Scientific Research Publishing

Journal of Power and Energy Engineering, 2022, 10, 1-21
https://www.scirp.org/journal/jpee
ISSN Online: 2327-5901
ISSN Print: 2327-588X

Window Air Conditioners Transition and Restriction in Saudi Arabia

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How to cite this paper: Al Ammar, E. and Dayil, A.B. (2022) Window Air Conditioners Transition and Restriction in Saudi Arabia. *Journal of Power and Energy Engineering*, **10**, 1-21.
https://doi.org/10.4236/jpee.2022.105001

Received: March 5, 2022
Accepted: May 13, 2022
Published: May 16, 2022

Abstract

This paper will provide a proposed solution for saving energy consumption due to residential air conditioners by reducing the window air conditioners type which is the most consumed energy and has a big percent of spreading inside KSA than the split type, also it will discuss some restrictions for trading and manufacturing of air conditioner devices inside KSA besides some restrictions on market and buildings to achieve the objective of reducing the consumption of energy which become a big trend in kingdom vision 2030. The results of this suggesting solution will help the decision-makers to start its plan for execution as it has a big difference between using window type from 2022 till 2030 and if we stop its sales and replace by an efficient one of split AC type in energy consumption in addition to CO_2 emission reduction and decreasing of energy cost, hence our kingdom can save petroleum raw materials and keeping the environment to become clean from pollutants so that these resources are delivered to successive generations correct and clean as we received them from those before us.

Keywords

Air Conditioners (AC), Terawatt-Hour (TWh), Saudi Standards Metrology and Quality Organization (SASO), Energy-Efficiency Ratio (EER) High Efficiency Air Conditioning (HEAC), Carbon Dioxide (CO_2), Heating, Ventilation, and Air Conditioning (HVAC), Saudi Building Code (SBC), Saudi Energy Efficiency Center (SEEC)

1. Introduction

The strong demand for Air-Conditioning in the Kingdom occurs because of extreme solar heating in Saudi Arabia [1]. The Kingdom of Saudi Arabia is one of the nations with much-blessed energy wealth, mostly fossil-fuel oil, and gas, where availability of energy supplies has been a core factor in all industries that

still have and maintain low energy prices for decades, such as industry, transportation, and buildings. Steady growth in per capita electricity use from 2008 to 2015 is recorded, with an average annual percentage increase of 10 percent every year [2], which has an effect on Saudi Arabia's peak demand as shown in Error! Reference source not found, which leads to an impact on the gross domestic product for the kingdom as shown in the Error! Reference source not found (**Figure 1**).

Several researchers have found that air conditioning use is mostly responsible for high electric peak loads. Besides air conditioners and refrigerators, light bulbs are also the third-largest source of energy in the home. Air conditioners are the main cause of high electrical demand during the hot summer months as most air conditioners are running on electricity in Saudi Arabia. With an average temperature in the Kingdom of 45C, due to that the residential, as well as non-residential buildings, have needed (**Figure 2**).

The cooling systems as seen in **Figure 3**, Saudi residential buildings consumed approximately 130 TWh of electricity in 2018, with air conditioning accounting for 66 percent of total electricity demand [3] [4]. Saudi Arabia's Green Initiative and the Middle East Green Initiative, as part of the kingdom's Vision 2030 economic transformation plan, have positioned Saudi Arabia at the forefront of regional attempts to achieve international environmental goals. By 2040, Saudi Arabia, a billion hectares of land will be restored, conserving, and sustainably managed. The Saudi Green project plans to plant 10 billion trees, just as 40 million hectares of damaged lands are restored. The goal is also 4 percent of the global initiative to reverse soil loss and one trillion trees. A similar programmer will be launched for the area by the Middle East Green Initiative. In Saudi Arabia, 50 billion trees will be planted throughout the Middle East with nations [5].

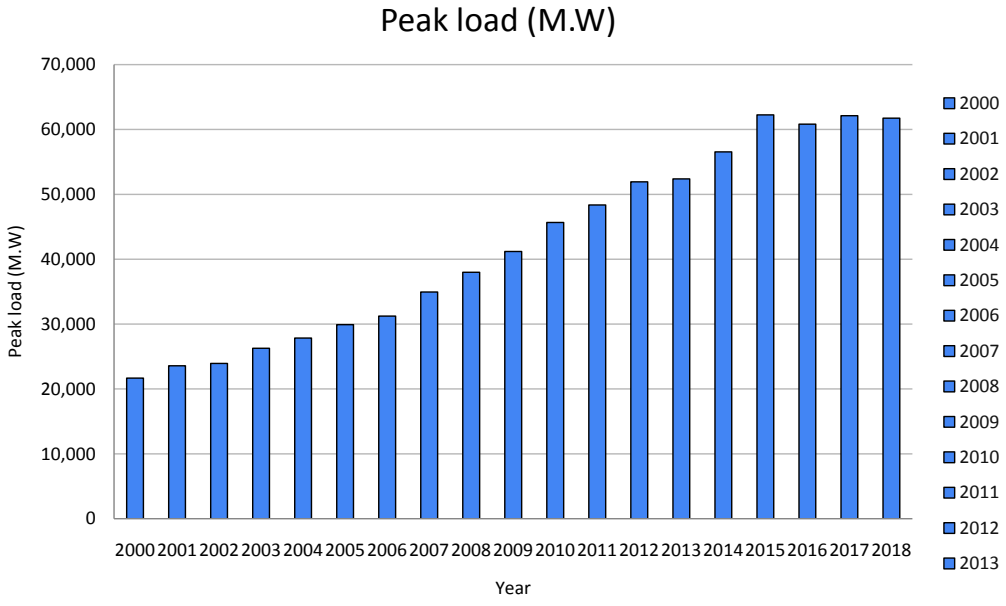

Figure 1. Peak load demand (Source: WERA [1]).

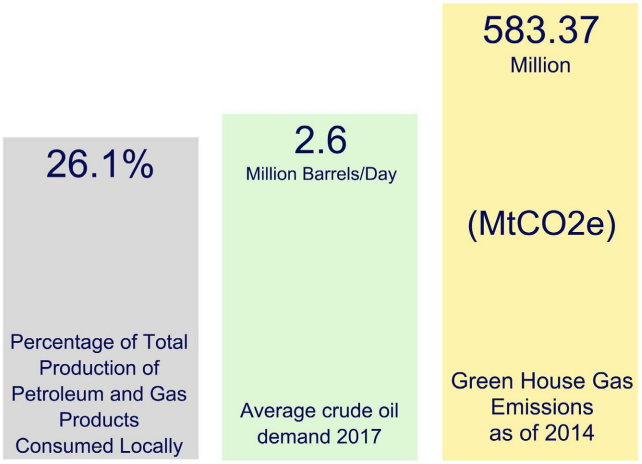

Figure 2. Kingdom consumption's impact (Source: ECRA [1]).

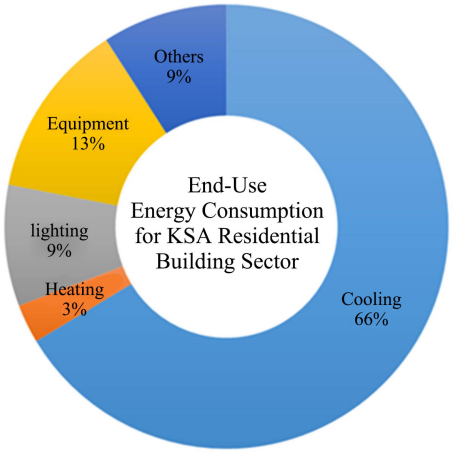

Figure 3. Distribution of KSA residential sector energy consumption by end-use (Source: N. Howarth 2020 [4]).

There is some national regulation in the Kingdom of Saudi Arabia that regulates the energy efficiency of residential air conditioners. The Saudi Standards, Metrology, and Quality Organization (SASO) has made significant efforts to establish the SASO 2663 Energy Labeling and Minimum Energy Efficiency Criteria for Air Conditioners in 2013 and later updated as shown in **Table 1**, which helps to reduce the energy consumed to form the Saudi grid

2. Importance of AC Window Units' Transition

Saudi Arabia is one of the most vulnerable nations to global warming. It has been 40 years since the average temperature in Riyadh and other cities in the country has risen more than 3˚C. Although the country remains the world's third-largest user of electricity for air conditioning (AC) after the United States and China, domestic energy reform and higher AC energy quality requirements have reduced the country's reliance on oil to stay cool [6], Cooling demand would also increase unabated if two feedback loops do not change direction. One is clear and global: the more fossil fuel we use to keep ourselves and our food

Table 1. New EER level according to SASO 2663/2017.

Level	EER Value
A	EER ≥ 16.6
B	16.5 > EER ≥ 14.5
C	14.5 > EER ≥ 13
D	13.0 > EER ≥ 11.8
E	11.8 > EER ≥ 10.8
F	10.8 > EER ≥ 9.8
G	9.8 > EER ≥ 9.0

cool, the more carbon we emit, the hotter the atmosphere becomes, and the more fossil fuel we continue to burn to stay cold. For example, in July 2014, Saudi Arabia burned a record 1 million barrels of oil per day to produce electricity, and air conditioning accounts for more than half of Saudi summer peak power demand. This loop must obviously be broken, both within the Kingdom and more broadly [7]. Air conditioning accounts for more than half of all annual energy use in homes, and about 70% at peak cooling demand. Since 2010, Saudi Arabia's energy use in buildings has increased at an average annual rate of about 6%. Typically, 70% of electricity use is attributed to cooling [3], which caused this trend. Just 10 countries account for 86 percent of the world's window AC devices, according to the Japan Refrigeration and AC Industry Association, although most global markets have largely prohibited or severely limited their use already [8] as shown in **Figure 4** country Share of households that have to air-conditioning (AC) in 2016 [9].

After the United States, Saudi Arabia is the second-largest market for window units in the world, with 772,000 units sold in 2018. As shown in **Figure 5** below Replacement of these purchased window units with the medium standard AC split relevant Saudi Arabian Standards Organization (SASO) will save about 20 terawatt-hours (TWh) of electricity (units) per year [4].

As a result, the use of window AC units is extremely high, and upgrading window AC systems to break or upgrading all AC systems to high-performance units with an EER of 13.0 has the greatest effect on saving both annual energy usage and consumption for all Saudi areas, as seen in **Figure 6** below.

Moreover, the Kingdom currently runs a customer benefit program called the High Efficiency Air Conditioning (HEAC) program, which offers a refund of 900 Saudi riyals (US$240) for each high-efficiency split device unit bought (energy efficiency value [EER] = 13.8 or higher), up to a limit of six units per household. If the HEAC plan is fully adopted, it is estimated that the residential sector will save nearly 35 TWh of electricity per year. This savings account for approximately 24% of the Kingdom's overall residential electricity generation in 2018 (144 TWh), or approximately 35% of total residential AC electricity consumption (101 TWh). Under these assumptions, SASO and HEAC will result in 14 million and 24 million tons of CO_2 annually reduction [3]. The prism of the broader energy industry can largely be used as cooling. A 70% of the country's

residential energy demand is estimated to be satisfied with air conditioners on excessively hot days in Saudi Arabia [7]. As of now, energy use has been a primary cause of greenhouse pollution. Nevertheless, modern technology will further decarbonize energy without forcing consumers to alter their behavior. Refrigeration and air conditioning were responsible for 10% of the world's CO_2 emissions, compared to the 3% caused by transportation [4]. In the context of this requirement, it calls for taking into consideration how technology interconnects with economies, especially individual users' actions. Technology can assist in more efficiently manufacturing, storing, transporting, and utilizing cold and cooling loads. Innovative economic models should be used to direct strategies, and therefore producer and consumer behavior, to minimize energy demand and accomplish other policy objectives [3].

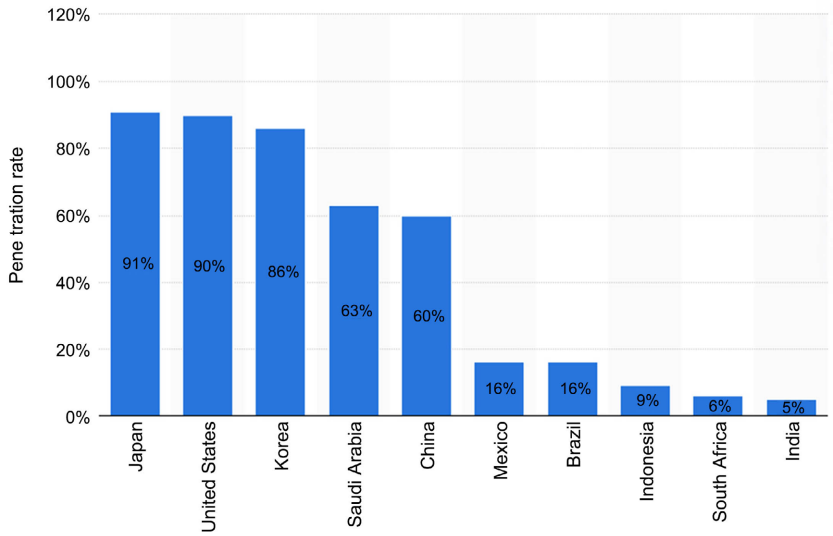

Figure 4. Share of households that have air-conditioning (AC) worldwide in 2016, by country (Source: statista [9]).

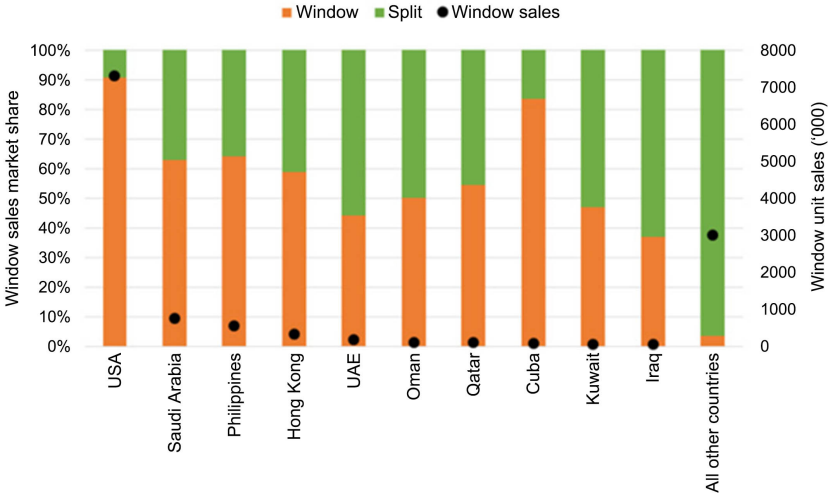

Figure 5. Global market share and sales of window versus split systems for room AC demand (Source: JRAIA [4]).

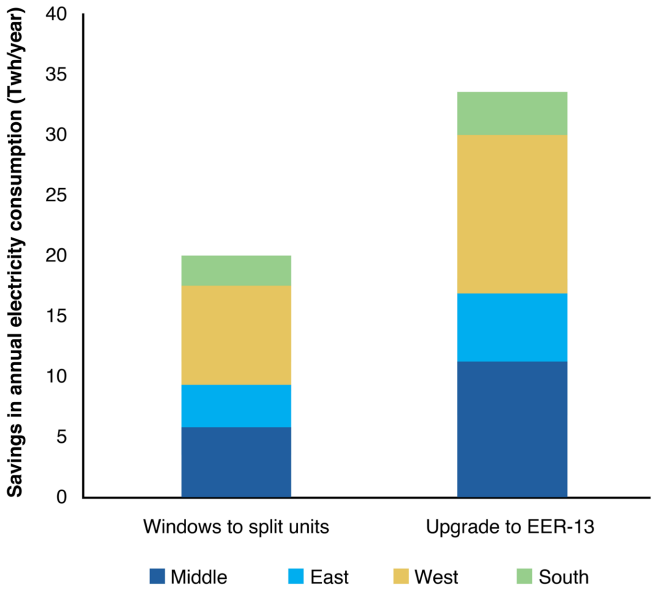

Figure 6. Electricity savings from a phase-out of window units and full implementation of Saudi Arabia's high Efficiency AC consumer incentive scheme (Source: KAPSARC [3]).

3. Worldwide Trend in Air Conditioners Technology: Specifically, in AC Window Units

The rise in residential construction has fueled the growth of the residential construction market and future demographic and economic factors (specific) or demographic/economic (general) looking ahead to make more profits Global population increases would drive overall demand A rush to urbanization more than doubled in 2030. The growth of the middle class stimulates the growth of the market escalation of the standard of living Renovation and Reorganization provides development opportunities the ability on creating opportunities for market share trends, philosophies, plots Consumers are purchasing more and more micro split-air conditioners and mini-surge-based split-air conditioners. The global demand for air conditioning systems is expected to rise by 48.6 million units during the forecast period [10]. Some solutions have been implemented worldwide for the available ac units.

3.1. Air Conditioner Diagnostics, Maintenance, and Replacement

The US Department of Energy's Office of Energy Efficiency and Renewable Energy has published several recommendations aimed at home performance contractors who are largely unfamiliar with HVAC systems, HVAC technicians who can learn from recent studies on AC system defects and diagnostic procedures, and program managers who can use this knowledge to structure effective HVAC tune-up services.

The first phase entails performing a fundamental evaluation and checks that can be performed by home performance contractors that have received BPI (Building Performance Institute) or related instruction to detect or diagnose,

and in certain cases correct, comparatively non-technical problems such as low airflow and clogged condenser coils. The second phase is a comprehensive approach to identifying device faults that are intended to be applied by qualified HVAC technicians. In [11], 65 percent of the 8873 systems tested needed repairs, according to the survey, and in [12], 72 percent of devices had excessive refrigerant fees, and 44 percent had improper airflow, according to field measurements of 4168 air conditioners. This recommendation aims to close the gap between future savings and energy savings in the whole home. The aim of these recommendations provided is to provide simple-to-implement, cost-effective solutions for homeowners [13]. This guidance identifies big issues and in certain situations remedies them at cheap costs, which leads to lower energy charges for heating and refrigeration and increases the homeowner's comfort and protection. Two methods are defined to satisfy various levels of preparation and experience, as well as time and cost limitations. It aims to detect and fix significant issues quickly; the other includes further testing, diagnosis, and remediation to ensure the proper functioning of the devices. The benefits that accrue from maintenance are overly complex, just as the number of problems faced is incredibly large. The repair systems have failed to show consistent energy savings [14]. Nevertheless, the discovery of a significant saving of 38% on air and refrigerant around the Arkansas program is promising [15].

3.2. Using Inverter Products

Inverters are frequency converters that regulate the voltage, current, and frequency of the electrical current. An inverter can power the compressor very precisely. In comparison, shown in **Figure 7** inverter-conditioned motors and heat exchangers consume 58% less energy than traditional ones [15]. An inverter and non-cooling AC of the same capability and type were investigated to measure the variations in the levels of CO_2 emission and consumption. Energy usage was conducted from July 16th to October 31st to discover. The weather and air conditioning remain constant throughout the experiment (18,000 BTU). The results show that when used daily, the inverter will save up to 44 percent of electrical consumption Furthermore, according to the Total Equivalent Warming Impact study, inverters will save up to 49 percent of CO_2 emissions [16]. Another comparison has performed at the Saudi Arabian Standards Organization (SASO) in Jeddah, Saudi Arabia. In the car repair office building, the comparison is conducted in two rooms, which have equal dimensions and have the same number of workers in each. Each space can accommodate three employees.

The entire measurement cycle is 108 days, 24 hours a day, seven days a week. The analysis of two separate units was carried out. One was a 1.50-ton inverter unit with a 13.35 Energy Efficiency Ratio (EER) and the refrigerant R32. The other one was a 1.50-ton non-inverter unit, a 12.15 EER unit, and an R410a coolant. The entire assessment time from July 16 to October 31 is used in the test result review (108 days). In the case that the average daily room temperature differs by 1˚C or less, the temperature should have been set between 22 and 24

degrees Celsius, based on the estimated daily energy intake Figure 8. The estimated daily energy consumption of an inverter air conditioner is 11.6 KWh, while that of a non-inverter air conditioner is 20.8 KWh. This means that the inverter AC saves about 44% of its electricity. The annual electricity uses as seen in Figure 9 below, the inverter R32 unit decreases CO_2 emissions by 49.4 percent as opposed to the non-inverter R410A unit [16].

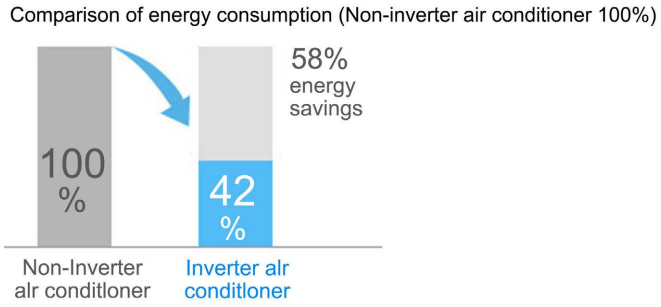

Figure 7. Comparison of energy consumption [15].

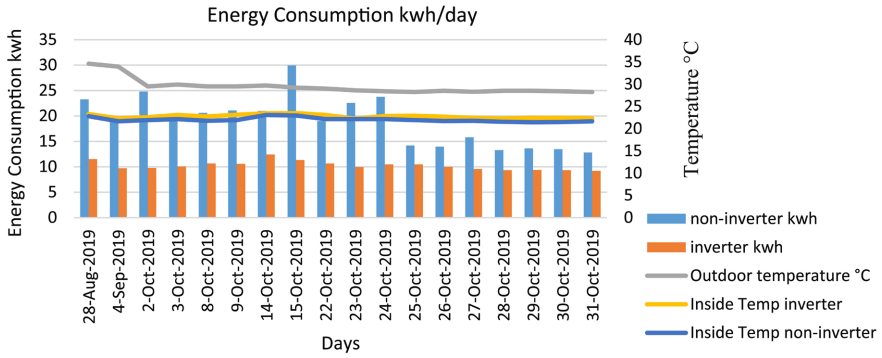

Figure 8. Energy consumption of R32 and R410a [16].

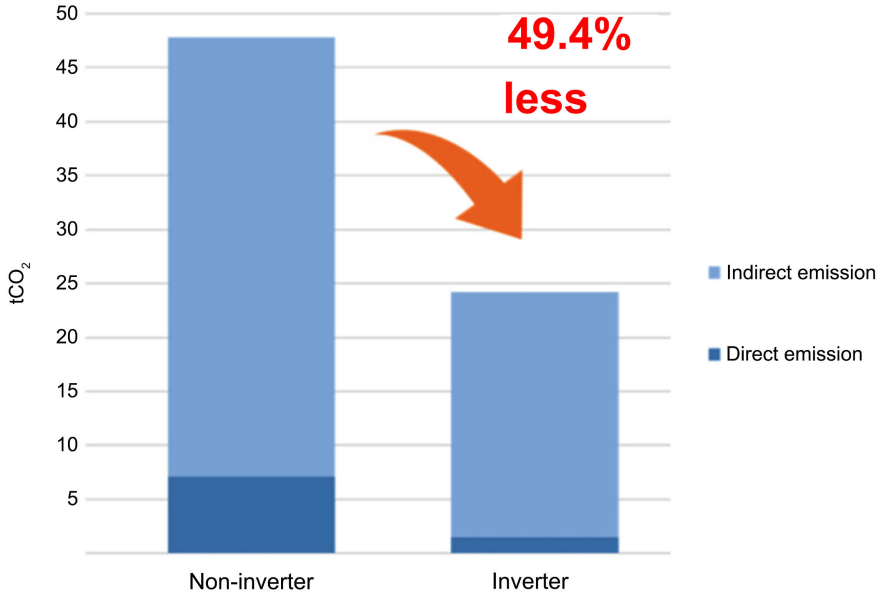

Figure 9. CO_2 direct/indirect emission [16].

The benefit of using inverter air conditioners instead of non-inverter air conditioners, particularly for the weather in Saudi Arabia, is that energy consumption can be reduced. Inverter technologies will offer considerable savings with the projected increase in AC usage and atmospheric temperature rise due to global warming. Furthermore, because of the need to reduce greenhouse gas emissions, the inverter type is more suitable for lowering CO_2 emissions. Seasonal EER more closely represents energy efficiency than EER and switching from EER to Seasonal EER will lead to greater energy efficiency in KSA.

3.3. Regulation for Air Conditioner Use

New rules and guidelines can be published, as has already occurred in Japan and the United States, where regulations for the use of air conditioners have been enforced. Japan established a default setting of 28 degrees Celsius for air conditioners. While in the United States, states such as California have imposed restrictions on reducing the air temperature to 26 degrees Celsius [17]. By November 2020, India has implemented new regulations set by the Bureau of Energy Efficiency (BEE) in collaboration with the central government that require all room air conditioners sold in India to have a default temperature of 24 degrees Celsius [18].

3.4. Removal of Window AC Types

The objective of this initiative is to minimize the use of AC windows. This approach does not apply globally, as was the case for Canada's biggest affordable housing provider, Toronto Community Housing [19], which is owned by the City of Toronto and provides housing for over 60,000 low- and moderate-income families in over 100 of the city's neighborhood hoods. Its 2100 facilities represented a $10 billion public asset in 2008. Adding new air conditioning in high-rise buildings makes maintenance costs higher. In nearly all high-rise and lower-rise buildings, the expense of services is included in the rent and paied by Toronto Community. Few incentives are available for tenants to build and/or use productive appliances to minimize energy consumption. As initial costs for an AC unit are always a question for renters, many units are bought on the secondary market or at the lowest possible rate. These are usually high-energy-consumption models that do not run at their optimal performance. Further energy inefficiencies (winter and summer) are created by worse AC systems as well as also safety issues. In 2007, a consultancy was hired to do a detailed study of the state of the AC unit installation, and the report's summary results are as follows: Approximate number of buildings with window air conditioners was 400+, approximate number of window air conditioners in operation was 16,000, and the average age of window air conditioners was 5 to 10 years [20], Toronto Community Housing Corporation (TCHC) declared on December 2, 2019, that balcony AC units are no longer appropriate In addition, the TCHC declared that the AC Exchange program would be expanded and that the window AC units in building 3 or

higher flowers should be removed with a better AC unit [21]. This project's aim is to help the environment by decreasing both the consumption of electricity and greenhouse gases, by making current and future buildings more energy-efficient, either through retrofits or using sustainable architecture concepts.

3.5. Incentives for Using Efficient AC

The Kingdom is currently running a High-Performance Air Conditioning (HEAC) initiative that provides a refund of 900 Saudi riyals (US$240) for each high-efficiency split device unit bought (energy efficiency value [EER] = 13.8 or higher), up to a limit of six units per household. Another initiative launched by Austin Energy is to enable citizens to purchase ENERGY STAR-window air conditioners, which consume up to 15% less energy than standard ones. Austin Energy is offering a $50 discount to assist you in purchasing a new ENERGY STAR qualified window air conditioner. They also have considered whole-house energy quality upgrades by Home Performance with ENERGY STAR® whether your home is 10 years or older. Their participating Home Performance contractors will do an energy audit to assess the most cost-effective energy-saving upgrades for your home [22]. Austin Energy has included an extra $600 refund for programs on April 15, 2021. Rebates from Austin Energy for this service usually range between $1800 and $2500. Austin Energy partners with Velocity Credit Union to offer zero-interest funding for eligible Rebate & Loan programs [22]. Since 2007, the Italian government has offered a 55% tax deduction on the cost of replacing heating, ventilation, and air conditioning (HVAC) facilities with more efficient units, as well as on the cost of other home efficiency improvements. In December 2010, the scheme included a 20% tax exemption for repairing old refrigerators. A new tax exemption of 50% has been proposed for the substitution of white items such as refrigerators, dryers, washers, ovens, freezers, and gas cookers [23]. Canada has many refund options for replacing the home convenience devices, such as furnaces, air conditioners, and water heaters. The Ontario Heating and Cooling Incentive is an excellent example of this. It is open to businesses and homeowners who have bought and installed qualifying central heating or central air conditioning systems from a participating provider. You will get up to $650 of such benefits including [24]: When you upgrade the old heater with a modern high-efficiency unit, you will gain $250. An Electronically Commutated Motor is needed in your new central heating system (ECM). Up to $400 save if purchasing a new central air conditioner, 250$ when a certified ENERGY STAR® model has been purchased and installed, $400 for the purchase and installation of a more energy-efficient device Alberta is promising a few rebates, including up to $1500 for window AC replacement and up to $1000 for tankless water heater replacement.

4. Demand Side Management: Different Approaches

The chapter discussed the different approaches that can be followed to control

the use of AC window units. Several solutions with their details can be studied from different perspectives of each on the consumption, CO_2 emission, cost of energy, and so on. With a market value of $2709 million in 2019, the Saudi Arabian heating, ventilation, and air conditioning (HVAC) market is expected to reach $3197.4 million by 2030, rising at a CAGR of 3.2 percent over the projected period (2020-2030) as shown in **Figure 10**. The sector is being driven by increasing infrastructure investment and the country's growing hospitality industry [25]. It required a look at the HVAC Saudi market.

In 2019, the Central area accounted for the lion's share of Saudi Arabia's HVAC industry, owing to the large number of commercial projects completed in and around Riyadh. In addition, the country has four cities with populations over one million, 20 cities with populations between 100,000 and one million, and 45 cities with populations between 10,000 and 100,000. Due to the high population centers being where new developments can be built, the Central area is now the most profitable for heating, ventilation, air conditioning, and refrigeration projects [26]. It can expose some of the restrictions on using the non-efficient AC units as a suggestion to our government decision-makers to eliminate the effect of AC units as general and Window type as especial and can study in four places.

4.1. Restrictions on the Import of AC Units

The government can encourage the national industry of AC units by its regulations that can meet the demand for energy-saving and efficient types of AC units like what happens in India and this only targets the low-efficiency units from entering the kingdom. The Indian Government prohibited imports of "air conditioning with coolants" in October 2020. "The import regulation for some types of air conditioners has been changed from free to banned," the Directorate General of Foreign Trade announced in an Oct. 15 announcement. In accordance with Atmanirbhar India's policies, the government aims to reduce the import of non-essential commodities and encourage domestic manufacturing [27].

4.2. Restrictions on the Manufacturing of AC Units

The government can control the quality level of industry and used material inside AC units and hence it can eliminate the effect of AC units on the environment, especially the global warming phenomena and CO_2 percentage by using good refrigerants like what happened in the European Union. For single split systems, it appears important to use R32 refrigerators rather than R410A, which has been the traditional refrigerant option in the past, since R32 has a temperature effect that is less than a third that of R410A while providing equal or better energy and cost performance [16]. An assessment of the current EU market shows that most single split systems sold in the EU no longer use R410A. [18] The energy efficiency of R32 is much higher than that of the previously used refrigerant (known as R410), and the governments should require the producers to use a refrigerant with a more friendly global warming effect on the environment.

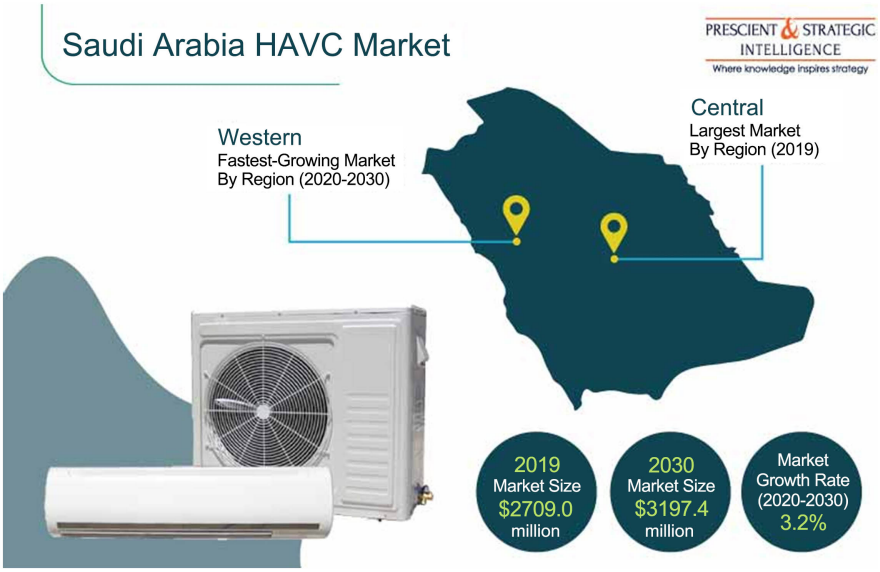

Figure 10. Saudi Arabia HVAC market (Source: SEEC [25]).

4.3. Restrictions on the Trader in Saudi Markets for AC Units

With such expected growth in the HVAC market in Saudi Arabia to reach $3197.4 billion by 2030. it is important to set rules and control the market Strong measures for controlling the quality of air conditioner goods should be taken by the government and draft SASO 2663:2021, where authorized SEER (Seasonal Energy Efficiency Ratios) **Table 2** to be used instead of EER before quality control should be increased [20], and expect to raise the MEPS (Minimum Energy Performance standard) to satisfy the need for lower energy usage by requiring our market to use energy-efficient air conditioners.

Essentially, the government should be investigating three large-scale energy efficiency-enhancing programs [4]: 1) Enforce compliance with new MEPS standards on all existing air conditioners. This policy requires the replacement of old air conditioners with modern systems that meet energy efficiency ratio (EER) ratings of 9.8 for window units and 11.8 for split units. This policy reduces annual electrical demand to 18.3 TWh and greenhouse emissions to 13.0 million tons. 2) Increase the MEPS standards for window units' EER ratings or replace them with split units with a minimum EER of 11.8. This scheme would save 20.0 TWh of power demand and 14.3 Million Tons of carbon dioxide annually. 3) All Saudi households should be encouraged to upgrade their air conditioners with systems with a minimum EER rating of 13.0, as recommended by the High Efficiency Air Conditioners (HEAC) initiative. If fully adopted, the initiative has the potential to reduce annual energy use by 33.6 TWh and carbon emissions by 24.0 Million Tons.

4.4. Restrictions on the Buildings Used AC Units

The updated Saudi Building Code (SBC) was announced to the public in November 2018 by the National Committee of the Saudi Building Code (SBC). The

Table 2. SEER levels according to SASO 2663:2021 draft [25].

Bar Color/Class	EER value
A	EER ≥ 16.6
B	16.5 > EER ≥ 14.5
C	14.5 > EER ≥ 13
D	13.0 > EER ≥ 11.8
E	11.8 > EER ≥ 10.8
F	10.8 > EER ≥ 9.8
G	9.8 > EER ≥ 9.0

new SBC standards and processing programs are designed to improve the energy efficiency of new buildings. However, the current 5.47 million housing units would still generate a huge cooling demand [28]. The government took several steps to prevent a potential economic recession caused by high energy demand, including establishing a new SBC, activating SEEC, ceasing to subsidize utilities such as water, power, and fuel, and developing proposals for renewable energy sources. Current residential buildings need more advancements for thermal conductivity control through the building walls (envelope). To identify the need for future developments, it is necessary to analyze and measure the energy use of existing buildings. Recent improvements in building energy use and consumer behavior have not yet been studied [29]. Recently, building codes were issued for neighborhoods in the city of Riyadh and this should be circulated to all regions of the Kingdom. Building codes can be used by adding restrictions on non-energy-saving air conditioners or window air conditioners.

5. Result and Discussion

After discussing the different approach that can help for using more efficient residential AC units inside KSA and control for reducing the percent of window AC type which represent about 73% of the total quantity of residential AC units in KSA in 2019 in addition to the low EER level of most window AC types used inside KSA which may be level G and little for level F, so it should explain in next chapter the importance of removing or reducing this percent of window AC type by numbers and show the effect of replacing the non-efficient window AC unit by another efficient split AC unit within the period of 2020-2030 which will have very good effects on reducing the energy consumptions in the residential sector, CO_2 emission reduction and reducing the energy cost of generation. As this solution is more effective and has low cost and has low consequences after implementation compared to other solutions. Removal of AC window type practically, this suggestion will be hard to implement in a short time, but it can be implemented by a long-term plan and for most places using window AC type, and consumes more energy, but if this suggestion is implemented in Saudi Arabia and replaces all window AC units by an efficient split AC units, it will be more effective on the Energy consumption and CO_2 emission. This solution is dis-

cussed above with Canada's largest social housing provider (Toronto Community Housing). According to the General Authority Statistics information of 2019, the number of different types of air conditioners in KSA is 18.3 M units for windows air-conditioners and 6.65 M units of split air conditioners [28]. Thus, the percentage of Windows is about 73.4% of total AC units while the split type is 26.6% of total AC units inside KSA. As there is a growth rate of 3% each year in both split or window units, as represented in **Figure 11**: Forecasted AC share in Saudi Arabia till 2030 for the period of 2019 till 2030.

As the implementation of removal suggestion is extremely hard as it will be more expensive so the suggestion will be stopping the window AC units from market to sale and replace by efficient split AC units from 2022 till 2030 Thus, it can decrease the percentage of Windows to be 58% instead of 73.4% of total AC units while split type increases to be 42% instead of 26.6% of total AC units inside KSA. This leads to decreasing the total energy consumption as illustrated below in **Figure 12** flowchart of calculation and methodology used in this study.

Imagine the importance of the removal of window AC units, it should be known that the reference data used to calculate the difference which matching the contribution of AC units from the kingdom load profile. The reference scenario is in **Tables 3-6**.

All new AC units will sale inside KSA for the residential sector will be according to EER 13 for 24,000 BTU and EER 12 for 18,000 BTU. The results show in terms of energy consumption for the period of 2022-2030, there is a saving of around 0.2155 TWh which represents 11% of Energy saving as shown in **Figure 13**, the energy consumption compression for the baseline and suggested scenario is 299 TWh and 250 TWh, respectively.

As the energy production is expensive and according to Levelized Cost of Energy and our value in 2018 for LCOE High-end cost with 73$/MWh and LCOE High-end cost with 44$/MWh, so we can get this chart of cost for the consumption related to air conditioner units of the residential sector at KSA as in **Figure 14** and **Figure 15**, and could collect these costs for both types of Low end and high end from 2020 to 2030 as **Table 7**.

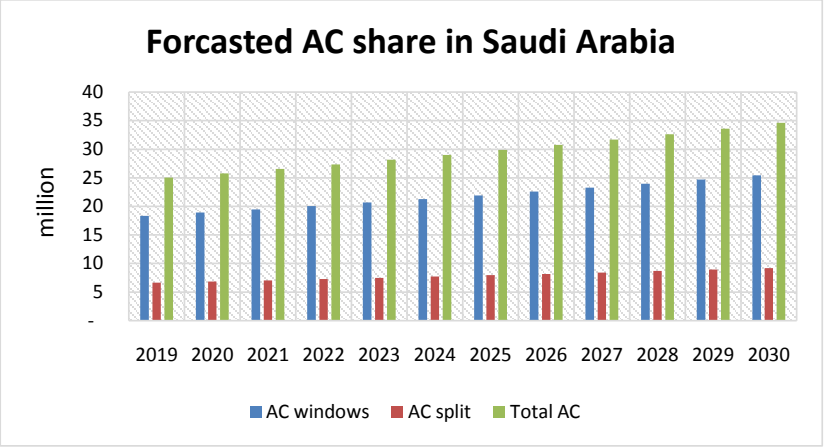

Figure 11. Forecasted AC share in Saudi Arabia till 2030.

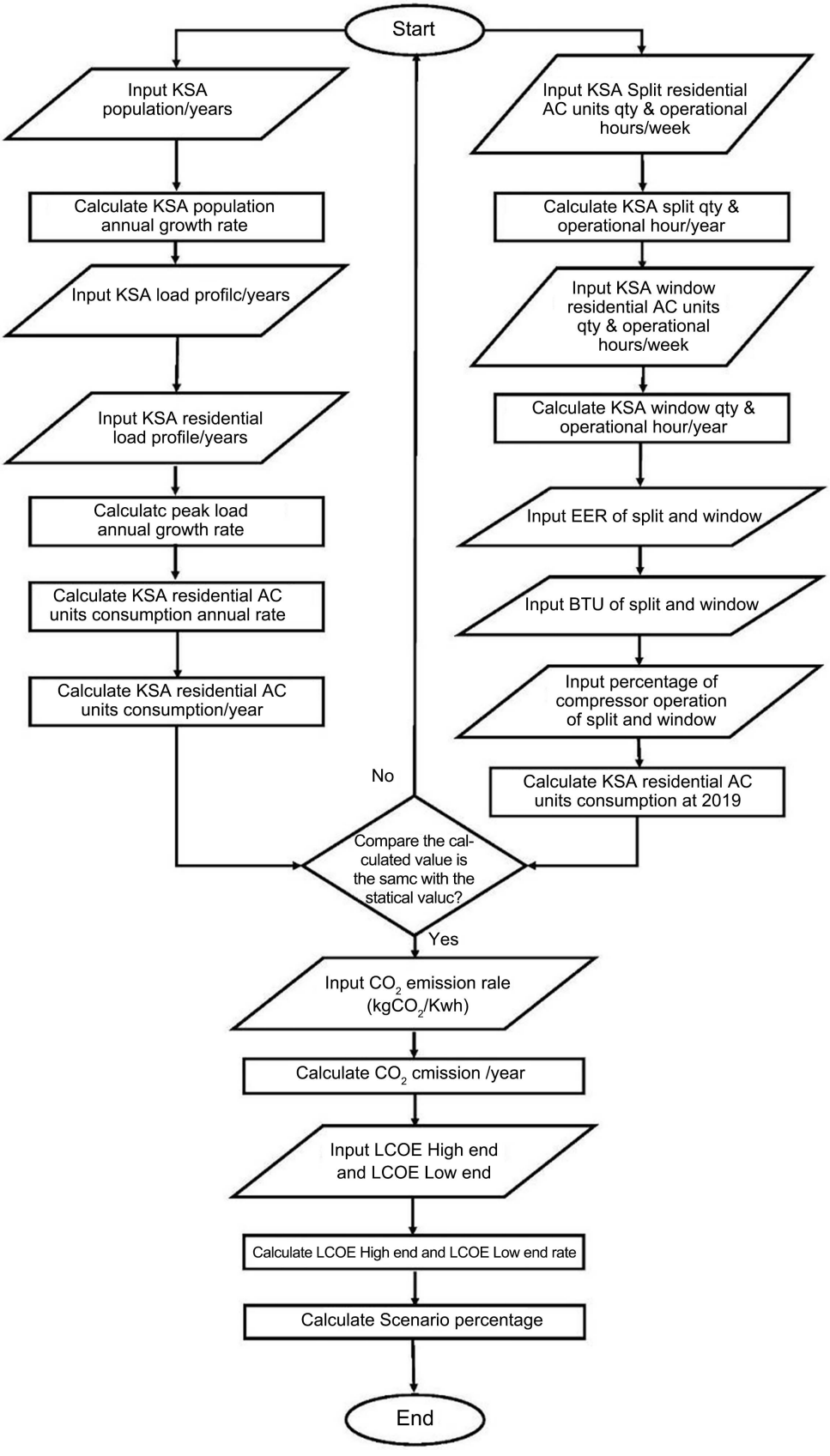

Figure 12. Flowchart of calculation and methodology used.

Table 3. Baseline scenario parameters.

Sector	Def.	%
Electricity Sector	Customers Annual growth rate 2018-2040	4.20%
	Electricity Consumption (GWh) Annual growth rate 2018-2026	3.70%
	Electricity Consumption (GWh) Annual growth rate 2026-2030	4.00%
	Peak load (MW) Annual growth rate 2018-2040	3.00%
	kWh/Capita Annual growth rate of 2018-2040	2.00%
	I nstalled capacity Annual growth rate 2018-2040	5.00%
Population	Contribution of Riyadh city for (Central Region Residential sector)	61.04%
	Population Annual growth rate	4%
Load Profile	Contribution of AC units form Load profile	64%
LCOE	Cost of generating electricity using Gas Combined Cycle "Maximum cost"	73.00$/MWh
	Cost of generating electricity using Gas Combined Cycle "Minimum cost"	44.00$/MWh

Table 4. Baseline scenario parameters.

Split Air conditioners quantity in Riyadh City	6,654,878	EER1 of AC unit	13
Split Average operational hours /Week Winter	18	Btu unit 1	24,000
Split Average operational hours /Week Rest	65	Percentage of Btu 1	20%
Percentage of ac Split units working with full Compass "Required"	35%	EER2 of AC unit	12
Percentage of ac Split units working with 50% Compass "Required"	65%	Btu unit 2	18,000
		Percentage of Btu 1	80%

Table 5. Baseline scenario for window units.

Window Air conditioners quantity in Riyadh City	18,359,820	EER of AC unit	9.5
Window Average operational hours /Week Winter	23	BTU unit	18,000
Window Average operational hours /Week Rest	70		

Table 6. Consumption of the Baseline scenario of the year 2019.

Split consumption TWh/year	30.42
Window consumption TWh/year	168.23
Total consumption TWh per year	198.65

Table 7. Cost of Low and High end cumulative.

Saving Low End (Billions)	$9.86
Saving High End (Billions)	$16.37

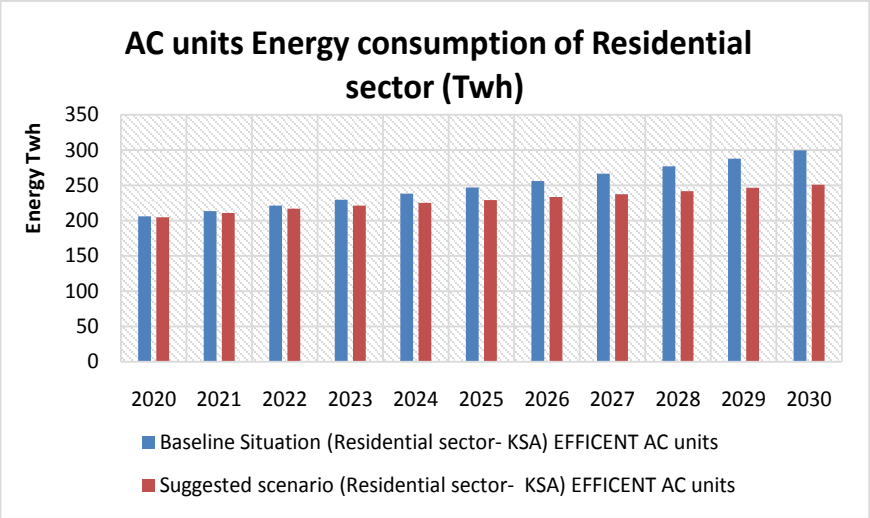

Figure 13. Forecasted AC share in Saudi Arabia till 2030.

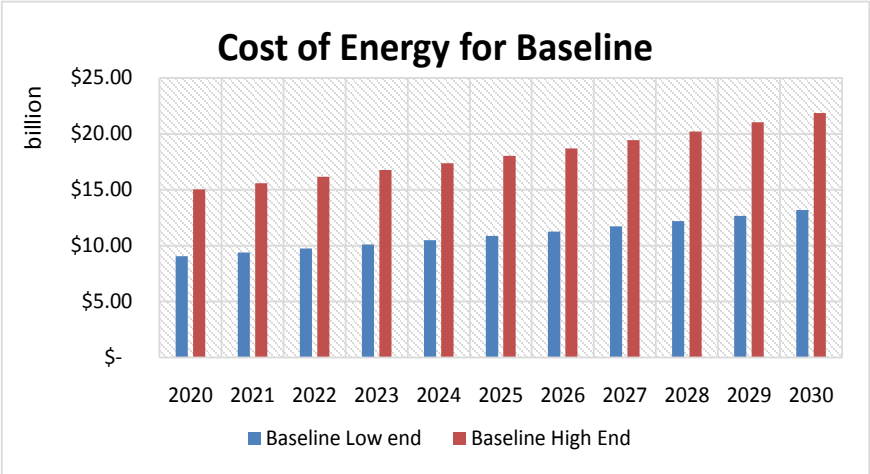

Figure 14. Cost of energy for baseline.

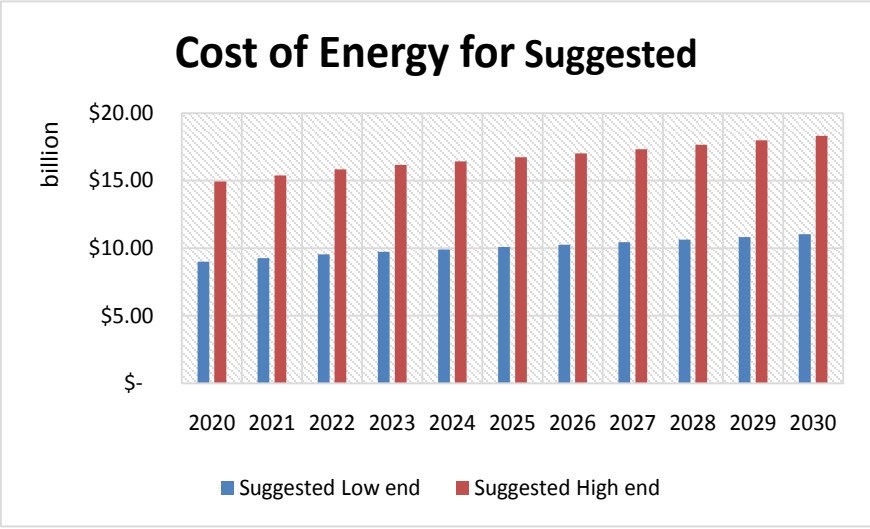

Figure 15. Cost of energy for suggested.

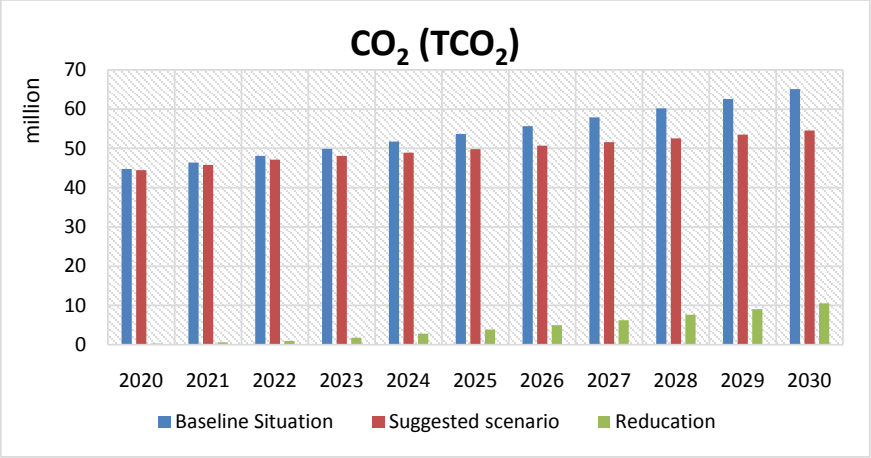

Figure 16. Forecasted AC share in Saudi Arabia till 2030.

Saudi Arabia is the third country globally for energy consumption due to AC units so we need to know how can help in solving global warming by reducing CO_2 emissions if we apply one of our suggestions by reducing the number of window AC units.

Figure 16 is expected according to the consumption of AC units in the residential sector at KSA and the CO_2 emission intensity which is 217 Tons CO_2/GWh.

6. Conclusions

In a conclusion, and answering the question that is "will we get the benefit if we implement a restriction of selling AC windows in the market?" First of all, The cost of an efficient AC split unit in the Saudi market is higher by 30% after the refund from the government compared to a non-efficient AC window, but the problem It isn't promise a return on investment for the end-user in addition to that it can get the solution of high energy consumption and get the KSA demand for reducing this consumption used due to residential AC units which represent about 64% of the total consumption of KSA where the main reason is the window AC units which represent about 73% of the total quantity of AC units used inside KSA for Residential sector.

The result shows the difference of using new efficient split AC units instead of window AC units in the period 2022 till 2030, it has a good effect for all branches like Energy consumption and Energy cost, around 215 k Gwh of energy saved lead to reducing pressure on the gross domestic product in terms of petroleum. The government could save around 1.2 B$ per year and only by implementing restriction on selling AC window in the market for 8 years only, 1.2 B$ represent around 0.2% of the yearly kingdom budget. Also, in cost-benefit analysis, the kingdom required only a regulation to implement this suggestion no major financial investment will be paid. For the Environmental effects of around 50 k TCO_2 emissions reduction of implanting this solution, this could work with The Saudi Green Initiative which targeting to element 130 M TOC_2 and Cut carbon

dioxide emissions in the Middle East.

The government could implement a full roadmap that includes Restrictions on the import of AC units, Restrictions on the manufacturing of AC units, Restrictions on the trader in Saudi markets for AC units, and Restrictions on the buildings using AC units. Providing restrictions on the market means some businesses will have closed, for example, the assembly line of AC window in Saudi Arabia and available stock in the market which required the government to provide solutions for these issues like exporting the available stoke or so. Some new technology should be introduced to the industry in Saudi Arabia like the refrigerator R32 which is a promising technology that has a high impact in terms of energy-saving and CO_2 reduction.

All stockholders in the electricity field must contribute and assist in saving electrical energy, which led to saving petroleum raw materials and keeping the environment to become clean from pollutants so that these resources are delivered to successive generations correct and clean as we received them from those before us.

Last, the social impact has not been measured in this study since this solution has not been implemented worldwide it is required to know the impact of this solution like how the society sees this solution and what is their opinion of the forbidden AC window in the market? Will they support this decision or not?

Data Availability

The data that support the findings of this study are openly available S. A. in S. Arabia, "Statistical Authority in Saudi Arabia Database", 2020, reference number [20].

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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