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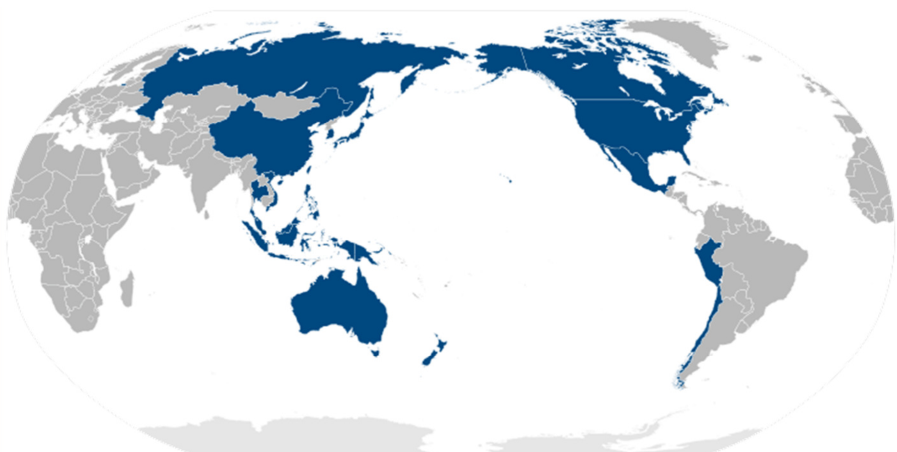
Energy Efficiency Potential for Distribution Transformers in the APEC Economies



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Disclaimer

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Acronyms

APEC	Asia-Pacific Economic Cooperation
BIL	Basic Impulse Level
BUENAS	Bottom-Up Energy Analysis System
CCE	cost of conserved energy
CLASP	Collaborative Labeling Appliances and Standards Program
CO_2	carbon dioxide
CEA	Canadian Electricity Association
CCNNIE	Comité Consultivo Nacional de Normalización de Instalaciones Eléctricas
DL	Design Line
EECA	Energy Efficiency and Conservation Authority
EES&L	energy efficiency standard and labeling
EGAT	Electricity Generating Authority of Thailand
EMSD	Electrical and Mechanical Services Department
EVN	Viet Nam Electricity
GWh	gigwatt-hour
HEPS	higher energy performance standard
ICA	International Copper Association
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IPCC	Intergovernmental Panel on Climate Change
kt	kiloton
kVA	kilo-volt ampere
LL	load losses
LRMC	long run marginal cost
MSP	manufacturer selling price
MEA	Metropolitan Electricity Authority
MEPS	minimum efficiency performance standard
MOIT	Ministry of Industry and Trade
MSP	Manufacturer Selling Price
Mt	million tons
MVA	mega-volt ampere
MWh	megawatt-hour
NEMA	National Electrical Manufacturers Association
NPV	net present value
MoE	Ministry of Energy
NES	national energy savings
NIC	National Installed Capacity
NLL	no-load losses
NOM	Norma Mexicana
NOx	nitrogen oxide
PEA	Provincial Electricity Authority
PF	power factor
PLN	Perusahaan Listrik Negara
PNTP	Proyecto de Norma Técnica Peruana
RMS	root mean square
S&L	standards and labeling
SEAD	super-efficient equipment and appliance deployment

SEC	Superintendencia de Electricidad y Combustible
SO_2	sulfur dioxide
SWER	single wire earth return
T&D	transmission and distribution
TBN	Tenaga Nasional Berhad
TEPS	Target Energy Performance Standard
TSD	technical support document
TWh	terawatt hour
U.S. DOE	United States Department of Energy
UEC	unit energy consumption
VAT	value-added tax

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Executive Summary

Transmission and distribution (T&D) losses in electricity networks in Asia-Pacific Economic Cooperation (APEC) member economies range between 4% and 17.4% of final energy consumption (IEA, 2012c). Because approximately one-fourth of T&D losses take place in distribution transformers, there is significant potential to save energy and reduce costs and carbon emissions through policy intervention to increase distribution transformer efficiency. For this reason, APEC created a project on efficient distribution transformers, in collaboration with the Chinese National Institute of Standards and the International Copper Association.

APEC economies encompass a wide range of economic development and experience with energy-efficiency standards and labeling (EES&L) programs. As a result, there is considerable potential to save energy in APEC economies through best practices to reduce T&D losses.

The goal of this report is to create awareness among APEC economies of the cost-effective potential to increase distribution transformer efficiency by introducing or raising mandatory minimum efficiency performance standards (MEPS) for distribution transformers in individual APEC member economies. Complementary activities have been carried out in parallel to LBNL's study by the firm Econoler, which analyzed enablers for and barriers to introducing or raising MEPS for distribution transformers in individual APEC member economies; reviewed the experiences, successes and failures of current EES&L programs, identified the best practices across the APEC member economies and provided frameworks for developing national roadmaps for introducing or raising MEPS. A further report by ZBSTRI covers the People's Republic of China. Therefore the reports of Econoler, ZBSTRI and this report should be read together for a more complete picture of APEC distribution transformer efficiency. Also, LBNL's report was prepared in close coordination with existing activities of the Super-efficient Equipment and Appliance Deployment (SEAD) initiative on distribution transformer energy efficiency and test procedure harmonization, for which the Collaborative Labeling Appliances and Standards Program (CLASP) is the operating agent. A separate forthcoming report from LBNL will compare the different test procedures in the APEC region and provide recommendations for harmonized test procedure.

Our quantitative analysis shows that the cost-effective potential for distribution transformers in the APEC economies represents:

- 30 terawatt hours (TWh) of electricity savings in 2030
- 20 percent reduction over the 153 TWh electricity distribution losses projected in 2030
- 17 million tons (Mt) of annual carbon dioxide (CO_2) emissions reductions by 2030
- 126 Mt of cumulative emissions savings between 2016 and 2030
- 17.5 billion USD in cumulative consumer financial benefits

<u>Scope:</u>

We focus on liquid-type distribution transformers from 10 kilovolts ampere (kVA) to 2,500 kVA, operating with an input voltage of 34.5 kV or less, an output voltage of 600 volts or less, and rated for operation at a frequency of 50 or 60 Hertz, depending on the economy. Dry-type distribution transformers are excluded from the analysis because of lack of data.

Quantitative analysis:

Our quantitative analysis evaluates the national benefits of cost-effective improvements in distribution transformer energy efficiency in APEC economies. Benefits are quantified in terms of energy, emissions mitigation, and net present value of programs.

The analysis uses a bottom-up, engineering-based approach, to develop economy-specific cost curves and determine efficiency levels of cost-effectiveness for distribution transformers. We use the Bottom-Up Energy Analysis System (BUENAS), developed at Lawrence Berkeley National Laboratory (LBNL), to estimate the national cost-effective potentials of distribution transformer efficiency that will save maximum energy while not penalizing consumers (in this case, utilities) financially.

To determine the cost-effective potential of distribution transformer efficiency, we collected information on existing energy-efficiency programs, markets, distribution transformer stocks, and distribution transformer energy use, along with energy sector data from APEC economy representatives. To address situations for which data are not available, we developed a methodology for making first-order estimates of cost-effective potential. There is significant uncertainty in the national results for economies for which we do not have data. We leveraged U.S. Department of Energy (U. S. DOE) engineering data from past rulemakings to develop otherwise scarce cost vs. efficiency data for every APEC economy. We then calculated cost of conserved energy (CCE) for different efficiency levels and compared it with the cost of electricity generation for the utility to determine the cost-effective targets for each economy. Finally, we propagated the unit-level results into the stock-accounting framework of BUENAS to calculate impacts of the MEPS in terms of national energy savings, net present value, and CO_2 emissions reductions. As an alternative to MEPS programs, we also analyzed the impact of labeling programs that would capture only a portion of the cost-effective potential.

Table ES-1 presents the estimated annual and cumulative energy savings, CO_2 emissions reductions, and net financial benefits for the MEPS scenario.

Table ES-1 – Summary Results for all APEC Economies under the MEPS Scenario

	Annual Impacts				**Cumulative Impacts**		
	National Distribution Losses	**Energy Savings**	**% Red.**	**CO_2 Emission Savings**	**Energy Savings**	**CO_2 Emission Savings**	**Net Financial Benefits**
	2030	**2030**	**2030**	**2030**	**2016-2030**	**2016-2030**	**Total**
	GWh	GWh	%	Mt	TWh	Mt	Million USD
Australia	9,402	2,759	29%	2.32	21.5	18.1	1,982
Brunei*	63	21	33%	0.02	0.2	0.1	47
Canada	10,058	1,464	15%	0.27	11.4	2.1	463
Chile	3,254	1,259	39%	0.52	9.3	3.8	732
Hong Kong, China	586	95	16%	0.07	0.7	0.5	15
Indonesia	4,980	1,130	23%	0.80	7.1	5.1	686
Japan	15,492	2,558	17%	1.07	20.5	8.6	1,330
Korea	7,354	1,428	19%	0.76	10.8	5.8	460
Malaysia	4,516	2,072	46%	1.51	15.6	11.3	2,467
Mexico	6,295	1,434	23%	0.65	10.8	4.9	833
New Zealand	455	153	34%	0.02	1.2	0.2	152
Papua New Guinea*	156	52	33%	0.03	0.3	0.2	71
Peru	1,646	435	26%	0.13	3.0	0.9	145
Philippines*	2,230	746	33%	0.36	5.0	2.4	668
Russia*	22,031	7,368	33%	4.71	52.9	33.8	3,238
Singapore	814	272	33%	0.14	2.1	1.0	188
Chinese Taipei*	4,562	1,246	27%	0.96	9.4	7.2	226
Thailand	3,821	1,047	27%	0.54	7.2	3.7	674
United States	51,117	3,138	6%	1.64	24.8	12.9	2,604
Viet Nam	4,008	1,216	30%	0.53	7.5	3.3	458
Total	**152,840**	**29,893**	**20%**	**17**	**221**	**126**	**17,439**

*Results for this economy are subject to a sizeable uncertainty

Our analysis shows that:

- Distribution transformer efficiency improvements are achievable in APEC economies and would save significant energy and reduce CO_2 emissions at a net negative cost.
- On average, electricity distribution losses in the APEC region can be reduced by 20 percent in 2030.
- As a result of this reduced energy consumption, annual CO_2 emissions would be reduced by 17 Mt in 2030. Overall, between 2016 and 2030, more than 126 Mt of CO_2 emissions would be avoided.
- The net present value of the financial benefits of the programs that would achieve the above savings is estimated at about 17.5 billion USD.

1. Background

Transmission and distribution (T&D) losses in electricity networks in Asia-Pacific Economic Cooperation (APEC) member economies range between 4% and 17.4% of final energy consumption (IEA, 2012c). Because approximately one-fourth of T&D losses take place in distribution transformers, there is significant potential to save energy and reduce costs and carbon emissions through policy intervention to increase distribution transformer efficiency. For this reason, APEC created a project on efficient distribution transformers, in collaboration with the Chinese National Institute of Standards and the International Copper Association. The goal of the project is to create awareness among policy makers from the APEC economies of the cost-effective potential to increase distribution transformer efficiency, by introducing or raising mandatory minimum efficiency performance standards (MEPS) or labeling programs for distribution transformers in individual APEC economies.

APEC economies encompass a wide range of economic development and experience with energy-efficiency standards and labeling (EES&L) programs. As a result, there is considerable potential to save energy in APEC economies through learning and implementing best practices to reduce T&D losses. Given the variability of the economy situations in the region, it is important to assess economy by economy the current status of energy efficiency programs and the cost-effective potential given the local market and economic conditions. To this end, we leverage the extensive technical research that has been performed to support the U.S. standard programs (also known as rulemakings) as a basis to estimate the energy efficiency potential in the APEC economies.

In the report, we quantitatively analyze the national benefits of cost-effective improvements in distribution transformer energy efficiency in APEC economies in terms of electricity savings, emissions mitigation, and net present value of programs. The analysis uses a bottom-up, engineering-based approach, to develop economy-specific cost curves and determine efficiency levels of cost-effectiveness for distribution transformers. We use the Bottom-Up Energy Analysis System (BUENAS), developed at Lawrence Berkeley National Laboratory (LBNL), to estimate the national cost-effective potentials of distribution transformer efficiency that will save maximum energy while not penalizing consumers (in this case, utilities) financially.

After defining the scope of study, we describe the methodology to estimate the cost-effective potential in the APEC region and finally present economy profiles, providing EES&L status, input data and quantitative analysis of potential savings for every economy.

Complementary activities have been carried out in parallel to LBNL's study by the firm Econoler, which analyzed enablers for and barriers to introducing or raising MEPS for distribution transformers in individual APEC member economies; reviewed the experiences, successes and failures of current EES&L programs, identified the best practices across the APEC member economies and provided frameworks for developing national roadmaps for introducing or raising MEPS (Econoler, 2013). A further report by ZBSTRI covers the People's Republic of China. Therefore, the reports of Econoler, ZBSTRI and the present report should be read together for a more complete picture of APEC distribution transformers efficiency.

Finally, the present report was prepared in close coordination with existing activities of the Super-efficient Equipment and Appliance Deployment (SEAD) initiative on distribution transformer energy efficiency and test procedure harmonization, for which the Collaborative Labeling Appliances and Standards Program (CLASP) is the operating agent.

2. Potential for Distribution Transformers Energy Efficiency in APEC Economies

This section presents the scope definition of the study, the methodology that was developed to analyze the cost effective potential for distribution transformers in the APEC region. Finally, we provide economy profiles that summarize our assumptions and findings for each APEC economy.

2.1. Scope definition

This study focuses on distribution transformer efficiency. A transformer is a device made up of two or more coils of insulated wire that transfers alternating current by electromagnetic induction from one coil to another to change the original voltage or current value. In this study, we cover distribution transformers that have an input voltage of 34.5 kilovolts or less, an output voltage of 600 volts or less, and are rated for operation at a frequency of 50 or 60 Hertz, depending on the economy's network.

We use DOE's definition in order to characterize the market of distribution transformers, based on insulation type (dry or liquid), number of phases (one-phase vs three-phase) and capacity (ranging from 10 kVA to 2500 kVA) (USDOE, 2013a). There exist two types of distribution transformers: liquid-type and dry-type distribution transformers, referring to the type of insulation:

-Liquid-immersed transformers typically use oil as both a coolant (removing heat from the core and coil assembly) and a dielectric medium (preventing electrical arcing across the windings). Liquid-immersed transformers are typically used outdoors because of concerns over oil spills or fire if the oil temperature reaches the flash-point level. In recent decades, new insulating liquid insulators (e.g., silicone fluid) have been developed which have a higher flash-point temperature than mineral oil, and transformers with these liquids can be used for indoor applications. However, environmental concerns along with high initial costs for these less-flammable, liquid-immersed transformers, relative to the cost of dry-type units, prevents widespread market adoption.

-Dry-type transformers are air-cooled, fire-resistant devices that do not use oil or other liquid insulating/cooling media. Because air is the basic medium used for insulating and cooling and it is inferior to oil in these functions, dry-type transformers are larger than liquid-immersed units for the same voltage and/or kVA capacity. As a result, when operating at the same flux and current densities, the core and coil assembly is larger and hence incurs higher losses. Due to the physics of their construction (including the ability of these units to transfer heat), dry-type units have higher losses than liquid-immersed units. However, dry-type transformers are an important part of the transformer market because they can offer safety, environmental, and application advantages.

Because dry-type distribution transformers are generally owned by commercial and industrial establishments, their application varies greatly, and their energy use can be difficult to characterize. Although some recent energy-efficiency regulations and voluntary programs cover dry-type distribution transformers (E3, 2011; KEMCO, 2012; USDOE, 2013a), there are few or no data characterizing this market. Studies carried out in support of the new regulations note the lack of data for dry-type distribution transformers. Because of the lack of data on dry-type transformers, this study focuses on liquid-type distribution transformers which are primarily owned by utility companies, and for which there are readily available, robust data.

2.2. Methodology

2.2.1 Data Collection

LBNL compiled the data for the quantitative analysis of distribution transformer energy-efficiency potential from the following sources:

- Technical documentation supporting existing standards and labeling programs (E3, 2011; USDOE, 2007b, 2013b)
- Existing reports, including (Choi, 2012a; McNeil et al., 2011a; McNeil et al., 2011b)
- Current activities of the Super-efficient Equipment and Appliance Deployment (SEAD) initiative (SEAD, 2013a, b)
- Publicly available databases: (CLASP, 2011; IEA, 2012b, c)

In addition to reviewing publicly available data sources, we sent economy-specific data requests to each of the APEC economy representatives to complete/confirm the data available from the resources listed above. When data were not available, LBNL used economy proxies to provide savings estimates for every member economy as explained in the engineering and cost-benefit analysis sub-sections below.

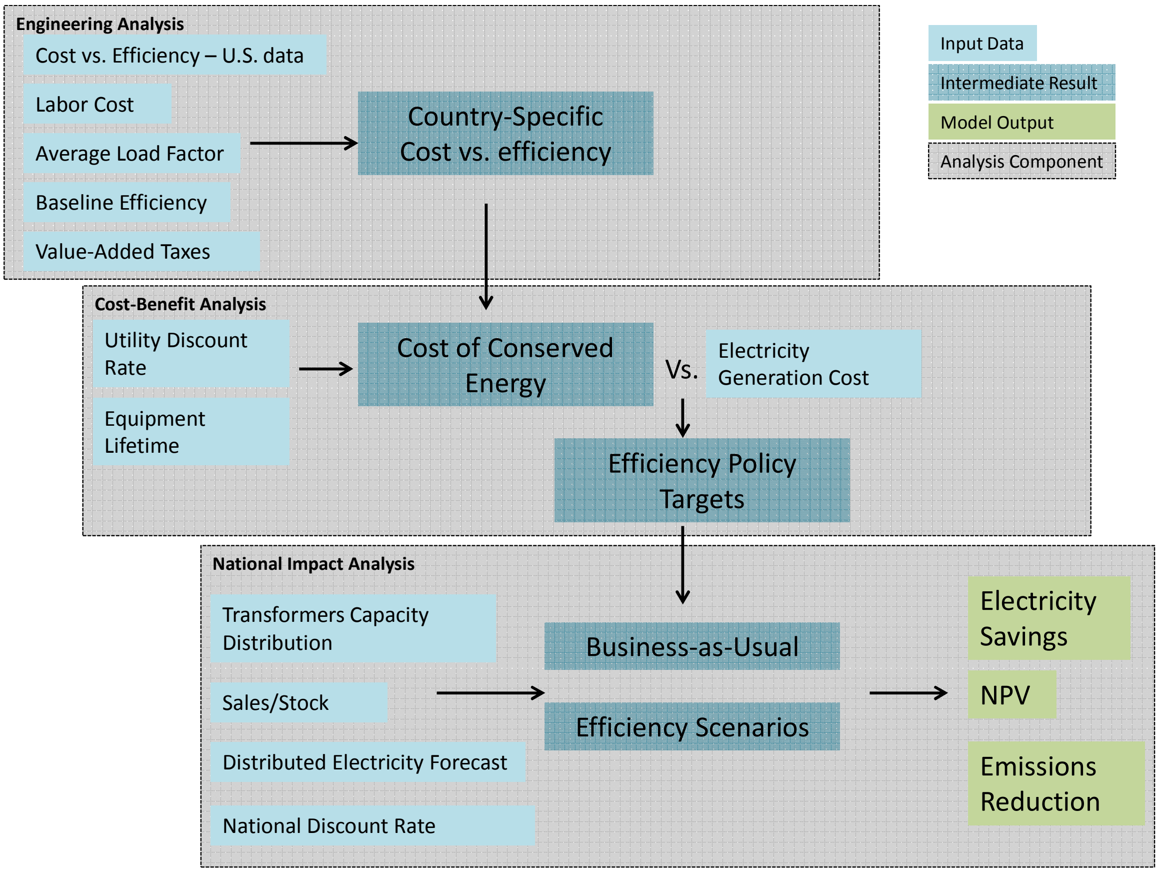
The following data were required for our analysis:

- Baseline efficiency by capacity
- Baseline load losses (LLs) and no-load losses (NLLs)
- Baseline cost by capacity (manufacturer selling price [MSP] and retail price)
- Sales tax
- Root mean square (RMS) or average load factor
- Labor cost
- Cost of electricity generation
- Discount rate (consumer and national)
- Lifetime
- Unit sales
- Units in the stock
- Installed capacity
- Capacity distribution
- Emissions factors

2.2.2 Quantitative Analysis

The flow chart in Figure 1 summarizes the components of our analysis.

Figure 1 – Quantitative Analysis – Methodology Flowchart



The following methodology section reflects the organization of the flowchart above and describes the sequential components of the quantitative analysis: engineering analysis, cost-benefit analysis and finally the national impact analysis.

Engineering Analysis

The engineering analysis establishes the relationship between the Manufacturer Selling Price and distribution transformer efficiency. This relationship is the basis for cost/benefit calculations for both individual consumers and the nation as a whole. This section describes the "reverse engineering" analysis we performed using the data set[1] that supported the U.S. rulemaking for distribution transformers in 2007 (USDOE, 2007b). We analyze the following four design lines (DLs) that the U.S. DOE chose as representative of the liquid-immersed distribution transformer market:

-DL 1: 50kVA, single phase, rectangular tank
-DL 2: 25kVA, single phase, round tank
-DL 4: 150kVA, three phase
-DL 5: 1,500kVA, three phase

A fifth design line identified by U.S. DOE, DL3 (Liquid immersed, 500kVA, single phase) transformers, was not analyzed here because these transformers represent a small portion of the market (less than 1% in the U.S).

Extension of the U.S. data set to other APEC member economies depends on two facts: transformers perform a basic engineering function that does not vary significantly among economies, and transformer costs are driven strongly by basic materials costs. Therefore, we characterize the dependency of transformer efficiency on materials expenditures and then adjust labor and other costs according to economy-specific parameters.

Determining price-efficiency dependence

The objective of our analysis is to determine the increase in price needed to decrease NLLs or to reduce LLs by one watt. NLLs are caused by stray currents in the steel core of the transformer, and LLs arise from Joule losses in the coils surrounding the core. Reduction of NLLs is generally achieved by increasing the amount and grade of core steel, and LLs are reduced by increasing the amount of copper in the windings. This is why incremental costs to increase efficiency are primarily driven by materials costs rather than labor costs[2] as noted above. The price vs. efficiency regression equation is:

$$MSP(\eta) = b_0 + b_{NLL}m_{NLL} + b_{LL}m_{LL} \qquad \text{Eq. 1}$$

Where:
b_{NLL} = unit price of material added to decrease NLLs (primarily core steel)
b_{LL} = unit price of material added to decrease LLs (primarily copper).
m_{LL} and m_{NLL} are functions of LL and NLL and are strongly correlated with materials costs. Losses tend to decrease with increasing material, so one would expect an inverse relationship. In fact, the following transformation yields the highest correlation:

$$m_{NLL} = \frac{1}{\sqrt{NLL}} - \frac{1}{\sqrt{NLL_0}}, \qquad m_{LL} = \frac{1}{\sqrt{LL^{50\%}}} - \frac{1}{\sqrt{LL_0^{50\%}}} \qquad \text{Eq. 2}$$

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[1] The data set was produced by Optimal Program Services, Inc. under a contract with U.S. DOE. This data set was chosen instead of the more recent data set because of the high baseline assumed in the more recent analysis. This high baseline resulted from the U.S. standard, which came into effect in 2010 and is likely significantly higher than the baseline efficiency in other APEC member countries

[2] *NLL* and *LL* are highly correlated, presumably because of the algorithm, which removes some physical combinations that are not economically sensible.

The variables m_{NLL} and m_{LL} are defined relative to the baseline losses, represented as NLL_0 and $LL_0^{50\%}$, which are taken simply as the highest loss values in the data set. In this way, we expect m to drive incremental price increases and incremental materials costs in a relationship that should be more directly proportional than absolute price and efficiency.

Linear regression using these variables yields very high values of R^2 and statistically significant determinations of b_1 and b_2. For this reason, these are considered to be suitable regression variables. The ability of these two variables to explain the price of a transformer model was found to be very strong within a configuration category, usually determined by core type or steel grade. Therefore, data were combined only within a category for regression. The result was a distinct set of parameters determined for each category and each design line.

In addition to the amounts of core steel and copper wire used to construct a transformer, a second critical determinant of cost and efficiency is the grade of core steel, which is the material used for the high- and low-voltage conductor, and the core type (grain-oriented or amorphous). For each of the four design lines considered, there are between seven and 10 main design option combinations (C01 to C10). Because the choice of design option combinations affects the relationship between efficiency and price, a separate regression was performed for each design option combination. Table 1 shows the results of the regressions.

ear regression between transformer design option price and losses

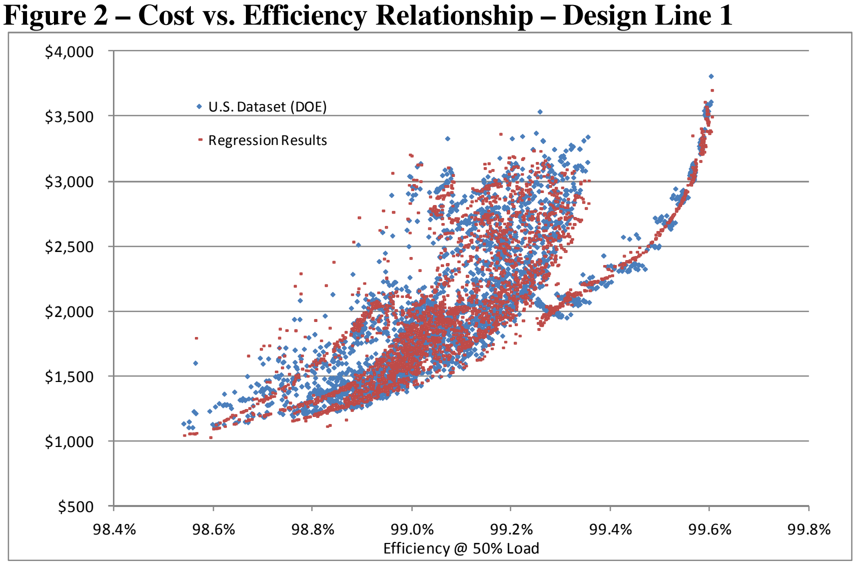
C01	C02	C03	C04	C05	C06	C07	C08	C09	C10
841	568	983	749	973	810	795	1,005		
15,412	31,801	11,495	17,909	21,032	21,856	23,161	11,453		
18,494	32,083	17,326	23,770	28,473	28,449	28,984	30,869		
1	1	1	1	1	1	1	1		
38	92	52	81	91	118	94	64		
446	460	475	632	679	823	690	854	804	1,285
9,569	11,979	8,837	11,039	7,519	4,835	7,470	5,363	7,478	1,802
8,669	10,894	9,407	12,105	10,732	10,470	11,681	11,182	12,635	12,033
1	1	1	1	1	1	1	1	1	1
29	49	30	38	53	132	71	128	52	29
2,141	2,051	1,441	1,747	1,998	2,000	1,813			
68,803	69,455	121,472	106,429	100,387	106,332	62,848			
52,095	62,247	105,717	102,511	105,073	102,234	123,554			
1	1	1	1	1	1	1			
91	132	204	241	267	264	172			
7,729	7,024	9,378	7,798	10,137	13,509				
808,890	2,009,593	1,244,010	1,373,477	1,098,113	850,080				
1,089,794	2,986,556	2,475,133	2,547,750	2,149,799	1,778,777				
1	1	1	1	1	1				
1,207	3,174	4,241	4,374	5,290	4,986				

Table 1 shows the expected relation between cost and transformer capacity. The goodness of fit is indicated by R^2 values, which are generally very high, especially for Design Lines 1, 2, and 4. Only one category – design configuration C07 of Design Line 5 – was eliminated because of a poor fit to the model.

In developing the aggregate cost curve and calculating CCE, we used the minimum price of all design configurations. This analysis did not consider potential supply chain constraints, such as availability of high-grade or amorphous steel, for any of the design configurations.

Figure 2 is a scatter plot showing the results of the cost vs. efficiency regression analysis for Design Line 1. The regression analysis reproduces the "cloud" of design options on the plot. This gives confidence that the regression, which is admittedly simple, adequately reproduces at least the majority of the performance and cost outputs of the more complicated algorithm. More importantly for the current analysis, the regression analysis results suggest that materials costs are the main driver of the incremental cost of improving transformer efficiency. Labor and other overhead costs are either small or relatively constant with respect to efficiency. This is what one might expect because higher-quality components do not generally require more time to assemble.[3] Thus, incremental costs of efficiency are not likely to vary significantly among economies because the component materials are commodities that are generally traded in international markets, which tends to equalize their prices.

Figure 2 – Cost vs. Efficiency Relationship – Design Line 1



[3] An exception to this is the addition of coils, which may increase winding time.

Cost Optimization of High-Efficiency Designs

A variety of configuration combinations can be used to build a transformer, and these will have different overall efficiencies given the average loading. Therefore, the optimal price for a transformer of a given efficiency varies with load. Our goal is to find the least-cost design to meet efficiency level η given an average system load β. The method we use follows from the generic loss formula:

$$W_{TOT} = NLL + LL \quad \text{(Eq. 3)}$$

Where:
W_{TOT} = total losses
LL = load losses at the operating load

For a given transformer design line, W_{TOT} determines transformer efficiency η according to:

$$\eta = \frac{\beta S_{DL} cos\theta}{\beta S_{DL} cos\theta + NLL + LL}$$

Where:
S_N = rated capacity of the design line
$cos\theta$ = power factor, which we assume equal to 1 when calculating efficiency levels in the engineering analysis, following transformer efficiency specifications, such as the TP 1-2002 (NEMA, 2002)

In addition to these relationships, the price is given by combining Eq. 1 and Eq. 2:

$$MSP(NLL, LL_{50\%}) = b_0 + \frac{b_{NLL}}{\sqrt{NLL}} + \frac{b_{LL}}{\sqrt{LL_{50\%}}} \quad \text{Eq. 4}$$

Using the relationship between LL and $LL_{50\%}$, the price can be reduced to a single-variable equation in terms of LL for a given value of W_{TOT}:

$$MSP(LL, W_{TOT}) = b_0 + \frac{b_{NLL}}{\sqrt{W_{TOT} - \frac{LL}{4\beta^2}}} + \frac{b_{LL}}{\sqrt{\frac{LL}{4\beta^2}}}$$

The minimum price for a given efficiency is therefore found by setting the partial derivative of *MSP* with respect to *LL* to zero:

$$0 = \frac{\partial MSP}{\partial LL} = b_{NLL} \times \left(-\frac{1}{2}\right) \times \left(W_{TOT} - \frac{LL}{4\beta^2}\right)^{-\frac{3}{2}} \times \left(\frac{-1}{4\beta^2}\right) + b_{LL} \times \left(-\frac{1}{2}\right) \times \left(\frac{LL}{4\beta^2}\right)^{-\frac{3}{2}} \times \left(\frac{1}{4\beta^2}\right)$$

Dividing by constants and rearranging yields:

$$b_{NLL} \times \left(W_{TOT} - \frac{LL}{4\beta^2}\right)^{-\frac{3}{2}} = b_{LL} \times \left(\frac{LL}{4\beta^2}\right)^{-\frac{3}{2}}$$

Solving for *LL* yields:

$$LL = \frac{4\beta^2 W_{TOT}}{\left(\frac{b_{LL}}{b_{NLL}}\right)^{\frac{2}{3}} + 1} \quad \text{Eq. 5}$$

Test Load Adjustment

Although the average load on transformers, and therefore the optimal design characteristics, vary from economy to economy, efficiency is typically defined in terms of a test load, which is commonly 50%. Therefore, our methodology employed an algorithm for cost optimization at actual load compared to a standardized baseline transformer. The algorithm assumes that the baseline transformer is constructed in the least expensive way to meet the minimum efficiency requirement when tested at 50% load. In addition, the algorithm assumes that, to exceed the performance of the baseline, manufacturers will design the transformer in the most cost-effective way for the actual operating conditions, which are assumed to be the national average load. The algorithm entails the following:

- Consider the baseline efficiency $\eta^{50\%}$ measured at 50% load and calculate the equivalent total losses $W^{50\%}_{TOT}$.
- Find the design that achieves this efficiency at least cost using Eq. 3 with $\beta = 50\%$.
- Evaluate the operating efficiency of this unit at the operating load η^{β} using Eq. 5 with β equal to the average load for that economy.
- Compare least-cost options at the operating load to this efficiency baseline.

Calculation of equipment cost according to economy-specific parameters

Equipment cost (EC) is calculated based on MSP, distributor's markups, and value-added taxes (VAT). MSP is adjusted to local market conditions by accounting for the share of labor costs in the MSP and scaling according to labor costs in the manufacturing industry for each economy[15]. When labor costs are not available, we use ratios between gross domestic product per capita (GDP/cap) to scale the cost of labor from one economy to another. We then apply VAT (TMF, 2013) and a distributors' markup (USDOE, 2007b). For this analysis, we did not include installation or shipping costs because we assume that these stay constant across efficiency levels. In sum, equipment cost for any APEC economy e is defined as:

$$EC_e = \left(MSP_{mat} + MSP_{labor} \times \frac{LabCost_e}{LabCost_{US}}\right) \times Markup \times VAT$$

Where:
MSP_{mat} = materials component of MSP
MSP_{labor} = labor cost component of MSP
$LabCost_e$ = labor cost in economy evaluated
$LabCost_e$ = labor cost in U.S
$Markup$ = distributors' markup
VAT = value-added taxes in economy evaluated

Cost-Benefit Analysis

Although there are various metrics for measuring the economic implications of a given investment, this study uses CCE because this metric allows for easy identification of the largest energy savings that still provide a net savings to consumers. CCE represents how much an end user must pay in terms of annualized incremental equipment investment for each unit of energy saved by higher-efficiency equipment. To calculate CCE, we first define a baseline and target efficiency levels.

Baseline Efficiency Definition

Baseline efficiency is a key determinant in the cost-benefit analysis. For economies with mandatory S&L programs, the baseline efficiency is defined by these programs. However, if a economy has never regulated distribution transformers, baseline efficiency information is difficult to obtain. To determine the "floor" of distribution transformer energy efficiency in these economies, we rely on estimates of baselines in other countries from *before* those countries implemented their first distribution transformer efficiency program. This information is available for the U.S. and China. Table 2 summarizes the baseline estimates for both countries.

Table 2 – Estimated baseline efficiency before first MEPS in China and U.S. (at 50% load[4])

	1-phase		3-phase	
	50 kVA	25kVA	150kVA	1,500kVA
China	98.5%	98.2%	98.5%	98.7%
US	98.6%	98.2%	98.4%	98.9%

Because the pre-program baseline efficiencies for the two countries are very similar, our calculations, we define the U.S. baseline from before the economy's first MEPS as the technical floor, for reasons of simplicity and consistency.

Efficiency Levels

Even though the results of the engineering analysis are a continuous spectrum of efficiency levels η (as shown Figure 2), we define a few efficiency levels (EL0 to EL4) that we evaluate specifically to facilitate comparison of results across economies. These efficiency levels are defined as shown in Table 3.

Table 3 – Efficiency level definitions by design line

Efficiency Level		DL1	DL2	DL4	DL5
EL0	Baseline	98.6%	98.2%	98.4%	98.9%
EL1	Intermediate level	98.82%	98.48%	98.74%	99.20%
EL2	U.S MEPS 2016	99.10%	98.95%	99.16%	99.48%
EL3	Intermediate level	99.30%	99.21%	99.38%	99.59%
EL4	Max tech 2013 rulemaking	99.50%	99.47%	99.60%	99.69%

We adjust EL0 to take into account current policies in every economy. The technical floor is used for economies that do not have distribution transformer efficiency regulations.

Cost of Conserved Energy

CCE divides annual incremental equipment cost by the energy saved in a year, which gives the investment needed per unit of energy savings (USD/kWh) as follows:

$$CCE = \frac{\Delta EC \times q}{\Delta UEC}$$

Where:

- ΔEC = incremental equipment cost between high-efficiency equipment and baseline technology (output from engineering analysis)

[4] Although there are other ways to define distribution transformer efficiency requirement (i.e maximum LL and NLL and defining maximum efficiency), we recommend using the 50% load factor requirements in defining a MEPS or other efficiency program. See: Sampat, M., 2011. Transformers : Which MEPS?, 11th International Conference on Transformer, New Delhi, India.

- ΔUEC = resulting annual energy savings. UEC is calculated from the *LL*, *NLL*, and the load β in field conditions (multiplied by the number of hours in a year):

$$UEC = (NLL + LL \times \beta^2) \times 8760$$

- q = capital recovery factor, defined as:

$$q = \frac{d}{(1 - (1 + d)^{-L})}$$

Where:
- L = product lifetime, i.e., the average number of years that a product is used before failure and retirement. We use a constant lifetime of 32 years across all economies (USDOE, 2013a)
- d = discount rate at which utility companies value their investments. Unless we have economy-specific data, we use IEA's projected cost of energy generation discount rates of 5% and 10% in our analysis, for developed economies and economies in transition, respectively (IEA, 2010).

Using these parameters, we calculate CCE for each efficiency level for each design line. The results of this calculation, given in each economy section of this report, are the basis for constructing the efficiency scenario.

We then compare the CCE to electricity prices. Because liquid-immersed transformers are owned primarily by utility companies, the price of electricity represents the operating cost to the utility of meeting the next increment of load at any given time. To determine the cost of generation in every economy, we use the fuel mix in 2015 (APERC, 2012) combined with IEA's projected cost of electricity generation (IEA, 2010) to calculate a weighted average cost of generation. We assume that electricity rates remain constant at these levels, an assumption that is likely conservative.

National Impact Analysis

The national impact analysis estimates potential distribution losses avoided and assesses the net present value of consumer benefits at the national scale.

Stock and Sales Analysis

The model starts with an estimate of the overall growth in distribution transformer capacity and then estimates sales for particular design lines using estimates of the relative market share for various design and size categories. The availability of data varies greatly among the APEC economies, so the methodology we used to develop the aggregate stock and sales model varies according to the following:

- Sales data are available: If sales data are available, they are used as direct input into the model and, based on the APERC Energy Demand and Supply Outlook (APERC, 2012), we estimate the national growth in transformer capacity to forecast sales to 2030. This method was used for Australia, Canada, Chile, Japan, Malaysia, New Zealand, and the U.S.

  The National Installed Capacity (NIC) is then given by:

$$NIC(y) = S_{ave} \times Stock(y) = S_{ave} \times \sum_{age} Sales(y - age) \times Surv(age)$$

Where:

- S_{ave}= average capacity (kVA)
- *Stock (y)* = number of units in operation in year *y*
- *Sales (y)* = unit sales (shipments) in year *y*
- *UEC(y)* = unit energy consumption of units sold in year *y*
- *Surv(age)* = probability of surviving to *age* years (using a normal distribution)

- Sales data are not available. If no sales data are available, we estimate the installed capacity of distribution transformers in the stock based on national generation data from APERC and assuming a), according to the following:

$$\mathrm{NIC(y)} = \frac{\mathrm{TDE(y)}}{\beta \times cos\theta \ \times 8760}$$

Where:

- *NIC(y)* = national installed capacity (MVA) in year *y*
- *TDE (y)* = total distributed electricity (MWh) in year *y*, which is taken from the IEA energy database (IEA, 2012c) as the sum of the sales in all sectors and the T&D losses
- β = average load factor (in absence of data we use 50% as defined in reference test procedures)
- $cos\theta$ = average power factor (assumed to be equal to 0.9 in the absence of data)

We then project the stock according to the overall growth in transformer capacity based on APERC's national generation forecast. Finally, we calculate the sales in every year from increases in stock and replacements:

$$\mathrm{Sales(y)=Stock(y)\text{-}Stock(y\text{-}1)+\sum\nolimits_{age} Ret(age)\times Sales(y\text{-}age)}$$

Where:

- *Sales (y)* = unit sales (shipments) in year *y*
- *Stock (y)* = number of units in operation in year *y*
- *Ret(age)* = probability that a unit will retire (and be replaced) at a certain age

Once we have constructed the aggregate shipments forecast, we separate the market into liquid- and dry-type distribution transformers and then apply the market shares for each design line DL1 through DL5 (excluding DL3).

Average Load factor Calculation

The equation used to determine the stock in economies for which there are no sales data can also be used to calculate the average load factor when the average load factor is not available (for economies for which we have sales data), according to[5]:

[5] Load system diversity factor is not taken into account here because of a lack of data for countries for which we have to apply this equation

$$\beta = \frac{\text{TDE(y)}}{\text{NIC(y)} \times \cos\theta \times 8670}$$

Capacity Adjustment: Size Scaling of Losses and Costs

The engineering analysis gives the relation between cost and efficiency for the four main representative product classes. To adapt these cost curves to different markets, we need to adjust for capacity differences between the representative product classes and the actual average capacity in each market. We use a scaling relationship from (USDOE, 2013a) to project the economic results from a given transformer design line to similar transformers of different sizes. This relationship is a key element in adjusting losses and costs from a representative transformer in the engineering analysis to the range of transformer sizes that is incorporated in the national impact analysis and that is subject to potential standards. We use the *0.75 scaling rule* to scale the cost and efficiency results for the modeled kVA values to the full capacity range for each type. The 0.75 scaling rule is discussed in greater detail in Chapter 5 of (USDOE, 2013a).

The following equation describes the scaling of losses and cost:

$$\boldsymbol{EC_{Avg} = EC_{DL} \times \left(\frac{S_{Avg}}{S_{DL}}\right)^{3/4}}$$

$$\boldsymbol{UEC_{Avg} = UEC_{DL} \times \left(\frac{S_{Avg}}{S_{DL}}\right)^{3/4}}$$

Where:

- UEC_{DL} = loss for the design line unit, from the engineering analysis
- UEC_{Avg} = sales-weighted average loss of transformers represented by a particular design line
- EC_{DL} = cost for the design line unit, from the engineering analysis
- EC_{Avg} = sales-weighted average cost of transformers represented by a particular design line
- S_{DL} = capacity of the representative design line unit, from the engineering analysis
- S_{Avg} = sales-weighted average capacity of transformers represented by a particular design line

Energy and emissions savings model

As laid out in (McNeil et al., 2013), we calculate national energy savings (NES) in each year by comparing the national electricity losses from distribution transformers, *E,* from the Business-As-Usual (BAU) case to the Policy case, as follows:

$$NES(y) = E_{BAU}(y) - E_{Policy}(y)$$

BUENAS calculates final energy demand according to the UEC of equipment sold in previous years:

$$E \quad = \sum_{age} Sales(y - age) \times UEC \quad (y - age) \times Surv(age)$$

Where:

- *Sales (y)* = unit sales (shipments) in year *y*
- *UEC(y)* = unit energy consumption of units sold in year *y*
- *Surv(age)* = probability of surviving to *age* years

We calculate total reduction in CO_2, SO_2, and NO_x emissions in million tons (Mt) or kilotons (kt) using a typical electricity generation fuel mix and fuel combustion factor.

CO_2, SO_2, and NOx emissions savings are calculated from energy savings by applying a specific emissions factor to site energy savings, as follows:

$$\Delta CO_2(y) = \Delta E(y) \text{ x } f_{CO2}$$
$$\Delta SO_2(y) = \Delta E(y) \text{ x } f_{SOx}$$
$$\Delta NO_x(y) = \Delta E(y) \text{ x } f_{NOx}$$

Where:

- $\Delta CO_2(y)$ = CO_2 emissions mitigation in year *y* (Mt)
- $\Delta SO_2(y)$ = SO_2 emissions mitigation in year *y* (kt)
- $\Delta NO_x(y)$ = NO_x emissions mitigation in year *y* (kt)
- $\Delta E(y)$ = final energy savings in year *y*
- f_{CO2} = carbon conversion factor (kilograms per kilowatt hour [kg/kWh])
- f_{SO2} = sulfur dioxide conversion factor (g/kWh)
- f_{NOx} = nitrogen oxide conversion factor (g/kWh)

Financial impact: Net Present Value

Net present value is calculated according to total incremental costs of equipment over a given forecast period, electricity bill dollars saved, and the national discount rate.

National financial impacts in year *y* are the sum of equipment costs (1) and operating costs (2).

- (1) National Equipment Cost (NEC) is equal to the Equipment Cost times the total number of sales, given by:

  $$NEC(y)=EC(y) \text{ x } Sales\ (y)$$

- (2) National Operating Cost (NOC) is the total (site) energy consumption (*E*) times the energy price (*P*), given by:

  $$NOC(y)=E(y) \text{ x } P\ (y)$$

The net savings in each year result from the sum in first costs and operating costs in the efficiency scenario versus the BAU scenario, ΔNEC and ΔNOC.

We define the net present value (NPV) of a policy as the sum over a given period of time of the net national savings in each year, multiplied by the appropriate national policy discount factor:

$$NPV = \sum_{y=y_0} \frac{\Delta NOC(\mathrm{y}) + \Delta NEC(y)}{(1+DR_N)^{(y-y_0)}}$$

Where:

- y_0 = current year
- DR_N = national discount rate

2.3. Economy Profiles

2.3.1 Australia

In the current analysis, we estimate that the impact of introducing more stringent or additional S&L programs for distribution transformers in Australia would be:

- 2.8 TWh annual electricity savings from MEPS by 2030
- 29% reduction in national distribution losses by 2030
- 2.3 Mt CO_2 emission avoided by 2030 from MEPS
- 2 billion USD net financial benefits from MEPS
- 1.3 TWh annual electricity savings from endorsement label by 2030
- 1.1 Mt CO_2 emissions avoided by 2030 from endorsement label
- 920 million USD net financial benefits from endorsement label

Test Procedure, S&L Status

Since 2004, the Australian and New Zealand governments have agreed to regulate the following transformers to comply with MEPS: single- and three-phase, dry and oil-immersed, with power ratings between 10 kVA and 2,500 kVA and which are designed for 11-kV and 22-kV networks. The current MEPS for transformer efficiency is defined in AS 2374.1.2-2003 for a rated load of 50% (AS/NZS). AS 2374.1.2-2003 also identifies voluntary higher energy performance levels (HEPS) as aspirational targets. The MEPS also defines devices that are exempt from the regulation, such as instrument transformers, auto transformers, traction transformers mounted on rolling stock, etc.

The test methods for the minimum energy performance standards are designated in the AS/NZS 2374.1.2-2003. Although there is no designated test procedure developed specifically for the efficiency requirements, the test method is based on the power loss measurement techniques specified in the Australian/New Zealand power transformer Standard AS/NZS 60076.1, which is adopted from the IEC Standard IEC 60076 – Power Transformers, Part 1: General. The test procedure includes variations applicable to Australia, such as commonly used power ratings and preferred methods of cooling, connections in general use, and details of connection designation.

The equipment energy efficiency program (E3) is currently in the process of reviewing the MEPS for distribution transformers, considering a possible increase of the MEPS levels to approximately the same as current HEPS levels as well as possible expansion of the scope to include 33-kV networks (wind farms) and larger transformers up to 3,150 kVA (E3, 2011).

Table 4 and Table 5 present the requirements for liquid-type distribution transformers.

Table 4 – Requirements and Proposed Revisions for Liquid-Type Transformers for Australia

Liquid-type 50 Hz	**kVA**	**Efficiency at 50% Loading**	
		2004 MEPS	**MEPS2 (proposed)**
Single phase (and SWER[6])	10	98.30	98.42
	16	98.52	98.64
	25	98.70	98.80
	50	98.90	99.00
Three phase	25	98.28	98.50
	63	98.62	98.82
	100	98.76	99.00
	200	98.94	99.11
	315	99.04	99.19
	500	99.13	99.26
	750	99.21	99.32
	1,000	99.27	99.37
	1,500	99.35	99.40
	2,000	99.39	99.40
	2,500	99.40	99.40
	3,150	n/a	99.40

NOTE: For intermediate power ratings, the power efficiency level shall be calculated by linear interpolation.

[6] Single-wire earth return (SWER) or single-wire ground return is a single-wire transmission line for supplying single-phase electrical power from an electrical grid to remote areas at low cost. Its distinguishing feature is that the earth (or sometimes a body of water) is used as the return path for the current, to avoid the need for a second wire (or neutral wire) to act as a return path.

Table 5 – HEPS and Proposed Revisions for Liquid-Type Transformers

Liquid-type	kVA	Efficiency at 50% Loading	
50 Hz		2004 HEPS	HEPS2 (proposed)
Single phase (and SWER)	10	98.42	98.74
	16	98.64	98.83
	25	98.80	98.91
	50	99.00	99.10
Three phase	25	98.50	98.80
	63	98.82	98.94
	100	99.00	99.10
	200	99.11	99.26
	315	99.19	99.34
	500	99.26	99.42
	750	99.32	99.45
	1,000	99.37	99.46
	1,500	99.44	99.48
	2,000	99.49	99.49
	2,500	99.50	99.49
	3,150	-	99.49

Data inputs

Total distributed electricity is calculated from IEA data as the sum of the sales in every sector of the economy plus the T&D losses (IEA, 2012c). We use the growth rate from the national electricity demand forecast to 2030 in the *APERC Energy Demand and Supply Outlook*, 5th Edition (APERC, 2012) to project total distributed electricity to 2030. We collected stock data as well as market data including sales and market share by capacity from the E3 study (E3, 2011). Based on the data available, we calculate an average load factor of 27%.

Economic data such as value-added taxes (VAT) and labor costs were collected from publicly available sources (BLS, 2012; TMF, 2013). The E3 study (E3, 2011) estimates the cost of losses through distribution transformers to 11.4 cts/kWh.

The CO_2 and NO_x/SO_2 emission factors are taken from the IEA data set on CO_2 emissions from fuel combustion (IEA, 2012a) and calculated based on fuel mix and Intergovernmental Panel on Climate Change (IPCC) guidelines (IPCC, 1997).

Table 6 summarizes the input data developed for Australia.

Table 6 – Economy-Specific Inputs Summary for Australia in 2010

	Value		Source/Note
Total Distributed Electricity	230	TWh	(IEA, 2012c)
Distribution transformers Capacity	110,640	MVA	calculated
Stock	0.67	Millions	(E3, 2011)
Average Load Factor	27	%	calculated
Average Capacity	493	kVA	(E3, 2011)
Annual Sales	31,000	Units	(E3, 2011)
Consumer Discount Rate	8.8	%	(E3, 2011)
National Discount Rate	3	%	assumption
VAT	10	%	(TMF, 2013)
Cost of Electricity Generation	0.114	$/kWh	(E3, 2011)
CO_2 Emission Factor	0.841	kg/kWh	(IEA, 2012a)
SO_2 Emission Factor	1.247	g/kWh	(IPCC, 1997)
NO_x Emission Factor	0.847	g/kWh	(IPCC, 1997)
Labor Cost	46	USD/hour	(BLS, 2012)

Cost-Benefit Analysis

To determine the market baseline efficiency, we rely on a publicly available registry database from the E3 program (E3, 2013), which reports product characteristics (such as capacity and efficiency) for every model sold on the Australian market. We calculate the average baseline efficiency for each of the design lines. We find that the market efficiency is at EL1 or slightly above. Then, we calculate the cost of conserved energy for different levels of efficiency ranging from the calculated baseline efficiency to EL4. Finally, we compare the cost of conserved energy to the cost of electricity generation to determine the highest cost-effective efficiency targets. These targets produce the greatest energy savings while ensuring a net financial benefit to the consumer (in this case, the utility company).

We find that a MEPS harmonized with the 2016 U.S. MEPS would be cost effective for all design lines in the Australian context. DL1, DL4 and DL5 are found to be cost effective at the highest efficiency level EL4.

Table 7 presents the results for the four representative design lines we study:

Table 7 – Cost-Benefit Analysis for Representative Units in Australia

	Baseline	Target
	Representative Design Line 1, 1-phase 50kVA	
Efficiency Rating (%)	98.9%	99.5%
Losses (kWh/year)	1,445	591
Price (USD)	$ 1,723	$ 2,741
CCE (USD)		$ 0.075
	Representative Design Line 2, 1-phase 25kVA	
Efficiency Rating (%)	98.6%	99.0%
Losses (kWh/year)	971	748
Price (USD)	$ 987	$ 1,337
CCE (USD)		$ 0.099
	Representative Design Line 4, 3-phase 150kVA	
Efficiency Rating (%)	99.0%	99.6%
Losses (kWh/year)	4,324	1,541
Price (USD)	$ 5,117	$ 7,802
CCE (USD)		$ 0.061
	Representative Design Line 5, 3-phase 1500kVA	
Efficiency Rating (%)	99.4%	99.7%
Losses (kWh/year)	24,476	12,737
Price (USD)	$ 25,371	$ 45,451
CCE (USD)		$ 0.108

National Impact Analysis

As explained in the methodology section, the results from the cost-benefit analysis are scaled to represent the units found on the Australian market and then propagated into BUENAS to calculate national energy savings, avoided CO_2 emissions, and financial impacts in terms of net present value (NPV).

We use the model numbers collected from the E3 database (E3, 2013) as a proxy for number of sales, and we estimate market shares by product class, which we then map onto the four representative design lines. Table 8 summarizes the market shares and average market capacities used to scale the unit-level results to the national level. The table also includes the resulting scaled UEC and price inputs.

Table 8 – Design Lines (DL) Market Shares and Market Average UEC and Price for Australia

	DL1	DL2	DL4	DL5
DL Market Shares	3.0%	12.8%	61.1%	23.2%
Average Capacity (kVA)	50	19	243	1,472
Scaled Baseline UEC (kWh/year)	1,445	779	6,214	24,136
Scaled Baseline Price (USD)	1,723	793	7,354	25,019
Scaled Target UEC (kWh/year)	591	600	2,214	12,560
Scaled Target Price (USD)	2,741	1,073	11,212	44,821

We analyze two policy scenarios in this study:

1- A MEPS taking effect in 2016, set at the maximum cost-effective level for all representative design lines.
2- An endorsement label targeting the cost-effective levels for all representative design lines, which would drive a 10% increase in the sales market share every year starting in 2015, up to a maximum of 50% market share by 2020.

Table 9 presents the national impact analysis results for Australia in 2020 and 2030.

Table 9 – National Impacts Analysis Results for Australia

		Units[a]	Year	MEPS Scenario	Labeling Program Scenario
Annual Impacts	Energy Savings	GWh	2020	867.2	348.2
			2030	2,758.8	1,296.9
	CO_2 Emissions Savings	Mt	2020	0.7	0.3
			2030	2.3	1.1
	SO_2 Emissions Savings	kt	2020	1.1	0.4
			2030	3.4	1.6
	NOx Emissions Savings	kt	2020	0.7	0.3
			2030	2.3	1.1
Cumulative Impacts	Energy Savings	GWh	through 2020	2,578.2	947.1
			through 2030	21,509.5	9,570.4
	CO_2 Emissions Savings	Mt	through 2020	2.2	0.8
			through 2030	18.1	8.0
	SO_2 Emissions Savings	kt	2020	3.2	1.2
			2030	26.8	11.9
	NOx Emissions Savings	kt	2020	2.2	0.8
			2030	18.2	8.1
	Operating Cost Savings	Million USD		4,875.7	2,259.7
	Equipment Cost	Million USD		2,893.7	1,341.1
	NPV	Million USD		1,982.0	918.6

[a] kt – kilotons

These results show the significant savings achievable through an increase of the current MEPS levels further beyond the present HEPS to the maximum cost effective level or through a labeling program for higher efficiency transformers. In contrast to a MEPS, a labeling program does not make the sale of efficient models mandatory, so the impacts of an endorsement label presented in Table 9 must be considered indicative only.

In sum, the impacts of adopting a MEPS requiring the highest cost-effective efficiency level are:

- 867 GWh of electricity savings in 2020 and 2,759 GWh in 2030
- 21.5 TWh cumulative electricity savings between 2016 and 2030
- 0.7 Mt of annual CO_2 emissions reductions by 2020 and 2.3 Mt by 2030
- 18.1 Mt cumulative emissions reduction between 2016 and 2030
- 1,982 million USD estimated net present value of savings

2.3.2. Brunei Darussalam

In the current analysis, we estimate that the impact of introducing S&L programs for distribution transformers in Brunei Darussalam would be:

- 31 GWh annual electricity savings from MEPS by 2030
- 33% reduction in national distribution losses by 2030
- 0.02 Mt CO_2 emission avoided by 2030 from MEPS
- 47 million USD net financial benefits from MEPS
- 9.9 GWh annual electricity savings from endorsement label by 2030
- 0.01 Mt CO_2 emissions avoided by 2030 from endorsement label
- 22 million USD net financial benefits from endorsement label

Test Procedure, S&L Status

Our research on Brunei Darussalam did not find any test procedure, standards, or labeling programs in that economy.

Data inputs

Total distributed electricity is calculated from IEA data as the sum of the sales in every sector of the economy plus the T&D losses (IEA, 2012c). We use the growth rate from the national electricity demand forecast to 2030 in the *APERC Energy Demand and Supply Outlook*, 5th Edition (APERC, 2012) to project total distributed electricity to 2030.

Given the lack of data for Brunei Darussalam, some of the other data inputs necessary for the analysis were from neighboring countries such as Malaysia for the VAT, Philippines for the cost of labor (scaling GDP/cap), and Indonesia for cost of generation per fuel type (USAID, 2007). Fuel mix is taken for the year 2015 from (APERC, 2012) in order to calculate the weighted average price of electricity generation.

The CO_2 and NO_x/SO_2 emission factors are taken from the IEA dataset on CO_2 emissions from fuel combustion (IEA, 2012a) and calculated based on fuel mix and IPCC guidelines (IPCC, 1997).

Table 10 summarizes the input data developed for Brunei Darussalam.

Table 10 – Economy Specific Inputs Summary for Brunei Darussalam in 2010

	Value		**Source/Note**
Total Distributed Electricity	3.5	TWh	(IEA, 2012c)
Distribution transformers Capacity	880	MVA	calculated
Stock	0.012	Millions	calculated
Average Load Factor	50	%	assumed
Average Capacity	73	kVA	(USDOE, 2013a)
Annual Sales	400	Units	calculated
Consumer Discount Rate	10	%	(IEA, 2010)
National Discount Rate	3	%	assumed
VAT	6	%	Malaysia proxy
Lifetime	32	years	(USDOE, 2013a)
Cost of Electricity Generation	0.12	$/kWh	derived from (IEA, 2010)
CO_2 Emission Factor	0.798	kg/kWh	(IEA, 2012a)
SO_2 Emission Factor	0	kg/kWh	(IPCC, 1997)
NO_x Emission Factor	0.512	kg/kWh	(IPCC, 1997)
Labor Cost	34	$/hour	derived from GDP/cap

Cost-Benefit Analysis

Baseline efficiency is a key determinant in the cost-benefit analysis. In general, if a economy has not had a program on distribution transformers, this information is difficult to obtain. As explained in the methodology section, to determine the "floor" of energy efficiency that we define as EL0, we rely on estimates of baselines taken from other countries *before* they implemented their first distribution transformer program. Then, we calculate the cost of conserved energy for different levels of efficiency ranging from EL0 to EL4. Finally, we compare the cost of conserved energy to the cost of electricity generation to determine the highest cost-effective efficiency targets. These targets result in the greatest energy savings while ensuring a net financial benefit to the consumer (in this case, the utility company).

We find that a MEPS set at the maximum technical level (EL4) would be cost-effective in the Brunean context.

Table 11 presents the results for the four representative design lines we study:

Table 11 – Cost-Benefit Analysis for Representative Units in Brunei Darussalam

	Baseline	Target
	Representative Design Line 1, 1-phase 50kVA	
Efficiency Rating (%)	98.5%	99.5%
Losses (kWh/year)	3,241	1,139
Price (USD)	$ 898	$ 2,391
CCE (USD)		$ 0.075
	Representative Design Line 2, 1-phase 25kVA	
Efficiency Rating (%)	98.0%	99.5%
Losses (kWh/year)	2,225	911
Price (USD)	$ 493	$ 1,518
CCE (USD)		$ 0.082
	Representative Design Line 4, 3-phase 150kVA	
Efficiency Rating (%)	98.3%	99.6%
Losses (kWh/year)	11,292	4,722
Price (USD)	$ 2,035	$ 5,833
CCE (USD)		$ 0.061
	Representative Design Line 5, 3-phase 1500kVA	
Efficiency Rating (%)	98.9%	99.7%
Losses (kWh/year)	71,727	20,919
Price (USD)	$ 11,077	$ 40,736
CCE (USD)		$ 0.061

National Impact Analysis

As explained in the methodology section, the results from the cost-benefit analysis are scaled to represent the units found in the Bruneian market and then propagated into BUENAS to calculate national energy savings, avoided CO_2 emissions and financial impacts, in terms of net present value (NPV).

The following table summarizes the market shares, and average market capacities used to scale the unit level results to the national level taken from (USDOE, 2013a) along with the resulting scaled UEC and Price inputs.

Table 12 – Design Lines Market Shares and Market Average UEC and Price in Brunei Darussalam

	DL1	DL2	DL4	DL5
DL Market Shares	24.9%	68.3%	4.6%	2.2%
Average Capacity (kVA)	46	26	256	1,451
Scaled Baseline UEC (kWh/year)	3,053	2,281	16,837	69,961
Scaled Baseline Price (USD)	846	506	3,035	10,804
Scaled Target UEC (kWh/year)	1,073	611	4,036	20,404
Scaled Target Price (USD)	2,252	2,223	10,510	39,733

We analyze two policy scenarios in this study:

1- A MEPS taking effect in 2016, set at the maximum cost-effective level for all representative design lines.

2- An endorsement label targeting the cost-effective levels for all representative design lines, which would drive a 10% increase in the sales market share every year starting in 2015, up to a maximum of 50% market share by 2020.

Table 13 presents the national impact analysis results for Brunei Darussalam in 2020 and 2030.

Table 13 – National Impacts Analysis Results for Brunei Darussalam

		Units	Year	MEPS Scenario	Labeling Program Scenario
Annual Impacts	Energy Savings	GWh	2020	6.729	2.692
			2030	21.087	9.860
	CO_2 Emissions Savings	Mt	2020	0.005	0.002
			2030	0.017	0.008
	SO_2 Emissions Savings	kt	2020	-	-
			2030	-	-
	NOx Emissions Savings	kt	2020	0.003	0.001
			2030	0.011	0.005
Cumulative Impacts	Energy Savings	GWh	through 2020	20.042	7.352
			through 2030	165.547	73.276
	CO_2 Emissions Savings	Mt	through 2020	0.016	0.006
			through 2030	0.132	0.059
	SO_2 Emissions Savings	kt	2020	-	-
			2030	-	-
	NOx Emissions Savings	kt	2020	0.010	0.004
			2030	0.085	0.038
	Operating Cost Savings	Million USD		56.8	26.0
	Equipment Cost	Million USD		9.7	4.4
	NPV	Million USD		47.1	21.5

These results show the significant savings achievable through a MEPS or a labeling program. As opposed to MEPS, the labeling program does not make the sale of efficient models mandatory, so the impacts of an endorsement label presented in the table above have to be taken as indicative.

In sum, the impacts of adopting a MEPS requiring the highest cost effective efficiency level are:

- 7 GWh of electricity savings in 2020 and 21 GWh in 2030.
- 165 GWh cumulative electricity savings between 2016 and 2030.
- 0.005 Mt of annual CO_2 emissions reductions by 2020 and 0.017 Mt by 2030.
- 0.13 Mt cumulative emissions reduction between 2016 and 2030.
- The net present value of the savings would be an estimated 47 Million USD.

2.3.3. Canada

In the current analysis, we estimate that the impact of introducing more stringent or additional S&L programs for distribution transformers in Canada would be:

- 1.5 TWh annual electricity savings from MEPS by 2030
- 15% reduction in national distribution losses by 2030
- 0.27 Mt CO_2 emission avoided by 2030 from MEPS
- 460 million USD net financial benefits from MEPS
- 0.69 TWh annual electricity savings from endorsement label by 2030
- 0.13 Mt CO_2 emissions avoided by 2030 from endorsement label
- 210 million USD net financial benefits from endorsement label

Test Procedure, S&L Status

The Canadian Government regulates the efficiency of dry-type transformers only. However, a voluntary agreement between NRCan and the Canadian Electricity Association (CEA) to adopt the minimum efficiency level based on the CSA C802.1-00 standard is being used for liquid-immersed transformers. The process of regulating minimum efficiency levels for liquid-immersed transformers was stopped after several years of development. In place of a mandatory standard, CSA harmonized the Canadian standard with NEMA's voluntary standards, selecting the range of regulated equipment, the efficiency levels, and the transformer test procedures based on NEMA TP 1 and TP 2. However, a market analysis revealed that the liquid-immersed transformer market in Canada is dominated by the nine provincial electric utilities, each of which had already incorporated energy efficiency into its transformer procurement practices. As a result of these practices, more than 95 percent of the liquid-immersed distribution transformers sold in Canada already meet the NEMA TP 1 efficiency levels (USDOE, 2013a).

The test procedure is defined in CAN/CSA C2.1 & 2.2, which refers to NEMA TP 2-2005 (NEMA, 2005).

Table 14 gives the specifications of the voluntary agreement.

Table 14 – Voluntary Standard for Liquid-Type Distribution Transformers in Canada

kVA	Min. Low Voltage	Efficiency	kVA	Min. Low Voltage	Efficiency
10	120/240	98.20	15	208Y/120	97.89
15	120/240	98.41	30	208Y/120	98.20
25	120/240	98.63	45	208Y/120	98.41
50	120/240	98.84	75	208Y/120	98.63
75	120/240	98.94	150	208Y/120	98.84
100	120/240	98.94	225	208Y/120	98.94
167	120/240	99.05	300	208Y/120	98.94
250	120/240	99.15	500	208Y/120	99.05
333	120/240	99.01	750	208Y/120	99.15
333	277/480Y	99.15	1,000	208Y/120	99.06
500	277/480Y	99.26	1,000	480Y/277	99.15
667	277/480Y	99.37	1,500	480Y/277	99.26
833	277/480Y	99.37	2,000	480Y/277	99.37
-	-	-	2,500	480Y/277	99.37
-	-	-	3,000	480Y/277	99.37

Data inputs

Total distributed electricity is calculated from IEA data as the sum of the sales in every sector of the economy plus the T&D losses (IEA, 2012c). We use the growth rate from the national electricity demand forecast to 2030 in the *APERC Energy Demand and Supply Outlook*, 5th Edition (APERC, 2012) to project total distributed electricity to 2030. In absence of data for Canada, we use U.S. data directly as a proxy or as a way to scale the inputs to the local conditions (for sales and stock calculation, for example).

Economic data such as sales taxes and labor costs were collected from publicly available sources (BLS, 2012; TMF, 2013). Fuel mix is taken from APERC for the year 2015 from (APERC, 2012) to calculate the weighted average price of electricity generation from generation cost by fuel type (IEA, 2010).

The CO_2 and NO_x/SO_2 emission factors are taken from the IEA data set on CO_2 emissions from fuel combustion (IEA, 2012a) and calculated based on fuel mix and IPCC guidelines (IPCC, 1997).

Table 15 summarizes the input data developed for Canada.

Table 15 – Economy-Specific Inputs Summary for Canada in 2010

	Value		Source/Note
Total Distributed Electricity	530	TWh	(IEA, 2012c)
Distribution transformers Capacity	415,200	MVA	calculated
Stock	5.7	Millions	derived from U.S data
Average Load Factor	34	%	same as U.S.
Average Capacity	73	kVA	same as U.S.
Annual Sales	110,000	Units	derived from U.S data
Consumer Discount Rate	7.4	%	same as U.S.
National Discount Rate	3	%	assumption(NRCAN, 2011)(NRCAN, 2011)(NRCAN, 2011)(NRCAN, 2011)(NRCAN, 2011)(NRCAN 2011)[26](NRCAN 2011)
VAT	12.4	%	(TMF, 2013)
Cost of Electricity Generation	0.07	$/kWh	derived from (IEA, 2010)
CO_2 Emission Factor	0.186	kg/kWh	(IEA, 2012a)
SO_2 Emission Factor	0.223	g/kWh	(IPCC, 1997)
NO_x Emission Factor	0.148	g/kWh	(IPCC, 1997)
Labor Cost	37	USD/hour	(BLS, 2012)

Cost-Benefit Analysis

We use the definition of the NEMA TP1 as our baseline because 95% of the market meets that requirement (NEMA, 2002). This places the market average efficiency between EL1 and EL2 (2016 U.S MEPS).

Then, we calculate the cost of conserved energy for different levels of efficiency ranging from the baseline to EL4. Finally, we compare the cost of conserved energy to the cost of electricity generation to determine the highest cost-effective efficiency targets. These targets provide the greatest energy savings while ensuring a net financial benefit to the consumer (in this case, the utility company).

We find that a MEPS set at the maximum technical level EL4 would be cost effective in the Canadian context for DL1 and DL4. DL5 is found to be cost-effective at the EL3 level. We don’t find any cost-effective option for DL2.

Table 16 presents the results for the four representative design lines we study.

Table 16 – Cost-Benefit Analysis for Representative Units in Canada

	Baseline	Target
	Representative Design Line 1, 1-phase 50kVA	
Efficiency Rating (%)	98.9%	99.5%
Losses (kWh/year)	1,737	727
Price (USD)	$ 1,550	$ 2,620
CCE (USD)		$ 0.067
	Representative Design Line 2, 1-phase 25kVA	
Efficiency Rating (%)	98.7%	No Cost-Effective Option
Losses (kWh/year)	1,052	
Price (USD)	$ 1,017	
CCE (USD)		
	Representative Design Line 4, 3-phase 150kVA	
Efficiency Rating (%)	98.9%	99.6%
Losses (kWh/year)	5,429	1,795
Price (USD)	$ 4,508	$ 7,729
CCE (USD)		$ 0.056
	Representative Design Line 5, 3-phase 1500kVA	
Efficiency Rating (%)	99.3%	99.6%
Losses (kWh/year)	32,740	19,736
Price (USD)	$ 21,092	$ 34,410
CCE (USD)		$ 0.065

National Impact Analysis

As explained in the methodology section, the results from the cost-benefit analysis are scaled to represent the units found on the Canadian market and then propagated into BUENAS to calculate national energy savings, avoided CO_2 emissions, and financial impacts in terms of net present value (NPV).

Table 17 summarizes the market shares and average market capacities used to scale the unit level results to the national level taken from U.S. DOE (USDOE, 2013a). The table also includes the resulting scaled UEC and price inputs.

Table 17 – Design Lines (DL) Market Shares and Market Average UEC and Price

	DL1	DL2	DL4	DL5
DL Market Shares	24.9%	68.3%	4.6%	2.2%
Average Capacity (kVA)	46	26	256	1,451
Scaled Baseline UEC (kWh/year)	1,636	1,078	8,095	31,934
Scaled Baseline Price (USD)	1,460	1,043	6,722	20,572
Scaled Target UEC (kWh/year)	685	1,078	2,677	19,250
Scaled Target Price (USD)	2,467	1,043	11,525	33,563

We analyze two policy scenarios in this study:

1- A MEPS taking effect in 2016, set at the maximum cost-effective level for all representative design lines.
2- An endorsement label targeting the cost-effective levels for all representative design lines, which would drive a 10% increase in the sales market share every year starting in 2015, up to a maximum of 50% market share by 2020.

Table 18 presents the national impact analysis results for Canada in 2020 and 2030.

Table 18 – National Impacts Analysis Results for Canada

		Units	**Year**	**MEPS Scenario**	**Labeling Program Scenario**
Annual Impacts	Energy Savings	GWh	2020	456.27	183.25
			2030	1,464.08	688.70
	CO_2 Emissions Savings	Mt	2020	0.09	0.03
			2030	0.27	0.13
	SO_2 Emissions Savings	kt	2020	0.10	0.04
			2030	0.33	0.15
	NOx Emissions Savings	kt	2020	0.07	0.03
			2030	0.22	0.10
Cumulative Impacts	Energy Savings	GWh	through 2020	1,355.76	498.11
			through 2030	11,364.01	5,059.46
	CO_2 Emissions Savings	Mt	through 2020	0.25	0.09
			through 2030	2.12	0.94
	SO_2 Emissions Savings	kt	2020	0.30	0.11
			2030	2.54	1.13
	NOx Emissions Savings	kt	2020	0.20	0.07
			2030	1.69	0.75
	Operating Cost Savings	Million USD		1590.5	737.6
	Equipment Cost	Million USD		1127.9	523.1
	NPV	Million USD		462.6	214.6

These results show the significant savings achievable through an increase of the current MEPS levels to the maximum cost effective level or through a labeling program for higher efficiency transformers. In contrast to a MEPS, a labeling program does not make the sale of efficient models mandatory, so the impacts of an endorsement label presented in Table 18 must be considered indicative.

In sum, the impacts of adopting a MEPS requiring the highest cost-effective efficiency level are:

• 456 GWh of electricity savings in 2020 and 1464 GWh in 2030.

- 11.3 TWh cumulative electricity savings between 2016 and 2030
- 0.09 Mt of annual CO_2 emissions reductions by 2020 and 0.27 Mt by 2030
- 2.12 Mt cumulative emissions reduction between 2016 and 2030
- 462 Million USD estimated net present value of savings

2.3.4. Chile

In the current analysis, we estimate that the impact of introducing more stringent or additional S&L programs for distribution transformers in Chile to be:

- 1.3 TWh annual electricity savings from MEPS by 2030
- 39% reduction in national distribution losses by 2030
- 0.5 Mt CO_2 emission avoided by 2030 from MEPS
- 732 million USD net financial benefits from MEPS
- 0.6 TWh annual electricity savings from endorsement label by 2030
- 0.2 Mt CO_2 emissions avoided by 2030 from endorsement label
- 340 million USD net financial benefits from endorsement label

Test Procedure, S&L Status

Since its inception in 1985, the Superintendencia de Electricidad y Combustible (SEC) (Fuel and Electricity Superintendence) has been responsible for developing and enforcing S&Ls for electrical technologies in Chile. The office is currently developing several mandatory comparative labeling schemes for lighting technologies. These schemes are scheduled to take effect at the end of 2013. At this point, the Chilean S&L programs focus mainly on domestic equipment. Apart from residential-sector end uses, induction tri-phase motors are the only other type of product to which mandatory comparative labeling is applied. MEPS are currently being developed for refrigerators and general lighting equipment. APEC, as one of the international organizations specializing in supporting development of S&Ls, has been offering assistance to Chile for past and current implementation of mandatory comparative labels and MEPS.

Chile has a voluntary labeling program defined in NCh3039 (INN, 2007c), which refers to NEMA TP-3 (NEMA, 2000). This program covers both dry- and liquid-type distribution transformers. Table 19 gives the labeling program definition.

The test procedure is defined by two norms, NCh2660 and NCh 2661, which refer to NEMA TP 1-2002 and NEMA TP 2-2005, respectively (INN, 2007a, b; NEMA, 2002, 2005). The procedure covers single-phase distribution transformers from 10 kVA – 833 kVA and three-phase distribution transformers from 15 kVA to 2,500 kVA.

Table 19 – Voluntary Energy-Efficiency Levels for Liquid-Type Distribution Transformers in Chile

kVA	Single-phase	Three-phase
10	98.4	-
15	98.6	98.1
25	98.7	-
30	-	98.4
38	98.8	-
45	-	98.6
50	98.9	-
75	99.0	98.7
100	99.0	-
113	-	98.8
150	-	98.9
167	99.1	-
250	99.2	-
225	-	99.0
300	-	99.0
333	99.2	-
500	99.3	99.1
667	99.4	-
750	-	99.2
833	99.4	-
1,000	-	99.2
1,500	-	99.3
2,000	-	99.4
2,500	-	99.4

Data inputs

Total distributed electricity is calculated from IEA data as the sum of the sales in every sector of the economy plus the T&D losses (IEA, 2012c). We use the growth rate from the national electricity demand forecast to 2030 in the *APERC Energy Demand and Supply Outlook*, 5th Edition (APERC, 2012) to project total distributed electricity to 2030. Total stock and stock distribution by capacity were provided by the APEC economy representative for Chile at the Ministry of Energy (MoE). Additional customs data provided by ICA indicate that 60,000 units were imported in 2012. The stock data provided by the ministry imply annual sales of about 10,000 units in the same year. To reconcile the two figures, we have to assume that there is no domestic production in Chile. Also, the imports figure includes dry-type distribution transformers. The shares of dry-type and liquid-type transformers have been estimated to be about the same as in the U.S and Australia (E3 used figures from the E.U. as a proxy), i.e., 25% dry and 75% liquid type (E3, 2011; KEMA, 2002; USDOE, 2013a).

We estimate that the cost of electricity generation in Chile was 0.12 USD/kWh in 2008 (INE, 2008). However, historical trends show that the cost of generation has been increasing steadily since 2000, which leads us to think that 12cts/kWh is an underestimate of the cost of production, especially in the year of the prospective MEPS and during the rest of the forecast period. Other economic data such as sales taxes and labor costs were collected from publicly available sources (BLS, 2012; TMF, 2013).

The CO_2 and NO_x/SO_2 emission factors are taken from the IEA data set on CO_2 emissions from fuel combustion (IEA, 2012a) and calculated based on fuel mix and IPCC guidelines (IPCC, 1997).

Table 20 summarizes the input data developed for Chile.

Table 20 – Economy-Specific Inputs Summary for Chile in 2011

	Value		Source/Note
Total Distributed Electricity	65	TWh	(IEA, 2012c)
Distribution transformers Capacity	27,000	MVA	calculated
Stock	0.58	Millions	calculated from sales
Average Load Factor	28	%	calculated
Average Capacity	46	kVA	MoE
Annual Sales	45,000	Units	imports data + LBNL's correction
Consumer Discount Rate	10%		(IEA, 2010)
National Discount Rate	7%		Assumed
VAT	19%		(TMF, 2013)
Cost of Electricity Generation	0.12	$/kWh	(INE, 2008)
CO_2 Emission Factor	0.410	kg/kWh	(IEA, 2012a)
SO_2 Emission Factor	1.176	kg/kWh	(IPCC, 1997)
NO_x Emission Factor	0.503	kg/kWh	(IPCC, 1997)
Labor Cost	10	$/hour	derived from GDP/cap

Cost-Benefit Analysis

Because the program in Chile has been voluntary rather than mandatory, obtaining efficiency data has been difficult. In the absence of data showing an improvement in market efficiency since 2007, we assume that the program has not moved the market and use the technical floor baseline EL0 as the average market efficiency in Chile.

Then, we calculate the cost of conserved energy for different levels of efficiency ranging from EL0 to EL4. Finally, we compare the cost of conserved energy to the cost of electricity generation to determine the highest cost-effective efficiency targets. These targets provide the greatest energy savings while ensuring a net financial benefit to the consumer (in this case, the utility company).

We find that a MEPS set at the maximum technical level would be cost effective in the Chilean context.

Table 21 presents the results for the four representative design lines we study.

Table 21 – Cost-Benefit Analysis for Representative Units in Chile

	Baseline	Target
	Representative Design Line 1, 1-phase 50kVA	
Efficiency Rating (%)	98.5%	99.5%
Losses (kWh/year)	2,029	622
Price (USD)	$ 856	$ 2,277
CCE (USD)		$ 0.106
	Representative Design Line 2, 1-phase 25kVA	
Efficiency Rating (%)	98.0%	99.0%
Losses (kWh/year)	1,444	762
Price (USD)	$ 470	$ 1,123
CCE (USD)		$ 0.101
	Representative Design Line 4, 3-phase 150kVA	
Efficiency Rating (%)	98.3%	99.6%
Losses (kWh/year)	7,588	3,248
Price (USD)	$ 1,938	$ 5,555
CCE (USD)		$ 0.087
	Representative Design Line 5, 3-phase 1500kVA	
Efficiency Rating (%)	98.9%	99.7%
Losses (kWh/year)	44,613	13,011
Price (USD)	$ 10,548	$ 38,793
CCE (USD)		$ 0.094

National Impact Analysis

As explained in the methodology section, the results from the cost-benefit analysis are scaled to represent the units found on the Chilean market and then propagated into BUENAS to calculate national energy savings, avoided CO_2 emissions, and financial impacts in terms of net present value (NPV).

Table 22 summarizes the market shares and average market capacities provided by the MoE, which were used to scale the unit-level results to the national level. The table also includes the resulting scaled UEC and price inputs.

Table 22 – Design Lines (DL) Market Shares and Market Average UEC and Price in Chile

	DL1	**DL2**	**DL4**	**DL5**
DLMarketShares	35.4%	64.0%	0.6%	0.0%
AverageCapacity(kVA)	83	25	180	
ScaledBaselineUEC(kWh/year)	2,968	1,444	8,699	-
ScaledBaselinePrice(USD)	1,252	470	2,222	-
ScaledTargetUEC(kWh/year)	910	762	1,800	-
ScaledTargetPrice(USD)	3,330	1,123	7,696	-

We analyze two policy scenarios in this study:

1- A MEPS taking effect in 2016, set at the maximum cost-effective level for all representative design lines.
2- An endorsement label targeting the cost-effective levels for all representative design lines, which would drive a 10% increase in the sales market share every year starting in 2015, up to a maximum of 50% market share by 2020.

Table 23 presents the national impact analysis results for Chile in 2020 and 2030.

Table 23 – National Impacts Analysis Results for Chile

		Units	Year	MEPS Scenario	Labeling Program Scenario
Annual Impacts	Energy Savings	GWh	2020	349.6	141.2
			2030	1,259.4	597.2
	CO_2 Emissions Savings	Mt	2020	0.1	0.1
			2030	0.5	0.2
	SO_2 Emissions Savings	kt	2020	0.4	0.2
			2030	1.5	0.7
	NOx Emissions Savings	kt	2020	0.2	0.1
			2030	0.6	0.3
Cumulative Impacts	Energy Savings	GWh	through 2020	1,024.1	377.3
			through 2030	9,273.9	4,170.4
	CO_2 Emissions Savings	Mt	through 2020	0.4	0.2
			through 2030	3.8	1.7
	SO_2 Emissions Savings	kt	2020	1.2	0.4
			2030	10.9	4.9
	NOx Emissions Savings	kt	2020	0.5	0.2
			2030	4.7	2.1
	Operating Cost Savings	Million USD		1,494.69	693.77
	Equipment Cost	Million USD		762.34	353.85
	NPV	Million USD		732.35	339.93

These results show the significant savings achievable through a MEPS or a labeling program. In contrast to a MEPS, a labeling program does not make the sale of efficient models mandatory, so the impacts of an endorsement label presented in Table 23 must be considered indicative only.

In sum, the impacts of adopting a MEPS requiring the highest cost-effective efficiency level are:

- 350 GWh of electricity savings in 2020 and 1,259 GWh in 2030
- 9.3 TWh cumulative electricity savings between 2016 and 2030
- 0.1 Mt of annual CO_2 emissions reductions by 2020 and 0.5 Mt by 2030
- 3.8 Mt cumulative emissions reduction between 2016 and 2030
- 732 Million USD estimated net present value of savings

2.3.5. Hong Kong, China

In the current analysis, we estimate that the impact of introducing S&L programs for distribution transformers in Hong Kong, China would be:

- 95 GWh annual electricity savings from MEPS by 2030
- 16% reduction in national distribution losses by 2030
- 0.07 Mt CO_2 emission avoided by 2030 from MEPS
- 15 million USD net financial benefits from MEPS
- 45 GWh annual electricity savings from endorsement label by 2030
- 0.03 Mt CO_2 emissions avoided by 2030 from endorsement label
- 7 million USD net financial benefits from endorsement label

Test Procedure, S&L Status

Based on communication with the energy efficiency office from the Electrical and Mechanical Services Department (EMSD) from the government of Hong Kong, China, it was noted that the majority of the distribution transformers in Hong Kong has a rating of either 1000kVA or 1500kVA. For these reason, we focus on DL5 (3-phase 1500kVA) in the analysis for Hong Kong.
Most of the distribution transformers are designed and tested with IEC 60076. There is no mandatory regulation governing the minimum efficiency performance of distribution transformers. However, the Government has signed the Scheme of Control Agreements (SCA) with the power companies. By signing the SCA, the power companies should undertake to provide sufficient facilities to meet present and future electricity demand of their respective supply areas. In return, they are entitled to receive a permitted rate of return on their fixed assets. The SCAs also provide a framework for the Government to regulate the power companies and monitor their corporate affairs to protect the interests of consumers. Notwithstanding, as a private enterprise, it is believed that the two power companies (CLP Power Hong Kong Limited and Hong Kong Electric Company Limited) would take all the necessary steps to reduce their operating expenses through optimization of their generation, transmission and distribution systems (including the distribution transformers).

Data inputs

Total distributed electricity is calculated from IEA data as the sum of the sales in every sector of the economy plus the T&D losses (IEA, 2012c). We use the growth rate from the national electricity demand forecast to 2030 in the *APERC Energy Demand and Supply Outlook*, 5th Edition (APERC, 2012) to project total distributed electricity to 2030.

Economic data such as sales taxes and labor cost have been taken from China and adjusted based on GDP/cap (BLS, 2012; TMF, 2013). Fuel mix is taken for the year 2015 from (APERC, 2012) in order to calculate the weighted average price of electricity generation from generation cost by fuel type (IEA, 2010).

The CO_2 and NO_x/SO_2 emission factors are taken from the IEA dataset on CO_2 emissions from fuel combustion (IEA, 2012a) and calculated based on fuel mix and IPCC guidelines (IPCC, 1997).

Table 24 summarizes the input data developed for Hong Kong, China.

Table 24 – Economy-Specific Inputs Summary for Hong Kong, China in 2010

	Value		Source/Note
Total Distributed Electricity	47	TWh	(IEA, 2012c)
Distribution transformers Capacity	12000	MVA	calculated
Stock	0.01	Millions	calculated
Average Load Factor	50	%	assumed
Average Capacity	1250	kVA	EMSD
Sales	305	Units	calculated
Consumer Discount Rate	10	%	(IEA, 2010)
National Discount Rate	5	%	assumed
VAT	17	%	China proxy
Cost of Electricity Generation	0.04	$/kWh	derived from (IEA, 2010)
CO_2 Emission Factor	0.723	kg/kWh	(IEA, 2012a)
SO_2 Emission Factor	1.108	g/kWh	(IPCC, 1997)
NO_x Emission Factor	0.890	g/kWh	(IPCC, 1997)
Labor Cost	17	$/hour	derived from GDP/cap

Cost-Benefit Analysis

Some data on baseline efficiency and prices have been provided by the two utilities companies in Hong Kong through the EMSD. Prices are from 1988, which we don't believe are appropriate to use for this analysis. Instead we apply the standard methodology using U.S costs as a basis for analysis. The baseline provided for the main representative unit match our efficiency level EL1. We evaluate the cost of conserved energy for different levels of efficiency ranging from EL1 to EL4. Finally, we compare the cost of conserved energy to the cost of electricity generation in order to determine the highest cost-effective efficiency targets. This target provides the greatest energy savings while ensuring a net financial benefit to the consumer (in this case, the utility company).

We find that a MEPS harmonized with the 2016 US MEPS (efficiency level EL2) would be cost-effective in the Hong Kong context.

Table 25 presents the results for the representative design line we study:

Table 25 – Cost-Benefit Analysis for Representative Units for Hong Kong, China

	Baseline	Target
	Representative Design Line 5, 3-phase 1500kVA	
Efficiency Rating (%)	99.2%	99.5%
Losses (kWh/year)	52,980	34,584
Price (USD)	$ 16,264	$ 25,932
CCE (USD)		$ 0.033

National Impact Analysis

As explained in the methodology section, the results from the cost-benefit analysis are scaled to represent the units found in the Hong Kong market and then propagated into BUENAS to calculate national energy savings, avoided CO_2 emissions and financial impacts, in terms of net present value (NPV).

The APEC representative noted that the majority of distribution transformers in Hong Kong have a rating of either 1000kVA or 1500kVA. Given this information, we assume that the market is made of units represented by DL5, with an average capacity of 1250kVA. The following table presents resulting scaled UEC and price inputs.

Table 26 – Design Lines (DL) Market Shares and Market Average UEC and Price in Hong Kong, China

	DL1	DL2	DL4	DL5
DL Market Shares	0.0%	0.0%	0.0%	100.0%
Average Capacity (kVA)			-	1,250
Scaled Baseline UEC (kWh/year)			-	46,209
Scaled Baseline Price (USD)			-	14,185
Scaled Target UEC (kWh/year)			-	30,164
Scaled Target Price (USD)			-	22,617

We analyze two policy scenarios in this study:

1- A MEPS taking effect in 2016, set at the maximum cost-effective level for all representative design lines.

2- An endorsement label targeting the cost-effective levels for all representative design lines, which would drive a 10% increase in the sales market share every year starting in 2015, up to a maximum of 50% market share by 2020.

Table 27 presents the national impact analysis results for Hong Kong in 2020 and 2030.

Table 27 – National Impacts Analysis Results for Hong Kong, China

		Units	**Year**	**MEPS Scenario**	**Labeling Program Scenario**
Annual Impacts	Energy Savings	GWh	2020	27.99	11.20
			2030	95.15	44.49
	CO_2 Emissions Savings	Mt	2020	0.02	0.01
			2030	0.07	0.03
	SO_2 Emissions Savings	kt	2020	0.03	0.01
			2030	0.11	0.05
	NOx Emissions Savings	kt	2020	0.02	0.01
			2030	0.08	0.04
Cumulative Impacts	Energy Savings	GWh	through 2020	82.50	30.28
			through 2030	719.91	319.27
	CO_2 Emissions Savings	Mt	through 2020	0.06	0.02
			through 2030	0.52	0.23
	SO_2 Emissions Savings	kt	2020	0.09	0.03
			2030	0.80	0.35
	NOx Emissions Savings	kt	2020	0.07	0.03
			2030	0.64	0.28
	Operating Cost Savings	Million USD		49.1	22.7
	Equipment Cost	Million USD		34.4	16.0
	NPV	Million USD		14.6	6.7

These results show the significant savings achievable through a MEPS or a labeling program. As opposed to MEPS, the labeling program does not make the sale of efficient models mandatory, so the impacts of an endorsement label presented in the table above have to be taken as indicative.
In sum, the impacts of adopting a MEPS requiring the highest cost effective efficiency level are:

- 28 GWh of electricity savings in 2020 and 95 GWh in 2030.
- 720 GWh cumulative electricity savings between 2016 and 2030.
- 0.02 Mt of annual CO_2 emissions reductions by 2020 and 0.07 Mt by 2030.
- 0.5 Mt cumulative emissions reduction between 2016 and 2030.
- The net present value of the savings would be an estimated 15 Million USD.

2.3.6. Indonesia

In the current analysis, we estimate that the impact of introducing more stringent S&L for distribution transformers in Indonesia would be:

- 1.1 TWh annual electricity savings from MEPS by 2030
- 23% reduction in national distribution losses by 2030
- 0.8 Mt CO_2 emission avoided by 2030 from MEPS
- 686 million USD net financial benefits from MEPS
- 530 GWh annual electricity savings from endorsement label by 2030
- 0.4 Mt CO_2 emissions avoided by 2030 from endorsement label
- 317 million USD net financial benefits from endorsement label

Test Procedure, S&L Status

The Perusahaan Listrik Negara (PLN) utility, which is the sole utility in Indonesia has developed mandatory standards for single and three-phase liquid-type distribution transformers in 2007, that entered into effect in 2011. The following tables present the efficiency requirements for PLN's new distribution transformers.

Table 28 – Energy Efficiency Requirements for Single-Phase Liquid-type Transformers for Indonesia

Transformer rating	Watt loss for 22-24 kV		Efficiency at 50% load
kVA	No load loss	Load loss	%
1	2	3	99.5%
10	40	185	98.3%
16	50	265	98.6%
25	70	370	98.7%
50	120	585	98.9%

Table 29 – Energy Efficiency Requirements for Three-Phase Liquid-type Transformers for Indonesia

Transformer rating	Watt loss for 22-24 kV		Efficiency
(kVA)	No load loss	Load loss	
1	2	3	99.5%
25	75	425	98.6%
50	125	800	98.7%
100	210	1420	98.9%
160	300	2000	99.0%
200	355	2350	99.1%
250	420	2750	99.1%
315	500	3250	99.2%
400	595	3850	99.2%
500	700	4550	99.3%
630	835	5400	99.3%
800	1000	6850	99.3%
1000	1100	8550	99.4%
1250	1400	10600	99.4%
1600	1680	13550	99.4%
2000	1990	16900	99.4%
2500	2350	21000	99.4%

Data inputs

Total distributed electricity is calculated from IEA data as the sum of the sales in every sector of the economy plus the T&D losses (IEA, 2012c). We use the growth rate from the national electricity demand forecast to 2030 in the *APERC Energy Demand and Supply Outlook*, 5th Edition (APERC, 2012) to project total distributed electricity to 2030.

Sales taxes were collected from TMF (TMF, 2013), and labor costs were derived from GDP/cap using the Philippines as a reference for the scaling factor. The average cost of electricity generation by fuel relies on estimates from USAID (USAID, 2007) and is weighted using the fuel mix in 2015.

The CO_2 and NO_x/SO_2 emission factors are taken from the IEA data set on CO_2 emissions from fuel combustion (IEA, 2012a) and calculated based on fuel mix and IPCC guidelines (IPCC, 1997).

Table 30 summarizes all of the data developed for Indonesia:

Table 30 – Economy-Specific Inputs Summary for Indonesia in 2010

	Value		Source/Note
Total Distributed Electricity	160	TWh	(IEA, 2012c)
Distribution transformers Capacity	40,000	MVA	calculated
Stock	0.55	Millions	calculated
Average Load Factor	50	%	assumed
Average Capacity	73	kVA	(USDOE, 2013a)
Annual Sales	17,400	Units	calculated
Consumer Discount Rate	10	%	(IEA, 2010)
National Discount Rate	5	%	Assumed
VAT	10	%	(TMF, 2013)
Cost of Electricity Generation	0.12	\$/kWh	(USAID, 2007)
CO_2 Emission Factor	0.709	kg/kWh	(IEA, 2012a)
SO_2 Emission Factor	1.674	g/kWh	(IPCC, 1997)
NO_x Emission Factor	0.807	g/kWh	(IPCC, 1997)
Labor Cost	3	\$/hour	Derived from GDP/cap

Cost-Benefit Analysis

Based on the values calculated in Table 28 and Table 29, we find that the baseline efficiency level is between EL1 and EL2 for all the DL analyzed. We calculate the cost of conserved energy for different levels of efficiency ranging from the calculated baseline efficiency to EL4. Finally, we compare the cost of conserved energy to the cost of electricity generation to determine the highest cost-effective efficiency targets. These targets result in the greatest energy savings while ensuring a net financial benefit to the consumer (in this case, the utility company).

We find that a MEPS set at the maximum technically feasible efficiency level EL4 would be cost effective in the local context for DL1, DL4 and DL5. DL2 is found to be cost effective up to the EL3 level. All design lines are found to be cost effective at the 2016 U.S. MEPS level.

Table 31 presents the results for the four representative design lines we study.

Table 31 – Cost-Benefit Analysis for Representative Units for Indonesia

	Baseline		Target	
	Representative Design Line 1, 1-phase 50kVA			
Efficiency Rating (%)		98.9%		99.5%
Losses (kWh/year)		2,330		1,104
Price (USD)	$	1,261	$	2,076
CCE (USD)			$	0.070
	Representative Design Line 2, 1-phase 25kVA			
Efficiency Rating (%)		98.7%		99.2%
Losses (kWh/year)		1,428		885
Price (USD)	$	791	$	1,306
CCE (USD)			$	0.099
	Representative Design Line 4, 3-phase 150kVA			
Efficiency Rating (%)		99.0%		99.6%
Losses (kWh/year)		6,710		2,681
Price (USD)	$	3,734	$	5,967
CCE (USD)			$	0.058
	Representative Design Line 5, 3-phase 1500kVA			
Efficiency Rating (%)		99.4%		99.7%
Losses (kWh/year)		42,390		20,490
Price (USD)	$	17,644	$	34,668
CCE (USD)			$	0.082

National Impact Analysis

As explained in the methodology section, the results from the cost-benefit analysis are scaled to represent the units found on the Indonesian market and then propagated into BUENAS to calculate national energy savings, avoided CO_2 emissions, and financial impacts in terms of net present value (NPV).

Table 34 summarizes the market shares and average market capacities used to scale the unit-level results to the national level. The table also includes the resulting scaled UEC and price inputs.

Table 32 – Design Lines (DL) Market Shares and Market Average UEC and Price in Indonesia

	DL1	DL2	DL4	DL5
DL Market Shares	24.9%	68.3%	4.6%	2.2%
Average Capacity (kVA)	46	26	256	1,451
Scaled Baseline UEC (kWh/year)	2,195	1,464	10,005	41,346
Scaled Baseline Price (USD)	1,188	811	5,568	17,210
Scaled Target UEC (kWh/year)	1,040	907	3,997	19,985
Scaled Target Price (USD)	1,955	1,339	8,898	33,814

We analyze two policy scenarios in this study:

1- A MEPS taking effect in 2016, set at the maximum cost-effective level for all representative design lines.
2- An endorsement label targeting the cost-effective levels for all representative design lines, which would drive a 10% increase in the sales market share every year starting in 2015, up to a maximum of 50% market share by 2020.

Table 33 presents the national impact analysis results for Indonesia in 2020 and 2030.

Table 33 – National Impacts Analysis Results for Indonesia

		Units	Year	MEPS Scenario	Labeling Program Scenario
Annual Impacts	Energy Savings	GWh	2020	217.2	86.9
			2030	1,129.6	528.2
	CO_2 Emissions Savings	Mt	2020	0.2	0.1
			2030	0.8	0.4
	SO_2 Emissions Savings	kt	2020	0.4	0.1
			2030	1.9	0.9
	NOx Emissions Savings	kt	2020	0.2	0.1
			2030	0.9	0.4
Cumulative Impacts	Energy Savings	GWh	through 2020	606.2	223.1
			through 2030	7,137.1	3,194.0
	CO_2 Emissions Savings	Mt	through 2020	0.4	0.2
			through 2030	5.1	2.3
	SO_2 Emissions Savings	kt	2020	1.0	0.4
			2030	11.9	5.3
	NOx Emissions Savings	kt	2020	0.5	0.2
			2030	5.8	2.6
	Operating Cost Savings	Million USD		1046.3	485.2
	Equipment Cost	Million USD		360.0	168.6
	NPV	Million USD		686.2	316.7

These results show the significant savings achievable through a more stringent MEPS or a labeling program. In contrast to a MEPS, a labeling program does not make the sale of efficient models mandatory, so the impacts of an endorsement label presented in Table 35 must be considered as indicative.

In sum, the impacts of adopting a MEPS requiring the highest cost-effective efficiency level are:

• 217 GWh of electricity savings in 2020 and 1,130 GWh in 2030
• 7.1 TWh cumulative electricity savings between 2016 and 2030
• 0.2 Mt of annual CO_2 emissions reductions by 2020 and 0.8 Mt by 2030
• 5.1 Mt cumulative emissions reduction between 2016 and 2030
• 686 Million USD estimated net present value of savings

2.3.7. Japan

In the current analysis, we estimate that the impact of introducing more stringent or additional S&L programs for distribution transformers in Japan would be:

- 2.6 TWh annual electricity savings from MEPS by 2030
- 17% reduction in national distribution losses by 2030
- 1.1 Mt CO_2 emission avoided by 2030 from MEPS
- 1.3 billion USD net financial benefits from MEPS
- 1.2 TWh annual electricity savings from endorsement label by 2030
- 0.5 Mt CO_2 emissions avoided by 2030 from endorsement label
- 610 million USD net financial benefits from endorsement label

Test Procedure, S&L Status

Distribution transformers are included in the top runner program which specifies target levels of total losses for use in determining transformer efficiency (METI, 2010). Rather than separating the no load and load loss, the program provides empirical formulas that can be used to calculate the losses for any specific transformer rating. The loss formulas are given for both 50 and 60 Hz to cover the two different power frequency systems that operate in separate parts of Japan. The program covers single-phase liquid-type transformers from 5kVA to 500kVA and three-phase dry-type transformers from 10kVA to 2000kVA.

The method JIS C4304 – 2005 is used for measuring the losses 6kV oil-immersed distribution transformers. The test method is based on the IEC 60076 family of standards, however there are modifications that have been made to the Japanese national standards.

Table 34 – Japanese Top Runner Program Requirements

Category				Maximum Energy Consumption E (W)
Transformer Type	**Number of Phases**	**Rated Frequency**	**Rated Capacity**	
Liquid-type transformer	Single Phase	50 Hz		$E = 15.3 \times S^{0.696}$
		60 Hz		$E = 14.4 \times S^{0.698}$
	Three Phase	50 Hz	Up to 500 kVA	$E = 23.8 \times S^{0.653}$
			Over 500 kVA	$E = 9.84 \times S^{0.842}$
		60 Hz	Up to 500 kVA	$E = 22.6 \times S^{0.651}$
			Over 500 kVA	$E = 18.6 \times S^{0.745}$

Table 35 – Japanese Top Runner Program Converted to Efficiency

Liquid-Type, Single-Phase (60Hz)			Liquid-Type, Three-Phase (60Hz)		
kVA	**E_{max} (W)**	**Efficiency***	**kVA**	**E_{max} (W)**	**Efficiency***
10	71.8	98.24%	15	131.7	97.85%
15	95.3	98.44%	30	206.9	98.31%
25	136.2	98.66%	45	269.4	98.53%
37.5	180.7	98.81%	75	375.6	98.76%
50	220.9	98.91%	112.5	489.1	98.92%
75	293.2	99.03%	150	589.9	99.03%
100	358.4	99.11%	225	768.0	99.15%
167	512.6	99.24%	300	926.2	99.23%
250	679.4	99.33%	500	1291.6	99.36%
333	829.9	99.38%	750	2578.9	99.32%
500	1102.2	99.45%	1000	3195.3	99.36%
			1500	4322.2	99.43%
			2000	5355.3	99.47%
			2500	6323.8	99.50%

*Note: Efficiency is defined at 40% loading for 500 kVA and below and 50% for units greater than 500 kVA.
Source: (SEAD, 2013a)

Data inputs

Total distributed electricity is calculated from IEA data as the sum of the sales in every sector of the economy plus the T&D losses (IEA, 2012c). We use the growth rate from the national electricity demand forecast to 2030 in the *APERC Energy Demand and Supply Outlook*, 5th Edition (APERC, 2012) to project total distributed electricity to 2030. Sales data were available from the Japan Electrical Manufacturer Association between 1990 and 2009 in terms of number of units and annual capacity sold in kVA (JEMA, 2012). This allowed us to estimate the average transformer capacity. As described in (EES, 2007), we find that the Japanese distribution system uses many more lower capacity units than in other economies.

Economic data such as sales taxes and labor cost were taken from publicly available database (BLS, 2012; TMF, 2013). Fuel mix is taken for the year 2015 from (APERC, 2012) in order to calculate the weighted average price of electricity generation from generation cost by fuel type (IEA, 2010).

The CO_2 and NO_x/SO_2 emission factors are taken from the IEA data set on CO_2 emissions from fuel combustion (IEA, 2012a) and calculated based on fuel mix and IPCC guidelines (IPCC, 1997).

Table 36 summarizes the input data developed for Japan.

Table 36 – Economy-Specific Inputs Summary for Japan in 2009

	Value		Source/Note
Total Distributed Electricity	960	TWh	(IEA, 2012c)
Distribution transformers Capacity	716,000	MVA	Calculated from (JEMA, 2012)
Stock	15.5	Millions	Calculated from (JEMA, 2012)
Average Load Factor	22	%	calculated
Average Capacity	46	kVA	
Annual Sales	400,000	Units	(JEMA, 2012)
Consumer Discount Rate	5	%	
National Discount Rate	5	%	
VAT	10	%	(TMF, 2013)
Lifetime	32	years	(USDOE, 2013a)
Cost of Electricity Generation	0.10	\$/kWh	(IEA, 2010)
CO_2 Emission Factor	0.416	kg/kWh	(IEA, 2012a)
SO_2 Emission Factor	0.816	g/kWh	(IPCC, 1997)
NO_x Emission Factor	0.487	g/kWh	(IPCC, 1997)
Labor Cost	36	USD/hour	(BLS, 2012)

Cost-Benefit Analysis

Baseline efficiency is a key determinant in the cost-benefit analysis. We use top runner efficiency definition from Table 35 as our baseline, which is between EL0 and EL1 for single-phase distribution transformers and EL1 and EL2 for three-phase distribution transformers.
Then, we calculate the cost of conserved energy for different levels of efficiency ranging from the baseline to EL4. Finally, we compare the cost of conserved energy to the cost of electricity generation in order to determine the highest cost-effective efficiency targets. This target provides the greatest energy savings while ensuring a net financial benefit to the consumer (in this case, the utility company).

We find that a MEPS set at the maximum technical level EL4 would be cost effective in the Japanese context for DL1 and DL4. DL5 is found to be cost-effective at the EL3 level. We don't find any cost-effective option for DL2.

Table 37 presents the results for the four representative design lines we study:

Table 37 – Cost-Benefit Analysis for Representative Units for Japan

	Baseline	Target
	Representative Design Line 1, 1-phase 50kVA	
Efficiency Rating (%)	98.9%	99.5%
Losses (kWh/year)	1,365	514
Price (USD)	$ 1,459	$ 2,480
CCE (USD)		$ 0.076
	Representative Design Line 2, 1-phase 25kVA	
Efficiency Rating (%)	98.7%	No Cost-Effective Option
Losses (kWh/year)	873	
Price (USD)	$ 911	
CCE (USD)		
	Representative Design Line 4, 3-phase 150kVA	
Efficiency Rating (%)	99.0%	99.6%
Losses (kWh/year)	3,926	1,350
Price (USD)	$ 4,671	$ 7,155
CCE (USD)		$ 0.061
	Representative Design Line 5, 3-phase 1500kVA	
Efficiency Rating (%)	99.4%	99.6%
Losses (kWh/year)	20,898	15,552
Price (USD)	$ 24,251	$ 31,865
CCE (USD)		$ 0.090

National Impact Analysis

As explained in the methodology section, the results from the cost-benefit analysis are scaled to represent the units found in the Japanese market and then propagated into BUENAS to calculate national energy savings, avoided CO_2 emissions and financial impacts, in terms of net present value (NPV).

The following table summarizes the market shares, and average market capacities used to scale the unit level results to the national level along with the resulting scaled UEC and price inputs.

Table 38 – Design Lines (DL) Market Shares and Market Average UEC and Price in Japan

	DL1	**DL2**	**DL4**	**DL5**
DL Market Shares	24.9%	68.3%	4.6%	2.2%
Average Capacity (kVA)	33	17	99	991
Scaled Baseline UEC (kWh/year)	1,000	640	2,876	15,312
Scaled Baseline Price (USD)	1,069	668	3,423	17,769
Scaled Target UEC (kWh/year)	377	640	989	11,395
Scaled Target Price (USD)	1,817	668	5,243	23,347

We analyze two policy scenarios in this study:

1- A MEPS taking effect in 2016, set at the maximum cost-effective level for all representative design lines.
2- An endorsement label targeting the cost-effective levels for all representative design lines, which would drive a 10% increase in the sales market share every year starting in 2015, up to a maximum of 50% market share by 2020.

Table 39 presents the national impact analysis results for Japan in 2020 and 2030.

Table 39 – National Impacts Analysis Results for Japan

		Units	**Year**	**MEPS Scenario**	**Labeling Program Scenario**
Annual Impacts	Energy Savings	GWh	2020	858.2	343.5
			2030	2,557.7	1,196.1
	CO_2 Emissions Savings	Mt	2020	0.4	0.1
			2030	1.1	0.5
	SO_2 Emissions Savings	kt	2020	0.7	0.3
			2030	2.1	1.0
	NOx Emissions Savings	kt	2020	0.4	0.2
			2030	1.2	0.6
Cumulative Impacts	Energy Savings	GWh	through 2020	2,574.3	944.1
			through 2030	20,548.7	9,086.4
	CO_2 Emissions Savings	Mt	through 2020	1.1	0.4
			through 2030	8.6	3.8
	SO_2 Emissions Savings	kt	2020	2.1	0.8
			2030	16.8	7.4
	NOx Emissions Savings	kt	2020	1.3	0.5
			2030	10.0	4.4
	Operating Cost Savings	Million USD		3,884.9	1,790.0
	Equipment Cost	Million USD		2,554.9	1,177.2
	NPV	Million USD		1,329.9	612.8

These results show the significant savings achievable through a revision of the current Top-runner program targeting cost-effective levels or a labeling program targeting higher efficiency distribution transformers. As opposed to MEPS, the labeling program does not make the sale of efficient models mandatory, so the impacts of an endorsement label presented in the table above have to be taken as indicative.

In sum, the impacts of adopting a MEPS requiring the highest cost effective efficiency level are:

• 858 GWh of electricity savings in 2020 and 2,558 GWh in 2030.
• 20.5 TWh cumulative electricity savings between 2016 and 2030.
• 0.4 Mt of annual CO_2 emissions reductions by 2020 and 1.1 Mt by 2030.
• 8.6 Mt cumulative emissions reduction between 2016 and 2030.
• The net present value of the savings would be an estimated 1.3 Billion USD.

2.3.8. Korea

In the current analysis, we estimate that the impact of introducing more stringent or additional S&L programs for distribution transformers in Korea would be:

- 1.4 TWh annual electricity savings from MEPS by 2030
- 19% reduction in national distribution losses by 2030
- 0.8 Mt CO_2 emission avoided by 2030 from MEPS
- 460 million USD net financial benefits from MEPS
- 0.7 TWh annual electricity savings from endorsement label by 2030
- 0.4 Mt CO_2 emissions avoided by 2030 from endorsement label
- 210 million USD net financial benefits from endorsement label

Test Procedure, S&L Status

The MEPS program for dry and liquid-type transformers in Korea has been adopted in July 2012 (KEMCO, 2012). The regulation covers single-phase distribution transformers between 10 and 3000kVA and three-phase transformers between 100 and 3000kVA, as defined in the test methods KS C 4306, KS C 4311, KS C 4316, KS C 4317.

Within these standards, the regulations cross-reference the measurement methodologies that are published in the IEC 60076 standards, which have been adopted without modification (i.e., "identical") as national Korean Standards (KS). KS C IEC 60076-1, Power transformers – Part 1: General, corresponds to IEC 60076-1:1993 and is identical to that standard. presents the Korean standards harmonized with IEC 60076.

Table 40 – Korean Test Methods Standards Harmonized with IEC 60076

Standard	Description	Date
KS C IEC 60076-1	Power transformers－Part 1：General	2002.10.29
KS C IEC 60076-2	Power transformers－Part 2：Temperature rise	2002.10.29
KS C IEC 60076-3	Power transformer－Part 3：Insulation levels, dielectric tests and external clearances in air	2002.10.29
KS C IEC 60076-4	Power transformers－Part 4：Guide to the lightning impulse and switching impulse testing－Power transformers and reactors	2008.03.31
KS C IEC 60076-5	Power transformers－Part 5：Ability to withstand short circuit	2008.03.31
KS C IEC 60076-7	Power transformers－Part 7：Loading guide for oil-immersed power transformers	2008.11.20
KS C IEC 60076-8	Power transformers－Part 8：Application guide	2002.10.29
KS C IEC 60076-10	Power transformers－Part 10：Determination of sound levels	2003.12.29
KS C IEC 60076-10-1	Power transformers－Part 10－1：Determination of sound levels－Application guide	2008.11.20
KS C IEC 60076-11	Power transformers－Part 11：Dry-type transformers	2008.03.31

The energy efficiency regulation sets a MEPS and Target Energy Performance Standard (TEPS) at 50% load factor for three different type of primary voltage/secondary voltage combination as shown in , and .

Table 41 – MEPS and TEPS for Low Voltage Liquid-Type Distribution Transformers in Korea

Type	Primary voltage/ Secondary voltage	Number of phase	Capacity (kVA)	MEPS (%)	TEPS (%)
KS C 4316, KS C 4317	3.3 ~ 6.6 kV/ Low voltage	Single	100	98.4	99
			150	98.4	99
			200	98.4	99
			250	98.5	99.1
			300	98.5	99.1
			400	98.6	99.2
			500	98.6	99.2
			600	98.6	99.2
			750	98.7	99.3
			1000	98.8	99.3
			1250	98.8	99.4
			1500	98.9	99.4
			2000	99	99.4
			2500	99	99.4
			3000	99.1	99.4
		3-phase	100	98	99
			150	98.1	99
			200	98.2	99
			250	98.3	99.1
			300	98.4	99.1
			400	98.4	99.2
			500	98.5	99.2
			600	98.5	99.2
			750	98.6	99.3
			1,000	98.7	99.3
			1,250	98.8	99.4
			1,500	98.8	99.4
			2,000	98.9	99.4
			2,500	99	99.4
			3,000	99.1	99.4

Table 42 – MEPS and TEPS for Low Voltage Liquid-Type Distribution Transformers in Korea

Type	Primary voltage/ Secondary voltage	Number of phase	Capacity (kVA)	MEPS (%)	TEPS (%)
KS C 4316, KS C 4317	22.9 kV/ Low voltage	Single	10	97.4	98.6
			15	97.7	98.6
			20	97.9	98.7
			30	98.1	98.8
			50	98.4	98.8
			75	98.6	98.9
			100	98.7	99
			150	98.4	99
			200	98.4	99
			250	98.5	99.1
			300	98.5	99.1
			400	98.6	99.2
			500	98.6	99.2
			600	98.6	99.2
			750	98.7	99.3
			1,000	98.8	99.3
			1,250	98.8	99.4
			1,500	98.9	99.4
			2,000	99	99.4
			2,500	99.1	99.4
			3,000	99.2	99.4
		3-phase	100	98	99
			150	98.1	99
			200	98.2	99
			250	98.3	99.1
			300	98.4	99.1
			400	98.4	99.1
			500	98.5	99.1
			600	98.5	99.2
			750	98.6	99.2
			1,000	98.7	99.3
			1,250	98.8	99.3
			1,500	98.8	99.3
			2,000	98.9	99.3
			2,500	99	99.4
			3,000	99.1	99.4

Table 43 – MEPS and TEPS for 22.9kV Liquid-Type Distribution Transformers in Korea

Type	Primary voltage/ Secondary voltage	Number of phase	Capacity (kVA)	MEPS	TEPS
KS C 4316, KS C 4317	22.9 kV/ 3.3 ~ 6.6 kV	Single	100	98.4	99.0
			150	98.5	99.0
			200	98.5	99.0
			250	98.6	99.1
			300	98.6	99.1
			400	98.7	99.2
			500	98.8	99.2
			600	98.8	99.2
			750	98.9	99.3
			1,000	98.9	99.3
			1,250	99.0	99.4
			1,500	99.0	99.4
			2,000	99.1	99.4
			2,500	99.1	99.4
			3,000	99.2	99.4
		3-phase	100	98.1	99.0
			150	98.2	99.0
			200	98.2	99.0
			250	98.3	99.1
			300	98.4	99.1
			400	98.5	99.2
			500	98.6	99.2
			600	98.6	99.2
			750	98.6	99.3
			1,000	98.7	99.3
			1,250	98.8	99.4
			1,500	98.9	99.4
			2,000	99.0	99.4
			2,500	99.1	99.4
			3,000	99.2	99.4

Data inputs

Total distributed electricity is calculated from IEA data as the sum of the sales in every sector of the economy plus the T&D losses (IEA, 2012c). We use the growth rate from the national electricity demand forecast to 2030 in the *APERC Energy Demand and Supply Outlook*, 5th Edition (APERC, 2012) to project total distributed electricity to 2030.

Economic data such as sales taxes and labor cost were collected from publicly available sources (BLS, 2012; TMF, 2013). Fuel mix is taken for the year 2015 from (APERC, 2012) in order to calculate the weighted average price of electricity generation from generation cost by fuel type (IEA, 2010).

The CO_2 and NO_x/SO_2 emission factors are taken from the IEA data set on CO_2 emissions from fuel combustion (IEA, 2012a) and calculated based on fuel mix and IPCC guidelines (IPCC, 1997).

summarizes the input data developed for Korea.

Table 44 – Economy-Specific Inputs Summary for Korea in 2010

	Value		Source/Note
Total Distributed Electricity	426	TWh	(IEA, 2012c)
Distribution transformers Capacity	107,700	MVA	calculated
Stock	1.48	Millions	calculated
Average Load Factor	50	%	assumed
Average Capacity	73	kVA	(USDOE, 2013a)
Sales	46,800	Units	calculated
Consumer Discount Rate	10	%	(IEA, 2010)
National Discount Rate	5	%	assumed
VAT	10	%	(TMF, 2013)
Cost of Electricity Generation	0.07	$/kWh	(IEA, 2010)
CO_2 Emission Factor	0.533	kg/kWh	(IEA, 2012a)
SO_2 Emission Factor	0.671	g/kWh	(IPCC, 1997)
NO_x Emission Factor	0.498	g/kWh	(IPCC, 1997)
Labor Cost	19	USD/hour	(BLS, 2012)

Cost-Benefit Analysis

Market data was available from a report based on testing data published in 2010 by the Korea Electric Research Institute to support a establishment of MEPS for distribution transformer (Choi, 2012b). The data consist in 188 transformer models taken from different manufacturers. Market average efficiency and costs were from the data set. We find that the market average efficiency is at EL0. Then, we calculate the cost of conserved energy for different levels of efficiency ranging from EL0 to EL4. Finally, we compare the cost of conserved energy to the cost of electricity generation in order to determine the highest cost-effective efficiency targets. This target provides the greatest energy savings while ensuring a net financial benefit to the consumer (in this case, the utility company).

We find that a MEPS set at the maximum technical level EL4 would be cost effective in the local context for DL1 and DL4. DL5 is found to be cost-effective at the EL3 level. We don’t find any cost-effective option for DL2.

presents the results for the four representative design lines we study:

Table 45 – Cost-Benefit Analysis for Representative Units for Korea

	Baseline	Target
	Representative Design Line 1, 1-phase 50kVA	
Efficiency Rating (%)	98.9%	No Cost-Effective Option
Losses (kWh/year)	2,418	No Cost-Effective Option
Price (USD)	$ 1,328	No Cost-Effective Option
CCE (USD)		No Cost-Effective Option
	Representative Design Line 2, 1-phase 25kVA	
Efficiency Rating (%)	98.7%	No Cost-Effective Option
Losses (kWh/year)	1,437	
Price (USD)	$ 882	
CCE (USD)		
	Representative Design Line 4, 3-phase 150kVA	
Efficiency Rating (%)	98.4%	99.6%
Losses (kWh/year)	10,889	4,319
Price (USD)	$ 2,086	$ 3,380
CCE (USD)		$ 0.021
	Representative Design Line 5, 3-phase 1500kVA	
Efficiency Rating (%)	99.0%	99.7%
Losses (kWh/year)	67,706	21,278
Price (USD)	$ 11,321	$ 37,748
CCE (USD)		$ 0.060

National Impact Analysis

As explained in the methodology section, the results from the cost-benefit analysis are scaled to represent the units found in the Korean market and then propagated into BUENAS to calculate national energy savings, avoided CO_2 emissions and financial impacts, in terms of net present value (NPV).

The following table summarizes the market shares, and average market capacities used to scale the unit level results to the national level along with the resulting scaled UEC and price inputs.

Table 46 – Design Lines (DL) Market Shares and Market Average UEC and Price in Korea

	DL1	**DL2**	**DL4**	**DL5**
DL Market Shares	24.9%	68.3%	4.6%	2.2%
Average Capacity (kVA)	46	26	256	1,451
Scaled Baseline UEC (kWh/year)	2,277	1,473	16,236	66,039
Scaled Baseline Price (USD)	1,251	904	3,110	11,042
Scaled Target UEC (kWh/year)	2,277	1,473	3,958	20,754
Scaled Target Price (USD)	1,251	904	10,103	36,819

We analyze two policy scenarios in this study:

1- A MEPS taking effect in 2016, set at the maximum cost-effective level for all representative design lines.
2- An endorsement label targeting the cost-effective levels for all representative design lines, which would drive a 10% increase in the sales market share every year starting in 2015, up to a maximum of 50% market share by 2020.

presents the national impact analysis results for Korea in 2020 and 2030.

Table 47 – National Impacts Analysis Results for Korea

		Units	Year	MEPS Scenario	Labeling Program Scenario
Annual Impacts	Energy Savings	GWh	2020	421.7	168.7
			2030	1,428.4	667.9
	CO_2 Emissions Savings	Mt	2020	0.2	0.1
			2030	0.8	0.4
	SO_2 Emissions Savings	kt	2020	0.3	0.1
			2030	1.0	0.4
	NOx Emissions Savings	kt	2020	0.2	0.1
			2030	0.7	0.3
Cumulative Impacts	Energy Savings	GWh	through 2020	1,243.4	456.3
			through 2030	10,824.1	4,799.9
	CO_2 Emissions Savings	Mt	through 2020	0.7	0.2
			through 2030	5.8	2.6
	SO_2 Emissions Savings	kt	2020	0.8	0.3
			2030	7.3	3.2
	NOx Emissions Savings	kt	2020	0.6	0.2
			2030	5.4	2.4
	Operating Cost Savings	Million USD		927.5	425.1
	Equipment Cost	Million USD		467.7	214.8
	NPV	MillionUSD		459.9	210.3

These results show the significant savings achievable through an increase of the current MEPS and TEPS levels to the maximum cost effective level or through a labeling program for higher efficiency transformers. As opposed to MEPS, the labeling program does not make the sale of efficient models mandatory, so the impacts of an endorsement label presented in the table above have to be taken as indicative.

In sum, the impacts of adopting a MEPS requiring the highest cost effective efficiency level are:

- 422 GWh of electricity savings in 2020 and 1,428 GWh in 2030.
- 11 TWh cumulative electricity savings between 2016 and 2030.
- 0.2 Mt of annual CO_2 emissions reductions by 2020 and 0.8 Mt by 2030.
- 5.8 Mt cumulative emissions reduction between 2016 and 2030.
- The net present value of the savings would be an estimated 460 Million USD.

2.3.9. Malaysia

In the current analysis, we estimate that the impact of introducing S&L programs for distribution transformers in Malaysia would be:

- 2.1 TWh annual electricity savings from MEPS by 2030
- 46% reduction in national distribution losses by 2030
- 1.5 Mt CO_2 emission avoided by 2030 from MEPS
- 2.5 billion USD net financial benefits from MEPS
- 1.0 TWh annual electricity savings from endorsement label by 2030
- 0.7 Mt CO_2 emissions avoided by 2030 from endorsement label
- 1.1 billion USD net financial benefits from endorsement label

Test Procedure, S&L Status

We were able to locate a paper *Transformer Manufacturers in Malaysia: Perspective In Manufacturing And Performance Status* that was presented at a Kukum Engineering Research seminar in 2006 (Daut and Uthman, 2006). This paper states that the distribution transformers are designed, manufactured and tested to IEC 60076 standards. Further research did not find standards or labeling programs in Malaysia.

Data inputs

Total distributed electricity is calculated from IEA data as the sum of the sales in every sector of the economy plus the T&D losses (IEA, 2012c). We use the growth rate from the national electricity demand forecast to 2030 in the *APERC Energy Demand and Supply Outlook*, 5th Edition (APERC, 2012) to project total distributed electricity to 2030. Sales data between 1999 and 2005 are available by capacity from (Daut and Uthman, 2006). We find a high average unit capacity as it was found in other economies such as Hong Kong. Using sales data and average capacity we estimate the installed capacity in Malaysia to 42,000MVA. The main utility Tenaga Nasional Berhad (TBN) reports a total transmission capacity of 82,990 MVA(TNB, 2010). It is difficult to compare the two figures on installed capacity for transmission and distribution, but this indicates that our estimates are in the right ballpark. We calculate a load factor of 30%, which would decrease as our estimate of the installed distribution capacity would increase (the product of all variables being constant).

The average cost of electricity is estimated at 10 cts/kWh by the TBN utility (TNB, 2010). Sales taxes were collected from TMF (TMF, 2013), and labor costs were derived from GDP/cap using the Philippines as a reference for the scaling factor.

The CO_2 and NO_x/SO_2 emission factors are taken from the IEA data set on CO_2 emissions from fuel combustion (IEA, 2012a) and calculated based on fuel mix and IPCC guidelines (IPCC, 1997).

Table 48 summarizes the input data developed for Malaysia.

Table 48 – Economy-Specific Inputs Summary for Malaysia in 2010

	Value		Source/Note
Total Distributed Electricity	103	TWh	(IEA, 2012c)
Distribution transformers Capacity	44,900	MVA	calculated
Stock	0.058	Millions	calculated
Average Load Factor	30	%	calculated
Average Capacity	770	kVA	(Daut and Uthman, 2006)
Annual Sales	4,700	Units	derived from historical data (Daut and Uthman, 2006)
Consumer Discount Rate	10	%	(IEA, 2010)
National Discount Rate	5	%	assumed
VAT	6	%	(TMF, 2013)
Cost of Electricity Generation	0.10	\$/kWh	(TNB, 2010)
CO_2 Emission Factor	0.727	kg/kWh	(IEA, 2012a)
SO_2 Emission Factor	0.677	g/kWh	(IPCC, 1997)
NO_x Emission Factor	0.685	g/kWh	(IPCC, 1997)
Labor Cost	9	\$/hour	derived from GDP/cap

Cost-Benefit Analysis

Baseline efficiency is a key determinant in the cost-benefit analysis. In general, if a economy has not had a program on distribution transformers, this information is difficult to obtain. As explained in the methodology section, to determine the "floor" of energy efficiency that we define as EL0, we rely on estimates of baselines taken from other countries *before* they implemented their first distribution transformer program. Then, we calculate the cost of conserved energy for different levels of efficiency ranging from EL0 to EL4. Finally, we compare the cost of conserved energy to the cost of electricity generation to determine the highest cost-effective efficiency targets. These targets result in the greatest energy savings while ensuring a net financial benefit to the consumer (in this case, the utility company).

We find that a MEPS set at the maximum technical level EL4 would be cost effective in the local context.

Table 49 presents the results for the four representative design lines we study:

Table 49 – Cost-Benefit Analysis for Representative Units for Malaysia

	Baseline	Target
	Representative Design Line 1, 1-phase 50kVA	
Efficiency Rating (%)	98.5%	99.5%
Losses (kWh/year)	2,124	663
Price (USD)	$ 756	$ 2,010
CCE (USD)		$ 0.090
	Representative Design Line 2, 1-phase 25kVA	
Efficiency Rating (%)	98.0%	99.0%
Losses (kWh/year)	1,505	794
Price (USD)	$ 415	$ 992
CCE (USD)		$ 0.085
	Representative Design Line 4, 3-phase 150kVA	
Efficiency Rating (%)	98.3%	99.6%
Losses (kWh/year)	7,880	3,364
Price (USD)	$ 1,712	$ 4,905
CCE (USD)		$ 0.074
	Representative Design Line 5, 3-phase 1500kVA	
Efficiency Rating (%)	98.9%	99.7%
Losses (kWh/year)	46,752	13,635
Price (USD)	$ 9,315	$ 34,256
CCE (USD)		$ 0.079

National Impact Analysis

As explained in the methodology section, the results from the cost-benefit analysis are scaled to represent the units found in the Malaysian market and then propagated into BUENAS to calculate national energy savings, avoided CO_2 emissions and financial impacts, in terms of net present value (NPV).

The following table summarizes the market shares, and average market capacities used to scale the unit level results to the national level taken from (Daut and Uthman, 2006) along with the resulting scaled UEC and price inputs.

Table 50 – Design Lines (DL) Market Shares and Market Average UEC and Price in Malaysia

	DL1	DL2	DL4	DL5
DL Market Shares	0.0%	0.0%	31.5%	68.5%
Average Capacity (kVA)	-	-	399	943
Scaled Baseline UEC (kWh/year)	-	-	16,413	33,012
Scaled Baseline Price (USD)	-	-	3,565	6,577
Scaled Target UEC (kWh/year)	-	-	3,456	9,628
Scaled Target Price (USD)	-	-	12,346	24,189

We analyze two policy scenarios in this study:

1- A MEPS taking effect in 2016, set at the maximum cost-effective level for all representative design lines.

2- An endorsement label targeting the cost-effective levels for all representative design lines, which would drive a 10% increase in the sales market share every year starting in 2015, up to a maximum of 50% market share by 2020.

Table 51 presents the national impact analysis results for Malaysia in 2020 and 2030.

Table 51 – National Impacts Analysis Results for Malaysia

		Units	Year	MEPS Scenario	Labeling Program Scenario
Annual Impacts	Energy Savings	GWh	2020	600.1	241.8
			2030	2,072.1	979.9
	CO_2 Emissions Savings	Mt	2020	0.4	0.2
			2030	1.5	0.7
	SO_2 Emissions Savings	kt	2020	0.4	0.2
			2030	1.4	0.7
	NOx Emissions Savings	kt	2020	0.4	0.2
			2030	1.4	0.7
Cumulative Impacts	Energy Savings	GWh	through 2020	1,766.6	650.2
			through 2030	15,552.3	6,969.0
	CO_2 Emissions Savings	Mt	through 2020	1.3	0.5
			through 2030	11.3	5.1
	SO_2 Emissions Savings	kt	2020	1.2	0.4
			2030	10.5	4.7
	NOx Emissions Savings	kt	2020	1.2	0.4
			2030	10.7	4.8
	Operating Cost Savings	Million USD		3,414.30	1,579.40
	Equipment Cost	Million USD		947.17	438.15
	NPV	Million USD		2,467.13	1,141.25

These results show the significant savings achievable through a MEPS or a labeling program. As opposed to MEPS, the labeling program does not make the sale of efficient models mandatory, so the impacts of an endorsement label presented in the table above have to be taken as indicative.
In sum, the impacts of adopting a MEPS requiring the highest cost effective efficiency level are:

- 600 GWh of electricity savings in 2020 and 2,072 GWh in 2030.
- 15.6 TWh cumulative electricity savings between 2016 and 2030.
- 0.4 Mt of annual CO_2 emissions reductions by 2020 and 1.5 Mt by 2030.
- 11.3 Mt cumulative emissions reduction between 2016 and 2030.
- The net present value of the savings would be an estimated 2.5 Billion USD.

2.3.10. Mexico

In the current analysis, we estimate that the impact of introducing more stringent or additional S&L programs for distribution transformers in Mexico would be:

- 1.4 TWh annual electricity savings from MEPS by 2030
- 23% reduction in national distribution losses by 2030
- 0.7 Mt CO_2 emission avoided by 2030 from MEPS
- 832 million USD net financial benefits from MEPS
- 0.7 TWh annual electricity savings from endorsement label by 2030
- 0.3 Mt CO_2 emissions avoided by 2030 from endorsement label
- 385 million USD net financial benefits from endorsement label

Test Procedure, S&L Status

Mexico is one of the regional leaders in Latin America in promoting and regulating energy efficient transformers. In recent years, other countries, such as Argentina, Ecuador, and Peru, have requested assistance from Mexico to develop and implement national efficiency programs.

Mexico began regulating distribution transformers more than three decades ago when it enacted NOM-J116 in 1977. The latest version of the Norma Mexicana (NOM) was enacted in 2010 when NOM-002 was revised to update several aspects of the standard. The new version of the document, NOM-002-SEDE-2010, was approved by the Comité Consultivo Nacional de Normalización de Instalaciones Eléctricas (CCNNIE) on July 8, 2010.

This standard, which applies to liquid-immersed units, is the only compulsory efficiency regulation for distribution transformers in Mexico. Table 52 describes the scope of the standard for liquid-type distribution transformers in Mexico.

Table 52 – Scope of Regulation for Liquid-Type Distribution Transformers in Mexico

Characteristics	**Specification**
Power Supply	Single-phase Three-phase
Nominal Capacity	5 to 167 kVA (single-phase) 15 to 500 kVA (three-phase)
Insulation Class	Up to 95 kV BIL (Up to 15kV) Up to 150 kV BIL (Up to 25 kV) Up to 200 kV BIL (Up to 34.5 kV)
Installation Application	Pad; Pole; Substation; Submersible
Status of Transformer	Newly purchased Repaired/Refurbished

Table 47 shows the MEPS definition for Mexican transformers, calculated from NLL and LL at a 50% load.

Table 53 – Minimum Efficiency Levels for Liquid-Type Distribution Transformers in Mexico

Type	kVA	**Up to 95 kV BIL** (Up to 15 kV) %	**Up to 150 kV BIL** (Up to 25 kV) %	**Up to 200 kV BIL** (Up to 34.5 kV) %
Single-Phase	5	98.07%	97.79%	97.02%
	10	98.43%	98.24%	97.81%
	15	98.59%	98.41%	97.98%
	25	98.76%	98.63%	98.32%
	37.5	98.87%	98.76%	98.50%
	50	98.96%	98.85%	98.65%
	75	99.08%	98.97%	98.82%
	100	99.12%	99.03%	98.90%
	167	99.17%	99.08%	99.02%
Three-Phase	15	98.11%	97.85%	97.56%
	30	98.45%	98.26%	98.00%
	45	98.58%	98.42%	98.21%
	75	98.74%	98.60%	98.43%
	112.5	98.84%	98.72%	98.61%
	150	98.90%	98.80%	98.73%
	225	98.88%	98.78%	98.68%
	300	98.95%	98.85%	98.76%
	500	99.05%	98.96%	98.89%

In February 2013 the Secretariat of Energy released tables of efficiency values and maximum losses for public comment (Anteproyecto de Norma Oficial Mexicana NOM-002-SEDE/ENER-2012).Table 54 shows the proposed MEPS definition for Mexican transformers, tested at 80% load.

Table 54 – Proposed Minimum Efficiency Levels for Liquid-Type Distribution Transformers in Mexico

Type	kVA	Up to 95 kV BIL (Up to 15 kV)	Up to 150 kV BIL (Up to 25 kV)	Up to 200 kV BIL (Up to 34.5 kV)
		%	%	%
Single-Phase	10	98.61%	98.49%	98.28%
	15	98.75%	98.63%	98.43%
	25	98.90%	98.79%	98.63%
	37.5	98.99%	98.90%	98.75%
	50	99.08%	98.99%	98.86%
	75	99.21%	99.12%	99.00%
	100	99.26%	99.16%	99.06%
	167	99.30%	99.21%	99.13%
Three-Phase	15	98.32%	98.18%	98.03%
	30	98.62%	98.50%	98.35%
	45	98.72%	98.60%	98.48%
	75	98.86%	98.75%	98.64%
	112.5	98.95%	98.85%	98.76%
	150	99.03%	98.94%	98.86%
	225	99.06%	98.96%	98.87%
	300	99.11%	99.02%	98.92%
	500	99.20%	99.11%	99.03%

Data inputs

Total distributed electricity is calculated from IEA data as the sum of the sales in every sector of the economy plus the T&D losses (IEA, 2012c). We use the growth rate from the national electricity demand forecast to 2030 in the *APERC Energy Demand and Supply Outlook*, 5th Edition (APERC, 2012) to project total distributed electricity to 2030. Sales data have been provided by ICA for all distribution transformers in Mexico between 2008 and 2012. We then disaggregated the sales figures into liquid-type and dry-type in order to focus on the scope of our study. By back casting sales from historical data, we calculate the existing stock and are able to estimate an average load factor of 31%.

Economic data such as sales taxes and labor costs were collected from publicly available sources (BLS, 2012; TMF, 2013). Fuel mix is taken for the year 2015 from APERC (APERC, 2012) to calculate the weighted average price of electricity generation from generation cost by fuel type (IEA, 2010).

The CO_2 and NO_x/SO_2 emission factors are taken from the IEA data set on CO_2 emissions from fuel combustion (IEA, 2012a) and calculated based on fuel mix and IPCC guidelines (IPCC, 1997).

Table 55 summarizes all of the data available for Mexico.

Table 55 – Economy-Specific Inputs Summary for Mexico in 2010

	Value		Source/Note
Total Distributed Electricity	240	TWh	(IEA, 2012c)
Distribution transformers Capacity	96,900	MVA	calculated
Stock	1.4	Million	calculated
Average Load Factor	31	%	calculated
Average Capacity	73	kVA	(USDOE, 2013a)
Annual Sales	70,300	Units	ICA data
Consumer Discount Rate	10	%	(IEA, 2010)
National Discount Rate	5	%	assumed
VAT	16	%	(TMF, 2013)
Cost of Electricity Generation	0.11	$/kWh	derived from (IEA, 2010)
CO_2 Emission Factor	0.455	kg/kWh	(IEA, 2012a)
SO_2 Emission Factor	1.000	kg/kWh	(IPCC, 1997)
NO_x Emission Factor	0.518	kg/kWh	(IPCC, 1997)
Labor Cost	6.5	USD/hour	(BLS, 2012)

Cost-Benefit Analysis

Based on the values calculated in Table 53, we find that the baseline efficiency level is between EL1 and EL2 for the DL covered by the regulation. DL5 is not covered by the current MEPS, so we assume that the efficiency level is at the technical floor EL0 for this design line. We calculate the cost of conserved energy for different levels of efficiency ranging from the baseline to EL4 and compare the cost of conserved energy to the cost of electricity generation to determine the highest cost-effective efficiency targets. These targets provide the greatest energy savings while ensuring a net financial benefit to the consumer (in this case, the utility company).

Even though the cost of conserved energy to harmonize with the 2016 U.S. MEPS level are very close to the cost of electricity generation that we estimated, we don't find any further cost-effective options for the single-phase distribution transformers (DL1 and DL2).. For DL4 and DL5, we find that the maximum technical level is cost effective (EL4).

Table 56 presents the results for the four representative design lines we study:

Table 56 – Cost-Benefit Analysis for Representative Units for Mexico

	Baseline	Target
	Representative Design Line 1, 1-phase 50kVA	
Efficiency Rating (%)	98.8%	No Cost-Effective Option
Losses (kWh/year)	1,707	
Price (USD)	$ 1,164	
CCE (USD)		
	Representative Design Line 2, 1-phase 25kVA	
Efficiency Rating (%)	98.6%	No Cost-Effective Option
Losses (kWh/year)	1,046	
Price (USD)	$ 791	
CCE (USD)		
	Representative Design Line 4, 3-phase 150kVA	
Efficiency Rating (%)	98.8%	99.6%
Losses (kWh/year)	5,541	1,685
Price (USD)	$ 3,414	$ 6,414
CCE (USD)		$ 0.082
	Representative Design Line 5, 3-phase 1500kVA	
Efficiency Rating (%)	98.9%	99.7%
Losses (kWh/year)	47,498	13,853
Price (USD)	$ 10,041	$ 36,928
CCE (USD)		$ 0.084

National Impact Analysis

As explained in the methodology section, the results from the cost-benefit analysis are scaled to represent the units found on the Mexican market and then propagated into BUENAS to calculate national energy savings, avoided CO_2 emissions, and financial impacts in terms of net present value (NPV).

Table 57 summarizes the market shares and average market capacities used to scale the unit level results to the national level. The table also includes the resulting scaled UEC and price inputs.

Table 57 – Design Lines (DL) Market Shares and Market Average UEC and Price in Mexico

	DL1	DL2	DL4	DL5
DL Market Shares	24.9%	68.3%	4.6%	2.2%
Average Capacity (kVA)	46	26	256	1,451
Scaled Baseline UEC (kWh/year)	1,608	1,072	8,263	46,328
Scaled Baseline Price (USD)	1,096	811	5,090	9,794
Scaled Target UEC (kWh/year)	1,608	1,072	2,513	13,511
Scaled Target Price (USD)	1,096	811	9,564	36,019

We analyze two policy scenarios in this study:

1- A MEPS taking effect in 2016, set at the maximum cost-effective level for all representative design lines.
2- An endorsement label targeting the cost-effective levels for all representative design lines, which would drive a 10% increase in the sales market share every year starting in 2015, up to a maximum of 50% market share by 2020.

Table 58 presents the national impact analysis results for Mexico in 2020 and 2030.

Table 58 – National Impacts Analysis Results for Mexico

		Units	**Year**	**MEPS Scenario**	**Labeling Program Scenario**
Annual Impacts	Energy Savings	GWh	2020	417.6	168.3
			2030	1,433.7	677.7
	CO_2 Emissions Savings	Mt	2020	0.2	0.1
			2030	0.7	0.3
	SO_2 Emissions Savings	kt	2020	0.4	0.2
			2030	1.4	0.7
	NOx Emissions Savings	kt	2020	0.2	0.1
			2030	0.7	0.4
Cumulative Impacts	Energy Savings	GWh	through 2020	1,230.3	452.8
			through 2030	10,789.1	4,832.2
	CO_2 Emissions Savings	Mt	through 2020	0.6	0.2
			through 2030	4.9	2.2
	SO_2 Emissions Savings	kt	2020	1.2	0.5
			2030	10.8	4.8
	NOx Emissions Savings	kt	2020	0.6	0.2
			2030	5.6	2.5
	Operating Cost Savings	Million USD		1,538.1	711.1
	Equipment Cost	Million USD		705.5	326.2
	NPV	Million USD		832.5	384.9

These results show the significant savings achievable through an increase of the current MEPS levels beyond the current proposed levels for three-phase distribution transformers to the maximum cost effective level or through a labeling program for higher efficiency transformers. For single-phase distribution transformers, we don’t find any cost-effective options, but given the small difference between the cost of conserved energy and the cost of generation, further work is needed to validate our assumptions. In contrast to a MEPS, a labeling program does not make the sale of efficient models mandatory, so the impacts of an endorsement label presented in Table 58 must be considered indicative.

In sum, the impacts of adopting a MEPS requiring the highest cost-effective efficiency level are:

- 417 GWh of electricity savings in 2020 and 1,434 GWh in 2030
- 10.8 TWh cumulative electricity savings between 2016 and 2030
- 0.2 Mt of annual CO_2 emissions reductions by 2020 and 0.7 Mt by 2030
- 4.9 Mt cumulative emissions reduction between 2016 and 2030
- 832 Million USD estimated net present value of savings

2.3.11. New Zealand

In the current analysis, we estimate that the impact of introducing more stringent or additional S&L programs for distribution transformers in New Zealand would be:

- 152 GWh annual electricity savings from MEPS by 2030
- 34% reduction in national distribution losses by 2030
- 0.02 Mt CO_2 emission avoided by 2030 from MEPS
- 152 million USD net financial benefits from MEPS
- 72 GWh annual electricity savings from endorsement label by 2030
- 0.01 Mt CO_2 emissions avoided by 2030 from endorsement label
- 71 million USD net financial benefits from endorsement label

Test Procedure, S&L Status

Since 2004, the Australian and New Zealand government have agreed to regulate single and three phase, dry and oil immersed transformers with a power rating between 10kVA and 2500kVA that are designed for 11kV and 22kV networks, to comply with MEPS to meet the efficiency requirement. The current MEPS for transformer efficiency is set out in AS 2374.1.2-2003, at a rated load of 50% (AS/NZS). AS 2374.1.2-2003 also sets out voluntary Higher Energy Performance levels (HEPS) as aspirational targets. The MEPS also defines transformers that are exempt from the regulation such as instrument transformers; auto transformers; traction transformers mounted on rolling stock, etc.

The test procedure is defined in AS 2374.1.2-2003 and is based on but not equivalent to IEC 60076-1:1993. It includes Australian variations such as commonly used power ratings and preferred methods of cooling, connections in general use, and details regarding connection designation.

The equipment energy efficiency program (E3) is currently in the process of reviewing the MEPS for distribution transformers considering a possible increase of the MEPS levels to approximately the same as current HEPS levels and expanding the scope to include 33kV networks (wind farms) and larger transformers up to 3150 kVA (E3, 2011).

Data inputs

Total distributed electricity is calculated from IEA data as the sum of the sales in every sector of the economy plus the T&D losses (IEA, 2012c). We use the growth rate from the national electricity demand forecast to 2030 in the *APERC Energy Demand and Supply Outlook*, 5th Edition (APERC, 2012) to project total distributed electricity to 2030. Sales data by capacity have been provided by the APEC representative at the Energy Efficiency and Conservation Authority (EECA) for the years between 2005 and 2011. We extrapolate the sales in order to calculate the stock and installed capacity, from which we can calculate the average load factor.

Economic data such as sales taxes and labor cost were collected from publicly available sources (BLS, 2012; TMF, 2013). Historical trends of cost of production between 1990 and 2011 have been provided by EECA. We use the 2011 data in order to compare to the cost of conserved energy.

The CO_2 and NO_x/SO_2 emission factors are taken from the IEA data set on CO_2 emissions from fuel combustion (IEA, 2012a) and calculated based on fuel mix and IPCC guidelines (IPCC, 1997).

Table 59 summarizes the input data developed for New Zealand.

Table 59 – Economy-Specific Inputs Summary for New Zealand in 2011

	Value		Source/Note
Total Distributed Electricity	41.5	TWh	(IEA, 2012c)
Distribution transformers Capacity	27,000	MVA	calculated
Stock	0.093	Millions	EECA/ LBNL extrapolation
Average Load Factor	19	%	calculated
Average Capacity	142	kVA	EECA
Annual Sales	3,300	Units	EECA
Consumer Discount Rate	8	%	
National Discount Rate	3	%	assumed
VAT	12.5	%	(TMF, 2013)
Lifetime	32	years	(USDOE, 2013a)
Cost of Electricity Generation	0.09	$/kWh	EECA
CO_2 Emission Factor	0.167	kg/kWh	(IEA, 2012a)
SO_2 Emission Factor	0.112	g/kWh	(IPCC, 1997)
NO_x Emission Factor	0.185	g/kWh	(IPCC, 1997)
Labor Cost	23	USD/hour	(BLS, 2012)

Cost-Benefit Analysis

Given the similarities between the Australian and New Zealand markets and regulations, we assume the same baseline efficiency in both countries, which was found to be between EL1 and EL2. Then, we calculate the cost of conserved energy for different levels of efficiency ranging from the baseline to EL4. Finally, we compare the cost of conserved energy to the cost of electricity generation in order to determine the highest cost-effective efficiency targets. This target provides the greatest energy savings while ensuring a net financial benefit to the consumer (in this case, the utility company).

As it was found in Australia, we find that a MEPS harmonized with the 2016 U.S. MEPS would be cost effective for all design lines in the local context. DL1, DL4 and DL5 are found to be cost effective at the highest efficiency level EL4.

Table 60 presents the results for the four representative design lines we study:

Table 60 – Cost-Benefit Analysis for Representative Units for New Zealand

	Baseline		Target	
	Representative Design Line 1, 1-phase 50kVA			
Efficiency Rating (%)		98.9%		99.5%
Losses (kWh/year)		1,270		488
Price (USD)	$	1,482	$	2,433
CCE (USD)			$	0.077
	Representative Design Line 2, 1-phase 25kVA			
Efficiency Rating (%)		98.6%		99.0%
Losses (kWh/year)		862		664
Price (USD)	$	864	$	1,168
CCE (USD)			$	0.097
	Representative Design Line 4, 3-phase 150kVA			
Efficiency Rating (%)		99.0%		99.6%
Losses (kWh/year)		3,883		1,309
Price (USD)	$	4,492	$	6,927
CCE (USD)			$	0.060
	Representative Design Line 5, 3-phase 1500kVA			
Efficiency Rating (%)		99.4%		99.7%
Losses (kWh/year)		21,400		11,136
Price (USD)	$	22,036	$	40,351
CCE (USD)			$	0.113

National Impact Analysis

As explained in the methodology section, the results from the cost-benefit analysis are scaled to represent the units found in the New Zealand market and then propagated into BUENAS to calculate national energy savings, avoided CO_2 emissions and financial impacts, in terms of net present value (NPV).

The following table summarizes the market shares, and average market capacities used to scale the unit level results to the national level along with the resulting scaled UEC and price inputs.

Table 61 – Design Lines (DL) Market Shares and Market Average UEC and Price in New Zealand

	DL1	DL2	DL4	DL5
DL Market Shares	0.8%	22.8%	74.2%	2.2%
Average Capacity (kVA)	50	19	155	1,039
Scaled Baseline UEC (kWh/year)	1,270	710	3,979	16,251
Scaled Baseline Price (USD)	1,482	711	4,604	16,734
Scaled Target UEC (kWh/year)	488	547	1,341	8,457
Scaled Target Price (USD)	2,433	961	7,099	30,642

We analyze two policy scenarios in this study:

1- A MEPS taking effect in 2016, set at the maximum cost-effective level for all representative design lines.
2- An endorsement label targeting the cost-effective levels for all representative design lines, which would drive a 10% increase in the sales market share every year starting in 2015, up to a maximum of 50% market share by 2020.

Table 62 presents the national impact analysis results for New Zealand in 2020 and 2030.

Table 62 – National Impacts Analysis Results for New Zealand

		Units	Year	MEPS Scenario	Labeling Program Scenario
Annual Impacts	Energy Savings	GWh	2020	48.594	19.498
			2030	152.836	71.784
	CO_2 Emissions Savings	Mt	2020	0.007	0.003
			2030	0.023	0.011
	SO_2 Emissions Savings	kt	2020	0.005	0.002
			2030	0.017	0.008
	NOx Emissions Savings	kt	2020	0.009	0.004
			2030	0.028	0.013
Cumulative Impacts	Energy Savings	GWh	through 2020	144.752	53.156
			through 2030	1,197.438	532.159
	CO_2 Emissions Savings	Mt	through 2020	0.022	0.008
			through 2030	0.180	0.080
	SO_2 Emissions Savings	kt	2020	0.016	0.006
			2030	0.135	0.060
	NOx Emissions Savings	kt	2020	0.027	0.010
			2030	0.222	0.099
	Operating Cost Savings	Million USD		270.4	125.2
	Equipment Cost	Million USD		118.1	54.7
	NPV	Million USD		152.4	70.5

These results show the significant savings achievable through an increase of the current MEPS levels beyond the present HEPS to the maximum cost effective level or through a labeling program for higher efficiency transformers. As opposed to MEPS, the labeling program does not make the sale of efficient models mandatory, so the impacts of an endorsement label presented in the table above have to be taken as indicative.

In sum, the impacts of adopting a MEPS requiring the highest cost effective efficiency level are:

- 49 GWh of electricity savings in 2020 and 153 GWh in 2030.
- 1.2 TWh cumulative electricity savings between 2016 and 2030.
- 0.01 Mt of annual CO_2 emissions reductions by 2020 and 0.02 Mt by 2030.
- 0.18 Mt cumulative emissions reduction between 2016 and 2030.
- The net present value of the savings would be an estimated 152 Million USD.

2.3.12. Papua New Guinea

In the current analysis, we estimate that the impact of introducing S&L programs for distribution transformers in Papua New Guinea would be:

- 52 GWh annual electricity savings from MEPS by 2030
- 33% reduction in national distribution losses by 2030
- 0.03 Mt CO_2 emission avoided by 2030 from MEPS
- 71 million USD net financial benefits from MEPS
- 24 GWh annual electricity savings from endorsement label by 2030
- 0.01 Mt CO_2 emissions avoided by 2030 from endorsement label
- 34 million USD net financial benefits from endorsement label

Test Procedure, S&L Status

Our research on Papua New Guinea did not find any test procedure, standards, or labeling programs in that economy.

Data inputs

Data for Papua New Guinea is difficult to obtain even from international databases. We couldn't collect total distributed electricity is calculated from IEA data. Instead we use electricity generation forecast to 2030 from the APERC Energy Demand and Supply Outlook, 5th Edition (APERC, 2012).

Sales taxes were collected from (TMF, 2013) and labor cost were from GDP/cap using the Philippines as a reference for the scaling factor. Based on fuel mix in 2015 (APERC, 2012), we calculate weighted average price of electricity generation from generation cost by fuel type that have been estimated for Indonesia (USAID, 2007).

The CO2 emission factor is not available from the IEA data set, instead we use the ratio of allocated CO_2 emissions to the electricity sector and electricity generation from (APERC, 2012) to calculate the national CO_2 emission factor. NO_x/SO_2 emission factors are calculated based on fuel mix and IPCC guidelines (IPCC, 1997).

Table 63 summarizes the input data developed for Papua New Guinea.

Table 63 – Economy-Specific Inputs Summary for Papua New Guinea in 2010

	Value		Source/Note
Electricity Generation	3.7	TWh	(APERC, 2012)
Distribution transformers Capacity	940	MVA	calculated
Stock	12,900	Units	calculated
Average Load Factor	50	%	assumed
Average Capacity	73	kVA	(USDOE, 2013a)
Annual Sales	410	Units	calculated
Consumer Discount Rate	10	%	(IEA, 2010)
National Discount Rate	5	%	assumed
VAT	10	%	(TMF, 2013)
Lifetime	32	years	(USDOE, 2013a)
Cost of Electricity Generation	0.20	$/kWh	derived from (USAID, 2007)
CO_2 Emission Factor	0.541	kg/kWh	calculated from (APERC 2012)
SO_2 Emission Factor	2.199	g/kWh	(IPCC, 1997)
NO_x Emission Factor	0.387	g/kWh	(IPCC, 1997)
Labor Cost	1.5	$/hour	derived from GDP/cap

Cost-Benefit Analysis

Baseline efficiency is a key determinant in the cost-benefit analysis. In general, if a economy has not had a program on distribution transformers, this information is difficult to obtain. As explained in the methodology section, to determine the “floor” of energy efficiency that we define as EL0, we rely on estimates of baselines taken from other countries *before* they implemented their first distribution transformer program. Then, we calculate the cost of conserved energy for different levels of efficiency ranging from EL0 to EL4. Finally, we compare the cost of conserved energy to the cost of electricity generation to determine the highest cost-effective efficiency targets. These targets result in the greatest energy savings while ensuring a net financial benefit to the consumer (in this case, the utility company).

We find that a MEPS set at the maximum technical level (EL4) would be cost-effective in the local context.

Table 64 presents the results for the four representative design lines we study:

Table 64 – Cost-Benefit Analysis for Representative Units for Papua New Guinea

	Baseline		Target	
	Representative Design Line 1, 1-phase 50kVA			
Efficiency Rating (%)		98.5%		99.5%
Losses (kWh/year)		3,241		1,139
Price (USD)	$	743	$	1,977
CCE (USD)			$	0.062
	Representative Design Line 2, 1-phase 25kVA			
Efficiency Rating (%)		98.0%		99.5%
Losses (kWh/year)		2,225		911
Price (USD)	$	408	$	1,256
CCE (USD)			$	0.068
	Representative Design Line 4, 3-phase 150kVA			
Efficiency Rating (%)		98.3%		99.6%
Losses (kWh/year)		11,292		4,722
Price (USD)	$	1,684	$	4,825
CCE (USD)			$	0.050
	Representative Design Line 5, 3-phase 1500kVA			
Efficiency Rating (%)		98.9%		99.7%
Losses (kWh/year)		71,727		20,919
Price (USD)	$	9,162	$	33,695
CCE (USD)			$	0.051

National Impact Analysis

As explained in the methodology section, the results from the cost-benefit analysis are scaled to represent the units found in the Papua New Guinean market and then propagated into BUENAS to calculate national energy savings, avoided CO_2 emissions and financial impacts, in terms of net present value (NPV).

The following table summarizes the market shares, and average market capacities used to scale the unit level results to the national level along with the resulting scaled UEC and price inputs.

Table 65 – Design Lines (DL) Market Shares and Market Average UEC and Price in Papua New Guinea

	DL1	**DL2**	**DL4**	**DL5**
DL Market Shares	24.9%	68.3%	4.6%	2.2%
Average Capacity (kVA)	46	26	256	1,451
Scaled Baseline UEC (kWh/year)	3,053	2,281	16,837	69,961
Scaled Baseline Price (USD)	700	418	2,510	8,937
Scaled Target UEC (kWh/year)	1,073	611	4,036	20,404
Scaled Target Price (USD)	1,863	1,839	8,694	32,866

We analyze two policy scenarios in this study:

1- A MEPS taking effect in 2016, set at the maximum cost-effective level for all representative design lines.
2- An endorsement label targeting the cost-effective levels for all representative design lines, which would drive a 10% increase in the sales market share every year starting in 2015, up to a maximum of 50% market share by 2020.

Table 66 presents the national impact analysis results for Papua New Guinea in 2020 and 2030.

Table 66 – National Impacts Analysis Results for Papua New Guinea

		Units	Year	MEPS Scenario	Labeling Program Scenario
Annual Impacts	Energy Savings	GWh	2020	11.483	4.594
			2030	52.249	24.431
	CO_2 Emissions Savings	Mt	2020	0.006	0.002
			2030	0.028	0.013
	SO_2 Emissions Savings	kt	2020	0.025	0.010
			2030	0.115	0.054
	NOx Emissions Savings	kt	2020	0.004	0.002
			2030	0.020	0.009
Cumulative Impacts	Energy Savings	GWh	through 2020	32.426	11.924
			through 2030	349.125	155.843
	CO_2 Emissions Savings	Mt	through 2020	0.018	0.006
			through 2030	0.189	0.084
	SO_2 Emissions Savings	kt	2020	0.071	0.026
			2030	0.768	0.343
	NOx Emissions Savings	kt	2020	0.013	0.005
			2030	0.135	0.060
	Operating Cost Savings	Million USD		84.03	38.85
	Equipment Cost	Million USD		12.97	4.92
	NPV	Million USD		71.07	33.93

These results show the significant savings achievable through a MEPS or a labeling program. As opposed to MEPS, the labeling program does not make the sale of efficient models mandatory, so the impacts of an endorsement label presented in the table above have to be taken as indicative.

In sum, the impacts of adopting a MEPS requiring the highest cost effective efficiency level are:

• 11 GWh of electricity savings in 2020 and 52 GWh in 2030.
• 0.35 TWh cumulative electricity savings between 2016 and 2030.
• 0.01 Mt of annual CO_2 emissions reductions by 2020 and 0.03 Mt by 2030.
• 0.2 Mt cumulative emissions reduction between 2016 and 2030.
• The net present value of the savings would be an estimated 71 Million USD.

2.3.13. Peru

In the current analysis, we estimate that the impact of introducing S&L programs for distribution transformers in Peru would be:

- 0.4 TWh annual electricity savings from MEPS by 2030
- 26% reduction in national distribution losses by 2030
- 0.1 Mt CO_2 emission avoided by 2030 from MEPS
- 145 million USD net financial benefits from MEPS
- 0.2 TWh annual electricity savings from endorsement label by 2030
- 0.06 Mt CO_2 emissions avoided by 2030 from endorsement label
- 67 million USD net financial benefits from endorsement label

Test Procedure, S&L Status

Efficiency requirements for liquid-type distribution transformers have been issued as part of the "Proyecto de Norma Técnica Peruana" (PNTP) in 2013. The 1st edition of the PNTP covers single-phase distribution transformers from 5 to 50kVA and three-phase distribution transformers from 15kVA to 630kVA. The test procedure NTP 370.002 is based on IEC 60076-1. Table 67 and Table 68 present the efficiency requirements defined in the PNTP.

Table 67 – Proposed Efficiency Requirements for Single-Phase Liquid-Type Distribution Transformers in Peru

	Liquid-Type, Single-Phase (60Hz) Low Voltage			Liquid-Type, Single-Phase (60Hz) Medium Voltage		
Capacity (kVA)	**NLL (W)**	**LL (W)**	**Efficiency (%)**	**NLL (W)**	**LL (W)**	**Efficiency (%)**
5	49	142	96.73%	62	144	96.2%
10	68	211	97.64%	81	233	97.3%
15	86	278	97.97%	101	319	97.6%
20	103	342	98.15%	125	388	97.8%
25	120	410	98.25%	150	469	97.9%
37.5	165	608	98.34%	196	629	98.2%
50	199	776	98.45%	240	793	98.3%

Table 68 – Proposed Efficiency Requirements for Three-Phase Liquid-Type Distribution Transformers in Peru

	Liquid-Type, Three-Phase (60Hz) Low Voltage			Liquid-Type, Three-Phase (60Hz) Medium Voltage		
Capacity (kVA)	NLL (W)	LL (W)	Efficiency (%)	NLL (W)	LL (W)	Efficiency (%)
15	106	451	97.17%	135	452	96.80%
25	146	595	97.70%	174	653	97.37%
37.5	188	866	97.89%	210	900	97.73%
50	232	1120	97.99%	248	1135	97.92%
75	300	1521	98.22%	327	1551	98.13%
100	374	1920	98.32%	417	1975	98.21%
125	442	2239	98.42%	483	2317	98.33%
160	537	2775	98.48%	571	2843	98.42%
200	606	3375	98.57%	648	3257	98.56%
250	734	3804	98.67%	771	3737	98.65%
315	837	4533	98.76%	866	4500	98.75%
400	968	5550	98.84%	1050	5429	98.81%
500	1179	6540	98.89%	1221	6464	98.88%
630	1411	8136	98.92%	1486	8144	98.89%

Data inputs

Total distributed electricity is calculated from IEA data as the sum of the sales in every sector of the economy plus the T&D losses (IEA, 2012c). We use the growth rate from the national electricity demand forecast to 2030 in the *APERC Energy Demand and Supply Outlook*, 5th Edition (APERC, 2012) to project total distributed electricity to 2030.
Sales information has been collected from the customs and indicates that 15,700 distribution transformers above 10kVA have been imported in 2012. When making the correction for liquid-type only distribution transformers (75% of the market[7]), we estimate the annual sales to be 11,800. The BUENAS model estimates are in very good agreement with calculated sales of 11,500 in 2012. The customs data also allow us to estimate an average capacity of 25kVA, with 90% of the market falling in this category (DL2), and also coincides with the capacities that will be regulated by the PNTP 370.400 presented above.

Sales taxes were collected from (TMF, 2013) and labor cost were from GDP/cap using the Mexico as a reference for the scaling factor. Fuel mix is taken for the year 2015 from (APERC, 2012) in order to calculate the weighted average price of electricity generation from electricity generation cost by fuel type (IEA, 2010).

The CO_2 and NO_x/SO_2 emission factors are taken from the IEA data set on CO_2 emissions from fuel combustion (IEA, 2012a) and calculated based on fuel mix and IPCC guidelines (IPCC, 1997). A summary of all the data available for Peru is given below:

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7 See Chile section for more details

Table 69 summarizes the input data developed for Peru.

Table 69 – Economy-Specific Inputs Summary for Peru in 2012

	Value		Source/Note
Total Distributed Electricity	33	TWh	(IEA, 2012c)
Distribution transformers Capacity	8,500	MVA	calculated
Stock	0.34	Millions	calculated
Average Load Factor	50	%	assumed
Average Capacity	25	kVA	Calculated from custom data
Annual Sales	10,800	Units	imports + LBNL correction
Consumer Discount Rate	10	%	(IEA, 2010)
National Discount Rate	5	%	Assumed
VAT	18	%	(TMF, 2013)
Cost of Electricity Generation	0.07	$/kWh	derived from (IEA, 2010)
CO_2 Emission Factor	0.289	kg/kWh	(IEA, 2012a)
SO_2 Emission Factor	0.220	g/kWh	(IPCC, 1997)
NO_x Emission Factor	0.299	g/kWh	(IPCC, 1997)
Labor Cost	4	$/hour	derived from GDP/cap

Cost-Benefit Analysis

Baseline efficiency is a key determinant in the cost-benefit analysis. In general, if a economy has not had a program on distribution transformers, this information is difficult to obtain. As explained in the methodology section, to determine the "floor" of energy efficiency that we define as EL0, we rely on estimates of baselines taken from other countries *before* they implemented their first distribution transformer program. Then, we calculate the cost of conserved energy for different levels of efficiency ranging from EL0 to EL4. Finally, we compare the cost of conserved energy to the cost of electricity generation to determine the highest cost-effective efficiency targets. These targets result in the greatest energy savings while ensuring a net financial benefit to the consumer (in this case, the utility company).

We find that a MEPS set at the maximum efficiency level EL4 would be cost effective in the local context for DL1 and DL4. DL2 is found cost effective at the US 2016 MEPS level.

Table 70 presents the results for the four representative design lines we study:

Table 70 – Cost-Benefit Analysis for Representative Units for Peru

	Baseline	Target
	Representative Design Line 1, 1-phase 50kVA	
Efficiency Rating (%)	98.5%	99.5%
Losses (kWh/year)	3,241	1,139
Price (USD)	$ 813	$ 2,164
CCE (USD)		$ 0.067
	Representative Design Line 2, 1-phase 25kVA	
Efficiency Rating (%)	98.0%	99.0%
Losses (kWh/year)	2,225	1,174
Price (USD)	$ 446	$ 1,067
CCE (USD)		$ 0.062
	Representative Design Line 4, 3-phase 150kVA	
Efficiency Rating (%)	98.3%	99.6%
Losses (kWh/year)	11,292	4,722
Price (USD)	$ 1,842	$ 5,279
CCE (USD)		$ 0.055

National Impact Analysis

As explained in the methodology section, the results from the cost-benefit analysis are scaled to represent the units found in the Peruvian market and then propagated into BUENAS to calculate national energy savings, avoided CO_2 emissions and financial impacts, in terms of net present value (NPV).

The following table summarizes the market shares, and average market capacities derived from the import data set, used to scale the unit level results to the national level along with the resulting scaled UEC and price inputs.

Table 71 – Design Lines (DL) Market Shares and Market Average UEC and Price in Peru

	DL1	DL2	DL4	DL5
DL Market Shares	0.8%	91.0%	8.3%	0.0%
Average Capacity (kVA)	69	18	105	-
Scaled Baseline UEC (kWh/year)	4,144	1,704	8,642	-
Scaled Baseline Price (USD)	1,040	342	1,410	-
Scaled Target UEC (kWh/year)	1,456	899	2,072	-
Scaled Target Price (USD)	2,766	817	4,882	-

We analyze two policy scenarios in this study:

1- A MEPS taking effect in 2016, set at the maximum cost-effective level for all representative design lines.

2- An endorsement label targeting the cost-effective levels for all representative design lines, which would drive a 10% increase in the sales market share every year starting in 2015, up to a maximum of 50% market share by 2020.

Table 72 presents the national impact analysis results for Peru in 2020 and 2030.

Table 72 – National Impacts Analysis Results for Peru

		Units	Year	MEPS Scenario	Labeling Program Scenario
Annual Impacts	Energy Savings	GWh	2020	101.10	40.45
			2030	434.51	203.18
	CO_2 Emissions Savings	Mt	2020	0.03	0.01
			2030	0.13	0.06
	SO_2 Emissions Savings	kt	2020	0.02	0.01
			2030	0.10	0.04
	NOx Emissions Savings	kt	2020	0.03	0.01
			2030	0.13	0.06
Cumulative Impacts	Energy Savings	GWh	through 2020	289.02	106.23
			through 2030	2,968.16	1,323.19
	CO_2 Emissions Savings	Mt	through 2020	0.08	0.03
			through 2030	0.86	0.38
	SO_2 Emissions Savings	kt	2020	0.06	0.02
			2030	0.65	0.29
	NOx Emissions Savings	kt	2020	0.09	0.03
			2030	0.89	0.40
	Operating Cost Savings	Million USD		263.38	121.54
	Equipment Cost	Million USD		118.35	54.96
	NPV	Million USD		145.02	66.58

These results show the significant savings achievable through an increase of the proposed MEPS levels to the maximum cost effective level or through a labeling program for higher efficiency transformers. As opposed to MEPS, the labeling program does not make the sale of efficient models mandatory, so the impacts of an endorsement label presented in the table above have to be taken as indicative.

In sum, the impacts of adopting a MEPS requiring the highest cost effective efficiency level are:

• 101 GWh of electricity savings in 2020 and 434 GWh in 2030.
• 3.0 TWh cumulative electricity savings between 2016 and 2030.
• 0.03 Mt of annual CO_2 emissions reductions by 2020 and 0.13 Mt by 2030.
• 0.9 Mt cumulative emissions reduction between 2016 and 2030.
• The net present value of the savings would be an estimated 145 Million USD.

2.3.14. Philippines

In the current analysis, we estimate that the impact of introducing S&L programs for distribution transformers in the Philippines would be:

- 0.75 TWh annual electricity savings from MEPS by 2030
- 33% reduction in national distribution losses by 2030
- 0.4 Mt CO_2 emission avoided by 2030 from MEPS
- 668 million USD net financial benefits from MEPS
- 0.35 TWh annual electricity savings from endorsement label by 2030
- 0.2 Mt CO_2 emissions avoided by 2030 from endorsement label
- 308 million USD net financial benefits from endorsement label

Test Procedure, S&L Status

Our research on the Philippines did not find any test procedure, standards, or labeling programs in that economy.

Data inputs

Total distributed electricity is calculated from IEA data as the sum of the sales in every sector of the economy plus the T&D losses (IEA, 2012c). We use the growth rate from the national electricity demand forecast to 2030 in the *APERC Energy Demand and Supply Outlook*, 5th Edition (APERC, 2012) to project total distributed electricity to 2030.

The average cost of electricity generation by fuel relies on estimates from the Philippine department of energy (USAID, 2007) and is weighted using fuel mix in 2015. Economic data such as sales taxes and labor costs were collected from publicly available sources (BLS, 2012; TMF, 2013).

The CO_2 and NO_x/SO_2 emission factors are taken from the IEA data set on CO_2 emissions from fuel combustion (IEA, 2012a) and calculated based on fuel mix and IPCC guidelines (IPCC, 1997).

Table 73 summarizes the input data developed for the Philippines.

Table 73 – Economy-Specific Inputs Summary for the Philippines in 2010

	Value		Source/Note
Total Distributed Electricity	60	TWh	(IEA, 2012c)
Distribution transformers Capacity	15,300	MVA	calculated
Stock	0.21	Millions	calculated
Average Load Factor	50	%	assumed
Average Capacity	73	kVA	(USDOE, 2013a)
Sales	6,700	Units	calculated
Consumer Discount Rate	10	%	(IEA, 2010)
National Discount Rate	5	%	Assumed
VAT	12	%	(TMF, 2013)
Lifetime	32	years	(USDOE, 2013a)
Cost of Electricity Generation	0.15	$/kWh	derived from (IEA, 2010)
CO_2 Emission Factor	0.481	kg/kWh	(IEA, 2012a)
SO_2 Emission Factor	1.144	g/kWh	(IPCC, 1997)
NO_x Emission Factor	0.682	g/kWh	(IPCC, 1997)
Labor Cost	2	$/hour	(BLS, 2012)

Cost-Benefit Analysis

Baseline efficiency is a key determinant in the cost-benefit analysis. In general, if a economy has not had a program on distribution transformers, this information is difficult to obtain. As explained in the methodology section, to determine the "floor" of energy efficiency that we define as EL0, we rely on estimates of baselines taken from other countries *before* they implemented their first distribution transformer program. Then, we calculate the cost of conserved energy for different levels of efficiency ranging from EL0 to EL4. Finally, we compare the cost of conserved energy to the cost of electricity generation to determine the highest cost-effective efficiency targets. These targets result in the greatest energy savings while ensuring a net financial benefit to the consumer (in this case, the utility company).

We find that a MEPS set at the maximum efficiency level would be cost effective in the local context.

Table 74 presents the results for the four representative design lines we study:

Table 74 – Cost-Benefit Analysis for Representative Units for the Philippines

	Baseline		Target	
	Representative Design Line 1, 1-phase 50kVA			
Efficiency Rating (%)		98.5%		99.5%
Losses (kWh/year)		3,241		1,139
Price (USD)	$	760	$	2,023
CCE (USD)			$	0.063
	Representative Design Line 2, 1-phase 25kVA			
Efficiency Rating (%)		98.0%		99.5%
Losses (kWh/year)		2,225		911
Price (USD)	$	417	$	1,284
CCE (USD)			$	0.069
	Representative Design Line 4, 3-phase 150kVA			
Efficiency Rating (%)		98.3%		99.6%
Losses (kWh/year)		11,292		4,722
Price (USD)	$	1,722	$	4,935
CCE (USD)			$	0.051
	Representative Design Line 5, 3-phase 1500kVA			
Efficiency Rating (%)		98.9%		99.7%
Losses (kWh/year)		71,727		20,919
Price (USD)	$	9,371	$	34,464
CCE (USD)			$	0.052

National Impact Analysis

As explained in the methodology section, the results from the cost-benefit analysis are scaled to represent the units found in the Philippine market and then propagated into BUENAS to calculate national energy savings, avoided CO_2 emissions and financial impacts, in terms of net present value (NPV).

The following table summarizes the market shares, and average market capacities used to scale the unit level results to the national level along with the resulting scaled UEC and price inputs.

Table 75 – Design Lines (DL) Market Shares and Market Average UEC and Price in the Philippines

	DL1	DL2	DL4	DL5
DL Market Shares	24.9%	68.3%	4.6%	2.2%
Average Capacity (kVA)	46	26	256	1,451
Scaled Baseline UEC (kWh/year)	3,053	2,281	16,837	69,961
Scaled Baseline Price (USD)	716	428	2,568	9,141
Scaled Target UEC (kWh/year)	1,073	611	4,036	20,404
Scaled Target Price (USD)	1,905	1,881	8,892	33,615

We analyze two policy scenarios in this study:

3- A MEPS taking effect in 2016, set at the maximum cost-effective level for all representative design lines.
4- An endorsement label targeting the cost-effective levels for all representative design lines, which would drive a 10% increase in the sales market share every year starting in 2015, up to a maximum of 50% market share by 2020.

Table 76 presents the national impact analysis results for the Philippines in 2020 and 2030.

Table 76 – National Impacts Analysis Results for the Philippines

		Units	**Year**	**MEPS Scenario**	**Labeling Program Scenario**
Annual Impacts	Energy Savings	GWh	2020	166.89	66.77
			2030	745.59	348.63
	CO_2 Emissions Savings	Mt	2020	0.08	0.03
			2030	0.36	0.17
	SO_2 Emissions Savings	kt	2020	0.19	0.08
			2030	0.85	0.40
	NOx Emissions Savings	kt	2020	0.11	0.05
			2030	0.51	0.24
Cumulative Impacts	Energy Savings	GWh	through 2020	474.74	174.53
			through 2030	5,011.19	2,235.77
	CO_2 Emissions Savings	Mt	through 2020	0.23	0.08
			through 2030	2.41	1.08
	SO_2 Emissions Savings	kt	2020	0.54	0.20
			2030	5.73	2.56
	NOx Emissions Savings	kt	2020	0.32	0.12
			2030	3.42	1.52
	Operating Cost Savings	Million USD		890.7	411.5
	Equipment Cost	Million USD		223.0	103.8
	NPV	Million USD		667.7	307.7

These results show the significant savings achievable through a MEPS or a labeling program. As opposed to MEPS, the labeling program does not make the sale of efficient models mandatory, so the impacts of an endorsement label presented in the table above have to be taken as indicative.
In sum, the impacts of adopting a MEPS requiring the highest cost effective efficiency level are:
• 167 GWh of electricity savings in 2020 and 746 GWh in 2030.
• 5.0 TWh cumulative electricity savings between 2016 and 2030.
• 0.08 Mt of annual CO_2 emissions reductions by 2020 and 0.36 Mt by 2030.
• 2.4 Mt cumulative emissions reduction between 2016 and 2030.
• The net present value of the savings would be an estimated 668 Million USD.

2.3.15. Russia

In the current analysis, we estimate that the impact of introducing S&L programs for distribution transformers in Russia would be:

- 7.4 TWh annual electricity savings from MEPS by 2030
- 33% reduction in national distribution losses by 2030
- 4.7 Mt CO_2 emission avoided by 2030 from MEPS
- 3.2 billion USD net financial benefits from MEPS
- 3.4 TWh annual electricity savings from endorsement label by 2030
- 2.2 Mt CO_2 emissions avoided by 2030 from endorsement label
- 1.5 billion USD net financial benefits from endorsement label

Test Procedure, S&L Status

Our research on Russia did not find any test procedure, standards, or labeling programs in that economy.

Data inputs

Total distributed electricity is calculated from IEA data as the sum of the sales in every sector of the economy plus the T&D losses (IEA, 2012c). We use the growth rate from the national electricity demand forecast to 2030 in the *APERC Energy Demand and Supply Outlook*, 5th Edition (APERC, 2012) to project total distributed electricity to 2030.

Sales taxes were collected(TMF, 2013), while labor cost was taken from (BLS, 2012) as the average from East Europe as a proxy. Fuel mix is taken for the year 2015 from (APERC, 2012) in order to calculate the weighted average price of electricity generation from generation cost by fuel type (IEA, 2010).

The CO_2 and NO_x/SO_2 2 emission factors are taken from the IEA data set on CO_2 emissions from fuel combustion (IEA, 2012a) and calculated based on fuel mix and IPCC guidelines (IPCC, 1997).

Table 77 summarizes the input data developed for Russia.

Table 77 – Economy-Specific Inputs Summary for Russia in 2010

	Value		Source/Note
Total Distributed Electricity	814	TWh	(IEA, 2012c)
Distribution transformers Capacity	206,000	MVA	calculated
Stock	2.82	Millions	calculated
Average Load Factor	50	%	assumed
Average Capacity	73	kVA	(USDOE, 2013a)
Sales	89,400	Units	calculated
Consumer Discount Rate	10	%	(IEA, 2010)
National Discount Rate	5	%	assumed
VAT	18	%	(TMF, 2013)
Lifetime	32	years	(USDOE, 2013a)
Cost of Electricity Generation	0.09	\$/kWh	derived from (IEA, 2010)
CO_2 Emission Factor	0.639	kg/kWh	(IEA, 2012a)
SO_2 Emission Factor	1.144	g/kWh	(IPCC, 1997)
NO_x Emission Factor	0.682	g/kWh	(IPCC, 1997)
Labor Cost	10	\$/hour	average East Europe from (BLS, 2012)

Cost-Benefit Analysis

Baseline efficiency is a key determinant in the cost-benefit analysis. In general, if a economy has not had a program on distribution transformers, this information is difficult to obtain. As explained in the methodology section, to determine the "floor" of energy efficiency that we define as EL0, we rely on estimates of baselines taken from other countries *before* they implemented their first distribution transformer program. Then, we calculate the cost of conserved energy for different levels of efficiency ranging from EL0 to EL4. Finally, we compare the cost of conserved energy to the cost of electricity generation to determine the highest cost-effective efficiency targets. These targets result in the greatest energy savings while ensuring a net financial benefit to the consumer (in this case, the utility company).

We find that a MEPS set at the maximum efficiency level would be cost effective in the local context.

Table 78 presents the results for the four representative design lines we study:

Table 78 – Cost-Benefit Analysis for Representative Units for Russia

	Baseline	Target
	Representative Design Line 1, 1-phase 50kVA	
Efficiency Rating (%)	98.5%	99.5%
Losses (kWh/year)	3,241	1,139
Price (USD)	$ 852	$ 2,268
CCE (USD)		$ 0.071
	Representative Design Line 2, 1-phase 25kVA	
Efficiency Rating (%)	98.0%	99.5%
Losses (kWh/year)	2,225	911
Price (USD)	$ 468	$ 1,440
CCE (USD)		$ 0.078
	Representative Design Line 4, 3-phase 150kVA	
Efficiency Rating (%)	98.3%	99.6%
Losses (kWh/year)	11,292	4,722
Price (USD)	$ 1,931	$ 5,534
CCE (USD)		$ 0.058
	Representative Design Line 5, 3-phase 1500kVA	
Efficiency Rating (%)	98.9%	99.7%
Losses (kWh/year)	71,727	20,919
Price (USD)	$ 10,509	$ 38,649
CCE (USD)		$ 0.058

National Impact Analysis

As explained in the methodology section, the results from the cost-benefit analysis are scaled to represent the units found in the Russian market and then propagated into BUENAS to calculate national energy savings, avoided CO_2 emissions and financial impacts, in terms of net present value (NPV).

The following table summarizes the market shares, and average market capacities used to scale the unit level results to the national level along with the resulting scaled UEC and price inputs.

Table 79 – Design Lines (DL) Market Shares and Market Average UEC and Price in Russia

	DL1	**DL2**	**DL4**	**DL5**
DL Market Shares	24.9%	68.3%	4.6%	2.2%
Average Capacity (kVA)	46	26	256	1,451
Scaled Baseline UEC (kWh/year)	3,053	2,281	16,837	69,961
Scaled Baseline Price (USD)	803	480	2,879	10,250
Scaled Target UEC (kWh/year)	1,073	611	4,036	20,404
Scaled Target Price (USD)	2,136	2,109	9,972	37,697

We analyze two policy scenarios in this study:

1- A MEPS taking effect in 2016, set at the maximum cost-effective level for all representative design lines.
2- An endorsement label targeting the cost-effective levels for all representative design lines, which would drive a 10% increase in the sales market share every year starting in 2015, up to a maximum of 50% market share by 2020.

Table 80 presents the national impact analysis results for Russia in 2020 and 2030.

Table 80 – National Impacts Analysis Results for Russia

		Units	Year	MEPS Scenario	Labeling Program Scenario
Annual Impacts	Energy Savings	GWh	2020	1,923.1	769.4
			2030	7,367.7	3,445.1
	CO_2 Emissions Savings	Mt	2020	1.2	0.5
			2030	4.7	2.2
	SO_2 Emissions Savings	kt	2020	3.3	1.3
			2030	12.7	5.9
	NOx Emissions Savings	kt	2020	0.4	0.1
			2030	1.3	0.6
Cumulative Impacts	Energy Savings	GWh	through 2020	5,579.4	2,049.1
			through 2030	52,865.8	23,508.6
	CO_2 Emissions Savings	Mt	through 2020	3.6	1.3
			through 2030	33.8	15.0
	SO_2 Emissions Savings	kt	2020	9.6	3.5
			2030	90.9	40.4
	NOx Emissions Savings	kt	2020	1.0	0.4
			2030	9.6	4.3
	Operating Cost Savings	Million USD		6,002.4	2,761.0
	Equipment Cost	Million USD		2,764.4	1,277.0
	NPV	Million USD		3,238.0	1,483.9

These results show the significant savings achievable through a MEPS or a labeling program. As opposed to MEPS, the labeling program does not make the sale of efficient models mandatory, so the impacts of an endorsement label presented in the table above have to be taken as indicative.

In sum, the impacts of adopting a MEPS requiring the highest cost effective efficiency level are:

• 1,923 GWh of electricity savings in 2020 and 7,368 GWh in 2030.
• 53 TWh cumulative electricity savings between 2016 and 2030.
• 1.4 Mt of annual CO_2 emissions reductions by 2020 and 4.7 Mt by 2030.
• 34 Mt cumulative emissions reduction between 2016 and 2030.
• The net present value of the savings would be an estimated 3.2 Billion USD.

2.3.16. Singapore

In the current analysis, we estimate that the impact of introducing S&L programs for distribution transformers in Singapore would be:

- 0.3 TWh annual electricity savings from MEPS by 2030
- 33% reduction in national distribution losses by 2030
- 0.1 Mt CO_2 emission avoided by 2030 from MEPS
- 188 million USD net financial benefits from MEPS
- 0.1 TWh annual electricity savings from endorsement label by 2030
- 0.06 Mt CO_2 emissions avoided by 2030 from endorsement label
- 86 million USD net financial benefits from endorsement label

Test Procedure, S&L Status

Singapore Green building Council has issues TFEL-04/14-022011 document that describes minimum efficiency for distribution transformers in both the utilities and in buildings to qualify under Green Building Certification(SGBC, 2010). The criteria for liquid-type distribution transformers are presented in Table 81:

Table 81 Minimum Efficiency for Voluntary Green Building Certification in Singapore

Power efficiency @ 50% load			
Single-phase		Three-phase	
kVA	%	kVA	%
10	98.4	15	98.1
15	98.6	30	98.4
25	98.7	45	98.6
50	98.9	75	98.7
75	99.0	150	98.9
100	99.0	225	99.0
250	99.2	300	99.0
500	99.3	500	99.1
		750	99.2
		1,000	99.2
		1,500	99.3
		2,000	99.4
		2,500	99.4

Singapore purchases transformer under IEC 60076-1 Standard, however efficiency definition and calculation are per IEEE definition. Since the transformers are designed per IEC specification, we can assume that Test Procedure would be per IEC 60076-1.

As a result of the voluntary program, Singapore market efficiency is equivalent to the Chinese standard D9 for single phase (JBT, 2002) and S9 for three-phase distribution transformer (data provided by APEC representative).

Data inputs

Total distributed electricity is calculated from IEA data as the sum of the sales in every sector of the economy plus the T&D losses (IEA, 2012c). We use the growth rate from the national electricity demand forecast to 2030 in the *APERC Energy Demand and Supply Outlook*, 5th Edition (APERC, 2012) to project total distributed electricity to 2030. We also have baseline efficiency data by capacity in 2010 from the data received from the economy representative from the Energy Market Authority.

Fuel mix is taken for the year 2015 from (APERC, 2012) in order to calculate the weighted average price of electricity generation from generation cost by fuel type (IEA, 2010).

The CO_2 and NO_x/SO_2 emission factors came from the IEA website and an IPCC 1997 emission conversion factors (IPCC, 1997) respectfully.

Table 82 summarizes the input data developed for Singapore.

Table 82 – Economy-Specific Inputs Summary for Singapore in 2010

	Value		Source/Note
Total Distributed Electricity	38	TWh	(IEA, 2012c)
Distribution transformers Capacity	9,700	MVA	calculated
Stock	0.13	Millions	calculated
Average Load Factor	50	%	assumed
Average Capacity	73	kVA	(USDOE, 2013a)
Sales	4,200	Units	calculated
Consumer Discount Rate	10	%	(IEA, 2010)
National Discount Rate	5	%	Assumed
VAT	7	%	(TMF, 2013)
Cost of Electricity Generation	0.12	$/kWh	derived from (IEA, 2010)
CO_2 Emission Factor	0.499	kg/kWh	(IEA, 2012a)
SO_2 Emission Factor	0.734	g/kWh	(IPCC, 1997)
NO_x Emission Factor	0.586	g/kWh	(IPCC, 1997)
Labor Cost	23	$/hour	(BLS, 2012)

Cost-Benefit Analysis

Baseline efficiency is a key determinant in the cost-benefit analysis. As previously explained, we find that the baseline efficiency is equivalent to the Chinese D9/S9 standard, which is equivalent to EL0. Then, we calculate the cost of conserved energy for different levels of efficiency ranging from EL0 to EL4. Finally, we compare the cost of conserved energy to the cost of electricity generation to determine the highest cost-effective efficiency targets. These targets result in the greatest energy savings while ensuring a net financial benefit to the consumer (in this case, the utility company).

We find that a MEPS set at the maximum efficiency level would be cost effective in the local context.

Table 83 presents the results for the four representative design lines we study:

Table 83 – Cost-Benefit Analysis for Representative Units for Singapore

	Baseline	Target
	Representative Design Line 1, 1-phase 50kVA	
Efficiency Rating (%)	98.5%	99.5%
Losses (kWh/year)	3,241	1,139
Price (USD)	$ 842	$ 2,240
CCE (USD)		$ 0.070
	Representative Design Line 2, 1-phase 25kVA	
Efficiency Rating (%)	98.0%	99.5%
Losses (kWh/year)	2,225	911
Price (USD)	$ 462	$ 1,422
CCE (USD)		$ 0.077
	Representative Design Line 4, 3-phase 150kVA	
Efficiency Rating (%)	98.3%	99.6%
Losses (kWh/year)	11,292	4,722
Price (USD)	$ 1,907	$ 5,465
CCE (USD)		$ 0.057
	Representative Design Line 5, 3-phase 1500kVA	
Efficiency Rating (%)	98.9%	99.7%
Losses (kWh/year)	71,727	20,919
Price (USD)	$ 10,378	$ 38,166
CCE (USD)		$ 0.057

National Impact Analysis

As explained in the methodology section, the results from the cost-benefit analysis are scaled to represent the units found in the Singaporean market and then propagated into BUENAS to calculate national energy savings, avoided CO_2 emissions and financial impacts, in terms of net present value (NPV).

The following table summarizes the market shares, and average market capacities used to scale the unit level results to the national level along with the resulting scaled UEC and price inputs.

Table 84 – Design Lines (DL) Market Shares and Market Average UEC and Price in Singapore

	DL1	DL2	DL4	DL5
DL Market Shares	24.9%	68.3%	4.6%	2.2%
Average Capacity (kVA)	46	26	256	1,451
Scaled Baseline UEC (kWh/year)	3,053	2,281	16,837	69,961
Scaled Baseline Price (USD)	793	474	2,844	10,122
Scaled Target UEC (kWh/year)	1,073	611	4,036	20,404
Scaled Target Price (USD)	2,110	2,083	9,847	37,227

We analyze two policy scenarios in this study:

1- A MEPS taking effect in 2016, set at the maximum cost-effective level for all representative design lines.
2- An endorsement label targeting the cost-effective levels for all representative design lines, which would drive a 10% increase in the sales market share every year starting in 2015, up to a maximum of 50% market share by 2020.

Table 85 presents the national impact analysis results for Singapore in 2020 and 2030.

Table 85 – National Impacts Analysis Results for Singapore

		Units	Year	MEPS Scenario	Labeling Program Scenario
Annual Impacts	Energy Savings	GWh	2020	80.15	32.07
			2030	272.23	127.29
	CO_2 Emissions Savings	Mt	2020	0.04	0.02
			2030	0.14	0.06
	SO_2 Emissions Savings	kt	2020	0.06	0.02
			2030	0.20	0.09
	NOx Emissions Savings	kt	2020	0.05	0.02
			2030	0.16	0.07
Cumulative Impacts	Energy Savings	GWh	through 2020	236.23	86.69
			through 2030	2,060.34	913.70
	CO_2 Emissions Savings	Mt	through 2020	0.12	0.04
			through 2030	1.03	0.46
	SO_2 Emissions Savings	kt	2020	0.17	0.06
			2030	1.51	0.67
	NOx Emissions Savings	kt	2020	0.14	0.05
			2030	1.21	0.54
	Operating Cost Savings	Million USD		298.5	136.8
	Equipment Cost	Million USD		110.5	50.7
	NPV	Million USD		188.0	86.1

These results show the significant savings achievable through a MEPS or a labeling program. As opposed to MEPS, the labeling program does not make the sale of efficient models mandatory, so the impacts of an endorsement label presented in the table above have to be taken as indicative.

In sum, the impacts of adopting a MEPS requiring the highest cost effective efficiency level are:

- 80 GWh of electricity savings in 2020 and 272 GWh in 2030.
- 2.0 TWh cumulative electricity savings between 2016 and 2030.
- 0.04 Mt of annual CO_2 emissions reductions by 2020 and 0.14 Mt by 2030.
- 1.0 Mt cumulative emissions reduction between 2016 and 2030.
- The net present value of the savings would be an estimated 188 Million USD.

2.3.17. Chinese Taipei

In the current analysis, we estimate that the impact of introducing S&L programs for distribution transformers in Chinese Taipei would be:

- 1.2 TWh annual electricity savings from MEPS by 2030
- 27% reduction in national distribution losses by 2030
- 1.0 Mt CO_2 emission avoided by 2030 from MEPS
- 226 million USD net financial benefits from MEPS
- 0.6 TWh annual electricity savings from endorsement label by 2030
- 0.4 Mt CO_2 emissions avoided by 2030 from endorsement label
- 104 million USD net financial benefits from endorsement label

Test Procedure, S&L Status

Our research on Chinese Taipei did not find any test procedure, standards, or labeling programs in that economy.

Data inputs

Total distributed electricity is calculated from IEA data as the sum of the sales in every sector of the economy plus the T&D losses (IEA, 2012c). We use the growth rate from the national electricity demand forecast to 2030 in the *APERC Energy Demand and Supply Outlook*, 5^{th} Edition (APERC, 2012) to project total distributed electricity to 2030.

Sales taxes and labor cost were collected from publicly available sources (BLS, 2012; TMF, 2013). Fuel mix is taken for the year 2015 from (APERC, 2012) in order to calculate the weighted average price of electricity generation from generation cost by fuel type (IEA, 2010).

The CO_2 and NO_x/SO_2 emission factors are taken from the IEA dataset on CO_2 emissions from fuel combustion (IEA, 2012a) and calculated based on fuel mix and IPCC guidelines (IPCC, 1997)

Error! Reference source not found. summarizes the input data developed for Taipei.

Table 86 – Economy-Specific Inputs Summary for Chinese Taipei in 2010

	Value		Source/Note
Total Distributed Electricity	214	TWh	(IEA, 2012c)
Distribution transformers Capacity	54,100	MVA	calculated
Stock	0.74	Millions	calculated
Average Load Factor	50	%	assumed
Average Capacity	73	kVA	(USDOE, 2013a)
Annual Sales	23,500	Units	calculated
Consumer Discount Rate	10	%	(IEA, 2010)
National Discount Rate	5	%	assumed
VAT	5	%	(BLS, 2012)
Cost of Electricity Generation	0.04	$/kWh	derived from (IEA, 2010)
CO_2 Emission Factor	0.768	kg/kWh	(IEA, 2012a)
SO_2 Emission Factor	1.150	kg/kWh	(IPCC, 1997)
NO_x Emission Factor	0.714	kg/kWh	(IPCC, 1997)
Labor Cost	9	$/hour	(BLS, 2012)

Cost-Benefit Analysis

Baseline efficiency is a key determinant in the cost-benefit analysis. In general, if a economy has not had a program on distribution transformers, this information is difficult to obtain. As explained in the methodology section, to determine the "floor" of energy efficiency that we define as EL0, we rely on estimates of baselines taken from other countries *before* they implemented their first distribution transformer program.

Then, we calculate the cost of conserved energy for different levels of efficiency ranging from EL0 to EL4. Finally, we compare the cost of conserved energy to the cost of electricity generation to determine the highest cost-effective efficiency targets. These targets result in the greatest energy savings while ensuring a net financial benefit to the consumer (in this case, the utility company).

We find that an harmonization with the 2016 U.S. MEPS (EL2) would be cost-effective for all design lines in the local conditions. Moreover, DL1, DL2 and DL5 are found to be cost effective at the maximum efficiency level EL4.

Error! Reference source not found. presents the results for the four representative design lines we study:

Table 87 – Cost-Benefit Analysis for Representative Units for Chinese-Taipei

	Baseline	Target
	Representative Design Line 1, 1-phase 50kVA	
Efficiency Rating (%)	98.5%	99.1%
Losses (kWh/year)	3,241	2,015
Price (USD)	$ 753	$ 1,458
CCE (USD)		$ 0.036
	Representative Design Line 2, 1-phase 25kVA	
Efficiency Rating (%)	98.0%	99.0%
Losses (kWh/year)	2,225	1,174
Price (USD)	$ 413	$ 988
CCE (USD)		$ 0.035
	Representative Design Line 4, 3-phase 150kVA	
Efficiency Rating (%)	98.3%	99.6%
Losses (kWh/year)	11,292	4,722
Price (USD)	$ 1,706	$ 4,889
CCE (USD)		$ 0.031
	Representative Design Line 5, 3-phase 1500kVA	
Efficiency Rating (%)	98.9%	99.7%
Losses (kWh/year)	71,727	20,919
Price (USD)	$ 9,283	$ 34,141
CCE (USD)		$ 0.031

National Impact Analysis

As explained in the methodology section, the results from the cost-benefit analysis are scaled to represent the units found in the Taiwanese market and then propagated into BUENAS to calculate national energy savings, avoided CO_2 emissions and financial impacts, in terms of net present value (NPV).

The following table summarizes the market shares, and average market capacities used to scale the unit level results to the national level along with the resulting scaled UEC and price inputs.

Table 88 – Design Lines Market Shares and Market Average UEC and Price in Chinese Taipei

	DL1	DL2	DL4	DL5
DL Market Shares	24.9%	68.3%	4.6%	2.2%
Average Capacity (kVA)	46	26	256	1,451
Scaled Baseline UEC (kWh/year)	3,053	2,281	16,837	69,961
Scaled Baseline Price (USD)	709	424	2,544	9,055
Scaled Target UEC (kWh/year)	1,898	1,204	4,036	20,404
Scaled Target Price (USD)	1,373	1,013	8,809	33,300

We analyze two policy scenarios in this study:

1- A MEPS taking effect in 2016, set at the maximum cost-effective level for all representative design lines.

2- An endorsement label targeting the cost-effective levels for all representative design lines, which would drive a 10% increase in the sales market share every year starting in 2015, up to a maximum of 50% market share by 2020.

Error! Reference source not found. presents the national impact analysis results for Chinese Taipei in 2020 and 2030.

Table 89 – National Impacts Analysis Results for Chinese Taipei

		Units	Year	MEPS Scenario	Labeling Program Scenario
Annual Impacts	Energy Savings	GWh	2020	366.5	146.6
			2030	1,246.1	582.7
	CO_2 Emissions Savings	Mt	2020	0.3	0.1
			2030	1.0	0.4
	SO_2 Emissions Savings	kt	2020	0.4	0.2
			2030	1.4	0.7
	NOx Emissions Savings	kt	2020	0.3	0.1
			2030	0.9	0.4
Cumulative Impacts	Energy Savings	GWh	through 2020	1,080.1	396.4
			through 2030	9,426.8	4,180.6
	CO_2 Emissions Savings	Mt	through 2020	0.8	0.3
			through 2030	7.2	3.2
	SO_2 Emissions Savings	kt	2020	1.2	0.5
			2030	10.8	4.8
	NOx Emissions Savings	kt	2020	0.8	0.3
			2030	6.7	3.0
	Operating Cost Savings	Million USD		667.46	308.73
	Equipment Cost	Million USD		441.11	204.45
	NPV	Million USD		226.35	104.28

These results show the significant savings achievable through a MEPS or a labeling program. As opposed to MEPS, the labeling program does not make the sale of efficient models mandatory, so the impacts of an endorsement label presented in the table above have to be taken as indicative.
In sum, the impacts of adopting a MEPS requiring the highest cost effective efficiency level are:

- 366 GWh of electricity savings in 2020 and 1,246 GWh in 2030.
- 9.4 TWh cumulative electricity savings between 2016 and 2030.
- 0.3 Mt of annual CO_2 emissions reductions by 2020 and 1.0 Mt by 2030.
- 7.2 Mt cumulative emissions reduction between 2016 and 2030.
- The net present value of the savings would be an estimated 226 Million USD.

2.3.18. Thailand

In the current analysis, we estimate that the impact of raising the stringency of S&L programs for distribution transformers in Thailand would be:

- 1.05 TWh annual electricity savings from MEPS by 2030
- 27% reduction in national distribution losses by 2030
- 0.5 Mt CO_2 emission avoided by 2030 from MEPS
- 674 million USD net financial benefits from MEPS
- 0.5 TWh annual electricity savings from endorsement label by 2030
- 0.3 Mt CO_2 emissions avoided by 2030 from endorsement label
- 310 million USD net financial benefits from endorsement label

Test Procedure, S&L Status

The two main utilities Provincial Electricity Authority (PEA) and Metropolitan Electricity Authority (MEA) have defined some mandatory High Energy Performance Standard (HEPs) for single and three-phase distribution transformers. The following tables present the HEPs requirements on load losses and no-load losses and the calculated efficiency at 50% load for the PEA and MEA utilities:

Table 90 – HEPS for Single-Phase Liquid-Type Distribution Transformers in Thailand (PEA)

Transformer rating	Watt loss for 22-24 kV		Efficiency at 50% load
(kVA)	No load loss	Load loss	%
10	60	145	98.1%
20	90	300	98.4%
30	120	430	98.5%
50	150	670	98.7%

Table 91 – HEPS for Three-Phase Liquid-Type Distribution Transformers in Thailand (PEA)

Transformer rating	Watt loss for 22-24 kV		Efficiency at 50% load
(kVA)	No load loss	Load loss	%
50	160	950	98.4%
100	250	1,550	98.7%
160	360	2,100	98.9%
250	500	2,950	99.0%
315	600	3,500	99.1%
400	720	4,150	99.1%
500	860	4,950	99.2%
630	1,010	5,850	99.2%
800	1,200	9,900	99.1%
1,000	1,270	12,150	99.1%
1,250	1,500	14,750	99.2%

1,500	1,820	17,850	99.2%
2,000	2,110	21,600	99.3%

Table 92 – HEPS for Three-Phase Liquid-Type Distribution Transformers in Thailand (MEA)

Transformer rating	Watt loss for 22-24 kV		Efficiency at 50% load
(kVA)	No load loss	Load loss	%
15	70	160	98.55%
45	160	360	98.90%
75	220	580	99.04%
112.5	255	840	99.18%
150	300	1000	99.27%
225	420	1530	99.29%
300	480	1860	99.37%
500	670	3030	99.43%
750	840	4370	99.49%
1000	1000	6400	99.48%
1500	1200	10000	99.51%

Data inputs

Total distributed electricity is calculated from IEA data as the sum of the sales in every sector of the economy plus the T&D losses (IEA, 2012c). We use the growth rate from the national electricity demand forecast to 2030 in the *APERC Energy Demand and Supply Outlook*, 5th Edition (APERC, 2012) to project total distributed electricity to 2030. Total distribution transformer capacity has been estimated by ICA to 52,050 MVA. The Electricity Generating Authority of Thailand (EGAT) estimates its transmission capacity to 72,640MVA, which is in agreement with the distribution capacity number (EGAT, 2010).

Sales taxes were collected from (TMF, 2013) and labor cost were from GDP/cap using the Philippines as a reference for the scaling factor. The average cost of electricity generation by fuel relies on estimates from (EGAT, 2010) and is weighted using fuel mix in Thailand in 2015.

The CO_2 and NO_x/SO_2 emission factors are taken from the IEA data set on CO_2 emissions from fuel combustion (IEA, 2012a) and calculated based on fuel mix and IPCC guidelines (IPCC, 1997).

Table 93 summarizes the input data developed for Thailand.

Table 93 – Economy-Specific Inputs Summary for Thailand in 2010

	Value		Source/Note
Total Distributed Electricity	148	TWh	(IEA, 2012c)
Distribution transformers Capacity	52050	MVA	ICA
Stock	0.71	Millions	calculated
Average Load Factor	36	%	calculated
Average Capacity	73	kVA	(USDOE, 2013a)
Sales	51,800	Units	calculated
Consumer Discount Rate	10	%	(IEA, 2010)
National Discount Rate	5	%	assumed
VAT	7	%	(TMF, 2013)
Cost of Electricity Generation	0.13	$/kWh	(EGAT, 2010)
CO_2 Emission Factor	0.513	kg/kWh	(IEA, 2012a)
SO_2 Emission Factor	0.359	g/kWh	(IPCC, 1997)
NO_x Emission Factor	0.583	g/kWh	(IPCC, 1997)
Labor Cost	4.5	USD/hour	Derived from GDP/cap

Cost-Benefit Analysis

Based on the information available from the PEA, we estimate the efficiency level to be between EL0 and EL1. The MEA efficiency standards for three-phase distribution transformers are at much higher efficiency level around the 2016 U.S MEPS. We calculate the cost of conserved energy for different levels of efficiency ranging from the baseline level to EL4. Finally, we compare the cost of conserved energy to the cost of electricity generation to determine the highest cost-effective efficiency targets. These targets result in the greatest energy savings while ensuring a net financial benefit to the consumer (in this case, the utility company).

We find that a MEPS set at the maximum technically feasible efficiency level EL4 would be cost effective in the local context for DL1, DL4 and DL5. DL2 is found to be cost effective up to the EL3 level. All design lines are found to be cost effective at the 2016 U.S. MEPS level.

Table 94 presents the results for the four representative design lines we study:

Table 94 – Cost-Benefit Analysis for Representative Units for Thailand

	Baseline	Target
	Representative Design Line 1, 1-phase 50kVA	
Efficiency Rating (%)	98.7%	99.5%
Losses (kWh/year)	2,071	768
Price (USD)	$ 883	$ 2,005
CCE (USD)		$ 0.090
	Representative Design Line 2, 1-phase 25kVA	
Efficiency Rating (%)	98.4%	99.2%
Losses (kWh/year)	1,312	662
Price (USD)	$ 605	$ 1,296
CCE (USD)		$ 0.112
	Representative Design Line 4, 3-phase 150kVA	
Efficiency Rating (%)	98.9%	99.6%
Losses (kWh/year)	5,693	1,886
Price (USD)	$ 3,378	$ 5,915
CCE (USD)		$ 0.070
	Representative Design Line 5, 3-phase 1500kVA	
Efficiency Rating (%)	99.2%	99.7%
Losses (kWh/year)	40,597	15,397
Price (USD)	$ 12,996	$ 33,594
CCE (USD)		$ 0.086

National Impact Analysis

As explained in the methodology section, the results from the cost-benefit analysis are scaled to represent the units found in the Thai market and then propagated into BUENAS to calculate national energy savings, avoided CO_2 emissions and financial impacts, in terms of net present value (NPV).

The following table summarizes the market shares, and average market capacities used to scale the unit level results to the national level along with the resulting scaled UEC and price inputs.

Table 95 – Design Lines (DL) Market Shares and Market Average UEC and Price in Thailand

	DL1	DL2	DL4	DL5
DL Market Shares	24.9%	68.3%	4.6%	2.2%
Average Capacity (kVA)	46	26	256	1,451
Scaled Baseline UEC (kWh/year)	1,951	1,345	8,488	39,597
Scaled Baseline Price (USD)	832	620	5,037	12,676
Scaled Target UEC (kWh/year)	724	679	2,813	15,018
Scaled Target Price (USD)	1,888	1,329	8,819	32,767

We analyze two policy scenarios in this study:

1- A MEPS taking effect in 2016, set at the maximum cost-effective level for all representative design lines.
2- An endorsement label targeting the cost-effective levels for all representative design lines, which would drive a 10% increase in the sales market share every year starting in 2015, up to a maximum of 50% market share by 2020.

Table 96 presents the national impact analysis results for Thailand in 2020 and 2030.

Table 96 – National Impacts Analysis Results for Thailand

		Units	**Year**	**MEPS Scenario**	**Labeling Program Scenario**
Annual Impacts	Energy Savings	GWh	2020	250.0	100.0
			2030	1,047.1	489.6
	CO2 Emissions Savings	Mt	2020	0.1	0.1
			2030	0.5	0.3
	SO2 Emissions Savings	kt	2020	0.1	0.0
			2030	0.4	0.2
	NOx Emissions Savings	kt	2020	0.1	0.1
			2030	0.6	0.3
Cumulative Impacts	Energy Savings	GWh	through 2020	717.0	263.5
			through 2030	7,230.7	3,221.6
	CO_2 Emissions Savings	Mt	through 2020	0.4	0.1
			through 2030	3.7	1.7
	SO_2 Emissions Savings	kt	2020	0.3	0.1
			2030	2.6	1.2
	NOx Emissions Savings	kt	2020	0.4	0.2
			2030	4.2	1.9
	Operating Cost Savings	Million USD		1122.0	517.4
	Equipment Cost	Million USD		448.3	208.0
	NPV	Million USD		673.7	309.5

These results show the significant savings achievable through a more stringent MEPS or a labeling program. As opposed to MEPS, the labeling program does not make the sale of efficient models mandatory, so the impacts of an endorsement label presented in the table above have to be taken as indicative.

In sum, the impacts of adopting a MEPS requiring the highest cost effective efficiency level are:

• 250 GWh of electricity savings in 2020 and 1,050 GWh in 2030.
• 7.2 TWh cumulative electricity savings between 2016 and 2030.
• 0.1 Mt of annual CO_2 emissions reductions by 2020 and 0.5 Mt by 2030.
• 3.7 Mt cumulative emissions reduction between 2016 and 2030.
• The net present value of the savings would be an estimated 674 Million USD.

2.3.19. United States

In the current analysis, we estimate that the impact of introducing more stringent or additional S&L programs for distribution transformers in the U.S. would be:

- 3.2 TWh annual electricity savings from MEPS by 2030
- 6% reduction in national distribution losses by 2030
- 1.6 Mt CO_2 emission avoided by 2030 from MEPS
- 2.6 billion USD net financial benefits from MEPS
- 1.5 TWh annual electricity savings from endorsement label by 2030
- 0.8 Mt CO_2 emissions avoided by 2030 from endorsement label
- 1.2 billion USD net financial benefits from endorsement label

Test Procedure, S&L Status

As reported in (SEAD, 2013a), the United States has been working on energy-efficiency for distribution transformers for over 20 years. Starting with the Energy Policy Act of 1992, the US Department of Energy (DOE) initiated a process to review and establish energy conservation standards for distribution transformers. In parallel with that effort, the National Electrical Manufacturer's Association (NEMA) in the US first published its voluntary standard, NEMA TP-1 in 1996 and was subsequently updated in 2002 (NEMA, 2002), covering the following distribution transformers:

- Liquid-filled distribution transformers, single and three-phase
- Dry-type, low-voltage, single and three phase
- Dry-type, medium-voltage, single and three-phase

In September 2000, USDOE initiated its work to develop energy conservation regulatory standards for liquid-filled (and dry-type) distribution transformers. In October 2007, the DOE completed its analysis, and published the Final Rule for Energy Conservation Standards for Distribution Transformers (USDOE, 2007a). This regulation stipulates that all distribution transformers manufactured or imported into the United States after January 1, 2010 must have efficiencies that are no less than the specified efficiency values at 50% of rated load. The US national regulation applies to liquid-filled transformers rated between 10 to 2500 kVA and medium voltage , dry type distribution transformers, rated between 15 to 833 kVA for single phase and 15 to 2,500 kVA for three-phase.

In addition to these regulations, US Congress passed the Energy Policy Act of 2005 which specified that the efficiency of all low-voltage dry-type transformers "manufactured on or after January 1, 2007, shall be the Class I Efficiency Levels for distribution transformers specified in table 4-2 of the 'Guide for Determining Energy Efficiency for Distribution Transformers' published by the National Electrical Manufacturers Association (NEMA TP-1-2002)." In adopting this language, Congress established the NEMA TP-1 -2002 requirements as mandatory efficiency requirements for low-voltage dry-type distribution transformers.

In 2011, DOE initiated work on reviewing its regulations on distribution transformers, including all three groups – liquid-filled, low-voltage dry-type and medium-voltage dry-type transformers. In April 2013, DOE completed this process and it published the new efficiency requirements that will become effective in January 2016 (USDOE, 2013a). The following tables present the U.S. regulations for all groups of distribution transformers, both the 2010 regulation and upcoming 2016 regulation.

Table 97 – MEPS for Liquid-type Distribution Transformers in the U.S.

kVA	Single-Phase % Efficiency 2010	Single-Phase % Efficiency 2016	kVA	Three-Phase % Efficiency 2010	Three-Phase % Efficiency 2016
10	98.62	98.7	15	98.36	98.65
15	98.76	98.82	30	98.62	98.83
25	98.91	98.95	45	98.76	98.92
37.5	99.01	99.05	75	98.91	99.03
50	99.08	99.11	112.5	99.01	99.11
75	99.17	99.19	150	99.08	99.16
100	99.23	99.25	225	99.17	99.23
167	99.25	99.33	300	99.23	99.27
250	99.32	99.39	500	99.25	99.35
333	99.36	99.43	750	99.32	99.4
500	99.42	99.49	1,000	99.36	99.43
667	99.46	99.52	1,500	99.42	99.48
833	99.49	99.55	2,000	99.46	99.51
-	-	-	2,500	99.49	99.53

As reported in (SEAD, 2013b), USDOE adopted its test method for measuring the efficiency of distribution transformers in April 2006. The DOE's test procedure is based on the test methods contained in NEMA TP 2-1998 and IEEE Standards C57.12.90-1999 and C57.12.91-2001. The final rule, without reference to other sources, determines the energy efficiency of distribution transformers through the measurement of no-load and load losses. The DOE test method specifies the temperature, current, voltage, extent of distortion in voltage waveform, and direct current resistance of the windings. The standard also prescribes provisions for calculating efficiency.

Data inputs

Total distributed electricity is calculated from IEA data as the sum of the sales in every sector of the economy plus the T&D losses (IEA, 2012c). We use the growth rate from the national electricity demand forecast to 2030 in the *APERC Energy Demand and Supply Outlook*, 5th Edition (APERC, 2012) to project total distributed electricity to 2030. We collected stock data and market data including historical and forecast sales, baseline efficiency, market share by capacity and load factor from the latest U.S rulemaking(USDOE, 2013a).

Economic data such as sales taxes and labor cost were collected from publicly available sources (BLS, 2012; TMF, 2013).

The CO_2 and NO_x/SO_2 emission factors are taken from the IEA data set on CO_2 emissions from fuel combustion (IEA, 2012a) and calculated based on fuel mix and IPCC guidelines (IPCC, 1997).

Table 98 summarizes the input data developed for the U.S.

Table 98 – Economy-Specific Inputs Summary for the U.S. in 2010

	Value		Source/Note
Total Distributed Electricity	3780	TWh	(IEA, 2012c)
Distribution transformers Capacity	2,206,900	MVA	calculated from sales
Stock	31.6	Millions	calculated from sales
RMS Loading	34	%	(USDOE, 2013a)
Average Capacity	73	kVA	(USDOE, 2013a)
Sales	780,000	Units	(USDOE, 2013a)
Consumer Discount Rate	7.4	%	same as U.S.
National Discount Rate	3	%	(USDOE, 2013a)
VAT	5.3	%	(USDOE, 2013a)
Cost of Electricity Generation	0.07	\$/kWh	(IEA, 2010)
CO_2 Emission Factor	0.522	kg/kWh	(IEA, 2012a)
SO_2 Emission Factor	0.567	g/kWh	(IPCC, 1997)
NO_x Emission Factor	0.524	g/kWh	(IPCC, 1997)
Labor Cost	36	USD/hour	(BLS, 2012)

Cost-Benefit Analysis

In order to identify additional cost-effective potential for the U.S, we calculate the cost of conserved energy for different levels of efficiency ranging from the 2016 U.S MEPS (EL2) to EL4. Then, we compare the cost of conserved energy to the cost of electricity generation in order to determine the highest cost-effective efficiency targets. This target provides the greatest energy savings while ensuring a net financial benefit to the consumer (in this case, the utility company). We find additional cost-effective potential for DL1 at EL3 and DL4 at the maximum efficiency level. We didn't find any cost-effective options for DL2 and DL5.

Table 99 presents the results for the four representative design lines we study:

Table 99 – Cost-Benefit Analysis for Representative Units for the U.S.

	Baseline		Target	
	Representative Design Line 1, 1-phase 50kVA			
Efficiency Rating (%)		99.1%		99.3%
Losses (kWh/year)		1,386		1,005
Price (USD)	$	1,798	$	1,652
CCE (USD)			$	(0.032)
	Representative Design Line 2, 1-phase 25kVA			
Efficiency Rating (%)		99.0%	No Cost-Effective Option	
Losses (kWh/year)		848		
Price (USD)	$	1,211		
CCE (USD)				
	Representative Design Line 4, 3-phase 150kVA			
Efficiency Rating (%)		99.2%		99.6%
Losses (kWh/year)		4,216		1,801
Price (USD)	$	5,257	$	7,175
CCE (USD)			$	0.065
	Representative Design Line 5, 3-phase 1500kVA			
Efficiency Rating (%)		99.5%	No Cost-Effective Option	
Losses (kWh/year)		24,275		
Price (USD)	$	26,577		
CCE (USD)				

National Impact Analysis

As explained in the methodology section, the results from the cost-benefit analysis are scaled to represent the units found in the U.S. market and then propagated into BUENAS to calculate national energy savings, avoided CO_2 emissions and financial impacts, in terms of net present value (NPV).

The following table summarizes the market shares, and average market capacities used to scale the unit level results to the national level along with the resulting scaled UEC and price inputs.

Table 100 – Design Lines (DL) Market Shares and Market Average UEC and Price in the U.S.

	DL1	**DL2**	**DL4**	**DL5**
DL Market Shares	24.9%	68.3%	4.6%	2.2%
Average Capacity (kVA)	46	26	256	1,451
Scaled Baseline UEC (kWh/year)	1,306	869	6,287	23,677
Scaled Baseline Price (USD)	1,693	1,242	7,839	25,923
Scaled Target UEC (kWh/year)	1,306	869	2,686	23,677
Scaled Target Price (USD)	1,693	1,242	10,698	25,923

We analyze two policy scenarios in this study:

1- A MEPS taking effect in 2016, set at the maximum cost-effective level for all representative design lines.
2- An endorsement label targeting the cost-effective levels for all representative design lines, which would drive a 10% increase in the sales market share every year starting in 2015, up to a maximum of 50% market share by 2020.

Table 101 presents the national impact analysis results for the U.S. in 2020 and 2030.

Table 101 – National Impacts Analysis Results for the U.S.

		Units	**Year**	**MEPS Scenario**	**Labeling Program Scenario**
Annual Impacts	Energy Savings	GWh	2020	1,014.3	406.7
			2030	3,138.4	1,472.2
	CO_2 Emissions Savings	Mt	2020	0.5	0.2
			2030	1.6	0.8
	SO_2 Emissions Savings	kt	2020	0.8	0.3
			2030	2.4	1.1
	NOx Emissions Savings	kt	2020	0.6	0.2
			2030	1.9	0.9
Cumulative Impacts	Energy Savings	GWh	through 2020	3,028.0	1,111.5
			through 2030	24,774.8	10,993.6
	CO_2 Emissions Savings	Mt	through 2020	1.6	0.6
			through 2030	12.9	5.7
	SO_2 Emissions Savings	kt	2020	2.3	0.8
			2030	18.9	8.4
	NOx Emissions Savings	kt	2020	1.8	0.7
			2030	14.6	6.5
	Operating Cost Savings	Million USD		3,470.4	1,604.4
	Equipment Cost	Million USD		866.0	400.4
	NPV	Million USD		2,604.5	1,204.1

Although the recent U.S. rulemaking captured a large portion of the cost-effective potential, we identify an additional 5% cost-effective savings, which could be achieved through an increase of the MEPS levels or a labeling program, such as energy star, targeting higher efficiency distribution transformers. As opposed to MEPS, the labeling program does not make the sale of efficient models mandatory, so the impacts of an endorsement label presented in the table above have to be taken as indicative.

In sum, the impacts of adopting a MEPS requiring the highest cost effective efficiency level are:

• 1,014 GWh of electricity savings in 2020 and 3,138 GWh in 2030.
• 24.8 TWh cumulative electricity savings between 2016 and 2030.

- 0.5 Mt of annual CO_2 emissions reductions by 2020 and 1.6 Mt by 2030.
- 12.9 Mt cumulative emissions reduction between 2016 and 2030.
- The net present value of the savings would be an estimated 2.60 Billion USD.

2.3.20. Viet Nam

In the current analysis, we estimate that the impact of introducing more stringent or additional S&L programs for distribution transformers in Viet Nam would be:

- 1.2 TWh annual electricity savings from MEPS by 2030
- 30% reduction in national distribution losses by 2030
- 0.5 Mt CO_2 emission avoided by 2030 from MEPS
- 458 million USD net financial benefits from MEPS
- 0.6 TWh annual electricity savings from endorsement label by 2030
- 0.2 Mt CO_2 emissions avoided by 2030 from endorsement label
- 211 million USD net financial benefits from endorsement label

Test Procedure, S&L Status

The national testing standards used to measure performance are called "Tiêu chuẩn Việt Nam" (TCVN), which in English means "Viet Nam Standards". . In November 2011, the Ministry of Industry and Trade (MOIT) of Viet Nam has adopted mandatory efficiency regulations for distribution transformers that should enter into force on January 1, 2015 (MOIT, 2010). Viet Nam's regulation on distribution transformers is contained in TCVN 8525: 2010 (Distribution Transformers - the minimum energy efficiency and methods for determining energy efficiency). This standard establishes the MEPS and test method of determining the energy efficiency for three-phase liquid-filled distribution transformers with nominal capacity from 25 to 2,500 kVA and nominal voltage up to 35 kV and frequency of 50Hz. In TCVN 8525:2010, the regulation cross-references loss measurement procedures adopted in the Vietnamese Standard TCVN 6306-1, which is harmonized with IEC 60076. Table 102 presents the minimum efficiency requirement in TCVN 8525:2010.

Table 102 – Minimum Efficiency Requirements for Three-Phase Liquid-Type Transformers for Viet Nam

Capacity	**Minimum Efficiency at 50% Load**
kVA	%
25	98.28
32	98.34
50	98.5
63	98.62
100	98.76
125	98.8
160	98.87
200	98.94
250	98.98
315	99.04
400	99.08
500	99.13
630	99.17
750	99.21
800	99.22
1,000	99.27
1,250	99.31
1,500	99.35
1,600	99.36
2,000	99.39
2,500	99.4

Data inputs

Total distributed electricity is calculated from IEA data as the sum of the sales in every sector of the economy plus the T&D losses (IEA, 2012c). We use the growth rate from the national electricity demand forecast to 2030 in the *APERC Energy Demand and Supply Outlook*, 5th Edition (APERC, 2012) to project total distributed electricity to 2030. In 2010, the national utility Viet Nam Electricity (EVN) reports that the transmission network has a total transformers' capacity of 500 kV network of 7,500 MVA, the capacity of 220 kV network was 19,094 MVA, and the 110 kV network had a capacity of 25,862 MVA. It is impossible to make up the distribution capacity from the numbers above, but these figures indicate that our calculated distribution capacity of 23,000 MVA is in the right ballpark.

Economic data such as sales taxes and labor cost were collected from publicly available sources (BLS, 2012; TMF, 2013). Fuel mix is taken for the year 2015 from (APERC, 2012) in order to calculate the weighted average price of electricity generation based on estimates from the Electricity Generating Authority of Thailand (EGAT, 2010), as a proxy.

The CO_2 and NO_x/SO_2 emission factors are taken from the IEA data set on CO_2 emissions from fuel combustion (IEA, 2012a) and calculated based on fuel mix and IPCC guidelines (IPCC, 1997).

Table 103 summarizes the input data developed for Viet Nam.

Table 103 – Economy-Specific Inputs Summary for Viet Nam in 2010

	Value		Source/Note
Total Distributed Electricity	90	TWh	(IEA, 2012c)
Distribution transformers Capacity	22,600	MVA	calculated
Stock	0.31	Millions	calculated
Average Load Factor	50	%	assumed
Average Capacity	73	kVA	(USDOE, 2013a)
Sales	9,800	Units	calculated
Consumer Discount Rate	10	%	(IEA, 2010)
National Discount Rate	5	%	Assumed
VAT	10	%	(TMF, 2013)
Cost of Electricity Generation	0.09	$/kWh	derived from (EGAT, 2010)
CO_2 Emission Factor	0.432	kg/kWh	(IEA, 2012a)
SO_2 Emission Factor	0.567	g/kWh	(IPCC, 1997)
NO_x Emission Factor	0.524	g/kWh	(IPCC, 1997)
Labor Cost	1	$/hour	Derived from GDP/cap

Cost-Benefit Analysis

We use the MEPS definition for DL4 and DL5 as our baseline (which correspond to an efficiency level between EL1 and EL2. For the design lines that are not covered by the regulation, we use EL0 as our baseline. Then, we calculate the cost of conserved energy for different levels of efficiency ranging from the baseline to EL4. Finally, we compare the cost of conserved energy to the cost of electricity generation in order to determine the highest cost-effective efficiency targets. This target provides the greatest energy savings while ensuring a net financial benefit to the consumer (in this case, the utility company).

We find that a MEPS set at the maximum efficiency level would be cost effective in the local context.

Table 104 presents the results for the four representative design lines we study:

Table 104 – Cost-Benefit Analysis for Representative Units for Viet Nam

	Baseline	Target
	Representative Design Line 1, 1-phase 50kVA	
Efficiency Rating (%)	98.5%	99.5%
Losses (kWh/year)	3,241	1,139
Price (USD)	$ 742	$ 1,974
CCE (USD)		$ 0.062
	Representative Design Line 2, 1-phase 25kVA	
Efficiency Rating (%)	98.0%	99.5%
Losses (kWh/year)	2,225	911
Price (USD)	$ 407	$ 1,253
CCE (USD)		$ 0.068
	Representative Design Line 4, 3-phase 150kVA	
Efficiency Rating (%)	98.9%	99.6%
Losses (kWh/year)	7,647	2,654
Price (USD)	$ 3,288	$ 5,955
CCE (USD)		$ 0.056
	Representative Design Line 5, 3-phase 1500kVA	
Efficiency Rating (%)	99.4%	99.7%
Losses (kWh/year)	42,985	21,085
Price (USD)	$ 17,158	$ 33,421
CCE (USD)		$ 0.078

National Impact Analysis

As explained in the methodology section, the results from the cost-benefit analysis are scaled to represent the units found in the Vietnamese market and then propagated into BUENAS to calculate national energy savings, avoided CO_2 emissions and financial impacts, in terms of net present value (NPV).

The following table summarizes the market shares, and average market capacities used to scale the unit level results to the national level along with the resulting scaled UEC and price inputs.

Table 105 – Design Lines (DL) Market Shares and Market Average UEC and Price in Viet Nam

	DL1	DL2	DL4	DL5
DL Market Shares	24.9%	68.3%	4.6%	2.2%
Average Capacity (kVA)	46	26	256	1,451
Scaled Baseline UEC (kWh/year)	3,053	2,281	11,403	41,927
Scaled Baseline Price (USD)	699	418	4,903	16,736
Scaled Target UEC (kWh/year)	1,073	611	3,958	20,566
Scaled Target Price (USD)	1,859	1,836	8,879	32,598

We analyze two policy scenarios in this study:

1- A MEPS taking effect in 2016, set at the maximum cost-effective level for all representative design lines.
2- An endorsement label targeting the cost-effective levels for all representative design lines, which would drive a 10% increase in the sales market share every year starting in 2015, up to a maximum of 50% market share by 2020.

Table 106 presents the national impact analysis results for the U.S. in 2020 and 2030.

Table 106 – National Impacts Analysis Results for Viet Nam

		Units	**Year**	**MEPS Scenario**	**Labeling Program Scenario**
Annual Impacts	Energy Savings	GWh	2020	222.7	89.1
			2030	1,216.5	568.8
	CO_2 Emissions Savings	Mt	2020	0.1	0.0
			2030	0.5	0.2
	SO_2 Emissions Savings	kt	2020	0.1	0.1
			2030	0.7	0.3
	NOx Emissions Savings	kt	2020	0.1	0.0
			2030	0.6	0.3
Cumulative Impacts	Energy Savings	GWh	through 2020	617.6	227.4
			through 2030	7,537.5	3,376.4
	CO_2 Emissions Savings	Mt	through 2020	0.3	0.1
			through 2030	3.3	1.5
	SO_2 Emissions Savings	kt	2020	0.3	0.1
			2030	4.3	1.9
	NOx Emissions Savings	kt	2020	0.3	0.1
			2030	4.0	1.8
	Operating Cost Savings	Million USD		820.2	380.8
	Equipment Cost	Million USD		362.5	170.1
	NPV	Million USD		457.6	210.8

These results show the significant savings achievable through a MEPS or a labeling program. As opposed to MEPS, the labeling program does not make the sale of efficient models mandatory, so the impacts of an endorsement label presented in the table above have to be taken as indicative.

In sum, the impacts of adopting a MEPS requiring the highest cost effective efficiency level are:

• 223 GWh of electricity savings in 2020 and 1,216 GWh in 2030.
• 7.5 TWh cumulative electricity savings between 2016 and 2030.
• 0.1 Mt of annual CO_2 emissions reductions by 2020 and 0.5 Mt by 2030.
• 3.3 Mt cumulative emissions reduction between 2016 and 2030.
• The net present value of the savings would be an estimated 458 Million USD.

3. Discussion and conclusions

Our study shows that implementation of optimized policies targeting cost-effective efficiency levels in APEC economies can reduce losses through distribution transformers by 30 TWh in 2030, or a 20% reduction in national distribution losses. As a result, annual CO_2 emissions in the APEC region would be reduced by 17 Mt. The net present value of the savings would be an estimated 17.5 Billion USD. Table 107 summarizes the savings from the MEPS studied, for every APEC economy. Situation varies greatly among economies in terms of current progress to date and future opportunities. For example, because of the recently accomplished rulemaking in the U.S., we only identify an additional 6% saving for this economy, while other economies which are still in the process of updating their regulation (such as Australia and New Zealand) present quite a high cost-effective potential. On the other end, a lot of economies in the APEC region have not yet regulated transformers, which makes the assessment of cost-effective potential more difficult because of the lack of data, but also means that opportunities of savings are even greater.

As explained above, most economies where distribution transformers have not been yet regulated were not able to provide us with data; therefore, results for these economies are subject to a significant uncertainty because of the assumptions that had to be made regarding the main drivers of the results. These economies are marked with an asterisk (*) in Table 107. For economies that provided us with at least some data, we believe that the robustness of the results is much greater than for the economies for which we had no data. Therefore, economies that provided data are not marked with an asterisk.

Table 107 – Summary Results for all APEC Economies under the MEPS Scenario

	Annual Impacts				Cumulative Impacts		
	National Distribution Losses	Energy Savings	% Red.	CO_2 Emission Savings	Energy Savings	CO_2 Emission Savings	Net Financial Benefits
	2030	2030	2030	2030	2016-2030	2016-2030	Total
	GWh	GWh	%	Mt	TWh	Mt	Million USD
Australia	9,402	2,759	29%	2.32	21.5	18.1	1,982
Brunei*	63	21	33%	0.02	0.2	0.1	47
Canada	10,058	1,464	15%	0.27	11.4	2.1	463
Chile	3,254	1,259	39%	0.52	9.3	3.8	732
Hong Kong, China	586	95	16%	0.07	0.7	0.5	15
Indonesia	4,980	1,130	23%	0.80	7.1	5.1	686
Japan	15,492	2,558	17%	1.07	20.5	8.6	1,330
Korea	7,354	1,428	19%	0.76	10.8	5.8	460
Malaysia	4,516	2,072	46%	1.51	15.6	11.3	2,467
Mexico	6,295	1,434	23%	0.65	10.8	4.9	833
New Zealand	455	153	34%	0.02	1.2	0.2	152
Papua New Guinea*	156	52	33%	0.03	0.3	0.2	71
Peru	1,646	435	26%	0.13	3.0	0.9	145
Philippines*	2,230	746	33%	0.36	5.0	2.4	668
Russia*	22,031	7,368	33%	4.71	52.9	33.8	3,238
Singapore	814	272	33%	0.14	2.1	1.0	188
Chinese Taipei*	4,562	1,246	27%	0.96	9.4	7.2	226
Thailand	3,821	1,047	27%	0.54	7.2	3.7	674
United States	51,117	3,138	6%	1.64	24.8	12.9	2,604
Viet Nam	4,008	1,216	30%	0.53	7.5	3.3	458
Total	152,840	29,893	20%	17	221	126	17,439

*Results for this economy are subject to a sizeable uncertainty

In order to understand the variability on the results between economies, we identify the main drivers of the results along with the uncertainty and its effect on the results in Table 108.

Table 108 – Summary of Level of Uncertainty and Impact of Results by Driver

Drivers of cost-effectiveness	Uncertainty/Effect	Drivers of magnitude of savings	Uncertainty/Effect
Load factor	High/High	Size of the stock	Medium/Medium
Baseline efficiency	Medium/High	Sales	Medium/Medium
Baseline costs	Medium/High	Distribution capacity	Medium/Medium
Cost of generation	Low/Medium	Electricity generation forecast	Low/Low

Further analytical work is needed to support and implement standards and labeling programs in the APEC economies, but this study provides a first-order set of results showing the significant potential for energy savings, environmental benefits, and financial savings from standards and labeling for distribution transformer efficiency. In addition, this report contributes to current discussions about test procedure harmonization among the APEC economies.

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