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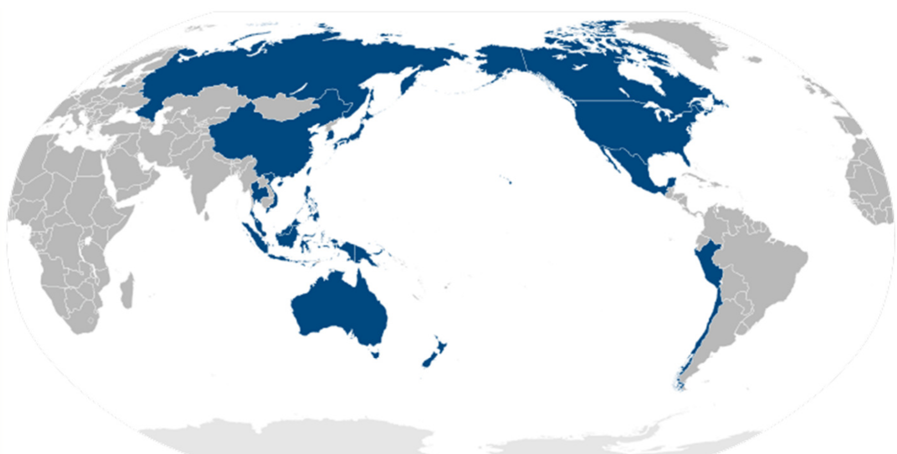
Energy Efficiency Potential for Distribution Transformers in the APEC Economies



Environmental Energy Technologies Division

October 2013

This work was supported by the International Copper Association through the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

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Acknowledgements

The authors want to thank our sponsor the International Copper Association for their support and collaboration during this project. Specifically, we are grateful to Ajit Advani for his guidance and flexibility and Mayur Karmarkar and Glycon Garcia for their technical inputs. We thank Christopher Bolduc and Nikit Abhyankar from LBNL for sharing their expertise and for reviewing the report, along with Nan Wishner, our technical editor. We also want to thank Gabrielle Dreyfus from USDOE, Jenny Corry from CLASP and Michael Scholand from N14 for closely coordinating the SEAD activities on distribution transformers with us. We want to thank Jeremy Tait for sharing his work for the IEA 4e project on distribution transformers and pointing us to valuable resources. Finally, we want to thank Terry Collins and all the EGEE&C APEC representatives for their participation in the project.

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	Vietnam 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
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
PF	power factor
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 2.8% and 15.6% of final energy consumption (IEA). Because approximately one-third 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.

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 countries 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
- 19 percent reduction over the 157 TWh electricity distribution losses projected in 2030
- 17 million tons (Mt) of annual carbon dioxide (CO_2) emissions reductions by 2030
- 120 Mt of cumulative emissions savings between 2016 and 2030
- 18.5 billion USD in cumulative consumer financial benefits

Scope:

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 country. 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 country-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 country 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 countries 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 country. 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%	2.3	21.5	18.1	1,982
Brunei*	63	19	30%	0.0	0.1	0.1	43
Canada	10,058	1,464	15%	0.3	11.4	2.1	463
Chile	3,254	1,248	38%	0.5	9.2	3.8	724
Hong Kong	586	95	16%	0.1	0.7	0.5	15
Indonesia*	7,913	2,361	30%	1.7	14.9	10.6	1,634
Japan	15,492	2,558	17%	1.1	20.5	8.6	1,330
Malaysia	4,516	1,957	43%	1.4	14.7	10.7	2,320
Mexico	6,295	1,434	23%	0.7	10.8	4.9	833
New Zealand	455	153	34%	0.0	1.2	0.2	152
Papua New Guinea*	156	47	30%	0.0	0.3	0.2	65
Peru	1,646	392	24%	0.1	2.7	0.8	130
Philippines*	2,230	665	30%	0.3	4.5	2.2	619
Russia*	22,031	6,574	30%	4.2	47.2	30.1	3,184
Singapore	814	243	30%	0.1	1.8	0.9	180
South Korea	7,354	1,325	18%	0.7	10.0	5.4	514
Taipei*	4,562	1,183	26%	0.9	8.9	6.9	214
Thailand	4,980	1,491	30%	0.8	10.3	5.3	1,066
United States	51,117	3,138	6%	1.6	24.8	12.9	2,604
Vietnam	4,008	1,107	28%	0.5	6.9	3.0	460
Total	**156,932**	**30,212**	**19%**	**17**	**222**	**127**	**18,532**

*Results for this country 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 19 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 127 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 18.5 billion USD.

1. Background

Transmission and distribution (T&D) losses in electricity networks in Asia-Pacific Economic Cooperation (APEC) member economies range between 2.8% and 15.6% of final electricity consumption (IEA). Because approximately one-third 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. The goal of this 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 countries through learning and implementing best practices to reduce T&D losses. Given the variability of the country situations in the region, it is important to assess country by country 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 countries.

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 country-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 country profiles, providing EES&L status, input data and quantitative analysis of potential savings for every country. A forthcoming separate report will compare the different test procedures in the APEC region and provides recommendations for harmonized test procedure.

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 country profiles that summarize our assumptions and findings for each APEC country.

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 country'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 country-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 country proxies to provide savings estimates for every member country as explained in the engineering and cost-benefit analysis sub-sections below.

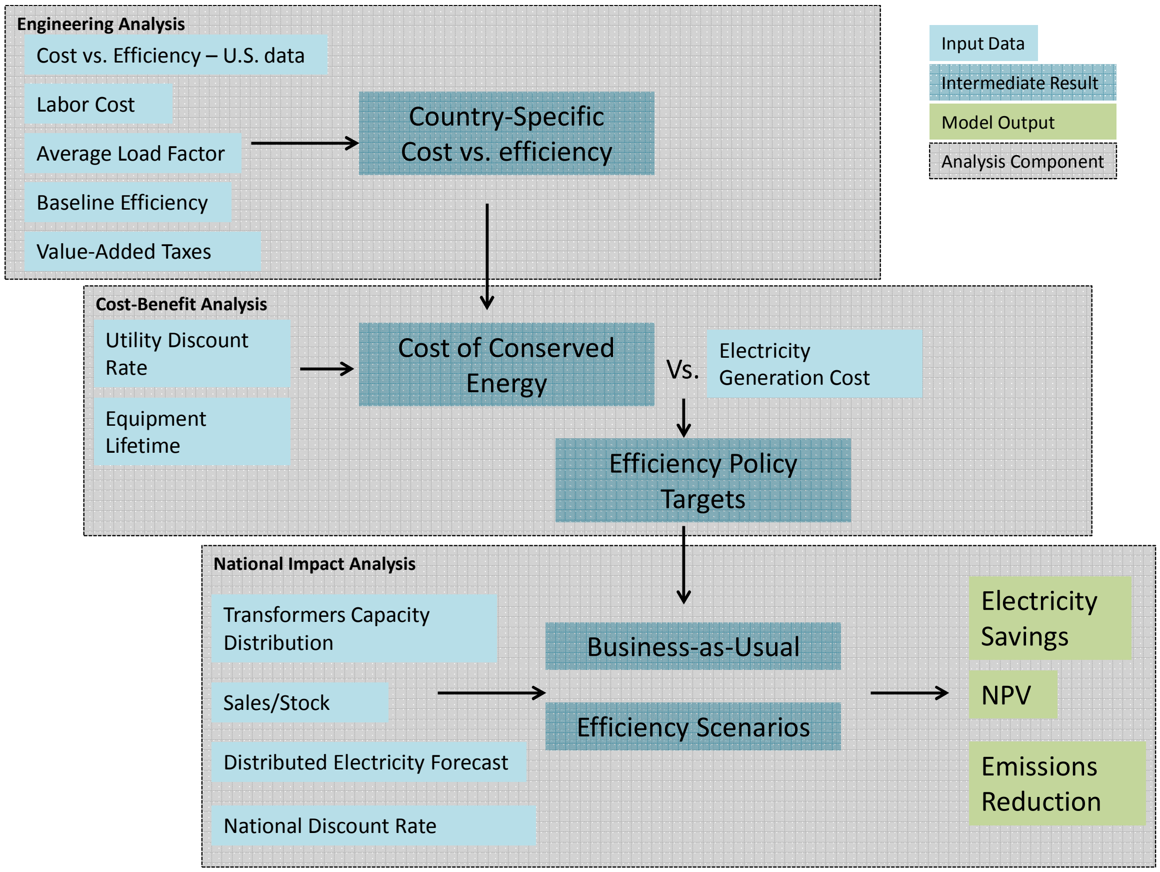
The following data were required for our analysis:

- 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 countries depends on two facts: transformers perform a basic engineering function that does not vary significantly among countries, 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 country-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.

Table 1 – Results of linear regression between transformer design option price and losses

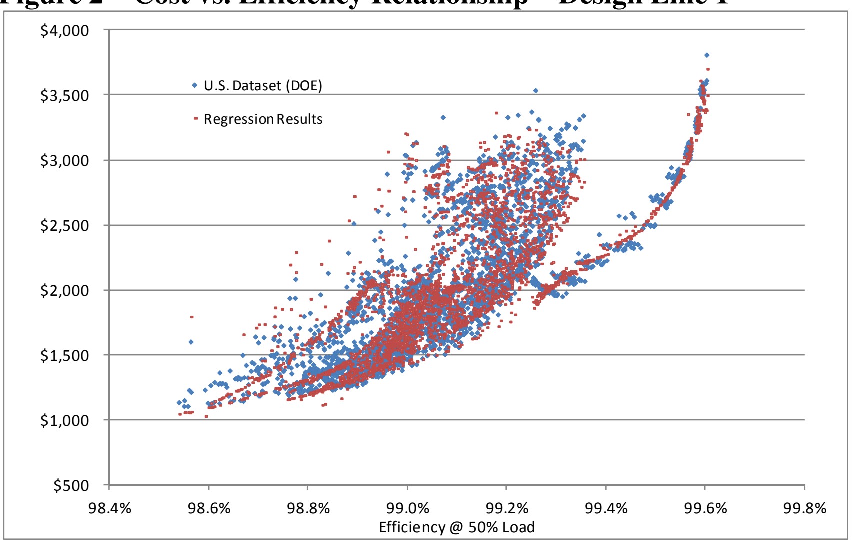
Design Line		C01	C02	C03	C04	C05	C06	C07	C08
DL 1 (Liquid immersed, 50kVA, single phase, rectangular tank)	b_0	841	568	983	749	973	810	795	1,00
	b_{NLL}	15,412	31,801	11,495	17,909	21,032	21,856	23,161	11,45
	b_{LL}	18,494	32,083	17,326	23,770	28,473	28,449	28,984	30,86
	R^2	1	1	1	1	1	1	1	
	σ	38	92	52	81	91	118	94	6
DL 2 (Liquid immersed, 25kVA, single phase, round tank)	b_0	446	460	475	632	679	823	690	85
	b_{NLL}	9,569	11,979	8,837	11,039	7,519	4,835	7,470	5,36
	b_{LL}	8,669	10,894	9,407	12,105	10,732	10,470	11,681	11,18
	R^2	1	1	1	1	1	1	1	
	σ	29	49	30	38	53	132	71	12
DL 4 (Liquid immersed, 150kVA, three phase)	b_0	2,141	2,051	1,441	1,747	1,998	2,000	1,813	
	b_{NLL}	68,803	69,455	121,472	106,429	100,387	106,332	62,848	
	b_{LL}	52,095	62,247	105,717	102,511	105,073	102,234	123,554	
	R^2	1	1	1	1	1	1	1	
	σ	91	132	204	241	267	264	172	
DL 5 (Liquid immersed, 1500kVA, three phase)	b_0	7,729	7,024	9,378	7,798	10,137	13,509		
	b_{NLL}	808,890	2,009,593	1,244,010	1,373,477	1,098,113	850,080		
	b_{LL}	1,089,794	2,986,556	2,475,133	2,547,750	2,149,799	1,778,777		
	R^2	1	1	1	1	1	1		
	σ	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 country to country, 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 country.
- Compare least-cost options at the operating load to this efficiency baseline.

Calculation of equipment cost according to country-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 country[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 country 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 countries with mandatory S&L programs, the baseline efficiency is defined by these programs. However, if a country has never regulated distribution transformers, baseline efficiency information is difficult to obtain. To determine the "floor" of distribution transformer energy efficiency in these countries, 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 country'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 countries. 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 country. The technical floor is used for countries 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)

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[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 country-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 country 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:

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

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:

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

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 countries 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 countries 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:

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

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:

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

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:

$$NEC(y)=EC(y) \times Sales\ (y)$$

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

$$NOC(y)=E(y) \times P\ (y)$$

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. Country 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 – Country-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

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

- 19 GWh annual electricity savings from MEPS by 2030
- 30% reduction in national distribution losses by 2030
- 0.015 Mt CO_2 emission avoided by 2030 from MEPS
- 43 million USD net financial benefits from MEPS
- 8.8 GWh annual electricity savings from endorsement label by 2030
- 0.007 Mt CO_2 emissions avoided by 2030 from endorsement label
- 20 million USD net financial benefits from endorsement label

Test Procedure, S&L Status

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

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.

Given the lack of data for Brunei, 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.

Table 10 – Country Specific Inputs Summary for Brunei 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 country 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

	Baseline		Target	
	Representative Design Line 1, 1-phase 50kVA			
Efficiency Rating (%)	98.5%		99.5%	
Losses (kWh/year)		3,241		1,139
Price (USD)	$	927	$	2,391
CCE (USD)			$	0.073
	Representative Design Line 2, 1-phase 25kVA			
Efficiency Rating (%)	98.0%		99.5%	
Losses (kWh/year)		2,225		911
Price (USD)	$	501	$	1,518
CCE (USD)			$	0.081
	Representative Design Line 4, 3-phase 150kVA			
Efficiency Rating (%)		98.3%		99.6%
Losses (kWh/year)		11,292		4,722
Price (USD)	$	2,075	$	5,833
CCE (USD)			$	0.060
	Representative Design Line 5, 3-phase 1500kVA			
Efficiency Rating (%)		99.0%		99.7%
Losses (kWh/year)		69,046		20,866
Price (USD)	$	11,933	$	40,818
CCE (USD)			$	0.063

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

	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	67,346
Scaled Baseline Price (USD)	873	513	3,094	11,639
Scaled Target UEC (kWh/year)	1,073	934	7,040	20,353
Scaled Target Price (USD)	2,252	1,556	8,697	39,813

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 in 2020 and 2030.

Table 13 – National Impacts Analysis Results for Brunei

		Units	Year	MEPS Scenario	Labeling Program Scenario
Annual Impacts	Energy Savings	GWh	2020	6.004	2.402
			2030	18.814	8.798
	CO_2 Emissions Savings	Mt	2020	0.005	0.002
			2030	0.015	0.007
	SO_2 Emissions Savings	kt	2020	-	-
			2030	-	-
	NOx Emissions Savings	kt	2020	0.003	0.001
			2030	0.010	0.005
Cumulative Impacts	Energy Savings	GWh	through 2020	17.882	6.559
			through 2030	147.708	65.380
	CO_2 Emissions Savings	Mt	through 2020	0.014	0.005
			through 2030	0.118	0.052
	SO_2 Emissions Savings	kt	2020	-	-
			2030	-	-
	NOx Emissions Savings	kt	2020	0.009	0.003
			2030	0.076	0.033
	Operating Cost Savings	Million USD		50.7	23.2
	Equipment Cost	Million USD		7.6	3.5
	NPV	Million USD		43.0	19.7

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:

- 6 GWh of electricity savings in 2020 and 18 GWh in 2030.
- 148 GWh cumulative electricity savings between 2016 and 2030.
- 0.005 Mt of annual CO_2 emissions reductions by 2020 and 0.015 Mt by 2030.
- 0.12 Mt cumulative emissions reduction between 2016 and 2030.
- The net present value of the savings would be an estimated 43 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 – Country-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)[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:

- 1.2 TWh annual electricity savings from MEPS by 2030
- 38% reduction in national distribution losses by 2030
- 0.5 Mt CO_2 emission avoided by 2030 from MEPS
- 720 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 country 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 – Country-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)	$ 883	$ 2,277
CCE (USD)		$ 0.104
	Representative Design Line 2, 1-phase 25kVA	
Efficiency Rating (%)	98.0%	99.5%
Losses (kWh/year)	1,444	591
Price (USD)	$ 477	$ 1,446
CCE (USD)		$ 0.119
	Representative Design Line 4, 3-phase 150kVA	
Efficiency Rating (%)	98.3%	99.6%
Losses (kWh/year)	7,588	3,248
Price (USD)	$ 1,976	$ 5,555
CCE (USD)		$ 0.087
	Representative Design Line 5, 3-phase 1500kVA	
Efficiency Rating (%)	99.0%	99.7%
Losses (kWh/year)	42,946	12,979
Price (USD)	$ 11,364	$ 38,871
CCE (USD)		$ 0.096

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)	1,291	477	2,265	-
ScaledTargetUEC(kWh/year)	910	591	3,724	-
ScaledTargetPrice(USD)	3,330	1,446	6,369	-

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	346.4	139.9
			2030	1,247.9	591.8
	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	1,014.7	373.9
			through 2030	9,188.8	4,132.2
	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	10.8	4.9
	NOx Emissions Savings	kt	2020	0.5	0.2
			2030	4.6	2.1
	Operating Cost Savings	Million USD		1481.0	687.4
	Equipment Cost	Million USD		757.4	351.6
	NPV	Million USD		723.5	335.8

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:

- 346 GWh of electricity savings in 2020 and 1,248 GWh in 2030
- 9.1 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
- 723 Million USD estimated net present value of savings

2.3.5. 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
- 26% reduction in national distribution losses by 2030
- 0.9 Mt CO_2 emission avoided by 2030 from MEPS
- 210 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
- 99 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 country.

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 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)

Table 24 summarizes the input data developed for Taipei.

Table 24 – Country-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 country 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.

Table 25 presents the results for the four representative design lines we study:

Table 25 – Cost-Benefit Analysis for Representative Units for Chinese-Taipei

	Baseline	Target
	Representative Design Line 1, 1-phase 50kVA	
Efficiency Rating (%)	98.5%	99.5%
Losses (kWh/year)	3,241	1,139
Price (USD)	$ 777	$ 2,004
CCE (USD)		$ 0.037
	Representative Design Line 2, 1-phase 25kVA	
Efficiency Rating (%)	98.0%	99.0%
Losses (kWh/year)	2,225	1,174
Price (USD)	$ 419	$ 988
CCE (USD)		$ 0.034
	Representative Design Line 4, 3-phase 150kVA	
Efficiency Rating (%)	98.3%	99.6%
Losses (kWh/year)	11,292	4,722
Price (USD)	$ 1,739	$ 4,889
CCE (USD)		$ 0.030
	Representative Design Line 5, 3-phase 1500kVA	
Efficiency Rating (%)	99.0%	99.7%
Losses (kWh/year)	69,046	20,866
Price (USD)	$ 10,001	$ 34,210
CCE (USD)		$ 0.032

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 26 – 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	67,346
Scaled Baseline Price (USD)	732	430	2,593	9,755
Scaled Target UEC (kWh/year)	1,073	1,204	7,040	20,353
Scaled Target Price (USD)	1,887	1,013	7,289	33,368

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 Chinese Taipei in 2020 and 2030.

Table 27 – National Impacts Analysis Results for Chinese Taipei

		Units	**Year**	**MEPS Scenario**	**Labeling Program Scenario**
Annual Impacts	Energy Savings	GWh	2020	347.9	139.2
			2030	1,182.8	553.1
	CO_2 Emissions Savings	Mt	2020	0.3	0.1
			2030	0.9	0.4
	SO_2 Emissions Savings	kt	2020	0.4	0.2
			2030	1.4	0.6
	NOx Emissions Savings	kt	2020	0.2	0.1
			2030	0.8	0.4
Cumulative Impacts	Energy Savings	GWh	through 2020	1,025.3	376.3
			through 2030	8,948.2	3,968.4
	CO_2 Emissions Savings	Mt	through 2020	0.8	0.3
			through 2030	6.9	3.0
	SO_2 Emissions Savings	kt	2020	1.2	0.4
			2030	10.3	4.6
	NOx Emissions Savings	kt	2020	0.7	0.3
			2030	6.4	2.8
	Operating Cost Savings	Million USD		633.6	293.1
	Equipment Cost	Million USD		419.1	194.2
	NPV	Million USD		214.5	98.8

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:

- 348 GWh of electricity savings in 2020 and 1,183 GWh in 2030.
- 8.9 TWh cumulative electricity savings between 2016 and 2030.
- 0.3 Mt of annual CO_2 emissions reductions by 2020 and 0.9 Mt by 2030.
- 6.9 Mt cumulative emissions reduction between 2016 and 2030.
- The net present value of the savings would be an estimated 214 Million USD.

2.3.6. 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 , 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 28 summarizes the input data developed for Hong Kong, China.

Table 28 – Country-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 29 presents the results for the representative design line we study:

Table 29 – 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 30 – 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 31 presents the national impact analysis results for Hong Kong in 2020 and 2030.

Table 31 – 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.

2.3.7. Indonesia

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

- 2.4 TWh annual electricity savings from MEPS by 2030
- 30% reduction in national distribution losses by 2030
- 1.7 Mt CO_2 emission avoided by 2030 from MEPS
- 1.6 billion USD net financial benefits from MEPS
- 1.1 TWh annual electricity savings from endorsement label by 2030
- 0.8 Mt CO_2 emissions avoided by 2030 from endorsement label
- 760 million USD net financial benefits from endorsement label

Test Procedure, S&L Status

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

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 32summarizes all of the data developed for Indonesia:

Table 32 – Country-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

Baseline efficiency is a key determinant in the cost-benefit analysis. In general, if a country 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.

Table 33 presents the results for the four representative design lines we study.

Table 33 – Cost-Benefit Analysis for Representative Units for Indonesia

	Baseline	Target
	Representative Design Line 1, 1-phase 50kVA	
Efficiency Rating (%)	98.5%	99.5%
Losses (kWh/year)	3,241	1,139
Price (USD)	$ 776	$ 2,001
CCE (USD)		$ 0.061
	Representative Design Line 2, 1-phase 25kVA	
Efficiency Rating (%)	98.0%	99.5%
Losses (kWh/year)	2,225	911
Price (USD)	$ 419	$ 1,271
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)	$ 1,736	$ 4,882
CCE (USD)		$ 0.050
	Representative Design Line 5, 3-phase 1500kVA	
Efficiency Rating (%)	99.0%	99.7%
Losses (kWh/year)	69,046	20,866
Price (USD)	$ 9,988	$ 34,164
CCE (USD)		$ 0.053

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 34 – 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)	3,053	2,281	16,837	67,346
Scaled Baseline Price (USD)	731	430	2,589	9,742
Scaled Target UEC (kWh/year)	1,073	934	7,040	20,353
Scaled Target Price (USD)	1,885	1,303	7,279	33,323

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

Table 35 – National Impacts Analysis Results for Indonesia

		Units	Year	MEPS Scenario	Labeling Program Scenario
Annual Impacts	Energy Savings	GWh	2020	454.0	181.6
			2030	2,361.0	1,104.0
	CO_2 Emissions Savings	Mt	2020	0.3	0.1
			2030	1.7	0.8
	SO_2 Emissions Savings	kt	2020	0.8	0.3
			2030	4.0	1.8
	NOx Emissions Savings	kt	2020	0.4	0.1
			2030	1.9	0.9
Cumulative Impacts	Energy Savings	GWh	through 2020	1,267.0	466.3
			through 2030	14,917.0	6,675.7
	CO_2 Emissions Savings	Mt	through 2020	0.9	0.3
			through 2030	10.6	4.7
	SO_2 Emissions Savings	kt	2020	2.1	0.8
			2030	25.0	11.2
	NOx Emissions Savings	kt	2020	1.0	0.4
			2030	12.0	5.4
	Operating Cost Savings	Million USD		2186.8	1014.2
	Equipment Cost	Million USD		553.2	259.0
	NPV	Million USD		1633.6	755.2

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 35 must be considered as indicative.
In sum, the impacts of adopting a MEPS requiring the highest cost-effective efficiency level are:

- 454 GWh of electricity savings in 2020 and 2,361 GWh in 2030
- 14.9 TWh cumulative electricity savings between 2016 and 2030
- 0.3 Mt of annual CO_2 emissions reductions by 2020 and 1.7 Mt by 2030
- 10.6 Mt cumulative emissions reduction between 2016 and 2030
- 1.6 Billion USD estimated net present value of savings

2.3.8. 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 36 – Japanese Top Runner Program Requirements

<table>
<tr><th colspan="4">Category</th><th rowspan="2">Maximum Energy Consumption E (W)</th></tr>
<tr><th>Transformer Type</th><th>Number of Phases</th><th>Rated Frequency</th><th>Rated Capacity</th></tr>
<tr><td rowspan="6">Liquid-type transformer</td><td rowspan="2">Single Phase</td><td>50 Hz</td><td></td><td>$E = 15.3 \times S^{0.696}$</td></tr>
<tr><td>60 Hz</td><td></td><td>$E = 14.4 \times S^{0.698}$</td></tr>
<tr><td rowspan="4">Three Phase</td><td rowspan="2">50 Hz</td><td>Up to 500 kVA</td><td>$E = 23.8 \times S^{0.653}$</td></tr>
<tr><td>Over 500 kVA</td><td>$E = 9.84 \times S^{0.842}$</td></tr>
<tr><td rowspan="2">60 Hz</td><td>Up to 500 kVA</td><td>$E = 22.6 \times S^{0.651}$</td></tr>
<tr><td>Over 500 kVA</td><td>$E = 18.6 \times S^{0.745}$</td></tr>
</table>

Table 37 – 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 countries.

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 38 summarizes the input data developed for Japan.

Table 38 – Country-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 37 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 39 presents the results for the four representative design lines we study:

Table 39 – 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 40 – 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 41 presents the national impact analysis results for Japan in 2020 and 2030.

Table 41 – 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.

2.3.9. Malaysia

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

- 2.0 TWh annual electricity savings from MEPS by 2030
- 43% reduction in national distribution losses by 2030
- 1.4 Mt CO_2 emission avoided by 2030 from MEPS
- 2.3 billion USD net financial benefits from MEPS
- 0.9 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 42 summarizes the input data developed for Malaysia.

Table 42 – Country-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 country 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 43 presents the results for the four representative design lines we study:

Table 43 – 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)	$ 779	$ 2,010
CCE (USD)		$ 0.088
	Representative Design Line 2, 1-phase 25kVA	
Efficiency Rating (%)	98.0%	99.5%
Losses (kWh/year)	1,505	616
Price (USD)	$ 421	$ 1,277
CCE (USD)		$ 0.101
	Representative Design Line 4, 3-phase 150kVA	
Efficiency Rating (%)	98.3%	99.6%
Losses (kWh/year)	7,880	3,364
Price (USD)	$ 1,745	$ 4,905
CCE (USD)		$ 0.073
	Representative Design Line 5, 3-phase 1500kVA	
Efficiency Rating (%)	99.0%	99.7%
Losses (kWh/year)	45,005	13,601
Price (USD)	$ 10,035	$ 34,326
CCE (USD)		$ 0.081

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 44 – 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	31,779
Scaled Baseline Price (USD)	-	-	3,634	7,086
Scaled Target UEC (kWh/year)	-	-	7,007	9,604
Scaled Target Price (USD)	-	-	10,217	24,238

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

Table 45 – National Impacts Analysis Results for Malaysia

		Units	**Year**	**MEPS Scenario**	**Labeling Program Scenario**
Annual Impacts	Energy Savings	GWh	2020	566.7	228.4
			2030	1,956.9	925.4
	CO_2 Emissions Savings	Mt	2020	0.4	0.2
			2030	1.4	0.7
	SO_2 Emissions Savings	kt	2020	0.4	0.2
			2030	1.3	0.6
	NOx Emissions Savings	kt	2020	0.4	0.2
			2030	1.3	0.6
Cumulative Impacts	Energy Savings	GWh	through 2020	1,668.4	614.1
			through 2030	14,688.0	6,581.7
	CO_2 Emissions Savings	Mt	through 2020	1.2	0.4
			through 2030	10.7	4.8
	SO_2 Emissions Savings	kt	2020	1.1	0.4
			2030	9.9	4.5
	NOx Emissions Savings	kt	2020	1.1	0.4
			2030	10.1	4.5
	Operating Cost Savings	Million USD		3,224.5	1,491.6
	Equipment Cost	Million USD		904.4	418.4
	NPV	Million USD		2,320.2	1,073.3

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:

• 567 GWh of electricity savings in 2020 and 1,957 GWh in 2030.
• 14.7 TWh cumulative electricity savings between 2016 and 2030.
• 0.4 Mt of annual CO_2 emissions reductions by 2020 and 1.4 Mt by 2030.
• 10.7 Mt cumulative emissions reduction between 2016 and 2030.
• The net present value of the savings would be an estimated 2.3 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 46 describes the scope of the standard for liquid-type distribution transformers in Mexico.

Table 46 – 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 47 – 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 48 shows the proposed MEPS definition for Mexican transformers, tested at 80% load.

Table 48 – 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 49 summarizes all of the data available for Mexico.

Table 49 – Country-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 47, 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. 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 50 presents the results for the four representative design lines we study:

Table 50 – 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 51 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 51 – 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 52 presents the national impact analysis results for Mexico in 2020 and 2030.

Table 52 – 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 52 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 53 summarizes the input data developed for New Zealand.

Table 53 – Country-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 54 presents the results for the four representative design lines we study:

Table 54 – 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 55 – 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 56 presents the national impact analysis results for New Zealand in 2020 and 2030.

Table 56 – 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:

- 47 GWh annual electricity savings from MEPS by 2030
- 30% reduction in national distribution losses by 2030
- 0.03 Mt CO_2 emission avoided by 2030 from MEPS
- 65 million USD net financial benefits from MEPS
- 22 GWh annual electricity savings from endorsement label by 2030
- 0.01 Mt CO_2 emissions avoided by 2030 from endorsement label
- 31 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 country.

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 57 summarizes the input data developed for Papua New Guinea.

Table 57 – Country-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 country 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 58 presents the results for the four representative design lines we study:

Table 58 – 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)	$	767	$	1,977
CCE (USD)			$	0.060
	Representative Design Line 2, 1-phase 25kVA			
Efficiency Rating (%)		98.0%		99.5%
Losses (kWh/year)		2,225		911
Price (USD)	$	414	$	1,256
CCE (USD)			$	0.067
	Representative Design Line 4, 3-phase 150kVA			
Efficiency Rating (%)		98.3%		99.6%
Losses (kWh/year)		11,292		4,722
Price (USD)	$	1,716	$	4,825
CCE (USD)			$	0.050
	Representative Design Line 5, 3-phase 1500kVA			
Efficiency Rating (%)		99.0%		99.7%
Losses (kWh/year)		69,046		20,866
Price (USD)	$	9,871	$	33,764
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 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 59 – 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	934	7,040	20,404
Scaled Target Price (USD)	1,863	1,287	7,194	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 60 presents the national impact analysis results for Papua New Guinea in 2020 and 2030.

Table 60 – National Impacts Analysis Results for Papua New Guinea

		Units	Year	MEPS Scenario	Labeling Program Scenario
Annual Impacts	Energy Savings	GWh	2020	10.245	4.099
			2030	46.618	21.799
	CO_2 Emissions Savings	Mt	2020	0.006	0.002
			2030	0.025	0.012
	SO_2 Emissions Savings	kt	2020	0.023	0.009
			2030	0.103	0.048
	NOx Emissions Savings	kt	2020	0.004	0.002
			2030	0.018	0.008
Cumulative Impacts	Energy Savings	GWh	through 2020	28.932	10.639
			through 2030	311.503	139.049
	CO_2 Emissions Savings	Mt	through 2020	0.016	0.006
			through 2030	0.168	0.075
	SO_2 Emissions Savings	kt	2020	0.064	0.023
			2030	0.685	0.306
	NOx Emissions Savings	kt	2020	0.011	0.004
			2030	0.120	0.054
	Operating Cost Savings	Million USD		75.0	34.7
	Equipment Cost	Million USD		9.7	3.4
	NPV	Million USD		65.2	31.2

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:

- 10 GWh of electricity savings in 2020 and 47 GWh in 2030.
- 0.3 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 65 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
- 24% reduction in national distribution losses by 2030
- 0.11 Mt CO_2 emission avoided by 2030 from MEPS
- 130 million USD net financial benefits from MEPS
- 0.2 TWh annual electricity savings from endorsement label by 2030
- 0.05 Mt CO_2 emissions avoided by 2030 from endorsement label
- 60 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 61 and Table 62 present the efficiency requirements defined in the PNTP.

Table 61 – 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 62 – 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 63 summarizes the input data developed for Peru.

Table 63 – Country-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 country 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 64 presents the results for the four representative design lines we study:

Table 64 – 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)	$ 839	$ 2,164
CCE (USD)		$ 0.066
	Representative Design Line 2, 1-phase 25kVA	
Efficiency Rating (%)	98.0%	99.0%
Losses (kWh/year)	2,225	1,174
Price (USD)	$ 453	$ 1,067
CCE (USD)		$ 0.061
	Representative Design Line 4, 3-phase 150kVA	
Efficiency Rating (%)	98.3%	99.6%
Losses (kWh/year)	11,292	4,722
Price (USD)	$ 1,878	$ 5,279
CCE (USD)		$ 0.054

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 65 – 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)	1,072	347	1,437	-
Scaled Target UEC (kWh/year)	1,456	899	3,614	-
Scaled Target Price (USD)	2,766	817	4,040	-

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 Peru in 2020 and 2030.

Table 66 – National Impacts Analysis Results for Peru

		Units	Year	MEPS Scenario	Labeling Program Scenario
Annual Impacts	Energy Savings	GWh	2020	91.15	36.47
			2030	391.74	183.18
	CO_2 Emissions Savings	Mt	2020	0.03	0.01
			2030	0.11	0.05
	SO_2 Emissions Savings	kt	2020	0.02	0.01
			2030	0.09	0.04
	NOx Emissions Savings	kt	2020	0.03	0.01
			2030	0.12	0.05
Cumulative Impacts	Energy Savings	GWh	through 2020	260.57	95.77
			through 2030	2,676.00	1,192.94
	CO_2 Emissions Savings	Mt	through 2020	0.08	0.03
			through 2030	0.77	0.34
	SO_2 Emissions Savings	kt	2020	0.06	0.02
			2030	0.59	0.26
	NOx Emissions Savings	kt	2020	0.08	0.03
			2030	0.80	0.36
	Operating Cost Savings	Million USD		237.5	109.6
	Equipment Cost	Million USD		107.1	49.7
	NPV	Million USD		130.4	59.8

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:

- 91 GWh of electricity savings in 2020 and 392 GWh in 2030.
- 2.7 TWh cumulative electricity savings between 2016 and 2030.
- 0.03 Mt of annual CO_2 emissions reductions by 2020 and 0.11 Mt by 2030.
- 0.8 Mt cumulative emissions reduction between 2016 and 2030.
- The net present value of the savings would be an estimated 130 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:

- 0.7 TWh annual electricity savings from MEPS by 2030
- 30% reduction in national distribution losses by 2030
- 0.3 Mt CO_2 emission avoided by 2030 from MEPS
- 620 million USD net financial benefits from MEPS
- 0.3 TWh annual electricity savings from endorsement label by 2030
- 0.2 Mt CO_2 emissions avoided by 2030 from endorsement label
- 290 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 country.

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 67 summarizes the input data developed for the Philippines.

Table 67 – Country-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 country 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 68 presents the results for the four representative design lines we study:

Table 68 – 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)	$ 784	$ 2,023
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)	$ 423	$ 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)	$ 1,755	$ 4,935
CCE (USD)		$ 0.051
	Representative Design Line 5, 3-phase 1500kVA	
Efficiency Rating (%)	99.0%	99.7%
Losses (kWh/year)	69,046	20,866
Price (USD)	$ 10,096	$ 34,534
CCE (USD)		$ 0.053

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 69 – 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	67,346
Scaled Baseline Price (USD)	739	434	2,617	9,847
Scaled Target UEC (kWh/year)	1,073	934	7,040	20,353
Scaled Target Price (USD)	1,905	1,317	7,358	33,684

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

Table 70 – National Impacts Analysis Results for the Philippines

		Units	Year	MEPS Scenario	Labeling Program Scenario
Annual Impacts	Energy Savings	GWh	2020	148.90	59.57
			2030	665.24	311.07
	CO_2 Emissions Savings	Mt	2020	0.07	0.03
			2030	0.32	0.15
	SO_2 Emissions Savings	kt	2020	0.17	0.07
			2030	0.76	0.36
	NOx Emissions Savings	kt	2020	0.10	0.04
			2030	0.45	0.21
Cumulative Impacts	Energy Savings	GWh	through 2020	423.58	155.72
			through 2030	4,471.18	1,994.85
	CO_2 Emissions Savings	Mt	through 2020	0.20	0.07
			through 2030	2.15	0.96
	SO_2 Emissions Savings	kt	2020	0.48	0.18
			2030	5.12	2.28
	NOx Emissions Savings	kt	2020	0.29	0.11
			2030	3.05	1.36
	Operating Cost Savings	Million USD		794.7	367.1
	Equipment Cost	Million USD		175.2	81.5
	NPV	Million USD		619.5	285.6

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:

• 149 GWh of electricity savings in 2020 and 665 GWh in 2030.
• 4.5 TWh cumulative electricity savings between 2016 and 2030.
• 0.07 Mt of annual CO_2 emissions reductions by 2020 and 0.32 Mt by 2030.
• 2.15 Mt cumulative emissions reduction between 2016 and 2030.
• The net present value of the savings would be an estimated 620 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:

- 6.6 TWh annual electricity savings from MEPS by 2030
- 30% reduction in national distribution losses by 2030
- 4.2 Mt CO_2 emission avoided by 2030 from MEPS
- 3.2 billion USD net financial benefits from MEPS
- 3.1 TWh annual electricity savings from endorsement label by 2030
- 2.0 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 country.

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 71 summarizes the input data developed for Russia.

Table 71 – Country-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 country 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 72 presents the results for the four representative design lines we study:

Table 72 – 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)	$ 879	$ 2,268
CCE (USD)		$ 0.069
	Representative Design Line 2, 1-phase 25kVA	
Efficiency Rating (%)	98.0%	99.5%
Losses (kWh/year)	2,225	911
Price (USD)	$ 475	$ 1,440
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)	$ 1,968	$ 5,534
CCE (USD)		$ 0.057
	Representative Design Line 5, 3-phase 1500kVA	
Efficiency Rating (%)	99.0%	99.7%
Losses (kWh/year)	69,046	20,866
Price (USD)	$ 11,322	$ 38,727
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 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 73 – 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	67,346
Scaled Baseline Price (USD)	828	487	2,935	11,043
Scaled Target UEC (kWh/year)	1,073	934	7,040	20,353
Scaled Target Price (USD)	2,136	1,477	8,252	37,774

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

Table 74 – National Impacts Analysis Results for Russia

		Units	Year	MEPS Scenario	Labeling Program Scenario
Annual Impacts	Energy Savings	GWh	2020	1,715.8	686.5
			2030	6,573.8	3,073.9
	CO_2 Emissions Savings	Mt	2020	1.1	0.4
			2030	4.2	2.0
	SO_2 Emissions Savings	kt	2020	3.0	1.2
			2030	11.3	5.3
	NOx Emissions Savings	kt	2020	0.3	0.1
			2030	1.2	0.6
Cumulative Impacts	Energy Savings	GWh	through 2020	4,978.1	1,828.3
			through 2030	47,169.0	20,975.3
	CO_2 Emissions Savings	Mt	through 2020	3.2	1.2
			through 2030	30.1	13.4
	SO_2 Emissions Savings	kt	2020	8.6	3.1
			2030	81.1	36.1
	NOx Emissions Savings	kt	2020	0.9	0.3
			2030	8.6	3.8
	Operating Cost Savings	Million USD		5,355.6	2,463.4
	Equipment Cost	Million USD		2,171.8	1,003.3
	NPV	Million USD		3,183.8	1,460.2

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:

• 1,716 GWh of electricity savings in 2020 and 6,574 GWh in 2030.
• 47 TWh cumulative electricity savings between 2016 and 2030.
• 1.1 Mt of annual CO_2 emissions reductions by 2020 and 4.2 Mt by 2030.
• 30 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:

- 0.2 TWh annual electricity savings from MEPS by 2030
- 30% reduction in national distribution losses by 2030
- 0.12 Mt CO_2 emission avoided by 2030 from MEPS
- 180 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
- 82 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 75:

Table 75 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 country 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 76 summarizes the input data developed for Singapore.

Table 76 – Country-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 77 presents the results for the four representative design lines we study:

Table 77 – 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)	$ 868	$ 2,240
CCE (USD)		$ 0.068
	Representative Design Line 2, 1-phase 25kVA	
Efficiency Rating (%)	98.0%	99.5%
Losses (kWh/year)	2,225	911
Price (USD)	$ 469	$ 1,422
CCE (USD)		$ 0.076
	Representative Design Line 4, 3-phase 150kVA	
Efficiency Rating (%)	98.3%	99.6%
Losses (kWh/year)	11,292	4,722
Price (USD)	$ 1,944	$ 5,465
CCE (USD)		$ 0.056
	Representative Design Line 5, 3-phase 1500kVA	
Efficiency Rating (%)	99.0%	99.7%
Losses (kWh/year)	69,046	20,866
Price (USD)	$ 11,181	$ 38,244
CCE (USD)		$ 0.059

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 78 – 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	67,346
Scaled Baseline Price (USD)	818	481	2,898	10,905
Scaled Target UEC (kWh/year)	1,073	934	7,040	20,353
Scaled Target Price (USD)	2,110	1,458	8,149	37,302

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

Table 79 – National Impacts Analysis Results for Singapore

		Units	Year	MEPS Scenario	Labeling Program Scenario
Annual Impacts	Energy Savings	GWh	2020	71.52	28.61
			2030	242.90	113.58
	CO_2 Emissions Savings	Mt	2020	0.04	0.01
			2030	0.12	0.06
	SO_2 Emissions Savings	kt	2020	0.05	0.02
			2030	0.18	0.08
	NOx Emissions Savings	kt	2020	0.04	0.02
			2030	0.14	0.07
Cumulative Impacts	Energy Savings	GWh	through 2020	210.77	77.35
			through 2030	1,838.32	815.24
	CO_2 Emissions Savings	Mt	through 2020	0.11	0.04
			through 2030	0.92	0.41
	SO_2 Emissions Savings	kt	2020	0.15	0.06
			2030	1.35	0.60
	NOx Emissions Savings	kt	2020	0.12	0.05
			2030	1.08	0.48
	Operating Cost Savings	Million USD		266.3	122.1
	Equipment Cost	Million USD		86.8	39.9
	NPV	Million USD		179.6	82.2

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:

• 72 GWh of electricity savings in 2020 and 243 GWh in 2030.
• 1.8 TWh cumulative electricity savings between 2016 and 2030.
• 0.04 Mt of annual CO_2 emissions reductions by 2020 and 0.12 Mt by 2030.
• 0.9 Mt cumulative emissions reduction between 2016 and 2030.
• The net present value of the savings would be an estimated 180 Million USD.

2.3.17. South Korea

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

- 1.3 TWh annual electricity savings from MEPS by 2030
- 18% reduction in national distribution losses by 2030
- 0.7 Mt CO_2 emission avoided by 2030 from MEPS
- 510 million USD net financial benefits from MEPS
- 0.6 TWh annual electricity savings from endorsement label by 2030
- 0.3 Mt CO_2 emissions avoided by 2030 from endorsement label
- 240 million USD net financial benefits from endorsement label

Test Procedure, S&L Status

The MEPS program for dry and liquid-type transformers in South 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. Table 80 presents the Korean standards harmonized with IEC 60076.

Table 80 – 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 Table 81, Table 82 and Table 83.

Table 81 – MEPS and TEPS for Low Voltage Liquid-Type Distribution Transformers in South 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 82 – MEPS and TEPS for Low Voltage Liquid-Type Distribution Transformers in South 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 83 – MEPS and TEPS for 22.9kV Liquid-Type Distribution Transformers in South 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).

Table 84 summarizes the input data developed for South Korea.

Table 84 – Country-Specific Inputs Summary for South 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.

Table 85 presents the results for the four representative design lines we study:

Table 85 – Cost-Benefit Analysis for Representative Units for South Korea

	Baseline	Target
	Representative Design Line 1, 1-phase 50kVA	
Efficiency Rating (%)	98.9%	99.3%
Losses (kWh/year)	2,418	1,586
Price (USD)	$ 1,371	$ 1,495
CCE (USD)		$ 0.016
	Representative Design Line 2, 1-phase 25kVA	
Efficiency Rating (%)	98.7%	No Cost-Effective Option
Losses (kWh/year)	1,437	
Price (USD)	$ 895	
CCE (USD)		
	Representative Design Line 4, 3-phase 150kVA	
Efficiency Rating (%)	98.4%	99.6%
Losses (kWh/year)	10,889	4,319
Price (USD)	$ 2,124	$ 3,380
CCE (USD)		$ 0.020
	Representative Design Line 5, 3-phase 1500kVA	
Efficiency Rating (%)	99.0%	99.7%
Losses (kWh/year)	67,706	21,278
Price (USD)	$ 11,531	$ 37,748
CCE (USD)		$ 0.059

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 86 – Design Lines (DL) Market Shares and Market Average UEC and Price in South 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)	1,291	917	3,168	11,247
Scaled Target UEC (kWh/year)	1,493	1,473	6,440	20,754
Scaled Target Price (USD)	1,408	917	5,040	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.

Table 87 presents the national impact analysis results for South Korea in 2020 and 2030.

Table 87 – National Impacts Analysis Results for South Korea

		Units	**Year**	**MEPS Scenario**	**Labeling Program Scenario**
Annual Impacts	Energy Savings	GWh	2020	391.2	156.5
			2030	1,325.1	619.6
	CO_2 Emissions Savings	Mt	2020	0.2	0.1
			2030	0.7	0.3
	SO_2 Emissions Savings	kt	2020	0.3	0.1
			2030	0.9	0.4
	NOx Emissions Savings	kt	2020	0.2	0.1
			2030	0.7	0.3
Cumulative Impacts	Energy Savings	GWh	through 2020	1,153.4	423.3
			through 2030	10,041.2	4,452.7
	CO_2 Emissions Savings	Mt	through 2020	0.6	0.2
			through 2030	5.4	2.4
	SO_2 Emissions Savings	kt	2020	0.8	0.3
			2030	6.7	3.0
	NOx Emissions Savings	kt	2020	0.6	0.2
			2030	5.0	2.2
	Operating Cost Savings	Million USD		860.4	394.3
	Equipment Cost	Million USD		346.5	159.1
	NPV	MillionUSD		514.0	235.2

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:

• 391 GWh of electricity savings in 2020 and 1,325 GWh in 2030.
• 10 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.
• 5.4 Mt cumulative emissions reduction between 2016 and 2030.
• The net present value of the savings would be an estimated 514 Million USD.

2.3.18. Thailand

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

- 1.5 TWh annual electricity savings from MEPS by 2030
- 30% reduction in national distribution losses by 2030
- 0.8 Mt CO_2 emission avoided by 2030 from MEPS
- 1.1 billion 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
- 490 million USD net financial benefits from endorsement label

Test Procedure, S&L Status

Based on communication with ICA, it appears that the Department of Energy Alternative Energy Development and Efficiency (DEDE) has defined some voluntary High Energy Performance Standard (HEPs) for three-phase distribution transformers. The following table presents the HEPs requirements on load losses and no-load losses and the calculated efficiency at 50% load:

Table 88 – HEPS for Three-Phase Liquid-Type Distribution Transformers in Thailand

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%

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 89 summarizes the input data developed for Thailand.

Table 89 – Country-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

Baseline efficiency is a key determinant in the cost-benefit analysis. In general, if a country 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 90 presents the results for the four representative design lines we study:

Table 90 – Cost-Benefit Analysis for Representative Units for Thailand

	Baseline		Target	
	Representative Design Line 1, 1-phase 50kVA			
Efficiency Rating (%)		98.5%		99.5%
Losses (kWh/year)		2,400		780
Price (USD)	$	763	$	1,968
CCE (USD)			$	0.078
	Representative Design Line 2, 1-phase 25kVA			
Efficiency Rating (%)		98.0%		99.5%
Losses (kWh/year)		1,683		689
Price (USD)	$	412	$	1,250
CCE (USD)			$	0.088
	Representative Design Line 4, 3-phase 150kVA			
Efficiency Rating (%)		98.3%		99.6%
Losses (kWh/year)		8,720		3,699
Price (USD)	$	1,708	$	4,802
CCE (USD)			$	0.065
	Representative Design Line 5, 3-phase 1500kVA			
Efficiency Rating (%)		99.0%		99.7%
Losses (kWh/year)		50,928		15,391
Price (USD)	$	9,824	$	33,605
CCE (USD)			$	0.070

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 91 – 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)	2,260	1,725	13,003	49,675
Scaled Baseline Price (USD)	719	422	2,547	9,582
Scaled Target UEC (kWh/year)	735	706	5,515	15,012
Scaled Target Price (USD)	1,854	1,281	7,160	32,778

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

Table 92 – National Impacts Analysis Results for Thailand

		Units	**Year**	**MEPS Scenario**	**Labeling Program Scenario**
Annual Impacts	Energy Savings	GWh	2020	356.1	142.5
			2030	1,491.4	697.4
	CO2 Emissions Savings	Mt	2020	0.2	0.1
			2030	0.8	0.4
	SO2 Emissions Savings	kt	2020	0.1	0.1
			2030	0.5	0.3
	NOx Emissions Savings	kt	2020	0.2	0.1
			2030	0.9	0.4
Cumulative Impacts	Energy Savings	GWh	through 2020	1,021.2	375.3
			through 2030	10,299.2	4,588.8
	CO_2 Emissions Savings	Mt	through 2020	0.5	0.2
			through 2030	5.3	2.4
	SO_2 Emissions Savings	kt	2020	0.4	0.1
			2030	3.7	1.6
	NOx Emissions Savings	kt	2020	0.6	0.2
			2030	6.0	2.7
	Operating Cost Savings	Million USD		1,598.1	736.9
	Equipment Cost	Million USD		531.9	246.7
	NPV	Million USD		1,066.2	490.2

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:

• 356 GWh of electricity savings in 2020 and 1,491 GWh in 2030.
• 10.3 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.
• 5.3 Mt cumulative emissions reduction between 2016 and 2030.
• The net present value of the savings would be an estimated 1 Billion 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 93 – MEPS for Liquid-type Distribution Transformers in the U.S.

kVA	Single-Phase		kVA	Three-Phase	
	% Efficiency 2010	% Efficiency 2016		% Efficiency 2010	% 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 94 summarizes the input data developed for the U.S.

Table 94 – Country-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 95 presents the results for the four representative design lines we study:

Table 95 – 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 96 – 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 97 presents the national impact analysis results for the U.S. in 2020 and 2030.

Table 97 – 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. Vietnam

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

- 1.1 TWh annual electricity savings from MEPS by 2030
- 28% reduction in national distribution losses by 2030
- 0.5 Mt CO_2 emission avoided by 2030 from MEPS
- 460 million USD net financial benefits from MEPS
- 0.5 TWh annual electricity savings from endorsement label by 2030
- 0.2 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 national testing standards used to measure performance are called "Tiêu chuẩn Việt Nam" (TCVN), which in English means "Vietnam Standards". . In November 2011, the Ministry of Industry and Trade (MOIT) of Vietnam has adopted mandatory efficiency regulations for distribution transformers that should enter into force on January 1, 2015 (MOIT, 2010). Vietnam'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 98 presents the minimum efficiency requirement in TCVN 8525:2010.

Table 98 – Minimum Efficiency Requirements for Three-Phase Liquid-Type Transformers for Vietnam

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 Vietnam 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 99 summarizes the input data developed for Vietnam.

Table 99 – Country-Specific Inputs Summary for Vietnam 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 100 presents the results for the four representative design lines we study:

Table 100 – Cost-Benefit Analysis for Representative Units for Vietnam

	Baseline		Target	
	Representative Design Line 1, 1-phase 50kVA			
Efficiency Rating (%)		98.5%		99.5%
Losses (kWh/year)		3,241		1,139
Price (USD)	$	765	$	1,974
CCE (USD)			$	0.060
	Representative Design Line 2, 1-phase 25kVA			
Efficiency Rating (%)		98.0%		99.5%
Losses (kWh/year)		2,225		911
Price (USD)	$	413	$	1,253
CCE (USD)			$	0.067
	Representative Design Line 4, 3-phase 150kVA			
Efficiency Rating (%)		98.9%		99.6%
Losses (kWh/year)		7,647		2,654
Price (USD)	$	3,322	$	5,955
CCE (USD)			$	0.055
	Representative Design Line 5, 3-phase 1500kVA			
Efficiency Rating (%)		99.4%		99.7%
Losses (kWh/year)		42,985		21,085
Price (USD)	$	17,526	$	33,421
CCE (USD)			$	0.076

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 101 – Design Lines (DL) Market Shares and Market Average UEC and Price in Vietnam

	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)	721	424	4,954	17,094
Scaled Target UEC (kWh/year)	1,073	934	3,958	20,566
Scaled Target Price (USD)	1,859	1,285	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 102 presents the national impact analysis results for the U.S. in 2020 and 2030.

Table 102 – National Impacts Analysis Results for Vietnam

		Units	Year	MEPS Scenario	Labeling Program Scenario
Annual Impacts	Energy Savings	GWh	2020	202.63	81.07
			2030	1,107.02	517.64
	CO_2 Emissions Savings	Mt	2020	0.09	0.03
			2030	0.48	0.22
	SO_2 Emissions Savings	kt	2020	0.11	0.05
			2030	0.63	0.29
	NOx Emissions Savings	kt	2020	0.11	0.04
			2030	0.58	0.27
Cumulative Impacts	Energy Savings	GWh	through 2020	562.05	206.91
			through 2030	6,859.26	3,072.61
	CO_2 Emissions Savings	Mt	through 2020	0.24	0.09
			through 2030	2.96	1.33
	SO_2 Emissions Savings	kt	2020	0.32	0.12
			2030	3.89	1.74
	NOx Emissions Savings	kt	2020	0.29	0.11
			2030	3.60	1.61
	Operating Cost Savings	Million USD		746.4	346.6
	Equipment Cost	Million USD		286.6	134.4
	NPV	Million USD		459.8	212.1

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:

- 203 GWh of electricity savings in 2020 and 1,107 GWh in 2030.
- 6.9 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 Mt cumulative emissions reduction between 2016 and 2030.
- The net present value of the savings would be an estimated 460 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 more than 30 TWh in 2030, or a 19% 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 18 Billion USD. Table 103 summarizes the savings from the MEPS studied, for every APEC country. Situation varies greatly among countries 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 country, while other countries 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 countries 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 countries where distribution transformers have not been yet regulated were not able to provide us with data; therefore, results for these countries are subject to a significant uncertainty because of the assumptions that had to be made regarding the main drivers of the results. These countries are marked with an asterisk (*) in Table 103. For countries that provided us with at least some data, we believe that the robustness of the results is much greater than for the countries for which we had no data. Therefore, countries that provided data are not marked with an asterisk.

Table 103 – 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%	2.3	21.5	18.1	1,982
Brunei*	63	19	30%	0.0	0.1	0.1	43
Canada	10,058	1,464	15%	0.3	11.4	2.1	463
Chile	3,254	1,248	38%	0.5	9.2	3.8	724
Hong Kong	586	95	16%	0.1	0.7	0.5	15
Indonesia*	7,913	2,361	30%	1.7	14.9	10.6	1,634
Japan	15,492	2,558	17%	1.1	20.5	8.6	1,330
Malaysia	4,516	1,957	43%	1.4	14.7	10.7	2,320
Mexico	6,295	1,434	23%	0.7	10.8	4.9	833
New Zealand	455	153	34%	0.0	1.2	0.2	152
Papua New Guinea*	156	47	30%	0.0	0.3	0.2	65
Peru	1,646	392	24%	0.1	2.7	0.8	130
Philippines*	2,230	665	30%	0.3	4.5	2.2	619
Russia*	22,031	6,574	30%	4.2	47.2	30.1	3,184
Singapore	814	243	30%	0.1	1.8	0.9	180
South Korea	7,354	1,325	18%	0.7	10.0	5.4	514
Taipei*	4,562	1,183	26%	0.9	8.9	6.9	214
Thailand	4,980	1,491	30%	0.8	10.3	5.3	1,066
United States	51,117	3,138	6%	1.6	24.8	12.9	2,604
Vietnam	4,008	1,107	28%	0.5	6.9	3.0	460
Total	**156,932**	**30,212**	**19%**	**17**	**222**	**127**	**18,532**

*Results for this country are subject to a sizeable uncertainty

In order to understand the variability on the results between countries, we identify the main drivers of the results along with the uncertainty and its effect on the results in Table 104.

Table 104 – 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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