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Estimating the Multiple Benefits of Building Energy Efficiency in GCC Countries Using an Energy Productivity Framework

Summary Report

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About KAPSARC

The King Abdullah Petroleum Studies and Research Center (KAPSARC) is a non-profit global institution dedicated to independent research into energy economics, policy, technology and the environment, across all types of energy. KAPSARC's mandate is to advance the understanding of energy challenges and opportunities facing the world today and tomorrow, through unbiased, independent, and high-caliber research for the benefit of society. KAPSARC is located in Riyadh, Saudi Arabia.

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Key Points

This report quantifies the direct and key indirect benefits of energy efficiency investment in buildings in Gulf Cooperation Council (GCC) countries. It summarizes the key insights from individual country studies conducted as part of KAPSARC's energy productivity project. This analysis indicates that a strong case can be made for public energy efficiency programs that would encourage building owners to invest in the socially optimal amount of energy efficiency.

Driven by population growth, rapid development and low domestic energy prices, energy consumption from buildings across the GCC has risen by over 200% on average since 2000 in both absolute and per capita terms, posing sustainability concerns.

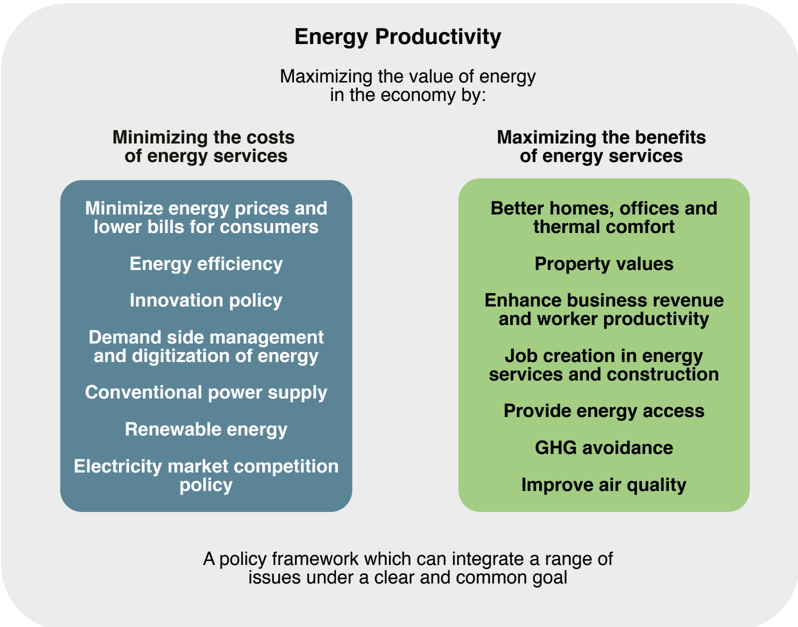
Even with the GCC's relatively low electricity prices, the most basic energy efficiency investment options such as programmable thermostats, LED lighting and stopping air leakage have payback periods of less than five years for the consumer.

Some energy efficiency retrofits, including more efficient air-conditioners and replacing windows and insulation, have longer payback periods.

The investment case for increasingly ambitious energy efficiency actions becomes more compelling once the broader system benefits are included, such as reducing the need for new electricity generation capacity, avoided carbon emissions and creating new jobs and investment.

A deep energy efficiency retrofit has a payback period for investors of between 11 and 70 years, depending on electricity prices; by incorporating the wider system benefits, this payback period improves to between 7 and 23 years on average across the GCC.

Figure 1. Energy productivity as a policy framework.



Source: KAPSARC.

Executive Summary

An important ingredient in the success story of Gulf Cooperation Council (GCC) countries has been the physical development of the building stock into modern cities and the access to energy services that this provides. For example, it is hard to imagine life today on the Arabian Peninsula without air-conditioning and the relief from the region's extreme temperatures that it gives in homes, shopping malls and places of work.

Since 2000, energy consumption in residential and commercial buildings has risen by over 200% on average across the GCC. This increase ranged from 133% in Kuwait to 326% in Qatar. In Saudi Arabia and the United Arab Emirates (UAE), the region’s two largest economies, it rose by 170% and 213% respectively.

As all GCC countries experienced rapid population growth over this period, it is important to put this growth in energy consumption from buildings in per capita terms. Between 2000 and 2016, Saudi Arabia had the highest rise of 42% in buildings energy consumption per capita among the GCC countries, followed by Oman with 38%, Bahrain with 23%, Kuwait with 15% and the UAE with a % rise. Only Qatar experienced a fall in per capita buildings energy consumption, with a 2% decline over the 16-year period from already very high levels.

While this rapid increase in energy consumption has enabled a fast pace of economic growth and improvements in welfare, it has also raised important questions around sustainability, potential wasteful behavior and whether the region is getting good value from this energy consumption and supply infrastructure.

Energy productivity is a new policy paradigm being applied by policymakers in leading G20 countries to encourage greater financial, social and environmental value from energy consumption.

While energy efficiency is a core element, the major value from energy productivity is its ability to incorporate a wider range of energy policy objectives than energy efficiency alone. This makes it a particularly strong policy narrative through which to analyze the multiple benefits of energy efficiency, beyond direct energy savings.

Research conducted by KAPSARC into the energy efficiency of the building stock of the GCC suggests that there is an investment potential of between $16 billion for the most basic energy efficiency measures, up to $270 billion for more comprehensive or deep retrofits. Such investments have the potential to deliver the following direct benefits:

> Energy efficiency can generate up to 180,000 gigawatthours (GWh) per year of avoided energy consumption within GCC countries, with 56% and 26% of this potential in Saudi Arabia and the UAE respectively.

> This avoided energy consumption could save consumers between $9 billion and $28 billion per year on their electricity bills, depending on the pace of further electricity price reform.

> While basic retrofits are economical at current prices, without further domestic price reform or energy efficiency subsidies, the payback timeframe for individual households from deep energy efficiency retrofits is prohibitively long.

Deeper retrofits become much more attractive once the wider economic, social and environmental benefits of energy efficiency are accounted for. These wider benefits include:

> Up to 43 gigawatts (GW) per year of generation capacity avoided across the GCC as a result of deep retrofits. This could potentially reduce the cost of electrical generation capacity by $73 billion.

The potential to avoid up to 129 million tonnes of carbon dioxide (CO_2) per year. This could provide a significant contribution to Gulf countries' efforts to meet nationally determined contributions to the Paris accord on climate change.

For every $1 million invested in energy efficiency, approximately two jobs can be created per year in building energy systems management and construction. Investing in energy efficiency is likely to be more labor intensive than investing in new supply and can help meet a key social objective to stimulate investment and create more employment opportunities for Gulf nationals.

As most of these wider benefits are captured at the utility or social level, there is a compelling argument for stronger energy efficiency policies from government. Without them, it is likely that building owners will not undertake the socially optimal amount of energy efficiency investment.

It should also be noted that this analysis does not include the value of avoided energy consumption in terms of the potential to sell it at higher prices on international export markets. This value is likely to be significant as oil and gas are often sold to utilities at close to the cost of production, which varies between approximately $6 to $15 for a barrel of oil in the Gulf. Compared with export prices of over $50 per barrel, there is a significant additional potential value from avoiding the opportunity cost of this energy use through enhanced energy efficiency. As such, the results in this report represent a relatively conservative estimate of the wider potential social benefits of energy efficiency.

Policies discussed in this study include increased electricity prices and/or energy efficiency subsidies, enhanced implementation of building codes tailored for local climatic and market conditions, investment and trade policies to promote the availability of energy-efficient appliances and materials, support for energy efficiency service company markets and energy efficiency investments from public financing organizations.

Establishing a regional energy efficiency or productivity network to facilitate the coordination of building codes, simulation tools and appliance standards would help reduce the cost of code compliance and promote greater policy learning in the GCC and other Arab countries.

Increasing energy efficiency helps reduce electricity costs for consumers and is an important facilitator for moving towards higher domestic energy prices. Energy efficiency should thus go hand in hand with reforms to deepen privatization as energy pricing reforms move market prices towards international benchmark levels.

KAPSARC's building sector energy efficiency analysis has involved developing simulation and optimization tools for each of the six GCC countries. Questions which have been identified as important for further investigation include:

What is the value of demand-side management options, including peak shaving and load shifting?

How can better integration of distributed renewable energy and household energy efficiency measures achieve more cost-effective pathways, towards realizing Saudi Arabia's renewable energy and energy efficiency goals?

What are the potential benefits of district cooling, both in new construction and retrofits?

What potential does the building sector have to contribute to CO_2 mitigation strategies?

This report is structured as follows. It first sets out the value of using energy productivity as a framework for analysis and policy, drawing on international developments on the topic. This positions energy productivity within related concepts such as the multiple and non-energy benefits of energy efficiency, and identifies where an energy productivity approach can add further value. It then describes the key energy consumption trends from buildings in the GCC, before outlining a summary of the multiple benefits of energy efficiency investment, drawing on individual country studies. It concludes with a discussion of the policy implications and potential areas for future research.

Energy Productivity as an Integrating Framework

Energy productivity, as a policy narrative, is part of an evolution of energy-related policy paradigms that have developed over time to reflect the policy needs and trends of different periods and contexts. For example, the theme of energy conservation emerged as a result of the oil crisis of the 1970s. Energy efficiency followed, focusing on ways to reduce the amount of energy needed to provide defined services (e.g., transport and heating). The emphasis then shifted to the amount of energy used per piece of equipment per unit use of output obtained. The concept of energy intensity gained prominence when its scope was broadened to the whole economy, with a focus on how much energy is used per unit of output or gross domestic product (GDP). In addition to energy efficiency considerations, this broader metric is driven by other factors such as the balance between energy-intensive and non-energy-intensive sectors, and a number of other geographically contingent factors such as the weather (Patterson 1996).

The concept of energy productivity builds on this tradition of using energy intensity as an important metric for public policy and analysis (e.g., Dimitropoulos 2007). Its emergence over the last ten years has focused on how energy can be used to create economic, social and environmental value (McKinsey 2008; Australian Government 2015; The Climate Group 2018; Global Alliance for Energy Productivity 2018; Australian Alliance for Energy Productivity 2018; African Alliance for Energy Productivity 2018; KAPSARC-UNESCWA 2017; KAPSARC-ERI 2018). These policy and research efforts have also shown how governments and corporations have applied the concept of energy productivity to help make strategic decisions about the allocation of energy resources.

Energy productivity as a macroeconomic indicator is the inverse of energy intensity and describes how much value (usually measured in GDP) can be produced using a given amount of energy (usually measured using total final energy consumption). A high ratio indicates that an economy is more effective and productive in extracting value – i.e., by generating goods and services – from the energy it consumes.

While enhancing energy efficiency is at the core of an energy productivity narrative, a major strength of energy productivity is its ability to integrate a wider range of energy policy issues, including renewable energy, electricity market reform and industrial policy (Figure 1).

Too often different energy policy agendas are pursued independently of one another and compete for policymakers' attention (IPEEC 2018). As such, a more integrated policy approach is needed. For example, energy efficiency policy is often pursued independently of renewable energy policy or broader energy market reform, such as privatization and increasing energy prices. Energy policies undertaken in each of these domains without reference to the others is likely to increase the costs of energy transition.

The KAPSARC energy productivity project aims to contribute to this agenda by investigating the application of energy productivity to the Gulf Cooperation Council (GCC) countries, especially Saudi Arabia.

Energy productivity has gained traction in some countries because of the perceived need to prioritize boosting growth and creating jobs in energy policy, while reducing energy-related emissions and environmental impacts remain as co-benefits. This focus on growth has given it a bipartisan appeal, even when climate change is politically contentious. This paper develops the concept by applying it to the buildings sector.

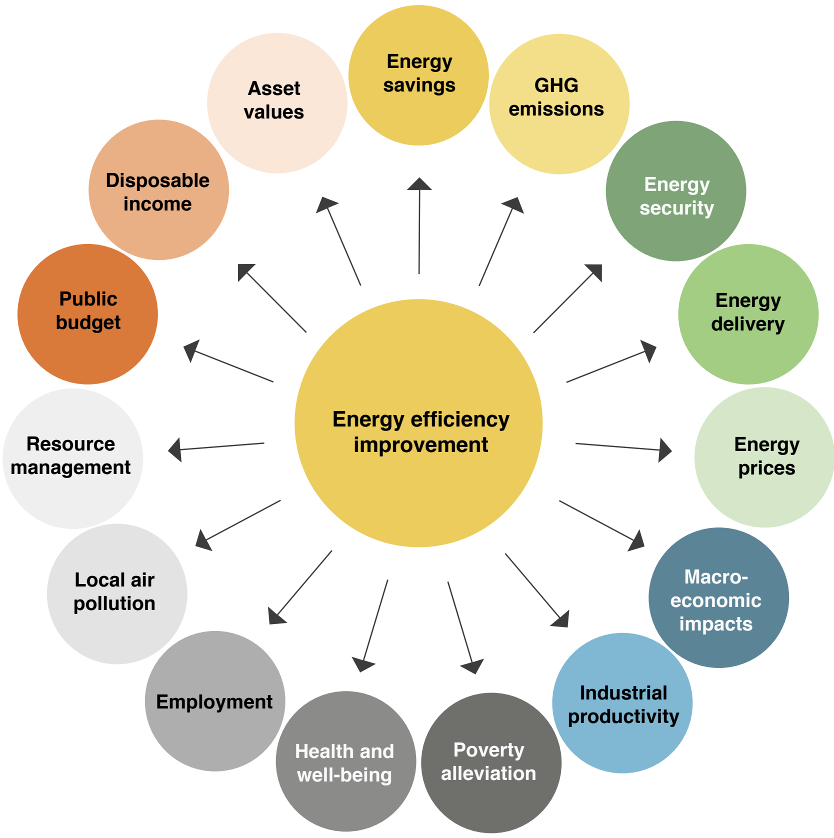
Energy Efficiency Within an Energy Productivity Framework

When asked to pick the most influential invention of the millennium, the prime minister of Singapore, Lee Kuan Yew, chose the air-conditioner. He explained that before air conditioning people living in hot climates were at a disadvantage as the heat and humidity negatively impacted the quality of their work (The Economist 2015). With average summer temperatures well above 40 degrees Celsius and humidity near 90% in the coastal cities of the Arabian Peninsula, there can be little doubt that air conditioning has similarly helped the region's development.

This example provides a clear case of how energy use in buildings can facilitate broader economic and social development. It is in this context that this analysis focuses on the direct and wider social benefits that energy efficiency retrofit programs can confer across the GCC. It also draws inspiration from work on the non-energy benefits (NEBs) associated with more efficient buildings.

An important concept related to energy productivity is the multiple benefits of energy efficiency (Figure 2) (IEA 2013). Work on this concept has highlighted that energy efficiency improvements deliver a range of NEBs, in addition to the well-documented energy savings and associated costs (Kats 2010; Yu et al. 2011; IMT 2018).

Figure 2. The multiple benefits of energy efficiency.



Source: IEA.

The incorporation of these wider NEBs of energy efficiency, both economic and social, is an important element of the energy productivity framework and analysis presented in this paper.

Some NEBs relevant to the buildings sector include enhanced productivity for businesses; increased property asset values; improved comfort, health and safety for occupants; reduced system operation and capital costs for electric utilities, and lower final energy demand for a given service.

Such NEBs are often not considered when assessing the cost-benefit ratio of energy efficiency interventions because their economic impacts are difficult to evaluate. In some instances, their monetary value is difficult to quantify, but efforts are being made to attach a financial value to the non-monetary impacts (e.g., social benefits) they provide. Several studies have attempted to evaluate the economic, social and environmental benefits of building energy efficiency programs, especially in Europe (Kuckshinrichs et al. 2010; Tuominen et al. 2013; Miniaci et al. 2014). Evaluation studies of energy efficiency programs are now starting to recognize NEBs and are including them in measurements and assessments of the cost-effectiveness of large-scale energy efficiency programs (Morrissey et al. 2013; Rusell et al. 2015).

Impact on work productivity

Several studies have evaluated the impact of indoor thermal comfort on work productivity by using specific case studies and surveys of subjects (Wyon 1996; Fisk and Rosenfeld 1997; Kosonena and Tan 2004; Romm and Browning 2004). Fisk and Rosenfeld (1997) have estimated that improving the indoor environment in United States (U.S.) office buildings has increased productivity by 0.5% to 5%, delivering an economic value of between $12 billion and $125 billion annually. A mere 2-degrees Celsius increase in indoor air temperature above a neutral comfort temperature (typically 24-degrees Celsius) can result in more than a 10% work productivity loss (Kosonena and Tan 2004). The reduction in work productivity represents an annual loss of approximately $200 per square meter, based on data detailing typical salaries in U.S. office buildings.

Impact on economic growth

Improvements in energy efficiency have been shown to directly affect economic growth. Vivid Economics found in a 2013 report that a 1% improvement in energy efficiency leads to a 0.1% increase in the annual growth rate of GDP per capita (Vivid Economics 2013), based on a statistical analysis of historical data for 28 Organization for Economic Cooperation and Development countries. Other studies have found similar results. For instance, the Rhodium Group (2013) estimated that doubling U.S. energy productivity would result in a $25 billion, or a 2% gain, in real GDP by 2030, an annual growth rate of about 0.13%. For Saudi Arabia, Gonand (2016) found that an annual increase of 4% in energy efficiency could result in around 1 million barrels of oil equivalent being avoided per annum by 2030, increasing oil revenues by between 50 billion Saudi riyals (SAR) to 100 billion SAR per annum by 2030, depending on market conditions. If recycled back into the economy through investments or public spending, the combined impact of this increase in energy efficiency could lift Saudi GDP growth by between 0.3 and 0.6% per year by 2030.

Impact on Property Values and Real Estate

Empirical evidence suggests that the asset value of sustainable buildings is higher than conventional structures (IMT 2018). Available data from several countries, including mostly Leadership in Energy and Environmental Design (LEED)-rated office buildings in the U.S., show that certified green buildings are 30% more expensive than non-certified buildings. Additionally, LEED and Green Star-rated buildings typically command rental premiums of up to 17%. Energy-efficient features such as daylighting in U.S. retail stores have been shown to boost floor sales by between 15 to 40% per floor area.

Summary quantification of non-energy benefits of energy efficiency programs

Several studies have suggested approaches to define and estimate the monetary values of NEBs related to a wide range of energy efficiency programs (Amann 2006; Russell et al. 2015; Skumatz 2014). Based on reported studies and results of surveys conducted on U.S. building energy efficiency programs (Diamond et al. 2006; Menezes et al. 2012; Russell et al. 2015), it is useful to summarize some of the main NEBs and their value estimates (as a percentage of the overall energy cost savings) for various stakeholders (Table 1).

Table 1. Summary of non-energy benefits of energy efficiency programs.

Owners/occupants of residential buildings		**Operators/occupants of commercial buildings**		**Power generators and utility companies**	
Impact/benefits	**Value (%)***	**Impact/benefit**	**Value**	**Impact/benefit**	**Value ($)**
Reduce lighting maintenance	28%	Improved productivity	Up to 10% increase in worker productivity	Avoided costs of transmission and distribution capacity	0-200/kW-year
Increase housing stock durability	10%	Reduced maintenance costs	7% of energy use savings	Avoided costs of generating capacity	22-434/ kW-year
Increase marketability of rental units	8%	Increased sales	Up to 17% relative to conventional buildings	Avoided costs of energy	0.02-0.19/ kWh
Increase safety, comfort and social status	18%	Enhanced public image	Increased attendance 3 days/year	Demand reduction induced price effects	0-0.024/kWh and 0.62-34/kW-year

Source: KAPSARC, based on a literature review. Note (*) % of the energy cost savings.

A Framework for an Energy Productivity Analysis of the Building Stock

Figure 3, builds on this body of work around the multiple benefits and NEBs of energy efficiency to present a framework for an energy productivity policy for buildings. The power sector is divided into two components: (1) grid provided, and (2) distributed generation and energy storage. It shows that electricity flows in two directions: from utilities to households, and from households back to the grid from distributed generation and storage. Electricity supplied directly from the grid into the building stock is one directional, though Figure 4 highlights the potential energy savings from energy efficiency as a directional flow back to the grid. This reflects a growing recognition that energy savings from energy efficiency can have important demand-side management benefits and can be regarded as a source of 'generation' capacity on a similar basis to distributed renewable energy (Oracle 2018).

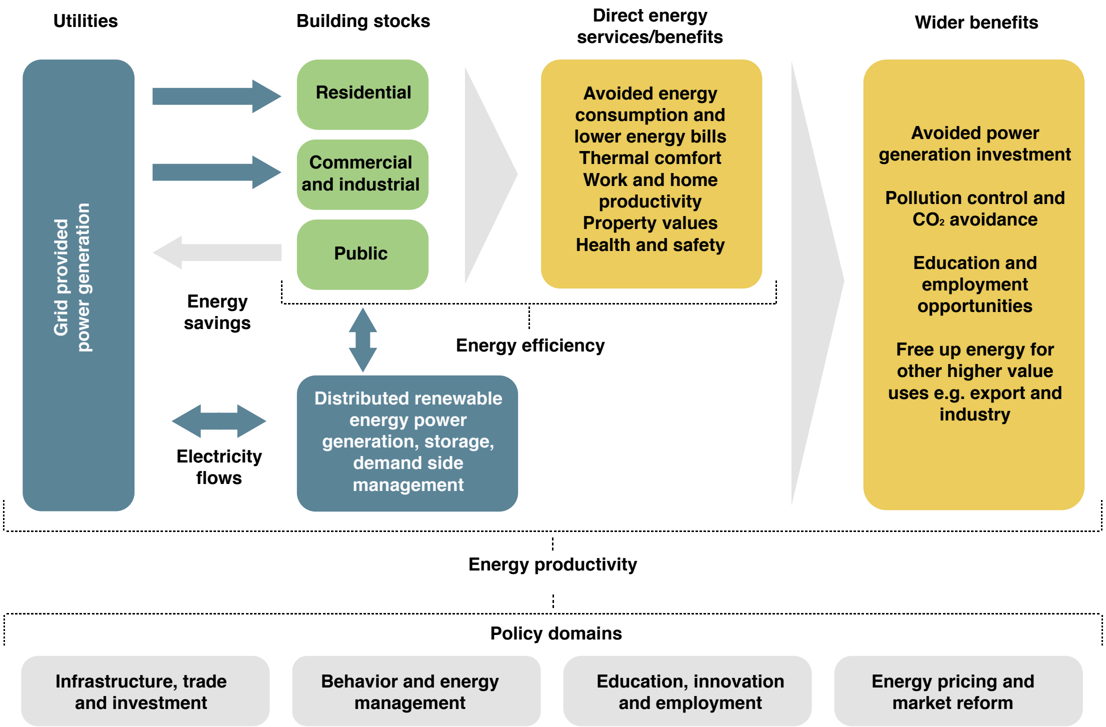
This study categorizes the building stock as residential, commercial, industrial and public sector. Residential users mainly use energy to produce non-monetary benefits or energy services such as heating and cooling, refrigeration, lighting and entertainment. Commercial and industrial users may incorporate some of these energy services but primarily use energy in their buildings to help support their businesses, whether retail or clerical. The scope of this study is limited to building use applications so excludes the operation of plant or machinery. Public sector buildings include government departments and museums, among other miscellaneous public buildings.

The direct benefits from energy efficiency in Figure 3 relate to the energy consumer. These include the reduction of energy bills and the NEBs of energy efficiency, such as increased worker productivity and wellbeing as a result of energy efficiency investments and any other aspect of energy use within the building sector. The broader social benefits include sources of value from energy efficiency investments that flow to the government, the utility or society at large. The consumer who undertakes the investment does not typically capture these benefits. Figure 3 shows some of the key broad areas of policy which support enhanced energy productivity. They include infrastructure, trade and investment, innovation and employment policies, behavioral change in energy use and energy management. Figure 4 is not intended to capture all the potential ways that the concept of energy productivity can be applied to the buildings sector, but rather highlights some of the main elements of energy policy which can potentially be incorporated and applied. It also presents the framework used to guide the analysis in this paper and helps open areas for future research.

The added value of using this framework, as opposed to concepts such as the multiple benefits of energy efficiency or NEBs of energy efficiency, is that it can place a clear focus on maximizing the wider social benefits from energy efficiency in buildings. It can also broaden the scope of analysis to include a wider range of energy policy issues, such as renewable energy.

The next section describes the main energy consumption trends in the GCC's buildings sector. Following this, the energy productivity framework of direct and wider benefits from energy efficiency in buildings is put to use in summarizing the results of individual country studies conducted as part of KAPSARC's energy productivity research.

Figure 3. Summary of non-energy benefits of energy efficiency programs.



Source: KAPSARC.

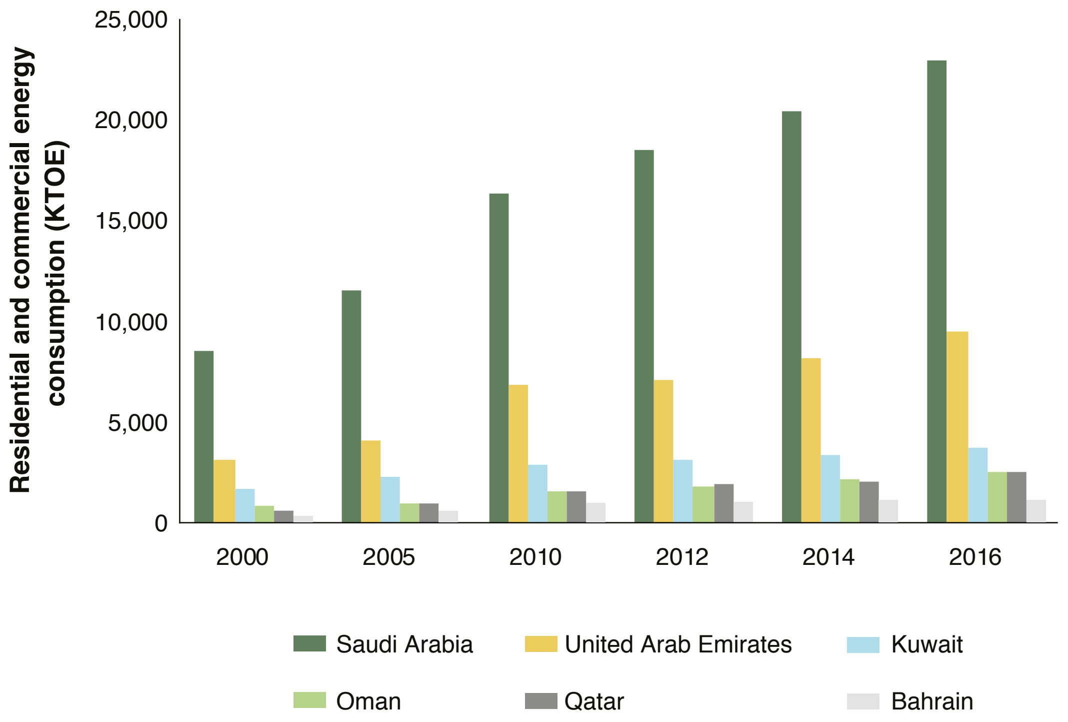
What are the Key Energy Consumption Trends in the GCC Building Sector?

The provision of modern energy services has brought great benefits in GCC countries but has also come at a price. Today, air conditioning accounts for around 70% of total energy consumption in a typical building, with buildings consuming around 75% of total electricity demand (Dubey, Howarth and Krarti 2016).

Energy consumption in residential and commercial buildings has risen by over 200% on average since 2000 across the GCC (Figure 4). The slowest growth was in Kuwait with a 133% rise; Qatar had the fastest growth rate of 326%. Energy consumption from buildings rose by 170% in Saudi Arabia and 213% in the UAE, the regions' two largest economies. Energy consumption in buildings in Oman also rose by around 213%.

Energy demand from the buildings sector is split between consumption in residential buildings and the tertiary or commercial and services sectors. The latter includes the particularly energy-intensive municipal buildings, schools, universities, hospitals, airports and public offices. This split reflects the relative sizes of retail and wholesale trade, restaurants and other commercial businesses that occupy shopping malls, office buildings and other commercial spaces in each country, compared with household demand (Figure 5). The UAE, perhaps the most diversified economy of the GCC, has the highest proportion of energy consumption from the services sector. Kuwait, which has among the lowest domestic energy prices of the region, has the lowest proportion.

Figure 4. Energy consumption in buildings (residential and tertiary sectors).



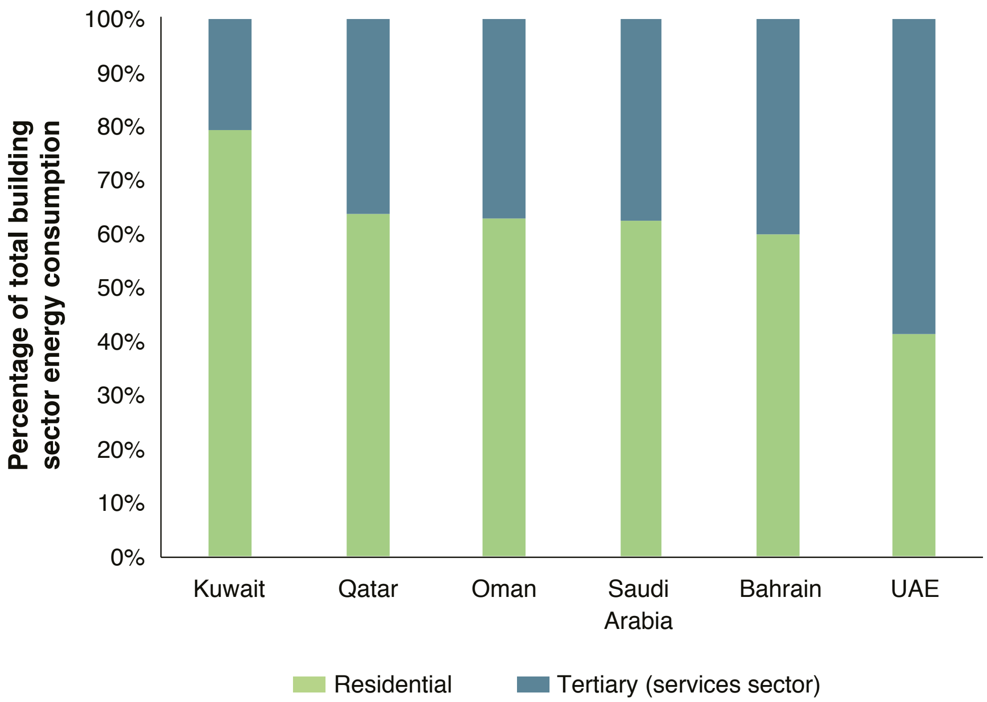
Source: KAPSARC, based on Enerdata.

This split between residential and tertiary energy consumption also provides some insight into where the value from energy consumption from buildings is being created. With a higher proportion of tertiary demand, the UAE is creating a lot of commercial value added from the buildings sector relative to the other countries of the GCC.

Comparing energy consumption in buildings on a per capita basis enables an assessment of the relative performance of each country's building stock. All GCC countries have experienced rapid population growth over this period. This growth has driven much of the energy consumption shown in Fgure 4. Normalizing energy consumption in per capita terms is one way to control for this effect.

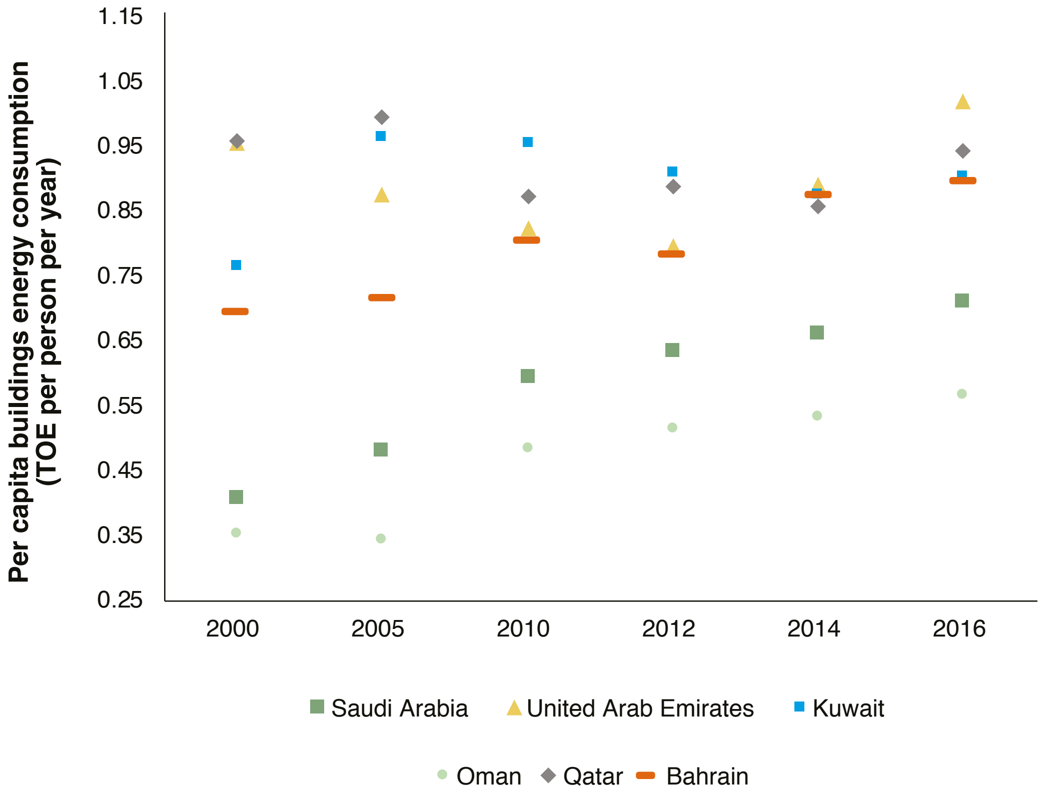
Saudi Arabia had the highest per capita increase in energy consumption from buildings, rising by 42% between 2000 and 2016. Oman experienced a 38% rise, Bahrain 23%, Kuwait 15%, and the UAE a 6% rise over the period. Only Qatar, starting from a very high level, experienced a fall in per capita buildings energy consumption, with a 2% decline.

Figure 5. 2016 energy consumption in the buildings sector (residential percent versus tertiary).



Source: KAPSARC based on Enerdata.

Figure 6. Per capita energy consumption in buildings (residential and tertiary) among GCC countries.



Source: KAPSARC based on Enerdata.

These per capita values for building energy consumption are consistent with most other G20 countries with similar levels of development (Howarth et al. 2017). While the GCC has among the highest per capita residential electricity consumption in the world, very little energy is used to heat households. As heating is often fueled by gas, per capita energy consumption from buildings is actually lower in all GCC countries than in countries with significant heating demand such as Canada and the U.S. (KAPSARC-UNESCWA, 2017).

However, there is an important difference between the GCC countries and most other countries with similar levels of per capita incomes: energy consumption in buildings is rising in both absolute and per capita values, whereas in most countries with similar incomes it is declining. This suggests that a transition towards greater energy efficiency is necessary to avoid energy waste and potential over-consumption.

The next section explores this issue by presenting a summary of results from a range of published KAPSARC studies on the energy efficiency investment potential of individual GCC countries. It also uses the energy productivity framework developed in this paper to provide a summary of both the direct and broader energy system and the social benefits that might arise from energy efficiency measures.

The Multiple Benefits of Energy Efficiency Investment in the GCC

The objective of this section is to bring together the results from individual GCC country studies on the benefits of energy efficiency investment in a consistent manner. Using the energy productivity framework described in Figure 3 the results are organized into direct and wider social benefits from energy efficiency investment (Tables 2-4). Appendix 1 gives further details on this report's assumptions and methodology. Further information on the methodology and assumptions can be sourced from the individual country papers on which this analysis draws:

Saudi Arabia

Dubey, Kankana, Nicholas Howarth and Moncef Krarti. 2016. "Evaluating building energy efficiency options for Saudi Arabia." KAPSARC Discussion Paper. October, 2016 KS-1655_DP049A.

The United Arab Emirates

Dubey Kankana and Moncef Krarti. 2017. "Economic and Environmental Benefits of Improving UAE Building Stock Energy Efficiency." KAPSARC Discussion Paper, June 2017 KS-2017-DP013.

Oman

Dubey, Kankana and Moncef Krarti. 2017. "Energy Productivity Evaluating Large-Scale Building Energy Efficiency Programs in Oman." KAPSARC Discussion Paper. May 2017 KS-2017-DP011.

Qatar

Krarti, Moncef, Fedaa Ali, Alaidroos Alaa and Houchati Mahdi. 2017. "Macroeconomic benefit analysis of large-scale building energy efficiency programs in Qatar." International Journal of Sustainable Built Environment, 6:2:597-609.

Bahrain

Dubey, Kankana and Moncef Krarti. 2017. "An Evaluation of High Energy Performance Residential Buildings in Bahrain." KAPSARC Discussion Paper, July 2017 KS-2017-DP016.

Kuwait

Krarti, Moncef. 2015. "Evaluation of large-scale building energy efficiency retrofit program in Kuwait." Renewable and Sustainable Energy Reviews 50:1069.

These papers assume three levels of building energy efficiency retrofit:

> Basic retrofits: Implementing low-cost energy efficiency measures, installation of thermostats, use of compact fluorescent lights or LED lighting, and the reduction of air leakages.

> Intermediate retrofits: All the measures from a basic retrofit plus the addition of energy-efficient cooling systems and more efficient appliances.

> Deep retrofits: All the measures from the basic and intermediate retrofits plus window replacement and glazing, cooling system replacement, installation of daylight control systems.

Direct Benefits

The costs of energy efficiency investments are typically borne by the building owner or occupier who also gains the direct benefits of reduced energy bills. The discounted value of these costs and benefits over time are calculated as the net payback period: the amount of time it takes for the investment to pay itself off.

Investment costs and avoided energy consumption

This paper estimates that there is an energy efficiency investment potential of between around $16 billion for the most basic retrofits, and up to $267 billion for deep retrofits across the building sector. This analysis focuses on three levels of retrofit: basic, intermediate and deep retrofits. Each level of retrofit adds new energy efficiency measures and incorporates the elements of the preceding level(s). Around 77% of this energy efficiency investment potential is in Saudi Arabia and around 8% in the UAE. This potential is driven by the size of the Saudi Arabian and UAE economies and the relative age of the building stock, with Saudi Arabia having a much higher proportion of older, less efficient construction. It is estimated that this investment could produce avoided electricity consumption of between 29 gigawatt hours (GWh)/year and 84 GWh/year, significantly reducing the need for extra capacity additions to the grid and reducing peak load requirements.

Value of avoided energy consumption and payback period of direct benefits

The direct benefits from avoided energy consumption to the consumer are dependent on assumptions regarding the future level of electricity prices. For example, assuming a range of between $0.05 per kilowatthour (kWh) and $0.15/kWh, this study estimates that energy cost savings to consumers in Saudi Arabia range between $0.8 billion and $2.4 billion for basic retrofits, to between $5 billion and $15 billion for deep retrofits.

The payback period of the investment also reflects the price of electricity. This study applies a 3% discount rate to the cash flows from avoided energy consumption. The payback period is attractive for basic retrofits, even with relatively low energy prices. The payback period for basic retrofits in the GCC is between 4 and 13 years on average, with higher energy prices improving the payback period of the investment. With its very low energy prices, Oman has a payback period for basic retrofits of between 7 to 30 years, the longest payback period in the region. Qatar and the UAE have the shortest payback periods ranging between 1 to 6 years, reflecting their relatively higher initial level of electricity prices.

Direct returns to the energy consumer from energy efficiency investment in intermediate retrofits and deep retrofits of the building stock are only attractive if energy prices are reformed significantly and set towards the upper bound of the $0.05/kWh to $0.15/kWh range. Indeed, payback periods for these more advanced retrofits would average over 100 years in the GCC at low electricity prices. This would mean that building owners would only undertake energy efficiency investment if motivated by other factors than energy cost savings, such as improving the quality of their housing. At higher energy prices, the average payback period for deep and intermediate retrofits is more attractive at around 13 years.

Table 2. Basic retrofits apply low-cost energy efficiency measures such as installing programmable thermostats, using LED lighting and weatherization of building shells to reduce air infiltration.

Basic retrofits										
Direct benefits					Wider social benefits					
Country	**Investment cost ($ billion)**	**Avoided energy (GWh/ year)**	**Value of avoided energy consumption ($ billion/year)***	**Discounted payback period for direct benefits only (years)***	**Avoided electricity generation capacity (MW)**	**Value of avoided generation capacity ($ billion)**	**Avoided carbon emissions ($MtCO_2$/ year)**	**Value of avoided carbon ($ billion/ year)***	**Discounted payback period for all benefits (years)***	**Jobs created (persons)**
Saudi Arabia	10.4	16,000	0.80 – 2.40	16.7 – 4.7	3,670	6.239	12.192	0.24384	4.3– 1.6	12000
UAE	2	7,550	0.38 – 1.13	5.9 – 1.8	1,410	2.397	4.049	0.08098	0.0 – 0.0	900
Kuwait	0.9	1,429	0.07 – 0.21	16.1 – 4.6	815	1.3855	1.244	0.02488	0.0 – 0.0	10460
Qatar	0.3	1,777	0.09 – 0.27	3.6 – 1.2	414	0.7038	1.191	0.02382	0.0 – 0.0	3213
Bahrain	0.6	869	0.04 – 0.13	18.1 – 5.0	200	0.34	0.662	0.01324	5.0 – 1.9	2053
Oman	1.6	1,652	0.08 – 0.25	29.4 – 7.3	370	0.629	1.063	0.02126	11.1 – 3.9	12293
Total	**15.8**	**29,277**	**1.46 – 4.39**	**13.2 – 3.9**	**6879**	**11.6943**	**20.401**	**0.408**	**2.3 – 0.9**	**40919**

* Value for avoided energy consumption assumes electricity price ranges of 2016 prices in each country up to U.S. $0.15/kWh. A discount rate of 3% is used for the payback periods. A carbon price of $20/tonne is assumed.

Source: KAPSARC.

Table 3. Intermediate retrofits improve the building envelope components to meet energy efficiency code requirements for new buildings, including using energy efficient cooling systems and appliances.

Intermediate retrofits										
	Direct benefits				Wider social benefits					
Country	**Investment cost ($ billion)**	**Avoided energy (GWh/ year)**	**Value of avoided energy consumption ($ billion/ year)***	**Discounted payback period for direct benefits only (years)***	**Avoided electricity generation capacity (MW/year)**	**Value of avoided generation capacity ($ billion)**	**Avoided carbon emissions ($MtCO_2$/ year)**	**Value of avoided carbon ($billion/ year)***	**Discounted paybackperiod for all benefits (years)**	**Jobs created (persons)**
Saudi Arabia	103.7	46,000	2.20 – 6.90	100 – 20.3	10,500	17.85	35.051	0.70102	66.1 – 14.0	123,000
UAE	10.7	21,700	1.08 – 3.26	11.9 – 3.51	4,000	6.8	13.134	0.26268	3.1 – 1.1	2500
Kuwait	5.4	4,110	0.21 – 0.62	52.53 – 10.31	2,348	3.9916	3.575	0.0715	5.6 – 2.1	63,974
Qatar	1.7	5,110	0.26 – 0.77	7.53 – 2.32	1,191	2.0247	2.524	0.05048	0.0 – 0.0	20,290
Bahrain	3.2	2,498	0.13 – 0.37	49.52 – 10.01	588	0.9996	1.903	0.03806	17.6 – 5.9	15,856
Oman	8.8	4,748	0.24 – 0.71	100 – 15.67	1,063	1.8071	3.277	0.06554	39.9 – 10.6	71,817
Total	**133.5**	**84,166**	**4.21 – 12.63**	**100 – 12.91**	**19,690**	**33.473**	**59.464**	**1.18928**	**27.5 – 8.3**	**297,437**

* Value for avoided energy consumption assumes electricity price ranges of 2016 prices in each country up to U.S. $0.15/kWh. A discount rate of 3% is used for the payback periods. A carbon price of $20/tonne is assumed.

Source: KAPSARC.

Table 4. Deep retrofits apply a wide range of energy efficiency measures, including replacing windows and/or cooling systems, using variable speed drives and installing daylighting control systems. To minimize implementation costs, this type of energy retrofit is typically linked with architectural refits.

Deep retrofits										
Direct benefits					Wider social benefits					
Country	**Investment cost ($ billion)**	**Avoided energy (GWh/ year)**	**Value of avoided energy consumption ($ billion/ year)***	**Discounted payback period for direct benefits only (years)**	**Avoided electricity generation capacity (MW/year)**	**Value of avoided generation capacity ($ billion)**	**Avoided carbon emissions ($MtCO_2$/ year)**	**Value of avoided carbon ($ billion/ year)***	**Discounted payback period for all benefits (years)**	**Jobs created (persons)**
Saudi Arabia	207.4	100,659	5.03 – 15.10	100 – 17.97	22,900	38.93	76.199	1.52398	49.8 – 12.3	247,000
UAE	21.4	47,200	2.36 – 7.08	10.74 – 3.22	8,800	14.96	28.553	0.57106	2.3 – 0.9	5,600
Kuwait	10.8	8,934	0.45 – 1.34	43.71 – 9.36	5,105	8.6785	7.773	0.15546	3.8 – 1.5	127,937
Qatar	3.4	11,108	0.56 – 1.67	6.86 – 2.14	2,590	4.403	5.487	0.10974	0.0 – 0.0	40,555
Bahrain	6.5	5,430	0.27 – 0.81	42.85 – 9.26	1,278	2.1726	4.138	0.08276	15.4 – 5.3	31,173
Oman	17.6	10,322	0.52 – 1.55	100 – 14.11	2,311	3.9287	7.122	0.14244	33.0 – 9.4	143,633
Total	**267.1**	**183,653**	**9.18 – 27.55**	**69.71 – 11. 63**	**42,984**	**73.0728**	**129.272**	**2.58544**	**23.1 – 7.3**	**595,898**

* Value for avoided energy consumption assumes electricity price ranges of 2016 prices in each country up to U.S. $0.15/kWh. A discount rate of 3% is used for the payback periods. A carbon price of $20/tonne is assumed.

Source: KAPSARC.

Wider Social Benefits

Not only does investing in energy efficiency retrofits have a direct benefit to consumers in the form of energy savings, but they also have important wider benefits that accrue at the utility or social levels.

Avoided electricity generation capacity and the value of avoided capacity

Avoided energy consumption from energy efficiency investment reduces the growth in electricity demand and peak capacity requirements. This benefits the utility in the form of demand-side management (peak-shaving) and in the avoided need to invest in new generation capacity. This study calculates that energy efficiency investments of between $16 billion and $270 billion could result in around 7 gigawatts (GW) to 43 GW of potential avoided electricity generation capacity across the GCC, for basic and deep retrofits of the building stock respectively. This study estimates that the avoided electricity generation investment costs resulting from energy efficiency investment range from between $11 billion and $73 billion, depending on the scale of the energy efficiency retrofit program.

Avoided carbon emissions

Fossil fuels provide the majority of electricity generation in the Gulf. As such, avoided energy consumption from energy efficiency investment also helps avoid carbon emissions (Appendix 1 shows the carbon intensity of electricity generation in each Gulf state). This can help meet GCC countries' nationally determined contributions under the Paris Agreement. This study calculates that basic and deep retrofits can mitigate between 20 million and 129 million tonnes of CO_2 per year. If CO_2 emissions are valued at $20 per tonne, the value to society of these emission reductions would be between $400 million and $2.6 billion per year.

Discounted payback period including direct and wider social benefits

The investment payback periods for energy efficiency investment in GCC countries improves substantially once these wider benefits are factored in. Basic retrofits have a payoff of less than one year for most countries. Most significantly, incorporating these wider social benefits makes ambitious retrofit programs much more attractive. Compared with only considering the direct return to the investor (a payback period of between 11 and 70 years depending on electricity prices), deep retrofits have a payback period of between 7 and 23 years on average across the GCC. Payback periods are fastest in Qatar and the UAE, and the most challenging in Saudi Arabia which has a larger and older building stock.

Employment benefits

Outside of this benefit-cost analysis, this study has evaluated the employment opportunities that could be generated by implementing a significant energy efficiency retrofit program. High rates of youth unemployment mean that generating high-quality jobs in energy management is an important co-benefit which increases the value of energy efficiency investment to society. Our work suggests that every $1 million of investment in energy efficiency will create approximately two jobs in buildings energy systems management and construction.

Policy Recommendations and Future Research

The fallout from the global recession and subsequent collapse in oil prices experienced from 2014 onwards, combined with ongoing concern over climate change, has called into question the past models of economic development in the Gulf. Still recognizing the importance of oil and gas, there is now a widely held belief that the cities and growth models of the future will be built less on energy intensity and more on knowledge-based foundations.

Towards this goal, all GCC countries have brought in significant changes to domestic energy pricing which has seen electricity prices more than double in most countries. Further increases are scheduled to come as the region removes energy subsidies and transitions to a system of pricing that is more consistent with international benchmarks.

At the same time, governments are seeking to attract significant private sector investment to build new cities. They also have ambitious renewable energy and energy efficiency plans. Taken together, these policies represent a shift more aligned with green growth or what this paper has referred to as an energy productivity growth model.

Because of the region's history of low energy prices, the building stock in the GCC has been geared towards a low-tech, low level of energy efficiency. The transformation of this building stock will involve changes to both the physical stock of buildings as well as the less tangible laws, social norms and patterns of behavior that govern how cities are constructed and lived in.

These physical and less tangible elements need to be integrated through a transition strategy aimed at moving from 'low-tech' labor-intensive construction and appliances towards the application of new materials as well as 'smart' or 'high-tech' equipment and systems.

The transition to more sustainable buildings for the cities of the future requires attention throughout all phases of the building lifecycle, from the initial project brief of new builds through to their design, implementation, commissioning and operation. It will require making technological choices concerning the right building envelope, high insulation levels, technical installations such as heating, ventilation, and air conditioning (HVAC) systems, lighting and appliances.

New building materials, such as special glazing systems for windows and insulation material can greatly improve building energy performance in the hot climates of the Gulf. This is in addition to optimal architectural design options such as orientation, disposition of spaces and use of daylighting.

The design of a building's technical installations, including its mechanical systems, HVAC systems, electrical systems, lighting systems, building controls and management systems, should be carried out with the utmost attention to local operating conditions and energy requirements. The building codes can cover part of this system design optimization. However, even more important are the architects and mechanical and electrical engineers involved in the design of the building. Guidebooks for designing energy-efficient buildings need to be developed, and adequate training needs to be provided to support these important actors.

For the building envelope and design, there is a need to develop or reinforce building energy performance codes based on current building energy simulation tools. These tools also need to be used in the building design process to meet or exceed the required energy performance levels. Such simulation and design tools can be adapted from existing and internationally recognized approaches. There is also a strong case for regional harmonization and adopting a common approach to these simulation approaches at the GCC level.

Each country can then use these tools to develop, review or update their building codes in a consistent manner, reducing compliance costs. Simply developing building codes is insufficient as there is an urgent need to provide a mechanism to ensure their implementation, and provide necessary training to construction workers and supervisory personnel.

A summary of key policy considerations for building energy efficiency in Arab countries was recently provided at the 4th Arab Renewable Energy and Energy Efficiency Summit held in Kuwait. It gives an important guide to key issues facing policymakers in the region (Bida 2018):

> Target the most energy-intensive buildings with the most basic measures first. Such buildings include airports, large commercial (e.g., malls), offices and governmental buildings, schools, universities and hospitals.

> Enforce building codes for all new buildings, especially energy-intensive ones. For example, require energy performance verification before connecting new buildings to the grid.

> Apply trade and commercial regulation to enforce the adoption of energy performance labeling and minimum energy performance standards (e.g., lighting, heating, cooling, refrigerators, air conditioners, televisions and washing machines).

> Improve knowledge of energy consumption patterns in the building sector through systematic statistical data collection for each of the main building types. Based on this, define and monitor relevant energy performance indicators.

> Strengthen education and training programs for energy management professionals, to maximize the employment opportunities for nationals.

While energy efficiency is a core element of an energy productivity agenda, this report has argued that there are advantages to taking a more integrated policy approach. This is important as energy efficiency as a stand-alone policy agenda rarely attracts the attention required to unlock its full potential. The policy impact of energy efficiency can be amplified when combined as an integral part of other agendas, such as building the new cities of the future (e.g., Saudi Arabia's NEOM project) or renewable energy plans (it is much easier to reach renewable energy targets when supported by ambitious energy efficiency goals).

The Global Alliance for Energy Productivity (2018), in their Energy Productivity Playbook: Road Maps for an Energy Productivity Future, outline the key elements of how to support such a transition in theory and practice (Figure 7).

This paper has highlighted how modeling the economic benefits of energy efficiency shows that evaluating the wider benefits provides a much more compelling case for energy efficiency investment than focusing on energy savings alone. With governments and utilities capturing these wider benefits rather than individuals there is a compelling rationale for much stronger policies and public subsidies in the area of energy efficiency.

Figure 7. Elements of an energy productivity transition strategy.

Part 1
Energy Productivity Leadership Commission

Convening a high-level commission of public and private sector thought leaders is an important way to engage necessary expertise and gain widespread political support for the goal of increasing energy productivity.

Part 2
Modeling the Benefits

Economic modeling helps identify what constitutes reasonable targets for increasing energy productivity, as well as the economic benefits of achieving these goals.

Part 3
Core Policy Considerations

A successful road mapping process that offers effective policy recommendations will carefully consider global best practices in key policy areas that affect energy productivity. These include energy demand management, supply side efficiency and consumer education.

Part 4
Communicating the Benefits

When the commission completes its economic modeling and core policy recommendations and is ready to support the setting of energy productivity targets the final step is to disseminate the results to the public through a comprehensive communications plan.

Source: Global Alliance for Energy Productivity, based on U.S. and Australian experiences.

The experience of leading G20 countries, such as Australia and the U.S., also highlights the critical role of communicating the benefits of enhancing energy productivity to policymakers and the public. Establishing an energy productivity commission or a consultative body involving key stakeholders are pathways to achieving this. KAPSARC aims to support this process through its Energy Productivity Workshop Series.

While this paper focused on energy efficiency measures alone, possible future research topics include: an analysis of combining household renewable energy and energy efficiency options; district cooling; and demand-side management. These topics could be explored alongside the formalization of the modeling and analysis frameworks developed in each of the six studies that supported this report. Such models could then be made available to policymakers and others to run a variety of different simulations according to their needs, and to support greater awareness of the multiple benefits of energy efficiency in the region.

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Appendix 1. Background to the Analysis

Employment benefits of enhanced energy efficiency investment

An important benefit of building retrofit programs is their potential to create new employment opportunities in GCC countries. As Krarti (2015) outlines, the direct effects of retrofitting buildings include the creation of jobs to implement the energy efficiency measures, while the indirect effects stem from the work needed to produce and supply energy efficiency equipment and materials. Most of the jobs created in building retrofits would be in the construction and manufacturing industries, with a wide range of pay and technical specialization. The latter include electricians, HVAC technicians, insulation installers, energy auditors, building inspectors and construction managers.

Using the job creation model in Krarti's (2015) analysis, retrofitting the existing building stock in the GCC countries could create up to 600,000 jobs per year. Most of these jobs, including energy auditors, HVAC technicians and electricians, can be filled by the local populations of the GCC countries instead of expatriates. However, an investigation evaluating building capacity needs should be conducted to ensure that locals can meet the job requirements so that the large-scale building energy retrofit programs considered in this analysis can be implemented effectively.

Avoided carbon emissions

Based on available data, carbon emissions from electricity generation are estimated (IEA 2015) as follows:

- UAE – 0.605 kCO_2/kWh
- Bahrain – 0.762 kCO_2/kWh
- Saudi Arabia – 0.757 kCO_2/kWh
- Oman – 0.690 kCO_2/kWh
- Kuwait – 0.870 kCO_2/kWh
- Qatar – 0.494 kCO_2/kWh

Investment costs, avoided energy consumption and the payback period of direct benefits

The cost-effectiveness of the energy efficiency measures depends on their cost of implementation and the electricity rate charged to homeowners. Table A-1 lists the cost of avoiding 1 kWh per year of electricity consumption (using Saudi Arabia as the example), as well as the simple payback periods for the energy efficiency measures under two scenarios:

- The cost of electricity at $0.0479/kWh (i.e., electricity cost of production in Saudi Arabia).
- The cost of electricity at $0.1678/kWh.

The current Saudi electricity rate follows a tiered structure depending on the block of energy consumed monthly by households (Krarti et al., 2016). The Kingdom is currently undergoing energy price reform. It is expected that electricity prices will be closer to the second scenario than the first scenario, which relies on heavy energy governmental subsidies, within a few years. Typically, efficiency measures are recommended when their simple payback period is less than five years (Krarti 2012). Based on the results outlined in Table A-2, it is clear that under electricity price scenario 1 (i.e., $0.0479/kWh), the installation of high-efficiency air conditioning systems and the addition of thermal insulation in the roofs are not cost-effective. However, under electricity rate scenario 2 (i.e., $0.1678/kWh), all the listed energy efficiency measures listed in Table A-2 become cost-effective and are highly recommended for implementation by Saudi households. In fact, when the average electricity price is set above the threshold rate of $0.092/kWh, all the measures become cost-effective for Saudi households.

Table A1. Cost of avoided energy consumption and payback period of energy efficiency measures for Saudi Arabian households for two electricity price scenarios.

Energy efficiency strategy for households	Cost of avoided energy use ($/kWh)	Scenario 1 payback ($0.0479/kWh)	Scenario 2 payback ($0.1678/kWh)
Cooling temperature settings	0.00	0.00	0.00
Replace with LED lighting	0.0513	1.07	0.31
Reduce leakage in building shell	0.1220	2.55	0.73
Insulate roofs	0.4578	9.56	2.73
Install energy efficiency AC	0.2480	5.18	1.48

Source: KAPSARC analysis based on data from ECRA.

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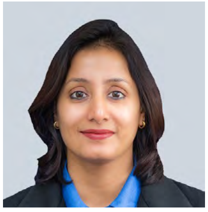

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About the Project

This paper synthesizes the key findings and insights from the buildings sector work stream of KAPSARC's energy productivity project and workshop series, conducted in partnership with the United Nations Economic and Social Commission for West Asia (UNESCWA). Energy productivity is a policy paradigm which is increasingly being applied by governments to help them navigate energy transitions in their countries. As a policy narrative, it focuses on maximizing the economic, social and environmental value created from energy consumption, while minimizing the costs of energy supply. This makes it particularly suitable for assessing the multiple benefits of energy efficiency, which extend beyond energy savings alone. Aside from its focus on energy efficiency, a potential strength of using an energy productivity framework is how it can integrate a wider range of energy policy issues including industrial policy, renewable energy and energy market reform. Too often such agendas compete for policymakers' attention, reducing their overall impact. Setting energy productivity targets and using them as planning tools can help promote a more integrated approach focused on a common objective – maximizing the societal value created from energy consumption.

Project Publications

Dubey, Kankana, and Moncef Krarti. 2017. Economic and Environmental Benefits of Improving UAE Building Stock Energy Efficiency. KS-2017--DP13. Riyadh: KAPSARC.

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Dubey, Kankana, and Moncef Krarti. 2017. An Evaluation of High Energy Performance Residential Buildings in Bahrain. KS-2017--DP16. Riyadh: KAPSARC.

Other Academic Publications Related to This Project Include:

Krarti, Moncef, Fedaa Ali, Alaa Alaidroos and Mahdi Houchati. 2017. “Macroeconomic benefit analysis of large-scale building energy efficiency programs in Qatar.” International Journal of Sustainable Built Environment, 6:2:597-609.

Krarti, Moncef. 2015. "Evaluation of large-scale building energy efficiency retrofit program in Kuwait." Renewable and Sustainable Energy Reviews 50:1069.

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Comments received will be gratefully acknowledged and inform further work on this topic.

Notes

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