><td>Need for high flexibility and adaptability with regard to possible changes in the production process, usually expressed as maximum payback period required
Investment priority for core elements of the production process; energy efficiency investments have lower priority</td></tr>
<tr><td>Smaller electricity distribution companies</td><td>Disincentives or no incentives from regulation of distribution tariffs; degree of disincentive depending on national regulation scheme
No incentives from emissions trading scheme, Directive on energy end-use efficiency and energy services, or from other policy instruments
Lack of information / knowledge</td></tr>
<tr><td>Small and medium industry and commerce</td><td>Lack of information / knowledge
Too small to build up own knowledge in this field: Outsourcing of investment planning to engineering firms, ESCOs, energy companies or consultants
Investment priority for core elements of the production or service process; energy efficiency investments have lower priority</td></tr>
<tr><td>Engineering firms, ESCOs, energy consultants, planners</td><td>Lack of information / knowledge
Disincentives or no incentive from tariff systems for planners; no incentive for optimisation of whole system
No incentive to change routines: One-to-one replacement of old transformers following traditional lay out of transformer design (often oversized)</td></tr>
<tr><td>Transformer manufacturers (and their suppliers)</td><td colspan="2">Risks of high investment in building up an amorphous production line
Limited production areas for extending or shifting production to amorphous metals
Hardly any demand for amorphous technology in Europe yet
Increasing prices for steel, aluminium and copper
Existing procurement routines: Customers specify their demand traditionally and very differently between countries and between companies</td></tr>
</table>

Up to the end of the year 2007, the existing policies and measures on EU and Member States level hardly affect the various barriers and obstacles the different market actors face (cf. the analysis in Deliverable 1 of the SEEDT project for more details with regard to the existing situation in the different EU Member States analysed):

- According to the analysis of the SEEDT project team, there seem to be only some kind of benchmarking of transformer losses in some countries, some obligations to document transformer losses, some funding of energy efficiency measures in general in Greece, and a special technical regulation in Denmark.
- Incentives to purchase energy-efficient transformers are rare or non-existing.
- In many countries, disincentives within the regulation schemes exist, which prevent electricity distribution companies from buying energy-efficient transformers.

With regard to the regulatory mechanisms, main concerns are:

- Most models of regulation rely on a partial redistribution of savings to consumers that discourages companies from making investments for efficiency assets, since cost reduction from the investment is shared with the consumers.
- Capital-intensive investments are very sensitive to future changes in the regulatory scheme, which is at the moment very “unstable”.
- The regulatory framework tends to concentrate on cost savings in the short term (e.g., within the regulatory period of a few years). These do not encourage companies to take the life cycle costs of equipment into account.
- Energy losses are calculated without consideration of external costs.

There is no signal yet, that the implementation of the EU Action Plan on Energy Efficiency will make a change in the next years. Moreover, price development at the steel, aluminium and copper market tends to make energy-efficient distribution transformers more expensive. Therefore, additional support by legislative or non-legislative strategies for the different market actors is needed.

4 The policy-mix proposed by SEEDT and its elements

4.1 Policy Instruments Analysed

4.1.1 Overview on policy instruments and respective policy models

Based on what can be learnt from the analysis of the existing European framework of national policies and measures and of the barriers and obstacles the different market actors are facing, the following list of policy instruments, that might be applicable to foster energy efficiency of distribution transformers, has been developed:

1. Regulatory mechanisms
   Income and investment of electricity distribution companies is mainly restricted by regulation due to the fact that distribution grids are in most cases natural monopolies. Therefore, the regulation scheme will have the largest impact on the decision of electricity distribution companies to buy or not to buy energy-efficient distribution transformers. From the analysis in the previous chapters, it can be learnt, that, in most cases, the regulatory mechanisms in place do not give any incentives or even provide disincentives to purchase of energy-efficient distribution transformers by electricity distribution companies.

2. Incentives from obligations or certificate schemes
   In addition to the regulatory scheme in place, in countries, in which obligations for energy companies exist to increase energy efficiency and to supply energy savings, these obligation or certificate schemes might be used to generate extra contribution margin from investing in energy-efficient distribution transformers, which might lead to a break-even of some energy-efficient transformers that otherwise would not be bought.

3. Other financial or fiscal incentives
   While the regulatory mechanism decides about the electricity distribution company's profitability of investing in energy-efficient distribution transformers, specific financial or fiscal incentives might give an incentive to industry and commerce to switch to the more efficient pieces.

4. Labelling
   Small and medium electricity distribution companies and companies in industry and commerce often do not pay enough attention to the efficiency and to the life cycle costs of distribution transformers. A labelling scheme could direct their attention to the more efficient transformers. Furthermore, it might support suppliers in selling the more energy-efficient transformers.

5. Voluntary or mandatory minimum energy efficiency standard
   Standards help to avoid that the least efficient transformers will be bought. Finally, dynamic standards will give a signal to suppliers in which direction the market will develop. A mandatory standard has to be taken into account in the regulatory schemes.

6. Information and motivation
   A lack of information and motivation to deal with the subject can be identified particularly in small or medium companies in the electricity distribution sector and in industry and commerce. Policies and measures could be designed to overcome this barrier. An information campaign will also be needed to inform about a labelling scheme, if such a scheme is introduced.

7. Energy Advice / Audits
   Initial energy advice and audit schemes in place or to be introduced to generally support industry and commerce should include the subject of electricity distribution transformers.

8. Tool-kits for buyers
   From the discussions with electricity distribution companies, suppliers and their clients in industry and commerce as well as planners it can be learnt, that particularly several small or medium companies in all sectors (industry and commerce and electricy distibution) often do not base their investment decision on sound life cycle cost calculations. Sometimes, just a transformer type is bought which has been always bought in the past (stable purchasing habit). Tool-kits might help them to identify more cost-effective solutions, which often are the more energy-efficient ones.

9. Co-operative procurement
   Large buyers, e. g. large electricity distribution companies, or companies in industry or the electricity distribution bundling their purchasing volumes together can influence the supply and the development and introduction of even more energy-efficient distribution transformer types.

10. Support to R&D and pilot or demonstration projects
    This kind of support might be needed to generally lead to further technical improvements and to ease the introduction of more energy-efficient transformer types.

The following figures give an idea how these policies and measures might address the different market actors to overcome the existing barriers and obstacles in the market.

Figure 4: Policy model for the distribution transformer market – R&D policy

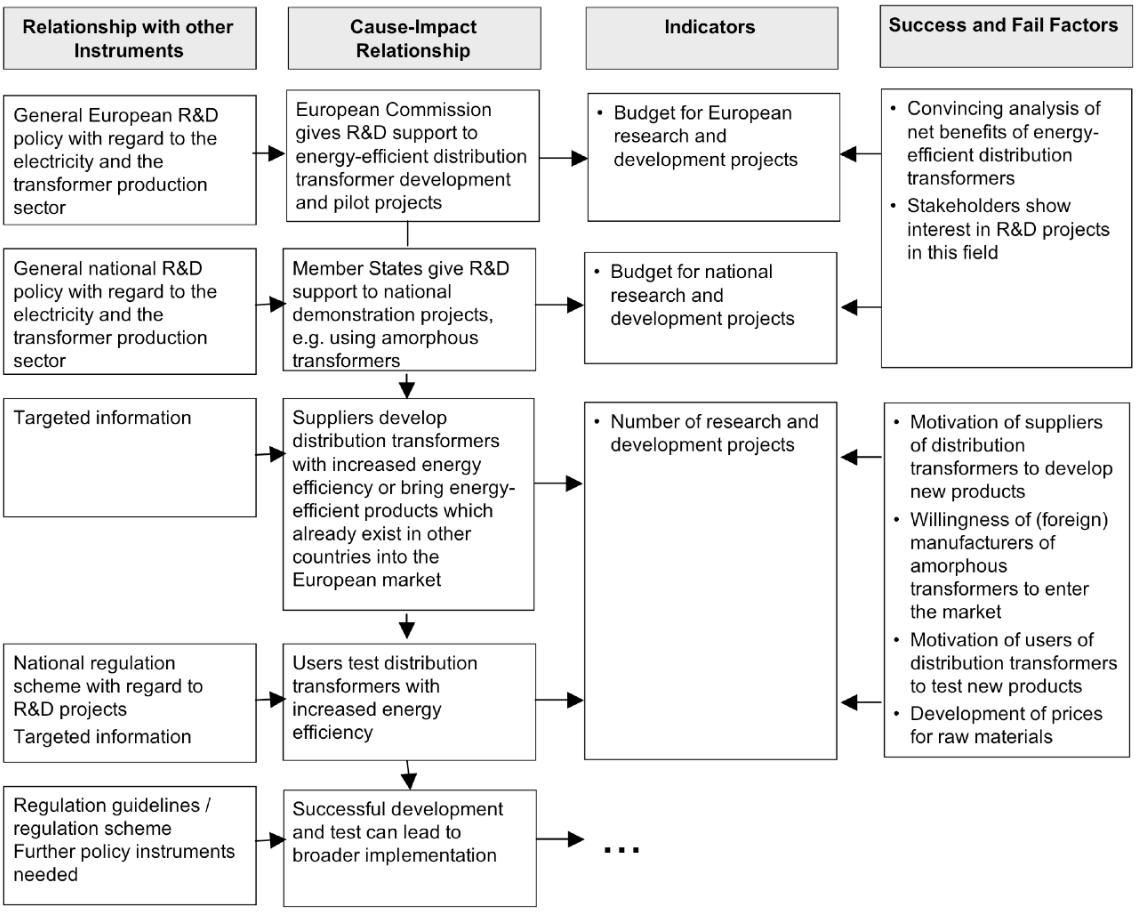


Figure 5: Policy model for the distribution transformer market – Regulation

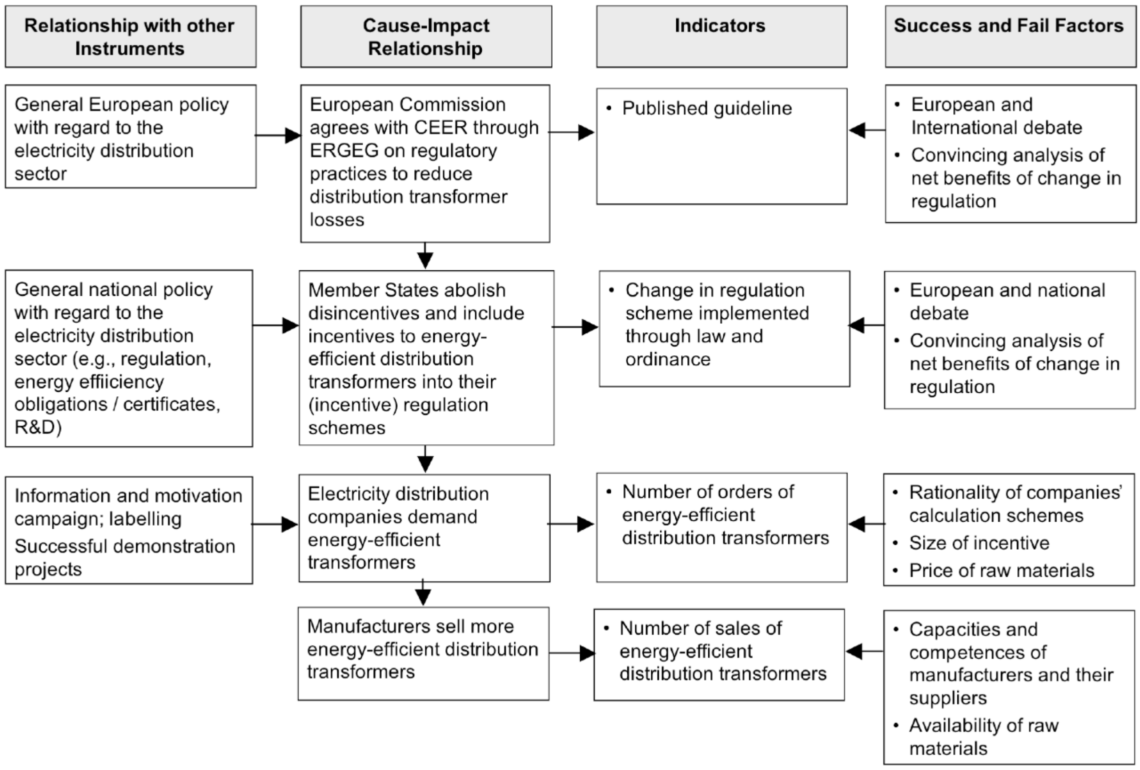
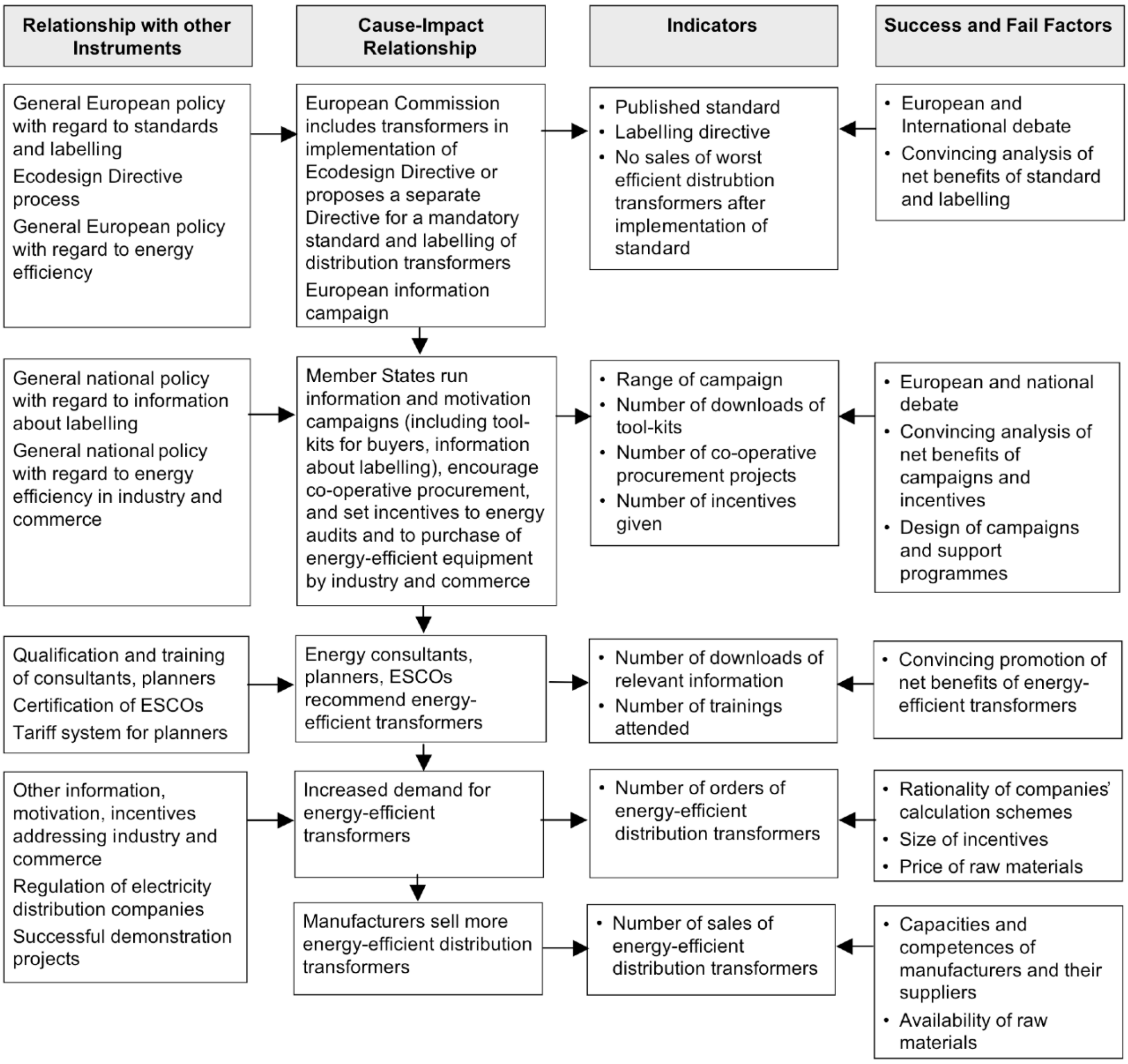


Figure 6: Policy model for the distribution transformer market – information, motivation, standards and labelling, financial incentives



Against this background, and before proposing 'ideal' or at least 'good' policy packages for the different market actors out of the list of policy instruments above, these policy instruments and how they could be designed will be analysed in more detail in the following subchapters.

4.1.2 Regulation of electricity distribution companies

4.1.2.1 Collection of data on treatment of distribution grid losses within regulatory schemes in EU-27

General information on the regulatory schemes in the different EU Member States is available (cf., e.g., diverse documents by the Commission, the regulators, or IEA 2006). However, publicly available sources ususally do not provide sufficient information on the treatment of electricity distribution grid losses including transformer losses.

Therefore, in the course of the SEEDT project, representatives of the regulatory authorities from the following European 27 states were identified and contacted to receive more detailed information on this subject: Austria, Bulgaria, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Netherlands, Poland, Slovakia, Slovenia, Spain, Sweden, United Kingdom (Great Britain) and additionally Croatia and Norway.

Especially in some Eastern European states the conversation was nearly impossible because of the language barrier; together with own investigations the SEEDT project team finally gathered respective data and information from the following 14 states: Austria, Denmark, Estonia, France, Germany, Greece, Hungary, Italy, Lithuania, Norway, Poland, Spain, Sweden, United Kingdom (Great Britain).

The investigation aimed at answering the following questions:

- How are energy losses of the distribution system (amount and price of grid losses and transformer losses) treated in the current national regulation schemes?
- Are there any incentives for utilities and system operators to reduce these losses? If yes, what kind of incentives?
- Are there any disincentives towards reducing energy losses? For example, are costs of energy losses not included in the cap, which will lead to a situation in which only the price of components (e. g., transformers) is relevant in case of a purchase decision, and not the life cycle costs?
- Are there any plans to change the current system in the near future? If yes, what are the proposals with regard to treatment of energy losses?

The following table gives an overview of the information collected.

Table 8: Overview of regulatory approaches towards losses in the national distribution systems in the EU-27 states and Norway and Croatia

Country	**Maximum values for amount and/or price of losses**	**General Incentives or Disincentives**	**Special Incentives concerning Losses**	**Plans of change**
Special incentives to decrease distribution grid or transformer losses:				
UK- Great Britain	Yes Each distribution network operator is evaluated based on a yardstick loss figure derived by taking total GWh losses for all firms and constructing a composite explanatory variable weighted GWh (70%), transformer capacity (20%), and network length (10%).	No	Yes In the fourth price control period, a distribution system operator is rewarded or penalised at 4.8 pence/kWh (in 2004/2005 prices). Losses targets are thereby set between the ranges of 4.96% and 8.73%. A rolling retention mechanism is in place to ensure that distribution system operators receive full benefit of incremental improvements in performance for a period of 5 years.	No
Italy	No	Diverse, e.g. with regard to smart grids.	Yes 2% additional interest rate above WACC for investing in distribution transformers of loss category BoAk or better in period 2008-2011	No
Austria	Yes Utilities have to report losses, which are validated individually by the regulatory authority. In case of implausible or to high values it comes to a detailed review and the regulatory authority might refuse to acknowledge losses above a certain limit. Costs for those exceeding losses have to be paid for by the company itself.	No	Yes Higher procurement costs for transformers with lower losses are acknowledged	Yes For the next regulation period (starting 2010), implementation of incentives is planned.

Country	Maximum values for amount and/or price of losses	General Incentives or Disincentives	Special Incentives concerning Losses	Plans of change
Special incentives to decrease distribution grid or transformer losses:				
Spain	No	Revenue cap regulation for each utility,	Yes But just valid for 4 years (regulatory period) compared to 40 years transformer lifetime. Savings are transmitted to the customers after this period.	Yes New distribution regulation has been approved in 2008 (R.D. 222/2008 of 15th February) in Spain, which establishes 4 years as the revision period for distribution regulation, including losses for every utility. Losses incentive / disincentive is provided : +-1 % of the payment received the year N-1, with regard to the target losses for this year and utility.
Estonia	Yes Losses are running costs, which can be passed on to consumers up to a certain limit. Exceeding losses have to be paid for by the company itself.	Regulatory authority approves the price limit for electricity purchased to cover losses; serves also as component of network charges.	Yes Regulatory Authority reduces the acknowledged amount of losses from one regulatory period to the next (current period 8%, next period 7%)	No

Country	Maximum values for amount and/or price of losses	General Incentives or Disincentives	Special Incentives concerning Losses	Plans of change
No special incentives to reduce grid losses or transformer losses, losses within the price cap or limits set for their inclusion into tariffs:				
Denmark	Yes Costs for losses are included in price cap as running costs and included in tariff calculation up to a certain limit. Exceeding losses have to be paid for by the company itself.	If losses are reduced, the profit of the year will increase but only up to a certain amount (profit cap)	No	No
Hungary	Yes Costs for losses are included in price cap as running costs and included in tariff calculation up to a certain limit. Exceeding losses have to be paid for by the company itself.	Revenue cap: if a company can save costs and exceeds the allowed profit half of the surplus must be returned to customers (profit sharing regulation).	No	No
Lithuania	Yes Costs for losses are included in price cap as running costs and included in tariff calculation up to a certain limit. Exceeding losses have to be paid for by the company itself. If energy was transferred through a certain voltage network, the corresponding network costs are included.	If a company's energy losses are lower than it was calculated in the price cap, they will increase profit. Price is equal to the electricity purchase price.	No	No
Sweden	Yes Standard values are used for both amount and prices of network energy losses: → Maximum volume values are set for each DSO according to calculation based on their specific reference network. → A standard price is used for all DSO and based on average spot price from Nordpool.Exceeding losses have to be paid for by the company itself. Individual maximum loss amounts are calculated from reference networks. A standard price is used for all DSOs.	No	No	Yes „We are currently investigating a move from ex-post to ex-ante regulation which would eventually lead to changes in our current regulation scheme“

Country	Maximum values for amount and/or price of losses	General Incentives or Disincentives	Special Incentives concerning Losses	Plans of change
No incentives to reduce grid losses or transformer losses, no limits set for their inclusion into tariffs:				
France	No	No	No Losses are part of non-quality costs. Technical and economic approach, to optimize losses in distribution transformers and in the grid: calculation of global capitalization cost on a 30 years period => purchase price + true losses costs (calculated loss costs for 30 years minus accounting lifetime) Finally customers pay for losses with tariffs.	No
Germany	Yes	Tendering for price component, but not fully implemented. Rate of return regulation	No	Yes Incentive regulation scheme planned where costs of energy losses will be completely outside the cap + just tendering for price component, i.e. no incentive to reduce amount of energy losses.
Poland	Yes	Utilities are in general obliged to keep transformer losses within certain limits (amount and price). However, due to lack of precise measurement of losses in network components, utilities are able to transfer costs of losses to customers. Revenue cap regulation, efficiency benchmark between companies	No	Yes At present there exist 14 distribution companies due to liberalization and competition this number is expected to decrease to 6; in consequence efficiency benchmark will not be able to operate anymore so the regulator is forced to find a new methodology.

Country	Maximum values for amount and/or price of losses	General Incentives or Disincentives	Special Incentives concerning Losses	Plans of change
No incentives to reduce grid losses or transformer losses, no limits set for their inclusion into tariffs:				
Norway	No	Economic regulation gives an overall incentive to stay relatively efficient compared to other utilities. Utilities have to buy energy for losses in the distribution system in the market, they keep focus on the price more than on the amount of losses. Revenue cap regulation allows including forecasted costs for losses in tariff calculation Revenue cap regulation is divided in 60 % based on historic costs and 40 % based on efficiency benchmark concerning performance of the utilities. The 60 % of the revenue cap that are not subject to competition, might be looked upon as a disincentive to reduce losses, or as it might halt the process of achieving the state where losses are at an optimum. The utilities feel that if they do an investment to reduce losses, and therefore costs, they are not fully reimbursed, because they do not keep the profit from the reduced loss, as efficiency measuring is included only with 40% in the regulation.	No	Yes The current level of the efficiency measuring part of the income is 40%. This will be 50% from 2009.
Greece	"The liberalization of the energy market in Greece has only been established on energy production. The distribution network owns exclusively to the Public Power Corporation (PPC) of Greece. After the liberalization, many small producers were added to the production network. However, the main energy producer remains the PPC. Concerning the distribution network, PPC has the monopoly on the distribution."			
Other EU-27 countries	*For the following countries, no information could be gained in the course of this study:* *Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Finland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Portugal, Romania, Slovakia, Slovenia*			

Source: Information from regulatory authorities and other interviewees; available on-line information; Jamasb/Pollitt 2007.

4.1.2.2 Treatment of network losses in the current national regulatory schemes

In general, electricity Distribution System Operators (DSO) have to **document and report** network losses to the national regulatory authorities. However, the degree of detailedness of reporting required differs between countries.

Besides reporting on losses, network losses are treated differently in the different regulatory schemes. The following options can be observed in practice:

- **No limits set for inclusion of loss costs in tariffs**
  - In several countries, there are no limits set for inclusion of loss costs in tariffs at all: France, Poland, Germany (but requirement to tender for price of energy to cover energy losses) and Norway
  - In these countries, loss costs are outside the cap, which is a real disincentive to investment in energy efficiency.
- **Grid losses within general caps**
  - In few countries, grid losses are subject to the general price cap: Denmark, Hungary, Lithuania. However, not all network losses can be influenced by the electricity distribution company.
- **Maximum values for inclusion of loss costs in tariffs**
  - In some countries, maximum values for amount and/or price to limit network losses exist; costs for exceeding losses have to be paid for by each company itself.
  - Austria and Sweden calculate additionally individual maximum values for the amount of loss energy for each company. In Austria companies higher procurement costs for transformers leading to lower losses can be approved in the regulatory process.
  - In Estonia, the regulatory authority reduces the annually acknowledged amount of losses from one regulatory period to the next (current period 8%, next period 7%).
  - If companies in Austria, Estonia and Sweden exceed the given limits, they have to cover resulting additional costs from their profit margin.
  - In Germany, the national regulatory authority has benchmarks for network losses at its disposal, but has not applied them yet in the current regulation scheme.
- **Specific incentives within regulation scheme**
  - Real incentives were only found in Great Britain, where the price controls includes an incentive on losses. For every kWh by which losses exceed or are lower than a target rate, the distribution network operator (DNO) is penalised or rewarded by £48/MWh (in 2004/05 prices) (information gained by email from National Regulatory Authority, OFGEM, 2007; Jamasb/Pollitt 2007).

- **Importance of the length of the regulatory period or how long cost savings can be retained by the electricity distribution company**
  - The Spanish example shows: a real obstacle for utilities to install efficient equipment will be if cost savings can not be retained after the regulatory period but have to be transmitted to the customers. This reduces the economic lifecycle of transformers from 40 years to 4 in the case of Spain.

4.1.2.3 Elements proposed for regulatory schemes in general

Based on this analysis, the SEEDT project recommends the following elements for the regulation of electricity distribution companies:

- Electricity distribution companies in Europe should regularly **report** on distribution network losses, number and size and losses of distribution transformers, and prices for loss energy in a unique, comparable way. In this context, for describing the efficiency of transformers, the labelling classes proposed could be used, or EN 50464 and HD 538 respectively.
- Based on this reporting, a national and European **benchmarking system** should be developed.
- **Deviations from a loss target** (benchmark) set should be **rewarded or penalised** like it is done in Great Britain.
- If there is no scheme with benchmarks for energy losses, other financial **incentives to buy energy-efficient distribution transformers with least life cycle costs** should be set within the regulatory scheme. For example, in Italy, in the regulation period 2008-2011, the regulator allows a 2% higher interest rate above weighted average costs of capital (WACC) for the first eight years of an investment into energy-efficient transformers of the category BoAk or better. ENEL has now announced to issue a call for tender for about 40,000 transformers with specifically high energy-efficiency requirements. Other possibilities are specific energy-efficiency investment budgets or bonuses. Such incentives should not be limited to one regulatory period only. A **sufficient payback period** for the investment in energy efficiency is needed. For example, it will not be fully clear yet if the eight years in Italy are sufficient. Jamasb and Pollitt (2007) argue that longer regulatory periods can reduce uncertainty with regard to long-term incentives and retain their benefits, although they alone might not be sufficient to fully incentivise investments in innovations with even longer payback periods.
- However, not in every country such an incentive scheme is feasible politically or in practice. For example, a high number of distribution companies will lead to extensive transaction costs if individual loss targets or investment rebates are given. In these countries, **at least**, existing **disincentives** towards investment in energy-efficient distribution transformers should be **removed**. Furthermore, in these countries, it could be considered to include specific **energy losses as a parameter into existing schemes that compare the economic efficiency of**

distribution companies and that reward or penalise those companies that behave better or worse than market average.

In any case, it should be noted that incentives to reduce transformer losses might face conflicting incentives on, e.g., capital efficiency, operating efficiency, and quality of supply. As the experience from UK shows, such conflicts can also occur between Capex and losses where firms may prefer to invest in conventional transformers rather than energy-efficient ones in order to reduce expenditures. In principle, this can be viewed also as a conflict between short-term and long-term efficiency requirements. While regulatory schemes are usually focusing the short-term perspective, they often ignore the fact that higher short-term costs, e.g. due to investment in energy efficiency, might lead to long-term efficiency improvements (Jamasb/Pollitt 2007 based on Ofgem 2003).

Therefore, not only single incentives or disincentives and their short-term impact, but the whole regulatory scheme has to be considered when redesigning it to reduce transformer losses in order to reduce life cycle costs of distribution transformers.

Since the regulatory schemes currently in place differ from one country to another, implementation of changes in regulatory regimes has to be adapted to the country-specific starting-point. In the following, such specific solutions for two countries are discussed in more detail, namely for Germany and Spain.

4.1.2.4 Specific solutions for selected countries – Germany

Situation in Germany 10 years after the start of the liberalisation process

In principle, it can be criticised that politicians and ministries in Germany, from the beginning of the liberalisation process, have not taken into account any incentives for energy companies to improve energy efficiency besides the incentives set within the emissions trading scheme. In particular, there is no guarantee within the energy system that the energy industry can refinance **investments** for cost-effective activities in order to decrease the consumer´s energy-bill by **increasing energy efficiency** on the demand side, e.g. financed by a slight increase in network tariffs, as the Wuppertal Institute suggested in several comments and expertises in the past (e.g. see Thomas 2007; Irrek/Thomas/et al. 2006; Wuppertal Institute 2003; Wuppertal Institute/ASEW 2003) and as it has been demanded by an association of municipal energy companies in Germany (ASEW) again recently. Such a regulation could meaningfully complement the rivalry for cheap kilowatt hours by competition between energy supply and efficient energy use.

Decree on an incentive regulation scheme of 29 October 2007

This situation will hardly be changed by the **new incentive regulation scheme** which came into force in November 2007, and which will substitute the existing cost-plus rate-of-return regulation scheme from 1 January 2009 onwards.

Nevertheless, this new scheme can be appreciated from economic and ecological perspective as well as from the consumer´s point of view to that extent as it (cf. also Leprich 2007)

- overcomes the disadvantages of cost-oriented rate-of-return regulation with regulatory audits carried out annually or every second year
- sets incentives for the limitation of the network operators´ revenues and for the improvement of their economic efficiency
- plans a regulation account which targets to balance network operators´ revenues by setting real revenues against appropriate revenues and to refund the overcharge of fee to consumers in the following periods
- is planning to provide a basis for the integration of incentives in the regulation scheme concerning assurance of supply reliability and service quality (from the second regulatory period onwards)
- tries to set sufficient incentives for necessary investments in grid infrastructure in a changing energy system, and
- contains substantial regulations for the increase in transparency.

In addition, former empirical analysis by the Wuppertal Institute identified the number of customer connections (differentiated by customer subgroups) and the change in the yearly peak load as particularly relevant **cost drivers** in the electricity grid in North-

Rhine-Westphalia (Leprich/Irrek/Thomas 2001; WI/Politecnico di Milano/MWMTV NRW/Energieverwertungsagentur 2000). The regulatory authority originally considered these factors as well as the most important cost drivers, but added further cost drivers to the list of parameters to be considered when comparing costs and economic efficiency of different electricity distribution companies.

However, the current treatment of **loss energy costs as a durably not influenceable cost element** in this new incentive regulation scheme will mean that loss energy costs can be passed on to consumers entirely even though network companies are able to at least partly **affect** these costs.

According to §11 (2) of the decree on the incentive regulation (Verordnung über die Anreizregulierung der Energieversorgungsnetze; Anreizregulierungsverordnung - ARegV), durably not influenceable cost elements in electricity networks are "as well such costs and revenues which underlie an **effective process regulation** as per specifications of the power network access or regulation (EG) No. 1228/2003 of the European Parliament and the European Council from 26 June 2003 concerning network access conditions for cross-border power trade..., in particular...costs which emerge for the purchase of energy for compensation activities", which includes specifically loss energy costs after the rationale of the present draft.

This is declared to be justified by the assumption that **tendering procedures for the delivery of loss energy** already provide sufficient incentives for cost reduction of loss energy. A concept that specifies requirements for these procedures has already been drafted by the regulator (BNetzA 2007) and will be concluded in the coming months.

However, this neglects the fact that loss energy costs result from multiplication of price for loss energy with amount of loss energy. The current regulation scheme as well as the coming incentive regulation scheme consider the **amount of loss energy** as invariant from the perspective of the electricity distribution company, although possibilities exist to influence the amount, e.g., by

- Investing in **energy-efficient distribution transformers**,
- Design and material used for **power supply lines**,
- **changes in the network structure**. For example, some (particularly urban) power network operators plan to reduce existing redundancies in the network and thereby as well their assets and current costs for maintenance and loss energy.

Suboptimal regulation result: Minimization of initial costs instead of minimization of life cycle costs

The purchase of more efficient equipment is generally connected with **higher initial costs.** While current loss energy costs can be passed on to consumers in the new incentive regulation scheme in Germany from 2009 onwards, costs for procurement belong to costs influenceable by network operators and are subject to the „cap", which will lead to the purchase of cheap, non-efficient equipment only. While this could represent an economically meaningful incentive in some cases, where initial investment costs are decisive, it will lead to the choice of the economically suboptimal solution in many cases.

In the above mentioned case of distribution transformers this means that finally transformers with **minimal initial procurement costs instead of minimal life cycle costs** are purchased. Although the regulator, in a letter to the parliamentary undersecretary of state of the Federal Ministry for Environment, stated that investment that increases energy efficiency of the grid should be adequately accounted for in the coming incentive regulation scheme (Kurth 2008: "Werden mit Investitionen auch Maßnahmen durchgeführt, die der Energieeffizienz des Netzes dienen, so werden diese in der Anreizregulierung adäquat zu berücksichtigen sein."), the incentive regulation scheme has not been designed yet accordingly.

Possible solutions and their feasibility

Three conceivable solutions for changes of the incentive regulation scheme (ARegV) have been analysed in the course of the SEEDT project:

- Option A:
  Loss energy costs are recognized in the context of the regulations only up to a given quantity of loss energy (**loss energy benchmark**). Exceeding loss energy costs are not refunded by network tariffs to network company. Alternatively, individual reduction rates for loss energy are set by the regulatory authority. Maximum energy losses could also be set as a kind of quality requirement within the part of the regulation scheme taking into account diverse quality aspects.
- Option B:
  Special investment budgets can be approved by the regulatory authority for extra costs of the procurement of particularly more energy-efficient equipment. As an additional incentive, a bonus of e.g. 10% of recognized extra costs for the investment in an increase in energy efficiency is granted to network operators as additional part of approved investment budget.
- Option C:
  Loss energy could be included as **parameter into efficiency comparison** between different electricity distribution companies.

Option A: Loss energy benchmark and default values for reduction in loss energy

There are examples and models of such (possible) default values for reduction of loss energy in regulating power network operators in some countries, e.g. in Indian states (e.g. see Kerala State Electricity Regulatory Commission; Uttarakhand Electricity Regulatory Commission).

However, the problem in designing a loss energy benchmark and default values for reduction of loss energy is, that the generation of parameters demands differentiation in voltage and transformation level as well as in further structural characteristics if necessary; whereas an incentive regulation scheme aims at abstaining from such a detailed regulation.

Furthermore, there is the possibility that network companies can partly escape such a detailed regulation by selling transformers to customers or third parties.

Alternatively, loss energy default values could be determined also by enterprises´ individual determination of loss energy reduction potentials, which would, however, require substantial time and effort considering the number of network companies in Germany.

Finally, maximum energy losses could also be set as a kind of quality requirement (quality benchmark) within the part of the incentive regulation scheme taking into account diverse quality aspects, which will be further extended in a coming second incentive regulation period.

Option B: Investment budgets for energy efficiency investments

Due to the doubts specified above, a second solution is discussed, offering special investment budgets for particularly energy-efficient investments, provided with additional bonuses. For the **determination of additional procurement costs for particularly energy-efficient technology, a „baseline“** has to be set. How this „baseline“ can be determined, will be illustrated in the following example of **distribution transformers**:

- First, for different types (oil-immersed/dry-type) and sizes (kVA) of transformers it is determined to which energy efficiency classes the purchased transformers in accordance with HD 538 and EN 54464 belong on average.
- In a second step, average purchase values for these transformer types are set on basis of publicly available literature, data of distribution companies and market data of manufacturers.
- Third, the resulting "Baseline" with regard to transformer costs is compared with actual initial costs for particularly energy-efficient transformers, while distribution companies are obliged to issue tenders when purchasing energy-efficient transformers.
- From this, additional procurement costs will be derived, and - in order to set an additionally incentive by bonus - multiplied by 110%. These 110% of additional investment costs will become part of a special investment budget.
- The „baseline“ is specified anew at the beginning of each regulation period. This can be done by extrapolation of the development of usually purchased transformers before beginning of the implementation of the incentive regulation and/or on basis of market data of transformers purchased by network operators in other countries

where no favorable conditions do exist for the procurement of particularly efficient technology.

Following these considerations, an **insertion of the following paragraph could be discussed as an amendment to §23 of the current decree on incentive regulation (ARegV):**

„Investment budgets can be approved by the federal net agency also for investments for increases in energy efficiency. This covers especially investments in particularly energy-efficient operational equipment (e.g. transformers), whereby the investment budget covers only extra costs of the procurement of particularly energy-efficient operational equipment compared with usally purchased technology (average values). Initial costs of a typically purchased technology are empirically determined at the beginning of the first regulation period by the federal network agency and become updated in the subsequent periods by means of suitable methods. Those procurement extra costs of particularly energy-efficient operational equipment are recognized only if procurements have been undergone via a public tender.“

The hereby reached asset optimization would surely be favourable. However, disadvantages of this option are that

- this kind of investment budget determination represents detailed regulatory intervention („micro regulation“), which contradict the idea of a slim regulation,
- the determination of investment budgets for hundreds of network operators appears very complex, and
- the grant of an additional budget is difficult to mediate politically, even if it is economical advantageous.

For these reasons this second model does not seem to be an optimal solution either.

Option C: Loss energy as parameter in the efficiency comparison

A definite, overall convincing solution does not seem to be available for the (transformer) loss energy problem. One possibility remains, i.e. to add loss energy as parameter for economic efficiency comparison between electricity distribution companies since it is - like already described – partly influenceable by network operators.

For further examination of the feasibility and possible way of inclusion of loss energy into an efficiency comparison, additional analytic and/or statistic investigations would have to be carried out. As a result, of such an analysis, it could be proposed to amend §13 of the decree on incentive regulation (ARegV).

4.1.2.5 Specific solutions for selected countries – Spain

Description of the problem in Spain

The new regulation applied to energy efficiency of distributors in Spain (R.D. 222/2008) is mainly performed on the basis of a parameter known as “Losses Incentive” (Px). The distributor suffers the overall responsibility on the energy losses between generators and consumers.

Every distribution company receives a basic remuneration of costs. In addition, it receives a “losses incentive” which is determined by the difference between the “standard losses” that have been recognised for every distributor and the “real losses” that had to be bought in the market.

Losses Incentive (n-1) = 0.8 x Pr (Standard Lossesn-1 – Real Lossesn-1) x (Eload+Egener)

Where:

n = year

Pr = price of energy losses

Losses Incentive must be between +-1% of the remuneration of year n-1

The reference remuneration for utility i is:

Ri base= Ci base + COMi base + OCD I base

Where:

C i base is the remuneration for the investment (assets)

COMi base is the remuneration for the O&M

OCD I base is the remuneration for other costs (Comercial management, metering, planning)

This incomes are updated as follows:

Rio = Ri base (1+IAo)

Ri1 = Ri0x(1+IA1) + Yio + Qio + Pio

Where:

Pio: Incentive or disincentive due to the reduction of real losses with regard to the goal losses for year n-1

Qio: Incentive or disincentive due to the real QoS with regard to the goal QoS

Yio: Increase of activity (demand)

IA: updating index regarding the evolution of prices

Proposals for a solution

Assuming that the new regulation for distribution companies in Spain includes a term for incentive/disincentive of losses, it seems an improvement with respect to previous regulation.

Nevertheless there are some drawbacks that could provide a real inefficiency to change the trend of increasing real losses that has been experienced until today:

- UTILITY REFERENCE FOR THE CALCULATION OF LOSS TARGETS: The reference for each utility should be the real losses history for each utility, in order to provide realistic signals to every company according to the structure of its market, network characteristics and location of embedded generation, among others. Therefore, any loss target calculated from “zero-based” optimal networks seems a real problem to overcome.
- TEMPORAL REFERENCE FOR THE CALCULATION OF LOSS TARGETS: In order to give each company the right signal about their real losses history, a history as long as possible should be used. This allows calculating a good trend, less affected by seasonal effects (i.e. hidraulicity, temperatures,..) than trends that use one year history. Endesa proposed to the “Energy National Committee” (CNE) to use at least 10 years of history. See OFGEM’s proposal 2004 (historic performance of the DNO, as measured by the average proportion of electricity lost between 1994/95 and 2003/04).
- APPLICATION PERIOD OF LOSS TARGETS: The loss target coefficients are revised every 4 years (regulatory period). It is very difficult to invest deeply in losses improvement when only 4 years are considered in the profitability analysis. Losses incentive of +-1% probably becomes an uncompleted signal to change the trend of distribution losses. Assuming that real life of utility assets are typically 40 years (or more), it seems reasonable that full investors (utilities) should receive the full benefit of incremental improvements in performance for a period of at least 10 years (the first 25% of its life expectation). The mechanism should allow the incremental change in actual losses, adjusted for growth effects, to be retained for a period of 10 years (at least) regardless of when the change occurs.

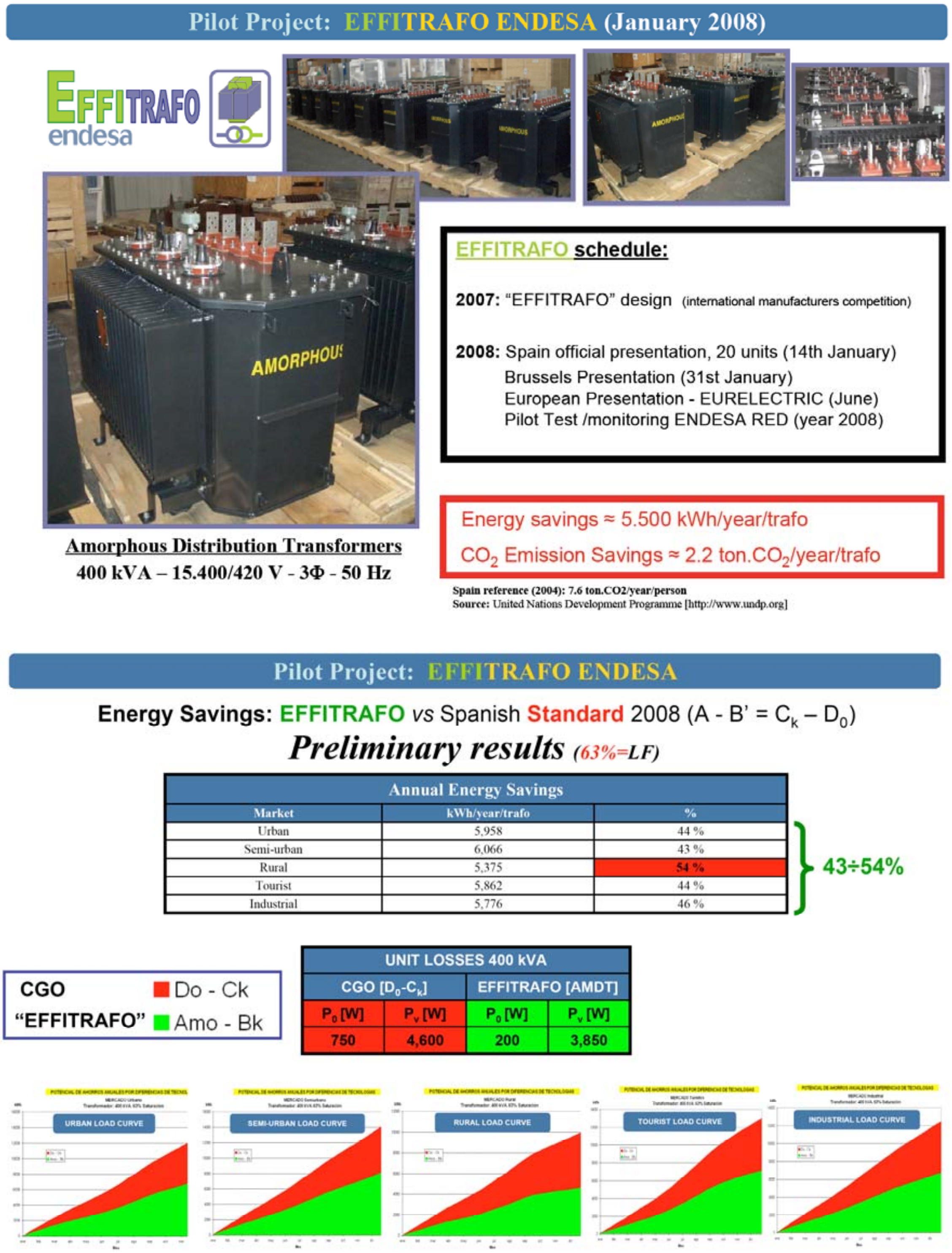
In this context, it must be taken into account that the distribution has not been affected by any other energy efficiency programme in Spain. Up to now, the Spanish Energy Efficiency Action Plans until 2007 (the so-called E4: “Estrategia de Ahorro y Eficiencia Energética en España and the evolution of E4+ for 2008-2012) have focused on consumers and national sectors such as Industry, Transportation, Construction (Buildings), Public Services, Residential, Agricultural and Fishing, and CHP plants. Utilities have been excluded from the E4 incentives 2006-2007 and from E4+, assuming that incomes from electrical distribution regulation should be enough to stimulate energy efficiency among utilities. The real situation is that technical losses from electrical networks are not decreasing in Spain and the expected contribution from this sector to the EU target of saving 20% by 2020 seems not to be focused.

While green energy is substantially supported, efficient transformers should be promoted at the same time and with homogeneous incentives.

In order to effectively promote energy savings, new and more efficient technologies should participate in the European transformers market. Amorphous transformers and hexaformers are two of these efficient technologies that are working very well abroad Europe (mainly in Asia), but haven't found their way into the European market. Endesa is working on this matter, and during 2007 performed several economic and technical analysis with manufacturers from Asia and USA, in order to test their products during 2008 (pilot tests).

In January 2008, ENDESA started an innovative pilot project in Europe, with 20 units of amorphous core transformers (400 kVA) with a reduction of more than 50% of no-Load losses with regard to the most efficient transformer standardized in Europe (Ao according to EN50.464-1). After 6 months of monitoring in different markets these AMDT units, ENDESA is planning to expand the pilot project to South-America in 5 countries (Brasil, Chile, Argentina, Colombia, Perú) installing AMDT transformers.

Figure 7: Effitrafo Endesa – Pilot project with 20 AMDT units



Annual Energy Savings		
Market	kWh/year/trafo	%
Urban	5,958	44 %
Semi-urban	6,066	43 %
Rural	5,375	54 %
Tourist	5,862	44 %
Industrial	5,776	46 %

UNIT LOSSES 400 kVA			
CGO [D_0-C_k]		EFFITRAFO [AMDT]	
P_0 [W]	P_v [W]	P_0 [W]	P_v [W]
750	4,600	200	3,850

Source: Dr Joan Frau, Endesa (Frau 2008)

4.1.3 Incentives from obligations or certificate schemes

In several countries (e. g., UK, France, Italy, Flanders), schemes exist that oblige market actors (in particular, energy distribution or supply companies) to achieve defined energy savings at their customers' sites or homes. These obligations can sometimes be traded as it is the case in UK, or white certificate schemes exist like in France or Italy, with tradable permits for certified energy savings. The Commission's Action Plan on Energy Efficiency even proposes to assess in 2008, to which extent a Community-wide White Certificate Scheme shall be introduced, complementing the emissions trading scheme and possible green certificate schemes.

Such obligation schemes might be applied, when

- aiming at energy savings in large end-user groups which are difficult to address.
- knowledge, financial and institutional barriers play a role.

Characteristics determining the success of this measure are (cf. AID-EE 2006):

- Is the target clearly set beyond business-as-usual?
- Is measurement and verification of savings possible at low cost, e.g. by standardization of energy saving measures?
- Is the cost-recovery mechanism (energy companies' costs passed to end-users) clear and transparent?
- Are there penalties in case of non-compliance?
- Are penalties set at such a level that target achievement is stimulated?
- Are financial incentives needed to stimulate end-users to implement EE measures?
- Is the market for tradable certificates transparent and reliable?
- Is there undesired overlap with other instruments?

If it is not possible to remove disincentives and include substantial incentives into the regulation schemes as it is proposed in Chapter 4.1.2, in those countries where energy saving obligations or white certificate systems exist, it should be allowed to

- offset part of an energy saving obligation a distribution company has by the implementation of energy-efficient distribution transformers beyond business-as-usual in its own premises; or to
- give certificates to energy supply companies obliged to generate savings for installing energy-efficient distribution transformers beyond business-as-usual at the sites of distribution companies.

Until now, in the current White Certificate and obligation schemes, this is not possible. According to information by ENEL received at a SEEDT workshop in Brussels in January 2008, the Italian ministry has recently refused the inclusion of such possibilities into the existing white certificate scheme. The ministry argued that the white certificate scheme would just focus on end-use energy efficiency, not on energy efficiency of the distribution system. However, laws might change: The French Regulator (CRE- Commission de Régulation de l'Electricité) is thinking about including energy-efficient distribution transformers as a possibility for white certificates.

Anyway, in order to avoid double incentives, the options to include energy-efficient distribution transformer measures into such certificate or obligation schemes should only be allowed if the regulatory scheme is insufficient. However, a third possibility should be allowed not depending on the regulatory scheme: Electricity distribution or supply companies obliged to generate savings should receive certificates for installing energy-efficient distribution transformers beyond business-as-usual at the sites of industrial or commercial customers as long as the sites / equipment is not subject to the emissions trading scheme.

Furthermore, it could be thought about allowing 'cross-JI' projects between different European Member States on energy-efficient distribution transformers, or other (unilateral) domestic offset projects implementing energy-efficient distribution transformers that might be allowed to offset emissions of installations obliged by the emissions trading scheme.

In Chapter 2.3, it is already explained in principle, how measurement and verification of savings or emissions reductions could be designed as a basis for generating certificates.

4.1.4 Other financial or fiscal incentives

If it is not possible to remove disincentives and include substantial incentives into the regulation schemes as it is proposed in Chapter 4.1.2 or to implement the alternative incentives described in the previous subchapter, other financial or fiscal incentives to electricity distribution companies have to be installed in order to offset disincentives from the regulatory scheme, which hinder the implementation of least-cost optimal solutions. Such financial (rebates, subsidies) or fiscal (deduction from taxes) incentives would be a temporary measure until the existing disincentives were removed and incentives were internalised within the regulatory scheme.

With regard to other customer groups, financial (rebates or cheap credits) or fiscal (deduction from taxes) incentives could be a temporary option to be included into a policy package aimed at overcoming the already described barriers and obstacles which hinder the implementation of least-cost optimal solutions in industry and commerce. The experience from other fields of application shows, that financial or fiscal incentive programmes are effective and efficient to attract attention from the target groups, because they signal that it will be worth to invest in this efficient technology. However, they need to be accompanied by information, qualification and training in order to pave the way from attracting customers and gaining their interest into the subject to demand for and implementation of energy-efficient transformers. ESCOs, energy consultants and planners, giving advice to industry and commerce, and being involved in planning and/or implementation should be well-informed about the financial or fiscal incentives, and therefore addressed by such comprehensive programmes, too. Moreover, ESCOs should be allowed to receive the incentive if they own the transformer.

4.1.5 Labelling

4.1.5.1 From improvement of the rating plate (nameplate) to a specific energy-efficiency label for distribution transformers

Buyers of distribution transformers usually already receive detailed technical specifications from their suppliers. However, the information on **rating plates (nameplates)** and specifications given in catalogues and on request differ between suppliers and countries, and non-load and load losses are not always stated on the nameplates. Therefore, in order to increase transparency, there should be a requirement to state non-load and load losses on every nameplate of any transformer sold in Europe, namely the **loss category according to the current norm as well as the losses as measured during the testing procedure**.

However, this data on the nameplates is not easily visible. A label would be one more piece of information more. It permits visible comparison between the different possible energy losses, because it allows a visual comparison, a very obvious classification of the performance of the product. Of course, this will be less useful for the more skilled energy companies or industries, but it can be of help to the others. Furthermore, it will constitute an encouragement for the manufacturers to propose and produce more energy-efficient transformers. Therefore, an **energy efficiency labelling** of distribution transformers is suggested here. Like in the circulator industry, the label does not have to be a mandatory one from the beginning, but could be a voluntary label when it starts.

As presented in the respective chapter in the SEEDT report on the existing situation (Deliverable No. 1), energy-efficiency labels are informative (and sometimes mandatory) labels affixed to manufactured products to shortly indicate the product's energy performance (usually in the form of energy use, efficiency, or energy cost); these labels give the buyers and consultants to buyers a quick information to make informed purchases.

This is particularly relevant to small and medium enterprises (industry, commerce, but also electricity distribution companies) and their consultants and planners who lack of information and knowledge, if the introduction of the labelling scheme is accompanied by an **information and qualification campaign** informing about energy-efficient distribution transformers and qualifying buyers and their assistants to choose least-cost optimal solutions.

4.1.5.2 What information should a label contain in general?

An energy efficiency label, designed for a given product, should contain at least two parts:

- One part to identify the transformer model type, including the name of the manufacturer, the brand name and the model, added by the rated power, which is the first element defining a distribution transformer;
- One part related to the energy efficiency of the product, with,

- Information on the energy-efficiency performance of the product,
- Information on the product itself to allow comparison with other products that fulfil the same usage (or the same service).

In general, the information on the energy-efficiency of the product should be on the very usage of the product:

- It is generally expressed for **one unity of service**, and not for the product in its totality, so that **exactly the same usage is compared**.
- The information should be given **for a defined usage**, if possible **representative of the most current usage of the product**.

This can be illustrated by two examples. For washing machines, the energy efficiency is defined by the energy consumption necessary to wash 1 kg of clothes, at a given temperature. Before defining the label, an inquiry was conducted, in order to know which cycles are the most commonly used, so the label can be defined for that cycle. Defining the energy consumption for one kg of clothes allows eradicating the difference of consumption due to the differences of size of the machines. It can include (and it includes for the washing machines) also the energy-efficiency of clothes drying. This conducts to a label with several letters, according to the number of parameters measured.

For refrigerators, the energy efficiency is expressed in order to maintain 1 kg of food at the desired temperature, so the size of the refrigerator is not influencing the energy performance indicated on the label. This point is particularly important, because a small refrigerator is, per nature, less consuming than a big one (the volume to refrigerate is smaller).

But the service given by a small refrigerator (let say 120 l) is not the same than the service given by a big one (let say 250 l). The small refrigerator is targeting single, the big one the 2 or 3 children family. Due to that, refrigerators are classified according to their size. For a range of size, the products can show efficiency from G until A.

One understands, with the previous example, the necessity to define typical use of products (categories of product, for instance per size) and to compare, with the label, only the products with the same usage. But it has to be concluded that the label should also give the information on the service realized by the product.

Coming back to the last example, this conducts to indicate on the refrigerator label the total capacity of the refrigerated volume.

Please note that no label is giving information on the choice how to satisfy one's own needs:

The label for refrigerator is not indicated the refrigerator volume you need if you are single or if you have 4 children.

4.1.5.3 What information could the label contain?

The existing European Union labels give other product-specific information than energy-efficiency-related information, that seem to be useful to compare different products of the same usage.

> *For instance, noise level is an information that is often indicated (on washing machine for instance). Washing machines includes also a value indicated the water consumption for one cycle.*

This is not mandatory, but should help the buyer. At this stage of the discussion, it should be asked: “Which information is important to buyers of distribution transformers?”. The answer depends on the skills of the buyers.

> *For example in France, small utilities base their choice on EDF requirements, because they do not have the internal skills to test distribution transformers.*

So the question that could be addressed is: “Which other information may be important for small utilities?”. One point to take care is to avoid repeating information given on other documents already produced and given to the buyers.

As an option the following parameters might be added to the label;

- the sound power level Lwa in dBa,
- the size (approximate length, width, height and wheelbase in mm),
- the weight (total or separately total and oil weight) of the DT.

Size and weight are parameters that are not changing during the lifetime of the label, which is not the case for noise level. Noise level has to be measured at the same load than the energy efficiency (see below).

> *Noise and size are important parameters; at least for utilities operating in urban area, where noise is a critical problem (one conclusion of the meeting with the Grenoble utility) and for distribution transformers to be put in shelter, where the size of the door can defined the size of the transformer.*

However, the label proposed here concentrates on the energy aspects only, because the other information is usually sufficiently included in other documents or even on the nameplate.

4.1.5.4 Who will be the addressee of a label and how shall it be addressed?

The label should address:

- Electricity distribution companies,
- Large, small and medium industry and commerce
- Engineering firms; ESCOs; consultants.

Of course, labelling will be more useful to small distribution companies and small industry and commerce than the big ones. It will be a concise help, for the point of view of energy, among the other criteria of choice.

It will have a side effect, as all the labels show: it will push the manufacturers to produce more efficient distribution transformers.

General rule about how to address the label is to put it on the sales place, in the catalogue, and in the technical information. The label has to be addressed in documents buyers are susceptible to look before deciding to buy.

4.1.5.5 Other requirement - The evolution of the label in the future

The future evolution of the distribution transformers' performances and how these new performances will be indicated on the label have to be anticipated today.

Contrary to what was stated by manufacturers when the domestic appliances labels were designed, the products rapidly reached the most efficient classes of the energy label, that is to say class B than A. Today, the fridges show two more classes: A+ and A++. This leads to a complex situation, not easy to understand for the general public.

The harmonization in progress with IEC for the different motors classification has taken into account the future evolution of motors, designing one empty class and one class only available for the most efficient Nema motors (only manufactured in the USA).

The design of the distribution transformer label has to anticipate this technologies' improvement, proposing some empty class(es).

In the context of the ecodesign directive process a new naming of labelling classes, maybe together with a scheme for regular dynamisation of labelling, might be introduced in Europe. In particular, a scheme for "automatic" regular dynamisation of labelling scheme is urgently needed as the discussion about "A++", "A+++", etc. shows. However, at the time of this SEEDT report, existing proposals like the open-end labelling proposal presented by the European domestic equipment manufacturers in December 2007 (CECED 2007) have not yet been finally discussed or decided on.

4.1.5.6 Application to distribution transformers

For distribution transformers, the kVA capacity is the element that defines the usage of the transformer. Therefore, a label should be defined for the different capacities of distribution transformers. In order to simplify the understanding, it is proposed to keep the different ranges of capacities existing today for the distribution transformers performances, that is to say 20, 25, 30, 40, 50, 63, 100, 160, 250, 315, 400, 500, 630, 800, 1000, 1250, 1600, 2000 and 2500 kVA. Some capacities may be grouped, if necessary. In case the non standardized kVA value the non-load losses (NLL) and load losses (LL) values should be calculated from the linear interpolation of two neighbouring kVA values, the lower and the bigger.

The process will cover transformers from 20 kVA to 2.500 kVA intended for operation in three-phase distribution networks, for indoor or outdoor continuous service, 50 Hz, immersed in mineral oil, natural cooling, with two windings:

- a primary (high-voltage) winding with a highest voltage for equipment from 3,6 kV to 36 kV; the „old" HD428 standard has only specified losses for transformers of (primary – high voltage winding) rated voltage up to 24 kV. Majority of distribution transformer fleet is included within this group. However the new EN 50464-1 standard introduces higher level of losses for transformers having 36 kV (high) rated voltage level. These transformers naturally are designed at higher rated losses to maintain manufacturing cost at reasonable level. The simplified solution to take this effect into account could be to use certain coefficient (multiplier) which would bring 36kV losses level to 24 kV losses level. SEEDT has performed no analysis on this subject but based on EN 50464 the coefficient could be 0,8 for load losses and 0,6 for no load losses. The meaning of this coefficient is that equivalent load or no load losses at 24 kV are product of nameplate losses at rated 36 kV, LL and NLL respectively and the coefficient. Alternatively losses for U ≤ 24 kV and for U = 36 kV can be specified separately.

- a secondary (low-voltage) winding with a highest voltage for equipment not exceeding 1,1 kV.

The European inventory study of distribution transformers and the life cycle cost calculations have led the SEEDT project team to conclusion that **labelling for dry type transformers is of much less importance**. First of all they account for about 25% of EU-25 newly purchased distribution transformers in terms of capacity (14 out of 56 GVA) but only for 11,5% in terms of volume i.e. number of units (15,700 to 137,000). They are already reasonably efficient, e.g. comparing to Canadian dry type transformers minimum efficiency standard C.802.02-00 and can bring very limited energy saving potential compared to oil immersed transformers. Furthermore, this saving potential is not always economical.

The considered load losses are at 75°C. Short circuit impedance for specified losses is defined according to EN 50464. This practically means that LL and NLL are specified for short circuit impedance of 4% for kVA values below 630 and 6% for values above 630. For 630 kVA capacity, two levels of losses for 4% and 6% are specified,

LL and NLL tests should be carried out according to CENELEC EN 60076-1 Power transformers Part 1: General. If the labelling procedures are in line or included into existing testing standards, additional transaction costs of manufacturers will be negligible. However, unlikely the situation when 15% of losses tolerance for NLL and LL and 10% tolerance for total losses was admitted or like in EN 50464 where the tolerance limits are to be settled in agreement between purchaser and manufacturer, we propose to set zero tolerance limit for NLL and LL.

Transformer below 50 kVA are not analysed in EU standards; on the contrary, they are included in American standards.

The label has to give an information on the ratio: Watt output (of the distribution transformer) / Watt intput (into the distribution transformer), i.e. the efficiency of the distribution transformer.

For distribution transformers, energy consumption is unfortunately not the right information to give, as no manufacturer and no utility are using this information. It has to be replaced by losses, divided in load losses and non-load losses (see below, the different proposals).

Losses will be expressed in W (Watt). For the calculation of LL, the loading of the transformer has to be known or assumed.

4.1.5.7 Three alternative proposals for a label for distribution transformers

According to current norms, the loss category of a transformer is indicated by two letters representing the category for non-load losses and the category for load losses respectively (cf. the SEEDT report on the existing situation, Deliverable No. 1, for more information on existing and planned norms). However, labels for other products like the above mentioned refrigerators or washing machines only contain one letter.

In the course of the SEEDT project, three alternative indications were discussed:

- one letter,
- two letters, or,
- one letter plus an additional indication (as "+", "0" or "-") or a numeric value.

One letter label is simple, easy to understand, especially for people from industry and commerce, who are not as skilled in distribution transformers as people from (larger) electricity distribution companies. Furthermore, a two letters label is more difficult to interpret, with risks of misunderstanding. The one letter label should use a mix of non-load and load losses at certain load factor or over the whole range of possible load factors. However, if this does not specify rated values of LL and NLL, technical people can feel that this information will not be accurate enough. A two letters label might look more precise.

Nevertheless, in order to keep the label simply and by looking at the main target group of a label, which is industry and commerce (and small electricity distribution companies), it was tried to find a one letter solution. However, first, since every solution has its advantages and disadvantages, three different proposals for a label were developed by the SEEDT project team. They are shortly discussed in the following:

Proposal 1 – a no-load losses label (named NLL label)

- This label focuses on no-load losses only.
- The reason of such an indication is that no load distribution transformer losses are responsible for 73% of European Union utilities losses and 71.5% of non utilities losses in distribution transformers.
- A complementary symbol, "+", "0" or "-", indicating the level of load losses could be added. A distribution transformers labelled B+ will have lower load losses (it will be more efficient) than one labelled B-. Except for class A and B “0” will mean the value of LL/NLL ratio between 8 and 12 equivalent to maximum efficiency between 28,9% and 35,5% of loading. “+” will indicate the transformer of LL/NLL below 6,

which reaches maximum efficiency at loading above about 40%, (more suitable for locations where loading is typically higher). "-" will indicate the transformer of LL/NLL ratio above 10 equivalent to maximum efficiency below 32% of loading (i.e. typically low loaded transformers). The reference of no load losses for class A and B will be this, of amorphous transformers. The ratio of LL/NLL will be much higher here than for classes C and further down. So, in case of A and B classes the "+" will indicate LL/NLL ratio of less than 12, while "-" will indicate the ratio of more than 20."0" will mean in this case the 12 to 20 interval.

- Alternatively, one letter symbol can be assisted by a number, in brackets, representing in %, the loading at which efficiency is maximum (load and no load losses are equal). For instance B(20) or B(40).

Proposal 2 – a label based on a simplified combination of no load and load losses (named simplified NLL+LL label)

- This label is based on a combination of no load and load losses, at 40% loading.
- It can be based on a very simple formula. Different ones have been tested, as for instance:

  Total Losses = No Load Losses + Load Losses, for a loading of 40%, i.e.
  Total Losses = NLL + LL * (0,4)

  which means to use the following formula for the label: label = NLL + 0,16 LL.

  Most often, efficiency in international standards is calculated at 50% loading. However, 40% loading is more practical as it is closer to typical average loading in EU25 (19%); 40% is a reference value in Japanese Top runner scheme and represents loading at which the efficiency of a transformer is most often close to its highest level (load and no load losses are equal).

- Alternatively, instead of just referring to one loading, it could be thought about referring to a weighted average of combinations of different loadings, e.g., for 25%, 50%, 75% and 100% loading like it has been done for the label of circulators by Bidstrup et al. (2003).

Proposal 3 – a label based on a precise combination of no load and load losses (named precise NLL+LL label)

- This consideration leads to the third proposal referring to the whole variety of possible loadings, while at the same time ending up with a simple formula including NLL and LL.
- The formula suggested is the following:

  Total Losses = No Load Losses + 1/3 Load Losses

  The rationale of this formula is the following:

  Net power (after deduction of losses) would be
  P = Sx - A - Bx2

  where
  P – net power
  S – rated power
  x – loading (expressed as ratio of rated power)
  A – no load losses
  B – load losses

  The integral of net power from x=0 to x=1 will be the following

  $$\max = \int_0^1 P(x)dx = \tfrac{1}{2}Sx^2 - Ax - \tfrac{1}{3}Bx^3$$

  concluding the sum of efficiencies for the whole variety of loadings from 0 to 1 can be expressed as $Label = NLL + \tfrac{1}{3}LL$ formula.

4.1.5.8 SEEDT project teams prefers the second labelling proposal

After long and detailed discussions among the SEEDT project team members, the second proposal has been preferred by the SEEDT project team. Reasons for preferring the **second proposal** are that

- Compared to the third proposal it is more realistic with regard to load factors existing in practice, although a lower level of, e.g., 20% would be even more realistic.
- The loading of 40% assumed fits to the loading levels used in US and Asian schemes, and thus might be internationally more acceptable. Furthermore, a higher consistency of the different international schemes could be achieved.

The focus in Europe should be currently more on no-load losses, even if a tendency towards slightly higher loading can be observed. Therefore, proposal 1 would be quite reasonable, too. However, in case proposal 1 is chosen, the complementary symbols should be left out in order to make the label not too complicated for buyers. Using two symbols or two letters for the losses may be disturbing the understanding of the label, as it is in the current system.

In general, in practice, for finding a least-cost optimal solution, the label might be a first help, but a detailed calculation is necessary (e.g., by the help of the calculation tool presented in Chapter 4.1.9). This is because for some loadings one combination of NLL and LL might bet he optimal solution, while for other loadings another combination might be preferred. The analysis of the existing situation (cf. Deliverable No. 1 of the SEEDT project) has shown that loadings can differ very much between and within sectors / user groups, i.e. between and within rural and urban electricity distribution companies, large or small industry and commerce.

4.1.5.9 Defining the classes of the distribution transformer label

The proposal by the SEEDT team follows the current use of energy-related labels in Europe, i.e., to have classes named from "A" to "G". If in the context of the ecodesign directive process a new naming of labelling classes (maybe together with a scheme for regular dynamisation of labelling) is introduced in Europe, the labelling proposal for distribution transformers has to be adapted accordingly.

It is suggested to define class "A" as an empty class today in order to anticipate the technology progress. This leads to the following categorisation of labelling classes, with the definition of seven classes of energy-efficiency according to the performance of the product for the load and the no-load losses:

A - VAT – very advanced technology (today an empty class)

B - MAT – more advanced technology (amorphous transformers, today)

C - EAT – energy advanced technology

D - BAT – business as usual technology

E - AST – average sold technology

F - AUT – average technology used

G – WOR – the worst technology today

The label itself might consist of the following elements (cf. the following table):

- Product information
- Energy information
- Other complementary information.

Table 9: Elements of the distribution transformer label proposed

<table>
<tr><th colspan="2">Identification of the product</th></tr>
<tr><td>Manufacturer
Type (oil immersed)</td><td>50 Hz, 3 phase, Primary voltage / secondary voltage [kV]
Rated power [kVA]</td></tr>
<tr><th colspan="2">Energy information</th></tr>
<tr><td>Drawing of the classes
A - VAT – very advanced technology
B - MAT – more advanced technology
C - EAT – energy advanced technology
D - BAT – business as usual technology
E - AST – average sold technology
F - AUT – average technology used
G – WOR – the worst technology today</td><td>Indication of the class of the product (by an arrow for instance)</td></tr>
<tr><td colspan="2">Other complementary information
Value of no load losses (in Watt)
Value of load losses (in Watt)</td></tr>
</table>

Following the three proposals described in the previous subchapter, and referring to the existing European norm EN 50464, the following tables describe how the classes could be defined for the three alternatives.

Table 10: Labelling classes in label proposal 1

<table>
<tr><th>Label</th><th colspan="2">Definition</th></tr>
<tr><td></td><td>No load losses NLL
(ref EN 50464)</td><td>Load losses LL
(either % of loading to reach maximum efficiency i.e. when LL = NLL) or see below</td></tr>
<tr><td>A</td><td colspan="2">Empty class today</td></tr>
<tr><td>B</td><td>NLL $\leq 0{,}45 \cdot C_o$</td><td>LL/NLL <12: “+”
12 ≤ LL/NLL ≤ 20: ”0”
LL/NLL > 20: “-“</td></tr>
<tr><td>C</td><td>$0{,}45 \cdot C_o$ < NLL ≤ $0{,}72 \cdot C_o$</td><td rowspan="5">LL/NLL < 6: “+”
6 ≤ LL/NLL ≤ 10: "0”
LL/NLL > 10: “-“</td></tr>
<tr><td>D</td><td>$0{,}72 \cdot C_o$ < NLL ≤ $0{,}88 \cdot C_o$</td></tr>
<tr><td>E</td><td>$0{,}88 \cdot C_o$ < NLL ≤ $1{,}00 \cdot C_o$</td></tr>
<tr><td>F</td><td>$1{,}00 \cdot C_o$ < NLL ≤ $1{,}25 \cdot C_o$</td></tr>
<tr><td>G</td><td>NLL > $1{,}25 \cdot C_o$</td></tr>
</table>

Table 11: Labelling classes in label proposal 2

Label	Definition
A	Empty class today
B	$\frac{NLL + 0{,}16LL}{REF} \leq 0{,}75$
C	$0{,}75 < \frac{NLL + 0{,}16LL}{REF} \leq 0{,}85$
D	$0{,}85 < \frac{NLL + 0{,}16LL}{REF} \leq 0{,}95$
E	$< 0{,}95 \ \frac{NLL + 0{,}16LL}{REF} \leq 1{,}05$
F	$1{,}05 < \frac{NLL + 0{,}16LL}{REF} \leq 1{,}2$
G	$\frac{NLL + 0{,}16LL}{REF} > 1{,}2$

with
REF is Watt loss calculated from the formula REF=Co+0,16·Bk where
Co – is Co class of no load losses as per EN 50464
Bk – is Bk class of load losses as per EN 50464 (CoBk = CC' of HD428)

Table 12: Labelling classes in label proposal 3

Label	Definition
A	Empty class today
B	$\frac{NLL + 0,333LL}{REF} \leq 0,82$
C	$0,82 < \frac{NLL + 0,333LL}{REF} \leq 0,92$
D	$0,92 < \frac{NLL + 0,333LL}{REF} \leq 1,02$
E	$1,02 < \frac{NLL + 0,333LL}{REF} \leq 1,12$
F	$1,12 < \frac{NLL + 0,333LL}{REF} \leq 1,22$
G	$\frac{NLL + 0,333LL}{REF} > 1,22$

with

REF is Watt loss calculated from the formula REF=Co+0,333·Bk where

Co – is Co class of no load losses as per EN 50464

Bk – is Bk class of load losses as per EN 50464

4.1.5.10 Summary of the three labelling proposals

Proposals number 2 and 3 are illustrated below as areas of labels B to G.

Figure 8: Illustration of labelling proposal 2 for 400 kVA transformer

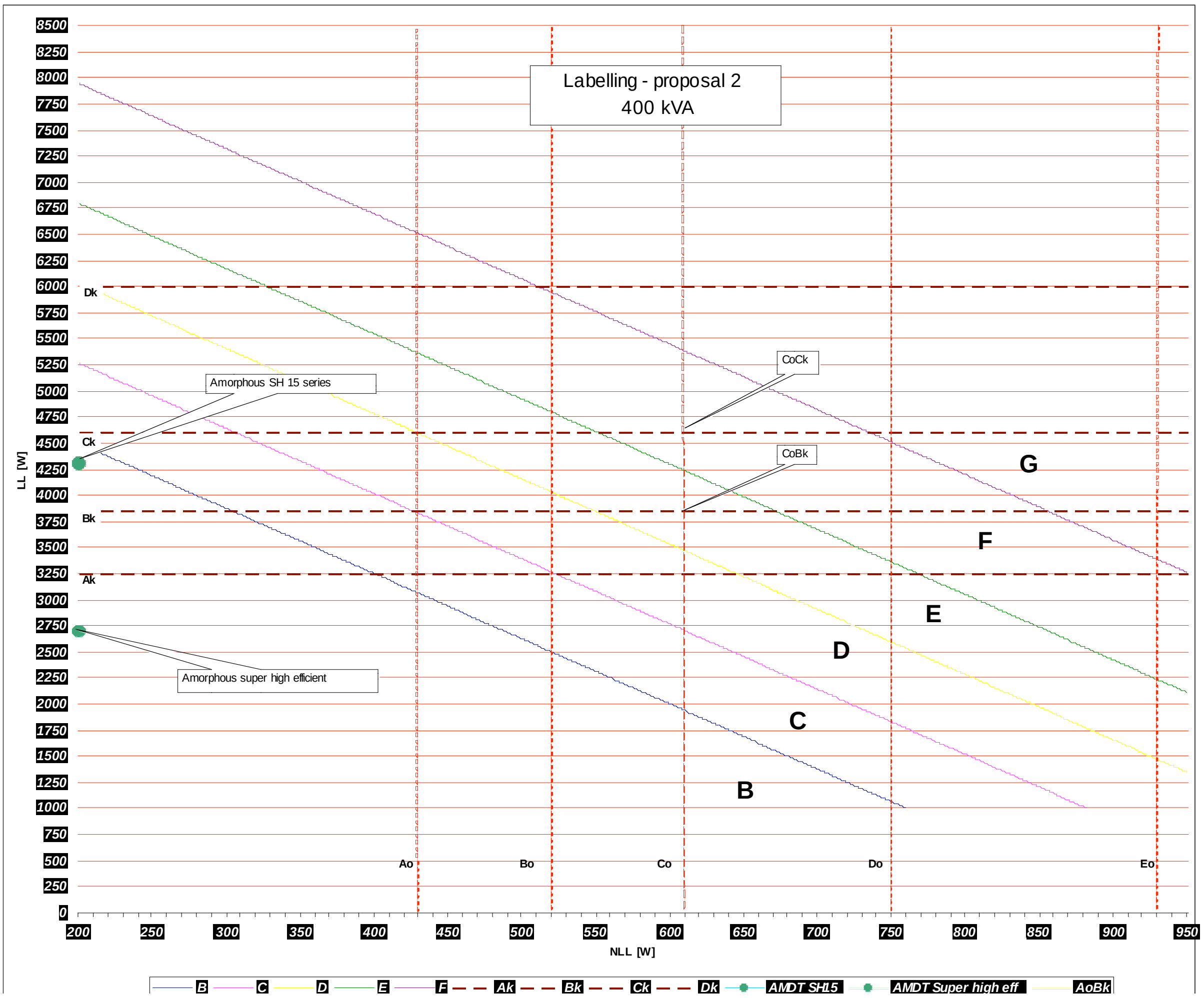
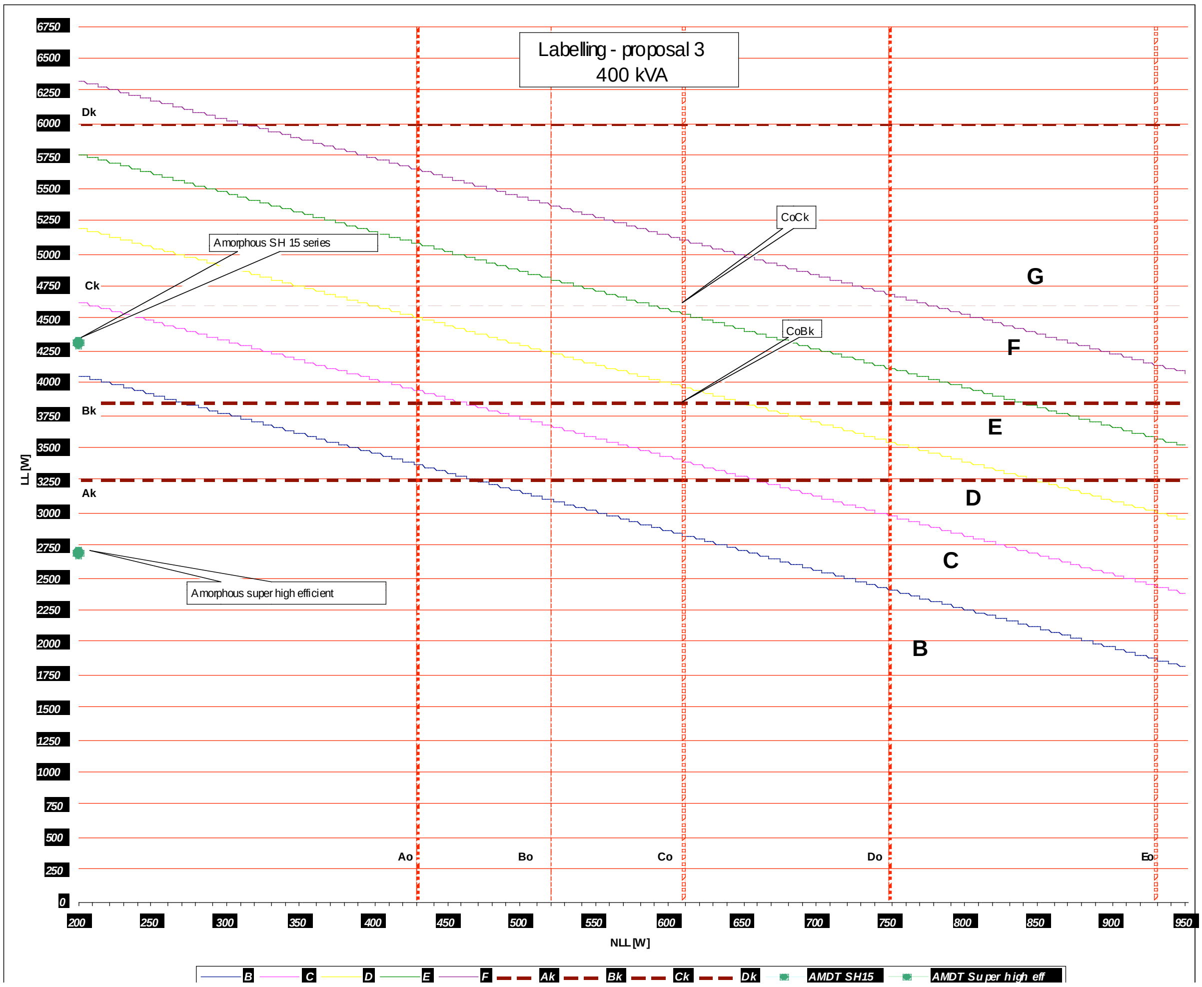


Figure 9: Illustration of labelling proposal 3 for 400 kVA transformer



The figures show that proposal 2 compared to proposal 3 is less sensitive to load losses – the variation of labels across one level of no load losses is smaller.

The following table presents summary of all proposals. The label classification of all existing loss classes is presented.

Table 13: Summary of all label classifications proposed and comparison with existing classification in EU norms EN 50464 and HD428

EN 50464	Proposal 1	Proposal 2	Proposal 3
Ao-50%Ak	B+/B0	B	B
Ao-50%Bk	B0	B	B
Ao-50%Ck	B-	B	C/D*
Ao-50%Dk	B-	B/C	E
AoAk	C0	C	B
AoBk	C0	C/D	C
AoCk	C-	D/E	E
AoDk	C-	F	G
BoAk	D0	C/D	C
BoBk	D0	D	D
BoCk	D0	E	E
BoDk	D-	F/G	G
CoAk	E+	D	C
CoBk	E0	E	D
CoCk	E0	F	F
CoDk	E0	G	G
DoAk	F+/G+	E	D
DoBk	F+/G+	F	E
DoCk	F0/G0	F/G	F
DoDk	F0/G0	G	G
EoAk	G+	F	E
EoBk	G+	G	F
EoCk	G+	G	G
EoDk	G0	G	G

"X/Y" ("C/D" etc.) means that the losses mix is close to boarder between label C and D (for some kVA’s it may be C for other D).

4.1.5.11 How to control the implementation of the labelling scheme?

While for the categorisation of transformers according to one of the three proposals already existing testing procedures and standards could be easily applied, controlling the implementation of the label might be more difficult. In contrast to domestic appliances, there is no shop open to the public where the equipment can be bought and the label be watched. Furthermore, carrying out a test of a transformer in order to control the categorisation needs much more resources. In addition, the comparability of transformers of the same type is limited since transformers are usually designed individually for every buyer.

Therefore, the possibilities of control are limited. If the label is a mandatory one, the easiest way to control the label will be to require the buyers to inform the responsible public authority about every procurement, so that the public authority might join the buyer during the tests he/she carries out anyway (routine tests of a small sample of transformers bought in the market).

4.1.6 Minimum efficiency standard

In Europe, a voluntary standard / agreement will not function in practice. In theory, it would work as a kind of agreement of transformer manufacturers who commit to gradually transform the market of distribution transformers into more efficient units. However, Cotrel as representative of transformers manufacturers has not developed such a voluntary agreement, and single manufacturers, if any, will not be effective enough to patronise such an idea.

The idea to introduce a mandatory EU-27 minimum energy efficiency standard for distribution transformers is reasonable in so far as it removes the worst efficient transformers from the market and thus eases (narrows) the choice particularly of those buyers that do not use sophisticated calculation tools to identify the least-cost transformer solution for them. As already described, many small and medium enterprises in the electricity sector, industry and commerce and their consultants and planners follow traditional procurement routines without questioning the cost-effectiveness and efficiency of the transformers they choose.

While a mandatory standard can improve the average efficiency of transformers in the market in principal, it has to be carefully designed in a feasible way.

A mandatory standard can only be introduced if the national regulation of electricity distribution companies acknowledges the higher investment costs needed for more energy-efficient transformers.

Furthermore, because of competition reasons, the standard should not apply to transformers of electricity distribution companies only (which could escape the standard by selling transformers to their customers or third parties), but to all distribution transformers (MV> 1kV<36 kV, LV< 1 kV) entering EU-27 market or are sold in the EU-27 market (direct sales and imports).

The new EN50464 norm has changed European situation in oil-immersed distribution transformer classification. It also gives more flexibility in setting mandatory or labelling proposals. Now, Cenelec TC 14 Committee has received a mandate to amend HD 538 standard for dry type transformers. The SEEDT team has kept away from any proposal for dry type transformers. Such proposals are reasonable but at later stage, particularly when Cenelec proposes new more efficient loss classes for dry transformers. However, it is also advisable to suggest to Cenelec, at this stage, that there is a demand for new efficient loss categories and a minimum efficiency standard and / or labelling scheme. The product line of amorphous dry type transformers exists and gives similar no-load losses reduction opportunities as for oil transformers.

The mandatory standard should be ambitious, but should allow buyers, manufacturers and their suppliers to adapt to it without too severe negative impacts. In particular, from the societal perspective, least-cost optimal solutions should be aimed at.

From manufacturing perspective it should be avoided to set standard levels that would require products to be constructed of a single, proprietary design or material.

Such a mandatory standard can be designed in one of the following ways:

- maximum allowable no load and load losses, or
- minimum efficiency at particular loading.

Maximum allowable losses standard would have the main drawback of lack of flexibility in selecting the optimum mix of losses. Of course it is possible to define it for different sizes and loading but these in turn are also different across Europe and from site to site. The labelling proposal presented in chapter 4.1.5 comes here with a rescue. It allows for certain flexibility in selections of mix of load and no load losses and thus loading adjustment. Furthermore such scheme will make it possible to steadily eliminate from the market least efficient classes.

Technical conditions, specifications and requirements are described in section 4.1.5 on labelling, on which this proposal of minimum efficiency mandatory standard is based.

This proposal of a minimum efficiency standard is not very demanding at all as explained in the last two paragraphs of this section. **It is proposed to set the mandatory standard in such a way that only transformers better than G class as defined in chapter 4.1.5 are allowed to be sold or imported in Europe at very nearest future.** G class labels' loss classes of any of the three labelling proposals include only the highest possible losses of HD428 or EN 50464 standards (B or Dk and A'or Eo) mixed with high or moderate losses of the second category (except for proposal 1 which eliminates all A' or Eo class). In next future (after 3-6 years with the first phase of a mandatory standard having eliminated class G from the market), **today's class F as defined in chapter 4.1.5 should be eliminated from the market.**

It might be even possible to set a **more ambitious energy efficiency standards**. For example, in the context of the SEEDT project, the manufacturer ABB stated in a notice sent to Wuppertal Institute in March 2008:

> *"Energy saving could be obtained by always selecting the A series of EN 50464-1 when purchasing new transformers (and never the other higher loss standard series of EN 50464-1). This could be agreed voluntarily, or the EU Commission could introduce it as a mandatory requirement.*
> *Then it becomes the task of the transformer manufacturers to reduce the losses accordingly at the lowest possible cost, either by means of conventional materials or by means of armorphous core material."*

However, the discussion at national workshops and in stakeholder meetings in Brussels showed that it will probably not be politically feasible to set an ambitious energy efficiency standard for distribution transformers. Many stakeholders argued against such a standard.

The second option to set a standard, the standard set as efficiency level would also be a practical solution. It has a lot of international references (cf. Chapter 2.4) and enables flexibility in selection of loss mix. The drawback is the standardised loading which is usually different for small and large units or urban and rural ones. If such a standard will be introduced, the standardised loading should be set possibly low (e.g. 30% close to EU average) to reflect actual loading conditions. On the other hand, 50% loading is most often referred to in international standards. The 40% loading which represents the practical value of optimum efficiency for manufactured units as a kind of average value would be kind of compromise (also referred to, in Japanese scheme). If this scheme is going to be favourised, the efficiencies would be classified, extremely demanding if Europe would like to follow new US scheme (cf. Chapter 2.4.8) i.e. close to AoAk losses level.

With regard to this new ambitious scheme, a few more comments on the new US rule should follow here: It will apply starting from January 1, 2010. It includes liquid immersed transformers (both single and three phase) and medium voltage dry type transformers. The standard has been prepared after extensive analysis taking account also life cycle costing of transformers. The final standard for liquid transformers is set in about one third between previous US NEMA TP 1 standard and efficiency resulted from minimum life cycle cost analysis.

As frequency affects losses (load losses are approximately the same but no load losses increase with a power of 1,3 to 2, lower value applies to hysteresis losses, higher one to eddy current core losses), American 60Hz system losses can not be compared directly to European 50Hz losses. Simply no-load losses in Europe will be lower for the same transformer operating at 60 Hz frequency. However trying to make such comparison the conclusion will be that new „10 CFR Part 431 Energy Conservation Program for Commercial Equipment: Distribution Transformers Energy Conservation Standards; Final Rule“ is equivalent roughly to lowest possible losses mix (AoAk) of new European EN50464 standard. Distribution transformers in US cannot be directly compared to European fleet also due to different network topology; however general conclusion can be made that new standard is very highly demanding. It should be noted that two parameters which have very strong influence on capitalization formula have been set up at levels fairly favorable for cost of losses differently than in many calculations referring European conditions. These parameters are: interest rate (or as referred to US terminology, discount rate) and transformer lifetime. American analysis has been checked for sensitivity at two rates, 3% and 7% and finally uses value of 4,2% for liquid transformers and 6,6% for dry type medium voltage transformers. Lifetime is US rule is set at 32 years. Many European calculation examples use 7% interest rate and some just even 10 years “economic” lifetime.

Directly following the ambitious US standard could mean that not always the least-cost option with regard to life cycle cost would be chosen in European following usual European calculation assumptions. The proposal of a minimum efficiency standard presented here will give maximum possibility to choose a least-cost option depending on the specific situation of the respective buyer (e.g., with regard to noise level of transformer). It just excludes the worst

technologies with regard to energy losses from the market, which, at the same time, will usually have higher life cycle costs than other options.

SEEDT has run several calculations of Life Cycle Cost which help to set standard limits. Similarly as in the labelling proposal, reference has been kept to EN50464 loss classes. As described above, the proposal is to set up maximum allowable loss classes.

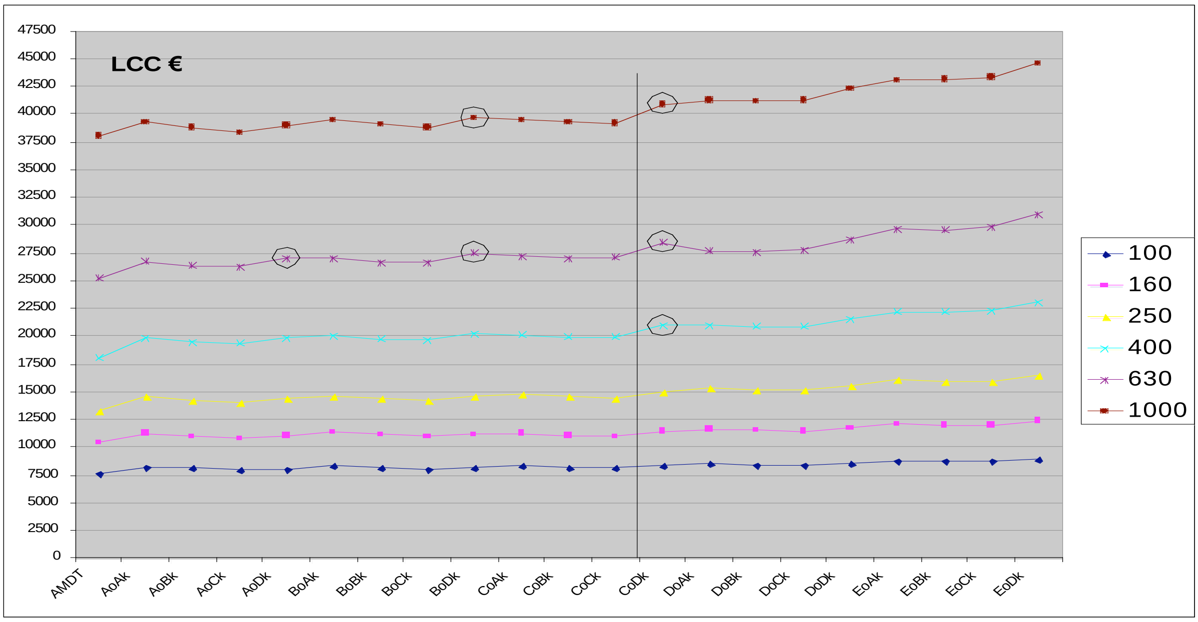
For the first run of calculations, the assumptions were set as follows:

Transformer lifetime - Years	35
Rate of return (discount rate)	0,05
Electricity price €/MWh	85
βs - peak load	0,53
βs increase yearly	0,01
τs	0,160285

Transformer lifetime is still maintained conservative as under current practice transformers are operated over long periods exceeding 40 years. Discount rate of 5% is close to the rate usually suggested by electricity and gas regulators for network operators. Electricity price of 85€/MWh is average EU electricity price for medium to large size industrial customer. Peak load, its increase and time of peak loss result from previous SEEDT calculations (D1).

The control of the implementation of the mandatory standard will probably as difficult as the control of the implementation of the labelling scheme as described before. Appropriate information requirements and possibilities for the respective public authorities to join tests run by buyers or to run tests by themselves (for a small sample of transformers) have to be set.

Figure 10: Life cycle cost for six transformer kVA values



The conclusion from this chart would be to set maximum allowable level of losses at the level of Co for no-load losses (excluding Do and Eo levels). As far as load losses are concerned Dk values, especially the one in combination with Co no-load loss (but also with Bo and even Ao, marked by circles) indicate that maximum allowable load losses should be limited at level Ck (level Dk to be excluded).

For dry type transformers the economic optimum of today is at reduction of both no-load and load losses by 10% in relation to HD 538 level. This reduction costs about 8% of incremental cost between HD 538 and HD 538$_{-10\%\ NLL\ +LL}$. Further reduction of losses increase “cost / losses reduction” ratio by roughly factor of 3. Cenelec TC14 Committee has recently started a process of HD538 standard update – evolution as done for HD428. It is recommended to wait for work results of this group to help in better referencing of proposed standard for dry type transformer.

4.1.7 Information, motivation & qualification

As already indicated in the previous subchapters, information, motivation and knowledge transfer by education and training are important instruments in case there are knowledge barriers of a medium to large target group. These measures have to be well-linked to the customer type within the target group, and clearly linked to other instruments like, e.g., financial incentives or voluntary agreements (cf. AID-EE 2006). Information programmes are also needed to inform about the labelling system proposed in Chapter 4.1.5.

While electricity distribution companies seem to be more or less well-informed about the different types and benefits and costs of energy-efficient distribution transformers, (small and medium) industrial and commercial customers, who seldom have to buy transformers, are usually not. Furthermore, information, education and training activities could address consultants and planners of industrial and commercial customers.

In general, with regard to informational measures, it can be differentiated between buyers information and users information needed:

- Buyers information
  - to lead the choice of transformers according to the size needed (avoiding oversizing), and according to its efficiency
  - to disseminate best practices
  - to create buyers clubs for collective purchases (co-operative procurement).
- Users information
  - about maintenance
  - about development of regular preventive maintenance
  - to disseminate best practices for users.

Information and motivation should be task of national and regional governments. It is important to use already existing channels and to include the information into existing information and motivation means addressing the target groups. For example, this could be:

- qualification programmes, promotion events, campaigns (labelling campaigns) and newsletters by national or local / regional energy agencies or similar actors
- communication means of existing networks of ESCOs or consultants, industry or commerce (meetings, conferences, newsletters)
- websites on energy efficiency
- software tools (cf. also Chapter 4.1.9)
- existing industry sector-specific energy efficiency concepts

- existing textbooks covering energy efficiency of industry and commerce.

Furthermore, manufacturers themselves could increasingly inform their customers about advantages of energy-efficient distribution transformers, and give advice how to identify least-cost solutions looking at minimising lifecycle costs.

4.1.8 Inclusion into energy advice programmes as one specific information and qualification activity

In several countries, as part of information and qualification activities, initial energy advice services or audits for industrial and/or commercial customers are supported by national or regional schemes in order to overcome information and knowledge barriers, and to overcome the problem that energy issues do not belong to the core activities of these firms. They often particularly promote energy-efficient cross-sectoral technologies in small and medium enterprises (SME) that are not subject to the EU emissions trading scheme. It is important that such schemes giving advice or identifying cost-effective, energy-efficient solutions and calculating their expected benefits and costs are well-linked to further policies and measures fostering the implementation of energy efficiency measures (like, e. g., financial incentives, or energy performance contracting schemes).

Energy-efficient distribution transformers should be included in the list of cross-sectoral technologies addressed in the course of such energy advice or audit programmes.

4.1.9 Toolkit for buyers (SEEDT TLCalc)

4.1.9.1 Description

As already mentioned, the information and qualification described should include information about how to identify least-cost optimal solutions adequate for the needs of the respective target groups in electricity distribution, industry and commerce. Furthermore, energy advice and audits should include such identification of cost saving solutions. Calculation tools applied by the target groups themselves or their energy consultants or planners could be an important help in this context.

TLCalc (***T***ransformer ***L***osses ***Calc***ulator) is an interactive tool developed by SEEDT. The aim of this tool is to compare two distribution transformers regarding both economical and environmental point of view. The comparison is achieved after calculations using financial, electrical and environmental parameters. The result is a side-by-side presentation of calculations of each transformer. The TLCalc tool indents to help distribution transformer users, buyers and others to see the benefits of a low losses distribution transformer compared with other old or normal-to-high losses transformer.

4.1.9.2 Using TLCalc

Reaching the tool

TLCalc can be found on SEEDT website (http://seedt.ntua.gr) at the main menu with the title “TLCalc”. It can be downloaded or used online. The main screen of the tool is shown in the following figure.

Figure 11: Part of SEEDT homepage with TLCalc buttons

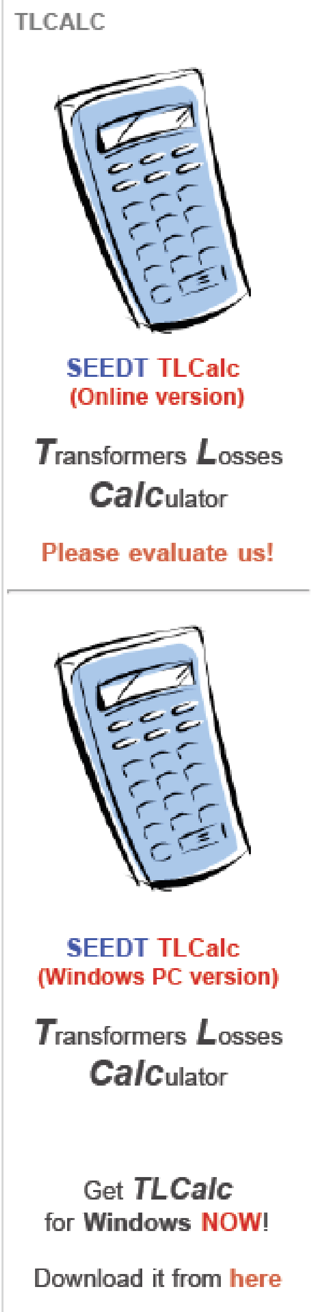
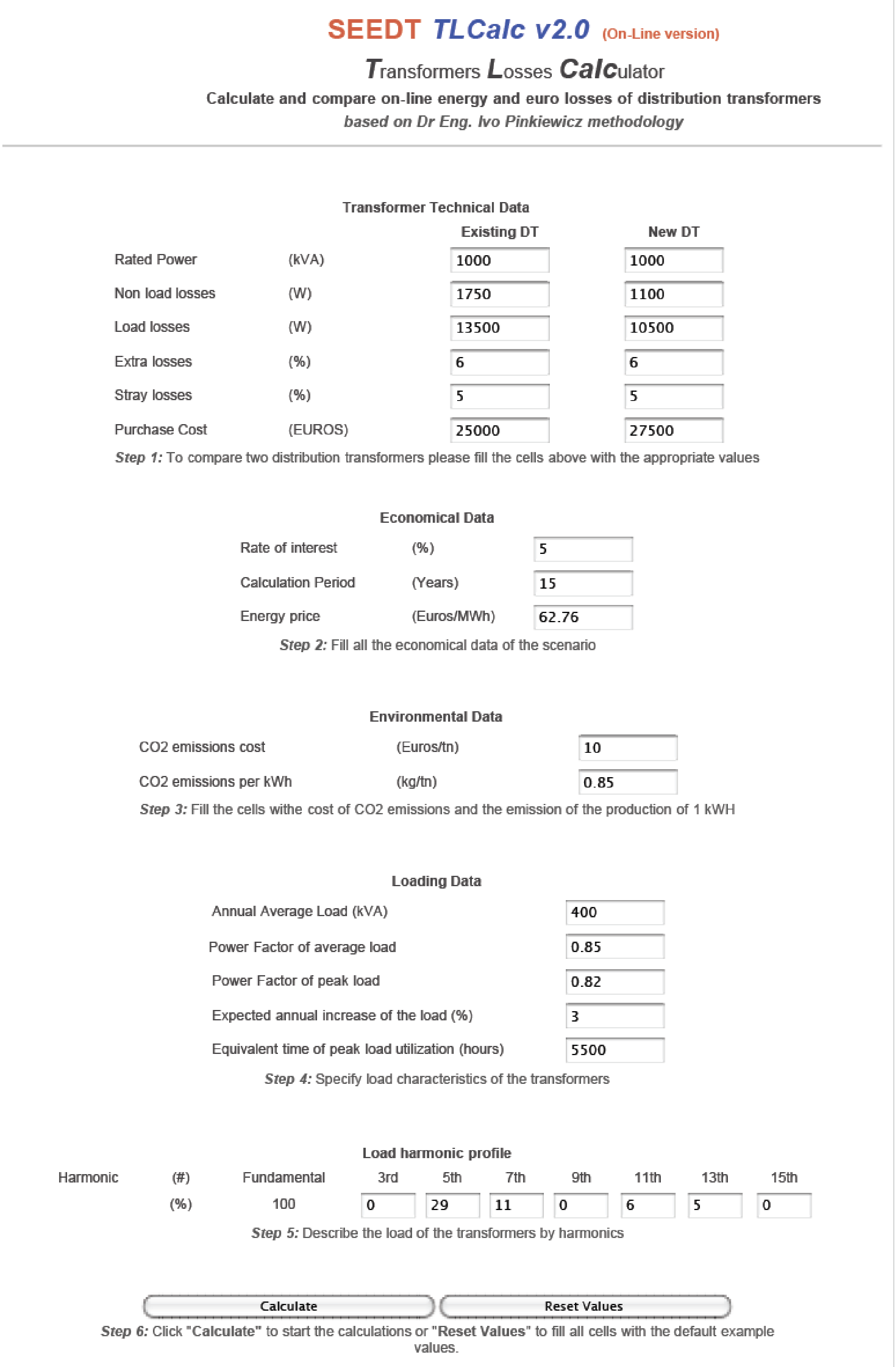


Figure 12: The main screen of TLcalc. The fields are filled with example values



4.1.9.3 Data input

In order to operate properly, several data must be entered to the available fields of the tool. All types of data are explained below with the corresponding figures.

Technical data

In the first step several technical data must be inserted (Figure 13). The column named "Existing DT" concern to the distribution transformer that is about to be compared with a new one. In proportion the second column concern to the new transformer. The available fields of this section and a short explanation are below:

- **Rated Power:** The rated power of each transformer. Transformers of different rated power can also be compared
- **Non load losses:** The non load losses given by the manufacturer of the transformers.
- **Load losses:** The load losses given by the manufacturer of the transformers.
- **Extra losses:** The extra losses in presentence of the rated power (given by the manufacturer).
- **Stray losses:** The stray losses in presentence of the rated power (given by the manufacturer).
- **Purchase cost:** The purchase cost of each transformer. The users can use this field in order to obtain a possible maximum expense for buying a new transformer.

Figure 13: Input fields for the technical data. The fields are filled with example values

Transformer Technical Data

		Existing DT	New DT
Rated Power	(kVA)	1000	1000
Non load losses	(W)	1750	1100
Load losses	(W)	13500	10500
Extra losses	(%)	6	6
Stray losses	(%)	5	5
Purchase Cost	(EUROS)	25000	27500

Step 1: To compare two distribution transformers please fill the cells above with the appropriate values

Economic data

In the second step some economical data must be inserted (Figure 14). The available fields of this section and a short explanation are below:

- **Rate of interest:** The current rate of interest.
- **Calculation Period:** The period that will be used for the calculations.
- **Energy price:** The current energy price.

Figure 14: Input fields for the economical data. The fields are filled with example values

Economical Data

Rate of interest	(%)	5
Calculation Period	(Years)	15
Energy price	(Euros/MWh)	62.76

Step 2: Fill all the economical data of the scenario

Environmental data

In the third step the environmental data must be inserted (Figure 15). The available fields of this section and a short explanation are below:

- CO_2 **emissions cost:** The cost of one tone of CO_2 emission as defined by the Kyoto protocol.
- CO_2 **emissions per kWh:** The amount of CO_2 emitted from the production of one kWh (different in each country, region or electrical network).

Figure 15: Input fields for the environmental data. The fields are filled with example values

Environmental Data

CO2 emissions cost	(Euros/tn)	10
CO2 emissions per kWh	(kg/tn)	0.85

Step 3: Fill the cells withe cost of CO2 emissions and the emission of the production of 1 kWH

Loading data

In the forth step a description of usage of the Distribution transformers must be inserted (Figure 16). These data concern both transformers. One year is divided into three periods. Each period is defined by the total hours and the mean load of the transformer in this period. The summary of the three periods must be equal to 8760 h (one year).

Figure 16: Input fields for the loading data. The fields are filled with example values

Loading Data	
Annual Average Load (kVA)	400
Power Factor of average load	0.85
Power Factor of peak load	0.82
Expected annual increase of the load (%)	3
Equivalent time of peak load utilization (hours)	5500

Step 4: Specify load characteristics of the transformers

Harmonic profile

In the final step the harmonic profile of the load must be defined (Figure 17). These data also concern both transformers and are related to the three periods of the previous step. The load of each period must be described by the harmonics up to the 15^{th}. Each harmonic is given as a presentence of the fundamental.

Figure 17: Input fields for the load harmonic profile. The fields are filled with example values

Load harmonic profile

Harmonic	(#)	Fundamental	3rd	5th	7th	9th	11th	13th	15th
	(%)	100	0	29	11	0	6	5	0

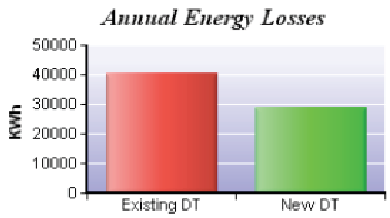
Step 5: Describe the load of the transformers by harmonics

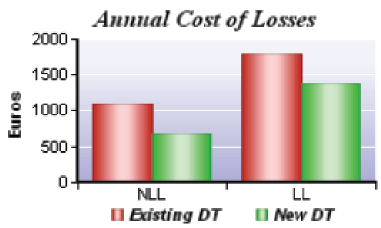
4.1.9.4 Calculation results

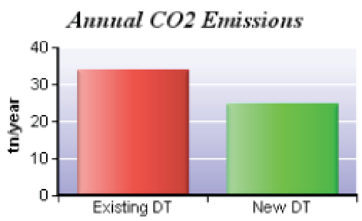
The screen of the calculation results is shown on Figure 18. The results are arranged side-by-side in two columns (one for each transformer) in order to be easy to compare them. Similar to input data, the results are divided into sections as described below. In addition, graphs visualise the results.

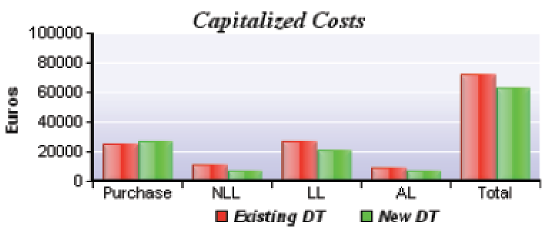
Figure 18: The calculation results screen. The fields are filled with example values

		Existing DT	New DT
Annual Energy Losses			
Non load losses	(kWh)	15330	9636
Load losses	(kWh)	18563	14438
Additional losses	(kWh)	6500	5055
TOTAL LOSSES	(kWh)	**40393**	**29129**
Cost of Losses			
Non load losses	â‚¬	1092	687
Load losses	â‚¬	1786	1389
CO2 emissions			
Annual CO2 emissions	(tn/year)	34	25
Capitalized Costs			
Cost of non load losses	â‚¬	11340	7128
Cost of load losses	â‚¬	26621	20705
Cost of additional losses	â‚¬	9321	7250
TOTAL COSTS		**72282**	**62583**
Evaluation figures			
Capitalized Cost of NLL per Watt	(â‚¬/W)	6.48	
Capitalized Cost of LL per Watt	(â‚¬/W)	2.01	
Pay back period	(years)	3.1	
Internal Rate of Return (IRR)	(%)	31.58	









Energy losses

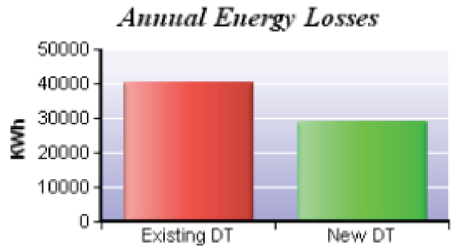
In the first section all the results concerning the energy are presented (Figure 19). Each row of the section and a short explanation are below:

- **Non load losses:** The losses that are related to non load losses for the defined calculation period.
- **Load losses:** The losses that are related to load losses for the defined calculation period.

- **Additional losses:** The losses that are related to extra and stray losses for the defined calculation period.

Figure 19: Energy losses results. The fields are filled with example values

		Existing DT	New DT
Annual Energy Losses			
Non load losses	(kWh)	15330	9636
Load losses	(kWh)	18563	14438
Additional losses	(kWh)	6500	5055
TOTAL LOSSES	(kWh)	**40393**	**29129**



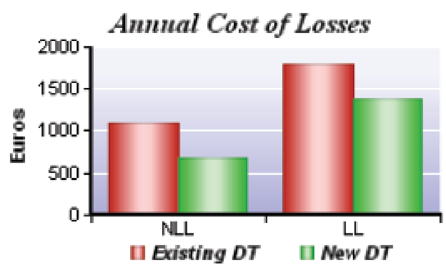
Annual cost of losses

In the second section the energy losses results are transformed to cost losses (Figure 20). Each row of the section and a short explanation are below:

- **Non load losses:** The cost of non load losses in one year.
- **Load losses:** The cost of load losses in one year.

Figure 20: Annual cost of losses results. The fields are filled with example values

Cost of Losses			
Non load losses	â‚¬	1092	687
Load losses	â‚¬	1786	1389

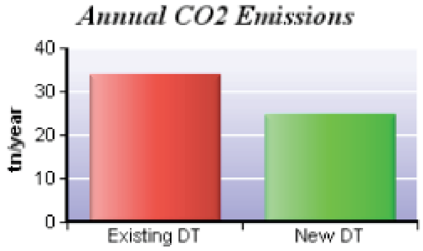


Emissions

In the third section the total CO_2 emissions are calculated for one year and for both transformers (Figure 21).

Figure 21: CO_2 emissions results. The fields are filled with example values

CO2 emissions			
Annual CO2 emissions	(tn/year)	34	25



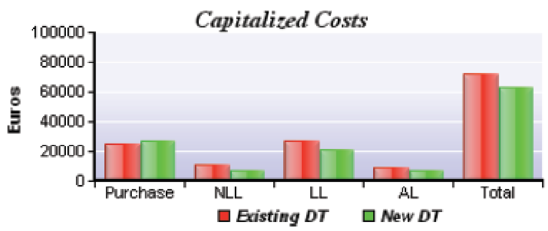
Capitalized costs

In the final section all some financial results are presented. Each row of the section and a short explanation are below:

- **Cost of non load losses:** The capitalized losses cost related to non load losses for the defined calculation period.
- **Cost of load losses:** The capitalized losses cost related to load losses for the defined calculation period.
- **Cost of additional losses:** The capitalized losses cost related to extra and stray losses for the defined calculation period.
- **Total costs:** The summarized costs each transformer.
- **Payback period:** The payback period in case of selecting the second transformer instead of the first.

Figure 22: Capitalised costs results. The fields are filled with example values

Capitalized Costs			
Cost of non load losses	â,¬	11340	7128
Cost of load losses	â,¬	26621	20705
Cost of additional losses	â,¬	9321	7250
TOTAL COSTS		**72282**	**62583**



Evaluation figures		
Capitalized Cost of NLL per Watt	(â,¬/W)	6.48
Capitalized Cost of LL per Watt	(â,¬/W)	2.01
Pay back period	(years)	3.1
Internal Rate of Return (IRR)	(%)	31.58

4.1.9.5 TLCalc Formulas

Below are all the formulas used by the TLCalc interactive tool.

Annual non-load loss = 8760*(NLL)

- NLL = non load losses.

Annual load loss (per period) = (Total Current)^2 * (1 – Extra losses – Stray losses) * * (LL) * (LF)^2 * (period hours)

- Total Current ,see below.
- LL = load losses.
- LF = Load factor [load of a period / total power of distribution transformer (kVA)]

Annual load loss = (Annual load loss)$_1$ + (Annual load loss)$_2$ + (Annual load loss)$_3$

, (addition for the 3 periods).

Annual Extra losses (per period) = [(Pfactor Windings * Extra losses * LL)+(Pfactor Stray * * Stray losses * LL)] * (LF)^2 * (period hours)

Annual Extra losses = (Extra losses)$_1$ + (Extra losses)$_2$ + (Extra losses)$_3$

, (addition for the 3 periods).

CO_2 **emission** = Annual total loss * CO_2 emissions per kWh

, Annual total loss = annual (non-load losses + load loss + extra losses)

Annual cost NLL = (Annual non-load loss) * (energy price + CO_2 emissions price)

, CO_2 emissions price = CO_2 emissions cost * CO_2 emissions per kWh.

Annual cost LL = (Annual load loss + Annual extra loss) * (energy price + CO_2 emissions price)

$$A = \frac{i(1+i)^{lifetime}}{(1+i)^{lifetime}-1}$$

$$\text{A-FACTOR} = \frac{1}{A} * (\text{energy price} + CO_2 \text{ emissions price}) * 8760$$

B-FACTOR = $\frac{1}{A}$ ***** [$(LF)^2_{period1}$ * (hours of period 1) + $(LF)^2_{period2}$ * (hours of period 2) + $(LF)^2_{period3}$ * (hours of period 3)] * (energy price + CO_2 emissions price)

CAPITALIZED COST

Cost of non-load loss = (A-FACTOR) * (NLL)

Cost of load loss = $\frac{B}{8760}$ * [(Total current1)^2 * (1 – Extra losses – Stray losses) * * (LL) * (hours of period 1) + (Total current2)^2 * (1 – Extra losses – Stray losses) * * (LL) * (hours of period 2) + (Total current3)^2 * (1 – Extra losses – Stray losses) * * (LL) * (hours of period 3)]

, where: Total current1, Total current2, Total current3 correspond to periods 1, 2, 3.

Cost of extra losses = $\frac{B}{8760}$ * [(Pfactor Windings1 * Extra losses * LL + Pfactor Stray1 * Stray losses * LL) * (hours of period 2) + (Pfactor Windings2 * Extra losses * LL + Pfactor Stray2 * Stray losses * LL) * (hours of period 2) + (Pfactor Windings3 * Extra losses * LL + Pfactor Stray3 * Stray losses * LL) * (hours of period 3)]

Total costs = Cost of non-load loss + Cost of load loss + Cost of extra losses + Purchase cost

Pay back time =

$$\frac{(price\_base\_case)-(price\_alternative\_case)}{(annual\_total\_loss[base]-annual\_total\_lose[alternative]*(energy\_price+CO_2\_price)}$$

Total Current = 1 + $\sum_{n=1}^{25} h_n^2$

, were "h" the value of "n" harmonic, expressed in (%) of the current value.

Pfactor Windings = 1 + $\sum_{n=1}^{25} h_n^2 * n^2$

Pfactor Stray = 1 + $\sum_{n=1}^{25} h_n^2 * n^{0,8}$

4.1.10 Co-operative procurement / Green procurement

Co-operative procurement programmes can play a significant role in encouraging the uptake of energy-efficient products (IEA 2006).

Typical circumstances in which to apply this instrument are (cf. AID-EE 2006):

- When there are sufficient possibilities to bundle large buyers of energy efficiency technologies
- When there is a limited number of market actors supplying energy efficiency technologies
- When potentials for further development and market transformation of new technologies are large enough.

Characteristics determining the success of this measure are (cf. AID-EE 2006):

- Is the programme management qualified and engaged?
- Can the buyers and suppliers group be motivated in principle?
- Is the buyers group involved in the programme set up?
- Is the buyers group sufficiently sized?
- Are the results of the programme well documented to facilitate market deployment?
- Is the programme well tuned with other policies (energy efficiency standards, labelling, research & development)?

With regard to distribution transformers, co-operative procurement could be a way to canvass potential buyers of energy-efficient distribution transformers to determine their criteria for choosing a transformer regarding performance, energy efficiency and price. In particular, co-operative procurement could play a twofold role and should therefore be supported by respective national or regional activities:

- Until today and in contrast to other countries and regions of the world, amorphous transformers do not play any role in Europe yet. This is in spite of their increasing advantages with regard to energy efficiency and possible net cost savings. Co-operative procurement could lead to a significant order size of amorphous transformers entering the European market, and thus make a change in the market.
- Co-operative procurement could lead to a larger order size of energy-efficient conventional transformers (with cold grain oriented steel technology), too. This could force manufacturers to optimise their offers with regard to the costs of energy-efficient products.

In addition, if one or more suppliers that can meet the criteria set by a consortium of buyers know that buyers are prepared to purchase their output of energy-efficient distribution transformers, they proceed with manufacturing these products. This might initiate further development in this field. (cf. also IEA 2006 for a description of the impact of a Swedish Technology Procurement Programme, carried out from 1999 to 2002, and having addressed, e. g., automation of sawmill plants).

Co-operations of buyers could be installed among (small and medium) electricity distribution companies that often already co-operate with each other in other fields of procurement, maybe also among ESCOs, retail chains or within an industry sector. However, since main buyers are electricity distribution companies, promotion of co-operative procurement should start there.

4.1.11 Support to R & D and pilot or demonstration projects

It might be too early to conclude whether amorphous core material will represent the most economical solution to the design of distribution transformers in future. Different manufacturers may also conclude differently.

However, the analysis of the existing situation in the different Member States has shown that any switch to AMDT is difficult for a buyer in Europe. There is no market for AMDT in Europe yet, and European manufacturers have difficulties in switching their production towards amorphous transformers due to

- initial investment costs of the production line,
- uncertainties about future price developments for raw materials and electricity, and,
- the larger space needed for installing respective production lines of same capacity.

However, if electricity distribution companies start buying amorphous transformers from abroad and test their implementation from technical and economic perspective, this will allow to better evaluate the use of amorphous cores in Europe, and might change the market situation of manufacturers.

Therefore, financial support to pilot or demonstration projects with amorphous transformers could be a way to overcoming existing barriers and obstacles towards testing this technology. If tests are successful, the introduction of amorphous technology into the European market and further dissemination of this energy-efficient technology could be the consequence. This, in turn, might also move the market for CGO technology towards more efficient units.

Moreover, such test will also help to better evaluate to which extent problems of noise and size of AMDT are still a problem today in practice, and how such possible problems can be solved where this is needed.

4.2 Policy Packages Proposed For the Different Market Actors and their expected impact on energy savings

4.2.1 Overview on policy packages for the different market actors

The following table gives an overview on the policies and measures proposed for the different market actors (cf. Chapter 4.1.1 for the respective cause-impact relationships / policy models assumed):

- With regard to **electricity distribution companies**, removing disincentives and including incentives in regulatory schemes should be the main activity to increase energy-efficiency of distribution transformers in this field. Other financial or fiscal incentives are alternative measures for the transition phase to an adequate regulatory regime.
- Clearly visible information required on the nameplate of a transformer, a mandatory standard and labelling scheme, information, motivation and qualification, the inclusion in energy advice and audit programmes as well as the provision of a toolkit for buyers (including the calculation tool provided by the SEEDT project) particularly address those market actors who lack of information and knowledge or who tend to follow traditional purchasing routines which do not lead to least-cost solutions. These are particularly **small and medium industry and commerce**, but also some **smaller electricity distribution companies**, **engineering firms, ESCOs, energy consultants and planners**. Only few larger companies in industry and in the electricity sector will need such information and qualification. A mandatory standard makes it necessary that the regulation of electricity distribution acknowledges the higher investment costs needed for the more efficient distribution transformers. The control of the implementation of a mandatory standard or labelling scheme might be a bit difficult. Appropriate information requirements and possibilities for the respective public authorities to join tests run by buyers or to run tests by themselves (for a small sample of transformers) have to be set.
- **Manufacturers and their suppliers** will have to comply with mandatory standards and the labelling scheme required, and might make use of available information and toolkits in their marketing activities. These market actors are directly addressed by R&D funding.
- All market actors can implement demonstration or pilot projects together with manufacturers (and their suppliers), but probably **larger companies** will particularly be prepared to make use of respective R&D support provided.

Table 14: Overview on policies and measures for the different market actors

Market actor	**Regulation**	**Mandatory standard**	**Labelling**	**Incentives from obligations or certificate schemes**	**Other financial or fiscal incentives**	**Information, motivation, qualification**	**Inclusion into energy advice / audit programmes**	**Toolkit for buyers**	**Co-operative procurement**	**R&D, pilot / demonstration projects**
Larger electricity distribution companies	**X**	(X)	(X)	(X) if not regulation	(X) if not regulation	(X)		(X)	(X)	**X**
Large industry		(X)	(X)		(X)	(X)		X	(X)	**X**
Smaller electricity distribution companies	**X**	(X)	**X**	(X) if not regulation	(X) if not regulation	**X**		X	X	X
Small and medium industry and commerce		**X**	**X**		X	**X**	**X**	X	(X)	X
Engineering firms, ESCOs, energy consultants, planners		**X**	**X**		(X)	**X**	**Service provider**	X	(X)	(X)
Transformer manufacturers (and their suppliers)		**Compliance required**						Can include it in marketing		**X**

bold = main focus within policy mix for this market actor
brackets = only partly relevant for this market actor, or just addressing small part within this target group

4.2.2 Environmental and economic impact of proposed policies and measures

In the following, the expected impact of the proposed policies and measures with regard to

- energy savings,
- reduction in CO_2 emissions, and,
- economic benefits and costs

will be roughly estimated based on the results of the calculation of savings potentials documented in more detail in the **SEEDT report Deliverable No. 9**.

A more detailed ex-ante evaluation of the proposed policies and measures has not been possible in the course of the SEEDT project. One reason for this is the insufficient database. As already described in other reports of the SEEDT project, the data collection in the EU-27 turned out to be much more difficult than originally expected. While it was possible to collect quite some good data on transformer population and transformer market in a range of European countries, data on investment costs remained insufficient. Furthermore, the investment cost data collected is difficult to compare due to the extremely dynamic development of prices for raw materials in the course of the last years. Some sensitivity analysis has been carried out for changes in steel and copper prices, for changes in the total level of transformer costs not depending on the transformer type, and for changes in additional costs of amorphous transformers compared to traditional ones.

The calculations were run for a possible **implementation of policies and measures in the years 2010 - 2025**. It was thereby assumed that transformers were replaced by more efficient ones at the end of their lifetime (no pull-forward effect, i.e. no increased replacement rates). Lifetimes assumed have been 40 years for (oil-immersed) transformers of electricity distribution companies, 25 years for oil-immersed transformers in industry and tertiary sector, and 30 years for dry-type transformers in industry.

All calculations have been made for **four different energy efficiency scenarios** compared to **two baseline scenarios**. The two baseline scenarios are:

- PRIMES-TRENDS: BAU development of the European electricity system with further increase in electricity demand, and,
- PRIMES EE/RES: Development of the European electricity system with strong increase in energy efficiency and renewable energies

Both baseline scenarios assume **2004 market behaviour** with regard to transformer procurement (BAU: business as usual development of transformer purchases behaviour in all sectors), i.e. **the calculations compare new energy-efficient transformers with new less energy-efficient transformers**.

The eight combinations are shown in the following tables. The tables present the potentials that can be realised with current replacement rates at the end of a fifteen years period (2010 - 2025), if an energy-efficient one will be bought every time a distribution transformer is replaced or a new distribution transformer is needed. In particular, it shows the calculation of electricity saving potentials compared to current procurment behaviour (i.e. comparing new energy-efficient transformers with new less energy-efficient, average transformers bought today), not compared to the existing transformer population (which would be comparing new, energy-efficient transformers with old, already existing transformer). In total, **up to 11.6 TWh electricity and 3.5 Mio t CO_2eq** could be **additionally** saved compared to BAU market behaviour by investing into enery-efficient distribution transformers between 2010 and 2025. More detailed information on the different assumptions and results of the calculations can be found in the respective **SEEDT report Deliverable No. 9.**

Table 15: Total energy saving potentials of energy-efficient distribution transformers in EU-27 in 2025 compared to BAU for two different developments of the electricity system

General development of electricity system	**Energy efficiency scenario 1** oil: AoBk / dry: HD 538	**Energy efficiency scenario 2** oil: AoAk / dry: HD538 LL ./. 10%, NLL ./. 10%	**Energy efficiency scenario 3** oil: Ao./.49% Bk+8% / dry: HD538 LL ./. 20%, NLL ./. 20%	**Energy efficiency scenario 4** oil: Ao./.49% Bk / dry: HD538 LL ./. 10% NLL ./. 40%
	[GWh/year]	[GWh/year]	[GWh/year]	[GWh/year]
PRIMES Trends	6,167	7,438	10,569	11,631
PRIMES EE/RES	5,015	5,761	7,915	8,163

Remarks: Baseline: 2004 market behaviour. Policies and measures beginning to have an impact in 2010. No change in replacement rates.

Table 16: Total GHG emission reductions of energy efficieny scenarios for distribution transformers in EU-27 in 2025 for two different developments of the electricity system

General development of electricity system	**Energy efficiency scenario 1** oil: AoBk / dry: HD 538	**Energy efficiency scenario 2** oil: AoAk / dry: HD538 LL ./. 10%, NLL ./. 10%	**Energy efficiency scenario 3** oil: Ao./.49% Bk+8% / dry: HD538 LL ./. 20%, NLL ./. 20%	**Energy efficiency scenario 4** oil: Ao./.49% Bk / dry: HD538 LL ./. 10% NLL ./. 40%
	[Mio t CO2eq / year]	[Mio t CO2eq / year]	[Mio t CO2eq / year]	[Mio t CO2eq / year]
PRIMES Trends	1.7	2.2	3.2	3.5
PRIMES EE/RES	1.5	1.7	2.4	1.3

Remarks: Baseline: 2004 market behaviour. Policies and measures beginning to have an impact in 2010. No change in replacement rates.

It should be noted that the total technical energy saving potentials of energy-efficient distribution transformers is substantially higher: If all current transformers were replaced at once by the most energy-efficient ones, energy savings would sum up to **18.5 TWh/year (static technical potential)**.

Realising the dynamic saving potentials between 2010 and 2025 would include a **net economic benefit for the European economy as a whole in all scenarios**, summing up to **more than 300 Mio. Euro/year in 2025** in the energy efficiency scenario 3 with PRIMES Trends development of the electricity system.

Table 17: Total net additional costs (positive values) or cost savings (negative values) of energy efficieny scenarios for distribution transformers in EU-27 in 2025 for two different developments of the electricity system from different economic perspectives

General development of electricity system	**Energy efficiency scenario 1** oil: AoBk / dry: HD 538	**Energy efficiency scenario 2** oil: AoAk / dry: HD538 LL ./. 10%, NLL ./. 10%	**Energy efficiency scenario 3** oil: Ao./.49% Bk+8% / dry: HD538 LL ./. 20%, NLL ./. 20%	**Energy efficiency scenario 4** oil: Ao./.49% Bk / dry: HD538 LL ./. 10% NLL ./. 40%
	[Mio. Euro/year]	[Mio. Euro/year]	[Mio. Euro/year]	[Mio. Euro/year]
Perspective of the whole economy (4% real discount rate)				
PRIMES Trends	- 224	- 187	- 303	- 295
PRIMES EE/RES	- 165	- 101	- 167	- 117
Perspective of electricity distribution companies (6% real discount rate)				
PRIMES Trends	- 81	- 13	- 103	- 113
PRIMES EE/RES	- 27	49	- 6	10
Perspective of industry and commerce - liquid-filled transformers (8% real discount rate)				
PRIMES Trends	- 193	- 137	- 199	- 203
PRIMES EE/RES	- 194	- 139	- 201	- 205
Perspective of industry and commerce - dry-type transformers (8% real discount rate)				
PRIMES Trends	15	- 9	23	86
PRIMES EE/RES	29	35	95	187

Remarks: Baseline: 2004 market behaviour. Policies and measures beginning to have an impact in 2010. No change in replacement rates.

With the **technology available today**, scenario 3 and 4 can only be realised with amorphous transformers (AMDT). While their introduction and diffusion into the European market would lead to the highest gains with regard to energy savings and GHG emission reductions, they are not always competitive from an economic perspective, and there are some limits with regard to their installation in existing transformer stations (e.g., with regard to noise and size of these transformers; cf. the SEEDT report Deliverable No. 1 for more details on technical aspects).

For **oil-immersed transformers**, the results of the economic analysis presented above and further sensitivity analysis carried out (cf. the SEEDT report Deliverable No. 9 for more details on these calculations) show that from the perspective of the different buyers in the market, energy-efficient distribution transformers, and in particular amorphous transformers (AMDT) are just competitive under specific assumptions. This means that the market actors always have to decide from case to case if, under the specific conditions in practice, the most efficient transformer is also the most economical one with regard to life cycle costs. The economic calculations presented above assume a favourable regulatory scheme that allows electricity distribution companies to choose the least-cost transformer.

For **dry-type transformers** in industry, the results indicate that a switch to the most efficient transformers will probably not be economical.

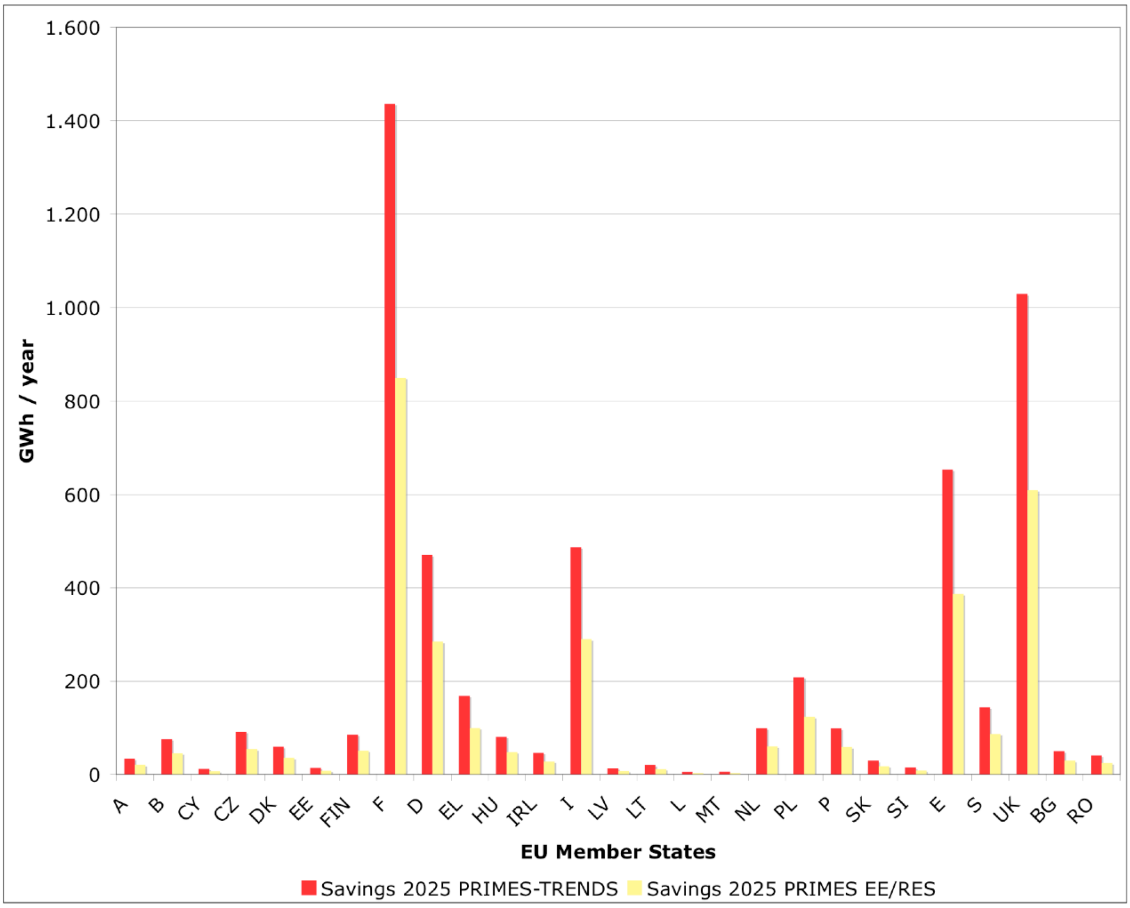
Nevertheless, the results show that **supporting the market introduction and diffusion of energy-efficient distribution transformers will effectively contribute to increasing energy efficiency, reducing dependence on imports of fossil fuels, and lowering GHG emissions in Europe**. **Since energy-efficient transformers are just on the edge of competitiveness, this strategy should be followed.** Moreover, and referring to sensitivity analyses carried out and documented in the SEEDT report Deliverable No. 9, if **avoided external costs** were included, if **electricity prices increased** or if **prices of energy-efficient transformers decreased**, the economic results would be even much more favourable for energy-efficient distribution transformers.

The **main question** is, to which extent the potentials presented above could be realised with the help of the policies and measures proposed in the previous subchapters. To a large extent, the answers by the SEEDT project to this question are rather speculative (experts' "guesstimates"). However, since no better database and calculations seem to exist in Europe at the moment, the considerations by the SEEDT project are presented here.

Nearly half of total potential electricity savings could come from **electricity distribution companies**. Therefore, a supportive regulatory framework is most important. Further measures like information and education could accompany the implementation of incentives and removal of disincentives in the current regulation schemes. As a rough estimate, about **80%** of the electricity saving potentials presented in the following figure could be realised by 2025 by such a policy package. In total, if the general development of the electricity system followed the PRIMES-Trends (PRIMES-EE/RES) scenario, this would mean additionally saving about **4,400 GWh/year (2,600 GWh/year) electricity in 2025** compared to BAU development with no change in replacement rates, about 8,600 GWh/year (6,800 GWh/year) electricity in 2025 with all existing transformers being replaced, and about 11,700 GWh/year (7,000 GWh/year) by 2050 with normal replacement rate and extrapolation of the development 2010-2025 to 2025-2050.

The following figure clearly shows that the largest absolute electricity saving potentials in electricity distribution companies seem to be in **France and UK**, followed by **Spain, Italy and Germany**. Therefore, changes in the regulatory schemes are most urgent and should particularly be implemented in these countries. Again, it should be noted that this figure only shows the technical energy saving potentials of energy-efficient distribution transformers in electricity distribution companies that can be realised within 15 years assuming current replacement rates and comparing new energy-efficient transformers with new less energy-efficient transformers. If new energy-efficient transformers were compared with old transformers existing in the distribution grid, electriciy saving amounts would be substantially higher.

Figure 23: Electricity saving potentials of electricity distribution companies that can be realised between 2010 and 2025 in the different Member States assuming current replacement rates and ocmparing new energy-efficient transformers with new less energy-efficient transformers [Scenario 4: oil: Ao./.49%, Bk; dry: HD538 LL ./. 10%, NLL ./. 40%]



Source: SEEDT project team based on data collected from different Member States (cf. SEEDT report Deliverable No. 1)

The second important target group for policies and measures should be actors that influence the decision processes on purchase of **oil-immersed transformers in industry and commerce**. Electricity saving potentials of this target group are nearly as high as in electricity distribution companies in PRIMES-Trends scenario, and higher than in electricity distribution companies in PRIMES-EE/RES scenario (up to 4,118 GWh/year by 2025 with constant replacement rates). Moreover, and most important, as shown in the table above, the net economic benefits of investing in energy-efficient distribution transformers are the highest from the perspective of this target group, because of the higher electricity prices these mostly small and medium enterprises have to take into account.

It is assumed that a large part of these electricity saving potential can be realised by introducing a mandatory standard, another part by the other policies and measures presented above, and addressing small and medium enterprises, engineering firms, ESCOs, energy consultants and planners. With regard to the **mandatory standard**, only a rough estimate was possible. This is due to the limited data available, which only made it possible to calculate with typical or average values of energy losses and thus energy efficiency potentials in the different countries and not with a detailed distribution of losses across populations, ratings and countries. Nevertheless, if it is assumed that the distribution of average purchases of typical transformers between countries in 2004 equals total distribution of transformers in Europe, some calculation of benefits from introducing a mandatory standard will be possible. If it is further assumed to take the third labelling proposal presented in Chapter 4.1.5 as a basis, and that a mandatory standard first removes transformers with labelling class "G", then "F" from the market, the mandatory standard could lead to additional electricity savings **up to about 3,300 GWh/year in 2025** (cf. the following table).

Table 18: Maximum of electricity savings reached in 2025 by introducing a mandatory standard for distribution transformers in Europe in 2010 that removes transformers with labelling classes "G" and then "F" from the market (rough "guesstimate")

Labelling classes removed [cf. the third labelling proposal proposed in Chapter 4.1.5]	**Total**	**Electricity distribution companies**	**Industry and commerce - oil**	**Industry - dry**
	[GWh/year]	[GWh/year]	[GWh/year]	[GWh/year]
Class "G" only	1,900	500	700	700
Classes "G" and "F"	3,300	1,300	1,100	900

Remarks: Baseline: 2004 market behaviour. No change in replacement rates. General development of the electricity system following PRIMES-Trends.

The package of **other policies and measures** like clear visibility of energy losses on the nameplate of a transformer, labelling, information, calculation tools etc. might contribute to exploiting **20%** of the total electricity saving potential in all sectors. In total, if the general development of the electricity system followed the PRIMES-Trends (PRIMES-EE/RES) scenario, this would mean additional energy savings of about **2,300 GWh/year (1,600 GWh/year) electricity in 2025** compared to BAU development with no change in replacement rates, about 3,600 GWh/year (2,900 GWh/year) electricity in 2025 with all existing transformers being replaced, and about 6,200 GWh/year (4,400 GWh/year) by 2050 with normal replacement rate and extrapolation of the development 2010-2025 to 2025-2050.

5 Conclusions and recommendations

The main types of **market actors** in the field of distribution transformers are:

- Electricity distribution companies as the main owners of distribution transformers
- Large industry, which often needs transformers that are specifically adequate for the relevant industrial processes
- Small and medium industry and commerce
- Engineering firms, ESCOs, and Consultants, and
- Manufacturers of the different transformer types and their suppliers.

These market actors face **different barriers and obstacles** with regard to the development, planning, sales and purchase of energy-efficient distribution transformers. Therefore, in order to adequately address these barriers and obstacles and to realise the existing energy efficiency potentials in this field, **different policies and measures** are needed. These policies and measures should be bundled in an appropriate policy-mix. Main elements of such a **policy-mix** are:

- Changes in the **regulatory schemes** (introducing incentives and removing existing disincentives) to increase energy-efficiency of distribution transformers in electricity distribution companies.
- A **bundle of "soft" measures** like the requirement of clearly visible information required on the nameplate of a transformer, a labelling scheme, Information, motivation and qualification, the inclusion in energy advice and audit programmes as well as the provision of a toolkit for buyers (including the calculation tool provided by the SEEDT project) particularly address those market actors who lack of information and knowledge or who tend to follow traditional purchasing routines which do not lead to least-cost solutions. These are particularly small and medium industry and commerce, but also some smaller electricity distribution companies, engineering firms, ESCOs, energy consultants and planners.
- A European **mandatory standard** would effectively contribute to realising the saving potentials by addressing the same market actors as the bundle of "soft" measures. A mandatory standard makes it necessary that the regulation of electricity distribution acknowledges the higher investment costs needed for the more efficient distribution transformers. A European mandatory standard would help Europe to catch up with the developments in the US and in Asia.
- All market actors can implement **demonstration or pilot projects** together with manufacturers (and their suppliers), but probably larger companies will particularly be prepared to make use of respective **R&D support** provided.

In total, very roughly estimated, **up to about 10 TWh additional electricity savings** could be realised per year **in 2025** per year compared to BAU, **if the policies and measures proposed by the SEEDT project were broadly implemented from 2010 onwards**, and if general development of the electricity system followed the PRIMES-

Trend scenario, and up to about 6.1 TWh/year if the electricity system followed the development in the PRIMES EE/RES scenario, i.e. the size of the electricity saving potential strongly depends on the general development of the electricity system. These potentials can be realised with technology already available today and current replacement rates.

The calculations clearly show that **changes in the regulatory schemes** are **most important** to realise the existing saving potentials and to make least-cost investments into transformers with lowest lifecycle costs possible. As long as disincentives remain and incentives are missing in the exiting schemes, additional financial or fiscal incentives to electricity distribution companies should be set. The largest absolute electricity saving potentials in electricity distribution companies seem to be in **France and UK**, followed by **Spain, Italy and Germany**. Therefore, changes in the regulatory schemes are most urgent and should particularly be implemented in these countries. However, until now, there are no concrete signals that regulators would be willing to accept a change. Therefore, a lot of effort to convince regulators is needed on European and Member State level. Furthermore, it would be needed to get confirmation by the regulators that incentives set and removal of existing disincentives in regulatory schemes would last for the long lifetime of the transformers.

Compared to saving potentials in other areas, the electricity saving potentials of distribution transformers seem to be small. For example:

- The three options proposed by the European Commission (2008) for implementing measures on general lighting equipment (domestic lighting) would lead to 47 to 78 TWh/year electricity savings in EU-27.
- In Germany alone, the implementation of an energy saving fund could lead to electricity savings of about 75 TWh/year within ten years, if twelve programmes proposed by Wuppertal Institute were broadly implemented (Irrek/Thomas 2006).

Nevertheless, every contribution to climate change mitigation and energy security is necessary, particularly if it is economical. Since energy-efficient transformers are just on the edge of competitiveness and since **a large part of the electricity saving potential is economical from different perspectives** following the assumptions set in the SEEDT project, it is recommended to implement the policies and measures proposed by the SEEDT project. Moreover, if avoided external costs were included, or if electricity prices increase compared to the assumptions taken in the SEEDT project, the economic results would be even more favourable for energy-efficient distribution transformers.

In principle, the **transformer industry** seems to be in favour of efforts taken to reducing the level of losses of transformers to optimise energy efficiency (T&D Europe 2008). This might be a good starting point for the development of an effective and efficient policy-mix.

6 Outlook on possible further research and monitoring

The need for further research and monitoring can be summarised as follows:

- Since the SEEDT project has just analysed the usage phase of distribution transformers, it has neglected possible impacts of different transformer design in **other phases of the transformer life cycle**. A more efficient transformer will need more copper or aluminium than a less efficient one (**trade-off between energy efficiency and material efficiency**). Furthermore, the switch from grain oriented steel to amorphous metals has an impact on energy use, the environment and the economy, particularly in the production phase, during transport of materials and final product, but also in the recyling and waste disposal phase, too (cf., e.g., Berti 2006). Furthermore, how raw materials like copper are produced matters, too (cf., e.g., Schüller/Estrada/Bringezu 2008 for a recent analysis of material flows and CO_2 emissions with regard to copper). Nevertheless, the impacts during the operation of the transformer remain by far the most important ones during the whole life cycle. Therefore, the total environmental impact of amorphous transformers over the whole life cycle will be less than the impact of conventional ones (cf., e.g., Berti 2006). However, for further studies, it is recommended to take such aspects into account, particularly if transformers are chosen as a product group by the European Commission for its working programme and for the next preparatory studies of the Ecodesign Directive.

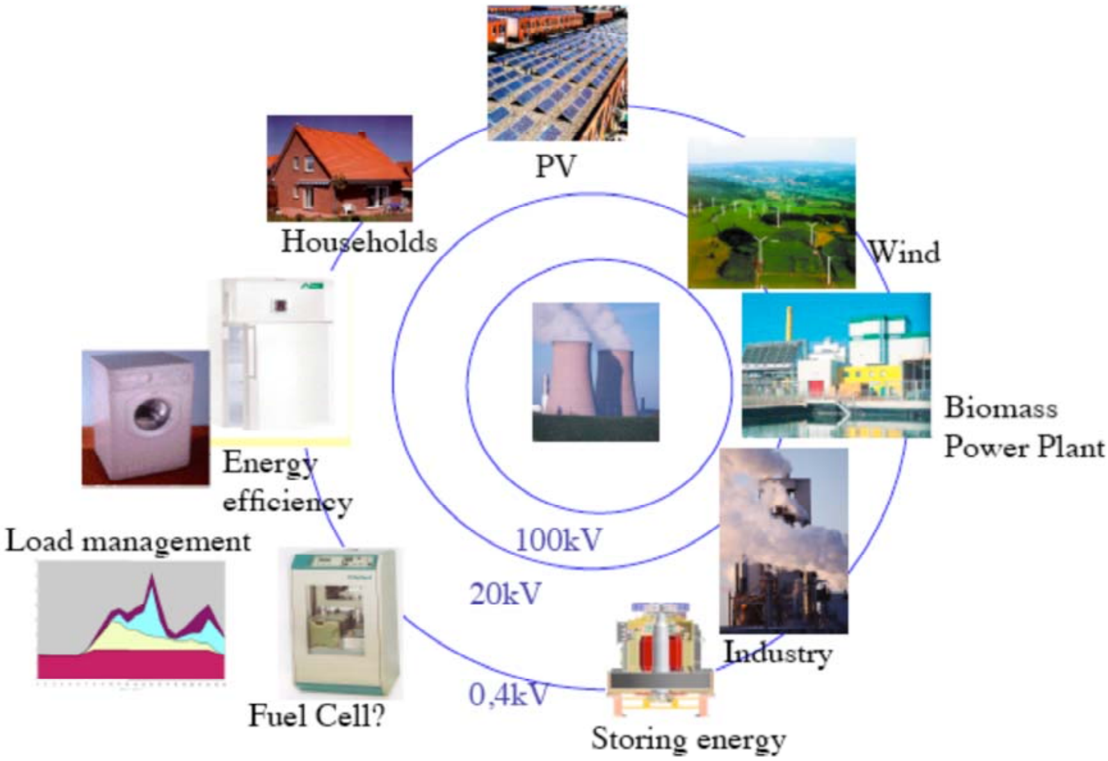
Table 19: Comparison of weight components of a conventional CGO distribution transformer and an AMDT

Material components of the distribution transformer	**CGO distribution transformer** [kg]	**AMDT** [kg]
CGO Steel	430	
Amorphous Metal		540
Steel	195	233
Copper	185	310
Oil	155	265
Paper	30	35
Porcelain	12	12
Brass	2	2
Resin Fiber Glass		2
Aluminium	1	1
Total weight	1,010	1,400

Source: Berti 2006

- The analysis of existing situation and the calculation of electricity and cost saving potentials in the different Member States have shown that publicly available **data and information** on energy efficiency of transformer population and market, on loading factors in practice and on investment costs of different transformer types is very limited. Therefore, at least in the context of revisions of regulatory schemes for electricity distribution companies, effort should be taken to improve the database. For example, some **monitoring requirements** could be set by the Commission to the Member States, which in turn could ask the electricity distribution companies to regularly report on these issues. For a possible preparatory study within the Ecodesign Directive process, it is recommended to focus on data collection from the beginning, particularly trying to collect more data from electricity distribution companies, industry and commerce on **loading factors** and **energy efficiency of transformer population**, and to receive more data from manufacturers on the **transformer market and transformer prices** than it was possible within the SEEDT project.

Figure 24: Revival of integrated resource planning?



Source: Wuppertal Institute

- Finally, it should be analysed, which role enery-efficient distribution transformers might play in **„smart grids“** or **„efficiency plants“**, that combine, integrate and optimise distributed generation (renewables and CHP), centralised generation, load reduction potentials, energy storage facilities and energy end-use efficiency measures so that CO_2 emissions can be further reduced at least cost. The research question would be if and how in such a system distribution grid losses could be minimised.

7 References

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8 Acknowledgements

The report has been written by Wuppertal Institute and further SEEDT project partners in the course of the EU project „Strategies for development and diffusion of energy-efficient distribution transformers (SEEDT)", co-ordinated by the National Technical University of Athens (NTUA) in the framework of the Intelligent Energy Europe programme (Project no. EIE/05/056/SI2.419632). Wuppertal Institute's work in this project has been co-financed by the State of North Rhine-Westphalia.

The authors would particularly like to thank all other SEEDT project team members for the intensive and fruitful discussion of preliminary results and proposals at project meetings and by email.

Furthermore, the authors are particularly thankful to all the stakeholders from electricity distribution companies, transformer manufacturers and their suppliers, energy agencies, science and ministries for their feedback to preliminary drafts and ideas of policy proposals and for their contribution to discussions at national workshops and in further bilateral meetings.