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PRESIDENT'S MESSAGE

I have been a member of the International Association for Energy Economics ever since, as a young researcher, I helped a colleague (and my mentor), Mr. Kenichi Matsui, organize the 8th IAEE International Conference in Tokyo. It was the first time IAEE came to Japan and I vividly remember the importance Matsui-san attached to such an undertaking. Many years later, he accepted to become President of the Association and often reminded me that such a prestigious organization was essential to the world.

Dear members, when you selected me as President-elect, more than one year ago, I felt very proud and honored that a little girl from a small country stuck in the corner of Asia could one day be considered as your representative. Thank you for your vote of confidence.

Although I have the title of professor, I am not an academic and very far from it. I am, however, responsible for quantitative and qualitative analyses on energy policy issues at the Institute of Energy Economics, Japan. As such, I am still developing my abilities to assimilate information and propose solutions or ways forward.

Now it is time for me to not only "put shoulder to the wheel" but to also initiate very small steering corrections that could direct us to our goal of advancing knowledge and understanding. The association is a very big ship to steer! I often ask myself how many "small" corrections have been made over the years by past presidents because, just a few decades ago, the driver seat was most often shared between energy and economic issues while the environment was "sometimes" riding in the back. In fact, the IAEE was established during the era of oil crises as a platform for energy economists in industry, academia, and government. Now the 3Es (economy, energy and environment) do own a legitimate driving license and all three deserve the opportunity to share in the steering.

Unfortunately, the changes or corrections I have in mind are like mini-seeds that could take years to mature and most of the path for the coming years is already under construction. For example, in the last few years we used as much acumen and vision as possible in the development of our annual international conferences which are now in their final planning stage.

For insights, I will heavily rely on the knowledge and wisdom of the past presidents, not limited to the immediate ones like David Knapp or Christophe Bonnery but also those before them if I can. I will need the help of the current president-elect (James Smith), the council members, the Executive Director (David Williams), the IAEE officers, editors and staff.

For foresights (if I can use the term) I would like to personally engage with

Continued on page 2

President's Message (continued)

the future generation of professionals in the field of energy economics - our PhD students and young professionals. I want them to be vocal and share their vision and dreams for the world they are inheriting.

I also would like more engagement with the business sector and governments with regard to technologies that will play a major role during the so-called energy transformation. Technologies are in the hands of industries for dissemination but to push new technologies into markets, we need supporting policies. The challenges we face now call for the creative and innovative spirit of getting together, exchanging views and ideas in a neutral environment, free of suspicions. IAEE's neutral stance is ideal for organizing such platform.

I am sure the coming year will be filled with references to the 17 SDGs and buzz words that resonate well. We need to keep track of what is going on with words such as Uncertainty, Transformation, Transition, Affordability, Availability, Accessibility, Smart this, Smart that, Security, Efficiency, Growth, Geopolitics, TCFD, ESG, etc. etc.

I certainly hope to see and meet many of you in Paris this coming 21-24 June as we will discuss climate and energy policies, and some of the conflicting objectives that need to be tackled. I must admit to having a particular bias towards the 2021 conference, as I would like to welcome you all in my town, Tokyo. We will touch on the theme of navigating in stormy waters inspired by Mapping the Energy Future. The following year we will meet in the Kingdom of Saudi Arabia (2022, Energy Market Transformation in a Globalized World) then in Turkey (2023, Overcoming the Energy Challenge) . What an exciting line-up! Don't miss it!

On the subject of Mapping the energy future, many think that we have not yet completed our analyses of the relevant parts of the energy problems. I think that incomplete mapping did not stop the explorers of the past to venture in stormy waters. Like us (economists), they assumed there was a "new world" ready to be discovered out there.

Aside from the annual international conferences, many regional events will be organized during the year or years to come. Just to mention a few, the 7th Asia-Oceania Conference in Auckland, New-Zealand (Theme: Energy in Transition, 12-15 February), and the 38th USAEE/IAEE North American Conference (Energy Economics: Bringing Markets, Policy and Technology Together, 1-4 November). I should also mention some of our ongoing other services, including IAEE summer school, autumn school, symposium series and electronic publication of EEEP.

As for me, I only hope to honor my mentor of many years ago. I truly believe that IAEE is a prestigious Organization essential to the world. We are 4000 members and it must be a force to recon with!

Yukari Yamashita

IAEE MISSION STATEMENT

The International Association for Energy Economics is an independent, non-profit, global membership organisation for business, government, academic and other professionals concerned with energy and related issues in the international community. We advance the knowledge, understanding and application of economics across all aspects of energy and foster communication amongst energy concerned professionals.

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:

- Providing leading edge publications and electronic media
- Organizing international and regional conferences
- Building networks of energy concerned professionals

Editor's Notes

We conclude our coverage of stranded assets in this issue. In addition, we're fortunate to have a review of the USAEE's early November North American meeting held in Denver, Colorado. We're indebted to Mark McCarthy for the compiling and editing of this. It begins on page 15.

Tilak Doshi notes that the September 14th take out of half of Saudi Aramco's oil facilities, the equivalent of 9/11 for the oil industry, was met with only a whimper. The shift from a perceived world of oil scarcity to one of abundance has occurred in a very short time by the advent of the fracking revolution in the U.S., the result being U.S. oil production is now the highest in the world. He details how oil geopolitics have been upended.

Dawud Ansari and **Amrbia Fareed** discuss the heated debate about stranded assets and argue that the term is conceptually flawed. Nevertheless, using data on the economic diversification of fuel exporters and numerical results from their recent modelling work, they show that the potential issue is too big to ignore.

Jiang Lin, Jiahai Yuan, Xu Liu, and **Weirong Zhang** write that China is facing increasing coal power stranded assets pressure given its overcapacity of coal plants, economic transition, and environmental and climate goals. It is estimated that total coal stranded assets could be 40-103 billion yuan in 2030. Supply-side reforms can reduce stranded asset and economic losses for all parties involved.

Andrew Akweny and **Rockson Sai** note that the call for sustainable energy has drawn much attention to the uncertainty of the value of potential assets in various sectors. Africa being resource-intensive region especially with new discoveries of non-renewals has attracted a lot of capital investments. Stranded assets in the midst of optimism economic development worth discussion.

Nawaz Peerbocus writes that the creative powers of dynamic capitalism leads to the destruction of old ways of doing things, making space for new ways of doing things. In many ways, the energy transitions happening globally are sub-processes of a larger creative destruction process resulting in stranded assets across many sectors of the economy.

Minh Ha Duong notes that in 2016, Vietnam planned to build a fleet of new coal-fired power plants, expanding capacity to 54.5 GW by 2030, from 13.1 GW in 2015. Three years later, the risk of stranded assets not only made this plan sub-optimal, it also made it infeasible because investors are looking elsewhere.

Thorsten Burandt, Pedro Crespo del Granado, and **Ruud Egging** apply a multi-sectoral energy system model to analyze the energy transition with ambitious decarbonization scenarios. Results show that significant amounts of gas-fired capacity might end up stranded. Introduction of capacity markets and using biogas, synthetic methane, or hydrogen instead of natural gas, can reduce the risk of stranded assets.

Antonina Scheer, Morgan Bazilian, and **Ben Caldecott** note that the Alberta oil sands may be among the first oil resources to suffer devaluations due to their high carbon intensity and relatively low quality. Assets may become stranded depending on project-level risks and wider potential drivers. They discuss how regulations at varying jurisdictional levels – provincial, federal, and international – contribute to this stranding process.

Andrew Pickford discusses the issues surrounding forecasting energy demand and reports from the December IAEE symposium held in Abu Dhabi.

Saeed Moshiri reviews the oil-macroeconomy relationship from the standpoint of both oil-exporting and oil-importing countries and then presents the case for trade and labor migration as factors easing the pain. He uses Canada as a case study to show the importance of trade and labor movements in mitigating the adverse effects of oil price shocks

Jared Woollacott and **Justin Larson** provide asset stranding characteristics and define stranding in financial accounting terms. They identify a typology of causes and explain how different modeling approaches capture key characteristics of asset stranding. They model a stylized shock for each cause and evaluate asset stranding using the ARTIMAS general equilibrium model.

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The Brave New World of Ample Oil

BY TILAK K. DOSHI

In the oil universe, the September 14th attack on Saudi Aramco's oil facilities is comparable to the 9/11 attacks on the twin towers in New York City. Yet, the taking out of half of the Kingdom's oil output led not to an oil shock but a whimper. Barely two weeks after the brazen attack, oil headlines were once again dominated by fears of over-supply and falling prices amidst a slowing global economy. Following an initial 20% intra-day price surge after the attack, the benchmark Brent crude oil price quickly retraced its steps back down to pre-attack levels.

The US oil production surge benefits Asia

The shift from a perceived world of oil scarcity to abundance has been brought about in an astonishingly short period of time by the advent of the "fracking" revolution in the US. This combines horizontal drilling and hydraulically-fracturing shale rock with high-pressure liquids to extract "unconventional" oil and gas. In the past decade, US crude oil production more than doubled. By mid-2019, US production was rated at over 12 million b/d, surpassing Russian and Saudi Arabian output as the world's largest.[1]

Academic studies suggest that global oil prices would have been higher by $10 to $50 per barrel higher if there had not been a fracking boom in the US. Given the scales involved, even with conservative estimates on the price impact, the US upsurge in unconventional oil production has probably led to the biggest transfer of wealth in history.[2] Largely at the cost of reduced oil revenues to OPEC and Russia, benefits have primarily flowed to the world's largest oil markets in the US, China, India, Japan and South Korea as well as the US unconventional oil producers.

From what was previously expected to be an inevitable growing dependence on Middle Eastern supplies, Asian oil refiners are now spoilt for choice. With Europe's long-declining oil demand trends, crude oil exports from the Russian Far East, West Africa and Latin America to Asian markets compete with the traditional large exporters of the Middle East. While the majority of Asian crude imports are still sourced in the Middle East, prices are set at the margin by competing crudes from other regions including the US.

Middle East imperatives for economic reform

While the US fracking revolution has benefited Asia's crude oil importers, it has burdened the Middle East oil producers. The Gulf states had built up extensive welfare states utilizing massive oil revenues to support social security, health, education and government employment programs. The social upheavals since the Arab Spring in 2010 led the Gulf states to further expand the social support programs to maintain their implicit social contracts with their citizens.

In 2015, the fiscal break-even oil price for Saudi Arabia – that is the oil price at which the government budget is balanced -- was estimated by the IMF to be $94.25/barrel while the reference "OPEC basket price" had plummeted to $49.50/barrel.[3] The situation since has generally been one of increased government spending, low economic growth and recurring budget deficits.[4]

The Gulf Arab states are reaching their limits of tolerance to declining oil export revenues. Low oil prices make the imperative of economic reforms and industrial diversification a central concern for the Gulf "rentier" oil states. The risks of a collapse in the social contract between the ruling regimes and their peoples in the Gulf region may be remote for now. The spectre of growing populations, unemployed youth and persistent budget deficits, however, will increasingly concentrate the minds of its planners and palace advisers.

Tilak Doshi is a consultant in the energy sector, and a Visiting Senior Research Fellow, Middle East Institute, National University of Singapore. He is the author of "Singapore in a Post-Kyoto World: Energy, Environment and the Economy" published by the Institute of South-east Asian Studies (Singapore, 2015). This article was first published in the Business Standard, 10 November 2019, https://www.business-standard.com/article/opinion/the-brave-new-world-of-ample-oil-119110901393_1.html

See footnotes at end of text.

Oil geopolitics upended

Ever since the historic meeting of Saudi Arabia's King Abdul Aziz (Ibn Saud) with US President Franklin D. Roosevelt on a warship cruiser in the Suez Canal in 1945, the quid pro quo of the strategic relations between the two nations has been clear: while the Saudis assured the Western world access to its oil exports, the US served as the security umbrella for the Kingdom. With its new-found unconventional oil and gas resources, the US is no more the energy supplicant in this relationship. Saudi Arabia and other Middle East oil producers still constitute the world's major source of low-cost conventional oil reserves. However, their overwhelming dominance is no longer a defining feature of global oil markets.

In the age of US-led oil abundance, conventional notions of geopolitical risk and perceptions of energy security have been upended. By effectively making the US the "swing" producer in global oil markets, the

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CONFERENCE OVERVIEW

The 43rd IAEE International Conference takes place in Paris, France, at the Palais des Congrès 21 – 24 June 2020, with the main theme **« Energy and Climate, Working hand in hand »**.

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

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

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

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

Paris has a distinctive identity that makes it an ideal location to foster these discussions. The city has been an academic hot spot for centuries and the 2015 United Nations Climate Change Conference made it an epicenter of climate policy. As a vibrant business capital, Paris is also home to a diverse energy sector and a unique collection of leading international organizations and think tanks.

For further information please contact: iaee2020@oyco.eu


Palais des congrès Paris

CONFERENCE VENUE

The conference will be held at the Palais des Congrès, the leading venue for international congresses in Paris. On the first conference day, our delegates are welcome to join the welcome reception at the Conference hotel: Le Meridien. The Hotel interior is inspired by mid-century modern design, with clean lines accentuated by sculptural forms and rich fabrics, that are unmistakably reflective of Paris.
Conference`s Gala dinner will be hosted by the City of Paris at the Hôtel de Ville. This unique venue will open its doors only for our delegates to guarantee an exclusive experience of the French hospitality and cuisine.

Paris is an international city with many centuries of history, offering an excellent starting point for travelling to France and exploring the beauty of the most fascinating city in Europe.




HOSTED BY: IAEE International Association for Energy Economics, WWW.IAEE.ORG — AEE Association des Economistes de l'Energie

43RD IAEE PARIS 2020 INTERNATIONAL CONFERENCE

21-24 June 2020 | PARIS | FRANCE
Energy and Climate, Working Hand in Hand

CALL FOR PAPERS

WHO'S INTERESTED?

The conference is intended for:

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

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

TOPICS TO BE ADDRESSED

The general topics below are indicative of the subject matters to be considered:

- Biofuels and Bioenergy
- Energy and climate change
- Energy transition
- Energy corridors and infrastructures
- Energy as a service
- Energy in transportation
- Energy systems
- Energy and macroeconomics
- Energy and finance
- Energy and business
- Energy policies
- Energy and local initiatives
- Energy and Big Data
- Fossil energy sources
- Nuclear energy
- Renewable energy sources
- Smart grids and new electricity market regulations

CONCURRENT SESSION ABSTRACT FORMAT

We welcome contributions from researchers and industrial sector representatives. Authors wishing to make concurrent session presentations must submit an abstract that briefly describes the research or case study to be presented. We will begin to receive abstracts from June 2019.

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 6 March 2020 of the status of their presentation or poster.
Final date for speaker registration fee, extended abstracts and full paper submission: 17 April 2020.

Abstract submission deadline:

Friday 24 January 2020

iaee2020paris.org

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 and to submit a paper for consideration in The Special PhD Session.

Students may inquire about scholarships covering conference registration fees.

For more information, please CONTACT:
iaee2020@oyco.eu

GALA DINNER: Hôtel de ville de Paris

IAEE/Affiliate Master Calendar of Events

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

Date	Event, Event Title	Location	Supporting Organization(s)	Contact
2020				
February 12-15	7th IAEE Asia-Oceania Conference *Energy Transitions in Asia*	Auckland, New Zealand	IAEE	Stephen Poletti *s.poletti@auckland.ac.nz*
May 8-9	3rd IAEE Southeast Europe Symposium Theme TBD	Tirana, Albania	IAEE	David Will iaee@iaee.org
June 21-24	43rd IAEE International Conference *Energy Challenges at a Turning Point*	Paris, France	FAEE/IAEE	Christophe Bonnery *Christophe.bonnery@faee.fr*
Sept 18-19	5th IAEE Eurasian Conference Theme TBD	Baku, Azerbaijian	IAEE	Vilayat Valiyev waliyev@gmail.com
November 1-4	38th USAEE/IAEE North American Conference *Energy Economics: Bringing Markets, Policy and Technology Together*	Austin, TX, USA	USAEE	David Williams *usaee@usaee.org*
2021				
March 21-23	8th Latin America Energy Economics Conference	Bogota, Colombia	ALADEE	Gerardo Rabinovich *grenerg@gmail.com*
July 25-28	44th IAEE International Conference *Mapping the Global Energy Future: Voyage in Unchartered Territory*	Tokyo, Japan	IEEJ/IAEE	Yukari Yamashita *yamashita@edmc.ieej.or.jp*
August 29 – September 1	17th IAEE European Conference *The Future of Global Energy Systems*	Athens, Greece	HAEE/IAEE	Kostas Andriosopoulos *kandriosopoulos@escpeurope.eu*
2022				
February 6-10	45th IAEE International Conference *Energy Market Transformation in a: Globalized World*	Saudi Arabia	SAEE/IAEE	Yaser Faquih *yasser.faquih@gmail.com*
July 24-26	8th IAEE Asia-Oceania Conference *Making the Transition to Smart and Socially Responsible Energy Systems*	Hong Kong	HAEE	David Broadstock david.broadstock@polyu.edu.hk
September 4-7	18th IAEE European Conference *The Global Energy Transition: Toward Decarbonization*	Milan, Italy	AIEE/IAEE	Carlo Di Primio *diprimio@gmail.com*
2023				
June 25-27	46th IAEE International Conference *Overcoming the Energy Challenge*	Istanbul, Turkey	TRAEE/IAEE	Gurkan Kumbaroglu *gurkank@boun.edu.tr*
2024				
May-June	47th IAEE International Conference *Forces of Change in Energy: Evolution, Disruption or Stability*	New Orleans	USAEE	David Williams *usaee@usaee.org*

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Stranded Assets: Conceptually Flawed but Still Relevant?

BY DAWUD ANSARI AND AMRBIA FAREED

Dawud Ansari and **Ambria Fareed** are economists at the German Institute for Economic Research (DIW Berlin), Department of Energy, Transportation, Environment. Dawud Ansari may be reached at ansari@eadp.eu

See footnote at end of text..

A new spectre is haunting the energy sector – the spectre of asset stranding. Prophets of the dawn of stranded assets, among them numerous scientists, paint a terrifying picture and warn of disastrous consequences: The climate crisis will coerce us into a stringent transition; it will be built on the extinction of fossil fuels and draw anyone dealing with them into a maelstrom of everlasting economic misery. On the other side of the aisle, we find the notorious sceptics: Agnostic nihilists who denounce the debate as scaremongering, solely designed to push personal (economic) agendas forwards.

Let us move beyond polarisation and scrutinise the issue. In its broadest form, stranded assets are “assets [that] suffer from unanticipated or premature write-offs, downward revaluations or are converted to liabilities” (Caldecott et al., 2013, p. 7). While the phenomenon is not necessarily connected to climate policies (though most popular in this context), stranded assets live in a world of abundant reserves and excessive supply. On a related note, the authors are grateful that contradictory empirical evidence has finally made an end of the times of fearmongering about peak-oil and Hotelling-style price curves (Ansari, 2019; Dale, 2016; Hart and Spiro, 2011). Instead, in the world of stranded assets, the future demand for fossil fuels would decline. A significant share of reserves would need to remain in the ground (McGlade and Ekins, 2015), devaluing reserves, companies, and infrastructure.

Conceptually Flawed

However, we agree that the concept suffers from several conceptual issues. Most significantly, stranded assets are paradoxical. Researchers typically compute them as the amount of reserves that need to stay in the ground (and they compute any economic effects thereof), or as the effects of altered parameters (e.g., demand, policies) on companies and economy. Such assessments, however, wilfully ignore that asset stranding is intrinsically tied to being “unanticipated”. If the devaluation of assets were the product of predictable (or, at least, very plausible) developments, it would hardly be consistent with the essence of stranded assets. In other words, scientists spend a great deal of effort to anticipate the unanticipatable.

Be not deceived; this point is not solely theoretical, but its implications are the focus of public debate. When sudden policies hit companies and the economy, compensation payments are on the agenda. For instance, Germany’s recently closed coal-exit deal entails compensation payments to industry and affected region of 4 billion Euros annually.

However, where exactly can we draw the line between stranded asset and bad investment? Consider an entirely different example: The closure of Istanbul’s Ataturk airport hit neighbouring hotel investments worth roughly 4 billion US-Dollars. Many of these hotels were constructed only years before the announced shut-down. Are these hotels stranded assets, and should the Turkish government compensate shareholders? Readers would probably disagree, and so does Timur Bayındır, President of the Turkish Hotel Association. He noted that the sector might have needed better investment judgment. Similarly, regardless of the actual extent to which climate policies will unfold, no shareholder or manager can claim they were unaware of the risk. Thus, efficient markets would need to adjust, and prices (financing cost, stock values) would need to reflect these risks accordingly.

Notwithstanding the foregoing, Helm (2015) enters the debate and promotes the role of discount rates. Investors, especially private ones, can choose from a wide variety of projects and prefer those with early payoffs – a discount rate is born. As a result, he argues, investors are hardly interested in the returns after ten years, let alone after many decades. Instead, he identifies asset stranding as an – unsuccessful – attempt of the climate community to mobilise private actors for decarbonisation; an issue that belongs rather to the sphere of policy than business.

This coincides with another conceptual flaw of stranded assets: The discussion suffers from a significant degree of normativity, which inherently leads to bias. Those who estimate stranded assets (which is, as elaborated, a paradoxical statement in itself) typically view them as the consequence of necessary climate policies. Hence, projecting stranded assets means not to estimate what will be, but what should be. Opponents, on the other hand, typically cite the very absence of market reactions as proof that there are no stranded assets – a Keynesian beauty contest gone wild. Both sides turn asset stranding into a self-fulfilling prophecy.

Economic Diversification and Demystification

In the face of asset stranding, one can argue that fossil-fuel dependency is an equal concern for developing and developed economies. Nevertheless, this argumentation misses the reality of many emerging and developing economies whose growth is led by fuel exports. Hence, for the remainder of this article: What, at least, if stranded assets were real?

The extractive sector is vital for economic growth, poverty reduction, and socioeconomic development; it has often been endorsed as a way out of 'aid dependency' (Lahn and Bradley, 2016). Also, domestic resources prove helpful in meeting domestic energy consumption (Schlösser et al., 2017). Therefore, moving away from fossil-fuel industries is often perceived as trading off growth and prosperity for the sake of an unfamiliar, foreign debate. The carbon lock-in, however, goes beyond the extractive industry and often covers oil-and-gas-dependent households, transport sector, and domestic industries (Bos and Gupta, 2018).

The perception of oil and gas in exporting countries has indeed witnessed a gradual change in the last years. It was primarily the oil price crash in 2014 that raised awareness for the fragility of export revenues. However, as analysed by numerous studies (e.g., Ansari, 2017; Ansari and Kaufmann, 2019; Fattouh et al., 2016), oil market shifts may have altered the market environment, but they have by no means nullified suppliers' prospects. Instead, fuel exports are arguably still the best (mid-run) revenue strategy.

Despite a general awareness for economic diversification, proper action stays limited. As noted by Albassam (2015) for the case of Saudi Arabia, plans to diversify the economy are not novel but often unfulfilled for decades. It is no wonder that many commenters are confused by the ambiguity of signals. Exporters investing in renewable energy projects are commonly mistaken as evidence for a global energy transition. Instead, exporters who decrease domestic fuel consumption often aim at increasing export capacities (Blazquez et al., 2019), leaving the CO_2 effect at zero. Remarkably, this process can also be reversed, as shown in the case of Iran: With tightening sanctions, the domestic consumption of Iranian fuel has been set to increase (Zaklan et al., 2018). Overall, as argued by numerous scholars (e.g., Ansari, 2016; Dale, 2016; Huppmann and Livingston, 2015), the oil industry is not losing grip; it is consolidating.

Perfunctory examinations of actual numbers (Table 1) may be puzzling too: The contribution of natural resources to the GDP is the most straightforward indicator for economic diversification. However, actual figures are moderate, even for major fuel exporters. For coal-supplying Colombia and Indonesia, resource rents remain below 4%. Natural resource powerhouse Russia draws only remarkable 9% of its economy from resource rents, and even figures from the Arabian Gulf range between modest 11% in the UAE and slightly higher 32% in Iraq and Kuwait.

The issue requires digging deeper and considering instead the diversification of exports and fiscal state: For Algeria, whose resource rents only account for 12% of GDP, fuels come up for 94% of exports. While fuel accounts for nearly 50% of Colombian and Russian exports, for Azerbaijan, Brunei, Kazakhstan, Kuwait, Oman, Qatar, and Saudi Arabia, this figure exceeds two-thirds of their exports. The unlucky winners of this competition are Nigeria with 96% and Iraq with 99.99% of their exports.

On the fiscal side, even economies that are otherwise diversified reveal their continued resource dependency. 68% of UAE government revenues originate from the resource sector, and so do 89% of Bahraini government revenues. In Saudi Arabia, the figure exceeds even 93%.

Ironically, the missing diversification reflects both the reluctance to opt-out of fossil fuels and the dangers of relying on them. Social contracts in resource-rich nations, which often encompass the domestic distribution of rents to stabilise the government (a topic too profound to discuss here), are rigid and at risk when fuel revenues decline. While price volatility is well-known to these economies, stranded assets

Country	**Natural Resources Rents 2016 % of GDP**	**2016 Fuel Exports % of Merchandise Exports**	**Resources Revenues 2014 % of Total Governm't Revenues**
Algeria	12.3	93.99	52.8
Azerbaijan	15.44	87.51	67.6
Bahrain	3.23	55.03	88.6
Brunei Darussalam	14.72	87.88	n/a
Cameroon	5.9	6.17	26
Colombia	3.42	49.96	19.3
Cyprus	0.02	19.76	n/a
Ecuador	3.75	33.1	28.9
Egypt, Arab Rep.	3.06	16.35	n/a
Ghana	11.65	22.15	13.9
Indonesia	3.06	19.3	20.4
Iran, Islamic Rep.	13.47	67.4	n/a
Iraq	31.34	99.99	92.4
Kazakhstan	12.39	60.74	51.6
Kuwait	32.15	89.69	89.7
Mexico	2.28	4.91	n/a
Mozambique	17.59	27.89	10.1
Myanmar	6.77	28.16	n/a
Nigeria	4.86	96.3	53.9
Norway	4.13	53	24.5
Oman	19.67	62.53	42.6
Qatar	15.35	81.55	52.7
Russian Federation	8.84	47.19	n/a
Saudi Arabia	20.03	74.53	93.4
United Arab Emirates	11.35	20.23	68

Table 1: Fossil-fuel dependency for selected countries. Data: World Bank, IMF, EITI, ICTD

project a much darker future of prolonged low revenues. Hence, stranded assets do not only threaten economic growth for exporters but also regional stability and security.

So, Who is in danger?

Based on our recently published DIW-REM energy outlook[1] (Ansari et al., 2019), we have assessed stranded assets for three regions: The Middle East, China, South America. All three regions are very different yet have a sizeable fossil-fuel sector in common.

The index combines two indicators: the risk for stranded capacity (i.e., the share of production capacity that is added in a production-intensive scenario but would not be used in a low-production scenario) and the importance of the respective sector for the regional economy (measured as the share of primary energy). In other words, the index indicates the risk that the respective regional industry is adversely affected by excess investments (i.e., stranded assets).

Figure 1 depicts the results. Based on the index, the

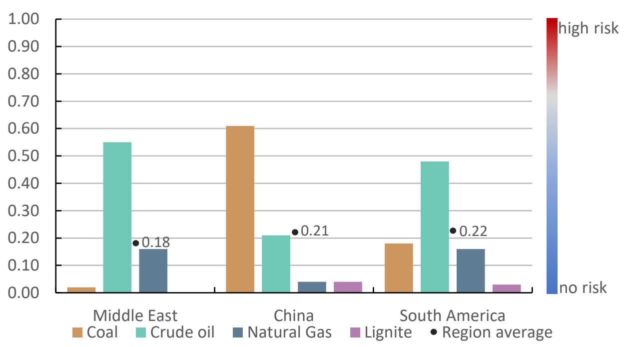

Figure 1: Stranded asset index from:

Chinese coal industry is subject to the largest stranded asset risk, followed by the Middle Eastern crude oil sector and the South American one. Furthermore, natural gas in the Middle East and South America as well as coal in South America and crude oil in China show a minor stranded asset risk.

Hence, and remarkably, the index suggests that all three regions are in a hazardous environment; regional averages are even similar (between 0.18 and 0.22). Moreover, the index challenges the perception that certain suppliers are on the safe side: While, for instance, Middle Eastern oil production continues to varying extents in all our scenarios, the differences between them are substantial, despite the region's favourable position in the global supply curve. The Chinese coal industry will be primarily influenced by the question of whether China continues to bet on stricter environmental policies but also by the technological progress of CCS technology. South America, finally, has an unfortunate role: Individual Latin economies are often dependent on a single type of resource (e.g., coal in Columbia or crude oil in Venezuela), such that asset stranding would lead to strong sub-regional effects. (Ansari et al., 2019)

Too Big to Ignore

It is true that the debate about stranded assets has a strong partisan note. Moreover, discussing stranded assets requires neglecting their numerous conceptual flaws and postulating a future with stringent climate policies or abrupt technological change.

However, stranded assets may be too impactful to ignore. Potential consequences of a large-scale asset stranding in non-diversified economies would be severe. Hence, even decision-makers who are convinced that a global energy transition is unlikely should consider the issue, if they think such a transition it at least possible.

Albeit the previous elaborations, we would even restrict the statement that most exporters focus solely on consolidating their industries. For instance, Saudi Arabia's intended IPO of Aramco, part of Vision 2030, speaks for that (although its failure speaks equally to the complexity and trade-offs regarding such strategies). Oil reservoirs and coal mines are no warehouses, whose stocks can be sold off the same day. Instead, the speed of resource extraction is bound by engineering and capital, giving bounds to market developments. Hence, the fear that asset stranding could trigger a large-scale green paradox (Sinn, 2015) are mostly unfounded.

Nevertheless, restating an initial point of Helm (2015)'s critique, the stranded asset lobby needs to be aware that the concept does not only require a declining production but also declining prices, which are a further obstacle to the deployment of non-fossil technologies. Presenting stranded assets as a market-led phenomenon challenges both its very concept and factual reality. Instead, the stranded assets debate is tied to political developments and should be used to understand and establish how international collaboration and coordination can achieve a global and *just* transition.

Footnote

[1] Our outlook features four distinct scenarios of energy, climate, and policy towards 2055. The scenarios elaborate different futures as the consequences of variation in current drivers, including geopolitics, economic development, political climate, and social factors. They were constructed in a three-step process that contains an expert-led qualitative analysis, a quantitative analysis with the numerical energy and resource market model Multimod, and a harmonisation of qualitative and quantitative analysis (Ansari et al., 2019).

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Doshi (continued from page 5)

fracking revolution has weakened the ability of OPEC and Russia to support crude oil prices by restraining output. It may be argued that US strategic interests in the Middle East might wane along with the decline in its energy imports from that region. But it would be a mistake to make too much of America's reduced dependence on Middle Eastern oil. Containing Islamic terrorism, mitigating the threat of nuclear proliferation and supporting Israel's defence needs in a volatile region remain strategic foreign policy imperatives.

It is also important to avoid a superficial understanding of "dependence" on oil imports from the Middle East. Oil is sold in fungible global markets, and its price for the large oil importers in Asia is linked to its price everywhere else. Ultimately it does not matter how much of the oil consumed in Asia comes from the Middle East. The price of oil depends on global demand and supply, and the disruption of oil trade flows anywhere affects consumers everywhere. The precepts of "energy security", founded on defunct Malthusian notions of scarcity, have been debunked. Asia's oil importers and the Middle East oil producers now face the brave new world of ample competing oil supplies, shifting geopolitics and an American energy renaissance.

Footnotes

[1] See Energy Information Administration website https://www.eia.gov/petroleum/

[2] O'Sullivan, M. L. (2017), "Windfall: How the New Energy Abundance Upends Global Politics and Strengthens America's Power" (Simon and Shuster, New York).

[3] See sources cited in St. Louis Federal Reserve website https://fred.stlouisfed.org/series/SAUPZPIOILBEGUSD

[4] Mogielnicki, R. (2019) "Year-on-Year Deficits Brewing in Gulf Economies", April 24th, Stratfor Worldview accessed at https://worldview.stratfor.com/article/year-year-deficits-brewing-gulf-economies

Coal: Stranded Assets in China

BY JIANG LIN, JIAHAI YUAN, XU LIU, WEIRONG ZHANG

Background and Definition

Stranded assets are "assets that have suffered from unanticipated or premature write-downs, devaluations or conversion to liabilities", which could result from changes in a variety of factors including environment, resources, government regulation, technologies, and social norms. (Caldecott Ben, 2015;Caldecott et al., 2016). As the world is addressing climate change and the progress of fossil-fuel phase-out, coal resources could become stranded.

China is experiencing the economic "New Normal" with a slower economic growth and a transition from the heavy industry sector to the service sector. Thermal power plants operating hours remained at a low level below 5000 hours per year during the past five years. We define coal power stranded assets as the assets that have to retire ahead of their lifetime because of the competitive environment and other external conditions. Given the overcapacity of coal power plants and economic transition in China, the extra coal power plants will become stranded assets. With the ongoing power market reform in China, less-efficient coal plants will face increasing challenges of being phased out (Yuan et al., 2019). Over 50% of coal power companies are losing money in 2018 based on an China Electricity Council estimate.

It is very important to understand the current stranded assets of coal power plants in China and provide policy recommendations to tackle this potential issue. In the next section, we analyze the existing drivers for the coal stranded assets in China. Then we evaluate coal stranded assets in 2030 in China. Finally, we provide policy recommendations.

Drivers of stranded assets in China

Environmental Impacts: Environmental pollution issues have drawn more and more attention in China. Chinese central and local governments have set many targets on the efficiency of and emissions from coal power plants. In 2015, the government required coal power plants in eastern, central, and western China to complete a low-emission retrofit by 2017, 2018, and 2020, respectively (NDRC, NEA and MEE, 2015). Since 2017, China initiated the national carbon trading program starting from the power sector (NDRC, 2017). As a result, coal power plants face a "double control", both environmental pollutant and carbon emissions.

Clean Energy Transition: China has committed to achieve 50% of non-fossil fuel power generation by 2030 (NDRC and NEA, 2016), almost double from 28% in 2017. To achieve this goal, coal consumption in the power sector needs to be controlled and its clean and efficient use needs to be promoted. In addition, renewable energy development will also facilitate the clean energy transition, which also limits the development of coal power plants.

Overcapacity: Coal power overcapacity in China has been widely recognized and China National Energy Agency has published several documents to reduce coal power overcapacity since 2018. During the 13th Five-Year Plan, China has stopped or postponed new coal power plant construction of 150 GW and phased out 20 GW less-efficient coal plants (NDRC et al., 2017).

Power Market Reform: "Opinions of Further Power Sector Reform" (Document 9) started the new round of power market reform in 2015 (the State Council, 2015). Eight provinces/regions have been identified to pilot wholesale markets to enhance the role of markets in resources allocation (NDRC and NEA, 2017). With the increase of market-based power transaction, coal power plants face growing pressure to make profits.

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Quantifying risks and stranded assets

Given the above external conditions, a lot of coal power plants bear a high risk of exiting the market and becoming stranded assets. We estimate coal stranded assets in 2030 under two different scenarios and evaluate the potential impacts on different stakeholders.

Under the reference scenario, where no further control policies are implemented, those new projects postponed or stopped during the 13th FYP will continue to be constructed from 2020 to 2030, and by 2030, total coal installed capacity reaches 1200 GW. If the entrance of new plants force old plants to exit the market, those old power plants will become stranded assets. In 2030, total value of stranded assets is estimated to be over 103 billion yuan.

Under the supply control scenario, where total coal installed capacity is constrained to 1100 GW by 2030 and stricter technical and environmental standards are implemented to force less-efficient plants to retire or retrofit into flexible operating plants. the total value of stranded assets could be 40 billion yuan, much lower than the reference scenario.

Under both scenarios, we broke down the stranded assets value into central, local, and bank stranded assets. We found that central stranded assets account for over 40% of total stranded assets, while local stranded assets account for less than 20% and banks bear the rest. As a result, coal power plants stranded assets will be mainly government-owned assets.

Policy Recommendations

To address the stranded assets issue, we provide policy recommendations in three areas, energy policy, fiscal policy, and financial policy.

Energy Policy: Make maximum use of the existing fleet. More specifically, the government could introduce a capacity auction mechanism to provide proper capacity prices for new and old units. For coal plants with high flexibility, strategic contracts could be signed to use those plants as back-up plants and peaker plants. For inefficient capacities that will be phased out from the power system, the government could provide compensation based on the years of operation. The government should also facilitate back pressure retrofitting for cogeneration units with longer service life and heating

Stringently control new capacity and eliminate backward capacity. From 2020 to 2030, no new coal power projects should be approved and others that were suspended during the 13th FYP should be built in order. Newly built coal power plants should stringently follow the requirements (State Council, 2016), and all the projects shall be subject to provincial government approval based on China's coal cap project, and must not be registered under the industrial project for archival purpose. For backward fleets that cannot meet the energy efficiency standards, they should be shut down and phased out.

Implement power market reform and a national carbon trading mechanism. First, a power market should be established in order to enable effective price signals to play a decisive role in guiding power resource investment. In addition the government should turn the cost-compensated ancillary service compensation mechanism, which is now determined by the administration, to a market-oriented value compensation mechanism. Meanwhile, quantify the system value of the service, consider the opportunity cost of the ancillary service, and replace the planning mechanism by adjusting the market mechanism. When setting up the market, both energy price and capacity price should be taken into consideration. Establishing the national carbon market can release an external price signal to guide coal power unit retrofitting and phase out. The release of external price signals would encourage enterprises to adopt energy-saving and emission-reduction measures, guide the enterprises to exercise retrofitting of units or eliminating outdated units, guide the direction of power investment, and improve industrial upgrading.

Combine the market mechanisms and judicial disposition to assist the disposing of zombie enterprises. Governments at all levels should have a deep understanding of the company's situation and propose a plan of disposition. The more complicated and difficult ones, such as bankruptcy cases, shall be handed over to the local judicial authorities for standardized judicial disposal.

Fiscal/state-owned asset handling policy: Establish special funds to assist the resettlement of personnel from the phased out projects. Money for the special funds could be taken partially from the power industrial restructuring and upgrading fund. The funds can be used to provide subsidies to laid-off employees to start new business or provide one-time lump-sum compensation to them.

Adjust the value base of preserving and increasing State-owned Enterprises (SOE) assets and eliminate the impact of asset write-down. In conducting supply side reforms, the central SOE generation groups have withdrawn some ineffective or inefficient assets, causing asset writedowns, which may affect the assessment of preserving and increasing SOE assets. We suggest that the State-owned Assets Supervision and Administration Commission of the State Council's (SASAC) separate this part of the withdraw assets from the whole when conducting an assessment, adjusting the asset base and ensuring that the assessments not have a negative impact on the companies that are actively conducting supply side reforms.

Financial policy: Provide financial institution support to facilitate supply side structural reforms while ensuring that the power system is stably operated. Continue providing credit to those in-service units that meet the environmental requirements, actively contribute to power generation, and fulfill corresponding peak-adjustment tasks. On the contrary, companies that do not meet the environmental requirements, suffer long-term losses and have low market competitiveness should have related loans withdrawn by the financial sector in a timely fashion.

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2019 CONFERENCE REPORT: USAEE 37th North American Conference in Denver

Welcome to the 2019 Conference Report for the 37th USAEE North American Conference held in Denver, November 3rd-6th, 2019. The theme of this year's conference was "Energy Transitions in the 21st Century." Conference speakers focused on the rapidly accelerating changes taking place across global energy as stakeholders balance decarbonization goals with energy demand requirements. Speakers provided insight on current and potential future implications of the transition for energy markets, policy, technology deployment, geopolitics, and much more. Included in the following pages are short summaries of conference keynotes, plenary sessions, tours, and other activities. Please note that the conference session write-ups do not aim to be comprehensive, but rather to capture some of the speakers' key points and serve as a resource on where to look for additional information on specific energy themes. Each conference section includes an embedded video link for a deeper dive on that content. Please also note that the write-ups include both paraphrasing and direct quotes of the conference speakers. Direct quotes may appear without quotation marks because the content was typically drawn from volunteers' conference notes, and that may not be specified. In every case, the intellectual content belongs to the speakers, regardless of the format. We encourage readers not to rely solely on the report, but to utilize the embedded video links and check primary sources for themselves on topics of interest.

Thank you to all the contributors to the conference report including communications committee members Robert Kleinberg, Eric Hittinger, Mark McCarthy and Seth Blumsack and volunteers Omar Cabrales, Carol Dahl, and Tina Vital. And a special thank you to all the speakers and USAEE members for their contributions in advancing the energy transition. We hope membership finds the report useful and hope to see everyone at the 2020 North American Conference in Austin, Texas, November 1st - 4th. Mark your calendars now.

Report Contents:

USAEE

USAEE North American Conference 2019

Opening Keynote Bill Ritter: States Are Filling Policy Vacuum on Decarbonization

Bill Ritter discusses decarbonization and state policy with NREL's Douglas Arent

In his keynote address, Former Colorado Governor Ritter addressed how U.S. states are filling the policy vacuum created by federal inaction on climate. State responses have been encouraging. 31 states have renewable portfolio standards. Of the 34 states electing governors in 2018, nine have candidates calling for 100% clean energy standards. Ritter runs a "state legislator clean energy academy" that develops model legislation that the states can adapt and adopt. One model example is regional agreements along the lines of the Obama-era Clean Power Plan. Ritter estimates. More than 4500 pieces of legislation will be introduced this year at the state level that would impact clean energy and climate. Ritter estimates about 600 to 650 of those bills would become law. Ritter added there are some "laggard states" on decarbonization to include Alabama and Mississippi. In addition, Ohio has repealed decarbonization initiatives. However, states may not be "allowed to lag for long." Shareholders for utilities and other corporations may force the transition. Power generators like the Southern Company and Xcel have decarbonization plans. Excel has pledged 80% CO2 reduction by 2030.

Regarding federal climate policy, Ritter stated there was still some "hope. There are 10 Republican Senators discussing climate policy centered on a carbon pricing with dividend framework. The outcome would depend on future presidential election results, but these Senators are helping lay groundwork for the future.

Ritter added that while policy is important, markets can be transformative. Federal pro-coal efforts have "failed miserably" due to market trends including falling costs for renewables and natural gas. Ultimately, greenhouse gases will need to be taxed. The price on carbon will drive innovation. Investment capital is waiting on the sidelines for that economic signal on decarbonization investments.

LINK: FULL VIDEO

Energy Transitions: Learning through History: Oil Entering a Twilight?

Energy Transition Panelists: Richard Newell, Resources for the Future (above); Amory Lovins, Rocky Mountain Institute; John Kingston, FreightWaves:

Is oil entering a twilight? Or not? FreightWaves' John Kingston raised these questions on oil's future and prospects of an energy transition. The smaller, nimble oil companies responsible for the shale revolution are struggling to create free cash flow, profits, and dividends. Their financial situation raises questions about the sustainability of the shale business model. At the same time, oil majors have strong free cash flows and oil production is booming in a number of countries. A glut of cheap abundant oil could continue well into the future and make the world "even more tied to it" (oil).

Rocky Mountain Institute's Amory Lovins' key point was there is too little attention being paid to "efficiency as resource." He stated that since 1975, the cumulative energy saved from reduced primary energy intensity is thirty times the cumulative increase from renewable energy. His second key point was that "integrated design" is a low hanging fruit for additional efficiency gains because it does not require technological change. Rather, it is based on a different conceptual approach to design that emphasizes multipurpose use, not singular benefits. For example more efficient auto lights also create the opportunity to reduce battery size. For more information, Lovins encouraged participants to read his paper, "How Big Is the Energy Efficiency Resource," which is available for download on the internet. Lovins encouraged the USAEE audience to conduct more research on the demand side. He said, there are "a lot of supply side papers" and many are insightful, but "on the demand side, not so much."

Resources for the Future's Richard Newell pointed out that previous energy transitions have been "additive." New dominant fuels emerged, but demand for old energy sources still continued to increase. The world consumes three times the biomass it did in 1800 and 60% more coal today than in 2000. Newell highlighted some positive trends in the underlying data. The US and EU are reducing the carbon intensity of their economies and energy usage, and that could be a future model for emerging nations. However, while the trends are "in the right direction" in the advanced economies, these regions are still "way off" the magnitude of change needed to address climate change.

FULL VIDEO PART I; PART II

USAEE North American Conference 2019

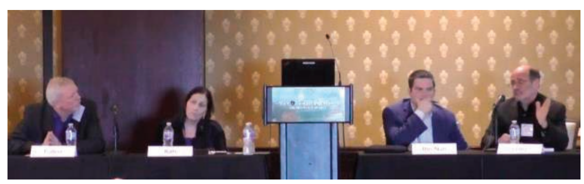
USAEE Student Activities: UC Berkeley's Susanna Berkouwer Wins Best Paper

Susanna Berkouwer of UC Berkeley accepts award for best student paper

Keeping with USAEE/IAEE tradition, there was a large slate of student-focused events during the conference. This started with the PhD Day on Sunday, sponsored by the Sloan Foundation. At this event, PhD students presented work-in-progress to each other, with plenty of time for discussion, critique, and networking. Later that day, the final round of the USAEE Case Competition took place, sponsored by the King Abdullah Petroleum Studies and Research Center (KAPSARC). During the summer, case competition teams had been issued packets describing a fictional customer worried about electrification of aviation. Student teams write consultant reports, with two selected to present at the conference. The winning team was Colin Sasthav and Dustin Gilmer, from the University of Tennessee Knoxville. A mentoring event capped off Sunday's student events, with five experienced energy professionals giving career advice to a rotating group of around 25 students.

On Monday, the Dennis J. O'Brien USAEE/IAEE Best Student Paper Award had its own concurrent session, with four great papers from current PhD students. The winner was Susanna Berkouwer from UC Berkeley for her paper entitled "Credit and attention in the adoption of profitable energy efficient technologies in Kenya". Monday also featured the student "work-in-progress" session, where students got feedback from academics on their research that is still underway. A student reception sponsored by the Center for Energy Studies at Rice University took place at the nearby Gordon Biersch Brewery on Monday night.

Global Decarbonization of Road Transport: EV Uncertainty & Occupancy Trading



Global Decarbonization of Road Transport Panelists: Lew Fulton, UC Davis; Marianne Kah, Columbia CGEP; Amitai Bin-Nun, SAFE; Paul Leiby, ORNL

Columbia's Marianne Kah highlighted the wide range of electric vehicle (EV) forecasts. Columbia's survey of third-party forecasters shows a range of between 15% to 95% penetration for EVs in 2040, a gap "wide enough to drive a truck through." In addition, more survey participants lowered forecasts in 2019 than raised them due to skepticism about falling battery costs, lower future car sales, and potential relaxation of US vehicle regulations. The survey results highlight the uncertainty of future EV market share and decarbonization pathways in the road transport sector, a more challenging sector than the power for low carbon solutions.

UC Davis' Lew Fulton stated EVs currently account for about 1.5% of LDV sales, but must reach a much larger market share to address climate issues. There is uncertainty on how to achieve the needed growth. Fulton expressed hope that shared mobility and automation could speed up EV penetration. Currently, China is the key region for EV growth. Fulton suggested that Chinese auto companies could soon be producing EVs for export.

SAFE's (Securing America's Future Energy) Amitai Bin-Nun recited a long list of optimization opportunities from autonomous vehicles that could contribute to road transport decarbonization, enhance energy security, and improve road safety. The list included optimized route choice, powertrains, occupancy, vehicle size, materials, and more. Bin-Nun said SAFE is heavily engaged in outreach because a vision showing societal benefits has to be communicated before policymakers will take the risk on the new technology. SAFE forecasts a decade-plus process for autonomous vehicle deployment in the fleet, and adds the process has already begun.

Oak Ridge National Lab's (ORNL) Paul Leiby stated that shared-automated-mobility holds strong potential to reduce transportations costs. However, reduced costs could result in a demand response that increases miles traveled. Leiby states policy strategies and incentives would be needed to offset higher demand. He is researching "occupancy standards" where vehicles running high occupancy trips would receive tradable credits and low occupancy vehicles would be obliged to purchase credits. Fees are another policy lever. Research shows that a 10% increase in road use costs leads to roughly a 5-10% reduction in VMT. Leiby also stated that EV domination of future autonomous shared-mobility is questionable. DC fast charging costs equate to around 8-12¢/mile, which would be roughly equivalent to \$3.20 to \$4.80/gallon for a 40MPG hybrid. Liquid fuels could retain a cost advantage in mobility in future.

FULL VIDEO PART I; PART II; PART III

USAEE

USAEE North American Conference 2019

Decarbonization of North American Power: Modern Grid Culture

Decarbonization of North American Power Panelists: Steve Berberich, CA ISO; Debra Lew, Debra Lew LLC; Jesse Jenkins, Princeton; Doug Arent, NREL

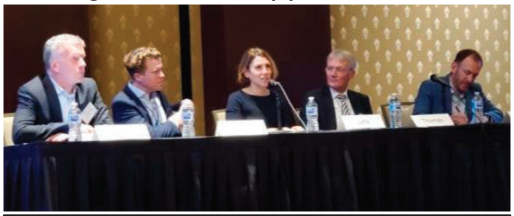
California ISO CEO Steve Berberich stated the California case demonstrates the ability to run a modern grid with high renewables penetration. CA regularly runs the grid with over 50% renewables, and often hits 70% peaks. He notes this figure does not include hydro and nuclear, which could increase the system's total clean power an additional 15%. Berberich stated he engages system operators all over the world, and concludes that the single biggest obstacle to higher renewables penetration is culture. It wasn't long ago that managing 20% renewables was considered a major challenge. CA grid operators formerly planned around a thermal system with some renewables. Now it's a renewables system with some thermal. Operators need to embrace new thinking. Berberich also discussed the importance of forecasting and geographic diversity for renewables.

Princeton's Jesse Jenkins identified political economy as both important and perhaps the most "under-studied aspect of power decarbonization. Aligning benefits for the majors shifts in infrastructure needed is the key to realizing grid decarbonization. If the transition "gores the ox" for well-established entrenched interests, without ameliorating the effects of economic dislocation, then the transition is going to run into a "political brick wall" and won't succeed at the pace needed. Jenkins called for more research that combines the technical, economic, and political pieces.

Consultant Debra Lew stated the industry hasn't tapped the biggest lever for balancing load, which is demand. She encouraged research on rate design and market structures that link up demand with the needs of the system. Operators need to incentivize customers to offload at peak to optimize available resources. Lew warned that electrification of other sectors is a double-edged sword. The industry has to have flexibility with new electric loads (EVs, heat) through price signals, direct control, or aggregators. Failure to design that flexibility would make the problem worse. Lew also stated the industry has to start thinking of curtailment as a resource as more renewables come on the grid. She cited ancillary services such as regulation reserve and spinning reserve as near-term options. Power-to-X (synthetic fuels) could be an option in future.

FULL VIDEO PART I; PART II

Geopolitics of the Energy Transition: Overcoming Zero Sum Approaches



Geopolitics panelists: Eirik Wareness, Equinor; Andreas Goldthau, IASS; Amy Jaffe, CFR; Wim Thomas, Shell; Morgan Bazilian, CSM

CFR's Amy Jaffe discussed scenarios related to the shift from an oil scarcity paradigm to oil abundance paradigm. Iran and Russia could be acting more aggressively to demonstrate they still have leverage and can't be ignored even if there is reduced need for their oil & gas supplies. Jaffe noted that if the politics of energy transition lead to decapitalization of oil companies, it could have the unintended consequence of increased oil dependence on National Oil Companies (NOC) and OPEC.

Equinor's Eirik Wareness identified geopolitics as a potential barrier to any energy transition. Today's geopolitical climate, characterized by low trust and zero sum thinking, make it difficult to meet sustainability goals. Long-term benefits, including reduced geopolitical tensions, may not be realized if the world can't overcome near-term challenges including higher costs, volatility, and changing interdependencies.

Shell's Wim Thomas commented that the US shale revolution has postponed a global energy transition by at least 10 years. The statement highlights the challenge of global climate coordination in an age of oil abundance. Thomas discussed Shell's "well below 2º" Sky energy transition scenario. The world has 50 years to go from 80% fossil to 20% fossil / 80% non-fossil. The transition requires overcoming the political problem of "who will pay?"

Andreas Goldthau of the Willie Brandt School outlined potential geopolitical implications of an energy transition through four scenarios. The first scenario includes a policy-driven "just transition" that includes a generous climate fund to soften the landing on dislocations. A second scenario is less cooperative with nations retaining cleantech breakthroughs for national advantage. The third "nationalist populist" scenario sees energy independence prioritized and reluctance to give up fossil fuels. The final scenario is a business as usual "muddling on" scenario.

LINK: FULL VIDEO PART I; PART II

USAEE North American Conference 2019

USAEE NREL Tour: A Driverless Shuttle and an Eagle Computer

USAEE tour of National Renewable Energy Lab (NREL); The automated electric shuttle (above right) was the highlight for the USAEE tour group

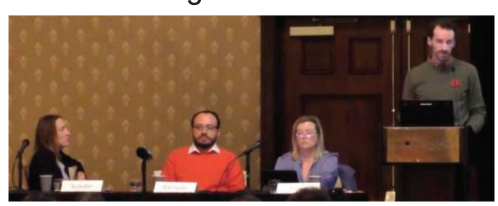
On November 6, 18 delegates to the USAEE Denver Conference toured the U.S. National Renewable Technology Labs Golden Colorado Campus. The tour started at the Golden Campus Education Center where NREL's James Bosch provided the group with an overview of the laboratory's mission, funding, and salient accomplishments. James explained that NREL, one of 19 Federal R&D sites, focuses on the science and engineering of energy efficiency, sustainable transportation, and renewable technologies. The lab partners with private companies, including many small and startup entities, and provides them with facilities and technical support as they conduct cutting edge research on technologies of the future. Of equal importance, when the research yields promising technologies, the lab provides companies with support and know how to help bridge the dreaded "valley of death", which is the point where companies look to move beyond R&D and into commercial viability.

After the overview, James led the tour to various laboratories where researches are working on areas such as battery technology, advanced manufacturing of energy efficient materials, bioenergy, and transportation. A highlight of the lab tour was seeing some of the lab's high performance computers, including their Eagle computer which has a peak performance of 8 petaflops. The tour participants learned that NREL is home to the most energy efficient data center in the world.

Throughout the tour, participants saw ways in which some of the materials and designs born in the lab are used in building construction at NREL. These include glass that darkens under sunlight to reduce the need for air-conditioning during certain times of the year, and wall cladding that helps reflect heat. Another highlight was watching NREL's autonomous shuttle vehicle perform test runs on a road lined with electric vehicles being charged.

The tour was a great opportunity for USAEE delegates to learn about the work being done at NREL.

North American Energy Infrastructure: Rise of the Fracking Zombie Movies?



Infrastructure Panelists: Tisha Schuller, Adamantine Energy; Luis Serra Barragan, Tecnologico e Monterrey; Paula Gant, GTI; Jean-Denis Charlebois, Canada Energy Regulator

GTI's Paula Gant introduced the panel highlighting how infrastructure projects have enhanced North America market integration and interdependence. However, new infrastructure projects are proving more challenging.

Canada Energy Regulator's Jean-Denis Chalebois stated Canada's oil & gas resources are globally competitive and the nation could increase oil production even with a price a carbon. However, "pipeline drama" has created bottlenecks. Crude oil production for export has increased faster than pipeline capacity. 5 major oil pipes have been proposed, but not yet built. This has led to steep discounts for Canadian crude. Canada has benefited from energy integration with the US, but needs more partners.

Adamantine's Tisha Shula discussed how shareholder resolutions are increasingly focused on environmental matters. The most popular issue is the 2 degree climate limit. In New York State, climate goals apply to all government actions. The oil and gas industry must ask what public is looking for. Consumers are not willing to pay for climate mitigation. Polls show that consumers value climate action at less than $10/month. A community will ban fracking but will not ban the use of oil & gas. There are two new movies about zombie invasions caused by fracking.

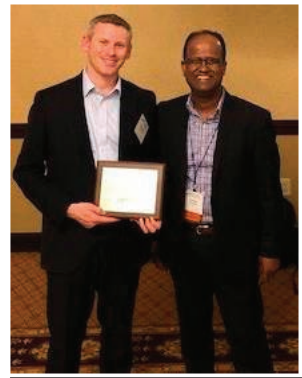
Monterrey Tech's Luis Serra Barragan discussed Mexico's challenges including social conflicts, lack of energy policy clarity, lack of transparency, and lack of regulatory independence. Economic growth is not the priority. The priority is national sovereignty, despite fuel shortages. PEMEX is designated as the cornerstone of the economy, despite being $100 billion in debt. Despite an overall lack of competitiveness, the cost of wind & solar energy is among the lowest in the world at about USD 20/MWh.

LINK: FULL VIDEO PART I; PART II

USAEE

Adelman Frankel Award to BP Statistical Review

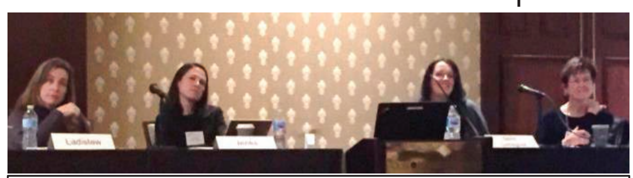
USAEE annually bestows the Adelman-Frankel award to an individual or organization that makes unique and innovative contributions to the field of energy economics. BP's US Chief Economist Michael Cohen accepted on the award on behalf of the BP Statistical Review. Cohen discussed the history of the publication highlighting the important role it filled on energy information in the 1950s, 60s, and 70s before there was an EIA or IEA. The information has always been accessible, BP data is all in one place. There are no passwords to be remembered, and no special programs you need to use. In addition, the information continues to improve. BP still tracks oil & gas, but has added new data sets such as the "materials that go in to EV batteries and rare earth metals, which will play increasingly prominent roles in the energy system in the decades to come." The data has "no politics. There is no spin. You can't argue with the facts. Dan Yergin, one of the great energy historians of our time, said that he always keeps two things in his briefcase: his passport, and a copy BP's Statistical Review. He called it "a global go-to source for decision makers and analysts around the world."



BP's Michael Cohen accepts award on behalf of the BP Statistical Review

Government Policies and Low Carbon Transition: Multi-Trillion Dollar Gaps

Moderator Susan Tierney noted that the panel was taking place one day after the Trump administration officially started the process to leave the Paris Agreement. Tierney stated there is still terrific momentum on climate issues in the US despite the administration's position. Panelists discussed where the momentum is and future implications.



Government Policies Promoting Low Carbon Panelists: Susan Tierney, Analysis Group; Kelly Sims-Gallagher, Tufts; Carrie Jenks, M.J. Bradley & Associates; Sarah Ladislaw, CSIS

CSIS' Sarah Ladislaw discussed the challenges of optimizing policy in a suboptimal political environment. Ladislaw sees potential for pursuing climate policy through non-controversial, "familiar" policies that people understand. She identified Clean Energy Standards (CES) as having the advantage of political convenience. A Clean Energy Standard could be enacted by "adding dimensions" to the existing state Renewable Portfolio Standards (RPS). The CES policy could include support for nuclear, CCS, and potentially methane emissions. Congress isn't ready for a federal CES yet, but it's a policy option that could become more visible in future.

Carrie Jenks of MJ Bradley & Associates provided an overview of US subnational action on climate. 21 states have GHG reduction targets, 29 have an RPS/CES (covering 56% of US power), and 8 states have 100% zero emission goals. In addition, several states are pursuing transportation programs. She cited the Transportation Climate Initiative (US Northeast/Mid-Atlantic) as an example. Congress won't be ready to act in a significant way for another 2-3 years or longer. In the meantime, states are being forced to increase stringency in absence of federal leadership. The federal government could leverage these policy models when it is finally ready to take action, which could occur through overlapping policy or pre-emption.

Tufts' Kelly Sims-Gallagher discussed her research on climate policy effectiveness and highlighted four metrics for evaluation including 1. Mobilization of finance 2. Economic efficiency 3. Environmental integrity 4. Equality of access. Early results show that different policies have their pros and cons. The US loan guarantee program is effective at mobilizing money and inexpensive to taxpayers. However, it is perceived as unequal (recipients are bigger, wealthier firms) and is politically vulnerable. China's green bonds program is effective at mobilizing capital, but there are big questions about environmental integrity. The US tax credit program is transparent with equal access, mobilizes capital, but is expensive for taxpayers. Sims-Gallagher concluded that there is no silver bullet policy, but rather these policies need to be "nested" in a broader policy portfolio. Sims-Gallagher placed particular emphasis on mobilization of climate finance. She estimated there is currently about $460 billion per annum spent on climate related investments. However, the climate finance gap is still a staggering $3 to $6 trillion/year. Climate finance differs from other sectors. For example, it is more of a national process. 80% of existing finance is raised in the same country where it is spent.

FULL VIDEO PART I; PART II

USAEE North American Conference 2019

Keynote Speech: Canadian Consul-General Stephane Lessard

Consul-General Stephane Lessard speaking at the USAEE North American Conference in Denver.

In his keynote speech, Canadian Consul-General Stephane Lessard highlighted the strong energy links between Canada and the United states. The bilateral trade in energy between the two countries amounts to $116 billion a year. 74 oil and gas pipelines cross the border, and 46% of gas produced in Canada is exported to the US. Recently, crude-by-rail shipments to the US have tripled; this mode of transportation is inferior to pipelines, and the Keystone XL pipeline should be completed to solve this problem. Canada is looking forward to the confirmation of the US-Mexico-Canada (USMCA) trade agreement to restore a firm political footing.

Lessard also discussed the importance of energy to the Canadian economy and decarbonization plans. Energy is a major component of the Canadian economy, and Canada is a principal supplier to energy to the world. 11% of Canadian GDP is in the energy sector. Canada is the world's fourth largest producer of oil, the fourth largest producer of natural gas, the second largest producer of uranium, and the third largest producer of hydroelectricity. 17% of Canada's domestically consumed energy is renewable. Canada has a low carbon energy plan to meet its Paris commitments. Canadian provinces are taking different approaches to carbon pricing. Carbon taxes, cap-and-trade and regulation are all instruments being used. Technical innovation is also playing a role in decarbonization. Carbon dioxide emission from oil sands production is declining in intensity. Canada is home to a direct air capture pilot plant, which takes carbon dioxide out of the air.

Energy Trade: "The Nexus of the Interesting and Important"

Energy Trade panelists: Horace Hobbs, Phillips 66; Kevin Book, ClearView Energy; R Dean Foreman, API; Oliver Tuckerman, Cheniere

API's Dean Foreman introduced the energy trade theme as the "the nexus of what's both interesting and important." Foreman proceeded to tie trade issues to every important trend from the macroeconomy, industry, and climate. Foreman highlighted the importance of trade to the US energy industry and asserted the current trade frictions poses serious challenges to growth going forward. The trade war with China has already affected products important to the US oil industry from lithium batteries to turbines, valves, meters, and motors. LNG production is ramping up rapidly with 5.4 bcf/d of capacity online, 8.3 bcf/d under construction, and 13.1 bcf/d approved. Growth depends on trade partners.

Oliver Tuckerman reviewed LNG markets. He expects the US to become the largest LNG exporter by 2022. Tuckerman commented on the prospects for LNG from western Canada and US. Canadian LNG can be shipped to northern Asia in ten days, versus thirty days from the US Gulf Coast, an advantage for Canada of about $1/MMBtu. However, construction in northern British Columbia is much more expensive, primarily due to skilled labor constraints.

Horace Hobbs discussed international hydrocarbon trade flows with a focus on the US. The US is both the world's largest exporter and largest importer of gasoline NAFTA renegotiation put half of US gasoline exports at risk, but the situation seems to be settled. The US is world's largest producer and largest exporter (by far) of natural gas liquids. Tariffs have pushed US LPG to third countries, which then re-export to China. World trade is balanced, but at reduced efficiency. Hobbs noted that long-term US sustainable oil production could be as much as 17 Mb/d, which would imply an export capacity of around 9 MMb/d.

Kevin Book discussed US energy politics. A major theme is that the age of energy scarcity is over. The situation has led to presidential candidates taking the industry for granted. In that context, they are making proposals such as banning oil and gas drilling on federal land, or banning fracking altogether. In general, tariffs and sanctions have proved to be relatively low cost instruments of national power, and are likely to be harder to reverse than many think. There is a possibility that the US and China economies will become much less integrated. On the other hand, an emerging pressure point is strategic minerals, a challenge that will need to be faced by future administrations. Another emerging challenge is the prospect of a European border adjustment tax affecting fossil fuels.

FULL VIDEO PART I; PART II

USAEE

Night at the Geology Museum

The well lit M up on the mountain signaled that our buses were getting close to our reception venue at the Geology Museum at the Colorado School of Mines. Delegates could greet old friends and meet new ones over good food and drink while wandering amongst cases containing the most extensive public collection of Colorado minerals. Gold glittered and crystals sparkled from the cases. It was too dark to see the dinosaur tracks on the nearby geological trail. Come to think of it, they are hard to see even in the light.

The wall murals with mining scenes looked down on the happy crowd comparing their favorite events of the days, discussing the latest trajectory of market prices, pondering profits and other topics near and dear to the heart of those interested in energy economics. With the departure nearing a trip to the dessert bar in the lower level allowed a walk by not one, but two moon rocks. So not all the rocks were home grown. A walk through the cave to minerals that glow in the dark was a perfect end to a convivial evening that seemed to be enjoyed by one and all. If you can't visit the museum in person, check out some great pictures at the link: *VIRTUAL TOUR: CSM GEOLOGY MUSEUM*

Paths to a Sustainable Future: Sequestered Breath?

Paths to a Sustainable Future Panelists: Cindy Yeilding, Shannon Bragg-Sitton, INL; Carol Dahl, CSM; Sara Banaszak, ExxonMobil

Carol Dahl of Colorado School of Mines introduced the "Paths to Sustainable Future" panel by highlighting that there are different ways to get to a sustainable future. The panel featured one speaker each on potential future roles for nuclear energy, natural gas, and CCUS (Carbon Capture, Utilization, and Sequestration).

Idaho National Lab's Shannon Bragg-Sitton raised the following question. Given the importance of nuclear energy for achieving 2050 climate goals, why isn't nuclear energy thriving? She cited three key reasons including cost, public concern, and policy. Bragg-Sitton sees promise on the cost challenge through a shift to standardized design and manufacturing. The industry could address public concern with new designs that reduce the probability of accidents and mitigate the consequences if they occur. Regarding policy, she called on technology neutral frameworks that reward outcomes including emissions, reliability, and efficiency. If policy forecloses the role of nuclear, then society can't expect to see investment, and this could significantly delay progress towards climate mitigation while raising costs of deep decarbonization. Bragg-Sitton outlined a new vision of distributed small modular and micro-reactors providing power for industry, process heat, clean hydrogen, water, and possibly even synfuels from captured CO2.

Natural gas has an important role in the future energy mix, even in low carbon scenarios, according to Exxon's Sara Banazak. The IEA's 2018 two degree C° "Sustainable Development Scenario" (SDS) shows a significant role for natural gas even with a roughly 50% emissions reduction compared to the NPS base case. A range of other scenarios tracked by the Stanford Energy Modeling Forum also show a role for gas. The recent 2019 Bloomberg New Energy Finance outlook shows strong annual capacity growth for natural gas in power to 2050. The gas is primarily used for renewable energy backup and flexibility, but capacity still doubles by 2050. Banazak added that the key point is that all sources are needed to meet energy needs in 2050, even in low carbon scenarios.

BP's Cindy Yeilding provided a preview of the upcoming National Petroleum Council (NPC) CCUS study, which will be publicly released in mid-December. The study is a roadmap to "scale up" CCUS as a viable low carbon option. The study draws on the expertise of 110 organizations including oil & gas firms, financial institutions, and NGOs among others. The technology section of the report focuses on "capture" because it accounts for 80% of CCUS costs. The tech overview includes both "tried and true" options and promising new technologies. CO2 would need to be transported because capture directly over sequestration and utilization sites would be rare. Yeilding expects pipelines to be the main transportation option, though trucks and trains would also see usage. Storage would occur in oil & gas and saline reservoirs or products. Yeilding cited a number of potential products for captured carbon including potential exotic options such as "diamonds made from a beloved's breath." A centerpiece of the study is a cost curve developed from modeling almost 2000 actual US emissions sources. The study concludes with a series of policy recommendations to catalyze growth of CCUS. ***FULL VIDEO PART I; PART II***

Energy Entrepreneurship and Finance: Innovative Finance Supports Innovation

Energy Entrepreneurship and Finance Panel: Greg Taylor, Sequoia; Ambassador Robert Perry, Stevenson Group; Tina Vital, Castle Placement; Robert Fenwick-Smith, Aravaipa Ventures.

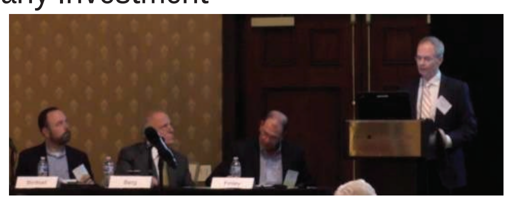
Ambassador Robert Perry of the Stevenson Group discussed the roles of the Trade and Development Agency (USTDA), the US International Development Finance Corp. (USIDFC), and US import-export Bank (EXIM). USTDA promotes exports, connects US firms with foreign project sponsors, coordinates with foreign delegations, manages grants, and more. USIDFC stimulates US investment in emerging markets. EXIM finances transactions that commercial lenders decline due to political or commercial risk.

Sequoia Investment's Greg Taylor discussed innovative energy infrastructure financing. Energy debt is typically private and higher yield than corporate bonds or leverage loans and is backed by energy assets or projects. Energy equity investors typically provide about 35% of the capital of the project company. Infrastructure bonds are typically resilient in a recession and are about 33% as volatile as corporate bonds.

Robert Fenwick-Smith discussed early-stage technology investment. Early stage is high risk with potential high returns—typically equity investments with no collateral. VC Funds typically take a portfolio approach—making 10-20 investments with an expected failure rate of 75%. Nearly all returns are generated by 10% of the investments. Fenwick-Smith stated that you have to take those odds and play those numbers. These types of investments are needed to support emerging technology and address climate change.

FULL VIDEO PART I; PART II

Changing Oil & Gas Company Investment



Oil & Gas Investment panel: Chris Birdsall, ExxonMobil; Mark Papa, Pioneer; Mark Finley, Rice University; Per Magnus Nysveen, Rystad

Oil investment panelists highlighted the need for robust capex spending despite the rise of electrified vehicles and the climate challenge. Rice University's Mark Finley highlighted the point in his introduction, stating the energy industry needs to invest trillions of dollars just to maintain energy supplies even during the transition to low carbon energy.

ExxonMobil's Chris Birdsall explained that Exxon continues to invest in its core business. Exxon has major oil investments in Guyana, Brazil, and the Permian Basin, and natural gas projects in Papua New Guinea, Mozambique and elsewhere. Birdsall said that the world does not yet have the technologies needed to achieve its climate goals. There are opportunities for technological breakthroughs in grid storage and in biofuels, both algae-based & cellulosic. In the meantime, fossil fuels would remain important in the industrial and power sectors.

Rystad's Per Magnus Nysveen presented an industry overview. Global average depletion of oil reservoirs is 12%/year, with infill drilling giving back about 6%. Global average breakeven is $26/bbl, tight oil breakeven cost is $45/bbl (of which operating expenses are typically $7/bbl to $9/bbl), and oil sands is the highest cost oil on the market at $83/bbl. All price figures are referenced to Brent. Globally, investments (OPEX+CAPEX) come to $500 billion/year, with a typical cost of developing production at $100,000/barrel/day. Tight oil has not been squeezed out by OPEC, but has been squeezed down by the supply curve. Tight oil production is flat at $40/bbl, and grows at $50/bbl. US production could reach 20 million bbl/d by 2030, but perhaps flattening by 2035.

Pioneer's Mark Berg focused on the Permian Basin. Permian oil production is now more than 4 million barrels per day, which is comparable to Ghawar, Saudi Arabia's largest oil field. Pioneer's operations are now in "manufacturing mode." Investors now insist on cash flow, and the growth rate is slowing due to capital discipline and depletion of resource. In fact, initial production rates are declining across all US tight oil plays. Pioneer uses a well spacing of 850-950 ft, having found that the 600 ft well spacing used by others is too close. Well productivity is improving each year, though the rate of improvement is now slowing. The breakeven cost of production is $26-$30/bbl, which has been achieved by driving down service costs and reducing cycle times. There is still room for equipment design improvement. Berg concluded by asking what world energy prices would be without tight oil and shale gas.

LINK: FULL VIDEO PART I; PART II

USAEE North American Conference 2019

USAEE Tour: Noble Energy's Oil & Gas Production Facilities, Denver Julesburg Basin

We left the warmth of the conference hotel early to catch the minibus and head N.W. to Wells County, Colorado. An occasional pump jack (also called nodding donkeys) signaled we were in oil country. The Noble Energy Operations in Colorado are in Wells County producing from the Denver Julesburg Basin, which extends into Wyoming and Nebraska. Our first stop was Noble's Operations Control Center. The light is low in this area full of computer screens telling those in the know what is happening out in the field 24×7×365.

USAEE tour of Noble Energy's Oil & Gas production facilities in Denver Julesberg Basin, 7 Nov 2019.

Temperatures, pressures, and fluid flows can all be monitored for problems at the Control Center. When something suspicious arises control room operators can call the lease operator for a consult or even shut down operations within minutes. Geological, leaseholder, and well maps along with real time drilling data allow one operator to control drilling on two wells at a time. From 8 – 24 wells can be drilled from a pad with the most usually being 6-8. Care must be taken not to drill into any other wells past or present. With improvements in directional drilling, operators have more ability to maneuver the drilling to hit the best hydrocarbon payload possible.

From the control room, we were taken to their training center. After the safety briefing, we donned hard hats and safety glasses and continued our lessons outside amongst simulator equipment for training on oil field operations. We learned more about artificial lift, blowout preventers, equipment to separate sand and natural gas out of the oil, the intricacies of metering.

Armed with heads full of information, we set off to the lease for more on compressors, measuring, and fluid flow. Near the shadow of the drilling rig, we learned more about drilling versus production casing, drilling mud, drill bits and smart pigs (not the type that produce ham, but the type that can clean pipelines between batches and check for corrosion). With low oil prices, they have learned to economize. Wells that used to take 17 days to drill can now be drilled in 4-5 days because of better bits, better motors, and more skilled rough necks. Longer laterals and more wells per drilling pad have reduced cost for drilling and fracking as well.

Noble not only focuses on cost and efficiency but also prizes being a good employer, a good neighbor and pays close attention to environmental issues. They have a policy of never flaring natural gas, have moved towards reduced use of combustion engines, switched pneumatic valves from natural gas to compressed air, and have infrared camera's to detect fugitive methane and VOCs in compliance with a 2014 Colorado law, the first in the country.

Within their leases most wells drilled are horizontal. Although vertical at first, at some point they make a turn. This horizontal or lateral portion is typically around two miles long. Once the well is drilled with the casing installed and cemented, the fracking operation can begin. It is done in stages starting at the far end of the well. A portion of the pipe is perforated. Then water, sand and other chemical are injected under high pressure into the wells to create cracks in the tight formation to release oil and gas that was formerly unavailable. The sand will help keep the cracks open so the hydrocarbons can keep flowing. When completed the first stage is sealed off, and another portion of pipe is perforated and fracked. Up to eighty such stages may be completed before seals are drilled out and the well starts to produce. Much of the first few days of production is water, which is recycled or else disposed of. But soon the hydrocarbons start to flow out and the cash can start to flow in. Although there is some disagreement on its spelling (hydraulic fracturing, fracking, fracing), there is no dispute it has recently returned the US to the status of number one oil producer for the first time decades. Good news for the economy, but more worrisome for OPEC and the climate.

The group would like to thank Noble Energy for the time and energy spent informing us about the technology and showing us their operations. We appreciate their warm hospitality and for not giving us a test at the end of the day.

USAEE

Energy Transition and Stranded Assets: What does the Future Hold for Africa?

BY ANDREW AKWENY AND ROCKSON SAI

Andrew Akweny and **Rockson Sai** are with Xiamen University. Akweny may be reached at andrewakweny@gmail.com

Following the discoveries of natural energy resources in some emerging economies in Africa, there have been substantial investments in the sector, especially for minerals, fossil fuels, and natural gas. However, global dynamics coupled with the threats of climate change have encouraged the transition to renewable energy across the world, including in fossil fuel resource-rich African countries. Despite Africa's increasing interest and investment in renewable energy, less emphasis is given to the issue of "stranded assets" in the region. In the case of Africa, being a new entrant with many emerging resource economies, the issue of stranded assets is one that needs to be handled with utmost urgency as several projects are likely to be undermined by the "stranded asset syndrome" thus posing big development and environmental questions.

The International Energy Agency defines stranded assets as "those investments which have already been made, though at a point in time prior to the end of their economic life (as assumed at the investment decision point), are seen to no longer earn economic returns as a result of changes in the market and regulatory environment brought about by climate policy" (IEA, 2013, p. 98).

In regard to the above definition, one is tempted to think that stranded assets/resources for Africa may not only arise as a result of climate change policies. There exist cases of assets that could possibly be stranded as a result of other factors such as; inconsistent government policies and wrecked institutional frameworks.

On the other hand, the Generation Foundation defines a stranded asset as "one which loses economic value well ahead of its anticipated useful life, whether that is as a result of changes in legislation, regulation, market forces, disruptive innovation, societal norms, or environmental shocks" (Generation Foundation, 2013, p. 21). Delving into Eastern Africa, the definition from Generation Foundation sheds more light on the state of affairs in the region. For example, Kenya, keen on reaching middle-income class status and becoming an industrialized economy has identified energy as one of the key enablers. In achieving this huge ambition, it plans to commission its first nuclear power plant by 2027. A major concern in this regard is the uncertainty from now till its completion. Rapid technology growth and uncertain political terrain might cause diversion of the nuclear investment (for cleaner and cheaper substitutes) due to its capital intensive nature, thereby increasing the likelihood of stranding. Besides, the connection of a 310 MW wind farm plant to the national grid in 2018 has led to a decision to close 3 thermal plants in the country. What does this mean for the country in the next few years?

Similarly, the government of Ghana has initiated reforms in the mining sector due to the growing concern of the sector's negative effect on river bodies, environmental issues, forest reserves, and livelihood. Authorities placed a ban on both legal and non-legal operators of artisanal mining for almost 23 months. Even though this action brings to light the achievement of climate change ambitions, it strands assets and resources and affects investors and citizens that benefit from these economic activities.

While the challenge of stranded assets cut across most resource-abundant countries, it is caused by a number of factors in Africa. First, it is created notably by the low-carbon energy transition prompted by the global drive to mitigate climate change as indicated in the Paris Climate Agreement.

The second factor is the challenge arising from uncertainty in economic predictions stemming from global oil price fluctuations. This is in spite of the improvement in production technologies and economies of scale, and applies to both conventional and renewable energy. The latter is at an all-time low.

Third, in many of the emerging economies in Africa, fossil fuels seem to be the trend. But the investment in technologies and infrastructure that support the massive disposition of renewable energies, including climate-proofing of current infrastructure, may lead to the stranding of resources in the region.

Despite clean energy taking a great leap in the African energy mix, conventional energy sources may still play a prominent role for some time because of the massive capital investment that has already allotted to this sector. This is because the transition to cleaner renewable energy comes at extremely high costs and its long term sustainability at this point in time is still questionable for these economies. Further still, looking at the political economy of the extractives sector in some African countries where despite instigation from literature, it's still evident that an array of elite political groups is using these resources to monopolize power and this shows that some African countries are not yet about to give up the use of non-renewable energy sources for other options which don't befit their interests.

Some schools of thought may not support the climate change drive that could especially strand assets/resources in Africa because they think this too could be a way for the early comers (in this case the developed countries) to kick away the development ladder for the latecomers. This is despite the fact that their average African carbon footprint at 4 percent is not significant as compared to that of other continents. Africa will continue to look at its natural resources

(continued on page 29

7th IAEE Asia-Oceania Conference 2020
Auckland, New Zealand | 12-15 February

Energy in Transition

Nau mai, piki mai, toia mai, haere mai.
Welcome, bring your energy, ascend the heights, welcome.

Programme Now Available for Download

To see the exciting line-up of speakers we have scheduled for IAEE Asia-Oceania 2020, visit our website's programme overview page.

If you're a speaker, make sure you have registered to attend.

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10 - 11 FEBRUARY 2020 | $899pp

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- Karapiro Power Station
- Huka Prawn Farm

Social Tour

15 FEBRUARY 2020 | $140pp

Registration is also open for the half-day social tour that begins with a scenic ferry ride across the Waitematā Harbour and takes you to Waiheke Island for tastings at the local wineries.

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- Obsidian
- Mudbrick

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He waka eke noa t¯t ou. We embark on a journey together.

Stranded Assets Risk Derails Vietnam's Plan for New Coal Power Plants

BY MINH HA-DUONG

Minh Ha-Duong is Director of Research, CIRED/CNRS & Vietnam Initiative for Energy Transition. He may be reached at minh.haduong@vietse.vn

Introduction: Vietnam's plan for a fleet of coal power plants

Vietnam has a socialist-oriented market economy, where the state sector plays the decisive role in directing economic development. State owned enterprises form the backbone of the energy sector. Development of the electricity sector is guided by ten-yea Power Development Master Plans, usually adjusted with a mid-term revision. The plans determine power source development, power grid development, connectivity with neighboring countries and electrification of remote areas. In addition to ensuring the engineering coherence of sources and grid developments, plans have administrative power: projects need to be included in the plan to be authorized.

The current Power Development Plan is PDP7 revised, the mid-term revision of the seventh plan, for 2011-2020 with a vision to 2030 (Nguyễn Tấn Dũng 2016). The core electricity supply strategy of PDP7 was to build a fleet of coal power plants. Vietnam achieved 13.1 GW of coal-based generation capacity in 2015. In January 2016, Vietnam's former Prime Minister, Nguyen Tan Dung, announced he would "review development plans of all new coal plants and halt any new coal power development". That was only partially realized in the 2016 PDP7 revision. The strategy was reduced by 23 GW, targeting 'only' 54.5 GW of coal in 2030 – out of 72 GW total additions. As Figure 1 shows, that meant building 33.7 GW of new coal power generation between 2016 and 2024.

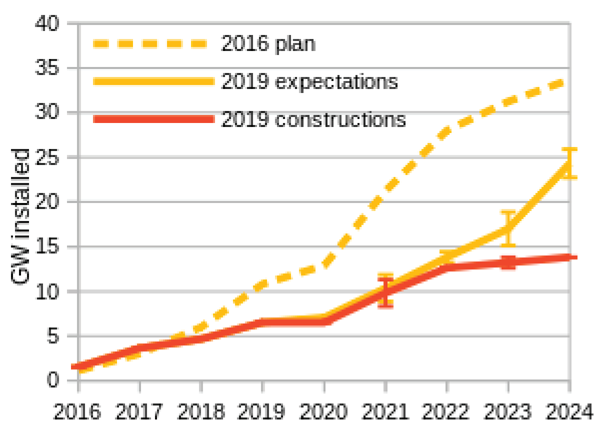

Figure 1: New coal power capacity in Vietnam since 2016

How it is not happening

Three years later, reality has diverged from the plan to a point where Vietnam is facing the prospect of power shortages from 2019 onward. The causes are discussed in the (Hoàng Quốc Vượng 2019) evaluation report. This is not because the nuclear power plans have been scrapped by the National Assembly in late 2016: those capacities were not scheduled to come online before 2028. This is not because renewable energy development has been slow: Vietnam's solar PV feed in tariff has been a spectacular success, in April 2019 the connected PV capacity was 150 MW, by the end of June deadline, over 4 460 MW was connected in 82 plants. According to (REN21 2019 table R17), only China, India, the U.S. and Japan installed more PV capacity in 2018.

The return to a supply-constrained situation is attributable to delays in the installation of large thermal power generation facilities. Natural gas power plants have been mostly constrained by fuel supply infrastructure delays, and will impact the security of supply mostly in the Southern part of Vietnam. And as Figure 1 shows, the delays in building new coal power plants means that coal capacity development fleet is behind schedule for 4.3 GW in 2019, up to around 14 GW in 2022. Beyond these years, the situation is more uncertain. If one expects, as in the evaluation report, that coal power plants today at the "permitted" or "pre-permit" stage will be constructed, the 2024 gap could be 9.4 GW. But if one assumes that no new coal power plant will start construction, that figure increases to 19.8 GW.

Who is responsible for these delays? The plan relied on three categories of actors to build the fleet of coal power plants: a/ Vietnam Electricity; b/ The other two state owned enterprises in the energy sector; and c/ foreign investors.

- Vietnam Electricity performed as planned or better. They commissioned 3 044 MW on or ahead of schedule in 2016-2018, with an additional 1 260 MW on track for 2019.
- The Vietnam Oil and Gas Group (PVN) owned four power supply projects with a total capacity of 5 400 MW in the Plan. All three projects under construction are delayed by 2-3 years or more, and PVN proposed to transfer the fourth to another project owner. The Vietnam National

Coal - Mineral Industries Holding Corporation Limited (TKV) was to undertake 4 projects with a total capacity of 2 950 MW, including 2 in the period of 2016-2020 and 2 in the period of 2021-2030. All 4 projects are now delayed by at least 2 years. Of the three projects undertaking investment preparation procedures, one has not found a project location and one is in the middle of changing its project owner. The fourth project has not yet undertaken investment preparation procedures.

- Given the finite capital capacities of the public sector, the plan also relied on a program of 13 Built-Operate-Transfer projects with foreign investors. Most projects (eleven) were supposed to come online before 2024. One project is operating: the Vinh Tan I power station, jointly owned by China Southern Power Grid and Vinacomin (TKV), was built successfully seven months ahead of schedule in 2018-2019. But others are delayed due to 'certain obstacles in negotiation' according to the evaluation report. Three are under construction, expected to open in 2021-2022 with one year delay (Duyen Hai II with Janakuasa and Hai Duong with JAKS, both from Malaysia, and Nghi Son II with Korean Electric Power Corp.) Four projects at the "Permitted" stage are expected to open in 2023-2025 behind the plan (Van Phong I one year, Vung Anh II two years, Nam Dinh I three years, Song Hau three years). Two at the "Pre-permit" stage are delayed by 2-3 years to after 2024, and the last three are unidentified and not expected before 2025.

In summary, all players but the national electricity company are lagging behind schedule. This situation is not unique to Vietnam. (IEA 2019) noted that "In 2018, coal-fired power Final Investment Decisions declined by 30% to 22 GW, their lowest level this century [...] The largest fall in FIDs was in China, but levels in Southeast Asia were their lowest level in 14 years."

Why: stranded assets risk demotivated investors

Investors' decisions are influenced by multiple causes. But profit being the main driver of companies, we may argue that the problem delaying investment in coal power generation is an excessive risk/rewards ratio. In which the risk of severe and fast depreciation – stranded assets – is a major component. There are three main reasons why an investor would be cautious about owning a coal power plant.

- While up to 2015, Vietnam was producing more coal than it used, the mining industry has not met the growth in demand. New coal plants run on imported fuel. The price of coal on the international market, while less volatile than oil or gas prices, is still very uncertain: since 2010 it has varied from a low of 50 to a high of 130 USD/Mt.
- The natural conditions for renewable energy sources are favorable in Vietnam, there is lots of solar irradiation and lots of wind offshore. Their cost is declining with innovation and economies of scale. After kickstarting the utility solar industry with a feed in tariff of 9.35 cents per kWh, the government is moving towards auctions to reduce the costs. According to (Jakob Lundsager, Nguyen Ngoc Hung, and Mikael Togeby 2019), by 2030 the levelized costs of electricity generation from wind and solar energy will be significantly lower than those from coal and gas in Vietnam.
- The environmental standards can only get stricter. The capital, Hanoi, is among the top three most polluted cities in Southeast Asia (Phan 2019). In 2015, coal power plants caused less PM2.5 air pollution in Hanoi than agriculture, transport or industry, but by 2030 the power sector would easily become the leading source of PM2.5 pollution in Hanoi (Amann et al. 2019), if the planned coal plants were opened. The energy sector is responsible for most of Vietnam's GHG emissions increase by 320% between 2010 and 2030 in its INDC's business as usual scenario. While Vietnam's climate change policy has been slow to touch the energy sector, cautious investors would assume that something such as an increasing Renewable Portfolio Standards will likely happen within the next few years.

A global analysis of 6 685 coal plants (Gray et al. 2018) finds that it is now cheaper to build new renewable generation than to run 35 percent of the coal plants worldwide. For those companies, holding on to coal power plant assets is not economically interesting, even if they are fully amortized. The same report concludes that by 2030, renewables beat out most of today's existing and planned coal-fired generation in Vietnam. The average plant age at retirement will be 13 years, and this creates a 11.7 billion stranded assets risk.

In a more focused and updated analysis, (Gray et al. 2019) estimated that the long run marginal cost of electricity from Vietnam's coal power plants was 47 USD/MWh in 2019, due to reliance on the seaborne coal market. They expect new solar PV to be cheaper than new coal by 2020 and new onshore wind by 2021. The year when new renewables will be cheaper than operating existing coal depends on assumptions about fuel prices and technical progress, but is between 2028 and 2033 in the central cases.

Vietnam Electricity, as the State owned company with the mission to provide electricity to the nation, is perhaps less affected by this business logic than other actors. But they cannot escape the economic constraints. Because of liquidity constraints, it is necessary to borrow or to equitize to finance the development of the power generation system. Borrowing is limited by the national debt / GDP ceiling, and most large financial institutions are restraining loans for fossil fuel plants anyway. Equitizing means convincing investors to buy shares in the electricity generation companies, those assets contain lots of aging hydro and thermal power plants. In February 2018, the initial public offering of EVN's subsidiary Power Generation Company 3 was a big failure, selling 7.45 million shares out of 267 millions offered. This demonstrates that investors had a very low appetite for these traditional assets.

Conclusions and recommendations

What are the implications for the Power Development Plan 8, for 2020-2030, currently under preparation to be published next year?

Vietnam's Prime Minister Nguyen Xuan Phuc recognized the need for "minimizing coal-fired thermal power, especially old-fashioned technology", and particularly in the Mekong Delta, as it would "affect the long-term benefits of the locality" (Hau Giang, September 28th, 2017). We advocate for a clearer and harder "No new coal power plants" line. The old strategy has failed to provide energy supply security and has to be replaced. Trying harder the same thing is not likely to work better. Because of the stranded assets problem, private and public investors have less and less interest in building coal power plants in Vietnam.

Since investors recognize that the economic window to build new coal generation projects in Vietnam is closed, only already permitted, or already started coal power generation units with a scheduled completion in or before 2025 should be kept in the next plan. The government can terminate all other projects on the basis of Circular 43 (Trần Tuấn Anh 2016), since they are late, and relieve investors who are struggling to obtain financing and the administrative and the social licenses to operate.

We hope that the 13th National Congress in January 2021 will adapt the Asian concept of ecological civilization as a key goal for Vietnamese society; leading to stricter pollution control norms; higher fossil fuel taxes and import duties; and leading the National Assembly to vote a 2021 Renewable Energy Law enacting Renewable Portfolio Standards for all. But even without political leadership into the energy transition, many coal power plants are already loosing money, and that will be generalized after 2030. The coal plants build under BOT contract will have no residual value. Vietnam Electricity should already be ready to decommission them after 20-25 years. We believe that market forces are driving towards an exit from coal before 2050.

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especially the non-renewables as a cursor for economic development.

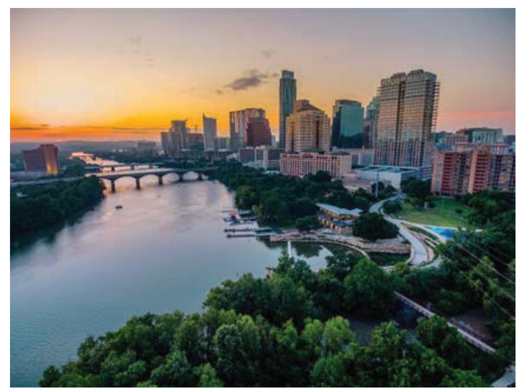
Conclusively, even though the Paris climate agreement has engendered energy transition and gradual elimination of fossil fuel production, Africa is still highly endowed in natural resources and new discoveries are being made in different regions. Notably, the huge population (over 600 million people) of the continent is living in both monetary and energy poverty and these discoveries are creating optimism for economic development. Attention needs to be paid to the stranding of assets/resources.

Conference Theme and Objectives

The development of energy as we know it, from production to conversion to end-use, whether from fossil-fuels, renewable power or other sources, results from an ongoing dynamic interaction between market needs and preferences, progress in technologies and public policy initiatives. Cutting across this to make sense of the ever-changing landscape is the analysis and language of energy economics: the essential ingredient that brings a common understanding of the forces and drivers in play.

The 38th annual USAEE/IAEE Conference provides a forum for informed and collegial discussion of how energy economics is contributing to the current and future thinking of businesses, consumers, technology developers and public policy institutions in North America and around the world as they drive towards the future world of energy.

In 2020, our conference takes place in Austin, Texas. Texas is a state rich in the history of energy as well as a vibrant proving ground for major changes in energy markets. In oil and gas, Texas was the home of the historic Spindletop discovery early in the 20th century; was at the heart of the US oil and gas developments for its first 70 years; and where the Texas Railroad Commission became a globally important regulatory authority. More recently, Texas has seen the birth of the US unconventional oil and gas business with the Barnett Shale in north Texas and the prolific Permian basin. Downstream, Texas is home to major refining and petrochemical plants as well as hosting new LNG export facilities. In electric power, Texas was a pioneer in opening up the market to retail competition and remains one of the few jurisdictions in the US where this remains the norm. And Texas has seen a huge build-out of low-carbon power generation, particularly wind energy, making the state a leader in this field. And last, but not least, Texas institutions like The University of Texas, Rice University, and an engineering school on the mid-Brazos, have been at the forefront of thinking and research about energy science and economics. There is indeed much to discuss and study just in relation to Texas energy markets and we expect conference delegates to benefit from this context.



As in previous years, the conference will highlight forward-looking energy themes at the intersection of economics, technology and public policy, including those affecting energy infrastructure, environmental regulation, markets, the role of governments, and international energy trade. Participation from industry, government, non-profit, and academic energy economists will enrich a set of robust, diverse and insightful discussions.

Topics to be addressed include:

The general topics below are indicative of the types of subject matter which may be considered at the conference. In practice, any topic relating to energy economics, markets, energy policy and regulation, energy trade, energy pricing, drivers of energy demand, adoption of new energy technologies etc. will be considered.

* Global impacts of growing US energy exports
* How are energy markets responding to the shift of U.S. energy policy?
* Pathways to decarbonization of energy and the economy
* Oil prices, the role of OPEC and OPEC/non-OPEC cooperation
* Energy implications of environmental regulations: future and impact
* The role and impact of distributed energy resources in developed and developing countries
* How are digital technologies, including blockchain and artificial intelligence and the Internet of Things impacting energy supply and demand
* What next for electricity storage technologies?
* Drivers and challenges for accelerated electric and autonomous vehicle adoption
* Effective policies to support growth in low-carbon energy
* The role of natural gas in the energy transition to a low-carbon world
* Other topics of interest including shifts in market structures and fundamentals, including those induced by policy and technological forces.
* Drivers and challenges for accelerated electric and autonomous vehicle adoption
* Role of natural gas in the energy transition to a low-carbon world
* Role and impact of distributed energy resources in developed and developing countries
* Evolution of electricity storage technologies
* Financing conventional and renewable energy
* Who is financing what and why it matters?

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Advance call for Concurrent Session Presentation Proposals

We are pleased to announce an advance call for Concurrent Session presentation proposals for the 38th USAEE/IAEE North American Conference, Energy Economics: Bringing Markets, Policy and Technology Together, to be held November 1-4, 2020 at the Sheraton Austin Hotel in Austin, Texas, USA. The deadline for receipt of proposals is May 31, 2020.

Concurrent Sessions

The concurrent sessions at the USAEE/IAEE conference offer opportunities for students, academic staff, as well as energy economists and practitioners in the business, government and research communities to present current analysis, research or case-studies on topics related to energy economics and energy markets. Presentations may be based on academic papers, but this is not a pre-requisite requirement. We stipulate that presentation proposals submitted for inclusion in the concurrent sessions should not have been previously presented at or published by USAEE/IAEE or elsewhere. Presentations are intended to facilitate the sharing of both academic and professional experiences and lessons learned. Those interested in organizing a concurrent session should propose a topic and possible speakers to David Williams, Executive Director, USAEE (usaee@usaee.org). Please note that all speakers in organized concurrent sessions must pay speaker registration fees and submit abstracts.

Concurrent Session Presentation Proposal Format

Authors wishing to make concurrent session presentations must submit a proposal that briefly describes the topic, research or case study to be presented.

The proposal must be no more than two pages in length and should include the following sections:

a. Overview or summary of the topic including its background and potential significance
b. Description of the context, data used, or illustrative example of the topic
c. Summary of key insights, results or further questions
d. Conclusions: Lessons learned, business or market implications, recommendations for further work

Please visit www.usaee.org/USAEE2020/PresentationProposalTemplate.doc to download a proposal template. All proposals should conform to the format structure outlined in the template. Proposals should be submitted online by visiting www.usaee.org/USAEE2020/submissions.aspx Proposals submitted by e-mail or in hard copy will not be processed.

Presenter attendance at the conference

At least one presenter of an accepted concurrent session presentation proposal must pay the registration fees and attend the conference to make the presentation in person. The person submitting the proposal must provide complete contact details—mailing address, phone, e-mail, etc. Presenters will be notified by July 13, 2020 whether their proposal has been accepted. Presenters whose proposal are accepted will have until August 24, 2020 to submit their final papers for publication in the online conference proceedings. While multiple submissions by individuals or groups are welcome, the proposal selection process will seek to ensure as broad participation as possible: any person may present only one topic at the conference. No person should submit more than one proposal as its single author. If multiple submissions are accepted, then a different presenter will be required to pay the registration fee and present each paper.

Students

In addition to the other opportunities, students may submit a paper for consideration in the Dennis J. O'Brien USAEE/IAEE Best Student Paper Award Competition (cash prizes plus waiver of conference registration fees). The paper submission has different requirements and a different deadline. The deadline for submitting a paper for the Student Paper Awards is June 29, 2020. Visit www.usaee.org/usaee2020/bestpapers.html for full details.

Students may also inquire about scholarships covering conference registration fees. Please visit http://www.usaee.org/usaee2020/scholarships.html for full details.

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Creative Destruction, Orderly Transitions and Stranded Assets

BY NAWAZ PEERBOCUS

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See footnotes at end of text.

Popularized by Joseph Schumpeter, the term 'Creative Destruction' refers to "the process of industrial mutation that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one." Simply put, the creative powers of dynamic capitalism lead to the destruction of old ways of doing things, making space for new ways of doing things.

In many ways, the energy transitions we are witnessing today are sub-processes of a larger creative destruction process that will inevitably result in winners and losers. Energy transitions can take several years to several decades depending on the definition used. Defined as the time it takes for the sector-specific technology to reach 80% of energy consumption for a service (or the peak it did not reach 80%), the average historical duration of energy transitions in the UK was 95 years[1]. Future global energy mix projections suggest wind and solar energy will not meet this average duration for a successful energy transition. By 2040, in IEA's Sustainable Development Scenario, renewables (including solar and wind) will account for 31% of the global primary energy demand[2]. Wind turbine was invented in the 1880s and solar photovoltaics in 1954. Clearly it will take much longer for these technologies to meet 80% of energy demand. Meanwhile fossil fuels (oil, gas and coal) will need to fill in the gap and meet 60 per cent of the energy demand by 2040[3].

Duration is indeed critical in energy transitions. When the transition is gradual, adjustment costs are low. When it is fast, adjustment costs are high. Both cases can however result in stranded assets. These are defined as 'assets that have suffered from unanticipated or premature write-downs, devaluations, or conversion to liabilities'[4]. Stranded assets pose systemic risks to the economy and in the case of the energy system, they can create energy security risks. Given a choice, most countries would prefer a gradual orderly transition which minimizes the impact of stranded asset risks. According to Carbon Tracker, under a fast energy transition scenario to limit temperature increase to 2C, almost a third of the roughly $5 trillion in planned fossil fuel capital investment from 2018 to 2025 risks being stranded. Companies can plan ahead to ride the wave of creative destruction. Some have started to internalize the cost of carbon in their investment decisions. BP, for example, assumes a carbon tax of $40 per ton in developing world-wide projects.

Stranded assets are not a new phenomenon. In the power sector, monopoly utilities often incur stranded costs -i.e., their assets become stranded-when the power sector is restructured, and competition is introduced. In the real estate sector, changing consumer preferences have rendered many property assets redundant. Indeed, stranded assets can occur in many sectors of the economy including fossil fuels, real estate, agriculture, mining, utilities and transport.

There are a variety factors that can cause stranded assets. These include falling technology costs, environmental concerns, consumer preferences, government regulations and policies. The recent rapid cost decline in solar PV and onshore wind technologies have led to a large deployment of renewables in the power sector. This additional supply coupled with weak grid-demand have contributed to a low-price environment that have caused many utilities in Europe to book multi-billion-dollar asset impairment charges on their balance sheets. In 2016, asset impairment charges for European power and utilities companies reach 23 billion EUR[5], roughly 9 per cent of the market capitalization of the utilities. Such charges reduce the market capitalization of these companies and hamper their ability to raise capital to finance new investments. This in turn can impact energy system security.

Environmental, social and governance concerns have increased pressure on asset owners and asset managers to pay attention to stranded asset risks. Divestment from over-exposed sectors are driving investment decisions. Norway's $1tn sovereign wealth fund was recently allowed by the Norwegian government to reduce shares in selected coal and energy companies. Japan's Government Pension Fund, on the other hand, is advocating more engagement with companies on climate change rather than divestment of shares. The financial community also has a vested interest to better understand stranded asset risks. Central banks and financial regulators are being encouraged to assess climate related financial risks into the financial system and to integrate climate-related risks into prudential supervision[6]. Three dozen central bankers recently announced they will consider environmental factors when regulating banks[7].

It might seem too much to expect the creative destruction process to go hand in hand with an orderly energy transition. Yet time is the great moderator and it allows ingenious humans to plan and devise creative solutions. While the creative destruction wave oscillates through time, there is a dire need to better understand how energy transitions to a low-carbon economy create stranded assets. This knowledge gap needs to be filled to help policy makers develop appropriate policy and regulatory responses that are consistent with the economic and strategic priorities of the respective countries.

(see footnotes on page 41

Stranded Assets, and the Role of Biomass and Hydrogen in the European Energy Transition

BY THORSTEN BURANDT, PEDRO CRESPO DEL GRANADO, RUUD EGGING

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See footnotes at end of text.

Introduction

The European Union (EU) plays a crucial role in the decarbonization of energy systems and the transition towards renewable energy sources (RES). For instance, with the Renewable Energy Directive 2009/28/EC[1], the member states of the EU agreed to provide National Renewable Energy Action Plans while defining renewable energy targets for 2020. Also, the Regulation (EU) 2018/842[2] sets a binding target for greenhouse gas (GHG) reductions until 2030. These targets lead to coal (hard and lignite coal) and other fossil fuels being phased-out across several European countries. Still, additional capacities of fossil-fueled power generation are being built (Caldecott and McDaniels 2014; Europe Beyond Coal 2019). In turn, higher shares of RES led to decreasing capacity factors of, especially, natural gas-fired power generation. This can be observed in several member states of the EU, for example, in Germany, Italy, or the Netherlands. There, additional capacities of gas-fired power plants increased by around 10% between 2010 and 2015, while the annual capacity factor dropped from 50% to approximately 35%. In general, stranded assets pose a high financial risk. As assessment by the Carbon Tracker Initiative (2015) concludes that globally, projects with a value of 2 trillion US$ of capital expenditures are in danger of ending stranded. This was also highlighted by a recent study by Mercure et al. (2018). In their study, they show that a substantial fraction of the global fossil fuel industry may end stranded, presenting a total wealth loss of 1-4 trillion US$. In general, a trend can be identified, where, driven by climate goals, high shares (50-80\%) of fossil fuels could become stranded, a phenomenon also known as "carbon bubble" (McGlade and Ekins 2015).

Nonetheless, the quick ramping possibilities and fuel flexibility of gas-fired power plants can help to achieve renewable targets of the EU, when using biogas, synthetic methane, or hydrogen instead of natural gas. In this regard, the objective of this study is to use a multi-sectoral energy optimization model to look at the role of these fuels in the EU energy transition. The paper focuses on addressing questions related to: How much of the current or future gas infrastructure is needed for a successful European energy transition and what options can help minimize stranded assets. Firstly, the use of biomass, biogas, and biofuels in different sectors will be analyzed. This is of particular importance, as biomass in Europe is generally a scarce resource with limited potential[3]. This potential is even projected to decrease in the next decades until 2050 (Elbersen et al. 2012). In this context, the value of hydrogen in different sectors will also be assessed. Secondly, an analysis of stranded or unused capacity will be performed for the pathways. Lastly, with hydrogen, biogas, and methanized synthetic gas, we approach the different sectors, the needed gas infrastructure will be analyzed.

Methodology, Data, and Key Assumptions

The study is carried out by using the open-source energy system model *GENeSYS-MOD (Global energy system model)*, built on the *Open Source Energy Modeling System (OSeMOSYS)* (Howells et al. 2011; Welsch et al. 2012). In general, *GENeSYS-MOD* is a linear cost-optimizing model encompassing the sectors electricity, heat (industrial, commercial), and transport (passenger, freight with different modal types) (Löffler et al. 2017). Also, different sector-coupling technologies (Power-To-X, Storages, Methanation, etc.) allow for

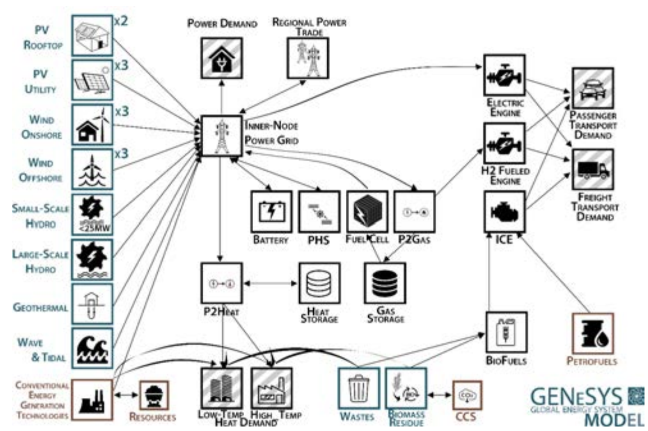

Figure 1: Overview of the technology options included in GENeSYS-MOD

a technology-oriented, integrated assessment of points in the future low-carbon transformation. The model calculates the optimal investments into capacity addition and generation for energy-producing, demanding, or transforming technologies, and thus the resulting energy mix. The objective function of the model minimizes the net-present value of the calculated energy system for the whole model period.

GENeSYS-MOD can be viewed as a network-flow cost-optimization model (Howells et al. 2011). In the network, nodes represent Technologies, and arcs represent Fuels. Examples for Technologies are production entities like wind or solar power generation units, conversion technologies like heat pumps, storages, or vehicles. In general, Fuels represent energy carriers like electricity or fossil fuels, but also more abstract units like passenger-kilometers for vehicles or areas of land are classified as Fuels. Also, Technologies may require different Fuels and can have more than one output Fuel[4]. Efficiencies of the technologies are accounted for and allow the modeling of energy losses due to conversion. Figure 1 gives a general overview of the different technologies in *GENeSYS-MOD* and the connections between them. The model allows for yearly investment and has perfect foresight over the total modeled period (2015-2050) with the base-year fixed to real values.

The general mathematical model formulation can be found in Howells et al. (2011) with the recent modifications presented in Löffler et al. (2017) and Burandt et al. (2018).

Input data, scenarios and key assumptions

For this study, Europe is presented in 17 nodes, each representing a country or geographic region. The model covers the EU-28 countries as well as non-EU Balkan states. Final demands for electricity, passenger & freight transport, and heat are given exogenously via scenario assumptions based on the four European energy transition pathways defined in the Horizon 2020 Project SET-Nav (Navigating the Roadmap for Clean, Secure and Efficient Energy Innovation), see Crespo del Granado (2019)

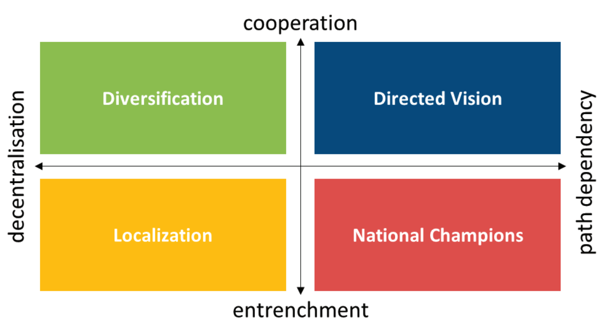

Figure 2: Overview of the scenarios.

The scenarios storylines are based on the level of cooperation and the level of centralization, as depicted in Figure 2. The *Diversification* pathway is characterized by heterogeneous actors and a high degree of cooperation and digitalization. The *Localization* pathway shares the same level of centralization and digitalization, but a local resistance to big infrastructure projects and exploitation of local (renewable) resources leads to a more entrenched scenario. From a European Union perspective, the *Directed Vision* pathway reflects a scenario with a strong policy framework, a shared vision, and a by the EU directed vision. Lastly, *National Champions* depicts a future energy system with strong local utilities, regulatory capture, and generally low transition costs. This scenario features the same focus on locally available potentials as *Localization*.

The model data is based on Burandt et al. (2018). Compared to the version of the model presented in Hainsch et al. (2018) and Löffler et al. (2017), several new additions have been made. Firstly, to better represent the need for flexibility options, ramping, together with ramping costs, has been added to the model alongside with a new time resolution of the model. The model now uses a reduced hourly time-series based on the algorithm presented by Gerbaulet & Lorenz (2017).

Also, the preexisting structure of high-temperature and low-temperature heat as depicted in has been altered. The new structure features four different temperature ranges with a more distinct differentiation in industrial (0-100°C, 100-1000°C, and >1000°C) and residential heating (0-100°C). For this new representation, a large variety of new technologies has been implemented.

Furthermore, a natural gas and LNG infrastructure has been added. Liquefaction and regasification plants have been added alongside gas pipelines and the possibility of LNG imports. Additionally, new vehicle-types using LNG were included in the model.

Results

This section presents key results of this study. The scenarios were abbreviated in the following figures as follows: *Diversification – DIV, Localization – LOC, Directed Vision – DIR, National Champions – NAT.*

Utilization of biomass and biofuels per sector

The resulting sectoral usage of biomass, biofuels, and biogas is shown in Figure 3. Whereas the picture for the utilization of solid biomass in 2020 looks uniform across the different scenarios, the usage per sector differs between the scenarios from 2040 on. The

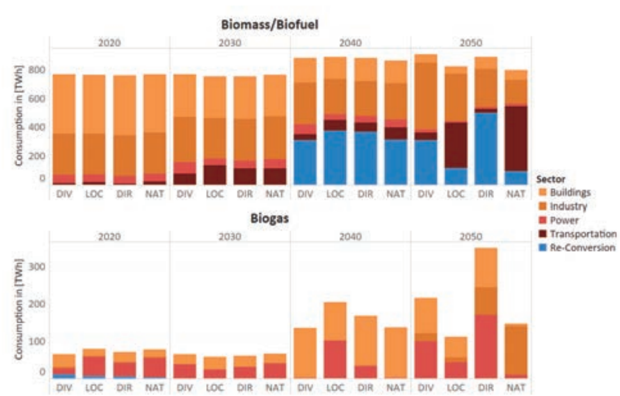

Figure 3: Consumption of biomass, biofuels, and biogas in different sectors.

trade of biomass is very limited in the entrenchment scenarios (*Localization* and *National Champions*), which have a significant effect on the utilization of biomass in the different scenarios.

The re-conversion of biomass into bio-methane is one of the most significant differences in 2050. Also, the amount and usage of bio-methane vary per scenario and sector. The scenarios with a high share of cooperation (*Diversification* and *Directed Vision*) see higher utilization of bio-methane in general and especially in the power sector. On the other side, the scenarios with less cooperation see higher use of biofuels in the transportation sector. Overall, biomass poses a flexible and versatile option for decarbonization in many areas. The final usage of biomass highly depends on the degree of cooperation in the low-carbon transformation.

Role of hydrogen

Contrary to the observations in the bio-energy sector, the use of hydrogen is not depended on the level of cooperation, but more on the degree of

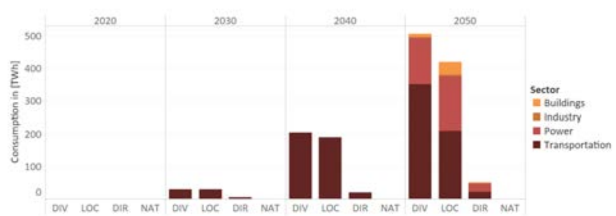

Figure 4: Consumption of Hydrogen and synthetic methane per sector and scenario.

centralization.

As seen in Figure 4, the scenarios with a high level of decentralization, *Diversification*, and *Localization*, pose the most consumption of Hydrogen. A cost-optimal use of the limited amount of hydrogen occurs in the transportation sector. Fuel-Cell Electric Vehicles (FCEV) pose a reliable alternative to purely electric Battery Electric Vehicles (BEV) especially in the later stages of the model runs. Especially with higher production of hydrogen, FCEV becomes, even more, cost-competitive compared to BEV or conventional cars fuels with biofuels.

In 2050, in the scenarios with large hydrogen production, hydrogen will also be used in the power sector (as methanized synthetic gas) as well as heating fuel in the buildings sector. Again, depending on the underlying assumptions and boundary conditions, hydrogen together with biomass pose to be very versatile fuels in future energy systems; especially providing flexibility in the power system as synthetic or bio-methane. Without sectoral emission targets, an introduction of those alternative gas-based energy carriers in the power sector allows for other sectors to emit more CO_2. This is especially important for the high-temperature industry sector (e.g., steel-making, glass-melting, etc.) as this sector is generally more challenging to decarbonize or electrify.

Gas infrastructure

Regarding the gas infrastructure developments, in the coming decades (2020 and 2030), natural gas is a backbone of the energy system with a high degree of usage in the power, industry and buildings sectors. But in all scenarios, a uniform decrease in this usage can be observed in Figure 5.

Figure 5: Total consumption of gas-based energy carriers.

Although the need for natural gas continues to decrease from 2030 until 2040, the overall consumption of gas-based energy carriers stays nearly stable from 2040 until 2050 for *Diversification* and *Localization*. As seen in previous figures, this is the result of the utilization of hydrogen in these sectors. In the *Directed Vision* scenario, also outlined in an earlier section, biogas plays a significant role in the energy system. Still, the sectoral usage of gas-based fuels changes in different sectors, compare Figure 5. Regarding the needed future gas infrastructure, it can be seen that from a total consumption of roughly 3000 TWh in 2020, only one-third is consumed in 2050. This implies that, apart from the currently existing infrastructure, no new additions are needed.

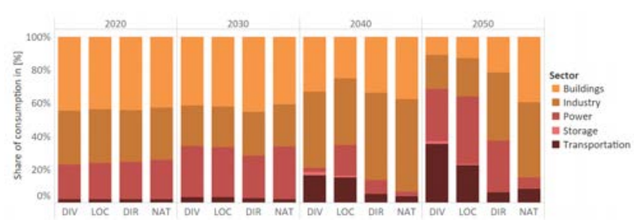

Figure 6: Sectoral shares of usage of gas-based energy carriers and their deviations (including Hydrogen and LNG/CNG).

Whereas gas-based fuels are mostly used for heating in 2020 and 2030, differences between the scenarios become clear in the last years of the modeling period.

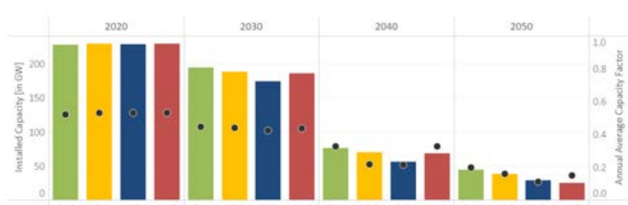

Figure 7: Installed capacities in GW and share of unused capacity in the power sector.

Only the *National Champions* and *Directed Vision* scenarios have similar shares of usage in all sectors compared to the current energy system. Here the most significant shares of gas-based fuels are still used for heating in the buildings or industrial sector.

Lastly, looking at the installed capacity of Open Cycle Gas Turbines, Closed Cycle Gas Turbines, and Steam Engines in the power sector, the previous trend of decreasing usage of gas-based energy carriers can also be observed here. The overall utilization of gas-based power plants stays nearly constant from 2020 until 2030. In 2040, the installed capacities, as well as the average use of gas-fired power plants, varies between the scenarios. In the later years, the gas-fired power plants are used alongside batteries and other sector-coupling technologies to balance large amounts of variable renewable energy sources in the power system. The scenarios with more decentralization, see comparably higher capacities and higher capacity factors in 2050, as more renewables in the power system in the case of Diversification or limited trading possibilities in the Localization scenario need more gas-fired utilities to balance the power system. As the results suggest, large amounts of capacity are unused, starting in 2040. In light of the current plans (grid operators) to install even more gas-fired power plants, the issue of the risk of these newly constructed assets being stranded is highlighted.

Overall, the investments into new gas-fired power plants need to be carefully considered by policymakers in the near future. Although gas-fired power plants are needed for providing flexibility alongside storages in 2050, the majority may still be stranded or operating with an extreme low-capacity factor. As proposed and analyzed in this study, there is a possibility to reuse the existing infrastructure for cleaner gas-based fuels, like hydrogen, synthetic methane, or biogas. Also, gas-fired combined-heat-and-power plants fueled by those energy carriers play an important role in reducing the emissions of the heating, and partly the industrial, sector. Refitting existing turbines with heat-recovery systems may thus decrease the risk of assets ending stranded.

Summary

Overall, a decrease in natural gas-based energy in all sectors is projected under ambitious decarbonization scenarios. Generally, the danger of assets being stranded (most notably gas-fired power plants) increases with each additional power plant being planned and commissioned. Hence, *GENeSYS-MOD* sees a decrease in the total usage of natural gas in the power sector. This is contrary to the current plans of many countries to increase the power production from natural gas.

Nevertheless, gas-fired power plants are needed in the future energy system (mostly utilizing biogas or hydrogen) for balancing a high RES share in the power system. The results note the importance of the flexibility and versatility of gas-based energy carriers in general. In most scenarios, hydrogen or bio-gas play a significant role in the future energy system either allowing for decarbonization of non-electricity sectors or providing balancing options for variable renewable energy sources in the power sector. This importance is even likely to increase in some of the scenarios beyond 2050. Meaning that in order to sustain a low utilization of the gas infrastructure, capacity markets beyond electricity should be considered. The business model for the future gas infrastructure requires gas capacity markets to reward and price the value of flexibility it provides to the power system; this will hinder the possibility of stranded assets.

Due to the regional disparity in the availability of renewable energy source (to produce hydrogen from excess energy in, e.g., the peak sun hours) and biomass, the level of international cooperation is an essential factor for future energy systems. The importance of trading in either power, solid biomass, or gas-based energy carriers will be a crucial factor for future energy systems.

Footnotes

[1] See https://eur-lex.europa.eu/eli/dir/2009/28/oj, last accessed 29.07.2019.

[2] See https://eur-lex.europa.eu/eli/reg/2018/842/oj, last accessed 29.07.2019.

[3] This study omits energy crops as possible option for biofuels.

[4] Therefore, co-generation of heat and electricity as well as co-firing with biomass can be implemented without introducing new technologies to the model.

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(continued on page 41)

Provincial, Federal, and International Regulatory Drivers of Possible Stranded Assets in Alberta, Canada

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Introduction

The Alberta oil sands are vast deposits of crude bitumen mixed with sand, water, and clay located on the Treaty 6 and 8 lands of the Cree, Dene, and Métis First Nations. The oil sands sector represents 10% of Canada's greenhouse gas emissions (Environment and Climate Change Canada, 2018) and contributes about 2.5% of national GDP (Statistics Canada, 2016). Due to the high energy needs of extraction, the carbon intensity of Canadian oil is among the highest in the world, after only Algeria, Venezuela, and Cameroon (Masnadi et al., 2018). Because oil sands bitumen is a low-quality high-sulphur heavy crude (Millington, 2018), it may be among the first oil resources to suffer devaluations as a result of various regulatory changes, including global decarbonization efforts. This situation makes Alberta a salient jurisdiction to study as a potential site of stranded assets, a concept that refers to "assets that have suffered from unanticipated or premature write-downs, devaluations, or conversion to liabilities" (Caldecott, 2018). A proposed typology for environment-related drivers of stranded assets includes changes in regulation, environmental impacts, resource landscapes, technologies, social norms, and litigation (Caldecott, 2018). This paper focuses on the first type of driver: regulation.

The analysis will adopt the theoretical lens of economic geography, which emphasizes the importance of multiscalar inquiry in understanding economic phenomena (Clark et al., 2018). Concerning the impacts caused by regulatory drivers of stranded assets, jurisdictional scale matters. Larger scale regulatory bodies have different priorities from local ones and therefore different impacts. This is partially explained by their lack of political proximity to those affected by their policies. Using the case of the Alberta oil sands, this paper will argue that policies of more remote regulatory bodies will be stronger drivers of asset stranding compared to regulations implemented by those with a closer physical and political proximity to the assets in question. Three key policies established at different jurisdictional levels will be explored. A range of environmental policy types were selected, since a major misunderstanding of the stranded assets concept assumes that climate policies are the only possible drivers and that they are not being established fast enough to ever create stranded assets. This paper goes beyond climate policy and also looks at regulations that target other environmental problems, since those are often overlooked as potential drivers of stranded assets.

At the provincial level, the Oil Sands Emissions Limit Act 2016 is a climate policy that could potentially cause stranded assets by constraining oil sands production. At the federal level, an increasingly restrictive approval process for pipelines could limit export capacity and thus impact oil sands operations. This regulatory environment is not specifically motivated by climate change concerns and instead aims primarily to reduce the local social and environmental impacts of resource development. At the international level, the International Maritime Organization (IMO) has recently established new standards on the sulphur content of shipping fuel, which has implications for crude oil refining across North America. The IMO regulation is a non-climate environmental policy that will impact the market for oil sands bitumen because it is a sour (i.e., high sulphur) crude. With respect to comparing the relative impacts of regulatory risks at multiple scales, there is a gap in the bourgeoning literature on stranded assets.

Stranded assets and climate policy

Most climate policy is intended to drive a global energy transition away from the use of fossil fuels. Along with the implicit concept of "unburnable carbon", climate policy is often interpreted as the only way that fossil fuel assets will become stranded (Butler, 2015). The idea of unburnable carbon gained public attention in 2009, when Nature published a paper stating that less than half of global fossil fuel reserves could be exploited if global warming is kept below 2°C (Meinshausen et al., 2009). A study on the financial impact of this article found that investors responded to the findings, leading to a small but significant 2% drop in American oil and gas companies' stock prices (Griffin et al., 2015). However, the study found that later media coverage on the possibility of a "carbon bubble" based on overvalued fossil fuel assets resulted in no significant stock price reaction. Based on these findings, it seems that projected climate policies are not yet impacting the valuation of oil assets in general, but may begin to do so in the future.

The concept of unburnable carbon is especially significant in Canada: if global warming is restricted to 2°C, 85% of Alberta's oil sands cannot be exploited (McGlade and Ekins, 2015). However, serious climate policy is still lacking, making some dismiss the entire possibility of stranded assets (Butler, 2015). What these critics fail to acknowledge is that policies focused on unburnable carbon are not the only possible regulatory drivers of stranded assets. Initially, asset stranding was imagined as resulting from the top-down enforcement of a carbon budget by governments, but the dominant view has now tended towards acknowledging that stranded assets may be caused by a bottom-up series of indirect policies, social pressures, and physical risks at many levels (Caldecott, 2018). Indeed, there are other policies, implemented at various scales and focused on environmental concerns beyond climate change, that could indirectly and unexpectedly strand fossil fuel assets. Those broader risks must be considered by asset owners.

Provincial regulation

For the past decade, oil and gas extraction has accounted for about 25% of Alberta's GDP (Government of Alberta, 2018a) so the phenomenon of asset stranding could severely affect the province's economy. In 2015, the leftist New Democratic Party (NDP) was elected after over forty years of conservative provincial governments. The NDP established a Climate Leadership Plan to phase out coal power, set a carbon price, and cap emissions from oil sands production at 100 megatonnes (Mt) of carbon dioxide equivalent (Government of Alberta, 2018b). In theory, this cap could restrict the oil sands' expansion, and cause stranded assets, unless producers decouple emissions from output. However, the 100 Mt limit is projected to be reached only in 2030 at current production growth rates (Millington, 2018). The Act itself notes that the limit is designed to provide "room for growth and development of our resource as a basis of a strong economy by applying technology to reduce our carbon output per barrel" (Oil Sands Emissions Limit Act, 2016). Therefore, the intention of this regulation is not to restrict oil sands production.

In April 2019, the United Conservative Party (UCP) won the provincial election. The NDP loss is partially due to the economic hardship caused by low oil prices throughout the government's time in office (Dehaas, 2019). The UCP repealed the provincial carbon tax but has so far left the oil sands emissions cap in place. As a climate policy, it seems resilient to government change, but perhaps only because it does not pose an imminent threat to the province's resource extraction priorities. Even under the NDP government, the primary motivation for climate policy in Alberta was improving the oil sands sector's rather negative environmental reputation (Boyd, 2018). The political proximity between the Alberta government and the oil industry is notable: in addition to lobbying, oil industry representatives use a "revolving door" to circulate in and out of regulatory agencies and political campaigns (MacLean, 2018). Due in part to this influence, climate-related regulations at the provincial level do not seek to constrain oil sands operations, but rather to allow them to grow while maintaining a degree of environmental respectability. This concern for reputation is a result of evolving social norms, which is another possible driver of stranded assets.

Federal regulation

The federal regulatory framework for pipeline approval has grown stricter under the current Liberal government, in part due to the severe opposition faced by pipeline projects in Canada. Most notably, the government recently passed Bill C-69, which alters the regulatory framework for environmental impact assessments. It replaces the existing National Energy Board with a less powerful regulatory body called the Canadian Energy Regulator and establishes an Impact Assessment Agency to determine if a given project is in the public interest (Bill C-69, 2018). The Bill is criticized for mandating laborious consultations and assessments that would restrain new energy infrastructure, lending it the nickname the "no more pipelines bill" (Neufeld, 2019). Critics claim the expansion of bureaucracy will increase the costs and risks of project development and thus reduce investments in Canadian energy infrastructure. By increasing the risks associated with a given project, regulatory delays could increase the minimum acceptable rate of return by $127 million on a $1 billion pipeline proposal, which would make the project uneconomic if that rate exceeds the project's rate of return on capital (Mintz, 2019). This could spillover into reduced investments in upstream oil sands projects.

A lack of export capacity through pipelines has been cited as one of the causes of the low relative market price for oil sands crude (Millington, 2018). Oil sands bitumen, a heavy sour crude, is valued at the oil price benchmark Western Canadian Select (WCS). Because most Albertan crude is shipped to American refineries, WCS is closely linked to the West Texas Intermediate (WTI) price for sweet Texas crude. WCS is priced at a discount of around US$13 per barrel relative to WTI due to its lower quality (Millington, 2018). If the price for oil sands falls and remains low, much of Alberta's bitumen could become uneconomic to extract and therefore stranded. There are two extraction methods used in the oil sands: steam-assisted gravity drainage, which uses steam to melt and extract bitumen from deep underground, and surface mining, which is more expensive. With a higher discount on WCS relative to WTI, caused by factors like pipeline construction delays, a higher overall oil price is required for extraction projects to be profitable. Fluctuations in oil prices, the exchange rate, and supply costs make it difficult to determine whether a given asset will be permanently or only temporarily stranded.

Federal pipeline policy thus may affect the valuation of oil sands assets both by increasing the risk of investing in associated infrastructure projects and by affecting the price of bitumen. While the provincial government is not likely to cause stranded assets because of its close proximity to the oil sands industry, the federal government is influenced by a broader scope of voices from other provinces. British Columbia, for example, strongly opposes the Trans Mountain pipeline expansion, which would transport greater volumes of oil sands crude to the west coast of Canada. The federal government's necessarily divided priorities of satisfying conflicting provinces leads it to make regulatory decisions that may moderately harm the valuation of oil sands assets.

International regulation

The new sulphur limit on fuel oil implemented by the International Maritime Organization (IMO) could affect oil sands assets. The IMO is a specialized agency of the United Nations that governs global shipping, ensures safety at sea, and prevents marine pollution (IMO, 2019a). In 2008, the International Convention on the Prevention of Pollution from Ships was amended to reduce the maximum sulphur content permitted in shipping fuel from 3.5% to 0.5% with the aim of preventing the health impacts in port cities and broader ecological impacts of sulphur emissions (IMO, 2019b). In order to comply, shipping companies can either purchase low sulphur fuel oil, blend or refine high sulphur fuel oil (HSFO), or install exhaust gas cleaning systems, also known as scrubbers. Only 3% of the volume of HSFO is likely to be addressed by scrubbers; the majority of shipping fuel will be made compliant through desulphurization in refineries (Nduagu et al., 2018). Roughly three quarters of Canadian crude oil is exported, almost exclusively to the United States (Natural Resources Canada, 2017). Thus, the effects of the sulphur standards on North American refineries will necessarily affect oil sands operations.

Due to the increased costs of refining compliant fuels, the IMO sulphur standard could decrease North American refinery margins by US$16-20 per barrel. This loss will be directly transferred to the price differential between light and heavy crudes, thus deepening the discount on WCS (Nduagu et al., 2018). Unless the widening price differential is offset by rising overall oil prices, the IMO regulation may seriously affect western Canada's oil sector. It is estimated that 20% of Albertan oil sands production is below the profitability threshold that is projected for 2020, when the IMO regulation comes into force (Nduagu et al., 2018). Such a large production drop threatens the valuation of oil sands assets and could potentially lead to permanent asset stranding. In terms of its regulatory decision-making, the IMO of course lacks any proximity to oil sands interests, so it takes little consideration of potential impacts on fossil fuel assets. This political distance allows for a greater potential to cause stranded assets. Regulations at the international level can be especially impactful because they can affect the demand for oil on a macro-level, which is likely to lead to more serious and persistent impacts on oil price. In addition, it is more difficult for provincial and federal actors to predict and mitigate these kinds of impacts.

Discussion: Why jurisdictional scale matters

Researchers in economic geography use a multiscalar framework to understand the forces that shape economic change (Clark et al., 2018). In the case of asset stranding in Alberta, jurisdictional scale matters for three reasons, summarized in the table on the next page. First, political proximity to affected assets restricts the strength of a potential regulatory driver. Regulatory pressures from institutions closer to the local resource may be weaker than regulatory pressures from more distant institutions. One reason for this difference is the political proximity of oil sands firms and workers to the provincial government and, to a lesser extent, to the federal government. Governing bodies at the intermediate national level are beholden to local industries and citizens, but must make political trade-offs to satisfy voters residing in other provinces, thus making the federal government a more likely cause of stranded assets than Alberta's provincial government. Political remoteness and a broad, globalized regulatory reach make international regulators an even more significant cause of stranded assets, though they may do so indirectly and unintentionally. In order to make a concrete statement about the relative strengths of each policy as a driver of stranded assets, their individual effects on oil sands valuation would need to be quantified.

Second, the scale of a jurisdiction implementing regulations that could cause stranded assets affects the permanence of their impact. Elections at the provincial and federal levels can lead to the reversal of policies that threaten to cause stranded assets. The new conservative government of Alberta is repealing much of the NDP's Climate Leadership Plan (Kaiser, 2019), while the federal conservative party has promised to repeal Bill C-69 if elected in the upcoming 2019 election (Harapyn, 2019). Such policy reversals mean that certain regulatory drivers may only temporarily cause stranded assets. In contrast, the lumbering giant of international environmental law, with its committees of numerous member states, does not often reverse its decisions (Birnie et al., 2009). Thus, the permanence of a regulation's impact on oil sands assets may depend on the scale of the jurisdiction implementing the regulation in question.

Third, the scale at which possible regulatory drivers of stranded assets are implemented determines the potential for vertical policy interplay, a concept that describes how regimes interact across different levels of social organization (Young, 2016). The possibility of policy interplay depends on the institutional proximity of the regulatory bodies in question. As conceptualized in economic geography, institutional proximity defines the relations between agents, laws, and organizations at the macro-level rather than the individual level (Boschma, 2005). There is greater vertical policy interplay between the provincial and federal governments than between the federal government and the IMO due to differences in institutional proximity. Canada is a confederacy, meaning the national government must seek provincial consent before assuming obligations that the country will adopt as a whole (Young, 2016). The vertical policy interplay between provincial and federal governments could either raise or lower the financial value of oil sands assets. The provincial NDP government worked mostly cooperatively with the federal Liberal government. For example, it established a carbon tax in response to the threat of a federal carbon price to be imposed on provinces that do not implement one themselves. The new conservative government of Alberta has promised to overturn provincial climate policies in order to more aggressively promote the oil sands. However, this combative policy interplay may threaten regulatory stability if the federal Liberal Party remains in power. Somewhat ironically, this instability, rather than the climate-related regulations of the previous provincial government, could represent a financial risk to the oil sands sector since investors seek jurisdictions with policy stability (Bakx, 2019).

		JURISDICTIONAL LEVELS		
		Provincial	**Federal**	**International**
REGULATORY CHARACTERISTICS	**Proximity to oil industry interests and oil-dependent communities**	high	moderate	low
	Permanence of established regulations under changing political conditions	low	low	high
	Potential for policy interplay between jurisdictional scales	high	high	moderate

Figure 1: Characteristics of potential regulatory drivers of stranded assets

Conclusion

The oil sands of Alberta are a potential site for stranded assets due to a range of regulatory and other drivers. By examining regulations that could cause stranded assets at three jurisdictional levels, this essay has argued that scale matters when considering the possible impacts of regulation on fossil fuel assets. The analysis of this multiscalar spectrum of risks found that, in the case of the policies discussed, regulations implemented by more remote governing bodies are more likely to cause stranded assets, and to do so more permanently. This is at least partially due to the proximity of oil industry interests to the provincial and federal governments, which lends them influence over policies that are developed at those levels. In addition, interactions between regulatory bodies at different scales can either protect or further threaten the oil assets of Alberta, depending on whether they are cooperative or combative. Both the federal and international policies discussed in this paper are not motivated by climate change concerns. Rather, they respectively focus on the local impacts of pipeline spills, and the global health and ecological impacts of sulphur. This paper contributes to the academic work on stranded assets, which has argued that owners of fossil fuel assets should consider potential risks beyond existing and potential climate policies.

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Forecasting Energy Demand

BY ANDREW PICKFORD

To attendees of the UN Climate Change Conference in Madrid this month, the partial sale of national oil company Saudi Aramco may have gone largely unnoticed. Those disappointed in the failure of the climate summit to reach any meaningful agreement may not have realised how highly the world's lowest cost oil producer - which has consistently produced 10-million barrels of oil a day - was valued. The company's initial public offering raised a record USD$25.6-billion, making it the most valuable listed company in the world (USD$1.7-trillion).

To the casual observer, there appears to be an obsession in the Western press with an imminent date for peak oil demand, generally associated with extremely optimistic (early) forecasts. However, overlapping trends including the decline of multilateral agreements, increasing nationalist sentiments and expanding energy use in the developing world are out of step with this commentary.

There is no disputing the fact that at some point in the next century we will reach peak oil demand, after which oil demand will decrease. However, the reason is unlikely to be due to the most cited causes. Neither internationally binding mandates to limit the use of coal, oil and natural gas, an explosive growth in renewables, nor relentless expansion of the global electric vehicle fleet will be the likely drivers, despite their dominance in economic forecasts and projections.

It is partly for this reason that there is no consensus on the date of peak oil demand – estimates range from as early as 2030 to as late as 2100. Attempts to forecast the date of peak oil demand are educated guesswork at best, and anyone who predicts a date with certainly is revealing their own bias.

Just as the emergence of shale production caused a shock to oil markets, other fissures which upturn conventional wisdom will result in new forecasts. A symposium in Abu Dhabi in December 2019, sponsored by the International Association for Energy Economics, examined these issues, which alongside other discussions, considered the role of oil in the global economy through to 2100.

Several interesting insights arose out of the symposium and discussions on the sidelines of the event:

Hydrogen may become an important energy carrier, even though much of the political and policy debate will be related to its origin and the carbon intensity of its production. Hydrogen will likely be labelled "blue", "green" or "grey" as well as other colour variations.

Regardless of a peak oil event, Gulf producers enjoy such a low production price point that they will be likely in the oil business well into the century, even if production shifts towards petrochemicals. High-cost producers will exit the market.

The demand for oil will change through to 2050 in both its composition (towards petrochemicals and materials) and location (towards emerging economies).

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Financing of international oil companies (IOCs) due to "ESG" demands (dependent on varied environmental, social, and governance measurements) may provide a competitive advantage to national oil companies (NOCs) which have different capital, debt and financing options. This could diminish the role of NOCs and have geopolitical implications.

While natural gas is no longer seen as a "transition fuel" in Western countries and is being penalised by some decision makers, an expansion of renewables will necessitate additional natural gas generation capacity. Jurisdictions which do not have deep electricity interconnections or access to hydro-electricity capacity will be forced to curtail intermittent renewable expansion or add natural gas generation capacity.

- Nuclear power is making a quiet comeback and small modular reactors could disrupt the existing business model of large, expensive units. This is evident in the Middle-East and Gulf region where there is a demand for fast electricity, and a need for desalination.
- Several Gulf countries appear to be embracing renewable and nuclear power for economic rather than environmental reasons. The ability to free up oil and natural gas for export earnings more than offsets the capital and running costs for these electricity investments.
- There is an increasing disconnect between the energy priorities of first world energy consuming nations, with flat and soon declining demand; producer nations; and developing nations which are experiencing fast demand growth. This global fragmentation points to less international consensus on climate agreements and energy priorities. It represents the prioritising of individual national interests.
- Oil demand appears to have good short- to medium-term prospects. Even under scenarios of strong growth of electric vehicles, the transition in developing countries towards first world living standards will see ongoing upward pressure on oil demand, which will not be limited to transport fuel but will also include demand for petroleum-based products.

Prior to the emergence of shale oil, most energy conferences were focused on determining a peak oil supply date and predicting a hard end point to the oil age. Outlandish predictions included an expectation of a $200 per barrel super-spike in 2008. Now, however, few speak of a peak oil supply date as markets and new technologies have re-written the outlook. Similarly, in the 2030s, it will be an interesting exercise to read the headlines about oil from 2019, which may sound as outlandish as the dire predictions of the last decade.

Trade and Labour Migration Effects on the Oil-Macroeconomy Relationship

BY SAEED MOSHIRI

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Oil has played a critical role in the economic performance of countries across the world for more than half a century. Although oil intensity has decreased in many countries through time, changes in oil prices still generate significant impacts on economic conditions. The effects of oil price changes on economic performance are not homogeneous across countries and depend on whether they are oil-exporters or oil-importers. A rise in oil prices alters the terms of trade in favor of the oil-exporting countries and causes harm to oil-importing countries. The outcome is inverse when oil prices fall. However, trade and labour migration may mitigate the adverse effects of the oil price shocks across the world. In this article, I first briefly review the oil-macroeconom relationship concerning both oil-exporting and oil-importing countries and then present the case for trade and labour migration as factors easing the pain.

In general, changes in oil prices generate primarily supply-side effects on the economy of oil-importing countries and mainly demand-side effects on the oil-exporting countries. Specifically, rising oil prices increase production costs in the manufacturing sector of the oil-importing countries leading to a decline in output and productivity and to higher prices (Hamilton, 1999; Balke et al., 1999). This is what happened during the first and the second oil-price shock in 1973, when Arab countries cut their oil exports to Western countries due to their support of Israel during the war, and in 1979, when oil-supply fell because of the Iranian revolution. Most of the following economic downturns in the U.S. economy were also preceded with a hike in oil prices (Hamilton, 1999). Monetary policy can also influence how the oil price shock affects the oil-importing countries. Depending on the policy stance of monetary authorities (accommodative, restrictive or neutral), an increase in oil price will impact the economic growth and inflation rate of oil-importing countries differently. For instance, Bohi (1991) and Bernanke et al. (1997) argue that a contractionary monetary policy following an increase in oil prices is the main source of economic slowdown in oil-importing countries. Furthermore, oil price volatility can send ambiguous signals to monetary authorities which then choose a potentially wrong monetary policy, consequently lightening or intensifying the real effects of oil price shock on the economic performance of oil-importing countries (Brown and Yücel, 2002).

The impact of oil price changes on oil-importing economies is, however, not symmetric. That is, although higher oil prices may lead to an economic downturn, lower oil prices may not contribute to economic growth significantly. Studies by Mory (1993), Mork (1994), Ferderer (1996), and Hamilton (1996, 1999) provide empirical support for asymmetric effects of oil price changes on the US economy by showing that negative responses in economic activities to the increase in oil prices are stronger than positive responses to a decrease in oil prices. One possible mechanism that could explain the asymmetric effects of oil price shocks is monetary policy. Assuming that nominal wages are sticky downward, a decrease in oil price and the subsequent rise in productivity and economic activities should be accompanied by a real wage rise to make markets clear. Since nominal wages are not limited to adjusting upward, monetary authorities do not interfere in the market. However, monetary authorities usually run a counter-inflationary monetary policy when oil prices increase and, if nominal wages are sticky downward, real wages will not fall with reduced productivity. Consequently, unemployment will increase, aggregate consumption will fall, and economic activities will be retarded beyond the level that stems directly from the supply shock (Brown and Yücel, 2002). The empirical results on the role of monetary policy in explaining the asymmetric effects of oil price shock are, however, mixed (Tatom, 1993; Ferderer, 1996; Bernanke et al., 1997; Balke et al., 1999). Another channel for explaining the asymmetric impacts of oil price is an indirect effect of adjustment costs (Hamilton, 1988). Adjustment costs could stem from sectorial resource reallocation and coordination problems between several firms and have an indirect negative impact on economic activities with either oil price decrease or increase. Therefore, when oil prices increase, two direct and indirect negative impacts are in effect retarding economic activities. On the other hand, when oil prices decrease, the direct positive impact is offset by the indirect negative impact and, thus, results in asymmetric effects of oil price shocks.

Unlike the experience of oil-importing countries, for oil-exporting countries, a hike in oil prices is considered good news. In an oil-exporting country, a windfall of oil revenues can improve the standard of living through increasing investment in physical and human capital and technology. This is particularly important as most of the oil-exporting counties are developing countries desperately in need of foreign capital to increase their economic growth. Nevertheless, the expected positive outcome of higher oil prices has not materialized and in some cases, economic conditions have worsened (Smith, 2004; Frankel, 2010). The traditional explanation for the detrimental effects of higher oil prices on the economic performance of oil-exporting countries is provided through the Dutch disease model (Corden and Neary, 1982). An oil boom will generate a de-industrialization process through an appreciation of exchange rates and resource movements, dampening the manufacturing sector in favor of non-traded sectors. Other studies have also examined the role of non-economic factors, such as political systems and institutions, to explain the poor performance of oil-exporting countries (Stevens, 2003, Mehlum et al., 2006).

In a more recent study, Moshiri (2015) shows that the oil price shock effects on many oil-exporting countries are asymmetric. That is, although lower oil prices hurt the economy by cutting oil revenues and spending, higher oil prices do not necessarily generate long-term growth. The asymmetric effects can be due to procyclical fiscal policy and the fixed-exchange rate policy in those countries (Husain et al., 2008; Frankel, 2010). Following a boom in the oil market, governments often increase spending dramatically on social programs and publicly-funded projects. In most cases, these large-scaled investment projects do not generate positive economic outcomes due to poor institutional quality, which leads to rent-seeking behavior and corruption. When oil prices fall, most of the unfinished projects stall due to lack of funding, and unemployment rises (Eifert et al., 2002; Farzanegan, 2011). Fixed exchange rate policies also work against the exports of non-oil products during the oil price fall. The oil reserve funds and international borrowing, which can be used to avoid volatility in economic activities arising from oil price changes, are also not often utilized effectively and borrowing may even exacerbate the condition by accumulating foreign debt.

Most studies on the oil-macroeconomy relationship have focused on a specific or a group of oil-importing or oil-exporting countries. However, with the rise in global trade and labour movements across the countries in recent decades, the dynamics of the relationship might have changed and, therefore, results focusing on countries in isolation might be misleading. The effects of the oil price shocks may spill over through trade or labour mobility between and within the countries. Failure to consider the spillover effects may thus lead to an overestimation of the overall effects of oil price shocks on the economy. Notwithstanding the rich literature on the relationship between oil price changes and macroeconomic performance, studies that include both oil-exporting and oil-importing countries and consider the spillover effects of the oil price shocks are limited. Only a few studies, such as Abeysinghe (2001), Korhonen and Ledyaeva (2008), and Husain et al. (2015), have examined the global impacts of oil price shocks, considering both oil-importing and oil-exporting countries. Abeysinghe (2001) shows that even oil-exporting countries may not be able to escape the negative impact of high oil prices because of the indirect effect through their trade with oil-importing countries. Korhonen and Ledyaeva (2008) also show that although oil-exporting countries such as Russia and Canada benefit from higher oil prices, they also suffer indirectly through their trade with the oil-importing countries which are hit negatively. The oil-importing countries that are adversely affected by the higher oil prices may also benefit from trade with the oil-exporting countries.

The cross-country studies that include spillover effects between oil-exporting and oil-importing countries shed more light on the overall effects of oil price impacts on the economy than single country studies do. However, given the differences in the structures of the economies, institution qualities, and political systems in the sample countries, the aggregate level studies may also be subject to biased estimation results and misleading policy implications. Two recent studies have examined the mitigating impact of the intra-federal labour mobility on cases of Dutch disease using a state/provincial panel data. Raveh (2013) shows that although natural resource wealth is a curse in the cross-country analysis, it is a blessing at the provincial level and can lead the economy towards the so-called “Alberta Effect.” He argues that the reduced factor mobility costs within federations could reverse, or at least alleviate, the Dutch disease symptoms at the intra-federal level. Beine et al. (2014) also addresses the question of whether Dutch disease symptoms could be overcome or at least mitigated through either interprovincial migration or international immigration flows of workers. They report that Dutch disease symptoms are observed in Canada in the form of a rise in the share of the non-tradable sector, but the immigration of workers into the booming provinces mitigates the effects of the Dutch disease. They also show that the mitigation effect is stronger with interprovincial migration flows and immigration flows associated with the temporary foreign worker programs. Moshiri and Bakhsimogaddam (2018) also investigate the effects of the oil price shocks on the Canadian economy. Canada is an interesting case study for the overall (direct and spillover) effects of the oil price shocks, because it includes autonomous oil-exporting and oil-importing provinces, which enjoy homogeneous institutional and political structures and the same monetary policy. Furthermore, trade and labour migrations take place between provinces without the barriers that exist among countries, even those in the same economic and political blocks. In this context, Canada can then be considered as a world including both oil-importing and oil-exporting countries, but with similar institutions and monetary system, free trade, and labour movement across the nations. Therefore, the oil price shock effects obtained from Canadian data will not be influenced by institutional and structural heterogeneities. Moreover, considering the interprovincial trade and labour movement across provinces will provide more accurate estimates of the spillover effects of the oil price shocks.

Like countries, Canadian provinces are subject to different demand side and supply side effects of the oil price shocks. For instance, high oil prices generate excess revenues for oil-exporting provinces, increasing aggregate demand. However, rising oil prices has adverse impacts on oil-importing provinces, because of increasing production costs, especially in the manufacturing sector. The standard Dutch disease effect may also be applicable, given the fact that the Canadian dollar moves with the oil prices. In addition to the direct demand and supply side effects in the two groups of provinces, interprovincial trade and labour migration can also influence how the oil price shocks affect the economy. When oil prices rise, the affluent oil-exporting provinces increase their imports from oil-importing provinces, alleviating the adverse supply side effect on oil-importing provinces. When oil prices fall, the beneficiary oil-importing provinces increase imports of oil and other commodities from oil-exporting provinces, easing the negative effects on the oil-exporting provinces. The labour movement would also have similar countercyclical effects in provinces, as labour moves from oil-importing provinces to oil-exporting provinces during oil booms and in the opposite direction when the oil market plummets (Helliwell, 1981; Raveh, 2013).

Figure 1 shows that per capita GDP in Canada and its two groups of oil-export and oil-import provinces along with the oil price trend for the period 1981-2012. The Canadian economy grew noticeably during the low oil prices in the 1990s and continued to grow, though at slower rates, during the sharp oil price increases in the 2000s. Figure 1 also shows that both oil-exporting and oil-importing provinces have been growing during different cycles of the oil prices, but the growth of oil-exporting provinces has been faster during the oil boom of the 2000s.

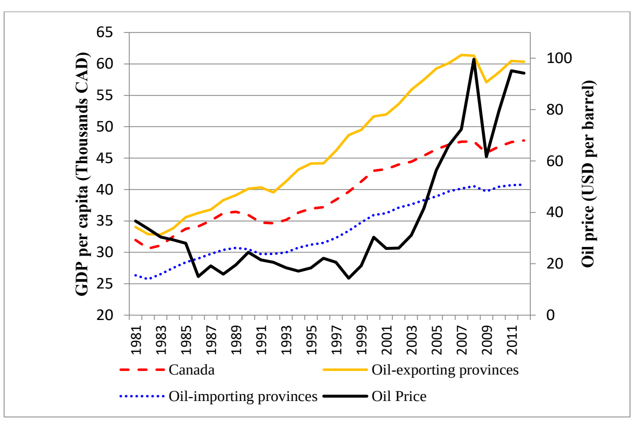

Figure 1- Oil prices and GDP per capita in Canada
Source: Statistics Canada, U.S. Department of Energy (EIA)

Figure 2 shows the interprovincial trade ratios in oil-exporting and oil-importing provinces. The trade ratios are much higher in the oil-exporting provinces, reflecting their lower total GDP compared to the oil-importing provinces, and have been increasing much faster since 2000. Figure 3 also shows the net migration from the oil-importing to the oil-exporting provinces. The oil-importing provinces have experienced a net labour inflow during the oil bust in the 1980s and a net labour outflow during the oil boom beginning in the late 1990s.

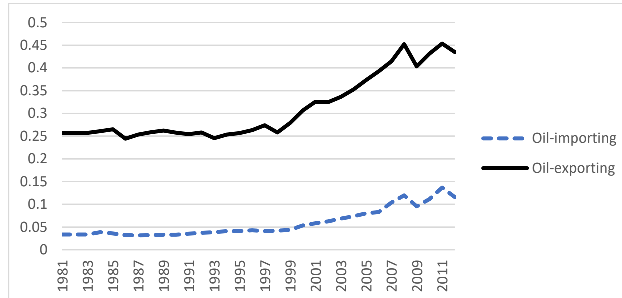

Figure 2- Trade Ratios in oil-importing and oil-exporting Provinces
Trade ratio is the sum of exports and imports as a ratio of GDP.
Source: Statistics Canada, CANSIM Table 384-0038, 384-0002 and 384-0003.

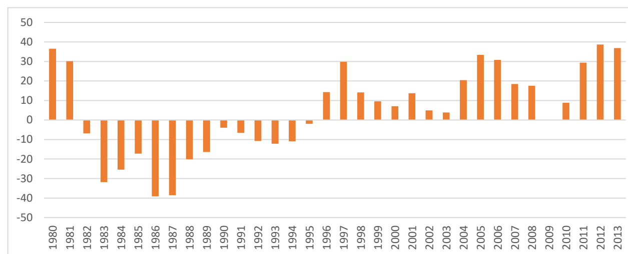

Figure 3- Net Migration from oil-importing to oil-exporting Provinces (1000 persons)
Source: Statistic Canada, CANSIM, Tables 384-0038 and 051-0019.

Moshiri and Bakhshimogaddam (2018) use a panel VAR model to tease out the impacts of the oil price shocks on the Canadian economy considering the trade and migration factors. The main variables included in the model are per capita GDP growth rate, interest rate, exchange rate, and oil price shocks. For a robustness check, they also include other variables such as investment ratio, government spending ratio, and real exchange rate. The results of the study show that oil price shocks do not have an overall significant effect on the Canadian economy. Nevertheless, the effects are heterogenous across the two groups of oil-importing and oil-exporting provinces. While oil-exporting provinces benefit from higher oil prices, oil-importing provinces suffer. However, interprovincial trade and labour migration have been able to mitigate those direct effects on the provinces. The results of the counterfactual exercise show that the responses of the economy when trade and labour spillovers are considered are different than those when the spillover variables are absent. Specifically, the long-run (5-year horizon) effect of oil price shocks on GDP growth rate of oil-exporting provinces in the presence of the trade spillover is higher by 0.23 percent, and the negative effect on oil-importing provinces is lower by 0.1 percent. The impulse response differences are also similar when labour migration spillover (0.23 percent and 0.12 percent for the oil-exporting and the oil-importing provinces, respectively) is used. As an alternative way to gauge the spillover impact, the oil shock - GDP growth nexus is also examined in two different periods with low and high trade ratios and labour movements. As Figure 2 shows, the trade ratio has been low and stable between 1981-2000 (25 percent on average) and began to rise markedly afterward (35 percent on average). Furthermore, Figure 3 shows that the net labour migration from the oil-importing to the oil-exporting provinces has shifted from negative to positive in the late 1990s and stayed the same since then. These data provide a form of natural experiment to get an insight about the importance of interprovincial trade and labour migration in the oil-macroeconomy relationship.

The results of the state/provincial studies may also be applicable to oil-exporting and the oil-importing countries in the global context. A new study by Moshiri and Kheirandish (2018) estimates the direct and spillover effects of the oil-price changes on 30 major oil-exporter and oil-importer countries. The sample data shows that more than 70 percent of the total exports of oil-exporters flows to major oil-importers in the developed countries and more than 40 percent of the total exports of oil-importers flows to major oil-exporters in the developing countries. The results of the study also indicate that while higher (lower) oil prices are harmful for oil-importing (oil-exporting) countries, international trade mitigates the direct effects significantly. That is, the boons of higher oil prices for oil-exporting countries spills over to oil-importing countries, and similarly, the positive impacts of lower oil prices on oil-importing countries flow to oil-exporting countries through their trade. Although this study does not specifically examine the international labour migration effect, empirical studies for the federated countries suggest that labour movement across the countries can similarly dampen the adverse effects of the oil price shocks on both groups of countries.

The results of these studies have important policy implications in national and global contexts, specifically in our current condition, as sanctions and restrictions on trade and immigration are the active policy agenda in the United States. Resuming sanctions on Iran's oil exports and its financial institutions after the recent unilateral exit of the U.S. from the 5+1 nuclear deal will generate an adverse supply shock causing harm to major oil-importing countries in developed and emerging economies, such as China and India, and thus hindering world economic growth. Moreover, restrictions on trade and labour migration will also intensify the negative impacts of the higher oil prices on industrialized and fast-growing emerging economies. On the contrary, stronger trade relationships and labour movement between the oil-importing and the oil-exporting countries will enhance the positive effects of oil price shocks and dampen their negative effects on the economies of both groups.

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Carbon-Impaired Investment: Understanding Stranded Assets in an Uncertain Energy Future

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See footnotes at end of text.

Definition

Expectations of future economic conditions guide decisions to invest liquid capital in illiquid assets. If economic conditions are less favorable than expected, investment returns may decline so much that, an investor would have altered their investment decision in order to avoid part of the investment becoming "stranded" in an underperforming asset. The longer the investment horizon, the less certain we can be of what conditions will prevail and the more likely some of an asset's value will become stranded.

Assets underperforming expectations is a common occurrence and financial accounting standards offer clear guidance on how to value them. Accounting standards refer to assets as "impaired" when their market value falls below their book value less depreciation. For example, U.S. firms follow Financial Accounting Standard No. 121 and statement 144 in "Accounting for the Impairment of Long-Lived Assets and for Long-Lived Assets to be Disposed of" when their assets undergo a significant loss in market value, loss in productivity, or encounter higher-than-expected fixed or operating costs. Climate-specific examples abound for such situations; e.g., adverse regulation in the form of GHG performance standards, physical damage from more intense or frequent storms, or higher fixed costs for constructing climate-resilient fixed assets (i.e., require adaptation capital).

Causes

Environment

The natural environment provides a suite of services and assets to the economy. Changes in the state of the environment can damage or otherwise degrade the performance of natural or built assets leading to impairment. The EPA Climate Impacts and Risk Analysis (CIRA) project provides a broad assessment of climate-related asset risks.[1] For example, sea level rise may degrade or demolish coastal real estate (Bin, Poulter, Dumas, & Whitehead, 2011; McNamara & Keeler, 2013). Increased storm frequency and intensity may depreciate and damage existing capital (Bouwer, 2010; Estrada, Botzen, & Tol, 2015; Nordhaus, 2010). Ocean acidification may undermine the health of marine ecosystems and fisheries (Branch, DeJoseph, Ray, & Wagner, 2013; Brander, Rehdanz, Tol, & Van Beukering, 2012; Narita, Rehdanz, & Tol, 2012).

Technology

Technological change, including the discovery of new technologies or improvement of substitute technologies, can reduce the cost-competitiveness of an asset. For example, the shale gas boom was a result of new technology that allowed us to access existing reserves at a lower cost. Natural gas then became cheaper for electricity generation in comparison to coal (Knittel, Metaxoglou, & Trindade, 2015). Improvements in electric vehicle, electricity storage, and renewable technologies have dramatically reduced costs and threaten to strand fossil fuels, coal not least among them.

Preferences

Consumer preferences for the goods and services they consume may change and raise costs or decrease revenue streams associated with an asset's performance. For example, changing consumer preferences on electric vehicles and increased electric vehicle adoption threatens to strand oil resources or oil-using assets (Azar, 2009). Societal preferences and perceptions of risk surrounding nuclear energy changed after the Fukushima Daiichi nuclear disaster, leading to initiatives across various countries to close existing nuclear power plants and stop the construction of new nuclear power plants. Winter tourists may change their preferences on snow sport destinations as ski-resorts experience shorter snow seasons with greater variability within the snow season, subsequently reducing the value of the ski-resorts (Gössling, Scott, Hall, Ceron, & Dubois, 2012).

Policy

Policy and regulatory changes can directly raise the costs or decrease the revenue streams associated with an asset's productivity. Policies may also require higher environmental or safety performance to generate greater public benefits, putting downward pressure on the value of existing production assets as new or retrofit equipment must be added. A cap-and-trade policy, such as RGGI, will increase the cost of carbon-emitting generation, potentially stranding coal-fired assets (Kim & Kim, 2016). However the stranding of coal may tip the marginal cost over the carbon capture threshold and make carbon capture more cost-competitive (Clark & Herzog, 2014; Johnson et al., 2015).

Modeling

A variety of approaches to energy-economic modeling exist. Calibrated simulation models provide a useful diagnostic tool for understanding key economic dynamics under different sets of assumptions or scenarios. A common approach, often referred to as "bottom-up," is to represent a single sector or group of sectors in the economy with high levels of engineering and economic detail but treat the rest of the economy in a reduced form or even fixed way. Larger energy-economy models integrate results from several sectoral supply or consumer demand modules with shared energy price and quantity information coordinated with certain high-level macroeconomic dynamics. General equilibrium models, often referred to as "top-down", represent factor supplies (e.g., capital, labor), intermediate, and final demand quantities and prices for the entire economy at some level of sectoral and regional aggregation.

Bottom-up and energy-economy models excel at providing technologically explicit representations of the physical operations of engineered systems. Their relative weakness is in capturing how inter-industry linkages and substitution behavior may dampen or amplify the total economic costs or benefits. General equilibrium models, particularly those with richer energy technology representations, can provide a worthwhile compromise between explicit representation of engineering detail and key macroeconomic dynamics. This tradeoff is particularly worthwhile in the case of stranded energy resource and technology assets whose value may depend on the full interaction of the surrounding environment, technology, preferences, and policies.

Irreversibility

A model should be able to track and fix investment in the sectors of interest in order to assess impairment and stranding. Models typically fix investments in sector-specific capital stocks by recording the amount of malleable (a.k.a. putty) capital invested and making it non-malleable (a.k.a. clay; cf. Phelps, 1963 on "putty-clay" capital dynamics) often fixing the associated production technology to that prevailing in the period. By fixing and tracking sector-specific capital formation one can compare the cost basis and market value of installed capital to assess impairment or stranding.

Uncertainty

There are two broad categories of how to treat inter-temporal dynamics: recursive and foresighted. Investment decisions in recursive models are based on intra-period market conditions or may follow exogenous rules. Foresighted models' investment behavior is based on current and expected future market conditions. As a result, foresighted models are more difficult to "surprise" with adverse events. Scenario costs measured between the model baseline and policy simulations may understate costs to the extent foresight lowers transition costs and recursive models may overstate scenario costs to the extent investment behavior is overly myopic or rigid.

Substitution

Not all model types make explicit use of substitution elasticity parameters, but they are implied by model behavior. For example, a model designed to choose generation only on cost implies perfect or infinitely elastic substitution. Simulation models may exogenously dampen the ease of substitution by limiting the rate of growth for specific technologies to prevent abrupt changes period-on-period, so-called "bang-bang" behavior (e.g., Hyman et al, 2003, Huppman and Egging, 2014 for discussion). Substitution elasticities are often larger as economic activities are aggregated or longer periods are considered and is an eminent feature of general equilibrium models. Regardless of explicit model structure, the implied degree of substitution between a potentially impaired asset and its substitutes will strongly guide the modeled risk of impairment and stranding.

ARTIMAS

An RTI Macroeconomic Analysis System (ARTIMAS) is a foresighted dynamic computable general equilibrium (CGE) model of the United States, with nine representative households by income, and can be run at national or regional geographies. The model represents 30 sectors with a focus on energy and pollution-intensive industries. ARTIMAS includes a technology-rich representation of the electricity sector based on RTI's Micro-level Environmental and Economic Detail of Electricity (MEEDE) database (Woollacott and Depro, 2016). The MEEDE database provides a unit-level characterization of environmental, engineering, and economic attributes of electricity generators and abatement equipment on the U.S. grid. The electricity sector in ARTIMAS represents approximately 60 electricity generation and abatement model technology configurations based on the MEEDE data. Capital stocks are vintaged by sector and by fuel type in the electricity sector. ARTIMAS tracks emissions for oxides of nitrogen and sulfur, particulate matter, mercury and four types of greenhouse gases in the electricity sector and GHGs from fossil-fuel combustion in the rest of the economy.

Results

We use the ARTIMAS model to evaluate a range of impairment risks, using stylized examples from each of the causes listed above. Impairment risks range from a low-risk example (chosen from environment), to intermediate (chosen from technology and preferences), to a high-risk example (chosen from policy). The impact scales are not intended to be compared. More rigorous simulations would draw on additional data to better articulate and calibrate the phenomena in the examples and might also revise model structure to capture additional factor and commodity market dynamics. We implement the shocks at the outset of the model period and evaluate the extent of impairment through percent changes in the price of capital associated with electricity generation and fossil fuel stocks (Figure 1 and Figure 2, respectively).

Environment

Increases in drought frequency and duration will impact hydroelectric generation capacity in the United States. Bartos and Chester (2015) examine the impacts of climate change on electricity generation in the western United States, where at least 60% of U.S. hydroelectric generation capacity resides and estimate that sustained droughts could reduce hydroelectric generation capacity by up to 8.8%.[2] Droughts could also diminish thermal generation assets with inadequate cooling water, which would in turn be called upon to offset lower hydroelectric generation during drought periods (Zohrabian and Sanders, 2018).

We model the impact of an 8.8% decline in hydroelectric output and do not consider any other impacts of drought (e.g., increased electricity demand for desalinization, reduced capacity of water-cooled thermal plants). A mild drought-induced capacity

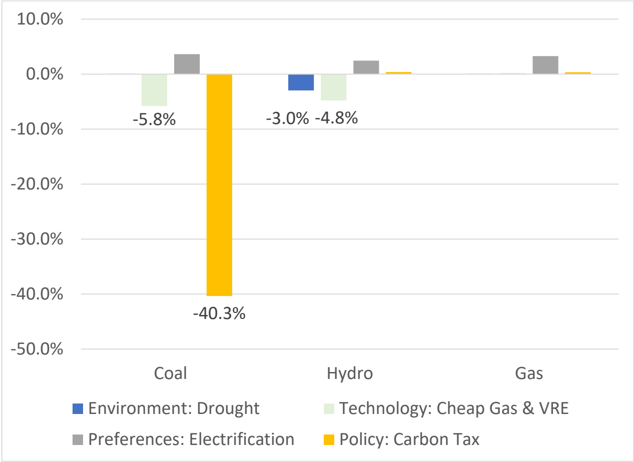

Figure 1: Percent Change in Value of Generation Assets Under Environment & Technology Shocks

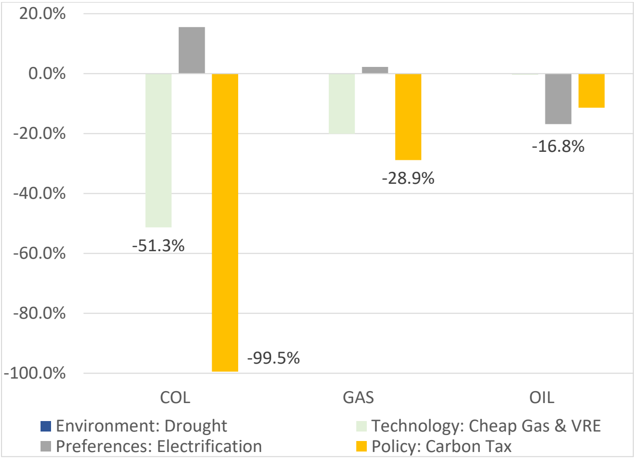

Figure 2: Percent Change in Value of Natural Resource Stocks

loss of 8.8% leads to a 3.0% decline in the value of hydroelectricity generating capital and has a negligible impact on other generating assets (Figure 1) and fossil fuel stocks (Figure 2).

Technology

Solar and wind generation costs have declined precipitously over the past decade (IRENA, 2019) and natural gas prices have halved since the mid aughts (EIA, 2019a). The cost of electricity generation from all three is projected to continue improving (EIA, 2019b). Lower than anticipated capital costs for these types of electricity generation will put downward pressure on the asset values of other types of generation. We examine a 20% reduction in the capital costs of variable renewable energy (VRE; i.e., wind and solar) electricity generation coupled with a 20% reduction in the cost of producing natural gas. Coal and hydroelectric generation capital show impairment with declines in value by 5.8% and 4.8% in this scenario (Figure 1). The value decline for coal resources is larger than generating capital at 51% (Figure 2).

Preferences

Electrification of primary energy uses will most likely occur through a mix of changing consumer preferences and lower cost, where we'd consider lower costs the result of technology improvements. Still, a significant component of electric vehicle adoption will depend on consumer preferences and attitudes independent of cost (e.g., Choo and Mokhtarian, 2004). We simulate such a change by shifting 90% of ground transportation and household demand for refined oil products to electricity demand. This would represent a significant increase in total vehicle miles traveled but this stylized approach isolates the substitution and income effects of the preference shift.[3] The value of oil resources declines by 16.8% (Figure 2) in this scenario and generation capital increases slightly for all types (Figure 1).

Policy

A carbon tax is perhaps the most eminent example of climate-related public policy that could impair or strand assets. We impose a carbon tax of $35 per ton of carbon dioxide held constant in real terms with a border carbon adjustment that taxes imports based on their embodied carbon. Given its relative carbon intensity, cost-competitive substitutes, and few alternative uses, we would expect coal stocks to be significantly impaired by such a policy. Figure 2 shows that the carbon tax strands coal stocks with a 99.5% decline in their value. The value of coal generating equipment is significantly impaired with a 40% loss in value suggesting that coal electricity generation remains in the generation mix only by purchasing coal effectively at the price of the carbon tax and accepting a significant write-down in the value of the generating assets

Conclusion

Negative effects associated with climate change continue to increase in intensity and frequency. Mitigating investments and policy changes are becoming more imperative and the need for assessing associated investment risks is growing. The balance of climate change and our responses are escalating the risks of asset impairment associated with changing environment, technology, preferences, and policy. We provided a typology of climate-related impairment causes and highlight the broad range of potential impacts to assets across a set of stylized simulations focused on the energy sector. Examples are numerous in each type of cause and a careful articulation of their nuances and the essential model structures required to effectively capture them is critical.

Leveraging models like ARTIMAS, investors and policy makers can make better-informed decisions that account for these risks. Further research on the nature and extent of stranding risk in these causal types is needed to provide better estimations of the risk facing assets in the face of climate change.

Footnotes

[1] https://www.epa.gov/cira

[2] US EIA, 2017. "Hydroelectric generators are among the United States' oldest power plants." Retrieved from https://www.eia.gov/todayinenergy/detail.php?id=30312

[3] Total transportation demand for motor gasoline was approximately 17 quadrillion BTU (17% of total demand in 2018) or $400 bn. See https://www.eia.gov/outlooks/aeo/data/browser/#/?id=2-AEO2019&cases=ref2019&sourcekey=0. (quantity), https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3-AEO2019&cases=ref2019&sourcekey=0 (price).

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Calendar

27-29 January 2020, European Gas Conference at Vienna Marriott Hotel, 12A Parkring, Wien, 1010, Austria. Contact: Email: ryan.barry@energycouncil.com, URL: http://go.evvnt.com/467235-0?pid=204

28-30 January 2020, Oil And Gas Council, MSGBC Basin Summit And Exhibition, Senegal 2020 at King Fahd Palace Hotel, Route des Almadies, Dakar, Senegal. Contact: Phone: +27210013885, Email: samantha.boustred@oilcouncil.com, URL: https://go.evvnt.com/430353-1?pid=204

09-12 February 2020, 7th IAEE Asia-Oceania Conference, Energy Transitions in Asia at Auckland, New Zealand. Contact: Phone: 216-464-5365, Email: iaee@iaee.org, URL: www.iaee.org

13-14 February 2020, 6th World Congress & Expo on Oil, Gas & Petroleum Engineering at Lisbon, Portugal. Contact: Phone: 7799790002, Fax: petrosummit2020.scifed@gmail.com, Email: petrosummit2020.scifed@gmail.com, URL: https://scientificfederation.com/oil-gas-petroleum-2020/index.php

18-19 February 2020, Utility GIS Applications 2020 at W Atlanta – Downtown, 45 Ivan Allen Jr Blvd NW, Atlanta, GA 30308, United States. Contact: Email: info@hansonwade.com, URL: http://go.evvnt.com/549829-3?pid=204

19-20 February 2020, SPE Symposium: ESP Journey to the Future | 19 - 20 Feb 2020, Muscat, Oman at Muscat, Oman. Contact: Phone: +44 (0) 20 7299 3300, Email: kdunn@spe.org, URL: https://go.evvnt.com/545727-0?pid=204

03-04 March 2020, Asia Pacific Energy Assembly | 3 - 4 March 2020, Singapore at Raffles City Convention Centre, Singapore, 80 Bras Basah Road, Singapore, 179103, Singapore. Contact: Phone: +442073848060, Email: melanie.richards@oilcouncil.com, URL: https://go.evvnt.com/558792-3?pid=204

05-06 March 2020, Wind O&M Europe 2020 at Holiday Inn Munchen - Stadtzentrum, 3 Hochstraße, Munchen, 81669, Germany. Contact: Phone: +44 (0) 207 375 7507, Email: lindsay@newenergyupdate.com, URL: http://go.evvnt.com/535676-0?pid=204

16-20 March 2020, Gas & LNG Markets, Contracts & Pricing at Singapore. Contact: Phone: +6563250352, Email: media@infocusinternational.com, URL: https://www.infocusinternational.com/gaslng

16-20 March 2020, Mastering Energy Storage & Charging Electric Vehicles (EVs) at Singapore. Contact: Phone: +6563250352, Email: media@infocusinternational.com, URL: https://www.infocusinternational.com/

26-26 March 2020, Sustainability Summit 2020 at De Vere Grand Connaught Rooms, 61-65 Great Queen Street, London, England, WC2B 5DA, United Kingdom. Contact: Email: events@economist.com, URL: https://go.evvnt.com/560121-0?pid=204

06-09 April 2020, 1st Asia Pacific SDEWES Conference Gold Coast 2020 at Gold Coast, Australia. Contact: Email: goldcoast2020@sdewes.org, URL: http://www.goldcoast2020.sdewes.org

15-16 April 2020, SPE Symposium: Unconventionals in the Middle East, 15-16 April 2020 Bahrain at Hotel Sofitel Bahrain Zallaq Thalassa Sea and Spa, 105 Zallaq Highway, Manama, 555, Bahrain. Contact: Phone: +44 (0) 20 7299 3300, Email: kdunn@spe.org, URL: http://go.evvnt.com/548218-0?pid=204

16-17 April 2020, Wind Operations Dallas 2020 (April 16-17 TX) OandM, Asset Management, Storage at The Westin Galleria Dallas, 13340 Dallas Parkway, Dallas, Texas, 75240, United States. Contact: Phone: +44 (0) 20 7375 7177, Email: rwatt@newenergyupdate.com, URL: https://go.evvnt.com/523889-3?pid=204

20-21 April 2020, Smart Water Systems 2020 at London, United Kingdom. Contact: Phone: 02078276000, Email: nhoward@smi-online.co.uk, URL: https://go.evvnt.com/550570-0?pid=204

23-24 April 2020, Renewable Energy 2020 at : Hilton New York JFK Airport Hotel, Jamaica, New York 11436, USA.. Contact: Phone: 16476969880, Fax: renewablenergy@longdommeetings.net, Email: renewablenergy@longdommeetings.net, URL: https://www.longdom.com/renewableenergy

10-11 June 2020, Petrochemical Supply Chain and Logistics 2020 at NRG Center, 1 NRG Park, Houston, TX, 77054, United States. Contact: Phone: 02073757209, Email: info@petchem-update.com, URL: http://go.evvnt.com/512395-0?pid=204

10-11 June 2020, Downstream 2020 Exhibition and Conference at NRG Center, 1 NRG Park, Houston, 77054, United States. Contact: URL: http://go.evvnt.com/486646-0?pid=204

10-12 June 2020, 2020 Sustainable Energy and Technology Summit at Budapest, Hungary. Contact: Phone: Hungary, Email: ryancooper@2020sets.org, URL: https://2020sets.org

18-19 June 2020, 5th Annual US Offshore Wind 2020 Conference and Exhibition, Boston, MA, USA at Hynes Convention Center, 900 Boylston Street, Boston, MA, 02115, United States. Contact: Phone: +44 (0)207 375 7239, Email: adam@newenergyupdate.com, URL: http://go.evvnt.com/523893-3?pid=204

21-24 June 2020, 43rd IAEE International Conference, Energy Challenges at a Turning Point at Paris, France. Contact: Phone: 216-464-5365, Email: iaee@iaee.org, URL: www.iaee.org

22-26 June 2020, Mastering Energy Storage & Charging Electric Vehicles (EVs) at London. Contact: Phone: +6563250352, Email: media@infocusinternational.com, URL: https://www.infocusinternational.com/energystorage

06-08 July 2020, Asia Climate Forum in Singapore - July 2020 at Marina Bay Sands Singapore, 10 Bayfront Avenue, 018956, Singapore. Contact: Phone: 441423524545, Email: tony@media-generation.co.uk, URL: http://go.evvnt.com/514664-0?pid=204

10-11 August 2020, 2nd World global Summit on Oil, Gas & Petroleum Engineering at Rome, Italy. Contact: Phone: +91 9853854854, Email: petroleumconference7@gmail.com, URL: https://petroleumconference.scientificmeeticon.com/

14-16 September 2020, The First World Energies Forum at Rome, Italy. Contact: Phone: +86 010 6280 0830, Fax: +86 010 6280 0830, Email: energies2020@mdpi.com, URL: https://sciforum.net/conference/WEF

22-23 September 2020, BIEE 2020 Conference: Energy for a Net Zero Society at Blavatnik School of Government Oxford UK. Contact: Phone: 07900216267, Email: conference@biee.org , URL: http://www.biee.org/conference-list/energy-net-zero-society/

25-28 July 2021, 44th IAEE International Conference, Mapping the Global Energy Future: Voyage in Unchartered Territory at Tokyo, Japan. Contact: Phone: 216-464-5365, Email: iaee@iaee.org, URL: www.iaee.org

06-10 February 2022, 45th IAEE International Conference: Energy Market Transformation in a Globalized World at Saudi Arabia. Contact: Email: yasser.faquih@gmail.com, URL: www.iaee.org

07-09 August 2022, 8th IAEE Asia-Oceania Conference, Making the Transition to Smart and Socially Responsible Energy Systems at Hong Kong. Contact: Phone: 216-464-5365, Email: iaee@iaee.org, URL: www.iaee.org

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