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CONTENTS

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PRESIDENT'S MESSAGE

As this edition of the *Energy Forum* is published, I begin my fourth and last quarter of service as your president. Each year seems to go by faster than before, and although circumstances of the pandemic have certainly tried our patience they have not actually slowed the clock, so it is hard to imagine that my term will soon be coming to a close. Let me say first how honored and grateful I am to have been able to help lead the IAEE through rather difficult times. Also, how grateful I am to all of the IAEE officers, Council members, Affiliate leaders, and regular IAEE members who have carried on and performed to their utmost to make this year an unexpected success for the Association. And I must also say how thankful I am to know that Peter Hartley stands ready to take up the reins as the next IAEE President, to be followed and assisted by President-Elect Jean-Michel Glachant. In these good hands, I am confident that IAEE will carry on with the spirit and success that have characterized the organization since its founding in 1977. Although many, perhaps most, of the energy challenges we now face were not anticipated back then, and could not have been, the IAEE and its membership have evolved with the times to remain in the vanguard of energy policy analysis, discussion, and debate.

Although the IAEE's usual cycle of conferences has been disrupted, the activities of the Association as well as those of many of our national Affiliates have proceeded apace. I am sure that no IAEE member remains unaware of the very ambitious and successful series of webinars and podcasts that have been produced through the voluntary efforts of so many of our members, with assistance and coordination provided by Dave Williams and Rebecca Lilley at IAEE Headquarters. Moreover, our journals have continued to expand in terms of the number of submissions and they have continued to evolve in terms of breadth of subject matter as well as the range of new research methods that are being brought to bear in this era of big data, machine learning, web scraping, etc. But let me say that the foundation of the research that we do publish is still grounded in the application of good old-fashioned economic principles. This year we are happy to celebrate the 10th anniversary of our policy-focused journal, *Economics of Energy and Environmental Policy*, and are also pleased to note that contributions of IAEE members' research to our *Energy Forum* newsletter have reached an all-time high.

Thanks to modern technology, even our schedule of conferences and meetings has maintained a small semblance of normality, a virtual version of business as usual as it were. I have previously commented on the success and broad participation in IAEE's First Virtual International Conference, held this past June. Still to come this year is the first USAEE/IAEE Virtual North American conference, sched-

(continued on page 2)

President's Message (continued)

uled for November 1-2. (Please see the IAEE or USAEE websites for more details). Additional meetings were organized this year by several of IAEE's other national Affiliates, including the SAAEE's (South Africa) annual conference held in February, the NAEE's (Nigeria) annual conference in July, and the special SAEE (Slovenia) meeting in June to celebrate of the Slovenian Presidency of the Council of the EU for 2021. Still to come as I write this is the HAEE's (Greece) annual symposium scheduled for late September as well as the AIEE's (Italy) annual conference in December. And there is continuing good news as we look ahead to next year, as planning is well underway for the 43rd IAEE International Conference, to be held in Tokyo at the end of July. Hope to see you all there (in person).

Those of you who attended IAEE's virtual conference in June may recall the very compelling keynote address given by Dr. Hoesung Lee, former IAEE President and current Chairman of the Intergovernmental Panel on Climate Change, regarding the important work and challenges facing the IPCC—past, present, and future. I was struck by Dr. Lee's suggestion that, moving forward, it might be a good idea to revise slightly the climate-change "call to arms." Rather than pleading for everyone to "Save the Planet," Dr. Lee suggested that a more effective plea would be simply to "Save Me." The idea is that we might be better motivated to fight climate change if its impact were personalized, rather than left as a general and rather impersonal proposition.

The idea of personal fight against climate change brings to mind an important economic distinction between efforts to *mitigate* climate change by reducing emissions, versus efforts to *adapt* to climate change that we cannot prevent.

We know the attempt to reduce emissions and mitigate climate change depends on many technological initiatives, but that a technical path to that end does exist—as the recent IEA "net zero" report has documented. Yes, it will entail some cost, but cost is not the real impediment to success. People are very willing to purchase individual insurance to protect the welfare of their homes and families. Investments to reduce emissions are just another example of insurance that people really do value and desire. The problem is about who shall pay for this insurance. The difficulty here comes from the "free rider" problem: I benefit whether it is you who reduces emissions, or me. And I prefer it to be you! A solution to this problem, if it exists, will not come easily. So, studies that hope to demonstrate the feasibility of achieving net zero must grapple not only with the technological developments that will facilitate the energy transition, but also with the behavioral obstacles that threaten its implementation.

In contrast, the "free rider" problem is not such an obstacle that impedes adaptation to the effects of climate change. Adaptation involves actions that are mostly local—efforts that involve local expense and that produce local benefits. As with other types of insurance, people are willing to invest in measures that will primarily protect their homes and families against the effects of climate change. Likewise, communities, states, and even nations are willing to invest in programs that will specifically protect the welfare of their own citizens. One prominent example is provided by the Panama Canal, which has recently initiated a $2 billion program to offset the reduction in rainfall and fresh water that is required to float ships across Lake Gatun and through the canal. Thousands of similar examples of such adaptation can be cited.

My point is that there is a behavioral bias that favors adaptation over mitigation when it comes to fighting climate change. I am not saying this is bad or good; I am only saying that it exists and that policy makers must take into account not only the technological requirements that could move us towards net zero—as in the IEA's report—but also the behavioral incentives that determine which measures individuals, communities, and nations are willing to undertake. Projections and forecasts that fail to account for the behavioral bias towards adaptation are bound to be wrong.

In closing, I want to again thank all of those IAEE members with whom I have had the pleasure of working during this eventful year, and I wish all of you good health and good fortune as we go forward.

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**

NEWSLETTER DISCLAIMER

Editor's Notes

We complete our coverage on vulnerabilities within the utility industry in this issue. Due to an overwhelming response to our call for articles on all aspects of energy transition, we will continue this topic in the first issue of 2022.

Josef Gochermann details that after hesitating until the mid-2010s, German industry has now embraced the energy transition and moved to a driver. The pioneers of change are the major energy companies, followed large parts of industry which have initiated radical changes. Even the energy-intensive industries steel and chemistry are phasing out fossil fuels.

Gonzalo Casaravilla and **Ruben Chaer** write about the change in the electricity generation matrix made in Uruguay between 2013 and 2017 and present possible future evolutions. The economic fundamentals that led to this change are shown, especially the reduction in cost risks in the electricity sector

Carlos Andrade, Sandrine Selosse, and **Nadia Maïzi** report that regions represent an essential scale for achieving the carbon neutrality objectives that France has set for itself. The prospective analysis of the different options available for the SUD PACA region allows the discussion of the relevant energy transition trajectories available for it.

Fateh Belaid and **Mohammad Al Dubyan** discuss a crucial topic that has emerged in the policy and economic literature in recent years: the potential role of energy efficiency in the current energy transformation process. It provides a straightforward analysis to explore the prominent role that building energy efficiency may play in shaping the energy transition and sustainability path. The focus of the investigation is the energy efficiency initiatives in Saudi Arabia, as an example of an economy very concerned by and very proactive in terms of efforts to boosting its energy transition. From a policy perspective, the paper emphasizes the importance of accelerating the decarbonization process in the building sector and suggests ways to consider a holistic view of energy efficiency policies in the building sector.

Mamdouh G. Salameh asserts that Energy transition is defined as a long-term structural change in energy systems. These have occurred in the past, and still occur worldwide. Contemporary energy transitions differ in terms of motivation and objectives, drivers and governance. He stresses the importance of separating the truths from the myths when discussing global Energy transition.

Tilak Doshi states that the so-called "energy transition" has dominated both media headlines and academic research concerning energy affairs in recent years, particularly in view of the upcoming UN climate conference in Glasgow, Scotland in November 2021. Nevertheless, this is akin to the tail wagging the dog, as demand for fossil fuels in the developing countries, especially in Asia, shows no signs of abating as these countries struggle to promote economic growth to meet the legitimate aspirations of four-fifths of the world's population for higher standards of living.

Minh Ha-Duong explains that Vietnam's recent energy transition experience shows that grid congestion issues limit how fast a country can turn to solar PV and wind power. Utility-scale battery storage could alleviate problems by time-shifting the variable electricity production, deferring the urgency to upgrade the transmission network. However, the technology is hardly bankable now in low- and middle-income countries. We propose that forming a collective of transmission network operators may accelerate access to this technology.

Inês Carrilho Nunes and Margarida Catalão-Lopes explain that COVID-19 presents both opportunities and challenges to the energy transition. This article presents a brief overview of the impacts of the pandemic on the energy sector and a reflection regarding three potential instigators of change: mobility, renewable energy sources, and the pace of the economic recovery together with government intervention.

Omoniyi Emmanuel Oluwafemi informs us that the impact of the global energy shift from a fossil system of energy to renewable energy on emerging economies like Nigeria deserves attention. The Gross Domestic Products would be adversely affected by this shift. Nevertheless, if policies that drive investment in renewable energy, agriculture, and solid minerals are established, such impacts would be mitigated

Chan Kung and He Jun explain that China has set an ambitious target of attaining "carbon peak" and "carbon neutral" in three decades. For China this goal is far more difficult than for most developed countries.

Tim Brennan writes that reliability and resilience do not necessarily go hand in hand. Designing a system to increase resilience—reduce the expected time to restore power once an outage occurs—need not improve the overall performance of an electricity grid.

Jackie Ashley and Michelle Nock let us know that cybersecurity is increasingly being regulated by incorporating a risk-based framework that is a process – not a set of standard or rules. This article describes this framework and proposes that it could also be used for climate related risks, such as extreme cold/heat events and wildfires.

Connemara Doran notes that the Texas polar vortex highlights the relationship between electricity cost and societal risk. We analyze six types of risk and possible policy responses, including R&D to improve wind-turbine deicing.

DLW

Navigating Energy Transitions

Economic Social, Technical and Policy Changes

38th Annual USAEE/IAEE North American Virtual Conference

November 1 - 2, 2021

Theme

The development of energy markets results from an ongoing dynamic interaction between preferences, progress in technologies, and public policy initiatives. Cutting across this to make sense of the ever-changing landscape is the analysis and language of energy economics.

Location

Our 2021 virtual conference takes place everywhere, from your browser, to keep the energy economics dialogue and debate alive, across North America and the world. Participation from industry, government, non-profit, and academic energy economists will enrich a set of robust, diverse, and insightful discussions.

Plenary Sessions

- Decoupling GDP from Energy Consumption - Real or Imagined? Can Our Models Answer the Question?
- Challenges and Solutions for a Just and Equitable Energy Transition
- Vital Energy Supply Chains: Past, Present and Future
- Promised Technology Solutions: Where Are They?
- Preparing for "Unlikely" Events in Texas and Elsewhere: Rethinking Economic Models, Infrastructure, and Regulatory Frameworks
- ESG Priorities for the Oil & Gas Sector: Investor Pressures, Company Responses, and Industry Implications

Registration for USAEE/IAEE members $125 | $150 after 10/1/21

For complete conference information and to register:

www.USAEE.org/conferences

USAEE United States Association for Energy Economics

IAEE International Association for ENERGY ECONOMICS

43rd IAEE INTERNATIONAL CONFERENCE

CALL FOR PAPERS

31 July - 4 August 2022

Mapping the Energy Future -Voyage in Uncharted Territory-

CONFERENCE OVERVIEW

The Institute of Energy Economics, Japan, and the National Graduate Institute for Policy Studies (or GRIPS) are pleased to host the 43rd IAEE international conference in Tokyo, between **31 July and 4 August 2022**.

The world is now clearly recognizing the need to quickly tackle the climate change issue. In this regard, many very important commitments for carbon neutrality by 2050 have been made over the last few years. Unfortunately, how to achieve those remarkable goals is still in development and results cannot be expected to occur overnight.

"Mapping the Energy Future -Voyage in Uncharted Territory-" is quite a timely and appropriate title for our conference. There will be 3 main topics to be featured at the Tokyo meeting.

The first one will highlight the different forms of zero-carbon energy. Not only will we talk about the traditional ones such as Renewable and Nuclear, but we will also introduce and emphasize unconventional ones, such as decarbonizing fossil fuels. The discussion on decarbonization will most probably be continued in Riyadh, Saudi Arabia, during their IAEE international conference to be held in 2023.

The second most important component is that a rapidly growing Asia and other emerging economies must meet their energy needs. Those innovative and yet affordable decarbonization technologies will help them meet their environmental aspirations.

The third highlight is that the Tokyo meeting will invite and host prominent, world renowned and high-ranking stakeholders from Industry, Academia and Governments. Those people should identify and analyze for us the implications of the commitments in terms of policy making and business planning.

The conference will feature 2 Plenary Sessions and 8 Dual Plenary Sessions complemented with a series of concurrent sessions for which the list of topics is quite extensive.

CONCURRENT SESSION ABSTRACT FORMAT

Those offering to make concurrent session presentations must submit an abstract that briefly describes their research or case study. Along with the overview, it must include its background and potential significance, methodology, results, conclusions, and references (if any). All abstracts must conform to the structure outlined in the abstract template. Abstracts are limited to no more than two pages in length and must be submitted online no later than **25 February 2022**.

Please see https://iaee2022.org for details.

PRESENTER ATTENDANCE AT THE CONFERENCE

At least one author of an accepted paper or poster must pay the registration fees and attend the conference to present the paper or poster. Authors will be notified by **8 April 2022** of the status of their abstract submission. The final date for the speaker registration fee, and full paper submission is **20 May 2022**.

Organizers of 43rd IAEE International Conference

IAEE International Association for Energy Economics — IEE JAPAN — GRIPS 政策研究大学院大学 National Graduate Institute for Policy Studies

43rd IAEE INTERNATIONAL CONFERENCE

31 July - 4 August 2022 JAPAN, TOKYO
Mapping the Energy Future -Voyage in Uncharted Territory-

CALL FOR PAPERS

IMPORTANT DEADLINES

- Deadline for abstract submission: **25 February 2022**
- Notification of abstract: 8 April 2022
- Submission of full paper and Registration: 20 May 2022

Submit your abstract at https://iaee2022.org/ after 6 September 2021 when the system is open.
For further information, please contact: iaee2022@jtbcom.co.jp

LIST OF TOPICS THAT COULD BE ADDRESSED

- Climate change
- CCS & CCU methods and solutions
- Economics and geopolitics of oil and natural gas
- Role of conventional energy sources under low carbon society
- Development of LNG markets
- Distributed generation under uncertainty
- Nuclear energy
- Energy sector investment and financing
- Efficient use of energy
- Renewable energy
- Connecting intermittent renewable to grids
- Prospects of alternative transport fuels
- Energy and emission modeling
- Experimental methods and behavioral economics in energy and environmental analysis
- Energy access issues

CONFERENCE VENUE

IAEE Tokyo conference will take place at the National Graduate Institute for Policy Studies (GRIPS), an international premier policy school with the aim of contributing to the betterment of democratic governance around the world.

Photo: Masao Nishikawa

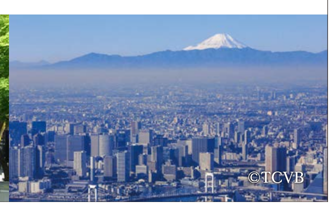
WHO SHOULD ATTEND

The conference is intended for:

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

STUDENT EVENTS

Students may, in addition to submitting an abstract, submit a paper for consideration in the IAEE Best Student Paper Award Competition.
We also encourage students to participate in the Student Poster Session. Students may inquire about scholarships covering conference registration fees.
For more information,
please CONTACT: iaee2022@jtbcom.co.jp



German Industry has embraced the Energy Transition

BY JOSEF GOCHERMANN

Abstract

After hesitating until the mid-2010s, German industry has now embraced the energy transition and moved to a driver. The pioneers of change are the major energy companies, followed large parts of industry which have initiated radical changes. Even the energy-intensive industries steel and chemistry are phasing out fossil fuels.

The role of industry in the energy transition

Germany is an industrialized country with internationally active companies, particularly in the automotive, plant and mechanical engineering, chemical and pharmaceutical, steel and manufacturing industries. In the past decades, the formerly nationally positioned energy suppliers have also developed into internationally successful energy concerns. However, the majority of the German economy is dominated by small and medium-sized enterprises with strong, mostly family-owned companies. Nevertheless, the large corporations are structurally formative. The impact of their decisions on the national economy is noticeable. Industrial groups therefore have an important guiding function for the implementation of the energy turnaround and the restructuring of energy systems.

Analyzing the behavior of the industry regarding the German energy transition (Energiewende) one can identify three characteristic phases [1], [2]:

- Phase I Renewable energies tolerated as an add-on (approx. 1990s and 2000s).
- Phase II Perception of the change of the energy system (mid 2010s).
- Phase III Acceptance and implementation of the energy transition (from the end of the2010s).

Industry and the German Energiewende in the past

In a simplified view, the energy transition is equated with the increasing use of renewable energies such as solar, wind or biomass. However, the energy transition is much more than just replacing fossil fuels with renewables. According to Rifkin, it is the change of the energy system part of the 4th industrial revolution, the change of the infrastructure element energy source [3]. Nevertheless, the share of renewable energies in the energy supply is a suitable measure to describe the change of the system. The conscious beginning of the energy transition in Germany can be dated back to 1990, when the Electricity Feed Act created the possibility of feeding electricity from renewable energies into the public grid. From then on, the share of renewables rose continuously.

Initially, renewable energies were regarded only as an environmentally friendly supplement. Industry and politics still assumed that energy demand would increase. Renewables could therefore be used in addition without questioning the existing energy sources and generation processes. Germany's excellently functioning supply system, which is characterized by stability, long-term planning, and predictability, was not affected by renewables.

German Industry continued to adhere to this old energy system until well into the 2010s. In a key issues paper from 2010, the Federation of German Industries (BDI) supported the expansion of renewable energies, but at the same time emphasized that "the construction of new, highly efficient coal-fired power plants ... as a replacement for older power plants" must be possible. In the BDI's view, nuclear energy also makes a significant contribution to achieving the climate targets [4].

In 2012, even after the reactor accident in Fukushima, the former head of the energy company RWE, Jürgen Großmann, affirmed that "German coal-fired power plants are the backbone of German industry - and will remain so" [2, p. 79].

The chemical industry also remained stuck in the old energy system. As late as 2015, the world's largest chemical company, BASF, was still railing against politicians, saying that "abroad there is only pity and ridicule for the German energy turnaround" [5].

For plant manufacturer Siemens, the energy turnaround is "an opportunity for tomorrow's markets," but Siemens CEO Joe Kaeser nevertheless believes in 2014 that "promoting photovoltaics in Germany makes as much sense as growing pineapples in Alaska." [6].

The automotive industry showed the strongest persistence. Until the end of the 2010s, it clung vehemently to combustion engines and consistently blocked the introduction of electro mobility. The German automotive industry held on to its cash cow, the internal combustion engine. This technology is mature and thus guarantees high profits with comparatively little investment in its further development. However, these technologies have mostly also reached their performance limits and there is a risk that they will eventually be overtaken by a more powerful technology [7].

The reasons for vehemently clinging to the previous energy system were a mixture of short-term profit skimming, a lack of will to change, and a dose of incredulity about the upcoming changes.

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Awareness of the turning reality

In the early to mid-2010s, more and more industries are realizing that the impending change is real and cannot be stopped. From around 2007/2008, more and more pilot projects were initiated, primarily by regional and municipal energy utilities [2, p. 163 ff.].

Energy consumption became visibly decoupled from economic growth, and the share of renewable energies in gross electricity consumption rose from 6 percent in 2000 to 32 percent in 2015 and even well over 40 percent by the end of the decade [8]. The increasing share of volatile power feed-in affects the system.

The first industrial companies in Germany to react actively to the change were the large energy supply companies, first and foremost RWE, E.ON and EnBW. The increasing share of renewable energies and the decision to phase out nuclear energy had put the energy corporations under economic pressure. The old business models of the previously vertically fully integrated companies began to falter. RWE and E.ON in particular were on the lookout for new business models, new structures and new ways of working.

E.ON, the energy utility, was the first to embrace the massive change and make a radical cut. The company was split into the new E.ON, with its renewables, energy networks and customer solutions businesses, and a new company, later called Uniper, with its conventional generation business, global energy trading, and exploration and production. Many analysts described Uniper as a "bad bank" into which the old energies that were being phased out were bundled. However, renewable hydropower is also part of Uniper. The division was based on a very sensible approach: the old energy world was characterized by stability, a long-term approach and predictability; the new energy world is volatile, small-scale and decentralized. The two systems are governed by different business logics, which formed the basis for the split-up of E.ON.

RWE also restructured the Group and recreated a new division, Innogy SE. However, the Group initially still adhered to full vertical integration, from energy generation to Smart Home household products.

If one places both structural approaches side by side, that of RWE and that of E.ON, one recognizes clear duplications, which were caused by the previous regional demarcation of RWE, E.ON, EnBW and Vattenfall (cf. [2]). Now, in a European, possibly in a global market, these duplications no longer made sense. In March 2018, E.ON acquired RWE's shares in Innogy. As part of a swap of business activities, RWE received all of E.ON's main renewable energy activities and Innogy's renewable energy business, a minority stake of 16.67 percent in the enlarged E.ON, and other assets [9]. In the process, RWE abandoned its fully integrated structure and will focus on power generation in the future. For this purpose, the company's own RWE Renewable Energies GmbH was founded.

This realignment of the two major energy companies was more than just a strategic reorientation. It cements the move away from the old German energy market structure and lays the foundations for a new energy market. This realignment is an essential cornerstone and an accelerator of the German energy turnaround.

Other industry groups followed the example of the energy suppliers. In 2020, Siemens spun off its energy division and founded Siemens Energy AG, which even joined the elite group of German listed companies, the DAX, only 6 months after its IPO. In mid-2020, Siemens CEO Joe Kaeser announced the phase-out of coal [10].

Changes are also becoming apparent in the automotive industry at the end of the decade. German automotive manufacturers are beginning to develop electric vehicles, first tentatively, then more decisively. However, the cause is likely to be less an increase in environmental awareness than the enormous market pressure from China, where a certain proportion of e-mobiles has been mandated in the product portfolio.

The irreversibility of the path became finally clear when the CEO of the oil company BP, Bernard Looney, declares the end of the oil age and announced a realignment of his company [11].

The revived discussions about climate change are accelerating the process, but they are not the cause. The transformation of the energy system is not taking place solely because of climate protection, but is also part of the 4th Industrial Revolution. Industry has largely recognized this.

Industry as a driver of the energy transition?

While the mid-2010s saw hesitation among the industry, a new momentum of change developed at the beginning of the new decade. In 2020, the EU Commission announced that it would further tighten the interim climate targets. Instead of widespread protest from the business community, at least international companies demanded stricter rules. Before the announcement of the new EU climate targets, the heads of more than 150 international companies such as Google, Apple and Deutsche Bank had called for a significant reduction in CO_2 emissions [12]. In a letter, they called on European leaders to reduce CO_2 emissions by at least 55 percent by 2030.

The signatories, who included the heads of U.S. software company Microsoft, Swedish furniture chain IKEA and clothing company H&M, said drastic CO_2 reductions were a way to "prevent the worst consequences of climate change." At the same time, stringent climate targets could enable a "sustainable, competitive economic recovery." It is "central" for businesses to get clarity on the EU's planned path to climate neutrality [12].

In Germany, too, industry is increasingly becoming a driver. A group of 17 industrial companies, including big names in German industry such as the chemical groups BASF, Bayer, Covestro, Lanxess and Wacker, the steel producers Salzgitter and ThyssenKrupp, and the building materials group Heidelberg Cement, together with the think tank Agora, the 2° Foundation and the management consultancy Roland Berger, drew up an appeal to policymakers in Berlin in February 2021: "Climate neutrality 2050: What industry needs from policymakers now!" [13]. According to the report, industry transformation is based on five pillars:

- Massive expansion of renewable power generation and the power grid.
- Electrification of industrial processes and energy efficiency enhancement.
- Establishment of a European & international climate-neutral hydrogen economy.
- Use of CCU/CCS and negative emissions for unavoidable residual emissions.
- Strengthening the circular economy.

It is important for companies to look at the entire value chain, from upstream (energy, raw materials, infrastructure), to midstream (production), to downstream (sales).

Are these targets too ambitious, especially for energy-intensive industries? At least intensive work is being done to achieve them, as some examples from the steel and chemical industries demonstrate.

On the way to green steel

Seven percent of global CO_2 emissions in 2019 were from steel production, according to the International Energy Agency. The one thyssenkrupp steel mill in Duisburg alone accounts for 2.5 percent of all German CO_2 emissions, much more than, for example, all domestic air traffic in Germany [14].

All major steel producers are working on concepts to decarbonize the steelmaking process or at least significantly reduce CO_2 emissions. Most steel mills operate with a classic blast furnace in which the iron ore is mixed together with the reducing agent coke and other components. Burning the carbon from the coke generates the necessary process heat and plenty of carbon monoxide, resulting in high CO_2 emissions. In order to become climate-neutral by 2050, some industrial companies want to replace coke with hydrogen in steel production. This so-called green steel is to be produced preferably with hydrogen derived from renewable energy sources.

Salzgitter AG has launched the SALCOS® R&D project. Since 2015, researchers and production specialists from the Group have been working with Fraunhofer institutes and other partners on the new technologies and their incorporation into an integrated steel mill [15]. With the two research projects GrInHy and GrInHy2.0, the Group is also working intensively on hydrogen production technologies. The image of the future is "The climate-friendly steel mill".

The traditional German group thyssenkrupp Steel is also working on CO_2 reduction. The aim is to make steel production at thyssenkrupp carbon-neutral by 2050. thyssenkrupp Steel is pursuing an open technology approach and is focusing on two paths: the avoidance of CO_2 through the use of hydrogen (Carbon Direct Avoidance CDA) and the use of CO2 produced (Carbon Capture and Usage CCU) [16]. To ensure the supply of hydrogen, thyssenkrupp Steel is planning a joint project with the energy company STEAG and the electrolysis supplier thyssenkrupp Uhde Chlorine Engineers for the construction of a water electrolysis plant at the STEAG site in Duisburg as well as the supply of green hydrogen and oxygen to the thyssenkrupp steel mill in the neighboring district [17].

ArcelorMittal is also working to reduce its CO_2 emissions. The company wants to use hydrogen for the reduction process and convert its plant in Hamburg. ArcelorMittal is working on a pilot plant in Hamburg that is expected to produce around 100,000 metric tons of sponge iron a year from 2024 onwards [18]. In Hamburg, initial considerations exist for the construction of a large electrolysis plant in the port, which would be supplied with energy from the wind turbines off the coast of Hamburg.

Roadmap Chemistry 2050

The German Chemical Industry Association (VCI) is also venturing a long-term view of the future, which is primarily oriented toward reducing CO_2 emissions. The "Roadmap Chemistry 2050", published in October 2019, describes the path to greenhouse gas neutrality from 2020 to 2050 in three paths, which are to be understood as different levels of ambition [19]:

In the *reference path*, companies continue to produce exclusively with today's technologies. Their investments remain at the current level. The companies are also focusing on more recycling. As a result, CO_2 emissions will be reduced by 27 percent between 2020 and 2050 by optimizing today's plant fleet and purchasing lower-CO_2 electricity.

In the *technology pathway*, heavy investment in new production technologies for basic chemicals such as ammonia and methanol are done. Further progress will be made through improved mechanical and chemical recycling of plastics used as feedstock for the production of basic chemicals. Adding measures to those from the reference pathway, emissions from the chemical sector can be reduced by around 61 percent from 2020 to 2050. The goal of largely greenhouse gas neutrality by 2050 is not achieved in this pathway.

In the *greenhouse gas neutrality path*, all restrictions are dropped; greenhouse gas neutrality is set as a target for the middle of the century. Technologies are introduced as soon as their use results in CO_2 savings, without regard to economic efficiency. From 2035 to 2050, all conventional basic chemical processes will thus be replaced by alternative processes with no CO_2 emissions. The new, electricity-based processes increase the electricity demand of the German chemical industry to 685 TWh per year from the mid-2030s. Companies would have to invest around 68 billion euros more from 2020 to 2050, with most of this again starting in 2040. The conversion of the basic chemistry processes alone entails additional investments of up to 45 billion euros. As a result, almost 100 percent less greenhouse gases can be achieved in 2050.

Industry motivation for change

Industry in Germany is urging politicians to make quick decisions on climate and energy policy. Is the

reason a change of mind or rational calculation?
Both dimensions are playing a role. First, industrial companies have recognized that industrial plants that would be built according to the old climate-damaging pattern would be investment ruins. Investments in large-scale technologies are designed to last for several decades. So the right investment decisions for 2040 and 2050 have to be made now and there should be no hesitation.

On the other hand, according to the think tank Agora, there is often a lack of a business model for building sustainable plants. If this dilemma is not resolved, Germany faces the threat of an investment blockade. For this, the industry needs a reliable long-term framework for decarbonization [14]. In addition, more and more industry managers have realized that the costs of using nature will increasingly fall on them and that it is more economical in the long term to invest now.

Beyond this, however, a change of mindset and of attitude has also taken place among many industry representatives. In interviews with top managers of RWE, E.ON and Siemens Energy, one sensed a growing conviction to actively tackle climate change and shape the energy transition [1].

In an interview in January 2020, for example, RWE CEO Rolf Martin Schmitz stated that he personally had learned a lot in the last ten years [20]. According to Schmitz, none of them had thought that climate change would come so quickly and that there would be irreversible developments, self-reinforcing effects. Five years ago, he himself did not believe, he said in a later newspaper interview, that climate change would become apparent so quickly. He had thought the buffering capacity of the atmosphere would be greater [21].

Conclusions

German industry has embraced the transformation of the energy system. Brakemen have become drivers, and in addition to the purely economic considerations, there is also a serious realization among many that the transformation of the energy system must be implemented quickly and decisively. German industry can thus be a pioneer and significantly influence technological and political trends in Europe and worldwide.

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Energy Transition of Uruguay

BY GONZALO CASARAVILLA AND RUBEN CHAER

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Abstract

The change in the electricity generation matrix made in Uruguay between 2013 and 2017 and a possible future evolution are presented. The economic fundamentals that led to this change are shown, especially the reduction in cost risks in the electricity sector.

The Uruguayan Electric System has changed substantially in recent years [1]. The country transformed its generation matrix, following an optimized investment plan, in which Non-Conventional Renewable Energies (NCRE) were the protagonists. Fig. 1 shows the speed with which the transformation was carried out from 2013 to 2017.

The year 2018 can be considered as representative of the current system, after the radical transformation carried out. Fig. 2 shows the expected value of the energy generated by the different sources, being Hydraulic 49%, Wind 38%, Biomass 7%, Solar 3% and Thermal 3%. Therefore, the new generation matrix in Uruguay is 97% based on renewable energies and in particular 48% is with NCRE (Wind, Solar and Biomass).

The thermal power plants (motor generators and aero derivative turbines), in Uruguay, are mainly backup and together with the hydroelectric plants they allow to guarantee peak demand.

Uruguay developed in the 80s of the 20th century 100% of its hydroelectric generation potential at an efficient scale, thus taking the first step towards a system based on renewable energies.

In expected value, 10% of the generation is associated with occasional surpluses and is exported to neighbouring countries. If it is taken into account that the maximum demand in Uruguay is 2,200 average MW (year 2021), the 2,000 MW of the interconnection capacity with Argentina and the 570 MW of interconnection with Brazil, together allow relatively important energy exchanges for Uruguay. Take into account that the Electricity System of Argentina and Brazil are, respectively, eleven and fifty times larger than that of Uruguay.

In Uruguay, the optimal economic dispatch of generation resources is carried out by assimilating the forecast information of the water inflows to the dams and the forecasts of wind and solar generation with increasingly powerful and sophisticated tools.

There are hours or days with little wind or sun, but the energy received on a bi-monthly scale from these sources, with probability 95% exceeds 90% of its expected value, contrasting in this sense with the availability of energy of hydroelectric origin that in Uruguay has significant variability at the annual level as shown in Fig. 3. To have the same confidence margin in Uruguay for hydroelectric energy, it is necessary to average 16 years. In Fig. 3 you can also see how the 11,000 GWh of demand in 2020 would have been supplied. Note that the hydroelectricity of 2020 is located in the 5% of the driest years in the history of hydroelectric generation in Uruguay.

If the generation matrix had not been changed, thermal generation (or imports) would have reached 65% of demand, totalling 7,200 GWh.

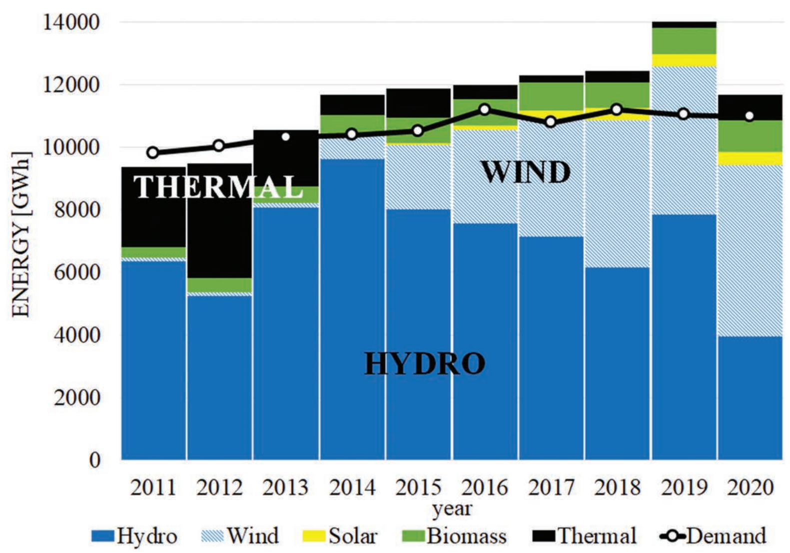

Fig. 1: Evolution of the Generation from 2011 to 2020 in Uruguay.

It can also be seen in Fig. 1 and Fig. 2 what happened in 2012, a moderately dry year and prior to changing the generation matrix. Fig. 4 shows the expenditure on the purchase of fossil fuels for electricity generation from 2010 to 2020. In 2012, 1015 MUS$ were spent on thermal generation and energy had to be imported from the region, at prices comparable to the costs of rationing, for another 369 MUS$. Between fossil

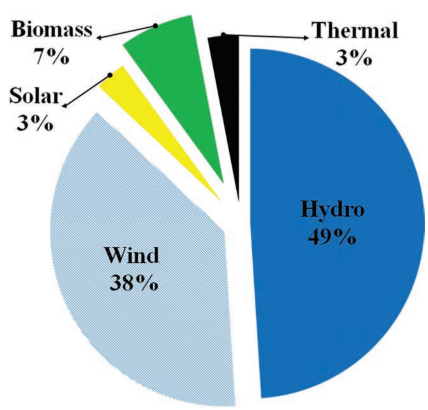

Fig. 2: Expected value of generation in Uruguay 2018.

fuels and imports, 1,384 MUS$ were spent. Said amount, for the Uruguayan economy, was extremely significant, representing 2.6% of the Gross Domestic Product in 2012. Fortunately, it was not as bad as it could have turned out. If the two main risk factors are considered, which are the hydroelectric generation of the year and the price of fossil fuels from thermal generation, the generation cost in 2012 could reach 2,400 MUS$ with a 5% risk of being exceeded. At that time, and in order to temporarily cushion this risk condition, a climatic insurance was contracted that combined the climatic aspect and the cost of a barrel of oil [2]. An Energy Stabilization Fund (ESF) was also implemented in 2011 [3]. Both instruments allowed the energy transition to be carried out with peace of mind and lost importance once the transformation was carried out. Due to the nature of the new generation matrix in Uruguay, with a high penetration of NCRE, the risk of system over-costs has been radically reduced. The climate insurance no longer makes sense to contract it and the ESF has been adapted to reflect the reduction in the need to stabilize costs.

As a result of the energy transition, the worrying Fig. 3 was replaced by Fig. 5. in which the current configuration of the Uruguayan generator park is observed. Fig. 5 shows what would happen for the year 2020 that was dry.

In 2020, a total of 11,662 GWh were generated. Thermal generation was 804 GWh which, as shown in Fig. 4, represented a cost of 99.5 MUS$, no thermal energy was exported, 514 GWh were imported, which if not imported would have also been generated with thermal power plants. Adding both values, it turns out that the equivalent thermal generation for 2020 was 1,319 GWh. The total equivalent generation was 12,176 GWh, the equivalent thermal generation being 11% of said value. Remember that for an average year the thermal generation is 3%. The drought of 2020 almost quadrupled the costs of thermal generation with respect to the expected value. But the new matrix still keeps them limited since the 1,319 GWh would be equivalent to a cost of 163 MUS$ (99.5x1,319 / 804). If the 7,200 GWh in Fig. 3 had to be generated, they would have cost 891 MUS$. It should be noted that the price of a barrel of oil in 2020 was definitely low. A risk analysis should consider values between two and three times higher, which corresponds to the 2,400 MUS$ already referred to.

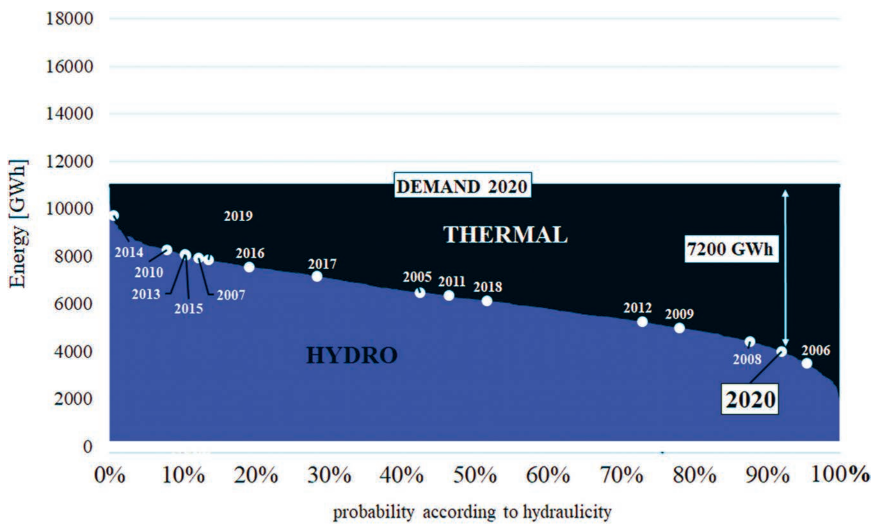

Fig. 3: Hydraulic and thermal generation expected in 2020 if the Uruguayan generation matrix and hydraulic generation verified between the years 2005 to 2020 were not changed.

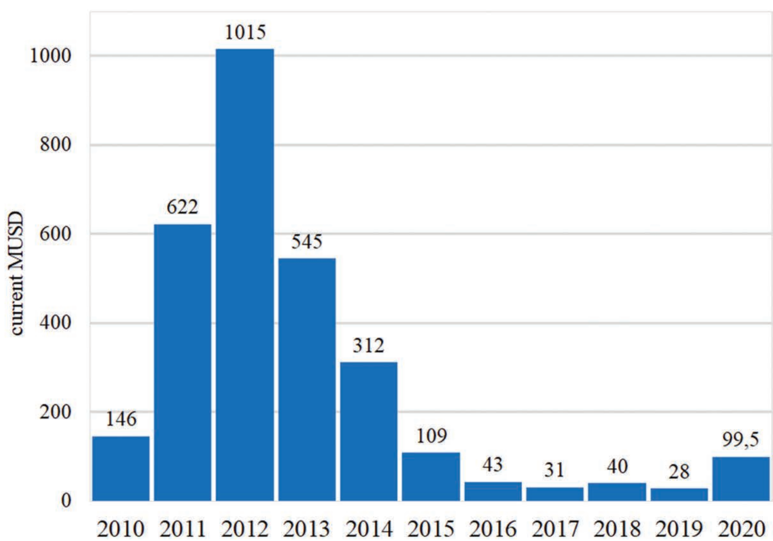

Fig. 4: Expenditure of fuels in thermal generation from 2010 to 2020.

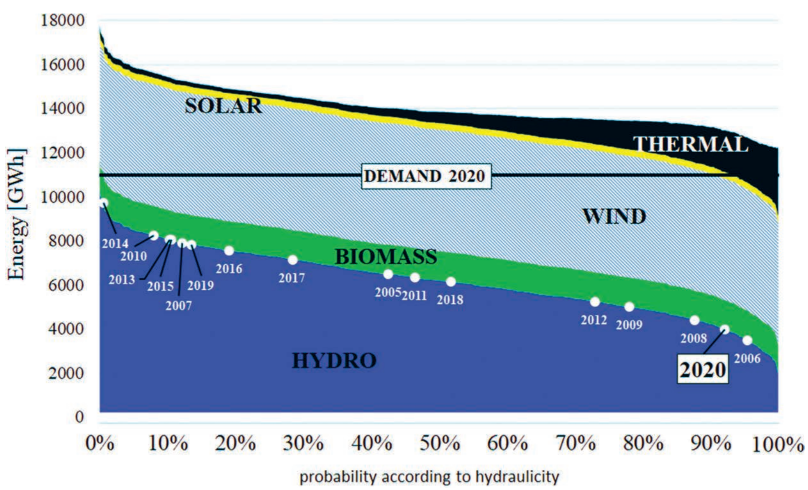

Fig. 5: Generation expected for the year 2020 for the current Uruguayan generator park and hydraulic generation verified between the years 2005 to 2020.

The cost of biomass, wind and solar generation in 2020 was 520 MUS$. It is enough to compare the 891 MUS$ with the 520 + 163 = 683 MUS$ to corroborate, even for extreme low values of a barrel of oil and not considering the income from exports, the benefit obtained from the change in the generation matrix in Uruguay.

Observe from Fig. 1 (reality) and Fig. 5 (expected values) that even in a dry year like 2020 there is export. For example, in 2020, exports reached 1,148 GWh, (almost 10% of generation) since it is associated with occasional surpluses associated with Uruguay's new generation matrix with high NCRE penetration.

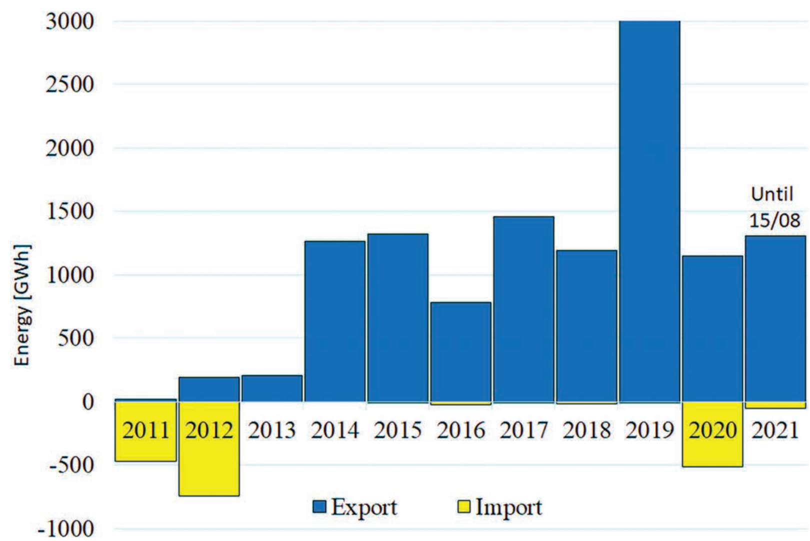

Fig. 6: Energy export and import balance from 2011 to 2021.

In Fig. 6 it is observed how Uruguay went from being a deficit country to being a net exporter, even and as already seen, under drought conditions. Note that although the year 2021 has been presenting itself as a moderate drought, as of August 15, 2021, the export balance already exceeded the expected value (compare with 2018, which is the one taken as the average year). This is due to the fact that neighbouring countries are also exposed to low hydroelectric generation, raising prices and justifying the purchase of generation at thermal power plant values. Thermal generation, as of 8/15/2021 represents 17%, which is projected at the end of the year will be a record value, possible due to the new generation matrix in Uruguay.

In recent years there has been a gradual and continuous improvement in occasional exchanges between the systems of Uruguay, Argentina and Brazil. These improvements are mainly related to flexibility in terms of being able to carry out occasional exchanges based on offers that allow taking advantage of the mutually beneficial opportunities created by renewable energies in the three systems. We can visualize it as a virtuous circle. The improvement of the market coupling in the region helps to increase the speed with which the generation matrices of Argentina and Brazil will be transformed, which in turn creates more opportunities for benefits from energy exchanges.

Thinking ahead, a possible evolution of Uruguay's optimal generation matrix is shown in Fig. 7. To optimize the expansion plan in Fig. 7, it was assumed that nothing new was installed until 2030, that all current aero derivative turbines and current motor generators are out of service due to obsolescence and that of the current thermal park, only the 540 MW Combined Cycle remains operational.

It is observed that the generation of thermal energy is increasing as we approach the year 2030. From 2030, the expansion is carried out based on Solar and Wind energy both to accompany the growth of demand and to replace wind and solar generation plants existing at the end of their useful life.

The optimum also includes the incorporation of new thermal power plants. In this case shown, a total of six aero derivative turbines of 60 MW are installed in the period studied. The previous result is consistent with the fact that the annual peak of demand, of the projection used in the optimization of the investment plan, grows on average 55 MW per year from 2030 to 2039.

This is a characteristic of the optimal expansions of systems with strong incorporation of NCRE and constant hydraulic capacity. These systems have a first stage in which the expansion with NCRE increases the firm-capacity (short-term energy availability) of the hydraulic power plants, avoiding the installation of thermal power plants. At the end of this stage, the hydroelectric plants can deliver up to their installed

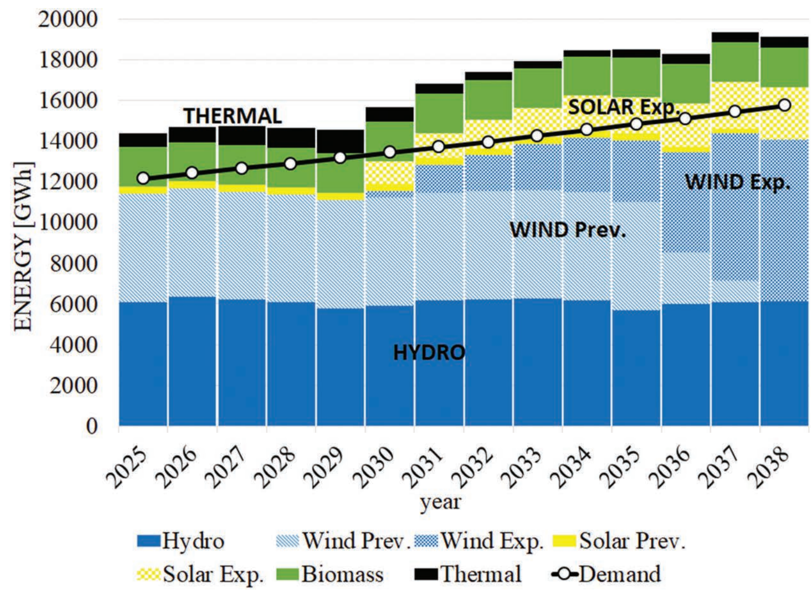

Fig. 7: Generation 2025-2039 with optimal expansion (WIND Exp. and SOLAR Exp.) from 2030 to 2039.

capacity at the times of greatest power requirements of the system. Once this limit has been reached, a second stage begins where the incorporation of more NCRE implies either the installation of peaking thermal power plants to cover the power requirements or possibly in the future control actions on possible demands with responses.

Conclusions

Uruguay has managed to complete its energy transition and its electricity generation is 97% renewable. During the 80s of the 20th century, 100% of the hydroelectric potential was developed. Between 2014 and 2017, NCRE was incorporated on a massive scale, accounting for 48% of the generation. This milestone was possible based on a multiparty political agreement in 2010 that provided the framework to turn the task into a national objective.

An attempt has been made to summarize the past, present and future of electricity generation in Uruguay with the corresponding generation matrices. The economic fundamentals of these matrices incorporate the fact that Uruguay does not have oil or natural gas deposits but has been favoured by nature with abundant resources of hydraulic, wind and solar energy.

For Uruguay, the future path is to continue incorporating NCRE. For this, more and better tools will be needed to perform the optimal dispatch of the generation resources system. It will be necessary to continue improving the forecasts of wind and solar generation as well as the flows of contributions to the dams. Optimal planning and dispatch tools will need to continue to be improved. All this is what has been done in a sovereign way in recent years. The history of having achieved in a few years the last stage of the energy transition managing a system with high penetration of NCRE augurs a promising future.

The development of NCRE and the transition of the remaining regional generation matrices are also promising. For now, each country will continue planning and guaranteeing its supply in a sovereign way. The economic rationality of the occasional exchanges is the first stage that would one day allow us to think about regional planning of infrastructures and a coordinated dispatch. But that is another story that surely needs a regional political stability that does not depend only on the electricity sector.

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Energy Transition of Local Territories: Lessons Learned from the Case of the Sud Paca Region in France

BY CARLOS ANDRADE, SANDRINE SELOSSE, AND NADIA MAÏZI

Abstract

Regions represent an essential scale for achieving the carbon neutrality objectives that France has set for itself. The prospective analysis of the different options available for the SUD PACA region allows the discussion of the relevant energy transition trajectories available for it.

Introduction

The last report from the Intergovernmental Panel on Climate Change (IPCC) reminded us that if humanity wants to limit the rise of temperatures to 2 0C or even 1.5 0C, it is required to start immediately a rapid and massive deployment of solutions targeting the reduction of greenhouse gas emissions (Masson-Delmotte et al., 2021). Especially, it is required to stop burning fossil fuels and start using other type of energies whose use is more environmentally friendly. In other words an energy transition is needed. In this sense, achieving such energy transition is one of the greatest challenges that humanity is facing nowadays because it does not depend just on the deployment of technological solutions, it demands a complete shift in how society interacts with the environment and how it governs energy systems. In fact, past energy transitions have mainly relied on technological innovation, such as the transition towards greater use of coal with the invention of the steam engine, or the transition to the use of oil products with the invention of the internal combustion engine. The current energy transition is above all driven by awareness of environmental issues and it is in this sense much more complex because it is not only a question of promoting new technologies or resources, but of putting in place a set of new ways of governing together with the promotion of technologies, the change in consumption behavior, which will be implemented through political and social actions (Millot & Maïzi, 2021). In this regard, the establishment of energy policy has to shift from a centralized manner to a more participative one, including different actors, in particular including the participation of the territories that can influence on a great deal of emissions. Through their actions they can massively contribute to the energy transition by the deployment of actions according to the reality of their local energy system and their responsibilities.

Territories, key actors of the energy transition

Territories can contribute to the decarbonization of energy systems by mobilizing their local decentralized energy resources; for example, the recovery of waste heat through heat networks, or the development of renewable resources. In addition, local authorities can deploy transversal actions through different sectors and further contribute to energy transition, for instance, through the implementation of actions for the transport sector and urbanization. In this way they can promote the use of decarbonized energies for private and public transport, and through a better organization of the territory they can favor the shift to the use of less consuming energy vehicles, such as electric bicycles. In this sense, they can also increase energy efficiency by fostering the renovation of buildings, and by including citizens in the energy strategies of the territory. Better energy consuming behaviors can be fostered and other strategies implemented with the aim to reduce the environmental impact of the territories' activities. This scale is all the more crucial if we consider the development of the circular economy (CE), whose strategy resonates with territorial development. CE emphasizes the reduction of the consumption of resources and the production of pollution by shifting the idea of conceiving something as waste, to instead considering it as a resource that has to be integrated into the economy. If it is not possible to do so, it should be reintegrated into the environment in a way that it can be absorbed naturally. Its application depends mostly in the proximity between producers and consumers, as the transport of the resources would increase their final cost, so the recovered resources should mainly be consumed locally. This is, for example, the case of municipal solid waste whose management is a responsibility of local authorities. In this sense, French territories have been receiving the competences that allow them to contribute to the energy transition, and the application of more sustainable solutions.

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The territorialization of energy policy in France

In France, through many different laws, energy policy was progressively declined to their territories, with an important milestone with the Grenelle I and II laws of 2009 and 2010, which reinforce the energy transition objectives of the territories by demanding the development of a "Regional climate air energy scheme" (Schéma régional climat air énergie (SRCAE)) where they have to set long-term ambitions to decarbonize their energy systems in line with national and European energy-climate objectives. In 2015, the law related to Energy transition and green growth (Loi relative à la transition énergétique et la croissance verte (LTECV)) profoundly renovates the tools of national and territorial governance to allow a more shared definition of policies and objectives. The means of action of local authorities are clarified and strengthened. This law introduces for the first time the CE concept into French legislation, which is enounced as an economic model that looks to reduce the environmental footprint of human activities, but ensuring economic growth or green growth. In addition, the "National low carbon strategy" (Stratégie nationale bas carbone (SNBC)) was also set up and defines for all sectors of activity the various strategic orientations that will guide France towards a sustainable and low-carbon economy. The law on the "New territorial organization of the Republic" (loi portant sur la nouvelle organisation territoriale de la République (NOTRe)) law was also adopted in 2015. It aims to modify territorial competences by giving French regions responsibility for energy, air, the environment, and adaptation to climate change, and asks local authorities to adopt the "Regional scheme for territorial planning, sustainable development and territorial equity" (Schéma régional d'aménagement, de développement durable et d'égalité des territoires (SRADDET). This SRADDET makes it possible to rationalize the number of existing documents by merging several sectoral plans, including the SRCAE. In addition, in April 2020, the latest revised version of the (SNBC) was published setting the goal of achieving carbon neutrality by 2050, which means a reduction in carbon emissions by a factor of 6 compared to 1990. All these directives must be considered into the SRADDET. Hence, in response to these guidelines, the regions in France started to adopt their own objectives targeting the decarbonization of their territories. In the case of the SUD PACA region at the south east of France, it has updated its targets for the decarbonization of its energy system by aiming for carbon neutrality by 2050. This region presents particular characteristics concerning its energy system, mainly a concentration of the energy consumption in littoral areas that represent around 80% of the final energy demand of the region, and an important potential for renewable energies, especially in the rest of the territory where energy consumption is lower. In this regard, different questions arise when envisioning the future regional energy system, in particular how to develop the regional energy resources and how? What are the best options to reconcile high and low consumption areas? Or how the application of CE perspective can help the development of the energy system and the achievement of the carbon neutrality.

Envisioning the future energy system of the SUD PACA region

For all these issues, different strategies can be followed, leading to different trajectories of evolution for the regional energy system. In this context, prospective modeling appears to be a valuable (not to say indispensable) tool for decision support, as does the model constructed for studying these different possible options. More precisely, using the TIMES framework which was developed under the IEA's Energy Technology System Analysis Program (ETSAP) (Gargiulo, 2009), $\text{TIMES}_{\text{PACA}}$ is a bottom-up model using a partial equilibrium under a linear optimization paradigm, with the objective to satisfy the final exogenous demand of energy services at the lowest possible discounted cost for the development of the energy system in a time period and under constraints defined by the user (Loulou & Goldstein, 2016a, 2016b). For a better representation of the regional energy system, and to better capture its energy consumption characteristics, the energy system has been divided into ten different zones which represent the six departments of the region, Alpes-de-Haute-Provence, Hautes-Alpes, Alpes-Maritimes (AM), Bouches-du-Rhône (BDR), Var, and Vaucluse. However, three of these departments, AM, BDR, and VAR present their energy consumption concentrated in littoral areas, so to better capture their energy characteristics, they were divided into high consuming and low consuming zones. The tenth region, called PACA, represents the regional energy consumption on which the energy policy established by the region has no impact, such as for vehicles coming from outside the rest of France and from Europe, or airplanes. The model includes different technologies that can be developed and that can help the decarbonization of the regional energy system including: electrolysis, gasification, methanation, carbon capture and storage, among others. The analysis is developed under six different scenarios that try to explore the evolution of the region's energy system through different perspectives. These scenarios are:

- *Reference*: analyses the evolution of the energy system based on trends observed in past years, including recent energy policies already in place.
- *SRADDET*: expresses the objectives that the SOUTH PACA region sets itself within the framework of its SRADDET and seeks to analyze how they can contribute to achieving carbon neutrality.
- *Circular economy*: to explore how a circular economy perspective could facilitate the implementation of a low carbon energy system.
- *Carbon neutrality*: to assess the public policy guidelines established in the SNBC, in particular considering the carbon budget and an increase in the electrification of the industrial sector
- *Hydrogen*: Promoting the production and consumption of hydrogen, to look at the role that power-to-gas technologies can have in the territory transformation.
- *Autonomy*: explores a possible autonomy of the regional energy system

From the analysis of these different scenarios, it is possible to get some insights about how the region can reach carbon neutrality. First, it has been shown that the application of a CE for the development of the regional energy system is a significant strategy that can massively help the transition towards the decarbonization of the regional energy system by the application of its principles of reduce, reuse and recycle. In this sense, for the residential and tertiary sector, the first priority should be the renovation of buildings as it helps to reduce final energy demand, and the second should be to develop the recovery of ambient and geothermal heat through heat pumps, which can help to cover heating, cooling, and water heating demand. The use of heat pumps is more attractive in the region as the weather is milder that the rest of France. Following the same perspective, a priority should also be the recovery of waste industrial heat through heat networks in order to cover heat demand, increasing at the same time the efficiency of the whole system. For the transport sector, there should be a shift to the use of individual mobility vehicles, such as electric bicycles which will help the reduction of final energy demand. This strategy should be followed by the electrification of private vehicles, and the recovery of end of live electric vehicles batteries that can be reused to back up solar roof production. For heavy transport vehicles and for buses the use of hydrogen should be an aim. In the case of the decarbonization of regional industrial activities, carbon capture and storage has to be developed for the steel and cement producing industries. The CO_2 captured should be mixed with hydrogen through methanation in order to produce synthetic methane, whose combustion produces less emissions than natural gas (14% less) (Meylan et al., 2017), which can help to reduce the use of other fossil fuels. But this synthetic methane should be only used for industrial activities as the other sectors can use other energies for its decarbonation.

For the energy supply side, electricity production can be completely decarbonized by the use of local renewable energy resources. First, onshore wind technologies should receive more attention from regional policy makers, and they have to overcome the current barriers that are affecting its deployment in the region as its production can really help in the regional energy transition (International Energy Agency, 2017). Hydro resources will still represent an important part of the electrical electricity production of the SUD PACA region in the future, but its development should be cautious, as climate change might have an important impact over the availability of the resources. In fact, with 1% more installed capacity in 2017 with respect to 2007, the region has produced 1% less electricity using this resource (Région SUD, 2018). The use of biogas and biomass for electricity production appears to be also an important leverage for the energy transition of the region as it helps to cover some of the peak and night electricity demand; the same applies for ocean electricity production. Finally, solar energy turns out to be one of the most important assets in this transition. Solar roof photovoltaic production is mostly developed in high energy consuming areas. Its production can cover residential and tertiary electricity demand, and the excess energy produced during high irradiation periods can be stocked in batteries and it can be also used to produce hydrogen through water electrolysis. Hydrogen is an important energy vector for the decarbonation of the regional energy system, as first it can contribute to the decarbonation of the transport sector, especially of freight transport vehicles, and it allows the reutilization of CO_2 in order to produce synthetic methane which helps in decarbonizing the industrial sector. One important asset that facilitates the production of hydrogen is the saline cavity present in the Alpes-de-Haute-Provence department as it allows the storage of hydrogen produced during high irradiation periods. In this sense, the region through the development of its renewable energy potentials, and the application of a CE perspective, can reach a carbon neutrality and can contribute to the decarbonation of the French energy system.

Territories have to further commit with the energy transition

The analysis of the energy transition of the SUD PACA region is an example of how a territory can develop its local available energy resources in order to decarbonate its energy system and how it can contribute to reaching national climate-energy objectives. But as stated at the beginning, decarbonization options have to be deployed right now, and as fast as possible. In this sense, local territories have to understand their undisputed role in achieving this energy transition, so they have to embrace their competences showing real commitments, and learn to overcome the different challenges affecting the deployment of climate-related actions in its territories, and find the paths to deploy coordinated actions including all the different actors of the territory. This applies in particular to the SUD PACA region as the ambitious objectives established in the SRADDET have been declared following a display logic, but without real concrete commitments, mainly because political and economic actors do not yet appear sufficiently invested and committed about the subject of energy transition (Haut Conseil Pour le Climat, 2020). This explains also the lack of commitment from industrial actors who appear not sufficiently involved in the decarbonization of their activities in the region, and without their actions, reaching carbon neutrality seems unlikely. In addition, there is a lack of joint work between the region and its local authorities as the leadership role of the region is not strong enough, and some of the departments are not interested in working side by side with it (Ibid). Consequently, France has to seek as well to reinforce the means that the territories have to act over the deployment of the energy transition, as the quality of their response will largely depend on the means at their disposal.

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The Role of Residential Energy Efficiency in Shaping the Energy Transition in Saudi Arabia: Key challenges and initiatives

BY FATEH BELAID AND MOHAMMAD AL DUBYAN

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Abstract

This paper discusses a crucial topic that has emerged in the policy and economic literature in recent years: the potential role of energy efficiency in the current energy transformation process. It provides a straightforward analysis to explore the prominent role that building energy efficiency may play in shaping the energy transition and sustainability path. The focus of the investigation is the energy efficiency initiatives in Saudi Arabia, as an example of an economy very concerned by and very proactive in terms of efforts to boosting its energy transition. From a policy perspective, the paper emphasizes the importance of accelerating the decarbonization process in the building sector and suggests ways to consider a holistic view of energy efficiency policies in the building sector.

Keywords: *Energy efficiency; Energy Transition; Sustainability; Saudi Arabia.*

1. Introduction

Currently, approximately 100 million barrels of oil are consumed in the world per day. The world population grew from 3.8 to 7.7 billion in barely 50 years, between 1972 and 2019, respectively. During the same period, annual energy demand per capita also went up from 57 to 75.7 gigajoules (GJ)(BP, 2020). This energy consumption pattern highlights the accelerating pursuit of mass usage and, consequently, energy demand across many developing economies. The contemporary global energy system has fueled this pathway and propagated it on a large scale. Nonetheless, the current global power system, while diverse in type, is still nearly uniform in terms of carbon source.

Demand is increasing regardless of the energy source. Since the world's population is projected to expand by approximately two billion people over the next two decades, and as standards of living improve, electricity generation is expected to increase by 50% by 2040. The U.S. Energy Information Administration's (EIA) recently released International Energy Outlook 2019 (IEO2019) Reference Case expects global energy consumption to increase by nearly 50% in the period from 2018 to 2050. The bulk of this increase originates from non-OECD countries, and it is being driven by regions where strong economic growth is stimulating demand, particularly in Asia. During this period, the overall energy consumed in the buildings sector, encompassing residential and commercial buildings, will increase by 65%, from 91 quadrillion to about 139 quadrillion Btu. This growth will be driven by a combination of rising incomes, urbanization, and increased access to electricity. We note that fossil fuels continue to largely dominate the contemporary world energy mix with a share of 80% (UN, 2021). In such context, by the following decades, even with a sustained high penetration rate of new technologies, the percentage of these alternative energies in primary energy generation will likely be less than 15-20% (Figure 1).

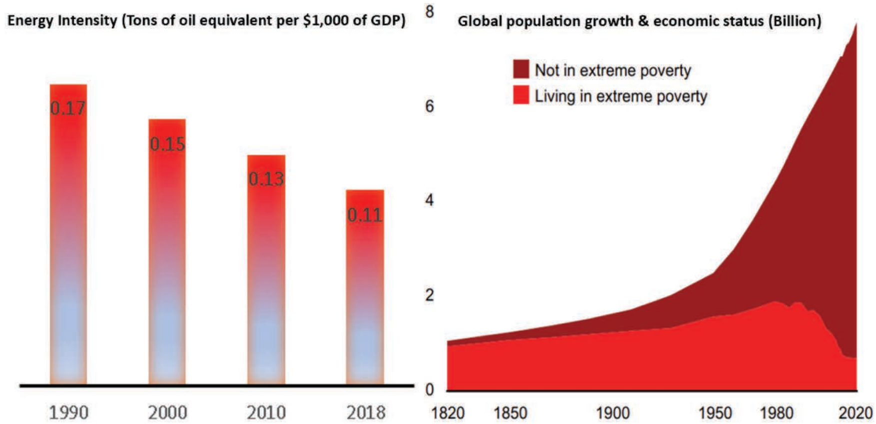

Figure 1: Energy intensity and global population growth (Sources: International Energy Agency & Our World in data).

Aware of the role that energy efficiency could play in accelerating the energy transition and meeting global climate and sustainability goals, several countries around the world have adopted energy efficiency plans as an effective strategy to reducing the energy demand in different sectors (e.g., building, transportation, industry, etc.). Despite the considerable effort made by various countries, the potential to drive further energy savings is still immense. According to the International Energy Efficiency Market Report of 2014, roughly 70% of world energy consumption is not subject to mandatory efficiency standards targets.

Nowadays, energy efficiency investments seem to lag behind public policy objectives set in several countries. In the economic literature, this phenomenon is commonly referred to as "Energy efficiency gap" or "Energy efficiency paradox"- a persistent and significant difference between socially optimal levels of energy efficiency investment - broadly defined as a substantial gap between levels of energy efficiency investment and actual investments made by individuals (Jaffe and Stavins, 1994; Gerarden et al., 2015; Belaïd et., 2019; Bakaloglou and Belaïd, 2022). The underlying assumption of this analytical framework is that energy efficiency investments are not as attractive as theoretically expected due to the existence of barriers that prevent their large-scale diffusion. These barriers include market and behavioral failures (Gillingham and Palmer, 2014).

Starting from this conjecture, this analysis will provide a comprehensive view of energy efficiency trends with a significant focus on Saudi Arabia. Specifically, it will explore the role of residential energy efficiency in shaping the energy transition and sustainability goals. Further, based on the analysis, the paper provides an integrated policy framework to accelerate and monitor the energy decarbonization process of the building sector. By so doing, this paper will help to gain a better understanding of the role of energy efficiency in addressing critical energy and environmental issues facing developing countries, particularly Saudi Arabia.

The remainder of this paper proceeds as follows. Sections 2 briefly introduces energy efficiency and discusses the unmet potential for energy savings in buildings. Section 3 reviews and comments on energy efficiency initiatives in Saudi Arabia. Finally, Section 4 concludes and offers some policy recommendations.

2. Energy efficiency in buildings: Huge untapped potential

Combined, the building and construction sectors are accountable for more than a third of the world's final energy consumption and for nearly 40% of total direct and indirect CO_2 emissions (IAE, 2021). Further, buildings use 25% of the world's water, 40% of the world's natural resources. This demand continues to grow, due principally to improved access to energy in developing countries, increased ownership and use of energy-using devices, and fast growth in building size worldwide.

According to the International Energy Agency's recent study, in 2019, direct and indirect emissions from electricity and commercial heat used in buildings reached 10 $GtCO_2$, which is the highest level ever recorded. This represents about 28% of total global energy-related CO_2 emissions. If emissions from the building and construction sector are included, this share reaches 38% of global energy-related greenhouse gas emissions.

This increase was driven by multiple factors, including growing energy demand for heating and cooling, increased air conditioner ownership, and recent extreme climatic events (IAE, 2021a). The recent BP Energy Outlook (BP, 2020) states the growth in energy use in buildings is entirely emanating from the developing world, as improvements in wealth and living standards enable people to live and work in greater comfort.

In 2018, the global residential sector solely consumed about 6008 TWh of electricity, with consistent growth over the last three decades (IAE, 2021b). This growth is driven by different factors, mainly the increase in global population, and hence the demand for housing, the rise in living standards, and, arguably, global warming (Lévy and Belaïd, 2019; Belaïd and Joumni, 2020). From 2010 to 2019, for instance, residential energy consumption increased by more than 5%, adding more pressure on emissions that witnessed a growth of about 4% during the same period, not accounting for the buildings construction industry (UNEP,2020). This remarkable growth is driven mainly by appliances in which energy efficiency plays a critical role in determining their demand, including air conditioning systems, residential appliances, and lighting. The International Energy Agency (IEA) estimates the number of air conditioning units to increase from 1930 to 5577 million units between 2020 and 2050 (Statista, 2020).

Therefore, buildings have a tremendous potential to deliver cost-effective GHG emissions reductions in both developed and developing countries. In addition, buildings' energy consumption can be significantly lowered by 30-80% with commercially available, mature technologies. There is a remarkable agreement that enhancing building energy efficiency in buildings will contribute to the Sustainable Development Goals achievement (Figure 2) and generate multiple advantages, including economic, environmental, and social benefits.

Arguably the most obvious potential benefits of energy efficiency investments are the environmental ones. More energy-efficient buildings would reduce the use of fossil fuels, leading to lower greenhouse gas (GHG) emissions, which is essential to achieving the goal of a decarbonized building stock by 2050.

The economic benefits are less obvious but prevalent. These include energy cost savings, creating jobs, and increasing propriety values. With more emphasis on energy efficiency measures, between €280 and €410 billion in energy costs could be saved, equivalent to nearly twice the annual electricity consumption of the United States (European Commission, 2015). The jobs generated could reach an average of 1.1 million net additional jobs by 2050 (European Commission, 2015).

Energy efficiency investment has the potential to "knock two birds down with one stone" by fostering healthier environments and improving well-being. Energy-efficient homes tend to be warmer and less moldy than energy inefficient homes. They also have better air quality. With less sickening settings, people will pay less on medical expenses, miss fewer days of work, and be more productive when they are at work. This increases well-being while encouraging economic growth.

Pressing agendas, including climate change mitigation, boosting the energy transition, and

Figure 2: Contribution of buildings decarbonization to the Sustainable Development Goals achievement (Source: Adapted from World Green Building Council).

strengthening energy security, have put the residential sector in many countries around the world in the spotlight due to its substantial energy-saving potential, which could be realized through investments in energy efficiency (Masson et al. 2015; Belaïd et al., 2019; Belaïd et al., 2020). Nevertheless, energy efficiency investments in the building sector appear to be lagging behind the public policy goals set in several countries (Belaid and Rault, 2021; Belaïd et al., 2021; Bakaloglou and Belaïd, 2022).

Building decarbonization initiatives are on a clear upward trajectory around the world. However, they must accelerate in both scale and pace to meet climate and sustainability goals of the Paris Agreement. These efforts are reflected, for example, in the (1) World Green Building Council's Net Zero Carbon Buildings Commitment. It represents a global action network comprised of around 70 Green Building Councils around the globe committed to transforming the building and construction sector to achieve the net-zero buildings operations by 2050; and (2) Science-based target initiative for business, which is a joint partnership between CDP, the UN Global Compact, the World Resources Institute (WRI) and the World Wide Fund for Nature (WWF). It federates approximately 1,000 companies committed to cutting carbon emissions beyond their own activities by including further indirect carbon emissions in their carbon mitigation plans.

Further, the EU has emphasized becoming a world leader in energy efficiency and pushing pro-environmental agendas. Particularly influential initiatives include the Energy Performance of Buildings Directive (EPBD) and Energy Efficiency Directive (EED) (European Commission, 2021). Both initiatives confirm the important role of the building sector in achieving the Union's energy efficiency target, as it accounts for about 40% of final energy consumption. According to the European Commission, the first priority in establishing the Energy Union rely on the full reinforcement and implementation of existing energy legislation. The key complementary goals of the EPBD are: (i) the stimulation of existing building renovation by 2050; and (ii) reinforce the modernization of the whole existing dwelling stock by implementing smart technologies with a close link to clean mobility.

As for Saudi Arabia, implementing a large-scale energy efficiency program on Saudi building stock was estimated to reduce energy consumption by 100 TWh/year and shrink peak demand by 25 GW. In addition, enforcing a more rigorous energy efficiency code in Saudi residential buildings can save up to 1.7 TWh/year and dampen peak demand by 468 MW/year (Krarti et al., 2017). Moreover, insulating all non-insulated housing units in Saudi Arabia could have saved up to 22 TWh in 2019, and upgrading all air conditioning units to an Energy Efficiency Rating (EER) of 12 could have saved up to 30 TWh in the same year (Krarti et al., 2021).

3. Energy efficiency initiatives in Saudi Arabia

Energy efficiency has been gaining the attention of Saudi policymakers in different sectors, including buildings, transportation, and industry. These three sectors account for 90 percent of local energy consumption. In 2010, Saudi Arabia established the Saudi Energy Efficiency Center (SEEC) with a sizable mandate to enhance energy efficiency in production and consumption to prevent depleting national resources and enhance economic and social welfare. Since its establishment, SEEC started the Saudi Energy Efficiency Program (SEEP) that aims at rationalizing energy consumption and improve efficiency. In residential buildings, SEEC was able to make a giant energy efficiency leap during the last decade through three main initiatives. These are labeling and energy ratings, public awareness campaigns, and updating MEPS.

In conjunction with the Saudi Standards, Metrology, and Quality Organization (SASO), SEEC has been regularly developing and updating the energy rating system of different residential appliances. As in some other countries, this energy rating system evaluates and ranks residential electric appliances in terms of energy efficiency as well as providing estimating the annual electricity consumption under normal usage. These rating systems have been updated frequently as technology, and hence efficiency, improves. In 2010, Saudi government enforced these labeling systems as mandatory for all electrical appliances. As a result, all imported and locally manufactured electrical appliances are not allowed to enter the Saudi market before being rated and labeled.

Since its establishment, SEEC believes that one of the main factors to reduce energy consumption is through changing consumers' behavior. In the last few years, SEEC has been investing heavily in public awareness via different channels, including local TV, social media, and billboards, to name some. within the framework of the Saudi Energy Efficiency Program (SEEP), a national awareness campaign was launched in 2014 to increase community awareness regarding the importance of energy rationalization and energy efficiency. This campaign was designed based on both scientific studies undertaken in association with local and international awareness-raising experiences, as well as studies of previous awareness-raising campaigns conducted around the world. These public campaigns target mainly the behavioral aspects of demand and how consumers reduced their electricity consumption only by changing their habits and choices when they are about to invest in new electrical equipment. For instance, prior to summer months, when demand for cooling starts to increase, SEEC encourages people to increase cooling setpoint temperature above 20 °C so they can see significant reductions in their electricity bills. Encouraging consumers to buy efficient residential equipment is another common public awareness that people see all year long.

One of the most critical elements in enhancing energy efficiency, especially with the fast improvements in technology, is the regular revision of the Minimum Energy Performance Standards (MEPS). In other words, all electrical equipment in the market, either imported or locally manufactured, should meet these MEPS. This practice ensures improving energy efficiency in the residential sector and eliminating cheap products that stimulate wasteful use of resources. It is worth mentioning that updating the MEPS is not isolated from how technology, and hence energy efficiency, has been evolving in electrical appliances industry. One of the appliances that has been witnessing recurrent MEPS updates is the air conditioners (AC). At the beginning of 2012, the minimum EER of small AC units was set to 7.5, including split and window units, which are the most common AC units in Saudi Arabia. In 2013, the minimum EER of the same size and type was further increased from 7.5 to 9.5. Three years later, in 2015, the minimum EER of these AC units was also boosted to 11.5, then to 11.8 in 2018. To ensure even a more efficient cooling process in buildings, Saudi Arabia enforced a stringent thermal envelop insulation in 2019 in which all new buildings, including residential, commercial, and government, are to meet this requirement in order to be connected to the electricity grid. Although other residential appliances do not consume as ACs do, their MEPS also have been updated on a regular basis. For example, the MEPSs of refrigerators, freezers, dishwashers, washing machines, dryers, and lighting, were revised and enforced in 2015 to ensure being within the efficient range.

These three main factors are expected to continuously dampen the energy demand growth that the electricity market has been witnessing in the last few decades. A recent study conducted by Aldubyan and Gasim (2021), uses an econometric technique to estimate the impact of different factors, such as price reforms and energy efficiency on electricity demand, has shown strong evidence of the impact of energy efficiency on reducing demand in the last few years, especially after 2014, when the upward trend of the total electricity demand reversed.

4. Discussion & Policy recommendations

This article aims to emphasize the important role that building energy efficiency can play in framing sustainability goals and the so-called welfare economic model. It also discusses the massive unexploited energy-savings potential of the building sector in the context of the energy efficiency paradox. The analysis supports the argument that building sector is associated with a substantial unrealized energy-saving potential. Further, scaling up energy efficiency in the building sector (new and existing buildings) will generate multiple benefits for the environment, economy and society. Compared to other major emitting sectors, buildings offer considerable greenhouse gas emission reduction potential. In parallel, decarbonizing the sector brings many economic benefits, including reducing energy bills, increasing competitiveness of industries and services, and easing pressures on national budgets. Finally, beyond the environmental and economic advantages, the efficient building sector has shown substantial social impacts, including well-being and health improvement. The analysis also documents the Saudi energy efficiency journey and its considerable efforts to improve energy efficiency, mainly in the building sector.

This article is not actually geared to evaluate a particular energy efficiency policy. Nonetheless, it raises questions about the importance of accelerating the decarbonization process in the building sector and suggests ways to consider a holistic view of energy efficiency policies in the building sector.

In line with this statement, an effective energy efficiency program in the building sector should be integrated and holistic to consider the complexity of the process and different barriers that policy implementation faces. Accordingly, as displayed in Figure 3, a successful program should include not only a single measure but a set of interconnected instruments to ensure a substantial transformation, including: (1) regulatory framework; (2) fiscal and financial schemes; (3) information and awareness campaign; and (4) institutional reforms.

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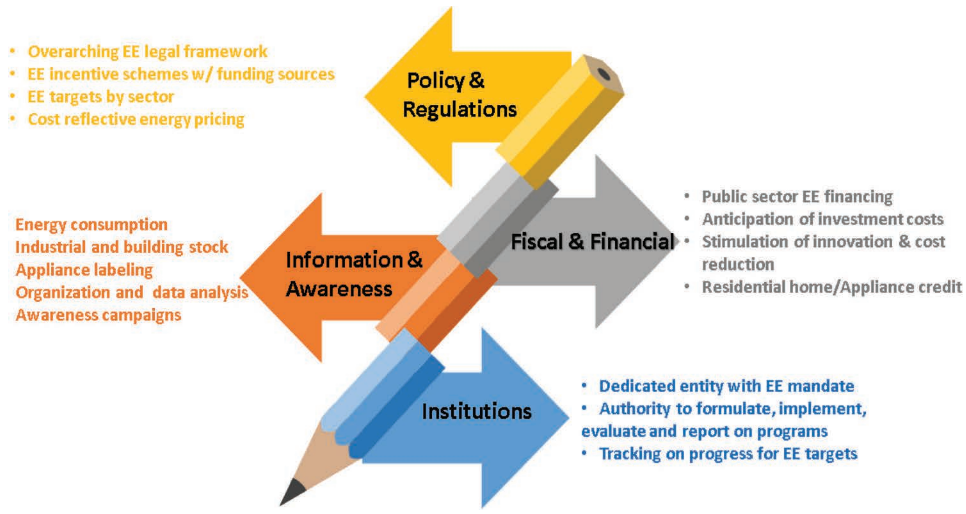

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The Truths & Myths about Global Energy Transition

BY DR MAMDOUH G. SALAMEH

Introduction

Energy transition is defined as a long-term structural change in energy systems. These have occurred in the past, and still occur worldwide. Contemporary energy transitions differ in terms of motivation and objectives, drivers and governance.[1]

In the context of climate change, energy transition means replacing hydrocarbons (oil, natural gas and coal) with renewable energy.

Increased use of renewable energy, combined with intensified electrification, could prove decisive for the world to meet key climate goals by 2050. Ramping up electricity to over half of the global energy mix (up from one-fifth currently) in combination with renewables would reduce the use of fossil fuels, responsible for most greenhouse-gas emissions.[2]

There is no doubt that climate change is happening. But the continuous bombardment of its destructive impact on the globe by media, environmental scientists and doomsday seers is not only infuriating a huge section of the world's population but it is also putting their backs out.

There were many instances where environmental scientists and University professors have massaged facts and stretched them to breaking point just to justify their research or their political leanings.

Therefore, it is quintessential to separate the truths from the myths when discussing global Energy transition.

Climate Change

Climate change is no longer a fiery apocalypse that we expect to happen in the far-off future. It is real and devastating. Rising sea levels, wild-fires, heatwaves and extreme weather events are already wreaking havoc everywhere and could cost the global economy a staggering $1 trillion dollars over the next five years in crumbling infrastructure, reduced crop yields, health problems, and lost labour according to the Carbon Disclosure Project (CDP).[3]

Since January 2019, we have recorded no less than three dozen extreme weather events across the globe, exacerbated by climate change. Each event caused more than $1 billion in damage. According to NASA, the earth's average surface temperature in 2020 tied with 2016 for the hottest years on record, making the last seven years the hottest on record.[4]

Unfortunately, any discussion about energy transition usually pits fossil fuels against renewables and quickly degenerates into another predictable polarization story.

There's little doubt that large-scale use of fossil fuels tops the list of factors contributing to climate change according to data from the Brookings Institute.

This begs the question that if there is such concrete evidence that fossil fuels contribute to climate change and other environmental problems, then why do we still use them? Why haven't we already quit using them? Why is it proving so hard to replace them?

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However, the issue isn't that simple. In order to have a nuanced discussion of climate change and global energy transition, we should objectively discuss claims about excessive weather conditions caused by climate change, drop unsubstantiated claims by environmental activists and divestment campaigners and accept facts as basis of the discussions.

If we go back in history to when records started we could easily find that the very same rising sea levels, wild-fires, heatwaves, and extreme weather conditions had also happened years before. Environmental science has yet to establish unequivocally whether these were caused by human beings alone using fossil fuels or as a result of natural developments or both.

However, some distinguished scientists don't believe that man's actions including the use of fossil fuels are solely behind climate change and global warming. For instance, Robert B. Laughlin, co-winner of the 1998 Nobel Prize in Physics says in an essay titled: "**What the Earth Knows"** that "what it knows is this: What humans do to, and ostensibly for, the earth does not matter in the long run, and the long run is what matters to the earth. We must think about the earth's past in terms of geologic time."[5]

Damaging this old earth is, Laughlin says, "easier to imagine than it is to accomplish." There have been mass volcanic explosions, meteor impacts, "and all manners of other abuses greater than anything people could inflict, and it's still here. It's a survivor."[6]

Laughlin acknowledges that "a lot of responsible people" are worried about atmospheric concentrations of carbon dioxide from burning fossil fuels. This has, he says, "the potential" to modify the weather by raising average temperatures several degrees centigrade and that governments have taken "significant, although ineffective," steps to slow the warming. "On the scales of time relevant to itself, the earth doesn't care about any of these governments or their legislation."

Someday, all the fossil fuels that used to be in the ground will be burned. After that, in about a millennium, the earth will dissolve most of the resulting carbon dioxide into the oceans. (The oceans have dissolved in them "40 times more carbon than the atmosphere contains, a total of 30 trillion tons.") The dissolving will leave the concentration in the atmosphere only slightly higher than today's. Then "over tens of millennia, or perhaps hundreds" the earth will transfer the excess carbon dioxide into its rocks, "eventually returning levels in the sea and air to what they were before humans arrived on the scene."

People can cause climate change, but major glacial episodes have occurred "at regular intervals of 100,000 years," always "a slow, steady cooling followed by abrupt warming back to conditions similar to today."[7]

When a celebrated environmentalist like Michael Shellenberger who was nicknamed by Time magazine as 'Hero of the Environment' finds himself forced to apologize on behalf of the environmentalists for the climate alarmism they had propagated over the past three decades and also for misleading the public about the imminent existential threat of climate change, it speaks volumes about the unsubstantiated claims made by the environmental lobby.

The renewables conundrum

Yet, environmentalists who call for an abrupt end to fossil fuels and a sudden adoption of renewable energy fail to recognize the obvious lack of logic in this. It is not possible in this particular reality to simply ditch fossil fuels for renewable energy in what is called a global energy transition.

The global energy transition aims to replace fossil fuels by renewables, achieve net-zero emissions by 2050 and limit global warming to well below 2 degrees and aim for 1.5 degrees.[8]

In sum, the story of energy transitions through history has been a constant move toward fuels that are more energy-dense and convenient to use than the fuels they replaced.

Fossil fuels are simply more energy dense than other energy sources. At 53.1 MJ/kg, natural gas boasts the highest energy density of any fossil fuel, followed by gasoline at 45.8MJ/kg and coal at 30.2MJ/kg. By comparison, Lithium-ion batteries, one of the most effective ways to store renewable energy, can only afford an energy density of 0.50 MJ/kg.[9]

Renewables are part of the answer but not the whole answer. On their own, they aren't capable of satisfying global energy demand because of their intermittent nature. Moreover, global energy transition won't succeed without major contributions from both natural gas and nuclear energy.[10] Furthermore, the global economy will come to an immediate standstill without oil.

Are Net-Zero Emissions by 2050 a Myth?

During the last five weeks, the global oil industry has come under unprecedented and concerted attacks from environmental pressure groups, courtrooms and boardrooms and noticeably from the Paris-based International Energy Agency (IEA) to force it to divest of its oil and gas assets as a way to reduce global emissions.

Royal Dutch Shell lost a landmark legal case in a Dutch court ordering it to cut emissions by 45% by 2030 whilst American oil giants ExxonMobil and Chevron both came under pressure from shareholders for not doing enough to mitigate the effects of their business on the climate.

But the big bombshell came from the IEA's net-zero emissions 2050 roadmap calling for an immediate halt to any new exploration for and investments in oil and gas beyond what is already approved if the world hopes to achieve net-zero emissions by 2050. Instead, the IEA calls for all new energy investments to be channelled to renewable energy. The IEA's roadmap was condemned almost universally by major oil companies and governments of the oil-producing nations with the Saudi energy minister Prince Abdulaziz bin Salman dismissing it wittingly as a 'la-la-land roadmap'.

Neither courtrooms nor boardrooms or the IEA's net-zero emissions roadmap could force the global oil industry to change its direction as long as there is global demand for oil.

Oil Is Here to Stay

At the height of the COVID pandemic there was a lot of talk by environmental activists and vested interests on how the pandemic could accelerate global energy transition from hydrocarbons to renewables and also speed up the peaking of global demand for oil. Nothing is further from the truth.

If anything, the pandemic has proven irrevocably the inseparable link between the global economy and oil. By destroying one you destroy the other and vice versa. There could neither be a global economy nor a modern civilization as the one we know and enjoy without oil. The global economy operates on oil and gas and will continue to do exactly that well into the future.

There will be no post-oil era throughout the 21st century and probably far beyond. It is very doubtful that an alternative as versatile and practicable as oil could totally replace oil in the next 100 years and beyond.

Also there will be no peak oil demand either. Global oil demand will continue growing well into the future underpinned by a growing population projected to rise from 7.9 billion today to 9.7 billion by 2050 and a growing economy projected to rise from $91 trillion in 2021 to $271 trillion also by 2050.[11] Nothing could totally replace oil in the next 100 years and beyond.

While an increasing number of electric vehicles (EVs) on the roads coupled with government environmental legislations could slightly decelerate the rate of growth of global oil demand, they could never arrest its growth. As a result, internal combustion engines (ICEs) will continue to be the dominant means of transport throughout the 21st century and far beyond.

Moreover, when oil majors like BP and Shell talk about an approaching peak oil demand, they mean their own peak and not the world's. Oil supermajors have oil reserves projected to last only 8-10.5 years and they are finding it extremely difficult to replace what they have already used because of resurgent resource nationalism. Shell, for instance, expects to have produced 75% of its current proven oil and gas reserves by 2030, and only around 3% after 2040.[12]

Oil and gas will continue to be the core business of the global oil industry well into the future. US oil giant ExxonMobil CEO Darren Woods and Occidental Petroleum CEO Vicky Hollub succinctly and eloquently made their position very clear on peak oil at the CERAWeek conference in March this year when both said that "reducing carbon emissions from fossil fuels and not the actual use of fossil fuels, offers the best way to combat climate change".

If this is the case, then why don't we stop this nonsensical talk about ditching oil and natural gas and focus instead on reducing the emissions occurring during the production of oil and gas.

Moreover, why don't we accept that we are now in an era of energy diversification where alternative sources to fossil fuels, notably renewables, are growing alongside and not at the expense of the incumbents?

The Hype about EVs

There are currently 2 billion ICEs on the roads worldwide compared with 10.9 million EVs or 0.55% of the total according to US Auto Research.

And yet, there is extraordinary hype about EVs by the media. But when Akio Toyoda, the President of Toyota, the world's biggest car company, says there is too much hype surrounding EVs and also notes that the electricity needed to charge EVs would strain grids and increase carbon emissions, the world should listen attentively.[13]

The ease of charging and also the availability of charging points are always on EV drivers' minds particularly when they are embarking on a long journey of hundreds of miles. Therefore, it is not surprising that 18% of EV drivers and 20% of plug-in buyers in California are switching back to gasoline cars. There will be a need for some 300 million charging points by 2040 needing estimated cumulative investment of over $589 billion in the next two decades.[14]

This is one very major reason why EVs will never prevail over ICEs. The other is the need for global expansion of electricity generation costing trillions of dollars to charge the supposedly millions of EVs that will be on the roads. How would this expansion be sourced: by solar, nuclear or hydrocarbons?

Is There a Future for Hydrogen?

The green hydrogen hype isn't warranted. Two major obstacles face hydrogen: hype and cost.

In 2020 roughly 87 Mt of hydrogen was produced worldwide amounting to a tiny 0.54% of global primary energy consumption.[15] So the projections of hydrogen share in the final energy by the International Renewable Energy Agency (IRENA), the Brussels-based Hydrogen Council and the EU at 12%, 18% and 24% respectively by 2050 are pure hype.[16]

Moreover, the production of green hydrogen is minuscule. IRENA, in its energy transition roadmap to 2050, estimates that global production of green hydrogen must reach approximately 400 Mt, which would require a total installed electrolysis capacity of 5 terawatts (TW) or 5,000 GW by 2050. Today, total installed electrolysis capacity worldwide is approximately 8GW.[17]

The cost is still a major obstacle. Producing green hydrogen from water by electrolysis using solar or nuclear energy is extremely expensive, at least twice that of fossil-based hydrogen and the quantity produced is minute. Also producing blue hydrogen from natural and grey hydrogen from fossil fuels is far more expensive than producing natural gas.

Whether green, blue or grey, hydrogen is a non-starter. It is more expensive to produce than natural gas. Furthermore, it needs far more energy to produce than it will eventually provide.

If this is the case, wouldn't be far more economical to skip the production of hydrogen altogether and use natural gas directly to generate electricity while employing carbon capture technologies to prevent CO2 being released?

Why not use the solar electricity or nuclear energy used in producing green hydrogen by electrolysis to enhance current electricity generation and make it cheaper to customers rather than using a convoluted process of electrolyzing it and then use it to generate electricity thus adding to customers' costs.[18]

Furthermore, the heat generated from high temperatures produced by nuclear reactors could be used to generate more electricity in a combined cycle for use in industrial plants instead of hydrogen.

The only country in the world where a hydrogen economy could possibly succeed is Iceland. The reason is that it has plentiful geothermal power and water. Geothermal power already generates virtually all Iceland's electricity.[19]

Conclusions

Climate change is a reality and its effects are devastating. Moreover, there's little doubt that large-scale use of fossil fuels tops the list of factors contributing to climate change.

Yet, environmentalists and divestment campaigners who call for an abrupt end to fossil fuels fail to recognize that renewables on their own aren't capable of satisfying global energy demand because of their intermittent nature. Moreover, global energy transition won't succeed without a major contribution from natural gas and the global economy will come to an immediate standstill without oil.

There will neither be a post-oil era nor a peak oil demand either throughout the 21st century and probably far beyond. Moreover, the notions of an imminent global energy transition and zero-emissions are illusions. Global energy transition can only be gradual with natural gas being the pivot for the transition.

Therefore, the best way to combat climate change is to focus on reducing carbon emissions from fossil fuels and not their actual use.

Footnotes

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West's Energy Transition Narrative Ignores The Reality in Asia

BY TILAK DOSHI

Abstract

The so-called "energy transition" has dominated both media headlines and academic research concerning energy affairs in recent years, particularly in view of the upcoming UN climate conference in Glasgow, Scotland in November 2021. Nevertheless, this is akin to the tail wagging the dog, as demand for fossil fuels in the developing countries, especially in Asia, shows no signs of abating as these countries struggle to promote economic growth to meet the legitimate aspirations of four-fifths of the world's population for higher standards of living.

BP released its annual "Statistical Review of World Energy" (70th edition) last week with updated global energy data for 2020. As usual, the publication -- widely hailed as the "bible of the global energy industry" -- was accompanied by widespread media coverage (here, here and here). The lead stories in newswires and major newspapers focused on two aspects: the impact of the Covid pandemic in drastically reducing energy demand (and hence carbon emissions) and on the continued "good news" of rapid growth in solar and wind energy capacity. The extensive coverage by the leading dailies were lacking in the far more consequential realities of the dominance of fossil fuels and the role of developing countries – which account for over 80% of the global population -- in the growth of energy demand.

As energy demand collapsed with the adoption of Covid lockdowns around the world, 2020 registered the biggest fall in carbon dioxide emissions since the Second World War according to the report. Spencer Dale, BP's Chief Economist, noted in remarks released ahead of the review that this puts the world closer to the path needed for "keeping global warming below 2^{0}C this century" but does not reflect the "decisive shift" needed to meet climate goals backed by the Biden administration, the EU and the whole host of multi-lateral agencies including the International Energy Agency, the World Bank, the International Monetary Fund and the European Central Bank.

While total energy consumption worldwide fell by 4.5% in 2020, the oil component fell even more steeply, by 9.3%. This reflected the collapse in demand for transport fuels in particular. In contrast, wind and solar capacity increase was described as "colossal" by Mr Dale who said that "The increase in installed capacity last year was 50% bigger than at any time seen in history, despite the world (being) in turmoil, despite the largest peace-time recession." Mr. Dale seems heartened when he says "The trends we are seeing here are exactly the trends we'd want to see as the world transitions to net zero…".

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While much of the above seems consistent with the "energy transition" narrative, it is akin to the tail wagging the dog. After decades of government mandates and hundreds of billions of dollars in subsidies in Western Europe and North America, renewables (which includes wind, solar and non-traditional biofuels) constituted a mere 5.7% of global energy use in 2020. Fossil fuels (coal, oil and gas) accounted for 83% of global energy use. Even for the rich countries, fossil fuels provide an average 78% of their energy needs. Another report published last month found that the share of fossil fuels in the world's total energy mix is as high as a decade ago despite the pressure on governments to act on climate change.

If fossil fuels dominate the energy mix, developing countries, in particular those in Asia, increasingly determine the geographical distribution of energy use. Developing countries accounted for 61% of global energy demand in 2020, with energy consumption in China alone exceeding that of the EU and the US combined. The importance of coal – that most demonized of the trio of fossil fuels – to developing countries in Asia is stark. Almost 82% of global coal consumption occurred in the developing world and developing Asia accounted for almost all of it. China alone was responsible for 54% of global coal demand.

Perhaps the role of developing Asia in the evolution of global energy demand is best measured in incremental terms. BP data show that in the 5 years to 2019, developing countries accounted for 88% of the increase in global energy demand. Developing Asia absorbed almost three quarters of the world's increase in energy demand in that period, with China alone accounting for 41%.

As the world emerges from the economic ravages of the pandemic lockdowns, these patterns of energy demand will re-emerge. Indeed, the early signs are already apparent. Energy demand has rebounded as covid vaccines roll out, governments ease lockdowns and passenger and freight traffic surge. Global oil consumption is now on track to reach pre-covid levels by the first quarter of next year. The bellwether Brent crude price is now at multiyear highs of over $75 per barrel. The average Brent price for 2020 was just under $42 per barrel. The Biden administration now faces the supreme irony of pressuring the OPEC+ cartel to open its oil taps while continuing in its quest to shut down domestic oil and gas production in the name of "fighting climate change". The country now has the highest gasoline prices since 2014, threatening the Democratic administration's already struggling popularity polls and its green and infrastructure spending agendas.

While Americans and Europeans pay more for oil and natural gas, the Middle East and Russia gain considerable leverage over these markets. But the most important driver of global energy geopolitics goes beyond the self-displacement of the US as the world's leading oil and gas producer on the supply side. The juggernaut of growing energy demand from the developing countries, above all in Asia, is the elephant in the room.

The plutocrats that regularly converge at the World Economic Forum and the policy makers in Western Europe and the US have been pushing their "Global Reset" and "Build Back Better" agendas in the wake of the covid pandemic. Can they deny 80% of the world's population from climbing up the very energy ladder that the now developed countries ascended in order to enjoy their higher standards of living and all the privileges that come along with being richer and healthier? Will they be able to block Chinese President Xi's 2049 centenary vision of a "great modern socialist nation in all respects", dependent as it is on fossil fuels?

The key oil and gas producers in the Middle East and Russia think not: they have been busy investing vast sums in expanding their production capacities. They can rest assured that demand for their energy resources will be required for human flourishing for decades to come.

On Technology Transfer and Utility Scale Power Storage

BY MINH HA-DUONG

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Vietnam's recent energy transition experience shows that grid congestion issues limit how fast a country can turn to solar PV and wind power. Utility-scale battery storage could alleviate problems by time-shifting the variable electricity production, deferring the urgency to upgrade the transmission network. However, the technology is hardly bankable now in low- and middle-income countries. We propose that forming a collective of transmission network operators may accelerate access to this technology.

Historical experience with the energy transition shows that installing lots of solar and wind generation capacity often leads to a curtailment problem. This problem is worse in developing countries, who find it difficult to expand their transmission network as fast as would be required. Constrained by the prospect of wasting much of the clean electricity produced during the windiest and sunniest hours, renewable energy policies are less ambitious. The grid expansion speed is a factor limiting a fast energy transition.

For example, Vietnam was able to install over 16.5 GW of PV capacity between 2018 and 2020. That saturated the transmission network in the southern provinces. In the first four months of 2021, the network operator had to curtail 13.3 % of solar (447.5GWh) and 4.8 % of wind production (19.7GWh)[1]. The practical answer has been that the next five years power development plan focuses on LNG[2].

Access to utility-scale electricity storage alleviates the curtailment issue. Storage de-couples the problem of installing solar and wind generation capacity from expanding the transmission network. Building hybrid solar + storage projects is not only a popular replacement option for diesel and gas turbine power generators in off-grid systems. More and more investors are starting to build hybrid solar + storage generation projects for the grid. For example, the 2.2 GW Huanghe Hydropower Development farm, completed in September 2020, includes 202.8 MW/MWh of storage capacity[3].

The market for battery storage is developing fast. Fortune Business Insights[4] found that « The global battery energy storage market size stood at USD 7.06 billion in 2019 and is anticipated to attain USD 19.74 billion by 2027, exhibiting a CAGR of 20.4% during the forecast period. » According to IEA Sustainable Development Scenario[5], the annual average energy investment in Battery Storage should increase by 855 % in ten years: from 3.235 billion dollars (2019) per year over 2015-2020 to 27.669 billion dollars per year (2019) over 2025-2030. However, lower-middle-income countries are only starting to integrate battery storage technology in their energy policy plans. In Vietnam, for example, the government briefly considered giving a preferential FIT to hybrid solar PV projects integrating 2 hours of storage at 25 % of capacity before dropping the idea (Draft decision 11 update, issued 25-02-2019 by MOIT).

Battery storage technology started to deploy at the top-end of the market because the less developed countries did not offer conditions to realize the value proposition of storage projects. Financing storage by arbitrage between the low and high prices periods requires a power market with spot pricing. Financing storage by fast-response ancillary services requires an ancillary services and frequency control market. Financing storage by time-shifting around curtailment hours requires a high electricity price and low battery costs.

Admittedly, the organization of the wholesale electricity market is not a simple function of a country's wealth. However, more complex power market structures require more capacity from the regulating agencies, which is more likely to be found in advanced economies. Vasigliasindi et Besant-Jones[6] found that « *a dichotomy emerges between high income countries characterized by a large system size for which unbundling and other reforms are significantly linked to better performance and low income countries characterized by small system power size for which there is no strong evidence that unbundling and other reforms delivered improvements in performance.* »

The value of time-shifting batteries to answer curtailment is driven by the value of electricity otherwise wasted. It depends on price and the severity of curtailment: how many days per year, for how many years. Consider a typical 50 MWp early solar power project in Vietnam from 2019. It receives a feed-in tariff of 9.35 of UScent/kWh for 20 years. As the Vietnam standard power purchase agreement stipulates, it does not receive payment when curtailed. There is no ancillary services market or congestion hours pricing, so battery storage at the PV farm can be motivated only by time-shifting or obligation.

The government considered the two hours of storage / 25 % capacity clause, which meant a 12.5MW/25 MWh system for a project like the one above. Typical storage modules pack two to four MWh in a twenty-foot container, so 25MWh amounts to less than a dozen modules. In 2019, systems this size were at the technology frontier and not ready for mass deployment in Vietnam, and the government dropped the clause.

One 25 MWh battery cycle at 9.35 of UScent/kWh would be worth 2 337 USD. According to the Vietnam Technology Catalogue[7], the capital cost for a 2-hour Lithium-Ion battery energy storage system will be around 0.7 $MUSD_{2019}$/MW in 2022. For a 12.5 MW size battery, it amounts to 8.75 $MUSD_{2019}$. Assuming O&M costs 1 USD/kWh ([7] quotes a range of 0.3 – 5 USD/kWh), they amount to 25 kUSD per year for the example system. There is a need to cycle the battery 3744 times, or once every day for 10.56 years, to cover the capital costs. The investment is not bankable, especially since curtailment will not happen every day for ten years.

As the cost of battery storage declines, fossil-fuel-based generation is less and less competitive with variable renewable + storage. At some point in time, this will happen even in countries where a weak power transmission infrastructure hinders the competitiveness of renewable energy. The Vietnam Technology Catalogue finds that storage costs may drop in 2050 to 0.20 $MUSD_{2019}$/MW. In our example, the investment return period would be three years, interesting for a private investor. However, the switch point may be more than ten years away. The Technology Catalogue forecasts storage costs to be 0.40 $MUSD_{2019}$/MW in 2030, which makes the return on investment duration larger than six years under our example, with best-case assumptions.

Utility-scale power storage is a crucial energy transition technology for low- and middle-income countries. We have shown that it remains expensive. The urgency to limit climate change requires asking how to accelerate the diffusion of this technology.

The Climate Convention has recognized the need for technology transfer measures to support countries from the South in the energy transition. To the best of our knowledge, the UNFCCC Technology Mechanism[8] has yet to support energy storage. In the case of Vietnam, the Climate Investor One fund, supported by the European Union, the Green Climate Fund, USAID, the Nordic Development Fund, and other donors, has invested in two wind power projects without storage. The projects may be profitable, but the impact is small because private investors finance 142 other similar projects.

Multilateral development, climate diplomacy and climate finance offer many possibilities to organize an accelerated uptake of utility-scale power storage in countries from the South. To start further discussions on this subject, what follows proposes a vision of an organizational arrangement in that direction.

The organization could be an alliance between transmission network operators (TNO) in receiving countries. A climate impact financial institutions collective could sponsor the alliance, which would form within an existing regional TNOs network. The intervention logic would be to capture the storage value from generation and transmission investment deferral or reduction[9]. The estimates above show that the economics are not there yet for private project investors. For infrastructure, however, long payback periods are more acceptable.

The organization could lease its members storage-as-a-service solutions to facilitate the learning curve for new adopters. Storage is a modular technology; it can be installed or removed in a few months. For TNOs, the decision to conduct a short term reversible trial is easier to take than committing to buying a new kind of asset. The organization would also provide vendor-neutral technical advice.

Collective action would make access to storage cheaper. Size gives bargaining power to negotiate quantitative discounts with hardware providers. When a member TNO does not need the assets anymore, the organization could move the batteries to another place. Reversibility reduces the risk that solving curtailment creates stranded assets. Finally, the organization would have access to capital at favourable rates by having rapid measurable emission mitigation benefits, in addition to facilitating long-term energy transition policies.

In conclusion, grid congestion headaches will continue to limit the speed of the transition to variable renewable energy sources, at least for ten more years in developing countries. However, unless wind and solar become the backbone of *all* countries' energy systems within the next ten years, the world is condemned to dangerous levels of climate change. The Paris Agreement requires to accelerate the access of all countries to utility-scale power storage technology.

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Opportunities and Challenges COVID-19 Poses to the Energy Transition

BY INÊS CARRILHO NUNES AND MARGARIDA CATALÃO-LOPES

Abstract

COVID-19 presents both opportunities and challenges to the energy transition. This article presents a brief overview of the impacts of the pandemic on the energy sector and a reflection regarding three potential instigators of change: mobility, renewable energy sources, and the pace of the economic recovery together with government intervention.

Introduction

The momentum and strength of the global climate movement was unprecedented before the COVID-19 crisis. The decarbonization of the energy system and the concept of energy transition was a current topic in political speech, the cost of some renewables was continuously falling (making them increasingly an economically viable option), fossil fuel divestment campaigns were emerging, and public support for action on climate change was at an all-time high (Pianta et al., 2021; Kuzemko et al., 2020). However, the macroeconomic and political circumstances under which these frameworks were conceived are no longer the same, as many countries are now addressing three different crises at the same time, the COVID-19 health crisis, the consequent economic crisis, and the climate crisis.

How institutions and policy makers adapt to these new circumstances and re-establish policy agendas, can have severe consequences for the low carbon energy transition. Yet, exogenous shocks, such as disruptive pandemics and extreme weather events, can generate new societal demands (e.g., for environmental sustainability). These new needs drive the existing socio-technical and innovation systems to change, thus transforming institutions and having enduring impacts on society (Sarkis *et al*. 2020; Wesseling *et al.* 2017).

Thus, the COVID-19 era, and its expected severe economic consequences, might compromise the low carbon transition. Yet, one should remember that even though economic stability is one of the factors that facilitates a transition, environmental policy arises as the main determinant for the progress and success towards a low carbon pathway. Thus, if properly managed with good governance, this disruption can lead to large and persistent changes in economic structures, favouring carbon neutrality and shifting the overproduction and overconsumption systems and lifestyles towards a more sustainable future trajectory. Most of post-industrial revolution transitions were not planned or governed. With governments proactively creating conditions to trigger a transition to a low carbon future, the coming energy transition may be substantially shorter than those experienced in the past (Chapman and Itaoka, 2018).

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The impact of COVID-19 on the energy sector

Containment measures, such as mandatory lockdowns, quarantines, closure of international borders and restrictions on travel, led to changes in mobility, social and work practices (Hoang et al., 2021; Kuzemko et al., 2020). As a result, and due to the slower pace of economic and production activities, energy and electricity demand dropped considerably. Indeed, the global energy demand in 2020 fell by around 4%, the largest ever absolute decline according to the IEA.[1] The drop in global primary energy demand was as much as three times greater than the impact of the 2008 financial crisis, reversing the increasing trends of the previous years (see Figure 1). Notably, this decrease came mainly from a decrease in coal power,

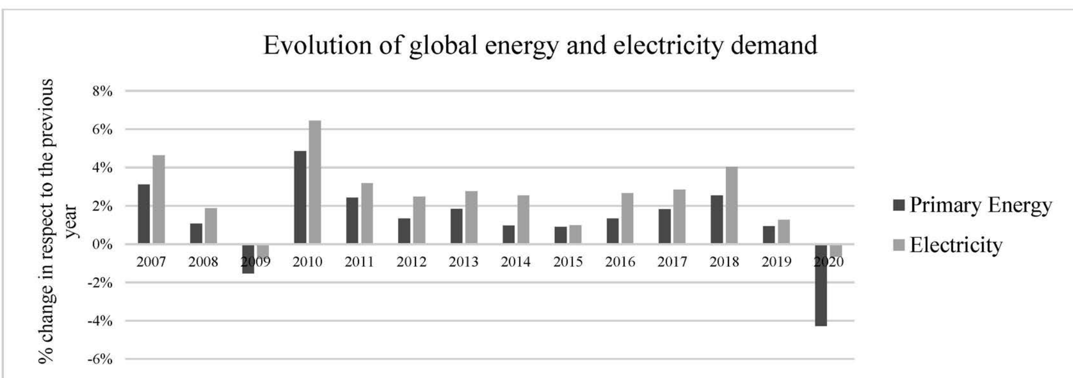

Figure 1 - Evolution of global total primary energy and electricity demand between 2007 and 2020. Source: BP Statistical Review of World Energy 2021.

leaving renewable power demand unchanged due to low operating costs and priority grid access. As a result, the share of renewables within the global energy mix is expected to increase considerably, to a level several years ahead of pre-pandemic expectations (Quitzow et al., 2021; Kanda and Kivimaa, 2020; Kuzemko et al., 2020).

Yet, and despite the increasing share of renewable power, investment in renewables declined along with overall investment in the power sector, with the EIA estimating that total energy investment fall by 20% in 2020.

Thus, and although not necessarily intended, responses to the pandemic have had substantial connections with energy demand and greenhouse gas emissions, which in turn triggered sharp declines and uncertainty in the patterns of electricity consumption, oil consumption, and industrial productivity (Sovacool et al., 2020).

Challenges and opportunities

In this section we cover three potential instigators of change arising from the pandemic: mobility, renewable energies, and the pace of the COVID-19 economic recovery as well as the intervention of governments. Overall, these can have enduring impacts on the energy sector.

Mobility

Global mobility needs and fossil-energy consumption could decrease in a post-COVID world due to changes related with the digitalization of work and other quotidian activities. The reduction of road travel needs by a segment of the population could make the ownership of a car superfluous, facilitating the expansion of shared mobility solutions. However, one should note that, in the short run while the pandemic is still active, these services may experience a slow down as social distance is still a concern (Kanda and Kivimaa, 2020).

Regarding air travel, the mobility regime more affected by COVID-19, domestic and international travel could become more sporadic as the world becomes more digitally connected. Moreover, the development of new infrastructures for alternative transport modes, like super-fast trains and ferry connections, could emerge as a substitute for commercial aviation, if the pandemic progresses as a propeller of landscape change in the mobility sector. However, these scenarios may be compromised if airline companies' bailouts and support for incumbent and high-emitting sectors prevail (Pianta et al., 2021).

Renewable energy sources

The effects of the pandemic on the development and deployment of renewable energy sources presents both challenges and opportunities to the energy transition. On the one side, the decrease in energy demand, due to the containment measures and the redistribution of public funding, as well as tightening fiscal management, postponed and reduced the number of auctions open for new renewable energy projects. Moreover, supply chain disturbances and the interruption of non-essential manufacturing caused delays in the deployment of many projects. Finally, grid integration of new projects was also suspended due to the postponement of non-critical operations. All these occurrences ended up interfering with the rhythm of the transition, lowering the incentive to invest in new renewable energy projects.

On the other side, the inclusion of sustainable investment measures as part of governments' recovery plans can lessen some of the difficulties that clean energy financing schemes are tackling. Indeed, these measures can promote investment in infrastructure, production capacity, as well as innovative business models, leveraging not only the deployment of clean energy sources, but also increasing employment opportunities in the sector. As noted by Pianta et al. (2021) and Hepburn et al. (2020), investing in clean energy can have a multiplier effect on the economy and on the job market. For instance, regarding the job market, every USD 1 million in green spending can create up to 7.49 jobs in renewables infrastructure and 7.72 jobs in energy efficiency, while creating only 2.65 jobs in fossil fuels (Garrett-Peltier, 2017).

Moreover, given that around 80% of countries are net energy importers, sustainable energy investments can increase the resilience and robustness of domestic energy systems, reducing reliance on foreign fossil fuels and contributing to reach carbon emissions reduction targets.

In addition, monetary policy interventions are expected to maintain interest rates at very low levels, which is perceived as favorable investment conditions by policymakers and project developers. Thus, the period of economic recovery can offer increased opportunities for the development of large-capacity renewable energy projects (such as utility-scale solar, onshore, and offshore wind farms, as well as other capital-intensive solutions, such as upgrading energy-efficiency in buildings).

Note that, at some point during the pandemic, historically low oil prices could be seen as a major cost disadvantage over renewable energy sources. Indeed, oil prices fall negative over a brief period in April 2020. However, as of today (August 2021) oil prices are at 2018 levels following several months of rise (see Figure 2), which poses an advantage to the deployment of renewable energy sources, which prices have continuously decreased (see Figure 3).

Economic recovery and government intervention

The speed and magnitude of the economic recovery of countries is highly uncertain and will influence the outlook of the global energy sector for the post-pandemic years.

The effects of an economic rebound on environmental pressures are highly influenced by the structure of the economy. Given that the service sector, which was severely hit by the pandemic,

Figure 2 - WTI crude oil price (2000-2021). Source: https://www.macrotrends.net/1369/crude-oil-price-history-chart.

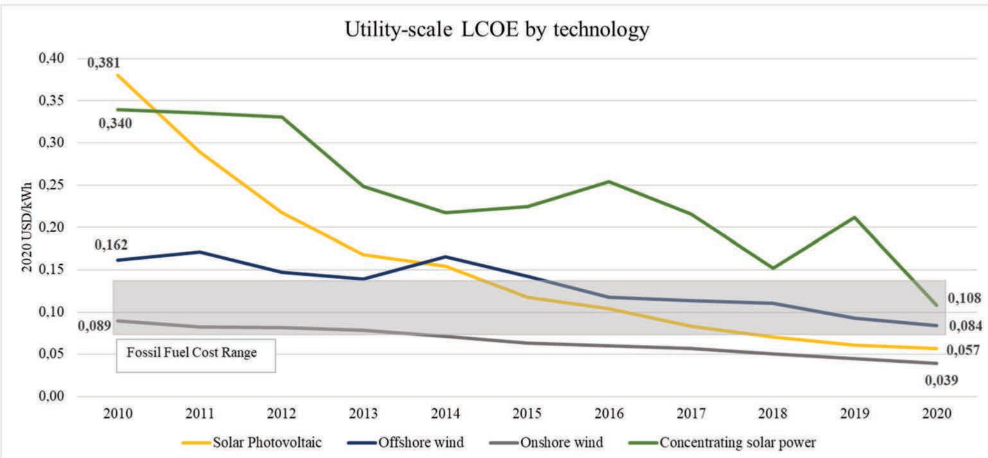

Figure 3 - Global weighted-average utility-scale levelized cost of energy (LCOE) by technology, 2010-2020. Source: IRENA (2021), Renewable Power Generation Costs in 2020, International Renewable Energy Agency, Abu Dhabi.

typically produces less emissions and uses fewer raw materials than most industrial sectors, it can be expected that, in countries where the service sector is dominant, the increase in environmental pressure due to the economic recovery will be smaller than the increase in GDP. In fact, according to the OECD (2021a), there is a projected long-term, and possibly lasting, downward impact of the pandemic on the levels of environmental strain of 1 to 3%, and a slow recovery could double these values.

Regarding government intervention, the pandemic revealed the powerful role governments can have in crisis circumstances. According to Kuzemko et al. (2020), this level of government intervention, not seen in many decades, could be a point of discontinuity with long term trends. Thus, although what happens in the close future will represent to a certain extent the continuation of processes that pre-date the pandemic, there is a chance that this discontinuity will result in an acceleration of trends towards a more sustainable future (versus the lock-in pathway of protecting existing jobs and incumbent industries).

Accordingly, as part of the pandemic recovery effort, governments are introducing large fiscal stimulus. For instance, in Europe the national plans are being complemented with a supranational recovery program, based on measures previously proposed in the European Commission's Green Deal, and with focus on digitalization, clean energy technologies, energy efficiency, and sustainable transportation. China doubled the deployment of renewable energy between 2019 and 2020 and introduced a National Green Development Fund for investment in clean energy infrastructure projects (Quitzow et al., 2021).

Thus, it is clear that many governments are pledging to use the stimulus packages for a green recovery, tackling two crises at once. However, according to OECD (2021b), while globally around USD 336 billion have been allocated towards environmentally positive measures, this value is almost matched by the value allocated to spending on measures classified as having mixed or negative environmental impacts (USD 334 billion). Moreover, spending allocated to clean measures represents only around 17% of recovery budget, suggesting that pandemic recovery packages might not be sufficient to deliver the transformational investments needed.

Conclusion

The pandemic has significantly disrupted lives, businesses, and economies, potentially changing social norms and practices indefinitely. It also introduced a high degree of uncertainty and economic strain which influences the future of a clean energy transition. Yet, if governments take advantage of key initiatives regarding mobility, renewable energy sources and recovery plans to support the clean energy transition, a win-win outcome is conceivable. Thus, the pandemic can become a small window of opportunity to accelerate the decarbonization of the energy system, decoupling economic recovery and environmental pressures.

However, there is no guarantee that governments will seize this opportunity (note that the 2008 financial crisis provided a similar window of opportunity for environmental intervention that was not grasped). The degree in which the pandemic turns out to be an ultimate driver of transition depends on how committed governments are to tackle the climate crisis side by side with the health and the economic crises. Moreover, given the scale of such clean transition, actively introducing green measures in stimulus packages is not sufficient, there is a need to discontinue pro-fossil fuel measures.

Finally, adverse shocks always produce winners and losers, tending to polarize the society. Moreover, the pandemic can potentially worsen the gap between leaders and laggards of the energy transition, exacerbating existing imbalances.

While we recognize the limitations in getting conclusions at a time of rapid change and uncertainty, our objective is to signal the opportunities and challenges the pandemic provides to creating a path of carbon neutrality.

A critical question remains. What actions are required to achieve a more sustainable energy future? Concerning the long run, the question will be how to design policy mechanisms that are shock-proof. The low carbon energy transition will take decades, and there will be more severe shocks.

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Footnotes

[1] Source: https://www.iea.org/reports/global-energy-review-2021.

Energy Transition and Its Potential Imapct on the Nigerian Economy

BY OMONIYI EMMANUEL OLUWAFEMI

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Abstract

The impact of the global energy shift from fossil system of energy to renewable energy on emerging economies like Nigeria deserves attention. The Gross Domestic Products would be adversely affected by this shift. Nevertheless, if policies that drive investment in renewable energy, agriculture, and solid minerals are established, such impacts would be mitigated.

Introduction

The global clamoring for sustainable and clean energy sources to replace the current fossil-based fuels with their attendant issues of climate change and energy security have continued to drive changes in the global energy policy. In light of the foregoing, renewable energies are currently receiving global attention and have begun to form part of the essential components of responsive nation's energy strategy for economic development sustainability. Consequently, oil and gas producing companies and oil producing nations around the world face a unique and intense period of change as they navigate through the energy transition. More worrisome are the general concerns of the impact of the global energy shift from fossil-based systems of energy production and consumption on global economies, particularly those of emerging economies like Nigeria, in West Africa.

The government, in their response to a global transition from fossil-based fuels, has come up with a policy known as National Renewable Energy and Energy Efficiency Policy (2015) for consideration. The Policy is aimed at removing the barriers that put renewable energy and energy efficiency at economic, regulatory, or institutional disadvantages relative to other forms of energy in Nigeria as well as to provide a conducive political environment that will attract investment in the renewable energy and energy efficiency arena. However, the effect of the Policy is yet to be felt in preparing the nation for the potential adverse effects of the Global energy transition on an emerging economy like Nigeria that depends largely on revenues from crude oil.

Economic Relevance of Hydrocarbon Resource in Nigeria

Nigeria as a nation is blessed with abundant natural resources. It is the 6th largest exporter and7th largest producer of crude oil in the world with a proven oil reserve estimated at 35 billion barrels and gas reserve of over 159 trillion cubic feet. According to the Organization of Petroleum Exporting Countries (OPEC) (2020), Nigeria's economy as evidenced by the available statistics of the contributions of revenues from crude oil to the total federation revenue is undoubtedly hanging on the happenings in the global oil market. For example, Nigeria's total revenue from crude oil rose by 29% to NGN7.3 trillion in 2017 from NGN5.68 trillion in 2016 reflecting impact of increase in production volume and increase in crude oil price per barrel. In 2017, the revenue from oil represented 69% of the total federation revenue which gained an increase of 22% to hit NGN10.6 trillion from NGN8.26 trillion achieved in 2016. In 2017, the average spot price of Nigeria reference crude oil, the Bonny Light (37°API) rose from \$52.92 per barrel in the third quarter of 2017 to \$62.48 per barrel in the fourth quarter of 2017. This represents an increase of 18.1% which was attributed to the production-cut agreement, demand growth from China, and increased refining activity in the United States.

Furthermore, according to the economic report released by the Central Bank of Nigeria (CBN) 2019, the total oil revenue rose to NGN9.4 trillion in 2018, representing an increase of 29%. However, in 2019, the economic report further indicated a decline in the oil revenue from NGN9.4 trillion in 2018 to NGN64.9 billion in 2019. The reduction in oil revenue threw the economy of Nigeria into a near recession even before the COVID-19 Pandemic which eventually crippled the economy. How long should Nigeria's economy be shaped by factors beyond her control?

Possible Impacts of Energy Transition on the Nigerian Economy

The current global energy transition program would undoubtedly affect the Nigeria's Gross Domestic Product (GDP) because the health of the economy depends largely on the revenues from the oil sector. The Nigeria GDP growth rate as shown in Figure 1 shows a modest recovery in 2017 with 0.5% after the oil shock in 2016 threw the GDP into -1.60%. The economic growth rate experienced a steady increase into 2018 and 2019 with 1.5% and 2.2% respectively before COVID-19 Pandemic plunged the economy into -1.79%.

Figure 2 shows the contribution of hydrocarbon resource to the Nigeria Gross Domestic Product (GDP). It is clear from the available data that Nigeria economy largely depends on the production and consumption of crude oil. From 2016 to 2019, just like the previous years, the dominance of oil in the Nigeria economy

Figure 1: Nigeria GDP Growth rate between 2016 and 2020
Source: World Bank calculations based on NBS

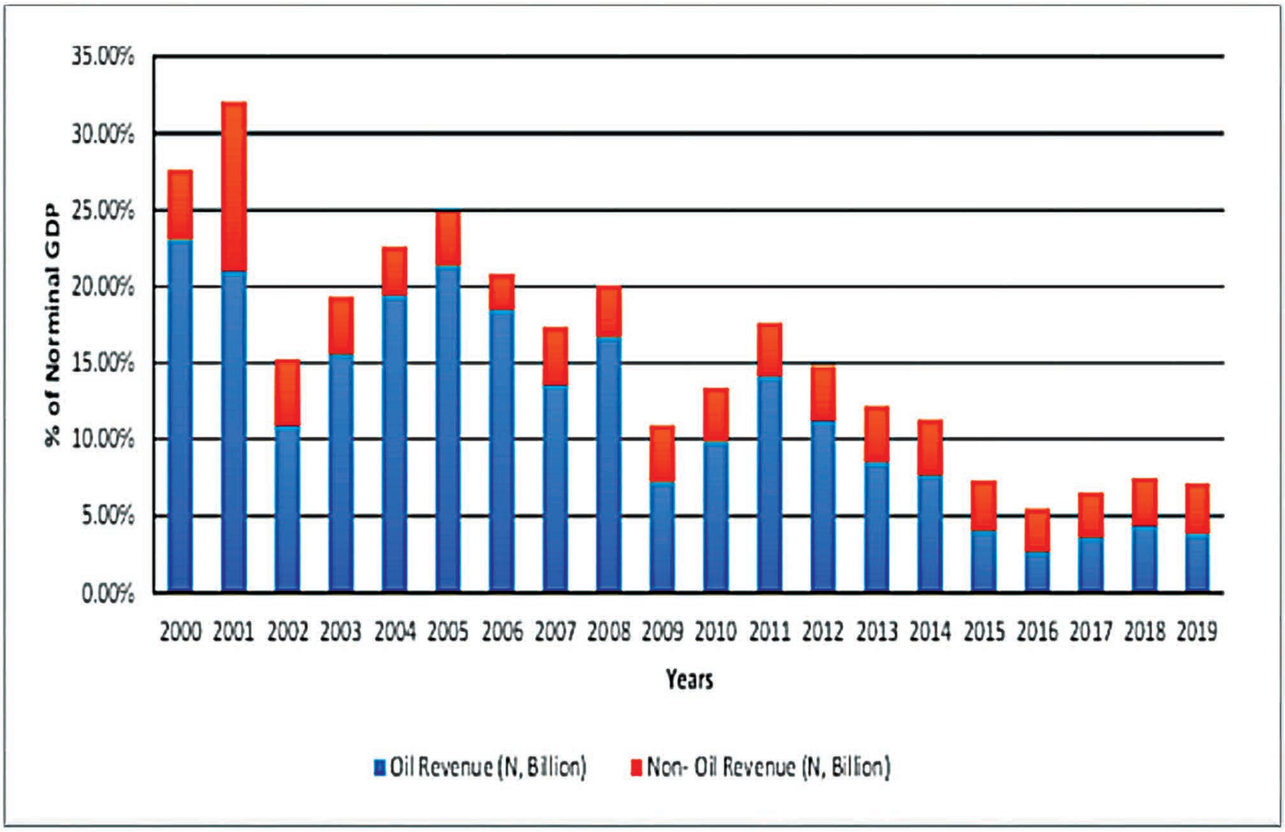

Figure 2: Oil and Non-oil contribution to the GDP in Nigeria between 2000 and 2019
Source: Data from Central Bank of Nigeria (CBN) Statistical Bulletin 2019

is clear. Thus, it is expected that the global shift from fossil fuel particularly crude oil will have adverse effects on the Nigeria economy if no seriousness is shown by the government towards diversification of the economy away from oil to potential revenue earning sectors such as solid minerals, agriculture, and manufacturing.

The areas of the Nigeria GPD that would be affected can be analyzed based on the definition of the Gross Domestic Product. For example if the GDP is defined as an allocation of Income to Consumption and Investment:

$$GDP = Consumption + Investment + Export - Import$$

Energy transition requires huge investment in renewable, decarbonization, electric vehicle batteries, and energy efficiency. Thus, increased investment in the new global energy order is expected to engender a vibrant renewable energy industry but such would cause a decline in the current oil exploration and production activities in Nigeria. Therefore, if the total new investment in the renewable energy technologies, decarbonization technologies, and energy efficiency technologies is greater than the total divestment in the oil industry due to low oil exploration and production activities, it is expected that Nigeria economy will receive a boost and the GDP will increase. This is even more true in the case of Nigeria's current economy that is far from equilibrium of full employment of available resources, and excess savings over investment due to lack of investment ideas. Thus, additional investment would cause a shift in the economy towards greater utilization of resources and the GDP would increase. However, if the total new investment in the new global energy order is lower than the total divestment in the oil industry, the economy would suffer a decline in growth rate due to reduced investment, low income, and loss of employment by the employees in the oil industry, oil service firms, and other sectors that are linked with the oil industry. Currently, the Nigeria oil industry according to International Labor Organization (ILO) employs 65,000 direct staff and 250,000 indirect staff. A decline in oil exploration and production activities would push huge numbers of the employees, both direct and indirect, into the labor market. If this happens in Nigeria, the economy will experience low spending, reduced taxes and high borrowing. This added to the current huge rate of unemployment and low revenue, generally, will cause the GDP to suffer a decline.

Moreover, the agriculture sector would share in the loss of revenue due to global shift from fossil fuels. Currently, Nigeria, as part of its efforts in integrating agriculture with the petroleum downstream is enforcing 10% ethanol blend with the auto fuel. This implies huge investment in crops such as cassava, corn and sugarcane. In Nigeria, the total estimated daily demand of petroleum motor spirit (PMS) is 38,200,000 liters and this would require 3,820,000 liters of ethanol. Thus, currently, there is a huge demand on ethanol input materials such as sugarcane, cassava and corn. However, the global energy shift from fossil based fuel to renewables would lead to a decrease in the demand for such agricultural products which are raw materials for ethanol production and consequently, there will be a reduced productivity from the agricultural sector and the GDP will decline.

The Manufacturing sectors in Nigeria could also suffer a set back because its rapid and sustainable development requires the functioning of petrochemical industries because they play key roles as industrial multipliers by catalyzing virtually all arms of the economy. Furthermore, production activities within and around the three major petrochemical industries in Nigeria; the Kaduna Refinery and Petrochemicals Company (KRPC), the Warri Refinery and Petrochemicals Company (WRPC) and Indorama Eleme Petrochemicals Company would slow down and this would cause a low productivity and consequently a slide in the GDP.

Nevertheless, if the country can show the deserved seriousness required for the implementation of the National Renewable Energy and Energy Efficiency Policy (NREEEP) to drive the required investments from both domestic and foreign investors, the adverse impact of the energy transition could be mitigated with sufficient investment in Renewable Energy as well as in Agriculture and Solid Minerals Sectors. For example, Nigeria's climate favors abundance renewable energy resources such as solar and wind energy.

For the consideration of solar energy, Nigeria lies within a high sunshine belt and within the country; solar radiation is fairly well distributed. According to NREEEP (2015), the annual average of total solar radiation varies from about 12.6 MJ/m^2-day in the coastal latitudes to about 25.2 MJ/m^2-day in the far North. Currently, the solar energy has a maximum capacity of about 3% but the government plans to increase the maximum capacity to 6% by 2030. For wind energy, the energy potential is also high. In Nigeria, The annual average wind speed at 10m height varies from about 2m/s in the coastal areas to about 4m/s in the far North. At 50m, the range is 2m/s to 8m/s. It is possible to convert wind energy to rotary mechanical energy and electrical energy for a variety of use ranging from water pumping, milling of grains to electricity generation.

Furthermore, there are abundant investment opportunities in the Nigeria Agro - raw materials ranging from cash crops to food crops. There are ample investment opportunities in grains and cereal production and processing that could mitigate the adverse effect of the global shift from fossil based fuels. Investment in maize farming, for example, could increase Nigeria's global market share from its present 1.01%. According to the Raw Material Research and Development Council of Nigeria, the worldwide production of maize is 785 million tons/annum, with the largest producer, the United States of America producing 42%. Africa as a whole produces 6.5% with Nigeria's total production of 8 million tons/ annum inclusive which represents just 1.01% of worldwide production. Aside from maize, there are other investment opportunities in plantation establishment and processing, Cashew production and processing as well as Cocoa production and processing among others. All these cash crops are exportable and they would generate foreign earnings.

Another non-oil investment opportunity area in Nigeria is in the Solid Mineral Sector. Nigeria is blessed with geological formations which favor the occurrence of various types of mineral resources. The country is well endowed with abundant mineral resources with potentials for being developed into mineral raw materials for both domestic industry and export. There are many minerals which are available in economic quantities and are of good quality, According to the Raw Materials Research and Development Council of Nigeria, there are about 44 different mineral resources that have been identified to occur in commercial quantities broken down into seven (7) categories which include: Precious Metal Gold, Base and Rare Metals, Ferrous Metals, Industrial Minerals, Energy Minerals, Construction Materials and Gemstones. For example, a Ferrous Metal like Nickel is a required metal input in the production of Electric Vehicle batteries. Thus, high demand for electric vehicle batteries would also lead to high demand for a metal like Nickel. This is a good investment opportunity in the Nigeria solid mineral sector.

Investment in renewable energy technologies, carbonization technologies and energy efficiency technologies would not only help Nigeria to provide sustainable energy for her economic activities without environmental pollution, but would also reduce dependence on energy importation and thus improve her trade position with the rest of the world.

Nevertheless, to attract investment particularly foreign investment, the business environment should be conducive. Investors would invest their money in a politically stable economy. Also, the government of Nigeria should promote investment policies that would provide incentives to attract foreign direct investment (FDI) as well as domestic investment. Infrastructure should be developed to support economic growth and development. The economy would require huge investment to mitigate the adverse effects that the shift from fossil fuel would eventually have on the economy.

Conclusion

In conclusion, the current global energy transition will surely disrupt economic activities of emerging economy like Nigeria. Its impact would be felt most in the oil sector as well as agriculture and linkage industries. Generally, the economy may experience a decline in GDP. Nevertheless, if measures that could boost FDI, domestic investment, good infrastructure and conducive business environment are prioritized, the economy will become vibrant and potential loss from fossil fuel rejection would be offset by gains from increased productivity in the new energy order and other sectors of the economy.

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An Evaluation on China's Energy Transition and Carbon Neutrality

BY CHAN KUNG AND HE JUN

Abstract

China has set its ambitious target of attaining "carbon peak" and "carbon neutral" in three decades, yet as far as China is concerned, this goal is far difficult than most developed countries.

More countries are pledging to the cause of carbon neutrality, with some EU countries carbon neutrality by 2050. China has pledged to the goal of "double carbon" in September 2020, i.e. carbon peak by 2030 and carbon neutrality by 2060. The United States, who recently rejoined the Paris Agreement on February 19, 2021, also shared its aims to achieve carbon-free power generation by 2035 and carbon neutrality by 2050 respectively; although some analysts are doubtful of the country's ability to do so. As it stands, most countries have already set their carbon neutral targets.

All pledged countries can be broken down into four categories depending on their rate of carbon emission: (1) Countries that are experiencing a post-carbon emission peak decline such as the United States, the United Kingdom, France, etc.; (2) Countries that are still seeing a growth in carbon emissions, such as India; (3) Countries in which carbon emissions have entered the "platform period", such as China; (4) And lastly, those that have yet to put their carbon emission reduction plans into practice, such as some agricultural-based developing countries.

Based on a series of latest research, Chinese Academy of Sciences academician Dong Zhili believes China will have no problems accomplishing its "double carbon" goal, as there is no "ceiling" in carbon peaks. Dong's team further added there is no need to concentrate the research on carbon peaks, as the focus lies in achieving carbon neutralization instead. Internationally there are no set rules and regulations for carbon peaks either, and countries are free to achieve carbon neutrality two ways. The first which is high peak, and the second which is low peak. If China hopes to achieve carbon peak by 2030, the country would enjoy more relaxed day before the year, yet it will face tremendous pressure on carbon neutrality post-2030. On the other hand, if it chooses to reach a low peak in 2030, then China will have to strictly limit carbon emissions.

China's pledge of reaching the "dual carbon" target is acknowledged by most countries in the world. That said, it would not be easy for China to attain the goal. Data from 2019 shows the country's total energy consumption was about 4.86 billion tons of standard coal. In the same year, China's total energy emitted 9.826 billion tons of carbon dioxide. Among them, carbon emissions under power generation end accounted for about 47%, and carbon emissions under consumer end accounted for about 53%. These findings show that China will face an uphill battle in achieving carbon neutrality in the days to come. The conditions set by the research team of the Chinese Academy of Sciences for China's carbon neutrality are as follows: the GDP doubles in 2035 and again 2060; the living standards is representative of the corresponding development stage; and industrial structure gradually develops towards mid-to-high end. Additionally, population changes must be taken into account (i.e. lower fertility and aging society).

Founder of Anbound Think Tank in 1993, **Chan Kung** is one of China's renowned experts in information analysis. Most of Chan Kung's outstanding academic research activities are in economic information analysis, particularly in the area of public policy. **He Jun** takes the roles as Partner, Director of China Macro-Economic Research Team and Senior Researcher. His research field covers China's macro-economy, energy industry and public policy

Regarding the direction of China's future energy transition, early judgments made by the research team of the Chinese Academy of Sciences mainly include: (1) For China, the increase in the proportion of non-carbon energy will not be linear, and it will be driven by technological progress; (2) Coal being the main source of energy, will continue to exist for a long period of time. Therefore, the advancement of clean coal utilization technology still requires greater attention; (3) If advanced fission energy can solve the problems of fuel, safety, inland plant construction and the issue of how it is perceived by the public, it can play a crucial role in carbon neutralization, and China should not follow the footsteps of certain countries that have abandoned the use of nuclear energy; (4) China's abundant wind, light, and geothermal resources, especially wind and light resources in the west, will be vital in achieving carbon neutrality.

The research suggests the key to achieving carbon neutrality lies in the utilization of non-carbon energy to replace fossil energy for power generation and hydrogen production, then using electricity and hydrogen to replace fossil energy in residential life, transportation, industrial processes, construction, agriculture and other fields. This in turn, helps to reduce carbon dioxide emissions substantially. The research also found that China has large-scale hydrogen-related industrial system-petrochemical and chemical industries, which will be the most crucial areas in hydrogen utilization, both now and in the future. If China can properly apply green hydrogen to the petrochemical and chemical industries, this will better reflect the value of green hydrogen and truly solve the major problem of industrial de-carbonization.

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If you are interested in registering for this conference visit https://www.aeaweb.org/conference/

IAEE Session

Advances in Energy Economics Research

Saturday, January 8, 2022; 10:00am – 12:00n Eastern

Organizers: Alberto J. Lamadrid, Lehigh University & Greg Upton, Louisiana State University

Presiding: Alberto J. Lamadrid, Lehigh University

Work-from-home, Electricity and Water: Evidence from Qatar

David Bernstein, University of Miami, Alecia Cassidy, University of Alabama, Ahmed Khalifa, Qatar University

Discussant: Todd Gerarden, Cornell University

Oil Prices, Gasoline Prices and Inflation Expectations

Lutz Kilian, Federal Reserve Bank of Dallas and Xiaoqing Zhou, Federal Reserve Bank of Dallas

Discussant: Bulat Gafarov, University of California, Davis

Economics of Grid-Scale Energy Storage in Wholesale Electricity Markets

Omer Karaduman, Stanford University

Discussant: Jose Miguel Abito, University of Pennsylvania

The time-of-day Travel Demand Elasticity Paradox

Cody Nehiba, Louisiana State University

Discussant: Arthur Van Benthem, University of Pennsylvania

IAEE/AEA Session

The Many Colors of Hydrogen: Progress and Challenges

Saturday, January 8, 2022; 12:15pm – 2:15pm
Presiding: Ted Loch-Temzelides, Rice University

Exploring the Role of Hydrogen for Decarbonizing the Energy System

Emre Gencer, MIT

Sector-coupling via Hydrogen and Implications for Economy-wide Decarbonization

Dharik Mallapragada, MIT

Hydrogen's Production Technology Diversity may well prove to be its Strength

Kenneth Medlock, III, Rice University

Pricing Policies to Promote Fossil Fuel Alternatives

Ian Parry, IMF

IAEE Session

Decarbonizing the Global Economy: Balancing Economic Efficiency and Political Feasibility

Saturday January 8, 2022; 3:45pm – 5:45pm

Organizer: Mark Agerton, University of California, Davis & Greg Upton, Jr. Louisiana State University

Presiding: Greg Upton, Louisiana State University

Session Description: The success of decarbonization policy proposals can be measured along at least three dimensions. First, and perhaps most obviously, proposed policies should reduce emissions. Second, the estimated costs of proposed decarbonization policies should be less than the anticipated benefits, especially in the medium to long run. Third, policy proposals should be politically feasible if they are to be implemented through apolitical process. Open communication between policy makers, economists, and industry stake holders is crucial to the creation of successful decarbonization policy. This panel session serves to contribute to this ongoing conversation on how policy makers can balance the speed, cost, distributional impacts, and political feasibility of decarbonization policy proposals.

Robert N. Stavins, Harvard University

Barry Rabe, University of Michigan

Adam Sieminski, King Abdullah Petroleum Studies & Research Center (KAPSARC)

Garret Graves, United States House of Representatives

Reliability and Resilience: Complements or Substitutes?

TIM BRENNAN*

Since the 1965 New York City blackout, "reliability" has been the policy and operational watchword for the concept for confidence that the lights will come on. In more recent years, the term "resilience" has come to the fore. From my vantage point, it looked initially like "resilience" was a term invented by the Trump Administration's Department of Energy to justify proposed regulations to protect coal-fired electricity generators from market forces that have made them increasingly unprofitable, apart from any emissions or carbon regulation. I thought this in part because at first glance the difference between "reliability" and "resilience" was far from clear.

Nevertheless, "resilience" persists, and has become much more widely used. Whether it has a different meaning than reliability remains unclear. For example, when using "climate resilience" to refer to the ability of a grid to withstand climate-related distress, the term "climate reliability" would be equally suitable. Presumably, however, resilience is more than a fashionable synonym for reliability, which perhaps had become mundane over the last 65 years.

Rather, I will infer that this different term has become prevalent because it has a definition separate from reliability. From the dictionary, the defining characteristic of resilience is the ability to recover from a shock. To be a little more precise, we can define resilience of an electricity grid or system as the probability that grid will be running at some time interval (minute, hour, day) following an outage. A measure of resilience under this definition would be the average or expected duration of an outage; the more resilient a system, the shorter that duration. Whether the cause of the outage is a random internal failure, like a generator going unexpectedly offline, or a random external event, like weather blowing down a transmission line, is immaterial to this definition here, although in practice a system can be more resilient to some outages than others, depending on the cause.

This invites a second concept that contributes to the overall expected performance of a grid: the probability that the grid will still be running at some time interval after it was already running. The relevant measure here would be mean time between failures. Again, whether the cause of that failure was internal or external is immaterial at this simple level. With some trepidation to be explained below, I will use "reliability" to refer to this idea, that is, that the longer the mean time between failures, the more reliable is the system.

The question posed here is whether reliability and resilience are complements or substitutes. The usual presumption seems to be that resilience goes hand in hand with reliability. This may be true, but I want to suggest that it need not be true—a more reliable system may be less resilient, and a more resilient system may be less reliable.

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Seeing this requires some notion of the object of the game. Keeping things simple, suppose that the goal of the electricity grid operator or regulator is to maximize the probability that the grid is running, or in other words, reduce the chance of an outage at any given time. The overall probability that a grid is running will thus depend on both reliability and resilience. The more reliable, by this definition, the less frequent will be outages. The more resilient, by this definition, the shorter will be the time the outage lasts.

Of course, not all outages are equally costly. Losing power during extreme weather events when one needs heat (if just the fan to circulate air heated by a gas furnace) or air conditioning will be more important to avoid than when circumstances are less threatening. Losing power during the workday will be more costly, generally, than the middle of the night. In actuality, a grid operator or regulator will care about these as well. Taking those complications into account would change specifics in practice, but the fundamental question of whether resilience and reliability could conflict with each other remains.

At one level, reliability and resilience may be substitute means for maximizing the overall likelihood of performance or, alternatively, minimizing the possibility of an outage. A grid operator or regulator interested in cost efficiency would choose to invest in reliability and resilience up to the levels where the incremental benefit to overall performance per dollar on methods to improve reliability would be the same as investments to improve resilience. However, that is consistent with the possibility that reliability investments improve resilience, and *vice versa*. It's just that methods to best target one may not be the same as methods to best target the other.

I want to raise the possibility, however, that the conflict may not just be on the best way to invest in one or the other, but that investing more in one reduces the other. Making a system more reliable may make the system less resilient, and making a system more resilient may make it less reliable.

The key idea involves repair. Systems that are harder to disrupt—more reliable—may also be harder to repair—less resilient. Compare cars of today to cars of fifty years ago. The latter were less reliable, but more resilient, at least for the many people with the interest and skill to fix cars themselves.

The most apparent example from the grid is burying distribution and transmission lines. Burying lines makes them more reliable, in that underground lines are less vulnerable to weather-related disruptions than above-ground lines. However, if something does go wrong with a buried line, it may take longer to repair than lines on poles, where damage is easier to detect and without digging required to repair it. Another possibility may be shutting down transmission lines during very hot weather—reducing reliability—to prevent fires that would delay restoration—promoting resilience.

There may be other examples; I am not a grid engineer. But the point is that proposals to increase resilience, tempting as those may be, could come at the cost of reduced reliability. One should be careful before giving in to that temptation. More resilience will promote grid performance "all else equal," but the nature of investments to promote resilience may keep all else—reliability—from being equal.

Before leaving, I return to that trepidation on terminology that I mentioned above. The framework here is simple, based on how long it takes to repair a grid that goes down, and how infrequent are such repairs necessary. Calling the first "resilience" seems pretty clear. Here, I defined "reliability" as the probability that a grid once operating will keep operating, with no term for the overall probability that the grid operates, taking both resilience and reliability so defined into account. If one likes long words beginning with an "r", perhaps "robustness" would be a good term for this overall probability.

Alternatively, one could define "reliability" as this overall probability of operation. We would then need another term for this "mean time between failures" concept. Perhaps "stability" would be a good one, although that may already be a term of art among grid engineers. Then, the central point of this paper would be that increased resilience might conflict with stability, and thus at some point reduce reliability as well.

I leave the choice of nomenclature to readers with more engineering expertise than I have. But whatever one decides to label as reliability, designing a system to increase resilience—reduce the expected time to restore power once an outage occurs—need not improve the overall performance of an electricity grid.

Footnotes

* I thank Karen Palmer for helpful comments. Remaining errors are my sole responsibility, and these views do not necessarily reflect those of anyone else at RFF.

Hackers and Extreme Weather: Using a Risk Based Framework to Protect Consumers from Both

BY JACKIE ASHLEY & MICHELLE NOCK

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Abstract

Cybersecurity is increasingly being regulated by incorporating a risk-based framework that is a process – not a set of standard or rules. This article describes this framework and proposes that it could also be used for climate related risks, such as extreme cold/heat events and wildfires.

Introduction

The February 2021 severe winter storms crippled the electricity grid in Texas and left millions of people shivering without power, heat and running water for several days. Most tragic of all were the deaths it caused, with some people dying from the cold and others from carbon monoxide poisoning while trying to keep warm.

A key contributor to the Texas outage was inadequately winterized electricity generation and natural gas equipment. This risk was already known – a winter storm in 2011 triggered widespread blackouts and revealed the power grid's vulnerability to cold temperatures. Unfortunately, recommended changes were not made.

What can utility regulators do to ensure that utilities proactively identify and address these types of weather-related risks, such as extreme cold, extreme heat, hurricanes, storms and wildfires?

Currently regulators tend to use input standards (such as planning criteria) or output metrics (such as desired reliability levels) to address reliability concerns. However, given the rapid evolution of the generation resource mix and increased frequency of severe weather events, these approaches on their own may no longer be sufficient to address emerging resilience risks.

This article suggests that utility regulators look to the risk-based framework developed to address cybersecurity risk for inspiration. These risk-based frameworks are a process – not a set of standards or rules – that focus the utility's attention on cybersecurity risks. A similar approach could also be used to ensure that weather related risks receive the attention they deserve.

NIST Cybersecurity Framework

To address cybersecurity risks, in 2014 the National Institute of Standards and Technology (NIST) produced a Cybersecurity Framework that utilized a risk-based approach. It is a voluntary framework developed through collaboration between industry and government. It was designed to be flexible enough so that it can be applied to organizations of any size, any cybersecurity risk level, and any level of cybersecurity preparedness, regardless of the industry or country.

The NIST Framework Core consists of five concurrent and continuous functions – Identify, Protect, Detect, Respond, Recover.

Figure 1: NIST Framework Core Functions (NARUC)

When considered together, these functions provide a strategic view of an organization's management of cybersecurity risk:

- **Identify** – Develop an organizational understanding to manage cybersecurity risk to systems, people, assets, data, and capabilities.
- **Protect** – Develop and implement appropriate safeguards to ensure delivery of critical services.
- **Detect** – Develop and implement appropriate activities to identify the occurrence of a cybersecurity event.
- **Respond** – Develop and implement appropriate activities to take action regarding a detected cybersecurity incident.
- **Recove**r – Develop and implement appropriate activities to maintain plans for resilience and to restore any capabilities or services that were impaired due to a cybersecurity incident.

The framework can be described as a basis for having a discussion or a template to start a conversation. The focus of this approach is therefore not to tell the utility specifically what it should do to manage risks (which could risk regulatory overreach as regulators do not have a mandate to manage the utility), but to ensure that the utility goes through the proper process to arrive at a plan that is in the public interest.

NARUC Cybersecurity 'Questions for Regulators'

The NIST framework has been used as the cornerstone for the development of risk-based cybersecurity approaches by regulators in the US, UK, Canada and Australia. This included development of questions for regulators to ask utilities and tools to evaluate responses.

For example, the National Association of Regulatory Utility Commissioners (NARUC) has developed a comprehensive suite of resources, collectively referred to as the "Cybersecurity Manual," to help public utility commissions gather and evaluate information from utilities to inform their decision making about cybersecurity risk management practices.

This includes "Understanding Cybersecurity Preparedness: Questions for Utilities" which contains a 4-page "Plain English" list of context-sensitive questions that regulators can ask of a utility to gain a detailed understanding of its current cybersecurity risk management program and practices. Regulators do not need to become cyber industry authorities or enforcers, but asking a utility a question can motivate the development of a well-founded answer.

These questions are organized by the five NIST core functions (Identify, Protect, Detect, Respond, and Recover) and are further divided into two categories "Policy and Plans," and "Implementation and Operations." Sample questions from this list are provided in Figure 2:

Sample Questions – Cybersecurity

1. Do you have a cyber risk management program? a) If so, who leads the program? b) Is executive leadership actively engaged? c) Are cybersecurity roles and responsibilities defined? d) Have you formed a cross-functional team that spans relevant business units to assess risks to and criticality of business functions? e) Is the program based on a cybersecurity framework (e.g., NIST, NERC CIP)?[1] f) Is the program integrated into overarching enterprise risk management? g) Are criteria for defining and managing cybersecurity risk included? If yes, please explain.
2. Have resources (funding, personnel, technology) been dedicated to meet cybersecurity risk management objectives? a) Are personnel dedicated full time, part-time, or as part of other duties? b) Is funding commensurate with cybersecurity risk management objectives? Are funding levels consistent?
3. Have you developed policies and procedures regarding cybersecurity event detection activities, including roles and responsibilities, oversight, and communications, to rapidly detect and mitigate cybersecurity incidents? If so, please describe a) the classification scheme for identifying and reporting cyber events, including thresholds; b) the system and network monitoring requirements; and c) the frequency of reviews and updates to policies and procedures.
4. Do you have cyber incident response policies and plans in place for minimizing the effects of a cyber incident? a) If yes, are roles and responsibilities for recovery defined? b) Are incident severity thresholds defined? c) Are escalation criteria defined? d) Are mandatory third-party incident notification requirements documented (e.g., to PUC, SEC)?[2] e) Does your response plan include interactions with third-party service providers?
5. Have you identified minimal operational functionality for recovery of critical assets?

NARUC Cybersecurity 'Evaluation Tool'

Just asking questions isn't enough—once the right questions have been asked of utilities, regulators bear the responsibility of understanding the answers to determine whether they represent prudent activities and investments.

To assist in this next step, NARUC have also developed a simple, easy to use "Evaluation Tool" to help regulators evaluate a utility's responses against generally accepted standards, best practices, and the utility's specific needs.

For example, evaluation criteria for the first category of "Questions for Regulators" (Identify – Governance: Policy & Plans) are shown below:

Evaluation Criteria: Governance

Policy and Plans	Maturity Level
❑ Does not have policy or plans related to this topic.	No Criteria
❑ Did not share information.	No Information
❑ Has plans and policies within its IT or security department that assign responsibilities for cybersecurity. ❑ Has dedicated security policies that govern IT and OT systems.	LEVEL 1: Initial
❑ Has a cybersecurity plan or strategy that includes an organizational structure stretching beyond IT and/or security departments that outlines the roles and responsibilities related to cybersecurity and information protection.	LEVEL 2: Established
❑ Regularly reviews, updates, and improves its cybersecurity plan, strategy, and other governance. ❑ Identifies relevant external stakeholders for cybersecurity events and effectively coordinates cybersecurity roles and responsibilities with external partners.	LEVEL 3: Mature
❑ Identifies a clear policy for incorporating senior leadership during a cybersecurity incident, meeting pre-identified thresholds, and has clearly outlined their roles and responsibilities with respect to providing strategic support for incident response activities.	LEVEL 4: Optimized

Figure 2: NARUC Evaluation Tool: Identify (Governance)

The "Evaluation Tool" does not require that utilities use a specific approach, and this flexibility accommodates a wide range of different cybersecurity practices. The specific needs of each utility differ and, as such, each utility would be expected to adopt the cybersecurity practices that best fit its unique circumstances.

Used together, the "Questions for Utilities" and "Evaluation Tool" provide a holistic view of a utility's cybersecurity risk management program that can complement compliance-based approaches already in place.

Application to Extreme Weather Risks & Wildfires

The NARUC cybersecurity "Questions for Utilities" and "Evaluation Tool" could provide a useful starting point in developing a similar risk-based approach to address other emerging and rapidly evolving threats and vulnerabilities, such as the extreme weather events seen in Texas.

This risk-based approach could help regulators identify gaps, spur utilities' adoption of additional mitigation strategies, and encourage improvements over time. It would allow regulators to assess the maturity of a utility's program to address extreme weather-related events (such as extreme cold, extreme heat, and wildfires), gauge improvements to the program year over year, and evaluate utility decisions and their approaches to planning for and making resiliency-focused investment.

To illustrate this approach, the 5 sample questions from NARUC's cybersecurity "Questions for Utilities" shown previously have been reworded to replace "cybersecurity" with "extreme cold":

Sample Questions – Extreme Cold

1. Do you have an ***extreme cold*** risk management program? a) If so, who leads the program? b) Is executive leadership actively engaged? c) Are ***extreme cold*** roles and responsibilities defined? d) Have you formed a cross-functional team that spans relevant business units to assess risks to and criticality of business functions? e) Is the program based on a cybersecurity framework (e.g., NIST, NERC CIP)? f) Is the program integrated into overarching enterprise risk management? g) Are criteria for defining and managing ***extreme cold*** included? If yes, please explain.
2. Have resources (funding, personnel, technology) been dedicated to meet ***extreme cold*** risk management objectives? a) Are personnel dedicated full time, part-time, or as part of other duties? b) Is funding commensurate with ***extreme cold*** risk management objectives? Are funding levels consistent?
3. Have you developed policies and procedures regarding ***extreme cold*** event detection activities, including roles and responsibilities, oversight, and communications, to rapidly detect and mitigate ***extreme cold*** incidents? If so, please describe a) the classification scheme for identifying and reporting **extreme cold** events, including thresholds; b) the system and network monitoring requirements; and c) the frequency of reviews and updates to policies and procedures.
4. Do you have ***extreme cold*** incident response policies and plans in place for minimizing the effects of an ***extreme cold*** incident? a) If yes, are roles and responsibilities for recovery defined? b) Are incident severity thresholds defined? c) Are escalation criteria defined? d) Are mandatory third-party incident notification requirements documented (e.g., to PUC, SEC)? e) Does your response plan include interactions with third-party service providers?
5. Have you identified minimal operational functionality for recovery of critical assets?

In reviewing these reworded questions, readers are asked to consider whether adoption of this risk-based approach after the Texas 2011 storms could have better focused utility management's attention on the severe cold problem, and so mitigated the significant negative impacts to customers of the Texas winter storms a decade later.

The above 5 questions are a sample only. Readers are encouraged to review the full 4-page list of questions included in NARUC's "Questions for Utilities" and the accompanying 9-page NARUC "Evaluation Tool."

In addition, NARUC have developed a complementary resource – "Smart Grid: Questions for Utilities" – for utilities with a high penetrations of distributed energy resources

Conclusion

Managing extreme weather impacts during a time of energy market transformation can be a highly complex undertaking, requiring significant coordination among widely diverse policymakers and stakeholders.

This article recommends that regulators look to the easy to use and innovative risk-based frameworks developed to address cybersecurity risks and consider repurposing them to address other risks, such as extreme cold, extreme heat, hurricanes, storms and wildfires.

Working together we will be able to provide good solutions and great pathways going forward.

Disclaimer

This article does not represent the views or opinions of the British Columbia Utilities Commission (BCUC), nor does it express, or intend to express, any opinion on pending or future matters before the BCUC. This article was developed personally by the author and not in a professional capacity as a BCUC employee.

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Footnotes

[1] North American Electric Reliability Corporation Critical Infrastructure Protection (NERC CIP)

[2] Public Utilities Commission (PUC); Securities and Exchange Commission (SEC)

Low-cost, High-risk Electricity and the Texas Polar Vortex

BY CONNEMARA DORAN

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Abstract

The Texas polar vortex highlights the relationship between electricity cost and societal risk. We analyze six types of risk and possible policy responses, including R&D to improve wind-turbine deicing.

Texas enjoys low electricity costs but suffers high risks of shutdowns. The Texas polar vortex of February 2021 provides a highly instructive case study of the problematic relationship between the cost of electricity and the societal risk of loss of power during an extreme, extended polar freeze and ice-storm.

We first examine the origin of these costs and risks in Texas. Next, we identify six types of societal risk associated with the polar vortex. Finally, after reviewing these risks and the possibility of abatement with respect to each risk, we conclude that technological innovation regarding the deicing of wind turbine blades is a necessity.

Societal risks were actualized in deaths, suffering, and losses. The Texas government officially tallies 151 deaths from the plunging temperatures. These deaths spread unevenly across Houston, for example, disproportionately affecting the poor, homeless, elderly, and already-ill. The U.S. Census Bureau reports that, in 2019, Texas had the twelfth-highest poverty rate (13.6%) in the nation, and the second-highest population.

Economic risks also took their toll in Texas. On March 3, Insurance Journal reported that the oldest and largest power cooperative in Texas had declared bankruptcy.[1] The Insurance Council of Texas, an industry group, faulted the energy companies for insurance losses of at least $20 Billion.[2] On March 5, AccuWeather specialists updated their estimate of damage and economic losses in Texas alone to $130 Billion, three times their earlier estimate.[3] News headlines declared the blackout "the most expensive disaster in Texas history."[4] Whatever the eventual losses, they will be very substantial.

Texas enjoys some of the lowest energy costs in the nation, ranking fourth lowest in terms of its cost of electricity. Average residential electricity costs for the U.S. as of May 2021 were 13.19 cents per kilowatt hour (kWh). Residential electricity costs were as high as 19.90 cents per kWh in California. But in Texas these residential electricity costs were only 11.36 cents per kWh.[5]

Texas features a free-market based energy economy where each energy firm must compete with every other energy firm for a share of the market. Demand and supply determine the price of energy in Texas, not a single utility or regulatory body which, as a monopoly, would set the price of energy for the whole society.

How much electricity a state uses varies with a number of conditions such as the climate, the productivity of each economy, the nature of industrial output, the quality of residential and commercial construction, the price of electricity, and the size of the population. As of 2018, Texas consumed about 1,177 kilowatts per month, or about 39.2 kilowatts per day. Across states, according to the Energy Information Administration (EIA), Texas is the sixth largest overall consumer of energy at 498 million BTU. California, the largest population state, uses only about 202 million BTU.

But in terms of their electricity rates, Texans benefit from very low energy costs. The average residence in California, benefitting from a relatively mild climate, consumes about half as much electricity per household as the average household nation-wide. Texas, where residential temperature extremes are larger and summers are consistently very hot (ranging from dry heat to extreme humidity), consumes more electricity per household, overall, especially for air-conditioning, than the average state.

Reliability, Societal Risk, and Financial Cost

Figure 1 depicts the dilemma a state faces regarding the reliability of electric energy supply during an extended deep freeze. This four-celled table places the financial cost of energy on the horizontal axis, societal risk on the vertical axis. Texas finds itself in Cell B with low financial energy costs but high societal risks regarding energy reliability. California finds itself in Cell D with high financial costs but low societal risks in

Societal Risk

Cell B: Low financial cost High societal risk **Texas**	**Cell C:** High financial cost High societal risk **AVOID**
Cell A: Low financial cost Low societal risk **GOAL**	**Cell D:** High financial cost Low societal risk **California** (outside wildfire season)

Financial Cost

Figure 1. Table depicting financial cost and societal risk regarding electric energy reliability in the winter months: Texas and California.

terms of a polar vortex. (If summer heat waves were to be included, California would move to Cell C while Texas would remain in Cell B).[6] Each actor seeks to avoid Cell C characterized by both high energy costs and high societal risks. Ideally, the goal for Texas and California is to enter Cell A with low costs and risks.

To enter cell A, Texas would need to reduce societal risks during winter weather crises without sacrificing its low energy cost; California would need to reduce its costs of electricity consumption without increasing societal risks. (Regarding summer weather crises, both Texas and California would need to reduce their societal risks). Each of these reductions is a serious strategic challenge.

At least six types of societal risk accompany severe winter freezes in Texas.

- Risk of maladministration
- Risk of insufficient spare capacity
- Risk of inadequate winterization (at wind turbine, natural gas storage unit, pipeline, utility)
- Risk of non-optimal grid expansion and connectivity
- Risk of a lack of citizen preparedness and the challenge of resilience
- Foregone hypothetical worst-case risks

Maladministration

Maladministration lurks in odd places, here in the logic of strategic best-practices. Concerned about summer hurricanes, Texas decision-makers planned equipment maintenance (with the accompanying impediment to electricity transmission) during winter months when down-time would interfere less with energy consumption. Severe winter weather (as in 1989 and 2011) destroyed the logic of this schedule, instigating assessments and recommendations to strengthen the system. The 2021 polar vortex prompted new laws regarding maintenance and enforcement (see below).[7] Maintenance should be programmed for the intervals between hurricanes and winter vortices (in spring and/or autumn) while remaining alert for black-swan events.

Insufficient Spare Capacity

When unanticipated spikes in electricity demand occur, a corresponding spike in electricity output may be needed to meet the increase in demand and/or offset the loss of production elsewhere in the system. But who would be paying for this spare capacity that may lay idle for years before being called upon during an emergency? If no one pays for the spare capacity, it does not exist.

Throughout the electrical grid crisis, natural gas (NG) continued to flow to direct users. The problem was in getting NG from storage unit to utility. No shortage of NG existed, since huge amounts were in storage. The difficulty was in ramping up access to stored NG beyond the peak normal load and transmitting that extra gas to the utilities.

In terms of base load considerations, nuclear was the most reliable in February. Of the four nuclear plants in operation, only one shut down very briefly, for instrument repair. Without the nuclear power supplied by these plants, the number of Texas residences lacking electric power would have been far greater.

Texas possesses a back-up system that is supposed to provide "capacity" during a crisis of any sort – a severe winter cold-spell, a summer hurricane, or hacking of the cyber network. In theory, inputs from some 28 standby generators called "black starts" can replace lost generator capacity. But they have not been fully tested as a unified system, which is complex, sensitive, and hard to coordinate. Vulnerabilities include "freeze damage and problems getting fuel" and unstable system frequency when power production cannot meet system demand.[8] During the polar vortex, 15 of the 28 black starts were periodically out of service, and only 13 have fuel oil as a backup in case NG fails. During the February 2011 freeze-up, 10 of the 21 then-extant black starts went down at the same time as the grid itself.[9]

Hence, spare capacity is very expensive and potentially unreliable, or both, especially when it goes unused for such long periods.

Inadequate Winterization

Winterization may be required at the NG well-head where frozen pipes and pumps can interfere with the flow of fuel to electric utilities or to consumers directly. Weatherization may be associated with underground NG storage units and/or wind turbines. Some users of electricity may require portable generators as backup. All of this energy substitution is expensive. Determining which types of weatherization may be necessary, how much and at what cost, needs to be carefully calculated. This process could be incorporated within larger-scale rationalization and modernization innovations in the engineering of the electric grid.[10]

Wind and solar are intermittent sources of energy. During periods of low wind, after sunset, and when expensive storage batteries are not available, NG is the principal go-to energy source for electric utilities. In Texas, NG is proximate and abundant. But the problem during the polar vortex was that the electricity to operate the wells, pumps, compressors, and pipelines was often unavailable.

Most of the necessary NG came from storage facilities, not from the wells directly. Large volumes of gas in storage had been accumulated for exactly the purpose of emergency supply. But this source of supply needed electric compressors to operate. The spike in energy demand during the polar vortex, accompanied by the downward spike in production, led to a cascading failure to provide electricity to those pumps. Absence of ability to transmit emergency gas in storage to the electric utilities led to a partial shutdown of the overall process of electricity generation and transmission lasting for days.

The associated effects of the grid distribution crisis were even more serious. Cascading effects included a shutdown of water pumping stations and of some sewage facilities.

Winterization at various locations would have solved many problems. That winterization did not exist is primarily the consequence of a single consideration. At present, with current technology, winterization is very expensive, especially when it protects against a threat that is rare.

The Problem of Non-optimal Grid Connectivity

The oldest regulatory commission in Texas, the Railroad Commission of Texas (RRC), was founded in 1891 to prevent price discrimination by railroads, but soon became the chief regulator of the oil and NG industry in the state, with the goal of defending public interests. Under the state constitution, the RRC "exercises its statutory responsibilities under state and federal laws for regulation and enforcement of the state's energy industries."[11] Texas Senate Bill 3, signed into law by Governor Greg Abbott on June 8, 2021, expanded the roles of the RRC to include participation in establishing "a process to designate certain natural gas facilities ... as critical during energy emergencies."[12]

Texas did not establish interconnectivity with either the large eastern or western power grids. Since efficiency of electrical transmission declines with distance, the more proximate 14-state Southwest Power Pool was more feasible for Texas, though the polar vortex severely affected some of these states as well. To make sense for Texas, an interconnecting power grid must be sizeable enough to offer meaningful backup capacity, exclude areas also hit by the polar event, meet Texas concerns about burden-sharing and fairness, exclude additional federal controls, and respect the Texas commitment to free market competition across electrical utilities.

Citizen Preparedness and Resilience

Texans are accustomed to preparedness in the face of catastrophic seasonal hurricanes, but they were not at all prepared for the devastations of an enduring winter deep freeze and ice storm. Going back more than 100 years, temperatures in Texas had plunged to below freezing for about a week at least five times. But Texas had not incorporated experiences from those disasters into advisory planning for citizens at the individual and community levels about how to survive a lengthy deep freeze. Resilience requires, minimally, access to a warm winter coat and knowledge of how to layer clothing, bedding to resist sub-freezing temperatures inside homes, and drinking water contained in bathtubs if necessary. Texas Senate Bill 3 includes a provision on monitoring weather and disaster preparedness education, which directly addresses these issues for "winter storms, hurricanes, floods, drought, fires, and other potential disasters."[13]

Foregone hypothetical worst-case risks

By employing a "rolling blackout" technique of electricity distribution, and a lot of luck, the Texas utilities were able to avoid a far worse fate in terms of human and economic impact. The entire system could have collapsed, and Texans might have been without electricity for as long as three weeks or even months. We identify this risk as a hypothetical worst-case risk.

The RRC had authority regarding transmission of oil and gas inside Texas; it had no direct responsibility regarding the electricity grid. But, since no one else was acting, and without formal authorization from the Governor's Office or the Texas Legislature, the head of the RRC, in a live communication with some 20 of the utilities, made a spur-of-the-moment executive decision to employ the rolling blackout approach to save the entire electrical system. By some estimates, the Texas electricity grid came within five minutes of catastrophic collapse.

The Need for Winterization Innovations

Loss of energy supply to the utilities began with the wind turbines. Wind energy as of January 2021 was providing 25% of the Texas electrical output. By 2 AM on February 15, the second day of the crisis, electricity generation from the wind turbines had already plummeted by more than 37% of its normal level of supply. By 7 PM, wind was providing only 2% of Texas total electricity generation.[14] Despite the effort of NG to fill the gap, when the wind turbines began to freeze up, the electric utilities had to start reducing their output of electricity.

Freeze-ups at the NG well-heads did occur, but these well-head problems affected supply only marginally. The central problem was elsewhere: NG from underground storage units was unable to make up for the loss of wind energy throughout the entire storm interval. Yet NG production never fell below its normal peak level of delivery. The problem was the freeze up of the wind turbines and the resulting loss of 23% of the electricity supply.

The policy implication is to winterize wind turbines effectively even against the impact of an ice storm. One way to pay for this would be to offer tax incentives to wind turbine operators for winterization.

The ice itself, not only freezing temperatures, was the problem. Even a "weatherized" wind turbine has difficulty operating when the turbine blades ice up. Normally, the way to deal with icing of turbine blades is to shut the turbine down. Operation of the turbine under an ice build-up will tear up the rotors and gears. Flying slabs of ice could create safety problems as well. Additionally, a recent study found that up to 80% of wind energy is lost due to icing.[15]

Regarding an ice storm, policy makers must identify exactly what "weatherize" means. The term "weatherization" is used several times in the Texas Senate Bill 3, but what are the requirements for weatherization, and applied to what phase of electrification? The term "winterization" is never used in the bill. Winterization of NG supply is even less easily defined than with wind turbines. Attempts to weatherize every NG well-head would involve a substantial waste of funds since the inability to get emergency increases in energy supply from NG storage was the result of electrical pumps that faltered for a lack of electricity, not frozen well-heads.

Wind power is central to long-term energy supply in Texas and globally. The problem is not that wind energy constitutes too high a proportion of the Texas electrical energy base. The Achilles-heel of energy supply in Texas, and the central lesson to be learned in policy terms elsewhere, is the failure to winterize the wind turbines in a way that could offset the effects of an ice storm.

How can Texas move in Figure 1 from a low-cost but high-risk energy situation (Cell B) to a low-cost and low-risk situation (Cell A)? How can Texas prevent another winter storm blackout? The answer, and challenge, is technological innovation. Current state-of-the-art deicers for wind turbine blades use hot air inside the blades combined with a carbon fiber outer coating that can be heated, requiring energy input into the process. Yet they have limited effectiveness and high cost. Can a more effective lower-cost device, strategy, or process be invented to prevent the icing-up of wind turbine blades?

Footnotes

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(Note: IAEE Cornerstone Conferences are in boxes)

Date	Event and Event Title	Location	Supporting Organizations(s)	Contact
2021				
November 1-2	USAEE/IAEE North American Conference *Navigating Energy Transitions: Economic in Social, Technical and Policy Challenges*	Virtual	USAEE	Doug Conrad usaee@usaee.org
2022				
March 2-3	*2nd MENA IAEE Symposium Combined with 5th Annual Derasat Forum*	Kingdom of Bahrain	IAEE	David Williams iaee@iaee.org
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/
Postponed to Fall 2022	8th Latin American Energy Economics Conference	Bogota, Colombia.	ALADEE	Gerardo Rabinovich grenerg@gmail.com
2023				
February 5-8	44th IAEE International Conference *Energy Market Transformation in a: Globalized World*	Saudi Arabia	SAEE/IAEE	Majid Al-Moneef moneefma@gmail.com
Postponed to 2023 Dates TBA	18th IAEE European Conference *The Global Energy Transition: Toward Decarbonization*	Milan, Italy	AIEE/IAEE	Carlo Di Primio https://www.aiee.it/
2024				
June 23-26	45th IAEE International Conference *Overcoming the Energy Challenge*	Izmir, Turkey	TRAEE/IAEE	Gurkan Kumbaroglu http://www.traee.org/
2025				
Postponed to 2025 Dates TBA	46th IAEE International Conference *Title TBA*	Paris, France	FAEE/IAEE	Christophe Bonnery https://www.faee.fr
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Calendar

06-08 October 2021, EM-Power Europe Restart 2021 at Messe Munchen, Messegelande, Munchen, Bayern, 81829, Germany. Contact: Phone: +497231585980, Email: info@em-power.eu URL: http://go.evvnt.com/603442-0?pid=204

12-22 October 2021, Downstream USA 2021 at NRG Center, 1 NRG Park, Houston, Texas, 77054, United States. Contact: Phone: +442075367253, Email: sasha.marks@thomsonreuters.com URL: https://go.evvnt.com/783332-2?pid=204

12-14 October 2021, SPE Russian Petroleum Technology Conference at Technopark Skolkovo, Bolshoy Boulevard 42, Building 1, Moscow, 143026, Russia. Contact: Phone: +74952680454, Email: lkhalmuradova@spe.org URL: http://go.evvnt.com/773176-0?pid=204

12-15 October 2021, SPE Russian Petroleum Technology Conference at Online. Contact: Phone: +74952680454, Email: lkhalmuradova@spe.org URL: https://go.evvnt.com/773176-3?pid=204

12-15 October 2021, Energy Networks Innovation Conference 2021 at Virtual. Contact: Phone: +442077065117, Email: enic@energynetworks.org URL: https://go.evvnt.com/830443-0?pid=204

13-14 October 2021, Reuters Events Offshore & Floating Wind Europe 2021 at Online, United Kingdom. Contact: Phone: +4402075138976, Email: Lindsay.Coulson@thomsonreuters.com URL: https://go.evvnt.com/799954-0?pid=204

18-20 October 2021, Power2Drive South America 2021 at Expo Center Norte, 333 Rua Jose Bernardo Pinto, Vila Guilherme, Sao Paulo, 02055-000, Brazil. Contact: Phone: +49 7231 58598-0, Email: info@intersolar.net.br URL: http://go.evvnt.com/603525-0?pid=204

18-22 October 2021, IEC 61850 Week 2021 at Gothenburg, Sweden. Contact: Phone: 02080571700, Email: registration@smartgrid-forums.com URL: https://www.smartgrid-forums.com/iec-61850-week-2021

18-20 October 2021, ees South America 2021 at Expo Center Norte, 333 Rua Jose Bernardo Pinto, Vila Guilherme, Sao Paulo, 02055-000, Brazil. Contact: Phone: +49 7231 58598-0, Email: info@intersolar.net.br URL: http://go.evvnt.com/603509-0?pid=204

18-20 October 2021, Eletrotec + EM-Power South America 2021 at Expo Center Norte, 333 Rua Jose Bernardo Pinto, Vila Guilherme, Sao Paulo, 02055-000, Brazil. Contact: Phone: +49 7231 58598-0, Email: info@intersolar.net.br URL: http://go.evvnt.com/603529-0?pid=204

19-20 October 2021, S&P Global Platts European Sugar Virtual Conference | 19-20 October 2021 at Online Event. Contact: Phone: (+44)2071760508, Email: alex.baird@spglobal.com URL: https://go.evvnt.com/863981-0?pid=204

20-21 October 2021, Carbon Capture Technology Conference & Expo at Bremen Exhibition Hall 4, 101 Hollerallee, Bremen, 28215, Germany. Contact: Phone: +44 1483330018, Email: charlie.brandon@trans-globalevents.com URL: https://go.evvnt.com/784301-0?pid=204

20-21 October 2021, Hydrogen Technology Conference & Expo at Bremen Exhibition Hall 4, 101 Hollerallee, Bremen, 28215, Germany. Contact: Phone: +441483330018, Email: charlie.brandon@trans-globalevents.com URL: https://go.evvnt.com/784299-0?pid=204

26-27 October 2021, Argus Vehicle Emissions and DEF Summit USA at Hyatt Centric Beale Street Memphis, 33 Beale Street, Memphis, Tennessee, 38103, United States. Contact: Phone: +442077804304, Email: charlotte.milman@argusmedia.com URL: https://go.evvnt.com/857888-2?pid=204

26-28 October 2021, Offshore Wind at Live Online Course. Contact: Phone: +6563250215, Email: abigail@infocusinternational.com URL: https://www.infocusinternational.com/offshore-wind

08-10 November 2021, Carbon Capture, Utilisation and Storage (CCUS) at Live Online Course. Contact: Phone: +6563250215, Email: abigail@infocusinternational.com URL: https://www.infocusinternational.com/ccus

15-18 November 2021, Electricity Economics in Changing Electricity Markets at Live Online Course. Contact: Phone: +6563250215, Email: abigail@infocusinternational.com URL: https://www.infocusinternational.com/electricityeconomics-online

November 22 - December 03 2021, Mastering Solar Power at Live Online Course. Contact: Phone: +6563250215, Email: abigail@infocusinternational.com URL: https://www.infocusinternational.com/solar-online

23-24 November 2021, SPE Eastern Europe Subsurface Conference | 23-24 November 2021, Kyiv, Ukraine at TBC, Kyiv, 02000, Ukraine. Contact: Email: kdunn@spe.org URL: https://go.evvnt.com/790163-0?pid=204

29-30 November 2021, World Energy Capital Assembly at TBC, London, England, SW6 3JW, United Kingdom. Contact: Phone: +442073848085, Email: natasha.johnson@oilcouncil.com URL: https://go.evvnt.com/802234-0?pid=204

November 30 - December 02 2021, 2021 Coal Association of Canada Conference at Sheraton Vancouver Wall Centre, 1000 Burrard St, Vancouver, British Columbia, V6Z 2R9, Canada. Contact: Phone: 17807579488, Email: info@coal.ca URL: http://go.evvnt.com/632221-0?pid=204

November 30 - December 01 2021, Hydrogen North America 2021 at Online. Contact: Phone: +442075138991, Email: diana.dropol@thomsonreuters.com URL: https://go.evvnt.com/843927-0?pid=204

01-02 December 2021, Energy from Waste Conference 2021 at Copthorne Tara Hotel London Kensington, Scarsdale Place, London, England, W8 5SY, United Kingdom. Contact: Phone: 02078276088, Email: hsidhu@smi-online.co.uk URL: http://go.evvnt.com/807707-0?pid=204

02-03 December 2021, Hydrogen Europe 2021 at Online. Contact: Phone: +442073757512, Email: luke.brett@thomsonreuters.com URL: http://go.evvnt.com/843820-0?pid=204

14-16 December 2021, Power2Drive India 2021 at Bombay Exhibition Centre, Western Express Highway, Mumbai, Maharashtra, 400063, India. Contact: Phone: +497231585980, Email: info@intersolar.in URL: http://go.evvnt.com/604710-0?pid=204

14-16 December 2021, Intersolar India 2021 at Bombay Exhibition Centre, Western Express Highway, Goregaon East, Mumbai, Maharashtra, 400063, India. Contact: Phone: +49 7231 58598-0, Email: info@intersolar.in URL: http://go.evvnt.com/604701-0?pid=204

23-24 February 2022, 14th International Conference on Biofuel and Bioenergy at United States. Contact: Phone: 7588755836, Email: biodiesel@scientificmeets.com URL: https://biodiesel.conferenceseries.com/

July 31 - August 03 2022, 43rd IAEE International Conference - Mapping the Global Energy Future: Voyage in UncharteredTerritory at Tokyo, Japan. Contact: URL: www.iaee2022.org

21-24 September 2022, 17th IAEE European Conference: The Future of Global Energy Systems at Athens, Greece. Contact: URL: www.haee.gr

05-08 February 2023, 44th IAEE International Conference: Energy Market Transformation in a Globalized World at Riyadh, Saudi Arabia. Contact: Email: moneefma@gmail.com URL: www.iaee.org

23-26 June 2024, 45th IAEE International Conference, Overcoming the Energy Challenge at Izmir, Turkey. Contact: Phone: 216-464-5365, Email: iaee@iaee.org URL: www.iaee.org

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