Trading appliance efficiency for electricity subsidies: the potential in emerging economies

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Abstract

Numerous countries use taxpayer funds to subsidize residential electricity for a variety of socio-economic objectives. These subsidies lower the value of energy efficiency to the consumer while raising it for the government. Further, while it would be especially helpful to have stringent Minimum Energy Performance Standards (MEPS) for appliances and buildings in this environment, they are hard to strengthen without imposing a cost on ratepayers. In this second-best world, where the presence of subsidies limits the government's ability to strengthen standards, we find that avoided subsidies are a readily available source of financing for energy efficiency incentive programs. Here, we introduce the LBNL Energy Efficiency Revenue Analysis (LEERA) model to estimate the appliance energy savings that can be achieved in several emerging economies by the revenue neutral financing of incentive programs from avoided subsidies. LEERA uses the detailed techno-economic analysis developed by LBNL for the Super-efficient Equipment and Appliance Deployment (SEAD) initiative to calculate the incremental costs of appliance efficiency improvements. We analyze the tariff structures and the long-run marginal cost of supply to calculate the marginal savings for the government from appliance efficiency. In this paper, we present our initial findings for Mexico, Russia and the United Arab Emirates (UAE). We find substantial market transformation potential for refrigerators and televisions in Mexico and for room air conditioners in the UAE. In Russia, we find that other sources of revenue need to supplement avoided subsidies to meaningfully transform appliance markets.

Introduction

Electricity consumption subsidies are common in countries around the world. While subsidies are found in OECD countries, the majority of subsidy programs are in developing countries, including the major emerging economies (UNEP 2008). In most of these countries, electricity and fuel subsidies were introduced as social programs that reduce the cost of energy for the poor (Komives et al. 2006). Hence, reducing or eliminating subsidies involves substantial political risk and is usually not part of the energy policy dialogue in many countries. Further, subsidies make it harder to introduce or strengthen Minimum Energy Performance Standards (MEPS) for end-uses, as they frequently are not cost-effective from the consumer perspective. We, at Lawrence Berkeley National Lab (LBNL), are developing the LBNL Energy Efficiency Revenue Analysis (LEERA) model to assist countries in meaningfully improving appliance energy efficiency without altering their subsidy programs.

LEERA is designed to assist subsidy-burdened governments in appliance incentive program design. The model calculates the financial and energy savings that will accrue to the government from the deployment of more efficient models for each type of appliance. It then draws on the product-specific techno-economic analysis of the Super-efficient Equipment and Appliance Deployment (SEAD) Initiative to calculate the efficiency improvements that can be achieved and to suggest incentive levels for each appliance if the incentive program is entirely financed by avoided subsidies. The model can support most types of incentive program design.

In this paper, we analyze the residential sectors in Mexico, the United Arab Emirates (UAE) and Russia which all receive net taxpayer funded subsidies on electricity. We focus on refrigerators, light emitting diode-liquid crystal display televisions (LED-LCD TVs) and room air conditioners (ACs). Our goal is to help these countries understand, precisely, the extent to which they can transform the markets for these major end-use appliances if they used revenue from avoided subsidies to finance incentive programs for these appliances. The paper is structured as follows. We first present an overview of energy subsidies and their adverse impact on demand for energy efficiency. Next, we introduce and explain the LEERA model. This is followed by a presentation and discussion of our initial results for Mexico, Russia and the United Arab Emirates (UAE). LEERA's analysis offers valuable insight for a number of problems in net subsidizing countries: What are subsidy savings from efficiency improvements for different appliances? For a given end use, can energy efficiency (EE) save the government enough in avoided subsidies to finance meaningful incentives for EE? If so, for each appliance, models at what efficiency levels can be included in an incentive program financed entirely by avoided subsidies? For each appliance model what incentive level can be provided?

Landscape of Energy Subsidies

Studies of global energy subsidies find that they are substantial and most are in non-OECD countries (UNEP 2008). Globally approximately $420 billion is spent on energy subsidies, making it one of the most subsidized sectors (Badcock 2010; Lewis 2012). Although most of these subsidies are for petroleum, much support is directed towards electricity consumption (Foster and Yepes 2006). In 2005 the International Energy Agency (IEA) estimated that the economic value of subsidies going to the electric sectors in Russia, China, India, Saudi Arabia and South Africa approached or exceeded $5 billion per year each (UNEP 2008). Importantly, even though the stated goals of most subsidy programs are to reduce poverty, there is considerable evidence that they are not well targeted (Komives et al. 2006).

Despite the massive amounts spent on subsidies, there is a paucity of data on energy subsidy programs at the international level. Studies have lamented the lack of a global or even OECD-wide inventory of programs (Badcock and Lenzen 2010; Gadgil and Sastry 2010). Badcock and Lenzen undertake a comprehensive review of subsidies for energy generation but they do not find a consistent definition of electricity subsidies, a consistent method of accounting for them or a consistent method for estimating them (Badcock 2010). Even the European Union does not use a uniform evaluation method (World Bank 2010). Part of the difficulty in evaluating and analyzing subsidies is the numerous forms that subsidies can take including direct cash transfers, tax credits, rebates, accelerated depreciation, cross subsidies, price caps, subsidized loans, waived dividends, risk assumption and even delayed system maintenance or improvement (Komives et al. 2005). Further, many countries, like India, have implicit subsidies by which government-owned utilities recoup their losses from the general fund on an ad-hoc basis.

ELECTRICITY SUBSIDIES AND UNDERINVESTMENT IN ENERGY EFFICIENCY

From an energy policy perspective, subsidies cause overconsumption of energy and lead to inefficient allocation of societal resources (IEA 2010a). From an energy efficiency perspective, end-use electricity subsidies typically make efficiency programs more challenging to implement. Consumers and utilities already underinvest in energy efficiency due to a number of market failures: first cost barriers, information asymmetry and the environmental externalities of energy production and use. Figure 1 shows that these market failures cause overconsumption of electricity and the resulting deadweight loss.

Electricity subsidies further increase this deadweight loss. Figure 1 illustrates an electricity market in which prices are set at the privately optimal level: where demand equals supply (supply represented by the private cost curve). In this market, suppliers produce energy until they meet the level of demand (Q_{PRIV}) at which they can charge consumers a price that equals the producers' private cost of production (P_{PRIV}). However, there is a market failure since there are added costs to society, externalities such as pollution, not included in the price consumers pay. If they were included, consumers would pay more, price P_{SOC}, and consume less, quantity Q_{SOC}. At price P_{PRIV} consumers use more energy than is socially optimal thus producing more pollution than socially optimal and creating the deadweight loss – a cost to society that is not paid for in sale of the electricity – indicated by the triangle.

Figure 2 shows a market in which the price to consumers (P_{SUB}) for electricity is reduced due to subsidies. Electricity becomes even cheaper compared to its socially optimal cost. Even more energy is used (Q_{SUB}), energy efficiency becomes even less valuable for consumers and a greater deadweight loss results. However, because subsidies increase electricity consumption, they make energy efficiency more valuable to the government, which can decrease its subsidy burden by reducing end-use energy consumption.

IMPROVING ENERGY EFFICIENCY IN SUBSIDIZED REGIMES

From a theoretical economic perspective, a pigouvian tax that captures the negative externalities associated with pollution from energy consumption would be a first choice EE policy. As discussed above, these policies can be challenging to implement. Financial incentives, on the other hand, are a politically feasible efficiency policy that can transform the market without any changes to existing subsidy program design. LEERA supports governments in designing incentive programs using the latter approach.

The LBNL Energy Efficiency Revenue Analysis (LEERA) Model

The objective of the LEERA model is to calculate the savings from avoided subsidies achieved through EE and to use these to suggest incentive levels for more efficient appliances. It does this by calculating the subsidy on the marginal unit of electricity consumed by a representative household, multiplying that by annual energy savings from a more efficient appliance and calculating the present value of the associated monetary savings over the life of the appliance. Using this approach we generate a curve of government savings at each level of appliance efficiency improvement over the baseline. We can compare this avoided subsidy revenue curve to various types of incentive program support. In this paper, we compare the avoided subsidy revenue curve to the incremental manufacturing cost curve.

LEERA calculates only subsidies that cover the difference between retail price recovery and long run marginal cost of generation because these are more likely to be available for financing incentive programs than other indirect subsidies. LEERA does not include social subsidies in the avoided subsidy equation because these are not real streams of revenue unless the country being studied already taxes energy for its externalities. In this aspect, LEERA underestimates the overall subsidy burden of the government which leads to an underestimate of the revenue available for EE incentive financing. We argue, however, that many of the more complex mechanisms of electricity subsidy delivery are not revenue streams that are clearly recognized or even permitted by the Government to be applied to energy efficiency incentives.

First the amount of money the government avoids spending for each unit of electricity saved is calculated. This is done using the gap-method: the supply cost minus the tariff equals the amount of subsidy. LEERA assumes that appliance efficiency savings occur at the consumer margin and hence the model uses the following equation to calculate avoided subsidy:

Avoided Subsidy
= Long Run Marginal Cost of Supply (LRMC)
– Marginal Tariff at which EE savings occur

In Figure 2, the avoided subsidy is shown as the difference between MC_{SUB} and P_{SUB}.

Estimating the LRMC of supply and the marginal tariff is data intensive. We were able to find detailed data for Mexico but not for Russia and UAE where we use average supply costs and average tariffs. As we explain above, we also ignore unaccounted costs such as deferred maintenance and/or system improvements.

Next, LEERA multiplies this avoided subsidy per unit by the annual electricity savings suggested by each efficiency improvement. The model then takes the present value of these annual savings over the lifecycle of the appliance to get the full value to the government of avoided subsidies. These subsidy savings are then be compared to the incremental cost of more efficient models which are derived in the SEAD technical analysis.

We also correct for rebound using estimates from literature (Nadel 2012, European Commission 2011, Davis 2012).[1] We apply an 11 % rebound for refrigerators and TVs and a 24 % rebound for room ACs (Nadel 2012). These values include direct and indirect rebound and substantially reduce the engineering savings estimates. We choose to show a conservative savings estimate for each appliance because we do not explicitly include program administration costs in this paper.

For example, a baseline refrigerator in Mexico uses 480 kWh per year. Thus switching to a 25 % more efficient model (engineering estimate) would yield energy savings of 106 kWh per year.[2] We calculate the subsidy on refrigerators to be \$0.14 per kWh producing a unit savings of \$15 per year. The net present value of this stream of savings over the course of the refrigerator's 15-year lifetime is \$150. The incremental cost to produce a model that is 25 % more efficient than the baseline model is \$107. A government incentive could cover the entire cost of making a more efficient machine and result in \$43 in savings from avoided subsidies.

In this paper, we present results for refrigerators (for Mexico only), room air conditioners (split style) and LED LCD televisions. We will extend the analysis to other appliances as country-specific cost curves for each are completed by the SEAD technical analysis. Baseline unit energy consumption (UEC) and incremental manufacturing costs are taken from the SEAD technical analyses for room ACs and TVs. For refrigerators we use data from LBNL's analysis in support of harmonization of Mexican and US refrigerator standards (LBNL 2011).

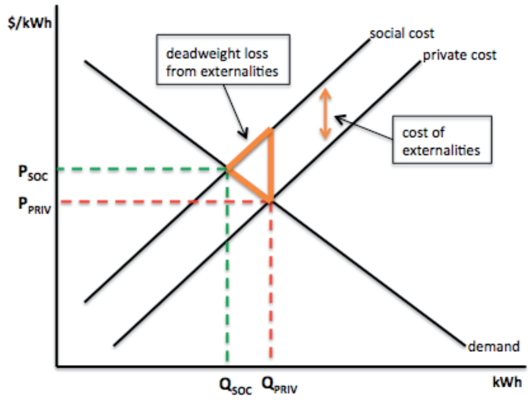

Figure 1. The economic cost (deadweight loss) of externalities in the electricity sector without subsidized tariffs. [P_{SOC} – Socially optimal price, P_{PRIV} – Privately optimal price, Q_{SOC} – Socially demanded quantity, Q_{PRIV} – Privately demanded quantity, kWh – kilowatt hours].

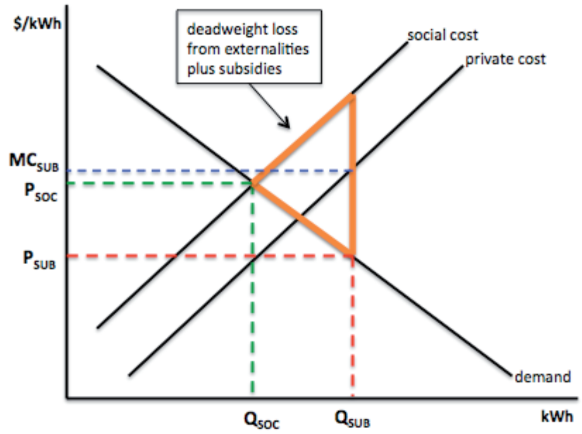

Figure 2. The added deadweight loss due to subsidizing electricity rates. [MC_{SUB} – Marginal Cost under subsidized pricing and demand, P_{SUB} – Subsidized electricity price, Q_{SUB} – Quantity demanded under subsidized pricing].

1. The rebound effect can be divided into direct and indirect effects. Rebound numbers quoted here are the sum of direct and indirect rebound effects for each appliance found in Nadel 2012.

2. 25 % corrected for an 11 % rebound effect results in a 22 % actual savings. 480 kWh * 22 % = 105.6 kWh saved per year.

Results

MEXICAN CONTEXT AND INPUT DERIVATIONS

Mexico has generous residential electricity subsidies that are appropriated to varying extents by all income groups (World Bank 2009). Mexico has had appliance MEPS for more than a decade but recent attempts to strengthen standards have been difficult precisely because stronger standards are not cost effective for consumers (LBNL 2011). There is one supplier of residential electricity in Mexico, the state-owned Federal Electricity Commission (CFE), which uses a complex Increasing Block Tariff (IBT) system in which tariff zones are defined by average regional temperature.

The LEERA model calculated tariffs for Mexico by taking the average, seasonally adjusted customer electricity consumption for each residential tariff zone and applying the IBT rate at that usage level. These tariffs for each zone were then weighted by the zone's proportion of customers and summed to get an overall tariff. AC use is correlated with the increasing average temperatures that define the tariff structure and is thus skewed towards certain tariff zones. LEERA thus calculates the tariff for ACs using a proxy minimum, seasonally adjusted customer usage based on baseline AC consumption. The model then uses this proxy to determine which income deciles in which tariff zones have ACs. It then compares this average usage in each decile to the tariff schedule to find the marginal tariff for that decile. Decile and tariff zone IBT rates are then averaged in the same way as for the other appliances.

In Mexico, fuel oil makes up 18 % of the electricity generation mix and it operates on the margin. LEERA uses the international price of crude oil, averaged over the period 2012–2022, to derive the LRMC per kWh_e delivered. Given that natural gas is steadily replacing fuel oil in the Mexican generation mix, we assume that 10 % of the savings will occur with natural gas on the margin.

MEXICO RESULTS

Our initial findings show that savings from avoided subsidies can finance incentives that cover the entire incremental manufacturing cost of refrigerators that are 27 % more efficient than baseline models. In the case of LED-LCD TVs, the full incremental cost of models that are 32 % more efficient than baseline LED-LCD TVs can be financed with just half of the savings from avoided subsidies. For room ACs, subsidy shifting could provide an incentive that would cover about two thirds of the incremental manufacturing cost of a 4 % efficiency improvement (see Figures 3, 4 and 5).

Potential savings for Mexican refrigerators result from three main sources: the large subsidies on each unit of refrigerator power consumption, a relatively high annual unit energy consumption (UEC) and the long life of the appliance. TV savings potentials also benefit from high proportional subsidization on the energy it uses. However, low incremental manufacturing costs and large savings per efficiency improvement also boost its potential. The smaller potential for ACs is due to a lower baseline UEC and shorter life compared to refrigerators but primarily due to the lower per kWh subsidies for households that own ACs. We plan to refine the Mexico results and quantify the contribution of each factor to the overall savings potential.

RUSSIA AND THE UNITED ARAB EMIRATES (UAE)

Results for Russia and UAE are preliminary pending further study of the energy sectors in each country. We obtained average tariff and average supply cost data for each country. Then we performed analyses for ACs and TVs using SEAD technical analysis data for UECs and incremental manufacturing costs. This method assumes that TV manufacturing costs will be the same or similar in all countries, a reasonable assumption given the global dominance of the few companies in this market. We ascertain the Russian average cost of supply by adding the fuel and operation and maintenance (O&M) costs for coal, gas and nuclear – together fuelling 80 % of the electricity generation – and weighting each by their proportion of the electricity generation fuel mix (IEA 2009, IEA 2010). The average Russian tariff is taken from SEAD technical analysis. For average tariffs in the UAE, LEERA uses numbers from SEAD technical analysis; a proxy for average supply costs is taken from the University of Cambridge, Electricity Policy Research Group's study of Abu Dhabi's generation capacity investments.

RUSSIA RESULTS

LEERA finds that avoided subsidies could finance nearly half of the incremental manufacturing cost of a 4 % improvement on AC units and one third of the cost of a 32 % efficiency improvement for TVs in Russia (see Figures 6 and 7). Due to a small per unit of electricity subsidy, even the higher baseline UEC for Russian ACs as compared to Mexican ACs does not add up to significant subsidy savings when compared to incremental manufacturing costs. For TVs, the much lower subsidy per kWh and a slightly higher Value Added Tax (VAT) result in a smaller potential for savings than in Mexico.

UAE RESULTS

In the UAE, even though the subsidy per kWh is even smaller – only two thirds of the Russian subsidy, we find that avoided subsidies could finance incentives for ACs that are 23 % more efficient than baseline models with no revenue impact for the government (see Figure 8). For TVs, nearly a third of the incremental manufacturing cost of models that are 32 % more efficient than baseline could be supported through avoided subsidies (see Figure 9). The savings potential for ACs is due to a very high baseline energy use, 4,695 kWh per year, and 0 % rate of sales tax on electricity. Although each unit saved offers little in the way of avoided subsidies, each percentage improvement in efficiency provides enough electricity savings to fund a significant incentive compared to incremental manufacturing costs. Furthermore, the government loses no income from reduced consumption since there is no tax on electricity.

Discussion

The LEERA model can support financial incentive program implementation in a number of ways. It can show how much, if any, energy savings can be achieved through financing incentives with avoided subsidies at no net cash flow impact to the government (or even with a net cash flow increase). In turn, this information can help inform incentive levels and incentive program design – i.e. what are the costs and benefits of directing an incentive upstream to manufacturers vs., say, delivering

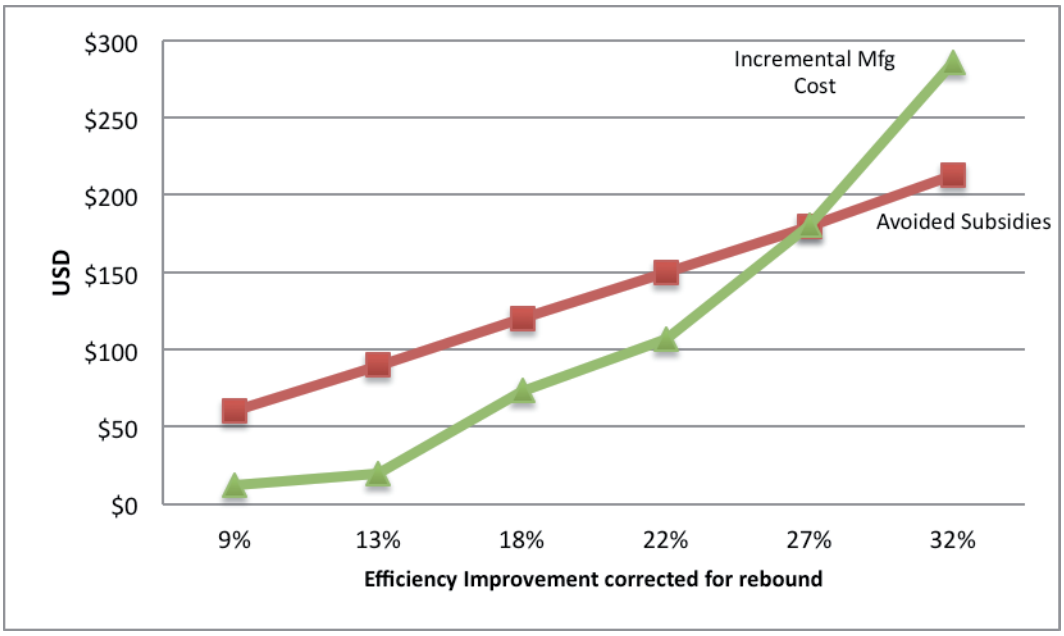

Figure 3. Mexican government avoided subsidies and incremental manufacturing costs for refrigerators.

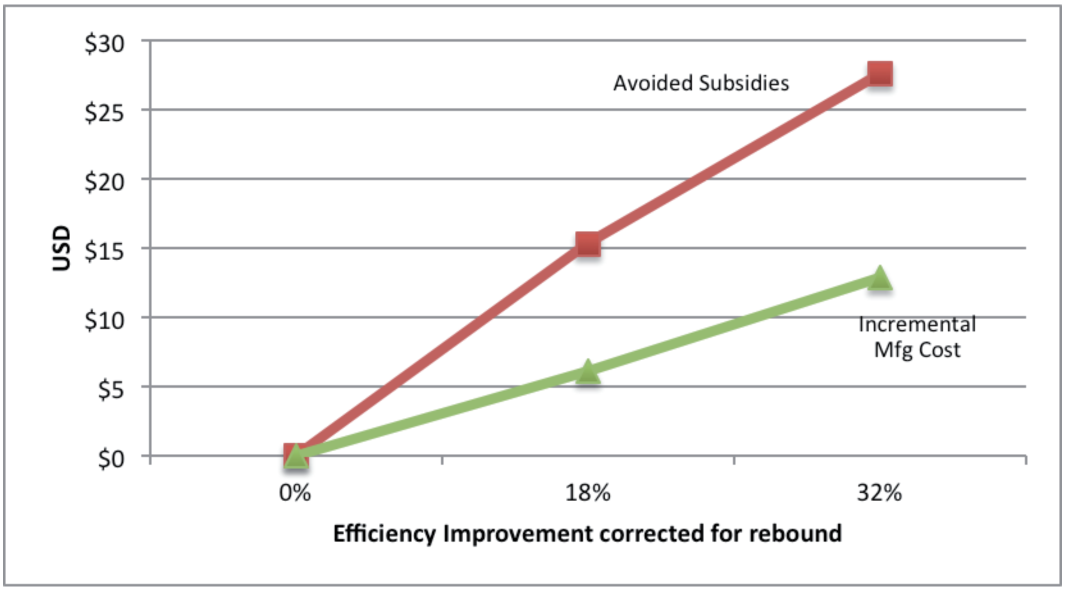

Figure 4. Mexican government avoided subsidies and incremental manufacturing costs for TVs.

it downstream to consumers (e.g. how much of the incremental manufacturing cost could be covered by avoided subsidies vs. how much of the installed cost to a customer could be covered). We can also extend LEERA to quantify the additional benefits of energy efficiency to the government from avoided additions to generation capacity and reduced pollution from the energy system. Importantly, we can calculate the same benefits of energy efficiency from a utility perspective in countries where they are not fully government owned.

LEERA could also be used to support standards and labelling programs. For example, together with Lawrence Berkeley National Laboratory's Policy Analysis Modelling System (PAMS) model, LEERA could be used to compare subsidy savings to consumer cost effective price levels for different appliances. This could show how financial incentives might be used to push minimum energy performance standards (MEPS) beyond levels that are cost effective for consumers (or support proposed levels that would push appliance prices beyond the consumer cost effective level). Where standards are in place, LEERA can be used to compare MEPS with efficiency levels that could be obtained with no net cash flow impact.

Finally, this model allows policymakers to compare and contrast the savings, both energy and financial, and the drivers of those savings, for different end uses. In countries that

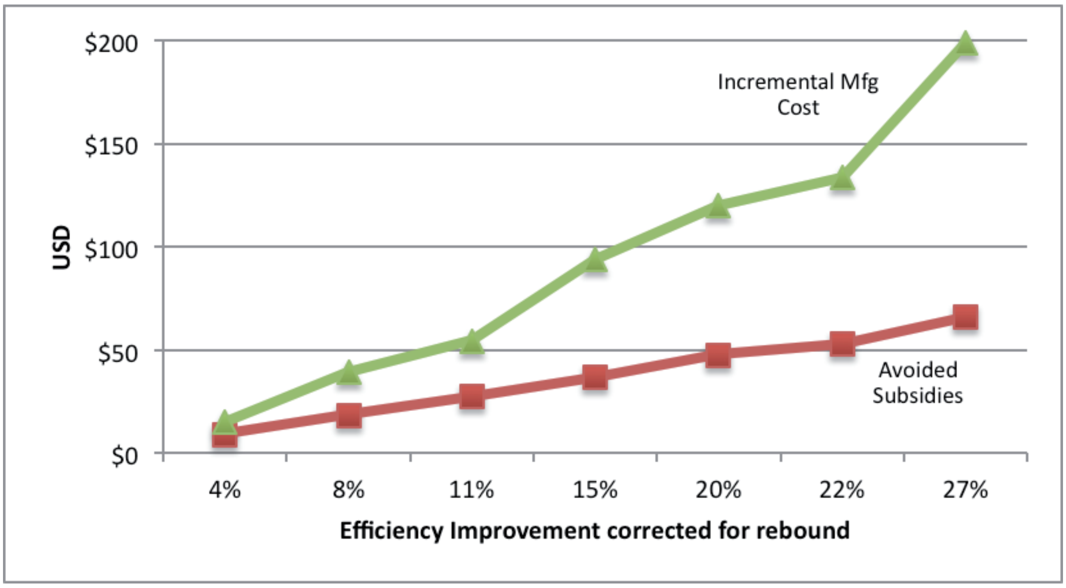

Figure 5. Mexican government avoided subsidies and incremental manufacturing costs for ACs.

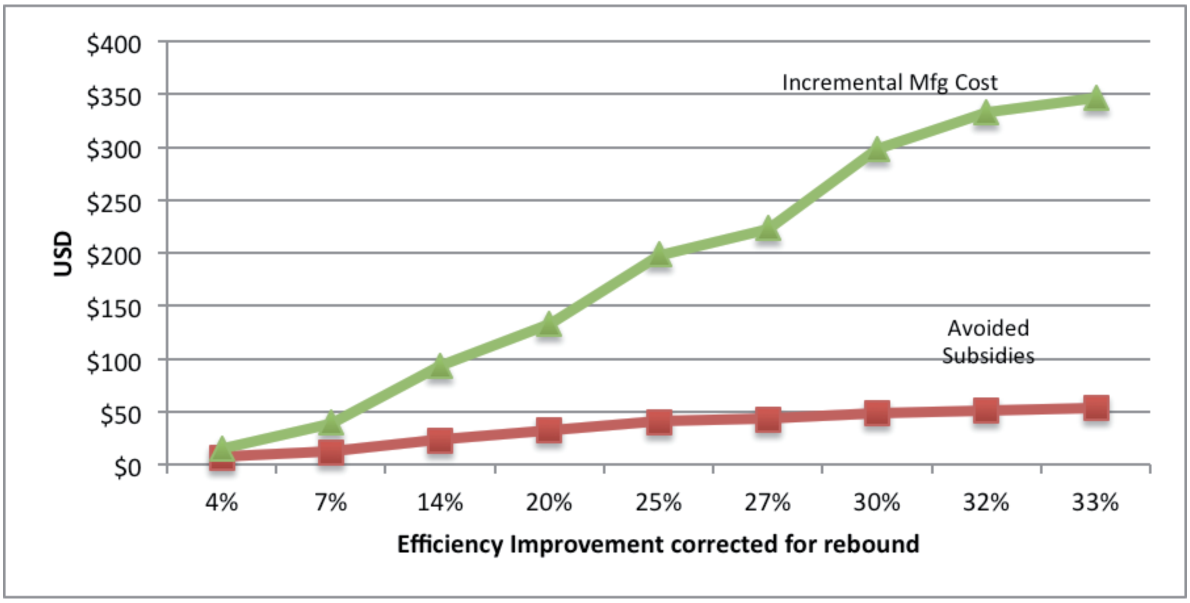

Figure 6. Russia – avoided subsidies and incremental manufacturing costs for ACs.

subsidize residential electricity – those contemplating implementation of financial incentive programs as well as those with programs in place – LEERA can be used to help policymakers implement and improve financial incentive programs. We plan several improvements to LEERA: developing the ability to analyse the impacts and implications of peak consumption and cross subsidization; using LEERA with other LBNL models, for example with PAMS to allow comparisons to consumer cost effectiveness and other cost benchmarks; and with LBNL's Bottom Up Energy Analysis System (BUENAS) to estimate macro impacts of using avoided subsidies to finance incentives.

Conclusion

Many countries around the world, including a number of emerging economies, subsidize electricity consumption, which promotes increased and inefficient energy consumption. Countries that subsidize electricity often find it politically difficult to lower or eliminate subsidies, and are also unable to strengthen MEPS for economic and political reasons. Properly designed energy efficiency incentive programs can slow the growth of energy consumption – and therefore reduce government expenditures on subsidies – without requiring either a reduction in subsidy levels or an increase in MEPS. We are therefore building the LEERA model to assist

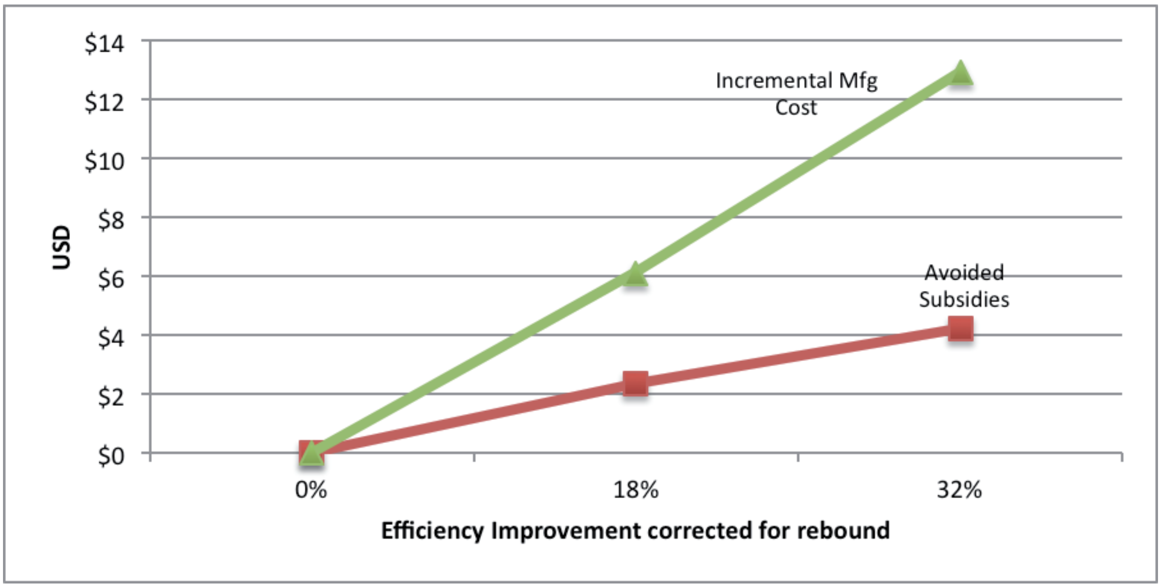

Figure 7. Russia – avoided subsidies and incremental manufacturing costs for TVs.

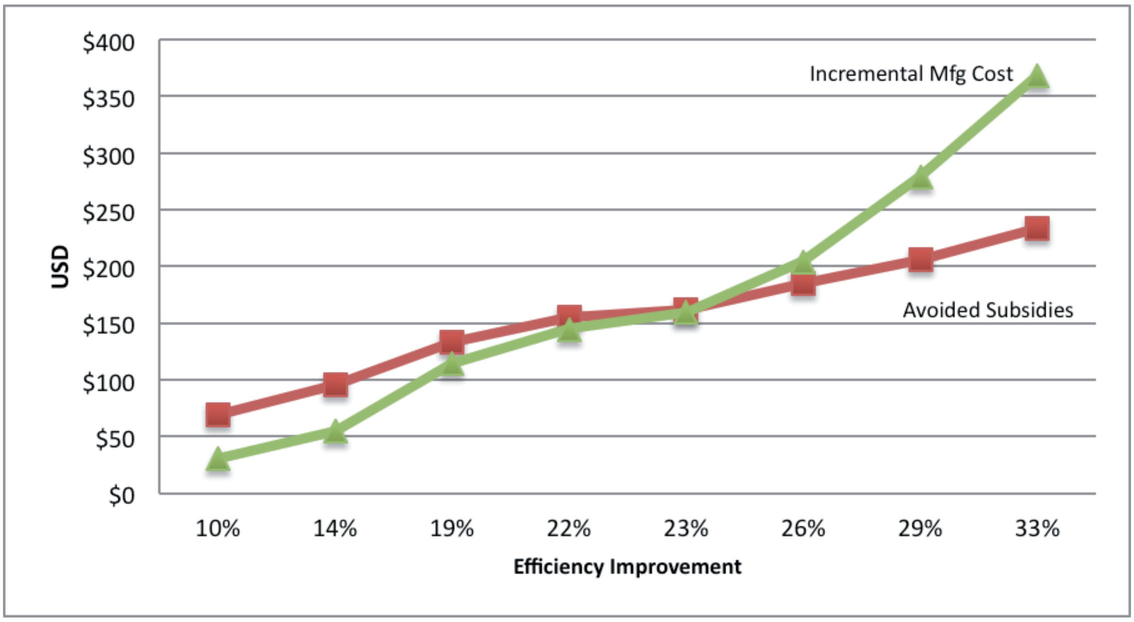

Figure 8. UAE – avoided subsidies and incremental manufacturing costs for ACs.

governments and others in designing financial incentive programs – e.g. informing incentive levels, providing input on incentive structure and giving guidance on which appliances may be most cost effective to incentivize given the avoided subsidies – under such regimes.

We find the greatest market transformation potential from incentive programs in Mexico and the United Arab Emirates (UAE). In Mexico, our initial findings show that monetary savings from avoided subsidies can finance incentives that cover the entire incremental manufacturing cost of refrigerators that are 27 % more efficient than baseline models. In the case of light emitting diode-liquid crystal display televisions (LED-LCD TVs), the full incremental cost of models that are 32 % more efficient than baseline LED-LCD TVs can be financed with just 50 % of the savings from avoided subsidies. For room air conditioners (ACs), avoided subsidies could finance an incentive that would cover about two thirds of the incremental manufacturing cost of a 4 % efficiency improvement. In the UAE, avoided subsidies can finance a 23 % improvement in room ACs and cover a third of the incremental cost of a 32 % improvement in LED-LCD TVs. In Russia, due to lower subsidy levels, we find that avoided subsidies can assist but not be able to cover the full incremental cost of more efficient models of room ACs or TVs.

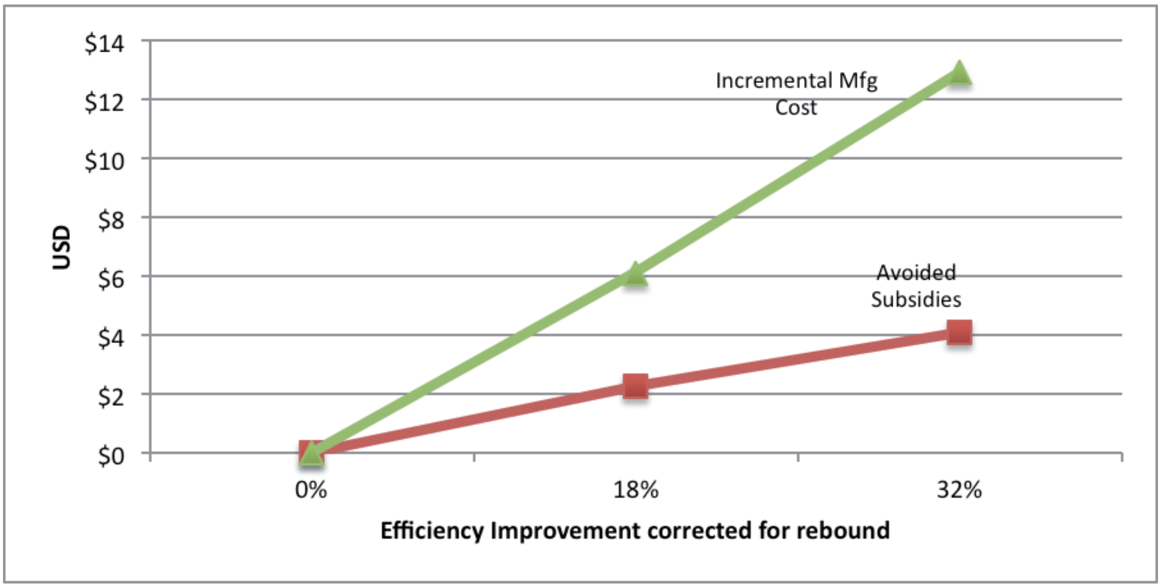

Figure 9. UAE – avoided subsidies and incremental manufacturing costs for TVs.

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Glossary

AC	Air conditioner
BUENAS	Bottom Up Energy Analysis System
CFE	Federal Electricity Commission (Mexico)
EE	Energy Efficiency
GHGs	Greenhouse gas emissions
IBT	Increasing Block Tariff
kWh	kilowatt hours
kWh_e	kilowatt hours of electricity
LED-LCD TVs	Light Emitting Diode-Liquid Crystal Display Televisions
LBNL	Lawrence Berkeley National Laboratory
LEERA	LBNL Energy Efficiency Revenue Analysis model
LRMC	Long Run Marginal Cost
MEPS	Minimum energy performance standards
NG	Natural Gas
O&M	Operation and maintenance
PAMS	Policy Analysis Modelling System
SEAD	Super-efficient Equipment and Appliance Deployment initiative
TV	Television
UAE	United Arab Emirates
UEC	Unit energy consumption
VAT	Value Added Tax

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