KAPSARC Quarterly

Research highlights

Designing Electricity Markets to Integrate Renewable Energy

In many regions of the world reducing fossil fuel use in electricity generation through transitioning to various forms of renewable energy has been given the highest priority as a policy objective. This transition toward a more sustainable energy mix has been particularly intense in the European....
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Many leading industry experts and commentators have warned about the threat of revenue erosion for electric utilities posed by the increasing market penetration of distributed energy resources. This is important …
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Renewable projects typically require government action to get started. However, it is often a struggle for governments to produce a renewable policy that achieves all its objectives because they usually compete against each other...
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Challenges for Widespread Renewable Energy Deployment: Fossil Fuel Price Responses

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How Will Natural Gas Adapt to the New Price Environment?

In our previous workshop brief 'Natural Gas: Entering the New Dark Age?' we explored the discrepancies between forecasts of a growing longer-term role for gas in the energy mix and the current reality of a slow growing fuel, facing competition from cheap coal and policy-supported...
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The Impact of Low Oil and Gas Prices on Gas Markets: A Retrospective Look at 2014-15

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LNG Markets in Transition: The Great Reconfiguration

2016 sees the LNG industry on the edge of a cliff. However, it is an open question whether itstands at the bottom ready to climb up in an orderly way or at the top and about to fall in a tailspin. The sector has embarked on such a vast expansion ...
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Saudi Arabia is an extremely water scarce country. In this desert Kingdom about 87 percent of water extracted is used for agriculture, and, as such, no policy to improve the sustainability of water resources can ignore...

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Water, energy and food are inextricably linked and, consequently, inefficient use of any of the three resources can have a negative effect on the other two. Managing this nexus requires a holistic approach. We compare …

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Group Choice with Interdependent Sublinear Voting

Many important decisions of policy are made in a collective manner, so a great deal of formal and informal analysis has been devoted to collective decision-making processes (CDMPs). One common approach …

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Solar Photovoltaic Toolkit

This dataset compiles capital costs (CAPEX) and levelized cost of energy (LCOE) data for the solar photovoltaic (PV) technology by year and country and presents the data in an interactive manner. Although, the dataset contains ...

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Energy Workshop Series

June

Human Geography of Energy – Colorado
June 7, 2016

September

Local Content/East Africa – Rabat
September 5-6, 2016

Gas Markets – Washington, DC
September 26, 2016

November

Coal Markets – New Delhi
November 15, 2016

India Energy Policy – New Delhi
November 16, 2016

Eastern Africa Natural Resource Developments – Cape Town
November 21-22, 2016

01 // Research Highlights

Focus on Renewables Policies

This quarterly update leads with our work on how to overcome the challenges to renewables adoption in markets around the world. These include revisiting the design of liberalized markets to facilitate economically sustainable integration of renewables, understanding whether solar rooftops are capable of triggering a utility 'death spiral' and a framework for considering the response of fossil fuel prices to renewables penetration.

Liberalized markets typically clear on the basis of marginal costs and this model has thrown up challenges for integrating intermittent renewables (with zero marginal cost) that require the back-up of dispatchable plants with much higher marginal costs. Although rooftop solar is typically not dispatched into the wholesale market, its priority may exacerbate this problem. However the available area of rooftops compared to electricity demand is typically insufficient to undermine the viability of distribution utilities. Instead, the greater threat arises from utility scale solar and that threat is to generators rather than distributors.

Increasing penetration of zero marginal cost renewable power causes the marginal generator to be further down the load curve – even if the full cycle costs of the renewables are higher than the incumbent resources they displace. This leads to a price and cost response in the fossil fuel pathways that increases the likely cost and duration of policy support for the ongoing energy transitions foreseen in the INDCs arising out of the Paris Agreement.

Additional work has examined the effectiveness of renewable support policies in terms of the trade-offs between the costs (both direct and indirect), ultimate level of installed capacity and pace of deployment. There is no 'best' policy because the objectives vary. However, our work seeks to provide a framework for understanding which policies achieve their objectives in the most cost effective manner.

Finally, in our focus on renewables, we held our first workshop on Indian Energy Policy – leading with renewables policy and the tension between goals of 100 GW of solar power, financial condition of the utilities and competition from coal-fired power in the energy hungry Indian economy. This has been accompanied by release of The India Solar Policy Atlas (available at www.kapsarc.org) as part of a broader push to create the knowledge infrastructure for policy development in the region.

The Great Reconfiguration of Global Natural Gas Markets

This quarter has seen the fruition of our work on natural gas with a briefing 'How will Natural Gas Adapt to the New Price Environment?' from our energy workshop series on natural gas, along with a review of the impacts to date of low oil and gas prices and the 'Great Reconfiguration' of LNG markets arising from the current supply surge.

Energy Productivity

Policymakers are prone to use energy productivity or intensity and the changes in these measures to compare the performance of their economies to their peers. Our paper, 'A policymaker's guide to the various ways of calculating energy productivity' explains that it may not be so simple …

01 // Research Highlights

Transport and Mobility

Our transportation work aims to provide insights into whether policy is doing enough to drive adoption of fuel efficient and electric vehicles and the outlook for alternative liquid fuels, given the last two years of low oil prices. The driving forces for alternatives to gasoline and diesel have changed compared to previous cycles – climate change having taken over from concern about high oil prices – which may limit any slowdown in investment as a result of current oil market conditions.

Climate change has also been a major driver of adoption of alternative fuel vehicles, including electric vehicles. To date, adoption has not matched aspirations in the absence of expensive policy support (of which Norway is perhaps one of the best examples). One of the main barriers appears to be that electric vehicles do not yet meet consumer needs sufficiently for mass market penetration. We have developed a novel methodology for estimating market penetration of new technologies with the goal of better understanding consumer attitudes. This is illustrated with a case study based on battery electric vehicles in the U.S.

Saudi Arabian / GCC Energy Economies

Work on GCC energy policy challenges continues apace with a briefing 'Opportunities and Challenges in Reforming Energy Prices in GCC Countries' from our energy workshop series, released along with analyses of GCC electricity demand elasticities.

Another key concern for Saudi policymakers is water use and its interaction with both energy and agriculture. We have developed a framework for weighing policy options to reduce water consumption in Saudi agriculture in such a way as to minimize the impacts on society. This represents the ‘low hanging fruit’ of changing the agricultural product mix before the harder job of incorporating technological advances. Some of the foundational work for this last study arose from our work on energy used to provide water for agriculture both in the GCC region and globally. Future work will examine how technical innovation can further improve the outcome.

OpenKAPSARC

We have expanded the tools and data sets available through OpenKAPSARC. These now include:

- An atlas of solar policies for India.
- The Solar PV Toolkit, aiding comparisons of quoted costs on a consistent ‘apples to apples’ basis.

For more information and to see the tools, please go to: https://www.kapsarc.org/openkapsarc/

… And finally, we have extended the methodologies related to KTAB with the release of a paper describing ‘Group choice with interdependent sublinear voting’.

Designing Electricity Markets to Integrate Renewable Energy

ENERGY WORKSHOP SERIES

In many regions of the world reducing fossil fuel use in electricity generation through transitioning to various forms of renewable energy has been given the highest priority as a policy objective. This transition toward a more sustainable energy mix has been particularly intense in the European Union and the U.S., where electricity systems were privatized and/or liberalized in the 1990s.

In liberalized wholesale markets, the price of electricity has traditionally been set by the technology with the highest marginal cost of production at any time. In other words, the price of electricity is equal to the operating costs (marginal costs) of the most expensive power plant that is generating electricity in each moment. This kind of market is known as a 'marginalist market'. This price, which can change in an instant, determines the flow of revenues for power generators. Under these market rules, technologies are not paid based on their total cost of producing electricity. If the price of electricity is sufficiently low for a long period of time, revenues simply do not compensate total full-cycle capital and operating costs and power generators suffer losses.

In liberalized markets that are based on fossil fuel technologies, however, generators can perform well financially, given the relatively high marginal costs of dispatch. Introducing renewable technologies to these markets disrupts wholesale electricity prices by reducing them because renewable technologies have zero or near-zero marginal costs. The outcome is to create a preference for dispatch of electricity with a higher overall cost of supply but a lower marginal cost.

Growth in renewable energy installations is shouldered by incumbent fossil fuel generators. This goes beyond a carbon price determined in the market. These traditional generators are forced to contend with both lower energy prices and the fluctuating output from wind and solar farms. A high penetration of renewable energy may substantially damage the value of incumbent utilities, making the cannibalization of their core business inevitable. The decline in wholesale electricity prices is a critical challenge for incumbent technologies and renewable technologies, though in the latter the problem is mitigated by the certainty of overall returns and avoiding being exposed to volatility in wholesale prices.

The installed cost of renewable capacity has fallen sharply in recent years, but current prices in liberalized markets still do not support investment under pure market conditions. Some argue that renewable energy policy has created a vicious circle: the financial support to renewable energy fosters deployment and deployment depresses electricity prices, increasing the need for additional financial support for not only renewables but even for the conventional technologies that are needed for integration and grid stability.

A consequence of this interaction between renewables and incumbent technologies is that liberalized markets may have to be redesigned. With the current structure of liberalized markets, there may be an argument for public ownership of the means to integrate renewables, as a form of public good, like other types of infrastructure. Alternatively, markets could be reorganized to recognize the long-term economic cost of renewable energy. The 'best' design of electricity markets, which facilitates the integration of renewable energy at the lowest possible societal cost, is still a fertile area for research.

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Can Adoption of Rooftop Solar PV Panels Trigger a Utility Death Spiral? A Tale of Two Cities

IQBAL ADJALI, PATRICK BEAN, ROLANDO FUENTES, STEVEN O. KIMBROUGH, MOHAMMED MUAAFA AND FREDERIC H. MURPHY

Many leading industry experts and commentators have warned about the threat of revenue erosion for electric utilities posed by the increasing market penetration of distributed energy resources. This is important not only for the companies and their stakeholders, but also for policymakers who expect utilities to make significant investments in the grid to support the transition to a decarbonized electricity sector.

Current U.S. tariff structures typically cover the fixed costs of transmission and distribution (plus regulated profit) with a small charge for connection, plus a charge based on the amount consumed, rather than a charge based on peak requirements. This means existing tariffs may incentivize 'free riding' behavior by households that have invested in solar because they reduce their contribution to the fixed costs through lower purchases from the grid. Thus, distributed generation not only has the potential to lower total revenues, it also can shift the costs of the transmission and distribution system from wealthier customers who can afford PV to lower income customers who cannot afford to install solar panels, raising equity considerations.

We developed an agent-based model to investigate the potential for rooftop solar installations to erode utility revenues. We use data from two distinct locations in the U.S. to assess the impact of residential rooftop solar PV adoption on the revenue streams of two utilities. Our model shows that worries about a utility 'death spiral' due to the adoption of residential rooftop PV, under current policies and prices in the U.S., are unfounded. We found, consistently for a number of scenarios, that the scale of PV penetration is minimal in terms of residential demand reduction and subsequent tariff increases. Also, the rate of adoption would probably be smooth rather than sudden, giving the physical grid, the utility companies, and government policies enough time to adapt.
Although our results suggest that fears of a utility death spiral from residential solar are premature, regulators should, of course, still monitor revenue losses and the distribution of

losses from all forms of distributed generation. If these hazards are left unchecked, utilities may struggle to find financing, recover their costs and make new investments. The concerns should lead to a more informed focus on tariff innovations and the interests of participants as well as richer modeling of distribution grids.

Download the Paper

Policy Instruments and Market Uncertainty: Exploring the Impact on Renewables Adoption

JORGE BLAZQUEZ, NORA NEZAMUDDIN AND TAMIM ZAMRIK

Renewable projects typically require government action to get started. However, it is often a struggle for governments to produce a renewable policy that achieves all its objectives because they usually compete against each other. The success of any renewable policy as such can be measured through three parameters:

- Total cost per megawatt (MW).
- Amount of renewable technology deployed over the lifetime of the policy.
- Speed at which the renewables are adopted.

Governments have a range of policies and instruments to promote the deployment of renewable energy, but we focus on the three most popular policy tools:

- Feed-in tariff.
- Feed-in premium.
- Investment credits.

The benefits and weakness of each tool are examined in this paper. The choice of which instrument to use depends on the government's priorities and targets. Furthermore, the government's choice is in part affected by how much private sector involvement it wants in the projects. Private investment in renewable energy will normally occur if there is an attractive balance between yield and risk. This study allows us to explore how policy instruments perform under different market conditions taking into account the impact of price volatility and uncertainty of those investments.

We developed a "renewable projects generator," using real Spanish onshore wind data, capable of identifying 1,000 feasible projects. Then, we defined the economic environment for those projects, using a stochastic future evolution of electricity prices. Finally, we calculated for each project, under each of the five policy instruments, what is its net present value and the best time to commission.

In reality, there is no "best policy instrument," since there are trade-offs among the different policy instruments. The best policy, in other words, depends on the government's priority between the total deployment of renewables, speed of adoption and cost of policies.

Our findings show that a feed-in tariff, in particular the contract-for-difference feed-in tariff, is the policy that yields the fastest adoption of renewables, but it is also the most expensive. Investment credit is the cheapest, while at the same time it is very successful in the total deployment of renewable technology during the lifetime of the policy. The floor feed-in tariff (that sets a minimum price of electricity for renewable producers) achieves the largest success in terms of total deployment, with 98 percent of the 1,000 projects commissioned. Results from the other two instruments, the floor and cap feed-in tariff (that sets a minimum and a maximum price of electricity for renewable producers) and the feed-in premium rank them between investment credit and floor feed-in tariff.

According to our analysis, investment credit is the most attractive policy instrument for policymakers, since it is the cheapest of the five under realistic market conditions. This is due to the capital intensive nature of renewable technologies. The main setback of this policy instrument is that it requires a large upfront payment, rather than a flow of relatively smaller sums over a long period of time. If the objective of the policymaker is to expedite the maximum deployment of renewables in a short period of time, with no regard to costs, then a contract-for-differences feed-in tariff is the preferred option.

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Challenges for Widespread Renewable Energy Deployment: Fossil Fuel Price Responses

EDWARD FOSTER, MARCELLO CONTESTABILE, JORGE BLAZQUEZ, BALTASAR MANZANO, MARK WORKMAN AND NILAY SHAH

Part of the policy strategy to avert the worst outcomes of global climate change is a transition to low carbon energy on an unprecedented scale. In particular, strong incentives are in place to promote the competitiveness of renewable energy technologies, stimulate their rapid uptake and displace fossil fuel power generation. In this paper we argue that the penetration of renewable energy into the power market can directly result in a price response of fossil fuels which in turn affects the relative competitiveness of renewable power generation, thereby reducing the rate of the renewable energy transition or increasing the cost of the policy support measures required to achieve it. The price response we hypothesise is distinct from the Green Paradox and Carbon Leakage theories, which in different ways address the effect of climate change policy on the extraction and use of fossil fuels. In order to assess the possible existence and scale of the problem, we identify a price response mechanism backed by standard economic theory, based on the specific characteristics of the fossil fuel markets considered, e.g., coal and natural gas.

Our analysis shows that the amount of fossil fuel demand displaced by renewables is likely to be significantly smaller than the equivalent amount of renewable power generation introduced. However, the price effect of this demand shift could be large, depending on the price elasticity of fossil fuel demand and supply: the more inelastic the demand and supply, the larger the price effect. While short-term demand for coal and gas is likely to be inelastic, supply elasticity can vary greatly as we move along the supply curve. In the case of elastic supply, however, a further price drop is possible as fossil fuel producers shift their supply curve downwards to compete for market share. In perfect markets, where price equals marginal cost, a supply curve shift is only possible if the cost of supply can be reduced through production efficiency gains, while in imperfect markets, as is the case of natural gas and coal, rents are also present, which resource owners can renounce to maintain competitiveness.

It is also worth noting that significant shares of coal and natural gas today are still traded based on long-term contracts and on regulated prices, which may limit the extent to which the price of these commodities can respond to the large-scale penetration of renewables. However this is true only in part, as even long-term contracts and regulated prices tend to adjust when they diverge too far from short term market prices.

Our findings support the price response theory and that a fossil fuel price response to the introduction of renewables is likely to occur. This would lead to a higher than anticipated cost of the renewable energy transition. However, the extent of this effect requires further analysis of the structure of fossil fuel markets in order to formulate successful renewable energy policy.

Download the Paper

Renewable Energy: Lessons from the European Union Experience

LAWRENCE HAAR

Although the costs of generating electricity using renewable infrastructure have been falling, the costs per unit remains higher than that of conventional generation because expenditure is spread over a smaller output. Under the current structure of competitive power markets, renewable energy may continue to require incentives in the form of subsidies because its low operating hours and intermittency mean it would not earn a sufficient return at market prices. No method of setting incentives for renewable energy, including cost-based, value-based or even market-based approaches like auctions, can guarantee costefficiency. The uncertain availability of renewable energy imposes costs upon grid operators and dispatchable generators, which are hard to allocate properly under the liberalized model of electricity markets.

The EU's historic policy of promoting renewable energy through incentives has proved effective in delivering capacity and output, but arguably was inefficient from a cost perspective and provided overgenerous returns to investors. Subsidies and incentives had not been calibrated to decide what was/is a 'just-sufficient' rate of return to attract investment. Further, the complexity and opacity in the design of renewable energy support schemes raised costs, promoted inefficiency and may have enabled abuse.
In addition to the direct costs of subsidizing renewable energy, its intermittency imposed indirect costs on dispatchable generators as they were forced to reduce capacity to accommodate electricity from wind turbines and solar photovoltaic (PV) power. The impact of idle capacity and capacity run as backup to renewables called into question the viability of the current structure of liberalized traded markets in electricity and led to fresh calls for reform of ancillary services, capacity and availability payments. The experience of the EU in incentivizing renewable energy suggests the need to redesign markets to improve both short-term performance and ensure the adequacy of long-term investment.

The EU experience in promoting renewable energy also revealed the shortcomings of pursuing national targets. Europe has promoted an integration of energy markets to rationalize capacity and ensure supply flows to price, but the piecemeal

design of renewable incentives at country level has led to inefficiency and suboptimal investment patterns compared to what might have been achieved under EU-wide incentives. Clearly, there is an opportunity to learn from the experience of the EU to design new policies which balance the needs for economic efficiency with the desired levels of renewables penetration.

Download the Paper

How Will Natural Gas Adapt to the New Price Environment?

ANNE-SOPHIE CORBEAU, RAMI SHABANEH AND SAMMY SIX

In our previous workshop brief 'Natural Gas: Entering the New Dark Age?' we explored the discrepancies between forecasts of a growing longer-term role for gas in the energy mix and the current reality of a slow growing fuel, facing competition from cheap coal and policy-supported renewables. Two key factors were identified as obstacles to a bright future for natural gas: it costs more than coal and policymakers do not promote it because it is a carbon dioxide emitter.

The lower gas prices that have been observed since mid-2014 might appear to have taken care of the price issue, but market realities continue to cloud the outcome for gas as the prices of competing fuels have also fallen. Gas consumption increased in countries where prices were low enough to make gas-fired plants more competitive than coal-fired plants and where ample supply was available, such as North America. Usage also rose in countries such as the U.K. where governments implemented a carbon tax to improve the competitiveness of gas-fired plants and where environmental measures led to the decommissioning of old coal-fired plants, leaving more room for gas. It has also increased due to higher supply in developing countries. In contrast, Chinese gas demand slowed down while Japanese and Korean consumption fell due to increased competition from coal and nuclear. Finally, while prices have declined in some markets, they have increased in many regulated markets. This raises questions as to how gas demand will react if subsidies are removed and prices start to reflect the cost of supply.

With a more ambitious global warming target of 1.5°C, the implications of COP21 – the United Nations Framework Convention on Climate Change held in Paris in 2015 – are still uncertain for natural gas. The inevitable growth in demand for coal in many Asian countries conflicts with the resolutions passed at COP21. To achieve its long-term positioning, gas needs political backing to replace coal. This requires altering policymakers' perception of gas as a costly resource while domestically produced coal and renewables are seen as preferable environmentally or economically to gas, especially shale gas or imported gas.

It also requires the gas industry to deliver gas at an affordable price and to limit boom and bust cycles, which are detrimental to consumers. However, the industry will likely face a serious boom and bust cycle when 150 mtpa of LNG capacity comes on stream over 2015-20. This large oversupply, estimated to arrive when LNG demand is weakening, combined with low oil prices at about $30-40 per barrel is likely to set back the next generation of LNG projects as investors await improved oil and gas prices and try to trim costs.

Beyond making sure that sufficient gas supply remains if and when demand rebounds, lower gas prices create another challenge. Most recent LNG projects were built on the premise of rapidly growing gas demand, with their economics underpinned by high prices. Both elements of this projection are now gone. By contrast, LNG projects will now have to sell their gas on the basis of their variable costs. In particular, the U.S. tolling fee model and take-or-pay agreements mean that many off-takers may consider liquefaction fees as a sunk cost. For example, for a company that has contracted to take 1 mtpa of LNG, a $3/MMBtu liquefaction fee implies an annual sunk cost of about $150 million. The extent to which U.S. LNG off-takers could face large losses – and potentially default – will also depend on how much LNG will be uncontracted and head toward Europe beyond 2017. If large volumes of U.S. LNG target Europe, and Russia decides to fight for its market share by letting gas prices fall, this could cause real difficulties for U.S. LNG exporters.

In this context, the question of price and indexation is more relevant than ever. Asian buyers were previously pushed for a move to hub indexation in order to lower prices. By contrast, now they see this as an indispensable tool to achieve flexible supply. But they need to clearly define the type and location of the hub desired. As in Europe and North America, the financial distress of key players – either sellers or buyers – could accelerate the formation of such a hub.

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The Impact of Low Oil and Gas Prices on Gas Markets: A Retrospective Look at 2014-15

ANNE-SOPHIE CORBEAU, RAMI SHABANEH AND SAMMY SIX

The era of high Asian gas prices and large divergences between the Asian, European and U.S. markets came to an end in 2014. Over the period 2011-2014, imported LNG prices were above $14/MMBtu – sometimes as much as $18/MMBtu – in several Asian countries, making gas increasingly uncompetitive. Even in Europe where prices were substantially lower at between $8 and $10/MMBtu, gas was losing ground to coal in power generation. Such high prices were harming future growth potential in established markets and in developing countries.

As we enter 2016, gas prices in Europe, Asia and North America have dropped to historical lows and have also started to converge. As of March 2016, NBP prices were at $4.23/MMBtu, Asian spot $4.45/MMBtu and Henry Hub $1.81/MMBtu. Such a slump is usually accompanied by a high demand growth trajectory, but it appears that the price effect has not been sufficient to trigger a massive rebound in demand, with the exception of the U.S. There are some signs that the situation is improving, but it also appears that low prices need to be supported by policy that would consider the environmental benefits of gas against other fossil fuels and help countries meet their climate change targets. There are two main reasons for the moderate demand growth. Firstly, the prices of other competing commodities – coal and also oil – have declined sharply. Coal-fired power stations remain more competitive than gas-fired in most regions, especially in Asia and Europe. The situation started to change in late 2015 as gas prices fell even further. Secondly, economic growth prospects were revised down, making it more difficult to evaluate the impact of lower gas prices.

In April 2014, the International Monetary Fund (IMF) had forecast that global economic growth will increase from 3 percent in 2013 to 3.6 percent in 2014 and 3.9 percent in 2015 (IMF 2014). In January 2016, the IMF revised this down to 3.4 percent in 2014 with expectations for 2015 and 2016 at 3.1 percent and 3.4 percent respectively (IMF 2016).
While most analyses focus on the main markets – largely due to better data availability – another important pricing trend is taking shape. Gas prices in local currencies have increased in a number of developing countries, which in the past have tended to be kept low. Price hikes were due to the need to attract more imported gas, develop domestic resources or budget constraints. Altogether, these countries (excluding Russia) represent a consumption of about 685 bcm in 2014, or 20 percent of global demand. The lack of timely demand data means we cannot yet analyze the impact of these price increases on demand and local production. In most of these countries, demand has often been considered as price-inelastic. So it remains to be seen whether demand growth trends will continue. According to the IEA's latest World Energy Outlook, additional demand from the Middle East, Africa and non-OECD Asia (excluding China and India) over 2013-2040 will amount to about 680 bcm, or around 40 percent of the world's incremental demand.

Last year also witnessed a small shift in trade. When LNG project sponsors approved FIDs over 2009-2014, they were mostly targeting Asia. However, Asia has yet to fulfill this promise, with demand dropping in the three largest markets – Japan, Korea and China. Consequently, additional LNG supply went to new importers in developing countries and was also shipped back to Europe. Looking ahead, as LNG supply builds up from 2017 onwards, sales to Europe are likely to face competition from pipeline sources, notably Europe's largest pipeline supplier, Russia, which is the only exporter to have large spare capacity. What happens in Europe will largely depend on how much LNG will be backed out of Asia.
Finally, a key question is the impact of lower oil and gas prices on production. There has not been enough history to perform a definitive analysis, but a slowdown in U.S. gas production growth has been observed. However, the larger impact of lower prices is likely to be felt as a result of companies cutting upstream investments generally. There is also the probability of a pause in FIDs on LNG projects in the coming years.

Download the Paper

LNG Markets In Transition: The Great Reconfiguration

ANNE-SOPHIE CORBEAU AND DAVID LEDESMA

2016 sees the LNG industry on the edge of a cliff. However, it is an open question whether itstands at the bottom ready to climb up in an orderly way or at the top and about to fall in a tailspin. The sector has embarked on such a vast expansion that it is impossible to see how it could emerge unchanged five years from now. The question is not just one of supply and demand, but also of whether the LNG industry's pricing and contractual frameworks will be fundamentally reconfigured.

Until 2014, the gas industry was looking at the new wave of LNG supply set to hit marketsthrough 2020 as the indispensable tool for greater gas penetration in the energy mix, notably in Asia. That sentiment has changed as of 2016: Final Investment Decisions (FIDs) taken during the period 2009-15 will lead to a `wave of LNG' coming on line between 2015 and 2020 (150 mtpa) unprecedented in absolute terms. It will have far-reaching implications for global gas markets, which may be quite different from what was originally expected. These new deliveries are remarkable not only in size, but also for their origin. About 40 percent of new LNG export capacity will originate from the US, which only 10 years ago was predicted to become a bigger LNG importer than Japan. Investors in US LNG have tended to move like a herd, based on the behaviour of a first bold mover (Cheniere), but questions remain as to how much US LNG will really be exported over the long term.

Faced with this new volume of LNG, the gas industry's concerns have swung back to demand (or lack thereof). Asia has always been regarded as a bottomless pit, but now seems set to confound expectations. In 2015, LNG purchases dropped in the three largest LNG importers (Japan, Korea and China). There is also a growing anxiety that the rest of the world could start looking like Europe, where gas is squeezed by renewable energy and coal in the power sector.

Pricing and costs are at the centre of a fierce debate. From 2011 through 2014, LNG prices were above $15/MMBtu in key importing Asian markets, making new LNG capacity seem like a profitable investment. This opportunity attracted the large quantities of LNG capacity that are under construction as we write. China crystallized this appetite for LNG investment, even though analysts failed to agree when forecasting its LNG needs. All gas industry players forecast a growing role for natural gas, portraying it as the fuel of choice. And yet in most parts of the world this 'inevitable' rise of natural gas is colliding with reality: gas is a high-cost energy resource trapped between cheap coal and policy-supported renewables.2 The affordability of gas supplies will therefore be a key factor as to whether 'gas demand blues' continues or consumption rebounds. In particular, Asia is not ready to accept additional expensive LNG, even if the only alternative is 'dirty' coal. By 2020, the number of LNG importing countries is likely to reach about 40, with most new importers expected to have wholesale gas prices lower than $7/MMBtu. Investors, however, were counting on higher prices to guarantee that their new LNG plants would be economical. This likely price squeeze creates a strong imperative to keep costs under control in order for the LNG industry to continue to prosper.

Absorbing this new LNG supply will affect trade-flow patterns amid competition with alternative gas supply channels and other fuels but also pricing mechanisms, which are currently dominated by oil indexation. Oil indexation is under attack with US LNG selling at Henry Hub-indexed prices (plus costs). LNG suppliers have been pressured to adopt different pricing mechanisms and provide more flexibility. However, they also face high costs and are reluctant to abandon a business model in which they have confidence. While Asian and European spot prices have come closer during 2015, a complete globalization is still an elusive prospect in the absence of a global gas price.

An important untouched element remains in the LNG business: long-term contracts. Conventional wisdom is that LNG export plants must be supported by long-term contracts covering most of their capacity due to high capital costs. Current market conditions and the increasing amount of gas that is likely to be traded on a short-term basis because of oversupply may challenge the future of long-term contracts as they stand today.

Download the Paper

A Policymaker's Guide to the Various Ways of Calculating Energy Productivity

ANWAR A. GASIM AND LESTER C. HUNT

The energy productivity of an economy, defined as the ratio of gross domestic product (GDP) to primary energy consumption (PEC), appears to have a simple and unambiguous definition. This has propelled it to the top of a list of energy and environmental indicators commonly used by policymakers. Energy productivity and, its inverse, energy intensity are often used to gauge the average level of energy efficiency in an economy, to draw comparisons and to monitor an energy economy's progress over time. However, the existence of different approaches to measuring PEC and GDP makes it difficult to achieve these objectives.

This guide presents a detailed, systematic survey of the different possible approaches to measuring PEC and GDP, and its implications on the calculation of energy productivity. We refer to combinations of different measures of PEC and GDP as different 'versions' of energy productivity. The analysis in this guide focuses on five frequently used versions of energy productivity in academic and policy studies.

Three of the five versions of energy productivity differ through the database from which PEC data is obtained. The three databases are from BP, EIA and IEA. Our analysis shows that the different measures of PEC derived from each database can produce higher or lower levels of energy productivity, depending on the characteristics of the economy in question.

> For economies in which renewables account for a large share of PEC, the assumption used on the conversion losses incurred in the generation of renewable electricity has a large impact. The calculated level of energy productivity in such economies is revealed to be higher with the IEA database, which assumes that renewables incur no losses. For example, Norway's calculated energy productivity increases by 65 percent with a zero-loss assumption.

> For economies with large marine ports, excluding the fuel consumed by ships engaged in international navigation from PEC, as the IEA does, will result in relatively higher levels of energy productivity. In the extreme case of Singapore, for example, its energy productivity is higher by a factor of three when the energy used by ships that dock in Singapore and engage in international navigation is excluded.

> For economies in which large amounts of wood, charcoal and manure are consumed by rural sections of the population for cooking and heating, excluding such energy use from PEC, as BP and the EIA do, will produce a relatively higher level of energy productivity. Nigeria's energy productivity, for example, increases by a factor of six when this type of energy consumption is excluded.

Three of the five versions of energy productivity also differ through the exchange rate used to convert an economy's GDP from local currency units to US$. The results of our analysis show that:

> Developing economies enjoy relatively higher levels of energy productivity when purchasing power parity exchange rates are used to convert GDP into US$ instead of market exchange rates.

> Purchasing power parity exchange rates for developing economies are imprecise, and are prone to large revisions over time. This in turn results in large revisions to the version of energy productivity that rests on these exchange rates.

The approach used to measure PEC and GDP not only affects the level of energy productivity, which makes it difficult to draw meaningful comparisons between economies, but also the growth rate. Different measurement approaches may produce conflicting trends in energy productivity, potentially misleading policymakers. As such, there is a need for a greater degree of standardization in the energy economics community on the accounting of energy productivity.

Policymakers will benefit from a deeper understanding of the different ways of calculating energy productivity and intensity, especially when using these indicators to tackle energy and climate change issues. Moreover, this process would be easier if there were a standardized approach.

Download the Paper

Substitutes for Liquid Fuels: Outlook in a Low Oil Price Environment

ENERGY WORKSHOP SERIES

Following the global financial crisis, three-and-ahalf years of abnormally stable crude oil prices at around $100/bbl had created expectations that this represented a 'new normal.' But, when the extent of oversupply in the market became obvious to participants, oil prices started declining in the summer of 2014. The drop turned into a rout when it became clear that market assumptions of a Saudi production cut to maintain prices proved wide of the mark. The resulting oil prices, in whatever new range they eventually settle, will inevitably curtail investments in expanding the pool of future conventional, unconventional and, importantly, alternative fuels. The Saudi (and OPEC) strategy appears to have a long-term horizon directed toward conserving oil's position in the global energy mix and in the transport sector in particular.

In December 2015, KAPSARC's workshop Substitutes for Liquid Fuels: Outlook in a Low Oil Price Environment was held in Riyadh. Expectations of high oil prices have now come to a rather abrupt end, but will the growth of alternative fuels taper off as it did during the 1980s price slump? Back then, investments in substitutes were almost completely shut down as a similarly oversupplied market alleviated shortage fears resulting from the oil crises that so markedly characterized the decade before. There are arguments that can be made that "this time is different," as the advancement of alternative liquid fuels could be driven by a combination of continuous technology gains, emission reduction policy goals and political considerations in specific sectors such as the corn-based ethanol mandate in the U.S.

Download the Paper

Understanding Adoption of Energy-Efficient Technologies: A Case Study of Battery Electric Vehicle Adoption in the US

RUBAL DUA, KENNETH WHITE AND REBECCA LINDLAND

Understanding what drives adoption of energy-efficient technologies is key to achieving success in improving energy utilization and reducing emissions. In order to promote higher penetration of energy-efficient technologies, stakeholders need a better understanding of what drives consumer uptake of such technologies. In particular, who are the current adopters, why are they adopting it, who are the next batch of potential adopters and what factors will induce them to adopt.

Revealed preference surveys can provide key insights on current adopters' reasons for purchase. For identifying potential adopters, stated-preference surveys are generally used. However, consumers generally tend to react differently to hypothetical choice experiments than they would facing the same alternatives in a real market. Thus, in this study, we present a novel data mining approach, "ex-post counterfactual inference," for understanding current and potential adopters of energy-efficient technologies using revealed preference survey

data. This is the first time such a method has been used in any field and has broad applications for the analysis of revealed preference survey data and technology adoption.

A proof-of-concept is demonstrated by analysing battery electric vehicle (BEV) technology adoption in the U.S. market, as it represents a topical policy matter. Ten U.S. states, including California, representing 28 percent of U.S. light duty vehicle sales, have set mandated sales targets for zero-emission vehicles (ZEVs) that could result in significant reductions in fuel consumption and carbon emissions. Battery electric vehicles (BEVs) represent the most widely adopted pure ZEV technology and hence are key to achieving this mandate. For the targets to be successful, stakeholders need a better understanding of: (i) who buys BEVs; (ii) who might buy BEVs; and (iii) what factors can induce them to buy?
To answer these questions and others, KAPSARC carried out a novel segmentation-sizing study of the U.S. automotive market based on quantitative consumer profiling analysis, utilizing large-scale revealed preference survey data of 88,404 new car buyers. The nationally representative survey was carried out by Strategic Vision.

Using a combination of factors related to buyers' reasons for purchase, demographics and geographical characteristics, the analysis identifies different types of BEV buyers. Using these buyer-types as a reference, analysis then identifies and estimates potential BEV buyers from among the non-BEV buyers that "statistically resemble" the BEV buyer types. This is the first time such a methodology has been used in any field and has broad applications for the analysis of revealed preference survey data and technology adoption.

Our study found that BEV buyers are tech savvy and green enthusiasts who prefer to lease BEV as a second vehicle for their household, thus alleviating to some extent both range and resale anxiety issues. On the other hand, non-BEV buyers prefer an aesthetically pleasing vehicle with tried and tested powertrain technology, with good expected resale value, towing capability and handling ability in inclement weather.

Among BEV buyers, there are three types: (i) "price conscious buyers" who care about price, leasing terms and rebates; (ii) "affluent adopters" who care about styling, prestige and performance; and (iii) "demanding buyers" who are both price conscious and care about styling, prestige and performance. Demanding buyers also have fewer additional cars in their household and could thus be range conscious. According to consumer adoption theory, the affluent adopters show risk-tolerant characteristics representative of "innovators" and "early adopters." While the demanding buyers with their high expectations exhibit characteristics more representative of the "early majority adopters."

The demanding BEV buyer type also showed the maximum scope for growth. We found that under favorable conditions, the BEV market could secure up to 2.4 percent of the U.S. national market.

Since the potential BEV buyers are a tough group to attract, various measures are needed on the part of automakers and government entities, such as: providing BEVs with better handling in inclement weather, offering a better resale value proposition, extending electric drive range or offering loan programs that allow BEV buyers to borrow non-BEVs for long distance trips, better styling, offering flexible leasing terms and building more charging infrastructure where potential buyers live and/or work.

However, adding the above features and initiatives could increase the manufacturing costs associated with BEVs. If the costs get passed on to the consumers in the form of higher purchase price, it would have a negative effect on adoption. Thus, in the short term, it is important to keep the purchase price of BEVs competitive, wherein a decrease in battery costs and continuation of current federal tax credits and state incentive programs would both help.
To bring down battery costs, economies of scale are needed. However, it's unclear if the potential BEV market share of 2.4 percent in the U.S., the second-largest automotive market in the world, would be enough to yield economies of scale given the different cell chemistries and configuration used by different battery suppliers.
Eventually, battery costs would have to fall even further to make-up for the inevitable termination of rebate and incentive programs as well as the cost of adding the suggested features. BEV adoption also faces stiff competition from fuel-efficient gasoline vehicles, which currently is the preference of the majority of potential BEV buyers. Thus, policies promoting sales of these fuel-efficient gasoline vehicles, such as the federal Corporate Average Fuel Economy (CAFE) standards, may reduce the growth of BEV adoption. However, CAFE and ZEV are not necessarily mutually exclusive because BEV sales count favorably toward CAFE standards.

There is also a need to consider competition from other alternative fuel vehicles (AFVs) when promoting BEV adoption. Although total AFV market share can increase, our results show that promotion of BEVs could reduce hybrid and plug-in hybrid sales.

Download the Paper

Drivers of Transportation Fuel Demand: Is Policy Expanding the Reach of Alternative and Fuel Efficient Vehicles?

ENERGY WORKSHOP SERIES

The transportation sector accounts for about 25 percent of all energy consumed worldwide. Light-duty vehicles, fueled primarily by motor gasoline in most regions of the world, comprise the largest portion of this sector. Understanding the role of policy in expanding the reach of more fuel efficient conventional vehicles and alternatively fueled vehicles is important because of the potential for significant growth in light-duty vehicle ownership in many non-OECD countries, as well as the desire to reduce petroleum consumption and greenhouse gas emissions in several OECD countries.

Although fuel efficiency and electric vehicle policies are often considered together, the drivers for these policies differ slightly. Greater light vehicle fuel efficiency is an important policy goal to reduce transportation-sector greenhouse gas emissions and to increase energy security in consuming countries. Encouraging light-duty electric vehicle use is also a priority in many countries, although the rationale for such promotion differs. In countries with a low-carbon electricity supply, such as Norway, reducing greenhouse gas emissions is a strong policy driver. In countries with higher-carbon electricity supply, such as parts of the United States and China, energy security concerns are more important.

Many governments have implemented policies to promote fuel efficiency and alternative fuel vehicles, especially electric vehicles. However, these policies have had only a minor impact on light-duty electric vehicle sales in major markets, reaching just 1 percent in China and the United States.

In contrast, policies in Norway have led to a new light-duty vehicle market share for electric vehicles of nearly 14 percent. However, replicating these policies in other countries could prove to be challenging, as there are market impediments to significant electric vehicle market penetration.

Download the Paper

Opportunities and Challenges in Reforming Energy Prices in Gulf Cooperation Council Countries

ENERGY WORKSHOP SERIES

Following the rise of oil prices during the last decade, countries in the Gulf Cooperation Council (GCC) experienced rapid economic growth. The large revenues generated made it possible for GCC governments to pursue multiple objectives: spurring investments in domestic energy-intensive sectors; providing the public with affordable access to water, electricity, and transportation fuels; and making large investments in infrastructure, education and social services. Fuel and feedstock prices are typically administered; set below world market prices but above marginal production costs to support domestic energy-intensive activities like petrochemicals production.

Partly as a result, per capita domestic consumption of primary energy in the GCC reached levels among the highest in the world. The GCC countries (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates) are six of the top 12 countries in energy consumption per capita. Qatar, in fact, consumes the most primary energy per capita of any country in the world, followed closely by Iceland.
The recent fall in oil and natural gas revenues has brought renewed attention to domestic energy pricing issues among GCC governments and also brought to light opportunities for further collaboration among GCC members to alleviate the challenge of decreased export revenue. GCC members can explore different pathways for reforming energy prices, resulting in more efficient production and consumption of energy and a positive contribution to a nation's finances. An environment of low oil and natural gas prices is an opportune time to introduce energy price reforms because the shock of price increases to stakeholders can be smaller compared to introducing reforms when world energy prices are high.

Download the Paper

Modeling Residential Electricity Demand in the GCC Countries

TAREK ATALLAH AND LESTER C. HUNT

The Gulf region has seen rapid population and economic growth over the past few decades, changing the landscape of the area, raising living standards and enabling millions to increase their consumption of essential services such as water and electricity. These services have mostly been provided by government-owned utilities at subsidized rates. Despite this, little research has been done on estimating the impact of the drivers of the demand for electricity in the region, with none taking into account factors such as weather and consumer behavior.

It is critical for a policymaker who is facing rising demand for electricity on the back of income and population growth to have comprehensive quantifiable information on which to base decisions. This paper seeks to estimate the way residential electricity demand responds to changes in prices, income, population, weather and other factors in the six Gulf Cooperation Council (GCC) countries – Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates (UAE). The responses are normally measured by the demand elasticity, which is defined as the percentage change in electricity demand, divided by the percentage change in the appropriate driver. Where drivers cannot be adequately measured, such as improvements in the efficiency of appliances and capital stock or exogenous energy-consuming behavior, the impact is captured by a non-linear trend. The estimated model therefore provides information on the price, income, population and weather elasticities as well as identifying the additional underlying trends for residential electricity consumption.

The results suggest that a good econometric relationship can be found for Bahrain, Kuwait, Oman and Saudi Arabia (whereas for Qatar and the UAE the results are a little problematical). The long run price elasticity of electricity demand for Bahrain, Kuwait, Oman and Saudi Arabia is found to range from -0.16 to zero suggesting that the electricity consumers' response to price changes is very limited – i.e., demand is very price inelastic. The income (represented by gross domestic product, GDP) and population elasticities are also found to be inelastic – but generally greater (in absolute terms) than the price elasticities. The long run income and population elasticities of electricity demand for the four countries are found to range from 0.4 to 0.9 and zero to 0.8 respectively.

Even for weather, in the form of cooling degree days, the influence on residential electricity demand is inelastic at 0.2 to 0.7. In addition, the underlying trends are found to vary across the four countries but with all of them generally showing exogenous electricity using behavior.

Our results suggest that given the current pricing regime in the GCC region, residential electricity consumption is likely to continue to increase apace. Based on our findings, successful policies to curtail future residential electricity consumption would likely include improving the efficiency of appliances and increasing energy usage awareness of consumers, possibly through education and marketing campaigns. Furthermore, the estimated price inelasticity of demand suggest that small price increase would have little impact on curbing residential electricity growth. For any significant effect, prices would have to be increased substantially so that expenditure on electricity becomes such a large proportion of income that the price elasticities increase in absolute terms.

Download the Paper

Policy Options for Reducing Water for Agriculture in Saudi Arabia

CHRISTOPHER NAPOLI, BEN WISE, DAVID WOGAN AND LAMA YASEEN

Saudi Arabia is an extremely water scarce country. In this desert Kingdom about 87 percent of water extracted is used for agriculture, and, as such, no policy to improve the sustainability of water resources can ignore the agriculture dimension. The benefits are not restricted to water savings alone. Reducing water consumption could lead to significant energy savings, particularly when the water saved is used to displace desalinated water.

We constructed a linear program to analyze the tradeoffs in water consumption within the agriculture and livestock sectors under a range of policy scenarios. We explored how crop substitution can reduce aggregate water use without compromising the current level of food security or aggregate farmer revenues. The effects of each scenario on total water use, total energy used to meet water demand and the diversity of crops produced are examined. We also built a collective choice model that estimates the balance of influence implied by announced policy preferences to evaluate the most pragmatic policy choices. Thus, we generated 28 scenarios and selected the results from the 10 most viable choices for discussion in this paper.

A key finding was that water savings of 47 percent could be achieved while retaining a broad slate of agricultural products and, according to our analysis, this was the least socially and politically disruptive scenario studied. This is well above the Ministry of Agriculture's stated objective to reduce water use by 30 percent by 2030. It shows that a diverse supply of crops can be produced domestically while achieving significant reductions in water use.

In an extreme case, water for agriculture could potentially be reduced by as much as 70 percent without compromising food security or aggregate farmer revenues. However, in this scenario certain sectors such as diary, fodder and grains were eliminated leading to a limited portfolio. The results show that if water usage is to be minimized while maintaining food production and farmer revenues, then the primary candidates for reduction are crops or livestock with high-water intensity and low revenue and/or output. These include fodder and wheat. Eliminating them would actually yield higher water savings than moderate cuts across a larger portfolio of crops at the lowest social cost.

Future analysis could explore the role of input prices and government subsidies for crop production choices. Furthermore, our research uncovered a lack of consensus around how countries define food security. There would be value in understanding how uncertainty of agricultural supply relates to uncertainty of food security outcome and which policies achieve the largest impact on the latter.

Download the Paper

Energy for Water in Agriculture: A Partial Factor Productivity Analysis

CHRISTOPHER NAPOLI AND BERENICE GARCÍA TÉLLEZ

Water, energy and food are inextricably linked and, consequently, inefficient use of any of the three resources can have a negative effect on the other two. Managing this nexus requires a holistic approach.

We compare the productivity of extracted water used for agriculture, and the energy required to withdraw that water, across countries. Agricultural productivity is measured from both an economic (contribution to GDP) and physical (metric tons produced) perspective. Our results offer insights into how water and energy are used by countries for agriculture production and what policies governments could consider for improving the sustainability of water resources. Specifically, our results suggest:

- There is significant variance in the economic productivity of water for agriculture, and the energy required to extract that water, in the countries we studied.
- The relationship between total water use for agriculture and the energy required to withdraw water is loosely correlated. When a lack of correlation exists it is because of differences in groundwater well depths and/or differences in rainfall available for crop production.
- Physical productivity (sometimes referred to as 'crop per drop') divergences are even greater than economic divergences among the countries studied, particularly for crops that consume a lot of water.

Our findings highlight the opportunity cost for some countries of engaging in certain types of domestic food production, and suggest that efficiency gains could be achieved through crop switching and importing water intensive crops.

The findings also suggest that there may be limits to how much the productivity of water can be increased in certain countries where water is extremely scarce. This gives further support for the potential benefits of virtual water trade. Our results suggest that productivity improvements are more easily achieved by emerging countries which have higher rainfall.

This paper represents a first attempt at understanding the productivity of water and energy for agriculture across countries.
The availability of more granular data on pump efficiencies, groundwater depths and water extraction would make the results more conclusive. Moving forward, countries must improve their data on how water is extracted for agriculture, as this will better determine the opportunity costs involved in growing certain crops domestically.

Download the Paper

Group Choice with Interdependent Sublinear Voting

BEN WISE

Many important decisions of policy are made in a collective manner, so a great deal of formal and informal analysis has been devoted to collective decision-making processes (CDMPs). One common approach to analyzing CDMPs is first to model the participants as exercising their 'votes' independently, and secondly to solve the model and identify a range of feasible outcomes. A potential criticism of this approach is that the actors may strategically modify their behaviors based on the behaviors of others. If such interdependent voting behaviors led to different outcomes, it would undermine the validity of analysis based on independent voting.

In this paper, we compare and contrast two models of collective choice. The first assumes that each participant decides how much effort to exert as if they were acting alone; the second assumes that each participant strategically takes into account the effort exerted by other participants. While the first model is simpler, the second is more realistic. This paper demonstrates that they produce the same collective outcome: the simple model can be used without sacrificing realism. More formally, we demonstrate the mathematical equivalence of these two different CDMPs:

- The simple strategy of independent proportional voting, and some simple results of applying it.
- The consequences when actors strategically modify their behavior to take into account each other's actions.

There are some subtle differences in how the 'negotiations' play out — the actors do tend to exert less effort because of free rider effects — but overall the modified CDMP gives the same result.

Thus, we can analyze CDMPs as if the actors used independent proportional voting and remain confident that the final result is also correct should actors be using more strategically sophisticated behavior.

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Solar Photovoltaic Toolkit

AMRO M. ELSHURAFA AND SHAHAD R. ALBARDI

This dataset compiles capital costs (CAPEX) and levelized cost of energy (LCOE) data for the solar photovoltaic (PV) technology by year and country and presents the data in an interactive manner. Although, the dataset contains information that dates back to the 1980s, most of the information covers the past 10 years.

With the exception of a small set of entries, all costs are reported in nominal U.S. dollars. If the costs were provided in a different currency, the amount is converted to U.S. dollars. Because several assumptions/factors affect the CAPEX and LCOE, these are included if they are reported in the source. Also when a range is provided for the CAPEX or LCOE, the median is reported.

In addition to the interactive dataset, a raw dataset is also provided in Microsoft Office Excel should the user wish to perform their own post-processing. Alongside the raw and interactive data, an LCOE Analyzing Tool accompanies this toolkit and is specifically tailored for the solar PV technology. The Analyzing Tool allows the user to attain the LCOE using the capacity factor or solar irradiation.

This documentation and associated files are free to use provided proper citation is included. Please cite this documentation as:

Elshurafa, Amro M. and Shahad R. Albardi. 2015. The KAPSARC Solar Photovoltaic Toolkit. Publication number KS-1630-MP024A. The interactive dataset is available at: https://www.kapsarc.org/openkapsarc/

We intend to update this dataset quarterly. If you would like to obtain more information about this dataset, contribute to its contents, suggest ways to enhance it, or bring to our attention any errors, please contact us at research@kapsarc.org and include ‘Solar PV Toolkit’ in the subject line.

Download the Paper

02 // OpenKAPSARC

Our tools & 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 is not proprietary to third parties can be downloaded and reused freely. The current key platforms are:

KAPSARC Energy Model (KEM)

An approach to analyzing energy economies in which government interventions override liberalized markets and competition in setting prices and allocating volumes. Initial implementations include KEM-Saudi Arabia, KEM-China and KEM-GCC. The latter two are under development but sub-modules that have been completed are available as well as more complete models of Saudi Arabia that cover partial equilibrium, long term static and multi-period versions. Shortly, a CGE version of the entire Saudi economy will also be ready.

KAPSARC Toolkit for Behavioral Analysis (KTAB)

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 Energy Policy Database (KEPD)

We are creating a comprehensive source of reference for underlying initiatives of energy policies within our geographic focus. Most policy databases provide original documents (sometimes with short summaries of the key elements). However, it is increasingly rare that individual policies restrict themselves to single issues. KAPSARC's approach of breaking down policies into their constituent initiatives allows for a richer understanding of the evolution of policy thoughts in a country as well as greater visibility on the alignment, or lack thereof, between insititutions when they attempt to regulate the same activity with differing objectives. Initial releases for China's coal industry and India's renewables industry are available. These will be continuously updated as additional policies are broken down and coded.

CMCC-KAPSARC Global Weather Database

Weather can have a profound effect on energy consumption, especially extremes of hot and cold temperatures. These variations drive residential and commercial energy demand because heating and cooling needs are important. Commonly available analyses tend to be either local or short term; or both. However, the customization of methodology to a particular geography renders comparisons of the effects of weather between countries invalid.
KAPSARC has worked with the Euro-Mediterranean Center for Climate Change (CMCC) to create a database covering 147 countries over a period of several decades, based on consistent methodologies such that the impacts of local climate on energy consumption can be analyzed and valid comparisons between regions performed.

Differences in energy productivity of countries are due to a variety of factors, some controllable (including the structure of the economy and efficiency standards) and some uncontrollable (including weather and access to water). The CMCC-KAPSARC Global Weather Database is one of the tools now available to policymakers to separate the signal from the noise in benchmarking performance and guiding policies aimed at improving the energy productivity of their economies.

KAPSARC India Solar Policy Atlas

We have developed a web-based energy policy reference tool that systematically describes energy sector policies. This tool, also of use to researchers, is intended to facilitate 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 that 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 Solar Photovoltaic Toolkit

This toolkit and dataset is intended for any individual or institution interested in the solar PV industry and its cost trends. It compiles capital costs (CAPEX) and levelized cost of energy (LCOE) data for solar photovoltaic (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 attain the LCOE using the capacity factor or solar irradiation.

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 include data on Saudi Arabia's energy economy and will grow over time in both the breadth of their scope and the area of coverage.

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.

03 // Team News

Growing our global team

In the last quarter the following members joined our Research team:

Andrew Howe

Andrew has joined KAPSARC's Human Geography of Energy research team, bringing with him extensive practical expertise in the areas of quantitative modeling and data science. He has worked in numerous industries including finance, education, insurance, healthcare, and energy – his energy experience spanning both electric utilities and upstream oil and gas.

Specific topics that interest Andrew include economics and policy relating to alternate energy sources, interactions between interconnected regions, and distributed power generation. Broader topics of interest include allocating energy resources in an economy, energy flows and market impacts, and spillover effects of energy policy choices. His research interests have resulted in publications regarding model selection, robust modeling, and statistical computing.

Andrew holds a doctorate in statistics from the University of Tennessee and an MBA with a finance concentration. He is also a certified Energy Risk Professional.

Noha Abdel Razek

Noha has joined the Energy Systems and Modelling Research team. Her previous postings include post-doctoral research associate at the China Institute at University of Alberta, energy researcher at the Centre for Applied Business Research in Energy and the Environment (CABREE) University of Alberta School of Business, and visiting assistant professor at the American University in Cairo.

Her research includes government expenditure crowding-in effect and lack of diversification in oil producing countries, the impact of oil-price fluctuations on the Canadian economy, market frictions in Alberta oil sands and competitiveness of Canadian LNG, and trend analysis of china's investment in Canada.

Noha has published on Albertan's views on China, the likely effect of carbon pricing on energy consumption in Canada, and aggregate energy consumption in Canada and the U.S. She holds a doctor of philosophy in economics from the University of Alberta and a master of arts in economics from the American University in Cairo.

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.

Our focus areas

Allocating resources in an economy

Options to allocate energy resources efficiently in regulated markets — where governments intervene in setting prices and/or volume quotas.

Scope includes: optimal energy and technology mix; effects of reforming market rules and energy prices; and environmental impacts of policy choices.

Energy flows and market impacts

The impacts of changes to energy flows between regions and the scale and nature of their effects on supply, demand and prices.

Scope includes: influence of energy prices on energy sources and flows; impact of local energy efficiency standards on relative energy demand growth; and effects of domestic policies on the local energy mix and the ripples they create in global markets.

Energy productivity

The value extracted from energy consumption, understanding the driving forces of energy productivity and its relationship to energy efficiency.

Scope includes: determining energy efficiency policies that deliver the largest productivity improvements; recognizing the drivers of productivity performance in energy intensive industries; and productivity improvements through diversification to higher value-added economic sectors.

Energy transitions

Focuses on economically efficient policy instruments for incentivizing a transition towards more sustainable power generation mixes, including nuclear, renewables and fossil fuels.

Scope includes: results of continuing innovation in incumbent systems, raising the bar for emerging energy sources and technologies; and balancing the efficacy and economic efficiency of renewables support policies.

Social and environmental spillovers of energy policy

The interrelationships between socio-economic, environmental and other factors that drive energy production and consumption choices.

Scope includes: identify practical policy options that balance the interests of different stakeholders; opportunities for localizing the economic effects of energy resource development; and recognition of the range and risk of potential departures from intended policy outcomes.

Transportation; modes, fuels and technologies

Transportation policies and how changes in technologies and choices between modes of transport affect energy demand.

Scope includes: influences on consumers to adopt different modes of transportation; impact of fuel efficiency regulations and prices on transportation fleet mix; and impact of evolving behaviors on demand for transportation.