Commercial and Industrial Distribution Transformers Initiative

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1 Initiative Overview and Purpose

Most of the electricity that is used to power the commercial and industrial sectors flows through distribution transformers on the customer side of the energy meter. These distribution transformers are relatively efficient; those sold today convert more than 97 percent of input power to output power. However, because most distribution transformers are powered 24 hours per day, 365 days per year, even incremental improvements can yield significant energy savings over time.

Transformer manufacturers are beginning to deliver transformers with greater than minimum efficiencies to the marketplace, but due to a variety of barriers, customer demand for high efficiency lags far behind the cost-effective potential. Factors behind lagging demand include:

- First cost of high performance equipment
- Market channel participants (specifying engineers and electrical contractors) and end users are not aware of the value proposition of high efficiency
- Typically transformer purchasers or specifiers are not the entity ultimately responsible for electricity costs (split incentive)
- Absence of a consistent, widely-accepted definition of high performance

The purpose of this Initiative is to drive market demand for high efficiency, through assisting member programs to overcome the barriers above, by:

1. Establishing a clear definition of high efficiency for efficiency program administrators and the distribution transformer market, to serve as a basis for both individual efficiency program administrators to determine their own programs, which may include financial incentives, and for commerce
2. Increasing customer awareness of the benefits of high efficiency transformers through efficiency programs
3. Engaging transformer manufacturers on an industry-to-industry basis to identify new products and emerging technologies, share results, and promote high performance

1.1 Product Definition

Products addressed by this initiative include low and medium voltage, dry-type, three-phase and single-phase distribution transformers between 15 kVA and 2.5 MVA. This range covers the most common transformers and the bulk of the market by capacity.[1] Low voltage transformers are defined by US Department of Energy (DOE) as having input voltage less than or equal to 600V, and range in size from 15-333 kVA for single phase and 15-1000 kVA for three-phase equipment. Medium voltage is defined as having input voltage >600V, ranging in size from 1-2.5 MVA. The scope of this initiative does not include utility-purchased transformers, as these are typically not eligible for efficiency program activity.

1.2 Initiative Scope

CEE will focus initially on identifying a clear definition of high performance for the low voltage distribution transformer market, through development and promotion of a CEE specification for both single-phase and three-phase equipment. Greater than 90% of low voltage transformers are purchased by commercial, institutional, industrial and agricultural customers.[2] Looking forward, the Initiative will develop messaging for use with low voltage transformer customers and customer representatives—those responsible for specifying transformer equipment for new construction projects. It will also include outreach to the transformer industry to identify and test key features and functions of distribution transformers that may serve additional efficiency program goals. Examples include grid communication and multiple core designs. The Initiative may additionally take on development of messaging for the medium voltage distribution transformer market focusing on the value of total ownership cost (TOC) calculation in purchase decision making and identification of an industry standard TOC methodology.

2 Technical Description

Distribution transformers are used in commercial and industrial applications to step down power from distribution voltage to be used in HVAC or process loads (220V or 480V) or to serve plug loads (120V). They are made up of one or more cores (typically carbon steel), two sets of metal windings (copper or aluminum), an insulating material (oil or air), and a container shell. Distribution transformers have no moving parts.

2.1 Energy Losses

Transformer energy efficiency is the ratio of output power to distribution voltage input power. Between input and output the transformer experiences losses, generally characterized as core losses (or no-load losses) and winding losses (or load losses). Core losses occur in the core materials of the transformer and are constant whenever the transformer is energized, regardless of load. Winding losses occur in the transformer windings, and increase exponentially with load. As Figure 1 indicates, the driver of a

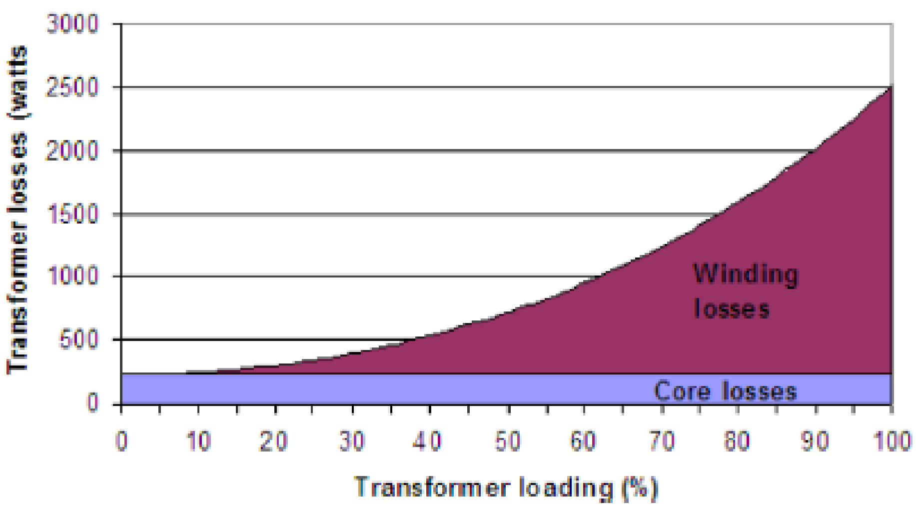
[1] Although equipment under 15 kVA comprise a large percentage of sales by unit volume, they comprise less than 5% of sales in terms of capacity and represent a small portion of the overall efficiency opportunity. Much of this equipment is sold to OEMs.

[2] Industry Interviews

transformer's total losses, and therefore its efficiency, may be either the efficiency of the transformer core or the windings, depending on load.

Transformers in commercial and industrial buildings are typically sized conservatively relative to their expected loads.[3] Transformer customers and specifiers may not be aware that dry-type transformers may be safely overloaded for brief periods. Conservative sizing is reinforced by National Electric Code requirements.[4] The US DOE test procedure assumes that low voltage dry-type distribution transformers are loaded at 35% and medium voltage at 50%. Data on actual loading of distribution transformers is incomplete and contradictory—for the purposes of this initiative CEE assumes 35% loading for low voltage and 50% loading for medium voltage distribution transformers, following the US DOE and transformer industry standards.

Figure 1. **Core and Winding Losses By Load (75 kVA Dry-Type Transformer)**



Source: DOE Distribution Transformers Technical Support Document, Chapter 3: Market & Technology Assessment, 2011

Transformer losses may be affected by changes to transformer design, core or winding material, and type and amount of insulation in the transformer. In general, higher grade steel (in the transformer core) and more copper (in the windings) will improve a transformer's efficiency. Design elements relevant to efficiency include the manner in which the core plates are joined (butt-lap, mitered, wound core), and the distance between the plates. Oil is a better conductor of heat and a more effective electrical insulator than air, allowing for a tighter core design and generally higher efficiencies than in dry-type transformers.

A number of new designs and materials have demonstrated the potential to significantly reduce transformer losses. Amorphous metal, a metallic material with a noncrystalline structure, may yield reduced core losses when used in place of silicon

[3] DOE Distribution Transformers Technical Support Document, Chapter 7: Energy Use & End Use Load Characterization, 2011

[4] US Fire Protection Association, *National Electric Code, Table 450.3(A)*, 2008

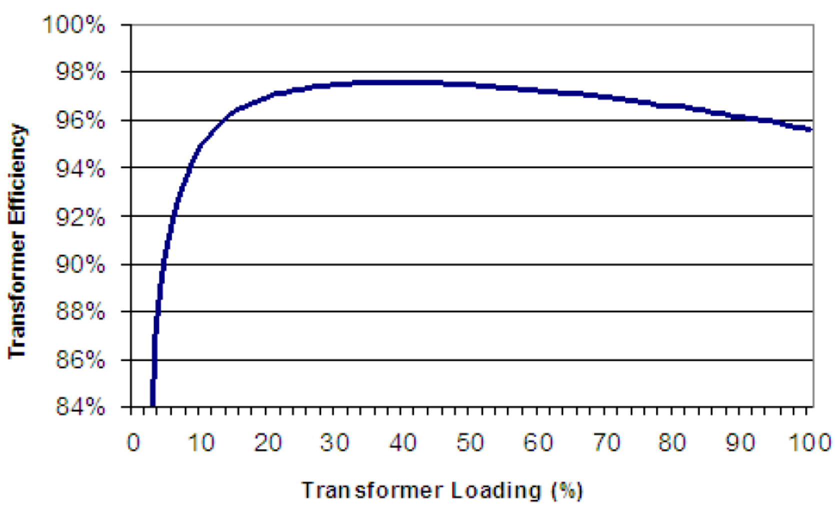
steel. Designs featuring multiple cores have also demonstrated improved losses relative to single core designs. Many techniques to improve transformer energy performance affect both core and winding losses, often inversely. For example, measures to reduce core losses, by using amorphous metal in the core or otherwise reducing core flux density, will result in the need for a larger core and increased winding losses.[5] It is important that transformer customers (or specifiers) understand their load, in order to determine the appropriate measures to improve transformer performance.

Other common transformer types and configurations, including harmonics filtering and connection type (e.g. delta-wye, wye-wye) do not significantly affect transformer losses, assuming linear load conditions. However, significant nonlinear loads and associated harmonics can impact energy performance somewhat in general purpose transformers. K-rated transformers are less prone to performance reductions caused by harmonics. Commercial and industrial building owners should consult with their electrical system designer or electrician in order to understand their load and any power quality concerns prior to purchasing a new distribution transformer.

2.2 Transformer Sizing

Because energy losses vary by load, transformer efficiency also varies according to load. In general, optimum efficiency is achieved at the point at which core losses and winding losses are equal. The relationship of transformer efficiency to transformer load is illustrated in Figure 2.

Figure 2. **Transformer Efficiency Relative to Load**



Source: DOE Distribution Transformers Technical Support Document, Chapter 3: Market & Technology Assessment, 2011

The importance of load to transformer efficiency means that transformer sizing is a key component of overall transformer energy performance. Oversized transformers experience high core (no-load) losses, whereas a transformer nearer its load limit will

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[5] DOE Distribution Transformers Technical Support Document, Chapter 3: Market & Technology Assessment, 2011

experience high winding (load) losses (see Figure 1). It is important that the transformer specifier understand the end user's load shape, in order to purchase a transformer that will regularly perform at its best efficiency point.

3 Market

According to US DOE, US sales of distribution transformers in 2009 totaled $2.09 billion.[6] Liquid-immersed, medium voltage equipment accounts for 76% of this market. This equipment is purchased primarily by electric utilities, and is not within the scope of this Initiative.

Distribution transformers may be found in virtually every commercial building and industrial facility. Commercial buildings and industrial facilities with an overall load >.5 MW are likely to have one or more medium voltage transformers; smaller buildings may have only low voltage equipment. Commercial buildings often have one or more low voltage distribution transformers on each floor to supply power for plug loads, HVAC, and other building systems.

Table 1 shows that within the dry-type equipment classes, low voltage, three-phase equipment accounts for 90 %of sales by unit volume and 70% of sales by capacity. Low voltage single-phase equipment makes up less than 4% of sales of dry-type distribution transformers. Medium voltage accounts for the remaining 26% of dry-type sales.[7]

3.1 Market Size

Table 1 **2009 US Distribution Transformer Shipments Estimate**

Equipment Class	Units Shipped	MVA Capacity Shipped	Shipment Value (Million $ US)
Low Voltage Dry-Type Single Phase	17,740	647	$22.0
Low Voltage Dry-Type Three Phase	206,929	15,778	$394.4
Medium Voltage Dry-Type Single Phase	1,457	55	$1.8
Medium Voltage Dry-Type Three Phase	3,882	6,118	$171.1
Medium Voltage Liquid-Filled (Utility Market)	733,465	54,260	$1,500.8
Total	963,473	76,858	$2,090.1
Total Dry Type (C&I Market)	230,008	22,598	$589.3

Source: DOE Distribution Transformers Technical Support Document, Chapter 3, 2011

Within the three-phase low voltage market, the most common sizes sold are 45 kVA, 75 kVA, and 112.5 kVA. Together these three sizes account for 60% of sales by unit volume and 55% of sales by capacity.[8] Three-phase, 75 kVA transformers alone account for 29% of sales (by unit volume and capacity).

[6] DOE Distribution Transformers Technical Support Document, Chapter 3: Market & Technology Assessment, 2011

[7] Ibid.

[8] DOE Distribution Transformers ANOPR Technical Support Document, Chapter 3: Market & Technology Assessment, 2005

The market for distribution transformers in North America may be divided into utility and nonutility purchasing. Electric utilities purchase a large volume of distribution transformers, primarily from the liquid-filled medium voltage class. Utility purchases represent a very small share of dry-type equipment sales volume. Dry-type transformers are purchased predominantly for use in commercial, industrial, and institutional applications.[9]

The market may also be broken down between stock and built-to-order equipment. Standard efficiency, low voltage dry-type transformers at and below 300 kVA are typically stock items, carried by transformer distributors. Transformers larger than 300 kVA, or with higher-than-minimum efficiency are typically built-to-order. Currently only one manufacturer carries NEMA Premium® efficiency transformers as stock items, and only at the four most common sizes, (40, 75, 112.5, and 150 kVA).[10] All medium voltage distribution transformers, regardless of efficiency, are built-to-order.

3.2 Market Drivers and Delivery Channels

The market for low voltage dry-type distribution transformers is driven primarily by new construction and facility expansion. Fully loaded, distribution transformers have an average useful life of 30 years[11]. It is common in commercial and industrial applications for distribution transformers to be loaded well below their full rated load. Under-loaded distribution transformers frequently outlive the buildings in which they are housed.[12] A small share of low distribution transformer sales come through replacement of functioning equipment, a common driver being building occupant turnover that necessitates different transformer equipment.[13]

The market delivery channel for distribution transformers varies according to customer type and order volume (see Figure 3). The delivery channel for commercial and industrial customers involves a number of players, including the stocking distributor, electrical contractor, or customer representative (typically a general contractor or architecture and engineering firm). For commercial and industrial customers, transformer equipment is typically specified by the customer or customer representative.

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[9] Industry Interview

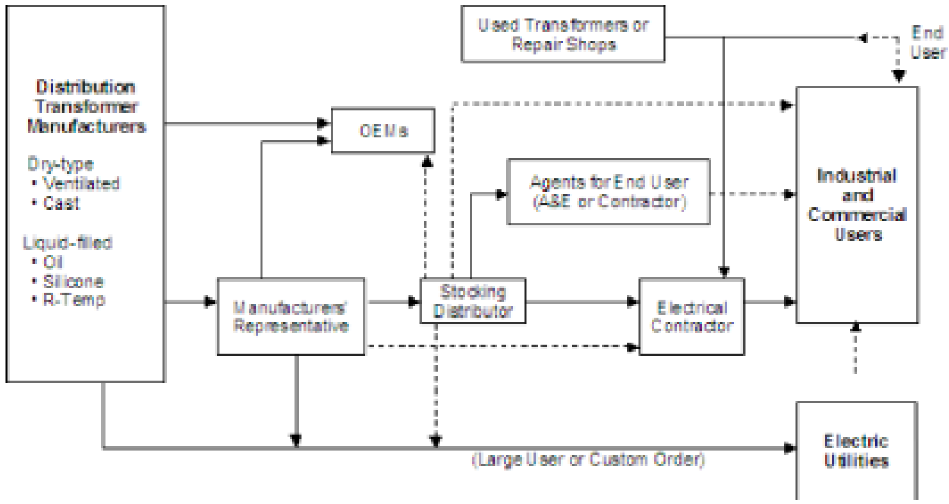
[10] Industry Interview

[11] Oak Ridge National Labs, Determination of Analysis of Energy Conservation Standards for Distribution Transformers, 1996

[12] ORNL has determined the average useful product life of a distribution transformer to be 33 years. Manufacturers consistently indicate that this is a conservative estimate.

[13] Industry interview

Figure 3. **Market Delivery Channels for Distribution Transformers**



Source: DOE Distribution Transformers, *Technical Support Document*, *Chapter 5*, 2011

3.3 Market Players

3.3.1 Manufacturers

There are more than 60 manufacturers and importers of distribution transformers in North America, however most of these companies are small or serve particular niche markets. Seven manufacturers represent more than 80% of sales in the low voltage dry-type market. These manufacturers are:

- Acme Electric Corporation
- Eaton Electrical, Inc.
- Federal Pacific Transformer Company
- General Electric
- Hammond Power Solutions, Inc.
- MGM Transformer Co.
- Schneider Electric-Square D

The medium voltage dry-type market is similarly dominated by a small number of large manufacturers. The following seven manufacturers account for more than 80% of the sales of medium voltage dry-type distribution transformers:[14]

- ABB Power T&D Company
- Federal Pacific Transformer Company
- Hammond Power Solutions, Inc.
- Jinpan International, Ltd.

[14] US DOE Distribution Transformers *Technical Support Document*, Ch. 5, 2011

- Magnetic Technologies Corporation
- MGM Transformer Company
- Olsun Electrics Corporation

3.3.2 Manufacturer Representatives

These representatives serve as the marketing arm of the manufacturers and may be salaried sales personnel or independent agents. They are a key source of technical information regarding distribution transformer products.

3.3.3 Stocking Distributors

Stocking distributors are independent electrical equipment sellers that maintain an inventory of low voltage equipment and often sell used equipment as well. Stocking distributors may play an important market transformation role, as currently few manufacturers maintain their high efficiency low voltage products as stock items.[15] Availability of high performance products at the distributor level will be important to advancing high performance products beyond niche markets.

3.3.4 Electrical Contractors

Contractors are responsible for electrical system installation, but have no direct concern regarding energy bills. Electrical contractors purchase transformers from stocking distributors or direct from the manufacturer representative. Equipment specifications are determined by the electrical contractor or the customer agent. Electrical contractors may have an incentive to purchase high performance equipment, depending on the customer's goals (e.g. LEED certification). Electrical contractors are a key group for targeted messaging and education regarding the definition of high performance.

3.3.5 Customer Agents

Customer agents are typically architecture and engineering firms or general contractors selected by the building owner to evaluate design options and specify equipment. They generally provide a specification to the electrical contractor, who actually procures the equipment. As with the electrical contractor, the agent may have an incentive to specify high performance, depending on the customer's goals. Additionally, a number of firms in this role will also provide building operations management, following construction, on a performance contract basis. In these cases, the agent has a direct incentive to pursue high performance. This is another key target for messaging regarding the definition of high performance.

3.3.6 National Electrical Manufacturers Association (NEMA)

The NEMA Transformer Section includes six of the seven largest US manufacturers of low voltage distribution transformers,[16] as well as many of the major manufacturers in

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[15] Industry Interview

[16] Of the above list, only Olsun is not a NEMA Distribution Transformers section member.

the medium voltage equipment classes. NEMA worked with CEE to promote high performance at the TP-1 level from 1998-2006.

In 2010 NEMA released a set of voluntary efficiency levels for low voltage dry-type distribution transformers under the NEMA Premium brand. Transformers complying with the NEMA Premium levels must exhibit a minimum of 30% fewer total load losses than specified by the TP-1 minimum standard level. NEMA characterizes the performance of NEMA Premium compliant transformers as 30% more efficient than TP-1 compliant equipment.

3.3.7 CEE

CEE launched the C&I Distribution Transformers Initiative in 1998, to establish a consistent definition of high efficiency, improve efficiency's visibility in the transformer market, and increase consumer demand for high efficiency distribution transformers. CEE determined that the appropriate program high efficiency level would be served well by the specification used by ENERGY STAR® and NEMA to define as high efficiency low voltage distribution transformers those that met or exceeded the NEMA TP-1 levels of energy performance. The CEE Initiative also included messaging for customers of medium voltage dry-type transformers, focused on the importance of lifecycle cost in transformer purchase decision making. In 2005, US DOE determined that market support was sufficient to implement federal minimum efficiency standards at the NEMA TP-1 levels endorsed by CEE and ENERGY STAR.

4 Energy Savings Potential

The energy efficiency gain achievable in distribution transformer technology is incremental. Under current US and Canadian federal minimum standards, transformers sold today must convert at minimum 97% of input power to output power. However, because these units are typically powered at all times and have useful product life of 30 years or more, small improvements in energy performance can lead to significant energy savings over the life of the product. US DOE estimates that dry-type distribution transformers—low and medium voltage, leaving aside liquid-filled which are typically purchased for use on the utility side of the meter—have the technical potential to generate approximately 2.5 Quads of energy savings over a 30 year period[17].

4.1 Unit Energy Savings

Energy savings potential at the unit level varies by equipment size. A transformer's size in kVA reflects how much power flows through the unit, and therefore how large that unit's losses will be. Energy efficiency thresholds—both minimum standards and voluntary levels—also increase as size increases (e.g. the federal minimum for a 75 kVA transformer is higher than for a 45 kVA transformer). For individual power users,

[17] US DOE Distribution Transformers *Technical Support Document, Chapter 10*, 2011

energy efficient transformers can lead to significant savings. Transformer losses account for 2-6% of a typical commercial building's electricity consumption[18].

4.2 The CEE High Performance Tier Levels

The CEE Tier 1 efficiency level provides a reduction of approximately 35% of total losses relative to the current federal minimum standard level; the CEE Tier 2 level yields roughly a 50% reduction in total losses relative to the minimum level. Assuming a baseline at the federal minimum level, a building owner could reduce their overall energy consumption 0.7-2.1% by choosing new transformers at the CEE Tier 1 level, and 13% with transformers at the CEE Tier 2 level. Table 2 lists the CEE Tier 1 levels for single-phase distribution transformers, and the Tier 1 and Tier 2 levels for three-phase distribution transformers.

4.2.1 Rationale for CEE Efficiency Tier 1

The CEE Tier 1 efficiency level is equivalent to the performance levels labeled NEMA Premium, and to Energy Efficiency Level 2 identified by US DOE in its August 2011 analysis.[19] Low voltage transformers with performance meeting the CEE Tier 1 level will demonstrate approximately 30% less total energy losses, as compared to the current federal minimum standard level, for both single- and three-phase equipment. According to CEE's research, 11 major manufacturers currently offer products that meet or exceed the CEE Tier 1 level. This Tier 1 level would serve as an update to the current CEE high performance specification for low voltage distribution transformers.

4.2.2 Rationale for CEE Efficiency Tier 2

In its 2011 engineering analysis, US DOE identified significant energy savings potential beyond the CEE Tier 1 level. US DOE Energy Efficiency Level 5[20] identified the level with the greatest overall economic benefit for customers over the lifetime of the product, and which could be manufactured using conventional transformer materials and designs. CEE Tier 2 level is equivalent to US DOE Energy Efficiency Level 5. Low voltage transformers meeting the CEE Tier 2 performance level will demonstrate 46-50% less total energy losses, as compared to the current federal minimum standard level. CEE Tier 2 level applies only to three-phase equipment.

CEE Tier 2 level will provide a signal to the transformer industry of where the efficiency program industry understands the current technical and market potential of this equipment to be. According to engineering analysis by US DOE, this performance level is currently attainable, though it may require higher grade core materials or copper

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[18] Howe, B. (1996) Selecting Dry-Type Transformers: Getting the Most Energy Efficiency for the Dollar. Tech Update TU-95-6 E Source, Boulder, CO August 1995

[19] US DOE Analytical Results In Support of Stakeholder Negotiations On Amended Energy Conservation Standards For Distribution Transformers, August, 2011

[20] Ibid.

windings, or construction techniques such as mitered cores or multiple core designs, relative to equipment at the federal minimum or CEE Tier 1 levels.[21]

The CEE Committee did not recommend a Tier 2 specification for single-phase equipment, which represents only ~5% of distribution transformer shipments.[22] The limited size of this market, and absence of manufacturers and products with performance significantly greater than the CEE Tier 1 level, makes a second tier level for single-phase equipment inappropriate at this time.

Table 2 **CEE High Performance Tier Levels**

Single Phase Transformers Low Voltage			Three Phase Transformers Low Voltage			
kVA	Baseline[1]	CEE Tier 1[2]	kVA	Baseline[1]	CEE Tier 1[2]	CEE Tier 2[3]
15	97.7	98.39	15	97	97.9	98.40
25	98	98.6	30	97.5	98.25	98.65
37.5	98.2	98.74	45	97.7	98.39	98.78
50	98.3	98.81	75	98	98.6	98.93
75	98.5	98.95	112.5	98.2	98.74	99.03
100	98.6	99.02	150	98.3	98.81	99.10
167	98.7	99.09	225	98.5	98.95	99.40
250	98.8	99.16	300	98.6	99.02	99.44
333	98.9	99.23	500	98.7	99.09	99.51
			750	98.8	99.16	99.56
			1000	98.9	99.23	99.59

[1] Baseline = Federal minimum standard effective January 1, 2007 (NEMA TP-1-2002).

[2] CEE Tier 1 criteria are identical to NEMA Premium voluntary standard levels and the US DOE Energy Efficiency Level 2 (Distribution Transformers Technical Support Document, 2011)

[21] US DOE Distribution Transformers *Technical Support Document, Chapter 5*, 2011

[22] US DOE Distribution Transformers *Technical Support Document, Chapter 3*, 2011

[3] CEE Tier 2 criteria are identical to US DOE Energy Efficiency Level 5 (Distribution Transformers Technical Support Document, 2011)

[4] Qualifying low voltage distribution transformers will be tested in accordance with DOE test procedure 10 CFR Part 431. The test procedure specifies constant, linear load at 35% of unit capacity. Efficiency levels assume a core temperature of 75° C during testing.

Table 3 lists the annual total losses (core losses and winding losses) of three-phase transformers at the federal minimum, Tier 1, and Tier 2 levels, their annual energy savings vs. the current federal minimum standard level, and the average marginal cost of Tier 1 qualifying equipment in 2010. Table 4 provides the most recent analysis of unit lifecycle cost and payback period from US DOE, assuming unit production at scale. Table 5 lists the annual total losses of single-phase transformers at the federal minimum and Tier 1 levels, and expected annual energy savings.

Table 3 **Total losses and energy savings associated with CEE Tiers for three-phase equipment**

KVA	Total Losses (kWh/yr)			Energy Savings vs. Baseline (kWh/yr)		Marginal Equipment Cost: Tier 1 vs. Baseline
	Baseline	Tier 1	Tier 2	Tier 1	Tier 2	
15	1380	966	736	414	644	$448
30	2300	1610	1242	690	1058	$807
45	3173	2221	1683	952	1490	$851
75	4599	3219	2460	1380	2139	$1,115
112.5	6209	4346	3346	1863	2863	$2,144
150	7818	5473	4139	2345	3679	$2,740
225	10348	7243	4139	3104	6209	$3,617
300	12877	9014	5151	3863	7726	$5,078
500	19929	13950	7512	5979	12417	$4,815
750	27594	19316	10118	8278	17476	-
1000	33726	23608	12571	10118	21155	-

[1] Average Marginal Cost data from survey of 3 manufacturers' current products in 2010; price to channel assuming constant linear load at 35% of unit capacity.

Average marginal cost of equipment, in Table 3, was collected from manufacturers in 2010, when CEE Tier 1 qualifying equipment had very little market share, and all units were custom built. The Committee asked four members whether this measure would qualify under their programs—all four indicated that CEE Tier 1 qualifying distribution transformers would qualify under individual program cost-effectiveness tests, and expressed the intention to recommend use of the specified levels as the basis of prescriptive program offerings. Moreover, based on CEE experience with other products, as well as discussions with manufacturers and others, it is also reasonable to assume that as market share of CEE Tier 1 qualifying equipment grows, the marginal cost of that equipment could decrease, improving customer return on investment, and yielding a highly cost-effective measure for program administrators.

The US DOE lifecycle cost savings and payback analysis, which assumes unit production at scale, found shorter payback periods than the Committee's analysis that relied on 2010 unit cost data. The US DOE lifecycle cost savings and payback analysis, for three representative low voltage dry-type distribution transformers included in the CEE initiative, is presented in Table 4 below.

Table 4 **Lifecycle cost analysis of low voltage distribution transformers at proposed CEE efficiency tiers**

	Proposed CEE Tier 1		Proposed CEE Tier 2	
Representative Unit	Mean LCC Savings	Median Payback	Mean LCC Savings	Median Payback
25 kVA Single Phase	$59	13.4 yrs	N/A	N/A
75 kVA Three Phase	$849	0.0 yrs	$1,328	8.1 years
300 kVA Three Phase	$3,554	4.0 yrs	$5,844	7.0 years

Source: US DOE, Analytical Results In Support of Stakeholder Negotiations On Amended Energy Conservation Standards For Distribution Transformers, August 2011

Note that DOE Analysis assumes unit production at scale.

Table 5 **Total losses and energy savings associated with CEE Tier 1 level for single-phase transformers**

KVA	Total Losses (kWh/yr)		Energy Savings vs. Baseline (kWh/yr)
	Baseline	Tier 1	Tier 1
15	1058	740	317
25	1533	1073	460
37.5	2070	1449	621
50	2606	1824	782
75	3449	2414	1035
100	4292	3005	1288
167	6656	4659	1997
250	9198	6439	2759
333	11231	7862	3369

Tier 1 energy savings represents savings vs. baseline assuming constant, linear load at 35% of unit

4.3 Market Level Energy Savings

Currently, high efficiency (at the NEMA Premium level) represents less than 5% of the market for low voltage distribution transformers. Increasing the market share of high efficiency distribution transformers from 5% to 20% (of total sales by unit volume), at the CEE Tier 1 level, would result in 78 million kWh saved per year, reducing commercial and industrial sector energy expenditures by $6.4 million per year. If that 20% of total sales came at the CEE Tier 2 level it would result in savings of 129 million kWh, $10.6 million per year.[23]

[23] Market level energy savings calculated using DOE 2005 shipments analysis, and assuming baseline efficiency at the current federal minimum standard level. Dollar savings estimates based on 2010 sales-weighted average commercial and industrial electric rates ($.082/kWh; EIA *Electric Power Monthly*).

4.4 Possible Changes to US Federal Regulation

The US DOE is considering increasing federal minimum standards for low voltage distribution transformers and may publish a final rule in 2012. CEE Tier 2 level could, in the case that US DOE does raise federal minimum standards, serve as the basis for ongoing efficiency program offerings for high efficiency equipment beyond implementation of the new standard. It should be noted that US DOE rulemakings typically allow three years before new minimum standards take effect, giving program administrators and equipment manufacturers sufficient time to transition their programs and manufacturing processes to accommodate the new federal standards.

5 Activities

Initiative activities will include:

- Developing a high performance specification for low voltage distribution transformer equipment
- Maintaining a Qualifying Products List of all low voltage equipment that meets the CEE Tier 1 and Tier 2 specification criteria
- Collecting annual program summaries of support for distribution transformers
- Seeking for possible promotion an industry standard methodology to calculate the total ownership cost of new medium voltage distribution transformers
- Exploring of new transformer products and emerging technologies that demonstrate potential energy savings.

5.1.1 High Performance Specification

The central component of the C&I Distribution Transformer Initiative is the CEE High Performance Specification for Low Voltage Distribution Transformers (the Specification; included as Appendix A). The specification includes single- and three-phase, dry-type equipment. This specification will provide Initiative participants with a common basis for their program offerings and provides a consistent definition of high performance for transformer customers, manufacturers, and other market actors.

5.1.2 Medium Voltage

CEE will seek and potentially promote a credible, objective methodology for determining the TOC of medium voltage transformers. If no such methodology currently exists, the Initiative will seek partnership opportunities with national organizations (e.g. Institute of Electrical & Electronics Engineers) that may have the expertise and credibility to develop an industry standard TOC methodology. The primary audience for messaging regarding TOC methodology will be industrial customers and commercial equipment specifiers and customer agents.

5.1.3 Emerging Technology

Distribution transformers have begun to incorporate new features and functions that may enable this equipment to contribute to efficiency program goals beyond the acquisition of energy savings. New equipment from certain manufacturers incorporates the ability to power down sections of the transformer core, in response to pricing signals or a grid demand response event. The Committee expects that other features may be enabled by the emergence of two-way communications technologies. These features may enable distribution transformers to play a role in load management and demand response in the future.

Going forward, the Initiative may develop additional member resources in the form of program guidance, an updated specification, or otherwise, to capture key takeaways and identify the critical functions and features of next generation transformers from an energy performance perspective.

6 Participation

As with all CEE initiatives, participation in the C&I Distribution Transformers Initiative is voluntary. To be considered an Initiative participant, a member program must meet a minimum set of requirements. Requirements of participation are as follows:

- Employ the CEE high performance specification for low voltage distribution transformers as the basis for program offerings
- Report program offerings to CEE on an annual basis, to be captured in the Distribution Transformers Program Summary

6.1 Benefits of Participation

By working together at the binational level through CEE, initiative participants leverage their collective resources and market coverage to transform this market more quickly and effectively than they could by acting individually.

In developing high performance specifications, CEE relies on input from the affected industry to ensure that our claims are robust and reasonable. CEE specifications entail a number of ancillary benefits including:

Providing consumers an unbiased, trustworthy basis to understand equipment energy performance

Setting consistent, voluntary binational targets for manufacturers to consider in the design and engineering of next generation equipment

Enabling manufacturers to benefit from third-party promotion of their products.

7 References

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Appendix A CEE High Efficiency Specification for Low Voltage Dry Type Distribution Transformers

The efficiency program opportunity in this equipment area is to address a poorly functioning market for high performance transformers. Though efficient transformers are now widely available, several manufacturers report that actual sales of this equipment represent a very small share of total sales.[24] CEE member efficiency programs have a role to address gaps in customer awareness and information regarding the benefits of energy efficient transformers, and to accelerate their market adoption by alleviating the high incremental cost associated with premium efficiency. The CEE high performance specification assumes operating conditions as specified in the US DOE test procedure 10 CFR Part 42: constant, linear load at 35% of unit capacity.

Table 6 **CEE High Performance Tiers**

Single Phase Transformers Low Voltage			Three Phase Transformers Low Voltage			
kVA	Baseline[1]	CEE Tier 1[2]	kVA	Baseline[1]	CEE Tier 1[2]	CEE Tier 2[3]
15	97.7	98.39	15	97	97.9	98.40
25	98	98.6	30	97.5	98.25	98.65
37.5	98.2	98.74	45	97.7	98.39	98.78
50	98.3	98.81	75	98	98.6	98.93
75	98.5	98.95	112.5	98.2	98.74	99.03
100	98.6	99.02	150	98.3	98.81	99.10
167	98.7	99.09	225	98.5	98.95	99.40
250	98.8	99.16	300	98.6	99.02	99.44
333	98.9	99.23	500	98.7	99.09	99.51
			750	98.8	99.16	99.56
			1000	98.9	99.23	99.59

[1] Baseline = Federal minimum standard effective January 1, 2007 (NEMA TP-1-2002).

[2] CEE Tier 1 criteria are identical to NEMA Premium voluntary standard levels and the US DOE Energy Efficiency Level 2 (Distribution Transformers Technical Support Document, 2011)

[24] Information obtained through conversations with two manufacturers and NEMA staff. The CEE Committee plans to ask NEMA about the possibility of collecting and reporting data re. the sales of high performance distribution transformers.

[3] CEE Tier 2 criteria are identical to US DOE Energy Efficiency Level 5 (Distribution Transformers Technical Support Document, 2011)

[4] Qualifying low voltage distribution transformers will be tested in accordance with DOE test procedure 10 CFR Part 431. The test procedure specifies constant, linear load at 35% of unit capacity. Efficiency levels assume a core temperature of 75° C during testing.

Table 7 **Total losses and energy savings associated with CEE Tiers for three-phase equipment**

KVA	Total Losses (kWh/yr)			Energy Savings vs. Baseline (kWh/yr)		Marginal Equipment Cost: Tier 1 vs. Baseline
	Baseline	**Tier 1**	**Tier 2**	**Tier 1**	**Tier 2**	
15	1380	966	736	414	644	$448
30	2300	1610	1242	690	1058	$807
45	3173	2221	1683	952	1490	$851
75	4599	3219	2460	1380	2139	$1,115
112.5	6209	4346	3346	1863	2863	$2,144
150	7818	5473	4139	2345	3679	$2,740
225	10348	7243	4139	3104	6209	$3,617
300	12877	9014	5151	3863	7726	$5,078
500	19929	13950	7512	5979	12417	$4,815
750	27594	19316	10118	8278	17476	-
1000	33726	23608	12571	10118	21155	-

[1] Average Marginal Cost data from survey of 3 manufacturers' current products; price to channel. Energy performance data prepared by members of the CEE Distribution Transformers Committee assuming a constant, linear load at 35% of unit capacity.

Table 8 **Lifecycle cost analysis of low voltage distribution transformers at CEE efficiency tiers**

Representative Unit	Proposed CEE Tier 1		Proposed CEE Tier 2	
	Mean LCC Savings	Median Payback	Mean LCC Savings	Median Payback
25 kVA Single Phase	$59	13.4 yrs	N/A	N/A
75 kVA Three Phase	$849	0.0 yrs	$1,328	8.1 years
300 kVA Three Phase	$3,554	4.0 yrs	$5,844	7.0 years

Source: US DOE, Analytical Results In Support of Stakeholder Negotiations On Amended Energy Conservation Standards For Distribution Transformers, August 2011

Note that DOE Analysis assumes unit production at scale.

Table 9 **Total losses and energy savings associated with CEE Tier 1 level for single-phase equipment**

KVA	Total Losses (kWh/yr)		Energy Savings vs. Baseline (kWh/yr)
	Baseline	**Tier 1**	**Tier 1**
15	1058	740	317
25	1533	1073	460
37.5	2070	1449	621
50	2606	1824	782
75	3449	2414	1035
100	4292	3005	1288
167	6656	4659	1997
250	9198	6439	2759
333	11231	7862	3369

Tier 1 energy savings represents savings vs. baseline
Energy performance data prepared by members of the CEE Distribution Transformers Committee