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AVOIDED ELECTRICITY SUBSIDY PAYMENTS CAN FINANCE SUBSTANTIAL APPLIANCE EFFICIENCY INCENTIVE PROGRAMS: CASE STUDY OF MEXICO

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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 efficiency improvements that can be achieved in Mexico by the revenue neutral financing of incentive programs from avoided subsidy payments. 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 Mexico's tariff structures and the long-run marginal cost of supply to calculate the marginal savings for the government from appliance efficiency. We find that avoided subsidy payments alone can finance incentive programs that cover the full incremental cost of refrigerators that are 27% more efficient and TVs that are 32% more efficient than baseline models. We find less substantial market transformation potential for room ACs primarily because AC energy savings occur at less subsidized tariffs.

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 (Morgan 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. Further, subsidies make it harder to introduce or strengthen Minimum Energy Performance Standards (MEPS) for end-uses, as greater stringency is frequently not cost-effective from the consumer perspective (Letschert et al. 2011).

We, at Lawrence Berkeley National Laboratory (LBNL), are developing the LBNL Energy Efficiency Revenue Analysis (LEERA) model to design incentive programs that meaningfully improve appliance efficiency with financing from efficiency-induced savings in subsidy payments. LEERA 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 subsidy payments. The model can support several types of incentive program design.

In this paper, we analyze refrigerators, light emitting diode-liquid crystal display televisions (LED-LCD TVs) and room air conditioners (ACs) for residential use in Mexico, a sector that receives generous net taxpayer funded electricity subsidies (Komives et al. 2009). Our goal is to help Mexico understand, precisely, the extent to which it can transform the markets for these major end-use appliances if revenue from avoided subsidy payments was used to finance incentive programs. The paper is structured as follows. We first present an overview of energy subsidies and the theory of their impact on demand for energy efficiency. Next, we introduce and explain the LEERA model. This is followed by a presentation and discussion of results for Mexico and their implication for appliance market transformation and financing for incentive programs. Finally, we discuss broader applications of LEERA.

OVERVIEW OF ENERGY SUBSIDIES

Studies of global energy subsidies find that they are substantial and most are in non-OECD countries (Morgan 2008). Globally approximately $420 billion is spent on energy subsidies, making it one of the most subsidized sectors (Badcock and Lenzen 2010; Lewis 2012). Although most of these subsidies are for petroleum, substantial 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 (Morgan 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 paucity of data on energy subsidy programs at the country level. Studies have lamented the lack of a global or even OECD-wide inventory of programs (Badcock and Lenzen 2010; Gadgil and Anjali Sastry 1994). 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 and Lenzen 2010). Even the European Union does not use a uniform evaluation method (Bacon et al. 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 or delayed system maintenance (Komives et al. 2005). Further, many countries, like India, have unplanned subsidies where government-owned utilities frequently recoup their losses from the general fund on an ad-hoc basis (Abhyankar and Phadke 2012).

Improving Energy Efficiency in Subsidized Regimes

From an energy policy perspective, subsidies cause overconsumption of energy and lead to inefficient allocation of societal resources (2010). From an energy efficiency perspective, end-use electricity subsidies typically make efficiency programs more challenging to implement (Bouton et al. 2010). Even in the absence of subsidies, society underinvests in energy efficiency due to market failures like first cost barriers, consumer information asymmetry and environmental externalities caused by energy production and use (Jaffe and Stavins 1994). Figure 1 shows the deadweight loss resulting from these market failures if electricity is priced at the privately optimal marginal cost (P_{PRIV}) instead of the socially optimal marginal cost (P_{SOC}).

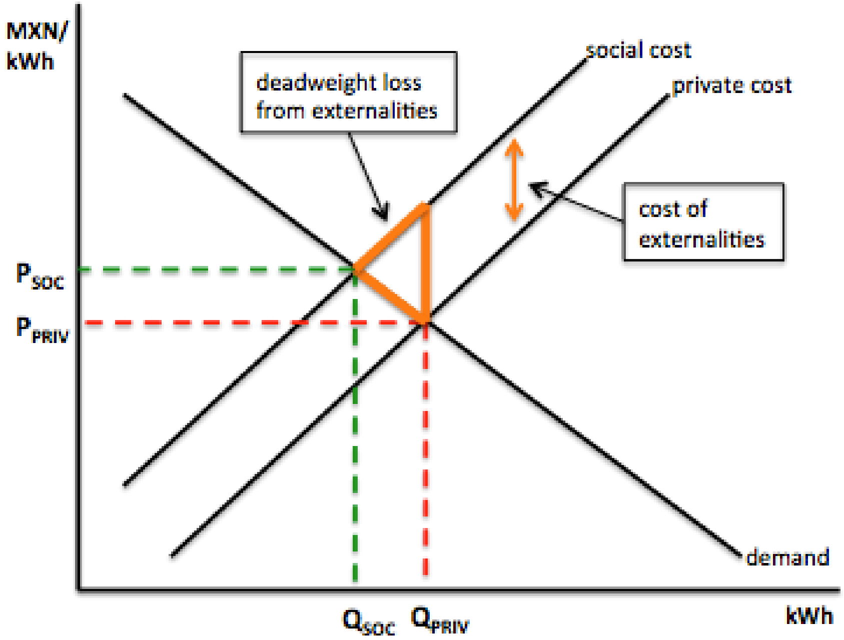

Figure 1: The economic cost (deadweight loss) of externalities in the electricity sector without subsidized tariffs. [MXN – Mexican Pesos, P_{SOC} – Socially optimal price, P_{PRIV} – Privately optimal price, Q_{SOC} – Socially demanded quantity, Q_{PRIV} – Privately demanded quantity, kWh – kilowatt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

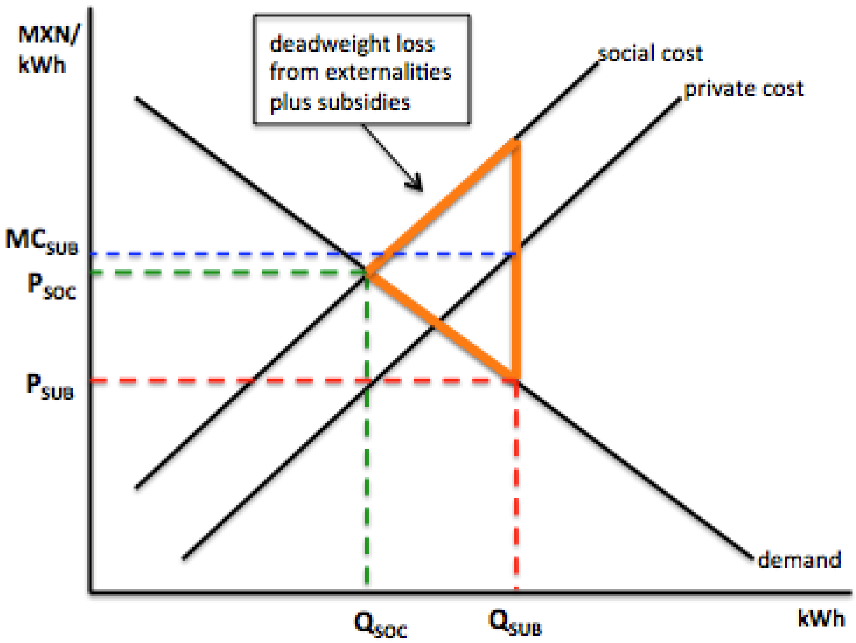

Figure 2: The added deadweight loss due to subsidizing electricity rates. [P_{SUB} – Subsidized electricity price, MC_{SUB} – Marginal Cost under subsidized pricing and demand, Q_{SUB} – Quantity demanded under subsidized pricing].

Electricity subsidies further increase this deadweight loss. Figure 2 shows a market in which the price to consumers (P_{SUB}) for electricity is reduced below P_{PRIV} due to subsidies. Electricity becomes even cheaper compared to its socially optimal cost, resulting in even greater demand (Q_{SUB}). However, subsidies make energy efficiency more valuable to the government, which can decrease its subsidy burden by reducing end-use energy consumption. From a theoretical economic perspective, a rollback of subsidies would be a first choice energy policy (Komives et al. 2009). However, as we discuss earlier, such policies have proven to be politically challenging (Bacon et al. 2010). 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. In the next section, we describe how the LEERA model supports the design of such incentive programs and identifies financing for them.

THE LBNL ENERGY EFFICIENCY REVENUE ANALYSIS (LEERA) MODEL

The objective of the LEERA model is to calculate the savings from avoided subsidy payments achieved by energy efficiency and to use these to finance incentives for 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 the deployment of 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 only calculates subsidies that cover the difference between retail price recovery and long run marginal cost of generation because these are likely to be available for financing incentive programs. LEERA does not include social subsidies in the avoided subsidy equation because these are not real streams of revenue unless policies to reduce externalities already exist. Hence, it can be argued that LEERA underestimates the overall subsidy burden of the government, which will most likely the bear the long run costs of environmental clean up.

First the amount of money the government avoids spending for each unit of electricity saved is calculated. This is done by calculating the difference between the tariff at which savings are realized and the supply cost. 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 energy savings occur

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

Next, LEERA multiplies this avoided subsidy per unit by the annual electricity savings from deploying more efficient appliances. The model then takes the present value of these annual savings over the life of the appliance to get the full value to the government of avoided subsidy payments at each level of improved efficiency. These subsidy savings are then compared to the incremental manufacturing costs of more efficient appliance models, which are derived in the SEAD techno-economic analysis.

We also correct for rebound using estimates from literature (Davis et al. 2012; Maxwell et al. 2011; Nadel 2012). We apply an 11% rebound for refrigerators and TVs and a 24% rebound for room ACs. These values include direct and indirect rebound and substantially reduce our estimated energy savings. We choose to show a conservative savings estimate for each appliance because we do not include program administration costs in this paper.

For example, a market average refrigerator in Mexico uses 480 kWh per year. Thus switching to a 25% more efficient model would yield energy savings of 106 kWh per year.[1] We calculate the subsidy for refrigerator use by a representative household to be $0.14 per kWh, which translates to saved subsidy payments of $15 per year. The net present value of this revenue stream 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. Therefore, a government incentive could cover the entire cost of making a more efficient machine and still leave $43 in savings from avoided subsidies.

In this paper, we present results for refrigerators, room air conditioners (split style) and LED LCD televisions. We plan to extend the analysis to other appliances and countries as cost curves for each are completed by the SEAD techno-economic analysis. Baseline unit energy consumption (UEC) and incremental manufacturing costs for room ACs and TVs are from the

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[1] 25% corrected for an 11% rebound effect results in a 22% actual savings. 480 kWh * 22% = 105.6 kWh saved per year.

SEAD techno-economic analysis. For refrigerators we use data from LBNL's analysis in support of harmonization of Mexican and US refrigerator standards (Letschert et al. 2011).

Applying LEERA to Mexico

For this paper, we apply LEERA to the Mexican residential electricity market. The state-owned *Comisión Federal de Electricidad (CFE)* provides all residential electricity in Mexico. The sector has a complex Increasing Block Tariff (IBT) system in which tariff zones are defined by average regional temperature. For electricity generation, fuel oil makes up 18% of the electricity generation mix and usually operates on the margin (2012a). In this section we describe how LEERA calculates the long run marginal cost (LRMC) of generation and the marginal tariff at which savings occur for each appliance.

Televisions and refrigerators have high residential penetration rates of 93% and 83% respectively (Davis et al. 2012). Hence, the LEERA model calculates marginal tariffs for these two appliances by taking the average, seasonally adjusted customer electricity consumption for each residential tariff zone and applying the tariff rate at that usage level. These marginal tariffs for each zone are then weighted by the zone's proportion of all customers and summed to get a nationally representative marginal tariff.

LEERA calculates the marginal tariff for rooms ACs differently because they are only present in wealthier households (penetration rate of 39%) and their use is greater in the hotter tariff zones. From SEAD and World Bank data, LEERA calculates the minimum energy consumption of an AC owning household (Komives et al. 2009; Shah). The model then uses this consumption level to determine which income deciles in each tariff zone have ACs. It then compares this average usage in each decile to the tariff schedule to find the marginal tariff for that decile. Income decile and tariff zone IBT rates are then averaged in the same way as for the other two appliances.

Given fuel oil's significant share of the generation mix and a 64% capacity factor, we estimate that 90% of marginal kWh are generated from this source (IEA 2012b). The remaining 10% of the savings occur when natural gas is on the margin. To calculate the fuel oil generation, LEERA uses its opportunity cost: the international market price. We assume that fuel oil savings from avoided power generation would be sold on the market. We use the average between 2012-2022 from the Energy Information Administration's (EIA) baseline forecast oil price ($140 per barrel) to calculate the long-run variable cost of generation (2012b). Based on power plant efficiencies, this translates to variable generation cost of approximately US$0.19 per kWh (Honorio 2003). We discount this generation cost for transmission and distribution losses, approximately 17% in Mexico (2012c), the LRMC of end-use delivered fuel oil electricity. The same procedure is used to calculate the LRMC of natural gas generation where we use the Henry Hub price for fuel cost. Finally, we do not include any fixed costs in our LRMC calculation. If we included some fixed costs, the value of efficiency would be even higher.

RESULTS

We find that savings from avoided subsidy payments 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, revenue from avoided subsidies could finance an incentive that would cover about two thirds of the incremental manufacturing cost of a 4% efficiency improvement (see Figures 3, 4 and 5 below).

Potential savings for Mexican refrigerators result from three main sources: the large subsidies on each unit of refrigerator energy consumption, a relatively high annual unit energy consumption (UEC) and the long life of the appliance. TV savings potentials also benefit from high marginal subsidies. Low incremental manufacturing costs and large subsidy savings for more efficient TVs further boost their potential. The smaller potential for ACs is due to lower baseline annual energy consumption and shorter life compared to refrigerators but primarily due to the lower marginal subsidies for households that own ACs. We discuss the results for each appliance in more detail below.

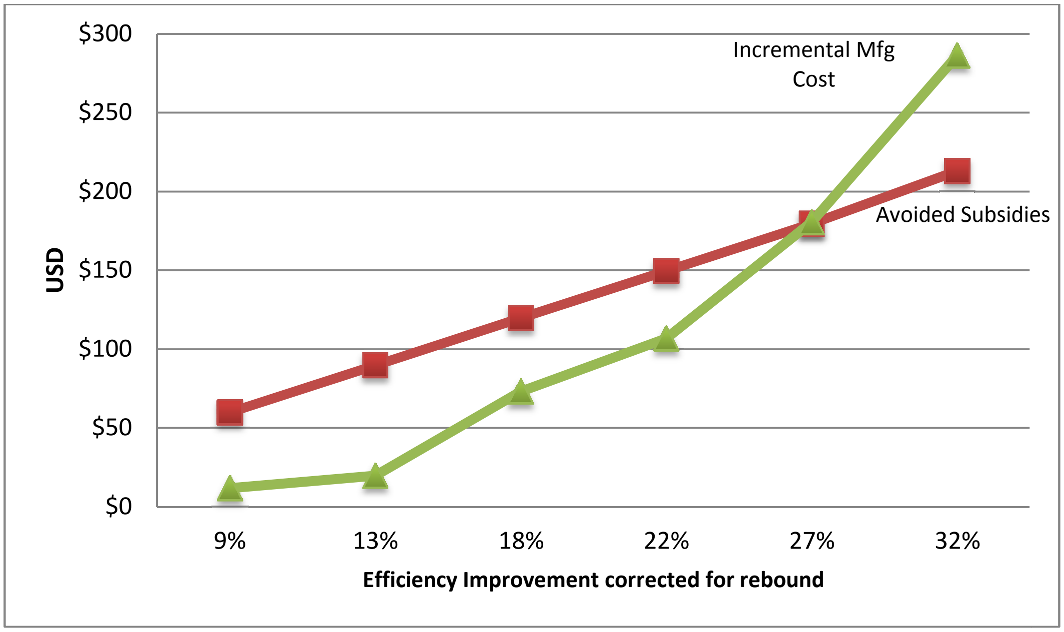

Figure 3: Mexican government avoided subsidies and incremental manufacturing costs for refrigerators.

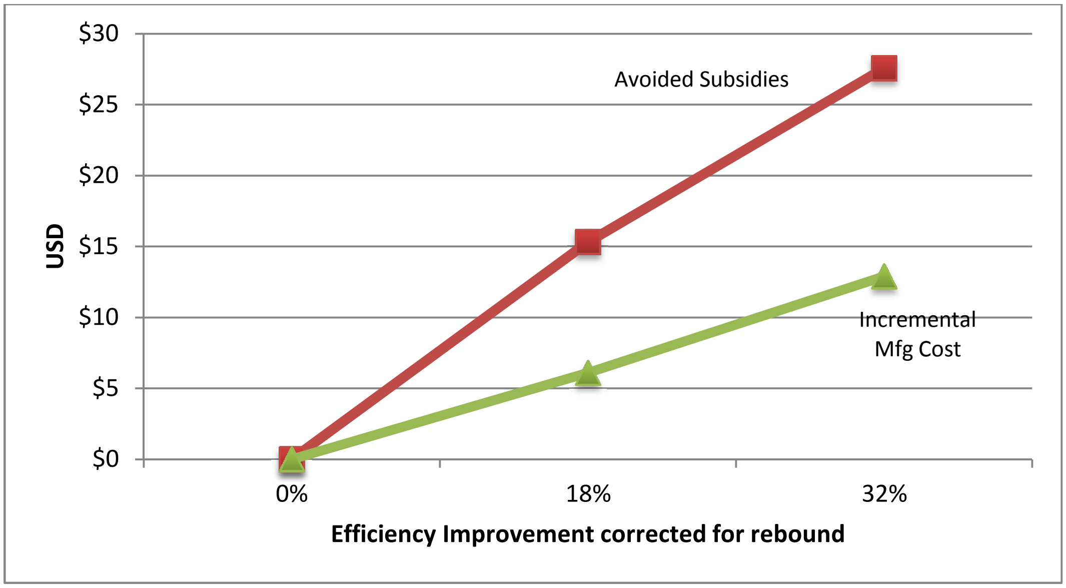

Figure 4: Mexican government avoided subsidies and incremental manufacturing costs for TVs.

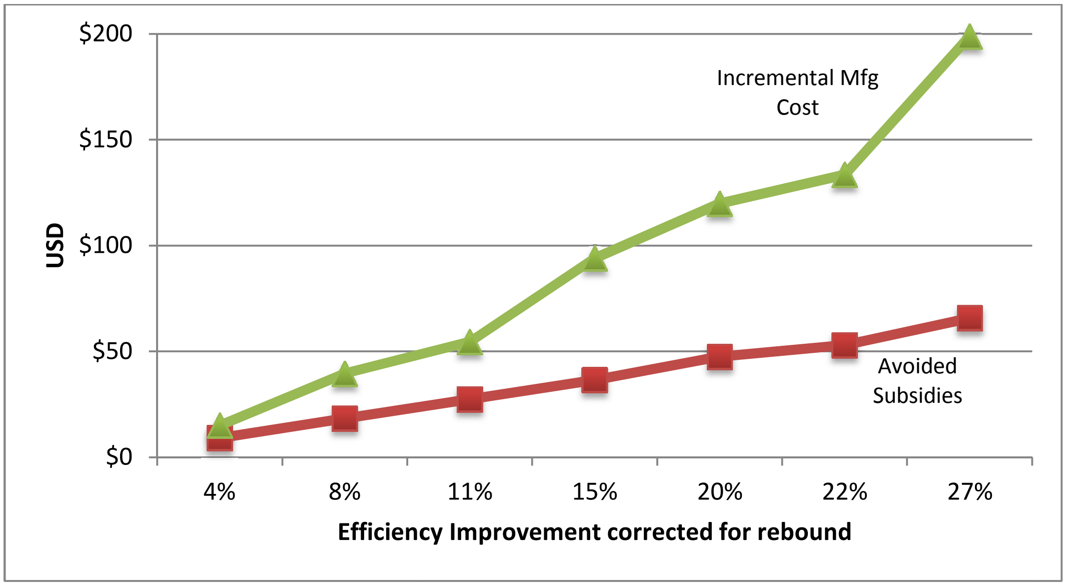

Figure 5: Mexican government avoided subsidies and incremental manufacturing costs for ACs.

Refrigerators

We find such dramatic savings opportunities in refrigerators for the following reasons. First, the baseline energy consumption for refrigerators is relatively high in nominal terms. This is because it is a passive appliance with a compressor that turns on continually over the course of the day. Thus each percentage increase in efficiency translates to substantial annual energy savings. Second, refrigerators have long lives – 15 years, the longest of any of the appliances analyzed here – so the large annual savings continue to add up over a long time period, all of which offset very high marginal subsidies. These findings suggest that using avoided subsidies to finance incentives for very high efficiency models would not only have no net revenue impact, it would also save a large amount of energy per incentivized unit.

LED-LCD Televisions

Currently, LED-LCD TVs have low market penetration in Mexico but are expected to constitute nearly 95% of the stock within a decade (Park 2011). Almost all new purchases today are LED-LCD models (Park 2011). Therefore, in our analysis, we choose an already efficient LED-LCD TV as our baseline model. We still find substantial potential for TVs because the incremental costs of more efficient LED-LCD models are quite low compared to the subsidy savings that they yield (Park 2011). Hence, even though annual TV energy use is much lower than refrigerators, a TV incentive program is very attractive since support for even the highest efficiency improvements result in a net positive cash flow to the government.

Room Air Conditioners

Room ACs differ from TVs and refrigerators in two ways that reduce their potential from the perspective of this analysis. First, improved AC efficiency yields only half the savings from avoided subsidy payments than for TVs and refrigerators. This is because AC savings occur in wealthier households that pay less subsidized tariff rates. Second, ACs have a rebound effect that is more than double that of TVs and refrigerators (Davis et al. 2012; Nadel 2012). Therefore, even with a high baseline consumption and a relatively long life (582 kWh per year, 12 years), savings from avoided subsidy payments are not sufficient to cover the entire incremental manufacturing cost of more efficient room AC models. Hence additional financing is necessary for a room AC incentive program in Mexico, although avoided subsidy payments can contribute a substantial share.

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 a zero or positive net cash flow impact to the government. In turn, this information can help inform incentive levels and incentive program design. For example it can compare the costs and benefits of directing an incentive upstream to manufacturers to delivering it downstream to consumers. 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 calculate national cost effectiveness of proposed strengthening of standards. Where standards are in place, LEERA can be used to compare MEPS with higher 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 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 analyze the impacts and implications of peak consumption and cross subsidization, and; linking LEERA 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 frequently unable to strengthen MEPS for economic and political reasons. In this environment, governments have an opportunity to use efficiency-induced savings in subsidy payments to finance appliance incentive programs that improve end-use energy efficiency. The LEERA model supports the design of such incentive programs down to the level of specific appliance models.

In the case of Mexico we find that savings from avoided subsidy payments 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, revenue from avoided subsidies could finance an incentive that would cover about two thirds of the incremental manufacturing cost of a 4% efficiency improvement.

ACKNOWLEDGEMENTS

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Annex

We present examples of examples of tariff schedules for two tariff zones here.

Examples of Tariff Schedules for Tariff Zones 1 and 1F. Source is CFE website, “Tarifas para el suminstro y venta de energía elétrica (2010-2011).”

Table A1: Tariff schedule for Tariff Zone 1 for July and December 2011.

Tariff Schedule for **Zone 1** (37% of sales by MWh, 55% of customers, mild climate)			
July	MXN	USD	
2.1 Charges for consumption up to 140 kWh per month			
Consumption	MXN	USD	
Basic	0.72	0.06	For each of the first 75 kWh
Intermediate	0.87	0.07	For each additional kWh up to 140
2.2 Charges for consumption above 140 kWh per month			
Basic	0.72	0.06	For each of the first 75 kWh
Intermediate	1.21	0.10	For the following 50 kWh
Excessive	2.55	0.20	For each additional kWh
December	MXN	USD	
2.1 Charges for consumption up to 140 kWh per month			
Basic	0.73	0.06	For each of the first 75 kWh
Intermediate	0.89	0.07	For each additional kWh up to 140
2.2			
Basic	0.73	0.06	For each of the first 75 kWh

Intermediate	1.23	0.10	For the following 50 kWh
Excessive	2.59	0.21	For each additional kWh

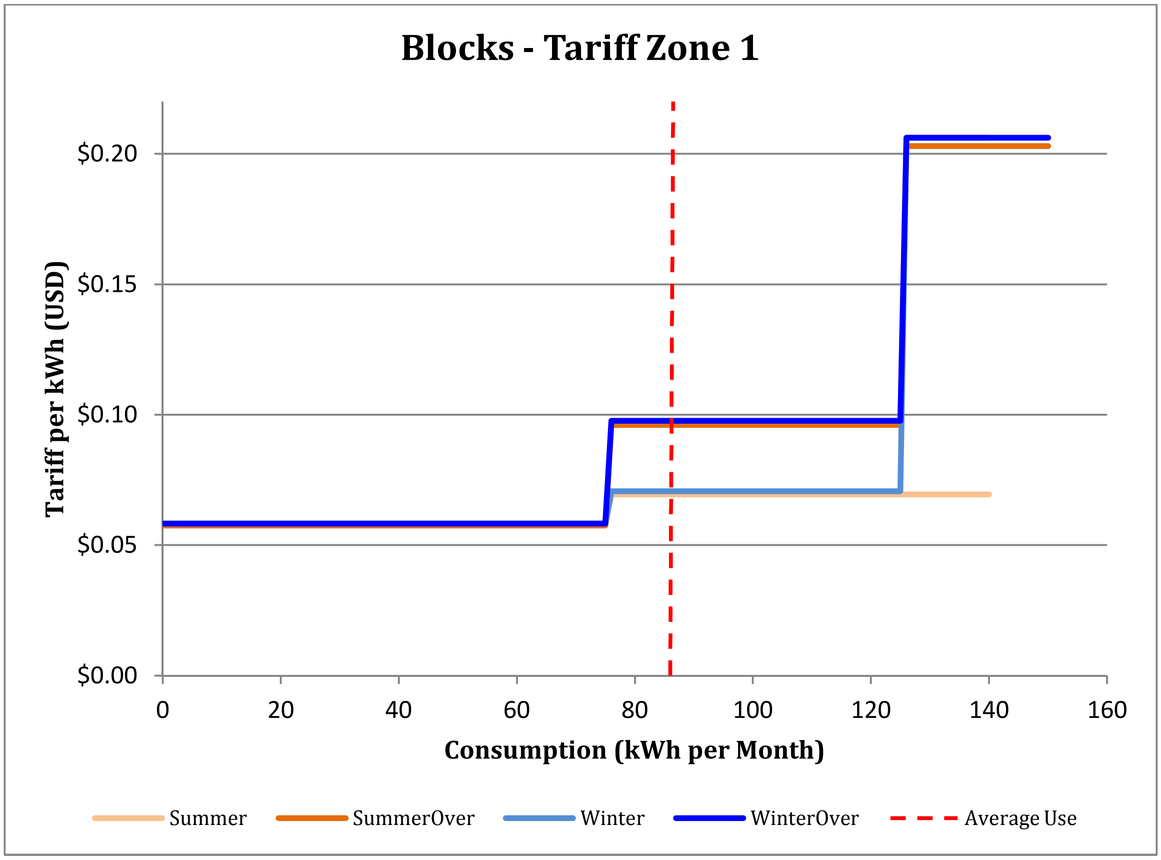

Figure A1: Graph of Increasing Block Tariffs for Tariff Zone 1.

Table A2: Tariff schedule for Tariff Zone 1F for July and December 2011.

Tariff Schedule for **Zone 1F** (11% of sales by MWh, 3% of customers, hottest zone)			
July	MXN	USD	
2.1.1 Charges for consumption up to 1200 kWh per month			
Consumption	MXN	USD	
Basic	0.53	0.04	For each of the first 300 kWh
Intermediate	0.67	0.05	For each additional kWh up to 1200

2.1.2 Charges for consumption above 1200 kWh per month			
Basic	0.53	0.04	For each of the first 300 kWh
Intermediate low	0.67	0.05	For the following 900 kWh
Intermediate high	1.61	0.13	For the following 1300 kWh
Excessive	2.55	0.20	For each additional kWh
December	MXN	USD	
2.1.1 Charges for consumption up to 250 kWh per month			
Basic	0.73	0.06	For each of the first 75 kWh
Intermediate	0.89	0.07	For the following 125 kWh
Excessive	2.59	0.21	For each additional kWh up to 140
2.1.2 Charges for consumption greater than 250 kWh per month			
Basic	0.73	0.06	For each of the first 75 kWh
Intermediate	1.23	0.10	For the following 125 kWh
Excessive	2.59	0.21	For each additional kWh

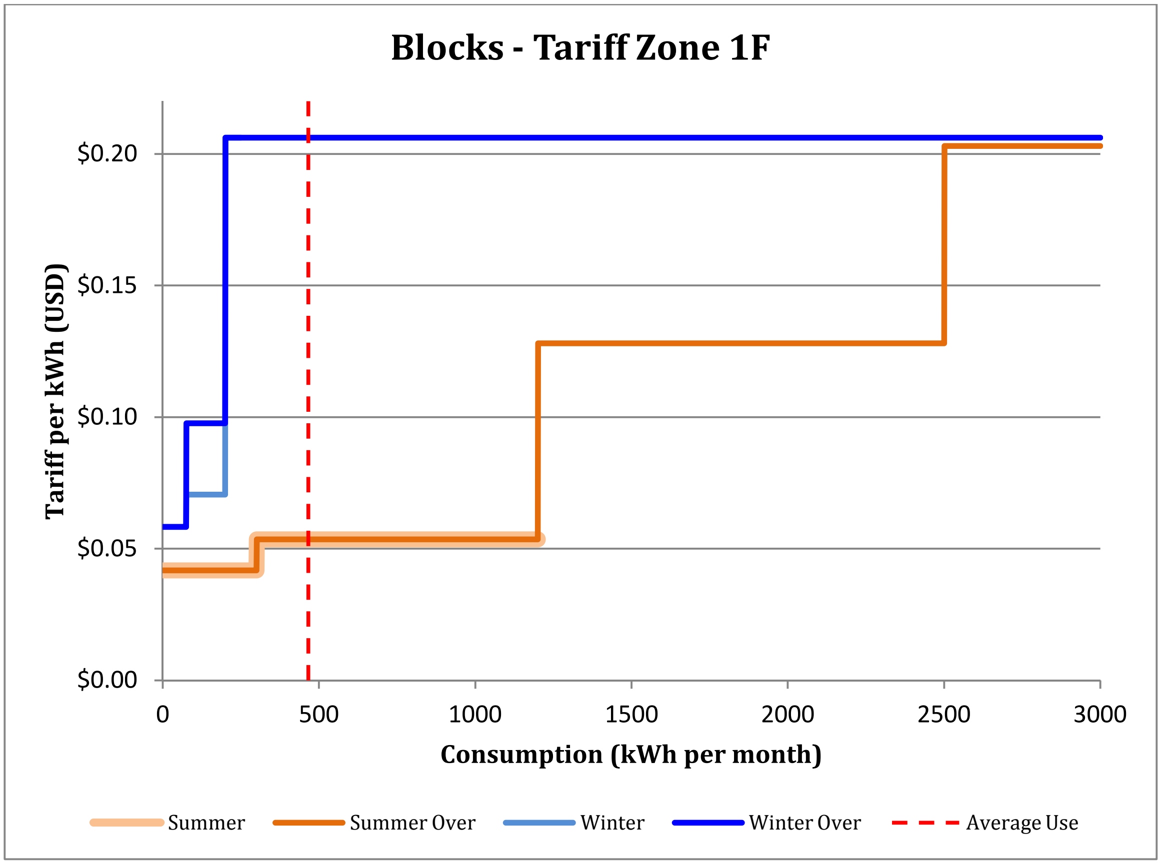

Figure A2: Graph of Increasing Block Tariffs for Tariff Zone 1F.