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Residential Energy Model for Evaluating Energy Demand and Energy Efficiency Programs in Saudi Residential Buildings

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Key Points

The Residential Energy Model (REEM) simulates Saudi Arabia's residential building stock, disaggregated by building type, vintage, and location, using an engineering bottom-up approach.

It utilizes open-source data and building codes to estimate energy use intensity according to building characteristics and climate.

REEM can assess total energy consumption and peak demand for each building type and vintage in different climates, disaggregated by province or region.

The model can evaluate the impact of various energy efficiency measures and demand-side management on total consumption and peak demand, providing policymakers with useful insights for designing energy efficiency programs.

Summary

This paper describes the development of the Residential Energy Model (REEM) for Saudi Arabia using an engineering bottom-up approach. The model can assess energy demand for the current residential building stock and the impact of energy efficiency and demand-side management programs. It accounts for the makeup and features of the Kingdom's existing housing stock using 54 prototypes of residential buildings defined by three building types, three vintages, and six locations representing different climatic zones. Using the resulting 54 prototypes, total demand can be estimated on provincial, regional, and national levels. The regional and national levels can then be calibrated against actual reported data for energy consumption associated with the country's four primary regions — central, east, west, and south — for any year to adapt to future changes in the housing stock.

The model utilizes open-source data provided by the government and other sources to simulate the entire building stock, disaggregated by the above three characteristics. It then allows calibration for unobserved qualities that affect electricity consumption, including consumption patterns, certain thermal characteristics, and appliance usage. The calibrated model provides useful insights on how electricity consumption and peak demand vary with building type, vintage, and location. It also disaggregates consumption by end use to determine the highest contributors to energy demand.

After calibration, REEM can evaluate the economic and environmental impacts of different energy efficiency retrofit options at 'micro' and 'macro' levels, individually or in combination. The model can also estimate the reduction in both energy consumption and peak demand associated with implementing specified retrofits, again disaggregated by building type, vintage, and location. Thus, REEM can assist policymakers in upgrading building codes and designing impactful energy efficiency programs for Saudi Arabia's residential sector.

Introduction

Residential buildings dominate the demand side of the electricity sector in Saudi Arabia. From 2009 to 2018, homes accounted for around 50% of total electricity consumption in the Kingdom, far more than commercial or government structures (SAMA 2019). Due to the hot climate, air conditioning (AC) alone comprised 64% of household electricity use as of 2019.

Until several years ago, residential electricity consumption grew swiftly alongside the country's steadily expanding housing stock. From 2007 to 2018, household electricity use increased 45%, driven by a 73% rise in housing units (SAMA 2019). However, the two trends have since diverged. Housing demand, especially from younger segments of the population, has continued to climb, to the extent that in early 2020, the Ministry of Housing launched an initiative to develop 200 million square meters of new residential projects around the country (Al Riyadh 2020). Yet since 2016, electricity consumption growth has decelerated significantly across all sectors, including residential buildings, largely due to government efforts to reform the energy sector and rationalize electricity markets. These have resulted in higher consumer electricity prices and increased energy efficiency, depressing demand.

Over the last two decades, the government has gradually introduced stricter standards and regulations to curb energy consumption in the building sector. Since 2001, the authorities have implemented and regularly updated minimum energy performance standards (MEPs) for refrigerators, freezers, washing machines, and air conditioners (SASO 2012, 2013, 2014b, 2018a, 2018b, 2018c, 2018d). In 2010, the government established the Saudi Energy Efficiency Center (SEEC), which "aims to rationalize and increase the energy efficiency in production and consumption in order to preserve the [Kingdom of Saudi Arabia] KSA natural resources and enhance the economic and social welfare of KSA population" (SEEC 2020). Regulators also adopted new thermal requirements in 2014 to improve the energy performance of new residential buildings. However, the energy efficiency of buildings in Saudi Arabia remains low, partly due to the difficulty of enforcing regulations (Alrashed and Asif, 2014; Shenashen, Alshitawi, and Almasri 2016; Krarti, Dubey, and Howarth 2017).

Energy efficiency retrofits can decrease both fuel consumption and the need for electricity generation capacity, potentially making them very cost-effective investments. Given their modest upfront costs and high rates of return, targeted energy efficiency programs will often prove attractive for households and businesses. Krarti, Dubey and Howarth (2017) found that Saudi Arabia has significant potential for energy savings through energy efficiency requirements, not only in new construction, but also through retrofitting energy systems in existing buildings. Their study estimates that in 2014, a nationwide retrofit program that included AC and insulation for Saudi Arabia's existing building stock could have saved over 100 terawatthours per year (TWh/year), or 25% of the Kingdom's total electricity consumption, and reduced its peak demand by 25 gigawatts (GW), or 27%.

This paper describes the methodological underpinnings of the Residential Energy Model (REEM) from the perspective of assessing the economic and environmental benefits of retrofitting Saudi Arabia's existing residential building stock. Our analysis considers the impacts of a wide range of energy efficiency measures (EEM) on both energy consumption and peak demand, for 54 prototypes of residential buildings defined by type, vintage, and location (climatic zone). The remainder of the paper is organized as follows. The first section outlines the characteristics and energy performance of the Kingdom's existing housing stock, based on reported data and surveys. The second section describes REEM and walks through its calibration using reported energy consumption data for the residential sector disaggregated by region. Finally, the paper concludes by utilizing REEM to assess Saudi Arabia's residential building stock in 2018 to illustrate the model's output.

Residential Building Stock Characteristics and Data Collection

Constructing a bottom-up model for the entire building stock of a country or region can be complex due to the uncertainty surrounding many parameters that shape energy demand. Two of the most difficult aspects are the physical characteristics of houses and the electricity usage patterns of households, both of which require granular data; these are necessary to simulate the current stock and estimate baseline electricity consumption. The General Authority for Statistics (GaStat), a government agency responsible for conducting surveys in Saudi Arabia, publishes two annual reports from which REEM directly incorporates data: the Housing Survey and the Energy Household Survey (GaStat 2018a, 2018b). These resources provide the number of housing units, total cooled floor area, total heated floor area, energy usage, number of appliances, and other such information, disaggregated by building type, vintage, and/or province. REEM utilizes the GaStat data, in conjunction with other published studies related to the Kingdom's housing sector, to create energy models for the 54 prototypes of housing units according to type, vintage, and location (climatic zone). These prototypes can be used to estimate 54 different energy use intensities (EUI) which can be then used to estimate the total electricity consumption in the residential building stock based on total livable areas of each building type, with different vintages, in different locations, as provided by GaStat.

After the model simulates the residential building stock, it can be calibrated and verified against actual electricity consumption data for the same year by region (central, east, west, and south) from the Electricity and Cogeneration Regulatory Authority (ECRA). ECRA provides an annual report on the electricity market in Saudi Arabia, which includes electricity sales broken down by suppliers, and electricity consumption by sector and geographical region (ECRA 2018). The calibration mechanism adjusts certain parameters for which data can neither be found publicly nor directly estimated, such as lighting intensity, the energy efficiency of certain equipment, and usage patterns.

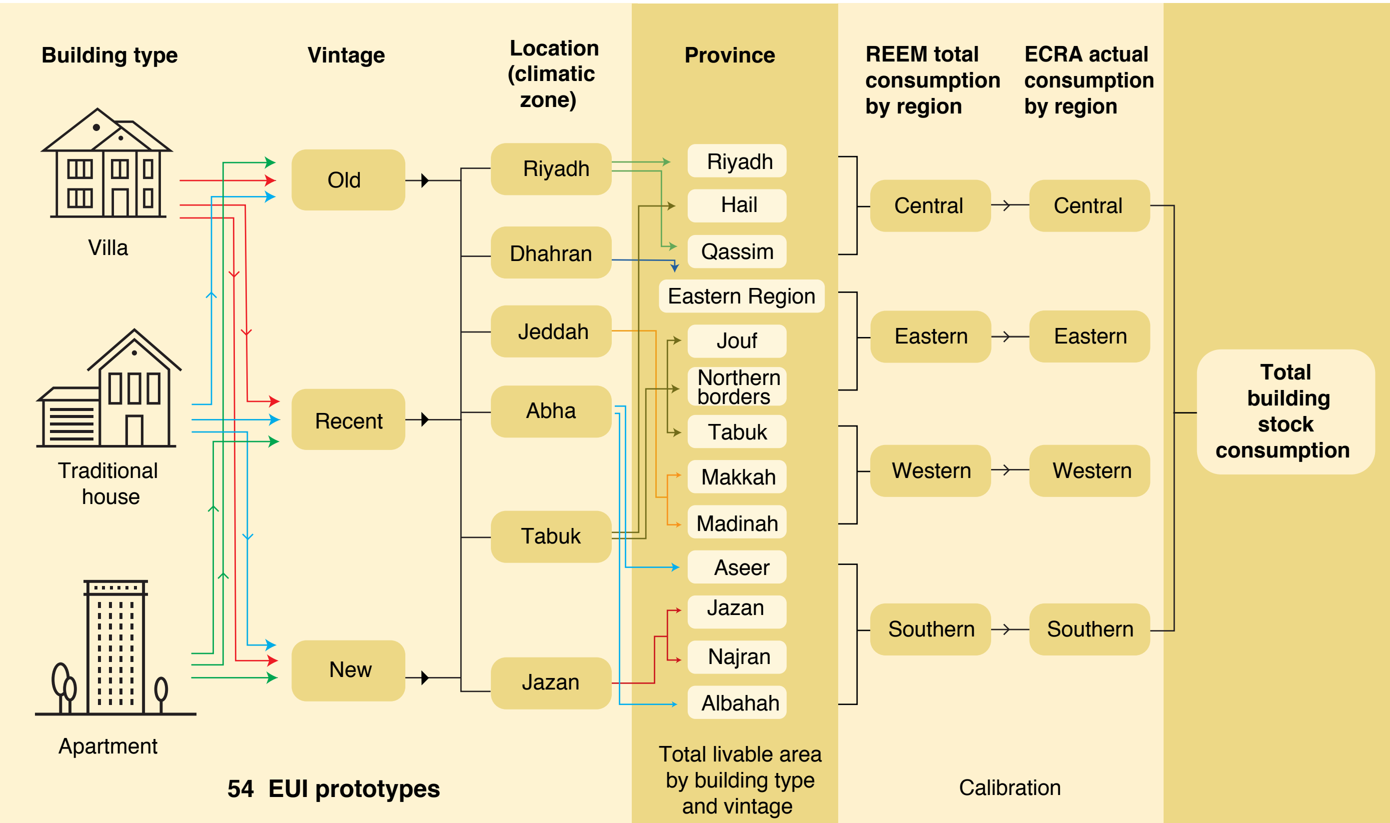
Description of the Residential Building Stock Model

REEM Development

The literature commonly features two approaches to predict energy demand and, hence, the energy consumption of building stocks.

- Top-down modeling methods correlate energy demand with other variables such as climatic parameters (e.g., degree-days, outdoor temperatures) and econometric factors (e.g., energy prices, income levels). These approaches rely heavily on historical datasets and are widely used in macroeconomic analyses (Edmonds, Wise and MacCracken 1994; Sailor and Lu 2004; Kyle et al. 2010).
- Bottom-up frameworks utilize building model prototypes representative of the building stock to estimate energy consumption and end uses. The outputs for the individual models are added using statistical or engineering analysis approaches to estimate the aggregated values for the entire building stock (Swan and Ugursal 2009; Kavgic et al. 2010; Oladokun and Odesola 2015). The number of representative building models varies widely depending on the application and the diversity of building stocks (Caputo, Costa, and Ferrari 2013; Davila, Reinhart and Bemis 2016; Luddeni et al. 2018).

Figure 1. REEM framework for the residential building stock in Saudi Arabia.



Source: KAPSARC.

REEM applies a bottom-up approach using deterministic engineering analysis of 54 representative building prototypes to predict electricity consumption and peak demand for the residential building stock in Saudi Arabia. The model can then evaluate the effectiveness of a wide range of energy efficiency programs targeting existing buildings. Figure 1 illustrates the residential building prototype framework used in this study.

This study considers three characteristics to represent Saudi Arabia's residential building stock: building type, vintage, and location (climatic zone).

Building type: Housing units available in Saudi Arabia comprise three primary types: villas, apartment units, and traditional houses. We define their respective characteristics using data collected from reported energy audit studies (Taleb and Sharples 2011; Algarni and Nutter 2013; Alaidroos and Krarti 2015). Table 1 summarizes the main features of the housing types. The prototype energy models have been calibrated as shown in Figure 2 based on the actual electricity consumption of these three reported energy audit studies.

Table 1. Building construction specifications for the three building types.

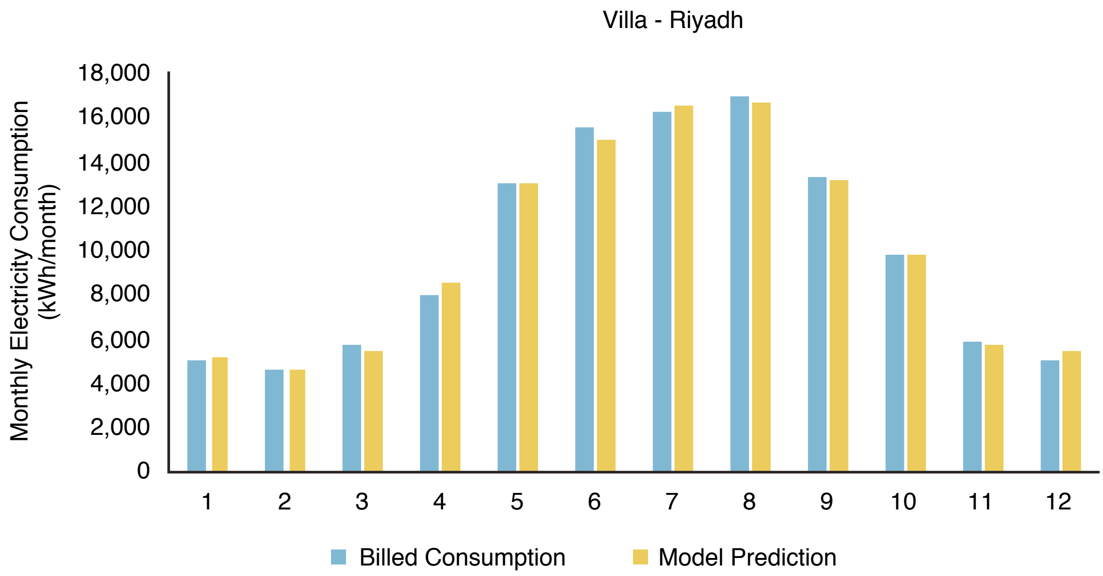
Building model	Villa	Apartment	Traditional house
Number of floors	2	3	2
Total floor area	525 m^2	1,260 m^2	232 m^2
Wall construction	20 mm plaster outside + 150 mm concrete hollow block + 20 mm plaster inside		
Roof construction	10 mm built-up roofing + 200 mm concrete roof slab + 13 mm plaster inside		
Floor construction	Ceramic tile + 100 mm concrete slab on grade		
Glazing	Single-clear with wood frames		
Window-to-wall ratio	13%	15%	15%
Infiltration	0.8 ACH	0.8 ACH	0.8 ACH
Cooling set point	23°C	24°C	24°C
HVAC system	Split DX	AC window	AC window
EER	7.5	8.5	8.5
Occupancy period	24-hour/day	24-hour/day	24-hour/day

Note: ACH = air change per hour; EER = energy efficiency ratio; HVAC = heating, ventilation and air conditioning; m^2 = square meters; mm = millimeter

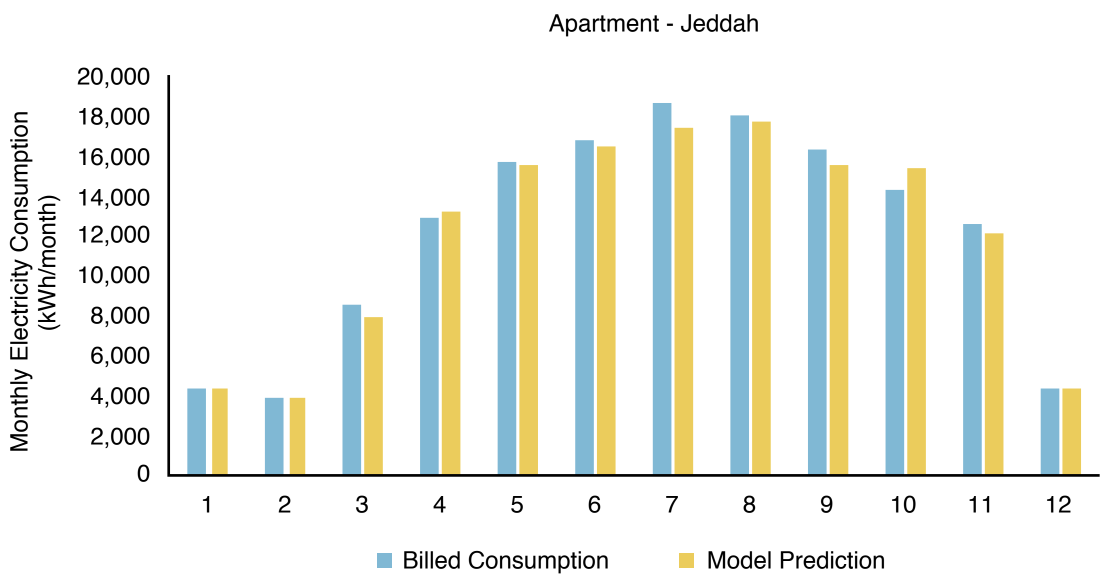
Sources: Taleb and Sharples 2011; Algarni and Nutter 2013; Alaidroos and Krarti 2015.

Figure 2. Calibration analysis results of housing prototype energy models.

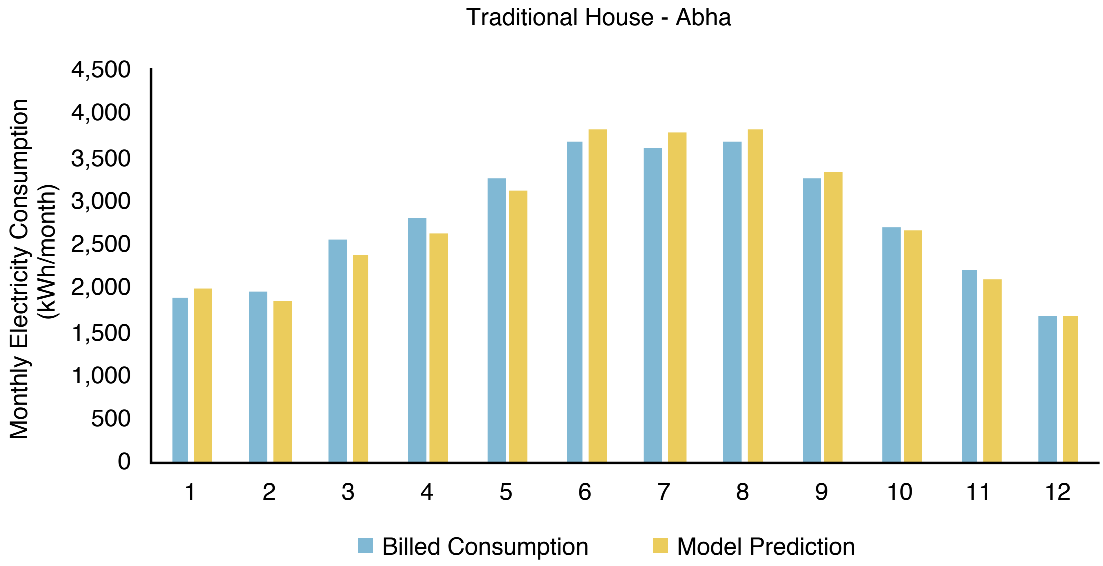
Villa (compared to data from Alaidroos and Krarti [2015])



Apartment (compared to billed data from Taleb and Sharples [2011])



Traditional house (compared to billed data from Algarni and Nutter [2013])



Vintage: Vintage reflects a housing unit's energy consumption efficiency. As of 2018, 33% of houses in Saudi Arabia were less than 10 years old, but only 20% were insulated (GaStat 2019). This is partly because mandatory thermal insulation was only implemented in 2010 (SEC 2020). The Saudi Standards, Metrology and Quality Organization (SASO) has been regularly updating the minimum energy performance requirements for different sectors, including buildings. Thus, a building's vintage, on average, reflects its efficiency in terms of insulation and numerous other parameters, such as window and roof specifications. Moreover, older buildings are generally in poorer condition and in greater need of renovation (GaStat 2018). This study defines three vintage classifications.

- Model-N: new construction (typically less than five years old, includes wall insulation, roof insulation, double-glazed windows)
- Model-R: recently built housing (between five and 10 years old, includes thermal insulation in walls and roof, but single-glazed windows)
- Model-O: old buildings (over 10 years old, no thermal insulation, single-glazed windows)

The annual GaStat Housing Survey provides data for the age of housing units in Saudi Arabia by province and dwelling type (GaStat 2018a).

Location: The energy performance of housing depends heavily on its geographic location and associated climatic conditions. Saudi Arabia comprises 13 provinces, typically grouped into four administrative regions (central, east, west, and south). While SASO building-envelope thermal requirements define only three climatic zones for the Kingdom, a study by Alrashed and Asif (2015) proposed five, represented by Jeddah, Riyadh, Dhahran, Tabuk, and Abha. For greater precision, this study incorporates climatic data for six different locations (Jeddah, Riyadh, Dhahran, Abha, Jazan, and Tabuk) that represent the range of weather conditions in the country, as summarized in Table 2.

Table 2. Geographical distributions, weather specifications, and weather classifications for Saudi Arabia.

Region	Province	Representative city	Cooling degree-days* (°C-days/year)	Heating degree-days* (°C-days/year)	SASO climatic zone	Weather condition
Middle	Riyadh	Riyadh	5,688	291	Zone-1	Riyadh
	Hail	Hail	4,428	601	Zone-2	Tabuk
	Qassim	Burydah	5,361	389	Zone-2	Riyadh
East	Eastern Region	Dhahran	5,953	142	Zone-1	Dhahran
	Al-Jouf	Al-Jouf	4,128	859	Zone-2	Tabuk
	Northern Borders	Turaif	3,395	1,168	Zone-3	Tabuk
West	Tabuk	Tabuk	5,359	571	Zone-2	Tabuk
	Makkah	Makkah	7,549	0	Zone-1	Jeddah
	Madinah	Madinah	6,680	9	Zone-1	Jeddah
South	Asir	Abha	3,132	486	Zone-3	Abha
	Jazan	Jazan	7,347	0	Zone-1	Jazan
	Najran	Najran	5,605	12	Zone-1	Jazan
		Al-Bahah	5,543	11	Zone-2	Abha

Source(s): * Al-Hadhrami (2013).

This study developed energy models for the 54 different housing prototypes (all possible combinations of building type, vintage, and location, from the three types, three vintages, and six locations defined) to represent the energy performance of Saudi Arabia's existing residential building stock. We generate the energy consumption values, $EC_{c,v,l}$ for the building energy models through detailed simulation analysis. Thus, the following equation represents the overall energy consumption, EC_S, of residential building stock, made up of N_S housing units:

$$EC_S = \sum_{c,v,l} f_{c,v,l} \,.\, N_S . EC_{c,v,l} \qquad (1)$$

Where $f_{c,v,l}$ corresponds to the fraction of housing units that belongs to each combination of building type, vintage, and location. As an alternative to Eq. (1), the energy consumption of the building stock can be predicted using the floor area related to each set of characteristics, $A_{c,v,l}$, and the energy use intensity (EUI), $EUI_{c,v,l}$, values that can be derived for the detailed simulation analysis of the 54 building energy models:

$$EC_S = \sum_{c,v,l} A_{c,v,l} \,.\, EUI_{c,v,l} \qquad (2)$$

GaStat (2018) reports the vintage distribution (i.e., $f_{c,v,l}$) for the entire housing stock for each province, and the data needed to estimate floor areas by building types and provinces (i.e., $A_{c,v,l}$). Thus, the energy consumption associated with the residential building stock can be estimated as follows:

$$EC_S = \sum_{c,v,l} f_{c,v,l} . A_{c,v,l} . EUI_{c,v,l} \qquad (3)$$

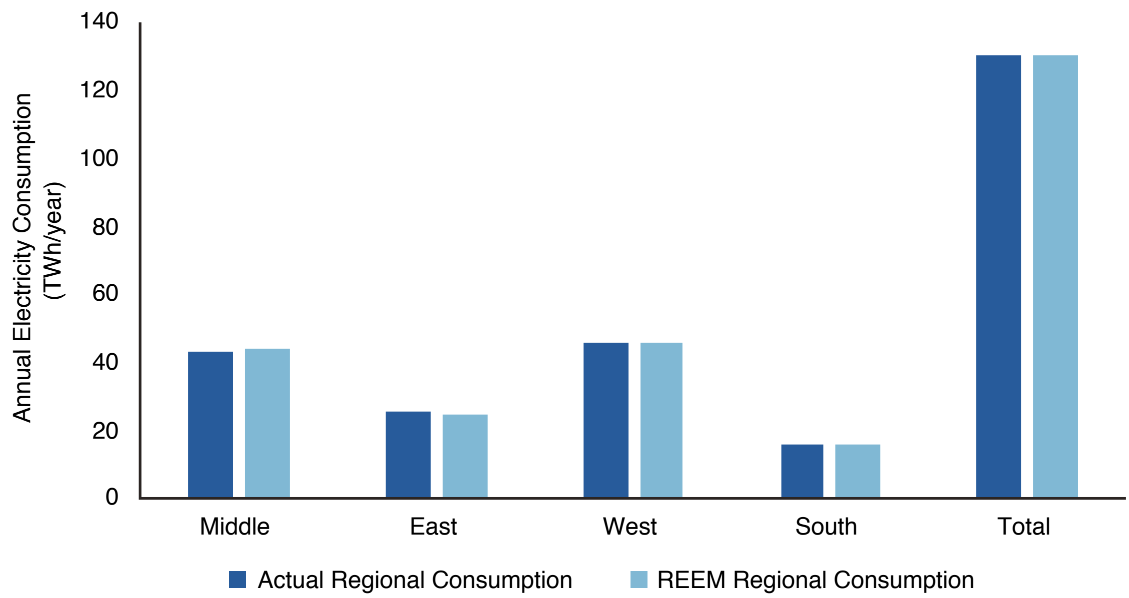
The bottom-up stock model represented by Eq. (3) can predict energy consumption for hourly, monthly, and annual timescales. The following section presents the calibration methodology to estimate the contribution of each region to total national electricity consumption.

REEM Calibration

As described in the previous section, regional energy consumption is estimated by applying the EUI of each prototype to the corresponding total livable floor area for each building type and vintage in each province (as depicted in Figure 1). The total energy consumption of each province is aggregated into the four Saudi regions (central, east, west, and south). This allows us to calibrate REEM against the actual regional consumption reported annually by ECRA. Due to the lack of publicly available data for certain building stock characteristics, such as lighting intensity, the energy efficiency of equipment, and usage patterns, and the inability to directly estimate them, the model's parameters can be adjusted to achieve a reasonable match with actual consumption.

As an example of the calibration flow, we simulated the residential building stock for 2018 and calibrated the results against actual electricity consumption by sector reported by SAMA (2018). Figure 3 illustrates the predictions of the building stock model for total energy consumption in the four regions and the entire country after a systematic calibration procedure. Specifically, three main parameters have been adjusted for the energy models specific to the building types and vintages:

Figure 3. Comparison between REEM predictions and reported electricity consumption by region (2018).



Source: SAMA (2018).

(i) AC system energy efficiency ratio (EER) for new housing vintages was adjusted to 9.0 to reflect minimum SASO efficiency requirements (2018a);

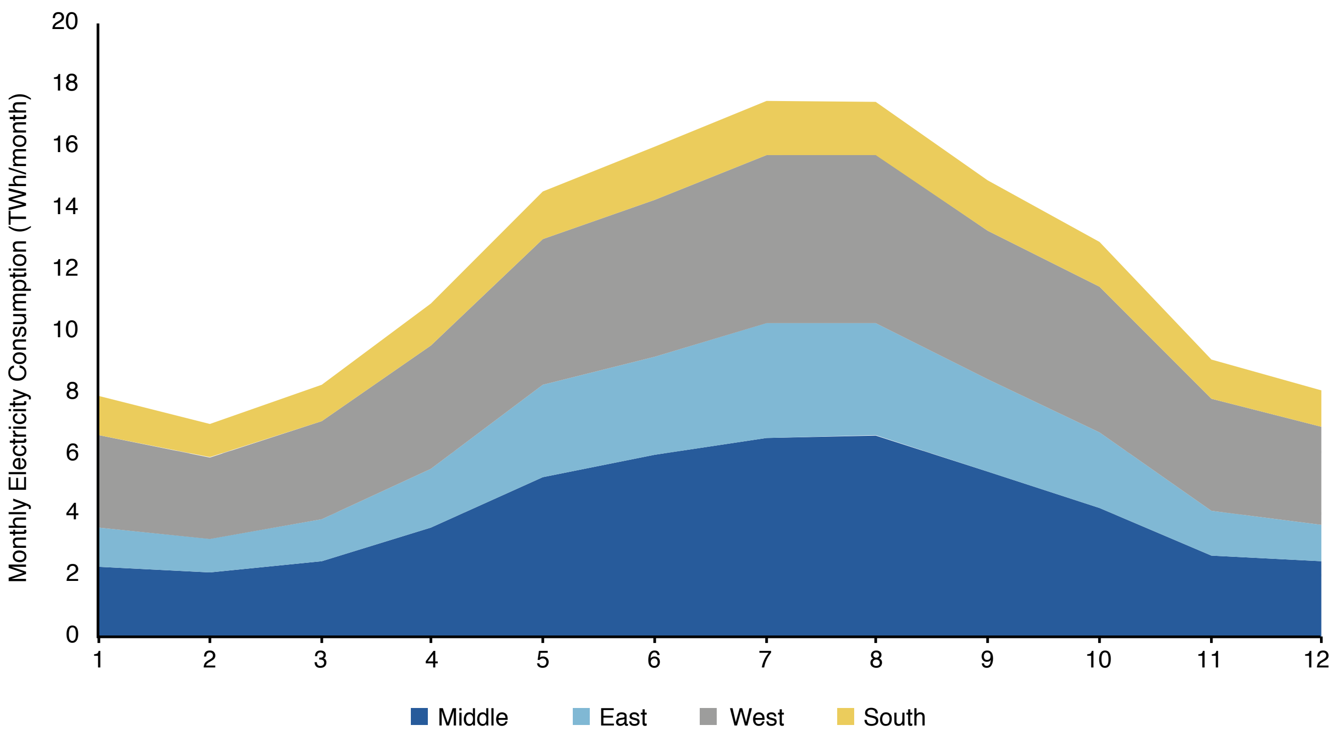
(ii) fan pressure drop for the AC was lowered (because most systems are ductless);

(iii) lighting power density was decreased to reflect the more prevalent use of compact fluorescent lamp (CFL) and light emitting diode (LED) lighting fixtures in recent years, even in old buildings.

After the calibration procedure, we achieved a good agreement between predictions from the building energy stock model and reported SAMA data, with relative errors of less than 2% for all regions and the entire country.

The model provides a distribution of the total energy consumption for residential building stock by housing type, vintage, and location. This can help policymakers determine the potential of each category and design effective energy efficiency programs. For example, REEM indicates that in 2018, single-family villas and apartments consumed the most electricity among housing types, representing 32% and 31% of total residential electricity use, respectively, followed by 21% for traditional houses and 16% for other categories such as floor units in subdivided villas and traditional houses. Villas and apartments represent 70% of the livable floor area of the Kingdom's residential buildings. Therefore, tailored programs specific to villas and apartments should be prioritized to improve the energy efficiency of the existing residential building stock.

Figure 4. REEM estimated 2018 monthly electricity consumption by residential sector and region.



REEM can also determine monthly electricity consumption by residential buildings in Saudi Arabia, categorized by housing type, vintage and region. These results can deliver useful insights into how household energy use responds to changes in ambient temperature throughout the year, and hence which energy standards and energy efficiency retrofits would be most effective. For instance, in 2018, we observed high electricity demand during the summer for the central and western regions, both characterized by high population density and hot climates, as shown in Figure 4. For such areas, energy efficiency measures that decrease space cooling loads would be effective in reducing both energy consumption and peak demand. The more temperate and sparsely populated southern region, on the other hand, did not significantly contribute to the nationwide increase in demand during the summer. Furthermore, REEM provides the annual end-use distribution of energy consumption, disaggregated by building type, vintage, and location, for space cooling, space heating, lighting, equipment, hot water, and other functions.

Evaluation of Energy Efficiency Measures

Following calibration, in its second phase, REEM assesses energy efficiency retrofits in terms of total electricity consumption and peak demand reductions. The model considers a wide range of EEMs that can improve various building energy systems by retrofitting the following:

- building envelope components (adding insulation with different R values[1] to walls and roofs, replacing single-pane windows with double-paned ones, reducing air leakage, adding window overhangs);
- lighting systems (using high-efficiency lighting);
- appliances (replacing refrigerators, freezers, washing machines, dryers and other appliances with Energy-Star rated equipment);
- air-conditioning systems (using more efficient cooling systems with higher EER ratings or using different air-conditioning technologies);
- occupancy behavior changes defined by cooling temperature settings (e.g., increasing the cooling set-point by 1 degree Celsius (^{o}C) or 2^{o}C, especially for unoccupied rooms);
- roofs (deploying 'cool roof' reflective coating on outer roof surfaces).

REEM can apply the above energy retrofits individually or combine two or more to estimate the effectiveness of different packages of EEMs, factoring in thermal interaction. Evaluating energy efficiency retrofits individually can help policymakers identify the highest priority upgrades, along with their economic and environmental impacts. Combining different EEMs can guide more complex policy options. With EEM prices surveyed, REEM can also calculate the rates of return and payback periods from both household and government perspectives (the latter will be especially relevant for policymakers evaluating financing or monetary incentives).

[1] Insulation R-value is expressed in RSI ($m^{2.o}C/W$) and R ($hr.ft^{2.o}F/Btu$).

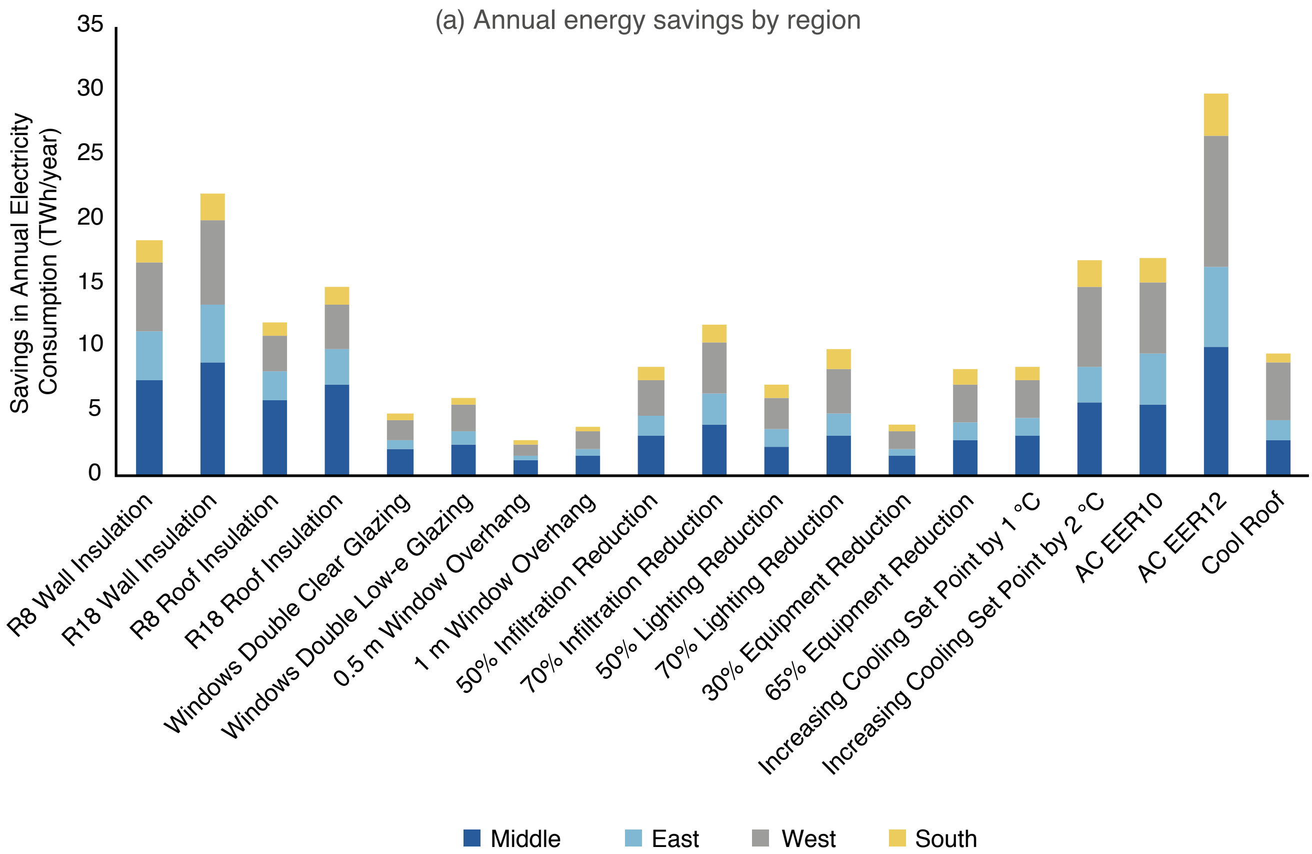
Application: The Impact of Different Energy Efficiency Measures

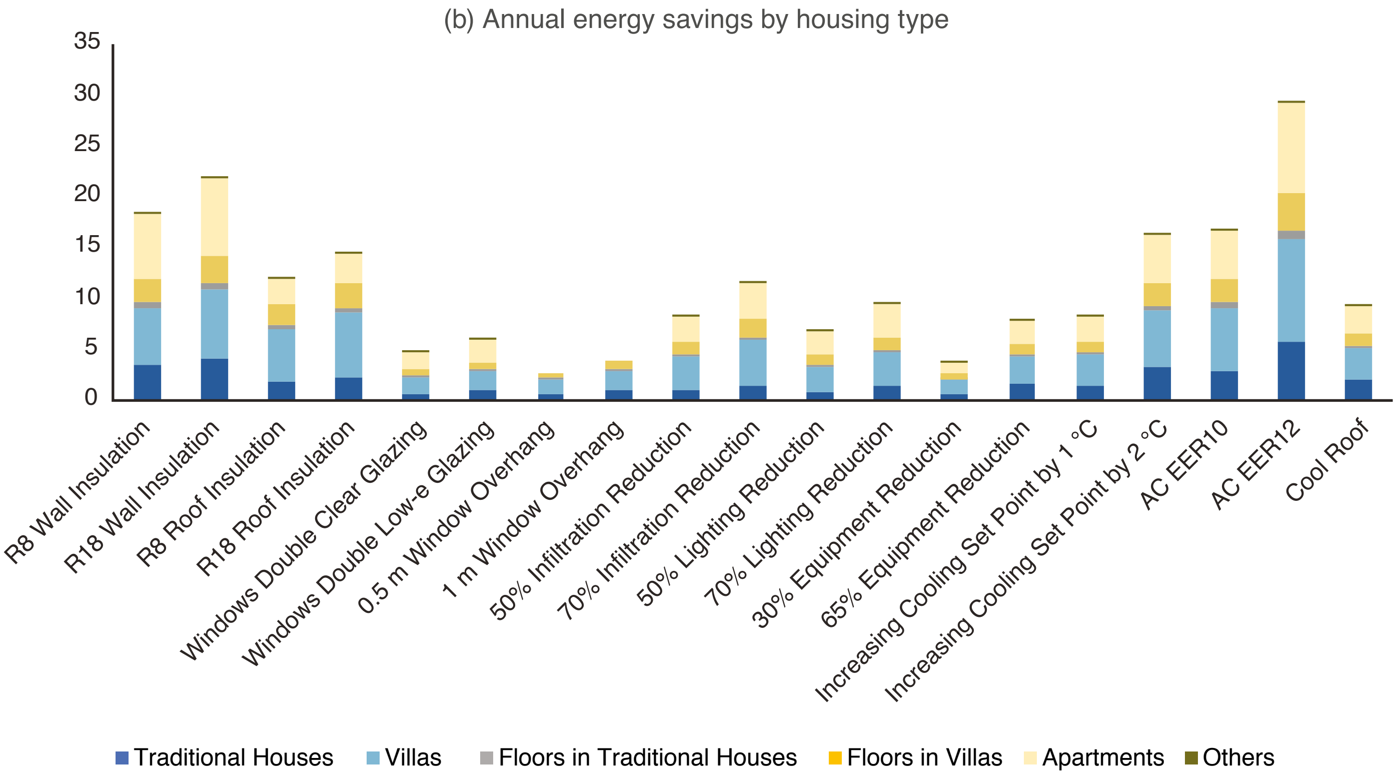
We utilized REEM to estimate the possible electricity savings in 2018 from the application of a set of energy efficiency measures with the below specifications:

- wall (R8) and roof (R18) thermal insulation
- double-clear and low-emissivity window glazing
- one- and two-meter window overhangs
- 50% and 70% reduction in air infiltration
- 50% and 70% reduction in lighting electricity consumption
- 30% and 65% reduction in equipment electricity consumption
- increasing the cooling setpoint by 1°C and 2°C
- enhancing the AC unit's EER to 10 and 12
- coating the roof with highly reflective material (SR=0.6)

The results of the analysis, depicted in Figure 5, confirm that retrofitting AC systems has the greatest potential for reducing the energy consumption of Saudi Arabia's residential building stock. Other impactful retrofit measures include the addition of thermal insulation in walls and roofs. Conversely, double-glazed windows are the least effective building envelop upgrade, for two reasons. First, some buildings already have them installed (including all new homes, to comply with SASO

Figure 5. Predicted savings in annual electricity consumption for various energy efficiency measures in 2018.





thermal regulations); second, the window-to-wall ratio for most residential buildings is relatively low (typically about 15%). As expected, retrofitting the housing stock in the central and western regions can achieve the greatest energy savings, since the majority of the population and housing units are located in these areas. Among housing types, villas and apartments hold the greatest potential for energy savings, as Figure 5(b) indicates.

As indicated in the previous analysis, replacing existing AC systems with high-efficiency units has the most significant impact in reducing energy consumption for the Kingdom's residential housing stock. Table 4 summarizes the current Minimum Energy Performance Standards (MEPS) for AC systems in Saudi Arabia, including their required EER values when the outdoor dry-bulb temperature is 35°C (T1) and 46°C (T3) (SASO 2018a).

Table 4. SASO 2663 requirements for window and split ACs in Saudi Arabia.

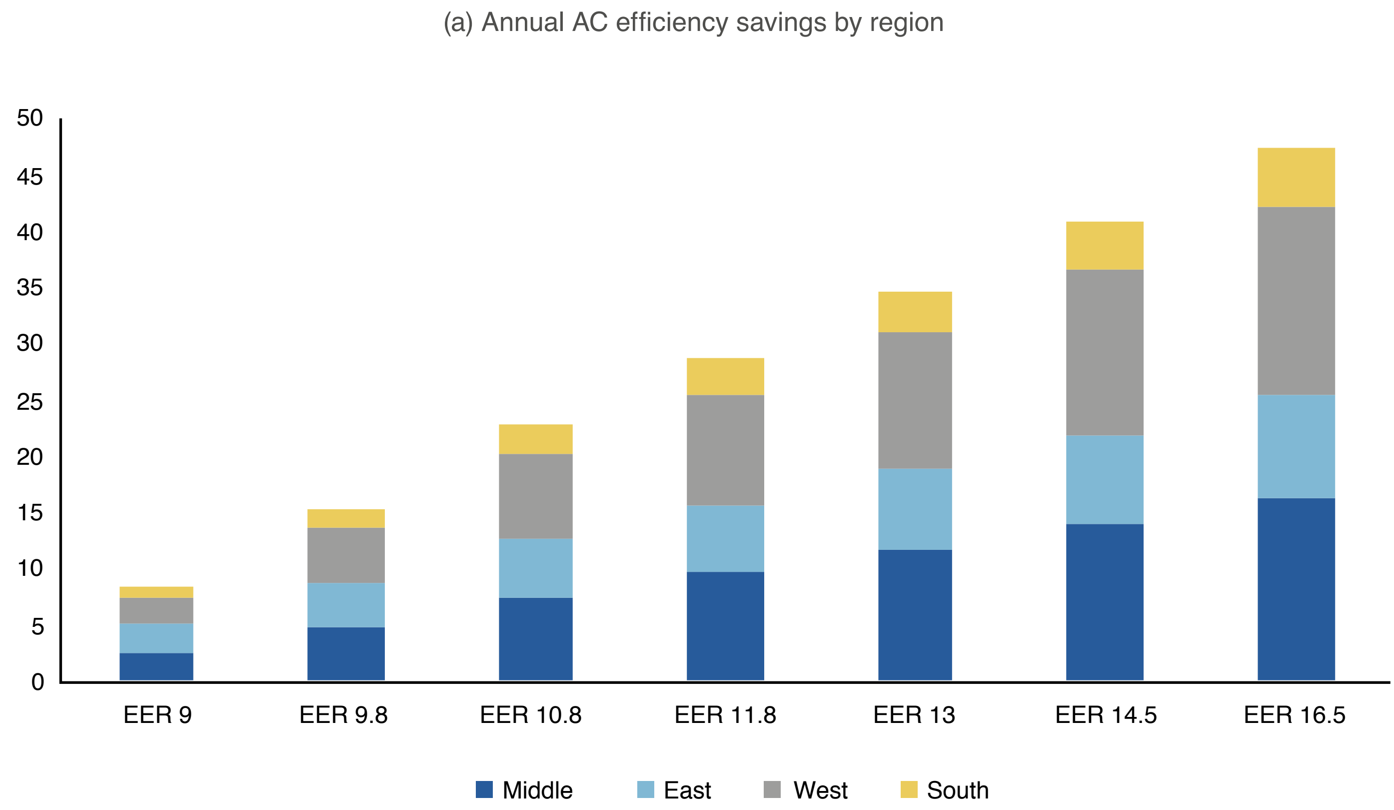
Type of air conditioner		January 1, 2018	
	Cooling capacity (CC) at T1 conditions in Btu/hr	EER at T1	EER at T3
Window AC	CC ≤ 24,000	9.8	7.0
	24,000 < CC ≤ 65,000	9.0	6.2
Split AC	CC ≤ 65,000	11.8	8.30
T1: EER test conditions at 35°C outside, 27°C dry bulb inside and 46.6% relative humidity.			
T3: EER test conditions at 46°C outside, 29°C dry bulb inside and 38.2% relative humidity.			

Source: SASO (2018a).

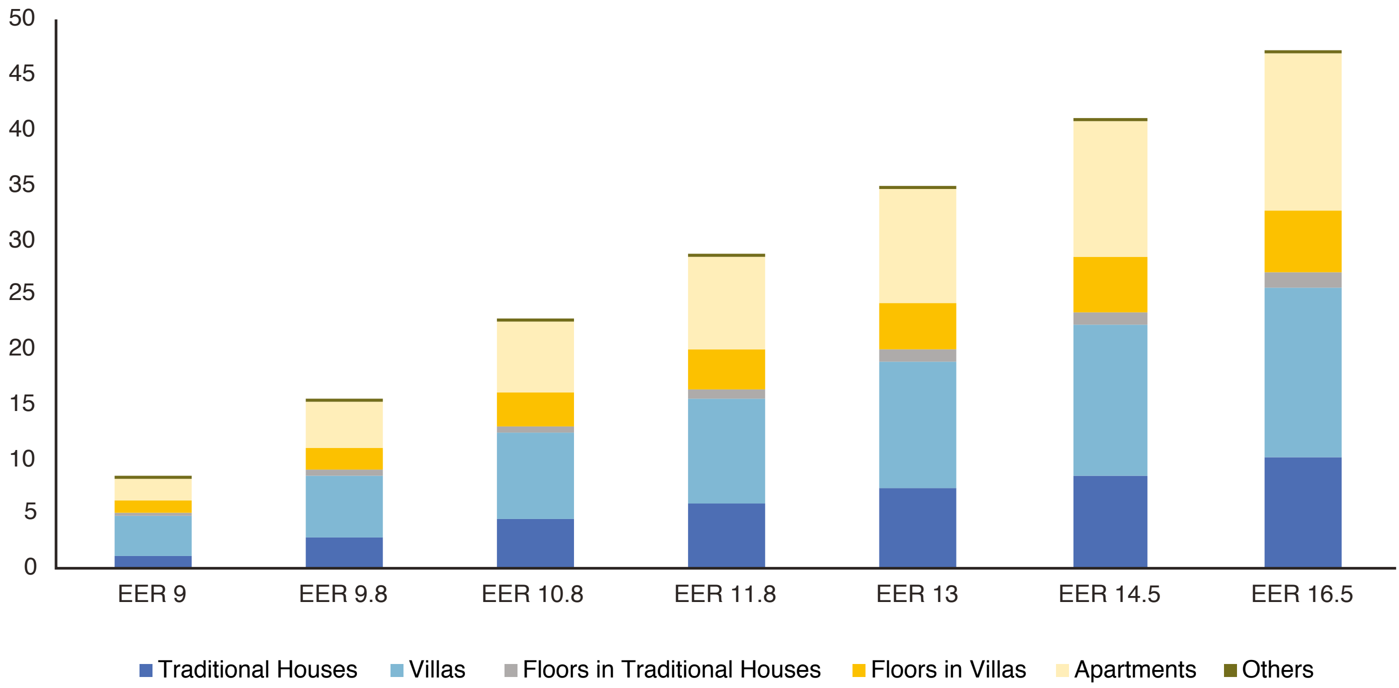
AC systems with higher EER, especially split-unit types, are currently available in Saudi Arabia, and would result in greater savings than those meeting only minimum standards. The government launched the High-Efficiency AC (HEAC) Initiative in early 2019 to encourage the local production of highly energy-efficient cooling systems and motivate citizens (i.e., only Saudi nationals qualify) to purchase systems with EERs of at least 13 by providing a 900 Saudi riyal (SAR) (240 United States dollars [US$]) discount per unit. To examine the impact of such a large-scale retrofit program, we ran REEM to simulate the impact of replacing all current AC units with more efficient systems, ranging from EER 9 to EER 16.5. The results show that upgrading all existing AC units with EER 13 systems could have reduced annual electricity consumption by up to 35 terawatthours per year (TWh/year). If all Saudi households installed EER 16.5 units, this would increase the savings up to 47 TWh/year. Figures 6(a) and 6(b) show the reductions in energy consumption for the range of EER ratings by region and building type, respectively.

As expected, replacing AC units in houses located in the central and western regions achieves the highest energy savings. For housing types, villas and apartments offer the greatest impact. From the individual household perspective, the payback period of replacing an existing EER 8 AC unit with an EER 13 one, factoring in the 900 SAR discount, ranges from 4.6 to 5.9 years, depending on the

Figure 6. REEM predictions of savings in annual electricity consumption for various AC efficiency ratings by (a) region and (b) housing type in 2018.



(b) Annual AC efficiency savings by building type



operating conditions. Our analysis shows that the government can quickly recover its spending on consumer EEM incentives through the resulting reduction in domestic fuel consumption, which frees up oil to be exported at higher international market prices. For example, if all current AC units had been replaced with EER 13 systems through the HEAC program in 2018, the government would have spent US$5.95 billion but increased its annual fuel exports by US$3.0 billion, thereby regaining its investment in less than two years (depending on oil prices).

Summary and Future Work

REEM was developed utilizing an engineering bottom-up approach. It incorporates energy models for 54 building prototypes representative of Saudi Arabia's existing housing stock. The housing stock is defined by the key characteristics of building type, vintage, and location, and is based on available governmental data and other published studies and statistics. REEM can evaluate energy consumption and end uses for the Kingdom's entire residential building stock, and simulate electricity consumption and peak demand, disaggregated by building type, vintage, and location, for hourly, monthly, and annual time scales. The regional total electricity consumption generated by REEM can be validated using actual regional residential electricity consumption data.

REEM can also estimate the impact of various retrofit measures on electricity consumption, peak demand, and carbon emissions. Our analysis indicates that the effectiveness of an energy efficiency upgrade depends on building type, vintage, and, most significantly, the location of the targeted stock. In addition, the model can simulate the economic and environmental consequences of different combinations of retrofit measures. REEM can therefore provide valuable insights for designing energy efficiency programs for the residential sector in Saudi Arabia.

REEM was developed primarily to provide policymakers with useful insights on how the Kingdom's residential building stock consumes energy and the potential of different energy efficiency programs in reducing demand. Therefore, subsequent studies can utilize REEM to model the impact of energy efficiency programs on residential energy consumption patterns in Saudi Arabia, including whether households exhibit a 'rebound effect,' increasing their consumption in response to the lower electricity bills achieved through energy efficiency measures. REEM can also be expanded to estimate the impact of changes in electricity prices on electricity demand in both the short and long run.

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Notes

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About the Project

In Saudi Arabia, the residential sector consumes most of the country's electricity and is the primary driver of peak electricity demand. The Residential Energy Model (REEM) simulates the Kingdom's entire building stock to provide insight to policymakers seeking to understand the impact of housing stock on the electricity market and national economy, and to develop and implement effective energy efficiency policies.

REEM is part of the **Modeling Residential Energy Demand and Energy Efficiency in Saudi Arabia** project, which aims to accurately model the country's entire residential building stock. The project's key goals are (i) to better understand the current status of the Kingdom's housing sector in terms of energy consumption, and (ii) to assess the potential of different energy efficiency programs and demand-response management to reduce electricity demand from the perspective of both households and the government. More broadly, the project aims to help KAPSARC conduct technical, economic, and environmental assessments of residential demand-side management options, and in turn to support policymakers seeking to design impactful energy strategies for Saudi Arabia's housing sector.

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