Power and distribution transformers Outlook on the energy market

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- New EU regulation 548/2014.
- Guidelines, features, characteristics and impact to transformers market.
- Available solutions and added value.
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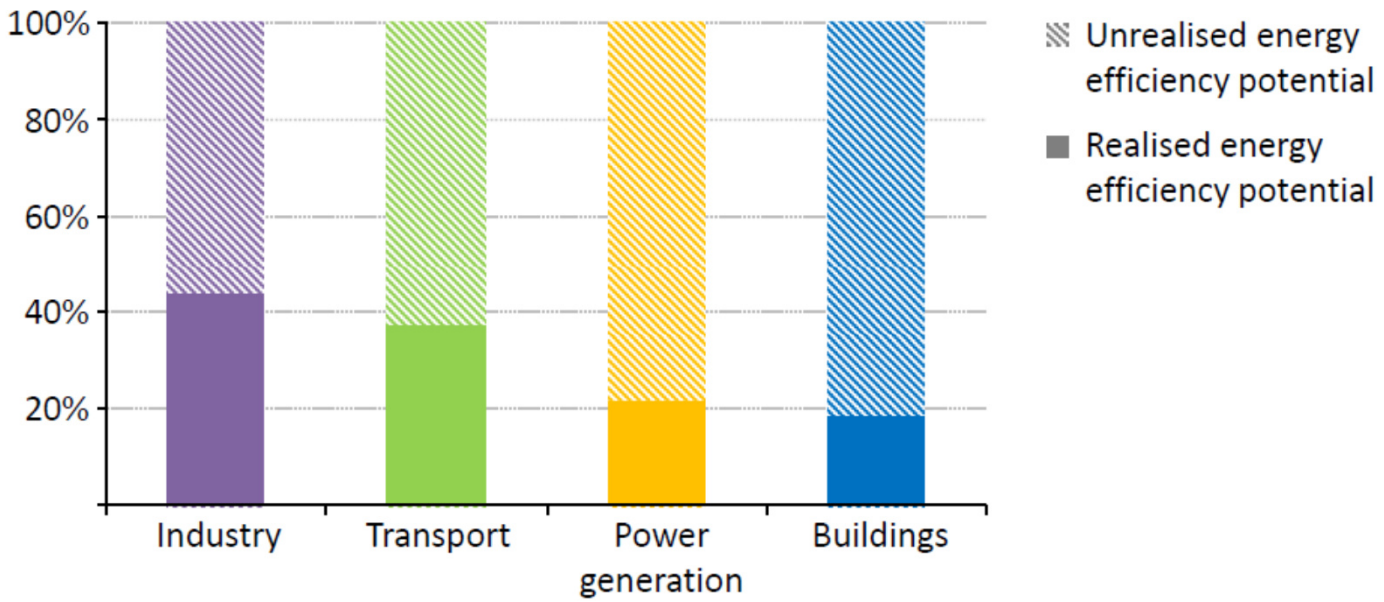
Introduction

Energy efficiency potential used by sector in the New Policies Scenario



Two-thirds of the economic potential to improve energy efficiency remains untapped in the period to 2035

Source: IEA (International Energy Agency, World Energy Outlook 2012

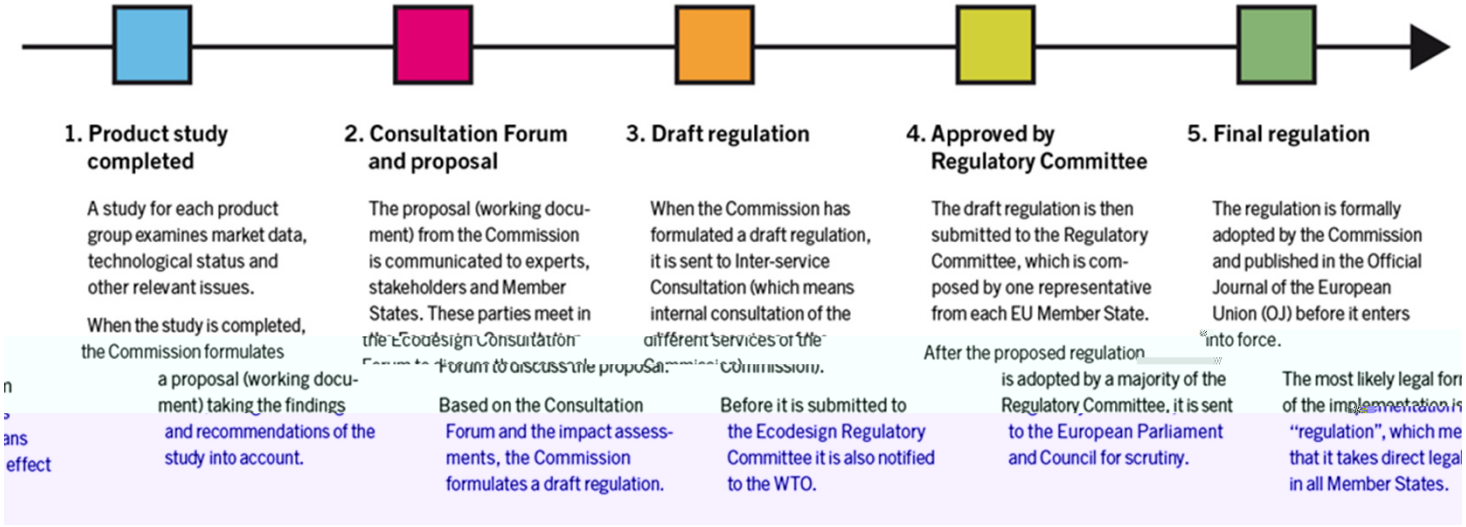
Transformers Energy Efficiency
Energy saving

The economic and energy crises have highlighted the need to increase the efficiency of many products. This stems from the fact that there is a commitment of the countries most responsible for reducing emissions of greenhouse gases (mainly CO2). This commitment has mainly two aspects: one on saving, the other the reduction of greenhouse gas emissions and thus the protection of the environment.

Transformers Energy Efficiency
Energy saving

- For electrical products the EU has already issued regulations (in accordance with the Eco Design Directive 2009/125/EC) prohibiting the circulation of low efficiency products, having already taken into account: lamps and motors.
- Regarding transformers a regulation, has been prepared, that will ban the circulation from 1 July 2015 of transformers, with losses greater than those displayed in the following slides. After an assessment of the market, if it is considered positive, starting from July 1, 2021, the losses will be further reduced.

Transformers Energy Efficiency
Energy saving



- The European Parliament had until 28 April to raise objections to the Transformer Ecodesign Requirements - no objections raised
- The regulation was adopted and published in the official journal of the EU on 21-22.05.2014.
- **548/2014 regulation entered in force on <u>June the 11th, 2014.</u>**

Transformers Energy Efficiency
European regulation published on May 22nd, 2014

22.5.2014 EN Official Journal of the European Union L 152/1

II

(Non-legislative acts)

REGULATIONS

COMMISSION REGULATION (EU) No 548/2014

of 21 May 2014

on implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to small, medium and large power transformers

THE EUROPEAN COMMISSION,

Link to the regulation (all EU languages):
http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2014.152.01.0001.01.ENG

Transformers Energy Efficiency
Standard in force for distribution transformers

Dry type transformers

- CEI EN 50541-1:2011-04, Three phase dry-type distribution transformers 50 Hz, from 100 to 3150 kVA, with highest voltage for equipment not exceeding 36 kV Part 1: General requirements

Standard prepared by CENELEC valid in EU including Italy, in force from 01-12-2011.

Oil immersed transformers

- CEI EN 50464-1: 2007-08, Tree-phase oil immersed distribution transformers 50 Hz, from 50 kVA to 2500 kVA, with highest voltage for equipment not exceeding 36 kV. Part 1: General requirements

Standard prepared by CENELEC Valid in EU including Italy, in force from 01-10-2007.

Transformers Energy Efficiency
Standard under preparation

Regarding the distribution transformers they are included in the Medium power transformers defined as: *a power transformers with a highest voltage for equipment higher than 1,1 kV, but not exceeding 36 kV and a rated power equal to or higher than 5 kVA but lower than 40 MVA. :*

Soon will be issued new European standards, prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association.

The following document has been prepared for medium power transformers and substitutes both the EN 50464-1 and the EN 50541-1:

- EN 50588-1: Medium voltage transformers 50 Hz, with highest voltage for equipment not exceeding 36 kV - Part 1: General requirements

This European Standard covers three-phase power transformers from 25 kVA up to 40 000 kVA for indoor or outdoor continuous service, 50 Hz with two windings with a highest voltage 1,1 kV ≤ Um ≤ 36 kV and at least one of the windings having a highest voltage for equipment not below 3,6 kV.

Transformers Energy Efficiency
Standard under preparation

EN 50588-1:2013 includes the following significant technical changes with respect to EN 50464-1:2007 and EN 50541-1:2011:

- both liquid filled and dry type transformers are covered in the same document;
- the scope of applicability is extended in terms of rated power;
- new values of no load loss, load loss and sound power level for different values of rated power are specified;
- for transformers having rated power above 3150 kVA, the concept of Peak Efficiency Index is introduced.

Transformers Energy Efficiency
Standard under preparation

Regarding the 'Large power transformer' defined as: *a power transformer with a highest voltage for equipment exceeding 36 kV and a rated power equal or higher than 5 kVA, or a rated power equal to or higher than 40 MVA regardless of the highest voltage for equipment.*

Soon will be issued new European standards, prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association.

The following document is completely new :

- EN 50629-1: Energy efficiency of transformers with Um greater than 36 kV

The scope of this European Standard is the following:

- Defining the appropriate energy efficiency criteria;
- Setting of benchmark minimum efficiency levels for new transformers based on an assessment of the energy efficiency of the European transformer population installed in the last 10 years;
- Proposing higher minimum efficiency levels for improving the energy efficiency of new transformers;
- Providing guidance for consideration of Total Cost of Ownership.

Transformers Energy Efficiency

Be careful

The technical aspects indicated in the Regulation Annexes shall prevail over any standard in force

Therefore the transformers placed on the market or put into service in the EU market shall be in compliance with the regulation.

European Regulation – Liquid filled transformers

- 1.1.**Requirements for three-phase medium power transformers with rated power ≤ 3 150 kVA**

  - **Table I.1: Maximum Load and No-Load losses (in W) for three-phase liquid-immersed medium power transformers with one winding with Um ≤ 24 kV and the other one with Um ≤ 1,1 kV**

	Tier 1 (from 1 July 2015)		Tier 2 (from 1 July 2021)	
Rated Power(kVA)	Maximum load losses Pk (W)	Maximum no-load losses Po (W)	Maximum load losses Pk (W)	Maximum no-load losses Po (W)
≤ 25	CK (900)	Ao(70)	Ak(600)	Ao-10% (63)
50	Ck (1100)	Ao(90)	Ak(750)	Ao-10%(81)
100	Ck (1750)	Ao(145)	Ak(1250)	Ao-10%(130)
160	Ck (2350)	Ao(210)	Ak(1750)	Ao-10%(189)
250	Ck (3250)	Ao(300)	Ak(2350)	Ao-10%(270)
315	Ck (3900)	Ao(360)	Ak(2800)	Ao-10%(324)
400	Ck (4600)	Ao(430)	Ak(3250)	Ao-10%(387)
500	Ck (5500)	Ao(510)	Ak(3900)	Ao-10%(459)
630	Ck (6500)	Ao(600)	Ak(4600)	Ao-10%(540)
800	Ck (8400)	Ao(650)	Ak(6000)	Ao-10%(585)
1000	Ck (10500)	Ao(770)	Ak(7600)	Ao-10% (693)
1250	Bk (11000)	Ao(950)	Ak(9500)	Ao-10%(855)
1600	Bk(14000)	Ao(1200)	Ak(12000)	Ao-10%(1080)
2000	Bk (18000)	Ao(1450)	Ak(15000)	Ao-10%(1305)
2500	Bk (22000)	Ao(1750)	Ak(18500)	Ao-10%(1575)
3150	Bk (27500)	Ao(2200)	Ak(23000)	Ao-10%(1980)

Losses comparison - Liquid filled transformers

- The reduction of no load losses indicated by the Regulation in comparison with those existing till now in the Italian private market.
- In the following slide the comparison for load losses.

No load losses from Table 3 of EN 50464-1 (Um ≤ 24 kV)			
Power	E0	A0	Δ A0 compared to E0
(kVA)	(W)	(W)	(%)
50	190	90	-53
100	320	145	-55
160	460	210	-54
250	650	300	-54
400	930	430	-54
630	1300	600	-54
630	1200	560	-53
800	1400	650	-54
1000	1700	770	-55
1250	2100	950	-55
1600	2600	1200	-54
2000	3100	1450	-53
2500	3500	1750	-50

Losses comparison - Liquid filled transformers

Load losses from Table 2 of EN 50464-1 (Um ≤ 24 kV)

Power (kVA)	Dk (W)	Ck (W)	Δ Ck compared to Dk (%)
50	1350	1100	-19
100	2150	1750	-19
160	3100	2350	-24
250	4200	3250	-23
400	6000	4600	-23
630	8400	6500	-23
630	8700	6750	-22
800	10500	8400	-20
1000	13000	10500	-19

Power (kVA)	Dk (W)	Bk (W)	Δ Bk compared to Dk (%)
1600	20000	14000	-30
2000	26000	18000	-31
2500	32000	22000	-31

Typical liquid filled distribution transformers

- Rated power — range 50 kVA-3150 kVA
- Rated voltages — max. 36 kV
- Tap-changer — off-circuit
- Windings materials — aluminum/copper
- Insulating fluid — mineral oil
- Technology — hermetic/conservator

- **Two Technologies covering all typical application!**

Transformers Energy Efficiency

Ultra low No Load losses: amorphous core

- The most efficient distribution transformers are manufactured with amorphous core material having No Load losses lower than those indicated by EU Regulation for Tier 2 (2021)

Transformers Energy Efficiency

Ultra low No Load losses: amorphous core

Power (kVA)	AAA_0 (W)	A_0 (W)
100	75	145
160	105	210
250	150	300
400	215	430
630	300	600

The No Load losses A_0 in comparison with amorphous core AAA_0 are reduced by 50%

Transformers Energy Efficiency
European Regulation – Dry type transformers

Table I.2: Maximum Load and No-Load losses (in W) for three –phase **dry-type** transformers with one winding, Um ≤ 24 kV and the other one with Um ≤ 1,1 kV.

	Tier 1 (1 July 2015)		Tier 2 (1 July 2021)	
Rated Power (kVA)	Maximum load losses Pk (W)	Maximum no-load losses Po (W)	Maximum load losses Pk (W)	Maximum no-load losses Po (W)
≤ 50	Bk (1700)	Ao(200)	Ak(1500)	Ao-10%(180)
100	Bk (2050)	Ao(280)	Ak(1800)	Ao-10%(252)
160	Bk (2900)	Ao(400)	Ak(2600)	Ao-10%(360)
250	Bk (3800)	Ao(520)	Ak(3400)	Ao-10%(468)
400	Bk (5500)	Ao(750)	Ak(4500)	Ao-10%(675)
630	Bk (7600)	Ao(1100)	Ak(7100)	Ao-10%(990)
800	Ak (8000)	Ao(1300)	Ak(8000)	Ao-10%(1170)
1000	Ak (9000)	Ao(1550)	Ak(9000)	Ao-10%(1395)
1250	Ak (11000)	Ao(1800)	Ak(11000)	Ao-10%(1620)
1600	Ak (13000)	Ao(2200)	Ak(13000)	Ao-10%(1980)
2000	Ak (16000)	Ao(2600)	Ak(16000)	Ao-10%(2340)
2500	Ak (19000)	Ao(3100)	Ak(19000)	Ao-10%(2790)
3150	Ak (22000)	Ao(3800)	Ak(22000)	Ao-10%(3420)

Transformers Energy Efficiency

Losses comparison - Dry type transformers

- No Load losses Table 5 EN 50541-1 (Um 17.5 - 24kV)

No Load losses as per Regulation in comparison with today standard transformers

Rated Power	C0	A0	Δ A0 compared to C0
(kVA)	(W)	(W)	(%)
100	460	280	-39
160	650	400	-38
250	880	520	-41
400	1200	750	-38
630	1650	1100	-33
800	2000	1300	-35
1000	2300	1550	-33
1250	2800	1800	-36
1600	3100	2200	-29
2000	4000	2600	-35
2500	5000	3100	-38

Transformers Energy Efficiency

Losses comparison - Dry type transformers

Load losses from Table 5 of EN 50541-1 (Um 17,5 e 24 kV)

Up to and including 630 kVA Load Losses remain Bk

Rated Power	Bk	Ak	Δ Ak compared to Bk
(kVA)	(W)	(W)	(%)
800	9800	8000	-18
1000	11000	9000	-18
1250	13000	11000	-15
1600	16000	13000	-19
2000	18000	16000	-11
2500	23000	19000	-17

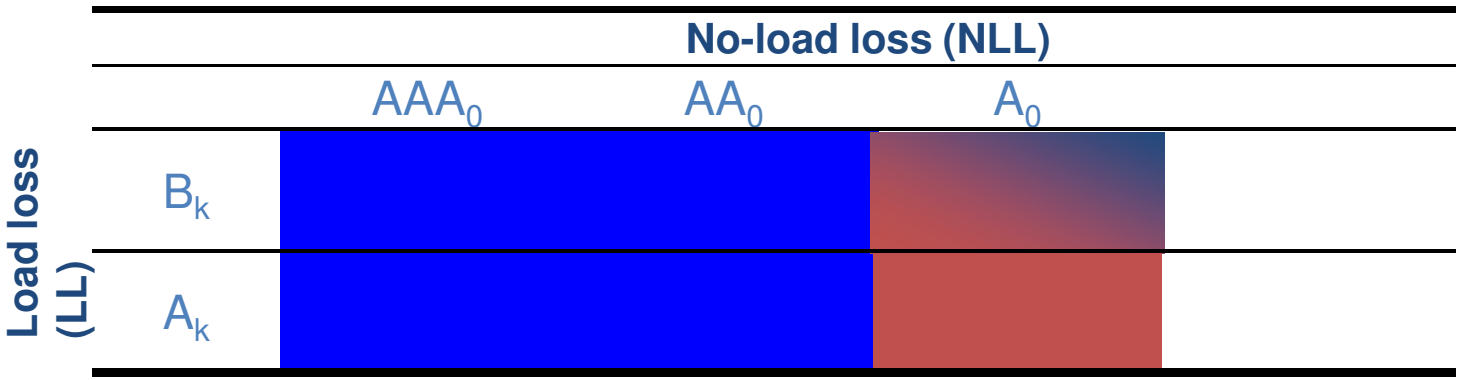
Transformers Energy Efficiency

Dry Type distribution transformers

Rated Power	range 100 kVA-2500 kVA
Rated Voltage	max. 36 kV
Tap-changer	off-circuit
Winding materials	aluminum/copper
Enclosures	IP23
Environmental classes	C2/E2/F1

Transformers Energy Efficiency

Dry type transformers – improved Efficiency



Solutions for more efficient transformers than those indicated by the Regulation are indicated in the standard under preparation .

- The AAA_0 transformer with amorphous core has -30% no load losses compared to A_0.

Transformers Energy Efficiency
Markings and documentation – Rating plate

Markings and documentation:

- from July 1st, 2015, the following transformer characteristics must be indicated in the rating plate, in addition to those as requested by EN 60076-1:
  - **CE marking**
  - **Values of No Load and Load losses, for transformers ≤3150kVA**
  - **PEI for transformers >3150kVA**
  - **Information on the weight of all the main components (including at least the conductor, the nature of the conductor and the core material)**

Transformers Energy Efficiency
Technical documentation

To comply with EU Regulation 548/2014, the following information shall be included in the technical documentation of all transformers:

a) manufacturer's name and address;

b) model identifier; an alphanumeric code to distinguish one model from other models not in compliance with EU Regulation of the same manufacturer

c) All information indicated in the rating plate, including a description of: conductor material, other materials, other components and accessories used in the manufacturing of the product.

d) The test report

Pay Back

Payback of the difference of the purchase cost of transformers of different efficiency

- Less accurate than TOC calculation, but easier to use
- Compare the cost of purchase of 2 transformers with different efficiencies and different price, and consider the annual cost savings due to increased efficiency.
- Dividing the difference in purchase costs of the two transformers for the annual savings you get the time in which the investment pays off.
- **Be carefull: system is not the most correct, because it looks a very short time horizon and does not take into account the change in the cost of electricity over the years and the present value of money.**

Calculation of Pay Back

$$n = (C_{AR} - C_{AS})/[A(P_{OR}-P_{OS}) + B(P_{KR}-P_{KS})]$$

Were:

- C_{AR}: reduced losses transformer purchasing cost
- C_{AS}: standard losses transformer purchasing cost
- A: present value (capitalization factor) cost of no-load losses €/kW
- P_{OS}: standard transformer guaranteed no load losses kW
- P_{OR}: reduced losses transformer guaranteed no load losses kW
- B: present value (capitalization factor) cost of load losses €/kW
- P_{KS}: standard transformer guaranteed load losses kW
- P_{KR}: reduced losses transformer guaranteed no load losses kW

Pay Back

A factor calculation					
Imput data (in red)				**Legend**	
	8760			Total annual hours	
d =	**0,15**	**€/kWh**		Energy cost	
Result (in green)					
A =	**1314**	**€/kW**			

Pay Back

B factor calculation

Depends on transformes annual loading hours

in particular from the hours worked per day, the days worked during the year and the loading factor

as indicated below

Imput data (in red) **Result (in green)**

	Hours per year	Hours per day	Days per year	Loading factor	Equivalent hours per year
	3200	16	200	0,7	1568

B = 235 **€/kW**

Comparative calculation for a transformer of:							1	MVA
Losses (kW)	**Standard C_0 + 13% B_K**	**Reduced C_0 B_K - 2%**						
P_{0G} =	2,6				KW	0,3	394	
P_0 =		2,3						
P_{KG} =	11				KW	1,2	282	
Pk =		9,8						
							676	
C_{AR} =	9500							
C_{AS} =		10600					1100	
					Pay-back years		1,63	
The return time of greater investment is:						1,6	**years.**	
So it pays to buy a transformer with reduced losses.								

Transformers Energy Efficiency
Questions & answers

Q & A