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IAEE Energy Forum

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Editor: David L.Williams

Published By:

IAEE

International Association for ENERGY ECONOMICS

PRESIDENT'S MESSAGE

We can hope that 2020 and 2021 will be labelled by future historians as "the" years of the coronavirus-19 pandemic. Regardless, they have been extremely stressful individually, for our communities, families, friends, and colleagues and for our Association. Fortunately for the Association, past management actions had allowed us to accumulate financial resources to weather the severe reduction in revenue.

Technology also enabled us to keep in touch with each other via online webinars, podcasts, and online conferences. Having the technology available is one thing. Being able to quickly gear up to use it effectively is something else. We are very grateful to Dave Williams and his team for all the effort they put into to making these online activities a success.

We also thank many of our regional affiliate councils and individual members for supporting, organizing, or sponsoring events. A special thanks is due to the French Association for Energy Economics and the team at the Florence School of Regulation for organizing the very successful online Paris International Conference in June of this year.

A major issue for the Association as we transition out of our "pandemic quarantine" is how best to sustain online activities, which many members have found very useful. While we had resources to support the online activities when face-to-face conferences were in abeyance, something different is needed going forward.

There is no doubt that the world is going more electronic all the time and that the pandemic accelerated that process. However, it also is clear that many organizations struggle with how to pay for the production, management, and dissemination of online content. This issue is perhaps linked to our ongoing efforts to grow our social media presence. Council is investigating and debating how we should take the best out of this experience and carry it forward in a sustainable way.

While the Association has missed in-person conferences, I am pleased to say that our publications provided a welcome continuing source of revenue, while also helping to sustain us as a community. They have been proven yet again to be a valuable part of IAEE. They also are feeling some pressures from the expansion of electronic communication. Council has set up a sub-committee that is examining many issues surrounding the way that we handle publications.

The process improvements in handling *Energy Journal* submissions, refereeing and publication since all operations were moved to headquarters have been notable. Although it has been a lot of work for Dave Williams and his team, we look forward to having *Economics of Energy and Environmental Policy* handled via the same methods. Changes instituted to raise the impact of both journals as measured by standard metrics have been bearing fruit. We are also looking forward to the energetic and experienced Charles Mason taking over as *EEEP* Editor-in-Chief.

(continued on page 2)

President's Message (continued)

The Association can thus begin 2022 with some positive momentum – something we were most uncertain about at this time last year. Nevertheless, we are also very anxious to get back to normal business, especially as regards face-to-face conferences. While the ready availability of teleconferencing has enabled many of us to continue working productively, I think we have all experienced the severe limitations of the technology.

We very much want you all to think about our 2022 International Conference to be held in Tokyo from July 31 - August 3, 2022 as your "coming back" party! Please visit https://iaee2022.org/ for the latest conference information and Call for Papers.

The other big shock for the IAEE in 2021 is that we learned that we are going to lose AMS as our Association Management Company (AMC) when our contract with them expires at the end of 2022. It is going to be extremely difficult to replace AMS, and to ensure that as much information and knowledge as possible is transferred to the new AMC. Like all transitions, there are undoubtedly going to be unforeseen problems with the new arrangement.

Council has been working on transition matters in part by establishing a "Transition Task Force". We are very pleased to say that AMS is working closely with us to write the RFP, interview candidates and select the best team for us in 2023 and beyond. Nevertheless, we believe it is important for IAEE Council to form its own views about what we should look for in the new AMC. We need to retain as much as possible of the prior arrangements that worked so well. When everything is working smoothly it is all too easy to ignore the effort required to keep it that way. We therefore need to look more explicitly and critically at the way we have been doing things. We need to identify what worked well, and what we think could be changed for the better as we transition systems and processes.

In summary, 2022 is going to be a significant and eventful year for IAEE. Let us try to make it as much as possible an opportunity that allowed us to improve the value we provide to our members.

I look forward to keeping you, our members, well informed throughout 2022.

Peter Hartley

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IAEE MISSION STATEMENT

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

We facilitate

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

We accomplish this through

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

Editor's Notes

We conclude our focus on vulnerabilities within the utility industry, continued from the fourth quarter 2021 issue. We are most grateful for the enthusiastic reader response on this topic.

Fateh Belaid and **Aisha Al Sarihi** write that the global energy sector is undergoing a rapidly accelerating transition. This accelerated path is motivated by a range of drivers. Tackling climate change is a critical consideration among these drivers, but policy makers and governments are faced with other priorities, including ensuring affordable energy supply, energy security, and energy access to everyone. Fossil fuel will continue to play a role in meeting future increasing energy demand. Two key energy policies to tackle change are: energy efficiency and renewable energy. Within this context, this analysis intends to: (1) explore the ongoing energy transition in Saudi Arabia; (2) examine the role of renewable energy in achieving the sustainability goals in Saudi Arabia. The results have important policy implications, highlighting how aggressive energy transition initiatives may achieve sustainability and climate goals in the context of very active and engaged economy in the energy transition. It can help policy-makers design effective mitigation policies and consider renewable energy as a vehicle for tackling climate change and building a better future.

Md. Nasimul Islam Maruf, Jos Sijm, and **Germán Morales-España** inform us that power-to-heat (P2H) technologies offer great potential for the European energy transition. This article identifies the vital P2H technologies to use in households and industries in future sustainable energy systems

Sophie Chlela, Sandrine Selosse, and **Nadia Maïzi** posit that the increase of renewable energy share in the power generation mix to achieve national and international targets of greenhouse gases emissions reduction comes with important consequences, especially for the electricity grid that has to increase its flexibility to assure the quality and reliability of supply. This requirement can be much more relevant when dealing with islands, as they have limited (or no) interconnections to the continent and thus have to rely more on more flexibile options to ensure the secure and cost-efficient operation of their energy system. In this context, a longterm prospective study, based on technico-economic optimization of TIMES model generator, is carried out to explore decarbonisation pathways that ensure grid flexibility of the two investigated European islands - Procida in Italy and Hinnøya in Norway. Emphasis is given to technical, economic and policy aspects of the evolution of the islands power systems.

Humphrey Oruwari and **Gordon M. Bubou**'s paper examines the impact of environmentally sound technologies on climate change in Nigeria and recommends ways for policy decisions. Using literature review and case study, it is revealed that energy companies use environmentally sound technologies to mitigate climate change. It recommends the need to embrace environmentally sound technologies,

Lilia García Manrique, Mónica Santillán Vera, and **Isabel Rodríguez Peña** note that transitioning to clean energy includes using natural gas as a transitional energetic. Nevertheless, for a country like Mexico, this transition is more of a static strategy. Gas infrastructure is planned to be highly dependent on US gas imports. This creates a gas lock-in strategy reliant on US gas supply.

Ernesto Elenter comments that Uruguay has proven in its first energy transition (2010-2020) that it has achieved a 97% renewable energy share and is among the top 2 in the world in terms of wind energy share. The country is currently outlining its second energy transition to decarbonize transportation, harness the vast renewable resources available, while solving the problem of high electricity and fuels prices that the country still faces.

Kimmo Palanne and **Anna Sahari** discuss that despite a high carbon tax introduced over 30 years ago, Finland's transport emissions have not decreased. Analysing data on households' vehicle ownership and driving indicates that fears of regressive fuel taxation may be overplayed.

Dieter Oesterwind and **Philipp Riegebauer** present that over the next two decades, the German energy system will be completely transformed. There is no one-dimensional path that will lead us to a climate-neutral future. Conflicting goals, obstacles and imponderables lurk along the way. The citizens decide on its success.

Javier Bustos- Salvagno apprises us of the Chilean experience's good example of how the energy transition is impacting the institutional design of the energy sector and how relevant institutions are to have a successful transition, with costs and benefits well-distributed, and a socially accepted paradigm shift .

Jinxi Yang writes that when modeling the energy transition, the agent-based model (ABM) approach is far less used compared to the optimization model approach. However, an ABM has the advantage of including important features of the energy transition such as heterogeneous characteristics of decision-makers, bounded-rationality, historic path-dependency, etc. This article illustrates and discusses how an agent-based model can complement an optimization model.

Andrew Kilmartin advises us that decisions and change management are crucial to energy transitions. We need a framework that can capture the whole energy system transition and its challenges and opportunities. An independent and transparent decision quality framework can provide the policy governance and facilitate a strategic Cost Based Analysis project review based on value and utility.

María Eugenia Ibarrarán and **Alejandro Rodríguez Chacón** report that the 2013 Energy Reform in Mexico led to lower wholesale electricity prices, an increase in renewables in the energy matrix, and lower GHG emissions. Changes will fade under the counter-reform proposed by President López Obrador.

Maryam Bello states that in Nigeria, the imbalance between power generation, transmission and consumption has resulted in unreliable supply and frequent blackouts. These necessitate Households to resort to self-generation using backup electricity generators. However, there is a recent gradual transition of replacing these fossil fuel backup generators with solar home systems.

Jamil Khan notes that Pakistan is a developing country and as such its power supply has become a challenging task. To support its growing middle class, industrial outputs, and to reduce pollution, Pakistan is pursuing its energy transition through renewables. The addition of Nuclear Power Plants to its grid shows its commitment to the Paris agreement for 2050

Douglas B. Reynolds explains in Energy Architecture and Economic Growth the physical characteristics of energy and how such architecture can enhance the power of technology to create economic growth. He also suggests that a transition from fossil fuels to renewable energy may require a lot of energy demand side technologies to compensate for the weaker energy architecture.

DLW

IEE JAPAN

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.

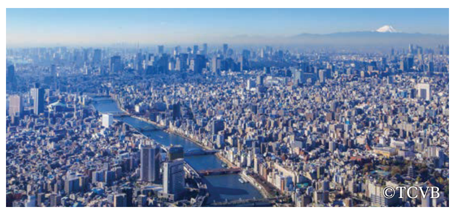
CONCURRENT SESSION ABSTRACT FORMAT

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.

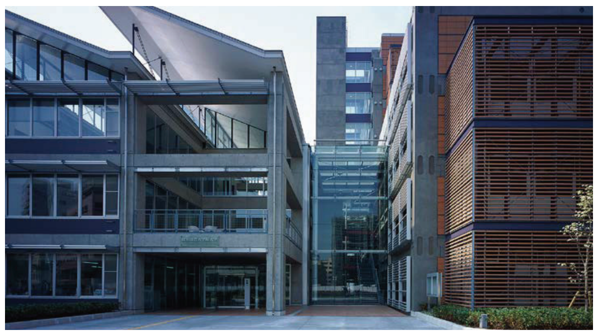


Photo: Masao Nishikawa

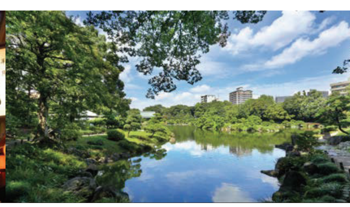
WHO SHOULD ATTEND

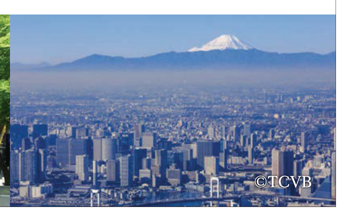
The conference is intended for:

- 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



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All IAEE members are invited to attend the following sessions to be held during the Allied Social Science Associations (ASSA) annual meeting which will be held virtually. For more information on this meeting please visit https://www.aeaweb.org/conference/2022/preliminary

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

We mourn the loss of another energy icon. David J. DeAngelo, 76, passed away on October 15, 2021. David was a past Treasurer (1989) of IAEE and past president (2000) of the United States Association for Energy Economics (USAEE).

David's fine analytical mind and research ability was second to none. Most of his career was spent with Pennsylvania Power & Light (PPL), one of the nation's largest utility companies, where he was Manager of Fuel Planning and Statistics. He also performed energy policy analysis for NATO at the U.S. Military Academy, as well as at the Pentagon. He was an instructor in business planning and fuel procurement at U.S. Aid which led him to sponsored programs in Egypt, India and the Ukraine. David served with honor with the United States Army where he achieved rank of Lt. Colonel, his last assignment representing West Point in the Lehigh Valley where he interviewed possible applicants.

David graduated from Lehigh University where he earned a BS in Business Administration and an MS in Business Economics; he was a member of Phi Kappa Theta fraternity. David was very active with Lehigh University, sponsoring the establishment of a USAEE Chapter on campus and assisting in the organizing of energy events. A true lover of wrestling, he and Bobbi would travel the states watching the Lehigh Wrestling Club in action.

I grew really close to David during his leadership years with the USAEE. He served as Secretary-Treasurer (1996), VP Conferences (1998) and eventually as President of USAEE. He single handedly organized the Philadelphia (2000) North American conference of USAEE/IAEE.

David would often call the office and we would talk at length about the energy industries, his state in retirement, what he and Bobbi were up to, family life and his love of wine. I learned much from David during his active time with the Associations. True to form, he passed on many analytical tips to me, how to approach complex issues with a cool head and, how to appreciate and source fine wines.

David is survived by his loving wife Bobbi, son Adrian and wife Emily and two grandsons, Luca Anthony and William Lorenzo.

He will be missed deeply by his family, friends and colleagues.

Dave Williams

Energy Transition in Saudi Arabia: Key Initiatives and Challenges

BY FATEH BELAID AND AISHA AL SARIHI

Fateh Belaid and **Aisha Al Sarihi** are with the King Abdullah Petroleum Studies and Research Center. Fateh Belaid can be reached at fateh.belaid@kapsarc.org

Abstract

The global energy sector is undergoing a rapidly accelerating transition. This accelerated path is motivated by a range of drivers. Tackling climate change is a critical consideration among these drivers, but policy makers and governments are faced with other priorities, including ensuring affordable energy supply, energy security, and energy access to everyone. Fossil fuel will continue to play a role in meeting future increasing energy demand. Two key energy policies to tackle change are: energy efficiency and renewable energy. Within this context, this analysis intends to: (1) explore the ongoing energy transition in Saudi Arabia; (2) examine the role of renewable energy in achieving the sustainability goals in Saudi Arabia. The results have important policy implications, highlighting how aggressive energy transition initiatives may achieve sustainability and climate goals in the context of very active and engaged economy in the energy transition. It can help policy-makers design effective mitigation policies and consider renewable energy as a vehicle for tackling climate change and building a better future.

Keywords: *Energy Transition; Renewable energy; Sustainability; Climate change; Saudi Arabia*

1. Introduction

Global warming is rapidly escalating, pushing the world to the edge of the precipice. This paper covers a timely and critical topic for accelerating energy transition and mitigating climate change effects. It develops a straightforward analysis to explore the ongoing energy transition. It focuses primarily on the role that alternative energy sources may play in shaping economic and sustainability goals. The setting of the study is the energy transition challenges and perspectives in Saudi Arabia, as an illustration of a particular developing economy that has been very conscious of the current situation and has invested significant efforts to accelerate the energy transition pace (Hilmi et al., 2020).

Energy transition has become one of the most prominent concerns of policy-makers around the world. In this context, alternative energy sources will undoubtedly play a key role not only in the long-awaited process of energy mix decarbonization, but also in the implementation of a new economic model, aiming to advance social well-being and sustainability (Belaïd et al., 2021a; Tiba and Belaid, 2020, 2021).

Considering the existence of ambitious policy goals to decrease global economy-related carbon emissions, the acceleration of the decarbonization process and its financing pose many challenging issues for researchers and policy-makers. In fact, the sustainable transition process depends on unpredictable future conditions, such as market innovations and energy prices.

However, in an attempt to understand the magnitude of the efforts and to try to place this enormous challenge within a broader economic and public policy framework, it is crucial to have a comprehensive overview of the existing efforts and feedback from the different initiatives. From a policy perspective, this will help policy-makers move beyond the specific types of single policies and practices and embrace a holistic approach to decision making in order to expand well-being economies. This will be reflected in national policy frameworks that mandate collaboration between different stakeholders, including government bodies and agencies, place well-being and sustainability in the center of budgeting decisions and introduce indicators of performance.

The rest of this article is presented as follows. Section 2 provides a global view of the main challenges associated with energy transition and sustainable paths. Section 3 reviews and discusses Saudi Arabia's efforts toward decarbonisation process. Section 4 concludes the analysis and provides some useful policy recommendations and avenues for future research.

2. Global view of the critical challenges associated with energy transition and tackling climate change

The crisis the world is going through these last years is patent. It includes economic, social, environmental, ecological, and even health aspects. In this setting, climate change poses a real threat to both human and ecosystem sustainability. The increasing frequency and intensity of storms and heatwaves, droughts, rising sea levels, melting glaciers, and oceans warming are threatening species and their habitats. Addressing this crisis requires an urgent need to reduce greenhouse gas emissions (GHG) and address the consequences of the threat which is already being faced (Belaïd et al., 2020).

However, despite existing divergences among economists, some convergences could be found on the best policy for the climate (Tol, 2020). It has been widely accepted since Nordhaus (1977), d'Arge (1979), and Schelling (1992) that climate change is, by and large, a negative externality and that GHG emissions should be priced, preferably taxed. Notably, most economists agree that sound climate policy starts modestly and then accelerates (Wigley et al. 1996, Goulder and Mathai 2000), although long-term climate goals continue to be the subject of intense debate (Stern et al. 2006; Nordhaus 2013).

Decarbonization initiatives in different sectors of the economy 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.

The global energy sector is undergoing a rapidly accelerating transition. This accelerated path is motivated by a range of drivers. Tackling climate change is a critical consideration among these drivers, but policy-makers and governments are faced with other priories, including ensuring affordable energy supply and reinforcing energy security and ensuring energy access to everyone. Within this context, fossil fuel will continue to play a role in meeting future increasing energy demand. Two key energy policies to achieve the Paris Agreement goals are: energy efficiency and renewable energy (see Figure 1).

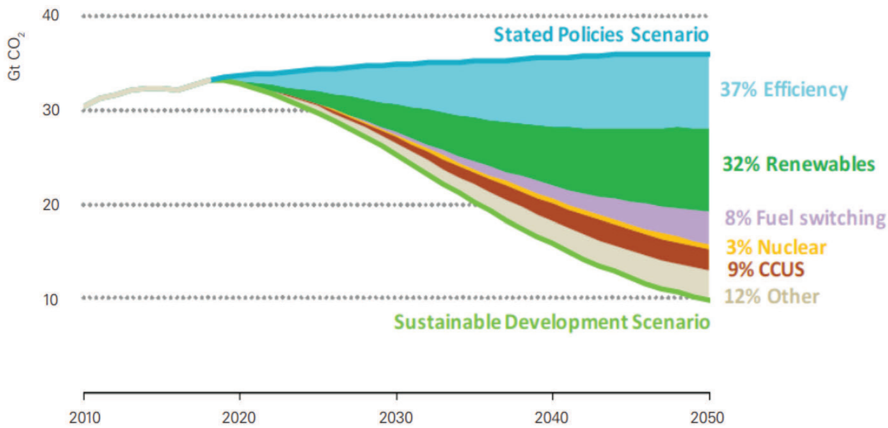

Figure 1: Drivers of GHG emissions reduction (in gigatons) within the framework of IEA's 66% 2 °C Scenario- relative to the New Policies Scenario (Source IEA, 20200). Note: CCUS = Carbon Capture, Utilization and Storage.

There are many challenges to accelerate energy transition pace. One of the success factors is to accelerate the development and rapid adoption of high-impact clean energy technologies (Mongo et al., 2021a, 2021b; Omri and Belaïd, 2021). While many technologies, such as batteries, solar, and wind, have achieved significant cost reductions and large-scale adoption thresholds, critical technology shortfalls exist in other sectors, including industry and transportation. Therefore, cooperative actions among public and private entities can accelerate the timeline for reaching these critical thresholds, sometimes by a decade or more, pursuing targeted R&D and implementation in domains such as long-term energy storage, hydrogen production, insulation materials, and industrial processes.

Second, reaching the well-being economic model goal requires the improvement of energy efficiency, which has multiples advantages. Energy efficiency improvement helps countries achieve their energy goals while sustainably meeting energy demand. Energy efficiency eases pressures on national budgets, increases competitiveness of industries and services, creates jobs, alleviates fuel poverty, and improves system reliability by reducing energy demand and peak load. In this framework, the energy efficiency potential in building sector is enormous both in existing and new constructions (Belaïd, 2016, 2017; Bakaloglou and Belaïd, 2022). Hence, deep renovation of existing buildings and electrifying end uses can be cost-effective and generate significant energy savings (Belaïd et al., 2021; Belaid and Rault, C 2021).

3. Key energy transition initiatives in Saudi Arabia

Along with joining global forces to addressing climate change and accelerating the needed energy transition, Saudi Arabia is driven by other socio-economic factors to developing alternative energy sources. Saudi Arabia's renewable potential is remarkable, especially solar and wind, and more so given the geographic location of Saudi Arabia within the sunbelt, there is a match between peak sun hours and electricity peak demand. Furthermore, the development of alternative energy sources will help meeting the Kingdom's increasing domestic energy demands resulting from general economic development, together with population growth and increasing standards of living. Additionally, developing alternative energy sources is in line with the Kingdom's economic diversification Vision 2030 which aims to diversify the economy by substantially reducing reliance on oil. Withing this context, Saudi Arabia has been actively engaged in joining global forces to addressing climate change and managing energy transition both at international and domestic levels.

At the international level, Saudi Arabia ratified the U.N. Framework Convention on Climate Change (UNFCCC), an international environmental treaty, by accession on December 28, 1994, and acceded to the Kyoto Protocol on January 31, 2005. In response to the protocol, the kingdom submitted its first, second, and third National Communications in 2005, 2011, and 2016, respectively. In December 2015, when parties to the UNFCCC reached a landmark agreement, i.e., Paris Agreement,[1] to combat climate change and accelerate and intensify the actions and investments needed for a sustainable low carbon future, Saudi Arabia submitted its Intended Nationally Determined Contribution (INDC) ahead of the Conference of Parties in December 2015 (UNFCCC, 2021), and ratified the Paris Agreement on November 3, 2016. Also, in April 2021, Saudi Arabia joined the 'Net Zero Producers Forum,' alongside the US, Canada, Norway and Qatar – together responsible for 40% of global oil and gas production, to come up with "pragmatic net-zero emission strategies," including methane abatement, advancing the circular carbon economy approach, development and deployment of clean-energy and carbon capture and storage technologies, diversification from reliance on hydrocarbon revenues, and other measures in line with each country's national circumstances (DOE, 2021).

At the domestic level, along with submitting its NDC, Saudi Arabia has adopted many targets and strategies to addressing climate change and accelerate energy transition. These include the country's initiatives in energy efficiency, renewable energy, nuclear, and hydrogen. Most notably, to ensure an inclusive and holistic approach to managing energy transition and GHG emissions, Saudi Arabia has adopted a circular carbon economy (CCE) approach that encompasses a broad range of transition pathways and options available, considering different national circumstances, while striving to meet shared global aspirations. The Saudi's energy transitions journey is displayed in Figure 2.

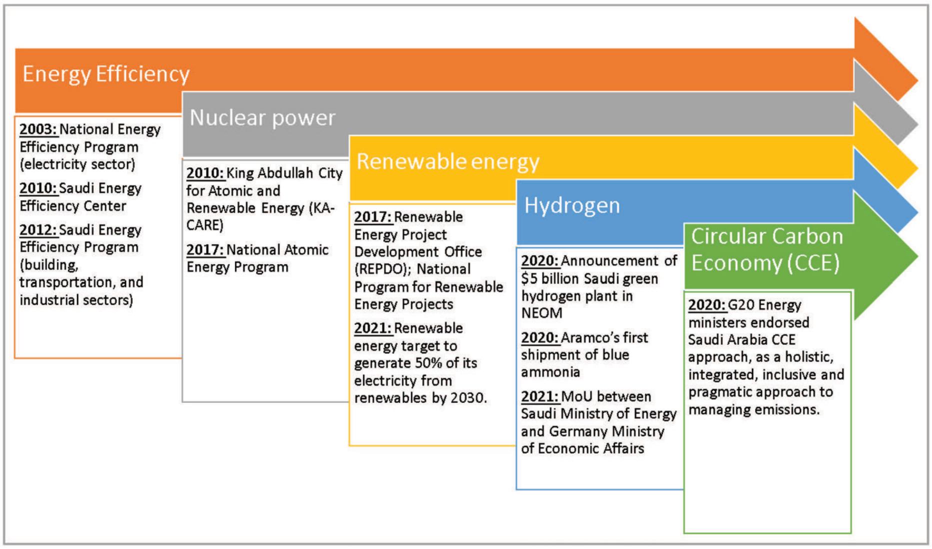

Figure 2: Saudi's energy transition journey. Source: Authors.

3.1 Energy efficiency

One of the first energy efficiency initiatives in the KSA is the launch of the National Energy Efficiency Program in 2003 as a three-year program to improve the management and efficiency of electricity generation and consumption in the kingdom. Building on the experiences gained during that period, a Council of Ministers' Decree established the Saudi Energy Efficiency Center in 2010. The center is managed by a Board of Directors composed of more than 26 entities from ministries, government departments, and the private sector. Its main tasks have included development of a national energy efficiency program, promoting awareness about energy efficiency, participating in the implementation of pilot projects, and proposing energy efficiency policies and regulations and monitoring their implementation. In 2012, the Saudi Energy Efficiency Center launched the Saudi Energy Efficiency Program to improve the kingdom's energy efficiency by designing and implementing energy efficiency initiatives. To establish the program, an executive committee was created by the Saudi Energy Efficiency Center board, chaired by Prince Abdulaziz bin Salman, vice minister of petroleum and mineral resources (now the Ministry of Energy), and composed of members from 14 government and semi-government entities. The executive committee targeted more than 90 percent of the kingdom's energy consumption by creating specialized teams that focused on the building, transportation, and industrial sectors. The National Energy Efficiency Plan is currently focusing on the design of the first energy conservation law and national and regional regulations, preparation of a new national database on energy supply and demand, capacity development of energy efficiency managers, and public awareness. Furthermore, in 2010, the Saudi Green Building Forum was launched to promote the construction of energy and resource efficient and environmentally responsible buildings. By the end of 2014, the kingdom had more than 300 green building projects, investing approximately $53 billion.

3.2 Renewable Energy

In 2017, a Renewable Energy Project Development Office (REPDO) was established at the Ministry of Energy. REPDO launched the National Program for Renewable Energy Projects to oversee the development of KSA renewable energy projects and achieving its renewable energy targets. After the launch of the National Program for Renewable Energy Projects in 2017, the target renewable energy source size was only 9.5 GW. Then, on January 9, 2019, REPDO announced its new plan to expand renewable energy projects by increasing the target to 58.7 GW, to be implemented by 2030. This new plan included developing more than 35 sites distributed throughout the Kingdom. The energy expected to be generated from three main sources is 40 GW of solar PV, 16 GW of wind power, and 2.7 GW of Concentrated solar power (CSP) (AlOtaibi, 2021). In January 2021, Saudi Arabia announced its intent to generate 50% of its electricity from renewables by 2030, with the other half coming from natural gas-fired power generation (Paraskova, 2021). The total renewable energy installed capacity in Saudi Arabia has increased from 3 MW in 2011 to 413 MW in 2020 (Figure 3).

3.3 Nuclear power

At present, Saudi Arabia has no nuclear power plants, but has plans to include atomic energy in its future energy mix and build domestic nuclear industry in anticipation to meeting rapid increase in energy demand across the industrial and residential sectors. Preliminary studies show that Saudi Arabia boasts an estimated 60,000 tonnes of uranium ore (Mansouri, 2020).

The Saudi government has put forward the legal and institutional framework that will regulate the Kingdom's nuclear energy sector. In 2010, the King Abdullah City for Atomic and Renewable Energy (KA-CARE) was established by Royal Order No. A/90, and in 2017, it launched the National Atomic Energy Program. Along with the National Atomic Energy Program, the government issued the National Policy for the Kingdom's Atomic

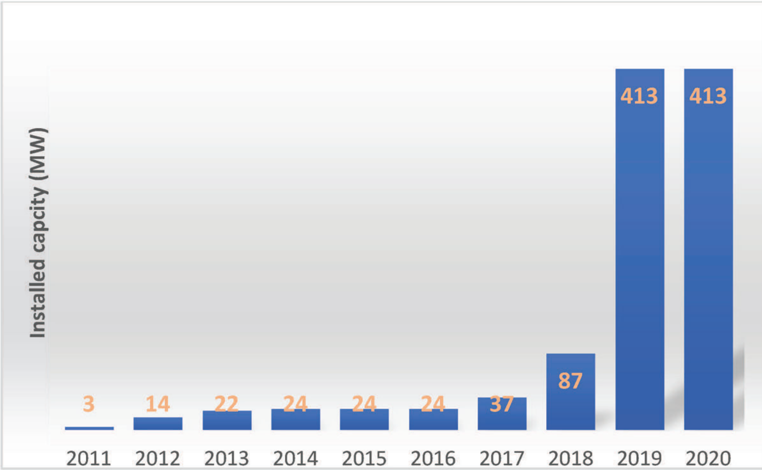

Figure3: Renewable energy installed capacity in Saudi Arabia, 2011-2020. Source: IRENA: 2021

Energy Program, the Nuclear Law, and the Law of Civil Liability for Nuclear Damage. It established the Nuclear and Radiological Regulatory Commission, an independent regulatory agency, to monitor the implementation of its nuclear energy program, ensure the program complies with relevant laws, the protection of humans and the environment, and ensure it maintains the highest operational safety standards (Mansouri, 2020).

3.4 Hydrogen

In line with its economic diversification plan, Vision 2030, and plans to adopt a circular carbon economy approach (CCE), Saudi Arabia has embarked in several hydrogen development initiatives. In July 2020, a $5 billion Saudi green hydrogen plant was announced, to be powered by 4 gigawatts (GW) from renewables and located in Neom city in the Tabuk Province of north-western Saudi Arabia (north of the Red Sea). Jointly owned by Saudi Arabia's ACWA Power and Air Products, it is planned that the plant will produce 650 tonnes of hydrogen by 2025 for exportation in the international market (Valley, 2020). Also, in September 2020, Saudi Aramco announced the world's first shipment of blue ammonia – produced from natural gas with CCS in the Hydrogen Plant in Jubail – to Japan where it is used in power stations to produce emissions-free electricity (Ratcliffe, 2020). Also, early this year, Energy Minister HRH Abdulaziz bun Salman Al Saud and Economic Affairs Minister of Germany, Peter Altmaier, signed a MoU on hydrogen with an objective to enhance bi-lateral cooperation between the two countries in hydrogen (Kane, 2021).

3.5 Circular Carbon Economy

As part of its G20 Presidency 2020, Saudi Arabia, led by the Ministry of Energy, has put forward the concept of the Circular Carbon Economy (CCE) and plans to put it at the center of its climate mitigation plan (Williams, 2019). A key insight from CCE is to achieve a pathway towards net zero emissions. This is based around 'four Rs:' **Reduce**: energy efficiency, renewable energy and other low carbon energy such as nuclear; **Reuse**: carbon capture and utilization (CCU) and emissions to value (E2V); **Recycle**: natural sinks such as forests and oceans, bio-energy and hydrogen; and **Remove**: carbon capture and storage (CCS) and direct air capture (KAPSARC, 2020). CCE builds on the kingdom's earlier efforts on reducing its carbon emissions, including the kingdom's first carbon dioxide enhanced oil recovery demonstration project, which commenced its operation in 2015. The Uthmaniyah carbon dioxide enhanced oil recovery demonstration compresses and dehydrates carbon dioxide from the Hawiyah natural gas liquid recovery plant in Saudi Arabia's Eastern Province (Global CCS Institute, 2018). The captured carbon dioxide is transported via pipeline to the injection site at the Ghawar oil field (a small flooded area in the Uthmaniyah production unit) for enhanced oil recovery. At the center of this ambitious CCE approach are the Ministry of Energy and the Energy Ecosystem consisting of King Abdullah Petroleum Studies and Research Center (KAPSARC), King Abdullah City for Atomic and Renewable Energy (KACARE), Saudi Energy Efficiency Center (SEEC), Designated National Authority (DNA), Electricity and Cogeneration Regulatory Authority (ECRA), Nuclear and Radiological Regulatory Commission (NRRC), and the Executive Committee for Governance of Price Adjustment of Energy and Water Products.

4. Conclusions & Policy recommendations

The global energy system is undergoing a fast transformation driven mainly by climate change mitigation, strengthen energy security, ensuring affordable energy supply for everyone, and alleviating energy poverty (Belaïd, 2018, 2019). Policy-makers are putting enormous efforts to decarbonize the energy mix. Withing this context, this paper provides a concise/overview/brief of the ongoing energy transition process in Saudi Arabia. It starts with discussing the energy transition landscape and the key challenges associated with energy transition and tackling climate change. Second, it reviews the ongoing energy transition initiatives in Saudi Arabia. This is to understand and identify the most successful initiatives dedicated to decarbonizing energy mix. From a policy perspective, this may help decision-makers to improve the effectiveness of their energy policy choices.

The analysis shows that Saudi Arabia has in place all the ingredients, including institutional, human and financial capacities, needed to weather the ongoing energy transition. Specifically, its adoption of CCE presents an opportunity to facilitate the Kingdom's energy transition with a holistic approach that enhances harmonization of national energy policy and avoid duplication of efforts or energy policy fragmentation. CCE assures both centrality of leadership to steering energy transition as well cross-sectoral collaboration between different stakeholders including from academic, government, and industry. Nevertheless, there is still a room for improvement to reaching Saudi Vision 2030 and the Kingdom's energy transition goals. Accordingly, we recommend:

Use existing arrangements and institutional architectures. Energy transition is cross-sectoral in nature and require collective action and coordination between actors representing different sectors and institutions. Saudi Arabia can take advantage of existing institutional arrangements dedicated to energy transition (see Section 3), but further enhanced coordination among different institutions (e.g., between public, private, financial, and academic) and sectors while planning for energy transition in order to reduce risks of conflicting strategies, additional regulatory burdens, or inefficient budget allocation. It is also essential to assigns clear duties and responsibilities to ensure effective coordination between entities.

Support research and evidence-based policy making. Additional efforts to enhance data collection and facilitate exchange of information and data between different stakeholders involved in decision making – including between research institutions and the political level, private sector, and other business sectors – is important to inform decision making and ensure cost-effective implementation of energy transition measures.

Support innovation in the energy sector. Saudi Arabia has the financial and human capacity to strengthen its national innovation system and stimulate cooperation between all stakeholders who can be potentially involved in energy innovation, including the academic, private and government sectors. Enhancing localization of alternative energy technologies is not only important to reduce dependence on other countries in importing technology and know-how, especially that most of the imported technologies do not work efficiently in the hosting countries, but also to enhancing the competitiveness of the Kingdom in a changing energy market. Specifically, the Kingdom's support of research on energy storage technologies would complement its ongoing energy transition initiatives.

Footnotes

[1] The Paris Agreement builds upon the convention and – for the first time – brings all countries, including developing countries, into a common cause to undertake ambitious efforts to combat climate change and adapt to its effects, with enhanced support to assist developing countries to do so. Entered into force on November 4, 2016, the Paris Agreement requires all parties to put forward their best efforts through Nationally Determined Contributions and to strengthen these efforts in the years ahead. This includes requirements that all parties report regularly on their emissions and their implementation efforts (UNFCCC, 2015).

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The Key Power-to-Heat Technologies for the European Energy Transition

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Abstract

Power-to-heat (P2H) technologies offer great potential for the European energy transition. This article identifies the vital P2H technologies to use in households and industries in future sustainable energy systems.

Power-to-heat (P2H) is a set of cost-effective technologies that offer many opportunities and advantages for the energy transition. P2H can use electricity from renewables, which may otherwise be curtailed, for the heating sector and provide additional flexibility to the electricity market [1]. By using renewable electricity for heating purposes, this helps to replace fossil fuels and protect the climate. Converting electricity into heat can also help keep power grids stable. This is because P2H technologies, when combined with thermal energy storage, can be used to preferentially absorb renewable-based electricity whenever a considerable amount of it is available. Many P2H technologies with different technology readiness levels exist to date. This article discusses the major P2H technologies expected to play a crucial role in the European energy transition. We have identified heat pumps, electric boilers, and electric resistance heaters as the most promising P2H technologies. Combining two or more of the technologies mentioned above is known as a mixed heating system. In addition, combined heat and power (CHP) plants can play a vital role in bridging the power and heat sectors.

The *heat pump* is a vital P2H technology that produces heating energy and, if required, hot water for single-family homes, apartment buildings, or even industries. Its distinguishing feature, however, is its method of heat extraction because, unlike most other heating systems, the heat pump does not have to burn any material to produce heat. Instead, it extracts the heat from the environment and harnesses it for our purposes, using very little electricity. This makes heat pumps particularly economically attractive and environmentally friendly. The way the heat pump works is often described as the "principle of the inverted refrigerator." Although there are specific differences in detail depending on the design of the heat pump, the basic principle is always the same: the heat pump extracts part of the stored thermal energy from its heat source (air, earth, or water) with the help of an evaporating refrigerant. In Europe, the heat pump is already on course for growth and on its way to becoming the most popular P2H technology. Heat pumps are beneficial because of their improved efficiency, lower energy price, simple installation, lower maintenance requirements, and higher safety standards compared to other heaters. According to the European Heat Pump Association, heat pump sales have achieved on average 12% growth per annum in the last six years [2]. High-temperature heat pumps are becoming more prevalent in industries, with food, paper, and chemical industries showing the highest potentials [3].

Photo: A new generation industrial heat pump. Source: TNO

The *electric boiler* is another popular P2H application often used in utility-related processes to generate hot water and steam. Electric boilers are generally categorized into two types: electrical resistance boilers and electrode boilers. The electric resistance boiler is connected at low voltage, while the electrode boiler is connected at medium voltage. Electrode boilers are popular in industrial applications for producing highly heated steam for industrial processes. Electric boilers are compact, affordable, and easy to install. In addition, they do not require a chimney or fuel supply. They require little maintenance and are quick and easy to install. Mobile use is possible in many cases without any problems, which is a clear advantage of electric boilers. In the last ten years, electric boiler usage increased by 86% in EU-27 and the UK [4].

Electric resistance heaters are our next choice as a P2H technology, including two different types: direct electric heating and electric storage heating. Direct electric heating gives off the heat directly to the heated room. The advantage of these heaters is that their installation is relatively inexpensive compared to central heating. However, their operating costs are comparatively higher. There are various direct electric heaters: electrically heated radiators, mobile fan heaters, electric floor heaters, etc. On the other hand, electric storage heaters heat their integrated heat storage during so-called off-peak times, which can be used as needed at a later time. It is a flexible P2H option as it can reduce the peak demand by storing heat at low energy price times.

Mixed heating systems generally refer to heat pumps coupled with an electric boiler or electric resistance heater. It can be a promising alternative in terms of flexibility but needs higher investment costs than the individual P2H technologies. In district heating systems, electric boilers are sometimes combined with CHPs to create hybrid systems. Hybrid systems can help improve overall system flexibility compared to single P2H-based systems.

CHPs consume fuel to produce both power and heat, and therefore can be a crucial technology to bridge the gap between these sectors. A recent study showed that the CHP share in total electricity generation increases with rising renewable shares [5]. CHPs offer high efficiency, reduced operational cost, decreased air pollution, higher reliability, improved power quality, flexibility and greater productivity. According to the JRC policy report, the conversion of existing power plants to CHPs will increase the overall efficiency of the European energy system, which is otherwise limited to 50% [6].

P2H systems fed by renewable energy are expected to contribute significantly to the European energy transition. P2H opens up new possibilities for using renewable energies for the heating market. However, economic viability would have to be ensured to exploit the potential of P2H fully. P2H could then be used on a larger scale to decarbonize the heating sector.

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Pathways to Decarbonization of European Islands: Ensuring the Integration of High Renewable Energy and Power System Flexibility

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Abstract

The increase of renewable energy share in the power generation mix to achieve national and international targets of greenhouse gases emissions reduction comes with important consequences, especially for the electricity grid that has to increase its flexibility to assure the quality and reliability of supply. This requirement can be much more relevant when dealing with islands, as they have limited (or no) interconnections to the continent and thus have to rely more on more flexibile options to ensure the secure and cost-efficient operation of their energy system. In this context, a long-term prospective study, based on technico-economic optimization of TIMES model generator, is carried out to explore decarbonisation pathways that ensure grid flexibility of the two investigated European islands - Procida in Italy and Hinnøya in Norway. Emphasis is given to technical, economic and policy aspects of the evolution of the islands' power systems.

Introduction

Climate change mitigation measures include the reduction of greenhouse gas emissions [1] which translates in the decarbonization of the energy systems. The increase of the share of renewable energy sources in the production mix appears to be a valid solution. First and foremost, these technologies can ensure energy production at low (or null) carbon emissions. Second, in terms of electric power generation, they represent fast-paced growing resources and finally, in many cases, have already become cost-competitive with fossil-fuel-based generation[2]. The European Commission offers a favourable framework for the development of renewable energy through the policy support through the *Clean energy for all Europeans package* and considers increasing its share as fundamental for the achievement of the continent's energy and climate objectives [3][4]. However, the introduction of renewable technologies comes with important challenges, especially when dealing with electricity supply. In fact, the electric grid should assure at all instant a balance between the production and demand. Meanwhile, the electricity generated from some of the most commonly used renewable sources, namely solar photovoltaics (PV) and wind turbines, is dependent on external parameters such as weather conditions, and thus is strongly variable. Therefore, as the share of variable renewable energy (VRE) sources increases, the necessity to ensure a reliable power system for the satisfaction of the electricity demand becomes more crucial especially with the stochastic nature of VREs which explains the growing need of power system flexibility.

In this framework, islands present specific challenges when it comes to energy supply and security and economic development. Owing to their small size, islands constitute a marginal market for international suppliers of energy and energy services, and they are often not able to obtain beneficial prices from bulk purchases. In addition, their remoteness implies high transportation costs. Moreover, islands are among the first victims of climate change: consequences for small islands vary from property damage to rising sea levels and coastal erosion. The introduction of renewable energy could be much more relevant when dealing with islands. These territories are often characterised by an over-dependency on energy imports [5]. This is mainly due to the additional geographical constraints presented by these territories which imply a limited or inexistent mainland grid connection, a limited space availability for power production installations and/or a lack of access to road infrastructure. Hence, islands would naturally consider investing in sustainable energy solutions like developing domestic renewable energy within their territory. These actions would fit in a long-term strategy to ensure their autonomy and enhance their resilience, hence going beyond the achievement of the decarbonization goal, however inexorably accelerated by the exploitation of renewable energy on these territories. Moreover, energy autonomy of islands – defined as the ability of the energy system to function (or have the ability to function) fully without the need of external support like imports [6] - has been linked to the potential to reduce the cost of energy, and the ability to significantly reduce the carbon emissions associated with a community or region [6], [7].

The challenge

System flexibility, in electrical energy system context, can be described as the ability of a power system, including generators, to sufficiently respond to changes in production and/or demand without jeopardising the grid stability [8]. There is an interest to share the burden of the grid flexibility with the whole energy system and explore potential synergy effects across energy subsectors. The International Energy Agency (IEA) provides a techno-economic definition of flexibility: *"the ability of a power system to reliably and cost-effectively manage the variability and uncertainty of demand and supply across all relevant timescales, from ensuring* *instantaneous stability of the power system to supporting long-term security of supply"* [9]. Flexibility describes the degree to which a power system can adjust the electricity demand or generation in reaction to both anticipated and unanticipated variability. It also indicates the capacity of a power system network to reliably sustain supply during transient and large imbalances [10]the inclusion of variable renewable energy sources (vRES.

Possible solutions

There are several well-proven supply and demand side flexibility measures that can be used to introduce a better flexibility into the traditional energy system:(1) institutional changes (policies), (2) the adaptation of operational methods and of the production mix (Adaptation to demand), and (3) storage, demand management, the introduction of a more flexible generation system, as well as many other mechanisms suitable to each situation are some to mention.

Storage

They refer to technologies that store electrical energy and release it on demand when it is most needed through the conversion of electricity to other forms of energy and back again [14]. Given their valuable potential contribution to the grid management, these technologies are considered a prominent solution to integrate large amounts of VREs in power systems. The electricity storage can be installed at any level of the energy system: at the transmission or distribution grid, coupled with other generation facilities of used in behind-the-meter applications (i.e. used by final consumers). According to its location and operational mode, the regulatory framework and the market, it can provide several different services to the grid [14]. For example, if used at transmission or distribution level it can provide grid services (such as ancillary services or distribution network support), whereas if coupled with supply technologies it can provide bulk energy services (it can for example shift the electricity production of VRE to no production times, supporting the integration of these sources in the electricity grid). It can also be used by final consumers for energy management services (i.e. self-consumption, that improves the bill management, power quality and reliability, other than supporting the deployment of VREs at distribution level). Electric batteries can also be used for electric vehicles in the transportation sector.

Demand side management

Demand side management is one of the central methods used to improve the flexibility of the electrical system. It consists of using different techniques in order to influence the final electricity consumption according to the grid's characteristics. Load levelling, valley filling, and load shifting are some of the demand management mechanisms. It consists in the planning, implementing, and monitoring activities of electric utilities which are designed to encourage consumers to modify their level and pattern of electricity usage [11]. Therefore, with this solution, the consumers become active participants in the energy system (i.e. they become prosumers).

The implementation of these techniques, based on price signals, has two main benefits: for the consumers it can represent a saving in electricity bills, whereas for the grid it allows to shift the energy consumption from peak to non-peak hours. The target customers are typically residential and industrial ones. However, a proper market design should be assessed to make this solution a viable flexibility source for the system. At this aim, the introduction of a new figure called aggregator, whose role is to manage the energy potential coming from the demand side, is gaining pace in the electricity market.

Electric vehicles charging

We can consider three types of charging strategies for electric vehicles [12]. The uncontrolled charging consists of charging the vehicle at maximum power as soon as it connects to the grid. For passive control, only encouragements are given to owners to charge during low tariffs of electricity. For active control or smart charging, the charging is mostly made during low tariffs or off-peak periods in addition to a modulation of the charging power. Two possibilities for smart charging exist: unidirectional (V1G) or bidirectional (V2G) which consists of injecting power back to the grid. Below is a schematic summarizing the EV charging strategies. The V1G is a flexible solution that could be used by DSOs to better manage the electricity load due to electric vehicles that are connected to the grid. It consists in a modification in the recharge profile of a part of the EVs that is made through a modification of the input current that feeds the vehicle. In this way, it is possible to decrease a part of the demand of EVs that occurs at peak hours by shifting this load in off-peak hours.

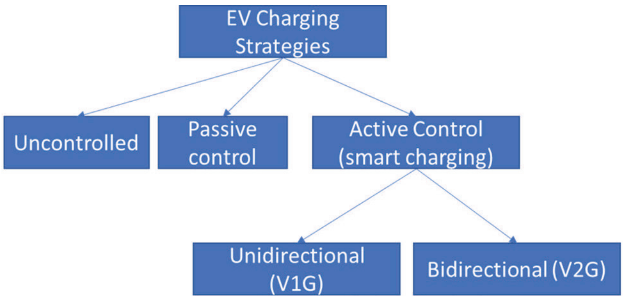

Figure 1 – Schematic summarizing the EV charging strategies adapted from [12]

Applications

Methodology

As part of this subject, a long-term prospective study is carried out to explore decarbonization pathways that ensure grid flexibility of two European islands, namely Procida in Italy and Hinnøya in Norway. Different possible evolutions of the energy system of the two territories are investigated through the implementation of long-term energy-planning models, based on the MARKAL-TIMES (Market Allocation) model, a methodological corpus developed within the ETSAP (Energy Technology Systems Analysis Program[1]). TIMES is an technico-economic model generator that can be applied to systems of any dimension, which provides a technology-rich basis for representing energy dynamics over a multi-period time horizon [13]. TIMES is a partial equilibrium model that uses a linear-programming approach in which the technical optimum is computed by minimizing the discounted global system cost. It is based on a bottom-up methodology, relies on investment, fixed and variable costs and are demand driven. Hence, the minimization of the total discounted costs of the modelled power system is made over a long time period (here 2050) under a number of environmental, technical and demand constraints [14].

Based on prospective studies using TIMES model, we investigate the applications of flexibility and the integration of renewable energy in the power systems. As such, for the case of the Italian island we study the investment in new technologies that include photovoltaics (PV) placed on rooftops of the buildings in the public, tertiary and residential sectors. They are coupled to Li-ion batteries and implemented in the model. We then implement a dynamic price of electricity during off-peak hours. As for the Norwegian island, we analyse the response of the low-emissive electric transportation to prices of electricity to control their charging.

Recommendations

This study is developed under a H2020 project, GIFT - Geographical Islands FlexibiliTy, as part of the European innovative projects developed to meet the sustainability goals for the energy sector. The achievement of the objectives proposed for this project will allow to decarbonize the energy mix and to increase the share of renewable energy sources in European islands. As part of the project, long-term prospective modelling will contribute to the realisation of energy transition. The results will enable municipalities to consider different regulatory policies to achieve the energy transition of the territory. Moreover, as Hinnøya and Procida are representative of completely different European contexts, the results obtained in this study will not be limited to these two demonstration sites, but other islands could benefit from the analysis.

The main results from the study are summarized below:

- When local variable renewables deployment is coupled with the storage technologies, the system becomes more cost-effective and reduces its dependency to imports. For instance, the results for Procida, show that the use of batteries allows to decrease the electricity imports at peak hours, when the grid is more subjected to congestion problems. However, the results also showed that in the long-term the use of photovoltaics alone is not enough to cope with the increase of electricity consumptions. Additional solutions should then be considered, such as policies supporting energy efficiency.
- Storage technologies are powerful in managing the electricity supply especially in cases of intermittent renewable energy. The use of these devices is strictly related to the amount of renewable energy integrated in the energy system, as the investments in these devices increase with the share renewable energy.
- Integrating renewable energy-based electricity to decarbonize sectors is facilitated by flexibility solutions as they present one way to manage the additional load and avoid creating peaks with the electrification of emissive sectors. This is the example of sector coupling made possible by electrifying the transport sector in the Norwegian island. The analyses focused on the transport passenger cars where charging control is necessary to avoid additional peak or to shift them in time according to low values of electricity prices and demand. In fact, the results for this sector at year 2035 show that 58% of the mix will be electrified till reaching 100% electrification in year 2050. However, both national policies and technology advancement have a great impact on the choice of electric vehicles: the first one with associating a taxation of the emissions of the fuel used by this sector and the second, with the reduction of the investment costs through the horizon.
- The option of self-consumption implemented in the Italian island decreases the dependency on the grid especially in marginal locations like the case of islands that are connected to the mainland. Combined with dynamic prices of electricity applied to all sectors studied (public, residential, tertiary) it enhanced the investments of storage in the most energy intensive sectors namely the tertiary and residential, which reduced the imports of electricity at peak moments of the day but not as the level at the energy system. Therefore, in terms energy dependency, it is better to have tariffs that are adapted to the sector where they are implemented, i.e according to the load time variation of the respective sector.
- Dynamic prices of electricity can be used for valley-filling where the objective is to flatten the demand curve on a diurnal basis. This would provide incentive to the electric vehicle owner to participate in charging control strategies. However, the impact will not be noticed unless the transport sector constitutes an important demand of electricity.
- Public and tertiary sectors are another source of demand-side flexibility on the islands as noticed by the use of the energy management system. The trend towards relying on electricity in the activities of these economic sectors is leading to harnessing the existing or new possibilities of flexible load. In general, this requires an increasing roll-out of smart meters, grid connected devices and the introduction of decentralized renewable energy and storage technologies, so that demand-side and thus "prosumers" (consumers that become producers) participation is enhanced.

- National and local authorities play an essential role in the deployment of low emission technologies for the energy transition: we noticed for instance, that the electrification of the transport is supported by the national authorities in Norway and is reflected on the island since shares the same context of the mainland. However, the context of Procida differs from the country of Italy, mainly due to its limited surface, where possibilities are constrained.

Footnotes

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Environmentally Sound Technologies for Mitigation of Climate Change

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Abstract

This paper examines the impact of environmentally sound technologies on climate change in Nigeria and recommends ways for policy decisions. Using literature review and case study, it is revealed that energy companies use environmentally sound technologies to mitigate climate change. It recommends the need to embrace environmentally sound technologies, renewables and the improvement of energy efficiency in all sectors

Introduction

Rapid growth of innovative technologies has significantly impacted oil and gas development in the last few decades. These trends have profound implications for the world economy such that, increasingly, major decisions around the world on energy issues are driven by sustainability. Industrialization and economic growth are responsible for many industrial environmental dangers in the developing and developing economies of the world. Air pollution caused by emission from fossil fuel combustion is a growing problem. (UNDP, 2000).

The availability of energy is critical for economic and industrial development, and so is the emerging consensus on the role of fossil fuels in promoting global warming. However, years of consumption of fossil fuels have led to several environmental issues. Some of those issues include global warming and air pollution with their attendant health challenges which impact of the quality of life of the world's peoples (Manisalidis, 2020; Martins et al., 2019). In fact, according to the World Bank's Global Gas Flaring Tracker Report, gas flared from the oil and gas industry releases certain pollutants into the atmosphere which include CO_2, methane and black carbon, also known as soot (The World Bank, 2021). These pollutants, particularly CO2 are the biggest contributors of climate change, which is now biggest risk facing mankind (Anderson, 2016). For instance, the top seven gas flaring countries of Russia, Iraq, Iran, the United States, Algeria, Venezuela and Nigeria are said to account for about 40% of global oil production and about 65% total gas flared into the atmosphere from their oil and gas activities (The World Bank, 2021). Within the last five years, the top seven countries have flared close 500 billion cubic meters of gas into the atmosphere. See Table 1 for volume of gas flared by the big seven for the last five years

Table 1: Volume of gas flared by the top seven gas flaring countries for 2016-2020 (billion cubic meters)

Country	2016	2017	2018	2019	2020	Total
Russia	22.37	19.92	21.28	23.21	24.88	111.66
Iraq	17.73	17.84	17.82	17.91	17.37	88.67
Iran	16.41	17.67	17.28	13.78	13.26	78.4
United States	8.86	9.48	14.07	17.29	11.81	61.51
Algeria	9.10	8.80	9.01	9.34	9.32	45.57
Venezuela	9.35	7.00	8.22	9.54	8.59	42.7
Nigeria	7.31	7.65	7.44	7.83	7.20	37.43
Grand Total						**465.94**

Source: Extracted from The World Bank, 2021.

In order to evolve a sustainable pattern, reduce the impact of fossil fuels on the planet, and ensure long-term development, there is now a major shift towards renewables and the improvement of energy efficiency in all sectors (Martins, 2019; UNDP, 2000). Conversely, achieving sustainable energy systems is herculean task despite the efforts made by stakeholders such as governments, international agencies, etc. (Martins, 2019).

The rapid globalisation and rationalisation of the energy industries generally and the petroleum industry in particular, coupled with the giant strides in environmentalism have made in the last two decades highlight the importance of the transfer of environmentally sound technology, cooperation, and capacity building. It is suggested that environmentally sound technologies (ESTs) that will lower the rate of air pollution be developed and applied in all industries (Manisalidis et al., 2020). ESTs can reduce environmental pollution by adopting of efficient technologies (Kumar et al., 2020). There is no universally acceptable definition of environmental sound technology (Robinson, 1992). The environmental soundness of technologies is a relative rather than an absolute term, as it is dependent on technical and economic conditions as well as the level of environmental standards.

It was nevertheless agreed at UNCED that environmentally sound technologies protect the environment, are less polluting, use resources in a more sustainable manner, recycle more of their waste and product, and handle residual waste in more acceptable manner than the technologies for which they were substitutes (Agenda 21). Such technology can be referred to as clean technologies and include air pollution cleaning equipment, others are renewable technologies such as solar panels and wind turbines, increasing the uptake of those technologies can result in several benefits for the environment (UNEP).

In the context of pollution, environmentally sound technologies are processes and "product technologies" which generate low or no waste, in order to prevent pollution. Also included in the concept are the "end of pipe" technologies for treating pollution after its generation. Environmentally sound technologies are more than just individual technologies, but systems which include know-how, procedure, goods and services and equipment including organisational and managerial procedures.

The need for favourable access to and transfer of environmentally sound technologies to Nigeria cannot be overemphasized. This is partly because the availability of scientific and technological information and access and transfer of environmentally sound technology are essential requirements for sustainable development.

Ibibia (2002) submitted that the increasing spate oil and gas exploration and development in Nigeria have brought considerable strain on the Niger Delta environment in Nigeria and highlighted the urgency for diffusion of clean technologies. Not being unmindful of the growing influence of international environmental law and the changing standards of environmental performance in the home countries of oil and gas multinational enterprise, the Nigerian Government has introduced environmental regulatory pressures to bear on oil and gas industry operations.

Furthermore, Ibibia (2002) posited that one possible way by which industry can avoid violating these new standards and yet remain competitive is to take the initiative in introducing clean technologies in all aspects of their operations rather than assume that because of their technological backwardness, Nigeria can serve as a dumping ground for obsolete technologies. But more importantly, the government has to chart the way forward.

In Nigeria, the awareness by country of the damage of pollution arising from projects where oil companies are located has increased their cost to the extent that communities are demanding compensation. According to Falobi (2009), natural gas in Nigeria has not attained its potential as a major source of fiscal revenue in the domestic economy because of inadequate funding for infrastructure development, inept pricing of natural gas for domestic gas policy and regulatory framework and environmental degradation due to gas flaring.

Other factors are:

i. The huge cost of developing major and interconnecting network of gas pipeline
ii. Limited no of appropriate reservoir conducive for gas reinjection/storage and economics of doing so
iii. Low technological and industrial base
iv. Limited regional and international gas market
v. Inadequate fiscal and gas pricing policies to encourage investment
vi. The difficult terrain of Niger Delta which hindered the gas gathering process

The combination of these factors sub-optimizes Nigeria's competitive position in a rapidly evolving and intensely competitive global gas business. However, the gas infrastructure blueprint aims to address these barriers and leverage a diversified industry player base to actualize this. According to this day report of 30th October (2013): Clear gas development policies can help boost the economy, power generation and improve the standard of living for Nigerians. The report stated further that the federal government of Nigeria should harness the potentials of the nation's enormous gas reserves by establishing a win-win situation that would serve as investments in domestic gas projects. The report also sought the creation of positive incentives to encourage local and international investments in the entire gas value chain, while promoting a willing buyer-willing seller market-driven pricing regime.

Against the backdrop the research question is what do policy makers need to know about oil and gas development project to produce development support strategies that are environmentally effective? The objective of the study is to examine the impact of environmentally sound technology on climate change in Niger Delta.

Methodology

The methodology involves collection of secondary data from literature review and the case study of international and indigenous oil and gas operators in Niger Delta region of Nigeria.

Result and discussion

Effective management of the environmental impact of project is a major concern in the oil and gas industry. According to Herriot watt Institute of petroleum studies (2005): *Pollution and other forms of environmental damage are common by products of most industrial activities and classified by economist as "externalities" implying zero financial implication to business. In the absence of effective penalties the avoidance of pollution increases operating cost and is likely to reduce rather than to enhance profitability. Therefore there is no direct, economics incentives for profit maximizing organisation to think about pollution. It is consequently necessary for government to build a framework of legislation for environment protection.*

Ecological analysis is necessary especially with the recent environmental degradation caused by pollution related industries. It is concerned with the analysis of how to mitigate possible damage to a manageable level. No industry has higher environmental and climate change concerns around the world than oil and gas. For policy makers it should be noted that environmental considerations and public opposition to oil and gas projects affect opportunities for investment and the cost of projects. Technology is both an input and output of business organisations as well as being an environmental influence on them.

Environmentally sound technology encompasses an evolving group of method and materials for production of essential nontoxic product by oil and gas operators. Oil and gas development are very important drivers for job creation and also a pillar of economic growth in many oil and gas producing countries. They play prominent roles in the development of developed countries in terms of creating employment opportunities. The oil and gas operators generate waste and pollution from their practices and business because of their informal nature and lack of regulation and supervision. The pollution produced by the oil and gas industries have contributed immensely to the global warming and natural resources depletion leading to many economic and social problems such as:

Case study of application of environmentally sound technologies by energy companies.

1. According to the investor village report (2011): The company Britania – U a marginal field operator currently produces 2.2mmscfd of gas from its Ajapa field out of which 1.8mmscfd is reserved to power the production system on board the Floating Production, Storage and Offloading owned by the company, while the balance of 400sctd is small to be used for anything, rather the company fixed sonic flare tip, which is the latest technology ever to be used in the country, which cleans out the poisonous elements and emits smokeless air into the environment.
2. Total energy Nigeria limited, as part of its drive towards clean energy and reduction of carbon emissions, embarked on the installation of solar energy at its offices, retail outlets, and project sites adding to the deployment of modern technologies in its operations. TotalEnergies, through its Joint Venture with the Nigerian National Petroleum Corporation (NNPC), earned $1.4 million through the sales of Carbon Credit on the United Kingdom market in 2020.
3. The Southern Swamp Associated Gas Solutions project captures gas produced alongside oil in the Niger Delta to help reduce flaring. The Shell Petroleum Development Company of Nigeria Ltd (SPDC) Joint Venture reported a 17% decrease in routine flaring in 2020. Further associated gas flaring reductions by SPDC are anticipated with the completion of commissioning of the Forcados Yokri gas-gathering project in 2021. This is in line with Vijay (2012), submission that: "By reducing gas flaring, oil producing countries and companies are improving energy efficiencies and mitigating climate change. Instead of wasting this valuable resource, we now need to develop gas market and infrastructure so the associated gas can be utilized to generate electricity and cleaner cooking fuels."

Conclusion and recommendations

The study set out the one of the strategies and mechanisms for implementing the techniques for managing the environmental aspect of the energy industry. It was revealed that technology may involve, but is by no means restricted to equipment, patients processes and copy rights. It is rather of host of intricate interconnected factors that traverse equipment, patients, processes and copyrights and most importantly knowledge of how to invent, manipulate and use the above-mentioned factors towards the attainment of definite goals. in recent time emphasis has shifted from the transfer of technology per se to environmentally sound technology for climate change mitigation.

- Research and development efforts should be geared towards innovation, dissemination and management of environmentally sound technology.
- Education and training program should be tailored to meet the need for environmentally sound technologies with interdisciplinary outlooks.
- There should be an emphasis on the building of capabilities for craft persons, technicians and middle level managers, scientist, engineers and educators as well as developing their corresponding social and managerial support systems.
- There should be collaborative efforts of governments, industries and individuals towards the implementations of environmentally sound technologies.

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Becoming Gas Reliant; How Mexico is Betting for a Risky Game

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Abstract

Transitioning to clean energy includes using natural gas as a transitional energetic. Nevertheless, for a country like Mexico, this transition is more of a static strategy. Gas infrastructure is planned to be highly dependent on US gas imports. This creates a gas lock-in strategy reliant on US gas supply.

Natural gas is considered the keystone for transiting to a cleaner energy matrix. Unfortunately, this is far from being true. Several factors undermine the possible green transition for Mexico, given the pressing presence of natural gas as a main fuel. In 2013 Mexico went through an energy sector reform, which opened the energy market to the private sector, this was reflected in the increase of private participation in electricity generation and opened new spaces for private investment in the oil and gas value chain.. The capital influx from private firms was meant to cover the underinvestment of infrastructure in the energy sector.

The energy reform fostered the increase of green energy projects. After three successful rounds of bid, wind and solar prices broke the record as the lowest prices for these technologies globally. However, the reality is that the energy matrix is still dominated by fossil fuels. Only 23.2% of electricity generation comes from clean energy. Despite the low participation of renewable energies, the current energy policy has focused on the promotion of fossil fuels. In the same line of promoting fossil fuels is the energy policy of the current administration, which aims to ensure energy sovereignty and therefore seeks to reactivate the extraction and refining of oil. However, the big problem lies in the dependence on natural gas from the United States.

The main energy guidelines coming from the government is to protect overall national energy security and strengthen the "State Productive Companies" in the oil sector (*Petróleos Mexicanos, PEMEX*) and in the electricity sector (*Comisión Federal de Electricidad, CFE*). This policy which, seems contradictory against a green agenda, is the mainguideline of the present administration.

Being a close neighbour of the United States opens the door to cheap natural gas, around 3 dollars for MBTU (millions of British thermal units). Compared to Europe or Japan, the MBTU is 5 dollars for the former and 10 dollars for the latter. Given these prices, natural gas was a clear option. But considering political or climatic risks like the outage in Texas at the beginning of this year makes vulnerable the energy systems. Relying only on gas imports from the US is a risky bet.

Although previous administrations were opting for clean energy, they were as well investing in natural gas infrastructure. As a result, from 2012 to 2019, the total importing capacity increased from 2758 to 11,000 mdcf (millionsof daily cubic feet). This increase in capacity was thanks to seven new interconnectors and the already existent internal ducts built by private firms that supply gas to the main public electricity producer (CFE).

This kind of infrastructure secures a contract of 25 to 30 years of an interconnection agreement. And given the present administration's plans where the main project is to create 6 new gas-dependent electric central, it is clear that gas infrastructure will increase.

Nevertheless, this investment is incomplete. Just as the Texas outage madeit clear, Mexico doesn't have enough gas storage capacity. Therefore, the electric system relies on a constant flux of gas coming from the USA that it is impossible to store. This is the combination for a perfect storm, just like the one happening early this year in Texas.

Another key factor that may make gas look like a safe bet is that it is not as unpopular as green energy infrastructure. As Andres Manuel Lopez Obrador mentioned, the "not in my back yard" movement against wind farms and solar panels is stronger in Mexico than reticent against gas infrastructure. Besides, given that gas is one of the leading energy fuels worldwide, technology and infrastructure have more investment. This leads to more efficient technologies in this niche, creating more money influx. This circle creates a constant and strong demand for gas.

Transiting to clean energy is a technology-feasible and cost-optimal option (Solano-Rodriguez, et al., 2018). But a projection of over investment in gas infrastructure in the following 15 years means locking in for a gas reliant energy matrix. Unfortunately, as the investment in gas interconnections with the US and plans of new electric gas-plants projections, it seems clear a lock-in depending on natural gas.

The big paradox with Mexico is a clear lock-in process going on without enough resources allocated in gas. This is a wrong strategy that happened as well in the oil sector. For example, recently, Mexico acquired the Deer Park refinery in Texas. This acquisition was to reduce the dependency on US refineries. Nevertheless, since the first acquisition in 1993 of 50% Deer Park, there was never an agreement on training human capital. Now, 28 years later, when Mexico is acquiring the other 50%, it faces a shortage of qualified workers. Therefore, all of the workers will be previous ones at Deer Park with salaries coming from Mexico. In this way, Mexico is buying a refinery highly reliant on private suppliers and foreign workers.

Just like Deer Park, the gas industry is facing a similar paradox. The present government is becoming highly reliant on gas but is not investing enough in infrastructure to extract the 9 258 BCF (billions of cubic feet) of proven reserves. Even worst, extraction has fallen since 2009, where it was 7,030.6 mdcf (millionsof daily cubic feet) to 4,894.1 mdcf in 2019. Besides, there are no clear plans to increase gas storage. Mexico is betting on more interconnections with the US without making robust national production of gas.

The path to achieving energy security and sovereignty in Mexico is still very bumpy ahead. It is creating a lock-in in gas-reliant technologies, and at the same time, there is a structural shortage of resources in this sector. Therefore, Mexico will only be relying on the stability of gas supply from the US. Even against the evidence that there will always be room for extreme events that can potentially harm the national energy security.

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Second Energy Transition for Uruguay

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Uruguay has proven in its first energy transition (2010-2020) that it has achieved a 97% renewable energy share and is among the top 2 in the world in terms of wind energy share. The country is currently outlining its second energy transition to decarbonize transportation, harness the vast renewable resources available, while solving the problem of high electricity and fuels prices that the country still faces.

1.- Uruguay's first energy transition

Uruguay is a small South America country with 3.5 million inhabitants, whose main economic activity is agriculture and livestock.

Since the country does not have fossil resources (there is no oil, coal or natural gas), it has to import oil and natural gas to meet its demand, with oil being the main import.

However, the country has abundant renewable resources, with biomass and hydropower being the traditional sources that have historically met much of the national demand. Since 2012, Uruguay has made an amazing transformation of its electricity sector, incorporating more than 1,500 MW of wind energy, and about 300 MW of photovoltaic solar energy. Considering that the maximum demand was 2,200 MW and the average demand of the country is barely 1,200 MW, it is easy to understand that wind energy is already the main source of energy in the country.

A recent world ranking shows Uruguay as the 2nd country with the highest penetration of unconventional renewable energy in the world after Denmark.

With these changes, the electricity system went from a hydrothermal system to one based on hydro and wind, with relevant contributions from biomass and solar, while thermal generation from fossil fuels represents only 2% or 3% of the electricity matrix (except in drought years, when it can represent around 7%).

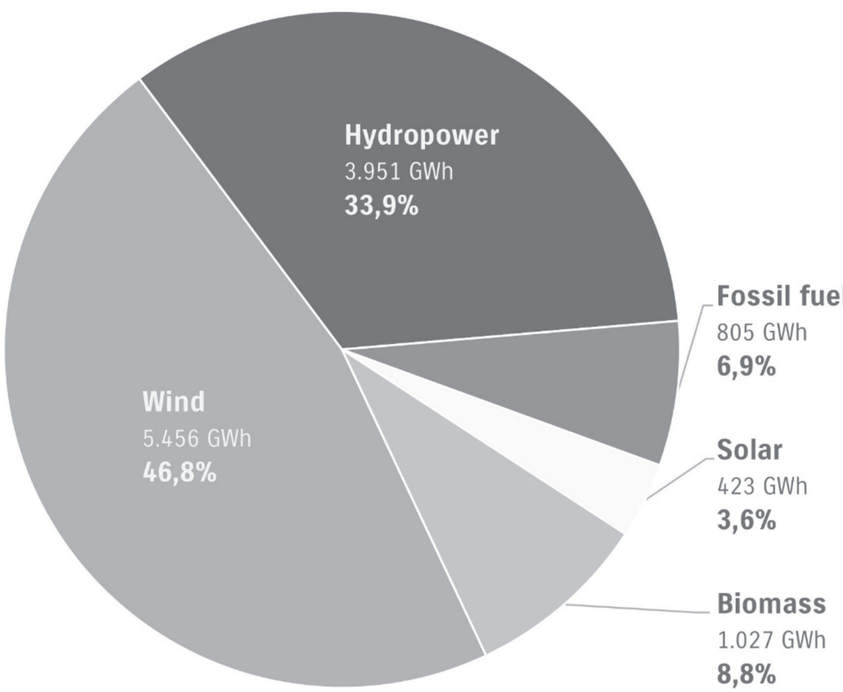
In addition to the environmental and macroeconomic benefits (improving the balance of trade by reducing oil imports), the electricity sector went from a situation of supply shortage (with supply risks in drought years and very high marginal costs) to being a country exporting electricity to neighboring Brazil and Argentina.

This transformation took place without subsidies and based on public auctions with PPA's at 20 years (wind) or 30 years (solar), which also determined a significant reduction in generation costs and the reduction of the country's vulnerability to climatic factors.

2.- Uruguay is planning its second energy transition.

Based on the experience gained and the abundance of renewable resources, Uruguay plans to carry out its second energy transition.

URUGUAY'S ELECTRICITY GENERATION MATRIX IN 2020



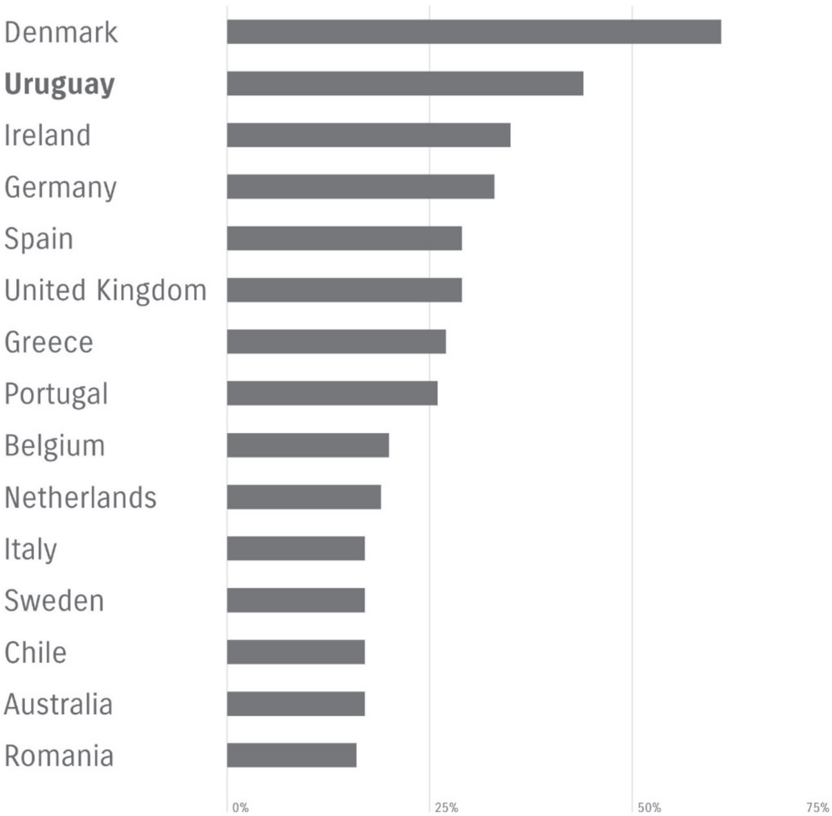
Source: Prepared by SEG Ingeniería based on data from "Histórico de la Composición Energética por Fuente", Administración Nacional de Usinas y Transmisiones Eléctricas (UTE, portal.ute.com.uy), September 2021.

Although Uruguay is a country with the mentality of a "small country", used to following the lead of other, more advanced countries, the energy revolution achieved in the last decade has generated enthusiasm and a level of self-confidence among stackeholders in the sector, that allows it to enter this new phase with optimism and confidence.

In addition to contributing to the reduction of emissions, many other benefits can be expected from this second transformation. On the one hand, attracting billions of dollars of investment will create quality jobs that are in line with the sustainable development goals, and on the other hand, continuing on the path of substituting fossil fuels with domestic sources will bring many other macroeconomic benefits to the country.

From the point of view of GHG emissions, the power sector is not relevant. However, the transport sector is responsible for 2/3 of Uruguay's

TOP 15 WIND AND SOLAR ELECTRICITY PRODUCTION RATIOS IN 2020



Source: Prepared by SEG Ingeniería based on data from "Top 15 Wind and Solar Power Countries in 2020", EMBER, July 2021.

emissions. Therefore, electric mobility is imposed as the main protagonist in this new phase.

The country has already put in place some incentive mechanisms to promote electric mobility. A small part of the taxi and bus fleet is electric, but more profound changes are needed to achieve a real transformation of the current fleet, which remains mainly running on petrol or diesel.

In addition to electric mobility, the country is preparing to incorporate new technologies to make the most of the potential of renewable energies, among which the following stand out:

Energy storage: based on lithium batteries, behind the meter or in front of the meter, this will help reduce the use of fossil fuel power plants during peak periods when there is little wind or sun.

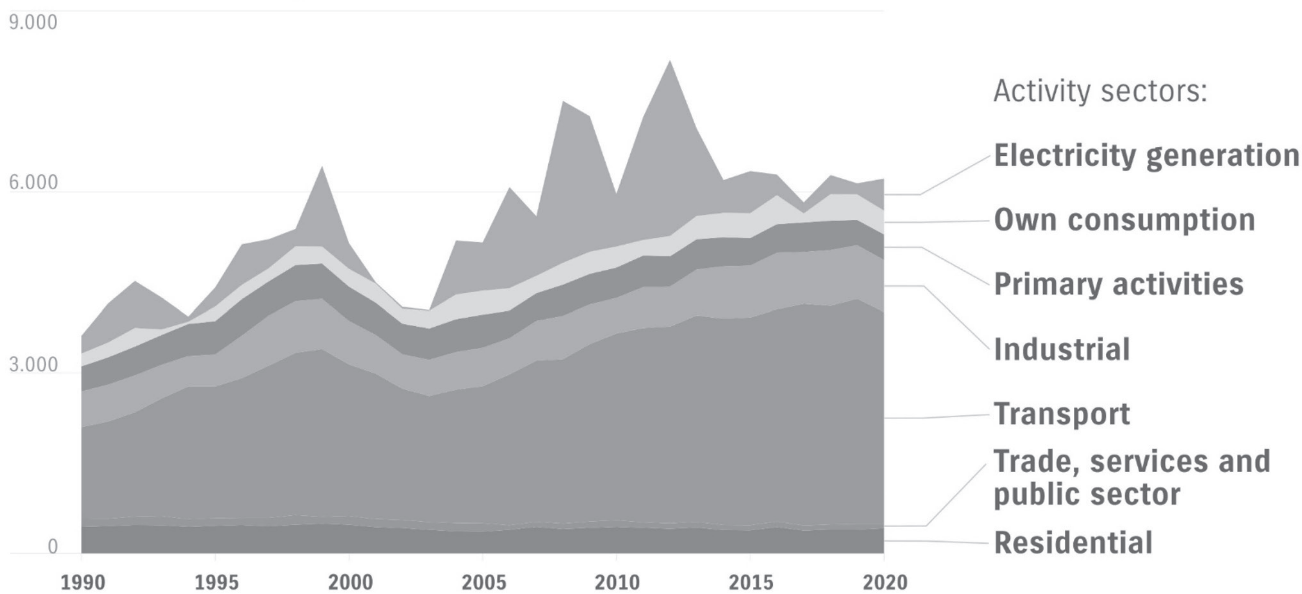
Demand management: several mechanisms are being explored to make demand more flexible. The high percentage of "Smart meters" already installed by the state utility company stands out.

Green hydrogen: the government is beginning to develop its green hydrogen roadmap, while also launching a pilot project to incorporate an H2 generation system to be used in a fleet of heavy-duty renewable trucks.

Heat Pumps: they have enormous potential to replace fossil fuels with green power. For both residential heating and some industrial applications, heat pumps will be a very efficient way to use electricity as a green source to generate thermal energy.

Power to X: at the industrial level, this option is indicated to convert electricity into thermal energy (electric steam boilers or hot water) during periods of electricity surplus. There is also much potential to produce green hydrogen or hydrogen derivatives (e. g. ammonia), which can be exported mainly to Germany, a country

URUGUAY'S TOTAL CO_2 EMISSIONS IN THE LAST 30 YEARS



Source: Prepared by SEG Ingeniería based on data from "Balance Energético Nacional 2020", Ministerio de Industria, Energía y Minería, September 2021.

developing a diversified green hydrogen import strategy.

3.- Challenges

On the one hand, the success of the first energy transition, which was mainly based on the use of wind energy, was unexpected, since by that time the cost of this technology had already dropped dramatically. On the other hand, Uruguay was behind in its investments in electricity generation, so there was a real urgency to install new power stations.

The dilemma was to rely more on fossils or on unconventional renewables, although they had almost no experience with this technology and also did not have much experience worldwide in using these technologies with high penetration rates of intermittent energies (wind or solar) in a system. Uruguay accepted the challenge and took some risks, which in retrospect turned out to be the best strategic decision.

In this new phase, Uruguay can once again take the leap to its second energy revolution and create the necessary mechanisms to incorporate these technologies. The big question is whether the country will have the same courage to plunge into this new challenge, given the risks involved.

At the same time, Uruguay should achieve a reduction in energy prices both for companies and for the population in general.

Uruguay has the highest petrol and diesel prices in Latin America, and electricity rates are also among the highest, especially for the residential sector.

Therefore, the challenge for the country seems to be even more complex, as not only is the conversion of a relevant part of the energy demand side required, but creativity is also needed to reduce tariffs for customers.

The Transport Challenge: A Nordic Perspective

BY KIMMO PALANNE AND ANNA SAHARI

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Abstract

Despite a high carbon tax introduced over 30 years ago, Finland's transport emissions have not decreased. Analysing data on households' vehicle ownership and driving indicates that fears of regressive fuel taxation may be overplayed.

Finland is a Nordic country endowed with a cold climate, ample forest resources and a small population sparsely spread around the country. The country consistently ranks high in standard of living evaluations, and places 14th in terms of GDP per capita in the OECD in 2019.[1]The share of renewable energy production has traditionally been relatively large, partly due to the forestry sector which has provided biomass and by-products for energy production. Finland also relies on nuclear power, with four power plants in operation and a fifth one in introduction. In 2019, renewables and nuclear accounted for 56 percent of total energy use, with the share being as high as 70 percent in total electricity consumption. The share of renewable energy will further increase in the near future, with wind capacity expected to double by 2023 and large municipalities planning to replace coal in heat production with heat pump and heat recovery technologies (FWPA 2021). In residential buildings, the share of oil heating has declined from 12 percent to 6 percent, while the share of energy from heat pumps has increased from 4 to 12 percent during 2008–2019.

Transport, however, has not seen visible changes to energy sources or energy use. Given Finland's northern location and low population density, transport forms a large share of final energy use: 17 percent in 2019. Road transport is the largest component of domestic transport, and passenger cars account for around 10 percent of total greenhouse gas emissions. Energy use in transport has increased 8 percent during the past 20 years, and energy sources have not changed. Fossil-based petrol and diesel currently account for almost 90 percent of energy use in road transport, while the shares of electricity and gas are practically zero.[2]

This is all despite Finland being the first country in the world to introduce a carbon tax in 1990. The tax was introduced as a component in fuel taxation, and its value is based on the lifecycle CO_2 emissions of each fuel type. Currently, the carbon tax level for petrol is 21.49 euro cents per litre, which amounts to 91 €/tCO_2. Overall, fuel taxation has consistently been high, with taxes averaging over 60 percent of the total price of petrol and over 50 percent for diesel during the past 20 years.

What is driving transport emissions?

Our analysis of the Finnish passenger car fleet during 2013–2019 shows that firstly, the number of cars has increased from 2.58 million to 2.72 million. The average number of kilometres driven per car has remained constant at around 15 000 km per year. This implies that driving has increased in aggregate. At the same time, the emission intensity of the vehicle fleet has hardly changed. Using car-specific data on kilometres and emission intensities, we estimated that the aggregate CO_2 emissions of the passenger vehicle fleet decreased only by about 2 percent, from just above 7.9 million tonnes in 2013 to just below 7.8 million tonnes in 2019.[3] (Palanne and Sahari, 2021).

One explanation for this increase in demand for driving could be Finland's low population density. There are few cities where public transport has dense operating networks and timetables, providing alternatives to car use. Also, active transport modes, such as cycling and walking, are easier to execute in densely populated areas which have sidewalks and bicycle lanes. However, our regional examination of car emissions reveals that less than 40 percent of total emissions come from sparsely populated or rural areas (Palanne and Sahari 2021). This would imply that not all options for reducing private vehicle use are currently exploited in cities and their surrounding areas.

How to decrease emissions from cars

The current development of transport emissions is in stark contrast with Finland's ambitious goal of being carbon neutral by 2035. This is stricter than the EU target of carbon neutrality by 2055. The current government also wants to halve the emissions from transport by 2030. This is going to be a big challenge, and because emissions are more difficult to cut in heavy duty vehicles, most of the burden will fall on cars.

Reducing emissions from passenger cars would require large and relatively immediate reductions in the number of kilometres driven, given the current composition of the motive powers in the car fleet. However, it seems unlikely that this could be achieved, especially in light of the recent flat trend in the aggregate kilometres driven.

What remains is to cut the emission intensity of cars by replacing existing vehicles with very low-emission alternatives, namely, electric vehicles. Electrification of the passenger vehicle fleet is currently supported by subsidizing investments into the charging network, both commercial and domestic, lower registration tax rates for zero-emission vehicles and preferential treatment for electric cars in company car taxation. There is also a direct purchase subsidy for electric vehicles. The supply of new cars is influenced by EU emission standards. Recent proposals to increase the standards would practically rule out the supply of new combustion engine vehicles by 2030.

The current measures will probably lead to an increasing market share of electric vehicles in new car purchases. However, new cars form a very small share of the passenger vehicle stock. On average, only three percent of the adult population buys a new car each year, whereas the purchase probability for a used car is over 10 percent. To replace combustion engine vehicles with cleaner cars, the scrappage rate of old cars should increase as should the supply of used electric vehicles.

The challenges of higher fuel taxation

Higher fuel prices are an efficient tool to reduce the kilometres driven by combustion engine vehicles, to speed up the scrappage of these vehicles and to encourage the purchase of more fuel efficient or zero emission vehicles. It is unlikely that the emission reduction targets set for the transport sector can be achieved without increases in petrol and diesel prices.

Combining Finland's early introduction of a carbon tax with the observed increase in road transport energy use would seem to imply that fuel demand is very inelastic to prices and would undermine the effectiveness of taxes in reducing fuel demand. However, looking at the consumer price for petrol over the past 15 years shows that the price has not actually increased. In fact, the price in constant terms is lower now than in 2005. This suggests that increases in fuel taxes could have been more prominent in the recent past and that there is room to further increase the level of taxation.

Higher fuel taxes are often opposed due to the view that they would mostly hurt low-income households, who are assumed to spend a larger share of their income on fuel expenses. However, empirical evidence suggests that this may apply mostly in the US, and that in Europe fuel expenses are more evenly distributed across income levels (Sterner, 2012). Furthermore, revenue recycling could be used to counteract or even reverse the potential progressivity of fuel taxation (see for example Bento et al. 2009 and West and Williams, 2004).

In Finland, the income share of fuel expenses follows an inverse U-shaped pattern across income deciles. The share peaks in the seventh decile at around 4 percent. In the first decile, however, the share is a bit higher than in the second decile, but it should be noted that averages in both the first and last decile are not representative of typical households due to outliers arising from very low and exceptionally high income values. It is also of interest to note that owning a car is not common in the lowest income groups. In the two lowest income deciles, the median value of fuel expenses is zero, as over half of the households in these groups do not own a car. (Palanne and Sahari, 2021).

Higher-income households thus drive more, which is documented both in Palanne and Sahari (2021) using administrative data and in Tiikkaja and Liimatainen (2020), who analyse the National Travel Survey from 2016. Tiikkaja and Liimatainen also show that the share of trips that could have been made by an alternative mode of transport is highest in high-income households.

These facts imply that fuel taxes in Finland may not be as regressive as the public and politicians fear. In the highest income groups, there is potential to avoid higher taxes by switching to other transport modes or replacing the combustion engine car with an electric vehicle. Potential adverse impacts on the lowest-income households could be alleviated by recycling tax revenues. This could also increase the political acceptability of higher fuel taxes.

In conclusion

Finland's goal of reaching carbon neutrality by 2035 will probably not be reached unless transport emissions are reduced significantly. This will require both an increase in the share of electric vehicles in the vehicle fleet and reductions in kilometres driven by the combustion engines that remain on the roads. Politicians have been very reluctant to advocate notable increases to fuel taxes, however it seems unlikely that emission reductions will be realized in the required timeframe if this tool is not used.

Statistics show that first, fuel prices are currently lower in real terms than 15 years ago. This suggests there is room for price increases. Second, high income households are currently driving the most and using a car for trips that could be made with an alternative mode of transport. Higher fuel prices would incite this modal shift and increase the cost effectiveness of electric vehicles. Third, a large share of the lowest-income households does not own a car and is therefore not affected by fuel taxation directly. Remaining concerns of adverse distributional effects of higher fuel taxation could be alleviated by revenue recycling.

Footnotes

[1] https://data.oecd.org/gdp/gross-domestic-product-gdp.htm

[2] The remaining 10 percent is covered by biofuels which are blended into petrol and diesel as required by the blending mandate.

[3] These values are based on reported emission intensities which have been corrected to reflect true emissions as reported by the ICCT (Tietge et al. 2019).

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Paths to a Climate-Neutral Future – the Citizens Decide on its Success

BY DIETER OESTERWIND AND PHILIPP RIEGEBAUER

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Abstract

Over the next two decades, the German energy system will be completely transformed. There is no one-dimensional path that will lead us to a climate-neutral future. Conflicting goals, obstacles and imponderables lurk along the way. The citizens decide on its success.

The EU and Germany have set themselves the goal of becoming climate-neutral by 2045/50. For the transition from the fossil to the regenerative age, the German government wants four technological paths to be followed: 1st the large-scale transformation of today's energy industry into a smart ecosystem (sector coupling), 2nd the expansion of renewable energies, 3rd the development of a hydrogen infrastructure, as well as 4th a significant increase in energy efficiency.

However, in focusing on the 2045/50 climate target, we must not lose sight of the fact that there is no one-dimensional path that will lead us to a climate-neutral future. A secure and affordable energy supply are equally important goals. This bundle of goals provides the background for the analysis of the pathways. Let's take a look at them.

Cross-sector electrification

Fossil energies will possibly be replaced by electricity in all consumption sectors. For example, in the transport sector through electromobility and in the heat supply using electricity-based heat pumps. These direct electricity applications are to be supplemented by climate-neutral hydrogen technologies. However, hydrogen is only a climate-neutral form of energy if it is produced with green electricity in an electrolysis process. The green electricity must be generated predominantly in wind and photovoltaic plants. Since the solar and wind supply fluctuates, it must be supplemented by flexibility options such as hydrogen salt cavern storage, decentralized batteries, and flexible loads.

This all makes green electricity the basis of our future energy system for all direct energy applications (light, power, heat). The corresponding processes are summarized under the term Power to X. By coupling the consumption sectors, the fluctuations in supply and demand can be balanced. In the future, sector coupling will regulate all energy flows and therefore play a major role in maintaining security of supply.

The digital ecosystem

While in the "old" fossil-nuclear centralized world 700 power plants had to be integrated into the electricity grid, today there are already almost 2 million photovoltaic systems and around 30,000 intermittent wind energy systems feeding into the grid. In addition to this fluctuation-dependent generation, there are around 200,000 battery storage systems and a rapidly growing number of new consumers such as electromobility, heat pumps and hydrogen applications. Decentralization, small scale and volatility of the physical energy flows increase the complexity of this energy supply concept. Intelligent management of sector coupling must therefore digitally process the entire energy industry infrastructure in real time. Making the complex networked infrastructure fail-safe and prevent external cyberattacks to the critical infrastructure is a daunting task.

Compared to today's energy system, however, sector coupling is not only more complex. There is another important aspect. Our current energy system is largely sectoral. We have fuels for mobility, natural gas for heating, and electricity for light and power. If mineral oil imports are interrupted, we can still heat with natural gas or have heating oil in the cellar tank. The electricity comes from our fossil and nuclear "continuous runners". If only natural gas is in short supply, we are left with the car, etc.. In future we will have a volatile, sometimes unpredictable electricity supply combined with (hydrogen) storage facilities that will have to be sufficient even if an unpredictable prolonged break of sun or wind brings electricity generation largely to halt. Otherwise, the PC stays off, the car remains in the garage and in winter the flat would become an icebox. No power, no action. To ensure that such a scenario remains a fiction, the goals of climate neutrality and security of supply must be reconciled. In the coming decades, this immense challenge will have to be overcome. Let's look at it and start with energy demand.

Energy efficiency first

For Germany the total energy consumption has to be reduced by 50 percent across all consumption sectors (transport, households, industry) by 2045/50 to reach federal climate targets.

- In transport, this is to be achieved with more efficient and climate-neutral drive technologies e.g. battery-electric drives, fuel cells and plug-in hybrids. To ensure that the owners of electric cars are not left behind, the charging infrastructure and the distribution networks in the residential streets must be expanded quickly across the board and a time-variable electricity tariff must be introduced to set incentive to balance the loads and to avoid peak loads. The hydrogen infrastructure for refueling trucks, trains, vans and buses is also still missing.

- The energy demand in the building is mainly used for heat generation in residential buildings. In Germany, the housing stock of single-family and multi-family houses was mainly built after the 1950s. In order to achieve a 50 percent increase in thermal efficiency by 2045/50, these houses must be modernized at an annual rate of 2 percent. For the existing large and small apartment buildings, which house half of all flats in Germany, there is a lack of alternatives suitable for the masses. Thus, the installation of electric heat pumps unfortunately still fails far too often due to the technical and economic conditions on site. Moreover, there is a lack of well-trained skilled workers to professionally renovate 20 million buildings in Germany. And as long as education policy does not pay more attention to the skilled trades, this will not change much.
- Let's move on to industry. With a share of 78 percent of the total industrial energy demand, process heat generation plays a significant role in CO_2 reduction. This means coal and natural gas must be replaced with electricity, hydrogen, synthetic gas and biocoal. Industry will be the largest consumer of hydrogen in the future.

The look into the "engine room" of the energy transition has revealed immense challenges to achieve the targeted energy efficiency goals. Let us now return from the "engine room" to the surface and be optimistic and confident that we can halve the final energy demand from today's approx. 3300 TWh (terawatt hours) to the order of 1600 TWh by 2045/50. Because this goal should be achieved at all costs. Every kilowatt hour that is not saved must be generated from renewable sources and every kilowatt hour that is saved increases the security of supply.

Quadruple the green power supply

Let us turn to the supply side. Depending on the study and scenario, the expansion potential of renewable electricity generation in Germany is between 700 and 1100 TWh. This wide range results from different assessments regarding economic viability, social acceptance, technological progress and nature conservation requirements (26 percent of all wind turbines are already located in protected areas). In order to generate 1000 TWh in 2050, renewable electricity generation must be increased by a factor of 4 from 243 TWh in 2019 to 471 GW. To this end, the German government reformed the Renewable Energy Sources Act (EEG) in December 2020. Among other things, it provides for higher expansion paths for photovoltaic and wind power plants. If these measures give new impetus to wind expansion - in recent years wind expansion has often been blocked by citizens' protests - 1000 TWh of green electricity from wind and photovoltaic plants will probably be available in 2045/50. But this appearance is deceptive. As 750 TWh will be needed for direct use the remaining 250 TWh green electricity does not match with 400 TWh of hydrogen needed for transport, energy use in industry and to bridge dark slack periods. But that is not enough. If we look beyond the energetic use of hydrogen to the use for the production of chemical raw materials in the basic chemical processes, according to calculations in the 2019 "Roadmap Chemie 2050" study by the German Chemical Industry Association - an additional electricity demand of 628 TWh to produce the green hydrogen is demanded. Since this additional demand cannot be met in Germany, the consequence is that in the future we will have to import considerable quantities of hydrogen and possibly other synthetic products.

Hydrogen imports as a beacon of hope

Regions with high solar radiation, long hours of sunshine and favorable wind conditions are ideal for import. Regions with these favorable conditions are North Africa, the Middle East, Patagonia, Canada, Iceland, Ireland and Norway. The technical know-how to build a worldwide hydrogen infrastructure for a worldwide market volume of up to 6000 TWh in 2050 is available. However, according to the analyses of the scientists of the Fraunhofer Institute for Systems Research (Policy Brief 03/2020), many questions still need to be clarified if Germany wants to get a piece of this pie. Are the potential regions politically stable enough to guarantee a reliable supply? Is there a sufficient supply of water for electrolysis without jeopardizing the water supply in the country of origin? This is why overarching governance structures that respect environmental and social standards and a fair balance of interests etc. along the entire supply chain are part of the content of energy partnerships, as envisaged in the EU Commission's hydrogen strategy and the German government's national hydrogen strategy.

Keeping an eye on the costs

Let's move on to the question "How much does it all cost".

According to studies by scientists from the Jülich Research Centre, two trillion euros are calculated for the conversion of the entire energy system over the next 30 years. This includes the investments, fixed and variable operating costs, costs for energy imports in the form of hydrogen, minus the saved import costs for mineral oil, natural gas and coal. The additional investments alone in 2050 compared to today, after deducting saved energy costs for fossil energies, will amount to 128 billion euros. In relation to the gross value added of around 3.1 trillion euros (today) and a 1.2 percent increase per year (real) this accounts for 2,8 percent in 2050. The financial investment in the climate-neutral energy system will bring employment and distribution effects that are already becoming visible.

A cautious businessman might ask whether the energy turnaround cannot be obtained more cheaply. Yes, it can! But with limitations! The 2 trillion euros are a sum that results from the assumption that 95 percent of our energy system is converted to climate-neutral sources. If we abandon the 95 percent and settle for 80 percent, the total sum shrinks to 655 billion euros. The reason for this difference is the marginal abatement costs for the last tons of CO_2 to be reduced. The technological path to the 80 per cent target is less electricity-based, but natural gas would continue to be used for the most part in buildings and correspondingly fewer wind and photovoltaic plants would have to be built.

Natural gas as a flexibility option

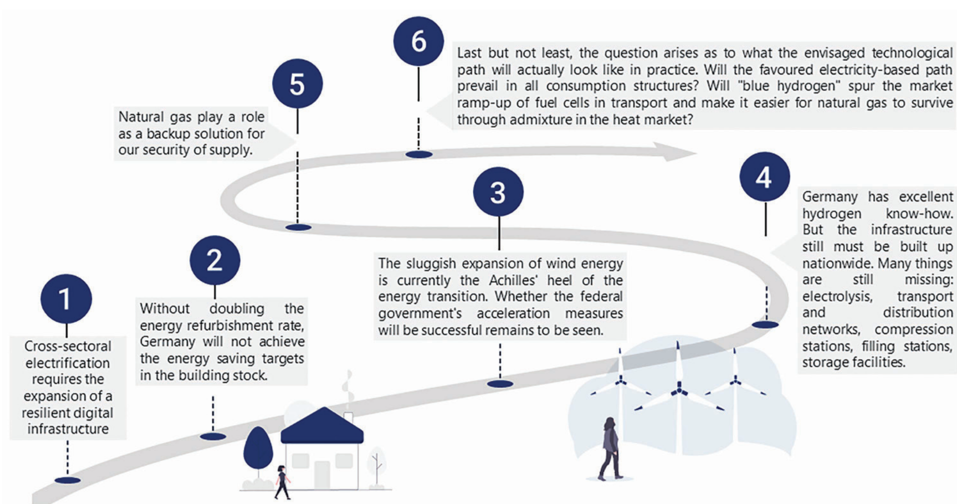
According to the ideas of the EU Commission and the German government, green electricity and hydrogen are the beacons of hope that will lead us to a climate-neutral world. Natural gas is no longer mentioned. Within the framework of the Green Deal, all coal-fired power plants are to be replaced by renewable energy in the medium term. But whether this will succeed is completely open.

In the north, the German government - against political pressure from the USA, Eastern European countries and the European Parliament - is vehemently defending the completion of the Nord Stream 2 pipeline. Why this political commitment? In Germany, nuclear and coal-fired power plants will be consistently shut down by the energy companies by 2038 according to a legally prescribed phased plan. However, if the capacity of wind and photovoltaic plants, including the high-voltage lines, is not increased to coincide with the shutdowns, there is a risk that part of the peak load forecast of up to 170 GW in 2050 will have to be covered by natural gas power plants.

To this end, it is possible to replace natural gas in the power plant turbines with hydrogen. In order to burn natural gas with lower emissions, more than 10 percent hydrogen could be added after retrofitting the distribution networks. Finally, there is the possibility of converting natural gas into “blue hydrogen” in steam reformers and splitting off the resulting carbon dioxide and storing it underground. Carbon Capture and Storage was already successfully tested ten years ago. However, its realization failed due to citizens’ protests in the Brandenburg communities where the CO_2 was planned to be stored in salt caverns sealed off from the atmosphere. Local resistance prevailed with the slogan “We don’t want to become Germany’s CO_2 toilet”.

Wrap-up

Decisions for the future must be made today. Only if we succeed in dissolving the obstacles and uncertainties in the near future can the path to a climate-neutral future be created. And perhaps there are even innovations that we haven’t even thought of yet. The figure briefly summarizes the discussed uncertainties of the energy transition:



It depends on the citizen

It is important to note that new technologies change the world, and, with the world, we change ourselves. This brings us to the crystallization point of the energy transition. There is no question that climate change has picked up speed and we are trying to fight it with new technologies.

But what about us, the people? Have we sufficiently internalized that humans can only survive in the long term in harmony with nature? Evolution has taught us that Homo sapiens could only remain adaptable and ensure its survival in the face of drastic climatic changes or other existential threats by trying out new techniques and sharing new behavioral and value concepts. It is normal for an “old world” to perish and a “new world” to emerge. So today, after 300 years, the fossil age is coming to an end. Whereas in prehistoric times it was the tribal leaders and later the kings and churches that dictated the way of life for the subjects, today it is the free will of the citizens that determines the destiny. This puts us in the middle of the social field of tension of the energy transition. In this field of tension, politics can only stimulate the goals (e.g. Climate Energy Law, decision of Federal Constitutional Court from 2021); whether they are achieved, politics cannot guarantee. Ultimately, it remains dependent on a basic social consensus. A basic consensus that recognizes that human-induced climate change shows the limits of its actions. This humble insight is not a restriction of freedom, but can become a source of inspiration. The containment of the imponderables associated with the energy transition will depend on whether citizens are willing to adapt their way of life, their expectations, norms and values to the political goals. This also means that the major parties must have more courage to discuss the impositions and new visions of the future with the affluent society. All this will be necessary if the climate crisis is not to become a crisis for humanity. (IPCC, Sixth Assessment Report, 2021) For this, we especially need new positive and hopeful images of the future for which it is worth fighting, arguing, and working.

After years of being used as “sewers”, lively fish are swimming in the rivers again. The sulphur fumes from power plants are a thing of the past. The air in the cities has become cleaner thanks to car catalytic converters. International efforts have drastically reduced the hole in the ozone layer. This positive list can be continued. There is always much to be done. The structures of a new global energy system are already visible on the horizon. The “fossil world” still dominates, but in recent years global investment spending on solar and wind plants has been higher than spending on fossil power plants. More and more green funds are investing in climate protection projects. To produce goods, the specific energy input is continuously reduced. And there is also a mosaic of many new visions of the future: we are transforming the previously car-oriented city of cars into a colorful city with lots of greenery, small shops, crafts, and affordable housing. Autonomous mobility will become more convenient and environmentally friendly. In the future, we will have farmers who are committed to animal welfare and organic farming. Consumers who don’t follow every fashionable trend, but focus on durable quality.

All over the world, ideas are already becoming visible. Nothing changes overnight. It takes time for a local idea to become a big movement. At the next UN World Climate Conference in Glasgow this autumn, perhaps the awareness will prevail that the global community expects more than mere tongue-in-cheek statements, but concrete, verifiable action. But this presupposes an awareness that accepts that all material goods, which are firmly anchored in the center of our lives, cannot be had without the consumption of raw materials and energy. They are our existential basis of life. We have an open society with its great creative potential that can show its strength here. A society that succeeds in embracing the imponderables of the energy transition will be able to be proud of its climate-neutral, reliable and affordable energy system at the end of 2050.

How do we want to live in the future? For a liberal democratic society, this is an exciting, emotional and perhaps even vital question. Discussing this is overdue. This is the challenging task of the new government resulting from the 2021 election in Germany.

Note

The orders of magnitude used are based on the most recent study by Forschungszentrum Jülich, “Wege für die Energiewende”, Jülich 2020, www.fz-juelich.de/zb.. Other relevant studies come to similar conclusions.

The Hellenic Association for Energy Economics (HAEE) is pleased to host the **17th IAEE European Energy Conference *"The Future of Global Energy Systems"***, in **Athens**, from **21 to 24 September 2022**, **the first physical IAEE European Conference in the post Covid-19 era.**

CONFERENCE OVERVIEW

We live in a time of unprecedented challenges for the energy sector. As the world begins to recover from the COVID-19 crisis, it becomes evident that the pandemic has brought to the surface economic and societal vulnerabilities, while its repercussions on energy systems have already started to become apparent.

On top of that, addressing the challenges of the energy trilemma seems more imperative than ever. National energy systems' resilience is dependent on their energy mix and the changes brought by decarbonization, digitalization and demand disruption. Additionally, although efforts are being made, millions of people still lack undisturbed access to affordable, reliable and sustainable energy, and hence energy equity is still lagging behind. As for the environmental sustainability of energy systems, many nations' struggle for decarbonization is counterbalanced by the rapid increase in energy consumption. Taking also into account that different national contexts lead to divergent energy policies and associated costs, there can be no single way for an effective energy transition.

In this framework, the Conference will provide an excellent platform where government officials, institutional leaders, renowned academics and corporate leaders will have the chance to meet, exchange views and address all the pressing issues of the energy sector.

WHO COULD 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
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Deadline for abstract submission: **18 April 2022**
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Institutional Factors for the Energy Transition: the Case of Chile

BY JAVIER BUSTOS-SALVAGNO

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Introduction

The world is undergoing an energy transition where different transformational forces are impacting the way energy is produced and used. It is generally recognized that decarbonization through the replacement of fossil fuels with renewables, digitalization that enables progress in smarter systems, and decentralization that facilitates the use of local energy sources, correspond to the predominant characteristics or trends of this new energy transition.

Under the framework of such trends, Chile, as well as other developing countries, has proposed to advance in the search for an economically, socially, and environmentally sustainable energy sector. At the same time, since the Paris Agreement, climate change commitments have grown in importance. In January 2020, the Chilean government committed to achieving carbon neutrality by 2050. Consequently, the current energy policy includes different measures that try to achieve a variety of goals in terms of emissions reduction, access to clean energy, use of distributed resources, among others.

It is worth asking whether the institutional framework in the energy sector is in line with the challenges presented by this transition, given that their original design was conceived in the 1980s for an energy sector based on the use of fossil fuels, with centralized and integrated energy production to reduce costs, and users as passive consumers. It should also be added that the challenge of the energy institutional framework should not only be understood in the technical scope of the aforementioned trends, but particularly from the social consequences they imply, given that today's society demands new standards of transparency, access, diversity and participation in decision making.

The institutional design is relevant, beyond the technical quality of standards and public programs, becoming relevant how they are developed, what incentives and balances exist in view of the weight of different actors and accountability mechanisms, as well as whether energy users finally accept them or not. Thus, it is possible that objectives, for example, of decarbonization, are not achieved, not because they are not proposed, or because regulations are not imposed or actions and roadmaps are not established for their achievement, but because the existing institutional design and governance in the sector are not providing the appropriate framework for this to occur.

Thus, the energy sector may end up in a case of failed energy transition, where opportunities are not taken advantage of, where energy policy objectives are not met or where the new socio-technical paradigm to be implemented is not socially validated.

What should we understand by "institutions" in the energy sector?

At this point it is convenient to define what we mean by "institutions" applied to the energy sector. Following the approach from institutionalist economics (North, 1990; Williamson, 1985; Ostrom, 2005), institutions are understood as rules, norms, and conventions - formal and informal - that frame the incentives that organizations have and on which they act. Organizations include both private actors and public bodies, which are subject to institutional norms, both formal and informal, incentives and sanctions. Therefore, understanding the effect that an energy transition can have requires consideration of the institutional environment in which it takes place.

The energy sector can be understood as a type of socio-technical regime (Smith et al, 2005), where markets and regulations coexist with the expectations, beliefs and values of the actors in the sector. Thus, the incentives and behavior of the actors will be conditioned by the socio-technical regime. In short, the objective of the energy transition is to "dislodge" the current socio-technical regime to make room for new configurations.

To understand how the new energy regime in transition and the previous regime differ and what they share, I will now describe the principles and bases of each.

a. Fossil-centralized energy regime

The current regime in the Chilean energy sector is based on the reforms implemented in the 1980s. The principles of this regime can be summarized in three: economic efficiency, energy security and subsidiarity of the State. Under these principles, the country seeks to develop those energy resources that have a lower total cost. The objective is that any technological change that reduces the costs of a technology could be quickly reflected in the cost of supply to consumers. Given the technological development prevailing in the 1980s and 1990s, this meant that fossil resources were used primarily, but also hydroelectric resources that the country still possessed in abundance. In any case, this regime also favored the importation of natural gas from Argentina in the 1990s. In short, this is how technological neutrality is enshrined as the basis of the fossil-centralized energy regime: it does not matter what the technology is if its use is cost-efficient.

Thus, because of the efficiency principle, the development of energy infrastructure was designed to take advantage of economies of scale and density, both in electricity generation and in its transportation and distribution. The same applies to the transportation of fuels, either by importing Argentine natural gas or LNG through port terminals.

The second principle established that energy supply must have adequate availability and security, balancing the costs of supply restrictions with the investment and operating costs required to reduce such restrictions. Thus, it is not efficient to avoid system failure at any cost. Given the lack of abundant fossil resources in Chile and the need to import them, ensuring energy independence understood as autarky was never a policy objective in this regime. On the contrary, what was relevant became the provision of a reasonable energy independence for the country, promoting the diversification of supply sources, both local and international.

For technological cost reductions to be translated into lower prices for end customers, it was essential to have competitive and transparent markets with low barriers to entry. To this end, Chile was inclined to liberalize the sector, establishing the subsidiarity of the State as a guiding principle. In the specific case of the energy sector, subsidiarity means that the State does not exercise business activities in this sector, to the extent that these are or can be exercised by private entities. To this end, the role of the State is to provide an eminently technical regulatory body that defines the boundary conditions for interaction between private agents. The active role of the State was reserved, for example, for the provision of energy access to remote locations.

Finally, one of the characteristics of the old regime is the passivity of the energy user or customer, who simply makes her consumption decisions based on price signals. She does not participate in the production chain nor is she considered to be able to contribute to demand management. Thus, the infrastructure is thought of in a unidirectional way, from production to consumption only. Thus, the user is also not conceived to participate in the technical or regulatory discussion of the sector. The regulator was there to protect their interests.

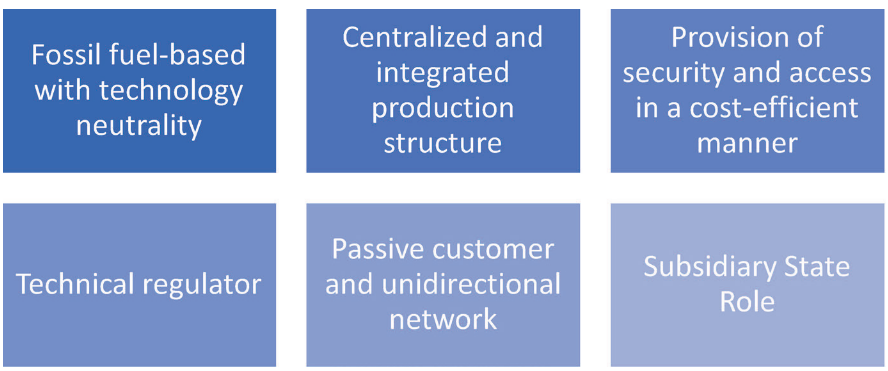

Figure 1: Characteristics of the fossil-centralized energy regime in Chile

b. New energy regime

It should be noted that the foundations of the new energy regime do not imply disregarding the forces that shaped the old regime. Indeed, cost-efficiency is a principle that is still present. However, the new regime is more complex because of energy transition trends. Thus, for example, it is no longer possible to speak only of energy security, but the new regime broadens the concept to include resilience, through adaptation to climate change. Also, access to energy remains important, but the demand for quality of service becomes more relevant.

Some of the characteristics of the new regime are evident because of the transition from fossil fuels to renewables. However, this is the result of forces that already existed, such as cost-efficiency, given that technological change has made them as or more competitive than traditional technologies, as well as new forces such as the need to decarbonize to reduce GHG emissions or the social pressure to reduce local pollution. The same happens with the development of distributed generation and storage as alternatives for the development of an equally or more efficient electric system, which reduces the impact of the energy infrastructure in the territory.

Other characteristics of the new regime are the result of forces that were not present in the old regime and are not part of the energy transition, although they are facilitated by the trend towards digitalization: the demand for citizen participation. Unlike what could be observed in the old paradigm, where the citizenry was conceptualized as a mere recipient user, in the new regime the user is not only active in terms of production considerations or efficient management of their energy consumption, but at the same time demands to participate in the definition of objectives and actions of public policy in this area.

The complexity of an energy system that is moving towards decentralization, with complex public policy objectives (for example, mitigation and adaptation to climate change) has redefined the bases of State action. Without abandoning its strictly subsidiary role (the State continues not to get involved where other actors can do so), it has come to take actions and define instruments to achieve energy policy objectives that go beyond the merely technical sphere. For this very reason, the governance of public agencies in energy matters has become more complex. It is no longer sufficient to have a technical regulator that defines tariffs, rules and regulations that provide a framework for the interaction of private agents. On the contrary, it has been necessary to advance in a sectoral political authority with the creation of the Ministry of Energy in 2010, to define energy policy objectives in 2015 and design concrete actions to achieve them. Likewise, the complexity of the sector's interaction has increased, requiring progress in new bodies, some of them independent, such as the independent system operator in 2017 to ensure adequate interaction between the different agents, both public and private.

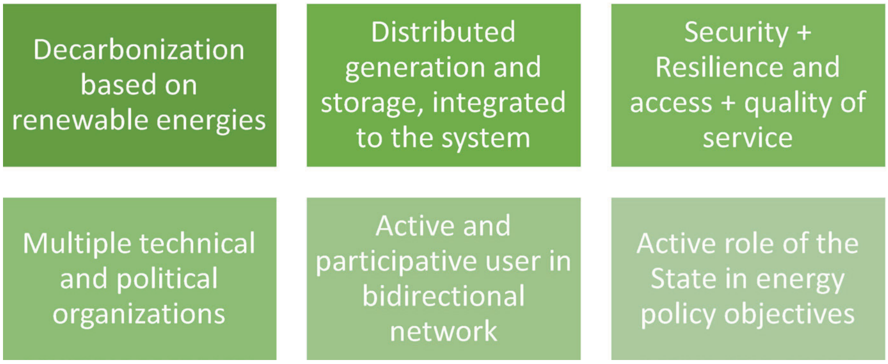

Figure 2: Characteristics of the new energy regime

How the institutional design can shape energy transition's success

According to the IEA, Chile has emerged as a world-class destination for solar and wind energy developers with legislation that encourages investment in generating capacity across the electricity sector. By July 2021, 28% of installed capacity corresponds to non- conventional renewables, which represents more than 7,3 GW, and there are 5 GW under construction.

The institutional drivers that allowed this renewable boom that started several years ago are credible commitment from the government, formal rules that contribute to complying with international climate change commitments and collective choice rules leading to monitoring.

Chile's first renewable legislation was enacted in 2008, first to reach 10% of the wholesale market and then the goal was level up to 20% in 2013. Also, electricity auctions for long-term contracts were enhanced in 2014 to foster competition in the generation market, increasing the participation of renewable generation. All these policies and a long-term goal of reaching 70% of renewables by 2050 create a credible commitment for the decarbonization process.

Complying with international commitments on climate change also contributed to renewable growth. Not only the Paris agreement but the more recent 2020's NDC where Chile committed to carbon neutrality by 2050. Perhaps one of the most important instruments to reach that goal started in 2019 with the public and private agreement on coal phase-out by 2040.

To achieve renewable energy targets, countries need formal and informal institutions to monitor compliance. Formal institutions include fines and other disincentives for non-compliance that discourage future non-compliance. In Chile, regulatory mandates were included in the legislation, but they were never used, since renewable growth outperformed the original projections of the regulator. Informal institutions, on the other hand, worked well in different communities where renewables were perceived, at least at the beginning, as less invasive and more environmentally friendly.

However, there are other situations where the current institutional framework did not work as well. As it was mentioned, energy development has historically taken the energy user only in his role as a customer, receiving prices that give her the right signals for her consumption. Under this paradigm, a smart meter policy was implemented in 2017. The idea was to deploy 6,5 million smart meters by 2025, reaching full coverage in distribution networks. The deployment was mandated to distribution companies, the cost of it was calculated by the regulator and paid by the consumers as an additional monthly charge in their bills. This is a good case of fossil-centralized perspective, even when the final goal was to contribute to a smarter network that could foster distributed generation and renewable use. First, the decision and estimation of the cost was made by the technical regulator through a regulatory process with the participation of only distributors, suppliers, and sectorial experts, but without any role for customer's organizations and other stakeholders. Second, the role of the customer was entirely passive since he could not decide anything about the process. Third, considering the subsidiary role of the state, the deployment must be made entirely by private distribution companies without any participation of public organizations, not even communication campaigns to explain the process. Finally, since the distribution company oversaw the deployment, all the process was vertically integrated and centralized at the natural monopoly.

When smart meters cost was included in electric bills by 2019, public debate on the benefits and costs for the consumers was very algid. There was a collision between an energy public policy, perhaps well-design according to a different socio-technical regime, with the energy transition regime. Customers demanded participation in the decision to change their meters, transparency in the process of cost determination and a guarantee of a better quality of service. A centralized regulator was blamed for implementing policies considering only the perspective of the utilities. By mid-2019, the Ministry of Energy and the regulator decided to modify the policy and make voluntary for the customer the decision to change the meter. Currently, there is no certainty of reaching a full coverage of smart meters in the following years due to a policy that was thought for a different paradigm and without considering the current institutional setting.

If Chile in some moment decides to discuss again about smart meters deployment, there are a couple of key institutional drivers to take into consideration. First, stakeholder participation where customers feel that their interest are consider in the process and decision are not taken arbitrarily by a centralized authority. Second, rules that facilitate innovation. Given the challenge of technological change in the energy infrastructure, it is important to have pilot programs and measures to facilitate innovation in the sector, considering that it is necessary to advance in a trial-and-error process. Third, there should be rules to promote transparency. In general, good information is required for decision making in any market. Information asymmetries generate widely known inefficiencies. Therefore, information transparency, facilitated by stakeholder participation, is very important in an energy transition process. Making information available to the public can generate public support, providing confidence and predictability about new technologies deployment.

What kind of institutions do we need for a successful energy transition?

As Koster and Anderies (2013) show, there are several key institutional drivers that enable a successful energy transition, in terms of renewable generation. To expand the perspective to an energy transition that includes decentralization and digitalization as well, it is necessary to define a concept of "socially accepted energy transition". For example, the centralized renewable development model that requires extensive transmission lines and extensive land use may not be socially validated and may end up being unsustainable. Or it may also be the case where the digitalization and decentralization of the sector occurs incompletely, due to the perception that new technologies are invasive or that they only benefit incumbent actors, resulting in a segmentation of the energy market between users with access to renewable energies - typically high-income - and other users with lower resources who must make do with fossil fuels and pollutants.

Also, public policies that facilitate energy transitions must be conceptualized as integrated plans that combine policy with practical physical considerations. In the case of energy, the public policy cannot simply focus on making rules and expecting compliance. Public policies must consider the existing energy system and the possible trajectories of change given it. For example, the inertia of the existing system is very important for the implementation of renewable energies. To integrate renewables into the grid it is necessary to modernize existing grids or create new systems. Therefore, it is important how the rules that do or do not facilitate new renewable technology being able to "retrofit" into existing infrastructure work.

Finally, it is important to recognize that we are transiting from a centralized regulatory governance to a polycentric governance. It would be very important to balance an increasing diversity of organizations and the required coordination among them. The resulting governance it is expected to be very country specific, depending, at least, on historic and geographic considerations.

In sum, the Chilean experience is a good example of how the energy transition is impacting on the institutional design of the energy sector and how relevant institutions are to have a successful transition, where costs and benefits are well-distributed, and the paradigm shift is socially accepted.

Acknowledgement

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Modeling the Transition to a Low-carbon Energy System - How can an Agent-based Model Approach Complement an Optimization Model Approach

BY JINXI YANG

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Abstract

When modeling the energy transition, the agent-based model (ABM) approach is far less used compared to the optimization model approach. However, an ABM has the advantage of including important features of the energy transition such as heterogeneous characteristics of decision-makers, bounded-rationality, historic path-dependency, etc. This article illustrates and discusses how an agent-based model can complement an optimization model.

Modeling the transition to a low-carbon electricity system

When studying the energy transition towards zero CO_2 emissions, a wide range of computational models have been employed for assessing its feasibility, consequences and costs. These models are useful as they may help decision-makers understand the potential consequences of various policy proposals and make informed decisions.

Among different modeling approaches, an optimization model approach is the most commonly used one in the field of energy system studies, because it shows the potentially optimal decisions and how a least-cost solution can be reached. Compared to an optimization approach, an agent-based model (ABM) approach is far less used, but its application has been growing, partly because the existing mainstream modeling tools are limited in their ability to include features such as heterogeneous characteristics of decision-makers, bounded-rationality, historic path-dependency of the energy system, imitation and interaction among market players. But all these features can be captured in ABMs in a reasonably simple way.

An agent-based model is typically composed of individual agents and an environment. In an energy system model, an agent can be anything from a (or a group of) power plant(s), investor(s), household(s), bank(s), government(s), social group(s), etc. Each agent individually assesses their situation and makes decisions based on its goals. The observed overall outcome, such as the transition of the energy system, is the emergent phenomena resulting from individual agents' actions and interactions.

One aspect in which the ABM can complement the optimization model is that the ABM captures the heterogeneity of agents and can investigate how does this heterogeneity impacts the agents' actions and interactions, and thereby, impacts the overall system. For example, in the field of energy transition study, one group of agents that embodies heterogeneity is the investors. Different investors can have different levels of risk averseness, they may have preferences for different types of technologies, and they may have different beliefs about the future climate policies, etc... In the following section, we demonstrate the implementation of such heterogeneity in an ABM and show the individual investors' different investment choices.

A simple example of using an ABM

We have developed the HAPPI (**H**eterogeneous **A**gent-based **P**ower **P**lant **I**nvestment) model and explore the transition to a low carbon energy system[1]. The agents in this model are power companies who make investment decisions in new power plants. The goal of a company is to maximize its profit for each investment. Companies are heterogeneous as they have different levels of risk averseness (represented by the hurdle rate value used by a company). In addition, companies have limited information about how future carbon tax levels and different companies expect different growth rates of future carbon taxes. Some companies underestimate the "real" carbon price, while some other companies overestimate and some correctly estimate the tax price that is implemented in the model.

Figure 1 shows that under an increasing carbon tax scenario, the system transits from a coal- and gas-based to a low-carbon electricity system. Figure 2 shows that heterogeneous companies make heterogeneous investment decisions. Companies that are using lower hurdle rates (first two rows of Figure 2) are in general more willing to invest, and they invest more heavily in wind and nuclear compared to companies that use higher hurdle rates. This is because a low hurdle rate lowers the investment cost of wind and nuclear plants more than the coal-fired power plant. It is interesting to notice that, after an initial expansion, the installed capacity of wind declines some twenty years later due to competition from nuclear, which then expands significantly. The impact of a low hurdle rate is thus different for wind and nuclear in the long run (Yang et al., 2021).

Another observation is that in the beginning years, while those companies who underestimate carbon tax (the first two columns in Figure 2) invest in coal power plants, companies that expect high carbon prices (the last two columns in Figure 2) start early in investing in

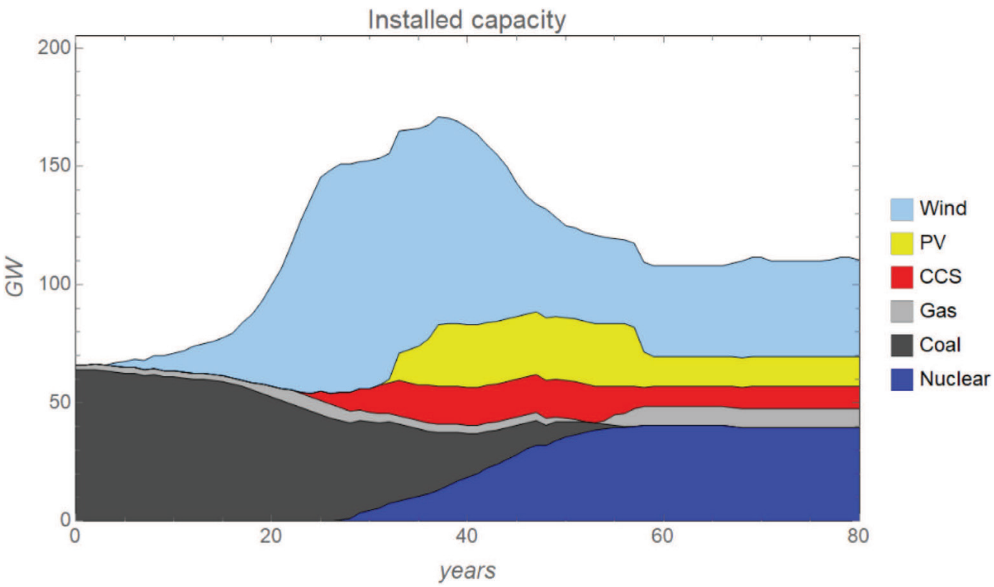

Figure 1 System installed capacity from year 0 to year 80 in the base case. The installed capacity of coal starts to decline around year 5, while wind starts to grow, and then decline some thirty years later due to competition from nuclear, which then expands.

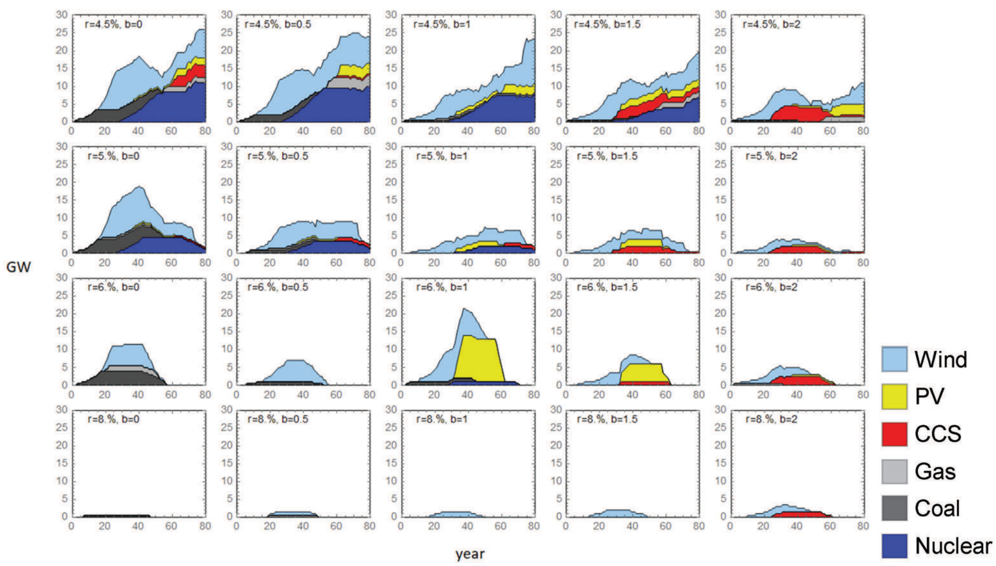

Figure 2 Installed capacity of 20 individual companies in the base case. ***r*** *is the hurdle rate agents use and* ***b*** *is the expected carbon tax parameter (for more detailed figure description and the model description, see: https://research.chalmers.se/publication/525564/file/525564_Fulltext.pdf)*

gas-fired plant with CCS, as they expect a higher carbon tax and therefore, estimate that the CCS technology would be profitable to invest.

How can ABM complement the optimization model approach?

This simple example above illustrates that the ABM can complement the optimization model approach by modeling the behavior and investigating the outcome on a micro-level. This micro-level modeling is important for the energy transition, because it is what happens on the micro-level that determines what will be observed on the macro level. As illustrated above, individual companies' investment choices determine what types of plants the system will have, therefore, depends on individual companies' investment choices, the transition to a low-carbon energy system may be accelerated or hampered.

Additionally, in an optimization model, it is usually assumed that decision-makers have perfect foresight, but, decision-makers have limited information, especially about the future, therefore, the optimal decisions showed in an optimization model may be hard to reach in reality. Hence, by comparing modeling results from an optimization model and an ABM, we may identify the differences and the reason for the inconsistancies. We may also identify difficulties or even infeasibilities of the transition pathways that an optimization demonstrated, and this might help to make more realistic model assumptions and even helps to make more effective policies for achieving the energy transition goals.

Footnote

[1] For more information about the study and the model, see: https://research.chalmers.se/publication/525564/file/525564_Fulltext.pdf

Reference

[1] Yang, J., Azar, C., Lindgren, K., 2021. Transition to a low-carbon electricity system — investment decisions under heterogeneity, uncertainty and financial feedback, https://research.chalmers.se/en/publication/?id=525564.

Unbundling the Energy Union: Energy Transition Governance and Review Framework

BY ANDREW KILMARTIN

Abstract

Decisions and change management are crucial to energy transitions. We need a framework that can capture the whole energy system transition and its challenges and opportunities. An independent and transparent decision quality framework can provide the policy governance and facilitate a strategic Cost Based Analysis project review based on value and utility.

Unbundling the energy union….what are we dealing with?

The energy transition is gaining momentum, backed by consensus over climate change impacts and the need to reduce or limit carbon emissions. The Energy Union is one of the programmes designed to deal with the energy transition in the EU. Yet, there is no clear consensus on how to achieve its aims collectively. More specifically, despite nationally determined contributions, there is a lack of a unified and coordinated intra or inter-regional response.

If we do not change the way we develop policy or select projects and market mechanisms to implement policy, we will not optimise the way we make investment decisions. This will affect how we manage the transitional energy mix over the next 20-30 years, and, if not kept in check, may result in policy makers losing control of the transition. We therefore urgently need a framework that can help ensure that we make the right decisions and ensure seamless changes during the transition period. This way, the efforts to achieve emission reduction, efficiency improvements, and interconnectivity targets can be managed strategically so that the market and sector coupling ambitions are realized and the transformation to net zero or low carbon is achieved.

If mismanaged, the transition process may lay waste to both renewable and non-renewable efforts, e.g., lack of storage and an infeasible energy mix restricted by transport and congestion issues. During the transition we may also experience a glut or shortage in capacity where insufficient storage and operational control problems cannot address market balancing and we could suffer excessive curtailment or extreme price volatility as a result. Worse still, we may end up with stranded assets on both sides of the renewable and non-renewable asset portfolio which will exacerbate the challenges of change and ability to manage the transition.

To that end we need to consider introduction of a framework that allows for governance of the policy process and simultaneously provides a comprehensive and collective review of the projects of common interest and application of policy mechanisms to realize policy implementation. This will ensure transparent and insightful appreciation of the policy impact and ensure that we have information to support and ensure that good decisions are made to deliver the change required. For that reason we should consider the Decision Quality (DQ) framework (Spetzler et al, 2016) to provide for good policy governance and infrastructure project and market mechanism impact review.

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Unboxing and reading the instructions … Policy Governance and Project Portfolio Review!

The energy transition is probably the biggest challenge that EU industry and society has faced in recent times. So much is at stake, and yet, so much uncertainty and debate prevails. On returning to university after 20 years in the energy and marine industry, I embarked on what would become an interesting career change from operations and engineering to focusing on risk and decision making methodologies. I wanted to understand and understudy how to better frame, structure and how to model energy systems so that we could make better investment decisions.

However, with the advent of sustainability and decarbonisation policy it became difficult to address policy and project dimensions simultaneously. We struggled with how to choose the modeling approach, use the data, and how to analyse the results or understand the insights to support good investment decisions that steer us towards a low carbon energy system. While researching this challenge, I discovered the Decision Quality framework outlined in Fig. 1 (Spetzler, 2016) which succinctly and thoroughly addresses the decision process to ensure we make good and unbiased decisions based on the information we have. I could also see how this could be applied to ensure good governance and provide a review of energy transition policy and implementation challenges.

By using this framework I was able to get a better overview of how policy was determined and how investment decisions were made. I wanted to see if this meant that good policy and good decisions were being made to support the energy transition – but the results were a little surprising. The process is not as transparent as one might hope. Quite quickly, I could identify a series of poor and counterproductive decisions that have been made. It may be that these decisions are a result of bias, overoptimism or overconfidence in new technology or readiness of infrastructure, including exaggerated claims regarding scalability, feasibility, and limited impact or benefits for society. This bias

Figure 1. The Decision Quality Framework (Spetzler et al, 2016)[1]

and over optimism is leading to the evolution of "battle lines" or "camps" in the energy sector between renewable and non-renewable resources, which may harm transition efforts and progress if not kept in check.

That said, the general dedication and focus on efforts to address energy transition challenges and plans for transformation are admirable. However, it seems that much is being left to market forces alone, which can be dangerous during a transition. There does not seem to be a consistent structure or agreed alignment regarding approach and direction in research efforts and subsequent analysis of timing and priority on what needs to be built, what needs to be decommissioned, and what we could salvage through modification and upgrade. This could be attributed to poor framing and lack of consideration of alternatives. We also seem to struggle with unreliable data and subsequently inadequate trade-off analysis which would help us achieve optimal energy mix at various stages of the transition process. Timing and implantation of changes at strategic milestones are paramount to the energy transition. The DQ framework could help highlight this.

In addition, to correctly frame and structure the decision making process and ensure that we have sufficient alternatives and a viable mix of modelling and solving methods, we cannot rely on models to deliver the decision. That is why we need to separate the decision making element from the modelling process, and reiterate that the energy system models and analysis are there to support the strategic decision making. This should be conducted through a separate cost-based assessment module with dedicated decision analysis which is based on model results that give insight into proposals regarding possible or potential energy mix and technological options that can be considered or need to be developed.

Moreover, we need to learn how to set and align the modelling requirements and constraints in the framing process, as it is currently near impossible to compare or combine energy system insights or results or outputs in order to allow for comparative analysis, or to collate the results into a type of confidence or capacity distribution to help the decision makers make informed decisions based on recommendations or insights form the modelling and analysis. Furthermore, we need the Decision Quality framework to illuminate the policy and project decision process to describe how the different model assumptions, constraints, data sets, and methods affect the results or insights attained or derived. This may help us combine or compare models in a much more beneficial and constructive way. In addition, it must be noted that during attempts to aggregate results or solutions, the spatial and temporal considerations between models (short term vs long term, local vs national, macro vs micro) extrapolation or clustering methods are clearly described, as this is often overlooked and ignored and can be (mis-)used to produce biased decisions.

Worryingly, we do not have a handle on stakeholder engagement and management, crucial to any change or transition process. In fact, there is so much debate about where we are and where we want to go that multiple pathways, options and opportunities are proposed, but these are not assessed by stakeholders or agents to arrive at some sort or agreed strategic energy transition at a regional and intra-national level. This means that no negotiation or compromise is resolved pertaining to priorities and timing of infrastructure and projects to meet policy implementation objectives. For example, most of the concrete implementations of EU energy transition decisions are planned and approved at country level and not agreed collectively at a European energy union level. Because of this, some opportunities or benefits may be left too late or lost altogether. If we persist in using "tried and tested" tools, metrics and models to evaluate, select and prioritize infrastructure projects or market mechanisms, we may miss out on potential value, benefits and opportunities that meet transition objectives in a more efficient and effective manner.

We should also remember that the cost based analysis (CBA) tools used in earlier regional development appraisals may not be fit to evaluate projects and infrastructure needs for the sustainable future as these were developed when sustainability and environmental impact issues such as climate change and biodiversity were not fully addressed and these market failures were not fully considered. In addition, financial and economic approaches to calculating project benefits may not be sufficient to bring about sustainable energy systems with limited impact on the environment and avoid market failures detrimental to society as the value or benefits to address these are not quantified or considered. This also affects the analysis to understand what options are feasible and affordable. The DQ can address this and help move beyond NPV. It can ensure that decisions regarding the energy mix and the infrastructure needed support the strategic direction of the transition are identified, agreed and properly specified. In addition, if we look beyond simple NPV analysis and introduce timing decisions (e.g., real options), values of flexibility and values of information, we can address the complexity and uncertainty surrounding the decision making; thus focusing on decisions where utility and value needs to be the main consideration.

We may need to open dialogue between stakeholders responsible for policy (decision board) and infrastructure needs and policy mechanism implementation teams about the decisions we are making and to help review if the policy and the projects or mechanisms that will be implemented are feasible and meet expectations. This review process will help support the decision making process. The Decision Dialogue (DD) (Fig 2.) (Spetzler et al, 2016) may be such a tool to capture these requirements.

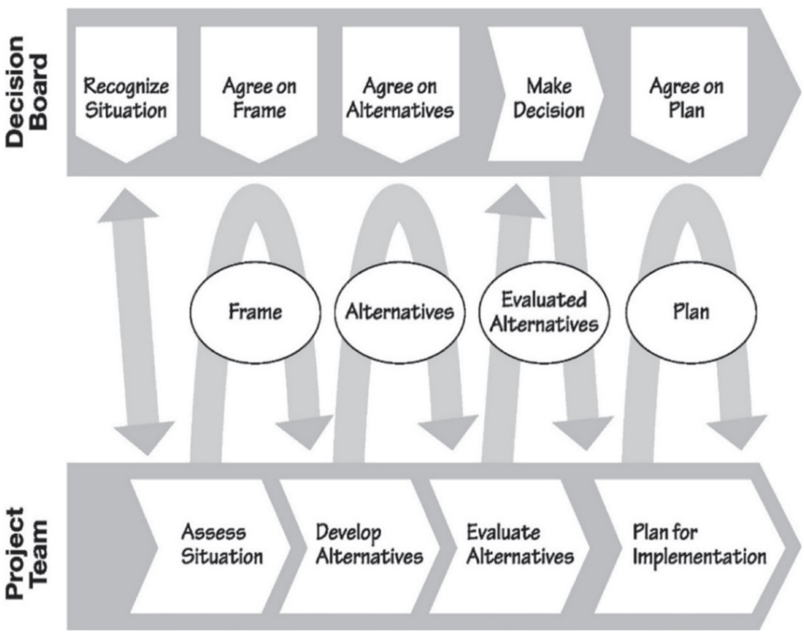

Figure 2. The Decision Dialogue Process (Spetzler et al, 2016)[2]

The decision dialogue above can be used in conjunction with the decision quality framework to help structure the stakeholder engagement and add a portfolio dimension to the policy governance and the project review. This will allow us to step back and get a structured review of our policy proposals and an independent cost-based analysis of the projects, mechanisms, and infrastructure needs that have been identified and approved. By combining policy governance and project reviews through dialogue with specified stage gate and approval points, any bias and over-optimism should be removed or addressed and we will end up with a spread of results that can support decision making which will be properly addressed using robust and appropriate metrics in a cost based assessment module. Maybe we will find or show that current or proposed tools and techniques are not entirely fit for this purpose and what changes need to be made to make comparative or integrated assessments to support the energy transition. Either way, the DD and DQ combined with CBA evaluation will allow for improved policy governance and project portfolios, including introduction of carrot or stick market mechanisms.

This way, any gaps or shortfalls in policy and project or mechanisms used in integrated energy system plans will be highlighted and through CBA moving beyond NPV, i.e. using real options, flexibility or value-based flexibility and strength of knowledge, the timing and urgency issues can be addressed to ensure that the infrastructure needed to integrate the renewable energy sources or lower carbon efforts to help non- renewable sources continue service are completed in time to meet the targets and benefits envisaged.

In addition, any DQ policy governance and implementation review can then be addressed through the DD. Then, the decision making can be addressed using the decision analysis (DA) captured in the established CBA to solve portfolio infrastructure and investment issues where utility and value are central to the process to ensure a successful implementation phase.

Repacking & rebooting …due diligence foundations to build the energy union!

We need a whole energy system approach to allow benefits of all options and mechanisms to be considered so that the timing and use of renewable and non-renewable energy sources can be efficiently and optimally managed before we end up with stranded assets and premature redundant capacity or introduction of infrastructure and renewable capacity that is underutilised. We are all in the energy transition together and the renewable and non-renewable energy industries both have a role to play in the transition phase. So, let’s get together, pool our resources, share our experiences and knowledge and learn to work together and contribute in a proactive and tangible way to achieve the low carbon society we need!

But, while doing so, we need to ensure that we address the correct situation, frame and structure the challenge correctly so that the modelling can throw up alternatives. We can then evaluate using the CBA with built in value and options. All of this can be addressed using the DD in conjunction with the DQ in tandem. So let’s get the governance and review process moving and by creating a dialogue around the process include all the stakeholders and show unbiased (and hopefully enlightening!) transparency surrounding the policy and decision process so we can learn to understand limitations of older approaches, address the market failures and keep the energy transition on track.

I am confident that by removing barriers to integration of renewable and non-renewable energy sources, through delivery of a coupled energy market and sector energy system, we will be able to resolve market share issues during the transition. This needs to be developed in conjunction with sufficient and suitably scoped and specified interconnection and storage based on value and utility. This will also help alleviate prevailing bias and feasibility issues concerning integration of the most viable and feasible energy sources that can make up a secure and reliable energy mix. Removal of these obstructions will allow constructive efforts to get on with the transition as we have no time to recover from bad decisions. This is necessary to avoid irreversible damage to a fragile start to the energy transition and avoid any further unnecessary delays in essential investments and infrastructure in either renewable or non-renewable entities to support the transformation we envisage. We need everyone to support this endeavour, such that a just transition where collaboration, diversification, innovation, sustainability and decarbonisation is on top of everyone's agenda.

By Andrew Kilmartin, Early Stage Researcher, The University of Edinburgh, Institute for Energy Systems. PhD Project Titled: "Energy market design to support the energy transitions"

Acknowledgements

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Footnotes

[1] Spetzler, C. S., Winter, H., & Meyer, J. (2016). *Decision quality : value creation from better business decisions*

[2] Spetzler, C. S., Winter, H., & Meyer, J. (2016). *Decision quality : value creation from better business decisions*

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The Short-lived Electricity Reform in Mexico and the Expected Aftermath

BY MARÍA EUGENIA IBARRARÁN AND ALEJANDRO RODRÍGUEZ CHACÓN

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Abstract

The 2013 Energy Reform in Mexico led to lower wholesale electricity prices, an increase in renewables in the energy matrix, and lower GHG emissions. Changes will fade under the counter-reform proposed by President López Obrador.

Introduction

Since the nationalization of the Mexican Electricity Industry in 1960 and until the Constitutional Reform of 2013, the Federal Electric Commission (CFE) was in charge of power generation, either through its own resources or with private investment. However, the only buyer of that energy was CFE, a de facto monopsony, who in turn was responsible of transmission and distribution networks. This is shown in Figure 1, that also illustrates self-supply could be for the generator´s own use or for other users.

The power company CFE charged a tariff for the service that they calculated and was then established by the Ministry of Finance. Often this tariff did not cover operating costs and therefore a subsidy scheme was required, where domestic and residential rates were subsidized by more than 50%. This low cost to some users was absorbed by commercial and industrial consumers that paid higher tariffs, above those in the US, Mexico´s main trading partner, reducing Mexico´s competitiveness. This price structure brought problems to CFE because year after year they operated with losses. This, together with the projected increase in demand and the lack of capital to make the required investments in generation, transmission and distribution led to the urgent need for a new model in the electricity sector.

The 2013 Energy Reform

The goal of the Energy Reform was to create competition in the power market to lower prices and reduce the burden on government resources by allowing private investment. Under the reform, CFE now competed with private generators to enter contracts with users, through figures created by the reform, such as Qualified Supplier and Basic Supplier Services that now represented consumers in the Wholesale Electricity Market (WSEM). The transactions made in this new market were made through the Spot Market which is operated by the National Energy Controller (CENACE by its acronym in Spanish) or through bilateral transactions (which must also be notified to CENACE). This new structure of the electricity sector is shown in Figure 2.

Transmission and distribution remain the responsibility of the CFE, which charges for this service through rates within the WSEM, and was regulated by the Energy Regulatory Commission (CRE by its acronym in Spanish). The reform also sought to incorporate renewable energy power plants to reduce greenhouse gas emissions and local air pollutants, and produce cheaper electricity.

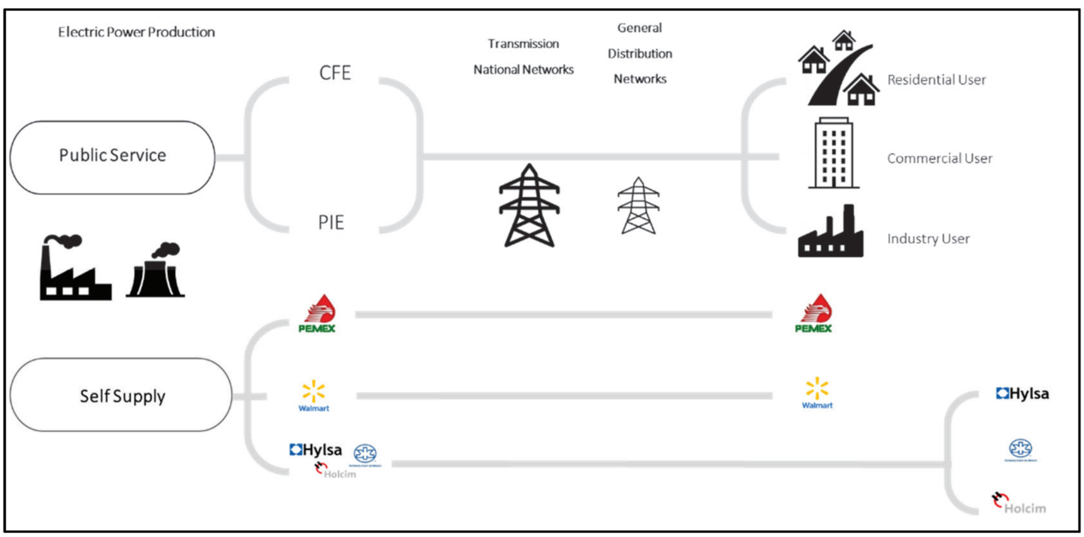

Figure 1 Electric Industry Structure before the 2013 Energy Reform
Source: Prepared by authors.

Some Background

Since 1960, when private sector companies were nationalized, Mexico entered into a model of public monopoly. This led to higher power prices and to productive inefficiencies or inefficiency X. This resulted from the

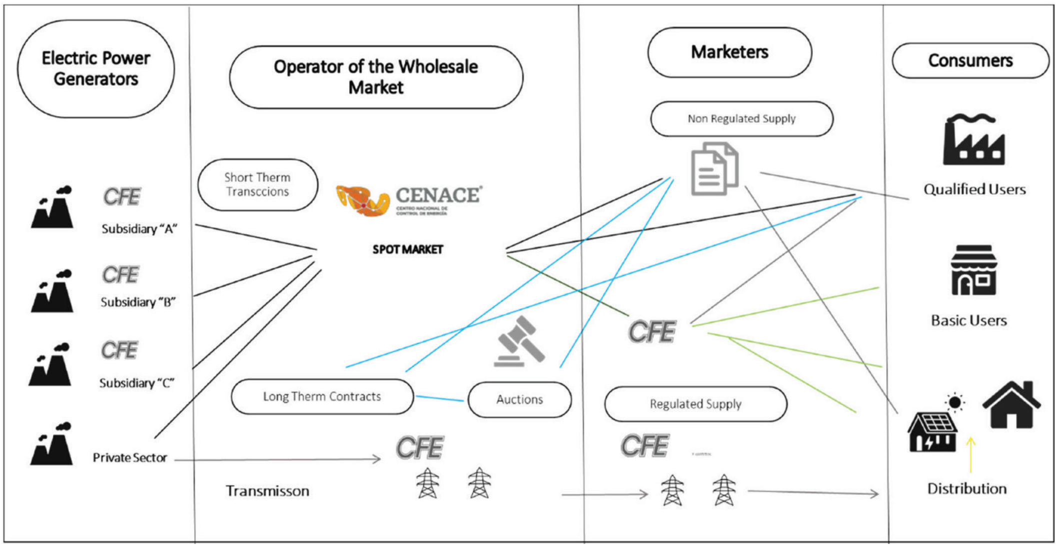

Figure 2 Electric Industry Structure after the 2013 Energy Reform
Source: Prepared by authors.

absence of incentives to reduce costs and improve management due to the absence of competition. This drove the costs of CFE above the costs of a competitive firm, and the state monopoly model did not allow either production costs or final prices to decrease. This market structure was supported by those who thought that public goods and services must be a monopoly since they are considered strategic and priority sectors in public agendas. Additionally, economic theory states that private monopoly has an objective function of profit maximization. In contrast, the public monopoly will not seek the maximization of profits and the price of the monopolist will be marked by its costs, that is, its benefits can be equal to or less than zero. In the case of Mexico, prices in the energy sector in both state (public) monopolies, CFE and PEMEX are even below costs, leading to a need for subsidies due to high production costs and the interest of the government in keeping prices low.

The 2013 Energy Reform, and in particular that of the power sector, was paradigmatic since it questioned the prevailing market structure and made a bet for competition within the sector.

In the case of the electricity sector, the reform brought competition into the market, although not of perfect competition given the highly capital-intensive market, it is open to the entry of new participants through a cost-based market model, where producers (generators) make their electricity offers based on their variable costs, in this case determined by the cost of the fuel for power generation.

In this new wholesale market scheme, the independent operator (CENACE) programs generation of individual plants through an economic dispatch. This means that the power plants that produce and inject energy into the system on the day of operation will be assigned in ascending order of costs. The intersection between supply and demand will set the price of energy (or local marginal price), thus seeking to generate the incentives for the incorporation of more efficient power plants, which will provide the consumer the best available price.

Thus, under the reform and following the figure of economic dispatch, electricity prices should fall as the cost of production with renewables is reduced and as renewables increase their share in power generation.

Indicators

There are different indicators that allow an evaluation to be made of the development and performance

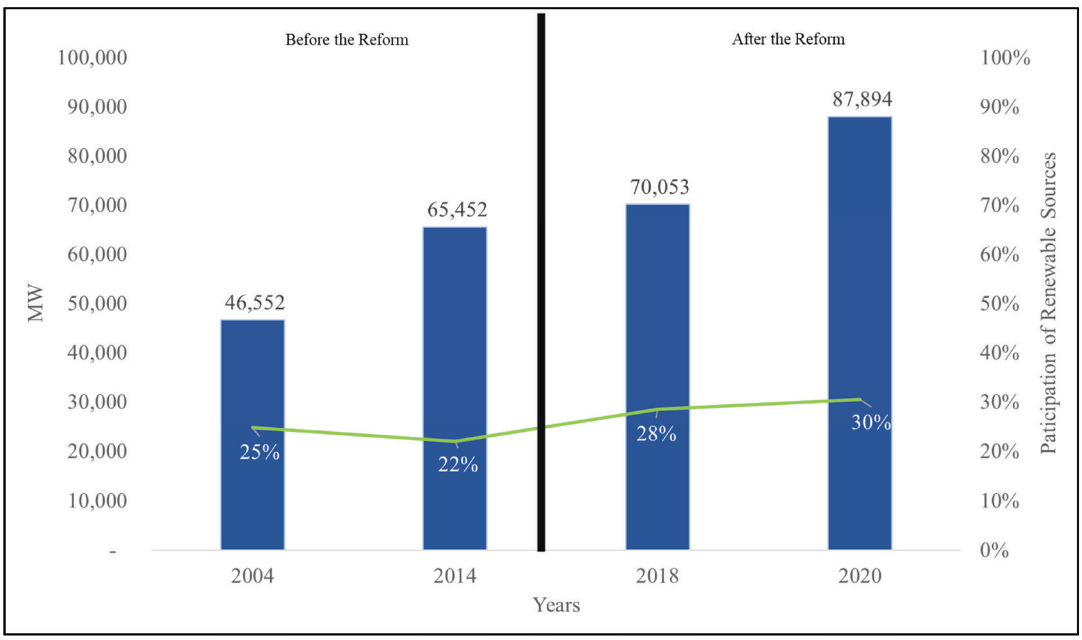

Figure 3 Installed Capacity and Renewable Energy Participation
Source: Prepared by authors based on SENER's data.

of the Mexican Wholesale Electricity Market. We review four in the remainder of this note: installed capacity, prices, and greenhouse gas emissions, and the financial situation of CFE.

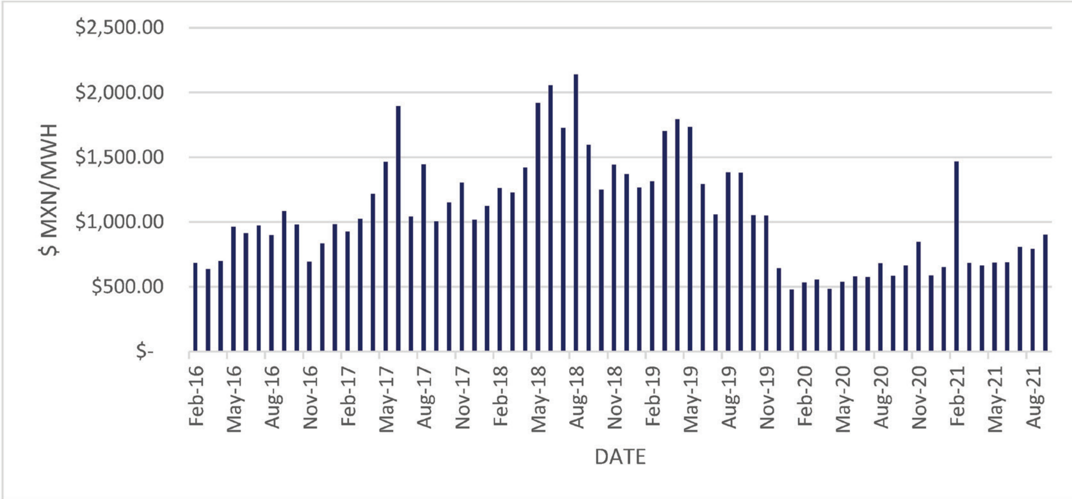

Figure 4 Historical behavior of the Local Marginal Prince in Querétaro Potencia
Source: Prepared by authors based on CENACE´s data.

Installed Capacity

On the one hand, we have the supply of energy, which is a determinant for prices within the market. A good proxy for this variable is Installed Capacity, that had a growth rate of 34% between 2014 and 2020. In addition, not only more generation was installed but more renewable energy plants were put in place, increasing from 22 to 30% of generation capacity, as seen in Figure 3. However, during that same period, the participation of CFE went from 83 to 51% in the sector. This means that most increase in installed capacity was built by private participants, who entered due to the reform.

Now, more Capacity with more renewable energy supply has two impacts: lower prices and a decrease in greenhouse gas emissions.

Prices

One of the indicators that can be used to evaluate the evolution of the electricity sector in Mexico after the 2013 reform, are the Local Marginal Prices, because they reflect the intersection between electricity demand and supply of power in the country.

According to the Independent Monitor of the Electricity Market, the fact that capacity has been expanded with lower fuel costs from renewable energy has been one of the determinants in the decrease in Local Marginal Prices (LMP). The historical behavior of LMP, taking as reference the prices in the Day Ahead Market of the Price Node "Querétaro Potencia", which is used as the reference node of the National Interconnected System, is presented in Figure 4.

However, domestic electric tariffs remain high. This, to the eyes of many, proves that the Energy Reform failed. The question that arises is, if more efficient power plants have been incorporated and local marginal prices have been lower, why haven't the tariffs to consumers come down? There are two parts to this answer. First, as shown in Figure 5, most of the energy that the Basic Services Supplier (SSB due to its Spanish acronym) count on, belongs to the Legacy Contracts, power plants owned by the CFE and those who had signed contracts with the CFE long before the reform took place. These power plants are old and inefficient.

On the other hand the cheapest energy available was awarded with the Long-Term Auctions that barely have any capacity because they disappeared in 2019. Something similar happens with the energy purchased in the Mexican Electricity Market (MEM), that even though the prices are low their share is not enough to supply the needs of Basic Users. It is worth mentioning that according to the Electric Industry Law (LIE by its

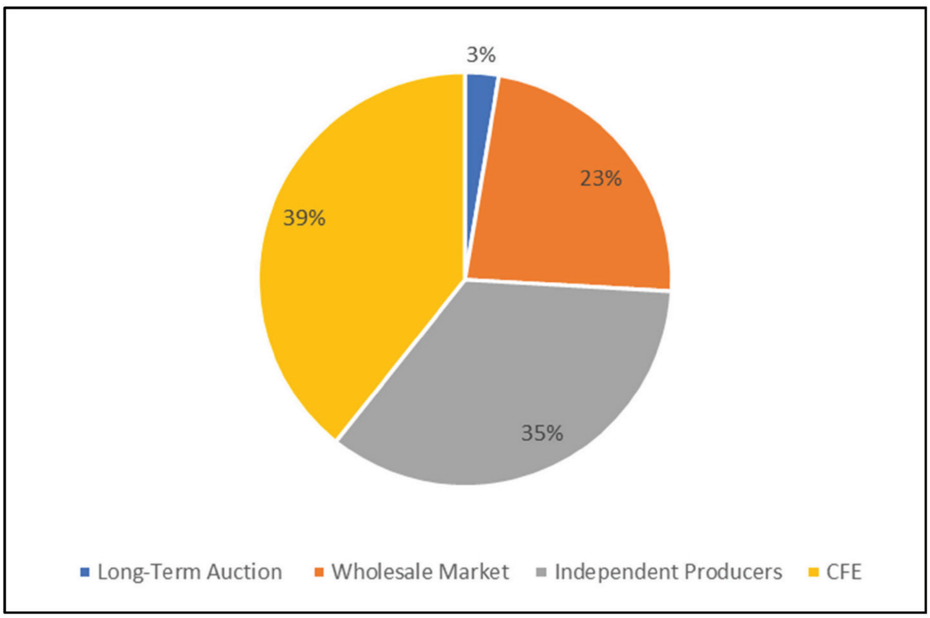

Figure 5 Basic Supplier Energy Matrix 2019
Source: Prepared by authors based on CFE´s data base (2021).

Spanish Acronym), the SSB have to buy the least part of its energy in the MEM. Given the cancellation of the Long-Term Auctions, CFE has chosen to breach that mandate.

The second part of the answer is that the SSB charges a regulated tariff, set by the Energy Regulatory Commission, and ratified or modified by the Ministry of Finance under non-transparent criteria so this final tariff price may not reflect the improvement in efficiency by CFE. The spirit of the reform was to reduce the costs of electricity generation for all participants, and to CFE in particular as its generation costs were lower due to the incorporation of more efficient energy and the removal of the more expensive power plants. This should be reflected in the tariffs.

It is important to highlight that since the beginning of the administration of President López Obrador, the removal of old power plants stopped and were instead refurbished, resulting in additional costs for CFE and keeps in operation expensive and polluting technology. During the process, the impact of the reform may not be reflected in the domestic tariffs, but it might in the amount of subsidy by the Federal Government, because if the costs are lower the amount of subsidy necessary should decrease to maintain tariffs at similar levels. Thus, the future behavior of electricity tariffs seems uncertain because of the government´s intention to strengthening CFE.

Greenhouse gas emissions

Climate change has been an issue that has gained relevance in the international agenda. Both of the Paris Accord and of the Sustainable Development Goals have concrete commitments endorsed by Mexico. Historically, electricity generation has been responsible for an average of 30% of total CO2 emissions, and they come from the burning of fossil fuels (Figure 6).

At the beginning of the Energy Reform, total emissions of CO2 from electricity production were growing steadily, however, the trend from 2016 has changed, as Figure 6 shows.

Nevertheless, recent investments have been towards refurbishing gas-powered power plants such that by 2020, 56% of the total installed capacity in Mexico is fossil fuels based. Looking to the future, if power plants that produce with natural gas were replaced by solar and wind capacity, emissions will decrease, and with the Reform of 2013, substitution was expected to occur progressively.

Finances

Despite of what most people think about the Reform, the financial situation of CFE was improving. This is because turning a vertical integrated company into an horizontal integrated one, new business areas opened, such as the sale of fuel to third parties. Production costs have remained at levels similar to those seen before the reform, however, the revenues increased. This diversification has allowed to go from experiencing losses until 2016, to reporting profits during the next 5 years after the Wholesale Market opened as shown in Figure 7.

Thus, the monopolistic structure prior to the implementation of the Reform was not only harming the consumers (commercial and industrial users), but also to CFE due to high production costs from using outdated technologies to generate electricity. The characteristics of this market denoted the need to eliminate or reduce inefficiencies given by the structure of the sector. To cover for inefficiencies, subsidies were offered, which generated even greater deterioration in CFE´s finances.

Under the Energy Reform, several results were achieved: production increased, energy sources diversified, there was a change in trend in emissions, marginal prices fell, and new business areas such as carbon markets and the sale of fuel to third parties allowed for positive financial results.

Reform Initiative 2021

Notwithstanding the aforementioned gains of the initial instrumentation of the reform, the current government has taken action against the new market structure during 2020 and 2021. The first action was the cancellation of long-term auctions. In late September 2021, the Executive filed a counter-reform proposal that seeks to change the economic dispatch and prioritize the CFE plants, even if this implies higher costs and more local and greenhouse emissions. It also goes against renewable energy, making it difficult to comply

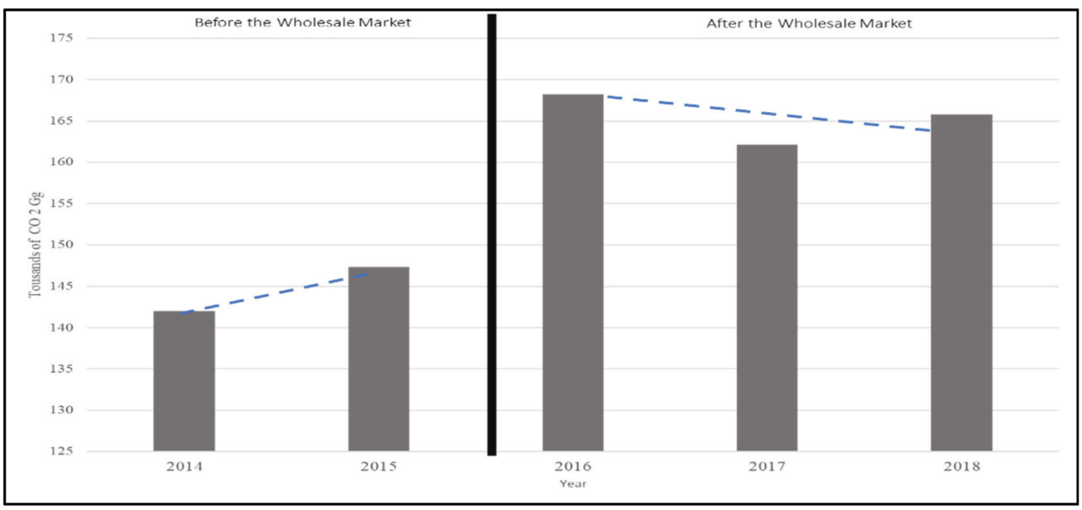

Figure 6 Mexico´s Historical Emissions of CO2
Source: Prepared by authors based on INECC database (2020).

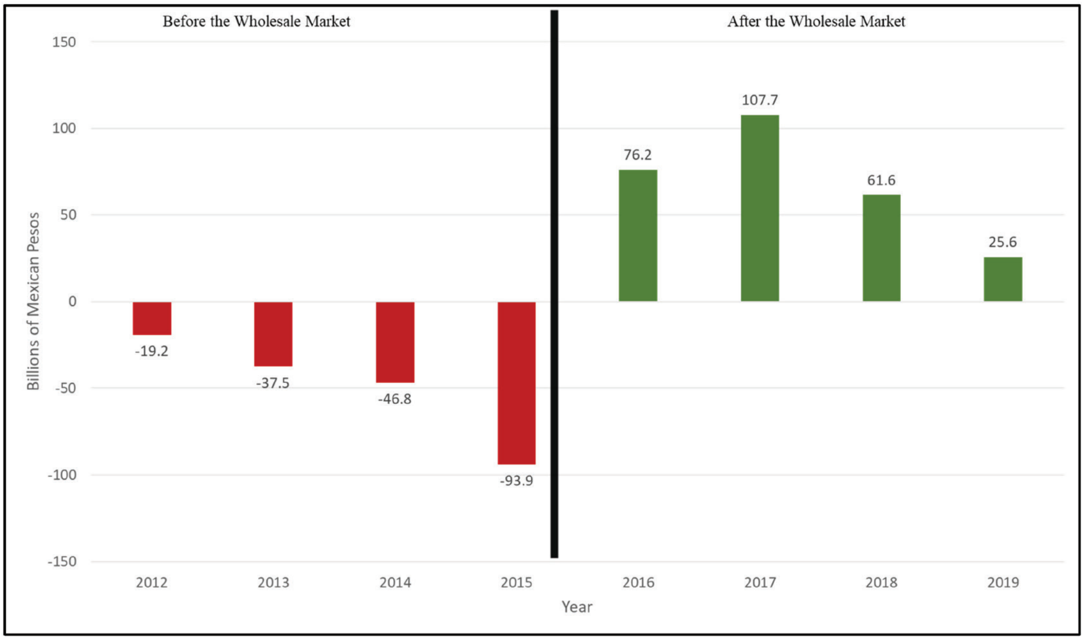

Figure 7 CFE´s Annual Finance Report
Source: Prepared by authors based on CFE´s data base (2021).

with international commitments emissions-wise. Prices of power have increased the financial effects on CFE and on federal public expenditure are yet to be seen.

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Transition to Solar Home Systems in Nigeria

BY MARYAM BELLO

Abstract

In Nigeria, the imbalance between power generation, transmission and consumption has resulted in unreliable supply and frequent blackouts. These necessitate Households to resort to self-generation using backup electricity generators. However, there is a recent gradual transition of replacing these fossil fuel backup generators with solar home systems.

1. Background

Reliable, affordable and sustainable energy is regarded as the key to economic development and the basis for enhanced economic growth. Access to electricity is above all critical to human development as electricity is, in practice, necessary for certain basic activities, such as lighting, refrigeration and the running of household appliances, and cannot easily be replaced by other forms of energy. Individuals' access to electricity is one of the most clear and un-distorted indications of a country's energy poverty status. Yet, an estimated 1.1 billion people-14% of the global population do not have access to electricity. Many more suffer from supply that is of poor quality. Around 84% of those without electricity access reside in rural areas and more than 95% of those living without electricity are in countries in sub-Sab-Saharan Africa and developing Asia (IEA, 2017).

Nigeria is a Sub-Saharan African Country with the largest economy and the richest oil resource centre of the African Continent. The country also remains the largest gas consumer and producer of West Africa. Yet, the country has the highest number of people without electricity in the region. It is estimated that about 40% of Nigeria's population do not have access to electricity (IEA, 2019). In Nigeria, the imbalance between power generation, transmission, and consumption is a major challenge for the population of around 200 million. While over 13 GW of grid power generation capacity is installed, only approximately 3.4 GW reaches consumers on average (PPI, 2019). The implication of this puts a large number of Nigerians without access to electricity at all, and those who have access battle with unreliable supply and frequent blackouts. Given this high level of unreliability, households in Nigeria have adopted different strategies to cope with this poor public provision. Some of these response adjustments include the use of kerosene lamps, kerosene stoves, rechargeable lamps, gas lamps, inverters, touch lights, mobile phones with touch lights, and self-generation through backup generators. Although all these responses are observable among Nigerian households, the most common and closest substitute to the electricity from the public grid is self-generation. Many households operate small size generators with capacity ranges between 0.4kW and 8kW for their own generation (Oseni, 2014). These small generators produce considerably high levels of noise and emit carbon monoxide (CO) which is inimical to human health. Sadly, many Nigerians who are unaware of the dangers associated with generators fumes have fallen victim of their own prized possessions.

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The continued heavy reliance on fossil fuel powered generators in Nigeria by government, institutions, and households for electricity supply constitutes a major threat to the nation's climate change plan and eventually pose a health risk.

However, with the growing concerns over the environmental consequences of emissions from the continuous use of fossil fuels, and the geopolitical climate surrounding fossil fuel production, renewable energy sources have emerged as an important component in the energy consumption mix. According to many studies, renewable energy has one of the most significant cost-effective potentials for reducing energy-related greenhouse gas emissions. Increasing the supply of renewable energy would allow for the replacement of carbon-intensive energy sources and significantly reduce pollutant emissions.

2. How Transition to Solar Home System is taking Place in Nigeria

Unreliable power supply through the electricity grid is a major challenge in Nigeria, and therefore alternative energy sources are often used to meet basic electricity needs. The household sector, which accounts for most of the energy consumption, resorts often to self-generation through backup generators. However, there is recently a gradual transition of replacing these fossil fuel backup electricity generators with solar power systems. This has led to the emergence of several off-grid solar companies providing access to cleaner and more reliable electricity to homes and small businesses. These companies usually installs rooftop solar panels and an indoor battery unit that supplies electricity to homes whenever there is a power outage from the national grid.

One of the most popular initiatives is an MTN franchise called "LUMOS", which provides customers with a mini solar kit to power critical loads in the home such as LED bulbs, computers, mobile phones, television sets, radios, fans and other small appliances. Importantly, the kits are provided on a pay-as-you-go basis to remove the upfront cost of acquiring a solar home system. Other companies and NGO's have implemented similar schemes, usually providing solar home systems comprising of solar panels, an inverter and batteries for energy storage. Their pitch has also been multidimensional: offering households clean and reliable electricity to boost productivity.

3. Limiting factors

Nigeria is endowed with abundant renewable energy resources which if well placed will meet the electricity demands of its growing population with clean, reliable electricity. These resources ranges from biomass, hydropower, solar, wind and potentials for hydrogen utilization as the most abundant. However, there are some identified structural barriers to a successful transition to renewable energy in the household sector. These include: i) lack of skilled personnel to meet a code of standard procedure, to install and maintain solar PV. ii) lack of adequate knowledge about how to use the solar home systems, for example improper identification of the ideal system capacity. iii) The initial setup cost is high and very few households can afford to buy and install the technology. iv) Most of these solar solutions can only power few appliances and are basically suited for use in rural areas. v) Another factor is cultural and behavioural changes required for full utilization of a solar home system.

4. Conclusion

Ensuring a smooth transition to renewable energy systems such as solar requires the enabling technologies, grid modernisation and expansion of appropriate business models, market design and system operation. Overall, this transmission is expected to reduce long-term power system cost, lower pollution and improve energy security as a result of reducing the reliance on fossil fuels.

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Pakistan on its Path for the 2050 Carbon-neutral Targets: An Ambitious Three Directional Plan Under the PM Initiatives

BY DR. JAMIL KHAN

Abstract

Pakistan is a developing country and as such its power supply has become a challenging task. To support its growing middle class, industrial outputs, and to reduce pollution, Pakistan is pursuing its energy transition through renewables. The addition of Nuclear Power Plants to its grid shows its commitment to the Paris agreement for 2050.

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With the drive for industrialization, population explosion, and lack of urban planning; electricity shortages have reached crisis proportions. During summer months, extended hours electricity outages add more miseries to everyday life and in many cities temperatures reach into triple digits. These power outages not only make people less productive, but also hamper productivity and the economic growth. The root causes of this crisis are lack of planning, policy mistakes, dilapidated power plants (pre/non-NPPs) with crumbling transmission lines, and a history of unpaid bills by every member of the society (the consumers, politicians, industrialists, and government officials)! Thus, there is no money for the power providers for the fuels' purchase, maintenance, and capacity increase. As a matter of fact, the power outages go back to the days of the creation of Pakistan. According to Sind Observer newspaper of that time, Mr. Jinnah was invited to speak to the Sind Assembly in 1947 (just a few days before the Independence Day) where he was anonymously chosen as the President of the Constitutional Assembly. Just before he was ready to speak, the power went out, the microphone went dead, and it was all but impossible to hear him. Since then, every government has promised to solve the electricity shortage but until this day, the power outages and the load shedding are common. During President Ayub Khan's period, Nobel laureate, Dr. Abdus Salam, then his Science Advisor, convinced him to build Pakistan's first commercial nuclear power reactor (KANUPP) in Karachi. Later, Zulfiqar Ali Bhutto, during his first visit to China as Prime Minister, successfully initiated NPPs technical exchange program between the two countries. This was the beginning of the nuclear power as the strategic source for Pakistan's fast growing power needs. Since then, China and Pakistan have been cooperating in many fields, including the nuclear power plants. Their friendship is based on mutual respect, trust, cooperation, and commitment to support each other in times of needs. With the passage of everyday, the friendship between China and Pakistan is getting stronger and reaching to its new highs, unparallel to any other friendship.

With the K2 nuclear power plant's inauguration late last month, Pakistan is on its way to improving its anemic power supply that has been causing persistent blackouts and load shedding since the creation of the country in 1947. Another identical plant is on its way to come on stream in early next year and with this peed of the clean power additions, soon the perpetual blackouts and load shedding will become things of the past! This is a remarkable and an exemplary friendship achievement between China and Pakistan allowing access to the latest nuclear power technology from a carbon-neutral source, the first of its kind in the world. The K2 plant joins the five already existing nuclear power plants that are operating in various parts of Pakistan and is going to be also managed by Pakistan Atomic Energy Commission (PAEC). Since the launch of the first nuclear power plant (indigenous) in 1974 and its continuous operations, Pakistan has demonstrated following an extremely high standard protocols for the safety, security, and overall maintenance of the nuclear power plants. The third unit (K3) will be ready to start supplying the electricity early next year. The technology used for both of these plants is called "Hualong One" and has been provided by China National Nuclear Corporation (CNNC) which is marketed in the international market as HPR1000. According to the reports, Hualong One is a third-generation nuclear power technology and its innovative security system meets the highest international standards. Currently, CNNC is building six more HPR1000 reactors, mostly for the BRI member countries.

Construction of the K2 plant was started in 2015 and it was completed in February of 2021. In March of this year, after successful commissioning safety tests, the plant was connected to the main grid. The plants initial life has been designed for 60 years and it can be extended for an additional 20 years, if needed. It has a refueling cycle at about 18 months' time intervals. According to the initial contract that was signed between CNNC (China) and PAEC (Pakistan) in 2013, the total cost for both of these plants (K2 & K3) will be 9 billion U.S. dollars. The design capacity of the plant is 1100 megawatts and its addition to the grid will greatly help to reduce the frequent load shedding, especially during the smoldering summer months. Additionally, this capacity will definitely help to meet the target of 8800 megawatts of nuclear power by 2030 and 40,000 megawatts by the year 2050 by building 32 additional nuclear power plants.

Both these plants are under the watch of the International Atomic Energy agency's safeguards. According to the CNNC, the project will produce about 10 billion kilowatt hours of power on an annualized basis once it is operating at its full capacity. It will not only help to provide electricity continually to the consumers but will also support in new job creations, higher industrial activities, and increase in exports due to more competitive cost structure through lower electricity rates.

Prior to the K2 plant, combined electricity capacity of all five (one in Karachi and four in Chasma) operated nuclear power plants was around 1400 megawatts. With the K2 capacity of 1100, total nuclear power plant capacity will be about 2500 megawatts.

On the global scale, USA and France are the front runner countries that are deriving major part of their electricity needs from the nuclear technology. According to the nuclear industry report, as of 2019 USA was using 97 reactors and deriving just over 19 percent of its electricity needs while France was deriving over 70 percent of its electricity generated from 58 nuclear reactors. To some industry estimates, France has the most experience in operating NPPs in the world.

Even though the nuclear power plants are cost intensive, they have longer lives. Over their life span period, their operating efficiency is usually over 90 percent, and they operate over 90 percent (336 days) time of the year, and the balance of the time (29 days) is used for their scheduled yearly maintenance. Thus, based on the total cost structure, technology efficiency, and the maximum operating capacity level, the NPPs are the most cost-effective power plants. At an operating rate of about 95 percent capacity, the nuclear power generated electricity on the average cost is about Rs11.16 (~7.4 cents) per Kilowatt hour, by all means making it the most competitive electricity source against the other viable sources of electricity in Pakistan.

When it comes to the nuclear power plants discussion, the Chernobyl (Russia) and 3 Mile Island (USA) accidents come to peoples' minds. However, as Pakistan is a newcomer in the nuclear power nations, to date in its more than 49 years history since embarking its journey in 1974 on the path of nuclear power by building its very first nuclear reactor KANUPP (K1) in Karachi, has built its own standards in the absence of the foreign assistance, that in many cases exceeds the International Standards. Miraculously, since the day one starting at KANUPP (K1), Pakistan has proven an impeccable operational record of safety, security, and maintenance. Since that day, more than 14 billion kilowatts hour of electricity have been generated through its five plants located in different parts of the country. Additionally, two of its reactors (Chasma units 2 & 4) have set new milestones in their sustainability, safety, and security by operating non-stop and round the clock for an entire year! This undoubtedly speaks to the intellectual capacity of Pakistani scientists & engineers, their research, training and capabilities and safety & security of the plants. This also clearly shows that even in chaotic time and during political instability, Pakistani nation can achieve excellence, no matter how difficult it may sound, but only if it puts its passion, dedication, commitment, and focus to pursue it! Because of all these attributes, Pakistan has been recognized globally for its outstanding achievements in developing its own safety protocols and training its staff with the best safety & security practices. As a result of these outstanding and unparallel performance, one of PAEC's facilities (PIEAS) has been recognized by the world body (IAEA) as one of its collaborating centers. As a matter of fact, in 2018, a former IAEA's Director General, Mr. Yukiya Amano, after visiting several Pakistani nuclear facilities was overly impressed with their safety and security protocols.

As the world is moving to its ambitious goal of carbon neutrality by 2050 through the collaboration of every nation, Pakistan is also relentlessly following the same course. Like in many other countries, regardless of their socioeconomic standings, many of its major cities are becoming centers for unprecedented chronic and upper respiratory illnesses. To address this widespread health crisis, PM Imran Khan's government has already embarked on a many-fold strategy. 1) Campaign of planting 10 billion trees across the country and forest restoration of more than a million hectares. These initiatives will help significantly in absorbing carbon dioxide emitted by automobiles and industrial activities using fossil fuels, major sources of atmospheric pollution that creates global warming. 2) Adaptation of new paradigms for mobility as part of transportation landscape modernization. Under this scheme, mass transportation players and the citizens are encouraged to buy the Electric Vehicles, as they become available. This initiative will greatly help and will have a significant impact in reducing the carbon dioxide and other pollutants from their exhaust and will be visible in a shorter period of time. 3) To meet its ever-increasing electricity needs, following a major change in its energy mix by building more NPPs is the right way to reduce its carbon footprint. Not only is the electricity generated from the NPPs cheaper than the other sources but is also a carbon neutral source. With this kind of landscape and commitment by the PM, Pakistan is definitely on the right trajectory for meeting its goals for carbon-neutral targets and is consistent with the Paris Agreement and the United Nations 2050 global targets.

Energy Architecture and Economic Growth

BY DOUGLAS B. REYNOLDS

One of the concerns within the Association, as expressed in its meetings around the world, is how to create economic growth, not just for developed OECD countries but for developing countries as well. Energy is central to economics and therefore to economic growth as much of history can attest. One way to understand such history is by using dialectic reasoning, or energy dialectics, where alternative options present themselves during a disputation but where a final resolution, or synthesis, creates a solution. For example, Carl Marx laid out in his Dialectic Materialism examples of history, such as the post Dark Age tension between the landed gentry (the thesis) and the peasants (the antithesis), and how such opposing sides ultimately created a dialectic resolution, such as capitalism (the synthesis). Then within that synthesis was a new dialectic between the capitalists (the thesis) and the workers (the antithesis) that would create the new synthesis of socialism, but may have actually created unions and unionization as the final resolution. Perhaps Carl Marx was not the consummate economist, but it is an interesting take on history nonetheless. It shows how a dialectic can affect the economy. In turn an energy dialectic, as explained in Reynolds (2021), of a transition from two potential and sometimes countervailing energy resources into a new energy resource synthesis can likewise be used to explain economic resolutions and indeed help explain economic growth.

By way of illustration, in the early 1800s, the method of lighting included using whale oil in lamps. Then as whales were over-hunted and the supply of whale oil followed a pattern of production exactly like that of M. King Hubbert's (1956) logistics curve, as explained in Bardi (2007), then the price of whale oil started increasing. This Hubbert pattern for whale oil was due to the rate of hunting being much higher than the rate of regeneration of whales and thus the information and depletion effects (see Reynolds) dominated. This meant that there were two main options for lighting during the mid 19th century energy dialectic. The one lighting option was whale oil for kerosene-type lamps, the source of which was the more serviceable but also the more increasingly expensive energy, and the other option was a simple wood fire for heat and light. A wood fire though was awkward to use for plain lighting and could not be easily carried to functional locations.

Another option at the time was called camphine, Kovarik (2013) and PBS (2008), which was an alcohol and turpentine concoction that was said to be 10 times more prevalent than whale oil, although at about a 25% lower Btu (joule) content per gallon (liter) and at a much lower price, which suggests it was not a perfect substitute for whale oil. Plus, there was emerging town-gas made from coal-to-gas. But the final energy dialectic synthesis that came to be the predominant choice was crude oil from far down in the ground when Edwin Drake conducted oil well drilling with his deep well in 1859. Interestingly, as in other energy dialectics, the new energy synthesis helped economic growth tremendously. The U.S. GDP per capita growth rate for the 100 years before 1859 according to Maddison (2004) statistics was 1.5% per year, but for the 100 years after 1859, it was 4% per year, a greater than 90% increase in the economic growth rate.

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1. Energy Architecture and Economic Growth

The normal reasoning about economic growth is that it is only about technology of and by itself, but energy architecture may also play a role that is often missed. Energy architecture has to do with the physical characteristics of a particular energy resource. One such characteristic, as explained by Smil (1991), is high power density concentrations of energy emitting from a relatively small area of extraction. Considering the effects of energy characteristics, though, there is no reason to expect a-priori that the 100 years before 1859 should have been any less or any more progressively productive than the 100 years after 1859 as far as overall U.S. economic growth per capita is concerned, unless technology works with energy architecture to create more or less potential. The predominant U.S. energy resource before 1859, as far as overall growth was concerned, was that of coal and wood, while after 1859 it was that of liquid petroleum. A solid versus a liquid.

Although lighting was the main issue surrounding the 1859 energy dialectic synthesis of crude oil, considered to be the 3rd great energy dialectic, nevertheless, coal was the most ubiquitous energy resource for growth related transformation during the previous economic epoch. But now consider the differences in energy architecture between coal and crude oil. For example, one type of energy architectural characteristic is the placement concentration of an energy resource. Coal can often have more Btus per acre than crude oil, roughly 500,000 MMBtus/Acre (250,000 Gigajoules per hectare). That is a coal mine when looking straight down from the ground level can pack more Btus per acre than crude oil can, not when comparing the East Texas oil field to that of an Indiana coal mine, but when comparing much of West Virginia to much of West Texas. So if that is the case, then why would oil be responsible for a greater than 90% increase in the growth rate of the U.S. if oil in general has less Btus per acre?

It has to do with a different energy architecture characteristic which is the energy source *state grade*. A state of a physical substance is whether it is a liquid, a gas or a solid or, as in the case of solar power, an energy field. Clearly a liquid state in energy terms is more useful than a solid state, but where a gaseous state is much less useful due to the lack of storability of a gas compared to a solid or liquid. In terms of storage, natural gas has 1000

Btu's per cubic foot at room pressure (35 Megajoules per cubic meter), and still only 177,000 Btus per cubic foot at 3000 pounds per square inch (200 atmospheres) compared to oil's 1 million Btus per cubic foot at room pressure. Coal is storable simply laying on the ground at about 500,000 Btus per cubic foot depending on the type of coal. And that is a storability that can last not just a day or a week but over the course of seasons and even for a couple of years or more.

The coal versus oil economic growth aspect of the 3rd Energy Dialectic, though, has to do with how useful a liquid is in comparison to a solid which has to do with internal combustion engines (with oil) versus external combustion engines (with coal). Liquid fuels can be used in small droplet quantities at a time within internal combustion engines which are then lighter in weight and more powerful in force per pound of engine than external combustion engines. A two cylinder internal combustion chainsaw might weigh only 10 pounds (4.5 KG), but a two cylinder external combustion coal-fired steam locomotive might weigh 10 tons. Even commensurate comparisons show the advantage of a liquid fuel. A Caterpillar 797f mining dump truck can carry 400 short tons 40 miles per hour with 4000 horse power. It weighs about 280 tons. While a steam locomotive could get up to 4000 horse power, but where its ability to stop and start are not as good and it where it is forced to be four times as heavy as the weight it pulls. So a locomotive pulling 400 short tons would need to weigh 1600 tons and stay on a track with water refilling stations every so often.

The least useful state is a field state, such as wind and solar power entail, because it lacks cheap, easy storability and also reduces the physical processes available to be used. For example, renewables can last a day or a month in some battery forms, but cannot easily or cheaply last a season or more. Solar is not useful with an internal or external combustion engine, where as such combustion engines, or even steam driven turbines, can produce electricity to compete with solar and where the energy source itself is quite storable. These kinds of mechanical engineering reasonings tend not to be emphasized in much energy economic analyses, but they need to be carefully looked at when determining economic potential of any given energy resource. The high quality potential of oil is a lot of what is behind the fact that the 100 years after 1859 were so much more successful than the 100 years before 1859. The crux of the growth enhancing aspect of these two energy resources, then, was that crude oil had greater potential to bring about economic growth inducing technological change due to its energy architecture of being a liquid energy resource rather than a solid.

2. An Energy Growth Comparison of Technologies

To put the energy architecture versus pure technology debate another way, consider the technology available for having a 21st century smart-grid application in everybody's household, i.e. a smart house or smart home automation or domotics. Such a technology can help gain demand side power variations in order to better match demand with the variable supply side electric power sources, or even match one demand entity with counter demand side entity variations. Such a smart home technology should be just as innovative and growth enhancing as say adding a separate condensing cylinder on an 18th century atmospheric steam engine, unless there is more to growth than merely technology.

Consider the two technologies: a 21st century smart-grid application in everybody's household or an 18th century separate condensing cylinder on an atmospheric steam engine. The second technology was useful in reducing the size of steam engines even as it increased the steam engine's power. This innovation led to a steam engine on a rolling platform such as a steam locomotive and bigger more powerful steam ships. That in turn engendered the ability to leverage the use of economies of scale in factories and the optimal location of such factories outside of high cost, inner-city land toward locations of low cost land areas outside of the city and often near a coal or iron ore mine. Such changes added tremendously to economic growth potential.

21st century smart gride home domotics tries to make the running of appliances occur at different times of day in order to reshuffle the time of day that a need for electric power on the demand side occurs and which can therefore make renewables, or base load nuclear power, more cost effective. Still, the domotics technology has much less ability to leverage economic growth since it is more about fixing renewables' inherent energy architecture deficiencies, specifically its lack of storability, than about creating growth potential energy leveraging. Not that renewables are not an important substitute to oil as oil supplies become constrained (see Reynolds), but the potential for creating new economic growth with renewables will be more limited in comparison to past energy changes which were generally to higher grade energy architecture characteristic resources. With renewables, it is all about government regulations to search for economic growth as opposed to past energy transitions where government regulations in regard to energy were about keeping people safe during the robust economic growth that materialized.

With domotics, let's say you need your clothes washed. So you use the smart grid and the smart electrical household to run the washing machine. That may mean that you have to fill the washing machine with your clothes and let it sit until the low cost part the electric utility day occurs, and thus everyone else in the household has to in turn wait for your cycle to complete to do their laundry. Then in the middle of the night or possibly in the middle of the working day with solar, the laundry gets done and it sits getting moldy until you can finally put the clothes in the dryer, or if in Europe it will wait until you get a chance to put it out on the line. Then you have to wait for the dryer cycle to go before you can get it out and fold it and, as well, everyone else who may need drying, might have to wait. Now maybe all that consternation is worthwhile to the consumer because of the money or carbon that is saved. Nevertheless, a close examination of consumer utility changes vise-a-vise cost reductions could find it less cost effective than meets the eye. In the meantime such forced exertions don't seem to leverage much in the way of new economic growth but only work to alleviate the energy architecture deficiencies of renewables.

Using the second technology, an 18th century separate condensing cylinder, means that train travel is possible. So with train travel, you can buy a train ticket, from say London to Leeds, which sounds like an appealing consumer utility increasing purchase, for travel, for experience of travel and for business. On the other hand, back in the 21st century, taking care to put in domestic laundry, dishes or water at appropriate times of the day to catch appropriate times of energy usage doesn't sound like quite the same eye-catching consumer opportunity. The 18th century train ticket can either be bought or not bought, the saving of money occurs by not buying and the expenditure of money occurs in the buying but with an overall increase in utility. The 21st century spending of money with having a smart grid home network is in the not using of energy or in the using of energy at a specific time of day a deterioration of consumer utility but at a savings.

Therefore, once the smart home computer is in place, you are forced to spend time and thought to attain its advantage even though you will have the help of an annoying computer, affectionately called by someone's name to make it sound better than it is, a good marketing ploy. It's no longer a one time decision to either go to Leeds or not to go, instead it becomes an everyday burden of whether you'll save money or not. It can become habit forming like remembering to turn off the lights or remembering to turn down the heat (or up the cooling) but it seems like taking care of weeds where if you don't to it, you sit looking at the weeds although you are resting.

3. Helping with Reductions in Carbon Emissions

Now because of global climate change, there may well be a need to use demand side management in order to help reduce carbon emissions, and as such, many will want to live with such demand side accommodations. That makes it important to specify the smart grid as a necessary evil rather than a great Smithian solution to a non-problem of elevating consumer utility of using electric power at a reasonable price. However, there is another need behind the electric systems usage which is how expensive petroleum will become once shale oil production goes voluminously downward and once OPEC+ members with the most market power realize that they can make more money selling less oil rather than more oil. Non-U.S. shale-oil has a "Loki" problem of substitutes in production. Electric demand side systems, from zoom to hybrid cars to plug in electric buses, may have to substitute for petroleum based systems even if the current energy dialectic synthesis turns out to be nuclear power rather than pure renewables, and where nuclear power has both elements of a solid and a field energy resource which enhances its storability.

Another interesting problem with demand side power management is how to implement putting in place energy efficiency applications. For example, in developing countries it is often challenging to get villagers to use improved biomass cook stoves, or even propane stoves, rather than using traditional stoves or open fires for cooking even though newer efficient stoves can save a lot of fuel over the course of months and years and can actually give a return on investment of as much as 10% to 100% per year. And yet there is a reluctance to buy such stoves even with low cost payment options available. This suggests that many energy consumers of daily energy utilization apparatuses have a very high internal rate of return that makes them very risk averse to buying energy saving equipment. Even in rich countries, the purchases of energy efficient refrigerators or washing machines can be hampered by this very same risk averse, high internal discount rate problem. That suggests that having external entities, such as the power company, come into homes and offer to replace old or inefficient appliances with a payment plan within their utility bill could help. It would induce more demand side electrical power management than simply relying on consumer sovereignty of and by itself. The power company could actually pay consumers for a power audit and switch out plan with adjustments made on power use billing rather than consumers paying for it.

Nevertheless, climate change will happen, and cities like New York or Utqiagvik (formerly Barrow) Alaska will inevitably have to choose between a Zuiderzee strategy of putting levies and ocean walls between a city and the ocean or a Dunkirk strategy of out and out abandoning the city. Also with COVID or further virus evolutions there may also be a need, like in the Middle Ages during plagues, to set up worker and family enclaves where new people and travelers have to undergo a quarantine to enter or leave such an area. But such enclaves can at least undergo better smart grid coordination to enrich demand side energy management including reductions in home to work commuting.

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IAEE/Affiliate Master Calendar of Events

(Note: IAEE Cornerstone Conferences are in boxes)

Date	Event and Event Title	Location	Supporting Organizations(s)	Contact
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
2026				
May-June	47th IAEE International Conference *Forces of Change in Energy: Evolution, Disruption or Stability*	New Orleans	USAEE	Howard Gruenspecht www.usaee.org

WELCOME NEW MEMBERS

The following individuals joined IAEE from 9/16/2021 to 10/31/21.

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George Beranek
USA

Ben Cahill
Ctr for Strategic and Intl Studies
USA

Chunda Chen
Lamar University
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