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PRESIDENT'S MESSAGE

Happy Fourth Quarter. This quarter we continue the topic raised in the last *Energy Forum* related to the role of renewables in the evolving energy mix. As one who comes from a multi-decade background of observing and analyzing fossil fuel markets and their related geopolitics and escalating environmental attention, this is new territory for me. Through it all, government energy policies related to security, trade, infrastructure, research and development have always been an important factor. The rise of renewables as alternatives to fossil fuel use has been a consequence of the policy but the policy is now becoming beneficiary of the improving market economics. Its easier to sell a policy when the consequences bring economic benefit, but it also sets up an endgame for removing unneeded help or at least reallocating it to new areas caused by growing shares of intermittent renewables.

As a microcosm of the shifting direction of energy economics within the IAEE, my company, Energy Intelligence, started a publication several years ago called *New Energy* as a companion for our dozen or so other publications, since it was critical to watch developments in the renewables sector in setting your outlook for competing fuels markets and the politics and economics surrounding energy markets in general. *New Energy* has now become a full partner with PIW, OMI, Energy Compass and our other more traditional energy publications, just as IAEE conference programs and journal articles have become more inclusive of renewables related issues.

Be aware that is by no means a zero-sum game and what has become clear to me traveling to developing energy economies in Africa and elsewhere and have commented here and in various presentations to IAEE and other audiences, "energy transition" should not be synonymous with "decarbonization." Energy Access and Energy Poverty must be included in the energy transition equation for many if not most of the developing economies, just as renewables need to be included.

IAEE's increasing understanding of conditions in our new member affiliates outside the traditional membership areas will go a long way in functionalizing the organization's role in helping set feasible, flexible and effective priorities with positive feedback for addressing generic energy issues to all economies. As I have also said many times before this is what we have been trained to do.

David Knapp

EDITOR'S NOTES

Articles in this issue look primarily at renewables. This was a popular topic and one which we'll continue in the next issue.

Tom Russo notes that environmental improvements from U.S. liquefied natural gas exports are often overlooked. But trade wars with China, Turkey, Mexico and other countries may increase LNG prices even further. This may force them to turn to other LNG suppliers or to fast track development of their own shale gas reserves instead.

Doug Reynolds looks at how the use of renewables requires natural gas as a backup source of power and heat and where natural gas politics strains international relations. Instead of renewables causing world harmony, they could instead induce tensions and conflict due to the security concerns over natural gas.

Julian Silk analyzes how natural gas and renewable energy affect other fossil-fuel electricity suppliers. He discusses the value of natural gas flexibility and the impact on retail electricity supply.

Anthony Owen considers three examples from around the world of where drought has caused nations to reconsider the vulnerability of their electricity supply to an over-reliance on hydropower. He also outlines two examples of how supply-security can be enhanced through regulation and, where possible, pump storage.

Mamdouh Salameh argues that while a wider use of electric vehicles (EVs) could decelerate oil demand growth; there will be an urgent need to expand global electricity generation to accommodate the extra electricity needed to recharge the millions of EVs on the roads. One innovative way to do exactly that is solar highways.

Perry Sioshansi posits that though big oil is still big it may have seen its best years. He notes the continuing pressure to move to a low carbon society, the investment by many of the oil majors into renewables, the rise in natural gas relative to oil and the continuing push into electric vehicles. Finally he notes the move by some investment funds to divestiture of fossil fuel entities.

Lynne Chester, Amanda Elliot and **Penny Crossley** discuss the current Australian energy landscape for households and propose new research directions to improve energy affordability—through access to solar PV—for low-income renters.

Farhad Billimoria and **Rahmatallah Poudineh** propose a new model for electricity market design – the insurer of last-resort model that creates commercial incentives for centralised decision-making and allows revealed consumer preferences to guide new capacity deployment and meet resource adequacy objectives.

Simon Risanger notes that intermittent renewable production is important to reach climate targets. In a day-ahead based market environment, imbalances from forecast errors occur. Intraday markets, which experience increased activity, can become an important tool to cancel imbalances and thus support efficient integration of renewables. He especially notes the recently established cross-border intraday project, XBID.

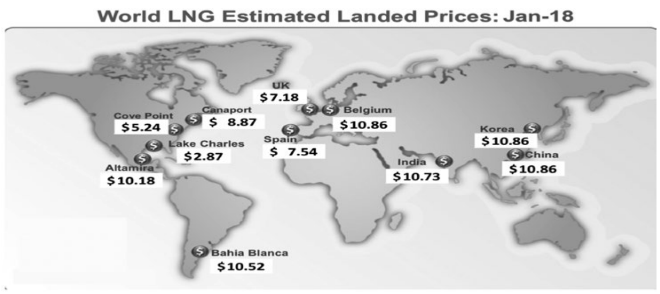
David Williams

Overlooked Environmental Improvements From U.S. Liquefied Natural Gas Exports

BY THOMAS N. RUSSO

Much of the discussion about liquefied natural gas (LNG) centers on growing U.S. exports, which are largely responsible for creating an LNG spot market and decoupling prices from oil. We often overlook or take for granted the environmental improvements that will occur in developing countries that import LNG or countries that choose not to develop their shale gas resources.

Greater demand for LNG is limited due to its higher price. Landed LNG prices exceed pipeline gas in North America ($2.90 per million Btu's) and Russia ($6.00–$7.00 per million Btu's). See Exhibit 1. In the last six months, prices in North Asia have been flirting with an almost $12-per-million-Btu price level in winter and have risen again during the summer. This increase may be due to rising global oil prices, on which many long-term LNG contracts are based.



Note: Prices are the monthly average of the weekly landed prices for the listed month. Landed prices are based on a netback calculation.

Exhibit 1

U.S. LNG exports are an underlying reason why LNG is becoming a global commodity just like oil.

The U.S. LNG industry still relies on long-term contracts, but sales and purchase agreements (SPAs) offer greater flexibility and don't have destination clauses. More important, the SPAs are tied to the price of natural gas at the NYMEX natural gas futures contract at Henry Hub; the agreements are not tied to oil prices. Many U.S. LNG companies are emphasizing reduced costs. Some companies, like Tellurian Inc., are encouraging purchasers to make equity investments in their company that would allow the buyers to lift LNG at the proposed Driftwood LNG export terminal in the U.S. Gulf Coast for $3.50 per million Btu's. That's good news for European countries that are reliant on Russian pipeline gas and Asian buyers that are exposed to very high LNG prices. See Exhibit 2.

The need to establish an LNG benchmark based on natural gas at the Henry Hub, rather than on oil, is also gaining traction. Lower LNG prices based on the former will encourage more widespread use of LNG and accelerate the replacement of highly polluting coal and oil. On July 10, 2018, CME Group and liquefaction/export pioneer Cheniere Energy Inc. announced an agreement in which CME Group will develop a Henry Hub–indexed LNG futures contract with physical delivery to the Sabine Pass terminal on the U.S. Gulf Coast.[1] Additionally, the Intercontinental Exchange launched an LNG futures contract for the U.S. Gulf Coast in March 2017. CME's new LNG futures contract could further erode pricing of LNG cargos based on the price of oil, a basis

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See footnotes at end of text.

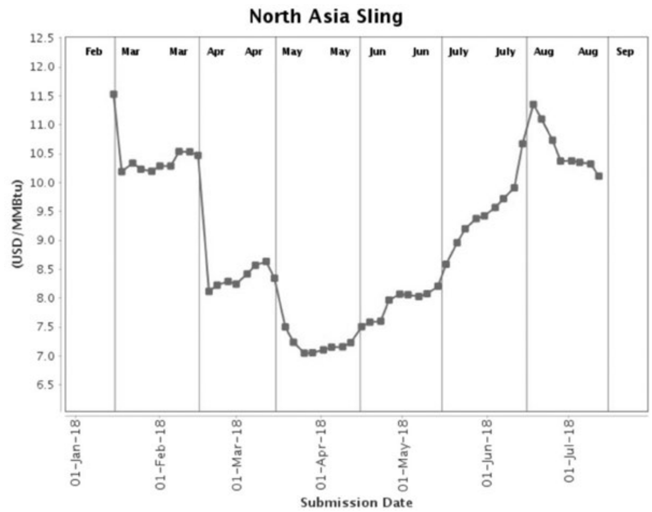

Exhibit 2

often used by the major LNG exporters like Qatar, Australia, and Russia. However, the success of CME's LNG futures contract will depend on whether or not LNG sellers and buyers, trading houses, and financial institutions use the futures contract and its liquidity.

Aside from giving LNG purchasers a tool to manage their risks, these new LNG futures contracts may result in lower LNG prices overall, which will encourage the use of LNG in the power sector, for residential heating, and as a marine bunker fuel.

Environmental Concerns and Government Mandates Drive LNG Imports

Natural gas is the cleanest of the fossil fuels.

Many developing countries have chronic air pollution problems, because these countries burn coal and fuel oil to generate electricity and for heating purposes. The use of diesel and gasoline in the transportation sector also contributes to air pollution. While LNG is much more expensive than pipeline gas, the governments of many importing countries are requiring existing power generators and others to switch from coal and fuel oil to cleaner-burning gas. Also, Japan and Germany are relying less on nuclear power and have little choice in the immediate future except to use gas-fired power plants to integrate growing solar and wind energy into their electric grids.

China

China has diversified its pipeline gas and LNG suppliers to include buying U.S. LNG.

Beijing aims to lift gas to supply 15 percent of its total energy demand by 2030, more than double the 6 percent in 2017. Chinese hotels, hospitals, and factories were forced to swap their coal-fired boilers for gas ones in 2017 as Beijing pushes to wean the country off coal.[2] This has created thousands of new standalone gas customers thirsty for the clean fuel. The demand for gas is being met by LNG trucking firms who deliver LNG within a 310-mile radius of the natural gas base in Tangshan, east of Beijing. Trucking LNG will play a critical role in keeping the world's most populous nation fueled as a winter fuel while China embarks on an experiment to heat homes in nearly 30 northern cities with gas.

China is not relying solely on LNG or natural gas to solve its air pollution problems. Beijing is also pushing electric cars as a preferred mode of transportation, with the country aiming to sell 2 million electric vehicles (EVs) by 2020 and attain an internal-combustion-engine-to-EV ratio of 1:1 by 2030. China is also well ahead when it comes to electrifying its mass transit. China had about 99 percent of the 385,000 electric buses on the roads worldwide in 2017, accounting for 17 percent of the country's entire fleet. Every five weeks, Chinese cities add 9,500 of the zero-emissions transporters—the equivalent of London's entire working fleet of electric buses, according to *Bloomberg New Energy Finance.*

In July 2018, Tesla announced a preliminary agreement with Chinese authorities to build a solely owned facility in Shanghai dubbed "Gi- gafactory 3." The planned facility is expected to begin producing EVs roughly two years after its construction begins and to ramp to a 500,000-vehicle-per-year production rate in two to three years. Some analysts may think that the electrification of China's transportation system is bad news for natural gas and LNG imports. That idea is not entirely true. The rise of EVs will increase electricity demand and the need for dispatchable gas-fired power plants until utility-scale electric storage batteries gain market share.

Until then, Chinese LNG imports can be expected to fill the gap between China's growing shale gas production and demand for natural gas for power, heating, and industrial purposes.

Mexico

Under former President Enrique Peña Nieto, Mexico is following in the United States' footsteps in greening its electric power sector and addressing air pollution by importing inexpensive and abundant U.S. pipeline gas and LNG at its regasification terminals in Altamira and Manzanilla.

While Mexico's new president-elect, Andrés Manuél López Obrador (often referred to as AMLO), would prefer Mexico to be self-sufficient, as a former mayor of Mexico City, he probably has a greater appreciation of how air pollution can affect the lives and health of common people than most leaders. I believe he will still rely on inexpensive U.S. natural gas pipeline imports, which average between $2.45 and $3.53 per million Btu's at the U.S./Mexico border,[3] assuming the North American Free Trade Agreement is renegotiated. In the future, AMLO will want to develop Mexico's own shale gas reserves and use associated gas from offshore oil fields.

The government expects 9.2 gigawatts of new natural gas–fired plants in the next four years, which will displace higher-polluting fossil fuels. The government also plans to oversee the Pajaritos Floating & Storage Regasification Unit, which will enable the government to alleviate supply constraints in southeast Mexico caused by a lack of U.S. pipeline imports and a sharp decline in PEMEX offshore associated gas.

India

Like China and Mexico, India is also trying to wean its power sector off coal to reduce chronic air pollution problems in its major cities. I believe India will stay the course and embark on an aggressive infrastructure program to build regasification terminals, pipelines, and distribution lines to get the gas to customers.

Trade Disputes and Natural Gas/LNG Exports

Thus far, the imposition of higher U.S. tariffs has not affected imports of U.S. LNG in the European Union, China, Mexico, or India, nor have tariffs affected U.S. pipeline gas exports to Mexico or Canada.

That could all change when it comes to national honor and the geopolitics at play between the United States and its trading partners. LNG-importing countries could simply purchase LNG from other suppliers. While U.S. LNG exports are sought by global buyers for diversification reasons, there is fierce competition from LNG producers in Russia, Qatar, Australia, Malaysia, and Indonesian. New LNG exports from Mozambique and the Middle East and additional capacity from Nigeria may disadvantage U.S. LNG exporters further if trade disputes spill over into energy.

If a full-scale trade war erupts that includes U.S. LNG and results in higher U.S. LNG prices, some LNG-importing countries that have shale gas reserves may opt to accelerate development to mitigate supply and price risks. That could include replicating U.S. shale gas production.

Plan B: China and Mexico Replicate U.S. Shale Gas Production—Correct Economics?

According to the *BP Energy Outlook*, by 2040 China will be the second-largest shale gas producer, after the United States, growing to 22 billion cubic feet per day by 2040. However, demand for natural gas in China is to grow by 194 percent during the same period, while coal demand is to decline slightly (down 18 percent). Renewables, including wind and biofuels, will grow

1 Asia and Oceania Share of world TRR: 28 per cent. Number of countries under review: 11 Comment: Together, China and Australia, accounted for three quarters of TRR in the region.	**2 North America** Share of world TRR: 23 per cent Number of countries under review: 3 Comment: The United States and Canada are commercial shale gas producing countries and respectively accounted for 36 and 33 per cent of regional TRR. Mexico represented 31 per cent of regional TRR, with nascent exploration activities.
3 Latin America and the Caribbean Share of world TRR: 19 per cent Number of countries under review: 8 Comment: Argentina is the main shale gas reservoir in the region, with 56 per cent of regional TRR, followed by Brazil (17 per cent) and the Bolivarian Republic of Venezuela (12 per cent).	**4 Africa** Share of world TRR: 19 per cent Number of countries under review: 7 Comment: With 69 per cent of TRR in Africa, North Africa appears to hold the largest share of TRR on the continent. Algeria accounts for more than half of TRR in Africa. South Africa also holds large resources, with 28 per cent of regional TRR. Countries in sub-Saharan Africa are almost excluded from the sample, with the exception of Chad, with 3.2 per cent of regional TRR.
5 European Union Share of world TRR: 6 per cent Number of countries under review: 11 Comment: France and Poland appear to hold most shares of regional TRR, with 30 per cent each. Poland and the United Kingdom of Great Britain and Northern Ireland (5.5 per cent) have taken steps towards the future production of shale gas. France decided to ban hydraulic fracturing in July 2011 (law No. 2011–835).	**6 Eastern Europe** Share of world TRR: 6 per cent Number of countries under review: 3 Comment: The Russian Federation ranks first within the group, with a share of about two thirds of regional TRR, followed by Ukraine (29 per cent).

Source: UNCTAD secretariat, based on EIA.

Exhibit 3

rapidly, by 789 percent. Nuclear and hydropower are to grow by 574 percent and 32 percent, respectively. See Exhibit 3.

According to the Mexico Institute, more than 50 percent of Mexico's energy comes from fossil fuels, with the transportation sector consuming 45 percent. Electricity has grown by half since 2000, and energy demand has increased by more than 25 percent. Mexico's energy outlook is impressive. More than 50 percent will come from offshore oil fields. Mexico estimates that $93 billion will be invested over the next 35 years offshore. By 2040, greater than one-half of the country's energy will come from offshore oil fields, including associated natural gas. Mexico's General Law on Climate Change requires emissions to be below 50 percent by 2050. Thus, more than one-half of power generation will be from renewables.

While it may be tempting for both China and Mexico to replicate U.S. shale gas, there are significant policy, monetary, and environmental costs that would be incurred, besides the economic feasibility of such a program. The U.S. model is unlikely to be directly replicable in other countries, according to a new report by the United Nations Conference on Trade and Development (UNCTAD).4

By importing pipeline gas and LNG, Mexico and China are saving considerably on shale gas infrastructure investments in drilling/fracking, gathering, processing, and storage. In addition, they don't have to deal with the associated environmental effects from the aforementioned activities. However, if LNG prices rise further for one reason or another, China and Mexico will have no choice but to accelerate development of their shale gas to make steady progress in meeting their air pollution reduction goals.

The United States produces approximately 80 billion cubic feet per day of natural gas from gas wells and oil wells. The capital expenditures (CAPEX) to accomplish this along the entire oil and gas supply chain amounted to $184.5 billion in 2018. Upstream costs are the lion's share of the investment at $132.5 billion. Even though the United States already has an extensive natural gas and oil pipeline network of 300,000 miles and 79,000 crude oil pipelines, CAPEX in natural gas pipelines increased by 144 percent. See Exhibit 4.

As China expands its shale gas development to offset its dependency on higher-priced LNG imports, China will be required to increase its CAPEX in drilling, gathering, processing, pipeline transmission, and distribution. China will also have to regulate upstream and midstream activities associated with hydraulic fracking and

	2018 million $	Change change, %	2017 million $	Change change, %	2016 million $
Exploration-production					
Drilling-exploration	111,180	9.0	102,000	37.8	74,000
Production	21,124	9.0	19,380	37.8	14,060
OCS lease bonus	200	65.3	121	-32.0	178
Subtotal	**132,504**	**9.1**	**121,501**	**38**	**88,238**
Other					
Refining and marketing	13,860	5.0	13,200	0.8	13,100
Petrochemicals	8,667	7.0	8,100	5.2	7,700
Crude and products pipelines	2,676	15.0	2,327	-89.5	22,130
Natural gas pipelines	18,751	144.0	7,685	18.7	6,475
Other transportation	4,300	19.4	3,600	2.9	3,500
Miscellaneous	3,750	25.0	3,000	25.0	2,400
Subtotal	**52,003**	**37.2**	**37,911**	**-31.5**	**55,305**
TOTAL	**184,507**	**15.7**	**159,412**	**11.1**	**143,543**

Exhibit 4

horizontal drilling and ensure that the supply chains for water, proppants, and chemicals are adequate to support drilling. Water is especially important, because unconventional gas wells require 15.5 liters per million Btu's, twice the amount of water used by conventional gas wells in extraction and processing.[5]

In addition, China will probably have to expand its gathering, processing, and pipeline transmission system to accommodate increased production. Depending on the natural gas liquids content of the gas, China may have to build additional fractionation plants and pipelines to send the more-pure products to petrochemical plants.

All of the activities associated with accelerating shale gas production require regulation to protect the environment and the public from methane leaks, explosions, and other impacts associated with the construction of pipelines and their operation. Annual budgets and staffing levels at the Federal Energy Regulatory Commission (FERC) and Pipeline & Hazardous Materials Safety Administration (PHMSA) provide some insight on the costs of regulating the midstream activities such as pipeline, storage, and LNG terminal construction and operation. FERC's 2019 fiscal year budget request is $70 million for its natural gas program, including enforcement staff. PHMSA's 2019 fiscal year budget request is $119 million to oversee the safety of over 2.6 million miles of pipelines and storage facilities in the United States. China would require at least a similar effort.

The above costs seem small compared to the required CAPEX to expand shale gas production. Costs are relatively low in the United States, because the oil and gas industry takes an active role in ensuring that the safety and operations of infrastructure and drilling do not violate existing laws and regulations. That role includes working with environmental groups like the Environmental Defense Fund to reduce methane leaks and flaring of natural gas.

The oil and gas industry in the United States is privatized and completely separated from government agencies that regulate the industry. In China, government-owned companies would be making the CAPEX investments and conducting the activities. In Mexico, it is likely that government-owned companies like Petróleos Mexicanos would be heavily involved in shale gas expansion. I believe China's and Mexico's environmental agencies will find it challenging to adequately protect the environment and safety from shale gas development along the entire natural gas supply chain.

By relying on U.S. LNG imports and pipeline gas, China and Mexico are assured that the gas has been extracted and transported with the appropriate level of environmental and safety oversight.

Better Economics To Import Rather Than Duplicate Effort

In conclusion, the value of U.S. LNG imports not only offsets the additional CAPEX needed to replicate U.S. shale gas production, but also reflects a high degree of environmental protection. Also, if U.S. LNG prices can be further reduced, they may delay accelerated shale gas production in China, Mexico, and other countries and quicken the adoption of gas to replace coal and oil.

The UNCTAD report on shale gas contains valuable information that countries will need to consider before developing their shale gas reserves or even attempting to replicate the U.S. shale gas experience. However, I don't believe China and Mexico will be dissuaded from trying to accelerate their shale gas production and ultimately replicate the U.S. shale gas production if the price of their pipeline gas or LNG imports continue to rise and air pollution adversely affects the health of their citizens.

Foonotes

[1] CME. (2018, July 10). CME Group and Cheniere Energy, Inc. reach agreement to develop first-ever physically deliverable LNG futures contract at Sabine Pass terminal. News release. Retrieved from https://www.cmegroup.com/media-room/pressreleases/2018/7/10/cme_group_and_cheniereenergyincreachagreementtodevelopfirst-ever.html.

[2] Aizhu, C. (2017). Stepping on the gas: China's truckers scramble to meet LNG demand. Reuters. Retrieved from https://mobile- reuters-com.cdn.ampproject.org/c/s/mobile.reuters.com/article/amp/idUSKBN1D70Q8.

[3] NGI's Mexico Gas Price Index, July 16, 2018, Vol. 2, No. 12.

[4] UNCTAD. (2018). Commodities at a glance: Special issue on shale gas, No. 9; p. 48. Retrieved from http://unctad.org/en/PublicationsLibrary/suc2017d10_en.pdf.

[5] Jackson, R., Vengosh, A., Carey, J., Davies, R., Darrah, T., O'Sullivan, F., & Petron, G. (2014). The environmental costs and benefits of fracking. Annual Review of Environment and Resources. Retrieved from http://www.annualreviews.org/doi/ pdf/10.1146/annurev-environ-031113-144051.

Natural Gas and International Relations: How Renewable Energy Creates Discord

BY DOUGLAS B. REYNOLDS

Introduction

The general public looks at renewable energy, and maybe even natural gas energy as green, as benevolent and tenably as peaceful resources. However, a high reliance on renewables typically creates a high reliance on natural gas as one of the few energy resources that can provide effective and reasonably priced backup power when needed, and indeed natural gas is one of the few fossil fuel sources for electric power that is tolerable to the general public in a green sense. Oil would be tolerable if it weren't so valuable for transportation. Nuclear power would be tolerable if it were not considered so dangerous. Wood and bio-fuels would be tolerable if the world's food supplies were not a concern. Coal is not tolerable although it is a cheap and reliable source of energy. The net result is that the world's energy portfolio is ever more dependent on natural gas which has international relations implications almost as powerful as oil has had in the past.

Energy Sources

Energy markets are dynamic. Energy supplies and energy customers are always changing, growing, or sometimes waxing and so you need a dynamic energy/infrastructure system to be able to match the market players. Throughout most of the 20th century energy markets had a number energy sources available such as wood, wind, coal, hydropower, oil, natural gas and then later on nuclear and solar power. Most of these were flexible, dynamic and competitive sources of energy. Even when coal, nuclear and hydropower plants took years to build and payoff, and so were inflexible as far as dynamic energy markets were concerned, nevertheless they were still supplied by reliable, competitive or storable feedstocks and the power plant itself merged the production of power with the consumption of power into one regulated utility all of which reduced the energy security concerns. However, upon close inspection of the natural gas part of the market there was a slight problem in bringing together the energy producer with the energy consumer as the two parts of the supply puzzle were not only distant from each other but they required a dedicated connection not unlike an electric power grid.

Therefore, with natural gas there has always been a challenge of getting the gas from the numerous producers to the numerous consumers because of the need for a long pipeline or, in the later part of the century, a large liquefied natural gas (LNG) facility. The pipelines and LNG facilities, though, have natural economies of scale and so have always been natural monopolies. Well, the world already learned with John D. Rockefeller that such natural monopolies can be bought out by one or another entity and made into a carrier monopoly, or at least a set of carrier oligopolies, which can force producers to sell at a low price even as customers at the other end pay a high price, and therefore most countries either own or control (regulate) natural gas infrastructure to reduce that kind of hostage taking.

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Well, the words "dynamic market" and "government control" don't always go hand in hand and so natural gas, even as valuable as it has been, was not always available when and where it was needed. However, for much of the 20th century that was not a concern as coal, oil and oil's components of propane and butane as well as uranium were widely available. Plus, these energy sources were dense enough to be transportable by rail, truck or ship without the need of a lengthy pipeline, although pipelines did add alternative transport options, and the densities made them storable to some degree so that power plants could wait out many market disruptions and therefore they were dynamically competitive. So, the energy sources were mostly competitive, even with OPEC, and the transportation was competitive which meant that energy markets could stay fairly dynamic throughout the 20th century no matter how slow or how fast natural gas supplies could be brought in. As such, even if governments were slow to react on the natural gas side of the energy markets, by taking a long time to approve and permit pipelines and LNG facilities, well, no problem you could just use coal, oil or other energy sources.

In the 21st century, though, things have changed. While there is a high demand for electricity to power the new information technology age, nevertheless, concerns for global warming have made coal into a non-option. New nuclear power generation is all but shut down due to the Fukushima disaster, although nuclear should be considered more seriously. Oil, and even propane and butane are becoming too valuable to be used for electric power, although they are still used to fill in some gaps. All of which leaves unreliable wind power, solar power and even hydropower, where the Colorado river is in an 18 year drought, to fill the void, oh, and natural gas. Still, on a winter's day in the north, solar power is all but unobtainable at 5:00 pm, even as electric demand is at its highest, and on hot summers after dark air conditioning is going full blast again creating a renewable supply deficiency. Wind is useful if you are willing to work during the time it blows and rest when it doesn't. Storing the electric power is costly, and indeed renewable backup systems such as batteries can require dumping the complexity of the electric power engineering from the utility onto the consumer, an implicit cost of customer self management time and money that may or may not be adequately identified in backup cost analyses. Plus, long distant power connections can actually exasperate volatility by over supplying too much or undersupplying too little electric power at a given time, rather than diversifying the volatility. This leaves natural gas as one of the most important backup power sources and heating sources available and which is still tolerable to the general public's intensifying greenness. Mighty natural gas.

The Peculiarities of Natural Gas

On the surface relying on natural gas to fill the renewable void should not be a problem as natural gas sources look to be plentiful and natural gas pipelines and LNG facilities are relatively cheap as are combined cycle gas power plants. But it takes only a small perturbation to a given system to suddenly see bottlenecks and sinister supply plots as the 2000/2001 California energy crisis shows. Nevertheless, relaying on natural gas is still a good option and backup systems can reduce such California style crises, plus regulators such as the U.S. Federal Energy Regulatory Commission (FERC) and other governments are doing their best to keep the natural gas markets competitive. Still, there is a kind of oligopoly of natural gas that is emerging and that threatens to undo this peaceful state of affairs. First, consider what a hard job the regulators have.

Typically, when governments regulate pipelines, they approve the fee structure which must be high enough to pay for the pipeline, but as low as possible so that more suppliers and consumers can hook up, i.e., they separate the transmission of the gas from the production and purchase of it. But if the pipeline's fee structure is too low, the pipeline could conceivably go broke and then another natural gas pipeline owner could buy that pipeline and soon, have market power over regional suppliers or regional customers. Even if the regulator caps tariffs, pipeline owners can show high costs and ratchet up the tariffs to make normal profits. So, to stop that from happening, regulators attempt to make sure there are ample supplies of natural gas at one end of the pipeline and ample demand for natural gas at the other end to ensure high throughputs so that the pipeline can keep tariffs low. Considering the complexities of planning, building and then running a pipeline, and considering the fact that you have to forecast supply and demand a decade or two into the future before you approve a project, and considering that it is difficult or expensive to have natural gas storage near the customer to mitigate variability, then regulating such an entity is no easy task where even a small change in tariffs creates a lot of political turmoil.

It is the same idea for LNG facilities, that is the regulator does not want any individual LNG facility to have long periods of low capacity which could require high tariffs and as such make the LNG facility become uncompetitive on the world market or cause regional producers to receive reduced revenue. Therefore, each LNG facility needs ample throughput to pay for it and that means you need an assured demand such as a decades long contract or political assurances that consumer countries will buy your country's LNG. And, *voilà*, suddenly natural gas supplies are not market oriented at all, but politically oriented even if its private companies supplying, transporting and consuming the gas.

International Tensions

Most major natural gas producer states have either a strong national regulator, like the U.S.'s FERC, or a strong national natural gas company like Russia's Gasprom. Some say that FERC is nothing at all like Gasprom, but in reality it is all about government control and governments in competition with each other. Even if FERC does not propose, build or run new natural gas pipelines or LNG faculties, they end up being forced to advocate for them which means the U.S. government like Russia's government, like Australia's government, like Qatar's government, like Iran's government, like Turkmenistan's government, like Norway's government, like the Dutch government, etc. all push their pet projects at the expense of other producers. Furthermore, each of these governments gets pushed very hard by public opinion in their own countries where one LNG project or one pipeline project can make a huge economic boom for a small local economy and where that local region then has outsized leverage on the national government's international relations. So, even though the natural gas business can be a small percent of a country's overall GDP, nevertheless it can have outsized political leverage. If one small region tells its government to push for a natural gas project, and that government does not push hard for it, whether it's a liberal, conservative or single party government, that government then is criticized loudly; newspapers carry stories about it all over the globe, letters and tweets and on-line discussions proliferate and the government and its agencies and diplomats suddenly feel the intense pressure from their constituents.

Each government, then, is determined to obtain market share for its own natural gas industry which makes this the one commodity in the world that has governments competing against governments for being first to market. The governments that buy natural gas are interested in diversifying supplies but also in cheap supplies. So, they are also competing and negotiating. So it becomes government against government in the buying and selling of natural gas rather like 18th century mercantilism. Indeed, it is ironic that the push to have consuming countries diversify their supply for political reasons actually increases their supply costs and reduces the feasibility of increasing the use of renewables for climate change mitigation, i.e., supply diversification for political reasons adds to global warming problems. Plus this government against government competition for LNG and natural gas pipelines seems to be intensifying as oil prices go up and global warming concerns for coal heat up.

Unfortunately, government against government competition leads more readily to conflict, threats of cut offs, embargoes and accusations of unfair competition leading to increased international tensions. So instead of possible war over oil in the future, we could see war over natural gas, and indeed may have already seen such with the Ukrainian crisis where one of the factors in that crisis was Ukraine not paying Russia for Ukraine's consumption of Russia's natural gas.

Alaska versus India

As an interesting example of counter political cultures of how natural gas can create international tensions look at Alaska and India. Alaska is a small state of less than 1 million people, but has nevertheless put a lot of pressure on the U.S. government into pursuing an Alaskan LNG project that would be less competitively priced than say a Russian far eastern project for supplying Pacific Rim gas. While most Americans are not concerned with the issue, such an LNG project is a boom to the local economy. And while such a project represents less than a hundredth of a percent of the U.S. GDP, nonetheless it induces a powerful country like the U.S. to spend at least some political capital pushing such a project.

By contrast, India is a huge country of over one billion people and yet they are mostly not in the natural gas competitive game. They tend to use coal and, even if they didn't have enough of their own coal, it is so competitive world wide that they could buy it from many sources with little if any government to government interactions, other than government to government concern for global warming. However, if India were to use renewables for a high percentage of their power, then they would need natural gas for backup power in which case they would join the government to government completion for natural gas. So, India as a huge country tends to reduce international tensions by not using a lot of natural gas whereas Alaska, as a small producer, adds outsized tensions to international relations.

Interestingly, India's use of coal also takes advantage of the sunk value of its entire coal energy system that already has in existence coal mines, coal trains, coal trucks, coal fired power plants, and, what is often missed in energy discussions, a labor force already trained in how to use the coal infrastructure. Thus, if India were to change quickly to renewables and natural gas it would not only require a lot of costly energy investments, but it would also force India to give up its sunk value of existing coal infrastructure and coal related human capital and force India to change now when maybe a better more reliable power source, such as better nuclear power, could be right around the corner. That sunk value is an opportunity cost of immense importance, that many economists do not properly account for. For an emerging economy like India, that sunk value allows it to have more money for health care, education and infrastructure that can help India to grow economically, although India may benefit using more clean coal technologies.

Conclusion

Global warming issues are important, there is no doubt about it. Nevertheless, the challenges of using renewables are under appreciated. Most renewable advocates emphasize how cheap and easy it is to use renewables, never mind the incredibly complex engineering, economic and political challenges of integrating renewable systems into our existing industrial society. Solutions to energy challenges need to be realistic and less one sided rather like Shell Oil's World Energy Expo 2017 exhibit "Energy Lab" in Astana, Kazakhstan where there was a discussion of having a diversity of energy solutions, as opposed to most of the country exhibits that emphasized renewables. If anything can create conflict between countries, energy can, and now that oil is becoming expensive, and may soon become more expensive, then natural gas could be the next center of conflict. However, because natural gas supplies are lumpier than oil, coal or at times even uranium, then the national security implications of natural gas could strain international relations.

IAEE International Association for Energy Economics
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42nd IAEE International Conference
Local Energy, Global Markets
Montreal May 29 – June 1, 2019

CALL FOR PAPERS

Abstract submission deadline: December 17, 2018

The Chair in Energy Sector Management at HEC Montréal, the Group for Research in Decision Analysis (GERAD), the International Association for Energy Economics and the Canadian Association for Energy Economics have the pleasure to invite you to attend the 42nd IAEE International Conference to be held in **Montreal (Québec, Canada) from May 29 to June 1, 2019**.

Energy is moving up the global political agenda with climate change, social inequity and energy security bringing an awareness of the need for a global energy transition towards a low carbon, sustainable energy future. This year's Conference theme, *Local Energy, Global Markets*, will focus on the development of local energy sources, their abilities and challenges to reach global markets and how local energy sources can be developed to better meet societies' future energy needs.

CONCURRENT & POSTER SESSION ABSTRACT FORMAT

Abstracts must be no more than two pages long and must present an overview of the topic including its background, significance, methodology, results conclusion and references. Abstracts can be submitted for a **concurrent** or a **poster** session.

All abstracts must be submitted online and conform to the prescribed format structure outlined in a template. Visit iaee2019.org/programme/call-for-papers to download the abstract template and to submit an abstract.

CUT-OFF DATES AND NOTIFICATION

Abstract due date:	**December 17, 2018**
Acceptance notification:	**January 31, 2019**
Full paper due date and presenter registration payment:	**April 1, 2019**

Website: iaee2019.org | Contact: info@ iaee2019.org

CONFERENCE TOPICS

Energy transition: national strategies, impact of circular and shared economy on energy

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We welcome abstracts presenting research using a wide diversity of methods:

- Business cases / case studies / benchmarking
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- Techno-economic bottom-up models
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Those interested in organizing a concurrent session should propose a topic and four possible speakers to info@iaee2019.org.

The abstracts proposed for a special session should be submitted, following the general submission rules within the deadline of December 17, 2018.

PRESENTER ATTENDANCE AT THE CONFERENCE

The **abstract cut-off date is December 17, 2018**. At least one author of an accepted paper or poster must pay the registration fees and attend the conference to present the paper or poster. The corresponding author submitting the abstract must provide complete contact details — mailing address, phone, email, etc.

Authors will be notified by January 31, 2019 of the status of their presentation or poster.

Authors whose abstracts are accepted will have until April 1, 2019 for registering to the conference and submitting their final papers or posters for publication in the online conference proceedings.

While multiple submissions by individuals or groups of authors are welcome, the abstract selection process will seek to ensure as broad participation as possible: each author may present only one paper or one poster in the conference. No author should submit more than one abstract as its single author. If multiple submissions are accepted, then a different author will be required to pay the registration fee and present each paper or poster. Otherwise, authors will be contacted and asked to drop one or more paper(s) or poster(s) for presentation.

NOTE all organized concurrent session speakers must pay the registration fee.

OTHER USEFUL INFO

- Registration to the IAEE 2019 Conference will start in October 2018
- Special early bird registration fee will be available for registrations before April 1, 2019
- Accepted presenters in concurrent and poster sessions must finalize registration payment by April 1, 2019
- Best Student Paper application deadline is January 17, 2019
- Gala Dinner will be at the Windsor Station, heritage building in downtown Montreal, on May 30th, 2019
- Special rates are available at the Delta Hotels by Marriott Montreal, between May 24 and June 6, 2019 (475 President-Kennedy Ave., Montreal H3A 1J7 Canada)
- Details for the pre-conference Summer School and technical tours will be announced on iaee2019.org

CONFERENCE LOCATION

HEC MONTRÉAL

Côte-Sainte-Catherine Building
3000 Côte-Sainte-Catherine Road
Montréal (Québec)
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IAEE/Affiliate Master Calendar of Events

(Note: All conferences are presented in English unless otherwise noted)

Date	Event, Event Title	Location	Supporting Organization(s)	Contact
2018				
October 18-20	3rd IAEE Eurasian Conference *Implications of Global Developments within The Energy Industry in the Caspian and Central Asian Region*	Baku, Azerbaija	IAEE	Vilayat Valiyev *waliyev@gmail.com*
November 2-4	6th IAEE Asian Conference *Energy Exploitation and Cooperation in Asia*	Wuhan, China	IAEE	Xiao Jianzhong *xjianzhong@cug.edu.cn*
December 6-7	1st IAEE Southeast European Conference *Southeast European Energy Challenges and Opportunities*	Sofia, Bulgaria	IAEE	Atanas Georgiev *atanas.georgiev@gmail.com*
December 10-12	3rd AIEE Energy Symposium *Current and Future Challenges to Energy Security*	Milan, Italy	IAEE	Andrea Bollino bollino@unipg.it
2019				
February 13-15	AAEE Conference *Heading Toward More Democracy in the Energy System – German/English Speaking*	Vienna, Austria	AAEE	Reinhard Haas *haas@eeg.tuwien.ac.at*
March 11-12	7th ELAEE Conference *Latin America: Decentralization, Decarbonization, Efficiency and Affordability in Energy Systems*	Buenos Aries, Argentina	ALADEE	Gerardo Rabinovhich *grenerg@gmail.com*
May29-June 1	42nd IAEE International Conference *Local Energy, Global Markets*	Montreal, Canada	CAEE/IAEE	Pierre-Olivier Pineau *pierre-olivier.pineau@hec.ca*
August 25-28	16th IAEE European Conference *Energy Challenges for the Next Decade:*	Ljubljana, Slovenia	SAEE/IAEE	Nevenka Hrovatin *nevenka.hrovatin@ef.uni-lj.si*
October 17-19	4th IAEE Eurasian Conference *Uncapping Central Asia's Potential: How Central Asia can Contribute to Global Energy Security?*	Astana or Almaty, Kazakhstan	IAEE	Vilayat Valiyev *waliyev@gmail.com*
November 3-6	37th USAEE/IAEE North American Conference *Energy Transitions in the 21st Century*	Denver, CO, USA	USAEE	David Williams usaee@usaee.org
2020				
February 9-12	7th IAEE Asia-Oceania Conference *Energy Transitions in Asia*	Auckland, New Zealand	IAEE	Stephen Poletti s.poletti@auckland.ac.nz
June 21-24	43rd IAEE International Conference *Energy Challenges at a Turning Point*	Paris, France	FAEE/IAEE	Christophe Bonnery *Christophe.bonnery@faee.fr*
2021				
July 25-28	44th IAEE International Conference *Mapping the Global Energy Future: Voyage in Unchartered Territory*	Tokyo, Japan	IEEJ/IAEE	Yukari Yamashita *yamashita@edmc.ieej.or.jp*
2022				
March	45th IAEE International Conference *Energy Market Transformation in a: Globalized World*	Saudi Arabia	SAEE/IAEE	Yaser Faquih *yasser.faquih@gmail.com*
August 7-9	8th IAEE Asia-Oceania Conference *Making the Transition to Smart and Socially Responsible Energy Systems*	Hong Kong	HAEE	David Broadstock *david.broadstock@polyu.edu.hk*
2023				
June 19-22	46th IAEE International Conference *Overcoming the Energy Challenge*	Istanbul, Turkey	TRAEE/IAEE	Gurkan Kumbaroglu *gurkank@boun.edu.tr*

Valuing Flexibility: Looking at the Effect of Renewables on Fossil-Fuel Electricity Generation

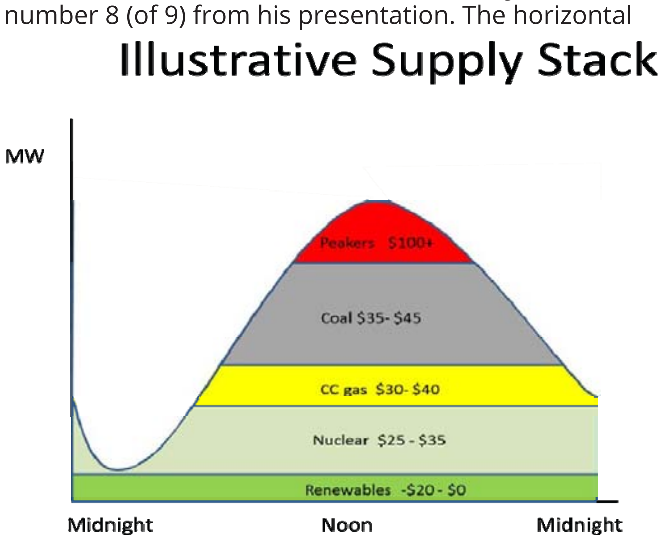
BY JULIAN SILK

Julian Silk is a consultant with Kapur Energy Environment Econimics (KEEE).The opinions expressed here are solely his own, and do not represent any taken by KEEE. All errors are his own as well.

The supercripts refer to references at the end of the text.

Re-Opening the Case

In Jenkins (2018), it is stated that "In short, cheap natural gas may be killing the profitability of nuclear power producers in the PJM Interconnection, but stagnant electricity demand and expectations of future growth in wind generation going forward may be accomplices."[1] There is no mention of the effect of the need to take on current supply of renewable energy in this list of the guilty. This is in stark contrast to the views of Scott Vogt, VP of Energy Acquisition, ComEd, "Integrating Renewable Energy into the ComEd Supply", in the Dual Plenary Session, "Challenges and Opportunities for Renewables", of the United States Association for Energy Economics (USAEE) meeting in Tulsa, Oklahoma in 2016[2]. The following is slide number 8 (of 9) from his presentation. The horizontal



axis should be taken to be hours in the day. The height of the figure in the vertical axis is the number of MW demanded during the hour. Crucially, this is *not* what can be or is *supplied* during the hour, but what is demanded – there is a big difference which is crucial for nuclear power.

When a surge of wind does come on, and the electric system has to take it, and the demand isn't there, the locational marginal price (LMP) at the node reflects the Independent System Operator (ISO) or some other agency *paying someone* else to take the power.

The distinction will be relevant for Maryland in short order. In Maryland, the state legislature, controlled by the Democrats, overrode Republican Governor Lawrence Hogan, who vetoed an attempt to increase the mandated renewable share of electricity produced in the state from 20% by 2022 to 25% by 2020, so their proposal will go into law[3]. This may have a direct effect on the Calvert Cliffs nuclear plant. The Calvert Cliffs nuclear plant has a number of similarities to the recently closed Indian Point nuclear power plant in Westchester County, New York. The Indian Point closure can be traced to a number of factors: political opposition from environmental groups in-state, which has extended to opposition to subsidies for upstate nuclear power as well; the age of the facilities (they would have had to be re-licensed), and the low price of natural gas[4]. But there are a number of similarities between Indian Point and Calvert Cliffs: the relevant facilities were built at almost the same time; the distance between the plant site and a major metropolitan area (or in the case of Calvert Cliffs, two – Baltimore and Washington, DC) is about the same; the same environmental groups oppose both; and both are about the same distance from the seacoast. Both plants are about the same size as well, since a planned third unit for Calvert Cliffs has been abandoned. Both face low natural gas prices. There have been more environmental problems with Indian Point than with Calvert Cliffs, and Maryland has a Republican governor, who supports Calvert Cliffs, while New York's Democratic governor Cuomo has consistently opposed Indian Point. Nevertheless, the similarities are striking, and Governor Cuomo does support nuclear power for upstate New York[5].

If natural gas prices stay low (relatively), and Calvert Cliffs faces financial difficulties, this will be support for the case made by Jenkins. But what if natural gas prices *rise* and are relatively high, and Calvert Cliffs faces financial difficulties? This would be support for the case made by Vogt. Vogt's case is also supported by Bajwa and Cavicchi (2017), which argued that increases in renewable energy use have led to increased frequency of negative electricity prices[6]. Negative electricity prices have also occurred elsewhere, particularly in Germany[7]. Davis (2017) argues the culprit for negative electricity prices is hydroelectricity[8]. But this can hardly be the case for Australia, which has also experienced frequent negative electricity prices[9].

The following is an attempt to outline conditions under which one case or the other can occur. This is probably a foolhardy venture, given the criticism launched by Green (2012)[10]. I am at fault in not making clear that the increase in costs is not an increase in operations and maintenance (O&M) costs per unit of energy for every unit of electricity the fossil producers supply. But the presence of renewable energy, the requirement to use it in the face of variable demand, and its intermittent nature and unpredictability are certainly *suspect* in increasing the difficulty the fossil producers are having. This is clear for natural gas, in that there must be some backup capacity that is used all the time – so the quantity of natural gas used is increased over what it would otherwise be. It is also relevant for both coal and nuclear; coal has to be prepared for some degree of ramping, and the insertion of nuclear into the relevant mix of supply is rendered more difficult. When Professor Green states: “Furthermore, I cannot conceive of a way in which, as in Dr. Silk’s world, the presence of a quota of high-cost generators somehow raises the costs of every other generator on the system”, this is almost a semantic distinction. The renewable energy doesn’t raise the supply costs, but it certainly is a possibility in raising the integration costs. Moreover, the reader may allow me to respond to “This somehow leads him to conclude that the fossil generators would now have a higher marginal cost than the wind farms and would, therefore, require a subsidy if they were to continue to operate” with some care. If the increased difficulties of nuclear power in Illinois that Vogt discusses are not *exclusively* because of low natural gas prices, (or at best the other suspects Jenkins mentions), but also because of the renewable portfolio standards, then the “require a subsidy if they were to continue to operate” is exactly what is happening. Note also that my argument was made years before these subsidies were approved by the state legislatures in question.

The argument here, necessarily awkward as a first attempt, will be an attempt to display flexibility, which seems to me to be the decisive factor, in graphs of the usual supply-demand type. It is my hope that this will illustrate what to look for in the particular cases, in particular, not just prices, but quantities used. It is beyond the scope here to do a statistical analysis to determine which is relevant at the present; it is possible that a panel data analysis using the renewable portfolio standard map provided by DSIRE vs. the financial statistics of the affected fossil fuel generators could provide some insight on this issue[11].

Cases

All the case descriptions that follow will be similar to those of the Hans Auer and Reinhard Haas graph, shown below as Figure 1[12]. My graphs will only describe immediate prices and the merit order that the Independent System Operators (ISOs) are facing in the immediate short run, and will definitely not be as descriptive as the Auer-Hass graph. In these graphs, the simplest possible cases are being described. So, for example, in the first case, there is no pretense that demand is always constant and stable, and certainly no pretense that renewable output is stable for the first two. It is just a matter of focusing on a particular aspect. As with the Auer-Hass graph, all vertical axes are price (though in $/MWH, though this makes no real difference as long as we are consistent), and all horizontal axes are MWh. To simplify life, we look at wind (assumed to have a cost of zero), nuclear and natural gas, and ignore everything else, including hydroelectricity and coal[13]. Quantities are intended to be indicative, not exact.

The Low Natural Gas Price Case –

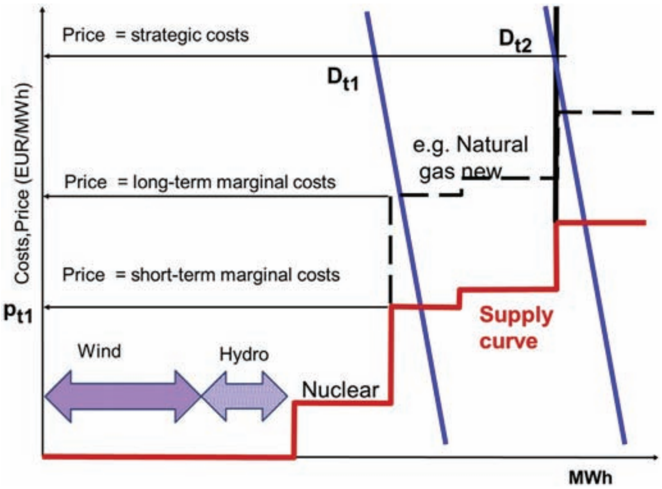
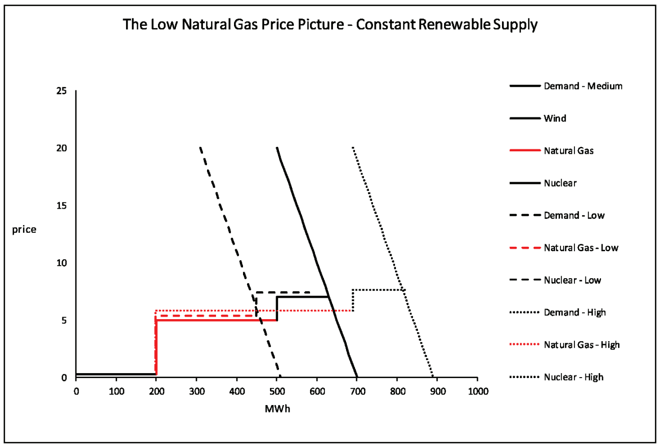


Figure 1 Merit order supply curve with additional wind capacities (incl. run-of-river hydro) at off-peak time with total costs or strategic bidding for conventional capacities. (Source: own illustration).

Constant Renewable Supply

The first case below should be reasonably transparent. When demand is medium, what is expected, the solid lines indicate the merit order of supply.

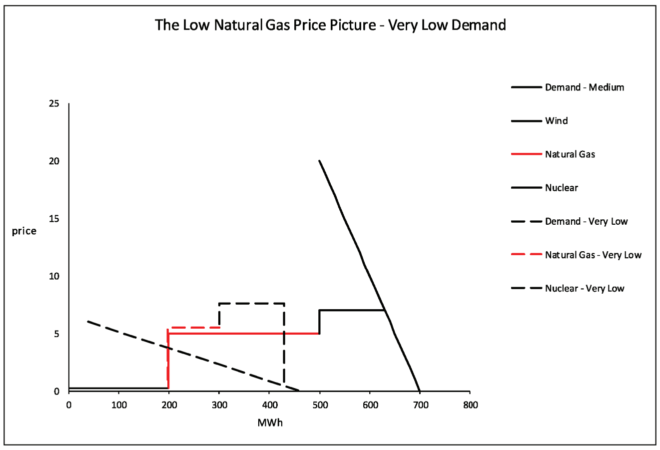


Renewable energy (the solid green line) is basically constant relative to how demand changes, and the ISO can easily cope with the very minor variations that occur. Natural gas supply (the solid red line) makes up the bulk of the supply. Nuclear energy (the grey solid line) always has a higher supply price (or marginal cost) than natural gas, and the difference remains constant. So nuclear energy marginal cost sets the market price, and nuclear energy makes no profits, but suffers no losses, while natural gas and renewable energy both make profits.

For low demand, natural gas output (the red dashed line) contracts significantly, because of its flexibility. Nuclear output (the grey dashed line) cannot contract. In this particular case, market price is in between the constant natural gas supply price and the constant nuclear supply price. This case is worth looking at because here again, both natural gas suppliers and renewable energy suppliers make profits. The nuclear suppliers, who can't contract, make losses, but the losses are not equal to total nuclear output times the difference between nuclear and natural gas supply prices. They are less. As long as market price is greater than zero, it will make sense for the nuclear suppliers to stay in the market in the short run, along the usual argument of price greater than average variable cost.

As long as demand does not fall below the minimum of natural gas supply plus the assumed constant renewable supply (suppose for simplicity this is 300 MWh total, at a price of $5/MWh), natural gas suppliers will not suffer losses. The renewable suppliers never do in this case, as long as price is greater than zero. But the nuclear suppliers do suffer increasing losses as demand declines, unpredictably. It will be easier to see this in the next case, but suppose we can imagine demand falls to 200 MWh at a price of $3/MWh. We can't have the same demand function and have positive or even zero prices, but suppose for simplicity that demand becomes more elastic in this very low price environment. As long as demand at a price of zero is greater than the sum of the all the supplies, the unchanging renewable supply, the minimum natural gas supply and the inflexible nuclear supply, a positive but very low price will prevail in the market. This is shown in the following graph:

Here, both the natural gas suppliers and the nuclear suppliers are suffering losses, but the same argument



keeps them in the market in the immediate short run. Of course, this is a very unlikely case, at least for the present, but it is included for completeness. The much more likely case is that the demand schedule does not change that much, even for very low demand, and prices turn negative.

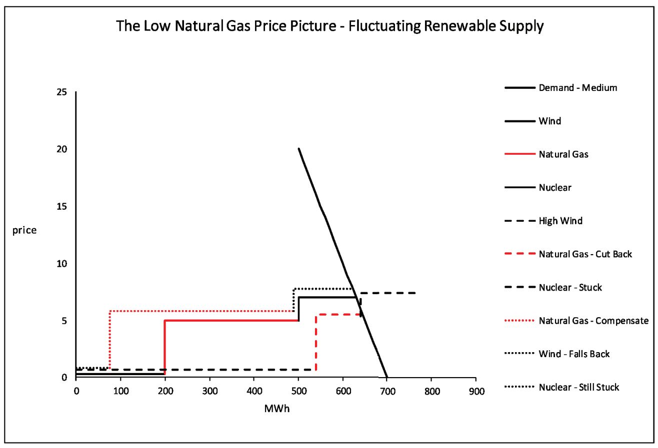
One more case is described in the *Low Natural Gas Price - Constant Renewable Supply* graph shown previously, in the case of high demand. Here natural gas supply expands dramatically and the natural gas facilities make profits once again. Here again, the nuclear suppliers make no profits, but do break even. The renewable suppliers do make profits.

Summing up, if renewable supply is relatively stable compared to demand, the renewable suppliers make profits. Given this situation but varying demand, natural gas suppliers can suffer losses, but the losses are only if market demand is low. The nuclear suppliers are the ones who really suffer dramatic losses if demand is low. The problem for them is that they never make profits to cover for these losses unless market demand, even if high, exceeds the sum of all the renewables can provide, all the natural gas suppliers can provide, and all the nuclear power suppliers can provide, here for the nuclear power supply price of $7/MWh. Such extreme cases would invite purchased power (the equivalent of imports) which would probably be natural gas also. It is possible to imagine excess purchases (of imported or locally produced natural gas) in the case of high local demand also leading to zero or negative prices, but these would seem to be unlikely. Barring this, the relevant point is that nuclear power losses should be highly correlated with low demand for this case of relatively stable renewable supply and low natural gas prices.

The Low Natural Gas Price Case – Fluctuating Renewable Supply

Here, to simplify life, demand will be assumed to stay absolutely constant. The flexibility of natural gas allows it to cope with fluctuating renewable supply. Here again, nuclear power suppliers suffer losses, but not always – only when renewable supply is high. For such cases, there are negative electricity prices.

It is important to note what happens in the high renewable supply case for the natural gas suppliers.



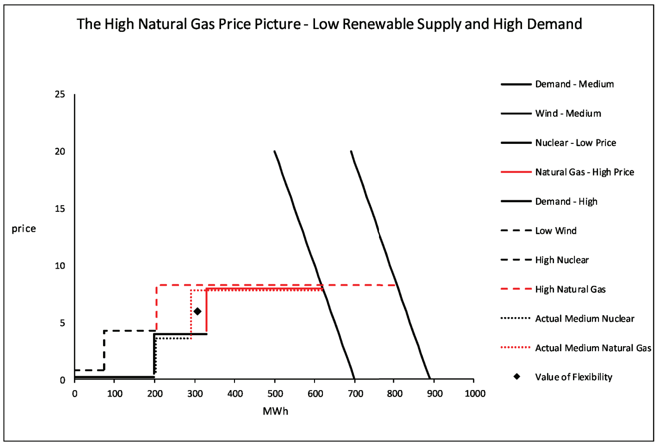
They also suffer the negative prices. But again, in the medium or low renewable supply case, they make profits to compensate for them. In the low renewable supply case, the renewable suppliers and the natural gas suppliers both make profits. But the nuclear power suppliers do not – they break even. So they have losses or they break even; they can't compensate for the losses.

The Value of Flexibility – The High Natural Gas Price Case

This will be the only really new argument. It will be argued here, for the case of high natural gas prices, that the ISOs will still choose natural gas as the compensating source of supply, even though the supply price of natural gas will be greater than that for nuclear generation. Why? Because there is enough uncertainty in *both* supply *and* demand to have a significant value for natural gas because of its flexibility, even though it doesn't show up in the reported (or reportable) costs.

It turns out that the value of flexibility occurs when there is a combination of events, not just one. Suppose we take the case of high market demand and low renewable output, occurring unpredictably after the standard normal case is observed. Then we have the following graph:

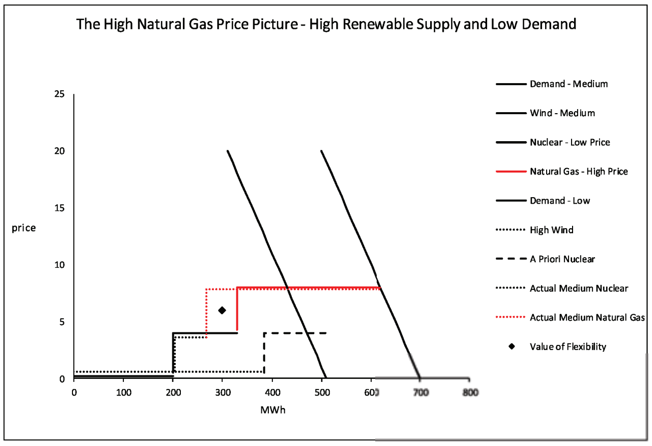
In order to be prepared for the unpredictable jump in market demand, coupled with the fall in renewable



output, more natural gas will be used than would be the case if everything were perfectly predictable far in advance. The (vertical) rectangular area denoted with the diamond is the value of flexibility in this case, the savings at the second for using nuclear power times the quantity of nuclear power foregone, so that if the high demand-low renewable case occurs, there will be enough flexible natural gas to cope with it.

It would seem that with the low demand, high renewable supply case that nuclear power would be used to the full. But this is misleading again; not only can nuclear power (as conventionally used) not go up enough and quickly enough, it can't come down enough and quickly enough, either. The situation is described in the following (similar) graph:

The value of flexibility is shown in the same area marked by a diamond, here a gold one. If nuclear



power were unchanged, then with the combination of circumstances, negative electricity prices would happen, since there is excess supply – this is shown with the "A Priori Nuclear". Even reducing the nuclear supply doesn't guarantee positive prices, if the renewable (wind) surge is big enough. But it reduces the probability.

The cases where natural gas is still used, because of the value of flexibility even with high natural gas prices thus result from a negative product of the difference between expected market demand and actual and the difference between expected renewable supply and actual. With a symmetric probability distribution of outcomes, there is reason to believe such negative product results could occur often, though perhaps not 50% of the time.

In the other two cases, where the product was positive, nuclear power would earn positive profits. Even so, unless nuclear power (and coal generation) could become flexible as well, the total profit earned would not (necessarily) be enough to compensate for all the foregone profits – for all the installed nuclear facilities - as natural gas is substituted for nuclear in the negative product cases[14]. Some of the nuclear would have to be cut back or put out of operation.

It is tempting to think that the cutback in nuclear could be analyzed by a simple expected value calculation. Suppose probability of the negative product cases is p(N), such that p(N) + 1 – p(N) = 1. Suppose the desired cutback in these cases would be r_N. Then it is natural to think that the actual cutback would equal p(N)*(r_N). If the negative cases were assumed to occur with 100% probability, then the cutback would be r_N itself. It is likely that the cutback will be somewhere between these two possibilities, and will depend on the actual probability distribution of the occurrence of the negative product – possibly using some sort of value at risk principles.

Of course, the value of flexibility is not infinite even in these two cases. If natural gas prices were high enough, and nuclear power was inexpensive enough, then nuclear power might be run at all times to power batteries or some other storage mechanism, and natural gas would be foregone. This is not a reasonably cost-effective solution in the immediate future, under any reasonable scenario for natural gas prices.

Conclusion – On Avoiding the Backlash Against Renewable Energy

The argument above is an attempt to isolate exactly what renewable energy is doing to cause financial distress for fossil fuel electric generation and when, and how whatever effect there is can be distinguished from the effect of natural gas. Shale gas has reduced natural gas prices significantly from what they were in 2000-2008, but it is likely that the trough has already been passed, though the rise may stall, or be slow. The one innovation here has been an attempt to argue that high natural gas prices, given the uncertainty of estimation of market demand and renewable energy supply, is by no means sufficient to avoid generating such financial distress.

The financial distress involved affects people's jobs and has already caused backlash. Oklahoma has joined West Virginia in repealing support for renewable energy, and it is possible that Indiana could also join in the near future[15]. It's easy to say that these are just bumps in the road: Dominion Virginia Power is planning to build offshore wind turbines (a first for the state), and Hawaii is looking into have all power supplied by renewable energy, so why worry?[16]

Such attitudes are very dangerous. The Center for the American Experiment, using IMPLAN, found that Minnesota's renewable energy mandate generated about 6,000 jobs, but the increased costs caused a loss of about 8,000 jobs[17]. Of course, this result has been criticized, and it is possible that some counting method that includes public health benefits might result in a net job gain, but to those who lose their jobs, this is very cold comfort[18]. The people who are losing their jobs are in the "red" (Republican) states, and one gets this sense of condescension, that these people really don't matter, and we know what's best for you. This can lead to political backlash, and can cause reduction in renewable sales and loss of momentum, at best, in any effort to reduce global warming with renewable energy.

There are outright hostile critics of renewable energy; the late Glenn Schleede was one[19]. The argument here has nothing to do with that; it is a matter of being honest about renewable energy costs.

This was behind my attempt to write down pricing for renewable energy in what in essence was a real-time pricing form. Suppose, for example, that wind energy (when all the capital costs are included) has a levelized cost of electricity of 18 ¢/KWh, fossil fuels have a cost of 12 ¢/KWh, and on average wind blows 1/3 of the time. We have a renewable mandate to use, say 25% of electricity from wind. Then our expected value of electricity cost is

$$(2/3)*12 + (1/3)*18 = 14 \text{ ¢/KWh}$$

and this is what retailers like Pepco or others will charge consumers. But this is making Pepco and the other retailers much more like insurance firms than they used to be; they are absorbing all the risk of the quantity renewable energy not conforming placidly to its average value. The real-time pricing idea was an attempt to see what would happen if risk were minimized for them.

It is possible that some model can be developed so that their absorption of the risk of renewable energy would increase profitability for them in a static setting. But it is worth considering the possibility that global warming may make the risk associated with any given level of renewable use increase, because the volatility of renewable supply increases, so that the problem becomes worse over time, and not better.

Clearly, there are market fixes for these problems to some extent. The increased use of renewable energy has resulted in a substantial increase in electricity transmission investment; this is one of the best effects it has had[20]. But there are efforts that can be made by targeted government intervention to bring jobs to the people who are being affected by renewables, or the effects of natural gas, once we are clear what they are. It is crucial that the jobs make use of the skills people have developed over their lifetimes, not what they might develop in several years in the future.

One project could be to spend $500 million (or more) to develop West Virginia factories making glass or other reflectors for concentrator photovoltaic (PV) cells. (Concentrator PV is more expensive than regular PV, but also more efficient in converting sunlight (Young, 2015)[21]. It is being developed in Canada with Morgan Solar's "Alberta Solar One" (Hamilton, 2016)[22]) A target for concentrator PV costs might be to $12 per watt power, part of the Department of Energy goal of $1 per watt power for PV of all types (Wesoff, 2017 and Wiesenfarth et. al., 2017) [23]. Mosser Glass could participate, but the project would be open to other entrants as well. The glass manufacture could use the silicates produced by the coal industry, and thus coal and renewable energy could start being seen as complements instead of substitutes.

Another could be looking at sequestration or pumped storage. Increasing natural gas production in shale and coalbed methane reservoirs in Central Appalachia has been discussed (Gilliland et. al., 2015)[24]. A similar project to sequester CO_2, if it could be developed, would enable tapping a lot of coal mines which aren't currently used. Mert Atilhan mentions that coal mines with nanoclay structures might be candidates, and there may be others[25].

Something similar might be done by construction of pumped storage hydroelectric power units in West Virginia like the one in Northfield Mountain in Massachusetts (Gellerman, 2016)[26]. This could be very expensive, but it would be very valuable as a backup for intermittent renewable power. The nature of its development could use the same engineering and laboring personnel (the miners in particular) who have suffered because of coal's troubles.

How exactly is developing concentrator PV or developing pumped storage, or sites for the storage of CO2 from natural gas (or coal) anti-renewable energy? What is the net effect of developing offshore wind if onshore wind is diminished? If the effects of renewable energy can be honestly and openly analyzed, with costs laid right out on the table, and the problems with natural gas or other features of energy supply can be distinguished and dealt with, then a political coalition of all parties involved will accomplish something real.

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(References continued on page 21)

Hydropower: Not So Renewable After All?

BY ANTHONY DAVID OWEN

Arguably, hydroelectricity is the ideal renewable technology for power generation.[1] It can operate to meet power requirements ranging from baseload to peak, can be brought on-line almost instantaneously and is thus ideal for regulating supply from solar and wind, and has a negligible short run marginal cost. However, the past few years have witnessed significant drought conditions, virtually globally, and in many countries the resulting impacts on power generation have been both costly and disruptive. In particular, it can have major repercussions for the world's poorer nations that rely primarily on hydropower for their electricity, with blackouts causing lost production, water restrictions, and, potentially, social unrest.

The Tasmanian Energy Crisis 2016

Tasmania is part of Australia's liberalized National Electricity Market, being joined to the mainland via the Basslink underwater interconnector to Victoria. Its electricity generation is primarily hydro and, as a result, the state is highly dependent on rainfall for electricity generation. Peaking capacity is provided by four gas turbines, with base load capacity from a combined cycle plant, all of which comprise the Tamar Valley Power Station. Due to high water levels and the interconnector, the combined cycle plant was thought to be redundant and was decommissioned in 2014 with the intention of it subsequently being sold.

However, on 20 December 2015 Basslink had to be shut down due to a cable fault offshore. This event coincided with a particularly dry period, leaving dams severely depleted, which meant that Tasmania's security blanket for such times of drought had been lost. Actions taken to minimise the consumption of water from Hydro Tasmania's storages included:

- Recommissioning of the gas-fired Tamar Valley Power Station;
- Striking agreements with the three major industrial customers – the two Tamar Valley smelters Bell Bay Aluminium and TEMCO, and Norske Skog's paper mill at Boyer - to reduce their load by a combined 180 MW;
- Deploying up to 200 MW of portable diesel generators; and
- Bringing Hydro Tasmania's cloud seeding programme, usually scheduled to start in May each year, forward by a month.

Despite these actions, wholesale power prices surged by more than 350% as a result of the crisis, and the economic "hit" to the state was estimated to be in excess of A$560 million. Fortunately, the gas pipeline from the mainland was still operational so that emergency supplies for the gas-fired power plants could still be delivered.

The Brazilian Drought Crisis 2014-18

The 2014–18 Brazilian drought has been a severe drought affecting the southeast of Brazil, including the metropolitan areas of São Paulo and Rio de Janeiro. As over seventy percent of Brazil's electricity is generated by hydropower there has been a concern that a lack of water may also lead to energy rationing in addition to water rationing. Thermal plants were used to fill the energy gap, but the switch was very costly. In response to decreased hydroelectric power, rolling power cuts have also been instituted.

The Brazilian water crisis is due not only to lower precipitation levels, but also to mismanagement of multiple uses of water. Clearly, hydropower plants are water-intensive and their energy production has been negatively impacted by water scarcity, resulting in failure to meet contractual power generation targets, legal uncertainty, and higher energy prices. In order to address these issues and support sustainable water management, the Brazilian government is currently discussing regulatory measures, including the implementation of a water market, which will reallocate water use, and prioritize collective agreements among water users.

A novel approach to the problem was to install floating PV arrays on dams to generate power when water supplies were depleted. The logic behind placing solar panels on dams is that hydro acts as a back-up for the variable output of the PV, and utilizes the same transmission infrastructure. Thus, water is "saved" during daylight hours. In addition, one of the most expensive aspects of grid scale PV is its associated transmission requirements which are avoided in this situation.

Floating solar panels are more efficient than land-based arrays, largely due to the fact that they have water on hand to cool them down. "Floatovoltaics" is also appealing because it is cheaper to float panels over water than to rent or buy land. In addition, they can be constructed more quickly than land-based installations, and more easily tucked out of sight. Finally, floating arrays also shade the water and consequently reduce algae blooms and water evaporation. Brazil's first floating solar arrays with a capacity of 304 kW came on-line in 2017. A further 5 MW of capacity is at the planning stage.

Zambia's Drought

Zambia has experienced daily 8-hour power-cuts

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See footnotes at end of text.

since July 2015. Low water-levels at the main reservoirs for hydroelectric generation have led to a power deficit of about one-third of electricity demand. With the country's historically sufficient power supply, the sudden crisis has exposed low diversification of the fuel mix and caught households and businesses unprepared and without alternative or back-up sources of electricity supply. Left without electricity many households have reverted to charcoal for cooking, causing a spike in prices and accelerating the rate of deforestation. While only 22% of the population has access to electricity, the entire population has been affected indirectly through negative impacts on the economy and public infrastructure services.

Zambia's shortage of power generation capacity has been estimated at about 1000 MW, and without significant inflows into the dams in the short term the situation is likely to get worse, as demand is growing by around 200 MW annually without matching increases in supply.

Short term measures to alleviate Zambia's electricity crisis are in limited supply and, where they do exist (such as diesel generators), are costly. The past heavy reliance on hydropower means that alternative technology back-up capacity is limited. In addition, imports are expensive and of limited availability given the overall electricity supply shortfall across Southern Africa.

Longer-term measures to avoid, or at least mitigate, the impact of future crises are readily available, but at a cost. In this context, of fundamental importance is "getting the prices right"! The current all-pervasive subsidies for electricity consumers encourage consumption, discourage investment, and divert government funds from more efficient avenues of allocation. Since 2014 the IMF has been negotiating the terms for a U.S.$1.3 billion bail-out package (i.e., budgetary support) for Zambia, but one of the conditions relating to the electricity sector was that all subsidies and support schemes be removed. Negotiations have stalled, largely due to Zambia's high level of external debt. However, the end of electricity sector subsidies has been promised by the government by year-end 2018.

On the demand side, there appears to be few attempts to introduce energy efficiency measures, such as mandatory energy labelling or minimum energy performance standards for both consumer and industrial products, which are commonplace in more developed economies.

The New Zealand Model

Hydroelectric generation contributes around 60% of New Zealand's total electricity supply, with many generators of widely varying sizes distributed throughout the country. Inflows (rainfall and snowmelt) can be stored in hydro lakes until needed. However, the lakes have quite limited operating ranges – for technical and resource consent reasons, each lake's level cannot be lowered below a certain point. It is not possible, therefore, to completely "empty" a hydro lake. In the absence of inflows, the lakes can only hold enough water for a few weeks of winter energy demand.

For security of supply purposes, hydro storage is divided into two categories: controlled and contingent storage. Generators can use controlled storage at any time, but contingent storage may only be used during defined periods of shortage or risk of shortage. During sustained dry periods, controlled and contingent storage are important indicators of overall supply risks. Storage is expressed in gigawatt-hours – GWh (a measure of the energy that can be produced using the water).

New Zealand has a liberalized power market, and therefore (the theory goes) as prices climb during periods of unusually dry conditions additional, fossil fuel, plants (currently moth-balled) would be encouraged to return to supplying the grid. However, at present, one of the generators is paid to keep a 500 MW gas and coal power station constantly in reserve, which is really in conflict with the liberalized market model. The correct approach would be to offer a backup dry-year supply determined by auction, but the market is probably too small to deliver a competitive outcome.

The New Zealand model clearly relies upon a surplus of generating capacity (and not just hydro), particularly for dry years. Nevertheless, drought-vulnerable countries could perhaps adopt the concept of controlled and contingent storage, or more generally the concept of water management, adapted for domestic conditions.

Pump Storage

Pumped storage projects store and generate energy by moving water between two reservoirs at different elevations. At times of low electricity demand, like at night or on weekends, excess energy is used to pump water to an upper reservoir. During periods of high electricity demand, the stored water is released through turbines in the same manner as a conventional hydro station, flowing downhill from the upper reservoir into the lower reservoir and generating electricity. The turbine is then able to also act as a pump, moving water back uphill.

The power used to move water back uphill would generally come from surplus generation capacity from inflexible technologies such as nuclear, brown coal, solar, and wind. In other words, technologies which cannot be easily ramped down during times of low demand, or those that are variable in output and generate power when conditions are favourable irrespective of demand.

According to the IEA, pumped-storage hydropower is the largest and most cost-effective form of electric energy storage at present.[2] It claims that the current global capacity of pumped-hydro storage could increase tenfold as some existing hydropower plants could be transformed into pumped-hydro storage plants.

In South Africa, the 1332 MW Ingula Pumped Storage Scheme commenced full operations in January 2017. The plant uses water from the upper reservoir to generate electricity during the peak demand periods of the day. At night, excess power on the grid generated by conventional coal plants and a nuclear power plant is used to pump water back to the upper reservoir. However, there are currently no plans to build pump storage hydropower elsewhere in hydro-vulnerable neighbouring countries, probably because the inflexible technologies mentioned above do not currently exist in those countries.

Conclusion

The lesson that can be learned from the above events is obvious: energy security is an essential element of any power system. In addition, diversity of energy technologies is an important aspect of energy security, as is diversification of supply sources. In the context of hydropower, however, the critical issue is effective and efficient water management.

Footnotes

[1] This paper does not enter the debate on whether a dam, as opposed to run-of-river, hydropower can indeed be classified as "renewable".

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Julian Silk *(continued from page 18)*

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Implications of global developments within the energy industry in the Caspian and Central Asian Region

18-20 October, 2018

CONFERENCE OVERVIEW

The 3rd Eurasian Conference will take place in Baku, Azerbaijan, on October 18 -20, 2018.

In addition to its rich program, with its informal social functions, the conference will provide a unique opportunity for networking and enhancing communication amongst energy professionals from business, government, academia and other circles worldwide.

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- Energy Supply, Demand and Economic Growth
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An Innovative Way to Expand Global Electricity Generation & Reduce Demand for Oil: Solar Highways

BY MAMDOUH G SALAMEH

Mamdouh Salameh is an oil economist. He is also a visiting professor of energy economics at the ESCP Europe Business School in London.

See footnotes at end of text.

Some experts are projecting a peak oil demand by 2036. Others like Fitch Ratings are saying that greater product awareness and technological changes could fast track the adoption of electric vehicles (EVs) that could plausibly lead to a peak oil demand before 2030.[1]

It is, however, debatable as to whether a peak oil demand could be reached during the 21st century. The one certain thing is that oil is expected to remain the world's primary energy source throughout the 21st century and probably far beyond. A major underpinning factor is the growing world population.

Global oil demand is projected to hit 100 million barrels a day (mbd) next year rising to 120 mbd by 2040 and accounting for 33% of global primary energy consumption in 2040 as it did in 2017 despite rising global oil production and consumption.

Are We on the Verge of a Post-Oil Era?

There could never be a post-oil era throughout the 21st century and far beyond because it is very doubtful that an alternative as versatile and practicable as oil, particularly in transport, could totally replace oil in the next 100 years. What will change is some aspects of the multi-uses of oil in transport, electricity generation and water desalination which will eventually be mostly powered by solar energy. However, oil will continue to be used extensively in the global petrochemical industry and other industries and outlets from pharmaceuticals to plastics, aviation and computers to agriculture and also in transport in most of the developing countries. Oil will continue to reign supreme throughout the 21st century and far beyond.[2]

Transport and electricity generation are the two biggest sectors in the global primary energy consumption accounting for 30% and 40% respectively. Global transport accounted for 73% of the global demand for oil in 2017.[3]

And while renewable energy sources have made great strides in the last thirty years, it only accounted for 3.6% of the global primary energy consumption in 2017.[4]

There is no doubt that global energy's future is ultimately in renewables. Solar power along with other alternative energy sources will ultimately provide all the electricity we need, will power water desalination plants and will drive our transport.

And while there are many alternatives to oil in electricity generation such as natural gas, nuclear energy, coal, solar, hydro, geothermal energy and wind, the alternatives to oil in transport are virtually limited to electric and hybrid cars as well as hydrogen fuel cell cars (FCVs).

Still, oil demand growth could be projected to decelerate a bit on the back of efficiency improvements driven by technological developments, a tightening of energy policies and a relatively low (albeit increasing) penetration of electric vehicles (EVs).

Could EVs Replace Oil?

A few experts are projecting that widespread EV use could spell the end of oil. The tipping point, they reckon, is 50 million EVs on the roads (see Figure 1) This, they believe, could be reached by 2024. However, 50 million EVs could hardly make a dent on the global demand for oil let alone replace it.

Figure 1

Currently, electric and hybrid cars combined number under 2 million cars out of 1.477 billion internal combustion engines (ICEs) on the roads worldwide, or a negligible 0.14%. This is despite large government subsidies. The total number of ICEs is projected to reach 2.0 bn by 2025 rising to 2.79 bn by 2040 according to U.S. Research. Bringing 50 million EVs on the roads will reduce the global oil demand by only 2.0 billion barrels (bb), or 2.4% by 2024. Other estimates suggest that the penetration of EVs into the light-duty vehicle market could erase an estimated 7.3 mbd or 3.0% of oil demand by 2040.[5] This will neither be the end of oil nor a tipping point.

A tipping point could only be reached once 739 million EVs (50% of the current ICEs) are on the roads worldwide within the next fifty years. This is impossible to achieve within that time frame.

Moreover, there will be a need for trillions of dollars of investment to expand the global electricity generation capacity in order to accommodate the extra electricity needed to recharge 50 million EVs.

According to Bloomberg research, electricity consumption from EVs is projected to grow from 6 terawatt-hours in 2016 to 1,800 terawatt-hours in 2040. Where will this staggering increase come from? Better not be coal or possibly even natural gas.[6]

Solar Highways to the Rescue

China has recently come up with a very innovative way to enhance global electricity generation and reduce demand for oil: solar highways. The solar highways are the next gambit because they take the 'farm' out of solar and free up the land for agricultural use.[7]

Led by a company called Pavenergy, in partnership with state-owned interstate construction firm Qilu Transportation, China is fast-tracking the country's first solar highway in Jinan, the capital city of the eastern Shandong Province.

The plastic-covered solar panels cover a portion of highway that is two-thirds of a mile long and is designed to absorb the pressure of some 45,000 cars and trucks that traverse it daily. And this patch of highway is close to an electricity substation, so it can be hooked up to the grid easily. It also runs through and around cities, so nothing is lost along the way. It's all captured for power.[8]

In the United States, the prospect of a solar highway is decidedly more complicated. With the exception of a smattering of bridges and specific sections of some interstate highways, American roads just won't cut it: They're asphalt heavy and they give just enough for solar panels to snap, according to one transportation engineering professor from the University of Texas, cited by the New York Times (NYT). But Chinese roads generally have a heavy concrete foundation.[9]

But it may be prohibitively expensive in either venue. It's definitely more expensive than asphalt.

In China's case, Pavenergy is hoping it can bring the cost down to around $300 per square metre from the now-exorbitant $460 per square metre for a solar road. They also argue that they would have to be replaced less frequently than asphalt currently requires.

They also argue that it could eventually pay for itself by producing around $15 of electricity per square metre of solar panel—per year. That doesn't sound like much, but a Chinese professor told NYT that it would mean that within 15 years it would pay for itself.

The thing about China's solar highway is that costs will come down once adoption becomes widespread, and the Chinese are the kings of forced, strategic adoption. In China, renewable energy gets invested and implemented before it makes any sense. In the United States, the reverse is true.

More than a decade ago, China overtook the U.S. as the world's biggest carbon dioxide emitter. Today, it's going for a complete 360 with a hungry drive to beat the United States at the renewable energy game. After all, this is largely a technology game, and China hopes to be the global technology leader, according to its strategic state plan, by 2030.

China is now the largest investor in solar energy. In fact, according to the NYT, the country is putting up new power generation projects so fast that substations that would connect them to the grid aren't keeping pace.

As we read about yet another way in which China is one-upping the United States on the technological battlefield, the war is not likely to be won through solar highways—one of the most complicated feats in renewable energy due to the cost of installation, questions about efficiency and repairs.

But the pace of investment in renewables is still staggering. According to *Bloomberg New Energy Finance* (BNEF), nearly half of the world's new renewable energy investment of $279.8 billion in 2017 came from China. Beijing's investment in renewable energy (for everything except hydro projects) jumped 30% in 2017 from the previous year (see Table1).

Countries	**Investment**
China	$126.6
US	$ 40.5
Japan	$ 13.4
India	$ 10.9
Germany	$ 10.4
Australi	$ 8.5
UK	$ 7.6
Brazil	$ 6.0
Mexic	$ 6.0
Sweden	$ 3.7

Table 1 New Renewable Energy Investments Made by Top 10 Countries in 2017 (U.S. bn)

Source: Courtesy of Bloomberg New Energy Finance

And it definitively outpaced U.S. investment by three times. In the U.S., investment in renewables even fell 6 percent in 2017, dropping to $40.5 billion.

The game is on, and the winner will be the one willing to spend loads of cash on projects, even when it's not immediately economically viable.

Is the Solar Industry Really in Trouble?

Goldman Sachs is projecting that the global solar panel market will shrink this year by 24%. It's not the only negative forecast either, which is understandable given the latest major developments in the sector.

Before Goldman Sachs slapped the solar industry with its forecast of 24% fewer installations this year, BNEF and Credit Suisse warned of a 3% and 17% decline respectively in the solar market after China suspended approvals for new installations due to the weight of payments it already needs to make for current solar farms and, of course, after the Trump administration slapped a 25% import tariff on Chinese-made PV panels.[10]

Whilst BNEF warned of a PV panel glut on a global scale, it also forecast that the glut will lower prices and stimulate demand, which will eventually reverse the gloom, allowing the market to recover as soon as next year.[11]

It seems that not everyone is as gloomy as Goldman Sachs. As BNEF correctly projects, the more panels there are, the lower their prices will be, and the lower the prices, the more attractive they would be. Also, these glut-caused lower prices will mitigate the impact of the Trump tariffs on the U.S. solar industry, although they won't be able to offset them completely.[12]

There are also new solar markets opening up: Saudi Arabia is one very ambitious new addition to the industry. The Saudi solar market is projected to expand at a compound annual rate of 30% between 2018 and 2024. The UAE is also very ambitious in the solar power department, planning to source a quarter of its energy from solar installations by 2030. Africa as a whole is another market that will likely become an emerging force in solar power.

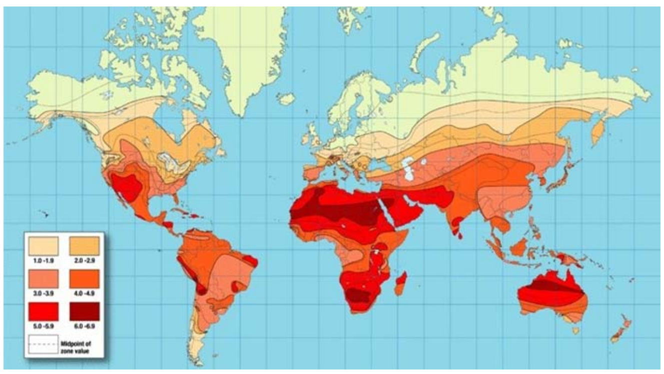
Saudi Arabia: From Oil Riches to Solar Power

Modern Saudi Arabia has been built on the back of the “black gold”. Under its sands lies the world’s second biggest proven oil reserves. It boasts the Ghawar oilfield, the largest onshore oilfield in the world and also the Safaniya oilfield, the world’s biggest offshore oilfield.

Whilst the world is still heavily dependent upon Saudi Arabia contributing more than 10% to global oil demand, it has been calculated that all of the world’s energy needs could be met with solar panels on just 1.2% of the Sahara Desert.[13] A map depicting global solar power resources shows the reason. There is no greater solar resource on the planet than a broad swath extending from the Sahara Desert of North Africa and into northwestern Saudi Arabia (see Map 1).

Despite its endowment, Saudi Arabia is planning for the future according to its Vision 2030 launched in 2016 by Saudi Crown Prince Mohammed bin Salman the de facto ruler of Saudi Arabia to diversify the Saudi economy and reduce Saudi dependence on oil revenue. The Kingdom recently announced that it would invest up to $7 billion this year to develop seven solar plants and a wind farm.

Now Saudi Arabia plans to have the world’s largest solar plant. Prince Mohammed bin Salman signed



Map 1 World solar insolation map

a memorandum of understanding for the massive project in April this year with Japanese multinational conglomerate SoftBank.[14]

The scale is unprecedented. The $200-billion project would produce 200 gigawatts of solar photovoltaic power and would take more than a decade to complete.

To put the project’s scale into perspective, U.S. solar PV capacity at the end of 2016 stood at 40 GW. The world’s entire installed solar PV capacity at the end of 2016 was 300 GW. This plant would be 130 times bigger than the world’s current largest solar plant, the 1,547-megawatt (MW) Tengger Desert Solar Park in China.[15]

The Saudi solar project is symbolic in that it denotes a country making a strong commitment to a different kind of energy future. It also denotes that Saudi Arabia aims to remain one of the world’s vital energy producers.

The project is an integral part of Saudi Arabia’s plans to eventually replace oil and natural gas currently used for electricity generation and water desalination with solar and nuclear energy. This makes economic sense since Saudi Arabia in 2017 consumed 39% or 3.9 mbd of the crude oil it produced principally for electricity generation (1.3 mbd), water desalination (1.7 mbd) and transport (0.9 mbd).[16] If this trend continues, Saudi Arabia will have no oil to export by 2030.[17]

If such a project enables Saudi Arabia to reduce the oil it currently consumes for electricity generation and water desalination by 50% or 1.5 mbd, then at current prices it will be able to save some $41 bn annually.[18] This means that the project could in theory finance itself in five years.

The fact is that the solar industry won’t stop growing, despite tariffs and the suspension of new projects in China, the world’s biggest solar market. These developments could slow down its growth for a while, but with more and more players entering the solar field any negative effects would be temporary.

Footnotes

[1] Tsvetana Paraskova, “Fitch: EVs Growth Could Lead to Peak Oil Demand by 2030”, posted by Oilprice.com in February 20, 2018 and accessed in February 20, 2018.

[2] Mamdouh G Salameh, “A Post-Oil Era Is a Myth” (a research paper posted by the United States Association for Energy Economics (USAEE) on 8 December 2016, USAEE Working Paper Series No:16-290).

[3] BP Statistical Review of World Energy, June 2018, p.9.

[4] Ibid.,

[5] Nick Cunnigham, “EVs Could Erase 7 Million Bpd in Demand”, posted by Oilprice.com on 21 May, 2018 and accessed on 21 May 2018.

[6] Mamdouh G Salameh, “A Post-Oil Era Is a Myth” (a research paper given at the 8th conference of the Joran’s Society for Scientific Re-searchm November 11, 2017, Amman, Jordan).

[7] Damir Kaletovic, “How China Will Win the Solar Race”, posted by Oilprice.com on July 17, 2018,and accessed on 20 July 2018.

[8] Ibid.,

[9] Ibid.,

[10] Irina Slav, “Is the Solar Energy Really in Trouble?” posted by Oilprice.com on July 24, 2018 and accessed on 24 July 2018.

[11] Ibid.,

[12] Ibid.,

[13] Robert Papier, “Saudi Arabia to Fund Giant Solar Project with Oil Riches”, posted by Oilprice.com on 7 April 2018 and accessed on 7 April 2018.

[14] Ibid.,

[15] Ibid.,

[16] BP Statistical Review of World Energy, June 2018, pp 14-15.

[17] Mamdouh G Salameh, “If Current Trends Continue, Saudi Arabia Could Become an Oil Importer by 2025” (a research paper posted on 11 December 2012 by the USAEE working Paper Series, Paper No: 12-151).

[18] My calculation is based on an oil price of $75 a barrel.

End Of Big Oil?

Don't Write off Big Oil Yet, But the Industry's Best Years May Be Behind Us

BY PERRY SIOSHANSI

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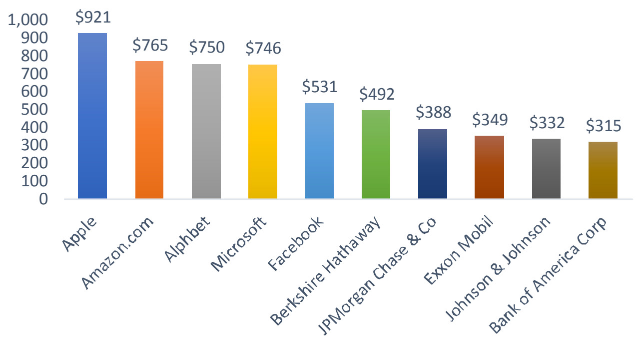
Big oil, while still big and still profitable, is not as big or as profitable as it used to be. Moreover, it is increasingly big oil-and-gas, or in the words of Patrick Pouyanne, Total's CEO, gradually turning into big gas-and-oil as the significance of natural gas continues to rise relative to oil. In the meantime, continued pressure to move towards a low carbon future is forcing some oil majors to diversify by investing in renewables – with Total, Shell and BP leading the way. Add the expected rapid rise of electric vehicles (EVs) and, more broadly, electrified transportation in the coming years, and big oil's long-term prospects begin to look even less rosy. This, in fact, is not just a likely scenario but in fact the most probable scenario gradually unfolding across the globe.



Top 10: Most valuable companies by market capitalization, $b, May 2018

Total has got the message and is – at least according to its public statements – contemplating a future where more of the global energy demand will be electric with an increasing share supplied from renewable resources and gas. Total is not only interested in renewables, it has already entered the electricity sector. Pouyanne also acknowledges the rise of EVs – he drives one.

Not all oil majors, in particular the American giants ExxonMobil, Chevron and ConocoPhillips, are ready to concede that oil's supremacy as a source of energy may be near its peak, potentially followed by a period of stagnant growth and eventual decline. Major oil exporting countries including Saudi Arabia and its national oil company, Saudi Aramco, are in total denial – they prefer to stick their heads in the proverbial sand, distracted by the daily turmoil of the global oil markets, constantly rising or falling prices and the uncertain geopolitical developments – which can be highly distracting.

In the case of Exxon, the biggest of the global listed oil majors, the official pronouncement is that all is well, and it is business as usual. In fact, Darren Woods, Exxon's new CEO, who replaced Rex Tillerson – the former U.S. Secretary of State who was famously fired via a Tweet by Donald Trump – is not only convinced that business-as-usual is here to stay, but he is betting on more of the same for the indefinite future.

Under pressure to turn the giant company around, in March 2018 he unveiled an ambitious plan to spend $230 billion to increase oil production by an additional 1 million barrels a day. Investors were apparently not overwhelmed by the grand strategy. Even while oil prices have risen 60% in the past year, Exxon's shares are up a mere 5% – trailing many of its smaller rivals.

There are other signs that Exxon's best days may be in the past. The company became the world's largest publicly traded company in 1975 and it remained among the most profitable for over 3 decades. Now, the $350 billion company is #8 in market value, roughly half as big as Apple (see adjacent chart). In 2016, Exxon lost its coveted triple-A rating, a cherished distinction it had enjoyed since 1930.

It is hard to imagine how Mr. Woods – or for that matter anyone else – can return the giant company to its former glory days. The problem is not that Exxon is not performing well but rather that investors have better options. Mark Stoeckle, the CEO of Adams Funds, a major Exxon shareholder, puts Exxon's problem this way, as reported in an article in The Wall Street Journal (14 Jul 2018):

"Most investors like Exxon, but they like other companies even better."

Commenting on Exxon's planned massive investment strategy, Stoeckle was quoted in the same WSJ article saying: "The market is not willing to reward Exxon today in hopes that it will bring good returns tomorrow."

Expanding oil production, especially if it is contingent on high and rising oil prices, may not be a good strategy for Exxon or any oil company. Electric vehicles (EVs), many are convinced, could make internal combustion engines (ICs) obsolete within a decade if not sooner. And once the critical tipping point is reached – where EVs are less expensive to buy, perform better and cost far less to operate and maintain – then few would want to buy yesterday's technology regardless of petrol prices.

Running an oil company, never easy, has become even more perilous and certainly riskier. The industry is likely to face increased pressures from multiple fronts in the coming years – most likely from those who wish to reduce global carbon emissions but also from the potential rise of electrified transportation – the most critical determinant of global oil demand.

Ireland is the world's first nation to divest completely from fossil fuels. Its parliament passed a bill compelling the €8.9 billion (US$10 b) Ireland Strategic Investment Fund (ISIF) to withdraw all money invested in oil, gas and coal. While miniscule in scale, the move is nevertheless an important milestone.

Ireland's Fossil Fuel Divestment Bill passed in mid-July requires ISIF to offload direct investments in fossil fuel undertakings – estimated to hold around €318 million ($370 m) invested in 150 companies – within 5 years while forbidding any future investments in the fossil fuel industry.

The law defines "fossil fuel undertakings" as those "whose business is engaged .... in the exploration for or extraction or refinement of a fossil fuel where such activity accounts for 20% or more of the turnover of that undertaking." Indirect investment in fossil fuels is also ruled out, unless there is no more than 15% of an asset invested in a fossil fuel undertaking.

Ireland follows Costa Rica, which has also vowed to "abolish fossil fuels" from its economy – without much clarity or on how this is to be accomplished or when.

Similar moves are spreading elsewhere. For example, New York City's Mayor Bill de Blasio announced in Jan 2018 that the city would divest its $189 billion pension fund from fossil fuel holdings – estimated to hold roughly $5 billion in such investments.

Congratulating the move, Bill McKibben, the leader of 350.org – a global movement that is trying to keep global CO_2 concentrations under 350 parts per million – said, "This (bill) will make Ireland the first country to commit to divest (public money) from the fossil fuel industry."

Thomas Pringle, a member of the Irish parliament and the sponsor of the bill, first introduced in 2016, was less upbeat. He said, "With this bill we are leading the way at state level ... but we are lagging seriously behind on our EU and international climate commitments."

Others, including Norway's sovereign wealth fund, have also made commitments to reduce and eventually divest of investments in fossil fuel companies. Fossil fuels will increasingly be squeezed from all sides.

Already, carbon-heavy sources of oil such as those from Alberta's tar sands have turned into environmental liabilities that few oil majors wish to be associated with. And if more companies and countries follow the example of Ireland, which is planning to divest from fossil fuel investments, big oil's future prospects will only get grimmer.

Don't write off big oil yet. At the same time, don't expect the consistent demand growth or high profitability either. If you are seeking high growth and profits, look elsewhere for better options.

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Improving Energy Affordability for Australian Low-Income Renter Households

BY LYNNE CHESTER, AMANDA ELLIOT AND PENNY CROSSLEY

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See footnotes at end of text.

Introduction

Australian household energy affordability is a major political and public concern after a sustained period of significant electricity and gas price increases. Solar photovoltaic (PV) energy provides a key means for greater household control over the cost of electricity bills. Australia has led the world with household adoption of solar PV.

The common business model to encourage household solar system adoption is structured around individual ownership requiring an upfront cost from the dwelling owner. This model advantages owner-occupiers with adequate financial resources and suitable rooftop capacity. The upfront cost excludes low-income households, and renters are further disadvantaged without rooftop property rights. This unequal access to solar PV, as low-income households experience the most deleterious impact from substantive energy price increases, raises important energy justice principles and practices.

This article sets out the current Australian 'energy landscape' for households and the affordability issues facing low-income households, presents findings from a recent research project to progress new options for low-income households to have greater control over the cost of their electricity bills, and proposes future research directions to improve energy affordability—through access to solar PV—for low-income renters.

The current 'energy landscape' for Australian households

As in other advanced economies, electricity plays a significant social and economic role in Australia—for the standard of living of all Australians and as an intermediate input for all industries. The increase in total Australian electricity consumption, particularly since 1960, reflects growth in both energy intensive industries and household use. Nearly 100% of Australian households use mains electricity as a source of energy and 50% use mains gas.

Energy consumption is a significant contributor to carbon emissions due to the high reliance on fossil fuels (about 83%) to generate Australia's electricity despite the growth in renewable energy sources which accounted for 15% of electricity generation in 2016 (Energy Council of Australia 2016). Wind and solar photovoltaic (PV) now account for 50% of renewable energy resources to produce electricity.

Since 2006, Australian household electricity prices have rapidly escalated, primarily driven by regulated transmission and distribution prices (AEMC 2017; Chester 2015). The cumulative effect of these price increases has been most deleterious for low-income households (Chester 2013, 2014). As the impact of significant year-on-year price increases became more extensive, particularly for business, energy affordability has become a major political concern (ACCC 2018; Australian Government 2017).

Concurrent with rapidly rising energy bills and the growth of household energy impoverishment, Australia has been leading the world in household adoption of solar energy with more than 20% of homes estimated to have installations (Australia PV Institute 2016). The rapid residential uptake of solar PV has been encouraged through the availability of Australian State government feed-in-tariffs and other incentives such as rebates.

Although many households are now 'prosumers', being both producers and consumers of electricity, barely 2% of installed solar PV capacity is independent of the centralised electricity grid. This means that—without significant additional capacity—most prosumer households will be impacted by future electricity price increases.

All Australian electricity retailers have developed business models for the uptake of small-scale solar PV connected to the centralised networks. These models are based around installation ownership by an individual, third party or community. The most common model is individual ownership requiring an upfront capital cost from the dwelling owner and rooftop capacity which are prohibitive for low-income households and those who are renters.

The situation for low-income households

Around 1.8 million (21%) of all Australian households fall within the lowest income quintile, are highly dependent on income from government pensions and allowances, and more than one third are renters (with nearly 22% in the private rental market) (ABS 2017b). The number of renting households has grown as home buying costs have escalated. The number of low-income households dependent on private rental housing has also grown as the availability of public and community housing has not matched demand.

Australian low-income households have higher proportions with 5 or more persons, multiple families, and no dwelling access to the internet. Poor households also spend higher proportions of income and expenditure on energy, and thus energy costs have a disproportionate impact on households (Chester and Morris 2012).

These characteristics mean that the poorest households experience greater disadvantage from electricity price increases and indicate the scale of household exclusion from the opportunity to reduce energy bills using solar PV. Low-income household characteristics also indicate the contracting, billing and technology access issues to be addressed if 'energy justice' is accessible for all households.

The feasibility of low-income households accessing solar PV will also depend *inter alia* on the willingness of these households to shift from their current energy supply arrangements. Russell-Bennett et.al (2017: 6) found that motivation by Australian low-income households to adopt energy efficiency was driven by "awareness, low perceived cost, incentives and rebates, comfort and health/wellness/stress [and] the top five barriers were high perceived costs, knowledge gaps, lack of trust, split incentives and low literacy/cultural barriers".

Other studies of household motivators and barriers to adopting solar and other microgeneration technologies have found:

- a higher willingness if adoption achieves household independence of (UK, Irish, German and Swedish) energy suppliers and protection against future energy costs (Balcombe et. al 2014; Claudy et. al 2011; Karakaya et. al 2015; Palm et.al 2011);
- concerns about costs, reliability, maintenance, lack of regulation, administrative difficulty and installation logistics (Palm 2018; Palm et. al 2011; Wolske et. al 2017);
- motivations differed for different microtechnologies and for older and younger (New Zealand) households (Baskaran et. al 2013);
- community solar ventures were more likely to be joined by those motivated by environmental concerns or peer effects (Bauwens 2016; Noll et. al 2014);
- lack of time, interest, ability or scepticism were reasons why (UK) rural households would not participate in community ventures (Rogers et. al 2008);
- financial incentives attracted younger Italian households whereas the environment was of greater concern to Austrian households (Braito et.al 2017);
- younger age, higher income, ownership and independent roof were positively correlated with uptake in Malta (Briguglio et. al 2017);
- concerns that technology may be surpassed, reliability and life of technology were barriers for Taiwanese households (Shih and Chou 2011);
- availability or not of feed-in tariffs influenced satisfaction with adoption by Western Australian households (Simpson and Clifton 2015);
- information through social networks was important for Queensland households (Sommerfeld et. al 2017); and
- ways for (Canadian, Danish and UK) energy co-operatives to overcome the barriers of perceived usefulness and experience with renewable energy (Viardot 2013).

Recent research findings

Existing research focuses on current models for solar PV adoption and does not address the barriers posed for low-income households without the financial capacity or who are renters rooftop property access rights. As a first step towards the development of new consumer options to increase the accessibility of low-income households so that they may have greater control over the cost of their electricity bills, we conducted a small research project in the first half of 2018.

This project examined:

- the advantages and disadvantages of existing solar PV models for Australian home-owning and renting (public or private) low-income households;
- the issues which influence a low-income household's decision-making about the adoption of solar energy to meet its energy needs;
- the primary information sources which low-income households use to make a decision about switching to solar; and
- the legislative and regulatory barriers to the adoption of distributed energy solutions like solar PV.

Focus groups were held in the Fairfield Local Government Area (LGA) of Sydney, Australia's largest capital city, to understand the issues influencing a lower income household's decision-making about using solar energy to meet their energy needs.[1] Income and demographic data by LGA from the 2016 Census was mapped against the data on solar energy installations in each LGA. A review was conducted of the different types of offers from electricity companies, and small-scale projects provided by some local councils, commercial and not-for-profit organisations to encourage households to install a solar energy system. The legal and commercial issues—for different household types— arising from the different models were analysed.

The project's key findings were:

- Older lower income households consider that they are managing their electricity bills, and more so since their children are no longer living with them;
- There is a high level of understanding about the common marketing offer for household solar installation with high upfront costs for the dwelling owner and suitable rooftop space;
- Older lower income households generally consider that they will not live long enough for

a 'return' on the initial high cost to install a solar energy system;
- There is concern about deciding which are the best solar products and installations, from whom to seek expert advice, and a lack of trust in marketing information;
- Family, friends and neighbours are sources of advice although many households consider that government should help them manage the risk by providing clear information when complex technical decisions are needed about installing or using a solar energy system;
- Older lower income households perceive little difference between the electricity companies and thus consider they have little control over prices paid and no need to switch companies;
- Decisions about the ways to manage household energy use and responsibility for bill paying differ between household types;
- LGAs with high proportions of lower income households have the highest capacity for solar due to the high number of dwellings with rooftop capacity although many are rental housing;
- Internet access from home is much less in those LGAs with high proportions of lower income households;
- The majority of offers for household solar installations are structured around the dwelling owner having the financial resources to pay upfront for the system and installation costs;
- There is some provision of household solar energy through community and third-party ownership schemes although these involve a very small number of households;
- Different household types (e.g., renter, with young children, multiple family, older) need different options to the current common upfront cost scheme to install a solar system which is met by the dwelling owner; and
- Alternative schemes for household adoption of solar energy will need to address several issues such as: roofing suitability; responsibility for operation and maintenance; access to consumer data; buyout options; equipment warranty periods; property access issues; consumer protections; and control of the system.

These results suggest that: the accessibility to solar PV by low-income households needs to be reframed from being a problem to be solved by the individual household if energy justice is to apply to all—not some—households; a 'shotgun' approach to uniform incentives or business models will exacerbate not ameliorate energy injustice; policymakers should not ignore the role and influence of peers and social norms on energy consumption decisions by households and particularly older lower income households; different household types do not fit the existing business and economic models that assume consumer and prosumer behaviour will change with price and incentives; local government could play a very significant role in improving the energy justice for low-income households; and, the motivations, barriers and success factors for solar PV adoption are highly influenced by the household's income level.

The project results also provide new insights into: the different forms of energy injustice that arise from existing solar PV business models and incentive schemes; older person household attitudes to solar energy which is highly relevant as Australia is experiencing a strong demographic shift to an aging population; and, the role of family, friends and neighbours as a trusted source of advice about adopting solar PV.

Future research

The option for renters to access solar energy has received least attention by policymakers, businesses or researchers and often is referred to as 'too hard a nut to crack'. This is primarily because of the range of parties involved (e.g., dwelling owner, real estate agent, housing authority) in addition to the consumer-electricity supplier relationship, and thus the complexity of issues to resolve. The current situation for Australian low-income households, the growth in renting households, and our research findings, demonstrate the need for a national research project that focuses upon low-income renter households.[2]

Future research could develop new consumer-focused options—for widespread application to private, public and community rental housing—that overcome barriers to low-income household solar energy use and are supported by electricity retailers, real estate agents, landlords, tenants' unions, public and community housing authorities, affordable housing developers and local councils. This would be assisted by delineation of the different stakeholder issues to be addressed if new consumer options (business models) for low-income households are to be feasible. Such issues may include, for example, lease duration, metering options, responsibility for operation and maintenance, access to consumer data, buyout options, equipment warranty periods, property access, and control of the system. Data could also be collected about the energy needs of low-income renters, their household practices, key energy decision-making issues, and willingness to use solar. Such data could be used to create 'energy profiles' for different low-income renter types and used to inform the design of a set of consumer options (by rental type and household type) to access solar energy which meet the consumer's needs and the legal, commercial and other needs of the multiple stakeholders involved in rental housing.

Solar energy provides a key means for greater household control over the cost of electricity bills. Yet low-income renter households will remain excluded from this step towards energy justice unless there is development and widespread application of new consumer options that are not dependent on upfront capital costs and roof ownership. Future research is needed to advance energy justice for low-income renters.

Footnotes

[1] Across the 33 Sydney LGAs, Fairfield has the highest proportions of households with: an annual income of less than $65,000, multiple families, 5 or more persons and no dwelling access to the internet. In 2016, Australian average weekly earnings were $62,000 p.a. and the minimum wage was $36,000 p.a.

[2] Low-income household characteristics vary across the Australian States (e.g., multiple family, separate dwelling, languages spoken, energy use mix), and there are different State government policy settings supporting solar. A national project can address the implications arising for these differences.

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Resource Adequacy in a Decarbonised Grid: An Insurance Overlay on Electricity Market Design

BY FARHAD BILLIMORIA AND RAHMATALLAH POUDINEH

Introduction

Energy-only market designs face renewed scrutiny in an increasingly decentralised and decarbonised electricity system. The 'missing money' challenge has been given new relevance under a dynamic which has seen the introduction of variable, intermittent and distributed forms of energy. Increasing penetrations of low marginal cost renewables could present a dynamic where it is no longer economic for flexible generation to remain in the market resulting in a disorderly withdrawal of dispatchable generation capacity (Nelson 2017). The design fails to trigger investment sufficient to meet the resource adequacy needs of the market especially when there is no forward market in which investors hedge against market risks (missing market problem).

Additionally the energy-only design has been argued to be vulnerable to distortions that arise from interactions with environmental policies (Simshauser & Tiernan 2018), illiquidity in contracts markets (Simshauser 2018; AEMO 2018) and market power (Chattopadhyay & Alpcan 2016).

In the face of challenges of energy only design under the electricity sector transition, a common option considered by policy makers is to incorporate some form of capacity mechanism with centralised decision-making. (Cramton 2017; Bushnell et al. 2017; Doorman et al. 2016). However, there are two key issues with this approach.

The first is that capacity mechanisms are often disconnected from consumer preference. With the growth of distributed energy resources (DER) consumers have increasingly elected to self-source for a portion of energy supply, rather than rely on a centralised grid.

Traditionally, electricity market frameworks have attempted to provide the same basic level of service to all consumers (Kurlinski et al. 2008). Many designs look to central agencies to make decisions on behalf of consumers relating to the reliability needs and safety margins of the system. This notion however can be challenged in an increasingly distributed and decentralised grid (Kiesling & Giberson 2004; Keay 2016; Keay & Robinson 2017). Rooftop PV, distributed storage and energy management systems have unlocked supply options for consumers. Load control and communications technology also exists to allow for differentiated tiers of reliability (Kurlinski et al. 2008; Bushnell et al. 2008). This suggests the potential for increased differentiation between consumers as to supply preferences and their value of lost load (VOLL). Some users may have high financial impacts, while others may be less sensitive to supply interruption. For example, the consumer experience of the 2016 statewide blackout in South Australia provides an indication of the differentiated economic impacts across a range of participants. It is reported that of the estimated A$367 million in total costs, almost a third was borne by four big businesses (Business SA 2016).

The second challenge with centralised capacity mechanisms is related to the incentives of the central party. In deregulated markets the central party allocated with decision rights is typically a non-commercial entity like the Independent System Operator (ISO). As a non-commercial entity, the incentives of the central party are indirect and non-pecuniary in nature. A central authority faces no financial penalties for overinvestment or underinvestment, nor is rewarded for striking the right balance. There are potentially strong political pressures to avoid under-investment and lost load events. Some argue that this leads to 'risk aversion' and a tendency to over-protect the system – to the detriment of consumer costs and efficiency (Newbery & Grubb 2014). As against this, the central party may face criticism or stakeholder pressure from energy market participants if costs are considered inordinate.

On both sides, the incentive to act is indirect – the financial implications of decisions are not directly borne by the party itself but by others, typically consumers, that face the ultimate financial brunt of either over-investment through additional energy costs, or under-investment through the financial impact of an unreliability or 'lost-load' event.

Managing reliability in electricity markets is concerned with the operational and financial management of extreme or tail-risk events. Risk transfer for tail risk events often takes place through insurance arrangements (Manove 1983).

In this article we propose a new model for electricity market design – the *insurer of last-resort* model. This model aims to overcome the challenges of centralised capacity mechanisms by introducing a financial risk and reward structure for the central authority making decisions over capacity and reserves. This serves as an overlay on existing market design with the aim of (i) aligning incentives for centralised decision making and

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See footnote at end of text.

(ii) allowing revealed consumer preferences to guide new capacity deployment.

An 'insurance based' model for reliability

The concept

The scheme would involve the establishment of a commercially-mandated central insurance company ("the Insurer of Last Resort" or "IOLR"). The company would offer last-resort electricity interruption insurance to electricity consumers in return payment of an insurance premium.[1]

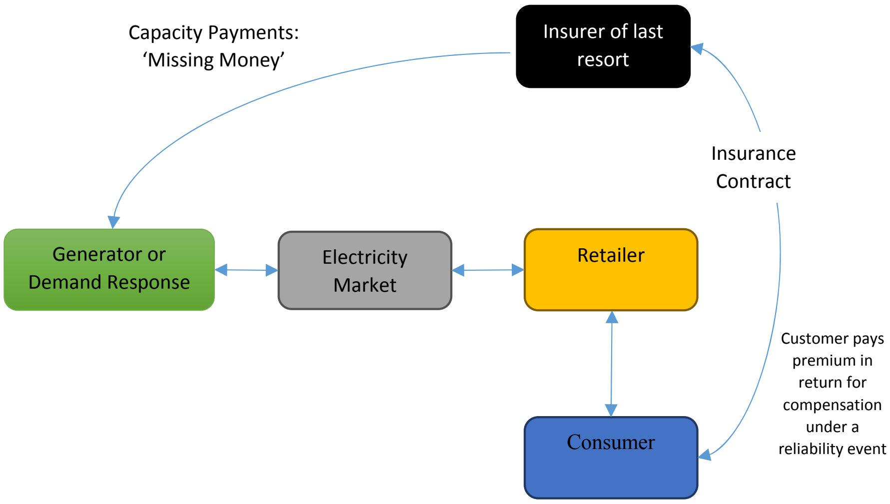

Figure 1: Reliability Insurance Model

The objectives of the company would be to manage the reliability compensation scheme, but also to undertake loss limiting activities with respect to reliability, where economically efficient to do so. Where it observes a resource adequacy gap, the company would be able to take steps to execute capacity contracts with new generation or demand-response resources to provide 'missing money'. However, its commercial focus would restrict this to situations where the capacity resource can specifically improve reliability and where the all-in cost of those contracts are cheaper than the loss-adjusted risk of payout. Faced with the following question: Is it economically efficient to add capacity at a cost of $X million in order to reduce the risk of reliability lost load by Y% (or Z hours etc) – the central insurer would be required to weigh the cost of additional capacity contracting, against the benefits of reduced reliability compensation.

Importantly, the insurer model works as an overlay on top of existing market signals, rather than replacing them (see Figure 1). The insurer would be tasked with assessing the reliability gap between what the market is naturally delivering through scarcity price signals. By doing so, it provides residual or back-stop procurement, where the energy-only design does not provide the required response.

The market structure for this model might be initially in the form of a regulated monopoly (with the need for government regulation regarding setting the premiums) but over time can transition into a competitive market. This is because as it is currently done with some current business interruption insurance contracts, commercial insurance providers will also be able to offer insurance coverage to consumers (in addition to IOLR). Consumers can chose between rates and coverage offered by commercial providers, against that of the centralised IOLR. These different providers would compete to offer reliability insurance to consumers, and to deploy investment capital into new capacity. Further consideration would need to be given to the size of the market, potential for market abuse and competitive dynamics.

This model would develop an economic signal for investment in reliability driven by revealed consumer preferences. Importantly, the goal of the insurer is not to guarantee reliability, but to make economically efficient and commercially oriented decisions on resource adequacy, as it has financial exposure to lost load events.

The business model for the insurer would involve the investment of a capital base ('the insurance capital

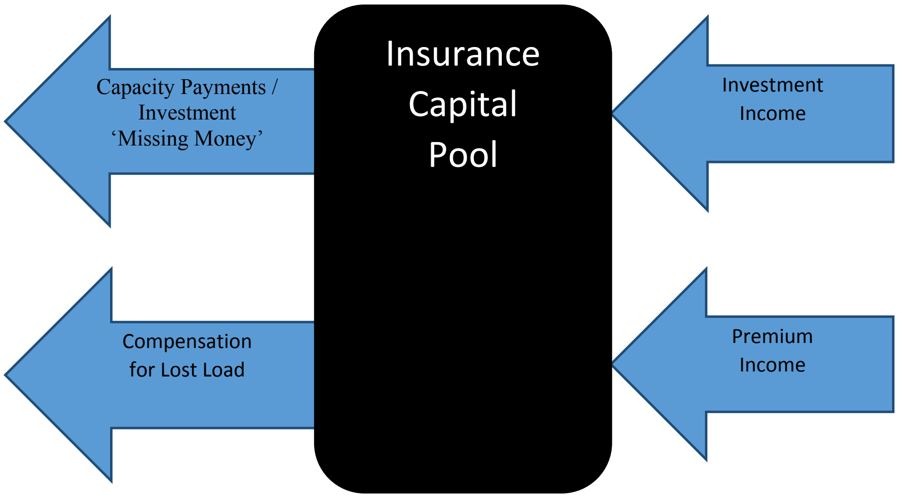

Figure 2: Flows in to /out of Insurance Capital Pool

pool') and management of loss events. Primary sources of cash outflows would include compensation payments, capital investments and payments for capacity contracts (see Figure 2). Primary sources of cash inflows would include premium income and investment income.

Implementation Considerations

The practical implementation of such a scheme would require the consideration of a number of factors.

Customers would have the choice to elect whether to take up the insurance and the level of financial coverage required. Those customers that decline to participate would then form part of a load shedding scheme and be available for disconnection by the system operator during a reliability event (see Figure 3). This mitigates the impact of 'free-riding' (Fumagalli et al. 2004; Abedi & Haghifam 2013) where consumers elect not to participate in the insurance mechanism but benefit from preventive actions by the insurer.

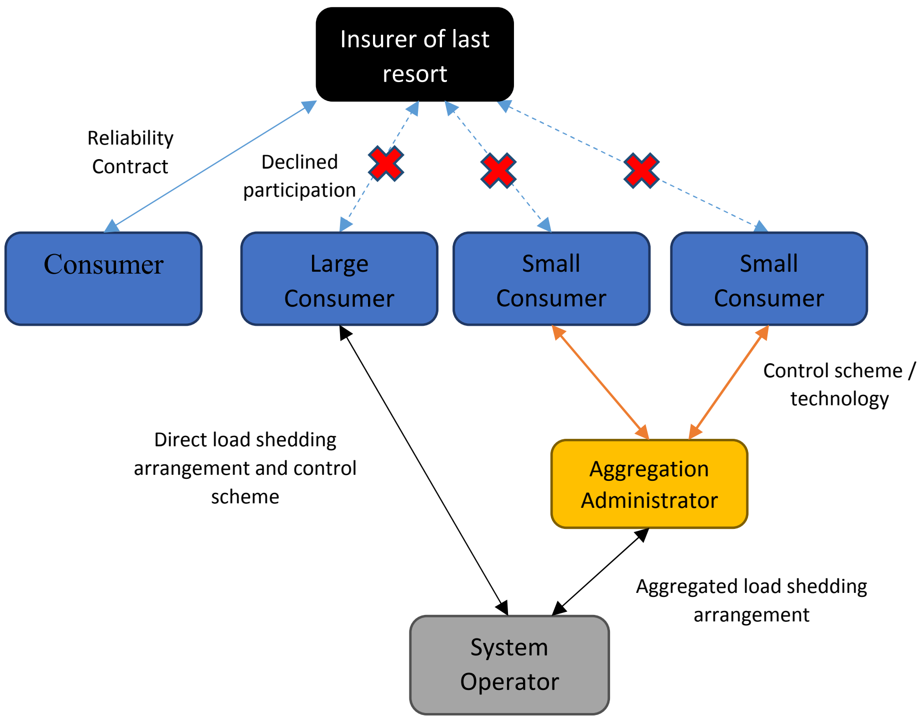

Figure 3: Non-participating Customer Load Shedding Arrangements

Consumers would need to evaluate their need for electricity during scarcity as well as the frequency of such conditions (Doorman et al. 2016). This may be politically difficult, with some research suggesting consumers don't want this level of choice (Stenner et al. 2015). As against this, it is not necessary that there be a large 'as-available' consumer base on day one – this could develop as options for consumer self-supply and backup power emerge. Nevertheless the approach to educating consumers and implementing their preferences would need careful management.

The insurer is initially funded through capital contributions from its ownership base. The determination of the ownership base is an important consideration. Any government funding must be appropriately caveated by clear governance protocols to limit the impact of political or government intervention. Commercial funding would require that a sufficient commercial rate of return is built into the financial and revenue structure.

Ensuring a sufficient competitive dynamic for provision and pricing of insurance will also need to be encouraged. The ability of the consumer to elect for coverage would mean that demand is elastic, encouraging supplier pricing discipline. Regulatory oversight and monitoring would also be important.

Conclusion

Existing energy only market design has faced a number of conceptual and practical challenges under the recent energy transition. Increasingly, the response of many jurisdictions faced with similar challenges is to incorporate capacity mechanisms with centralised decision.

Centralised decision making puts increased focus on the efficiency of central authority decision making and the alignment of incentives. We propose an 'insurer-of-last-resort' model that would incorporate insurance-based risk management concepts and allow consumer preferences for system reliability to be directly incorporated into centralised resource adequacy decision making. This serves as an overlay on existing market design with the aim of (i) aligning incentives for centralised decision making and (ii) allowing revealed consumer preferences to guide new capacity deployment. Key issues that will require focus include the extent of coverage, regulatory model and governance. Competitive models of insurance provision may also emerge to enhance competition in prices and coverage.

Footnote

[1] Our model builds on the previous works in this area. Fumagalli, Black and Vogelsang (2004) introduced the concept of electrical grid insurance in the context of an integrated distribution utility model, extending prior work done with respect to insurance schemes for curtailment priority (Chao & Wilson 1987; Deng & Oren 2001; Manove 1983).

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Bangladesh Affiliate Founded

A new IAEE affiliate, the Bangladesh Association for Energy Economics (BDAEE), was founded in Dhaka, Bangladesh on February 1, 2018. Following the IAEE bylaws, three faculty members from North South University, Dhaka, Bangladesh and one leading energy entrepreneur from ME SOLshare Ltd. were elected to run the BDAEE for two years. Dr. Sakib Bin Amin, an Assistant Professor at North South University, Bangladesh and a visiting Commonwealth scholar at Durham University Business School is president of BDAEE. Sakib's research mainly focuses on Energy Sector Reform and Energy Policy in Developing Countries, and he has a long-term research record with Bangladesh Energy Regulatory Commission (BERC). Dr. Sebastian Groh, an Assistant Professor at North South University, is the vice-president of BDAEE. Sebastian is also the Managing Director of ME SOLshare Ltd. and on behalf of ME SOLshare, he received the Microsoft Airband Grant 2018, Intersolar Award for Outstanding Solar Businesses, the UN Momentum for Change Award, both in 2016, as well the 2017 Start-Up Energy Transition Award by the German Energy Agency (DENA) and the 2017 UN DESA Powering the Future. The BDAEE Secretary Mr. Daniel Ciganovic is also the Co-Founder and Director of Business Development of ME SOLshare Ltd. Ms. Mahjabeen Ahmed, a senior lecturer in the School of Business and Economics at North South University (NSU), is the treasurer at BDAEE. She has been teaching at NSU since 2013, and her research mainly focuses on energy economics.

The inaugural Energy Lecture of BDAEE was held on 6th September, at North South University. This event was held in amalgamation with the inauguration of the energy hackathon, as part of the "Power & Energy Week 2018", organized by the Ministry of Power, Energy, and Mineral Resources of Bangladesh. The Vice President of BDAEE, Dr. Sebastian Groh inaugurated the event with a formal introduction of BDAEE to the audience. The keynote speaker of this lecture was Bangabandhu Chair Professor Joyashree Roy from the Asian Institute of Technology (AIT). Professor Roy has also been among the network of scientists of the IPCC-2007 Nobel Peace Prize-winning panel, has been a chapter author of Global Energy Assessment. The Honorable Secretary of Power Division, Ministry of Power, Energy and Mineral Resources Government of Bangladesh, Dr. Ahmad Kaikaus, graced the event as the chief guest. Professor Dr. G. U. Ahsan, Pro Vice-Chancellor (Designate), North South University, Bangladesh and Professor Dr. Mahboob Rahman, Dean of the School of Business and Economics, North South University, Bangladesh also attended the event, along with other distinguished guests. Also present at the event where over 500 students from different universities in Bangladesh, highly motivated and keen on solving Bangladesh's energy challenges, as participants of the hackathon, 2018.

Are the European Electricity Markets Ready for More Renewables?

BY SIMON RISANGER

The last decade has witnessed a substantial increase in the share of renewable production, and even more is required in order to complete the energy transition and reach the climate targets. A growing concern in academia and industry is the intermittent nature of solar and wind production, which constitutes the two major renewable sources for new investments. The straight-forward approach to handle uncertain production is to include flexible units or storage. However, this is easier said than done. Flexible gas units carry high operational expenses and produce emissions, while the investment cost for large storage facilities is massive for the current technologies. These challenges encourage a somewhat unconventional question; could it be that we actually possess sufficient resources, but are not dispatching them efficient enough?

We will investigate the question from a European market perspective. A traditional centralized structure of dispatchable units has created a majority of trade to occur on day-ahead markets. Producers are able to plan well ahead and dispatch their most efficient units, while retailers provide accurate forecasts over a somewhat static demand side. Recent generation expansion trends, however, are contrasting to the traditional market structure. New investments are often distributed, solar and wind production are non-dispatchable, and the demand side is more active. We should therefore consider different market arenas than solely day-ahead trading, and in fact, increased activity is currently taking place at European intraday markets. EPEX SPOT announces annual increases in intraday activity. Their 71.0TWh turnover of 2017 was a 15.1% increase from 2016, and significant compared to the 6.7TWh of 2009 (EPEX SPOT, 2010, 2018). Although notably smaller in turnover, arguably due to significant flexible hydropower reserves, Nord Pool also experiences similar growth (Nord Pool, 2017). Annual turnovers are outlined in Figure 1. Intraday activity is still substantially lower than day-ahead activity, but the development is promising. Especially if we consider the newest intraday feature, the cross-border intraday project (XBID), who reported a successful go-live in June 2018 (XBID, 2018a).

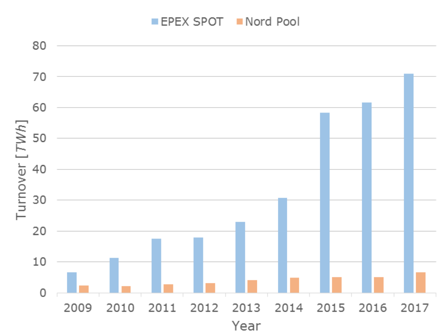

Figure 1: Turnover from EPEX SPOT and Nord Pool intraday markets, collected from their annual reports. The considerable increase in turnover of EPEX SPOT from 2014 to 2015 is partly due to the inclusion of Belgium, the Netherlands and UK through APX.

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EPEX SPOT, Nord Pool, and consequently XBID allows for continual trading within the day on their intraday markets. If a producer experiences problems with committed generation, or errors occur in forecasts for renewable production, it can be adjusted by participation in the intraday market. Forecast errors have become increasingly important as the share of intermittent resources increase. In the day-ahead market, producers must estimate production for the next twelve to 36 hours. In spite of sophisticated forecasting techniques, errors are likely to occur at these time scales. Even as forecasting techniques improve, the increase in intermittent production will still create a significant imbalance volume (Borggrefe & Neuhoff, 2011). As time to delivery approaches, the accuracy of forecasts will improve (Giebel, Brownsword, Kariniotakis, Denhard, & Draxl, 2011). Producers can therefore adjust their imbalances whenever they choose in the intraday market. Because errors can be both overestimations and underestimations, a diversifying effect occurs where positive and negative errors can correct each other; an effect that increases when the trading area becomes larger. The XBID initiative will provide a significant intraday market cover, as shown in Figure 2. Additional countries will also be included in the second go-live in 2019.

Despite its existence for several years, the intraday market has been notoriously illiquid. In contrast to the periodic double auction held at day-ahead markets, where a market equilibrium between supply and demand is found through the formation of merit order curves from market offers, the intraday markets of EPEX SPOT and Nord Pool utilize a continuous double

Figure 2: Countries in orange partook in the first go-live of the XBID initiative in June 2018. Snapshot from XBID (2018b).

auction. (Notice that Spain and Portugal have a periodic double auction held six times intraday. What would be continuous trades are thus aggregated to provide sufficient liquidity at the auctions, at the expense of flexibility in timing.) In a continuous double auction scheme, limit orders form an order book of bids and asks sorted by price and time of offer, similar to equity markets. Even though the continuous double auction is a common market structure, the operation of intraday markets must comply with the power system characteristics. Most notably, system security and a constant equilibrium between consumption and production. Strategies concerning intraday operations quickly become complex; they must solve optimal bidding, dispatch, timing, unit and system constraints all combined. The opportunity for continual activity and exposure to uncertainty produce a multi-stage stochastic problem. Day-ahead operation, however, has only one decision stage for all further operations. This simplifies daily decisions significantly compared to intraday models. Still, the development of sophisticated short-term bidding models in electricity markets looks promising, as exemplified by the models of Gönsch & Hassler (2016) and Jiang & Powell (2015). Proper decision tools for participants will be an important step to reduce risks and make intraday markets more appealing.

Improved liquidity is of great importance in order to improve intraday market design (Weber, 2010). It can be debated whether illiquidity is a cause or an effect for low participation in intraday markets. Producers may conclude that the transaction cost outweighs the potential benefits, and thus their reluctance to participate causes low liquidity. The imbalances will be corrected in the balancing or regulating market operated by the transmission system operators (TSOs) regardless. However, it is a fallacy to consider balancing markets as a traditional marketplace. Its main function is to ensure system stability, not to offer an active trading strategy (Garnier & Madlener, 2015). As imbalances increase, so does the need for stability. TSOs may therefore be forced to dispatch expensive and possibly polluting flexible units, such as gas turbines. Even though positive and negative imbalance positions will cancel each other out, the responsibility is transferred unto the TSO and not the responsible party. Not only does this require extra resources and challenging real-time stability control; the costs are also incurred to society. Moreover, the main objective of the balancing market is to ensure system stability, not efficient dispatch. Operation of larger social surplus are hence likely to occur in a market based environment, such as the intraday market, where this is indeed the objective.

With respect to liquidity being the effect of low intraday activity; we may argue that producers are willing to participate intraday, but the low liquidity pose additional financial risks which they are not willing to undertake. The steady growth in intraday activity seems to demonstrate a willingness to participate. Furthermore, the XBID initiative may be the necessary trigger for intraday markets to become more prevalent. Even if the trades are still bounded by transmission constraints, it encourages intraday participation and shifts perspective towards an international market arena.

Intraday markets are in growth and represent an important market function to ease the implementation of renewable resources. Researchers, policy makers, and engineers should therefore produce appropriate policies and tools to facilitate the process. It is unreasonable to expect that intraday market can perform the integration by itself. An emission-free power system of the future is likely achieved by a combination of market design, improved forecasting techniques, transmission expansion, storage, flexible units, demand side management and so forth. Yet, intraday markets can play a significant role in the merger of the different elements and help to accelerate the process. Regardless of future developments, it will be interesting to follow the XBID initiative and its results in the following years.

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The **IAEE-International Association for Energy Economics** and the **CUG-China University of Geosciences** have the pleasure to invite you to attend this conference entitled

Energy Exploitation & Cooperation in Asia

That will be held at the Optics Valley Kingdom Plaza Hotel**, Wuhan, China**, **2-4 Nov. 2018**. The conference will be organized by School of Economics & Management, CUG(Wuhan), School of Humanities & Economic Management, CUGB, School of Economics & Management, BUAA, Institutes Of Science And Development, CAS and Hubei University of Economics.

Some suggested topics for discussion (but not limited):

- Energy pricing issues within Asian economies
- Forecasting Asian energy demands and supplies in total and by primary energy source and geography
- Forecasting needed energy infrastructure investments in Asia
- Opportunity and challenge in energy exploitation and cooperation
- National security and strategic implications of meeting Asian energy growth
- Energy efficiency improvements
- Possible changes in the structure of Asian energy markets
- The Impact of Advanced Energy Technologies
- Energy and Electricity markets reform
- Grid and Power industry
- Climate change policy and effective CO_2 removal
- Investment issues in liberalized markets
- Economics of Oil and Gas (Upstream, Midstream, Downstream)
- Electricity and Gas Trading
- Energy Poverty, Subsidies and Tax Policies
- Geopolitical Impacts on the Energy Sector in Asia

We have confirmed following professors to be **Keynote Speakers**

Nov.3rd, Saturday, Plenary Session I

Zhang Zhongxiang

Founding dean, Ma Yinchu School of Economics; Director, Tianjin University, Environmental and Industrial Economics; China Country Representative, the European Association of Environmental and Resource Economists.

Title: *Global and Asian Governance Mechanisms in The Energy Market*

Masakazu Toyoda

Chairman & CEO, The Institute of Energy Economics, Japan

Title: *Forthcoming*

Timo Kuosmanen

Professor, Aalto University School of Business; Docent, University of Eastern Finland, Department of Business.

Title: *(De)Regulation of Energy Sector: Yardstick Competition of Local Monopolies in Electricity Distribution*

Nov.3rd, Saturday, Dual Plenary Session

Gürkan Kumbaroğlu

Professor, Department of Industrial Engineering, Boğaziçi University

Title: *Diffusion Prospects for Electric Vehicles, Infrastructure Requirements and Sustainability*

Philip Andrews-Speed

National University of Singapore, Energy Studies Institute, Senior Principal Fellow

Title: *Meeting Multiple Energy Challenges A Institutional Perspective*

Larry Chow

Retired Professor, Department of Geography, Hong Kong Baptist University; Hong Kong Baptist University Foundation Honorary President

Title: *Projection of Word Oil Prices: A Combination of Technical Analysis and Fundamental Factors.*

Chen Bin

Professor of Beijing Normal University's School of Environment; Editor of the Journal of Ecology

Title: *Forthcoming*

Zhang Xiliang

Professor/Fellow, Director of Energy Systems Analysis Research Institute, Institute of Nuclear and New Energy Technology, Tsinghua University; Executive Director, Institute of Energy Environmental Economics, Tsinghua University

Title: *CO_2 Emission and Climate Change*

Nov.4th, Sunday, Dual Plenary Session

Zhu Lei

Adjunct Professor, School of Economics and Management，Beihang University

Title: *Energy Investment and Technology Evaluation*

Yan Jinyue

Energy engineering expert; "Applied Energy" Editor-in-Chief; Chairman of Swiss China Science and Technology Cooperation Promotion Association, Overseas Chinese Academy of Sciences.

Title: *Transition of Energy Systems*

Nov.4th, Sunday, Concluding Plenary Session II

Adonis Yatchew

Professor, Economics Department, University of Toronto; Editor-in-Chief, The Energy Journal

Title: *Forthcoming*

David C. Broadstock

Deputy Director, CESEF, Hong Kong Polytechnic University;
IAEE Council member and Representative of Asia-Oceania of IAEE

Title: *Supporting OBOR Investment Through Socially Responsible ('Green') Finance：Opportunities, Challenges and Policy Priorities*

Ronald D. Ripple

IAEE, Vice President
Mervin Bovaird Professor of Energy Business and Finance, University of Tulsa

Title: *The Belt and Road Discussion Related to Natural Gas Movements in The Region and into China.*

Learn more about the conference by visiting

http://iaee2018.csp.escience.cn

Welcome you in Wuhan!

WELCOME NEW MEMBERS

The following individuals joined IAEE from 7/1/2018 to 9/15/2018

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Calendar

08-09 October 2018, Connected Customer: Utilities at Golden Tulip, 4 Landgrafenstraße, Berlin, 10787, Germany. Contact: Email:k.lenihan@tacook.com, URL: http://go.evvnt.com/253266-0?pid=204

09-10 October 2018, RECSO EnviroSpill - Conference and Exhibition 9-10 October 2018 at Emirates Palace, West Corniche Road, Abu Dhabi, United Arab Emirates. Contact: Phone: 02033289581, Email: james@bme-global.com, URL: http://go.evvnt.com/235429-0?pid=204

10-11 October 2018, China Energy Assembly at China World Summit Hotel, China World Tower 3 (China Ballroom), No.1 Jianguomenwai Avenue, Beijing, 100004, China. Contact: Phone: +442073847963, Email: simon.hoare@energycouncil.com, URL:http://go.evvnt.com/237524-0?pid=204

14-19 October 2018, The Society of Exploration Geophysicists 88th Annual Meeting at Anaheim Convention Center, 800 W Katella Ave, Anaheim, CA 92802, United States. Contact: Phone: 1 (918) 497-5500, Email: meetings@seg.org, URL: http://go.evvnt.com/151569-0

14-16 October 2018, Argus Fuel Oil Summit at W South Beach, 2201 Collins Avenue, Miami Beach, 33139, United States. Contact: Phone: 7137665001, Email: kendall.webb@argusmedia.com, URL: http://go.evvnt.com/236117-0?pid=204

15-17 October 2018, Hydro 2018 - Progress Through Partnerships at Gdansk, Poland. Contact: Phone: 44-20-8773-7244, Email:hydro2018@hydropower-dams.com, URL: www.hydropower-dams.com

15-17 October 2018, SPE Russian Petroleum Technology Conference at Holiday Inn Sokolniki, 24 Rusakovskaya St., Moscow, 107014, Russia. Contact: Phone: 79263294551, Email: mberezinskaya@spe.org, URL: http://go.evvnt.com/208723-0?pid=204

15-16 October 2018, World Congress on Climate Change at Rome, Italy. Contact: Phone: 408-429-2646 , Email:climatechange@pulsussummit.com, URL: https://climatechange.pulsusconference.com/

16-18 October 2018, Solar & Storage Live, Birmingham, UK at NEC, North Avenue, Marston Green, Birmingham B40 1PW, United Kingdom. Contact: Phone: +44(0)2078710122, Email: jandrews@solarmedia.co.uk, URL:https://go.evvnt.com/230942-0?pid=204

16-18 October 2018, International SAP Conference for Mining and Metals, Prague, 2018 at Clarion Congress Hotel Prague, 33 Freyova, Praha 9, 190 00, Czech Republic. Contact: Phone: 01212003810, Email: j.duffy@tacook.com, URL: http://go.evvnt.com/227005-0?pid=204

16-18 October 2018, SPE International Hydraulic Fracturing Technology Conference and Exhibition at Sheraton Oman Hotel, 40 way Ruwi, Muscat, 112, Oman. Contact: Phone: 97144575800, Email: registrationdubai@spe.org, URL: http://go.evvnt.com/244788-0?pid=204

17-19 October 2018, Argus Bitumen Trading Asia 2018 at TBC, Singapore. Contact: Phone: +6564969966, Email:asiaconferences@argusmedia.com, URL: https://go.evvnt.com/240470-0?pid=204

22-24 October 2018, Argus Biofuels and Carbon Markets Summit at The Meritage Resort and Spa, 875 Bordeaux Way, Napa, 94558, United States. Contact: Phone: 7133607566, Email: bel.cevallos@argusmedia.com, URL: http://go.evvnt.com/243572-0?pid=204

22-23 October 2018, 9th World Convention on Recycling and Waste Management at Osaka, japan. Contact: Phone: 7025088061, Fax: 7025088061, Email: wastemanagement@geologyseries.com, URL: https://wastemanagement.conferenceseries.com/

22-24 October 2018, Offshore Energy Exhibition And Conference 2018 at Amsterdam RAI, Europaplein 22, Amsterdam, 1078 GZ, Netherlands. Contact: Phone: +31 (0)10 209 2674, Email: pmu@navingo.com, URL: http://go.evvnt.com/213625-0?pid=204

22-26 October 2018, Gas / LNG Contracts: Structures, Pricing & Negotiation at Johannesburg, South Africa. Contact: Email:abigail.harris@infocusinternational.com, URL: http://www.infocusinternational.com/gascontracts

22-23 October 2018, 3rd International Conference and Expo on Petrochemistry & Natural Resources at PRAGUE, Czech Republic. Contact: Phone: 7799790001, Email: petrochemistry-2018@scientificfederation.com, URL: petrochemistry-2018@scientificfederation.com

23-23 October 2018, The SPE London Conference: 23 October 2018, London at TBC, London, United Kingdom. Contact: Phone: +44 (0) 20 7299 3300, Email: kdunn@spe.org, URL: https://go.evvnt.com/262291-0?pid=204

24-26 October 2018, Oil and Gas Council, MSGBC Basin Summit and Exhibition, Dakar 2018 at King Fahd Palace Hotel, Route des Almadies, Dakar, 8181, Senegal. Contact: Phone: 27210013885, Email: samantha.boustred@oilcouncil.com, URL:http://go.evvnt.com/246331-0?pid=204

29-31 October 2018, Argus Biomass Nordics and Baltics at Radisson Blue Scandinavia Hotel, 70 Amager Boulevard, København, 2300, Denmark. Contact: Phone: 020 7780 4341, Email: bioconf@argusmedia.com, URL: https://go.evvnt.com/245077-0?pid=204

29-30 October 2018, Solar and Storage Finance USA - New York, October 2018 at Harmonie Club of The City of New York, 4 East 60th Street, New York, 10022, United States. Contact: Phone: +4402078710122, Email: jandrews@solarmedia.co.uk, URL:https://go.evvnt.com/241614-0?pid=204

30-31 October 2018, 9th Argus Middle East Oil Products Conference at Fairmont The Palm, Palm Jumeirah, Dubai, United Arab Emirates. Contact: Phone: +97145683946, Email: prithika.manivel@argusmedia.com, URL: http://go.evvnt.com/251173-2?pid=204

October 31 - November 02 2018, SPE's Annual Caspian Technical Conference and Exhibition: Oct 2018 Kazakhstan at Palace of Independence,52 Tauelsizdik Avenue,010000,Astana,Kazakhstan. Contact: Phone: +44 2072993300, Email: kdunn@spe.org, URL:http://go.evvnt.com/261692-0?pid=204

04-08 November 2018, Gas / LNG Contracts: Structures, Pricing & Negotiation at Dubai, United Arab Emirates. Contact: Phone: +65 6325 0274 , Email: abigail.harris@infocusinternational.com, URL: http://www.infocusinternational.com/gascontracts

05-07 November 2018, Argus Mexican Refined Products Conference at Hyatt Regency Houston/Galleria, 2626 Sage Road, Houston, 77056, United States. Contact: Phone: 7133607566, Email: bel.cevallos@argusmedia.com, URL: https://go.evvnt.com/258244-0?pid=204

05-06 November 2018, US Biogas 2018 at Hilton San Diego Mission Valley, 901 Camino del Rio South, San Diego, 92108, United States. Contact: Phone: +44(0)2073757528, Email: diana@newenergyupdate.com, URL: https://go.evvnt.com/230973-0?pid=204

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