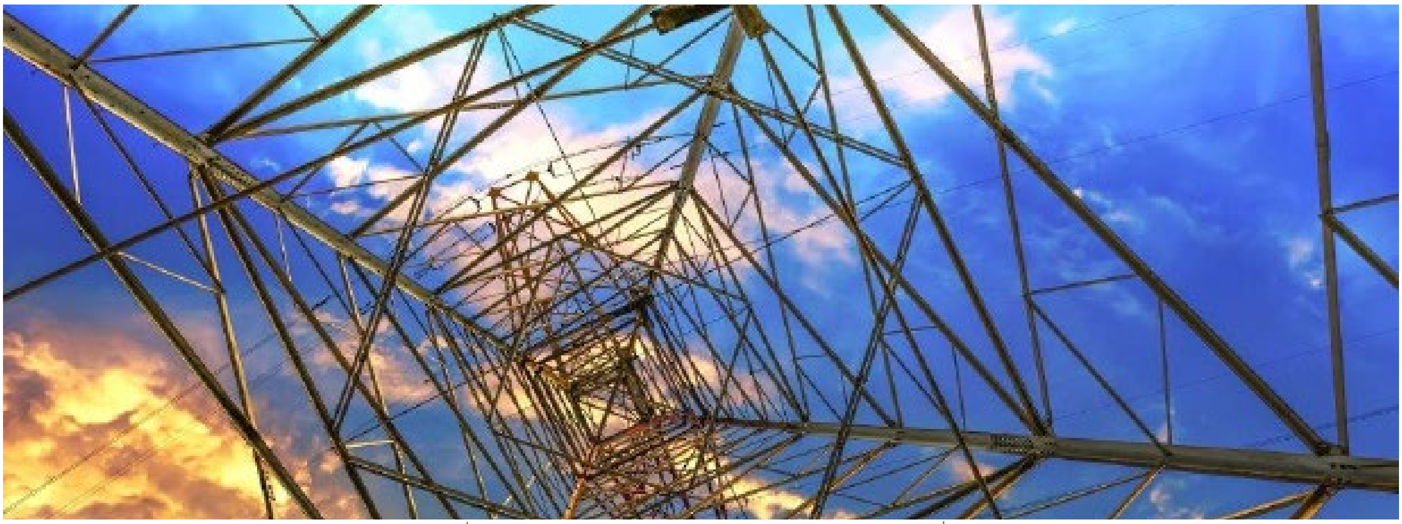
Issue 6

KAPSARC Quarterly

Research highlights



Technological Disruptions and Service-Based Business Models in the Power Sector

The power sector, in many countries, is undergoing major changes largely driven by technological developments that are affecting both electricity supply and demand. Entrepreneurs are seeking to turn the traditional top-down supply model, which flows from generation through...

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Electricity Transmission Formulations in Multi-Sector National Planning Models: An illustration using the KAPSARC Energy Model

Large-scale national policy models date back to the 1970s (Hall and Buckley 2016) and have adopted different levels of detail, with the ultimate purpose of informing policy decisions. These models make...

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Restructuring Saudi Arabia's Power Generation Sector: Model-Based Insights

Saudi Arabia plans to reform and privatize its power generation sector as part of its Vision 2030. International experience shows that it will face two challenges: achieving sufficient supply reliability during peak demand and reducing the potential for price manipulation through the exercise...

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GCC Energy System Overview – 2017

This paper presents datasets that support economic and policy analyses of countries in the Gulf Cooperation Council (GCC). The objective is to provide an overview of the GCC energy systems and serve as a reference for researchers performing quantitative modeling and analysis. The following data have been collected...

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Welfare Implications of the Rebound Effect From More Energy-Efficient Passenger Cars

Conventional wisdom suggests that improving energy efficiency is a worthwhile investment. Many engineering and economic models have shown that energy-efficient technologies across a number of sectors are welfare enhancing, with higher benefits than costs. However...

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Gasoline Savings From Clean Vehicle Adoption

The goal of many transportation policies is to increase clean vehicle market share. Quantifying the benefits of these policies requires assumptions about what consumers would have purchased in the absence of the policy. For example, existing literature assumes that consumers who purchase plug-in electric vehicles...

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Role of Oil in the Low Carbon Energy Transition

In 2016 and 2017, a number of scenario reports from respected global energy organizations highlighted how the energy transition is likely to impact global oil demand. All of these scenarios pointed to slowing demand for hydrocarbons, including oil, and several suggested that...

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The Political Feasibility of Policy Options for the UAE's Energy Transition

This paper applies a model of collective decision-making processes (CDMPs) to evaluate the political feasibility of six different policy options that could help achieve the efforts of the United Arab Emirates (UAE) to change its energy...

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Towards More Pragmatic Global Climate Goals and Policies

The 2015 Paris Agreement represents an important step forward in global climate change agreements, by combining national goal-setting with a global framework to drive collective action. However, the sum of individual countries' nationally determined contributions falls far short of actions...

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Enhanced Oil Recovery and CO_2 Storage Potential Outside North America: An Economic Assessment

Despite significant interest in using carbon pricing to stimulate the application of CO_2-based enhanced oil recovery (CO_2-EOR) to cost-effectively reduce CO_2 emissions, to date there is only limited information available on how carbon prices influence the economic viability of CO_2 storage...

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Growth Through Diversification and Energy Efficiency: Energy Productivity in Saudi Arabia

While Saudi Arabia's Vision 2030 has set clear goals related to its overall objective of transitioning to an economy less reliant on oil exports by lifting non-oil private sector growth, the strategy for domestic energy consumption that would deliver this is less clearly mapped out. This report makes...

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Managing Oil Stabilization Funds: A Framework for Developing Policies

Fluctuations in government expenditures result in welfare losses for risk-averse households and negatively impact the investment climate. Various oil-exporting countries have created income stabilization funds to cover the short- and medium-term expenses of government so as to reduce economic volatility...

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How to Achieve Economic Prosperity Through Industrial Energy Productivity Improvement

While the energy economies of China and Saudi Arabia differ in many respects, they are similar in that both countries have rapidly growing economies that are in transition. In both countries the industrial sector accounts for the majority of energy demand at around 75 percent and 60...

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Coal in Asia: The Challenge for Policy and the Promise of Markets

Policymakers in Asia have for decades focused on securing the cheapest energy for their growing economies. This meant that Asian countries invested heavily in cheap and often locally available coal and the resulting infrastructure – mines, ports, railways and power plants and electricity grids. Asian energy policies supported...

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East Africa Shared Gas Initiative

The current problem of low energy supplies in Eastern Africa does not stem from the availability of resources including natural gas but from the inability of governments, utilities and oil and gas companies to move forward with development plans. As countries transition their economies toward middle-income status, they need to improve energy...

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Energy Workshop Series

March 2018

Energy Security in the GCC and Northeast Asia

Riyadh, *March,29*

April 2018

The Future of Transportation Energy Demand for Freight in Fast Growing Economies

New Delhi, *April 3*

Oil Strategies for the Low Carbon Energy Transition

The Hague, *April 9*

KAPSARC Toolkit for Behavioral Analysis (KTAB)

Washington D.C., *April 30 - May 1*

May 2018

KAPSARC Toolkit for Behavioral Analysis (KTAB)

Washington D.C., *April 30 - May 1*

Integrating Saudi Electricity into Regional Markets

Riyadh, *May 8*

Resilience in Energy Systems

Riyadh, *May 9*

June 2018

Future Energy Demand of China

Beijing, *June 28*

01 // Research Agenda

We are pleased to bring you our latest Quarterly Research Update. In the last quarter we released 15 reports through kapsarc.org and refreshed our research agenda for 2018. While this agenda is extensive, as in previous years, it focuses on questions of topical interest to our national stakeholders.

KAPSARC Research Agenda for 2018

Some initiatives are new and some of our previous initiatives have served their purpose, allowing redeployment of capabilities to higher value activities. We have, however, maintained some flexibility to respond to events and collaboration opportunities as they arise. The key initiatives are:

1. Productivity and Economic Diversification in Saudi Arabia

The competitiveness of a more diversified, dynamic and knowledge-based economy, which can support the aspirations of the Kingdom of Saudi Arabia and advance the quality of life, depends on a set of conditions that underpin productivity and economic growth. Among the productivity factors identified in the economic literature are labor (human capital), capital (means of production: plants and equipment), land (natural resources, including energy, and income drawn from them), and entrepreneurship (business creation and moving economic resources across the economy).

Significant elements of the Saudi Vision 2030 revolve around human capital development, including support for small and medium-sized enterprises and entrepreneurs to more fully employ an emerging young population, of which half is under 25 years of age. Harnessing this ‘demographic dividend’ through skills development and entrepreneurship is seen as a key step towards economic diversification and the achievement of sustainable economic growth.

The main strategic objective of this initiative is to build on work that has studied the dimensions of productivity as they relate to the energy economy, including renewables and energy efficiency in Saudi Arabia. The new element of the initiative will involve a particular focus on employment and the links to sustainable economic growth as the Kingdom embarks on a fundamental transition to a ‘post-oil’ knowledge-based economy. Taking into consideration the particular context of the Saudi economy, it will also pay attention to the substitution of productivity, including capital and resources and the consequences on the Kingdom’s economic diversification, among other factors.

2. Energy and Economic Vulnerability

Energy systems deliver a critical output that is essential for basic health and social welfare, economic expansion and prosperity, and the integrity of nation states. Without the provision of energy to its population, the continued survival of a state would be in question. For those countries whose economies are dependent on the extraction of energy, this criticality extends to the well-being of their extractive industry as well.

The threat of disruption to energy systems and the extraction of energy is thus a core issue of concern for the Kingdom, other countries whose economies depend primarily on oil and gas, and the remainder of the world that is concerned about the security of supply. The form of these threats can vary, whether a natural disaster that can challenge the integrity of a physical energy system (e.g., an electricity grid) or an economic disruption (e.g., the volatility of price in the global oil market). Regardless of the nature of energy-economic vulnerability, the mitigation of risk and the resiliency of energy systems and energy industries are often understudied and remain primary concerns for every nation state.

The purpose of this initiative is to carefully evaluate the characteristics, scope, and the nature of the risk to both physical and economic energy systems. Once the range of threats has been defined, a strategy to enhance the resiliency of energy-economic systems can be effectively constructed. Research under this initiative will analyze the threats to energy systems that result from natural disasters, and the differential risk faced by different parts of major municipalities. Not all threats of disruption are the same. As a result, research will also differentiate the range of price shocks that can disrupt oil and gas markets, to identify the scale of the threat. Finally, we will explore economic and financial strategies that provide resilience to disruptions, such as a stabilization fund or other hedges against market volatility.

3. Evaluation of Public Investment Projects: The Opportunity Costs of Oil and Gas in Saudi Arabia

The welfare of citizens ultimately depends on how resources are used in the economy. Altering the usage of a resource has a welfare opportunity cost. In an ideal 'textbook' economy, this opportunity cost is equal to the market price of the resource. However, Saudi Arabia's economy is subject to distortions including energy price controls, and opportunity costs can differ from market prices as a result.

The Kingdom's economy has embarked on a transformational journey where some resources will be freed from existing usages and allocated to new development opportunities. Making decisions based on the wrong opportunity costs could lead to over- or underinvestment in projects and might prevent the Kingdom from fully realizing its economic potential.

National stakeholders have already investigated the question of the opportunity costs of resources such as oil and natural gas. However, there is value in revisiting it now because domestic and international market conditions have changed significantly since this question was last addressed. Multiple economic distortions prevent us from arriving at a simple answer. In particular, determining the opportunity costs of oil and gas is potentially complicated by policies on areas such as resource depletion, production or export caps, spare capacity and quota allocations.

The purpose of this initiative is to inform economic decision-making in Saudi Arabia with estimates for the opportunity costs of domestic resources, especially oil and natural gas. More generally, the initiative will contribute to delivering a framework for evaluating public investment projects that takes into account the specific characteristics of the Saudi economy.

4. Future of Transportation and Fuel Demand

Freight Movement

The changing nature of freight movement globally, including within Saudi Arabia, will alter its demand for energy. This initiative simultaneously tests out two approaches to understand and predict the change. The first is an economic approach which looks at China and India as case studies due to their status as the biggest importers of oil from Saudi Arabia, whose fast-growing economies are also becoming interesting laboratories for research. Freight is a derived demand of economies, and this approach explores the linkages between specific demand and production sectors of economies and the modes of freight that serve them. The changing nature of freight movement in China and India, due to the changing structure of their economies and their constantly evolving economic and transport policies, forms the basis of this work. The initiative then looks at how these changing freight patterns affect energy consumption.

The second part of the initiative is a spatial approach which looks at the global distribution of production and consumption centers through maritime shipping routes. We are creating a visualization tool, to be made available on OpenKAPSARC, which identifies nodes and models freight movements across Saudi Arabia using night lights and other satellite data. This model will be used to support policy plans in the Kingdom for freight mobility that uses less energy-intensive modes, like rail and shipping.

Personal Mobility

Passenger transport energy demand is a function of three factors: passenger transport activity, expressed in passenger kilometers traveled; the mode of transport chosen (e.g., public or private; road, rail or air); and fuel efficiency (i.e., the fuel used per passenger kilometer traveled). These three factors are interconnected, and each of them depends on a number of variables. For example, passenger transport activity crucially depends on the spatial distribution and density of residential and commercial buildings. Variables including income, available transport modes, their cost, speed and convenience influence modal choice. Fuel efficiency is a function of technological innovation, resulting from the interplay between industry, government and consumer preferences. This initiative aims to advance the understanding of the determinants of passenger transport energy demand, and is organized along the following research activities, exploring spatial and non-spatial approaches simultaneously:

- Conducting a network analysis of future passenger transport activity for particular geographic areas of interest, starting from the urban area of Riyadh in Saudi Arabia and extending it to other regions as appropriate.
- Analyzing how the developments of new fuel technologies, including the electrification of cars, and potentially disruptive new mobility paradigms such as shared and automated vehicles, influence consumer choices of personal transport.

5. Future of Global Oil Markets

In Saudi Arabia, as in other major oil exporting countries, oil is a leading source of fiscal revenue and accounts for a significant share of economic activity. Consumption of oil has risen almost continuously since the modern oil industry was born, but concerns about greenhouse gas emissions, local air quality and plastic waste are combining to raise doubts about the long-term trajectory of demand. Large, long lead-time investments characterize the industry, and future supply will likely require long-term visibility of demand.

Technology, geopolitics, international finance, the evolution of capital markets and oil trading will inform the transition to a greener, more economically diversified Saudi economy.

This research initiative will provide insight into the value and competitiveness of oil in its geographical and sectoral range of uses, to inform future demand scenarios. These uses include non-combustion applications of oil as a feedstock and the potential costs of decarbonizing oil as a fuel. We will assess its changing portfolio of applications to help understand what role oil can play in an environmentally sustainable future energy and feedstock mix. The initiative will also assess investment behavior and the role of technology in changing the cost and lead time of supply, to identify the likelihood of oil remaining competitive against alternatives. Finally, we will investigate the reliability and resilience of global oil value chains (for crude oil and derivative products), to understand evolving trading relationships and appropriate levels of inventories to support continuing trust in oil as a reliable long-term component of the supply mix.

6. Future of Natural Gas Markets Including Potential Saudi Linkages to Global Markets

Natural gas is an important part of the global energy mix. It provides reliable and cost-effective energy, promoting industrial development in many developing countries that have a growing demand for power and need to improve their air quality. Natural gas has an expanding role in sectors including the petrochemical industry and transport over the long term.

There has been tremendous growth in natural gas supply and demand, with major new exporters (particularly liquefied natural gas, or LNG) joining the global trade. Gulf Cooperation Council (GCC) members are increasingly becoming importers of natural gas, linking their markets to the global market.

GCC countries, including Saudi Arabia, face the challenge of restructuring their natural gas market to remove economic distortions that likely suppress domestic supply, ration demand and create market barriers to imports.

The main objective of this initiative is to explore the potential of consumption, domestic supply and trade of natural gas in Saudi Arabia in the global context. We will assess if Saudi Arabia needs to import LNG to promote the economic growth and industrialization of the Kingdom. Ultimately we will provide a road map to create a functioning, competitive and globally connected natural gas market in the country.

7. Regional Energy Markets: GCC Market Integration and Policy Drivers of Demand in China and India

GCC Market Integration

Regionalization of energy markets is a concept that seems to be under consideration around the world. If the classic economic thinking around economies of scale translates to a complex system like electricity grids, then the efficiencies gained by extending the size of an electricity market to include multiple nations may justify the capital costs. Moreover, there is the potential for a geographic spread of electricity generation to offset the challenge of intermittency for renewable energy. If the distances between centers of generation allow for optimal placement of wind and hydro, then the implementation of regional market integration could contribute to clean energy objectives as well. Such integration would rely on different local demand dynamics being out of sync with each other and for different timings of solar power generation, based on the movement of the sun across different time zones.

However, the assessment of the net economic benefit and the optimal arrangement of a regionalized electricity market remains a source of debate. What is the optimal configuration of energy mix, geolocation of generation, and the rules by which the market operates, given the inclusion of different countries in a regional market? It is also important to consider the feasibility from a policy and political perspective. When different national markets operate according to different market design principals, with governments underwriting low administered prices that they do not want to export, then policy across a region must be harmonized and reconciled before market integration can take place. Moreover, the political incentives of national stakeholders may compete with the motivation for economic efficiency that a regionalized electricity market would deliver. Concerns about energy security, sovereignty, geopolitical tension, income redistribution, and other factors may impede the willingness of national decision-makers to engage in regional power trading.

This initiative focuses on addressing the feasibility of energy market integration among GCC countries and beyond. It will consider the questions of political feasibility, policy alignment and market design. This initiative will also explore the efficiencies and cost savings achieved through optimizing the energy mix, the location of energy assets, and the scope of market integration. The consideration of these various factors for market integration, in the GCC and beyond, should result in a more practical set of recommendations for policymakers in Saudi Arabia.

Policy Drivers of Demand in China

The Chinese economy has been in a state of transition amid growth that is increasingly led by domestic consumption instead of exports. It is shifting slowly from energy and resource-intensive manufacturing to light and service industries with more stringent environmental requirements. As the world's biggest energy consuming country and largest fossil energy importer, as well as the largest investor in renewables and energy efficiency, the future growth of energy demand and domestic supply, and the pace, focus and scope of the Chinese investment in the energy sector, have a major impact on global markets. In the meantime, energy security continues to play an important role in China. How China strategizes and deals with these growing energy security concerns is significant for the Kingdom of Saudi Arabia, other GCC countries and the rest of the world.

Our objectives are to assess the main drivers behind China's energy demand (particularly oil and gas) and how these drivers shape demand; to better understand China's energy policies and Belt and Road Initiative and energy security strategies; and to assess the implications of China's changing energy demand, energy policies and security strategies for Saudi Arabia and the rest of the world.

Policy Drivers of Demand in India

As the pace of growth in China subsides, India is becoming the largest fast-growing economy and is likely to see growth in its demand for imports of oil and gas. Domestic resources will likely support coal demand growth, but there can be no guarantees that the need for clean air will not result in a solar and natural gas-based energy system expansion at the expense of coal.

Public transport, and the pace of adoption of smart mobility, will influence India's oil demand growth, as will its adherence to global climate commitments. India will seek to balance energy security with affordability in its own way, perhaps denying access to additional imports of expensive fossil fuels even to those businesses that are prepared to pay.

We will analyze the primary catalysts for India's changing energy demand, and evaluate the significance of its energy policies and security strategies for Saudi Arabia and the global community.

8. Electricity Sector Transitions

A combination of market liberalization, decarbonization policies and the rapid development and deployment of transformational technologies is fundamentally changing electricity sectors in many countries. This shift raises a range of new challenges for the operation, development and governance of power systems and markets. In particular, this transition is testing the limits of existing market, business and regulatory models, and raising concerns about their ability to adapt quickly enough to continue to provide affordable and reliable electricity services as the transition progresses.

How should governments respond to these emerging challenges? What combination of laws, regulations, market rules and other policies supports more adaptable, innovative, and environmentally sustainable electricity sectors at least cost? These are crucial questions for Saudi Arabian policymakers as they embark on a major electricity sector restructuring program that is part of the Kingdom's plan to transform the trajectory of its economic and social development well into the 21st century.

This initiative brings together research that is of direct relevance to the development and implementation of the Kingdom's electricity sector liberalization program. It will inform decision-making on the key strategic issues that will ultimately shape the development of the sector. These include identifying the market models that deliver reliable and environmentally sustainable power at least cost, the means to finance the infrastructure required, and the role of the consumer in shaping the system.

9. Climate Change Policies and Governance

A continuation of global economic development is crucial for achieving the UN sustainability goals, and this, in turn, depends on maintaining and extending access to affordable and reliable modern energy services. However, modern economic development based on growing consumption of unabated fossil fuels is generating high levels of carbon emissions which could create climatic conditions that jeopardize future growth and prosperity. A pragmatically flexible and adaptable policy approach is needed to strike an effective balance between economic development and climate change goals.

The 2015 Paris Agreement reflects this reality. It fundamentally altered the nature of global cooperation to address climate change, introducing a decentralized approach based on national carbon mitigation goal-setting to drive collective action. Under the Agreement, Saudi Arabia has expressed its ambition to avoid up to 130 mtpa of carbon emissions by 2030 compared to business as usual.

Cost-effective low- and zero-emission energy technologies will be crucial for achieving a timely and affordable transition toward a decarbonized global economy. In particular, opportunities exist for Saudi Arabia to deploy novel technologies to enhance oil recovery while sequestering carbon emissions to effectively ‘decarbonize’ oil production. Deployment of these and other low-emission energy technologies could provide a way for Saudi Arabia to achieve its national carbon mitigation goals while addressing concerns over future oil demand in a more carbon-constrained world.

This initiative will investigate energy and climate change policies that balance socio-economic and environmental considerations, to provide options to Saudi policymakers as they implement the Paris Agreement and prepare to negotiate the next round of nationally determined contributions. It will also examine key energy technologies and technology development pathways that can help Saudi Arabia achieve its economic and carbon abatement goals, including related policy, regulatory and commercial issues.

10. Models, Data and Tools

KGEMM model for policy analysis in the Kingdom

Macro-econometric models are commonly used for simulating economies in the short and medium terms. However, existing global models tend to use an oversimplified representation of Saudi Arabia’s economy. There is therefore a need for a macro-econometric model that can evaluate the effects of policy scenarios such as energy price reforms and fiscal policy changes, and that links Saudi Arabia’s macroeconomic-energy environment with the global economy, especially energy markets.

The initial structure of the KAPSARC Global Energy Macroeconometric Model (KGEMM) is that of the Global Economic Model of Oxford Economics. However, we have changed the structure of Saudi Arabia’s economy in the model significantly and have considerably enriched the representation of some of its key components. This work is ongoing and will expand the model’s capabilities for studying the Saudi economy.

KAPSARC has used KGEMM to assess macroeconomic effects of energy price and fiscal reforms, the cornerstones of the Fiscal Balance Program. We collaborate with various stakeholders including Saudi Aramco Corporate Planning, the Saudi Arabian Monetary Authority, the Ministry of Economy and Planning, and the Ministry of Energy, Industry and Mineral Resources. We also collaborate with Oxford Economics to help improve the representation of the Saudi economy in their global model.

KEM model for policy analysis in the Kingdom

Energy economic models are a well-established tool for evaluating tradeoffs of policy choices. KAPSARC has developed an advanced energy modeling platform for Saudi Arabia and the GCC. This work is motivated by the large size of the energy and energy-intensive sectors in the Saudi economy and the structural changes that the economy will undertake as the size of the non-energy sectors increases. The novel KAPSARC Energy Model (KEM) methodology can investigate pricing rules, subsidies and other government interventions specific to Saudi Arabia. We have designed the platform to analyze the immediate consequences and ripple effects of existing and potential policies. Our development strategy is driven by stakeholders' policy questions, existing modeling gaps and innovative methodologies as necessary.

The objective of this initiative is to continue development of the platform so that it meets stakeholders' policy questions. Model development will progress along three pathways:

- Macroeconomy – to capture all feedback between the energy and non-energy components of the Saudi Arabian economy when evaluating policies. We are building a general-equilibrium version of the model that includes the rest of the economy.

- GCC coverage – we are adding the power and water sectors in the rest of the GCC to study potential gains from market integration.

- Platform development – to streamline the creation of new modules and policy scenarios by restructuring the model code. This activity will reduce development and analysis time and facilitate the use of our models by stakeholders.

A series of studies relevant to domestic and regional stakeholders have been and will be performed using the KEM platform.

KTAB toolkit — models of collective decision-making processes

The economic consequences (both positive and negative), as well as the technical challenges facing energy policy, are a familiar topic to policymakers, corporations, analysts and the media. Economic models are a well-established approach to evaluate the utility of one or more policy options. However, little time and rigor are usually devoted to the policymaking process itself. That is, the political process that results in the selection of a particular policy, or even implementation of a policy in the face of political and social opposition, is almost never considered with the benefit of a systematic and evidence-based approach.

To remedy this shortcoming in the analysis of energy policy and energy economics, KAPSARC has developed the KAPSARC Toolkit for Behavioral Analysis (KTAB), an open source capability to model collective decision-making processes (CDMPs). The methodology has a wide range of applications for policymakers and anyone who wishes to better understand how groups of people influence each other to make decisions. For example, questions such as the following could be analyzed with KTAB to produce unique and actionable insight:

- Can the stakeholders (e.g., decision-makers, their constituents, members of relevant ministries in the government, industry, and the public) impacted by a policy arrive at a consensus for the details of a reform policy? What are politically feasible and infeasible policy outcomes?

- Will a government's policy choices be received with support by impacted agencies and citizens, resulting in the effective implementation of a policy initiative?

- How does a board of directors, composed of different individuals with distinct priorities and objectives, agree on how to allocate funds to one project versus another?

This initiative continues the development and the real world application of this unique capability, to better understand the behavioral component of energy policy. We will focus our research on the extension of the modeling platform to enable the realistic simulation of government decision-making, consumer choice, and the political feasibility of energy policies. KTAB provides a methodology to examine these processes systematically, and to provide insight into how a decision is likely to be achieved. Additionally, we will analyze a number of behaviorally-driven questions that have a significant impact on global energy markets.

Energy data portal and web apps

"Fueling energy research with clean and machine-readable data."

Researchers often lack access to open and reliable data, which is critical for energy research success. Furthermore, researchers want to make their output easily sharable and reproducible so that others can build on their insights and their research can further evolve. Data copyrights often restrict usage or access. KAPSARC has found around 150 data sources that provide energy-related data in disparate formats, in which 32 percent of the critical datasets were not in machine-readable format. We source the data relevant to our research questions and, on the basis that others will likely be interested in these data, we make them universally available. Often the datasets are stored in pdf documents, and researchers have to spend significant time in converting the data into a usable format for their analyses. We are leveraging advanced data management technologies and data governance best practices to source, capture, standardize and publish API-ready high-quality data on KAPSARC's energy data portal.

We designed the energy data portal to improve the understanding of energy economics and to act as a catalyst for dialogue. It enables easy search, analysis, geo-map lookup and charting tools, and the ability to share data views with just a few clicks. The advancement of big data and associated analytical tools means that application programming interface (API) ready data demand will rise significantly, leading to new energy insights. As a result, we are building an energy data portal to serve the needs of energy researchers within Saudi Arabia and globally.

New data portal developments have recently emerged in the region, including the Saudi open data portal and JODI data portals for oil and gas. We are collaborating with the Saudi Open Data initiative, which covers datasets for nine themes out of 16 that we have identified as being relevant to energy research. KAPSARC's unique energy data portal is the most prominent data portal in the region, making all critical energy data themes available in API format and allowing other platforms to access this data within minutes.

We will expand our understanding of energy demand data in fast-growing developing countries. Our initial focus is on key countries, including Saudi Arabia, GCC countries, India and China. We will develop datasets tailored for these countries, to advance energy research. We will draw lessons and develop best practices that can be scaled, to increase our understanding of the global energy supply chain and help shape Saudi Arabia's energy policies.

By supplying open access to clean data, KAPSARC's energy data portal initiative aims to overcome three barriers to the advancement of research:

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- Highly time-consuming data preparation for research.
- Hundreds of disparate data sources through which to access data.
- Non-availability of critical energy-relevant data.

KAPSARC's data portal tackles these problems by identifying data sources, transforming the data into a machine-readable API-ready format, and publishing it in a clean interface for open access, ready to download. These efforts will dramatically expand access to open energy data, carrying multiple economic benefits and further advancing the pace of research.

We started our data portal initiative planning in 2015 and launched the portal to the public in 2016 on OpenKAPSARC. OpenKAPSARC includes web applications and analytical tools that enable stakeholders to better understand KAPSARC models, and tools and insights to accelerate economic development, reduce the environmental impact of energy production, and meet energy access goals.

Last year, researchers from over 90 countries downloaded 11,500 datasets. Our goal is to extend data access to 20,000 global organizations by 2020.

Access KAPSARC’s data portal at https://datasource.kapsarc.org/

Access OpenKAPSARC at https://www.kapsarc.org/openkapsarc/

02 // Research Highlights

We begin this quarter with a set of papers focused on the electric power sectors of Saudi Arabia and its GCC neighbors. The workshop brief, ***Technological Disruptions and Service-Based Business Models in the Power Sector***, provides insights into the way that 'smart grid' technologies act as enablers of business models that are providing the economic push towards low carbon, distributed energy systems. These technology trends can be applied globally. The original international workshop created demand from leaders in the Saudi power sector for a follow-up workshop in Riyadh, to explore ways of applying the insights to the liberalization and restructuring of the Kingdom's internal market.

Creating a balance between providing sufficient granularity and keeping models simple and usable is a continuing challenge for analysts studying the Saudi electricity sector; there is no general purpose model. ***Electricity Transmission Formulations in Multi-Sector National Planning Models*** examines the insights gained from adding electricity transmission constraints to a model in which intermittent renewable energy resources are added in different regions. As plans for restructuring and privatizing the Saudi Electricity Company gather pace, we take the opportunity to consider how the lessons of such competitive markets in Europe and the Americas can be applied in the Kingdom. ***Restructuring Saudi Arabia's Power Generation Sector: Model-Based Insights*** finds that market restructuring delivers some $4 billion of annual surplus to the economy, and identifies different potential beneficiaries of this surplus depending on the adopted market structure. What is clear is that reform of fuel and electricity prices will deliver more value to the government shareholders, and maximize proceeds, if conducted before privatization.

GCC Energy System Overview – 2017 provides a transparent description of the input data and assumptions of our partial equilibrium models of the energy systems of the GCC. It allows researchers around the world seeking to model the region's energy markets to understand the KAPSARC Energy Model and provides sources for all data employed. This transparency reflects our commitment to making the model code and data freely available wherever obligations to providers of proprietary data do not constrain us.

Our study of the oil and oil product markets has examined the extent to which increasing fuel economy standards improves overall welfare. The rebound effect is well known for eating into planned fuel savings achieved through efficiency improvements but, as ***Welfare Implications of the Rebound Effect from More Energy-Efficient Passenger Cars*** argues, this rebound need not be welfare reducing under the right circumstances. The authors propose a framework for regulators to identify when to design policies to reduce rebound effects and when they need not be so concerned. A paper on a related topic shows that consumers may underestimate the level of fuel savings achieved through the adoption of electric vehicles (EVs). ***Gasoline Savings From Clean Vehicle Adoption*** argues that we must consider what the consumer would have bought had they not chosen an EV – typically less fuel-efficient than the average vehicle – leading to larger fuel savings than would normally be recognized. However, as the level of adoption increases, this effect can be expected to decline because future EV buyers will be more 'average.'

The threat from alternative fuel vehicles and other policy pushes to reduce and even reverse the growth of global oil demand seems remote for the time being. Many of the conventional forecasts of oil demand growth see no reversal during the next quarter century. However, the study of the timing and likelihood of ‘peak demand’ has become popular among energy and economics think tanks around the world. KAPSARC has been pushing ahead with research on viable economic adaptation strategies for major oil producers in the event that a demand peak becomes inevitable. A series of consultative workshops on the topic have provided insights for ***Role of Oil in the Low Carbon Energy Transition***. This paper suggests there are strategies that will allow the low-cost oil producers to thrive in such an environment, potentially at the expense of oil importers that may assume that carbon taxes or other policies to reduce oil product demand will accrue to their own national accounts. The project is ongoing, and forthcoming workshops will lead to a final report to be released through kapsarc.org.

Two collaborative projects came to fruition during the quarter, continuing the subject of the energy transition. Working with researchers from the Khalifa University of Science and Technology in Abu Dhabi, ***The Political Feasibility of Policy Options for the UAE’s Energy Transition*** delivers a case study for using the KAPSARC Toolkit for Behavioral Analysis (KTAB) to examine the political feasibility of various options to reduce the carbon intensity of the UAE’s economy. Looking more globally, our collaboration with the Institute of Energy Economics Japan (IEEJ), ***Towards More Pragmatic Global Climate Goals and Policies***, considers the merits of broadening the framework for climate governance measures, to recognize the inevitability of some damage being sustained, and to incorporate this alongside the costs of mitigation and adaptation.

One of the uncomfortable truths about attempts to limit greenhouse gas (GHG) emissions from energy is that no matter how efficiently we consume energy nor how efficiently we extract energy from combustion of carbon-based fuels, the GHG emissions will be determined by the quantity of fuel combusted. If fossil fuel demand rises in absolute terms, the quantity of GHG emissions rises unless carbon capture, usage or storage (CCUS) is deployed. ***Enhanced Oil Recovery and CO_2 Storage Potential Outside North America: An Economic Assessment*** builds on work done to inventorize the physically available pore space in oil fields around the world by adding the economic and fiscal perspective. The study that resulted from our collaboration with Rystad Energy finds that economically viable pore space within 500 km of CO_2 sources amounts to some 40 billion tonnes of CO_2 outside North America, enough to cover four years of Chinese emissions.

Our joint project with the United Nations Economic and Social Commission for West Asia (UN ESCWA) has culminated in the release of a consultation document, ***Growth Through Diversification and Energy Efficiency: Energy Productivity in Saudi Arabia***. This multi-year project has resulted in the release of many papers on the intergenerational welfare benefits of improving energy productivity, approaches to financing energy productivity investments, and sectoral diversification strategies, among others. KAPSARC would welcome feedback on the report as it moves to the final published version. Two other studies that seek to throw light on insulating the Saudi economy from resource-based volatility are ***Managing Oil Revenue Stabilization Funds: A Framework for Developing Policies*** *and* ***How to Achieve Economic Prosperity Through Industrial Energy Productivity Improvement***. The first of these studies develops a framework for optimizing the buildup and drawdown of stabilization funds, using past decades to demonstrate the additional wealth that this approach could create for the Saudi economy (by efficiently stabilizing macroeconomic consumption while delivering the same levels of social welfare).

KAPSARC conducted the latter study in collaboration with the Energy Research Institute (ERI) within China's National Development Reform Commission (NDRC). It identifies the lessons that Saudi Arabia can incorporate into its own economic diversification based on China's experience of transitioning to a higher energy productivity growth path.

Finally, for this quarter, we share the workshop briefs from our global coal and natural gas markets analysis. ***Coal in Asia: The Challenge for Policy and the Promise of Markets*** explains how the last great hope of coal markets may transition away from the fuel as advances in renewables leapfrog coal's own technical advances regarding boiler efficiency and emissions reduction. Our joint gas research project with Columbia University's Center on Global Energy Policy (CGEP) and the Fondazione Eni Enrico Mattei (FEEM) looks at the value of consuming gas resources locally rather than exporting them through large-scale LNG projects. As one of the most proximate sources of LNG to the GCC (with Qatar apparently not an option even in the longer term) East Africa could be an important source of supply to both the Gulf region and the Indian subcontinent. The workshop brief, East Africa Shared Gas Initiative, provides an interim view of this potential with a final report due later this year.

We hope you will find the papers shared in this update provoke your thinking and look forward to you engaging with us as we move forward to execute against our research agenda. More of our studies now result from collaborations with other highly rated institutions, and our ambition is for this to become a more general rule rather than the exception.

Technological Disruptions and Service-Based Business Models in the Power Sector

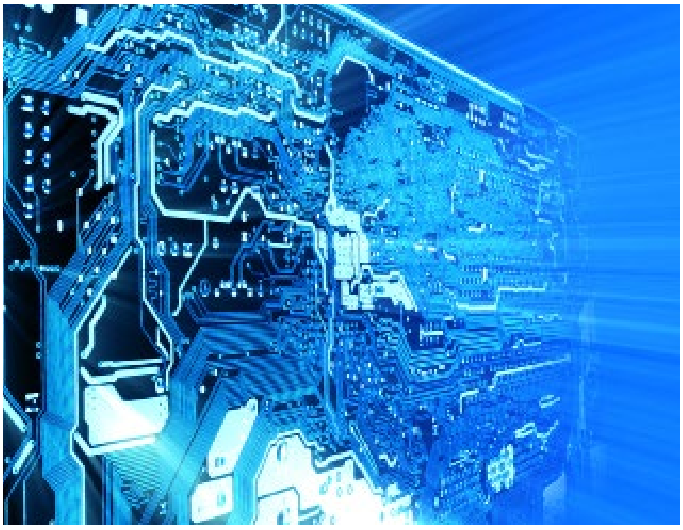
Workshop brief

The power sector, in many countries, is undergoing major changes largely driven by technological developments that are affecting both electricity supply and demand. Entrepreneurs are seeking to turn the traditional top-down supply model, which flows from generation through transmission and distribution to retail, on its head by embracing the emergence of distributed energy resources (DERs), allowing households to produce, consume, store and trade power.

A fundamental shift is taking place from the notion of electricity as a traded commodity to becoming a component in a range of value-added and flexible services that are currently dormant in consumer demand. Distributed ledger technologies, such as blockchain, have opened the distribution and retail sectors to diverse innovators and startup companies, which are developing services and applications that bring together producers, consumers and third-party service providers. Some of these new businesses are at the intersection of energy, finance and internet. If this approach takes off, it would probably require new forms of regulation that reflect the integrated business proposition rather than falling between functional silos that are the responsibilities of banking, communications and utility regulators.

Innovation in distributed energy technologies allows end users to produce their own power locally and also sell any surplus. Although DERs are usually not owned by utilities, most new businesses ultimately rely on the safety net provided by the utility as the electricity provider of last resort. Utilities must therefore manage their business models at the retail end to keep up with the changes brought about by distributed generation and demand.

However, societal benefits could be jeopardized if new business models endanger the financial viability of the utility, or if the new business models become a dominant platform that prevent the incubation of fresh ventures. The regulatory framework must therefore adapt to the new environment; regulations will need to be formulated in parallel with markets, by allowing innovators



and newcomers to fill the gaps as well as develop services enabled by technological progress.

Technology also introduces new risks that may not have been imagined when regulatory systems were designed. Establishing industry-wide standards that deal with these new risks will be crucial in helping build trust and confidence in the new electricity systems as they grow.

Download the Paper

Electricity Transmission Formulations in Multi-Sector National Planning Models: An illustration using the KAPSARC Energy Model

Walid Matar and Amro M. Elshurafa

Large-scale national policy models date back to the 1970s (Hall and Buckley 2016), and have adopted different levels of detail with the ultimate purpose of informing policy decisions. These models make trade-offs in what to represent and how to represent it, while making the models tractable and relatively easy to solve.

In partial economic equilibrium models, such as the core of the National Energy Modeling System (NEMS) of the Energy Information Administration (EIA) and the International Energy Agency's TIMES (The Integrated MARKAL-EFOM System), power generation expansion models have been understandably favored to electricity transmission models. They have typically adopted transshipment, or transportation, formulations of power flows that do not adhere to Kirchhoff's Current and Voltage Laws. Taking these laws into account, a transmission model would consider two key features of power flows; the flows cannot be controlled, although some devices allow for partial control, and power travels via all paths between generators and load. Models that rely on a transshipment method in place of a proper transmission model generally underestimate additional transmission capacity requirements (Krishnan et al 2016). The aim of this paper is to assess the effects of introducing a transmission component in a national planning model. Specifically, would the addition of transmission alter the decisions of the sectors linked to it?

For this case study, a transmission sub-model is integrated in the KAPSARC Energy Model (KEM) for Saudi Arabia. The model already consists of several economic sectors, such as oil refining and power generation, but it does not have a proper electricity transmission representation. Similar to other models of its type, it adopts a transshipment formulation. We include a direct current optimal power flow (DCOPF) formulation in the KEM with and without transmission losses; the DCOPF problem is also estimated using a single node and three nodes per region. We then compare output from all versions of the model using two fuel pricing policy scenarios: 2015 regulation and deregulation of fuels. The effect on investment decisions made by the power generation sector and the cost of delivering electricity are of particular interest.

There are two areas where we think the addition of a transmission component can directly influence policy assessments. Firstly, we hypothesize that introducing transmission constraints in the model can impact power generation investment decisions, especially in renewable technology. Whereas the basic model could integrate large quantities of variable renewable technologies if fuel prices were sufficiently high, it did not consider the possible intermittent congestion arising in the regional transmission lines or the physical limitations of the grid. Secondly, the marginal cost of delivering electricity is expected to change as a result of different investment decisions, which may affect the levels of electricity demand.

There may also be tertiary effects that have wider ramifications on the economy. One example is the domestic market-clearing price of natural gas. Since the technology mix is expected to change in power generation, fuel consumption may also change, and therefore the consumption of natural gas and its level of scarcity may change.

These ideas, coupled with the lack of a proper transmission representation in existing national planning models, motivated this work. Compounding all these changes, our modeling analysis generates about $20 billion in avoided full-cycle investment in power plants in the long run. To get an idea of the size of the sector, the operating revenue of the local power utility, the Saudi Electricity Company (SEC), was around $11 billion in 2015 (SEC 2016). The paper contextualizes these savings.

This paper is structured as follows: the next section provides a review of studies that have previously explored this topic and current multi-sector models. We then describe the approach undertaken to answer the research question. We conclude by displaying and discussing the results.

Download the Paper

Restructuring Saudi Arabia's Power Generation Sector: Model-based Insights

Bertrand Rioux, Fernando Oliveira, Axel Pierru and Nader AlKathiri

Saudi Arabia plans to reform and privatize its power generation sector as part of its Vision 2030. International experience shows that it will face two challenges: achieving sufficient supply reliability during peak demand and reducing the potential for price manipulation through the exercise of market power by electricity producers. Restructured markets in the Americas and Europe have had to address this market power and introduce additional market instruments to incentivize investments sufficiently to meet reliability requirements.

To provide analytical insights, we developed a model that simulates the restructuring of the electricity market. We assume that the Saudi Electricity Company's (SEC) existing generation assets are unbundled and equally distributed to four new generation companies (Gencos). The model includes an electricity market and – in some scenarios – a capacity market, both with zonal pricing in four operating areas, the possibility of new entrants, a Transmission System Operator (TSO) who manages the electricity network and a Principal Buyer who designs and operates auctions for capacity and electricity. Also, arbitrageurs who buy and sell electricity, eliminating price distortions between regions. Wholesale prices are assumed to be passed on to consumers.

To describe different possible market outcomes, we designed several scenarios calibrated to Saudi Arabia's data projected to the year 2020, and we compare them with a Business As Usual (BAU) scenario that captures the current market structure. In the BAU scenario fuel prices are administered, the expansion of private generation firms is restricted and the Principal Buyer uses long-term power purchase agreements (PPAs). In the other scenarios, fuel prices are partially or fully deregulated, generation is privatized and firms bid into a daily auction for electricity. To assess the potential impact of price manipulation we introduce scenarios where the large Gencos exercise market power, as well as scenarios in which all firms operate in perfect competition with no room for price manipulation.

We find that the elimination of market power through competition or regulation is particularly important at peak demand times when competition is very limited and price spikes increase the profits of baseload producers. By reducing the fixed cost of plants, especially among small companies operating at low utilization rates, a capacity market can promote competition among peak generators and reduce electricity prices during peak demand.

The study shows results for three scenarios in which all fuel prices are partially deregulated to an energy equivalent of $3/MMBtu. The values in parentheses represent the percent difference from BAU. In the first two scenarios, there is only an energy market (no capacity market), all firms behave competitively in the Competitive Energy Market scenario, while the large Gencos exercise market power in the Cournot Energy Market scenario. The Capacity Market scenario adds a capacity auction to the Cournot Energy Market scenario.

The fuel subsidies are measured as the difference between the international oil price (assuming $58 per barrel) and the administered prices paid by the generators. Consumer surplus measures the value that consumers get for electricity beyond the price they pay. It is calculated from estimates of how consumers' electricity demand reacts to price changes. The total surplus is equal to firms' profits plus consumer surplus minus fuel subsidies. The average cost of electricity (the consumer price if no rents were available for the utilities) includes electricity production and transportation costs.

In all scenarios, market restructuring delivers an increase in annual total surplus of more than $4 billion. However, much of that gain comes at the expense of consumers, with a significant increase in electricity prices. The very large price increase observed in the Cournot Energy Market scenario results from the strategic behavior of the Gencos, which restrict their production in order to maximize profits. This shows that, at least in theory, there is potentially significant room for price manipulation.

Allowing firms to exercise market power results in a slightly bigger total surplus because of the large increase in the firms' profits and the savings in fuel subsidies (due to a lower quantity of electricity generated). This result is specific to a country with significant subsidies for crude oil used in power generation.

In the Competitive Energy Market scenario, the saving in fuel subsidies exceeds the loss in consumer surplus. Therefore, the government can transfer fuel savings to low-income consumers with a net surplus. This is not the case with the Cournot Energy Market scenario. Allowing for both the exercise of market power and reforming fuel prices result in an increase in the market value of SEC's existing assets, due to higher rents on production capacity. This justifies reforming fuel prices before restructuring the market in order to maximize government revenues from selling assets to the private sector.

The paper shows that the capacity market improves reliability by providing more reserve margins nationally, which is not factored in the change in total surplus. In the Cournot Energy Market scenario, electricity purchased from neighboring regions during peak demand periods can remain cheaper than the survival and growth of local generators, leading to negative reserves in some regions. This phenomenon is much more attenuated in the Capacity Market scenario. We also show how adjusting the design of a regional Capacity Market influences the generators decision to invest and retire capacity. Therefore, the principal buyer can design the market to establish which technologies should survive in order to promote efficiency gains, improve reliability and to preserve existing government investments.

Download the Paper

GCC Energy System Overview – 2017

David Wogan, Shreekar Pradhan and Shahad Albardi

This paper presents datasets that support economic and policy analyses of countries in the Gulf Cooperation Council (GCC). The objective is to provide an overview of the GCC energy systems and serve as a reference for researchers performing quantitative modeling and analysis. The following data have been collected from public sources, using the most recent complete datasets available.

We begin by describing the GCC in terms of electricity systems specific to each country. For each system, we compile and present information about how electricity and water are supplied in terms of technologies and fuels. A key point is the linkage of electricity and water production in the GCC. Power plants typically produce a combination of electricity and water, primarily through desalinating seawater using waste heat. This linkage must be considered when analyzing how energy is transformed in the GCC.

An assessment of fossil and renewable resources follows in the third section. The GCC states are well endowed with fossil and renewable resources. To date, fossil energy has been exploited for export and domestic consumption while the use of renewable resources has been negligible in terms of total primary energy supply.

The fourth section presents government administered fuel prices and electricity tariffs. These provide a context for understanding the composition of the energy and water sectors. Regulated energy prices are a characteristic of the GCC. Administered prices on the supply (electricity production) and demand side (electricity consumption) have been, and continue to be, a key barrier to electricity trade and greater penetration of renewable technologies in the power and water sectors. Ongoing price reforms are expected to improve the prospects of electricity trade and cost-effectiveness of renewables.

Existing energy policies, future targets and power sector reforms are covered in the fifth section. GCC countries have announced plans to both diversify electricity production (by deploying renewables and nuclear capacity) and to reduce demand (through efficiency measures). Recently announced targets in all six GCC states suggest that renewable resources and nuclear energy will be a prominent component of the region's future energy systems. Almost 80 GW of renewables will be installed, around four times the amount of nuclear power that is planned in the region.

The accompanying datasets are available on the OpenKAPSARC data portal and will be updated as new data are available.

Download the Paper

Welfare Implications of the Rebound Effect From More Energy-Efficient Passenger Cars

Ziyad Alfawzan and Anwar A. Gasim

Conventional wisdom suggests that improving energy efficiency is a worthwhile investment. Many engineering and economic models have shown that energy-efficient technologies across a number of sectors are welfare enhancing, with higher benefits than costs. However, many of these models fail to account for the rebound effect and its impact on welfare.

Improving the energy efficiency of passenger cars, for example, makes it cheaper to drive, leading consumers to drive more. This additional driving, which offsets some of the expected energy savings from energy efficiency, is known as the rebound effect and is often perceived negatively. This paper is the first to conduct a welfare analysis of the rebound effect from more energy-efficient passenger cars for a large number of countries. The results are then included in a complete welfare analysis of the energy efficiency improvement that accounts for the ensuing rebound effect.

Our findings reveal the rebound effect to be welfare reducing in most cases because of the large externalities associated with increased driving. These externalities include air pollution, greenhouse gas emissions, congestion and accidents, which we find to outweigh the benefits from additional driving. Furthermore, the rebound effect is found to be worse (that is, more welfare reducing) in countries that had some combination of low gasoline prices, high congestion and high accident costs.

Our results carry important implications for energy efficiency policymaking, particularly in the road transport sector, given that many evaluations of energy efficiency do not account for the rebound effect, which can be misleading. We find the rebound effect to have a significant impact on overall welfare. In fact, in countries with the worst rebound effects, we demonstrate that even a ‘free’ energy efficiency improvement (that is, with zero upfront costs) in passenger cars can become welfare reducing once the negative impact of rebound is taken into account.

Our work has three key messages for policymakers. First, it highlights the importance of accounting for the welfare implications of the rebound effect, which can have a considerable impact on decisions to move forward with energy efficiency policies. In some countries, the welfare reduction created by the rebound effect may be large enough to overturn the welfare enhancement brought about by the energy efficiency improvement. However, in others the welfare enhancement produced by rebound may help increase the net benefits of energy efficiency.

Second, energy efficiency policies such as fuel economy standards are less likely to deliver net benefits when fuel prices are low, or congestion and accident costs are high, partly because of the rebound effect. Thus, energy efficiency policies may be more effective when combined with policies that raise fuel prices. Furthermore, complementary policies that can mitigate congestion and reduce road accidents can indirectly improve the net benefits of energy efficiency policies in road transport.

The third key message is that the rebound effect is not always welfare reducing, as some studies have suggested. For some countries, rebound in passenger cars is found to be welfare enhancing. Moreover, when we set the congestion and accident costs to zero to model the potential welfare implications of rebound in other areas, such as building lighting or air conditioning, we find the rebound effect to be welfare enhancing in most cases. It is therefore important to model and understand the welfare implications of the rebound effect before considering any policies to mitigate it. More work in this area could help change the negative perceptions that the rebound effect holds in energy policy discussions. Ultimately, for most energy efficiency policies, the primary goal is to maximize welfare rather than minimize energy consumption, and the rebound effect could help support that goal.

Download the Paper

Gasoline Savings From Clean Vehicle Adoption

Tamara Sheldon and Rubal Dua

The goal of many transportation policies is to increase clean vehicle market share. Quantifying the benefits of these policies requires assumptions about what consumers would have purchased in the absence of the policy. For example, existing literature assumes that consumers who purchase plug-in electric vehicles (PEVs) would otherwise purchase an economy or midsize car. Without the option to purchase plug-in electric and/or hybrid vehicles, conventional counterfactuals used in the literature may underestimate the fuel savings from clean vehicle adoption, thus overestimating the costs of securing associated environmental benefits.

A choice model of vehicle purchases based on a nationally representative sample of new U.S. vehicle purchases in model year 2015 was developed. The choice model also incorporates heterogeneity of consumer preferences across demographic and attitudinal variables. Using this model, predictions are made on the national vehicle market share at the make-model level assuming unavailability of 1) PEVs and 2) PEVs and hybrid electric vehicles (HEVs). These predictions are used to construct counterfactual fleet fuel economy and gasoline consumption for both scenarios.

In Scenario 1 when PEVs are not available, less than 5 percent of the would-be PEV buyers (who make up 0.81 percent of the total market) purchase HEVs instead. More would-be PEV buyers purchase SUVs (11 percent) and pickups (11 percent) instead. Overall, more than a quarter of the would-be PEV buyers switch to a light truck, leading to an increase in overall light truck market share (from 48.24 percent to 48.45 percent) and decrease in passenger car share (from 51.76 percent to 51.55 percent). These trends are exacerbated in Scenario 2 when HEVs are also unavailable, with light truck share increasing to 49.36 percent and passenger car share decreasing to 50.64 percent.

Results suggest that if PEVs were not available, fuel economy of cars would decrease nearly 1 percent and that of light trucks would drop by 0.23 percent for a total decline in fleet fuel economy of 0.60 percent. If PEVs and HEVs, which jointly account for 3.38 percent of the 2015 market share, were not available, then fuel economy of cars would decrease by 2.49 percent and that of light trucks would drop by 0.37 percent for a total decline in fleet fuel economy of 1.68 percent. Lastly, since PEV and HEV consumers also tend to drive more miles, in the absence of clean vehicles gasoline consumption rises by 1.71 percent, greater than the decrease in fleet fuel economy.

Together, these results imply that clean vehicle adoption has led to a significant reduction in gasoline consumption. Finally, the study estimates greater increases in fuel economy and decreases in gasoline consumption relative to counterfactuals relied upon in existing literature (‘conventional counterfactuals’). A simple calculation estimates that the cost of the gasoline savings resulting from PEV adoption incentives to be $6.90 per gallon, assuming a vehicle life of 10 years. While relatively expensive, it is significantly less than the $8.75 per gallon that is estimated using conventional counterfactuals.

Download the Paper

Role of Oil in the Low Carbon Energy Transition

Workshop brief

In 2016 and 2017, a number of scenario reports from respected global energy organizations highlighted how the energy transition is likely to impact global oil demand. All of these scenarios pointed to slowing demand for hydrocarbons, including oil, and several suggested that demand will peak and start declining within a foreseeable future. Recent flattening of growth and even decline in demand for coal, the pace of investment in renewables and evolving trends in smart mobility suggest that we are entering into an energy transformation, already dubbed by some as the 'Grand Transition', comparable to the switch from coal to oil at the beginning of the 20th century.

This transition has been driven by concerns about climate change in richer economies and by air quality in those that are still developing. The debate has coalesced into a single target: the need to limit global warming to 2^{o}C above the level recorded in pre-industrial times. The Paris Agreement established a system of voluntary measures known as Nationally Determined Contributions (NDCs). Independent analysis of the net effect of all the measures announced to date in the NDCs suggests we are far from achieving the 2^{o}C cap. For the time being, actions do not match the rhetoric and apparent urgency required. But what if policymakers were to act as if the emissions limits were binding?

The conflation of energy policy and climate policy has been challenged by the U.S. withdrawal from the Paris Agreement, but the pace of technological innovation means that the continuing drive to low carbon energy, storage and reducing energy intensities will still challenge fossil fuels where their hold is most tenuous. However, the pace of change may be over-estimated by proponents of new business models. Testing the limits of what is foreseeable for the displacement of oil, for example, leaves plenty of room for coexistence and long-term demand, even if at levels that are one-third lower in 2040 than today. Low carbon technologies would include carbon capture, usage and/or storage (CCUS) if costs can be reduced by anything similar to the renewables technology cost curves.

For oil-producers in the Gulf Cooperation Council (GCC) region, in particular, any slowdown in oil demand represents a transient threat while markets rebalance and a longer-term loss of revenue as prices stabilize at a lower level than previously anticipated. But the region's low cost base means that it is likely to retain a larger share of a smaller cake against higher cost resource-holders. This possibility is already recognized by strategies to diversify national economies away from oil dependency – it is a process that is already well underway in the region.

The financial sector, in line with its normal response to risk, has begun reallocating asset portfolios and reducing exposure to sectors where there is real and perceived risk from the effects of the transition. The risk is greater for international oil companies (IOCs) whose core business model is increasingly under threat and there is evidence that they recognize this and are diversifying into areas such as natural gas, which still have some room for continued growth – at least in the medium term.

In the meantime, doubt remains as to the speed of the current trajectory of the energy transformation and its ability to ensure climate targets are achieved. Will policy interventions by anxious governments change the current dynamic? Or will a breakthrough technology emerge leading to an even faster transition?

Whatever future is viewed as most likely, long-term economic success requires that policymakers prepare for the worst case and develop strategies to thrive in the midst of hardship. Workshop participants tested this proposition by imposing a constraint that free-riders could be eliminated and challenging them to devise strategies, representing nine different archetype economic blocs, which minimized the damage to their societal welfare in meeting the now binding targets. All participants proposed policy prescriptions that would meet their goals in isolation, but the equilibrium effects of policy interaction between blocs resulted in less than 25 percent reduction in greenhouse gas (GHG) emissions (versus a needed 75 percent reduction).

Conventional strategies, including carbon taxes, increased forestry, energy efficiency and the like did not deliver the target and future workshops will force deeper strategic thinking from which, perhaps, free-drivers may emerge – economies that can meet their targets without damaging their own economies but at the expense of others. Our intuition is that current expectations of rich economies benefiting at the expense of those still emerging from poverty is not inevitable and that more constructive policies may emerge if all participants see the potential to end up as losers if they do not cooperate.

Download the Paper

The Political Feasibility of Policy Options for the UAE's Energy Transition

Brian Efird, Steve Griffiths, Paul Mollet, Imtenan Al-Mubarak, Sgouris Sgouridis and Itsung Tsai

This paper applies a model of collective decision-making processes (CDMPs), the KAPSARC Toolkit for Behavioral Analysis (KTAB), to question the political feasibility of six different policy options which could help achieve the efforts of the United Arab Emirates (UAE) to change its energy system to a less carbon-intensive one. We consider each of six policy alternatives, in turn, that could be used to execute the UAE energy transition:

- Carbon pricing
- Renewables
- Nuclear energy
- Energy efficiency
- Energy subsidy reform
- Natural gas

For each of the actors involved in this study, there are likely to be a number of different motivations for their policy choices. These differences will largely be reflected in how the actors approach each of the options identified in this study. Whereas some actors are driven more by reducing the cost of energy, others are more interested in minimizing the climate impact of energy production. More externally focused actors might choose policies based on the notion of energy security, or take a position that is conditioned by their understanding of geopolitics and regional political interests. Other actors may have business interests in one policy instrument as compared to others, or have some personal desire and motivation that drives their advocacy on this issue.

How the UAE chooses to move forward with a particular mixture of policies to achieve an energy transition is based upon both the expected impact of the policies, as well as the potential political consensus that can be achieved in order to define and implement policy. Decision-makers and other stakeholders will have to reconcile their differing motivations and priorities to arrive at a set of policies. In the case that the key decision-makers and implementing authorities do not arrive at a consensus about a policy instrument, we would consider that instrument to be politically infeasible. When decision-makers and implementing authorities arrive at a consensus about a policy instrument, then it is likely that it will be both selected and implemented effectively.

In consultation with a group of 10 subject matter experts, we identified actors that reflect the federal makeup of the UAE, including decision-makers, government institutions, representatives of industry and business, and those that may try to influence decision-makers. Some top actors are active at the federal level as well as in their respective emirate, while others are only relevant to their own emirate. In exclusively federal issues, such as carbon pricing and price reform, this duality has little, if any, impact. We found that currently there is no consensus regarding carbon pricing, a positive consensus in favor of renewables, and uncertain consensus for the remaining policy instruments. In other words, there is uncertainty and debate around each policy option considered in this study.

The KTAB simulation of the CDMP among actors for each policy option allowed us to evaluate the political feasibility, based on the consensus possible among stakeholders given their differing interests, objectives, and priorities. Carbon pricing appears to be politically infeasible, based on a weakly negative consensus, both renewables and nuclear energy appear to be supported by a strongly positive consensus, energy efficiency less so, and energy subsidy reform and natural gas enjoy only a weakly positive consensus. In all cases except carbon pricing, some form of policy is politically feasible, but a substantive policy seems most likely only for renewables, nuclear and energy efficiency.

Download the Paper

Towards More Pragmatic Global Climate Goals and Policies

Samantha Gross, Brookings Institution and KAPSARC; Yuhji Matsuo, Institute of Energy Economics, Japan

The 2015 Paris Agreement represents an important step forward in global climate change agreements, by combining national goal-setting with a global framework to drive collective action. However, the sum of individual countries' nationally determined contributions falls far short of actions needed to limit warming to 2°Celcius (C), the goal agreed to under the Agreement.

In this paper, we explore the climate and economic impact of four emissions pathways through 2200. Two of them do not consider economic efficiency: a reference scenario without additional climate policy and a scenario that meets the 2°C by 2100 goal established in the Paris Agreement. Two further scenarios are the result of modeling practical emissions paths to minimize the economic impact of climate change, including mitigation, adaptation and residual damage costs. These two scenarios consider different rates of decline in greenhouse gas (GHG) mitigation costs over time: one a constant rate of 0.5 percent and another with greater reduction in costs after 2050. For our analysis, we use the dynamic integrated climate economy (DICE) model developed by William Nordhaus of Yale University, with a global GHG mitigation cost curve developed by the Institute of Energy Economics, Japan (IEEJ).

The differences among these scenarios may offer insights for policymakers. The optimized case with greater cost-reductions after 2050 results in a peak global average temperature increase of 2.3°C to 2.7°C, higher than the 2°C goal of the Paris Agreement. However, the scenario that meets the Paris temperature goal incorporates disproportionately high economic cost up to 2100, with costs reaching nearly 4 percent of global GDP around 2090. By comparison, the more gradual emissions reduction paths associated with the optimal global welfare scenarios keep costs below 3 percent of GDP at all times. Furthermore, the optimized case with greater cost reductions after 2050 could achieve an outcome consistent with the 2°C scenario depending on the speed and degree of international collaboration.

Our modeling results demonstrate that balancing the mitigation, adaptation and residual damage costs is crucial to minimizing the overall cost of climate change to society. Although the agreed global goals may be challenging to reach, the mitigation commitments made in Paris do not come close and also do not meet our lower, economically efficient emissions paths. Reconciling the bottom-up approach of the Paris Agreement with the collective effort needed to respond effectively to climate change will be an ongoing challenge.

These results also emphasize the importance of continuing research and development in low carbon and zero-carbon technologies. This represents a valuable hedge against uncertainty, as does carefully targeted financial support to move technologies from the demonstration to the commercial stage. Some action on climate change might be delayed until technologies become less expensive, but if the long-term costs associated with a changing climate are to be minimized, the substantial investment in research and development required to make this cost-reduction possible should be made now.

Fundamental uncertainties make climate change policymaking highly problematic, while the transition to a low-carbon energy system will take decades to complete. Together these realities magnify the policymaking challenge facing governments. A practical approach to climate change policymaking provides the flexibility to respond quickly and effectively to evolving scientific knowledge, technological developments, community aspirations and commercial innovations. It would also support a more consistent and predictable approach that would allow for the incremental development of specific policy and regulatory responses over time while providing sufficient high-level policy clarity to build confidence and encourage investment. This is a crucial precondition for encouraging efficient and innovative responses to achieve a timely transition that helps to meet climate change goals at least cost. Well-functioning markets could be key enablers in this context.

The Paris Agreement anticipates revisions and refinements every five years, which provides much-needed scope for incremental policy development at the national level. A practical approach to climate change policymaking would complement the Paris framework, allowing governments to capitalize on its flexibility by facilitating the use of more incremental and adaptable policy responses that better reflect local resource endowments and socio-economic circumstances

Download the Paper

Enhanced Oil Recovery and CO_2 Storage Potential Outside North America: An Economic Assessment

Colin Ward, Wolfgang Heidug and Nils-Henrik Bjurstrøm

Despite significant interest in using carbon pricing to stimulate the application of CO_2-based enhanced oil recovery (CO_2-EOR) to cost-effectively reduce CO_2 emissions, to date there is only limited information available on how carbon prices influence the economic viability of CO_2 storage — and hence the total amount that could be economically stored. This study uses a bottom-up approach to shed light on the issue, combining data on oil fields and emission sources. As analyses of storage potential in North America are widely available, our study focuses on situations in other regions.

The methodology first involves screening to identify fields amenable for CO_2-EOR. In a second step, we seek to connect emission sources with CO_2-EOR opportunities, allowing for CO_2 transportation distances of up to 500 km. Additionally, we stipulate that sources must produce sufficient CO_2 to meet peak demand of the CO_2 flood.

In a final step, we estimate cost and revenue of a CO_2-EOR project to assess the profitability and cost-effectiveness of CO_2-EOR in terms of net present value (NPV) for the operator, considering potential source and storage combinations. This calculation considers both situations in which the CO_2-EOR operator pays for the CO_2 used or is paid for the CO_2 stored. The former arrangement reflects the present U.S. situation; the latter corresponds to a scenario in which carbon price policies are implemented to reduce CO_2 emissions into the atmosphere.

Results of our analysis are most effectively assessed in terms of the combinations of CO_2 value and amount of CO_2 stored that deliver a break-even NPV (discounted at 10 percent) for specified oil prices. This criterion marks the onset of profitability and cost-effectiveness. For a fixed oil price, an increasingly positive CO_2 supply price makes it profitable to store more CO_2. However, after a certain point, this effect tapers off. For instance, outside of North America, at an oil price of $50 per barrel (bbl), irrespective of the CO_2 supply price, the potential for storage caps at 40 gigatonnes of CO_2 ($GtCO_2$) because all potential has been utilized. In this case, 40 $GtCO_2$ can be interpreted as the economic potential for CO_2 storage by CO_2-EOR.

Since the storage potential of CO_2-EOR is sensitive to CO_2 supply prices, minor policy adjustments can significantly impact

the amount stored. We show that even at an oil price of $50/bbl, a CO_2 supply price of $20/$tCO_2$ is sufficient to exhaust virtually all of the profitable storage capacity outside of North America. Moreover, for the same oil price, about 6.1 $GtCO_2$ could be stored when the CO_2 supply price is negative (i.e., the CO_2-EOR operator pays to acquire CO_2). The calculation assumes a net utilization of 0.6 tCO_2/bbl, which exceeds the typical utilization factor of about 0.3 tCO_2/bbl for business as usual EOR operations. This increased CO_2 utilization corresponds to a situation in which the operator increases CO_2 consumption to produce more oil, leading to increased storage.

The economically viable storage potential of 40 $GtCO_2$ is contingent upon cost-effective access to the CO_2 supply from currently operating and emitting CO_2 sources. If CO_2 supply considerations are relaxed, the storage potential of CO_2-EOR increases vastly. Under the relaxed conditions, the technical CO_2-EOR storage potential in Saudi Arabia is about 25 $GtCO_2$, making it a top contender for this technology globally. In real-world circumstances, however, limited access to CO_2 could become the main factor constraining the development of CO_2-EOR projects.

Download the Paper

Growth Through Diversification and Energy Efficiency: Energy Productivity in Saudi Arabia

Consultation Report

Energy productivity, or the amount of economic activity per unit of energy consumed, is an indicator that has been used in different contexts to help manage the balance between economic growth and domestic energy consumption. It reflects the level of structural diversification between energy-intensive and non-energy-intensive activities and the overall energy efficiency of the economy.

Recognizing the combined risks of an economy that is over-reliant on oil exports, a rapidly growing population with high youth unemployment, and rapidly growing domestic energy consumption, the Kingdom of Saudi Arabia has introduced an ambitious reform program called Vision 2030. This includes major subprograms such as the National Transformation Program and Fiscal Balance Program which, among other goals, aim to diversify the economy, increase energy prices and improve energy efficiency.

Low energy prices and strong growth in the production of relatively low value-added, energy-intensive, basic commodities make improving energy productivity a challenge in Saudi Arabia. Economic diversification to higher value-added activities and increased energy efficiency offers a way forward to reduce the fiscal and economic risks associated with the current oil-based growth model. This structural change could lift per capita incomes and transform the level and composition of long-term domestic energy and economic demand, increasing energy productivity.

Some estimates suggest domestic energy consumption could potentially double by 2030 from current levels of around 4.4 million barrels of oil equivalent per day (MBOED). Enhancing energy efficiency in the economy by up to 4 percent per annum could avoid the consumption of as much as 1 MBOED by 2030. This does not include the potential from structural change from diversification strategies. KAPSARC estimates the avoided energy consumption from a 4 percent improvement in energy efficiency per annum could be worth between approximately Saudi riyal (SAR) 50 billion and SAR 100 billion per annum in extra revenue to the government by 2030, depending on international oil market conditions. If reinvested in the economy, this could lift GDP growth by between 0.3 and 0.6 percent per annum by 2030, helping achieve a variety of Vision 2030 goals.

Using energy productivity as a framework for industrial strategy would build on the Kingdom's competitive advantages by enabling a strong and energy-efficient industrial base of basic commodity production. This could be achieved by ensuring that basic energy-intensive products are produced in the most energy-efficient way, so as to support competitiveness, increase profitability and grow market share.

The Fiscal Balance Program that forms part of Vision 2030 has set out energy price reforms. Using energy productivity as a guiding logic for energy price reform suggests that, on the one hand, energy prices should not rise beyond the level required to maintain Saudi Arabia's competitive advantage in energy-intensive industries. On the other hand, however, they should be close enough to international reference prices to incentivize energy efficiency and enhanced development of higher value-added downstream industries.

The industrial sector, including the consumption of energy as a feedstock, or non-energy use, is the largest and fastest growing source of energy demand in the Kingdom comprising around 54 percent of total final energy consumption. This points to where some of the biggest gains from energy efficiency can be made – in the petrochemical sector, which is the largest industrial consumer.

The transport sector accounts for around 30 percent of total final energy consumption in the Kingdom. While other countries, such as the U.S., have achieved a decoupling of economic growth and transport energy consumption, in Saudi Arabia they are linked virtually on a one-to-one basis. This suggests there is significant scope for energy efficiency in this sector. Improved urban planning, public transport and the implementation of energy efficiency vehicle regulations will play a key role.

The residential and services sectors constitute around 16 percent of total final energy consumption in Saudi Arabia, mostly reflecting energy consumed in buildings. However, given the low electricity prices in the Kingdom, there is little incentive for building owners to invest in energy efficiency. This will likely remain an issue, even after the announced price reforms are fully implemented. However, when the broader social benefits from avoided energy consumption, such as the reduced need to build new electricity generation capacity, are taken into account, energy efficiency investments are highly cost effective.

The future for energy productivity will depend on the choices of policymakers, particularly in terms of economic diversification. Saudi Vision 2030 and its supporting programs are aimed at achieving a substantive transition towards more sustainable growth – economic, social and environmental. Navigating a course toward reform may be easier if the value of improving energy productivity as a metric for measuring progress and supporting decision-making is recognized.

Download the Paper

Managing Oil Stabilization Funds: A Framework for Developing Policies

Nader AlKathiri, Tarek N. Atalla, Frederic H. Murphy and Axel Pierru

Fluctuations in government expenditures result in welfare losses for risk-averse households and negatively impact the investment climate. Various oil-exporting countries have created income stabilization funds to cover the short- and medium-term expenses of government so as to reduce economic volatility. Even though Saudi Arabia has not officially established a stabilization fund, the government deposits and reserves at the Saudi Arabian Monetary Authority have historically served as a buffer to decouple government budget from oil revenue fluctuations.

The nature of the revenue movements determines the character of the fund. Due to economic forces, technological changes and new discoveries, oil revenues tend to stay within the same band and then switch to another band, which we term a regime. We use a Markov switching regime model to represent the movements among regimes. The model fits the random ways oil markets can switch from being oversupplied, balanced or tight. When estimating the model for per-capita oil revenues in Saudi Arabia, we find three different regimes.

Using these oil-revenue regimes, we develop a model that optimizes the buildup and draw down of a stabilization fund. The key factors we take into account beyond oil revenue movements are the effects of government spending on household well-being. The optimal policy consists of additions and withdrawals that are a function of the fund levels and oil revenues with the goal of improving household well-being. In practice, implementing the policy is easy since it depends on the actual revenues without regard to the regime.

The policies we develop satisfy common sense in that the larger the fund, the smaller the contribution during periods of high oil revenues and the bigger the withdrawal during periods of low oil revenues. Assuming that the Saudi government had used these policies during the period 2003-2015, we determine the evolution of the fund size by applying the policies to the historically observed oil revenue. The pattern of the optimal buildup is similar to that historically observed for the government deposits and reserve, but the differences illustrate the potential for improved economic welfare gains from an optimization approach.

Simulating random paths for oil revenues captures the potential fluctuations in the size of the stabilization fund. The fund level is below $41,000 per capita ($866 billion in total when using the 2015 Saudi population) 95 percent of the time and has an expected value of $14,512 per capita ($307 billion in total). The buildup of funds rarely achieves the maximum fund size before the market switches from a high to a low-revenue regime. The fund is empty 16 percent of the time because of extended stretches of low oil revenues. Starting from the average size, as a worst case it provides almost five years of supplementary revenues before reaching zero, during which the economy can adjust to a collapse in oil revenues.

Our approach also offers insight for the fund investment strategy. We divide the fund into tranches and consider that the lower tranches are tapped first. For each tranche we can estimate the probability distribution of the first time the tranche is tapped. The shape of the probability distribution is skewed to longer time periods, with the higher tranches having longer time distributions that are more stretched out. For instance, starting at a fund size of $42,000 per capita (≈ $900 billion in total) and breaking it down into six tranches, tapping the last tranche would occur at year six in the worst case and the average time to start tapping is 18.5 years. This means the higher tranches can be invested in longer duration assets that provide higher returns. These assets transition into the kinds of assets that are appropriate for a sovereign wealth fund.

Download the Paper

How to Achieve Economic Prosperity Through Industrial Energy Productivity Improvement

Workshop brief

While the energy economies of China and Saudi Arabia differ in many respects, they are similar in that both countries have rapidly growing economies that are in transition. In both countries the industrial sector accounts for the majority of energy demand at around 75 percent and 60 percent, respectively, compared with industry consuming around 40 percent of total energy globally. The question of how industrial energy productivity supports economic growth is thus of particular importance for sustainable development in both countries. The insights from this workshop are organized around five main themes:

What is the added value of focusing on energy productivity?

When considering which factors of production drive economic growth, labor and capital are often emphasized, while energy is simply incorporated into 'other resources' or 'materials' of production. However, given the critical importance of energy and the dramatic shifts underway in how we secure, price and use it, there is a strong case to focus on how energy supports economic growth, from both technical and policy perspectives. Energy productivity is an emerging policy agenda focusing on how energy can best be used to create value in the economy, and it also incorporates a number of specific indicators that integrate economic performance and energy consumption. As an indicator, its connotations differ at the macroeconomic and microeconomic levels. At the macroeconomic level, energy productivity is equivalent to its mathematical inverse of energy intensity – or how much energy it takes to produce a unit of gross domestic product (GDP). At the microeconomic level, energy productivity focuses on the revenue produced per unit of energy consumed by a company or sector. Energy efficiency, on the other hand, is generally focused on the output produced per unit of energy consumed (e.g., GJ/tonne of cement). Because of this difference, energy productivity provides a better foundation for industrial policy than a sole focus on energy efficiency does. Energy productivity more strongly incorporates industrial upgrading and structural reform, as well as energy efficiency.

What are the key economic and energy objectives in both China and KSA and how does industrial energy productivity support these plans?

Saudi Arabia has entered a new era of deregulation and privatization with vast potential investment opportunities for the private sector. Industrial diversification and upgrading, renewable energy and energy efficiency are all priority areas that are likely to raise energy productivity in the Kingdom. China has a lot of experience managing the economy with national energy intensity targets, applying industrial sub-sector energy efficiency benchmarks to energy-intensive industries, and transitioning domestic energy price reform from an administered to a more market-based approach. There are many potential benefits in establishing a greater mutual understanding of economic reform plans and in shared leadership of energy efficiency. Several international initiatives have been launched at facilitating this, including through the G-20, International Energy Agency (IEA) and International Partnership for Energy Efficiency Cooperation (IPEEC).

How far can energy efficiency in energy-intensive industry move the needle?

As the single largest energy consuming sector of both China and Saudi Arabia, industry should offer some of the best potential opportunities for improving overall energy consumption per unit of GDP.

Both countries have established energy intensity sectoral targets and programs to improve energy efficiency in their biggest energy consuming companies. Transparency in the publication of sector and sub-sector targets is likely to assist companies looking to invest and also help encourage the energy efficiency service company sector. For example, the electricity sector in Saudi Arabia has a target to improve fuel utilization in power generation from a baseline of 33 percent to 40 percent by 2020. In addition to energy efficiency in heavy industry, finding a way to produce water with less energy will deliver significant benefits to the Kingdom.

What is the importance of industrial strategy for managing structural economic change?

It is not preordained that economies will naturally evolve from relying on basic resource-dependent and energy intensive industries to high-value growth models. In China, the supply-side structural reform process initiated in 2015 dominates economic policymaking, shaping everything from the government's efforts to reduce excess industrial capacity to incentives to reduce property inventory, curb high levels of corporate debt and lower corporate costs. The drive against overcapacity is focused on basic and energy intensive industries, but might be extended to other sectors including automobiles, new materials and renewable energy. Transformation to higher value production depends on a professional skill base, research and development, and higher incomes to support domestic demand. The evolution of industry requires careful policy management to maintain a competitive advantage in energy-intensive sectors while cultivating more value in the production of downstream high-value products and activities.

How does energy price reform support industrial transformation goals?

When goods are priced higher, society tends to value them more and put them to their highest value use. Saudi Arabia's industrial sectors have been distorted by low energy prices that do not reflect true market demand and supply. Energy price reform is key to encouraging energy efficiency and achieving the right incentives for industries to develop. There is no reason why price reform cannot be structured to both preserve the competitive advantage of energy-intensive industries and provide sufficient incentive for energy-intensive industries to align with international benchmarks of energy efficiency. A hybrid pricing system that allows some market flexibility within politically acceptable bounds is one strategy that has been successful in China.

Download the Paper

Coal in Asia: The Challenge for Policy and the Promise of Markets

Workshop brief

Policymakers in Asia have for decades focused on securing the cheapest energy for their growing economies. This meant that Asian countries invested heavily in cheap and often locally available coal and the resulting infrastructure – mines, ports, railways and power plants and electricity grids.

Asian energy policies supported fuel security and affordability. Regional disparities in per capita income and a highly competitive export-led growth focus has meant that few countries could diversify their energy mix to include comparatively cleaner but more expensive fuels such as natural gas and renewables (mainly hydro) unless they were available domestically. While world coal consumption grew at a sedate pace of 0.7 percent (annualized) from 2007-2016, Asia witnessed comparatively stronger growth of 2.28 percent over the same period. However, the Asian growth rate has declined significantly from the earlier 7.44 percent, which was prevalent during 1998-2007, driven primarily as China and India aggressively added coal capacity.

Over the past decade, renewables (mainly solar) have immensely grown in capacity as increasing acceptability and technological developments drove prices down, making it a viable choice for a diversified energy mix. Solar electricity consumption has shown strong growth (albeit from a far smaller base), with Asia growing at almost 50 percent, comparable to world solar consumption growth at 46 percent during 2007-2016. Societal pressure regarding local air quality and increasing awareness of the impact of carbon emissions on the climate have also forced policymakers to focus on increasing the penetration of renewables in their energy mix.

As a result, Asian policymakers now have to pivot from their earlier fuel choices and initiate a transition to a cleaner and more sustainable energy mix. They have been forced to acknowledge the externalities of coal, but have so far not been able to move completely away from the relative cost economics of coal given the sunk costs involved. Legacy infrastructure issues have made the transition much more difficult and policy choices have been dictated by the availability of resources and finances.

Complacent in the continued belief of unabated growth of their markets, coal producers are suddenly being forced to accept that their markets have changed to being driven by policy, rather than the economics of supply and demand. The coal industry has been a laggard in developing highly efficient clean coal technology and left behind by technological developments in renewables. For coal to continue its growth in Asian markets, it has to address the emission concerns associated with its usage. Stricter international emission norms and increasing global awareness of the impact of unabated carbon emissions are serving to shrink the policy acceptance of cheap coal.

For coal to compete on environmental grounds with cleaner renewables, the industry needs to enhance investments in technology and address climate change concerns by tackling the externalities of carbon. The challenge for policymakers, on the other hand, is to ensure a transition to a low carbon energy model without burdening their economies with excessive costs. Asia will continue to utilize coal because of its current cost economics. However, the environmental externalities associated with coal are going to be increasingly priced in by policymakers. This will impact the future competitiveness of coal in Asia.

Download the Paper

East Africa Shared Gas Initiative

Workshop brief

The current problem of low energy supplies in Eastern Africa does not stem from the availability of resources including natural gas but from the inability of governments, utilities and oil and gas companies to move forward with development plans. As countries transition their economies toward middle-income status, they need to improve energy access to create a positive entrepreneurial spiral enabling energy access, sustainable economic development, employment, billable utility demand, profitable energy market and investment (both private and public).

While natural gas demand remains low in the region, small-scale liquefied natural gas (LNG) units are seen as worthwhile solutions to nurture natural gas demand robustness prior to committing capital-intensive gas pipeline investments.

Natural gas could contribute to electrification, especially in the urban setting, and also be used in the industry and transport sectors. How such developments will fit with a significant focus on developing renewables in the region is still unclear.

Rural settings with no access to the electricity grid seem to be the privileged target for decentralized power production using renewable sources. Urban settings could leverage the flexibility and cleanliness of natural gas for industry heating purposes, power generation and transport, using compressed natural gas (CNG) or LNG vehicles.

As with any commodity market that has high capital requirements, the global LNG market follows a cyclical development. Currently, overcapacity is the rule of the game. According to most analysts, LNG prices are set to rebound once the current loose market tightens. East African countries should plan accordingly and prepare for an adaptive energy and investment policy in line with the global LNG market cycles.

Download the Paper

03 // Viewpoint

How fast is the cost of solar PV actually falling?

By Amro Elshurafa, Research Fellow, KAPSARC and David Hobbs, Vice President of Research, KAPSARC

One of the big energy stories of the past five years has been the apparent precipitous drop in the costs of solar power. It is not uncommon to hear statements such as: “nobody predicted the pace of cost reductions” or “…at this rate, solar will be cheaper than fossil fuels within a decade and it will be game over!” or “costs are coming down at 20 percent per year.” These sweeping comments aside, a deeper understanding of how costs evolve for new technologies, and for solar photovoltaics (PV) specifically, is vital to assessing future competitiveness compared with existing or incumbent technologies.

There is a risk of unwittingly misleading policymakers and the public if the message on PV cost reductions is oversimplified. There are three ways this could happen. First, the “learning curve” on PV systems is not a function of time but of increases in the installed capacity – i.e., it is calculated from the percentage reduction in the cost of a system after each doubling of installed capacity. Second, the learning rate for solar modules should be calculated from their cost of production rather than their selling price (or even more confusingly, from the price at which developers offer electricity in the first year of a long-term power purchase agreement). Third, the learning rate for a complex system may be a function of learnings related to each of the major components – in the case of a solar power facility, the costs of the solar modules and the costs of the “balance of systems” (including site works, support frames, cables, installation and equipment to turn the electricity produced into a form that can be used by consumers).

The average selling prices of solar modules (rather than their costs – an important distinction as we shall explain) have followed a learning curve that suggests a cost reduction of 20 percent for each doubling of total produced capacity, which is almost exactly in line with expectations. For example, the price of a 100 watt (W) module was $1,000, equivalent to $10/W in the early 1990s and the total installed capacity of solar panels was around 0.1 gigawatts (GW). After doubling the installed capacity 10 times (to 100 GW by the end of 2012), their cost would have been expected to decline to $1/W. Today the capacity of solar modules installed globally is close to 400 GW and following the learning curve, the cost would be $0.6/W. This is indeed in line with what happened. One note of caution is that many solar panel makers have either become bankrupt or are headed in that direction, indicating that the price at which they are selling modules might be less than the cost of manufacture.

However, crucially the capacity to manufacture and install new solar modules was increasing exponentially in the early 2000s such that it took less than two years for each doubling of installed capacity. But, since 2012, the rate of doubling has slowed. The result is that moving from 160 GW to 320 GW took around three years and at current manufacturing capacity, it is expected to take four years to reach 640 GW. This means that, on an annualized basis, the rate of cost reduction has fallen from nearly 20 percent in 2010 and 2011 to nearer 5 percent in 2016. But does this reflect the learning curve for an entire solar PV system?

KAPSARC research on the learning curve for the balance of systems found that the equivalent cost reduction for each doubling of total system capacity is only 11 percent compared with 20 percent for modules.

Furthermore, with the modules making up a smaller share of the total system because of their rapid reduction in costs, the overall learning rate is nearer 15 percent. So in reality, we should not be surprised if the next few years see 3-4 percent annual declines in cost and that this rate slows further over time unless there is a major technology break-through that alters the paradigm for solar PV. So, what about the dramatic reduction in the equivalent price of electricity generated from solar PV? Over the past few years, every new project seemed to set a new world record for the lowest offered price of electricity – Masdar's bid for the Sakaka project in Saudi Arabia and Enel's project in Mexico potentially establishing new benchmarks of less than $0.018/kWh.

KAPSARC research suggests some caution on these apparent world records as well. Firstly, there is little consistency in reporting these figures, and our studies demonstrated this by normalizing the 'levelized cost of energy' (LCOE) reported by project sponsors. Secondly, a major component of the LCOE is the cost of financing. There may be some 'learning' in terms of risk reduction through better project planning and implementation that would reduce the financing cost premium over bank prime rates. However, unless the global economy continues to rely on the support of historically low interest rates, prime lending rates do not have scope to fall any further and are more likely to rise. Thirdly, prices for electricity in contracts are rarely held constant from one year to the next. They are normally escalated in line with some measure of inflation. The base price in the first year of the contract is rarely the price that will be paid for electricity in the final year and there is scope to depress the reported base price in the first year by applying a higher rate of escalation for calculating the prices in subsequent years.

The rate at which solar power costs are falling is indeed remarkable but not because costs are reducing faster than expected. Rather, it is because the quantities being installed are greater than anyone expected and this has been driven almost entirely by government policies. Incentives that turned out to be too generous in hindsight precipitated more investment than analysts expected because they underestimated the appetite of governments to continue subsidies.

Here in Saudi Arabia, and also the GCC generally, the economic case for installing utility-scale solar power is stronger than in many other countries. The opportunity cost of consuming domestic resources rather than earning export revenues on avoided consumption is high enough to support these investments based on fuel prices alone, not to mention the avoided capital investment in new thermal power plants to supply a growing population. The efforts to customize technologies to be suitable for the hot, dusty conditions of the region will only make this economic case stronger.

The risks of overpromising on the pace at which solar PV costs are shrinking and the prospects for competitiveness with fossil fuels arise from undermining investor confidence in the long-term. Oil and gas have the potential to be produced at much lower costs than current global market prices. If demand for oil were actually to decline, prices would fall to an even greater extent than what we saw in 2014 – a period when demand was still growing, but less quickly than supply was expanding. Oil and gas have the potential to remain competitive with solar PV for much longer than commonly assumed. Policy that ignores this reality could end up being more costly and run greater risks of failure than if the empirical evidence is incorporated into the planning framework.

04 // OpenKAPSARC

Our Tools and Datasets

A core part of our mission at KAPSARC is to equip stakeholders with the models, tools and data to make the most educated and informed decisions possible.

We have invested in the development of several analytical platforms, some of which have resulted in tools and datasets that we are now making available through our website. The model codes can be downloaded, and any data that are not proprietary to third parties can be downloaded and reused freely. The current key platforms are:

KAPSARC Energy Data Portal

This easy-to-use data portal is a source of critical energy data, enabling users to better understand energy, economy and policies. We focus on identifying key energy information sources from Saudi Arabia, the GCC, India, China and East Africa, as well as selected global energy data.

The energy datasets cover 16 themes: crude oil and refined products, natural gas, coal, renewable and alternative fuels, nuclear, electricity, water, transportation, industry, residential, agriculture, environment, economy, demography, trade, and policies. The datasets can be exported in CSV, JSON, and EXCEL formats or accessed using API for use in mobile and web applications.

KAPSARC Energy Model for Saudi Arabia (KEM-SA)

KEM-SA has been developed to understand the dynamics of Saudi Arabia's energy system. It is a partial economic equilibrium model that characterizes some of the major energy producing and consuming sectors in the country. The sectors represented are: electric power, petrochemicals, refining, water desalination, upstream oil and gas, and cement production.

Each sector is contained within its own sub-model and acts as an agent that makes decisions on fuel usage, investment and technology to minimize its cost or maximize profit. The model is being expanded to include more sectors from the demand-side of the economy.

KAPSARC Global Energy Macroeconometric Model (KGEMM)

KGEMM is a domestic policy analysis tool that captures the interactions between the Kingdom of Saudi Arabia and global economies. Unlike commonly available models, KGEMM takes into account the importance of the energy sector in the Kingdom and the growing significance of the domestic economy as a driver of domestic demand and, hence, available oil exports.

This easily customizable macro-econometric model, covers the real, monetary, fiscal, external energy and labor sectors of the Kingdom's economy; allowing stakeholders to evaluate different policy scenarios such as energy price reforms, fiscal policy changes and the impacts of different oil price regimes.

KAPSARC Toolkit for Behavioral Analysis (KTAB)

This toolkit comprises a suite of building blocks for analyzing collective decision making processes (CDMPs). These can include political bargaining, commercial negotiation and any multi-stakeholder issue where an understanding of how each player's attempts to maximize their own positions drives the ultimate settlement (or not). The software for each type of CDMP is available and we are building a library of illustrative applications to help users understand the limits and benefits of this type of analysis.

KAPSARC Vehicle Fleet Model

This scenario model enables policymakers to explore the incremental user cost implications of different passenger car powertrain technology choices. The context for the analysis is a future where today's low carbon powertrain technologies are fully developed and manufactured at scale. Driving behavior input is based on today's data, however, provision is made in the model for behavioral change scenarios to be tested.

Aimed at simplicity and transparency, the model does not include all the detailed complexity of the problem but aims at adequately capturing the main factors that influence the incremental user cost of different passenger car powertrain mixes. It has also been designed to make it easy for the user to improve and update the input to the model as new evidence becomes available.

Other platforms/ datasets

We have built a data transformation team that serves our internal research needs but will also increasingly release curated data resources to all our stakeholders. These will grow over time in both the breadth of their scope and the area of coverage.

For more information email

datasource@kapsarc.org

KAPSARC Solar Photovoltaic Toolkit

This toolkit and dataset are intended for any individual or institution interested in the solar photovoltaic (PV) industry and its cost trends. It compiles capital costs (CAPEX) and levelized cost of energy (LCOE) data for PV technology by year and country, and presents the data in an interactive manner. In addition to the interactive dataset, the raw dataset is provided in Microsoft Office Excel should the user wish to perform his/her own post-processing. An LCOE analyzing tool, specifically tailored for solar PV technology, accompanies this toolkit, enabling the user to acquire the LCOE using the capacity factor or solar irradiation.

KAPSARC India Renewable Energy Policy Atlas

We have developed a web-based energy policy reference tool that systematically describes energy sector policies. This tool, also of use to external researchers, is intended to facilitate a better understanding of policy instruments and track evolution of policies from draft to enactment worldwide.

KAPSARC has released part of this research in a Solar Policy Atlas, which provides specific, state and national level coverage of policies in India. It presents a policy landscape using large numbers of policy design elements that are relevant in different geographies, to gain holistic insights of policy frameworks and make comparisons. Each policy design element has a comprehensive description in the context of India and is intended to improve the understanding of the subject at national and state levels.

KAPSARC develops economic frameworks to reduce the overall costs and environmental impacts of energy supply, increase the value created from energy consumption and achieve effective alignment between energy policy objectives and outcomes.

We collaborate with leading international research centers, public policy organizations, and industrial and government institutions, freely sharing our knowledge, insights and analytical frameworks.

05 // Team News

Growing Our Global Team

In the last quarter, our Research team welcomed the following members:

Abdullah Al Jarboua

Abdullah joins the Energy Systems and Macroeconomics program as a senior research analyst following an internship. He holds a bachelor's degree in computer engineering from Tennessee Technological University and a master's degree in computer science from King Abdullah University of Science and Technology.

Aljawhara AlQuayid

Aljawhara is a research analyst in the Policy and Decision Science program. Previously, she completed an internship at KPMG where she worked closely with clients on public-private partnerships. Aljawhara obtained a B.Sc. in Business Administration from Alfaisal University, during which time she carried out research for the university on the socio-economic aspects of the Saudi labor market.

Chay Allen

Chay is a senior editor whose professional experience includes editing and writing for academic and mainstream titles. He holds a D.Phil. in Fine Art from Oxford University, an M.Phil. in History of Art and Architecture from Cambridge University, an M.St. in History of Art from Oxford University and a B.A. in History of Art from the University of London.

Elizabeth Carey

Elizabeth is a senior research associate in the Energy Transitions and Climate Change program. She has worked as a researcher and public affairs professional for a number of international organizations, think tanks and governments. Elizabeth holds a Doctorate in Political Science - International Relations from Université Paris II Panthéon-Assas, an M.Sc. in Political Science from MIT, and a B.A. in History from Oxford University.

Fatih Karanfil

Fatih is a research fellow in the Energy Systems and Macroeconomics program. Previously, he was an associate professor of economics at the University of Paris Nanterre and a researcher at EconomiX–CNRS. Fatih has published many articles in the fields of energy economics and environmental and energy policy. He holds a B.A. in Economics from Galatasaray University and an M.A. and a Ph.D. in Economics from Panthéon-Sorbonne University – Paris 1.

Jeyhun Mikayilov

Jeyhun is a research fellow in the Energy Systems and Macroeconomics program. His primary research interests include applied econometrics, the economics of energy and the environment, and sustainable development. Before joining KAPSARC, Jeyhun was an associate professor in the Azerbaijan State University of Economics Statistics Department. He holds a B.S. and M.S. in Mathematics from Azerbaijan State University and a Ph.D. in Applied Mathematics from Azerbaijan Scientific-Research Institute of Agro-mechanics.

Mohammad Al Dubyan

Mohammed is a senior research analyst focusing on solar and geothermal energy systems, with a particular interest in energy efficiency in buildings. He holds a bachelor's degree in mechanical engineering from Qassim University and a master's degree in renewable and clean energy from the University of Dayton.

Nourah Alhosain

Nourah joins the Policy and Decision Science program as a research analyst after completing a seven month internship. While studying for a computer science degree from Prince Sultan University, Nourah participated in several competitions and clubs and also conducted a number of workshops for high school students.

Othman Al Saleh

Othman is an operations manager. He has experience working in Saudi Arabia's public and private sectors including at Taqnia Energy and King Abdullah City for Atomic and Renewable Energy (KACARE). Othman holds a master's degree in engineering management and leadership, with a minor in sustainable energy, from Santa Clara University.

Paul Mollet

Paul is a research fellow in the Policy and Decision Science program. He is a former journalist and analyst with almost thirty years of experience in international energy markets. Paul's former roles have included working for the World Energy Council and Petroleum Development Oman as well as carrying out research assignments for the African Development Bank. He holds a degree in Hispanic and Latin American Studies from Liverpool University.

Thamir Al Shehri

Thamir is a senior research associate in the Productivity, Energy Demand and Efficiency program. He previously worked as a casual lecturer and also has entrepreneurial and industry experience working on award-winning projects. His doctorate from the Queensland University of Technology is focused on intelligent energy management systems. He also holds a Master of Information Technology from the University of Tasmania and a Bachelor of Computer Information Systems from Ajman University of Science and Technology.

Ryan Alyamani

Ryan is a research analyst in the Energy Information Management team. He previously worked as a researcher on the Mercer University Honors Program and has also completed an engineering internship with Al Jomaih and Shell Lubricating Oil Company Ltd. in Riyadh. Ryan holds a B.S. in Mechanical Engineering from Mercer University.

Turki Alaqeel

Turki is a research associate in the Productivity, Energy Demand, and Efficiency program. Before joining KAPSARC, Turki worked for Woodward in the U.S. as an economic analyst focusing on the natural gas industry and markets. He also worked in electric power systems design, protection and control, commissioning and business development at ABB-Saudi Arabia. He holds a degree in electrical engineering from King Saud University, and an MBA and a Ph.D. in Electrical Engineering from Colorado State University.

Robert Arnot

Robert is a research fellow in the Energy Transitions and Climate Change program, with more than 30 years of policy-related experience at the interface of energy, technology, and environmental science. He has worked in all areas of environmental policy with a keen orientation towards climate change mitigation and energy technology research and development. Robert holds a Bachelor of Chemical Engineering degree from Queen's University and an MBA from the University of Western Ontario.

About KAPSARC

Our Mission

To advance understanding of energy economics and act as a catalyst for dialogue, charting a path to better welfare for societies, locally and globally.

Our Values

We strive to combine creativity and rigor in our research and operations.

We achieve results with effective teamwork and collaboration.

We seek to maximize positive societal impact.

About Us

Affordable, sustainable energy underpins the growth of a country's economy and the wellbeing of its citizens. Yet effective energy policy is one of the greatest challenges for governments and other stakeholders across the globe.

KAPSARC was founded as a global non-profit institution for independent research into the economics of energy and understanding its complex intersections with energy policy, technology and the environment with the objective of contributing to societal wellbeing and prosperity.

From our base in one of the world's most important energy-producing regions, KAPSARC develops economic frameworks to reduce the overall costs and environmental impacts of energy supply, to increase the value created from energy consumption and to better understand energy policy such that policy objectives and outcomes are better aligned.

We collaborate with leading international research centers, public policy organizations, and industrial and government institutions through workshops, joint papers and the development of open-source datasets and tools, freely sharing our knowledge, insights and analytical frameworks.

KAPSARC studies topics of global scope with a particular focus on the Kingdom of Saudi Arabia, the GCC, China and India.

Research Initiatives 2018

1. Productivity and Economic Diversification in Saudi Arabia

2. Energy and Economic Vulnerability

3. Evaluation of Public Investment Projects: The Opportunity Costs of Oil and Gas in Saudi Arabia

4. Future of Transportation and Fuel Demand

- Freight Movement
- Personal Mobility

5. Future of Global Oil Markets

6. Future of Natural Gas Markets Including Potential Saudi Linkages to Global Markets

7. Regional Energy Markets: GCC Market Integration and Policy Drivers of Demand in China and India

- GCC Market Integration
- Policy Drivers of Demand in China
- Policy Drivers of Demand in India

8. Electricity Sector Transitions

9. Climate Change Policies and Governance

10. Models, Data and Tools

- KGEMM model for policy analysis in the Kingdom
- KEM model for policy analysis in the Kingdom
- KTAB toolkit - models of collective decision-making processes
- Energy data portal and web apps