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IAEE ENERGY FORUM

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PRESIDENT'S MESSAGE

Before all else, fellow IAEE members, let me welcome you to the springtime edition of the IAEE Energy Forum. And let me say how much I hope you have all managed to stay safe and healthy, but also busy and occupied, as we wait for the pandemic to subside. Hopefully, that time is just around the corner now that a variety of vaccines are being dispensed. Of course, many of us have long since been overly occupied; having to balance regular work responsibilities (often performed in a less than ideal environment) with home schooling, self-provided daycare, and the variety of increased householding chores that come with all that activity.

I begin by reminding all of you to mark your calendars for the upcoming first IAEE International Virtual Conference, scheduled for June 7-9. The conference theme is Energy, COVID, and Climate Change, and this event will offer the usual mix of plenary sessions, roundtable discussions, and concurrent sessions that has made previous IAEE conferences so successful. Please join us for this event in June. You will find details of the call for papers and other registration information elsewhere in this newsletter and, of course, on the IAEE website: IAEE.ORG.

As I mentioned, previously the pandemic has made it more difficult for most of us to do our jobs, whether in academia, industry, or government. But it has not made our jobs any less important. By way of example, let me say a few words about my own situation here In Texas, where we recently suffered through a nearly unprecedented energy catastrophe. In mid-February, a bitterly cold and frigid winter storm descended on us—covering the entire state—with temperatures dipping below -14C and remaining there for six days. At the outset, many of our wind turbines froze up and went off the grid. Texas leads the US in power generation from wind, so this was a significant loss of capacity. At the same time, demand for power rose to unprecedented levels as people desperately sought to heat their homes and businesses. To fill the developing gap between load and generation, many standby natural gas-fueled generating power plants fired up and came online to offset the loss of wind power and to address the extra demand. Within a day, however, many of these plants (and coal and even a nuclear plant, as well) went offline. In the case of gas-fueled plants, the cause was related to the lack of supply of natural gas from Texas wells, which had frozen up.

At its worst, 40% of Texas' total power generating capacity dropped off the grid, at the worst possible time. To maintain balance, the system operator had to institute rolling blackouts. For most people, blackouts lasted for at least 24 hours, for many others the blackouts persisted for 3-4 days. It was cold, inside

(continued on page 2)

President's Message (continued)

and outside. Water pipes in the walls and ceilings of homes and businesses froze and burst, flooding everything. At the same time, the loss of so much water through leaks dropped water pressure throughout the system and forced many water utilities to reduce or stop service.

I am not telling this story to win your sympathy. We will somehow get by. The point of the story, however, is that the energy systems that we rely on in the modern world are complex, with many potential vulnerabilities that sometimes lead to disaster. When this happens, a common reaction is to immediately cast blame on those whom we believe to have been at fault.

Indeed, at the outset of emergency hearings that were opened by the State Legislature, elected officials began the affair by informing witnesses that the primary objective of the proceedings was to find out who was to blame. The legislators, it was said, "didn't want to hear anything vague about systems, but who's at fault." And it was announced that this question would be put to each and every witness. Of course, as the press reported at the time, a common theme in the day's testimony was that the person to blame was someone other than the person testifying. We always tend to blame our adversaries, never ourselves. And this does nothing to solve the problem or reduce the likelihood of future repetitions.

That is why the role of the energy economist is so important. Our job is not to lay blame, but to understand through careful and objective analysis the technological and market systems required to maintain our energy economy, the investment incentives that are required to build and operate appropriate infrastructure, and the regulatory framework that is needed to govern the multi-dimensional aspects of this complicated system. I am afraid that we cannot look to politicians to perform this service—it is a job for energy economists. And as I said previously, the job has never been more important than it is today.

So, again, I encourage all of you to continue with the important work that is required to promote and realize IAEE's mission and goals. We need your ideas, your participation, and your feedback. I close with my wish to see you soon (virtually) at the June IAEE International Conference. And, as always, stay safe.

James L. Smith

IAEE MISSION STATEMENT

IAEE's mission is to enhance and disseminate knowledge that furthers understanding of energy economics and informs best policies and practices in the utilization of energy sources.

We facilitate

- **Worldwide information flow and exchange of ideas on energy issues**
- **High quality research**
- **Development and education of students and energy professionals**

We accomplish this through

- **Leading edge publications and electronic media**
- **International and regional conferences**
- **Networking among energy-concerned professionals**

Editor's Notes

We wrap up our focus on world's electricity systems from the first quarter 2021 issue. Our next issue will focus on operational vulnerabilities and market outcomes within the utility industry and how risk exposure may be mitigated.

Aldren Vernersbach discusses how the specificities of the Brazilian electrical system were decisive for raising the energy tariff, which reveals the urgency of diversifying renewable sources, in a context of electrification of the economy and energy transition.

Andy Van Horn reports on August's heat wave and prior decisions' contributions to rotating outages in California. Future shortfalls can be avoided by modifying regulatory, market, and grid processes and by adding reliable, carbon-free geothermal power plants.

Amina Talipova writes that Ubekistan's turbulent history has impacted electricity generation in the country due to corruption and authoritarian policies. Recent developments aim to attract investors and privatize and deregulate the industry. Uzbekistan must start consistently, without shocks for the population, increasing the potential of existing power units and increasing electricity generation in general. At the same time, it is necessary to develop a legislative framework for renewable energy and carry out privatization and deregulation of the market.

Geoff Betram provides some comments on the New Zealand electricity market reform experience. The 30-year radical reformation of the electricity system has sufficient data to support evaluation of outcomes. Three key areas are considered in this paper: economic efficiency, social equity, and physical reliability of supply.

Robert Diels, **Martin Lienert**, and **Felix Müsgens** analyze market design in Germany since liberalization, discuss theory and empirics of flexibilization in the electricity system and give insights into the empirics of security of supply indices and market induced load-shedding.

Oluwapelumi Egunjobi and **Alvaro Gomes** write that smart and innovative solutions are required to foster the penetration of renewable energy sources (RES). Blockchain has been identified as an enabling technology to provide such platform with capabilities for decentralized operations, like local energy transactions, while handling other problems associated with complex grid management at large.

Humphrey Otombosoba Oruwari examines the constraints to efficient electricity supply in Nigeria, and recommends ways for policy decisions. Using literature review and case study, it is revealed that efficient electricity supply is dependent on the political, technical, economic and social factors which need to be addressed.

Doug Reynolds looks at something called Don King Economics with electric utility systems to induce incentivized management. Don King was a boxing agent, but the idea may enhance utility efficiency.

Farhad Billimoria states that large scale distributed energy resource deployment is expected to result in negative regional demand in grid-edge markets. While the price signal provides the economic rationale for consumption, a cohesive risk management framework for negative prices underpinned by foundation risk trading mechanisms are required for co-ordinated operational, commercial and investment decision-making.

DLW

Careers, Energy Education and Scholarships Online Databases

IAEE is pleased to highlight our online careers database, with special focus on graduate positions. Please visit http://www.iaee.org/en/students/student_careers.asp for a listing of employment opportunities.

Employers are invited to use this database, at no cost, to advertise their graduate, senior graduate or seasoned professional positions to the IAEE membership and visitors to the IAEE website seeking employment assistance.

The IAEE is also pleased to highlight the Energy Economics Education database available at http://www.iaee.org/en/students/eee.aspx Members from academia are kindly invited to list, at no cost, graduate, postgraduate and research programs as well as their university and research centers in this online database. For students and interested individuals looking to enhance their knowledge within the field of energy and economics, this is a valuable database to reference.

Further, IAEE has also launched a Scholarship Database, open at no cost to different grants and scholarship providers in Energy Economics and related fields. This is available at http://www.iaee.org/en/students/ListScholarships.aspx.

We look forward to your participation in these new initiatives.

IAEE
Energy, Covid and Climate Change
the first IAEE virtual conference

THE INTERNATIONAL ASSOCIATION FOR ENERGY ECONOMICS IS PLEASED TO INVITE YOU TO THIS CONFERENCE ON 7– 9 JUNE 2021 ONLINE

An ideal climate and energy policy regime should simultaneously address possibly conflicting objectives: ensuring energy security, promoting universal access to affordable energy services, and fostering greener and sustainable energy systems.

These policies notoriously have heterogeneous impacts on states, consumers, factor prices, energy technologies and existing assets like fossil reserves and carbon-intensive capital stock. Building credible and effective policies is a difficult task and needs to take into account geopolitical, economic and environmental realities to make them acceptable especially in COVID times.

Against this background, the pressing quest for credible and sustainable solutions requires rapid development of deep and broad analyses of policy instruments and institutions. It requires a broad mobilization of the concepts and notions used in economics, natural sciences, humanities or other social sciences to inform the numerous public policy debates affecting international energy trade, environmental regulation, markets vs. government intervention, energy infrastructure and technology choices.

What is the IAEE online conference?
The IAEE International Online Conference aims to be a bridge between the latest science in energy economics and its relevance to practical hands-on experience in the energy sector. The digital edition addresses a wider global audience, enhancing the event experience and offering several opportunities for networking, interaction and knowledge exchange across all the different topics, audiences and time zones.

REGISTRATION DEADLINE
15 May 2021
For further information, please contact:
iaee2021@oyco.eu

Who Should Attend
Academics and scholars working in the fields of energy, natural resources or environmental economics; Policy makers and officials in governments, international institutions and regulatory agencies; Energy analysts working for local authorities, development agencies, consumer bodies, NGOs; Business leaders and practitioners.

Join us online
The conference provides a unique online platform for academics, policy-makers and business leaders from around the world to present and discuss the latest economic research on pressing energy issues in an open and nonpartisan setting. The conference also welcomes the many environmental and natural resource economists working on these topics.

Call for papers
From a methodological perspective, the conference welcomes contributions based on: analytical models, econometrics, experiments, surveys, rigorous institutional analyses and case studies, simulation models, equilibrium models, optimization models. Interdisciplinary works with all areas of the natural, social or engineering sciences are also welcome.

Registration Fees (non-refundable)
- Presenter (IAEE member): **300€**
- Presenter (non-member): **390€**
- Presenter (student): **200€** (one-year IAEE digital-only membership)

Delegate (IAEE member)
- **35€** (3-day/full conference)
- **20€** (single day)

Delegate (non-member)
- **125€** (3-day/full conference)
- **110€** (single day)

Delegate (student)
- **25€ for 3-day** (includes one-year IAEE digital-only membership)

Online Venue
The online Conference will take place from Monday 7th June to 9th of June 2021. Sessions will run from early morning to late evening in Central European Summer Time (CEST) to facilitate international covering of the event.

#IAEE2021ONLINE **iaee2021online.org**

IAEE - APEEN Student Prize for Portuguese students

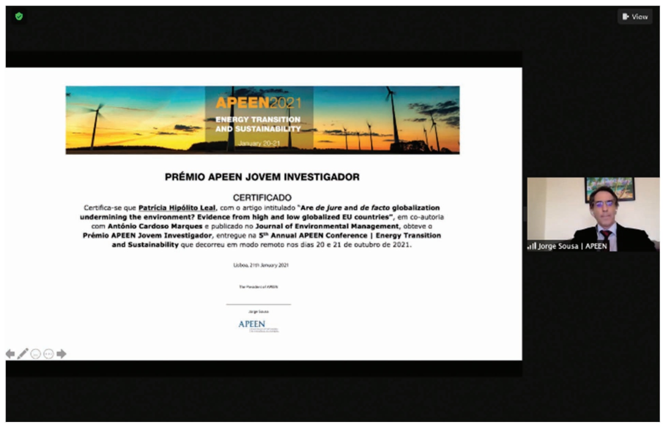
On the past 20-21 January 2021 took place the 5th Annual Conference of the Portuguese Association of Energy Economics (APEEN), fully dedicated to all aspects of the Energy Transition and Sustainability, organized by CENSE (Center for Environmental and Sustainability Research) from NOVA School of Science and Technology.

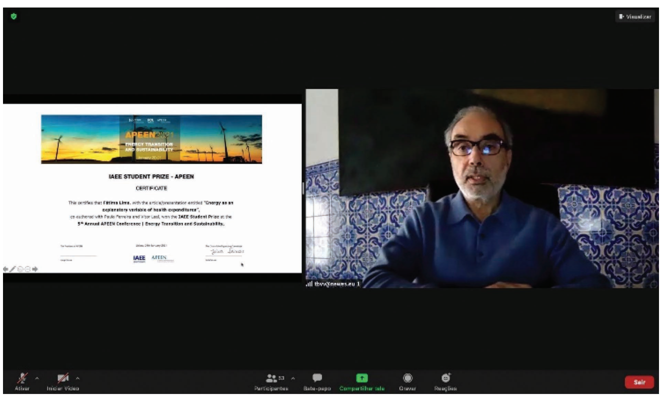
The best article/presentation in 2021 APEEN Annual Conference was awarded with the International Association for Energy Economics (IAEE) Student Prize, that is $350 and the annual membership rate payment of $50 to join APEEN/IAEE for one year.

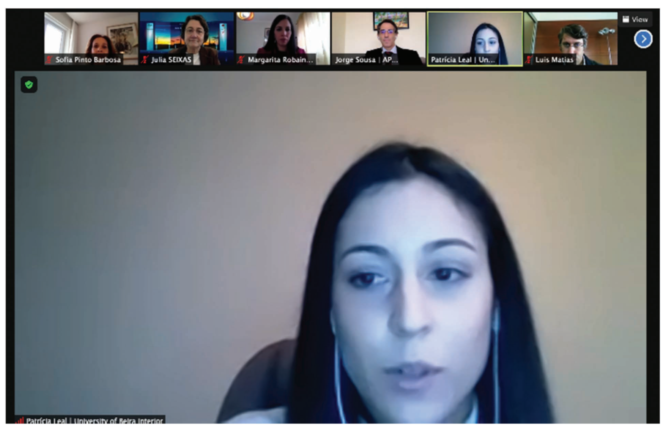
The IAEE prize was promoted and offered by IAEE, in an effort to encourage more students to join the Association and to investigate in the Energy Economics area. More than 20 articles of MsC and PhD students were presented at the conference and were candidates to this prize.

The prize was awarded to the student Fátima Lima with the paper "Energy as an explanatory variable of health expenditures", co-authored with Paula Ferreira and Victor Leal.

APEEN also gives in its annual conference the Young Researcher Award with the objective of rewarding the scientifically relevant work in Energy Economics by young researchers, as well as promoting the growth and renewal of this scientific area in Portugal. The Young Researcher award has the monetary value of 1000 € and the candidates have to send an article published in a scientific journal, have at least 35 years old, and be an APEEN member. This year the winner was Patrícia Hipólito Leal, with the article "Are de jure and de facto globalization undermining the environment? Evidence from high and low globalized EU countries", co-authored with António Marques and published in the Journal of Environmental Management".







APEEN
Associação Portuguesa de Economia da Energia

Working Paper Series

— CALL FOR ENERGY RESEARCH PAPERS —

The USAEE and IAEE have combined efforts to create a working paper series that gives all USAEE/IAEE members a chance to increase the circulation, visibility, and impact of their research. If you have an unpublished research paper that addresses any aspect of energy economics or energy policy, we would like to feature your paper in this new series. There is no cost to you, only benefits:

- Place your work where it can be seen and used on a daily basis.
- Gain timely feedback from other researchers working on related topics.
- Create a permanent and searchable archive of your research output within the largest available Electronic Paper Collection serving the social sciences.
- Provide unlimited, hassle-free, public downloads of your work on demand.
- Raise your research profile, and that of the USAEE/IAEE, by joining with fellow members to establish a new energy research *trademark* that is unparalleled in terms of its breadth and depth of focus.
- Have a chance to win a complimentary registration to attend one of USAEE/IAEE's conferences in 2022.

The *USAEE/IAEE Working Paper Series* is a component of the Social Science Research Network (SSRN) *Research Paper Series*. SSRN is the leading online source of full-text research papers in the social sciences and is accessible at the following link: http://www.ssrn.com/. SSRN is indexed by all major online search engines, ensuring that anyone who does a keyword search in your area of research will be directed to your paper, receive free downloads, and will be provided with your contact information. SSRN tabulates the number of abstract and full-text downloads of each paper in the series and publishes various "top-ten" lists to indicate which papers are most highly demanded within individual subject areas.

To view current working papers in our series please click here.

Contributor Guidelines

The USAEE/IAEE Working Paper Series includes only papers that present original, scholarly research related to energy economics and policy. Editorials, marketing tracts, and promotional material and papers carrying a high degree of opinion to analysis will not be accepted. Other than this initial screening, the working papers will be unrefereed and authors are solely responsible for their content. Authors will retain all rights to their work, including the right to submit their working papers (or subsequent versions thereof) for publication elsewhere. Neither USAEE/IAEE nor SSRN will assume or usurp any copyright privileges with respect to papers included in the series.

Each working paper included in the *USAEE/IAEE Working Paper Series* must be authored or co-authored by a member in good standing of the USAEE/IAEE, and be submitted by that member. All papers will be assigned a USAEE/IAEE Working Paper number.

To include your research paper (or papers) in the *USAEE/IAEE Working Paper Series*, please email a copy of the work (***in PDF format***), including a brief abstract, to Colin Vance, Manuel Frondel, and Doug Conrad at wps@iaee.org.

Colin Vance
USAEE Working Paper Series Co-Coordinator since June 2018
RWI – Leibniz Institute for Economic Research

Manuel Frondel
USAEE Working Paper Series Co-Coordinator since June 2018
RWI – Leibniz Institute for Economic Research

Doug Conrad
USAEE Executive Director

Annual USAEE/IAEE Best Working Paper Award

Papers submitted from January 1 through December 31, 2021 will be reviewed by the USAEE/IAEE Best Working Paper Award Committee. One paper will be selected by a committee. This Committee will evaluate papers based on their contribution to the literature, scholarship, and originality. Prior to the review, the lead author will be requested to affirm his/her willingness to present the paper at one of USAEE/IAEE's 2022 conferences should the paper receive the Best Paper Award. The lead author of the paper that receives the USAEE/IAEE Best Working Paper Award will receive complimentary registration to attend one of USAEE/IAEE's conferences in 2022 and will be asked to present the paper in one of the 2022 conference's concurrent sessions.

In Memoriam – Pablo Mulás

The idea is that we humans could extract geothermal energy from volcanos. Sure, I said. Hot rocks, hot water. So what's new? No, Pablo replied. Geothermal from active volcanos! (Of which Mexico has many.) The concept was to drill tunnels into the chamber and recirculate water.

That is a snapshot of a typical conversation between Pablo and me, nearly always with our good friend Juan Eibenschutz. Who knows when, there were so many of these conversations, so lively, across so many topics over so many years. Always with good food, tequila and nice wines. Not a bad deal, wining and dining my way through Mexican energy with my two Wise Men.

Always curious, always wondering, always questioning – that was Pablo. And, always dedicated to public service. When he served as president of the Mexico affiliate, AMEE, in 2000 his desire, along with those of our other colleagues there, was to reinvigorate the affiliate. That year, during my turn as President-Elect of USAEE, Pablo and the AMEE group organized an event that would lead to a full Mexico City-based North American conference in 2003. Adam Sieminski was then at the helm for USAEE and I was IAEE president (and John Jimison contributed a mean piano). We had completed a North American trifecta, for the first time in IAEE history.

Pablo inherited the Mexico Committee for the World Energy Council from Juan. He was dedicated to WEC and convinced that the Council, through its country memberships and collegiality, could help improve understanding of energy complexities. His podcast, recorded before his passing, reflects that belief. More than anything, Pablo was convinced of the importance and value that humans can derive from civilian nuclear. Together with Juan, "Mr. Nuclear" in Mexico for his long push (some 24 years) to build competency and achieve the Laguna Verde facility, Pablo was a steady champion for this clean, green but misunderstood and often maligned energy source. (It's a confidence thing, an eloquent point made by Juan: "If you want to project confidence, you have to act with confidence" not least among nuclear regulators.)

As Guy puts it: "I really enjoyed working with him [Pablo] over many years especially the last several years in Mexico City alongside the Energía conference [led by long-time friend Jesus Reyes Heroles and Herman Franssen, another that I miss dearly]. In his capacity as President of the Mexican chapter of WEC, he was very kind to arrange a World Energy Council Mexican chapter breakfast meeting for me to present to concurrently with Energía. He was always very insightful at IAEE events and at the USEA meetings."

"I will miss him very much," Guy adds.

Pablo was part of Energía a Debate. This is what Pablo did – he connected, supported, befriended, imparted, and, yes, argued, always strenuously (Mexico's policy on daylight savings time was memorable), but always in the most genteel way.

As Juan put it: "The number of adjectives applicable to Pablo is enormous. Above all, he was a gentleman in the full sense of the word. During the sixty years of our friendship, I never saw him lose his temper. Kind, but firm during the periods when he managed different institutions, always ready to learn, and blessed with the capacity to innovate end think differently. Witness to his personal characteristics the very big number of people that has manifested grief and sorrow at his departure."

He also cooked fantastic Chiles en Nogada, and my own deep regret is that I was never able to join the fun at his annual gathering in Cuernavaca. From Juan: "The last time I saw him, few weeks ago, he repeated a favorite saying of his, 'cuando te toca aunque te quites'. May he rest in peace." Indeed.

Michelle Michot Foss with
Juan Eibenschutz and Guy Caruso

A new basis for the Brazilian electrical system: diversification of the renewable energy matrix

BY ALDREN VERNERSBACH

Aldren Vernersbach is an Economist–Researcher with Institute of Economics / Federal University of Rio de Janeiro (UFRJ), Public Policies, Strategies and Development (PPED), and Energy Economics Group (GEE-UFRJ). He can be reached at aldren.vernersbach@gmail.com

Introduction

The Electrical Industry of Brazil forms one of the largest electrical systems in the world[1], bringing together the segments of generation, transmission and distribution of energy in a wide unified and branched network. The institutional model designed in its conception originated an industrial organization based on the State's monopoly on generation and transmission activities, with permission for private companies to do the distribution.

The model of "dominant State" was justified by the need for national coordination to (i) manage energy flows in a regionally distinct territory; (ii) ensuring sufficient energy for an economy with strong growth and urbanization; (iii) and preserve the rational use of the country's energy sources. Subsequently, in the context of the State's fiscal crisis in the 1990s and with the intention of technologically updating the sector, an open market was established, implementing a new institutional model, with competition and concessions through auctions in each segment. To maintain control of the system, the National System Operator (ONS) and the National Electric Energy Agency (ANEEL), the sector's regulatory body, were created.

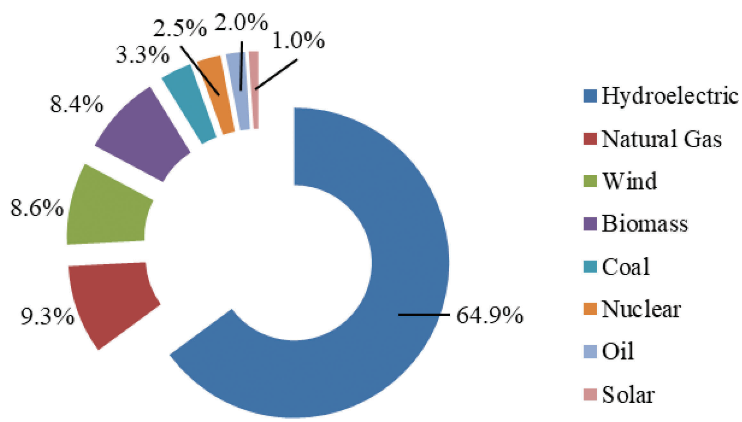
The shape of Brazil's electrical system is a globally successful case, as it supports immense demand and takes advantage of electricity generation across the country, ensuring unified supply. However, the concentration of generation in an intermittent source of energy – hydroelectric – has provided an oscillating supply, increasing the cost of electricity. The supply of energy is complemented by the thermoelectric park, whose infrastructure is costly, which contributes to the increase in electricity. Therefore, the Brazilian electrical system produces energy with a very variable cost, which is reflected in the costs of the entire economy. This is currently a problem to be addressed in the sector, which is a global example in the generation of renewable energy.

A very peculiar system

The Brazilian electrical system has very particular characteristics, which distinguish it from other global systems. Its uniqueness stems from the complete interconnection of the entire infrastructure, encompassing its segments throughout the extensive national territory, forming a large energy network called the National Interconnected System (SIN). Thus, both in terms of supply and demand, there is total network integration, capable of supplying the country, directing electricity according to the behavior of consumption and the capacity of energy generation assets.

The other peculiarity of the Brazilian electric sector is the conception of its matrix, based on the use of abundant natural resources.

The electrical matrix was consolidated based on renewable sources, notably the hydroelectric source, responsible for 64.9% of the energy produced in the country, followed by wind with 8.6%, biomass with 8.4% and solar with 1%. Therefore, about 83% of Brazil's electric matrix is sustainable, made up of renewable sources, a unique case for the world sector[2] (EPE, 2020b).

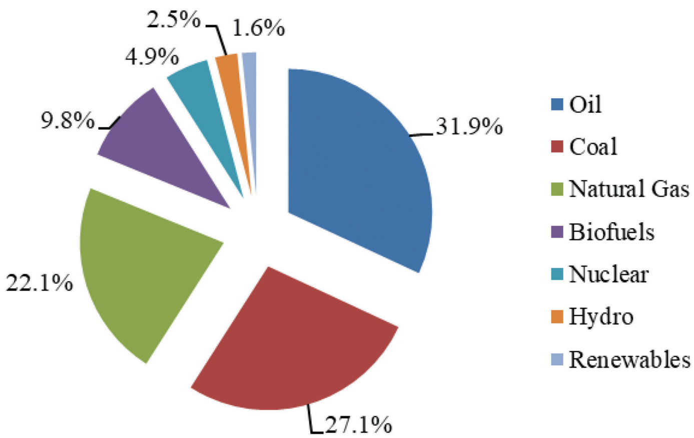


Graph 1 - Electric Matrix of Brazil – 2019
Source: Elaboration based on EPE data (2020).

The Brazilian matrix has an inverse composition to the global matrix, whose base is formed by non-renewable sources for electricity generation.

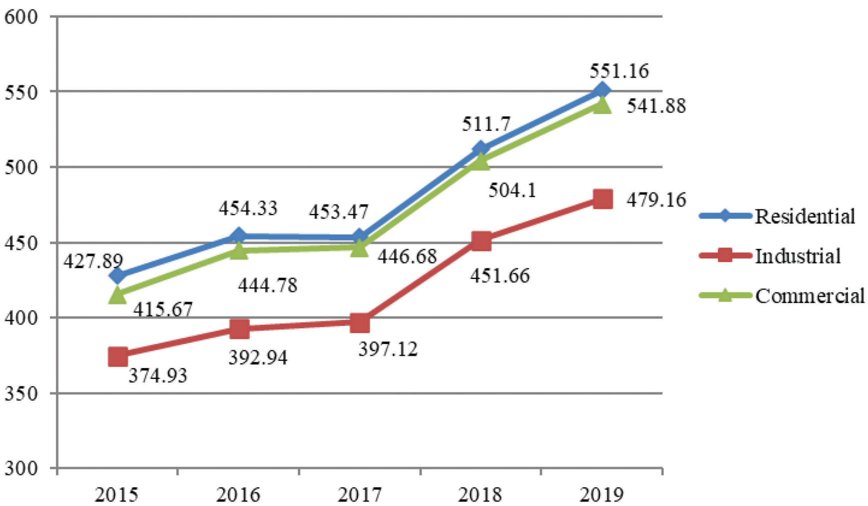
In the global electric matrix, renewable sources account for only 22% of generation, indicating the enormous process that the electric sector still needs to execute, aiming at the decarbonization of electricity generation. The demand for electricity grows 2.1% per year and considering the scenario of declared public policies, consumption will double by 2040. Considering a scenario of application of sustainability policies, the demand for electricity will be 31% of the primary energy to be consumed (IEA, 2020a, 2020b).

In Brazil, despite the use of renewable sources, generation concentrated on the use of the country's water potential has reduced the efficiency of the system, since the risks of the hydroelectric model have kept the energy tariff at very high levels. In view



Graph 2 - Global Electrical Matrix – 2018
Source: Elaboration based on IEA data (2018).

of the increase in the use of energy in the economy, expansion of access to electricity and an increasingly deep and rapid process of electrification of economic activities, energy supply and tariffs have become an issue to be discussed urgently.



Graph 3 - Energy tariff in Brazil by segment (R$/MWh)
Source: Elaboration based on EPE data (2020).

In the last decade, the energy tariff has grown every year, indicating a gradual increase in electricity in Brazil. Analyzing the specific data, the residential tariff increased 65.3% between 2012-2019. For the industrial sector, the increase was 86.2% between 2012-2019. Water crises, with different levels of severity, have caused an increase in the electricity tariff (EPE, 2020b).

The participation of hydroelectricity in generation puts the system hostage to hydrological risk, natural to this type of model, with multi-annual regularization. The system is managed efficiently, seeking to optimize the water resources in the reservoirs, in order to minimize the cost of using thermoelectric plants. However, the alternative generation apparatus to complete the offer does not provide cheap energy. It is necessary to add a new efficient, diversified, sustainable and low-cost generator set to the system.

In this context, the energy policy for the country is faced with the need to define a new set of sources to be explored and to find ways to expand investment in the efficiency of energy use and in the digitization of microsystems. This change has become essential to maintain the energy transition and reduce the cost of electricity.

The use of the photovoltaic source is an alternative to the sector, by stimulating private investments in solar fields. However, there are regulatory hurdles and low financial incentives for large-scale expansion. The regulation applied to the generation of solar energy is still incipient and the incentives could be greater. Only the state of Minas Gerais has a policy of tax exemption and greater incentive for the creation of solar parks in its territory. The device allows the exemption from ICMS[3] to all models of shared generation, therefore, units of multiple consumers such as condominiums, consortia and cooperatives and remote self-consumption units. Exempt generating plants are those that produce up to 5 MW, which limits the benefit.

Thus, the photovoltaic sector does not achieve considerable growth compared to the others. The generation of electricity by the photovoltaic source increased 92.1% between 2018-2019 and the installed capacity was increased by 37.6%. However, investments are still small in order to create a complementary and cheap generation park.

In 2018, global production of electricity from renewable sources grew. In the case of the solar source, there was an increase of 24.3%. The energy produced from wind farms grew by 12.4%. These numbers indicate to the gradual expansion of the share of renewables in the global electrical matrix, in a diversified form (IEA, 2019).

Renewable energies are expected to account for 95% of the net increase in global energy capacity by 2025. The solar sector is expected to account for 60% of additional renewable generation capacity, and wind energy 30%. Regarding the wind sector, due to the drop in costs, generation on offshore bases is already growing, and should account for about 1/5 of the additional wind capacity (IEA, 2020c).

In the Brazilian case, the solar generation model has been developed by some companies in the country, but the high initial investment in photovoltaic technology and the tax structure discourage larger investments and long-term maturation. This set of factors hinders the expansion of the solar park in the country.

The diversification of the renewable matrix in Brazil is necessary in order to consolidate an alternative capable of counterbalancing the intermittency of the hydroelectric arrangement. In this way, it will be possible to reduce the energy tariff, which is essential, since the cost of electricity generation corresponds to a considerable portion of the total costs of the production chains. It is worth mentioning that the hydrological risk still discourages the increase in the electrification of the economy when it becomes a cost for sustaining the sector. Therefore, diversifying the use of renewables sources to mitigate the fluctuation of the energy tariff, making electricity more accessible and cheap, is essential to economic growth.

An alternative system that ultimately guarantees the transition

Brazil's electricity system needs diversification of renewable sources to become more efficient and less costly. This diversification can also be added to a new subsystem that mitigates the general intermittency of renewable sources. In this sense, the expansion of the park of thermoelectric plants using natural gas is one of the most appropriate alternatives. Natural gas is a hydrocarbon with low emission of pollutants, reasonable energy efficiency and reduced cost.

Brazil has substantial gas reserves to make this alternative viable. The consolidation of a gas-fired thermal park can guarantee the energy security of the renewable system. Thermoelectric plants can be activated in circumstances of extreme fluctuation in generation from renewable sources already consolidated in Brazil.

In this way, a supply crisis such as the one in California is avoided, in which the cost of energy has increased, consumption has expanded and the system has not been able to support the demand for not having a sufficiently large electricity generation capacity, to supply the consumption shock. The California system did not expand its energy storage capacity and there was no planning that indicated the need for a complementary system to guarantee supply, considering the intermittency of renewable sources and the period of expansion of sustainable and low-risk electricity generation.

Conclusions

The diversification of energy generation requires a public policy that aligns economic interests with energy, environmental and social interests. To expand access to decentralized and cheaper energy, it is essential to make this objective transversal to public policies in Brazil.

The Brazilian energy policy needs to insert the new generation models in its consolidated framework of energy sources, in order to sustain the energy supply. The demand for electricity is constantly expanding, indicating that the Brazilian economic development, linked to the increase in the pattern of consumption and electrification of the economy, leads to a scenario of great demand, imposing an increase in power generation.

Making the Brazilian energy matrix more diversified is possible and necessary to reduce the electricity tariff, combined with the insertion of new renewable sources in the national electricity system. The incentive to wind and solar plants is essential to accelerate this process and allow the capacity of each source to be sufficient to meet the demand in a complementary way.

The conception of an economic regulation adequate to the new models of electric generation and the creation of incentives for the increase of renewable energy plants, are essential to form a base of devices that enable the expansion of other renewable sources of energy in the Brazilian electrical system.

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Footnotes

[1] Brazil is the seventh largest producer of electricity in the world.

[2] Data for the year 2019.

[3] ICMS is a Tax on Operations Relating to the Circulation of Goods and Provision of Interstate and Intermunicipal Transport Services and Communication.

Causes of California's Rotating Outages and A Resilient, Reliable Remedy: Geothermal Power

BY ANDREW J. VAN HORN

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Abstract

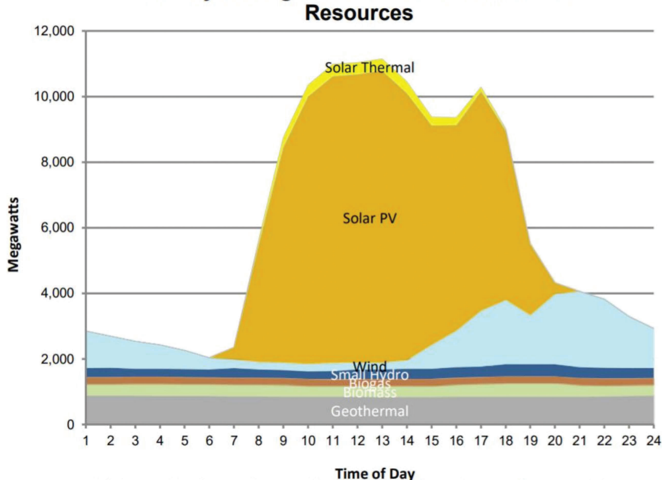
In August, a heat wave and prior decisions contributed to rotating outages in California. Future shortfalls can be avoided by modifying regulatory, market and grid processes and by adding reliable, carbon-free geothermal power plants.

What Happened on August 14th and 15th?

Who supplies and regulates California's electricity markets? California's electricity customers are served by a diverse generating portfolio that typically provides 70% of delivered MWh from in-state generators and 30% from out-of-state power resources. In 2019, 32% of in-state generation came from eligible renewable resources that include wind, solar, geothermal, small hydro and biomass. The grid balancing authority is the California Independent System Operator (CAISO), a non-profit, public benefit corporation. CAISO is responsible for managing about 80% of California's electricity demand and operates a competitive wholesale electricity market for its members, manages the high-voltage transmission system and provides a real-time energy imbalance market (EIM) across eight western states. CAISO is regulated by the Federal Energy Regulatory Commission (FERC), the National Electric Reliability Council (NERC), and the Western Energy Coordinating Council (WECC). At the state level the California Public Utilities Commission (CPUC) regulates the investor-owned utilities (IOUs) and sets reliability requirements and customer rates. Electric utilities regulated by the CPUC supply about 91% of the electricity demand served by CAISO. The California Energy Commission (CEC) carries out power plant licensing functions, funds innovative research and prepares forecasts of natural gas and electricity demands for system planning and policy analyses. The California Air Resources Board (CARB) administers California's successful economy-wide cap-and-trade program for greenhouse gases (GHG). Effective communication among these organizations is essential, and the development of better aligned capacity and reliability targets, procedures and coordinated policies is critical.

What happened In August 2020? California was burning with wildfires and the western U.S. baked during a six-day heat wave. High electricity demands taxed generation resources throughout the western United States. On Friday, August 14, CAISO reported a 750 MW unit was offline. At 2:56 pm the Blythe Energy Center, a 494 MW natural gas-fired generator generating at 475 MW, went down. Contingency resources were then dispatched.[1] Out-of-state imports were constrained, because that power was needed in other states and was not under firm contracts to California entities. To maintain load and resource balance, 800 MW of demand response resources were dispatched at 5:15 pm. At 6:36 pm CAISO reserves fell below the level required to meet minimum contingency reserve requirements, and a Stage 3 emergency was declared. Load-shedding of 500 MW was implemented. A further 500 MW of load was shed at 6:46 pm. By 7:56 pm electricity demands had decreased enough for CAISO to satisfy its load and contingency reserve obligations, and power began to be restored.[2] At 8:54 pm the emergency declaration was lifted.[3]

On Saturday, August 15, cloudy and smoky conditions across the state reduced solar generation, and breezes were erratic. At 4 pm wind generation increased rapidly, requiring other generators to back down quickly. But after 5 pm, about 1 GW of wind stopped blowing, requiring thermal power resources to ramp up quickly to meet loads, while power supplied by utility solar and behind-the-meter PV systems dropped. Figure 1 shows CAISO hourly generation on August 15 by renewable resources.



This graph shows the production of various types of renewable generation across the day.

Figure 1. CAISO Hourly Average Renewable Generation on August 15, 2020. http://content.caiso.com/green/renewrpt/20200815_DailyRenewablesWatch.pdf

Between 5 and 6 pm, CAISO Area Control Error was -1,413 MW. At 6:13 pm, a 470 MW gas-fired generator ramped down from 394 MW to 146 MW, due to a scheduling mistake by PG&E. At that point CAISO didn't have enough committed capacity to ramp up to meet net load,[4] and couldn't access sufficient imports to avoid a Stage 2 alert. Stage 3 conditions followed. At 6:25 pm, 470 MW of load shedding/rotating outages were instituted.[5] Soon after, the wind ramped up, net load declined, and emergency assistance enabled load to be restored at 6:47 pm.

Because the 100+ degree Fahrenheit heat wave was forecast to continue, CAISO issued an Intent to Solicit and Procure Additional Capacity. CAISO reminded power purchasers not to under-schedule loads in the day-ahead market. Fortunately, better management of resources and "Flex-Alerts" calling for demand reductions avoided similar rotating outages in the following months.[6]

Contributing Causes

Why was California short of power and what changes should be considered? There are many factors that contributed to the August episodes. These include:

1. *Heat waves across the West that lasted for six days*. These increased loads and reduced California's ability to import out-of-state power. Rotating outages became necessary to avoid cascading, uncontrolled outages, when California generators unexpectedly went down, the sun was obscured by smoke, reducing solar generation, and the wind stopped blowing.
2. *A lack of diversity in grid resources added over the last decade.* Additions of wind and solar power plants combined with retirement of the San Onofre nuclear plant and reliance on aging natural gas plants mandated for retirement left California's grid with fewer than necessary dispatchable resources. Over-dependence on variable, non-dispatchable wind and solar power plants caused steep late afternoon/early evening ramp-ups in net load, added volatility to net loads, increased the complexity of grid operation, necessitated tariff and product changes, and reduced the diversity of proven resources. All these factors helped make the current grid more vulnerable to a variety of foreseeable conditions.
3. *The CPUC's misplaced emphasis on "least-cost, best-fit" metrics used to approve contracts and capacity additions.* Planning and decision-making has focused on near-term economic costs rather than long-term and lifecycle economic and environmental costs. Significant risks have been unexamined. Additions of proven flexible, baseload and energy storage resources are needed to avoid future risks[7] and to satisfy growing demand, e.g., from electric vehicles.

   How have capacity additions been analyzed and mandated? "The CPUC's reliability (termed resource adequacy [RA]) requirements are set based on the peak demand shown in the CEC's demand forecast, plus a planning reserve margin (PRM) of 15% [above the monthly load forecast]. The PRM is comprised of a 6% requirement to meet grid operating contingency reserves, as required by the WECC reliability rules, and a 9% contingency to account for unplanned plant outages and higher-than-average peak electricity demand."[8] The CPUC has mandated procurement of specific technologies deemed capable of meeting RA needs and California's Renewable Portfolio Standard (RPS) requirements. RA needs are determined using CEC demand forecasts that incorporate load reductions from forecasted demand response measures. Wind and solar resources are assigned Qualifying Capacity values to meet RPS and CAISO Net Qualifying Capacity (NQC) values to determine whether enough generation capacity has been contracted to meet local and system RA requirements. The methodology has overestimated capacity values for solar and wind. (Note that RA capacity values for stand-alone solar plants go down as more solar is added.)

   To date the CPUC and CEC have not fully considered lifecycle impacts, reliability needs under foreseeable stress conditions nor potential unintended consequences of intermittent solar and wind generation. California's aggregate energy supplies must be able to avoid a range of impacts of "high consequence" events and scenarios resulting from climate change, heat waves, fires and falling trees in forests, as well as less predictable events, like explosions in natural gas pipelines, gas storage field releases, earthquakes, cyber-attacks on the grid, terrorist acts, electro-magnetic pulses from the sun, and volcanic eruptions that affect global weather, which have obscured the sun for months. Such events have already occurred but could be more frequent and have greater consequences in the future.

   As a first step toward revising policies and practices, the CPUC, CEC and CAISO submitted a Preliminary Root Cause Analysis report to the Governor on October 6. CPUC President Marybel Batjer said, "The extreme heat storm in August was an extraordinary one-in-35-year event that, with climate change, is unfortunately becoming more common… We will absolutely adjust our planning, procurement, and market policies to meet these changing circumstances and ensure our energy future is clean, reliable, and affordable for all Californians." The report admits: "In transitioning to a reliable, clean and affordable resource mix, resource planning targets have not kept pace to lead to sufficient resources that can be relied upon to meet demand in the early evening hours. This makes balancing demand and supply more challenging. These challenges were amplified by the extreme heat storm."[9]

   In the October 14 webinar held by the Power Association of Northern California with discussants from the CPUC, CEC and CAISO, the CEC representative, Siva Gunda, aptly stated that California needs "least-regrets" generation capacity to be built today, so that we can meet our long-term needs.
4. *The slow implementation of a truly integrated western regional grid, of demand response measures and distributed energy resources*. These measures have technical and political hurdles to overcome and will take time to fully implement. The desirability of an integrated western grid and WECC-wide supply planning has been recognized since at least the 1980s. CAISO's Energy Imbalance Market is a recent step toward improved operations across eight states.

   Demand response measures are important, but measurement, verification, and cost-effectiveness issues remain. DER received a boost this September from landmark FERC Order 2222, which allows DER aggregators to compete in all organized regional wholesale electricity markets in the US. FERC's Order should encourage innovation and enable competition to bring down consumer costs.[10]

5. *The failure to heed some of the key "lessons learned" from California's 2000-2001 electricity crisis and to penalize practices detrimental to the grid.* Twenty years ago, California experienced rolling blackouts/rotating outages during a period referred to as the California electricity crisis.[11] Market manipulation by firms such as Enron caused power shortages and rotating outages. One practice that contributed to power shortages in the real-time market was the chronic under-scheduling of generation resources in the day-ahead market. Under-scheduling by entities such as Southern California Edison violated FERC rules to schedule at least 95% of the next day's forecasted load in the day-ahead market. Eventually, chronic under-scheduling meant that sufficient generation was not procured to meet real-time demand; customers were curtailed.

   October's "Preliminary Root Cause Analysis" report shows that the current practice of under-scheduling contributed significantly to the August 14-15 outages: "Scheduling coordinators representing LSEs [Load Serving Entities] collectively under-scheduled their demand for energy by 3,386 MW and 3,434 MW below the actual peak demand for August 14 and 15, respectively… During the net demand peak time, the under-scheduling was 1,792 MW and 3,219 MW for August 14 and 15, respectively. The under-scheduling of load by scheduling coordinators [that reduced the day-ahead price] had the detrimental effect of not setting up the energy market appropriately to reflect the actual need on the system and subsequently signaling that more exports were ultimately supportable from internal resources. [Text added in brackets]"[12] Since the actual and net peak demands were 46,802 MW and 42,237 MW, respectively, on August 14 and 44,957 MW and 41,138 MW on August 15, under-scheduling distorted the market price and disrupted grid operations.

6. *Other interactions that contributed to the August 14-15 "perfect storm."* Additional areas of concern and actions to address other causes are described in the "Preliminary Root Cause Analysis" report. These actions include changes to the CAISO's Convergence Bidding process that "masked tight supply conditions" and enabled exports that should not have been scheduled, and changes to the CAISO's "residual unit commitment (RUC) process that provides additional reliability checks based on the CAISO's forecast of CAISO load after scheduling coordinators provide all of their schedules and bids for supply, demand, but excluding convergence bids."[13] The sheer complexity and interactions of these processes makes it quite difficult to stress-test grid operations in advance, particularly when good utility practices are not followed.

A Resilient Remedy Available Now: Geothermal Power

It is easy to forget that electric infrastructure is long-lived, capital intensive with lots of equipment beyond originally planned lives. The grid can't be entirely revamped in just a few years. One proposed panacea, expensive advanced battery storage, can't supply energy for longer than four hours and must be replaced and safely disposed of in about 10 years with significant adverse lifecycle environmental impacts. Like Northwest hydro generation, short-term and seasonal energy storage is energy-limited.

What if there were beneficial resources that would keep our lights on, when intermittent and energy-limited generators are not available? Fortunately, such a resource is already available, dependably supplying power during all California's outages. Figure 1 demonstrates that California's most dependable renewable resource is geothermal power. Geothermal energy uses Earth's abundant heat to generate around the clock, producing electric power and direct heat worldwide. In 2019, 15.4 GW of geothermal power operated in 27 countries. California is a world leader with 43 operating geothermal power plants with an installed capacity of 2.7 GW. However, it has been almost a decade since a new geothermal plant came online in California.

Geothermal energy can displace fossil fuels, charge a growing fleet of electric vehicles, balance the electric grid, and help countries around the world meet greenhouse gas reduction goals. Drilling costs are declining, and US contract prices for geothermal power are around $60-80/MWh. EIA estimates a total system levelized cost of $37.5/MWh for geothermal plants coming on-line in 2025.[14] Although this LCOE is higher than stand-alone solar and wind LCOEs, geothermal power provides several times more value over 8,760 hours than solar with batteries, because geothermal is 90-95% available, weather resilient and fuel-secure. It is estimated that 1 MW of geothermal with a much smaller footprint can economically displace 4-5 MW of solar with storage capacity.[15]

Recent advancements have made possible closed-loop geothermal (CLG) energy systems that can operate in a broader range of temperatures and rock compositions than conventional hydrothermal projects. CLG not only expands the potential supply of clean, carbon-free power, but does not require fracking and brings versatility by supplying both heat and power to new applications, such as hydrogen production, desalination, and lithium extraction.[16] CLG can also produce power from some unproductive geothermal and oil and gas wells.

Figure 2. GreenFire Energy's demonstration of a Closed-Loop Geothermal (CLG) energy system at the Coso, California geothermal power plant. September 2019.

CLG systems require the creation of a sealed well or multiple wells drilled into the subsurface hot rock strata. A sealed pipe (or pipes) enables a working fluid to continuously circulate and absorb heat to be delivered to downhole heat exchangers or the surface. CLG can go much deeper and hotter than conventional hydrothermal projects, so the potential energy resource is many times greater. Because it only extracts heat, CLG does not produce unwanted substances, does not require fracking and will not cause seismicity.

During 2019, GreenFire Energy tested a CLG system at the Coso, California geothermal power plant. This successful demonstration extracted heat from an existing unproductive well, separately testing water and supercritical carbon dioxide as working fluids to generate power.[17] CLG projects are now being initiated in Asia, Europe, and North America.

Today, carbon-free geothermal energy systems are poised to make significant contributions to global decarbonization and worldwide energy and environmental needs. When innovative geothermal technologies are further developed and deployed, cost-effective geothermal energy will increase employment in the clean energy sector, while enhancing the reliability, resilience, and security of supply in electricity grids around the world.

Footnotes

[1] California ISO, "Fact Sheet: Outage Report – Heat Wave of August 2020."

[2] California ISO, John Phipps, "Briefing on System Operations." Board of Governors Meeting, August 17, 2020.

[3] CAISO, News Release, "ISO Stage 3 Emergency declaration lifted; power restored statewide." August 14, 2020.

[4] "Net load" is the electric load that remains after non-dispatchable solar and wind generation is supplied. Net load is met by dispatchable power plants, e.g., natural gas, nuclear, geothermal, hydro, biomass, and combustion turbines. Studies in 2015 projected an afternoon ramp-up of 13,000 MW by 2020, but in early 2019 the ramp-up reached 15,600 MW due to increased additions of solar and wind. California's net load profile is called the "duck curve," and is typically met by aging, load-following natural gas-fired power plants.

[5] Ibid.

[6] Public Safety Power Shutoffs were carried out to reduce the risks of electrical equipment igniting wildfires in areas with high winds and extremely dry conditions.

[7] Sepulveda, N, et al., "The Role of Firm Low-Carbon Electricity Resources in Deep Decarbonization of Power Generation." Joule 2, 2403–2420, November 21, 2018.

[8] California ISO, California Public Utilities Commission, California Energy Commission. "Preliminary Root Cause Analysis Mid-August 2020 Heat Storm," October 6, 2020. Cover letter to the Governor and Executive Summary, pp 2-5.

[9] Ibid.

[10] "DERs are located on the distribution system, a distribution subsystem or behind a customer meter. They range from electric storage and intermittent generation to distributed generation, demand response, energy efficiency, thermal storage and electric vehicles and their charging equipment." FERC News Release: September 17, 2020. Docket No. RM18-9-000. Item No. E-1, Fact Sheet, Order 2222.

[11] Sweeney, J., "The California Electricity Crisis." (Stanford, California: Hoover Institution Press, 2002), 291 pages, ISBN 0-8179-2911-8 (hardcover).

[12] California ISO, California Public Utilities Commission, California Energy Commission, "Preliminary Root Cause Analysis Mid-August 2020 Heat Storm," October 6, 2020. Executive Summary, pp 12-14.

[13] Ibid.

[14] U.S. EIA, "Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2020," February 2020.

[15] Bartosz, A and Thomsen, P., "The Value of Geothermal in California," GRC Bulletin, Vol. 49, No. 3, June 2020: "...while geothermal is not the lowest cost resource on a levelized cost basis, it is by far the highest economic value in renewable resources that are operating in California and the surrounding region. Even as we see the contract prices for wind, solar PV, and lithium ion battery prices decline, geothermal's economic value over the life of long-term purchase agreements remains competitive as California and the region move to higher penetrations of renewable energy."

[16] Van Horn, A.J., et al., "New Opportunities and Applications for Closed-Loop Geothermal Energy Systems." Geothermal Resources Council Transactions, Vol 44, 2020, pp 1123-1143.

[17] GreenFire Energy, "Closed-Loop Geothermal Demonstration Project, California Energy Commission report, CEC-300-2020-007, June 2020.

Attempt to save Soviet-era electricity network: Uzbekistan case to reform electricity generation industry.

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"Energy is the "oxygen" of the economy and the life-blood of growth, particularly in the mass industrialization phase that emerging economic giants are facing today..." - Peter Voser CEO, Shell, World Economic Forum.

Overview

Today Uzbekistan is a Post-Soviet country in Central Asia with a 34 mln of population and $58 bln of GDP. It is located in the heart of the Central Asia Region, occupying a geopolitically strategic position between Russia and China. For almost three decades, the country was mostly closed to the outside world due to the post-soviet period of uncertainty, civil wars in neighboring countries, and gradually intensified authoritarian regime under the first President's I. Karimov 26-years rule. With an iron fist and cracking down all political opposition, this regime led the country to one of the most corrupted[1], unattractive to foreign investors, and state-regulated in leading industries. The oil and gas sector was the only one that could boast of a short period of investment, from 2005 to 2014, from Petronas, CNPC, KNOC, Lukoil, Gazprom, and several more foreign companies. However, no oil boom occurred, and some companies left the country with a political scandal[2]. Only Lukoil has shown a successful business development strategy, and today accounts for about 25% of all gas production in the country. Significant changes on political and economic fronts have been outlined by the death of long-serving leader Islam Karimov. The rise of his accessor President Shavkat Mirziyoyev has enabled the country to pursue a new course and move away from the authoritarian state-led model. One of the main reforms was the liberalization of the foreign exchange. All state statistics have been tied to the previously fixed exchange rate while the residents could not publically buy foreign currency. Therefore, GDP was artificially inflated, the prices for gas, electricity, and other household utility services have been set. The prices haven't reflected the economic or market component. Among the reforms, new President declared a target to improve the investment climate with the further goal of privatization and deregulation of the economy. The oil and gas and, for the first time, the generation industries have become key targets of new reforms.

Problem statement

The scientific lay of literature gives numerous evidence that economic growth directly depends on access to energy sources (U.S. Energy Information Administration, 2017; Yergin and Gross, 2012; Ozturk et al., 2010; Fotis et al., 2017). Natural gas (84.8%), coal (5.2%), oil (8.8%), a small amount of water power (1.2%), and biowaste (<0.01%) are the primary energy sources in Uzbekistan (Figure *1*, *A*). It can be noted that neither the energy balance nor the consumption of energy resources has structurally changed. Moreover, looking at (Figure *1, B*), one can see the perceptible oddity. While energy consumption and its structure have not changed, the population in 20 years added almost 10 million people. The officially reported GDP grew at an incredibly high rate at an average of 6% per year.

Unfortunately, the main reason was the reduction in energy consumption per person and the deliberate distortion of statistics towards its overestimation. The new President first recognized these challenges. Among the systemic problems is state regulation of prices for electricity, gas, water, and other utilities, depletion of gas fields and reduction in production, obsolescence, and deterioration of infrastructure built in Soviet Union times (Figure *2*), an insolvent population with high

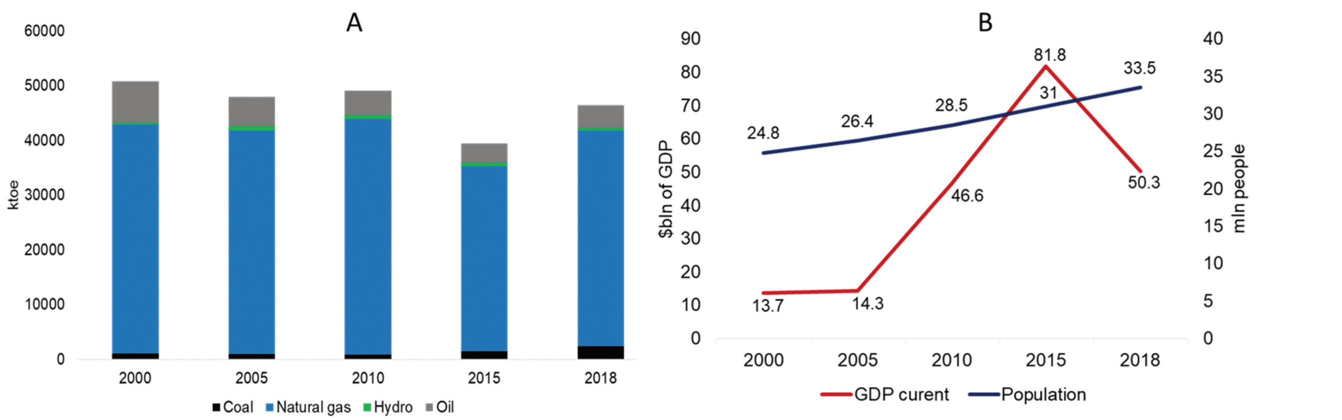

Figure 1. Energy mix, population, and GDP growth in Uzbekistan 2000-2018. Sources: EIA, World Bank.

Figure 2. Sample picture of old gas distribution facilities in the Tashkent Region, Uzbekistan. Source: author.

unemployment and, as a result, with massive debts for utilities, and a high level of corruption.

The problems lead to corresponding consequences. Thus, the old infrastructure leads to systematic blackouts and shutdowns in cold-season times, supply interruptions, and, most importantly, leaks and losses during gas transportation or electricity transmission. Infrastructure problems do not also allow full loading of oil refining capacities[3]. Gas shortages have led to a massive transition of transport vehicles to CNG coupled with the ban on gasoline or diesel fuel imports. In the absence of significant fossil fuel production growth and specifically natural gas (Figure *3, A*), this expectedly affected electricity generation and ways to save consumption. Not surprisingly, given fixed prices on electricity, the only way to balance the system is to keep consumption. Therefore, electricity cut-offs can often be observed in rural areas for no reason. While regions are accustomed to living for days without electricity and gas, these problems have not been felt in the capital (Tashkent) for a long time and have not received due attention. Even now, schools and kindergartens in the rural areas are heated by the so-called "kizyak" (manure-made bricks) that is a significant pollutant.

Thus, the lack of growth in energy sources production, ineffective management system, and a lack of infrastructure renovation have led to a decrease in the evolution of energy and electricity consumption per capita. At the same time, the electrification level in the country is almost 100%. The main problem in the short and long-term is the practical reform of the generation industry to fully secure and sustainably meet the demand against the decrease in fossil fuel extraction and natural gas production (Figure *3, B*).

Reforms and proposed solutions

Electricity market reforms took place in many countries with different economic development levels (Littlechild, 2006; Abbott and Cohen, 2018; Toke, 2011; Arciniegas et al., 2003; (Gencer et al., 2020). At the heart of the reforms, a common feature was the industry unbundling into generation, transmission, and delivery to consumers. Further reforms mainly consisted of creating wholesale markets, balancing, consumer zoning, and privatization. Researchers propose that proper policy regulation leads to competition and consumer price drop as a consequence (Hartley et al., 2019; Kaller et al., 2018; Ahmed and Bhatti, 2019). Unlike proponents of reforms, other researches show that privatization and deregulation do not necessarily guarantee reliable supplies and the lowest prices since oligopolists, dominating suppliers, and collusion can occur, leading to shortages and insecure supply (Woo and Zarnikau, 2009; Woo et al., 2003; Del-Rio et al., 2019; Valadkhani et al., 2018) and even weakening competition (Letova et al., 2018).

The new concept of the reform of the generation industry in Uzbekistan is based on:

- unbundling and further privatization;
- energy efficiency;
- renewable energy sources development,
- renewal and building new infrastructure.

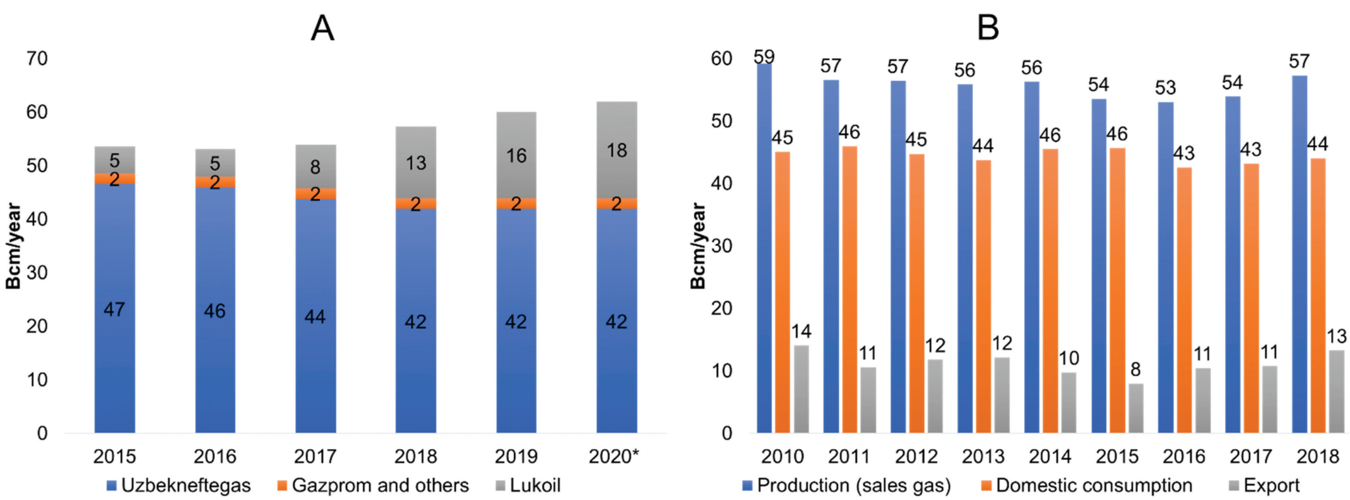

Figure 3. Gas production by company in Uzbekistan (A) and gas balance (B). Source: Oxford Institute for Energy Studies (Pirani, 2019), Uzstat.

The authorities also see the solution in a nuclear power plant construction. Unfortunately, neither the infrastructure nor the consumers are ready for this due to a high unemployment rate and insolvent demand. Besides, the country has serious problems with the water supply to talk about nuclear energy easily. According to the National Concept of Power Generation Industry Development and IEA, by 2030, Uzbekistan will raise the share of renewables in energy balance

Table 1. Uzbekistan generating capacity targets to 2030. Source: IEA, Ministry of Energy of Uzbekistan.

Indicator	Forecast generation capacity increase (MW)					Share of electricity generation, %	
	2019	2020	2021	2022	2023-2030	2018	2030
Total	1074.1	886.8	1961.5	1061.6	14017.8	100	100
Traditional energy	1050	1807	1777	2259.4	10910.2	90	75
Including capacity withdrawal	0	1060	320	740	4280	0	0
Total renewables	24.1	119.8	504.2	542.2	7387.6	10	25
hydropower	24.1	119.8	204.5	42.2	1487.6	10	11.2
solar power			300	400	4300		8.8
wind power				100	1600		5

from 0% (excluding hydropower) to 25% and more than double its current generation capacities.

The concept raises many challenges, given that, according to statistics from the Ministry of Energy of Uzbekistan, more than 40% of the infrastructure has been in operation for more than 50 years and has more than 80% wear and tear. This, however, did not prevent regulators from starting market sharing reform. The approach is very similar to the reforms undertaken in other countries, especially Georgia (Asian Development Bank, 2015). It involves allocating generation, transmission, and delivery to consumers with further privatization and developing a guaranteed transmission operator.

Will the new reform provide a reliable electricity supply and eliminate shortages and blackouts?

Despite a reasonably logical general concept of reforming the industry, its main drawback is that it is like two peas to reforms in many other countries. Unfortunately, as studies above show, reform and privatization have led to security supply and sustainable power generation not everywhere. The concept worked out by the Ministry of Energy doesn't contain a plan following characteristics of the current state of the industry in the country and under socio-economic realities

In October 2020, Uzbekistan reported a 20% drop in natural gas production and warned all household consumers about expected electricity shortages. The authorities also warned that they would disconnect all catering, restaurants, and all other food providing business owners from the gas supply for at least the whole winter. It means that the lack of natural gas puts the authorities before choosing whether to supply consumers with the gas or redirect it to electricity generation. In 2020, there is still no stable electricity and gas supply in the regions. The authorities continuously report solar power plants' launch and intentions to build a nuclear power plant.

The country lacks a substantiated assessment and plan for further developing regions and remote areas. Considering that the development of industries, schools, hospitals in the whole country is impossible without access to energy is unbelievable without a well-developed plan and strategy,

The following aspects and barriers will hinder the successful implementation of the concept:

1. Reforms are not consistent. All stages are carried out in parallel: infrastructure renewal and plans for constructing solar power plants. Expectedly, there may not be enough funds, and some of the steps may not be implemented.

2. The system is not ready. More than double capacity in less than ten years, taking into account 50% of obsolete capacity, means constructing and renewing at least an additional 150% capacity. With a rise in government debt, a severe recession during the COVID-19, and a decline in exported gas prices, other loans or an increase in prices will be required. Renovating the electrical system includes many aspects up to replacing the meters for the residents. This plan looks too unrealistic for the current economic situation in the country.

3. The low-income population will suffer. Regulators do not consider the low incomes of the people. With the simultaneous privatization and reconstruction, the inevitable rise in prices will lead to a social crisis in

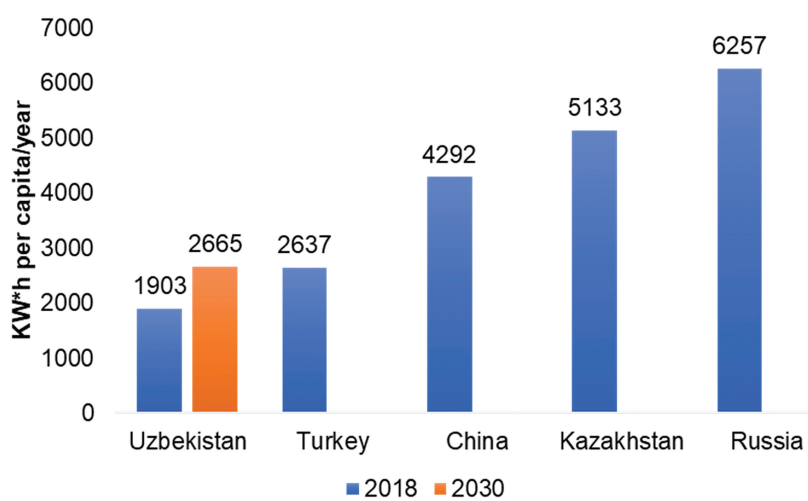

Figure 4. Electricity consumption per capita in different countries. Sources: Ministry of Energy of Uzbekistan, World Bank.

the country where income today is less than $2000 per year on average.

4. Still not enough. Even such an ambitious plan, if it is yet implemented, will not equalize Uzbekistan in terms of consumption and access to electricity at the level of some developing countries today. No doubt, a more strategic plan is needed in line with the forecast of population growth and the prospect of developing industries.

Conclusion

The energy reform is undoubtedly necessary for the country after almost 30 years of stagnation. However, reforms must be real and correlate with the country's ability to release them, despite the world's current trends, and no matter how much the state wants to develop more clean energy. It is most reasonable for Uzbekistan to start consistently, without shocks for the population, increasing the potential of existing power units and increasing electricity generation in general, even if at the initial stage it will be coal-fired. At the same time, it is necessary to develop a legislative framework for renewable energy and carry out privatization and deregulation of the market when all industries and populations will be ready for new clean energy sources.

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Footnotes

[1] Transparency International. URL: https://www.transparency.org/en/countries/uzbekistan (date accessed: 11.11.2020)

[2] See for example. URL: https://www.azernews.az/oil_and_gas/54364.html and https://www.refworld.org/docid/52f20719100.html (date accessed: 11.11.2020)

[3] See interview of the Minister of Energy of Uzbekistan to Petroleum Econmist. URL: https://www.petroleum-economist.com/articles/midstream-downstream/refining-marketing/2020/uzbekistan-plans-giant-leap-in-refining

Problems with the "Reformed" New Zealand Electricity Market

BY GEOFF BERTRAM

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1. Introduction

Radical reform of the New Zealand electricity system commenced in 1986 and took three decades to complete. The final shape of the restructured sector has now been established for nearly a decade and there is adequate published data to support evaluation of outcomes against the promises of the architects and promoters of reform. Three key areas are considered in this paper: economic efficiency, social equity, and physical reliability of supply.

The reform agenda carried through from 1986 to 2014 was premised on the idea that reliability of physical supply could be maintained to a high standard while introducing "market disciplines" - first to drive economic efficiency gains, and second to ensure that those gains were passed through to consumers (especially low-income domestic consumers). The risk from the outset was that market forces, once unleashed, might yield opportunism, rent-seeking, and monopolistic price gouging, rather than outcomes consistent with textbook perfect competition. The failure by policymakers to anticipate that risk has led in practice to failure of the reform programme in terms of those original goals. Along the way, powerful vested interests have been created which now block the path to fixing the problems that have emerged.

2. Summary of the reforms[1]

The pre-reform structure comprised two tiers of publicly-owned monopolies, each with a democratically-enforced mandate to supply electricity as an essential service on a non-profit basis, at prices that recovered all costs on a cash basis. The top tier - bulk wholesale supply – was owned by central government and comprised large-scale central generators integrated with a national transmission grid and a merit-order dispatch system. The lower retail tier was part of local government and comprised local distribution networks integrated with retailing, appliance sales and servicing, and some small-scale local generation.

Designed and run by engineers to high standards of both construction and physical performance, the pre-reform system provided households and industry with the fourth lowest power prices in the OECD[2], while sustaining a massive programme of infrastructure construction to keep ahead of growing demand. Peak shaving was done by remotely-operated "ripple control" of electric water heaters, and the hydro lakes were managed with a constant eye to preserving stored water against the risk of a dry winter. As an example of a planned publicly-owned system designed for the specific conditions of New Zealand and operated using optimal control principles, the New Zealand electricity system was outstandingly successful.

Why, then, did policymakers in the 1980s and 1990s embark on a radical and disruptive reform programme? The central motivation was ideological - the familiar neoliberal desire to shrink the public sector and privatise as much of it as possible. Supporting this was the fiscal authorities' perception that investment spending needed to increase while the revenue-generating potential of state-owned enterprise in general was being suppressed by the political goal of keeping prices low.

Always in the background in the 1980s was the strong international tide of economic opinion in favour of electricity sector restructuring, triggered first by the US Carter Administration's quest to remove entry barriers for new providers (the 1978 PURPA legislation) and second by new thinking about markets for power stemming from the work of Schweppe and Joskow. Opening the New Zealand electricity sector to competitive new entry and corporate profit-oriented management seemed in tune with this international current of opinion, and might (local reform proponents hoped) uncover efficiency-enhancing options suppressed or overlooked under the not-for-profit engineer-dominated regime.

The reforms began with two pieces of legislation. First was the strongly deregulatory Commerce Act 1986 which removed not only the previous automatic regulation of monopoly profits but also most barriers to anti-competitive conduct. Second came the State-Owned Enterprises Act 1986 which converted former government departments into commercial corporate entities with profit-maximisation as their goal, and with social equity objectives explicitly removed from their mandate[4].

Restructuring of electricity began with the state-owned generation-transmission monopoly, which was quickly corporatized in 1987. To prepare it for privatisation it was then split into two separate generation and transmission companies[3]. In November 1995 the generation company was split up into two state-owned companies, ECNZ and Contact Energy; then in 1999 ECNZ was split into three, while Contact was privatised. Finally, during 2013 and 2014 the Government part-privatised the remaining state-owned generators by selling off 49% of the shares on the open market.

Meantime at retail level, in 1992 the Energy Companies Act forced the former Electricity Supply Authorities (ESAs)(against much local opposition) to corporatize by 1994, and subsequently several of the larger ones were privatised.

Next came the creation in 1996 of a wholesale market which in theory was supposed to enable new retailers to enter and compete to supply final consumers with electricity purchased wholesale from grid-connected generators and delivered to local networks by the transmission grid.

With the ostensible intention of opening up space for retail competition, in 1999 the former ESAs were compelled to divest either their lines networks or their generation and retail activities. All except one (Trustpower) opted to keep their lines networks and to sell off their generation and retail activities. Far from opening the way for retail competition to flourish, the absence of regulatory restraint enabled the large generators to snap up blocks of retail customers, creating vertically-integrated energy companies known as "gentailers" with massive market power.

As of 2020, the industry's post-reform structure is fully bedded in. Generation and retailing are dominated by five large players with a small marginal "fringe" at each level. Transmission and system operation remain in the hands of a state-owned monopoly, Transpower. The natural-monopoly local lines networks are held partly by large corporates (some of them owned by municipal authorities) and partly by smaller companies owned by consumer trusts (an arrangement that reflects local defiance of the dictates of central Government reformers as well as the genuine advantages of local trust control[5]).

3. Efficiency outcomes

The belief of the New Zealand Treasury in 1984 was that untapped potential efficiency gains were waiting to be captured in publicly-owned enterprises and that corporate, profit-driven management was the way to realise those gains. Experience has not borne out either of those hopes. The best evidence on the outcome of reform comes from the productivity statistics prepared as part of the annual national accounts. Those statistical series enable us to track various sectors' labour productivity, capital productivity and total factor productivity, in terms both of output per unit of inputs and of value added per unit.

Over the thirty-three years 1986-2019, the sector "electricity, gas distribution, water and waste services" – a sector which is dominated by electricity - has exhibited a dramatic decline in its productivity; see Figures 1-4. Figure 1 shows that up to the mid-1980s when reform began, this sector was one of the economy's star performers but that since then it has switched from positive productivity growth to steadily-worsening productivity decline. Multifactor productivity was down by over 30% in 2019 compared with 1986. Over the nineteen years 2000-2019 (shown in Figures 2 and 3) labour productivity fell roughly 40%

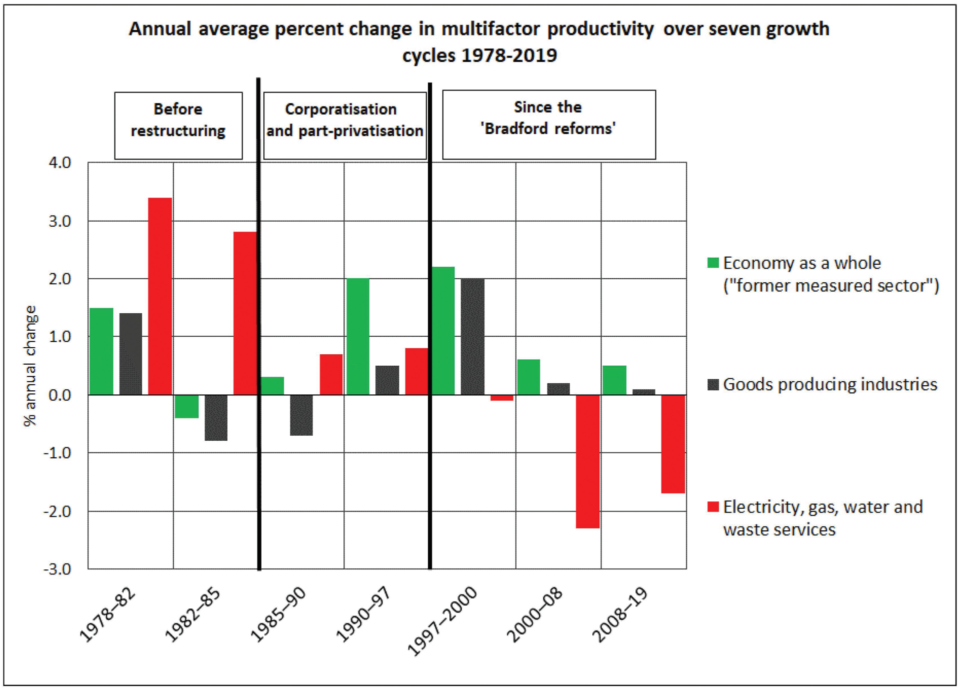

Figure 1
Source: Statistics New Zealand, Productivity Date 1978-2019, downloaded February 2020 from https://www.stats.govt.nz/assets/Uploads/Productivity-statistics/Productivity-statistics-19782019/Download-data/productivity-statistics-1978-2019-productivity-by-industry.xlsx

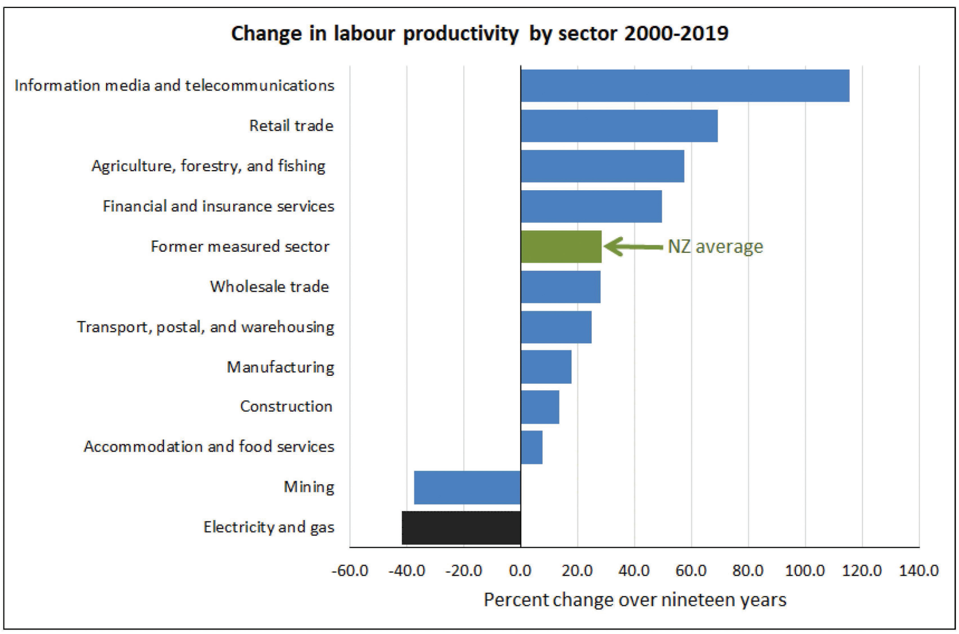

Figure 2
Source: Statistics New Zealand

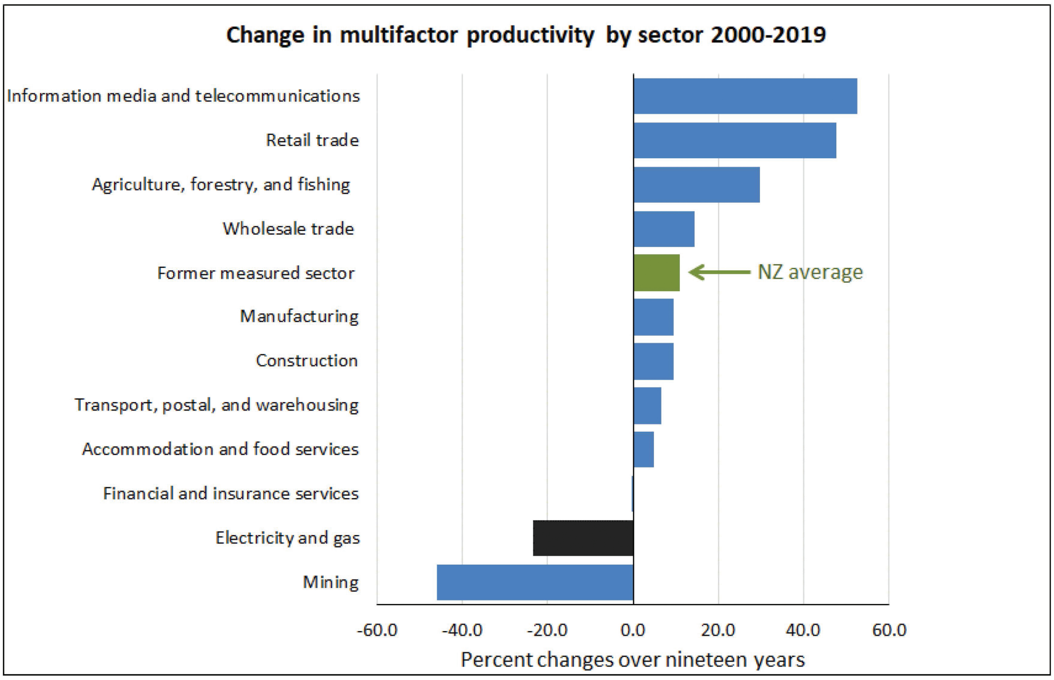

Figure 3
Source: Statistics New Zealand

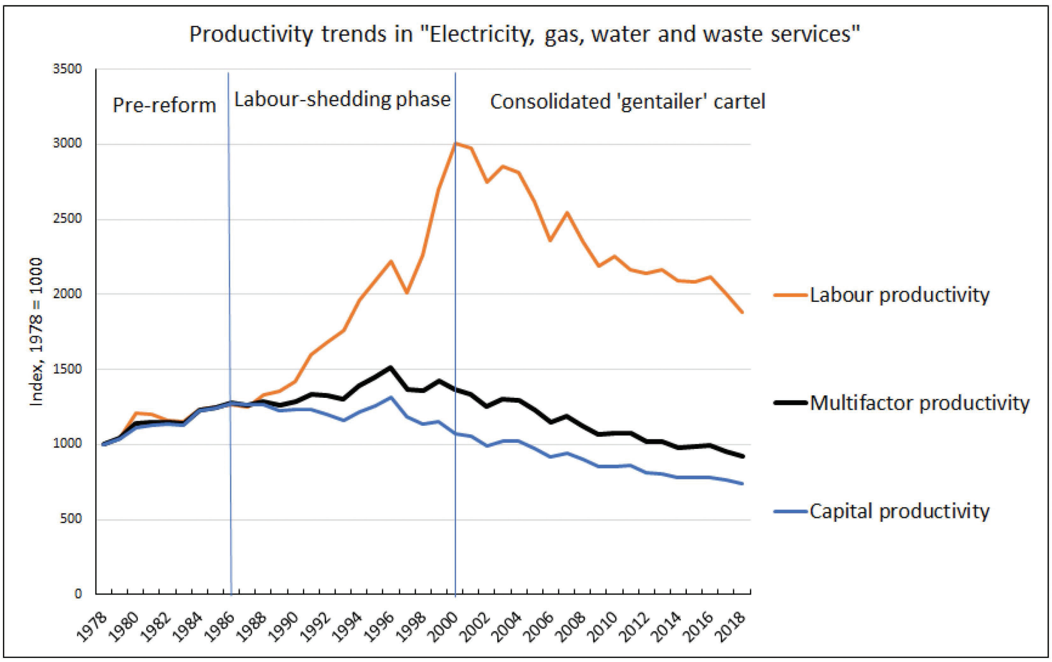

Figure 4
Source: Statistics New Zealand online Infoshare Table PRD014AA as at 21 February 2019, from http://infoshare.stats.govt.nz/infoshare/.

while multifactor productivity fell more than 20%, in an economy where other sectors (apart from mining) exhibited rising productivity.

The sole sign of efficiency gains under market-driven corporate management came in the sector's labour productivity surge during the first decade (Figure 4), as ruthless labour-shedding was driven through. In the one-and-a-half decades 1986-2000 the industry's labour force was halved, producing the short-lived "sugar high" in labour productivity seen in Figure 4, before the consolidated post-reform industry began hiring again, more than doubling its labour inputs 2000-2019. But whereas the early-stage layoffs consisted to a large extent of technically-proficient engineering and maintenance staff, the new hirings since 2000 have been focused on marketing, PR, financial management, executives and legal staff, all on high salaries but many of them performing unproductive roles in terms of what the national accounts measure.

4. Prices and profits: the equity issue

While productivity sagged, the industry's profits rose dramatically over the three decades of reform, on the back of a doubling of the electricity prices charged to household consumers (industry's prices barely changed while prices to commercial users fell).

These price trends, seen in Figure 5, reflect very clearly the degree of countervailing market power exercised by the three groups of consumers in the face of monopolistic conduct by suppliers. Strong countervailing power exercised by industrial and commercial interests has enabled them to resist price increases in real terms, which has shifted the burden of funding the industry's rising monopoly rents and falling productivity onto dispersed and powerless residential consumers, who have lacked any powerful champion to offset the industry's imposition of Ramsey pricing principles. Central government, which in pre-reform days treated residential electricity supply as an essential service and held prices down, has since 1986 treated the industry as a fiscal cash cow and has welcomed the dividend revenue from

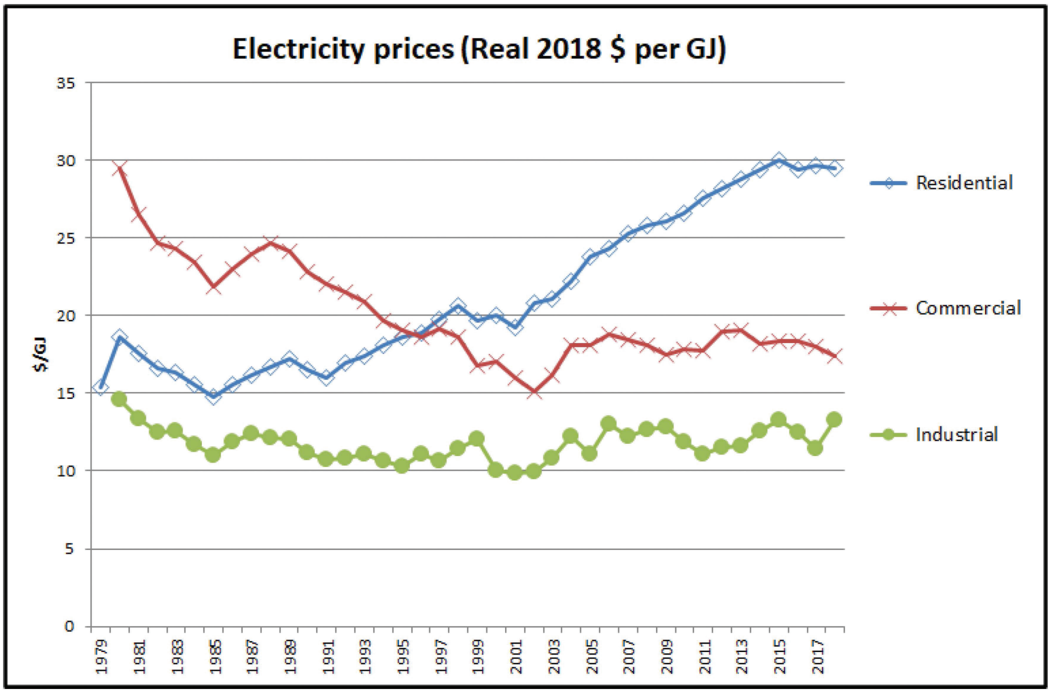

Figure 5
Source: https://www.mbie.govt.nz/assets/Data-Files/Energy/nz-energy-quarterly-and-energy-in-nz/Prices.xlsx downloaded November 2019.

its ownership stakes in generation, transmission and retailing (Barry 2018). No regulatory mechanisms exist to control the detailed structure of retail prices. (The Commerce Commission ineffectually regulates the total revenue allowed to lines networks but not its allocation across customer groups. The Electricity Authority exercises no price control functions.)

There was from the outset a regulatory problem associated with placing strategic public assets into the hands of corporate management, often combined with private ownership. Enormous market power is associated with the supply of electricity by a large centralised system in a country as small as New Zealand, with no pricing discipline available from international trade (there is no prospect of interconnection with the nearest country, Australia). The clear risk was that the new managers - oriented to profit and shareholder value - would pursue cost-cutting and price-hiking to inflate margins and raise asset values, rather than passing gains through to consumers. To confront this threat, the original reform architects foreshadowed policy measures (i) to prevent natural-monopoly lines owners from exercising that monopoly power, and (ii) to facilitate open entry and exit in the generation and retail markets.

In the event, no such effective policies were forthcoming. In the case of lines networks, over the decade 1994-2004 the owners were not merely permitted, but actively encouraged, to drive their prices, profits and asset values up to textbook monopoly profit-maximising levels, in the mistaken belief that “market contestability” would then provide some equivalent to competitive disciplines. From 2008 on the companies were then placed under a standard regulatory regime that locked-in the monopoly asset values while guaranteeing a commercial return on those assets and fully indexing company revenues and profits to inflation. The resulting transfer of wealth from consumers to producers has been of the order of several billion dollars and the regulator (the Commerce Commission) has served as a shield behind which the companies have sustained their profitability. The story of lines regulation has been a classic example of regulatory capture.

For generation and retailing the story was more complex but no less negative in its effects on residential consumers. The two separate activities of producing and selling energy were considered potentially competitive, and the original premise of reform was that freedom of entry and exit would impose competitive pricing discipline and drive innovation. In practice, any hope of competitive outcomes was foreclosed in 1999 when Government permitted the five large generation companies to buy up the retail customers being forcibly divested by distributors. Once vertically integrated, the resulting cartel of large ‘gentailers’ successfully erected strong barriers to independent entry and relegated the few surviving independent retailers to perpetual fringe status.

The industry’s favoured anticompetitive practice has been the withholding from independent would-be retailers of access to a full range of arms-length competitively-priced hedge contracts that could protect them from being squeezed by wholesale price spikes at time of supply shortage. While the gentailers themselves stand to gain from shortages that raise prices, independent retailers without secure contracted supply are continually at risk of being bankrupted. The most spectacular instance of this exercise of market power to drive out independents was the 2001 bankruptcy of OnEnergy, a large retailer that lacked generation assets of its own and consequently was dependent on wholesale market supply. Despite being owned and backed by a deep-pocketed overseas company (Australia Gas and Light), OnEnergy quickly folded after incurring hundred of millions of dollars of losses. The experience confirmed that to survive as a large independent retailer in the New Zealand market, it is essential for a company to be internally hedged by owning its own generation. Retailers without such in-house supply can never hope for more than a precarious existence at the outer margins of the market. There has to date been no effective regulatory response to the problem despite it having been well recognised since the 1990s.

A great deal of regulatory effort has, in contrast, gone into the promotion of retail switching by small customers, and high churn rates (driven by promotional hype as much as by continual customer frustration with rising prices) have been hailed by the Electricity Authority as evidence of retail-level competition. No actual competitive discipline on prices flows from high switching rates, however, because the members of the 'gentailer' cartel have no incentive to expand their retail market shares beyond the limits of their in-house generation. (No gentailer wishes to be placed in the position that On Energy faced in 2001, of being exposed to wholesale price spikes charged by its notional competitors.) Overall retail market shares have consequently been very stable throughout a decade of supposedly fierce competition. However, to satisfy the political need to demonstrate some progress, the industry has shuffled its retail customer bases across regions to produce lower regional Herfindahl-Hischman indices, which the Electricity Authority proudly parades as evidence of regulatory success.

5. Physical reliability

In the context of the industry's failure to improve efficiency and the massive equity costs of the reforms, the only bright spot is that the lights have stayed on. With occasional hiccups (see below), New Zealand's electricity supply has been maintained at a high standard of reliability, by the dedicated efforts of engineers at all levels.

The hiccups, however, speak volumes about the effects of shifting from an engineer-driven to a profit-driven model. A familiar and predictable pattern of conduct by profit-driven management is to cut back on maintenance spending, and the radical labour-shedding and cost-cutting of the first decade of reform resulted in a legacy of costly failures. The first of these, in 1998, caused a total blackout of the business centre of the biggest city, Auckland, for five weeks in 1998[6]. The second, in 2006, again cut power to Auckland due to failure of a corroded Transpower shackle at a substation[7].

A catastrophic failure of the inter-island HVDC link loomed as a threat when the link was allowed to be reduced to a single pole between 2008 and 2013[8] as the single remaining pole began to deteriorate; an additional line was hastily installed, but only after the country had (by good luck) survived several years at less than the recommended (n-1) level of security.

Most recently Aurora Energy, the lines operator serving Dunedin City and the Central Otago region, incurred a $5 million legal sanction for increasing outages resulting from decades of sweating its assets, and is being allowed by the regulator (the Commerce Commission) to raise its prices to fund a $400 million upgrade of its systems. (As usual the regulator has required no write-down of the high valuation of the existing deteriorated assets on which customer charges are calculated, so that the full burden of remedying the company's failure falls not on its owners but on its customers[9].)

Beyond these hiccups lie two much bigger issues for the future. One is the issue of dry years. The other is the role of the electricity industry in decarbonising the New Zealand economy in response to the threat of climate change.

The dry-year issue

New Zealand's electricity system is dominated by hydro generation which accounts for roughly 60% of total supply. Because the dams are on long narrow rivers they have very limited storage capacity, which means that a winter with low rainfall results in shortages. The problem for planners has always been how to protect against these events. In the pre-reform era the solutions were giant construction programmes to increase total capacity ahead of demand growth, combined with rationing arrangements (power cuts) when shortages struck. Reform proponents suggested that the switch to market disciplines would result in some optimal response to the issue. In practice the opposite was the case. A dry-year produces system-wide stresses requiring a coordinated response, while individual generators have no ability nor incentive to solve the problem on their own. Unsurprisingly, industry players opted to free-ride in the knowledge that in a dry year the government would have no alternative but to implement some sort of rationing arrangements, while the shortages would bring high prices (hence profits) for the gentailers.

This classic coordination failure was on show in 1991, the first serious dry year of the reform era. Not only had commercial management allowed lake levels to drop below prudent levels over the previous summer; they responded to the experience of being obliged to operate high-cost fossil-fuelled plant during the shortage period by immediately decommissioning that plant as soon as the crisis had passed, increasing in the process the economy's exposure to future recurrences.

The next dry year was in 2001 and again the industry collected high prices while leaving Government to manage the rationing. Fortunately since then there has been no major episode – but the industry's investment programme has failed to improve the economy's resilience. On the contrary, gentailer-owned windfarm sites for which consents were granted years ago have remained undeveloped (but withheld from independent entry), and the industry (supported by its ostensible regulator the Electricity Authority) has obstructed the entry of distributed generation – particularly rooftop solar – that could provide dry-year insurance but would threaten the gentailers' profits and market share.

The latest development is that given the industry's failure to provide dry-year security of supply, the burden of doing so is to be picked up yet again by taxpayers, through the proposed spending of $4 billion of a huge pumped-storage scheme at Lake Onslow in Otago.

Climate change

Electrification of the economy will be central to New Zealand's ability to meet ambitious greenhouse-gas emission targets. Again the profit motive has proven counter-productive in the absence of effective regulatory policy. New Zealand's main policy instrument to place a price on carbon emissions is its Emissions Trading Scheme (ETS) which interacts in a strikingly perverse way with the structure of the wholesale electricity market. The market, by design, sets the spot price at the highest offer price in the generation merit-order stack, which means for most of the time one of the fossil-fuelled generators, whose costs (and hence bids) include the carbon price. Because all generators receive the same price, the effect is that electricity consumers are forced to pay carbon tax on electricity supplied from hydro and wind. But since hydro and wind generators pay no carbon tax on their operations, the resulting revenue flow goes directly to their bottom lines and asset values.

The result is that the ETS which is ostensibly aimed to incentivise a move away from carbon instead creates a perverse incentive both to dampen down substitution in final energy uses away from fossil fuels towards electricity (for example, switching from internal combustion cars to electric vehicles) and for electricity generators to ensure that there is always fossil-fuelled generating plant at the market margin.

6. Conclusion

This quick overview of some of the major features of New Zealand's experience with electricity sector reform has not found much to celebrate. Certainly the promises that were made by policymakers at each stage of the reform process have proved to have been empty ones. Neither efficiency gains nor lower consumer prices have been achieved. Confronting future needs for dry-year security of supply and decarbonisation of the economy will involve difficult policy choices in the face of well-organised and strongly funded rentier vested interests. The strength of the industry's position in opposing effective regulatory change is reinforced by the fact that part-privatisation has created an alignment of interest amongst the big industry corporate players, a substantial cohort of share-owning citizens, and a Treasury that continues to collect large sums in dividends and taxes from the profits that would be squeezed by regulation.

Footnotes

[1] For detail see Bertram (2006, 2013, 2016) and MBIE 2015.

[2] International Energy Agency, *IEA Energy Prices and Taxes Statistics*, database accessed through OECD i-Library, 1986 data comparing prices in US dollars at Purchasing-Power-Parity.

[3] See Geoff Bertram "Why the Commerce Act 1986 is unfit for purpose" *Policy Quarterly* 16(3): 80-87, August 2020, https://ojs.victoria.ac.nz/pq/article/view/6562/5726.

[4] A 1987 District Court judgment confirmed that the profit goal overrode all others unless Government exercised its power under the Act to direct, and pay for, pursuit of any other goal. That power has never been exercised in relation to electricity supply.

[5] Kalderimis 2000.

[6] See https://en.wikipedia.org/wiki/1998_Auckland_power_crisis .

[7] See https://en.wikipedia.org/wiki/2006_Auckland_Blackout .

[8] See https://en.wikipedia.org/wiki/HVDC_Inter-Island

[9] See https://comcom.govt.nz/__data/assets/pdf_file/0017/228023/Draft-decision-Aurora-Energy27s-proposal-to-customise-its-prices-and-quality-standards-12-November-2020.pdf .

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The German Example – 20+ Years of Secure Electricity Supply after Liberalisation

BY ROBERT DIELS, MARTIN LIENERT, AND FELIX MÜSGENS

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Abstract

Germany relies on the market design of an Energy-Only-Market. Over the past 20+ years, quality of supply improved, and Germany has not seen a single hour of insufficient capacity. At the same time, RES-E increased substantially. Nevertheless, Germany decided to implement a Strategic Reserve as additional 'braces to the belt'.

Index Terms: *Resource Adequacy, Market Design, EOM, CRM, RES-E integration, Security of Supply, Strategic Reserve*

1. Introduction

Around 25 years ago, the European Union passed EU directive 96/92/EC which liberalised electricity generation in Europe. Germany implemented this European directive into national law with a reform of the Energy Law – Energiewirtschaftsgesetz (EnWG) – in 1998.

Since then, Germany relies on the market design of an Energy-Only-Market (EOM) and recently on the so-called EOM 2.0, which is characterized by an EOM accompanied by a strategic reserve. In the meanwhile, Germany has seen numerous capacity additions as well as substantial decommissioning's of older conventional power plants accompanied by a sharp increase of intermittent RES-E penetration by wind and solar. The quality of supply enhanced further during these RES-E additions, shown by the development of the System Average Interruption Duration Index (SAIDI). Additionally, Germany has not seen a single hour of insufficient capacity for more than twenty years, i.e. close to a full investment cycle. Since 2005, only one event of forced load shedding occurred due to a grid fault (so called "Emslandzwischenfall").

Hence, we argue in this article that an EOM can provide power supply reliably over long periods of time, even despite a sharp increase in intermittent RES-E. We believe this is an important contribution to the literature because it is often stated in public debates (at least across Europe), that CRMs are needed to guarantee a certain Resource Adequacy- (RA-) Level (i.e. reliable power supply). And even if conventional systems could reliably provide power, at the very latest additional intermittent RES-E penetration would tip the system. As of today, neither of these concerns materialised in the German example.

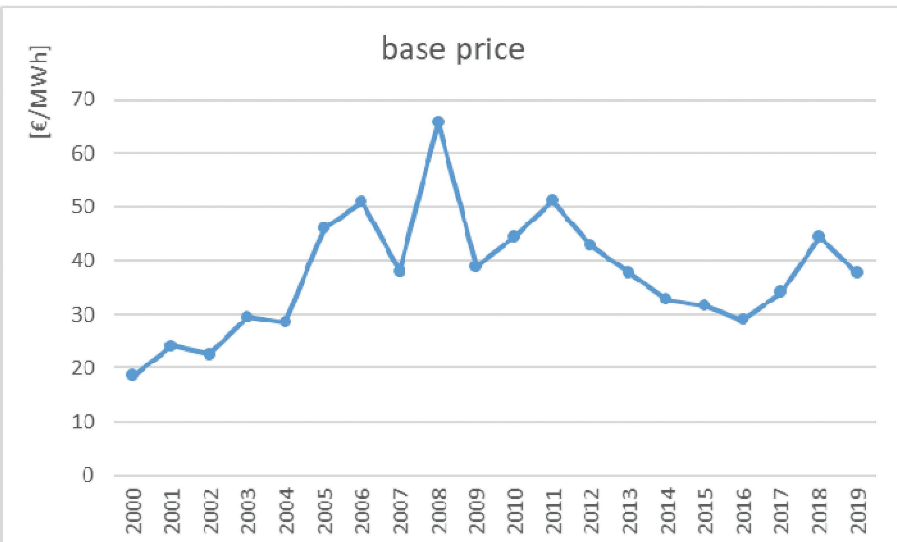
In the following we analyse market design in Germany since liberalisation, discuss theory and empirics of flexibilization in the electricity system and give insights into the empirics of security of supply indices and market induced load-shedding.

2. Past Developments

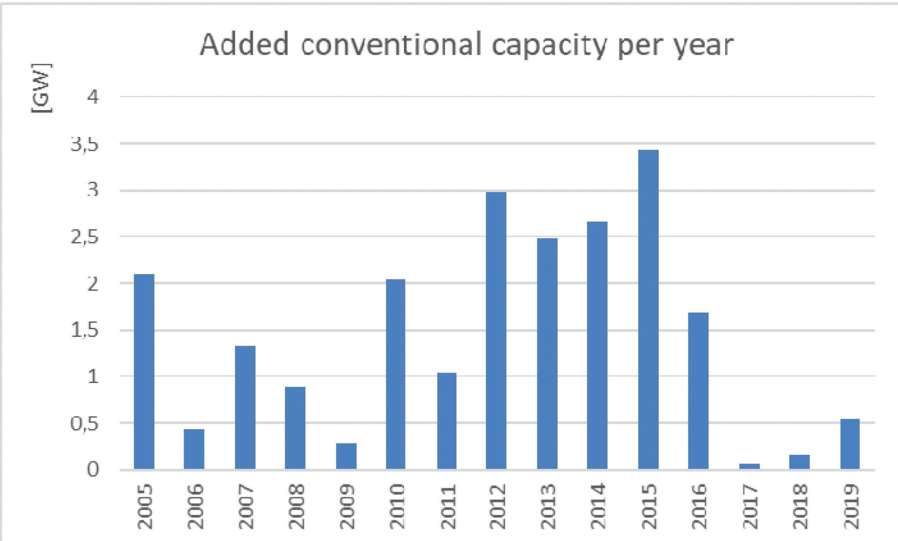
Power plants in Germany earn their revenues on the wholesale market (including intraday and balancing power markets). No long-term capacity payment provides additional revenues.[1] While this has been true for more than 20 years, the market design evolved over time. These changes will be described in the following paragraph if they contributed to the flexibilization of consumption and generation, for which we also discuss theoretical aspects and show some empirical findings.

2.1 Market Design

Since the liberalisation of the European internal electricity market (IEM) Germany relies on an EOM. Starting with a pure energy-only market, the European liberalisation from 1996 was implemented in German law in 1998. When the liberalisation process was completed the German electricity market was characterized by excess capacities.[2] Due to the resulting low electricity wholesale prices, some less efficient conventional power plants became unviable and shut down (or left the market once major overhaul investments would have become necessary). The development of electricity wholesale prices since 2000[3] is given in the following graph.[4]



With capacities leaving the market the wholesale prices consolidated and several new investments took place. Germany has seen numerous capacity additions. In particular, more than 21 Gigawatts (GW) of conventional capacity (i.e. gas, oil, hard coal, lignite, multiple fossil fuels) were added between 2005 and 2019.[5] The



following graph shows the yearly conventional capacity additions.

Despite these numerous investments happening in an energy-only market framework, stakeholders in Germany claimed the necessity for a capacity remuneration mechanism (CRM). The strongest argument of these stakeholders were concerns on security of supply due to insufficient dispatchable resources, when not implementing a CRM.[6] Some referred to the sharp increase in RES-E which depressed electricity wholesale prices, making existing units and new investments unviable. Yet others combined reliability with decarbonisation, essentially trying to use CRMs to replace coal fired with gas fired generation.[7] Driven by this public debate on missing money and thus insufficient resources to guarantee a certain reliability standard, the responsible Federal Ministry of Economics and Energy – BMWi explored and evaluated these arguments in several studies.[8] These studies comprehensively assessed the functioning of the EOM, and compared it to various forms of CRMs. The studies found that an EOM is functioning[9], if a well-designed imbalance pricing and balancing responsibility mechanism is implemented. Furthermore, the studies found that an EOM is less costly than adding any of the assessed CRM forms, while enabling more flexibility in the electricity system (in particular via more price volatility on wholesale markets). This in turn fosters the ability to integrate large shares of intermittent RES-E. Consequently, resource adequacy is achieved by an energy-only market design in an economically efficient manner.

Based on this scientific contribution, the BMWi conducted an intensive and extensive stakeholder interaction process including the release of a *Green Paper*[10] followed by a *White Paper*[11] on *'An Electricity Market for Germany's Energy Transition'*. The process ended with a political compromise, the so called 'Electricity Market 2.0' ('Strommarkt 2.0'), in which the EOM is accompanied by a strategic reserve as additional 'braces to the belt'. The German strategic reserve is an out-of-the-market back-up resource accomplished by a no-way-back-rule to prevent distortions of the wholesale electricity markets. This reserve is called, if the electricity wholesale market does not clear, i.e. if demand exceeds supply given the technical price limits (i.e. 3k €/MWh day-ahead; 10k €/MWh intraday). Then demand not satisfied by the market is provided by the strategic reserve, while BRP's with a negative imbalance have to pay at least twice the price of the technical intraday price-cap for imbalance energy (i.e. 20k €/MWh).[12] The strategic reserve is provided by existing quick starting gas- or oil-fired power plants.

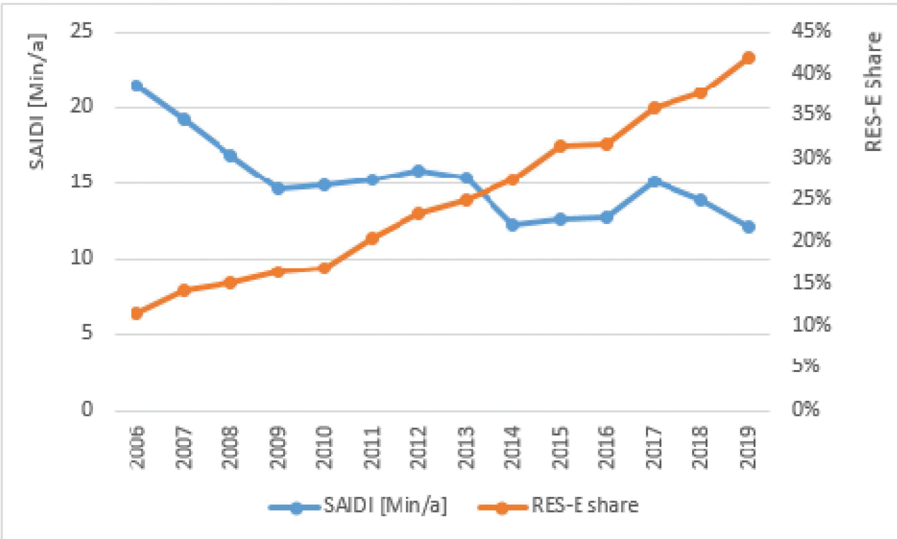
Additionally, Germany implemented a so called 'security standby' (so-called 'Sicherheitsbereitschaft') as an out-of-the-market resource, which is provided by almost three Gigawatts of existing lignite fired power plant capacities. The 'security standby' can secure the power supply in the event of unforeseeable prolonged extreme situations. Both, the strategic reserve as well as the 'security standby' have yet to be called upon.

This is even more remarkable as Germany decided to phase out of nuclear in parallel. By the end of 2020, only 8.1 GW out of 21.5 GW remain in operation. They will also phase-out until the end of the year 2022. On top of this, Germany decided to phase out coal at the latest by the end of the year 2038, starting with capacity reductions of around 8 GW hard coal and 4 GW lignite until the beginning of the year 2023, leaving only 15 GW each in the market. This phase-out processes are accompanied by a further ramp up of generation from wind and PV, which is intermittent and providing very little to secured generation.

Furthermore, barriers to market entry and flexibilization of the electricity markets were removed (e.g. implicit and explicit price caps , minimum capacity requirements were lowered, etc.) and trade products were adjusted to meet requirements of a wind and photovoltaic dominated electricity system (i.e. shorter trading periods were implemented). To improve the responsibility of BRPs, the imbalance pricing mechanism was strengthened. As a consequence, market liquidity in continuous intraday market trading up to physical delivery increased in Germany.

2.2 Evolution of Security of Supply Indices under RES-E development

In Germany, which is one of the frontrunner states in integrating huge amounts of intermittent RES-E in the light of the German Energy Transition, the reliability of supply did not suffer from this RES-E expansion. Contrarily, Germany's SAIDI started at an internationally[13] comparably low value of 22 minutes per year. The following graph shows the evolution of the SAIDI[14] and the RES-E share[15] in Germany.



Despite the increasing share of intermittent RES-E, the German SAIDI did not increase but decrease. The 2019 SAIDI, when the RES-E share was around 42 percent, was only 12 Minutes in Germany. However, the SAIDI measures grid failures and does not include forced load shedding of consumers resulting from insufficient generation resources. Hence, we want to emphasise that forced load shedding in Germany in the past 20 years did not occur due to insufficient generation resources. The only event leading to forced load shedding in Germany in our period of observation resulted from a grid fault (so-called Emslandzwischenfall in November 2006).[16]

2.3 Theory and empirics of the role of flexibility in the EOM

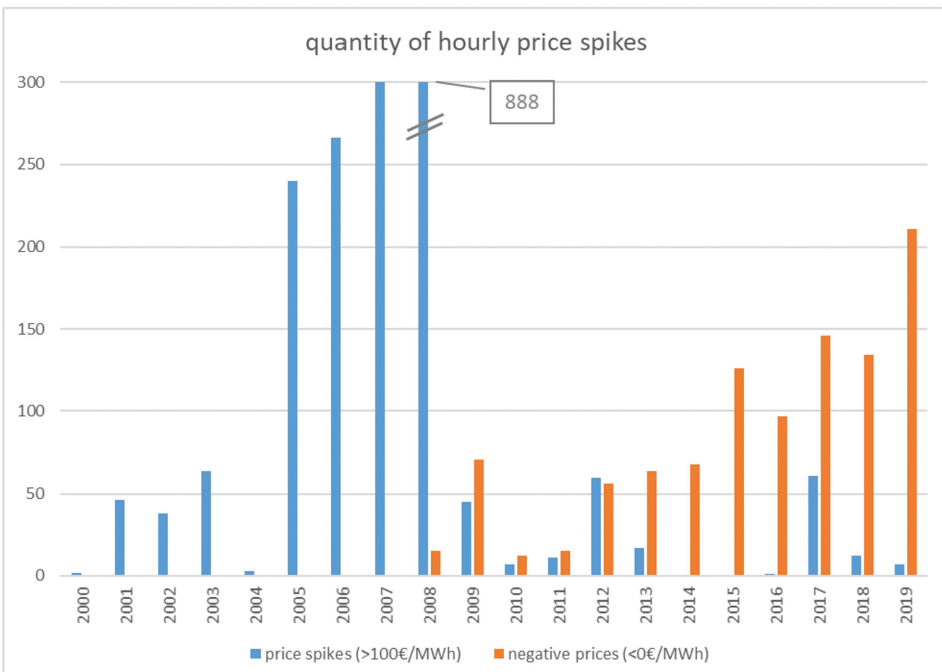
The theoretical background of the EOM is discussed in various literature sources.[17] In its core the EOM relies on the concept of peak load pricing, complemented by a well-designed imbalance pricing mechanism. We can define price peaks as wholesale power prices exceeding the variable costs of the most expensive conventional power plant available, since in this periods all available suppliers are producing and also able to recover a contribution to their fixed costs.[18]

Furthermore, in an EOM such price peaks signal beginning scarcity, which also incentivises more flexibility options both on the supply and on the demand side. Additionally, the commissioning of additional resources can become viable when scarcity occurs more frequently.

Flexibility is not only vital during price peaks but also during very low or even negative price events. The sharp increase in intermittent RES-E feed-in causes such situations. This mechanism enables opportunities for storages and contributes to reduce 'must-run' via a flexibilization of conventional power plants (e.g. coal, nuclear) and CHP-Units to avoid negative contribution margins during those periods.

The following graph shows both the annual number of hours with price peaks and with negative price events in Germany. In the graph, we assume the occurrence of 'price-spikes' whenever the hourly wholesale price is above 100 €/MWh.

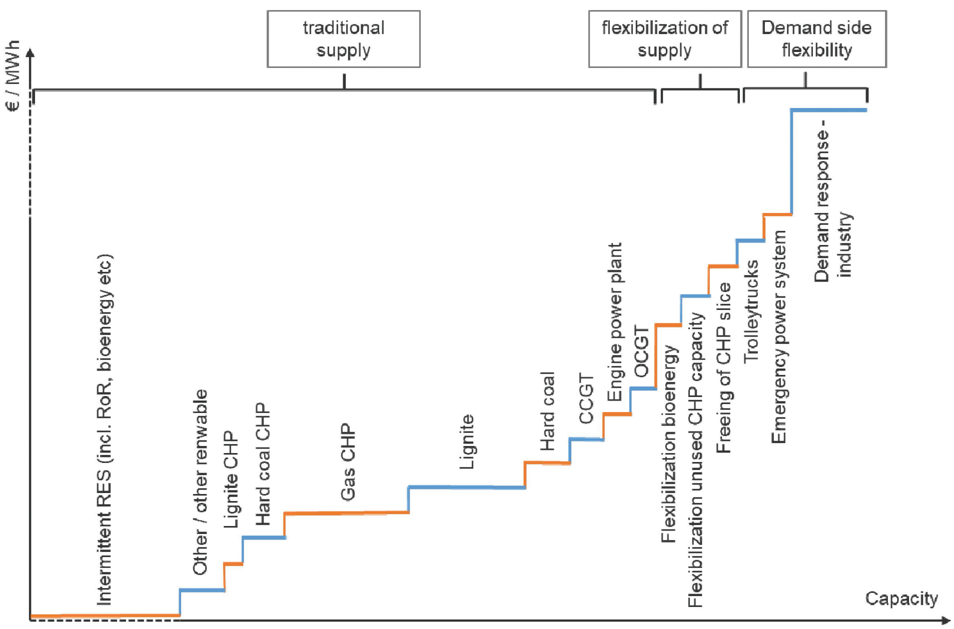
Directly after the liberalization during the year 2000, above mentioned excess capacities prevented the occurrence of price spikes – and also made them unnecessary as no investment signal was needed. Consequently, the electricity wholesale price exceeded 100 € per MWh during two hours only. The occurrence of price spikes in the following years increased until 2008. In this period, the strong econ-



omy was driving the electricity prices. Furthermore, there were concerns that four big generation companies (with more than 80 % market share) may have used their market power and withheld power station capacities.[19] From 2009 on only moderate amounts and heights (i.e. < 230 €/MWh) of price spikes occurred until now, but the occurrence of negative prices increased more or less constantly over the past 10 years. On the one hand peak-load-pricing is contributing to the functioning of the EOM 2.0. On the other hand the occurrence of negative prices contributes to a better / more efficient integration of large amounts of intermittent RES-E feed-in, since it incentivizes reducing must-run via flexibilization of Conventional and CHP units and enables business opportunities for storages.

These empirical results confirm that the market reacts on scarcity with price spikes. However, we do not perform a detailed analysis whether observed spikes where sufficient to cover investment costs in this article. Besides spikes, this also depends on a power plant's utilization, availability, investment costs and revenues on other markets (balancing power, heat for CHP, subsidies for CO_2-allowances or RES-E, ...). Furthermore, investors in power plants – as investors in all other markets – face uncertainty at times of investment. In a competitive market, investment may in retrospect prove profitable or futile. Given the amount of excess capacity in the German market, it seems reasonable to assume that some investors were too optimistic with regard to wholesale price expectations.

Regardless of whether all investment was profitable, supply and demand were met every single hour over the past 20 years. The reason for this – despite some subsidized RES-E and CHP capacity additions – is the availability of flexibility options on both – supply and demand side. The following graph illustrates the 'traditional merit order' supplemented by further various forms of flexibilities of supply and demand on electricity markets. The availability of these flexibilities has ensured that market always cleared accompanied by only moderate price spikes according to peak-load pricing theory.



To the right of the 'traditional merit order' (i.e. right of the OCGT) flexibilization of supply may provide further flexibility at moderate costs. And – as one can see, on the consumption side not only industrial DSR is contributing to the further needs of overall flexibility and hence plays a role in scarcity situations with expected price-spikes. Also plenty other demand-side flexibility options, such as the use of (behind the meter) emergency power systems or – in the future – bidirectional electric vehicle charging or overhead bivalent trolley trucks switching to diesel-use, may contribute to peak-load-pricing, when no overcapacities or market entry barriers inhibit the activation of these flexibility potentials.

3. Challenges for the Future

Up to this point, we have shown that security of supply was achieved in the German EOM market framework, both measured by low SAIDI and persistently sufficient generation capacity. This result held despite the sharp increase of intermittent RES-E in Germany. However, while we can learn from the past, the successful history is no guarantee for a successful future. Firstly, we will argue in the following that, from a theoretical perspective, a reliability level of 100% would not even be economically efficient. Secondly, we will emphasise that the German market design in reality is far from a pure EOM, as various regulatory measures interdependent to the wholesale electricity markets exist, which may distort market outcome. And thirdly, measures in other European countries may send potentially distorting market signals towards the German market.

Regarding the first point, it needs to be said that full reliability in terms of adequate resources is not achievable, because at least at very low probability all resources may be subject to forced outages at the same time. Thus regardless of the market design (and thus including EOM as a market design), it is neither rational nor economically efficient for market players to have spare resources for every possible case that could occur – even when the probability for that case is very small. For this reason, German politics implemented the strategic reserve, leading to an even higher reliability standard than the EOM market outcome would provide (and consider efficient), since additional capacities are contracted as an out-of-the-market resource.

Furthermore, policy measures both domestic and abroad may lead to inefficiencies or 'shocks' of the electricity markets. In this sense various German measures tend to distort the pure EOM price signals or to be 'shocks' to the electricity markets. In the former case e.g. CHP-Units or RES-E Units are remunerated outside of the EOM via subsidy schemes, possibly distorting market price signals leading to inefficiencies. While in the latter case political decisions, i.e. to phase-out nuclear and coal power generation at the same time, are possibly challenging / interruptive for the electricity markets. Apart from domestic measures interdependent to the EOM, also surrounding CRMs (e.g. in United Kingdom, France, Italy, Poland and in perspective Belgium) are interdependent to the German EOM and the European IEM as a whole, since the revenue streams of the CRM's may distort signals from the Energy-Only IEM. This could possibly decrease efficiency of the market outcome.

Last but not least, recent 'near-brown-out'-events, e.g. in Germany[20], and a 'brown-out'-event in United Kingdom[21] in 2019, have shown, that even if there is no fundamental issue of insufficient generation resources, technical failures and other imperfections may lead to critical events in terms of the reliability of electricity supply. These two cases show that reliability issues may occur independently from the specific market design (i.e. w/o CRM), with Germany relying on the EOM whereas UK has implemented a market-wide CRM in the year 2014.

4. Conclusions

First, we want to conclude, that the EOM market design in Germany was able to provide a highly reliable electricity supply since market liberalisation in 1996/98, i.e. for more than 20 years. Second, security of supply remained high despite the integration of large shares of RES-E in the system. Third, the German EOM market design fosters innovation-forces of the electricity markets since price-volatility on electricity markets incentivises flexibilization of supply and demand.

Germany's decision to rely on an EOM is also in line with recent EU-legislation in the so-called 'Clean Energy for all Europeans'-Package (CEP). According to the CEP, any form of a CRM must always be regarded as so-called second-best solution, only meant to serve as temporary solutions until existing barriers or false incentives within the EOM are removed.

Footnotes

[1] Renewable energy sources and CHP plants receive additional subsidies.

[2] C.f. e.g. Müsgens (2006).

[3] Data for year 2000 is only available from June, 16th,since then the exchange started operation.

[4] Source of data: https://www.bmwi.de/Redaktion/DE/Binaer/Energiedaten/energiedaten-gesamt-xls.xlsx?__blob=publicationFile&v=85

[5] Source of data: https://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/Sachgebiete/Energie/Unternehmen_Institutionen/Versorgungssicherheit/Erzeugungskapazitaeten/Kraftwerksliste/Kraftwerksliste_2020_1.xlsx?__blob=publicationFile&v=3

[6] C.f. Deutsche Energie-Agentur GmbH (dena) 2008; Kurzanalyse der Kraftwerks- und Netzplanung in Deutschland bis 2020 (mit Ausblick auf 2030). www.vku.de/fileadmin/get/?24103/EMD_Gutachten__Langfassung.pdf; https://www.ewi.uni-koeln.de/cms/wp-content/uploads/2015/12/EWI_Studie_Strommarktdesign_Endbericht_April_2012.pdf

[7] C.f. https://www.oeko.de/uploads/oeko/oekodoc/1586/2012-442-de.pdf

[8] C.f. e.g. r2b energy consulting (2014): https://www.bmwi.de/Redaktion/DE/Publikationen/Studien/funktionsfaehigkeit-eom-und-impact-analyse-kapazitaetsmechanismen.pdf?__blob=publicationFile&v=5 , Frontier Economics / Consentec (2014): https://www.bmwi.de/Redaktion/DE/Publikationen/Studien/folgenabschaetzung-kapazitaetsmechanismen-impact-assessment.pdf?__blob=publicationFile&v=5 .

[9] i.e. Functioning of an EOM in the sense that every consumer is supplied with electricity, as long as their individual willingness to pay is equal or higher than the wholesale electricity price

[10] C.f. https://www.bmwi.de/Redaktion/EN/Publikationen/gruenbuch.html

[11] C.f. https://www.bmwi.de/Redaktion/Migration/DE/Downloads/Publikationen/weissbuch-englisch.pdf?__blob=publicationFile&v=2

[12] This penalty-mechanism additional to the imbalance settlement price mechanism leads to strong incentives for market players to avoid being responsible for calling the strategic reserve due to insufficient resources, lowering the probability of calls of the Strategic Reserve and thus its necessity itself. Thus the design of the strategic reserve provides incentives lowering the probability of calls of the Strategic Reserve and thus its necessity itself.

[13] Compared to e.g. North America, where the mean SAIDI is around 1.5 hours (90 Minutes); c.f. https://www.eia.gov/todayinenergy/detail.php?id=37652#

[14] Source: https://www.bundesnetzagentur.de/DE/Sachgebiete/ElektrizitaetundGas/Unternehmen_Institutionen/Versorgungssicherheit/Versorgungsunterbrechungen/Auswertung_Strom/Versorgungsunterbrech_Strom_node.html

[15] Source: https://www.erneuerbare-energien.de/EE/Redaktion/DE/Downloads/zeitreihen-zur-entwicklung-der-erneuerbaren-energien-in-deutschland-1990-2019-excel.xlsx?__blob=publicationFile&v=23

[16] C.f. https://dserver.bundestag.de/btd/19/099/1909901.pdf

[17] C.f. e.g. Stoft (2002): Power System Economics - Designing Markets for Electricity, Müsgens and Peek (2011), Müsgens (2017), r2b energy consulting (2014), Frontier Economics / Consentec (2014).

[18] As long an EOM is designed as a 'pay as cleared' remuneration mechanism.

[19] C.f. https://www.bundeskartellamt.de/SharedDocs/Meldung/EN/Pressemitteilungen/2011/13_01_2011_SU-Strom.html?nn=3591568 as well as Müsgens (2006)

[20] C.f. https://ga.de/ga-english/news/in-june-the-german-power-grid-was-at-risk-of-a-blackout_aid-44073039

[21] C.f. https://www.ofgem.gov.uk/system/files/docs/2020/01/9_august_2019_power_outage_report.pdf

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Blockchain: An Enabling Technology for Decentralized Grid Management

BY OLUWAPELUMI EGUNJOBI AND ALVARO GOMES

Abstract

Smart and innovative solutions are required to foster the penetration of renewable energy sources (RES). Blockchain has been identified as an enabling technology to provide such a platform with capabilities for decentralized operations, like local energy transactions, while handling other problems associated with complex grid management at large.

Situation Overview in 21st Century Electricity Grid Operation

Advancements in Information and Communication Technology (ICT) is enabling the growth and development of smart grids, with increased contribution of RES in grid generation mix and improved energy efficiency, thus contributing to decarbonizing our societies and leading to a more sustainable development. For example, in Portugal, in May 2020, RES consisting of hydro, solar, wind, and biomass constituted over 70% of electricity generation mix according to (APREN, 2020) report. The country has also consistently maintained RES percentage of over 60% of the electricity generation in 2020. Unfortunately, with increased RES penetration comes complexities in grid management and control, demanding for higher flexibility of power systems. This is attributed to a number of reasons such as:

- **Intermittent nature of some RES:** is a long and widely known reason as explained by (Houseman, 2009) and (IEA ETSAP and IRENA, 2015). Some RES like wind and solar are intermittent and difficult to forecast in the long run which makes them non-dispatchable. In addition, large contribution of RES may lead to the absence of inertia, causing the grid to respond more nervously to events. Besides, often exists mismatch between available RES and demand hence requiring support from other technologies.
- **Active participation of consumers:** is another reason as described in (Mollah et al., 2020) report while emphasizing the need for decentralization. In smart grid, the number of end-users participating in electricity generation increases (prosumers) and as such the typical centralized grid control system fails to accommodate the peculiarities of each prosumer and generation group in real-time or near real-time.
- **Data privacy and security:** is also a well-known concern from the beginning of widespread adoption of smart grid according to (Cavoukian, Polonetsky and Wolf, 2010) and (Miglani et al., 2020). Data privacy and security concerns arises from risk associated with the unavoidable data exchange among smart grid components and stakeholders.

All of these reasons influence grid operation planning and hampers RES adoption. The solution to these is in the application of novel and innovative solutions for which blockchain has identified as being supportive of. Blockchain is an enabling technology that enables decentralized operation and control in near real-time, the exchange of large volumes of data and seamless automation of processes. These features of the technology provide it with capabilities that makes it useful for developing and implementing solutions for decentralized grid and RES management.

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Blockchain as an Enabling Technology

Blockchain technology is a system of nodes characterized by decentralized data storage system, decentralized transaction, peer-to-peer (P-P) data exchange, integrity and verification. The technology uses a distributed ledger system that is trustless and capable of managing large volume of data exchange. Every node in the blockchain system maintain a copy of data or references a trusted node that maintains a copy. Blockchain uses a trusted consensus mechanism system to validate data and implements different network protocol to achieve data privacy. (Wang *et al.*, 2019) reports that the first version of blockchain technology, the blockchain 1.0 was mainly for cryptocurrency trading but blockchain 2.0 provides integration with other technologies like the smart contract. Smart contract is a self-executing set of code blocks of digital transaction protocol.

The rise of RES in decarbonized economies changes the dynamics of transaction processes. In such economies, direct interaction can occurs between prosumers and consumers in local communities and in micro-grids. In more complex scenarios, interactions may transverse across several micro-grids. These interactions which may be simple or complex includes energy contract negotiations, energy trading for various purposes, data exchange for grid management and energy settlement transactions. Seamless interaction in such system is key to foster RES and management of grid operations.

Many blockchain based projects already exist but most are particular seeking to explore the technology to improve energy trading. Typically, energy transaction processes are characterized by many inefficiencies which includes:

- **Bureaucracy:** resulting from the presence of intermediaries, need for concessions and approvals which constitute delays in many energy trades.
- **Transparency, trust and standardization problem:** because many energy trades involve series of internal processes to reach agreement and many of the time these processes are not known to all parties involved in the trade.
- **High investment and transaction costs:** emanating from intermediary cost, investment collateral cost and transaction execution cost.
- **Commitment, risk and error concern:** because of error associated with manual trade execution coupled with investors trust, shares payout and profitability concerns.

Energy trade solutions are leveraging on smart contract to provide solutions to these inefficiencies. Blockchain integration with smart contract provides automation of data and transaction processes. This integration provides decentralization, data security and privacy control, automation and trust. The solution eliminates the need for an intermediary and automates the trading process.

However, despite the possibilities that blockchain has to offer, its adoption in the energy operations has been slow having experienced several setbacks. The report by (World Energy Council and PwC, 2017) identifies uncertainties in the viability and reliability of applications on blockchain, security and regulations as responsible for some of these setbacks. As such governments, private companies and research organizations in many developed countries are actively involved in funding and stimulating research in this area in order to tap into the full potential that the technology has to offer.

Blockchain Trend in Energy Operations

There are a number of blockchain based energy projects in the pipeline with some records of already successfully implementation.

In the area of energy investment, Sun Exchange developed a system for solar assets such that investors can invest in solar PV generation and a smart contract system is used to ensure automated transaction and payment to investors without delays (Sun Exchange, 2019). The system has helped develop several solar powered businesses and schools in South Africa. Similarly, a different project, Impact PPA uses a blockchain based system to provide investment for micro grid power projects (Impact PPA, 2018). The system which is equipped with automated payouts to investors, owners and the government also uses a smart meter connected to blockchain to monitor consumption and allows consumers in the micro-grid pay for electricity via their mobile devices. Impact PPA has successfully deployed the technology in Haiti, Ghana, India, Somalia and others.

In the area of security, Electron in the UK is working on a blockchain based encryption system for gas and electricity smart meters to solve cyber-security and privacy problems associated with registering consumers. The system will also allow consumers switch from one energy provider to the other with ease. Similarly, Guardtime in the US has a number of developed and on-going energy projects on blockchain to resolve scalability problems in public ledger technology.

In the area of energy trading, (Khatoon *et al.*, 2019) proposes the use of blockchain based technology in Italian White Certificate Scheme (IWCS) aimed at promoting energy efficiency. In the report it expresses that blockchain technology with smart contract can used in handling complex processes in verification, monitoring and trading of certificates. Similarly, Power Ledger in Australia has also developed a wide range of blockchain based application. One of such is the peer-to-peer (P-P) local community trading system between prosumers and consumers in a micro grid system with a successful pilot test for solar photovoltaic (PV) producers (Andoni *et al.*, 2019).

In Spain and Portugal, blockchain use in the energy industry is receiving numerous attentions. Iberdola in 2019 reported the deployment of blockchain based platform using technology from Energy Web Foundation (EWF) to track and monitor supply of RES. The system provided transparency and authenticates the source of energy supply. Similarly, (Enterprise *et al.*, 2020) EDP Portugal in 2018 began deploying blockchain based solution in the Brazil using low cost crypto tags for solar energy production tracking in order to provide transparency and authenticity of energy data. Generally, the Portuguese government is exploring at different levels and stimulating the development of blockchain based innovative solutions (Madeira A., 2020).

In Germany, project DENA was commissioned at the beginning of 2020 by the German government. This project led to the establishment of a Future Energy Lab to explore energy solutions on Artificial Intelligence (AI) and blockchain with focus on energy asset registration, carbon emission tracking and smart contract utilization. Also in October of 2020, Siemens demonstrated Pebbles, a demo project for P-P energy trading that enables prosumers sell energy directly to local consumers without interference of intermediaries.

Conclusion

Fostering RES penetration in decarbonized economies requires innovative solutions to manage complexities and difficulties posed by such dissemination. Blockchain has been identified as an enabling technology to drive such innovation. It is widely believed that the future of many energy solutions for decentralized management will rely on blockchain. Consequently, in recent times the technology has received more attention, with governments of many developed nations providing funding and seeking private-public partnership to provide regulatory framework to encourage research and implementation.

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International Association for
ENERGY ECONOMICS

Constraints To Efficient Electricity Supply In Nigeria

BY DR. ORUWARI, HUMPHREY OTOMBOSOBA

Abstract

The objective of the study is to examine the constraints to efficient electricity supply in Nigeria, and recommend ways for policy decisions. Using literature review and case study, it is revealed that efficient electricity supply is dependent on the political, technical, economic and social factors which needed to be addressed.

Introduction

The magnitude of the standard of living in any society, the growth and development of such economy and its ability to affect the course of event is a function of the extent to which electric power system is effective and utilized. This is inline with the Sunny (2016) submission that lack of electricity has stunted socio-economic development, thereby causing a lot of misery which sometimes translates to civil unrest.

For instance, despite the investment in power sector, the Nigeria economy is continually plagued by problems related to electricity supply and disruption inadequacy. The lack of reliability associated with the power supply system still constitutes energy into one of the binding constraints on the pace of economic activities in the country. Anyaehie (2011) opined that inefficient electricity supply is unhealthy for national growth and so needs to be overcome. The power system failures and inadequate infrastructures have had a notable adverse impact on growth and have contributed to poverty in Nigeria.

Power sector reforms have been carried out in order to improve the electricity supply situation of Nigerians. Israel et al (2015) posited that in order to meet the desires of the public populace, the Nigerian government embarked on power sector reforms. The reform program led to the unbundling of the then National Electric Power Authority (NEPA) into seven generating stations, eleven distribution firms and one Transmission Company.

Despite power policy initiatives in promoting power sector reforms, efficient electricity supply has not been successful in Nigeria. The main problem against safe and efficient electricity supply in Nigeria is inadequate infrastructure, poor history of corporate governance and inadequate pricing structure to support the economics of power generation, transmission and end user distribution (NAPE, 2016). The Nigerian power sector has struggled to deliver efficient electricity supply to both individual and industrial consumers.

Experiences in other countries that have profitably succeeded in power sector reform and have attained efficient electricity supply have shown that in addition to adequate regulatory framework, the long-term successful development of efficient electricity supply requires synergy between the Nigerian government and the private investors in electric power sectors.

Currently, there is no adequate collaboration on the development of efficient electricity supply between investors in electric power sector and the Federal government of Nigeria. This study seeks to find answers to the following questions: what do policy makers need to know about electric power system to promote development support strategies that are economically, technically, socially and politically effective.

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History of Electric power industry in Nigeria.

Electricity was first generated in Nigeria in 1896. The Nigerian Electricity Supply Company (NESCO) commenced operation as an electric utility company in 1929 with the construction of a hydro-electric power station near Jos. The Electricity Corporation of Nigeria (ECN) was established in 1951, while the first 132KV transmission line was constructed in 1962, linking Ijora Power Station to Ibadan Power Station.

The Niger Dams Authority (NDA) was established in 1962 with a mandate to develop the hydropower potential of the country. Subsequently, ECN and NDA were merged in 1972 to form the National Electric Power Authority (NEPA) which as a result of unbundling and the power reform process, was re-named Power Holding Company of Nigeria (PHCN) in 2005 (World Bank, 2003)

Research methodology

The study adopted a qualitative multiple case study design and literature review in the interpretative research paradigm. Data was collected from secondary sources, arranged into themes and were analyzed for content. It is critical to highlight that the research approach looks at issues historically by addressing specific scenario that produce details when people answer to the why, how and what question (Hennink et al, 2011). The study used existing secondary data or empirical evidence to present issues especially in the literature review part. Several factors have constrained efficient electricity supply in Nigeria among which are:

Economic factors

Capital scarcity: There was a recognized major shortage of capital to finance the required expansion of power capacity in Nigeria, while historically Nigeria like other developing country government had financed their large state-owned power utilities and supplemented their capital with a multi-lateral development bank. It was recognized that these two sources would be inadequate to finance power sector investment in decades to come. The shortage of capital means power is rationed and that only those regions, major industrial or residential blocks that can pay, have a chance of receiving reliable power.

Payment risks and foreign exchange availability: PHCN's collection rates are low, with high levels of technical and non-technical losses, tariffs are not high enough to make PHCN financially self-sufficient, and it will be some time before power sector reform impact is felt. Also there is inadequate foreign exchange for timely purchased of needed spares. This is in line with the Benin electricity distribution company which has claimed that inadequate funds to develop infrastructure to accommodate generated power by generating company GENCO is hindering its operation (Oil, week).

Economic inefficiency: The electric power research institute (2003) conducted a pilot study of electricity consumption in California oilfields and found significant potential for reducing cost through energy efficiency improvements. It offers suggestions for reducing electricity consumption that if implemented could result in a system wide demand reduction and reduce the need for additional generation of power infrastructure capacity. Also, Ohajianya et al (2014) posited that there is over 50% power loss at the point of power generation in Nigeria. This is corroborated in a study carried out in Delta power which revealed that of the total installed power capacity only 30.5% are generated. This implies a loss of 69.5% of the generated power. A majority of electricity consumers in Nigeria leave their electric devices "ON" even when they are not needed. This is because of the inefficient billing system. In addition, this result in overloading of the power transmission and distribution equipment.

Technical factors

Weak human and technological capabilities: This is essentially a problem of research and development which is made worse by lack of trained man power and information on the deployment of resources particularly in developing countries like Nigeria. In general terms there is inadequate skilled human capital, and knowledge about electric power system design as well as personnel with adequate technical, financial, economical and management skills to identify and implement specific power policies and program, According to Ohajianya et al (2014) Nigerians rejoiced as government handed over generation, transmission and distribution of electricity to private companies. However, after six months, Nigerian still complained that power supply had gone from bad to worse (Ukokop et al 2014).

There is inadequate infrastructure across the entire value chain to service the power sector. For instance, the Uquo marginal oil field in Akwa Ibom state came on stream in 2009 and powered the 560MW Calabar plant, Ibom power plant which ought to be about 170MW, but with only one gas turbine functioning, produces 110 MW, Frontier oil field once fed Alaoji power plant but not anymore (Thomas, 2017).

Table 1 is a comparative analysis of electricity generation in Nigeria and population with other countries. According to Obioma (2010) Nigeria has about 3,545 MW (out of a total installed capacity of 5200MW) for a population of 160 million people and only a supply peak of 3700 MW out of a peak of load requirement of 5103MW and cannot supply power nationwide for 24 hours.

Table 1. Comparison of electricity generation and population

Country	MW	population
South Africa	40,000	50 million
Brazil	100,000	192 million
USA	700,000	308 million
Nigeria	3,450/ 5200MW	160 million

Table 2: Power stations in Nigeria

Power station	Types	Capacity (MW)	Year of completion
Kainji	Hydro	470	1968
Jebba	Hydro	482	1985
Shiroro	Hydro	450	1990
Egbin	Thermal (gas)	1100	1986
Sapele	Thermal (gas)	450	1981
Delta	Thermal (gas)	300	1966
Afam	Thermal (gas)	420	1965
Ijora	Thermal (gas)	60	1976
Geregu	Thermal (gas)	414	2006

Table 3: National integrated power project (NIPP)

NIPP	Project out-put (MW)
Calabar	562.5
Egbema	337.5
Ihovbor	450.5
Gbarain	252.0
Alaoji	960.0
Papalanto	675
Omotosho	451.0

Table 2 and 3 show the power stations in Nigeria and the different independent Power Projects in Nigeria. The total generated power is not adequate when compared to countries with similar population.

Inconsistent energy policies and over-dependence for government for sustenance: Ohajianya et al (2014) posited that the inconsistent energy policy has contributed to the problem of unreliable power supply because from the establishment of ECN in 1950 and setting up of NEPA in 1972, the policy has been that of monopoly. However, if after these years there is need to unbundle the power sector then the previous policy has been unhelpful. Also, the power sector in Nigeria has been privatized yet the company has depended on government for bail out on several occasions.

Social factors

Debt and deficit: The low performance of power generation companies and electricity distribution companies in Nigeria has been attributed to debt profile of ministry, departments and agencies of government, it contributes to the liquidity challenges in the power sector (Oil, week 2017).

In addition, domestic and commercial consumers are resistant to settle their bills as a result of estimated billing model adopted by the power distribution companies DISCOs. The Oil week (2017) stated that the Eko electricity distribution company debt owed by other companies has made it difficult for her to install prepaid meter to improve revenue collection and improve performance.

Vandalism /insecurity: As a result of poverty in Nigeria, there is high incident of power equipment vandalism. Vandals have a field day stealing of cables and wires. Also, insecurity aids this process of vandalism which results in low capacity utilization.

Poor maintenance culture: There is frequent breakdown of obsolete generating plants and equipment due to inadequate maintenance and lack of spare parts.

Political factors

Poor history of corporate governance of electricity industry: In Nigeria the electricity sector is facing low productivity and corruption. This factor has resulted in commercial unsustainability of the power sector and hence make planning very difficult. Mismanagement also means misallocation of resources which further worsens the availability of quality power service.

According to the exclusive power probe report (2008) (as cited in Israel et al 2015) of all the house of representative committee on power the sum of $16 billion was misappropriated in the power sector between 1999 and 2007. The committee recommended that 17 figures of interest should be investigated and or disciplined. These figures included the then president of the Federal republic of Nigeria, the minister of power in that period, some federal legislators, some top management of PHCN, some top business men and some companies. Consequent upon the allegations and counter allegations over the power corruption saga, the power probe committee was dissolved and never set up again.

Lack of transparency: This also affected the development of new energy for power generation, most governments in the world seem to prefer centralized distribution systems where everything seems to come from the headquarters or capital before any consideration to other areas. This tendency is a serious barrier to the development of new energies for power generation, which are usually at scattered locations and are produced on relatively small scale.

Damas (2016) posited that there is the need, therefore, to take a second look at the policy of generating, transmitting and distributing power based on national grid principle or format. The national grid principle is a system whereby whenever and wherever power is generated it has to find its way to the national transmission and distribution network. This principle therefore fore closes the ability to produce and distribute power in situ, based on the location and the resources. We could try to produce wind power where there is adequate wind, be it very remote or localized, and use this power so generated for the immediate environment or locality. The same will go for where there are tidal waves or hydraulic or thermal resources. This area could thus be offloaded from the natural grid, thereby increasing accessibility of power to some areas of the country.

Most new generation capacity in Nigeria is likely to be based on natural gas. Electricity transmission losses over long distances, combined with the high cost of building and maintaining electricity transmission infrastructure, mean that in almost every case it is likely to be more economic to transport gas by pipeline and generate close to centers of demand, rather than to generate close to the supply of gas and incur electricity transmission costs. However, this is only apparent if the true costs of both gas and electricity transmission are made transparent and can be compared by investors (World Bank 2003).

Right pricing of electricity: Appropriate price is central to the subject of electricity power reform. This is because the optimal pricing model must take into account cost recovery over planning horizontal- cost recoverability which is contingent on appropriate pricing is a central requirement for sustainability of electricity sector, the price that is ultimately set must therefore not be too high or not too low. If it is high, access to electricity will be highly circumscribed for the poorer segment of the society and may therefore require subsidization by government. If it is too low, the investors in electricity business will not be able to recover their costs.

A major constraint to efficient electricity supply in Nigeria has been the presence of subsidies in the electricity pricing structure, these subsidized prices have not only promoted an inefficient pattern of end use, but have also prevented the recovery of capital costs, greatly discouraging investment in more energy efficient processes in general and in particular for the the electricity sector. Ohajianya (2014) posited that at the point of consumption majority of power consumers do not switch electric devices “OFF” even when they are not required, because of the default billing method applied by the power distribution company.

Conclusion and recommendations

In Nigeria the power sector have been constrained by high technical losses, a lack of cost recovery pricing, poor maintenance culture , low equipment reliability, low productivity , corruption, a crippling non-payment of mounting debt, these factors have resulted in the commercial unsustainability of power supply which are unable to attract needed private investment. Other major problems confronting the electricity sector in Nigeria are summarized as capital scarcity, economic inefficiency, lack of basic industries to service the power sectors, vandalism, insecurity, ineffective billing method, debt and deficit. Power sector reform have been carried out in order to improve the electricity supply situation in Nigeria. Sambo (2010) suggested addressing the issue of collapsing infrastructure for improvement and efficiency. The suggestions on how to resolve the problem of electricity supply are highlighted as follows:

Right pricing of electricity and abolishment of estimated billing: There should be correct pricing of electricity to ensure adequate return on investment for entrepreneurs. Tariff levels need to reflect the cost of electricity supply.

Provision of infrastructures and security: Basic engineering infrastructure for the local manufacturers of electricity should be established. There should be effective measures to ensure security of electrical installations.

Increased funding: There should be appropriate financing to support indigenous investment in the electricity industry. Also, there should be adequate supervision and commitment to the NIPP projects and others.

Capacity building: This should ensure the participation of indigenous engineers in the execution of an on going and future project right from feasibility studies with the objective of establishing local capacity in the power sector.

Collaboration and granting of tax incentives: Indigenous contractors should be encouraged to manufacture and install pre-paid meters in collaboration with the distribution companies. Granting of tax incentives by the government would be a welcome development.

Research and development: There should be an intensified national effort in training, research and development with a view to generating electricity using other off-grid power solutions like solar and other renewables.

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Don King Energy Economics

BY DOUGLAS B. REYNOLDS

In politics as in economics there are two focal points to a majority of arguments: The Carl Marx side and the Adam Smith side. The Marxian side has everything to do with socialism, government ownership or command and control aspects of an economy, which is either considered socially egalitarian or inefficient. The Smithian side is everything to do with free market capitalism and dog eat dog competition which is either considered efficient or income inequality maximizing. Some of the greatest heroes for the Smithian side are entrepreneurs like Mark Zuckerberg who made all his money by "borrowing" the initial idea and creating a natural monopoly that has built in barriers to entry, economies of scale and merchandisable data. Other tech oligopolies are similar. A Marxian-type hero is U.S. President Franklin D. Roosevelt who initiated social security in America even though it relies on a dwindling cohort of young workers paying ever more money to keep the system afloat.

But maybe there is another economic system out there that could work better, at least in some instances: Don King Economics. Don King was an agent for heavy weight and other weight boxers. As one boxer said about him, before Don King came along, boxers were only receiving tens of thousands of dollars per fight but after Don King they were receiving tens of millions of dollars per fight. So if Don King makes so many millions of dollars as an agent, it is worth it to the fighter because Don King makes sure each fighter gets millions of dollars in pay. Indeed, boxers like Muhammad Ali (formerly Cassius Clay) did only receive so many thousands of dollars per fight, then after Don King, boxers like Floyd Mayweather received tens of millions of dollars per fight. So having a star negotiator can enhance the value to the economic agents involved, and possibly even to the paying public.

1. CEO Bonuses

This kind of Don King economics is alive and well within most corporations where star CEOs receive huge stock option bonuses for their work. And even though some of the stock option specifics could be questionable, nevertheless, most large and even smaller corporations have some form of stock option bonuses now. As The Economist's (2007) Special Report on Executive Pay said, "Where as executives in publicly traded companies earned about $3 per each extra $1,000 in profits, managers in the buyout firms earned about $64. According to Steven Kaplan of university of Chicago" p. 8 and "the lions share of executive bonanza was deserved in the sense that shareholders got value for the money they handed over." P. 4. So Don King economics is alive and well. But if it works for corporations, why not try it in other contexts too such as with monopoly electric power utilities.

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For some reason there is this belief in energy economics that having a free market electric generator system is the end all be all of electric power utilities and grids even though there is no easy entry or easy exit of such generators on to the market making such generators oligopolies or even making the utility grid a semi socialist system to make up for gaps in supply. But rather than putting the Smithian square peg into a natural monopoly round hole, a Don King system could work better. However, instead of a Don King system incentivizing the use of the natural monopoly characteristics of the utility to ratchet up the electric power price (or tariff) the system can rather be used to incentivize lower prices and if necessary lower carbon emissions.

Think of the beauty of Don King economics. The Don King electric utility monopoly CEO (or King or Tzar) would be given a bonus not for raising prices, but for lowering them. To incentivize long term investments and maintenance the CEO would also receive a bonus for keeping prices, or carbon emissions, low 5, 10 and 15 years after his or her term. And as Don King received millions but was worth it to the boxers, so the utility CEO might receive millions in bonuses but would be worth it to all the electric utility customers and businesses. Such a CEO will be able to use better coordination of generators, power lines and demand side incentives to reduce electric power prices and carbon emissions. The CEO can himself incentivize local utility customers to use energy efficient systems through various public relations steps or even with coordinated neighborhood power storage.

2. Consumer Sovereignty

Consider for a moment the whole idea of consumer sovereignty. The idea is, if you have real time power prices, then consumers will react and start to invest in more efficient appliances or better allocate their hourly use of electricity, or even invest in renewables. But having talked to a consumer once who had real time pricing, they said that after a few weeks of checking prices, they soon gave up and didn't bother with it anymore. This has to do with the costs and benefits of any given consumer action.

When consumers consider their one vacation a year, they may check several websites to save hundreds of dollars on different packages, but also in the process ruminate positively on the coming vacation. If time is worth say $30 per hour and in one or two hours they can save $300 on their vacation plan, and gain the imagination benefit of the vacation, then the cost to benefit value of their consumer sovereignty time is well worth it. But if it takes a protracted amount of time to check power prices and consider plans to mitigate power costs, the value the consumer gets may not be worth it, and then the cost to benefit net-value of their consumer sovereignty time is not worth it. Even using an automatic or AI system to check prices and possible strategies may take too much consumer time since AI systems can't go out and buy a new dishwasher. This is one of the problems with free markets for health care. You just can't obtain a lot of consumer sovereignty value when the time it takes to understand a market is high and the value you get from that understanding is low. Similarly, the whole behind the meter movement has to be looked at more articulately.

But having a Don King-like run utility can allow the CEO to use simplified prices and other easy to understand incentives for consumers to conduct demand side management techniques or even to engage in neighborhood renewables if that makes sense. With such a Don King-like utility, you will probably have more success in increasing social value of a utility then when you have a lot of inefficient consumer sovereignty in, around or outside the meter.

3. Next Administration Energy Team Research

When most of the general public, or for that matter competent engineers, look at all of the complex market mechanisms for free market electric utilities, they can't possibly know what is going on. On top of that, you have so much permitting for any given type of generator, it makes it impossible for the average Joe to enter the market. The real issue is that carbon emission reduction advocates are hoping to keep utilities as opaque as possible from proper economic analysis of any given renewable energy system because to them even one ounce of carbon emission reductions is worth thousands of dollars in their minds. So they don't like having transparency. If a Don King economic system were imposed, suddenly each ton of CO_2 reduction is going to be priced at a much lower price and the total amount of carbon reductions may not end up being as great as in a non-Don King system no matter how cost effectively carbon reductions are done. But that needs to be tested. Nevertheless, carbon reducing advocates want to keep everything as opaque as possible which is why there is such a focus on having the so called free market utility model pushed so hard.

What the next administration's energy team needs to do is to run some experimental economic studies to see if indeed a Don King economic system for electric utilities will work, because such a system would normally take years or even decades to see if it creates good economic outcomes otherwise. What some experimental economic runs could do would be to take data from one or another past utility history, even using older data and older technologies from decades ago, and use those older situations to simulate an in laboratory test of switching technologies or even utility re-organizations. They could run with that data to see what a CEO would do if incentivized and confronted with potential technology or organizational switches. That way a real time investment scenario over years can be reduced into one hour or even a few minutes so that the experimenters can tell which type of CEO bonuses work best for inducing cheaper electric power or even reducing carbon emissions over a short and long run time frame.

They could even run consumer experiments to see what types of incentives work best for inducing the kinds of consumer side changes that efficiently reduce power prices or carbon emissions, like for example inducing demand side management.

One such Don King energy economic scenario is given by Reynolds and Zhou (2019).

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'Over the edge' – energy risk trading in a negative demand environment

BY FARHAD BILLIMORIA

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Abstract

Large scale distributed energy resource deployment is expected to result in negative regional demand in grid-edge markets. While the price signal provides the economic rationale for consumption, a cohesive risk management framework for negative prices underpinned by foundation risk trading mechanisms are required for co-ordinated operational, commercial and investment decision-making.

Introduction

On Sunday 11 October 2020, just past midday, a new record for minimum demand of 300MW was set in the South Australia region of the National Electricity Market (NEM). Minimum operational demand levels in the region have been on a steep downward trend since 2012, and with ongoing deployment of rooftop solar is projected to tip over into negative minimum demand-between 2021 and 2024. While grids around the world have contended with the ramp challenges of the now famous 'duck curve', negative demand poses an enhanced set of challenges for grid operators and market participants alike. While the economic signals for additional consumption during the belly of the duck are manifest in negative prices, the question of how to elicit changing consumption patterns is still open. In particular, we point to the paucity of risk trading instruments that provide hedge protection against low and negative demand phenomena. In this paper, we highlight the operational and commercial implications of negative demand on a regional and system wide level. We further emphasise the importance of expanding the scope of exchange-traded and bilateral risk trading instrumentscatered towards a low or negative demand environment.

Minimum demand trends and tip-over points

With ongoing growth in rooftop solar deployment, South Australia is likely to be the first gigawatt scale power system in the world to reach negative operational demand. The Australian Energy Market Operator (AEMO) expects this to occur within the next 1-3 years. Other regions in the National Electricity Market (NEM)of Australia such Victoria are also following in this trend (with negative tip-over expected in the next 6-7 years), which suggests that by the next decade a significant portion of the grid may face negative minimum demand. While there are characteristics of the system and topology that make the challenge in NEM unique, this is also of relevance for grids experiencing significant expansion in distributed energy resources (DER) penetration.

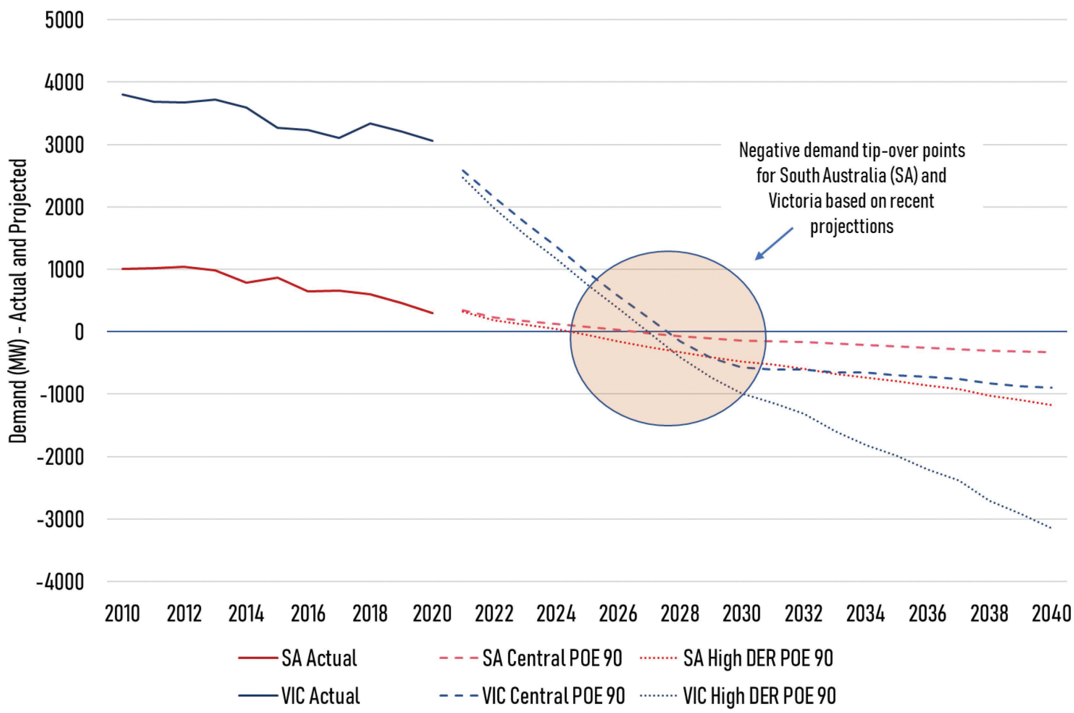

Figure 1. Minimum Operational Demand – Actual and Projected for South Australia and Victoria Source: AEMO. Scenarios presented are the 'Central' and 'High DER' cases underpinning the 2020 Electricity Statement of Opportunities (ESOO).

Operational demand is distinct from the concept of net load that is synonymous with the duck curve. While the duck curve measures 'net load' which is demand minus grid scale variable renewable energy (VRE) generation, operational demand only includes the impact of DER behind-the-meter, but does not include grid-scale VRE. This distinction is important for two reasons. First, the incorporation of the impact of grid scale VRE (particularly solar) on a negative minimum demand region exacerbate the rampingrequirements of the system. Second, the ability for a system operator (SO) to curtail grid-scale resources either via the security constrained dispatch process or as part of automatic generator shedding schemes provide a tool to manage security impacts (i.e. a safety valve if operators consider system security to be at risk). For the most part security-driven curtailment of distributed energy resources (DER)is not present in grids around the world, though this is an important measure under consideration in relation to grids reaching minimum demand operational limits.

A recent review of the South Australian minimum demand by AEMO raised a range of system security issues emerging from the issue of negative demand (AEMO, 2020). Two particular issues highlighted relate to (i) increased complexity and risks during islanded operation of the region (which while not considered an N-1 contingency – is part of a suite of risks requiring protection (ii) the risk ofvoltage-driven instability and disconnection of distributed inverters in low system strength conditions. It is important to note that while 'negative demand' is part of a subset of grid integration requirements under higher VRE and inverter penetration, it has the potential to exacerbate the existing suite of system risks. Of the range of measures highlighted to mitigate the issue, of particular criticality is the urgent enhancement of DER controllability and response (both as part of normal operation, as well as response under disturbance).It also underscores the rationale for more storage and "solar-soak" resources.

Market implications and the state of risk trading

These operational conditions are being reflected in the spot market with a greateroccurrence of low and negative prices[1]. A record occurrence of negative prices, 10% of the time, were experienced in South Australia during the third quarter of 2020, with September recording negative prices over 22% of the time. Reduced demand driven by DER, along with high VRE output and interconnector constraints were key drivers of this shift.

There has been some operational response to date from participants– certain renewable projectshave been observed to have self-curtailedtheir generation in response to negative prices (with suggestions that many renewable power purchase agreements now contain 'negative-price' clauses requiring a project to curtail if prices fall below certain thresholds (AER, 2020).In addition offer patterns and increased cycling of thermal dispatchable generation appear to reflect solar peak risks (McArdle, 2019).

Yet an energy-only market design is dependent upon transparent and deep risk trading mechanisms to enable these signals to flow into decisions on investment, expansion and retirement across a diversity of capital sources(Deng and Oren, 2006). Risk trading enables participants to better hedge and manage risk preferences, though we note that traditional risk trading mechanisms have been catered towards a positive price environment. Price dynamics in many markets continue to shift towards negative pricing periods given the VRE merit-order effects. Low or negative demand has the potential to exacerbate the persistence, recurrence and severity of negative prices, and as such risk trading and hedging instruments need to evolve to allow management of such price risks.

The renewable hedging problem has been a challenge for markets around the world and a range of different approaches have been adopted to date. Table 1 sets out a sample of products and instruments considered in hedging the risk of variability and uncertainty from renewable resources. Shape products, such as solar firming or super-peak products (Maisch, 2020), aim to adapt the volumetric profile of energy contracts to a renewable environment, evolving from the traditional peak / off-peak distinction. A range of weather-linked products have been developed based on wind and solar insolation patterns (Bhattacharya et al, 2015). Products such as 'Low Wind Day' and 'Low Wind Season' certificates provide opportunities for wind projects to obtain downside volume protection, but the issue of price protection still remains (especially under high and correlated wind outcomes across a market or region) . The Proxy Revenue Swap (Bartlett, 2019) has emerged as a popular form of risk hedging for renewable projects for 'proxy revenues' – which offer a fixed payment to projects in exchange for a formula-based estimate of a projects variable revenues given wind/insolation patterns and market prices, but with the project retaining operational risks. Counterparties for such contracts have included parties non-traditional energy counterparties including insurance/reinsurance companies, and hedge funds. Part of the rationale for such counterparties is the natural diversity offered by wind and solar projects, relative to other risks the party's portfolio. Finally 'price floor' contracts or put swaptions have also been proposed (NSW Department of Planning, Industry and Environment, 2020) – these provide a project with the right but not the obligation to sell its energy at pre-determined strike price. Thus should prices fall below the strike, the project is hedged from such price volatility. This would be the corollary

Table 1. A range of risk trading mechanisms for hedging variable renewable energy

Product Examples	Description	Risks hedged
Shape Products		
Solar Shape	Fixed-for-floating swap, volume sculpted to solar profile	Price risk over time block
Inverse Solar Shape	Inverse of Solar Shape Product	Price risk over time block
Super peak	Fixed-for-floating swap, volume sculpted to shoulder peaks	Price risk over time block
Weather linked-contracts		
Low Wind Day	Payouts based on wind/irradiance over day	Weather
Low Wind Season	Payouts based on wind/irradiance over season	Weather
Price trigger		
Swaptions/Price Floors	Provides payout if price falls below threshold	Low price volatility
Insurance products		
Proxy Revenue Swap	Fixed payment for proxy revenue	Multiple

of a price cap contract that underpins traditional risk management approaches to pricevolatility (for high prices) (Simshauser, 2018).

A proposal: exchange-traded zero exercise price put options (ZEPPO)

It is recognised that the management of financial risks relating to new energy sources is not a homogenous exercise. Indeed this heterogeneity can provide natural locational, temporal andseasonal-diversification in larger energy portfolios. As such, it is apparent that the approach to risk trading for each participant will be diverse and nuanced to reflect specific project or portfolio risks. However, it is also important that the market be anchored by a product or a set of products that provide participants with a transparent indication of price risks in the new environment.

This could come from an exchange traded 'price floor' contract that would mirror existing price caps contracts, which together with cap contracts and other derivates would provide a market guide for storage investment in electricity markets. A zero-exercise price put option (ZEPPO) would provide the buyer with the right to sell energy at a zero strike price (Figure 2). This would provide buyers with a payoff equivalent to the value by which the spot price is smaller than zero and provide generators with price protection from negative prices. Correspondingly for storage or consumers that are able to flexibly consume during negative pricing periods, it could provide a source of premium income to underpin short to medium term commercial decisions. This contract would provide an indication of market perceptions of negative price risks, and can provide a price guide for longer term agreements that underpinning investment.

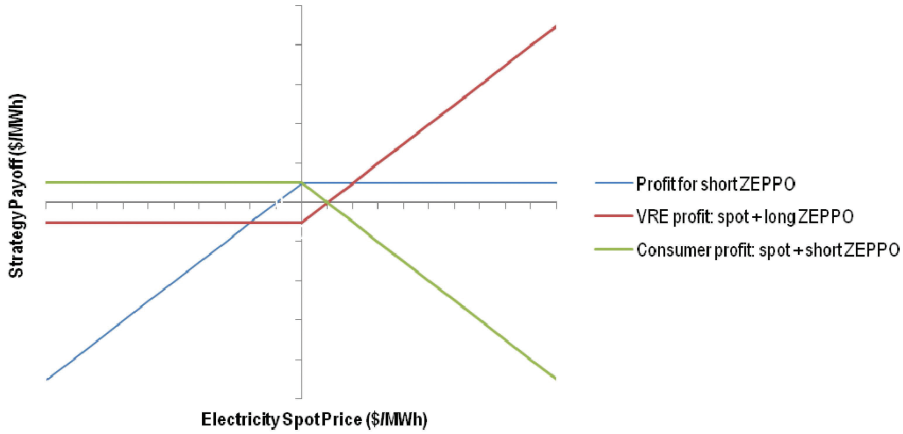

Figure 2. Hypothetical returns for a price floor product

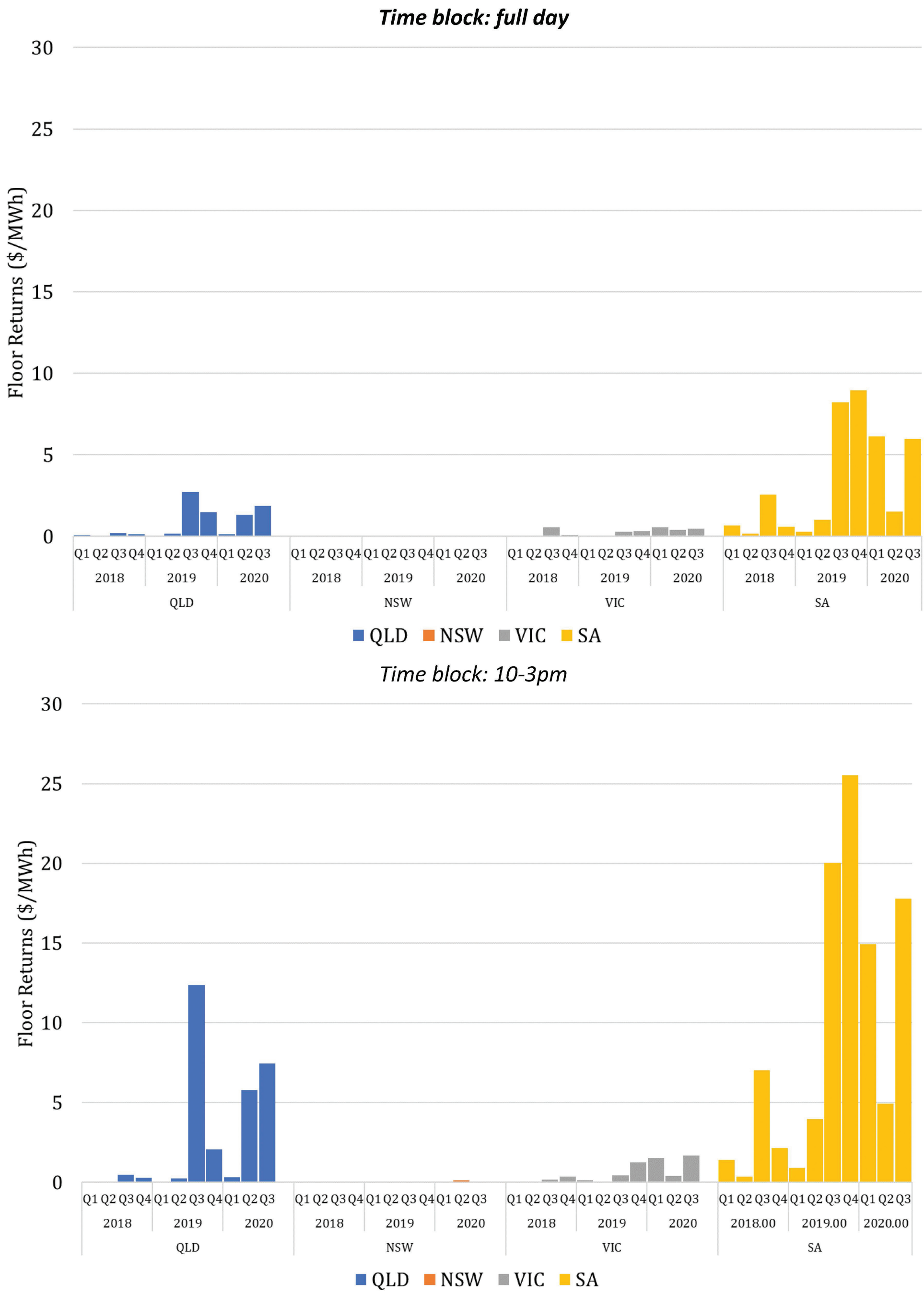

Figure 3. Hypothetical returns for a price floor product

Figure 3 maps the historical returns to a hypothetical ZEPPO (put option with a strike prices of $0/MWh) applying over two time blocks – the full day (top panel) and a 10am-3pm (bottom panel) time block. Given the increased frequency and quantum of negative prices, the returns to a hypothetical price floor has been increasing for certain regions, and should current trends continue downside risks require serious consideration for a modern electricityrisk manager.

While a price-floor may not be optimal for all projects and situations, an exchange-traded, transparent and liquid indicator of negative price risk perceptions would aid risk managers in managing downside prudential exposures, and would allow participants to use such price indicators in the structuring of more bespoke solutions.

A price floor could also be coupled with existing price cap contracts to form a contract that provides an indication of contracted returns to grid storage. This contract formed by the combination of shorting a price-cap (call option) contract and shorting a price-floor (put option) contract. An ideal counterparty for such a contract would be resource that can be confident of generating at prices above the cap price, and consuming at prices below the floor price. Such a contract, common in other commodity markets, would provide a sense of value for grid-storage. Again this would provide an important price anchor for project financiers and developers.

Finally we make the point that the development of risk trading instruments, exchange traded or otherwise are not enough in and of themselves. They need to be coupled with an enhanced prudential risk framework across the industry that provide standards for the management of these financial risks. With the expected growth of distributed and variable sources of energy, these risks are not likely to disappear any time soon, underscoring the criticality of industry leadership on negative price risk management.

Footnotes

[1] It is important to note that while prices are often an outcome of a variety of factors, negative demand has the potential to add further downward pressure.

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Date	Event and Event Title	Location	Supporting Organizations(s)	Contact
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Postponed to 2021 Dates TBA	3rd IAEE Southeast Europe Symposium *Delivering Responsible Infrastructure and Energy Solutions*	Tirana, Albania		Erlet Shaqe https://see20.iaee.org/
2022				
Postponed to 2022 Dates TBA	8th Latin American Energy Economics Conference	Bogota, Colombia.	ALADEE	Gerardo Rabinovich
July 31-August 3	43rd IAEE International Conference *Mapping the Global Energy Future: Voyage in Unchartered Territory*	Tokyo, Japan	IEEJ/IAEE	Yukari Yamashita https://iaee2022.org/
September 21–24	17th IAEE European Conference *The Future of Global Energy Systems*	Athens, Greece	HAEE/IAEE	Spiros Papaefthimiou http://haee.gr/
2023				
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