Chapter

Energy Savings Analysis of a Recommended Residential Air Conditioning Incentive Program in Saudi Arabia

Faisal Fahad Al-Musa

Abstract

Over the past couple of decades, the kingdom's annual per capita electricity consumption has been steadily growing by around 7%. One of the key causes for such a high growth is the intensive use of non-energy-efficient equipment, which was dominating the Saudi market. In 2017, the residential sector consumed around 143 TWh, which represents around 48% of the country's total electricity consumption. The aim of this study is to assess the feasibility of an air conditioning incentive program for citizens from energy and economic sides. This chapter is a detailed study where program gains from energy and economic standpoints were based on substituting participants' old air conditioning units with new units that are better in performance. The proposed program was designed over an 8-year period with three scenarios where the government will take care of all the capital cost, 75%, and none of the capital cost in these scenarios. The results of this study indicated that an accumulated savings of up to 17.11 TWh by 2025 with NPVs above $13 billion can be achieved in all scenarios. Moreover, it was estimated that the program will add an average of $0.5 billion per year to the kingdom's GDP over the duration of the program.

Keywords: energy efficiency, energy savings, air conditioning, HVAC, subsidy program, incentive program, residential, Saudi Arabia, KSA

1. Introduction

The Kingdom of Saudi Arabia is one of the nations that are blessed with plenty of energy resources, specifically fossil fuels in the form of oil and gas. In addition, it has a huge potential for renewable application which has not been leashed at full capacity yet. This wealth of energy resource was one of the main factors to have and maintain low energy prices for decades in all the sectors, namely, industrial, transportation, or buildings. For instance, the average electricity price was around $0.03/KWh for long time which is considered one of the lowest worldwide. Over the past years, the kingdom's per capita electricity consumption was rising swiftly with an average annual rise of 7% where the year 2000 electricity consumption was 5640 KWh per capita compared to a world's average of 2384 and the 2014 numbers were 9444 KWh per capita compared to the global average of 3127 as per the World Bank statistics.

The buildings sector is considered one of the main energy consumers in the kingdom with a total of nearly 9 million electrically connected customers in 2017, with the bulk, 7.1 million, being residential customers. As per the Saudi Electricity and Cogeneration Regulatory Authority (ECRA), the residential sector consumed nearly 143 TWh, which represents 48% of the country's electricity consumption. The high residential energy consumption is projected to keep rising in the future attributing to a number of factors among which are the expected population increase, the low energy prices despite of the recent rise, and the vibrant infrastructure expansion under the kingdom's 2030 vision.

Such existence of low energy prices coupled with the absence of stringent standards, building code enforcement, and standards and labeling (S&L) programs led to wasteful pattern of energy consumption among citizens which resulted in depleting the kingdom's natural resource at higher rates than normal compared to international records.

The Saudi government realized this fact and decided to change the existing situation. Hence, Saudi policy makers acknowledged the fact that energy efficiency and conservation shall be set as one of the nation's top priorities for the national energy security. This was apparent via inaugurating the Saudi Energy Efficiency Program (SEEP) activities to help in jump-starting the energy efficiency efforts within the kingdom by designing a comprehensive integrated framework consisting of several key pillars and enablers. In order to ensure sustainability, the Saudi Energy Efficiency Center (SEEC) was established in 2010 aiming for rationalizing the production and consumption of energy in all sectors in order to ensure the kingdom's efficiency along with unifying efforts in this field among governmental bodies and nongovernmental entities as well. The center's mission is to preserve the national wealth of energy sources in a manner that promotes development and the national economy and achieves the lowest possible levels of consumptions. The efforts made by the government since the inception of the energy efficiency program had a great and clear impact from different aspects in each and every sector. Zooming into the buildings sector, the efforts were obvious by completing several milestones including updating the Saudi Building Code along with introducing several Minimum Energy Performance Standards (MEPS) for a number of equipment, enforcement of insulation standards for new buildings, introducing S&L programs for different appliances, and much more.

The aforementioned efforts helped the market to be in a better situation by slowly getting rid of less efficient equipment along with changing the mindset of citizens to be mindful of their energy consumption patterns. Nevertheless, in order to further normalize the uncontrolled demand for building energy, it is vital that more energy-efficient improvement opportunities be assessed and progressively executed. One of these opportunities is to introduce an incentive program for the existing fleet of air conditioners with low energy efficiency ratings especially in the residential sector as the main consumer within the buildings sector of Saudi Arabia which is the topic of this chapter. However, before going into the details of the proposal, some light need to be shed on the purpose of such programs, the appropriate time for their introduction in a market, their implementation mechanism, and finally the main challenges or barriers that might face such programs. This will be detailed in the literature review section.

With regard to air conditioning in Saudi Arabia, The Saudi Standards, Metrology and Quality Organization (SASO) have done great efforts in developing the SASO 2663 standard for Energy Labeling and Minimum Energy Performance Requirements for Air-Conditioners (phase 1, 2013; and phase 2, 2015). Now it is time to start developing an incentive program that would help not only in reducing electric consumption and summer peak demand but would correspondingly avoid pricey power outages in peak hot summer months and cut greenhouse gases (GHG) emissions. Moreover, it would aid in supporting SASO 2663 for a further shift in efficiency levels.

2. Literature review

This section will provide an overview of the policy frameworks and program designs that will be helpful as a preparation to the reader into the proposed subject of residential air conditioning incentive program for the kingdom of Saudi Arabia. In addition, some light will be shed on energy analysis approaches. Finally, techno-economic assessment will be reviewed with focus on net present value.

Incentive programs usually complement standards and labeling procedures by speeding up market permeation of more energy-efficient products than required by current standards in place and by also preparing the market for further stringent future standards requirements. Incentives can be focused at several points in the appliance's supply chain; a precise point may be more effective than another subject to different factors including, but not limited to, the maturity of the technology and market permeation. Financial incentive packages have larger impact when they are focused toward highly efficient technologies that have a smaller market share, and those program designs will be going to depend on market barriers addressed, targeted equipment, and local market situation. Therefore, it is safe to say that there is no specific one program design that is inherently better than the other. The key here is to design an effective program by implementing a comprehensive understanding of the market and the identification of the vital local complications to the penetration of energy-efficient technologies [1].

Several barriers contribute in discouraging consumers from investing in energy-efficient equipment. These barriers may include absence of information, split incentives (between landlords and renters), and lack of energy-efficient equipment on the market [2–4]. One of the most major barriers that policy makers detect is the fairly higher up-front prices of efficient products. Usually these costs discourage potential buyers even when investments seem to be in consumers' interest (i.e., cost-effective over the lifetime of the equipment). Consumers set great value on instant savings and profoundly discount future savings [5, 6]. Additionally and as they might not be able to simply evaluate future savings, consumers tend to have less confidence in expected paybacks. Consequently, consumers regularly purchase the cheapest available options. Many incentive programs have been established worldwide to address these barriers and speed up the penetration of efficient equipment [6].

2.1 Policy frameworks

The classical policy frameworks in which incentive programs are developed are either (1) government rollouts with fund raised through taxes or (2) compulsory savings goals agreed for energy providers (i.e., utilities) to decrease their customers' energy consumption. Incentive programs, over the history, have been implemented by different governments for one main purpose, and that is to support long-run growing domestic clean product market [7].

Examples of compulsory savings goal schemes include those exist in Brazil, some Australian states, South Korea, China, India, and South Africa [8, 9]. In Australia, New South Wales State implemented the world's first obligatory GHG emissions exchange scheme in 2003, in which electricity GHG emissions are capped each year [7]. Since 1998, the Brazilian power regulatory authority, ANEEL, mandated utilities to invest at least 0.5 percent of the net revenues in energy efficiency programs. The Brazilian Congress necessitates that around half of these funds must be spent on energy efficiency measures targeting low-income households [10].

In India, the Maharashtra Electricity Regulatory Commission (MERC) introduced a public benefit type of electricity charge on utilities where funds are used to finance energy efficiency and renewable energy programs. In 2005, MERC requested utility companies to use these resources to start compact fluorescent light (CFL) programs in Mumbai's residential sector [11]. As can be seen from such examples, governments are developing policy frameworks in order to increase the role of energy efficiency.

2.2 Funding sources

Financial incentive programs are capital-intensive in nature, involving not only administration costs but costs of financial incentives for every participating appliance unit. In general, government-sponsored incentive programs are financed through government budgets funded by taxpayers. Developing countries governments can pursue monetary support from international financial institutions such as the World Bank. For example, India's Super-Efficient Equipment Program for electric fans is supported by the Clean Technology Fund, which is administered by World Bank [12].

Earmarked taxes can also finance energy efficiency programs. For instance, South Korea introduced a 5 to 6.5 percent tax on energy consuming appliances where the revenues from the tax were used to subsidize the procurement of efficient products by low-income households [13]. These types of policies are known as a feebate (a portmanteau of "fee" and "rebate") which is basically a fee on products with low energy efficiencies that is utilized in order to be directed as rebates on better-performing products [1].

Under the current budget limitations that the government of Saudi Arabia is facing nowadays, the feebate policy could be an appropriate vehicle to implement the proposed air conditioning incentive program.

2.3 Program designs

The major challenge of incentive program design is to accomplish robust market transformation [14, 15]. Programs need to be customized to address different stages of energy-efficient products' market diffusion to increase the products' penetration through a sustainable manner. In general, the diffusion of efficient technologies follows an S curve [16]. At the beginning, limited early participants will be willing to take risk in purchasing expensive new technologies, thus market diffusion is considered small at this stage. After the technology has been proven, the technology's market penetration rates rise faster. After that market penetration of technology levels off, only "idlers" will remain unwilling to implement new technologies [1].

Standard and labeling (S&L) programs are normally considered the first of policy intrusions to alter the market of a specific product. S&L programs approve technologies based on their energy performance and hence take out energy intensive technologies from a specific market, which ultimately results in raising efficiency levels. Incentive programs are better implemented if S&L programs are in place. A typical cycle of market conversion starts with energy-intensive products which are removed from a market by minimum energy performance standards (MEPS). Then, existing equipment efficiency is elevated utilizing energy inducement programs. Those inducement programs focus on highly efficient products with best-in-class identified equipment by the S&L programs. It is worth mentioning that programs focusing on consumers are called "downstream" programs, programs focusing on distributors and retailers are often called "midstream," and finally those focusing on manufacturers of products are usually called "upstream" [1].

In Saudi Arabia, the standard for air conditioners (ACs) was already issued and enforced since September 2013, and now it is time for incentive programs. The standard is SASO 2663: 2104 titled "Energy Labeling and Minimum Energy Performance Requirements for Air-Conditioners" and has the requirements presented in the table below:

Air conditioner appliance type	Cooling capacity (CC) limit (Btu/h)	Mandatory EER phase 1: 7 September 2013	Mandatory EER phase 1: 7 September 2013	Mandatory EER phase 2: 1 January 2015	Mandatory EER phase 2: 1 January 2015
	At testing conditions T1 (35°C)	T1 (35°C)	T3 (46°C)	T1 (35°C)	T3 (46°C)
Window type	CC <18,000	8.5	6.12	9.8	7.06
	18,000 ≤ CC < 24,000	8.5	6.12	9.7	6.98
	CC ≥ 24,000	8.5	6.12	8.5	6.12
Split type and other types	All capacities	9.5	6.84	11.5	8.28

Incentives raise equipment desire and consequently market a shift toward more efficient equipment which leads to price reduction over time and hence more production of such equipment by manufacturers. The increase in fleets' energy efficiency, realized through inducement programs, will be then paved by applying more stringent standards which will lead to endless sequence of improvements. This twirl can be continual as technology advances in developing more energy-efficient products. To further advance the penetration rate, further programs can be introduced such as awareness programs and awards [1].

In other countries which have weaker standards and S&L programs in place, incentive programs can aid to push for more efficient product penetration. Incentive programs can also be used as a vehicle to make more stringent standards acceptable to the public as well as manufacturers in a specific country. Furthermore, inducement programs affect people's buying choices, and if implemented with the existence of an S&L program, they will both definitely work in harmony to aid in enlightening citizens about the advantages of the more energy-efficient equipment. The availability of a consumer partial refund program is by itself a sign of the great value of the labeling program in place. Partial refund programs are usually connected with better energy-efficient units. Caution: when designing an incentive program, the program should address the issue of free ridership. Free riders are those who take advantage of incentives yet would have purchased efficient technologies even without the incentives [1].

Gold and Nadel settled that incentive programs should last for a limited time, typically around 5 years, since incentives become less effective over time [17]. Rosenberg and Hoefgen concluded that various harmonized market interventions over an extended period of time are more likely to affect the behavior of market actors than programs that include a single intervention during a short period of time [14]. With time, a program can raise the overall efficiency of the units on the market. Gold and Nadel found that the refrigerator tax credit upstream program in the USA has been essentially successful as each extension of the program pressed the efficiency standard higher so that next set of incentives would further increase the energy saved. One of the main reasons for the program's success was vigorous stakeholder engagement and education with regard to how to participate in the program [17].

2.4 Incentive beneficiary

Partial refunds can be delivered in any point in the equipment supply chain, but typically they are provided to end consumers. The decision shall be made based on specific market's characteristics and obstacles. For example, product manufacturers will be targeted if the production of more energy-efficient products is needed, while distributors might be targeted if efficient equipment accessibility is the main obstacle in that specific market [1]. In this chapter's proposal, end customers are targeted, and hence it is of a downstream-type program.

Downstream inducements have the benefit of increasing buyers' acceptance of energy-efficient units, which has helpful spillover effects (i.e., the purchase of energy-efficient units by nonparticipants in the program due to the enhanced knowledge about the benefits of energy efficiency). The presence of a refund by itself is a signal and could in some cases have greater impact than the cash amount. Furthermore, downstream-type programs have a unique feature where they can be easily directed to a particular group of the society such as low-income households. However, a drawback of such programs could be the massive operation costs required in delivering refunds to big numbers of beneficiaries on individual basis [1].

2.5 Evaluation

Programs and policies are not usually thoroughly evaluated. Governments do not at all times allocate money and time to assess their programs in details. Moreover, a certain program could have various goals, which can be wide-ranging, especially when they incorporate research and development elements; this complicates evaluation of the program's success. Evaluation of rate-funded programs is more likely to be performed more scientifically as a necessary input to plan for upcoming resource investment, and impact evaluations are normally part of the development of these programs [18].

2.6 Examples of downstream programs

The typical fiscal tools used for downstream programs along with consumer reward points and replacement programs are briefly described below.

2.6.1 Downstream fiscal instruments

Fiscal instruments that include income/sales tax reduction are popular incentives applied by governments. Since 2005, France has had an effective tax credit (tax credits reduce the taxes the consumer pays, whereas tax deductions lower the consumer's taxable income). As of 2010, more than 6.2 million households had benefited from this French tax credit [19]. Tax credits can be applied for the purchase of efficient boilers, windows, heat pumps, and even renewable energy equipment. Since 2007, the Italian government has offered a tax deduction of 55 percent for the replacement of heating, ventilation, and air conditioning (HVAC) systems with more efficient units and for the cost of other home efficiency improvements as well. Until December 2010, the program included a tax deduction of 20 percent for the replacement of old refrigerators. A tax deduction of 50 percent was newly added for the replacement of white goods including refrigerators, dryers, washers, ovens, freezers, and gas cookers [20].

2.6.2 Consumer reward points

South Korea and Japan have applied subsidies in the form of reward points to incentivize consumers to select efficient technologies. This approach aims at promoting low-carbon lifestyles by encouraging consumer responsibility and awareness [1].

2.6.3 Replacement programs

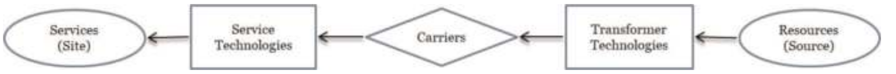
Replacement programs (i.e., premature retirement and direct install) replace wasteful products before their useful estimated life is ended with more energy-efficient ones. Such programs help in decreasing energy use by inspiring the placement of efficient products and confirming that non-efficient ones are taken away from the market [1]. Mexico's PNSEE has replaced large numbers of old appliances. The program offers government-funded subsidies to households in order to replace their old refrigerators and air conditioners with more efficient ones. The subsidies cover a percentage of the price of the new equipment and the costs for removing the old one. To receive the subsidy, households must surrender working refrigerators and air conditioners that must be 10 years old or older [21].

2.7 Energy analysis

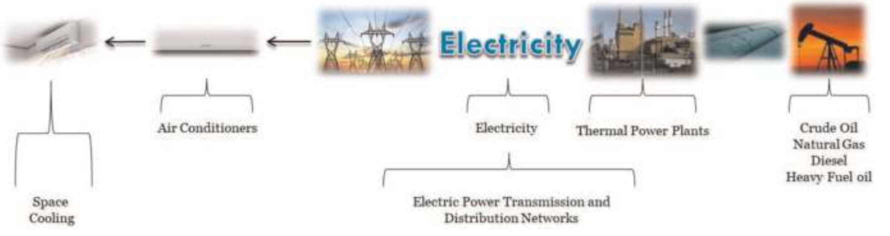
Approaches of energy savings vary between countries, and they have a major effect on results. For instance, in Europe the savings are commonly based on lifetime energy saving which covers accumulated savings over the life of the equipment over the program duration, while the California Public Utilities Commission objective is based on yearly energy savings gathered over a period of 3 years [1].

Also, diverse methods are utilized to estimate net savings from incentive programs. An inducement program's net energy savings are usually the percentage of savings related only to the program itself. Those gross savings do not include the savings coming from the freerides who are contributors that will purchase efficient equipment without the availability of the program. Yet, it includes savings from participants who were encouraged to purchase efficient products as a result from the program's impact on that market that are usually referred to as spillovers. Furthermore, gross savings does not include savings resulting from other programs such as existing standards/codes, S&L programs, other monetary inducement programs, and of course external events such as economic recessions/growths. Usually gross savings calculation is not easy considering the existence of different bodies within the country offering several other different monetary programs for the same equipment. A final concern that should be accounted for is the increase in energy consumption that happens within the program participants as a result of the decrease of their energy bills which is a phenomenon typically referred to as rebound effect. Continuous evaluation and assessments are important and shall be performed regularly by governments to keep program administrators up to speed and aware of possible drawbacks that incentive programs might face and how they can be fixed [1].

Moreover and before going into energy analysis and savings quantification in this chapter, it is vital to understand what an energy system is. Scott wrote a paper about "the energy system" and defined it from sources to services where services are basically what people wants and sources are what nature provides as can be seen in the figure below [22].



Sources, transformer technologies, and carriers together identify the energy sector. Hence, it can be understood that the energy sector is only a part of the energy system [22]. As we are evaluating air conditioning incentive program in this study, the below graph describes the energy system, as per Scott, of a space cooling service in Saudi Arabia.



In this chapter the focus will be on final or site energy savings quantification mainly not the primary energy saved. This is why it was important for the reader from a comprehension point of view to be provided with a glimpse of site-to-source energy systems. Since the proposal is about Saudi Arabia, it would be also useful to shed some light on Al-Musa et al.'s [23] efforts in implementing Scott's concept of energy systems to the Saudi electricity and LPG systems for cooking and water heating applications where they quantified the efficiency of the system by using the following formula [23]:

$$\eta\text{System} = \eta\text{Extraction}^{*}\eta\text{Transportation}^{*}\eta\text{Transformer Technology}^{*}\eta T\&D^{*}\eta\text{ServiceTechnology}. \quad (1)$$

They found out that the Saudi electric system efficiency from source to service is around 20 and 23% for cooking and water heating applications, respectively [23]. If a model to be developed for the space cooling applications is using the same formula, the efficiency of the service technology needs to be changed to consider window and split units' efficiencies. However, this is outside the scope of this chapter.

Another example from a developing nation is the efforts described by McNeil and Michael (2005) in their research where they studied the possible benefits from improved energy efficiency of key electrical products in India. The objective of the project was to assess the benefits which cost-effective enhancements in energy efficiency may get to developing nations. The project focused on four appliances among which are the air conditioning units. The life cycle cost analysis methodology was used in this project along with identifying the country's energy and environmental impacts in an attempt to offer through estimations of the possible returns of appliances energy efficiency programs in India [24].

The proposal in this chapter was analyzed with focus on energy efficiency and energy analysis. However, it is worth mentioning that several other researches focus also on exergy efficiencies and exergy analysis. Tolga Taner (2105) mentioned in his paper that energy analysis may be clarified with an exergy analysis where exergy is defined as the available energy [25]. Also, exergy could be defined as the available work or quality of energy. It basically quantifies the capability of a source to create useful work. Hence, exergy is considered a thermodynamic unit that offers a numerical value to the energy quality [25].

Muller et al. emphasized that exergy analysis is an essential tool which can be utilized in order to design and also operate an energy system. They also stressed on the importance of exergy analysis due to its significance for whole system exergy destruction [26].

Although very important, exergy efficiencies and analysis are outside the scope of this chapter, and it focuses mainly on energy efficiencies and energy analysis.

2.8 Techno-economic assessment (TEA)

This chapter attempted to quantify the energy savings and the associated economic feasibility from a proposed incentive program where several assumptions and estimations are needed and were utilized. Maximilian Lauer (2008) described several techno-economic assessment (TEA) methods among which are the net present value (NPV), annuity method, net cash flow table, and internal rate of return where he referred to the NPV method as the most common method utilized by the majority of professional practitioners of techno-economic assessment [27]. In this chapter the net present value (NPV) (discounted cash flow) will be used as one of the techno-economic assessment (TEA) methods where the net present value of each year will be discounted to year zero by the discount rate by means of the following formula [27]:

$$NPVn = \frac{NFC}{(1+d)^n} \tag{2}$$

Hence, the NPV of the project (i.e., NPV_{total}) will be the total of the discounted cash flow for each year over the project period [27]:

$$NPVtotal = \sum_{1}^{n} NPVn \tag{3}$$

Maximilian recommended performing sensitivity analysis to investigate the effect of input parameters on the results which will be performed in this chapter. Sensitivity analysis shall be implemented to describe how sensitive any outcome variable (for this proposal, the NPV in each scenario) to variations of input parameters. Since there are usually several input parameters, such technique can help in determining which parameter drives the majority of the deviations in the outcome [27].

Sensitivity analysis is commonly used in energy efficiency evaluations. For instance, Dae-HyunChoi and Le Xie (2016) recommend a novel analytical framework to measure the sensitivity of home energy management systems (HEMS) to fluctuations in input data for HEMS operation [28].

3. Statistical analysis

3.1 Methodology

In order to investigate different aspects of the study, several data collection methods were used such as questionnaire, interviews (site visits), and published data (through secondary research). The questionnaire targeted the end users, while the interviews targeted some major stakeholders in the air conditioning industry. The majority of the data analyzed in this chapter is coming from the questionnaire.

3.2 Questionnaire

3.2.1 Structure

The questionnaire had a total of 13 questions with the majority being of multiple-choice type which made it easier for respondents to respond and easier for the researcher to analyze. The survey was developed in Arabic using Google Docs platform.

3.2.2 Sample size

As per the Saudi General Authority of Statistics, the 2017 population of Saudi Arabia is around 20.4 million that the sample was drawn from. A statistically representative sample, using 99% confidence level and +/−5% confidence interval, would be less than 700 respondents (i.e., 666) using Survey System methodology as described in the below Equations [29]. The number of respondents in the study exceeded 4000, which is more than six times the needed sample size. The following formulas were used to calculate the needed sample size:

$$SS = \frac{Z^2 * (p) * (1 - p)}{C^2} \tag{4}$$

where SS is the sample size, Z is the Z value (2.58 for 99% confidence level), p is the percentage picking a choice, expressed as decimal (0.5 used for sample size needed), and C is the confidence interval, expressed as decimal (0.05 = ±5).

The sample size then needs to be corrected for a finite population as follows:

$$\text{New SS} = \frac{SS}{1 + \frac{SS-1}{pop}} \tag{5}$$

where pop is the population (i.e., 20.4 million).

3.2.3 Results

The survey was run over a 1-week period. Over that period, the survey link received more than 7500 clicks. While the total number of responses exceeded 4700, only 4649 were included in the analysis as some of the answers were inconsistent and hence excluded. The response rate could not be determined exactly given the lack of statistics on who really saw the tweet, post, or message. The response-to-click ratio, yet, is around 63%.

The below figures show the sociodemographic profiles of the 4649 respondents used in the analysis. The following subgroup contains the majority of respondents in their respective sociodemographic categories: Income level, 9000–15,000 SR income group (36%); citizenship, Saudi (99.5%); marital status, married (82.4%); and age: 30–39 years age group (52.2%). Geographically, the highest representative administrated areas (regions) were central (49%), western (25%), and then eastern (15%).

It was noticed that some groups (Saudis, male, married, 30–39 years old) are over represented in the sample. This is not surprising given the fact that those groups are the ones who are interested in the topic at hand, which is good for the survey and its results.

4. Program design

Before going into the details of the Residential Air Conditioning Incentive Program, below are the major assumptions undertaken during the development of the incentive program:

1. Administration cost of the program is not considered.
2. Units to be replaced are 10 years old or more. Moreover, old units are surrendered to program administrator when receiving the new unit.
3. Weighted average tonnage of the AC units is 2.0176 TR based on Saudi Label & Standard (SL&S) registration system.
4. Average annual operating hours is 2741.
5. 2016 existing residential stock of small units is around 23 million units.

6. Being conservative by assuming that old units to be replaced have EERs matching 2013 standard (i.e., window 7 and 8.5 for split).

7. Being conservative by not degrading the old units with temperature and only degrading the new units with temperature.

8. Benefits of installed ACs assumed to last for 20 years.

4.1 Program summary

Covered units	Ten-year-old or more residential window and split air conditioning units
Amount replaced	5.75 million units (i.e., 25% of 2016 stock) Window: 3.45 million unit Split: 2.3 million unit
Program duration	8 years
Program start/end years	Start on 2018 all the way to 2025
Replaced units' EER	Window: 7 Split: 8.5
New units' EER	Match exactly compliance standards at each specific year until 2022 where EERs of new units are fixed at that level until the year where the program ends (2025)

Based on the survey, by the time the program gets into the implementation phase, more than 33% of the ACs in the market would be 10 years old or more. The proposal is to replace 25% of 2016 stock as detailed in the below table.

Type	2018	2019	2020	2021	2022	2023	2024	2025	Total
Window	431,250	431,250	431,250	431,250	431,250	431,250	431,250	431,250	3,450,000
Split	287,500	287,500	287,500	287,500	287,500	287,500	287,500	287,500	2,300,000
Total	718,750	718,750	718,750	718,750	718,750	718,750	718,750	718,750	**5,750,000**

4.2 Stock estimates

The 2016 estimated stock of small units is composed of around 60 and 40% share of windows and split units, respectively. These shares are evolving over time as split units are becoming more favored by Saudi residential consumers, and hence the future percentage of shares are expected to shift more toward the split units in lieu of window units.

4.3 Costs

As in every incentive program, this program is capital-intensive. The main chunk of the capital is needed for the new air conditioning units that shall be installed. Moreover and in an effort to perform a sanity check of our utilized cost estimates, numbers were cross-checked through site visits to several retailers in Al-Khobar city where the average window unit price was around $384, whereas the price was $870 for split units which are not far away from our initial estimates. When discussing costs, our cost information may not address the expected increase in standards and their effects and only considered inflation along with normal technology evolution. In addition, a meeting with Zamil Air conditioners (the largest HVAC manufacturer in the Middle East) was held to check the impact of standards on the price of the units, and the below tables summarize the price impact on both manufacturers and end users.

- Impact on manufacturers

AC type	Increase in price (%) after the first increase in efficiency target	Increase in price (%) after the second increase in efficiency target
Window	7	10
Split	10	20

- Impact on end users

AC type	Increase in price (%) after the first increase in efficiency target	Increase in price (%) after the second increase in efficiency target
Window	5	10
Split	10	18

4.4 Energy efficiency ratio assumptions

By using compliance standard EER values at each specific year along with expected EER values at T1 in future years and utilizing the shares of the weighted average tonnage of small air conditioning units, it was found that the aggregated EER at T1 are as shown below:

EERs (T1)	2018	2019	2020	2021	2022	2023	2024	2025
Window	10.4	10.6	11.3	11.5	11.8	12	12.2	12.8
Split	12.6	12.8	13.9	14.2	14.5	14.8	15.1	15.5

In order to be conservative and not exaggerate with energy savings estimates, EER values beyond year 2022 were fixed at year 2022 levels. Hence, the aggregated EER values became as follows:

EERs (T1)	2018	2019	2020	2021	2022	2023	2024	2025
Window	10.4	10.6	11.3	11.5	11.8	11.8	11.8	11.8
Split	12.6	12.8	13.9	14.2	14.5	14.5	14.5	14.5

However, EER values are specified at T1 levels (i.e., 35 degree Celsius) only. It is known that the outside air temperature varies from 18 degrees Celsius where cooling load is required until extreme temperature levels which could occasionally exceed T3 levels of 46 degree Celsius. For the sake of this study, the analysis will be capped at T3 levels as beyond T3 levels are rarely reached. As an example, the average 15 years bin weather data for Dhahran City shows that only .58 of a day in the year is exceeding the 46 degree Celsius. This can be translated to only less than 0.2% of the years above the T3 level in Dhahran.

Although manufacturers provide EER values of an AC unit at several different outside air temperatures (OATs) including T1 (i.e., 35°C) and T3 (i.e., 46°C), they do not provide the EER value at each and every temperature above T1. Therefore, the EER value for each temperature point above T1 level needs to be identified first in order to be able to calculate the EER's percent reduction at each temperature value above T1. Hence, a linear regression model was applied for different Al-Zamil air conditioning window and split units with diverse EER values at T1. Then, the calculated weighted average value was utilized in energy savings calculations. The regression analysis was following the below equation:

$$Y = a + X \times b \tag{6}$$

where Y is the dependent variable (energy efficiency ratio of the air conditioner), X is the independent variable (outside air temperature), b is the slope of the line, and a is the y-intercept.

After performing the calculations on the different models, it was found that the weighted average EER drop for a given temperature above T1 value is around 2.1% per degree temperature. Thus, new window units' EER values (adjusted by taking into account EER degradation factor) were computed as follows:

Window								
Year	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
Adjusted EER	9.66	9.85	10.51	10.72	10.94	10.94	10.94	10.94

Similarly, new split units' EER values (adjusted by taking into account EER degradation factor) were calculated as follows:

Split								
Year	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
Adjusted EER	11.7	11.93	12.94	13.2	13.46	13.46	13.46	13.46

Having said that, the units subject to replacement (10 years old or more) are assumed to have the below EER values at T1. In order to be conservative with the calculation, T1 values for old units are used in calculating the corresponding energy consumption without considering the degradation with temperature:

EER at T1 for units subject to replacement										
Year	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
Window	7	7	7	7	7	7	7	7	7	7
Split	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5

5. Results and discussion

In this section of the chapter, energy savings resulting from the replacement of existing air conditioning units with new ones will be presented along with the economic impact from NPV, gross domestic product, and employment perspectives. The presented results will be also discussed in details in this section.

5.1 Energy savings

In order to quantify the overall savings of the program, the calculation started with quantifying the saved energy per unit going from a low-level EER to the proposed level at each specific year. Then, the saved energy per unit was multiplied by the replaced stock at that year in order to get the overall yearly savings. This approach was applied for both window and split units as can be comprehended from the below equations and tables:

$$\mathrm{EER} = \frac{\text{Desired Output}\left(\text{i.e.cooling load in}\,\frac{\text{BTU}}{\text{h}}\right)}{\text{Required Input (i.e.electri power in W)}} \tag{7}$$

Knowing that 1 TR equals 12,000 BTU/h and the weighted average tonnage (TR) of the AC units is 2.0176,

$$\text{Annual KWh of Air Conditioner} = \frac{12 \times \text{TR} \times \text{Average Annual Operating Hours}}{\text{EER}} \tag{8}$$

- *Window*

Year	New EER	Existing EER	New unit's Kwh	Existing unit's Kwh	Savings per unit	No. of units	Savings (TWh)
2018	9.66	7	6870	9480	2611	431,250	1.13
2019	9.85	7	6736	9480	2745	431,250	1.18
2020	10.51	7	6315	9480	3165	431,250	1.37
2021	10.72	7	6189	9480	3291	431,250	1.42
2022	10.94	7	6068	9480	3412	431,250	1.47
2023	10.94	7	6068	9480	3412	431,250	1.47
2024	10.94	7	6068	9480	3412	431,250	1.47
2025	10.94	7	6068	9480	3412	431,250	1.47

- *Split*

Year	New EER	Existing EER	New unit's Kwh	Existing unit's Kwh	Savings per unit	No. of units	Savings (TWh)
2018	11.70	8.5	5673	7807	2134	287,500	0.61
2019	11.93	8.5	5562	7807	2245	287,500	0.65
2020	12.94	8.5	5130	7807	2677	287,500	0.77
2021	13.20	8.5	5029	7807	2778	287,500	0.8
2022	13.46	8.5	4932	7807	2875	287,500	0.83
2023	13.46	8.5	4932	7807	2875	287,500	0.83
2024	13.46	8.5	4932	7807	2875	287,500	0.83
2025	13.46	8.5	4932	7807	2875	287,500	0.83

As can be seen from the above tables, the energy savings from window units starts at 1.13 TWh in the first year of the program and reaches 1.47 TWh on year 2022 onward. Similarly for split units, the savings starts from 0.61 TWh in 2018 and level at 0.83 TWh on year 2022 onward. The savings are higher from window replacements mainly due to the fact that the number of replaced units is higher than those of split units on yearly basis.

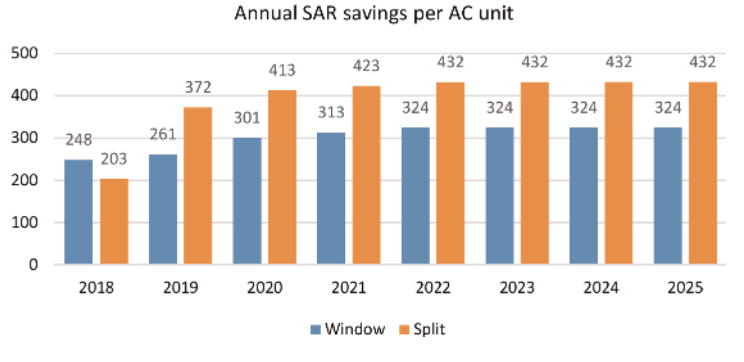
The savings from window and split units are added together in order to get the overall yearly savings along with the cumulative savings.

Year	Savings in TWh from windows	Saving in TWh from splits	TWh (yearly)	TWh (cumulative)
2018	1.13	0.61	1.74	
2019	1.18	0.65	1.83	3.57
2020	1.37	0.77	2.13	5.7
2021	1.42	0.8	2.22	7.92
2022	1.47	0.83	2.3	10.22
2023	1.47	0.83	2.3	12.52
2024	1.47	0.83	2.3	14.82
2025	1.47	0.83	2.3	17.11

As per Electricity and Cogeneration Regulatory Authority (ECRA) open data, the kingdom consumed, in 2017, around 298 TWh of electricity, while 143 TWh of this consumption was in the residential sector alone [30]. Therefore, the cumulative savings from the program would represent 6% of the 2017 kingdom's total electricity consumption and 12% of the residential sector. Of course this percent would reduce over time as the consumption of the kingdom is expected to increase progressively mainly due to more electrification, population growth, and economic development, yet still the numbers are considerable. Moreover, this suggested program would result in a reduction of a yearly average 7.5 million metric ton of CO2 emissions which is basically equivalent to removing 1.38 million cars from the streets or planting more than 27 million trees.

Furthermore, and assuming 80% utilization rate, the cumulative saved energy of 17.11 TWh by 2025 is equivalent to a power plant with around 2.5 GW of capacity. This 2.5 GW represents around 3% of 2017 kingdom's total capacity. The proposed program will help basically in shaving peak loads, reducing energy growth rates in addition to the avoided capital.

It is worth mentioning that the minimum annual SAR savings per AC unit for residential customer varies from SAR 248 to 324 per window unit and from SAR 203 to 432 per split unit depending on EER levels between new and replaced units.



5.2 Economic analysis

5.2.1 Net present value (NPV) and sensitivity analysis

Using 5.3% as commercial discount rates over 20-year impact period of new equipment, the net present value (NPV) summaries are shown below for three different scenarios.

1. Assuming the government will take the burden of the full cost of the new units

Type	$ Billion
PV cost (i = 5.3%)	2.74
PV savings (i = 5.3%)	16.44
NPV (i = 5.3%)	13.7

2. Based on the online survey results, a weighted average of 25% of the cost can be absorbed by the households. Hence, the government will take care of only 75% of the cost, and the results will be as follows

Type	$ Billion
PV cost (i = 5.3%)	2.03
PV savings (i = 5.3%)	16.44
NPV (i = 5.3%)	14.40

3. The capital cost will be transferred solely to non-efficient equipment buyers. Hence, almost no contribution from the government

Type	$ Billion
PV cost (i = 5.3%)	0
PV savings (i = 5.3%)	16.44
NPV (i = 5.3%)	16.44

The third scenario basically uses the "feebate" system where the government transfers the whole cost to consumers, and hence the government will not bear the capital cost of the equipment. They will only need to pay for administration cost although even the administration cost can be transferred to consumers depending on the fee rates on non-efficient equipment.

In summary and as can be seen from the above tables, the NPVs in all the three scenarios are positive with great values, and hence proceeding with the program is vital for the Saudi government at this stage and with any of the above scenarios. Thorough assessment of those scenarios and others shall be performed prior to program deployment and the program administrator shall critically evaluate several factors including, but not limited to, current market situation, manufacturer willingness, retailer/distributer readiness, government funding availability, etc.

A sensitivity analysis has been applied to the NPVs of all the three scenarios to check how sensitive the results are to several selected input variables that have been applied across all the scenarios. Five input variables were selected for the sensitivity analysis, and they are air conditioner cost, assumed EER values of the existing air conditioner fleet, assumed EER values of the new air conditioner fleet, utility discount rate, and the average annual operating hours of air conditioners. The applied variabilities to the input variables were ± 25% for each variable. The below table summarizes the results of the analysis.

Input variables	**Scenario 1 (100% gov.)**		**Scenario 2 (75% gov.)**		**Scenario 3 (0% gov.)**	
	NPV ($ billion)	**% Difference**	**NPV ($b)**	**% Diff.**	**NPV ($b)**	**% Diff.**
AC unit cost (+25%)	13.2	3%	14	3%	16.4	0%
AC unit cost (−25%)	14.5	−7%	15	−4%	16.4	0%
Assumed EER values of existing fleet (+25%)	6.8	50%	7.5	48%	9.6	41%
Assumed EER values of existing fleet (−25%)	24.8	−82%	25.5	−77%	27.5	−68%
Assumed EER values of new fleet (+25%)	18.3	−35%	18.9	−31%	21	−28%
Assumed EER values of new fleet (−25%)	6	56%	6.8	53%	8.8	46%
Utility discount rate (+25%)	11.2	18%	11.9	17%	13.8	16%
Utility discount rate (−25%)	16.9	−24%	17.7	−23%	19.9	−21%
Average annual operating hours of AC unit (+25%)	16.6	−22%	17.3	−20%	19.3	−18%
Average annual operating hours of AC unit (−25%)	10.8	21%	11.5	20%	13.5	18%
Current proposal NPV ($ billion)	**13.6**		**14.4**		**16.4**	

It can be noticed that varying the EER values whether for the existing or new fleets has the biggest impact on the results, while the input variable with the least impact among the five is the air conditioner unit cost. It can be also noticed from the above table that the AC unit cost variable has no impact on scenario three results as in this scenario the capital cost is transferred to non-efficient air conditioner buyers with no contribution from the government. In summary, despite applying aggressive variabilities to key input variables in all the three scenarios, the results still show positive net present values for all the scenarios which indicate that this proposal is valid and also highly recommended for deployment in order to reap such huge benefits.

5.2.2 GDP and employment contribution

In addition to the savings expected to be realized out of implementing the incentive program, there are other economic gains. Using input–output analysis ("I-O"), it was found that the program will add an average of $0.5 billion per year to the kingdom's GDP for the duration of the program. It was also estimated that around 2000 direct and indirect jobs will be created throughout the duration of the program.

The input–output analysis ("I-O") used in the analysis is a form of economic analysis based on the interdependencies between economic sectors. This method is most commonly used for estimating the impacts of positive or negative economic shocks and analyzing the ripple effects throughout an economy.

6. Conclusion

This chapter investigated the savings from a residential air conditioning incentive program rather than detailing the design of the program as this needs specialized entities who should evaluate different factors before designing such program. The proposed 8-year program included residential air conditioning units, namely, window and split, where participants are provided with efficient AC units as a substitute to their existing low efficiency AC units. The program was designed to replace 5.75 million AC units (25% of estimated 2016 stock) over an 8-year period. The proposal was presented under three different scenarios when it comes to the capital cost handling where the government will take care of all the capital cost, 75%, and none of the capital cost in scenarios 1, 2, and 3, respectively. The cumulative estimated savings from the program adds up to 17.11 TWh by the year 2025. Moreover, this suggested program would result in a reduction of a yearly average of 7.5 million metric ton of CO_2 emissions which is basically equivalent to removing 1.38 million cars from the streets or planting more than 27 million trees. Furthermore, the expected NPVs from the program are substantial, and they are $13.7 billion, $14.4 billion, and $16.4 billion under the three different scenarios. From the economics perspective, the program will add an average of $0.5 billion per year to the kingdom's GDP over the duration of the program. It was also estimated that around 2000 direct and indirect jobs will be created throughout the duration of the program.

As incentive programs regularly take care of the initial investment cost of energy-efficient products and hence implicate significant capitalization, the program administrator shall evaluate different experiences from developed and developing nations to instigate the development of new funding mechanisms to suit unique local circumstances such as Saudi Arabia. In addition, such programs will support the country's current efforts to improve the permeation of energy-efficient equipment in the Saudi market. Subsidy programs are essential to balance the present compulsory standards by increasing market permeation of equipment that have better energy performance than current standards requirement, therefore paving the road for further increase in standards stringency in the future. Moreover, the program administrator shall comprehend the fact that the success of such program depends heavily on an outstanding plan in place before the program initiation. The plans shall include monitoring and verification plans along with continuous evaluation plans in place in which a reserved budget for those purposes is crucial.

Acknowledgements

The author would like to extend sincere thanks to Hussien Mohammad, from Saudi Aramco, for his support in obtaining bin weather data for several Saudi cities along with his support in reviewing the EER degradation analysis. Also, the author would like to thank Aabed Saber, from Saudi Aramco, for his contribution in reviewing the chapter and providing useful insights especially concerning the questionnaire.

Author details

Faisal Fahad Al-Musa
Saudi Aramco, Dhahran, Saudi Arabia

*Address all correspondence to: faisal.mousa.1@aramco.com

References

[1] de la Rue du Can S et al. Design of incentive programs for accelerating penetration of energy-efficient appliances. Energy Policy. 2014;**72**: 56-66

[2] Sathaye J, Murtishaw S. Market Failures, Consumer Preferences, and Transaction Costs in Energy Efficiency Purchase Decisions. CA, USA: Public Interest Energy Research (PIER) Program; 2004

[3] Jollands N, Waide P, Ellis M, Onoda T, Laustsen J, Tanaka K, et al. The 25 IEA energy efficiency policy recommendations to the G8 Gleneagles plan of action. Energy Policy. 2010; **38**(11):6409-6418

[4] Murphy L, Meier F. Waking a sleeping Giant: Policy tools to improve the energy performance of the existing housing stock in the Netherlands. In: European Council for Energy-Efficient Economy, Summer Study. France: La Colle Sur Loup. 2011. p. 2011

[5] Hausman J. Individual discount rates and the purchase and utilization of energy-using durables. Bell Journal of Economics. 1979;**10**:33-54

[6] Houston DA. Implicit discount rates and the purchase of untried, energy-saving durable goods. Journal of Consumer Research. 1983;**10**:236-246

[7] Independent Pricing and Regulatory Tribunal (IPART). Compliance and Operation of the NSW Energy Savings Scheme During 2009. Report to Minister, New South Wales; 2010

[8] Balawant J. Best Practices in Designing and Implementing Energy Efficiency Obligation Schemes. Research Report Task XXII of the International Energy Agency Demand Side Management Programme; 2012

[9] Lees E. Energy Efficiency Obligations —The EU Experience. European Council for an Energy Efficient Economy, Briefing for DG Energy on EU Energy Efficiency Obligations on Energy Companies and Their Importance in Meeting Climate Change and Energy Security Challenges; 2012

[10] Taylor RP, Govindarajalu C, Levin J, Meyer A, Ward W. Financing Energy Efficiency: Lessons from Brazil, China, India, and Beyond. Washington, DC: World Bank and International Bank for Reconstruction and Development (IBRD); 2008

[11] Sathaye J, de la Rue du Can S, Kumar S, Iyer M, Galitsky C, Phadke A, et al. Implementing End-use Efficiency Improvements in India: Drawing from Experience in the US and Other Countries. Lawrence Berkeley National Laboratory report LBNL—60035; 2006

[12] Chunekar A, Singh D. A Guide Book on Super-Efficient Equipment Program (SEEP). Pune, India: Prayas Energy Group. 2013

[13] International Energy Agency (IEA). Energy Efficiency Governance; 2010. Available from: www.iea.org/papers/2010/eeg.pdf

[14] Rosenberg M, Hoefgen L. Market Effects and Market Transformation: Their Role in Energy Efficiency Program Design and Evaluation. California Institute for Energy and Environment; 2009. Available from: http://uc-ciee.org/downloads/mrkt_effts_wp.pdf

[15] Eto J, Goldman C, Nadel S. Ratepayer-Funded Energy-Efficiency Programs in a Restructured Electricity Industry: Issues and Options for Regulators and Legislators. Lawrence Berkeley National Laboratory Report LBNL-41479; 1998

[16] Rogers EM. Diffusion of Innovations. 5th ed. New York: Free Press; 2003

[17] Gold R, Nadel S. Energy Efficiency Tax Incentive, 2005–2011: How Have They Performed? American Council for an Energy Efficient Economy White Paper; 2011. Available from: http://aceee.org/files/pdf/white-paper/Tax%20incentive%20white%20paper.pdf

[18] U. S. Environmental Protection Agency (U.S.EPA). Aligning utility incentives with investment in energy efficiency. National action plan for energy efficiency, prepared by Val R. Jensen. ICF Int. 2007. Available from: www.epa.gov/eeactionplan

[19] French Ministry of Sustainable Development. Le Point sur le Crédit D'impôt Déve- loppement Durable. Commissariat General au Developpement Durable, Le Point sur—Numéro147–Octobre. 2012. Available from: http://www.territoires.gouv.fr/IMG/pdf/LPS147.pdf

[20] Pistochini P, Valentini G. The 55% tax reductions for building retrofitting in Italy: The results. In: EEDAL 2011 International Conference. 2011

[21] Salaverría A, Patricia D. Evaluación Ambiental y Plan de Mane jo Ambiental del Programa de Eficiencia Energética Coordinado por la Secretaría de Energía: Informe Final. SENER. KfW Group, World Bank; 2010

[22] Scott D. The energy system. The International Journal of Hydrogen Energy. 1994;**19**:485-490

[23] Al-Musa F, Youssef A, Yassein M. Potential energy savings by switching residential cooking and water heating appliances from electric to LPG in Saudi Arabia. In: ASHRAE Winter Conference. 2016

[24] McNeil Michael, Iyer Maithili, Meyers Stephen, Letschert Virginie, McMahon James E. Potential Benefits from Improved Energy Efficiency of Key Electrical Products: The Case of India. Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory, University of California; 2005

[25] Taner T. Optimisation processes of energy efficiency for a drying plant: A case of study for Turkey. Applied Thermal Engineering. 2015;**80**:247-260

[26] Muller DCA, Marechal FMA, Wolewinski T, Roux PJ. An energy management method for the food industry. Applied Thermal Engineering. 2007;**27**:2677-2688

[27] Lauer M. Methodology guideline on techno economic assessment (TEA). Generated in the framework of ThermalNet WP3B economics. In: Thermal Net TEA Methodology Guideline. 2008

[28] Choi D-H, Xie L. A framework for sensitivity analysis of data errors on home energy management system. Energy. 2016;**117**:166-175

[29] Available from: https://www.surveysystem.com/sample-size-formula.htm

[30] Available from: http://www.ecra.gov.sa/enus/DataAndStatistics/NationalRecord/HistoricalData/Pages/Home.aspx