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Cooling the Growth of Air Conditioners Energy Consumption

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Cooling the Growth of Air Conditioners Energy Consumption

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Abstract

One of the largest drivers of growing global energy demand is the increasing market penetration of air conditioners (ACs). The resulting energy consumption can be mitigated by two main policy interventions: regulatory measures, such as minimum energy performance standard (MEPS) or labeling programs, and voluntary measures, such as financial incentives programs. Financial incentives, also known as economic instruments, leverage private investments to pull higher efficiency technologies into the market. This paper focuses on this second policy option. Using detailed case studies of AC energy efficiency incentive programs, the paper explores their global experience, shows their significance and diversity, describes their program designs, and shares lessons learned from their implementation. The paper also describes how incentive programs can be designed to address additional pressing concerns of growing AC use such as the power supply reliability due to increase peak demand and global warming potential (GWP) of refrigerants used in ACs.

For policymakers and program administrators interested in addressing AC energy efficiency and willing to implement AC schemes, the paper provides examples of past and present programs and highlights concerns that need to be considered when making decisions on program design and implementation. After an overview of AC markets highlighting their growth, their savings potential and the typical barriers to the penetration of more efficient models, six AC incentive programs are selected and examined in depth based on evaluation reports and/or interviews with program administrators. Finally, we outline program design features that effectively a) increase penetration of energy efficient ACs, b) increase utility and customer participation in demand response (DR) programs targeted at reducing peak-load impacts on the grid and c) phase out the use of high-GWP refrigerants in ACs. We find that incentive programs are particularly effective when they target emerging technologies that still have a low market penetration.

Introduction

Increased AC penetration presents significant challenges and opportunities for policy makers desiring to support sustainable development. As emerging economies located in hot climates become wealthier, demand for air conditioning is expected to grow rapidly. Over the decade 2010-2020, the incremental electricity demand in emerging economies from residential ACs alone (600 TWh/yr) is estimated to consume more than half of the total solar and wind generation projected to be added globally over the same period (1100 TWh/yr) (Shah et al., 2013). This additional electricity demand will put tremendous pressure on the power sector of these countries by contributing significantly to increasing peak electricity demand. AC electricity demand can contribute to gaps in

power availability and undermine system reliability. In some countries and regions, incentive programs are a more cost-effective means to bridge the electricity gap than adding supply.

In addition, growth of ACs poses environmental issues due to the GHG emissions emitted during the production of electricity needed to power them, and due to the refrigerants that are used in their system.

For years, the most common refrigerant used in ACs was R-22 (HCFC 22). Today, production of systems using R-22 refrigerant have been phased out in developed countries under the Montreal protocol agreement but complete phase out in developing countries will only happen by 2020. R-22 is an ozone depleting substance (ODS) and also has a high global warming potential (GWP)¹ of 1,760. Its most common replacement is R410A (HFC-410A) which is considered ozone-friendly but still has a GWP of 1,924 (IPCC, 2014). ACs also make limited use of R32 (GWP= 675). These refrigerants have direct GHG impacts both from leakage during the life of an AC and when they are lost to the atmosphere at the end of the unit's life.

Opportunities for deep, cost-effective savings from AC efficiency improvements remain unexploited because of a number of barriers to their uptake. New, stronger and additional policy interventions are needed to overcome these barriers and lock down energy savings for the future. Standards and labeling (S&L) programs are generally the first order of policy intervention to transform the market by raising the “floor” of efficiency. Labels provide information to consumers that allows them to make a better informed purchase decision based on the energy efficiency of appliances. They also provide the necessary information on the performance of appliance on which an incentive program can be based. Energy efficiency incentive programs, also referred to as economic instruments, can complement this market transformation by raising the “ceiling” of appliance efficiency and accelerating the penetration of highly efficient technologies (de la Rue du Can, 2014).

Although S&L programs appear to dominate the current policy framework for ACs, the need for more market action and enhanced private-sector involvement is increasingly being highlighted.

This paper addresses the following questions:

- What role can incentive programs play in accelerating transformation of the AC market?
- Can incentive programs successfully leverage private investment to pull highly efficient technologies into the market?
- What has the experience been so far with AC incentive programs?
- What program designs have addressed the market barriers that hinder investment in energy efficiency?
- Are these programs successfully addressing the overall environmental challenges posed by increasing numbers of ACs?
- Are there incentive program designs that successfully combine multiple objectives e.g. refrigerant transition and efficiency improvement, or efficiency improvement and demand response participation?

Despite current interest in market transformation programs, there are few reports on the use of incentive programs globally, and even fewer focusing specifically on appliance incentive programs. This paper aims to fill this gap. Using detailed case studies, we show the significance and diversity of AC energy-efficiency incentive programs, describe their program designs, and share lessons learned from their implementation. We also cover emerging approaches to addressing growing cooling loads, particularly demand response (DR) programs, and approaches to addressing the GWP of AC's refrigerants. This report offers multiple strategies to address the multiple challenges that rapid adoption of ACs will present globally and looks at the key factors that decision makers should weigh when considering incentive program design.

Methodology

This report considers all types of programs that provide a financial stimulus to help move the AC market toward more efficient products. Incentives under these programs can be offered to various actors in the supply chain. Typically, incentives are offered directly to customers through what are known as downstream programs. In this case, incentive programs stimulate the purchase of new efficient products and can also be designed to dispose of old, inefficient appliances. By contrast, upstream incentives target manufacturers, encouraging them to produce more efficient equipment and accelerate technology upgrades.

After a first screening based on a literature search, we organized by program type the incentive programs that we had identified. Case studies were then selected to represent a diverse set of program types and participating countries. We selected programs based on the availability of documents that described them in detail. There are few national programs in emerging economies, and, for many programs, comprehensive information is not

¹ GWP is a relative measure of how much heat a greenhouse gas traps in the atmosphere compared to the amount of heat trapped by carbon dioxide for a similar unit of mass.

available. We ultimately chose six programs to examine in depth and conducted interviews with program administrators to complement the information we had collected and to help us understand the implementation process for the programs.

Table 1 lists the types of programs considered, their general objectives, and the corresponding case studies.

Table 1. Program Types Considered and Country Case Studies Selected

	Name	Goals	Implement. Agents	Program Type and main features
China	Promoting Energy-Efficient Products for the Benefit of the People	- Economic development - Market transformation	Government	- Upstream - Label Scheme
India (Mumbai)	Reliance Infrastructure Ltd. Five-Star Split AC Pilot Program	- Energy savings - Increased public awareness	Utility	- Upstream replacement - Competitive bidding process
Mexico	National Appliance Replacement Program	- Economic development - Poverty reduction - Energy savings	World Bank and Government	- Downstream - Early replacement - On bill financing - ODS recycling
U.S. (New York)	Consolidated Edison Residential Appliance Replacement Program	- Energy savings	Utility	Downstream
Indonesia	Promoting Energy-Efficiency for Non-HCFC Refrigeration and Air Conditioning (PENHRA)	- Transition from HCFCs to non-ozone-depleting low-GWP refrigerants - Energy savings	United Nations Development Programme and Government	- Upstream - Resource mobilization with HCFC Phase-out Management Plan (HPMP)
U.S. (Indianapolis)	Indiana Power & Light CoolCents Demand Response Program	- Demand response	Utility	- Demand response

Case Studies

China

No other country has injected as large an amount of money into boosting the sale of energy-saving appliances as China. China is also the country that has experienced the fastest growth of AC penetration on a relatively small period: the number of ACs in urban homes grew from 8% in 1995 to 128% in 2012 (NBS, 2014). To face the resulting growth in energy demand, a number of incentive programs have been implemented (de la Rue du Can, 2015). Among these, the “Promotion of Energy-Efficient Products to the Benefit of the People” program was launched in June 2009. The China Promotion program had dual goals: boosting sales of home appliances to help the economy recover from the 2008 financial crisis and promoting energy-efficient products to “the benefit of the people.”

The program encouraged consumers to buy energy-efficient products by lowering the up-front price of these products to match the price gap between energy-efficient products and products that met the MEPS. The program offered the subsidy upstream, to the manufacturers. Manufacturers were paid refunds by the government on a monthly basis.

The first round of the promotion program ended on May 31, 2011; a second phase started in June 1, 2013. Subsidies for variable-speed (VS) ACs only started during the second phase and were slightly larger than for fixed-speed (FS) ACs. Some details about the program are available in Table 2.

Table 2. China Promotion Program Case Study Summary

Time Frame	Phase 1: June 2009 to May 2011, Phase 2: June 2012 to June 2013
Financial Incentive	Phase 1: From \$22 to \$127 depending on the efficiency level (tier 1 or 2), size of the equipment, and time period Phase 2: From \$29 to \$63 depending on the type (fixed- or variable speed), the efficiency level (tier 1 or 2), and the size of the equipment.
Funding	Phase 1: Total: 16 billion renminbi (RMB) (US\$2.4 billion) AC only: 11.54 billion (RMB) (US\$1.85 billion ²) over 18 months Phase 2: Total: 26.5 billion RMB (US\$4.2 billion) ACs only: Not available
Impact	Phase 1 only: - 34 million energy-efficient AC units sold - Energy savings of 80 - 100 billion kWh over the life time of the ACs - Revision of MEPS

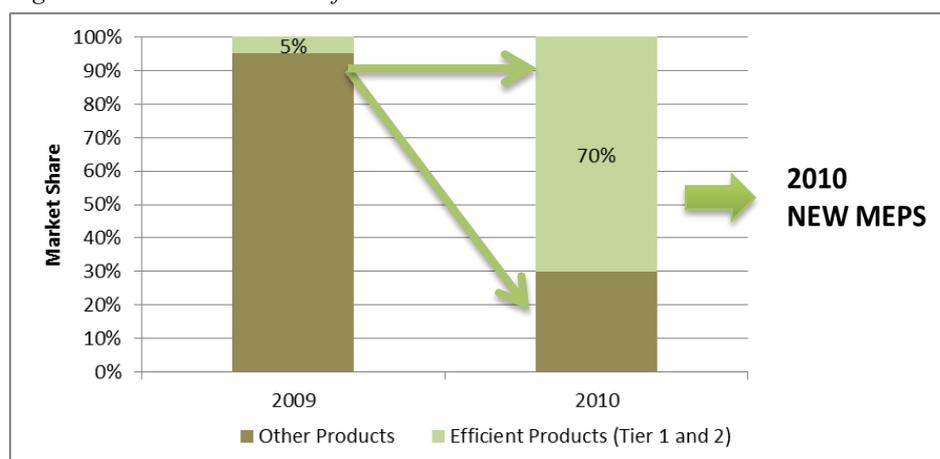
An interesting aspect of this program is that a specific label was developed for products that received the subsidy. This helps to raise consumer’s awareness of the programs and of the benefits of energy efficient products.

Over a period of 18 months, from June 2009 to December 2010, the central budget allocated RMB 11.5 B (US\$1.85 billion) to subsidize more than 34 million energy-efficient room AC units (China Energy label, nd-d). In June 2012, a new round of subsidies started – no breakdown is available for ACs only but the total budget was 26.5 billion RMB (US\$4.2 billion) for flat-panel TVs, ACs, refrigerators, washing machines, and water heaters (Zheng et al., 2013).

According to official estimates from China Energy label website, 10 TWh of first-year gross energy savings³ resulted from implementation of the program during the first 18 months (June 2009 to December 2010), representing 80 to 100 TWh of savings over the lifetime of the products (89 TWh with a 5% discount rate and a 12-year equipment lifetime). Summer peak electricity load was reduced by an estimated 30%. Based on these savings estimates and the budget of US\$1.85 billion, the cost of conserved energy for ACs was about \$0.02 per kWh.

One of the main successes of the program is the complete market transformation of FS ACs which lead to the implementation of new energy-efficiency standards. According to official reports, the program helped increase the share of tier-1 and -2 FS AC⁴ market units from 5% to 70% by the end of 2010, as shown in Figure 1 Figure 1. China Market Transformation(China Energy Label, nd-a; Li, 2014). This increase in the overall energy efficiency in ACs sold in China was codified in the 2010 MEPS revision for FS ACs, which specified a more stringent level, tier 2. During the period of the 2010 standard, the number of efficiency tiers was reduced from five to three; production of the least-efficient levels (tiers 3, 4 and 5) stopped, and level 2 became the new standard. The introduction of the new MEPS allowed completing the market transformation realized by the incentive program and ensured that its impact was permanent.

Figure 1. China Market Transformation



Source: adapted from Li, 2014

² 1 Chinese RMB equals 0.16 U.S. Dollar

³ No details are given about these savings, so we assumed that they were gross savings. As opposed to net savings which exclude free ridership, rebound effects, and other program effects but include spillover effects

⁴ Tier 1 is the most efficient, and tier 5 corresponds to the mandatory MEPS. For FS ACs, the number of tiers was reduced from 5 to 3 in 2010 during the MEPS revision; the same revision took place in 2013 for VS ACs.

No third party evaluation was found for the first phase of the program but a couple were found for the second:

- The second phase of the China program targeted ACs with an energy efficiency that already had a high penetration according to a market analysis of China's energy-efficient products (Li et al., 2013) conducted by CLASP and Top 10 China in 2012 (Top10, 2012). This tends to increase the risk of free ridership (the share of customers who benefited from the subsidy but would have purchased tier-2 products without it). In addition, the program incentivized a technology that was not the most energy-efficient on the market and that had a declining market share; the market share for VS ACs, which save much more energy than FS ACs, increased from 16% in 2009 to 44% in 2012 (Li et al., 2013). A more effective approach to transforming the market toward a higher level of efficiency would have been offering larger per-unit incentives that targeted only tier-1 and tier-2 VS ACs.
- According to official estimates, the subsidy scheme led to a significant drop in the retail price of energy-efficient ACs, of RMB 1,000 to 2,000 (US\$163 to \$326) (China Energy label, nd-d). However, Zheng et al. analysed the price of ACs in the second phase of the program and concludes that tier-1 products' prices were made artificially high so that manufacturers could profit from well-off consumers. This raises questions the effectiveness of the program's design, which was intended to pass the discount from the subsidy through to customers.
- In addition, a large number of appliance manufacturers were reported to have illegally obtained hundreds of millions of dollars in energy-saving subsidies (Global Times China, 2013). According to an audit by the National Audit Office (NAO), 348 companies reported fraudulent data that overstated their sales of energy-efficient products in order to obtain extra subsidies from the government. This fraud points to a lack of government oversight of the program and underscores the need for a robust monitoring and verification system in upstream program.

The China Promotion program demonstrates how a program can have opposite goals: increasing purchase of energy using equipment at the same time as decreasing wasteful energy consumption can be effective in transforming the market. The efficiency gains achieved during the first phase were then cemented by the implementation of new more stringent standard, resulting in additional savings. However, it is thought that more energy savings could have been achieved if the program had only subsidized the most energy-efficient technologies, ie VS ACs that had a very small market share and which are much more efficient. This case study also demonstrates the challenge of upstream programs monitoring and verification process. The government was able to minimize its subsidy by offering it upstream, but it also faced significant challenge to make sure the subsidy was passed to the consumers.

Mumbai, India

The power sector is regulated at the State level in India. The State of Maharashtra has pioneered demand-side management (DSM) activities with the active participation of power distribution companies (DISCOMs) and support from the Maharashtra Electricity Regulatory Commission (MERC). MERC was one of the first State regulatory commissions to adopt DSM regulations based on the forum of regulators guidelines published in 2010 (MERC, 2010). Reliance Infrastructure (RI) is one of the first Mumbai's DISCOMS to implement an incentive program targeting ACs.

RI provides discounted high-efficiency ACs for its commercial customers through a pilot program, the RI 5-Star Split AC scheme. Its aims are energy conservation and providing value-added services to commercial-sector RI customers (ACs account for 60% of commercial electricity consumption in RI's service territory). The program targets discounting 1,500 wall-mounted 5-star split AC units that will replace window units. Incentives are meant to close the price gap between 3- and 5-star AC models. Table 3 summarizes the features of the RI program.

Table 3 India Reliance Infrastructure Case Study Program Summary

Time Frame	February 2014 through January 2016
Financial incentive	\$67 - \$83 per unit
Funding	Approximately \$330,000
Expected Impact	1,500 wall-mounted 5-star split AC

A competitive bidding process was used to select the participating manufacturer to spur manufacturers to produce 5-star AC units at a reduced price in exchange of the exclusive right to sell a large order of ACs. RI pays the rebates to commercial consumers in addition to the discounted price that RI secured from the

manufacturer as part of the bid process: 4,000 rupees (R) (~US\$67) for a 1.5-ton ⁵unit and R5,000 (~US\$80) for a 2-ton unit.

Participation in the bidding process was low. Only two manufacturers bid, which program administrators say resulted in a smaller discount that they had hoped for (Pramod, 2013). Ultimately, Godrej Appliances was chosen to supply the AC units. Each of the two bidding competitors offered an all-inclusive price on each unit, which covers the discount on the cost of the new unit; the installation cost for the new unit; and removal, storage, and recycling costs for the replaced unit.

Approximately two crore (20 million) rupees (~US\$333K) were budgeted for the program. MERC regulations allow distribution licensees to recover all costs incurred in DSM-related activities (including planning, designing, implementing, and monitoring DSM programs) by adding these costs to their annual revenue requirements. This enables ratepayer-funded DSM investments.

There are no estimates of the energy, demand, or emissions savings from this project. However, the program goal is to incentivize participants to buy 1,500 5-star-rated AC models, which have a minimum non-seasonal Energy Efficiency Ratio (EER) of 3.5 in 2014, instead of 3-star models, which have EERs between 3.1 and 3.29 (India BEE, 2014). These numbers suggest that savings will be close to 10%. A wall-mounted AC unit bought in 2014 with a 5-star rating should consume approximately 3,703 kWh per year (Boegle et al., n.d.; India BEE, 2014) whereas 3-star units use between 3,939 kWh per year and 4,180 kWh per year (Boegle et al., n.d.; India BEE, 2014). Using these figures, we estimate that first-year unit savings would be between 236 kWh and 477 kWh for a consumer with a 5-star unit obtained through the program. These numbers are all ex-ante estimates, and net savings could vary significantly. Results from the program’s monitoring and verification will increase the accuracy of these estimates.

To participate, RI customers have to agree to cooperate with the program’s monitoring and verification procedures, which include RI installing plug-in electricity meters on the participant’s property to begin measuring consumption 15 days before installation of the new equipment. Monitoring continues for 15 days after the new unit is installed. This method is the basis for measuring overall electricity savings for each participant.

Mexico

The Government of Mexico ran a replacement program for room AC units under the Programa Nacional de Sustitución de Equipos Electrodomésticos (PNSEE), also referred as the Efficient Lighting and Appliance Project. PNSEE was designed to replace highly energy-consuming appliances, i.e., refrigerators and ACs, with more energy-efficient units. This program builds on previous experience from a refrigerator replacement program implemented from 2002 to 2006 (World Bank, 2010). PNSEE started in March 2009 with a target of replacing 1.7 million refrigerators and ACs by 2012 (World Bank, 2010). As part of the project, old refrigerators and ACs were collected from consumers and sent to scrapping centers for dismantling and recovery of the refrigerants. Table 4 summarizes the features of the PNSEE program.

Table 4 Mexico PNSEE Program Case Study Summary

Time Frame	2009 to 2012
Specification	Replaced units must be at least 10 years old and in working condition
Financial incentive	Between \$25 and \$70 in rebates and up to US\$470 in financing depending on monthly energy consumption
Funding	US\$600 million for appliance replacements (approximately 10% were air conditioners)
Impact	More than 150,000 participants

The program’s goals were multiples included non-energy benefits (WB, 2010): (i) stimulating domestic demand for energy-efficient products; (ii) strengthening social inclusion by improving the ability of low-income consumers to purchase more efficient appliances; and (iii) reducing GHG emissions resulting from the switch to more efficient appliances. In particular, the program aimed at helping low income households who tend to own very old and inefficient equipment.

To be eligible for the AC portion of the program, participants had to surrender a working AC that was at least 10 years old with a cooling capacity of at least 0.75 tons. Participants brought their utility bills to a participating retailer who scanned a bar code on the bill to find out the customer’s eligibility for rebate and financing.

⁵ This unit represents how much heat an air conditioner can remove from the house in an hour, one ton represents a capacity of 12,000 BTU/hr or 3517 watts. So 1 ton represents a capacity of 3.5 kW

PSNEE was financed with World Bank loans, a Global Environment Fund (GEF) grant, and the Mexican government's federal budget. The overall budget for appliance replacements was approximately US\$600 million for both refrigerators and ACs.

An innovative feature of PSNEE was that participants could finance their AC purchases through their utility bills. This strategy meant that the consumer's bill remained approximately the same but because of electricity saved by the new equipment, the difference between previous electricity use and post-replacement electricity use paid for the new equipment. Once the equipment was paid for, consumers enjoyed a reduced bill.

Another important feature of PSNEE was mandatory replacement and recycling of old units. A budget of approximately US\$30 per unit was added for collecting and recycling costs (World Bank, 2010). Participating retailers were in charge of most of the logistics. This mandatory replacement ensured that the participating household did not continue to use the old AC or sell it on the secondary market.

About 166.7 tonnes of CFC-12 refrigerant gas have been collected throughout the duration of the program and are now the subject of a pilot destruction project implemented by the Government of France and UNIDO (UNIDO, 2013). Currently, mechanisms governed by the Kyoto Protocol, such as the Clean Development Mechanism (CDM), do not cover these gases⁶, so CFC-12 destruction projects cannot earn Certified Emission Reductions under the CDM market. Other markets exist, among which the voluntary carbon market and the Mexican government is investigating applying for carbon reduction credits for retired refrigerants in these markets (CAR, 2014).

Program administrators sought to replace a combined total of 1.7 million old, inefficient ACs and refrigerators (about 170,000 ACs). These replacements were expected to reduce CO₂ emissions by 5.16 MtCO₂e and to save 10,041 GWh of electricity over the five years of the program (World Bank 2010).

In 2013, an evaluation using participant and non-participant utility bill data found that electricity consumption in households that purchased ACs through the PSNEE actually increased by 92 kWh per year (Davis et al., 2013). They attribute this result mainly to the take-back effects (also referred as rebound effects). As more efficient ACs cost less to use, participants tend to use them more to increase their comfort level. The increased energy usage observed by Davis et al is due to pent-up demand for cooling and contributes to the poverty reduction's goal of the program.

New York, USA

The New York utility Consolidated Edison (ConEd) has instituted a number of demand-reduction programs focusing on the residential, multi-family, and commercial sectors under the State of New York's Energy-Efficiency Portfolio Standard. In 2010, ConEd began a rebate program for room ACs. While central ACs⁷ is the most popular form of ACs found in the US, because of its old building stock, New York City concentrates the largest number of room ACs in the US (Coltro, 2014). The ConEd program offers US\$25 to all residential customers for the purchase of a new Energy-Star-rated room ACs. The offer is seasonal, only available from May to August. Table 5 lists the features of the ConEd program.

Table 5. U.S. - New York ConEd Program Case Study Summary

Time Frame	Began 2010, ongoing through at least 2015
Specification	Eligible units must be Energy-Star endorsed
Financial incentive	US\$25 per unit
Funding	Approximately \$1.1 million, budget from New York's System Benefits Fund
Impact	Between 2.3% and 4.6% of ConEd's eligible customer base participated from 2010-2011

ConEd hopes to achieve approximately 17% to 18% of the electricity savings goals mandated by the New York Public Service Commission (PSC), through the AC incentive program (this is between 11K MWh and 11.7K MWh over the 2012-2015 EEPs 2 time frame).

The original rebate amount was US\$50 per unit, which was established to ensure that program costs per unit passed the New York Technical Manual's Total Resource Cost test. However, this incentive was concluded to be high because it led to oversubscription of the program, so the rebate amount was decreased to the current US\$25 per unit. There is no size restriction on the new AC units and no requirement that new units replace old units. However, a separate program that recycles AC units can be used alone or paired with the rebate program.

⁶ the Kyoto Protocol excludes GHGs controlled by the Montreal Protocol, i.e., CFC and HCFC

⁷ Which use ducts to distribute cooled air to more than one room

ConEd does not break down its budget by program, but program managers estimate that the room AC program budget breaks down approximately as shown in Table 6.

Table 6. ConEd AC Budget Breakdown

Incentives	\$770,000	70%
Marketing	\$110,000	10%
Administration	\$165,000	15%
Evaluation, Monitoring and Verification (EM&V)	~\$55,000	5%

An evaluation of the program was conducted in October 2013 (ERS 2013) which revealed very high free ridership, estimated at 53%. To remedy to this, the evaluators suggested implementing tiered incentives that target higher-efficiency AC models. Another findings of the study was that hours of use were longer than expected, and consumption peaks were later in the day than expected, resulting in a lower peak coincidence factor for room AC. The lower-than-estimated savings meant that the program cost per kWh saved was greater than had been estimated.

Indonesia

The country received a grant from the Montreal Protocol's Multi-lateral Fund (MLF) for the implementation of a performance-based HCFC phase-out management plan (HPMP). Under the HPMP, industries producing refrigerators and AC equipment have to phase out HCFCs completely and convert to non-HCFC technologies by 2015. UNDP proposed that additional investments be made during this transition to non-HCFC, to enhance manufacturing of energy-efficient equipment. Table 7 lists the features of the Promoting Energy Efficiency for Non-HCFC Refrigeration and Air Conditioning (PENHRA) program.

Table 7. Indonesia PENHRA Program Case Study Summary

Time Frame	January 2014 to December 2016
Specification	Not yet defined
Financial incentive	Not yet defined
Funding	US\$5M GEF, US\$25M co-financing
Evaluation	The project is just starting.

The main goal of this project is to leverage MLF support for Indonesia's HPMP to simultaneously improve the energy efficiency of refrigeration and air conditioning equipment manufactured and sold in Indonesia. The idea is that the stakeholders that participate in Indonesia's HPMP will receive additional assistance to achieve higher energy efficiencies in the products they produce. One additional goal of this program is to learn from the design and implementation process to assess the potential for replicating it in other countries that have HPMPs funded by the MLF.

The PENHRA project consists of four main components: (1) policy framework, (2) public awareness, (3) manufacturing investment, and (4) training for the refrigeration and air-conditioning industry. The third component, manufacturing investment, is particularly interesting for this paper because it included grants to manufacturers that wished to upgrade to produce more efficient products. The grants are intended to cover the incremental costs incurred for energy-efficiency improvements.

The project description estimates that 3.97 Mt of CO₂ emissions reduction will result from project implementation. This estimation is calculated over 10 years of equipment lifetime and would be the sole result of penetration of more energy-efficient refrigerators and ACs, not including the changeover to low-GWP refrigerants. The assumptions consider a current AC baseline EER of 2.4 and EER of 3.2 resulting from the project. In 2009, 1.28 million AC units were sold. The project description also estimates a GEF unit abatement cost of about US\$ 1.26/t CO₂, considering a total funding of US\$ 5 million from GEF for the PENHRA project.

At this early stage, little can be said regarding the program's success or lessons that can be learned. However, the program concept may be interesting to other countries that have a refrigeration and AC manufacturing base and have to phase out HCFCs. The MLF has approved stage-1 HPMPs in 138 countries. As many as 40 countries are already preparing stage-2 HPMPs (UNEP, 2013b). During this conversion, new upstream incentive programs similar to the Indonesia example can be developed to target emissions reductions that are in addition to HCFC phase-out objectives through energy-efficiency enhancements. Those activities are not eligible for MLF funding but can be funded from other sources such as the GEF in the Indonesia example.

Indianapolis, USA

Indianapolis Power and Light (IPL) is a retail electric service provider in Indianapolis in the US. Since 2002, IPL has offered a direct load-control program that focuses on residential central ACs. The program employs an adaptive load control receiver installed outside the home, which can manage the AC's cycle rate so that the unit puts no demand on the grid during certain intervals of time, referred as Demand Response (DR) events. Aggregated over thousands of participants, this relieves IPL's need for significant amounts of capacity; it can ensure reliability if the grid is strained, and it can reduce IPL's need to pay for energy when energy is most expensive. Table 8 lists the features of IPL's program.

Table 8. Indianapolis Power and Light (IPL) Program Case Study Summary

Time Frame	2002 to the present
Specification	The program uses adaptive load control switches to manage participants' AC use during DR events
Financial incentive	\$5 per month during summer months (June through September), up to \$20 max
Funding	\$1.3 million in 2013
Impact	IPL's DR resources are equal to approximately 1% of installed capacity; in 2013, nearly 20% of eligible customers participated in the program

IPL offers an incentive of US\$5 per month to residential customers who allow IPL to remotely reduce their AC use. IPL will then place an adaptive load control switch on the customer's AC. The switch can "cycle" the unit, i.e., reduce the amount of time it is on, during a DR event. Generally the cycling is either unnoticeable or minimally noticeable from the customer's perspective. DR events are triggered based on an economic criteria: when wholesale of electricity costs rise above \$0.10 per kWh, IPL cause a proportion of participant ACs to begin cycling less often (this is direct load control).

IPL spent \$1.3 million on the CoolCents program in 2013 which is paid for with ratepayer funds. At the end of 2013, the program had approximately 39,000 customers which represents about 20% of IPL's eligible customer base.

The CoolCents program is evaluated each year and the one conducted for the 2013 program year found that the program had saved 28 MW of demand and 191 MWh of energy.⁸ The average program cost per kWh saved was \$0.069 compared to the minimum event-triggering criterion of a marginal price of at least \$0.10 per kWh.

The reduced cycling uses less energy at a time when the marginal kWh is most costly, so overall costs are reduced.⁹

Lessons Learned

Program Goals

Experience shows that incentive programs are often used to achieve additional goals to energy savings. For example, in the Chinese and Mexican examples, one of the objective of the incentive programs is to stimulate domestic demand to help the economy recover from the 2008 financial crisis. Furthermore, in the Mexican example, incentive programs have an additional goal to reduce poverty by improving the ability of low income households to pay for the replacement of their inefficient AC. In some cases (China and Mumbai), incentive programs are used to raise public awareness about the benefits of investing in more efficient products. In the US, the main goals of the programs is to meet energy demand with energy efficiency or demand response when investing in energy efficiency is more economic than investing in additional capacity.

The diverse goals of incentive programs show the necessity to tie energy savings to broader political goals such as economic growth and jobs, energy security, energy access, poverty reduction and well-being. Experience also shows that clearly defined goals facilitate communication of a program's efforts and value. They are also essential to define the metrics against which a programs success will be measured.

⁸ Energy savings are calculated by multiplying the power savings by the length of the event. These are not overall savings because reduced use during event hours is often followed by increased use after the event is over. However, they represent kWh that were avoided during the time when energy is most expensive.

⁹ This demand may shift to off-peak hours, when the marginal price per kilowatt hour is much lower.

Funding

Incentive programs are capital intensive, entailing not just administration costs but also monetary incentives for each participating AC unit as well as marketing. Therefore, funding is an important part of program development and scope. A variety of sources can be tapped for funds, as illustrated by the various case study programs.

The Chinese program illustrates how government funding can leverage very large amounts of capital and have a national impact. Ratepayer funds provide another source of funding. In the two U.S. cases, energy-efficiency programs are funded by a small levy or charge — a fraction of a cent per kilowatt-hour — on electricity sales. This levy goes into a common public fund that is used to recover the cost of implementing efficiency programs. A few programs in developing countries use monies from international climate funds. Mexico's PNSEE is supported by a loan from the International Bank for Reconstruction and Development (IBRD) and a grant from the GEF (WB, 2010), and Indonesia's PENHRA program is supported by a grant from GEF (GEF, 2013).

A few case studies (China and Mumbai) close the gap between the cost of more efficient ACs and the cost of ACs that meet the MEPS. In these cases, minimum private investment is leveraged by the incentive programs, only the part that is due to a reduction from the manufacturing cost. In programs that only cover a percentage of this gap, private investment from consumers is leveraged. These programs however tend to have lower participants share.

Program Design

Incentives can be directed at different points in the AC supply chain as one may be more effective than another depending on the technology's maturity, market penetration, supply chain and market barriers. Upstream incentives are effective for influencing a large portion of the market through fewer actors and therefore have lower transaction costs. This is one of the main reasons that the Chinese government used an upstream program for its very large market (Fu and Liu, 2014). In the Mumbai case study, an upstream program was used to achieve the maximum cost reduction in energy-efficient products. A bidding process was used to buy down the price of the efficient models, resulting in a reduced price to consumers through a combination of manufacturer discounts and program incentives. By reducing the price before products reach the market and therefore before the retailer markup, upstream programs have a greater impact on purchase price than downstream programs. However, the most challenging aspect of upstream programs is making sure that the incentive reduction is passed through to consumers. Program administrators must have robust monitoring and verification to ensure the full benefits go to the consumers. In the China and Mumbai programs, the incentives are delivered only after manufacturers prove that their products have been sold at a specific price. Upstream programs can be invisible to the consumers, but both of these programs used advertising to encourage consumers to buy the discounted products. This was part also of strategy to raise public awareness about the benefits of buying efficient products. Downstream incentives have the advantage of raising consumer awareness of the benefits of highly efficient products, which has positive spillover effects on other energy-efficiency purchases. The existence of a rebate is a signal in itself and may be even more important than the cash amount in some cases. Moreover, downstream programs have the flexibility to be directed to selected populations, such as low-income households, like in the Mexican example.

Cost Effectiveness

The costs of reducing energy consumption are a major concern for policy makers. However, measuring the success and calculating the cost effectiveness of energy-efficiency programs are very challenging tasks and difficult to compare. Comparison of cost and savings implies that they are calculated using the same methodology, but many factors enter in the equation: gross versus net savings, discount rate, and administrative costs, for example. Table 9 summarizes some of the findings based on the data and evaluation available for the case studies but should not be compared across programs, since a fair comparison would need to account for various contextual factors that are not represented in the energy saving cost per se.

Table 9. Case Study Program Cost per kWh Saved

<i>Program</i>	<i>Energy saving cost (\$US/kWh)</i>
China	\$0.02
Mumbai	\$0.05 – \$0.09
Mexico	\$0.086
US- New York	\$0.04 – \$0.09

The studies concluded that the cost of saved energy by ratepayer-funded energy-efficiency programs compares favorably to the cost of energy-supply options.

Program features

Replacement eligibility

A few programs (Mexican and Mumbai programs) have a replacement component in their eligibility criteria that requires participants to surrender old units to be eligible for the incentive. This feature accelerates the rate at which the old appliance stock is replaced. The programs aim to reduce electricity use by both encouraging the deployment of efficient ACs and ensuring that older, less-efficient ACs are removed from the stock. These programs have the added advantage of minimizing the potential for increasing demand from old equipment that could otherwise be re-sold on the secondary market. These programs are often directed at low-income households, which tend to have older, less-efficient appliances than the average household. Besides the energy-efficiency benefits, programs that replace old equipment are also attractive because they offer an opportunity to recycle old appliances and properly dispose of refrigerants that deplete ozone and contribute to global warming. However, replacement programs are effective only for specific markets that have already reached a high penetration rate of the products since first sales to consumers are excluded.

On- bill financing

The Mexican case study features an innovative financing design that allows participants to pay for the efficient unit through their electricity bills. This on-bill financing programs allow consumers to spread out the up-front cost of buying an energy-efficient appliance and to offset the monthly payments with the energy savings from the unit. Because most consumers are familiar with paying their electricity bill, even if they are not familiar with taking out a loan, on-bill financing could be used to reach many different consumer segments.

Evaluation

The rigor of program evaluations varies widely. Rate-funded programs tend to have the most rigorous evaluations because their level of success impacts planning for future resource investment and they are part of a cyclical regulatory process. Regulators need solid estimates of energy savings to plan for future energy capacity. Government-funded programs are not systematically evaluated. In addition, a particular program may have multiple goals, which can be broad, especially when the goals include economic stimulus; multiple goals complicate evaluation of the program’s success. International Climate fund projects are not evaluated at the project level. However, some institutions, for example GEF, require mid-term reviews and a final evaluation report.

Evaluations of energy savings help us estimate the net savings resulting from a program, i.e., the energy savings strictly attributable to the program. Net savings exclude free ridership, rebound effects, and other program effects but include spill over effects. Table 10 summarizes parameters that should be considered in estimating net energy savings.

Table 10. Parameters to Consider in Estimating Net Program Energy Savings

Effects	Description
Rebound effect	Reduction in energy costs causes customers to increase their energy use, diminishing the actual energy savings achieved.
Free ridership	Savings from program participants who would have undertaken the efficiency activities in the absence of the program should be excluded.
Spillovers	Savings beyond the program participants that resulted from the program’s influence should be included.
Other programs	Net savings also exclude the demand-reduction effects of other programs – such as standards and labeling, building codes, and other financial incentive policies – and of external phenomena such as economic recession or accelerated economic growth.

Third-party evaluations were available for four out of six programs studied in this report. The two U.S. programs (New York and Indianapolis) have regulatory obligations to retain third parties to evaluate their programs. In these cases, the evaluations helped the program administrators modify the programs to optimize impacts. Two other programs had evaluations sponsored by independent organizations.

Rebound Effect

ACs’ energy consumption is particularly vulnerable to the rebound effect. ACs are expensive to run and consumers tend to adjust their AC’s energy consumption according to the cost of the cooling service. In countries where consumer energy needs are not fully met due to affordability or un-reliable supply, efficiency improvements may increase consumption of energy. This is a result of the rebound (or take-back) effect, which is a behavioral reaction to the more affordable energy services and increased disposable income that result from

an efficiency improvement. For example, Davis, et al (2013) found that, in Mexico's AC replacement program, savings from improved efficiency led to an increase in energy consumption.

However, rebound effect is not necessarily a negative outcome. As pointed in a recent IEA publication (IEA, 2014), it can be a good thing from the perspective of contributing to economic and social objectives. Improved energy services, are important benefits of energy efficiency and are essential for wealth creation and social development. Certain regions and consumer segments may be more susceptible to large rebound effects than others. In this case it is important to assess its potential impacts on energy savings but also assess the non-energy benefits that results from this increase in energy service demand.

Policy makers should analyse all the trade-offs from the different stakeholders perspectives and for the society as a whole and chose the energy efficiency measures and programs that have the best comparative advantage for meeting the goals of increasing the welfare for the country.

Optimal efficiency levels

One important lesson learned is that energy savings impacts from incentive programs tend to be higher when they target efficiency levels that have a low market penetration. Otherwise, programs have a high share of free ridership, as demonstrated in the New York case study.

By increasing the market penetration of highly efficient technologies that are at an early stage of development, incentive programs helps to streamlining the production process and allows manufacturers to take advantage of economies of scale and learning effects. In a competitive market, this contributes to further reduce the cost of production. Incentive programs should be temporary and then target higher efficient levels. In Lees' evaluation of the British schemes, the Energy Efficiency Commitment (EEC) 1 and 2, the analysis suggests that technologies with a market penetration greater than 30–40 percent do not need to be financially incentivized (Lees, 2008).

In the case of ACs, it is also important to adopt a technology-neutral approach. Incentive programs should be employed to help move the market for VS ACs only which are the most efficient technology to cool air. In the case studies, incentives are often offered to both VS and FS ACs. This stems from the fact that S&L are not technology neutral in many countries and have performance rating for both technologies which can be misleading for consumers (Li et al, 2013).

Conclusion

Incentive programs can play a significant role in transforming the market of ACs toward more energy efficient products. This market transformation can then bring multiple benefits to an economy such as energy savings, reducing peak demand, increase grid reliability, reducing GHG, stimulating the economy, or reducing poverty. Achieving these benefits requires that:

- goals of the programs are clearly defined early on
- enough funding are ensured to cover all the programs cost
- the design of the program include features that help achieve specific goals
- evaluation are conducted frequently to measure progress and recommend modifications to maximize results
- efficiency requirement should be based on a neutral technology approach and should target highest levels.

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