Acting Globally: Potential Carbon Emissions Mitigation Impacts from an International Standards and Labelling Program

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Abstract

This paper presents an analysis of the potential impacts of an international initiative designed to support and promote the development and implementation of appliances standards and labelling programs throughout the world. As part of previous research efforts, LBNL developed the Bottom Up Energy Analysis System (BUENAS), an analysis framework that estimates impact potentials of energy efficiency policies on a global scale. In this paper, we apply this framework to an initiative that would result in the successful implementation of programs focused on high priority regions and product types, thus evaluating the potential impacts of such an initiative in terms of electricity savings and carbon mitigation in 2030.

In order to model the likely parameters of such a program, we limit impacts to a five year period starting in 2009, but assume that the first 5 years of a program will result in implementation of 'best practice' minimum efficiency performance standards by 2014. The 'high priority' regions considered are: Brazil, China, the European Union, India, Mexico and the United States. The products considered are: refrigerators, air conditioners, lighting (both fluorescent and incandescent), standby power (for consumer electronics) and televisions in the residential sector, and air conditioning and lighting in commercial buildings.

In 2020, these regions and enduses account for about 37% of global residential electricity and 29% of electricity in commercial buildings. We find that 850Mt of CO_2 could be saved in buildings by 2030 compared to the baseline forecast.

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Introduction

The purpose of this paper is twofold. First, it presents an analysis of the global potential of energy efficiency policy in a specific context. The program discussed is the initiation of a *Best Practices Network on Appliance Efficiency* (BPN), supported by the ClimateWorks, a non-profit foundation founded with a mission to apply funding provided by philanthropic organizations toward climate change mitigation in the most effective way possible. As part of this effort, the Collaborative Labelling and Standards Program (CLASP) has been designated as the appliance, lighting and equipment efficiency BPN, to apply its experience in development of energy efficiency standards and labelling (EES&L), in coordination with the regional climate foundations (RCFs) established in key countries and regions throughout the world. For over 10 years, CLASP – originally founded as collaboration between Lawrence Berkeley National Laboratory (LBNL), the Alliance to Save Energy and the International Institute for Energy Conservation but now an independent 501c(3) non-profit organization— has provided technical support to countries developing EES&L programs through its extensive network of international experts. The BPN has a mission to:

> *(1) provide technical assistance to energy ministries at the national level where most appliance standards are set; (2) empower the multitude of S&L experts already present around the world while also laying the seeds for the experts of tomorrow; and (3) engage industry in a dialogue about how to creatively pull the market towards higher levels of appliance efficiency as a supplement to its work within the regulatory regime.*

ClimateWorks considers carbon mitigation in the year 2030 (in tons of CO_2 equivalent) as a specific metric to evaluate the success of its initiatives. The first purpose of the paper is to present an analysis of the potential impacts in terms of this metric of the BPN on Appliance Efficiency. Furthermore, we limit the estimate to goals achievable in the first five years of the initiative (till 2014).

The second purpose of the paper is to demonstrate an application of an analysis framework developed by the authors. As part of previous research efforts, LBNL developed the Bottom Up Energy Analysis System (BUENAS), an analysis framework that estimates impact potentials of energy efficiency policies on a global scale. The current analysis applies the framework to the specific policy type of EES&L, and focuses on the building sector[1] . It also zooms in on a subset of the global model, by considering those countries and regions targeted by the BPN.

In order to maximize the impact of each dollar it spends on program implementation, ClimateWorks has limited its focus to a few economies that together will account for most of the world's emission by 2030. These are: the United States, the European Union, China, India, Brazil and Mexico. All three types of EES&L programs – minimum efficiency performance standards (MEPS), comparative labels and endorsement labels are currently active in the BPN regions of focus. Due to the complexity of the number of regions, sectors and end-uses considered in this analysis, we make the simplifying assumption that the entire market reaches the efficiency target in the implementation year – an assumption that corresponds to the implementation of a MEPS program, although other programs could achieve the same result in moving the average of the market to the same level.

It is infeasible to include every possible equipment type in a five-year program [2]. Therefore, it is important that the program – and the analysis concentrate on those end uses that will afford the most mitigation potential, due to a combination of either high baseline consumption, or a high efficiency improvement potential. The high-priority enduses include: residential lighting, refrigerators, air conditioners, televisions and standby power; commercial lighting and air conditioning[3].

Current policies in the high priority economies

All of the ClimateWorks' target economies have worked on appliance energy efficiency for some time with varying degrees of successful implementation and/or enforcement. The levels of energy efficiency currently being achieved by EES&L varies by country, as does the approach. There are, nevertheless significant additional opportunities for carbon mitigation in all of them.

United States - U.S. federal MEPS became effective starting in 1988. Since then, MEPS have been set and periodically updated for about 45 products. A comparison labelling program (EnergyGuide) was developed in parallel with the MEPS and took effect in 1980 for major household appliances. Finally, the ENERGY STAR

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[1] Most end uses covered by EES&L operate within buildings. Industrial lighting and electric motors are also typically covered. Industrial motors were covered for the BPN study, but we omit them here for brevity.

[2] To date, over 60 different energy consuming products have been the subject of EES&L programs throughout the world (CLASP, 2005).

[3] Commercial refrigeration was also considered in the analysis, but is omitted here for brevity.

endorsement labelling program was introduced in 1992, and has subsequently grown to 40 product categories, and has become the international standard for endorsement labelling.

European Union - The European Union has had a comparative labelling scheme since 1995. The scheme began with cold appliances and now covers most major household appliances. The comparative label is mandatory and equivalent in all EU member states. The European efficiency category system and label design has become a de-facto international standard, which has been adopted in many developing countries. Many European countries also use endorsement labels – these are administrated at the country level. In recent years due to the success of the program in shifting the market toward the most highly rated 'A' class products, the categories A+ and A++ have been added to the A-G scheme for some products. In 2005, the EU adopted a framework directive on the "Ecodesign of Energy-Using Products". The directive establishes a framework for setting energy efficiency requirements for the most commonly-used products. Priority products under the directive include HVAC, water heaters, electric motors, lighting, domestic appliances, office equipment and consumer electronics.

China - EES&L has become a prominent element in China's increasing emphasis on sustainable energy and its recently announced goal to reduce energy intensity of the economy by 20% by 2010. China has implemented a series of minimum energy performance standards (MEPS) and expanded the coverage of its voluntary energy efficiency label to over 40 products, including residential, commercial and industrial products. China recently added an energy information label which among other products is applied to household refrigerators, air-conditioners, and clothes washers.

India - Development of EES&L in India began with the 2001 Energy Conservation Act, which established the Bureau of Energy Efficiency (BEE), with responsibility for supporting the Central Government to specify "standards for any equipment, appliances which consumes, generates, transmits or supplies energy" and recommend "the particulars required to be displayed on labels on equipment or on appliances." In 2006, the program was launched for refrigerators and fluorescent tube lights with air conditioners following in 2007.

Brazil - Brazil first adopted labelling in 1984 and has since established voluntary and mandatory labels for many products. Comparative categorical labels are generally mandatory, and are administrated by the Brazilian national testing agency (INMETRO), in coordination with the Ministry of Mines and Energy (MME). In addition, an endorsement label administrated by a separate agency (PROCEL) accompanies many products, and is well-recognized in the Brazilian market. MEPS are currently being developed in Brazil.

Mexico - Mexico has a long and successful history of EES&L of all types. The first set of Mexican MEPS, implemented by the Mexican National Commission for Energy Efficiency (CONAE) took effect on January 1, 1995. Since then, MEPS for many products have been implemented, and efficiency requirements have gradually been aligned with those of the U.S., making Mexico's standards among the world's most stringent. In addition to MEPS, Mexico uses a continuous comparative label with a similar design to the U.S. EnergyGuide label. Finally, FIDE[4], a non-for profit private trust fund supported by the federal government administrates a successful endorsement labelling program.

Methodology

The current study follows the approach of recent work by the authors evaluating the potential carbon mitigation potential for EES&L programs worldwide, for a wide range of products. That study (McNeil, 2008) should be referred to for many technical details omitted here. This, and several previous studies (McNeil et al., 2005), (McNeil et al., 2006), (McNeil et al., 2007), (Letschert et al., 2007), (Letschert et al., 2008) share a common analysis framework, called the Bottom Up Energy Analysis System (BUENAS).

The strategy of the model is to construct the analysis in a modular way. The first module models demand for energy services (*activity*) at the end use level, while a second considers the final energy used to provide those services in the base case, and builds a high-efficiency scenario based on meeting equipment efficiency targets by a specified year. A third module tracks market penetration and stock turnover for efficient products. Finally, these three components are brought together, and savings are calculated as the difference in consumption and emissions in the efficiency scenario versus the base case.

Module 1 – Activity forecasting

Appliance ownership is projected according to a diffusion[5] model using readily-available national-level variables as inputs. A logistic function[6] describes the penetration of appliances in the households. Over 300 data points were

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[4] Fidelcomiso para el Ahorro de Energía Eléctrica

[5] The term "diffusion" refers to the number of products per household, which can be greater than one.

gathered in development of the global residential model for the following equipment: lighting fixtures refrigerators, air conditioners, washing machines, fans, televisions, stand-by products[7], and electric water heaters.

The diffusion relationship allows for interpolation of ownership rates to countries for which no data are available and also allows for extrapolation of ownership rates into the future, serving as the primary driver for the energy demand forecast. The model predicts future ownership rates according to the current relationship between ownership and income, urbanization and electrification. This curve is modeled via cross-country comparison.. In order to provide global coverage, an effort was made to parameterize ownership in terms of macroeconomic variables that are available for a wide range of countries. GDP growth is an exogenous input to the model. As a reference, we used the projections provided by the U.S. Department of Energy's International Energy Outlook 2007 (USEIA, 2007).

Commercial sector activity is driven primarily by commercial building floor space. Commercial floor space modeling proceeds in a similar manner to residential appliance diffusion, by modeling the percentage of workers employed in the commercial sector, and the amount of floor space (m^2) occupied by each employee, both of which are modeled as a function of GDP per capita according to cross-country time series comparison.

Figure 2 shows selected results of the forecast for the U.S. and India. For the residential sector, diffusion rates of main appliances are shown in percent (left axis). The charts also show the evolution of commercial floor space, in millions of square meters (right axis). As might be expected, diffusion rates in the U.S. are high, but nearly flat, due to saturation effects. Refrigerator diffusion climbs very slowly as additional households choose to purchase a second refrigerator. Air conditioner rates are also nearly constant, since areas in the U.S. where air conditioning is desirable currently have nearly 100% penetration of central air conditioning in new homes. On the other hand, in India, refrigerator rates are still rising, but ownership of televisions is saturating and leveling off. Air conditioning ownership increases from 3.5% in 2010 to 4.7% in 2030, a relative rise of 34%. Air conditioner rates are expected to remain low according to the model, since, although household incomes rise significantly in relative terms, average household income is still low, rising from $2100 annual per household in 2010 to $4700 in 2030, which is below the "takeoff" point for air conditioners, which are a relatively expensive appliance. It should be noted however, that shifts in income distribution are not taken into effect in this aggregate model. Economic growth may be concentrated in middle- and high-income families, significantly increasing the percentage of households that can afford an air conditioner. In addition, real prices for air conditioners may drop over time, making them more accessible. Therefore, the air conditioner adoption rates may be somewhat of an underestimate.

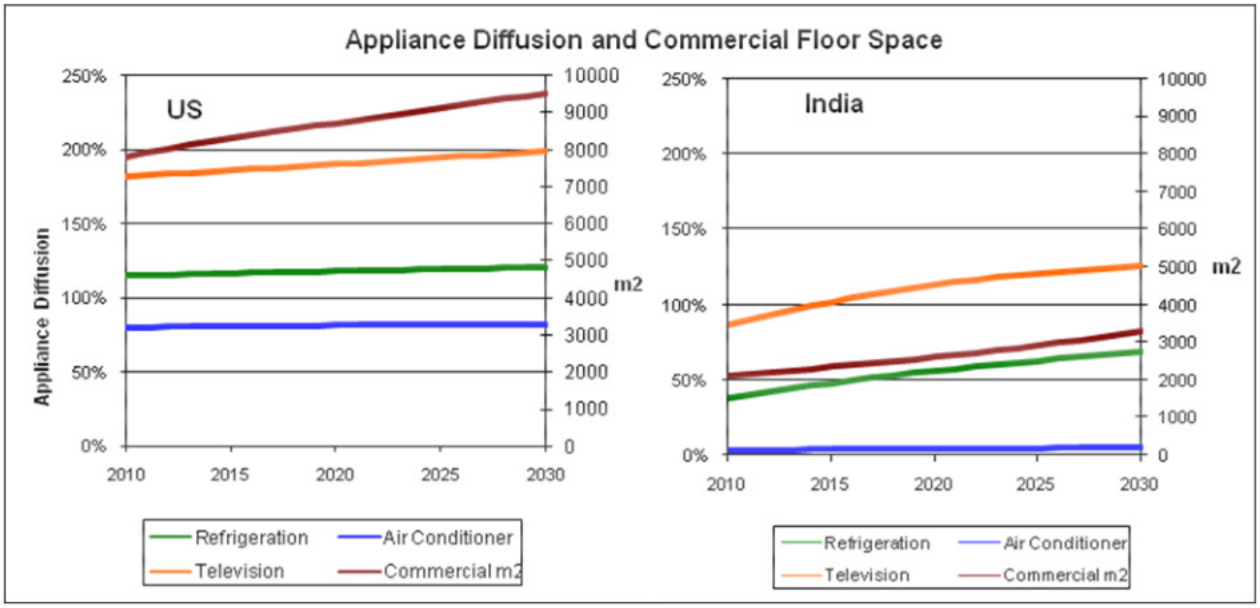

Figure 2 –Activity forecast for residential and commercial building sectors.

Module 2 - Unit energy consumption and savings potential

The second module, which determines the energy consumption to provide the services modelled in Module 1, resembles a database of engineering and usage parameters. The two main outputs of Module 2 are Unit Energy Consumption (*UEC*) of end use technologies currently installed and available on the market (*baseline UEC*) and efficiency targets to be achieved at a market average level through implementation of EES&L programs.

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[6] Because of its S-shape, the logistic function is often used in consumer choice models

[7] The number of products using stand-by consumption is based on total standby wattage divided by 5W which is assumed to be the average device stand-by power.

A detailed investigation of baseline energy efficiency and available high-efficiency options by region was made for the *Global Impacts* study (see McNeil et al., 2008). In that study, we considered implementation of EES&L in two phases – by 2010 and 2020. The approach for determining efficiency levels for EES&L in 2020 was to identify levels demonstrated to maximize cost-effectiveness in some region, or to be widely purchased in some economy (such as the European A+ level for refrigerators). The 2010 levels were then conceived of as an intermediate, short-term step toward the 2020 levels. The basic assumption of the analysis of the BPN is that it will result in an *acceleration* of EES&L, so that the 2020 levels from the global report could be achieved by 2014. The assumptions for each economy and end use are given in Table 1.

Table 1 – Base Case and 2014 Target Efficiency Levels for Priority End Uses

End Use	Region	Units	Base Case	2020 Target	Assumption
Fluorescent Tubes	US	W (Tube 3+ Ballast)	34.6	34.6	No further improvement for Central AC based on cost-benefit analysis (Rosenquist, 2006)
	EU		41.4	34.6	Electronic Ballasts
	India		51.6	40.6	Electronic Ballasts
	Other		44	34.6	Electronic Ballasts
Incandescent Lamps	All	% of CFL	variable	50%	50% share of CFLs by 2030
Refrigerators	US	kWh/yr	562	391	EU A+ level by 2014.
	EU		364	271	EU A+ level by 2014.
	China		489	302	EU A+ level by 2014.
	India		548	223	EU A+ level by 2014.
	Brazil		493	232	EU A+ level by 2014.
	Mexico		341	188	EU A+ level by 2014.
Air Conditioners	US	EER (W/W)	3.37	3.37	No Further Improvement
	EU		2.8	4	Current baseline and Levels currently set by Japan's Top Runner Program
	LAM		2.64	4	
	China		2.6	4	
	India		2.4	4	
Televisions	All	Efficiency	100%	148%	Potential efficiency improvement relative to current baseline according to (Armishaw, 2006)
Standby Power	All	W	44	9	1W in 2014
Commercial Lighting	US	Efficacy	0.97	1.27	See (McNeil, 2008) for definition of efficiency metric and technology assumptions
	EU		0.94	1.18	
	LAM		0.84	1.12	
	CPA		0.84	1.09	
	India		0.84	1.11	
Commercial Air Conditioning	US	EER (W/W)	2.49	2.64	Minimum LCC for Commercial AC+HP
	EU		3.27	4.07	A' level by 2014.
	Other		3.14	4.07	Same as EU, except baseline at 'E' level

Module 3 – stock accounting and calculation of energy savings

In order to account for equipment turnover, the stock of each end use in each year is calculated, and the portion impacted by programs in place by 2014 is made. This portion is determined by the increase in the total appliance stock (due to increased uptake and population/floor space growth), and by retirement and replacement of old products. The time necessary to replace all of the pre-program stock depends on the average life of the product. The stock is assumed to decrease linearly and reaches zero after 1.5 times the average lifetime (McNeil et al., 2008). With this, the stock in each year can be divided into two categories: pre- and post- program implementation, with a different UEC for each. The difference between total energy consumption of the stock in the Base Case and Efficiency Scenario are yields energy savings.

Results and Conclusions

Using the methodology described in the previous section, we forecast electricity demand by end use for each economy, and the potential savings from the BPN, in terms of both electricity and carbon emissions. Figure 3 shows the savings results for the U.S. and China. Interestingly, the total electricity savings for the two countries in 2030 is similar, at about 1000 TWh. In the U.S. however, this reduction will take place against a high baseline, but the results imply the potential to reverse the growth of electricity demand in U.S. buildings. In percentage terms, the savings in China is dramatically higher than the U.S., reflecting not only the large expected growth, but also the relative low-efficiency of the baseline.

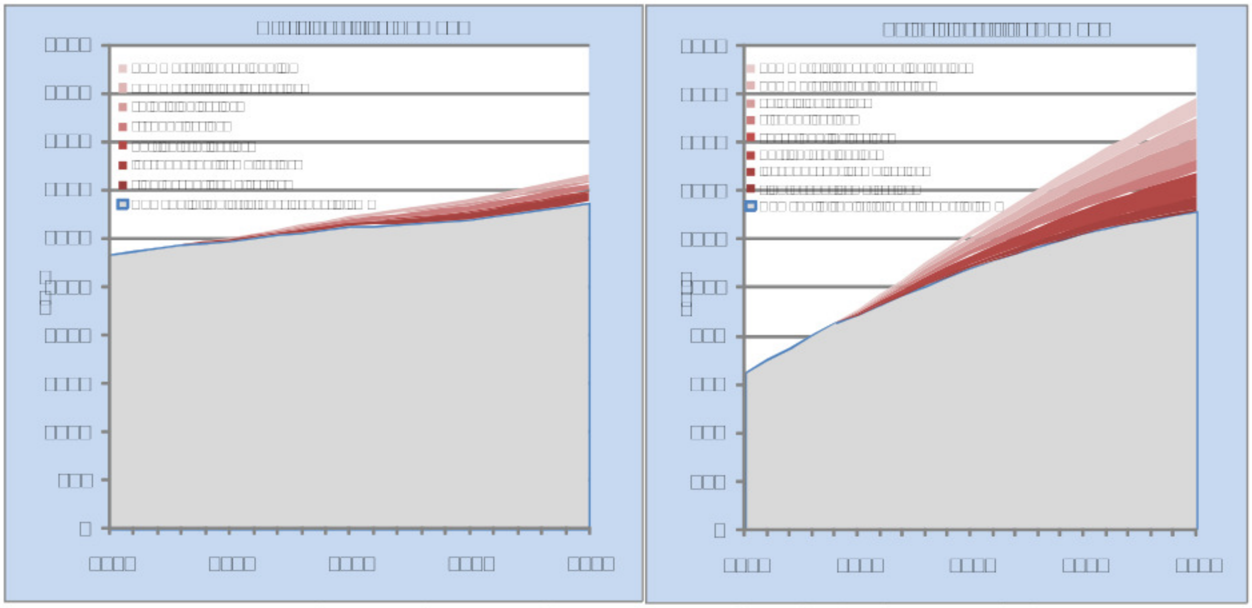

Figure 3 – Electricity forecast and Savings Potential Results for the U.S. and China

Table 2 shows the electricity savings for each end use and economy. Total electricity savings is 1301 TWh in 2030, with the bulk of it (886 TWh) arising from savings in the residential sector, but with a significant amount (415 TWh) yielded by just two commercial end uses (lighting and air conditioning). For comparison, a recent study by the U.S. Department of Energy forecasts total world electricity consumption in 2030 at 7800 TWh (USEIA, 2007). The savings afforded by the initiative considered in this paper is 17% of this figure.

Table 2 – Electricity Savings Potential in 2030 by Economy and End Use (TWh)

End Use	BRAZIL	CHINA	EU	INDIA	MEXICO	US	TOTAL
Residential Lighting	11	63	39	29	10	102	254
Refrigeration	19	100	18	66	6	26	235
Residential Air Conditioning	8	2	17	21	12	0	60
Standby	4	26	30	10	4	33	108
Television	12	98	37	45	7	32	230
Residential Subtotal	**54**	**289**	**140**	**171**	**38**	**193**	**886**
Commercial Lighting	9	82	39	19	9	69	228
Commercial Air Conditioning	13	81	35	36	11	12	187
Commercial Subtotal	**22**	**163**	**74**	**54**	**20**	**81**	**415**
TOTAL	**77**	**453**	**214**	**225**	**59**	**273**	**1301**

Electricity savings are converted to emissions mitigation by multiplying savings in each economy by a regional carbon factor developed by IEA data, extrapolated to 2030[8]. Figure 4 shows the resulting annual emissions mitigated in 2030, for each region and end use.

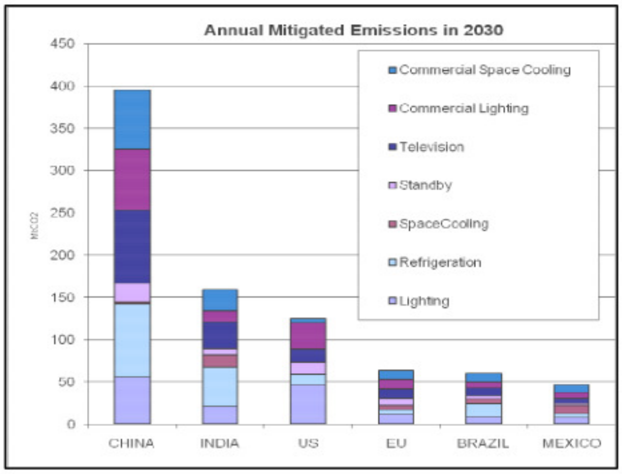

Figure 4 – Carbon Mitigation Potential by economy and end use.

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[8] We assume a 1% annual reduction in carbon factor (g CO_2/kWh) for all regions.

In terms of total emissions, the mitigation potential is by far the largest in China, which shows more than twice the opportunity of the U.S. This result is largely due to the higher carbon factor for electricity generation in China. India, which is also largely dependent on coal for electricity production, and likely to experience very high growth, shows the second highest potential. The figure also shows the contribution of each end use. The priority end uses necessarily have variable contributions in different economies, with no end use being clearly dominant. Total emissions reduction potential is 850 Mt CO_2.

In the current study, we ask the question of the potential for standards that are limited to only the highest priority economies and only a handful of the most important end uses, but are endowed with the resources to significantly accelerate the adoption of best practices. The results show that such a targeted program does in fact have the potential to match the impacts of a wider but more 'diffuse' development of EES&L programs. The global study found a total carbon mitigation potential in the buildings sector of 1400 Mt CO_2 in 2030, compared to the above result of 850 Mt CO_2, or 60% of the global result. This is not surprising if one considers the following: (1) most of the worlds energy-related emissions are currently accounted for by the target economies, a situation that is likely to persist, especially as India and China's emissions grow; (2) the bulk of emissions (if not energy) savings is to be found in electric end uses, due to conversion energy and (3) the implementation of best practice standards by 2014 guarantees that by 2030, nearly all of the stock of these end uses will have been converted to high efficiency. We hope that the analysis presented contributes to dialogues in the energy efficiency and policy community of the relative benefits of a focused, but more intense set of efforts than has been implemented to date.

While we believe the results of the study to be sufficiently robust to inform policy planners of the benefit of an initiative of the kind considered, the analysis is not without limitations. Most obviously, the projection of energy growth and stock turnover is highly dependent on the economic forecasts used. A constant growth scenario may give reasonable results over the very long term, but interruptions in this pattern such as the current global economic downturn will surely have strong short- and medium-term effects. Predicting and confirming the impacts of this crisis on global energy demand using a bottom-up approach will present an engaging research area over the coming months and years, and test the limits of the methodology to model effects on a shorter timescale. Second, the model of equipment uptake assumes that an appliance affordable for a household of a certain income today will be just as affordable for a household of that income in the future. In reality, uptake rates are likely to be higher than we've projected, due to lower equipment prices afforded by technological advances in manufacturing, and economies of scale. Finally, the model considers technologies that are available today, but much more efficient products may well be available and affordable in the future, permitting even more stringent targets to be cost-effective.

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