Energy efficiency appliance standards: Where do we stand, how far can we go and how do we get there? An analysis across several economies

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Abstract
This paper analyses several potential savings scenarios for minimum energy performance standard (MEPS) and comparable programs for governments participating in the Super-efficient Equipment and Appliance Deployment (SEAD) Initiative, of the Clean Energy Ministerial, which represent over 60 % of primary energy consumption in the world. We compare projected energy savings from the main end uses in the residential sector using three energy efficiency scenarios: (1) recent achievements, (2) cost-effective saving potential, and (3) energy efficiency technical potential.

The recent achievement scenario (1) evaluates the future impact of MEPS enacted or under development between 2010 and 2012. The cost-effective potential scenario (2) identifies the maximum potential for energy efficiency that results in net benefits to the consumer. The best available technology scenario (3) represents the full potential of energy efficiency considering best available technologies as candidates for MEPS and incentive programs. We use the Bottom Up Energy Analysis System (BUENAS), developed by Lawrence Berkeley National Laboratory in collaboration with the Collaborative Labelling and Appliances Standards Program (CLASP), to provide a consistent methodology to compare the different scenarios. This paper focuses on the main end uses in the residential sector. The comparison of the three scenarios for each economy provides possible opportunities for scaling up current policies or implementing additional policies. This comparison across economies reveals country best practices as well as end uses that present the greatest additional potential savings. The paper describes areas where methodologies and additional policy instruments can increase penetration of energy efficient technologies. First, we summarize the barriers and provide remedial policy tools/best practices, such as techno-economic analysis, in response to each barriers that prevent economies from capturing the full cost-effective potentials of MEPS (Scenario 1 to 2). Then, we consider the possible complementary policy options, such as incentive programs, to reach the full technical potential of energy efficiency in the residential sector (Scenario 2 to 3).

Introduction
As part of the ongoing effort to estimate the foreseeable impacts of minimum energy performance standards (MEPS) programs in 11 major economies participating into the Super-efficient Equipment and Appliance Deployment (SEAD) Initiative of the Clean Energy Ministerial, Lawrence Berkeley National Laboratory (LBNL) has developed the following energy efficiency scenarios:

1. The "recent achievements" (RA) scenario estimates the impact of MEPS that were implemented, announced, or are being considered from January 2010 to July 2012 (Kalavase et al., 2012).
2. The "cost-effective scenario" (CEP) seeks to identify the maximum energy savings while providing net positive benefits to consumers (Letschert et al., 2012a).
3. The "best available technology" (BAT) scenario seeks to determine the maximum potential savings that would result from large scale adoption of the most efficient available technologies in these major economies (Letschert et al., 2012b).

We use the Bottom-Up Energy Analysis System (BUENAS) to estimate potential impacts and savings for a wide range of residential and industrial end uses and to generate and analyze these scenarios. BUENAS has previously been used to estimate potential national energy demand savings[1] and carbon dioxide (CO_2) mitigation potential from MEPS around the world for the Collaborative Labeling and Appliance Standards Program (CLASP) and the SEAD Initiative (McNeil et al., 2013).

In this paper, rather than focusing on the energy demand in each scenario, we study the differences between the three efficiency scenarios to reflect the impact of current policies and identify additional opportunities for scaling up current policies or implementing additional policies. This comparison across economies reveals best practices as well as end uses that present the greatest additional potential savings. The paper describes areas where methodologies and additional policy instruments can increase penetration of energy efficient technologies. First, we cover the barriers and identify remedial policy tools/best practices to capture the full cost-effective potential of MEPS such as techno-economic analysis (Scenario 1 to 2). Then, we consider the possible complementary policy options such as incentive programs to reach the full technical potential of energy efficiency in the residential sector (Scenario 2 to 3).

The study focuses on electric end uses in the residential sector, specifically on the most energy-intensive end-uses for which data are available across most economies (i.e. lighting, refrigerators, air conditioners, televisions, standby power and washing machines). We present the results of each scenario, by economy and for each end use in terms of annual energy demand savings in 2030.

Scenarios Description

The three efficiency scenarios are built on the business-as-usual (BAU) scenario developed in (McNeil et al., 2013). As described in the section below, we consider different criteria to define the target efficiencies in each scenario. The underlying data and assumptions for each end use and economy are available in the technical reports referenced in the following scenario descriptions.

BUSINESS-AS-USUAL SCENARIO

The BAU scenario is a projection of energy consumption by end use from 2010 (base year) to 2030 for the residential, commercial and industry sectors. In the residential sector, which is the focus of the present study, the BAU takes inputs from product ownership rates, product sales, annual unit energy consumption, and per unit percentage improvement potential. In the absence of reliable market data, the model forecasts appliance ownership using an econometric model relying on macro-economic variables, such as household income, urbanization, electrification, and climate variables. Stock and sales are then calculated through a stock turnover analysis considering historical sales, population (number of households), and appliance lifetime. As a consequence the drivers of energy demand in the model are numerous and vary by economy depending on data availability. Table 1 lists the key drivers from the BAU and their relative impacts on the energy demand results. A complete discussion of input parameters, methodology, results and error analysis can be found (McNeil et al., 2013).

RECENT ACHIEVEMENTS IN SEAD PARTICIPATING GOVERNMENTS

The recent achievements (RA) scenario is built on the BAU scenario developed in BUENAS. To build the RA scenario, we collect and compile information on standards and labelling (S&L) programs in SEAD economies and analyze the impacts of individual policies that were implemented, announced, or are being considered between January 2010 and July 2012 in those economies (Kalavase et al., 2012) (McNeil et al., 2012) [2]. These programs have either entered into force since 2010 or will enter into force before 2016. Impacts of these programs are projected to 2030. It should be noted that the assumptions and data used in the BUENAS model may be different from those use by each government, and as a result the model projections can possibly differ from each program own projections.

The following S&L programs were analyzed:

- Equipment Energy Efficiency (E3) program of the Australian Department of Climate Change and Energy Efficiency
- ecoENERGY Efficiency for Equipment S&L program of Natural Resources Canada (NRCan)
- Ecodesign program from the European Commission
- S&L program from the Bureau of Energy Efficiency of India (BEE)
- Top-Runner program from Ministry of Economy, Trade and Industry of Japan (METI)
- S&L program from Korean Energy Management Corporation (KEMCO)
- S&L program from the National Commission for Energy Efficiency (CONUEE) in Mexico
- Building and Technology program of the U.S. Department of Energy (DOE)

Even though S&L programs exist in Brazil and Russia (CLASP, 2011), the data were not sufficient to model the impacts of recent activities. As for South Africa, the appliance standards program is still at an early stage of development, so it has not been included in the present analysis.

COST-EFFECTIVE POTENTIAL IN SEAD PARTICIPATING ECONOMIES

The CEP scenario is built on the BAU scenario developed in BUENAS. CEP targets are determined according to the cost of conserved energy (CCE) of various design options/technologies that provide higher appliance energy efficiency. The CCE is defined as the ratio between the annualized incremental appliance cost[3] and the energy saved in a year, which shows the investment needed per unit of energy savings ($/kWh).

1. BUENAS scenarios estimate energy demand savings as opposed to energy consumption savings (i.e. they do not account for electricity demand not delivered).

2. The SEAD participating governments modeled in BUENAS are Australia, Brazil, Canada, European Union, India, Japan, Mexico, Russia, South Korea, South Africa, and the United States. The United Arab Emirates participate in SEAD, but have not yet been incorporated into the BUENAS model.

3. The annualized extra cost of purchasing a high-efficiency appliance is the product of the incremental investment and a capital recovery factor, which is a function of the consumer discount rate.

Table 1. Summary of Key Drivers and Associated Impact on Results.

Variable	Impact on Results
Data-Driven Variables	
Historical Sales	**Moderate**
Lifetime	**Moderate**
Base Year Efficiency Distribution	**Low** to **Moderate**
Usage	**Significant** for some equipment types
Field Consumption Variability	**Moderate**
Rebound Effects	**Moderate**
Forecast Parameters	
Sales Growth Rates	**Significant**
Population and Household Size	**Low**
GDP Growth Rate	**Moderate** to **Significant**
Urbanization and Electrification	**Low**
Efficiency and Product Class Trends	**Moderate** to **Significant**

The CCE is calculated from cost efficiency data from the Global Energy-Efficiency Cost (GEEC) database, a compilation of international cost curves for equipment and appliances (McNeil, 2012). The GEEC database builds upon a variety of sources, including technical analysis studies performed by LBNL in support of the SEAD Initiative, technical support documents (TSDs) developed for the U.S. DOE standards program, preparatory studies from the European Commission Ecodesign program, and retail price surveys. Where data are not available, we use regional market assumptions to extrapolate incremental costs for specific countries. The CCE is then recalculated using local parameters (discount rates and energy prices).

By comparing the CCE with the local electricity tariff in each economy, we determine the highest cost-effective efficiency targets for that country. These targets provide the greatest energy savings while ensuring a net financial benefit to consumers. The targets determined using the CCE are then propagated into BUENAS to estimate global savings over the full life of products shipped between 2015 and 2030 (Letschert et al., 2012a).

BEST AVAILABLE TECHNOLOGY SCENARIO

The BAT scenario targets represent the maximum achievable energy-efficient designs, based on emerging technologies that are commercialized (or will be soon) but have a small market share, or designs that combine the most efficient currently available components. In cases where neither of these options is available, the analysis uses an aggressive target from an existing efficiency program. BAT targets exclude promising technologies that are in development but are several years away from commercialization. In addition, large-scale production of products or technologies that meet the BAT targets must be feasible by 2015, which is the year we assume the MEPS would enter into effect (Letschert et al., 2012b). In the rest of the paper, the savings potential from a MEPS mandating best available technologies is also referred to as the *technical potential* for energy efficiency.

In contrast to previous efficiency scenarios (RA and CEP), in which country or regional considerations are taken into account in determining MEPS targets, in this analysis we identify one common international BAT target (or technology) for each end use. This target is generally characterized by an efficiency rating that we use to determine the unit energy consumption (UEC) of the BAT scenario for each country, according to the UEC and efficiency in the BAU scenario. The BAT targets are therefore adjusted for typical appliance capacities and usage profiles specific to each country. For example, the lighting UECs are adjusted for the typical wattage of incandescent bulbs in every country, along with the typical hours of usage. As a consequence, each country has a different UEC target even for the same technology with the same efficiency.

As it is the case for the other scenarios, the BAT scenario is built on the BAU scenario. BAT targets are determined according to the above criteria using a variety of sources, such as: technical analysis studies performed by LBNL in support of the SEAD Initiative, the Max Tech and Beyond study (Desroches and Garbesi, 2011), TSDs developed for the U.S DOE standards program, preparatory studies from the European Commission Ecodesign program, and the Japanese Top Runner program's target definitions.

SCOPE OF THE SCENARIOS COVERAGE

Because BUENAS has been used to support the activities of the SEAD Initiative, BUENAS includes all SEAD participating economies for which appropriate data is available[4]. The scope of the original studies covers 14 end-uses in the residential sector and motors and transformers in the industry sectors. In this paper, because we are trying to compare all economies on a consistent basis, we reduced the scope to electric appliances in the residential sector that are covered in most economies[5]. Table 2 shows the appliances and countries covered in the BAU, RA, CEP and BAT scenarios.

Scenario Cross-Cutting Analysis

In this section we combine the three efficiency scenarios and BAU scenario presented above in order to gain insights on energy efficiency achievements since January 2010 and potential future opportunities, as well as end-use specific energy efficiency potential.

4. See footnote 2.

5. I.e. data on water heating and space heating is scarce and doesn't allow for a comprehensive modeling in every country, so these end-uses have been taken out in this paper.

Table 2. Comparison of BAU and BUENAS Scenario Scope (Shaded cells = countries covered in BAU scenario; XX = covered in RA, CEP and BAT, X = covered only in CEP and BAT scenario).

Appliance	AUS	BRA	CAN	EU	IND	JPN	KOR	MEX	RUS	USA	ZAF
Air Conditioner*	XX	X	XX	XX	XX	XX	X	XX	X	XX	
Central Air Conditioners			X					X		XX	
Fans	X	X	X	X	X	X	X	X	X	X	X
Freezers				XX						XX	
Washing Machines				XX			XX	XX		XX	
Lighting	XX	X	X	XX	X	X	X	X	X	XX	X
Refrigerators	X	X	X	XX	XX	XX	X	XX	X	XX	X
Standby Power	X	X	XX	XX	X	X	XX	X	X	XX	X
Televisions	X	X	X	X	X	X	X	X	X	X	X

AUS = Australia; BRA = Brazil; CAN = Canada; EU = European Union; IND = India; JPN = Japan; KOR = South Korea; MEX = Mexico; RUS = Russia; USA = United States of America; ZAF = South Africa.

** Includes heating mode for reversible units.*

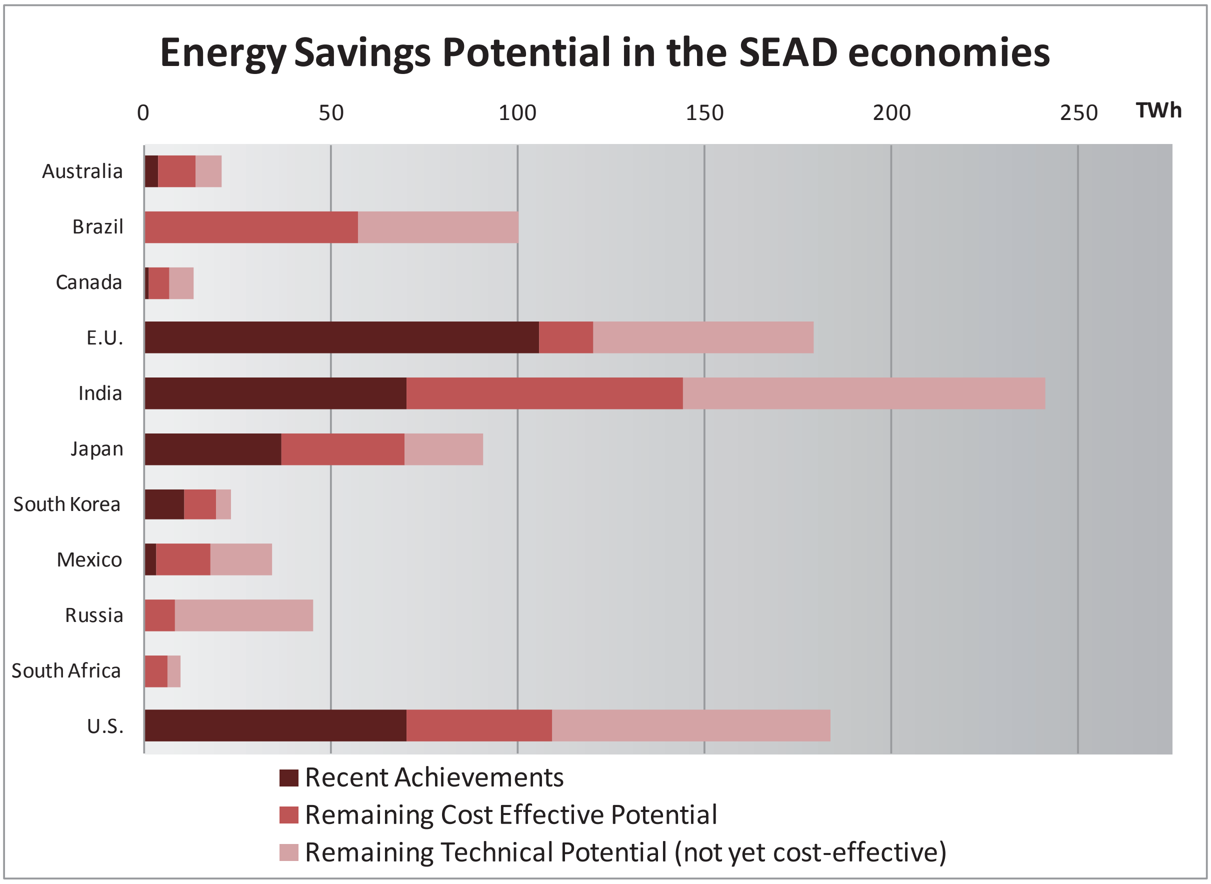

Figure 1. Annual Energy Savings in 2030 from Energy Efficiency Standards in billion kilowatt-hours (TWh) – Current Achievements and Potential for SEAD economies.

In Figures 1 and 2, we present the recent achievements scenario, the difference between the cost-effective potential and the recent achievements ("*remaining cost-effective potential*"), and the difference between the technical potential and the cost effective potential ("*remaining technical potential (not yet cost-effective)*"). Figures 1 and 2 show the annual energy savings in 2030 for each economy and end uses from BUENAS.

Another way to look at the scenarios is from the technical/engineering perspective: what appliances present a large potential for savings and are not being addressed – are not yet cost-effective to be addressed – by current policies? In light of recent technical analysis studies commissioned by the US DOE through the SEAD Initiative (Park et al., 2012; Sathaye et al., 2012; Shah et al., 2012), large cost-effective and technical potential has been revealed for televisions, air conditioners and ceiling fans. The cost vs. efficiency relationship determined in these studies have been incorporated into the CEP and BAT scenarios.

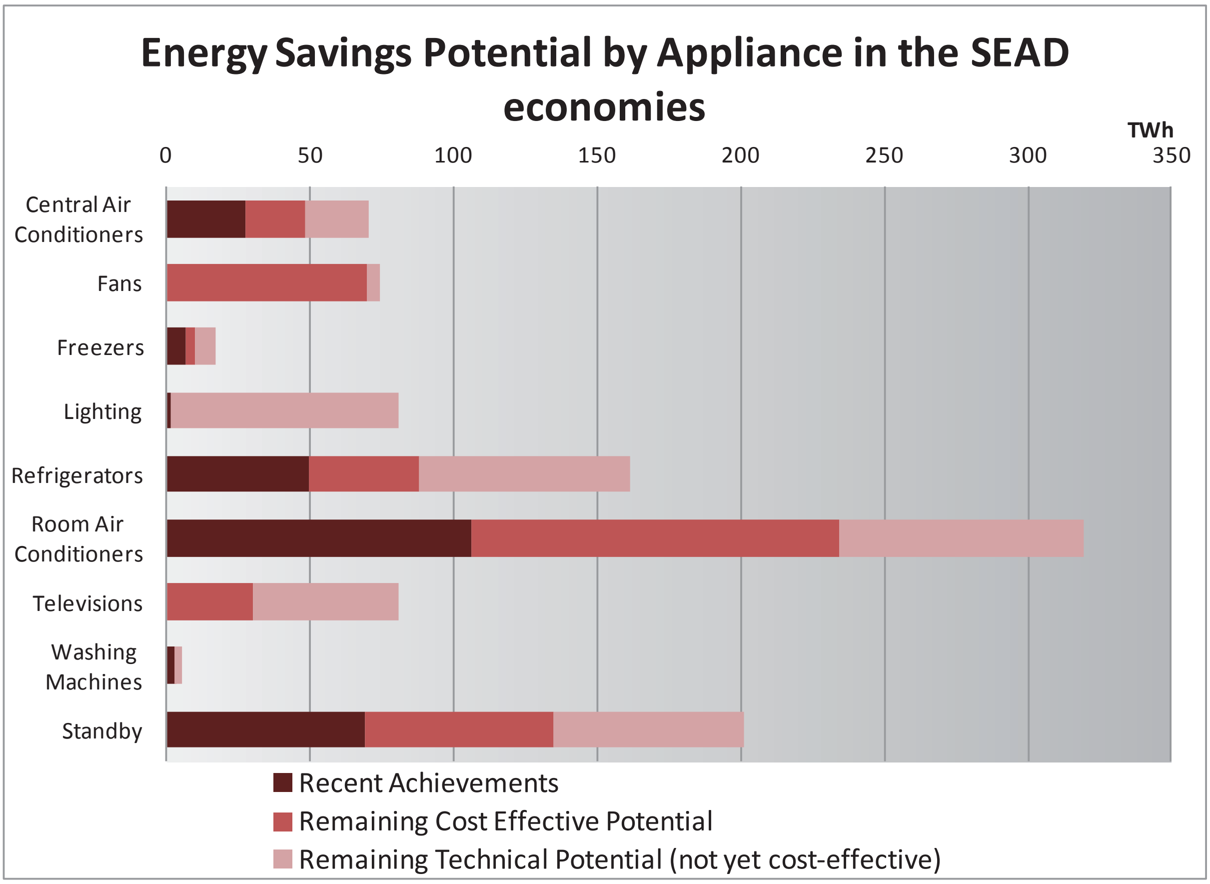

Figure 2. Annual Energy Savings in 2030 from Energy Efficiency Standards in billion kilowatt-hours (TWh) in SEAD economies by end-use product.

KEY DRIVERS:

As is the case for the BAU scenario (see Table 1), the magnitude of cost-effective and technical potentials is driven by appliance sales and forecasted economic growth rates. Besides these key factors, most of the variation between economies can be attributed to difference in usage patterns (for example, climatic differences affect potential savings from air conditioners and fans) and on the baseline efficiency of the existing equipment and appliance stock (countries like India with a very inefficient baseline stock in 2010 present a lot of potential savings). For the CEP, economic parameters – such as residential electricity price, price of appliances and discount factors – have a large impact on the target efficiency level as well. Also, there is a high correlation between the fact that there is a standard being developed in a country and the availability of data to model the impacts. As a consequence, the identification of cost-effective potential is highly dependent on the state of the policy development in a country. For example, the cost-effective potential in South Africa or Russia will grow as country-specific data become available.

KEY CONSIDERATIONS:

A few considerations on the recent achievement scenario have to be taken into account in order to weigh the results shown in Figures 1 and 2.

Schedule: Recent achievements do not reflect S&L programs implemented before 2010. Hence the variations between countries may be caused by different S&L implementation schedules and do not reflect don't reflect governments' commitments to S&L programs before 2010 (the base year in the BUENAS model). For example, Mexico has shown a strong commitment to MEPS since the mid-90s, which is not being reflected in the present analysis.

Data availability: When modeling the impacts of the current programs, we are limited to the data provided by each government or available from other sources.

Focus on MEPS: Complementary energy efficiency programs such as labels and other non-regulatory measures are not represented in Figure 1.

For these reasons, the estimates presented in the recent achievement scenario have to be taken as the lower bound of the projected impacts from all activities carried-out by the SEAD participating economies.

As well as a few considerations on the cost-effective potential and best available technology scenario.

Moving targets: Innovation and learning drive down the cost of efficient technologies, such that products and technologies from the BAT scenario that are not cost-effective today, may be cost-effective in one or more years. The same is true for BAT, because our analysis is limited to technology developments that are foreseeable and that can be evaluated in terms of energy performance as of today, our estimate of technical potential has to be seen as conservative.

As a result, our estimates of cost-effective and technical potential are the lower bounds of the likely cost-effective and technical potential just a few years from now.

KEY RESULTS:

By comparing the recent achievements to the cost-effective and technical potentials, we can identify additional opportunities for cost-effective potential savings and remaining technical potential savings.

Figure 1 illustrates the potential captured by the recent S&L activities as well as *what is left on the table* in the SEAD economies. With a multitude of standards on their way, the European Union is the region capturing the most cost-effective potentials by setting their standards at the most aggressive cost-effective levels for consumers, although the full potential is still unrealized. This remains true for the U.S. program, which captures two-third of the cost-effective potential of the end uses analyzed here. Notable good practices are found in South Korea and Japan, where, even though the price of electricity is high (which implies a high cost-effective potential), KEMCO's standby power MEPS and METI's Top Runner Program for room air conditioners address about half of the total cost-effective potentials in each country. India is achieving 50 % of its cost-effective potential thanks to BEE's recent activities on room air conditioners and refrigerators, representing respectively 80 % and 20 % of the recent achievement savings.

We can distinguish among three groups of appliances/technologies:

- **Established/conservative technologies:** end uses for which recent achievements have captured a fair portion of the cost-effective potential, and for which the cost-effective potential is about two-thirds of the technical potential[6]. This is the case for products that have been regulated on a regular basis such as refrigerators-freezers, room air conditioners, central air conditioners, washing machines and more recently standby power. These products all have remaining cost-effective potential and technical potential, and this potential is likely to be growing with innovation/learning.
- **Highly cost-effective technologies:** our study suggests that fans present high potential for cost-effective savings and that no standards have been proposed or implemented for this product since 2010. Two-thirds of the cost-effective potential savings are found in India.
- **Technologies not yet cost-effective:** though promising, these are still emerging technologies that are not cost-effective under any economic/usage conditions in the SEAD economies. These are namely: LEDs for general lighting purposes and OLED used in televisions. These technologies have not yet hit mass production, which means their price remains high, which is a barrier for new technology adoption. In this case, financial incentives (described in the last section) can serve as a tool to bring the technology to cost-effective levels and to foster adoption of new products, which is expected to induce a drop in price once mass-production occurs (Weiss, 2010).

6. This is an artifact of the way the cost-curves were built and the BAT was determined. We are looking at technology mass-producible in the near future and as a consequence in the engineering continuity of the existing technologies. Prototypes and new emerging technologies have not been selected for this study in order to be conservative.

Reaching Cost-Effective Potential

The previous section revealed that no government S&L program captures the full cost-effective potential for energy efficiency of the 14 end-uses studied. In this section we explore possible barriers to full adoption of cost-effective policies and provide insights on best practices that may enable governments to capture a great share of these potential savings.

BARRIERS AND BEST PRACTICES

Most of the SEAD participating governments already have or are in the process of developing S&L programs, which means they have overcome, or are in the process of overcoming, the challenges that often face governments developing their first program, such as policy makers' lack of confidence in the effectiveness of standards, lack of availability of testing laboratories, or lack of awareness of energy efficiency. However, program implementation stage varies widely among SEAD governments, hence the barriers confronted vary on a case by case basis (IEA, 2012; Wiel and J.E. McMahon, 2005). Table 3[7] describes the barriers, effects and potential solutions to implement MEPS that would move governments towards capturing the full cost-effective potential.

STUDY LIMITATION

In addition to some of the most important criteria for setting a standard – such as the consumer impact and national impacts (energy, environmental and financial impacts), there are a variety of additional criteria that should be considered at when designing a MEPS program. Based on a review of practices in the SEAD economies (EC, 2005; METI, 2010; USC, 1978), we have identified additional criteria:

- Impacts on the manufacturers/industry (e.g. lessening of competition, loss of revenue and job).
- Life-cycle analysis (e.g. environment impact from production phase to disposal).
- Market consideration (e.g. possibility of mass production, % of products impacted by MEPS) Political considerations.

The BUENAS model does not account for these considerations, some of which may contribute to the gap between the recent achievements and the cost-effective potential.

Moving toward Technical Potential

The BAT scenario shows that emerging technologies continue to generate more efficient products that have a large potential to reduce energy consumption as their market penetration increases. Moreover, the comparison of the cost-effective potential to the recent achievement potential shows that a significant amount of the cost effective potential is not currently captured by S&L programs. Hence, complementary energy efficiency policies, such as incentive programs, can help transform the market towards more efficient products.

7. PAMS-MEPS is a spreadsheet model developed by LBNL for CLASP and is available for download for free at: http://www.clasponline.org/en/ResourcesTools/Tools/PolicyAnalysisModelingSystem.

Table 3. Key Barriers and Best Practices/Remedial Policy Instruments.

	Barrier	Effect	Best Practices/Remedial Policy Instruments	Additional comments
Institutional	Lack of a public process that involves all stakeholders	Experiences from many countries have shown that effective standards are difficult to establish without stakeholder involvement.	Engage representatives of the principal stakeholders – including manufacturers, consumers, utilities, local governments, and environmental or energy – efficiency interest groups – in an open and transparent process to contribute information and raise concerns through all steps of the standards-setting process.	
	Standard schedules and scopes	Opportunities for additional cost effective potential that are not yet exploited	Establish systematic process for prioritization of standards and identifying opportunities for extension of scope. Tools such as BUENAS can support this process.	There is considerable evidence that the real price of appliances in the residential sector is declining over time(Desroches et al., 2013). Design options that were not cost-effective a few years again might well be a few years later.
	Lack of requirements of analysis	Standards are not optimized for energy savings and consumer financial benefits.	Mandate policy analysis in regulatory frameworks	Ideally, criteria to set the MEPS level are made explicit in the regulatory framework.
Economy	Energy consumption subsidies	Cost effective potential is underestimated	Remove subsidies or consider incentives for energy efficient appliances. Tools such as LEERA provide an analysis of this option.	LEERA is a spreadsheet model tool that analyzes the revenue transfer involved between government, manufacturers and consumers when subsidizing more efficient appliances (Gopal et al., 2013)
	High up-front cost of energy efficient products	Even though cost-effectiveness is known, the added first cost of purchasing energy efficient products may be a barrier to buyers.	This barrier can be reduced by rebates, attractive loan financing or leasing, tax credits, or government purchasing policies (see next section).	
Capacity	Lack of data	Damages the credibility of the analysis, increasing likelihood of stakeholder opposition to the standard	Involve a wide range of stakeholders in data collection to support the standard-setting process (see above).	
	Lack of analysis	Standards are not set at an optimal level that maximizes savings while ensuring consumer net benefits	Policy analysis tools such as the Policy Analysis Modeling System (PAMS-MEPS) can address such barriers. The model provides estimates of consumer impact (based on a comparative life-cycle cost analysis of different efficiency levels), potential energy savings and greenhouse gas emissions reduction potentials, and net present values resulting from future standards.	PAMS-MEPS relies on a database of international parameters to provide a simplified techno-economic analysis with limited or no additional data for more than 150 countries. Users can customize the model through a user-friendly interface to add relevant data in order to improve the accuracy of the results.
	Limited resources to carry-out analysis	Analysis is constrained and/or abbreviated	Simplified techno-economic analysis yields most important results at a minimum cost.	

Incentive programs offer a favourable complement to S&L policies by promoting energy efficiency improvements beyond building code and equipment standard requirements and preparing the market for increased future mandatory requirements. For purpose of this discussion, we consider information programs such as home energy audits, to be a form of incentive programs. By increasing the market penetration of most efficient products, incentives programs help reduce their cost of production through streamlined production and economies of scale (Weiss, 2010). The efficiency gains achieved through the incentive program can then be cemented by standards that capture the newly cost-effective efficiency savings, in a virtuous cycle of improvement. Incentives should not be viewed as a permanent instrument and can be phased out as the cost of efficient products decreases over time.

However, if an incentive program appears as a complementary policy to S&L, it is important to note that such programs are a different type of policy. Standards programs are mandatory, they affect all new sales and their cost of implementation only bears the administrative program cost. On the other hand, incentive programs are voluntary, they affect only program participants and bear the cost of providing incentives.

Many years of experience across the U.S. and other countries has demonstrated that energy efficiency programs that encourage the purchase of more efficient equipments by consumers through a combination of information and financial incentives can be effective at overcoming energy efficiency barriers. There is a substantial literature on the barriers to energy efficiency and on the importance of appropriate policy responses in overcoming these (Eto et al., 1996; Golove and Eto, 1996; Jollands et al., 2010; Sathaye and Murtishaw, 2004). In Table 4, we provide examples of programs whose instruments are designed to help address specific market barriers to energy efficiency. However, it is important to note that program design elements described in the table may address more than one barrier, and conversely, one barrier may need several program instruments to be addressed the most effectively. Therefore, there is no single answer to each barrier identified but multiple program design elements are often necessary to accelerate the penetration of more efficient equipment. Reviewing all programs designs to address all markets barriers is beyond the scope of our study.

Many program design examples exist and most of them have for objective to encourage consumers to invest in energy efficient equipment. Incentive programs need to be designed based on careful analyses and identification of the market barriers that prevent consumers from investing in cost-effective energy-efficient equipment.

INCENTIVE PROGRAMS OUTLOOK

More and more governments are implementing regulatory frameworks to support the development of incentive programs to reach higher energy savings, often under the form of energy reduction obligations from the energy sales of utilities (also referred as energy providers). These obligations induce the development of incentive programs to achieve energy savings. As an example, the directive recently published by the European Commission, the European Parliament, and the EU Presidency requires EU Member States to implement utility energy savings obligations equivalent to 1.5 % of annual sales (EC, 2012). Another example is South Africa, which has an energy-saving target of 4,055 GWh (and 1,037 MW) between 2011 to 2013. Eskom, the sole South African utility, has been allocated a budget of 5,445 M Rands (US$651 M) to develop incentive programs. In the U.S., 26 U.S. states have set goals for their electric energy providers and 12 also include goals for natural gas (DSIRE, 2012). According to the annual report of the Consortium for Energy Efficiency (CEE, 2012), a total of US$8 billion was budgeted for gas and electric efficiency programs in 2011, representing an increase of 20 % over the previous year.

We find that the effectiveness of a program depends on the market barriers that it attempts to remove (de la Rue du Can et al., 2011). Evaluations have tended to show that financial incentive programs are often most effective when they target efficiency specifications that have a small market share (i.e. BAT targets). Lees' evaluation of previous British schemes, Energy Efficiency Commitment (EEC) 1 and 2, shows that share of free ridership (or deadweight) increases as the market share of efficient product increases (Lees, 2008). The analysis suggests that products with a market penetration greater than 30 %–40 % do not need to be financially incentivized. Gold and Nadel (2011) find similar results and also point out that incentive programs should be of a limited time period, usually around five years as the technologies' market share can continue to grow and prosper on their own after the tax incentives end. Behavioral and information incentive programs, such as the reward programs and energy reports as described in Table 4, are most effective when consumers are already familiar with the energy efficiency product.

Well designed incentive programs can accelerate the penetration of more efficient technology and accelerate market transformation, including the potential to adopt cost-effective standards more quickly. They are the front end of market transformation and an essential link in the chain of achieving energy savings.

Conclusion

This analysis identifies over 900 billion kilowatt-hours (TWh) of potential annual energy savings in SEAD economies, out of which two-thirds have been found cost-effective. Although cost-effective savings are the low-hanging fruit in the energy efficiency potential space, SEAD participating governments have captured only about half of this potential on average through minimum standards proposed or implemented since 2010. This paper has identified barriers that may be faced by governments in setting more aggressive standard targets along with best practices and policy instruments to overcome these barriers, with the understanding that the situation of efficiency programs varies widely across SEAD economies and that these barriers have to be seen as general concepts that don't necessary apply to all. To capture the remaining technical potential savings that are not currently cost-effective, complementary measures such as financial incentives can help achieve higher penetration of efficient technologies. Standards and labelling policies and incentive programs can work to accelerate market transformation for energy efficient equipment and appliances by encouraging adoption of more efficient products, driving down the cost of efficient technologies, and removing inefficient products from the market.

Table 4. Examples of Best Practices Incentive Programs.

Barriers	Effect	Examples of Program Design used in Incentive Programs
Uncertainty of savings and perceptions of risk	Consumers do not have a high degree of confidence in expected savings. Savings are not easily evaluated by consumers and consumers tend to have a very high discount rate for energy savings.	Rebates: • Help to assure consumers that they are making cost-effective decisions • Provide a financial impetus to invest and reduce the risk in energy efficiency investment
Lack of information	Information on current and future prices, technological options and developments, and all other factors that might influence a purchase decision is not easily available or accessible at time of investment.	Individualized Energy Reports: • Provide information on energy usage compared with peers • Offer recommendations on how to save energy • Promote energy conservation
Transaction cost	The transaction cost refers to the time and effort required to identify and implement efficiency improvements. Even if consumers are interested in a particular product, they may face high hassle costs to acquire and install it.	Reward programs: behavioral programs that seek to motivate consumers' engagement by setting individual and community goals and offering rewards and recognition. • Provide challenge to motivate people to get over the hump of hassle costs • Reward good behavior
Limited access to Capital	Limited access to capital prevents investment in more efficient equipment that is more expensive up-front (Golove and Eto, 1996),	Replacement Programs: install the measures at no (or reduced) cost, for example by replacing inefficient residential appliances before the end of their useful lives with significantly more efficient appliances • Reduce electricity use by encouraging the deployment of more efficient appliances • Ensure that older, less-efficient appliances are removed from the market • Recycle old appliances in accordance with the appropriate environmental regulations and practices
Lack of energy-efficient equipment on the market	Restricted selection of higher energy efficiency equipment may dissuade consumers	Midstream Programs: incentives are offered to retailers to engage them in increasing their stock and promoting the value of energy efficient investment to the consumers. • Motivate retailers to sell energy efficient products by advertising signage or other marketing attractions • Increase stock of energy efficient products • Can provide field education support of the retailer sales force.
Split incentives	Split incentive occurs when the investor does not receive the benefits of improved efficiency. Ex: rental property where owners lack incentives to invest in efficiency improvements because it is the tenant who pays the utility bill and will benefit from the savings.	On-bill Financing Programs: spreads out the up-front cost by charging monthly installments on electricity bills, generally offset by energy savings • Link the loans to the meter, meaning that whoever lives at the house pays the fee and stops paying when they move. • Encourage renters and short-term owners
Uncompetitive market price	Scale economies and learning benefits have not yet been realized due to new low-volume products	Upstream Programs: incentives are offered to manufacturers to increase production of energy efficient products • Accelerate the market introduction and scale production of more efficient equipment • Accelerate the S-curve penetration of innovative efficient products • Influence a large portion of the market through fewer actors

Source: (de la Rue du Can et al., 2013).

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