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Margot Hurlbert, Mac Osazuwa-Peters

Emerging Issues in Energy, Climate Change and Sustainability Management

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Emerging issues in energy, climate change and sustainability management

Margot HURLBERT, Mac OSAZUWA-PETERS

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Abstract:

Aim: This editorial article provides a general introduction into the topic of this special issue on emerging issues in energy, climate change and sustainability management.

Design/Research methods: This article is based on a comprehensive review of this special edition journal and a comparison of the findings in the individual articles.

Findings: Barriers to sustainability include cost, regulatory architecture and perceptions of sustainability. Synergies of growing biomass, expanding biomass with carbon capture and sequestration to mitigate climate change have tradeoffs with food security.

Originality/value of the article: The main value of this introductory article of the special issue is that it provides an overview of the articles identifying barriers of regulatory architecture and perceptions to sustainability and synergies and tradeoffs highlighted in the articles.

Keywords: sustainability management, climate change synergies and tradeoffs, carbon capture and sequestration.

JEL: O13, Q01, Q4, Q5, Q54

The concept of sustainability is driving actions in both corporate and public spheres and at multiple layers of society. For example, current practices in resource exploration, usage and consumption are largely believed to be unsustainable, resulting in problems such as climate change and calls for action in mitigating climate change. However, climate change is a wicked problem, where actions to

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change current unsustainable practices causing climate change, result in new, sometimes unintended, challenges. Climate change is also a multi sector problem and this special issue focuses on challenges emerging as jurisdictions attempt to move toward sustainability in the energy sector. These challenges are known to have the capacity to either slow down the drive forward sustainable practices or completely inhibit a move toward a more sustainable energy future.

The scope of this special issue offers readers a look at some emerging issues in the broad subject area of sustainable energy and climate change management from a research, policy and practical viewpoint. The papers in the special issue discuss emerging challenges to a sustainable energy future using specific case studies; they highlight the different contexts influencing these challenges and responses or actions to meet them. This special issue covers the world - including Nigeria, Mauritius, the Seychelles, Canada (the city of Saskatoon in Saskatchewan and provinces of Alberta and Saskatchewan), Sweden, and the United States (the city of Anchorage in Alaska, and States of North Dakota and Texas). The papers of this special issue consider challenges of sustainability while also discussing solutions in relation to technology, policy, and governance.

The articles discuss clean energy technologies and resources including wind, solar, hydro, geothermal energy, carbon capture and storage (CCS), and biomass. This special issue notes several obstacles to deploying these technologies, including regulatory architecture (Analyzing the Regulatory framework for Carbon Capture and Storage), and perceptions of climate change (Governance and decentralized energy transitions). Each article discussed below outlines recommendations for policies and strategies for overcoming these obstacles. For example, regional solutions for cooperation and governance are outlined by “Islands in the Energy Stream”.

To be sustainable, climate change strategies must minimize trade-offs and build on synergies. In “The Impact of climate change on the value of growing maize as a biofuel” the trade-offs of growing biomass and the impacts of climate change are illustrated. Further consideration includes impacts on food security. Future sustainability will require that multiple complex problems like these are considered.

At a time when climate change is a crisis, utilization of all tools will be required. Current fossil fuel infrastructure will require CCS in the future to meet the 2050 goals of net zero carbon. “Analyzing Regulatory Framework for CCS” makes an important contribution for reducing risk of stranded infrastructure and bridging the technological transition to net zero emissions. While policies are important, regulations set the foundation for governance of sustainability management practices. Actors that include governments, cities, multilateral organizations, and regional associations and their important role are highlighted in these articles. A summary of the articles follows.

Sally Olasogba and Les Duckers provide another African case study in “The Impact of climate change on the value of growing maize as a biofuel. As awareness about the dangers of a carbon intense global system dependent on burning fossil fuels increase, calls to replace fossil fuel energy sources with renewable ones are growing. Thus, renewable resources such as wind, hydro, geothermal, wave and tidal energies are being deployed or explored. However, since every country in the world has some capacity for biomass, this article examines the role that a changing climate could have on the growing and processing of biomass for power generation purposes. The article points out a major concern for the use of biomass being climate change itself which could adversely affect the yield of crops, such as maize which are used in biomass processes. The study used four different Nigerian agricultural zones (AEZ) growing maize and modelled future climate conditions in each while forecasting the impact that such conditions may have on the yield of maize, and by extension the potential of biomass use in Nigeria. As climate change increases, biomass yields may decrease, an important factor in considerations of power production sources in the future.

Small island developing states are the focus in “Islands in the Energy Stream: Regional cooperation to enhance carbon literacy via integrated renewable energy initiatives.” In this article, Roy Smith and Rachel Welton considers the critical need for multi-stakeholder cooperation in creating a “coherent and sustainable response” to emergencies that may result in the future due to climate change. They argue that self-contained small island developing states (SIDS) provide an interesting case for “examining the roles and agendas of the varying stakeholders that need to cooperate in order to address and sustainably manage the challenges and opportunities involved in developing and implementing integrated renewable energy policies and practices”. The article goes ahead to discuss some of the challenges in hammering out a framework for cooperation among stakeholders, but shows the role of multilateral organizations such as the Indian Ocean Commission (IOC) and the Indian Ocean Rim Association (IORA) in creating appropriate frameworks for collaborative engagement and cooperation to take place. While broadly discussing SIDS, the article focuses on Mauritius and the Seychelles.

While the advent of an electric grid in a rural community in Guatemala provided increased opportunity for earned income it also increased vulnerability due to frequent and prolonged power failures. Thus in “Evaluating the Use of Renewable Energy and Communal Governance Systems for Climate Change Adaptation.” Deborah Ley et al. highlight the need for enhanced and continuous monitoring and evaluation methods for both energy projects and their supporting institutional structures. These processes help to increase reliability. Strong bonds of trust are necessary for community resilience in emergencies and for well-being and development of community independent of energy sources. Set in the aftermath of Hurricane Stan, the study shows that accountability, mediation mechanisms and transparency tools within energy institutions can allow more open communication and equitable treatment with agents of power. While findings don’t invalidate the case for polycentric governance, they point to these circumstances that need to be met for community management of common-pool resources to be effective and sustainable.

This next paper by Martin Boucher examines the influence of different governance frameworks on decentralized energy transitions efforts in three jurisdictions: Luleå (Sweden), Saskatoon (Canada), and Anchorage (United States). Based on community case studies conclusions surrounding good governance are made in “Governance and decentralized energy transitions: a comparative case study of three medium sized cities in Sweden, Canada, and the United State.” Through a comparative analysis of these regions, the study presents five governance dimensions that impact decentralized energy transitions. Further, it explains shows that these factors provide a more contextual understanding of patterns of decentralized energy transitions in cities. Innovative decentralized energy (DE) projects are growing around the world - from solar co-ops with unique ownership structures and energy efficient and self-generating systems for low income residences. There are also integrated combined heat and power (CHP) systems that provide community district heating to ambitious wind projects in some of the harshest weather conditions. These DE cases highlight the role of cities in climate change mitigation efforts. However, having more cities engage in DE projects require a clear understanding of governance frameworks that enable it, or otherwise slow it down. Five governance dimensions were found to be important for advancing DE in cities: utility market structure, multi-sector collaboration, decision-making capacity and autonomy, multilevel governance, and public perceptions of climate change. However, the conclusion of the research was the contextual interactions between these governance dimensions, and not one single dimension that was notable. This gave rise to new research questions including whether regulated or deregulated policy communities are more facilitative of DE?, How much does city level autonomy and capacity impact DE transitions?

Many scenarios to maintain global warming below 2 degrees Celsius require combinations of new technology including carbon capture and storage (CCS). As China and India increase the number of coal power plants being built, CCS increasingly plays a role in meeting global carbon commitments made in the Paris Agreement. However, a gap in implementation exists. The article "Analyzing Regulatory Framework for Carbon Capture and Storage (CCS) Technology Development: A Case Study Approach" by Mac Osazuwa-Peters and Margot Hurlbert considers the role of regulation and policy in closing a gap needed in relation to bridging current infrastructure into a decarbonized future. The focus on CCS cost as a barrier to deployment overshadows the needs for regulatory support as a means of reducing uncertainties and de-risking CCS investments. This article maps the regulatory landscape in six jurisdictions with CCS projects, are currently developing a CCS project or have considered deploying CCS technology. The authors argue that since regulations are grand statements providing contexts for action, they define when and how to act. It is therefore important that a clear analysis of what regulatory architecture currently exist in support of CCS technology and to establish what the gaps are. This allows jurisdictions considering CCS technology to make efforts to close the gaps and avoid regulatory pitfalls that have slowed down CCS deployment over the last two decades.

In closing, while each of these articles pertains to specific research, geographies, and contexts they are united in their concern for climate change and sustainability. Lessons within each important for policy makers and actors at all levels can be found. A complex, wicked problem of climate change will require multi sectoral, jurisdictional, and scalar solutions. This special issue advances this conversation. We also added a reflection paper entitled “COVID-19 – reflections on the surprise of both an expected and unexpected event”. The current events show that threats for sustainability may appear more quickly that we tend to think.

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The Impact of Climate Change on the Value of Growing Maize as a Biofuel

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Abstract:

Aim: According to COP23 Climate Change threatens the stability of the planet's ecosystems, with a tipping point believed to be at only +2°C. With the burning of fossil fuels, held responsible for the release of much of the greenhouse gases, a sensible world- wide strategy is to replace fossil fuel energy sources with renewable ones. The renewable resources such as wind, hydro, geothermal, wave and tidal energies are found in particular geographical locations whereas almost every country is potentially able to exploit PV and biomass. This paper examines the role that changing climate could have on the growing and processing of biomass. The primary concern is that future climates could adversely affect the yield of crops, and hence the potential contribution of biomass to the strategy to combat climate change. Maize, a C_4 crop, was selected for the study because it can be processed into biogas or other biofuels. Four different Nigerian agricultural zones (AEZ) growing maize were chosen for the study. Long-term weather data was available for the four sites and this permitted the modelling of future climates.

Design / Research methods: The results of this study come from modelling future climates and applying this to crop models. This unique work, which has integrated climate change and crop modelling to forecast yield and carbon emissions, reveals how maize responds to the predicted increased temperature, change in rainfall, and the variation in weather patterns. In order to fully assess a biomass crop, the full energy cycle and carbon emissions were estimated based on energy and materials inputs involved in farm management: fertilizer application, and tillage type. For maize to support the replacement strategy mentioned above it is essential that the ratio of energy output to energy input (the Net Energy, NE) exceeds 1, but of course it should be as large as possible.

Conclusions / findings: Results demonstrate that the influence of climate change is important and in many scenarios, acts to reduce yield, but that the negative effects can be partially mitigated by careful selection of farm management practices. Yield and carbon footprint are particularly sensitive to the application rate of fertilizer across all locations whilst climate change is the causal driver for the increase in net energy and carbon footprint at most locations. Nonetheless, in order to ensure a successful strategic move towards a low carbon future, and sustainable implementation of biofuel

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policies, this study provides valuable information for the Nigerian government and policy makers on potential AEZs to cultivate maize under climate change. Further research on the carbon footprint of alternative bioenergy feedstock to assess their environmental carbon footprint and net energy is strongly suggested.

Originality / value of the article: Unlike most studies, which focus only on farm energy use and historical climate change impact, this paper uses a fully integrated framework for the assessment of the impact of climate change on growing biofuels under various farm management practices. Thus it provides calculations of the net energy available from growing biofuel crops under future climates.

Keywords: Climate change, energy efficiency, life cycle analysis (LCA), climate models, Agricultural ecological zones (AEZs), carbon footprint (CF).

JEL: Q4, Q13, Q54

1. Introduction

1.1 The problem

The concentration of greenhouse gasses in the upper atmosphere is currently over 410 ppm (as equivalent in CO_2): substantially above the pre-industrial level of 280 ppm, and rising to create global warming. A temperature increase of 2.0°C is predicted to take us through a tipping point, beyond which it may be impossible to stabilise the World's Climate. Replacing fossil fuels with renewable energy is an essential strategy to avoid reaching this tipping point and the renewable energy of concern in this paper is biofuel. Most countries can grow crops for energy.

Here we consider the question of the impact of the changing climate on the energy value of growing crops. A major question is whether future climates might reduce the crop yield, by how much, and if the crop represents a net positive contribution. For example, if the energy derived from a biofuel source is less than the energy used to plant, grow, harvest and process that biofuel then it should not be used in an energy strategy. We have taken maize in Nigeria as a sample crop, and assessed its response to climate change.

1.2 The present situation

Maize is a staple crop in Nigeria, used for food, and animal food, as a raw material for industrial products and biomass fuel (Olaniyan 2015). The world production of maize is dominated by the USA, which produces some 42%, whilst Africa as a whole produces 6.5% and must import a quarter of its needs for food and commercial applications. Nigeria currently produces 8 Mt/a or about 1% of World production (Nwaogu et al. 2016).

Over the 12 months to July 2017 maize prices in Nigeria almost doubled from US$ 274/t to US$ 502/t (FoodBusinessAfrica 2017). The exchange rate in July 2017 was £1=482, US$=365₦, making the maize crop worth about US$4b (USDA 2018). The Nigerian GDP was worth US$405b in 2016 (World Bank 2016). Thus, the maize crop is extremely important to the Nigerian economy. The price rise is blamed, but without strong evidence, on various factors: A foreign exchange ban, effectively limiting maize imports to 0.2 Mt/a and causing commercial buyers to pay higher prices for a limited local supply, macro-economic uncertainties, spot buying at the farm gate by poultry farmers, insurgency in the north east of Nigeria, infestation of army worms. Growing maize as an energy crop, by producing ethanol, is thus in competition with growing it as a raw material, or as food. In terms of maize as a biofuel feedstock, ethanol, produced from maize has an energy content of 1.2 to 1.45 times the energy input (Liska et al. 2009). This is sufficient for it to be a valuable positive energy contributor, with low CO_2 emissions.

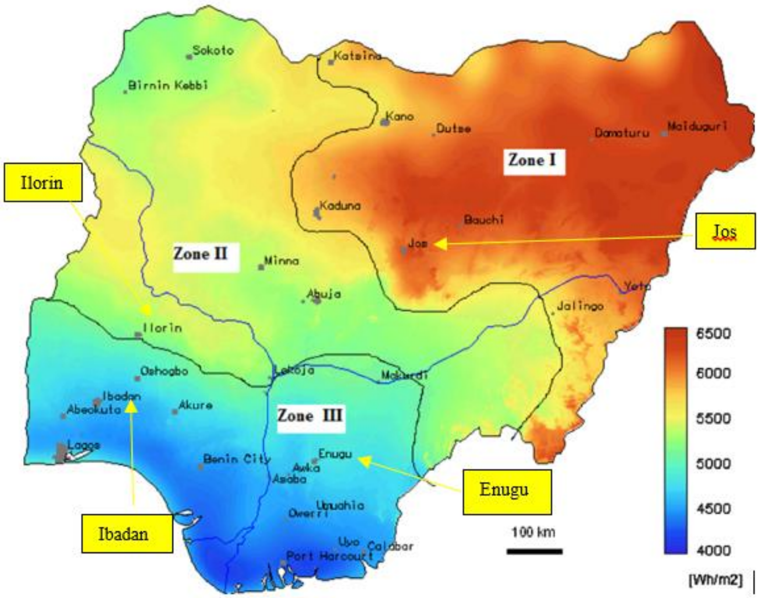
2. Modelling strategy

2.1 Modelling the likely impact of climate change on the yield of maize

Future climates are dominated by the influence of the enhanced greenhouse effect, resulting from the increased CO_2 concentration in the upper atmosphere, which traps long wavelength radiation, leading to temperature increase. The climate change, though, is not limited to a simple temperature increase, but to more chaotic weather: longer episodes of flood and drought, more storms and unsettled conditions. Sea level rise will compromise coastal regions. In terms of growing crops, we might anticipate that warmer conditions will aid crop yield, but in fact, higher temperatures can be counterproductive. Also crucial to successful crop growth is the availability of water and so episodic variations in rainfall could be a dominating damaging factor.

In order to model the crop yield under future climates, four Nigerian sites representing different agro-geographical zones were selected (see Figure 1). Historical weather data was collected for all sites, and this was used to calibrate and validate a climate model. The climate model, which consists of an ensemble of 40 GCMs, was then programmed to predict future climates under two representative scenarios: RCP 6.0 and RCP 8.5 for 2020, 2050 and 2080 timelines.

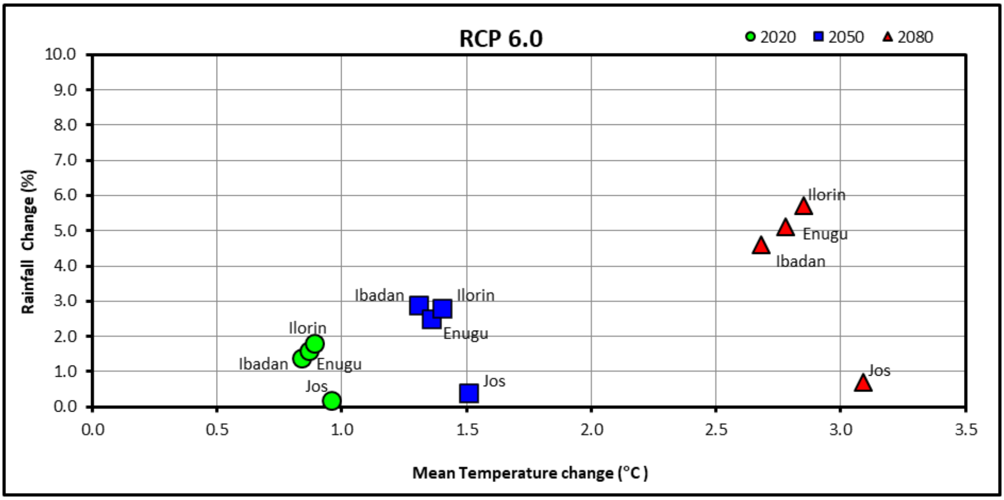
Figure 1. Solar insolation in Nigeria showing the location of the selected sites



Source: Ohunakin et al. (2014).

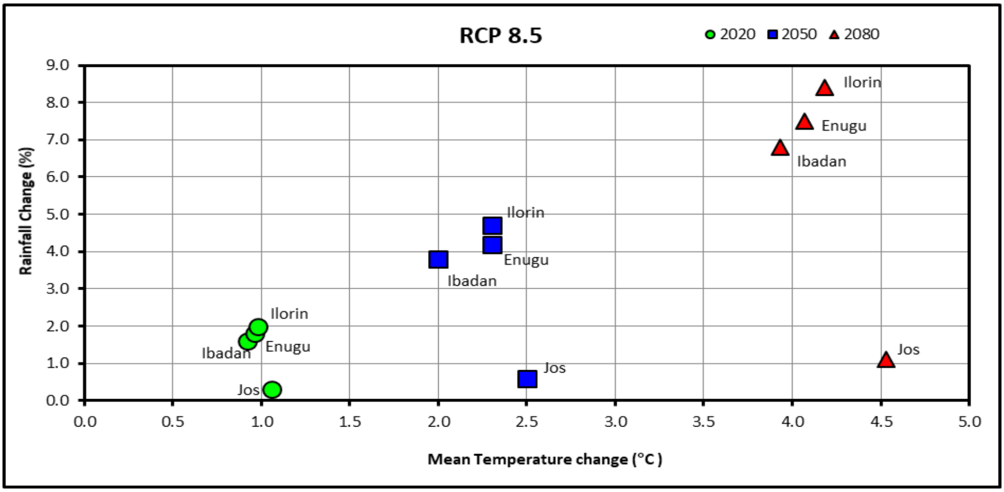
Based on the projected GCM results, which are indicative of gradual site-specific warming (see Figures 2 and 3), it is highly likely that climate change will have profound effect on maize crop productivity in the agro-ecological zones studied. Similar to Mereu et al. (2018), higher maize yield reduction in the Southern Guinea savannah of Nigeria (Ilorin) was due to a projected temperature increase of above 2°C, projected under the RCP 8.5 emission scenario especially.

Figure 2. Scatter plot used to visualise the spread of future changes in rainfall (%) and mean temperature (°C) with respect to baseline under RCP6.0 scenario. Each scenario year is colour coded (green – 2020; blue – 2050; red – 2080)



Source: Data processed by authors.

Figure 3. Scatter plot used to visualise the spread of future changes in rainfall (%) and mean temperature (°C) with respect to baseline under RCP 8.5 scenario. Each scenario year is colour coded (green – 2020; blue – 2050; red – 2080)

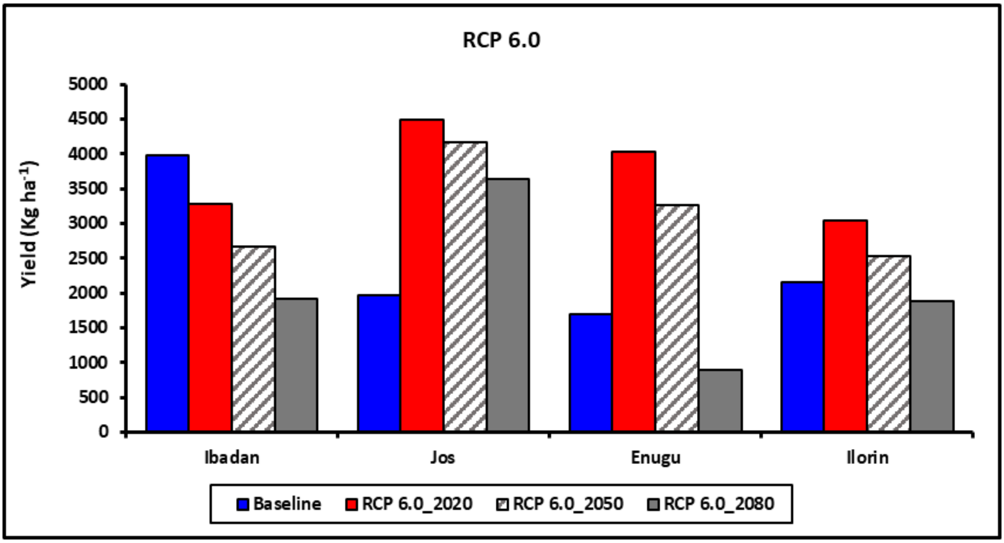


Source: Data processed by authors.

Results show that average projected temperature will increase by 2.4 °C and 3.3 °C towards the year 2080 relative to a 2010 climate baseline. Likewise, rainfall will increase slightly (±0.3 to ±8 %) across the locations studied: Ibadan, Jos, Enugu and Ilorin. Hence, adequate adaptation measures will be required to overcome the effects of these climatic changes on crop yield. Based on evidence from the latest IPCC AR5 report (2014), global warming in Africa is likely to become larger than global annual average warming (Niang et al. 2014; Hartley et al. 2015). The impact of climate change on yields of major cereal crops in sub-Saharan Africa will be negative overall, with strong regional variation in terms of the degree of reduction (Niang et al. 2014; Ezeaku et al. 2014; Parkes et al. 2018). Although different GCMs tend not to agree with predictions of the average amount of rainfall for the region, there is a consensus that the inter-annual variability of the amount of rainfall will increase (Traore 2014). According to Magugu (2016), local physiographic and atmospheric effects makes future rainfall projections less certain compared with temperature projections.

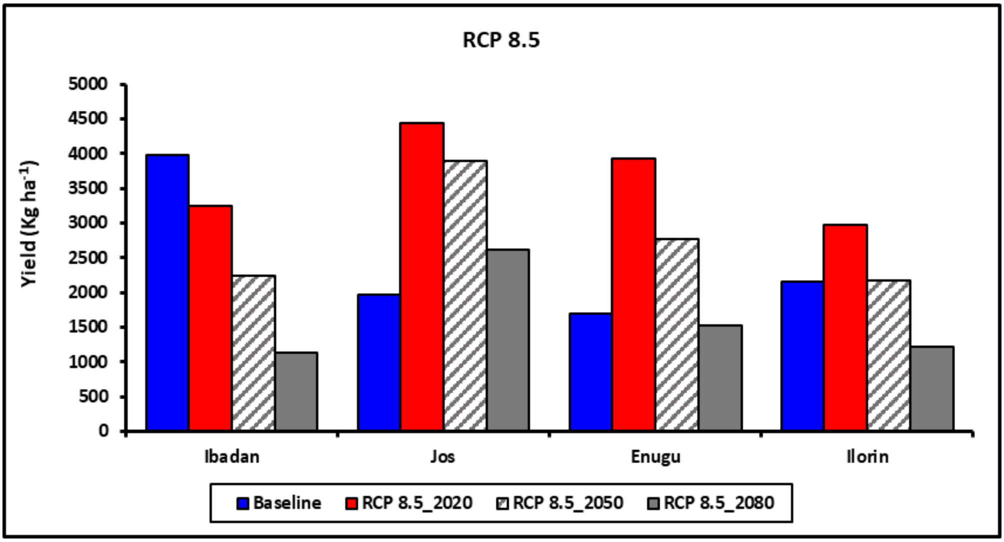
Climate change impact on maize yield varied across locations within the Derived savannah and Southern Guinea savannah AEZs. Maize yield increased in Jos, Enugu and Ilorin for both projected scenarios (RCP 6.0 and 8.5) and declined as the timeline shifted from 2020 to 2050, further declining below baseline levels by 2080. Climate change reduced yield under all scenarios in Ibadan compared to baseline yield (see Figures 4 and 5). The general decline in maize yield from year 2020 to 2080 suggests a greater negative influence due to warmer climate. This result is consistent with the projections of Corbeels et al. (2018) who found average maize yield would significantly decline in Southern Africa under the RCP 8.5 scenario. Increase in maize yield variability in response to climate change was positive for all location, which according to Parkes et al. (2018) represents a risk of crop failure and loss especially for northern and southern Nigeria.

Figure 4. Chart of simulated maize yield output for baseline and RCP 6.0 scenarios for the period 2020–2080 at four study sites



Source: Data processed by authors.

Figure 5. Chart of simulated maize yield output for baseline and RCP 8.5 scenarios for the period 2020–2080 at four study sites



Source: Data processed by authors.

Optimal fertiliser application is an adaptation strategy in the event of climate change impact on crop yield (Nasim et al. 2016; Mahama, Maharjan 2017). Maize yield response to varying nitrogen fertiliser rates (from 80 kg N ha^{-1} to 250 kg N ha^{-1}) was evaluated. The optimal application rate was 160 kg N ha^{-1} with the exception of one location (Jos) in the Southern Guinea savannah AEZ which required higher application rates (200 kg N ha^{-1} to 250 kg N ha^{-1}) to obtain maximum yield under both climate scenarios. Further evaluation of different maize genotypes is required to determine yield response to optimal fertiliser rates as suggested in this study under climate change.

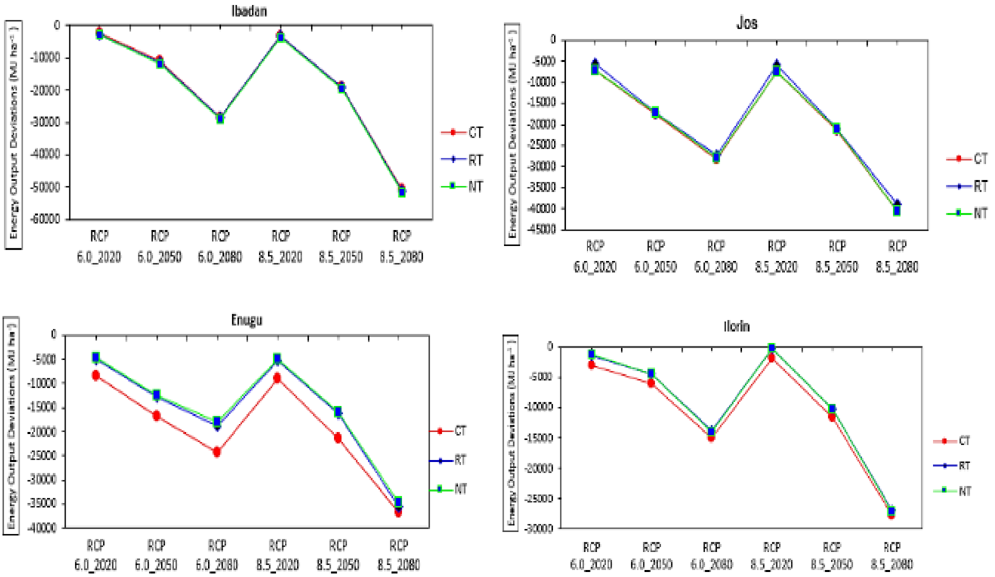
2.2 Evaluation of maize as a future biofuel feedstock

The environmental impact assessment of a farming system using the LCA framework is very common. This is because its holistic approach makes it possible to identify hot spots for environmental pollution, but also to avoid pollution trade-offs across the life-cycle stages (Bessou et al. 2013). This study applied a streamlined LCA method that focused specifically on a maize production system within the biofuel production network.

Energy use in maize production was estimated by varying both farm management practices and equipment energy input. Results show that climate change affected all energy indicators used to assess the efficiency of maize production but by varying degrees for each location studied, and dependent on the tillage method (CT, RT, NT) and fertiliser application rate (80 kg N ha^{-1}, 160 kg N ha^{-1}, 200 kg N ha^{-1}, 250 kg N ha^{-1}) adopted. Increasing fertiliser rates increased total energy input with a consequent reduction in energy use efficiency. The direct environmental effects as a result of the release of CO_2 and other GHG emissions, as well as the excessive use of natural resources are global concerns that must be addressed through efficient use of material inputs. A higher proportion of input energy was attributed to nitrogen fertiliser and diesel fuel in all 12 management scenarios, with averages of 71% and 14% respectively. The NT tillage system and a low fertiliser input of 80 kg N ha^{-1} (160 kg N ha^{-1} for maximum yield output) show a potential to reduce total energy input by a significant amount and could translate to reduced operational costs for farmers. These combinations should seriously be considered for future maize cultivation systems.

Energy output (MJ ha^{-1}) was positive for all climate change scenarios, which represents energy gain for maize produced. However, when compared to the baseline, energy gained reduced as climate change progressed to the year 2080 across all four AEZs, despite the application of a higher amount (250 kg N ha^{-1}) of synthetic nitrogen fertiliser (see Figure 6). The effect of using different tillage practices under future climate scenarios did not improve the overall energy output. The lowest energy use efficiency was predicted for the year 2080 under RCP 8.5 scenario but the efficiency improved across all scenarios by reducing soil tillage practices (NT tillage system). The system net energy value (NE) was positive which represents energy gain for all sites but the values reduced under climate change scenarios. Higher NE gain was obtained by adopting the NT method at Jos, Ilorin and Enugu but the CT tillage system was more beneficial at Ibadan.

Figure 6. Energy output (MJ ha^{-1}) deviations of RCP 6.0 and 8.5 scenarios from baseline at Ibadan, Jos, Ilorin and Enugu sites. Results are based on 250 kg N ha^{-1} rate. CT- (Conventional tillage); RT – (Reduced tillage); NT – (No tillage)

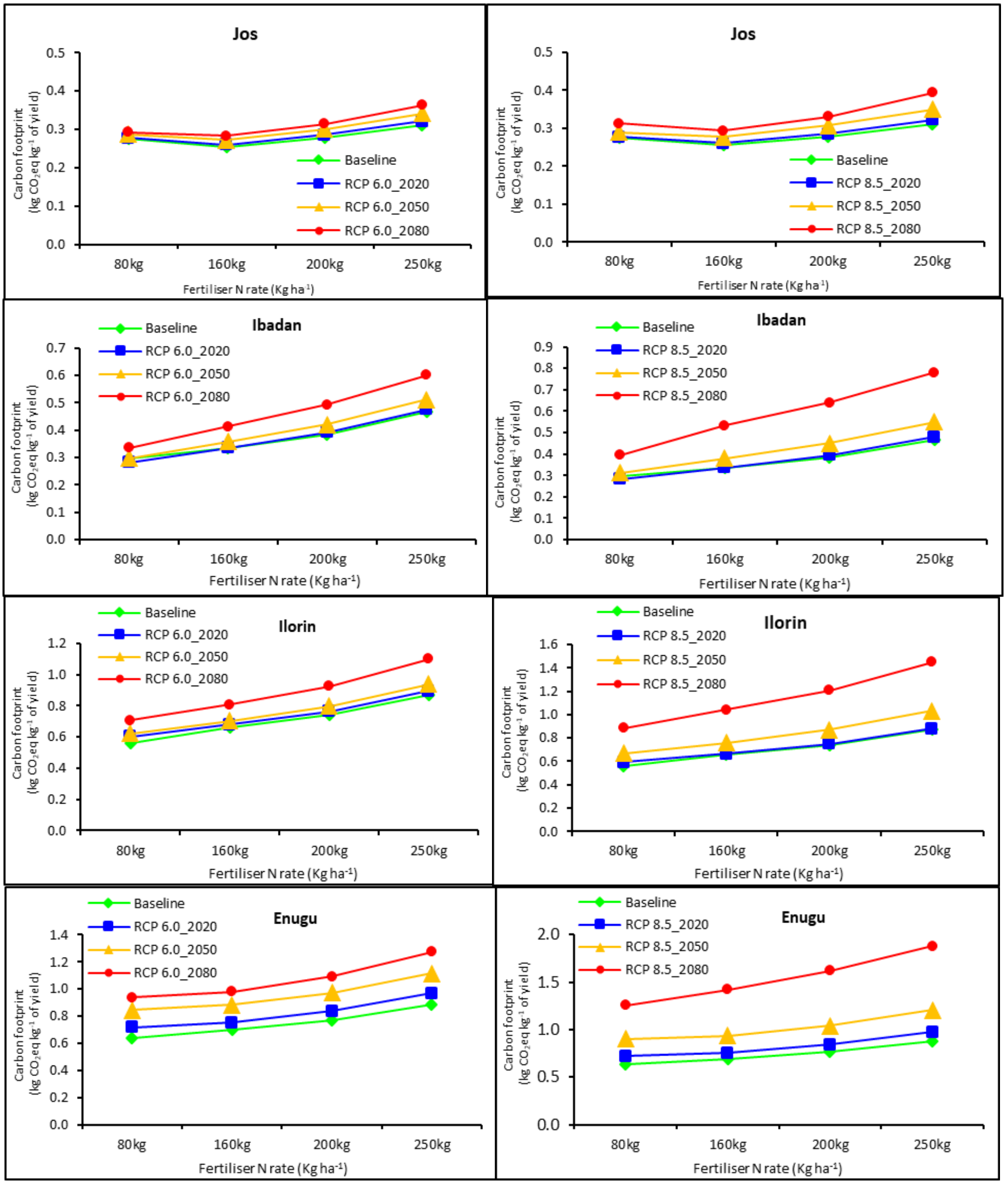


Source: Data processed by authors.

The LCA result shows the estimated emissions from soil due to fertiliser application adversely influenced the total GHG emissions, and carbon footprint increased per kg of maize produced. On average, total GHG emissions under farm management scenarios (fertiliser rate x tillage methods) was 2,931.4 kg CO_2eq ha^{-1}. These findings align with those of Ma et al. (2012) who reported a similar GHG emission range from a maize farm experiment based on three rotation systems. Direct and indirect soil N_2O emissions associated with the application of urea fertiliser were the main emitters (53.4%) followed by GHG emissions from the production of farm input materials (37.8%). Within this category, CO_2 emissions from fertiliser production was the highest. CO_2 emissions from field machinery operation and from urea application (emission due to soil hydrolysis) contributed small shares to the total GHG emission (4.4% and 4.3%). The impact of N fertiliser is therefore significant and underlines the importance of efficient N management. Studies have suggested that in addition to the split fertiliser method adopted in the simulation of crop yield, the use of enhanced efficiency fertilisers (EEFs) should also be utilised to maximise N-use efficiency and the reduction of N_2O emissions (Uchida, Rein 2018; Chen et al. 2018).

The carbon footprint (CF) per kg of maize grain produced was estimated based on the total GHG emissions from input production, field operation, soil emission, and the localised climate change impact on yield under farm management scenarios (see Figure 7). CF increased between 2020 and 2080 under both RCP 6.0 and 8.5 climate scenarios. The highest CF was associated climatically with the highest temperature increase scenario (RCP 8.5) in 2080, irrespective of the fertiliser rate or tillage system. This reflects the impact of harsher climate change on crop productivity compared to baseline. It indicates that generally, as grain yield declines under climate change, CF per kg of maize grain increases as expected, although with some exceptions. As an example, when considering CF response to fertiliser rates, results show that irrespective of the climate scenario, CF as well as yield increased as the amount of fertiliser increased. This was due to the higher GHG emissions (soil emissions) from higher fertiliser rate. Therefore, it did not matter if yield increased at any location, essentially, higher fertiliser rates affected CF per kg of maize grain produced (Qi et al. 2018).

Figure 7. Carbon footprint (kg CO_2eq kg^{-1} yield) of maize grain production under baseline and two RCP climate scenarios: Jos (a) RCP 6.0 and (b) RCP 8.5; Ibadan (c) RCP 6.0 and (d) RCP 8.5



Source: Data processed by authors.

3. Concluding remarks

Climate change will affect the yield of maize: but the impact may be positive in some locations and scenarios and negative in others. The variation in temperature, precipitation, and increasingly chaotic weather makes it difficult to predict the value of a particular crop. When the Net Energy approaches 1.0 the environmental cost of maize as a biofuel feedstock is just equal to the energy derived from it; meaning that when NE is less than 1.0 that maize becomes a negative energy source. Of course maize can also be used as a food, or commercial raw material, in which cases the energy balance is not necessarily applicable. Despite the huge potential for maize cultivation for biofuels, this may not be viable environmentally when climate change is factored in. Nonetheless, in order to ensure a successful strategic move towards a low carbon future, and sustainable implementation of biofuel policies, this study provides valuable information for the Nigerian government and policy makers on potential AEZs to cultivate maize under climate change. However, the approach used in this paper can be applied to all crops, for energy, food or raw material, and the technique used here will inform the policy on choice of crop type.

Abbreviations

GCM – Global Climate Model
RCP6.0 – Representative Concentration Pathway 6.0
RCP8.5 – Representative Concentration Pathway 8.5
CT – Conventional Tillage
RT – Reduced Tillage
NT – No Tillage
NE – Net Energy

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Islands in the energy stream: regional cooperation in the Indian Ocean tourism sector

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Abstract:

Aim: This article considers the need to move away from a dependency on fossil fuels towards more sustainable renewable sources of energy production. The focus is on the tourism sector in two Indian Ocean destinations, Mauritius and the Seychelles. The broader aim, however, is to highlight the interconnectedness between public and private stakeholders and how lessons learned from these case studies could have broader applicability elsewhere.

Design/research methods: A case study approach has been taken drawing on data supplied by both the private tourism sector in the destinations under consideration and relevant government and regional reports.

Conclusions/findings: Progress has been made in the shift towards decarbonisation policies and practices in these destinations. This has been achieved via a cooperative approach between public and private stakeholders, extending the development of renewable energy infrastructure and supply to include sustainable education policies supported by both governments' education departments and vocational programmes implemented by the larger hotels in these destinations.

Originality/value of the article: Although there have been other studies conducted on the promotion of renewable energy in small island states, there is a paucity of such research looking specifically at the tourism sector and the role of public/private partnerships in developing broader education for sustainable development programmes.

Implications: The case studies focus on highlighting how governments and tourism businesses can work towards shared goals, in this case decarbonisation and education for sustainability. The implication is that such a model could be applied elsewhere with equally positive results.

Key words: Sustainable development, tourism, energy security

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1. Introduction

The intersecting nexus between current mainstream, fossil fuel-based energy production, subsequent climate change impacts and the need to manage sustainable patterns of production and consumption are the most pressing issues in contemporary domestic and international politics (McKendry 2002). The Intergovernmental Panel on Climate Change (IPCC) has repeatedly warned of the need for a shift towards more renewable energy sources to avoid excessive global warming and the catastrophic impacts this is likely to have due to increasing and more extreme weather events (IPCC 2011). Groups such as Extinction Rebellion are raising the profile of this issue through direct action events and there is a clear sense that this message is resonating with a growing number of city authorities and political parties calling for national climate emergencies to be declared (Shah 2019). A precise definition of what such an emergency entails and exactly how to respond remains rather vague. That said, there can no longer be any doubt that significant changes are required to both mitigate against further climate-related risks and to adapt to those environmental challenges that are already occurring (Oreskes 2004; IPCC 2007).

In the so-called age of the Anthropocene, where future changes on a global scale are largely being driven by human activity, there is a requirement to recognize the scale and complex nature of multiple climate emergencies (Hughes et al. 2017). It is also important to be aware that to manage a coherent and sustainable response to these emergencies it is necessary to involve multiple stakeholders from cooperation between regional governments, through to including private sector initiatives and civil society groups down to the level of individual households or businesses (Pinkse, Kolk 2012). Everyone requires energy in some form or another. Not only for immediate household power consumption but also for the production and maintenance of everyday goods and services that are central aspects of modern life. How such energy is produced and consumed varies considerably, both in nature and scale (Asif, Muneer 2007). To make sense of this on a global scale is almost impossible with so many actors and other variables in play. For this task to be more manageable it is useful to focus on relatively small, self-contained territories such as small island states. While they are connected to global processes of climate change, in many cases they are among the communities most vulnerable to these risks. They can provide insightful coherent case studies for examining the roles and agendas of the varying stakeholders that need to cooperate in order to address and sustainably manage the challenges and opportunities involved in developing and implementing integrated renewable energy policies and practices.

This article considers energy security issues in the Southwest Indian Ocean, focussing on Mauritius and the Seychelles. Both small island developing states (SIDS) have tourism sectors that are key aspects of their national economies, which currently rely heavily on imported fossil fuels. They are also members of the Indian Ocean Commission (IOC) and the Indian Ocean Rim Association (IORA). These bodies provide institutional frameworks for their members to cooperate in addressing shared challenges. In May 2018 the IOC convened the first Regional Renewable Energy Forum for the Indian Ocean, held in Mauritius (IRENA 2019) In some respects, it is surprising that this event had not happened sooner, given that energy security in SIDS has long been recognised as an issue (Wolf et al. 2016). Both Caribbean and Pacific SIDS appear to be more advanced in discussing and tackling these issues in their respective regional institutions. Here we briefly outline the global drive towards tackling energy security issues, including regional initiatives, and then focus on Mauritius and the Seychelles in terms of relevant stakeholders and the drivers and possible blockers to achieving sustainable energy security.

The United Nations Sustainable Development Goals include SDG 7, which aims to ‘ensure access to affordable, reliable, sustainable and modern energy for all’ (UNDP 2019). Despite some sporadic, residual climate change denial, most the world’s climate scientists and policymakers now recognise that environmental damage is caused by anthropogenic greenhouse gas emissions (Zeebe 2013). The State of the Climate report 2018, produced by the World Meteorological Organization revealed that more than 90 per cent of the energy trapped by greenhouse gases goes into the oceans and whilst not wholly attributable to the burning of fossil fuels, this is a leading cause of air pollution and the acidification of the oceans as the CO_2 is absorbed. The Conference of the Parties to the International

Convention on Climate Change meets on a regular basis, COP21 was held in Paris in December 2015. This led to a historic agreement where 195 countries adopted the first ever legally binding global climate deal (Robbins 2016). Not all these countries subsequently ratified this agreement, notably the Trump administration of the United States. However, this agreement did demonstrate a higher level of political commitment to seriously addressing the issue of climate change than had previously been the case. SIDS have been at the forefront of calling for meaningful action to address these issues as some of the communities most at risk from climate change and sea-level rise.

The UN Conference on Sustainable Development in SIDS was held in the Caribbean in 1994. This led to the Barbados Action Plan, which is a fourteen-point programme that identified both energy resources and tourism resources as priority areas (United Nations 2008). The Caribbean Community (CARICOM 2019a) Secretariat launched an Energy Programme in 2008 within its Directorate of Trade and Economic Integration (CARICOM 2019b). Other sectors of regional government concern have also been addressed in a similar manner, but this indicates both an awareness of the significance of energy security issues and also recognition of the need to adopt a collaborative regional approach to tackling these issues. In the Pacific region there are two key regional organisations, the Pacific Islands Forum (PIF) and the Secretariat of the Pacific Community (SPC). In 2014 a meeting of Pacific Ministers of Energy and Transport endorsed the establishment of the Pacific Centre for Renewable Energy and Energy Efficiency based in Tonga. PCREEE is a multi-stakeholder partnership between Pacific Island governments, the UN Industrial Development Organization (UNIDO), the SIDS Sustainable Energy and Climate Resilience Initiative and the Austrian Development Agency (ADA) (PCREEE 2019). This is a good example of how SIDS work, not only with each other, but also with major inter-governmental agencies and donor partners, who are sometimes based well outside of the region in question.

International collaboration on renewable energy has a long history with a milestone event taking place in 1981 with the proposal for the creation of an International Renewable Energy Agency (IRENA). Despite general support for this proposal from the majority of the world’s governments the founding conference of

IRENA did not take place until 2009 in Bonn. This provides some insight into how complex and longwinded intergovernmental negotiations can be, even when there is broad agreement on the need for action. More positively, once established, IRENA has been very active in relation to the promoting of renewable energy production, including in SIDS. Launched in 2014 IRENA's SIDS Lighthouses Initiative has a target of 2020 to: 1) Ensure all participating islands develop renewable energy roadmaps, 2) Mobilise $US 500 million and 3) Deploy 120 megawatts of renewable energy capacity. Both Mauritius and the Seychelles are part of this initiative. According to a 2015 Quickscan analysis conducted by IRENA Mauritius is more advanced than the Seychelles in its transition from reliance on fossil fuels to renewable energy sources (IRENA 2019).

IRENA's analysis is based on seven categories of indicators: 1) Institutional Framework; 2) Knowledge Base; 3) Planning; 4) Financing; 5) Deployment; 6) Capacity Building and 7) Cooperation. Given that Mauritius and the Seychelles are roughly comparable in many ways regarding energy security and have both engaged in regional energy security initiatives it is surprising that they are making differing rates of progress. There are some notable differences with Mauritius importing 52% of their commercial energy in the form of petroleum, compared to a significantly higher figure of 95% for the Seychelles (Hadush, Bhagwat 2019). Arguably this should provide an even greater incentive to the Seychelles to address this issue. Having a national regulatory body for the energy sector is a fundamental aspect of monitoring and advancing the energy security agenda. Given the relative advantage Mauritius appears to have over the Seychelles, according to the IRENA analysis, it is also surprising to discover that the Seychelles established its Seychelles Energy Commission in 2009, whereas the equivalent Mauritian Utility Regulatory Authority was not established until 2016 (IRENA 2019).

The issue of regulation is important as it is central to developing a coherent national action plan and to ensure that governments have the necessary oversight and power to intervene and guide the energy sector towards the desired transition from fossil fuel dependency to more sustainable sources of renewable energy. In terms of a theoretical approach, such regulatory bodies can be viewed from a neo-Functionalist perspective adopting the adage of 'form follows function'. This is an approach developed by Ernst Haas and David Mitrany, initially in relation to the formation of what was to eventually become the European Union (Haas 1968). However, it can be applied equally well to CARICOM, PIF, SPC, IORA or the IOC. Notably one of the most significant outcomes of the IOC's Regional Renewable Energy Forum was the creation of the Association of Energy Regulators Indian Ocean. This body is intended to both ensure that all the IOC member states have regulatory bodies overseeing the energy sector and that they are collaborating in line with a common agenda. Importantly this body will also need to collaborate with other relevant state agencies dealing with economic development and environmental protection. Such collaborative efforts will also overlap with intergovernmental bodies, relevant non-governmental organisations and the private sector. Regarding the latter, the tourism sector is a major consumer of energy and, therefore, crucial to engage with in order to promote and facilitate the transition to a low-carbon economy.

This paper aims to examine the transition of two island states in the Indian Ocean to adopt more renewable energy sources and reduce their dependency on fossil fuels, within the context of the climate crisis. Mauritius and the Seychelles are both dependent upon fossil fuel reliant tourism for economic growth. On the one hand the public sector has natural resources that can provide energy and yet the infrastructure required to produce and supply renewables is often financially prohibitive. For the private sector energy issues focus tends to be energy efficiency, sustainability and cost reduction. These issues are explored initially by reviewing the energy requirements of the tourism sector and the greenhouse gases generated through transport and accommodation in tourism. This is followed by a review of the energy policies and ensuing tourism policies and how these are addressed through tourism education in Mauritius and the Seychelles. Finally, the interconnectedness between public and private stakeholders is examined with key points highlighted to provide broader applicability for islands.

2. Tourism and energy

In most island states tourism is the major economic sector and provides potential to generate foreign exchange earnings, increase foreign investments and through this reap the benefits of increased tax revenues, create new jobs and promote the nation in the global arena. As outlined by United Nations World Tourism Organization (UNWTO 2012), tourism represents a unique opportunity because it is less subject to, and can actually benefit from factors that are barriers to other forms of economic growth: small and dispersed populations, small land areas, remoteness from markets, and limited natural resources.

Within the Indian Ocean region there are some success stories as tourism has directly benefited the economies of both the Seychelles and Mauritius over the last decade and some key lessons can be learnt from their experiences. Mauritius has increased tourism arrivals at a phenomenal rate. In 1995 there were 315,000 international tourism arrivals and tourism receipts were US$211 million. In 2014 tourism arrivals exceeded 1.2 million (380% increase) and tourism receipts had grown to US$2,645 (Ministry of Tourism 2014). In 1995 the Seychelles had 120,716 tourist arrivals and this had increased to 231,857 in 2014 (92% increase) (NBS 2018). Both Mauritius and Seychelles experienced economic challenges and have had to adjust the generating region of the tourist arrivals (China for Mauritius and India, South Africa & Russia for the Seychelles) to ensure a constant supply of international tourists with foreign exchange is maintained. Mauritius has experienced less instability in the economy and has also used a trade policy to protect the domestic industries of sugar, export processing zones (EPZs) and tourism was used to underpin this economic growth.

International tourist arrivals have increased from 25 million globally in 1950 to 278 million and exceeded 1 billion in 2015. Likewise, international tourism receipts earned by destinations worldwide have surged from US$ 2 billion in 1950 to US$ 1,220 billion in 2016 (UNWTO 2017). The Indian Ocean islands of the Seychelles and Mauritius have both seen substantial growth in this sector of their economies. UNWTO (2017) states, international tourist arrivals in Africa increased by an estimated 8% in 2016 according to the comparatively limited data available to date, representing a strong rebound after a weaker performance in 2014 and 2015 in the wake of various health, geopolitical and economic challenges. The region welcomed 58 million international tourists in 2016 (5% of the world total), 4 million more than in 2015, earning US$ 35 billion in international tourism receipts (3% share), an increase of 8% in real terms. Sub-Saharan Africa (+10%) had the highest increase across all world sub regions. South Africa, the sub region's top destination, enjoyed 13% growth in international arrivals, partly thanks to simpler visa procedures. Kenya (+17%) and Tanzania (+16%) also boasted double digit growth in 2016, rebounding from weaker figures in 2015. Island destinations Madagascar (+20%), Cabo Verde (+15%), Mauritius (+11%) and the Seychelles (+10%) also posted double-digit growth.

3. Greenhouse gas emissions from tourism

The growth in tourism arrivals means that there are increases in energy requirements within the tourism industry. Tourism-related energy use and associated emissions of GHGs can be organized into three subsectors: transport to and from the destination, accommodation and activities (see UNWTO, UNEP, WMO 2008). Within this the transport sector, including air, car and rail, generates the largest proportion, with 75% of all emissions. The accommodation sector accounts for approximately 20% of emissions from tourism. This involves heating, air-conditioning and the maintenance of bars, restaurants, pools and so on. Clearly, this varies according to the location size and type of the accommodation. Finally, activities such as diving, museums, theme parks, events or shopping also contribute to certain amounts of emissions (approx. 3.5%) (UNWTO 2007). The current trends show that there is an increase in air travel over surface travel. In 2016, slightly over half of all overnight visitors travelled to their destination by air (55%), while the remainder travelled by surface transport (45%) – whether by road (39%), rail (2%) or water (4%). The trend over time has been for air transport to grow at a somewhat faster pace than surface transport, thus the share of air transport is gradually increasing (UNWTO 2017)

A recent UNWTO report (2018) reviewing tourism as a developmental tool established many positive prospects for destinations identifies that tourism produces profound and wide-ranging impacts across all dimensions of sustainable development. It also highlights that challenges persist such as tourism's susceptibility to market influences; over-dependence on tourism; issues of overcrowding; concerns over working conditions; emissions and pollution; potential adverse effects on biodiversity, heritage and communities; and a lack of comprehensive data on tourism's impacts on all aspects of sustainability.

Tourism is a significant contributor to greenhouse gas emissions (GHG). There are different views on the extent to which tourism contributes. The UNWTO (2008) states an estimated 5.2% – 12.5% of CO_2 emissions, the lower estimate does not take into account the radiative forcing of all greenhouse gasses (the range is attributed to the uncertainty in the role of aviation induced cirrus clouds in trapping heat) (UNWTO 2008). A more recent study, in "Nature Climate Change", estimates that global tourism, including transportation, accommodations, activities, food consumption, and all the energy and infrastructure required to accommodate visitors accounts of 8% of global emissions worldwide (Lenzen 2018). This is a considerable increase in the estimates used from the UNWTO on which the climate change reduction targets are based.

The continued growth of the tourism industry over the last six decades demonstrates that as the industry expands and diversifies to respond to shocks and takes advantage of new opportunities through the development of many new tourism destinations. The UNWTO produced a 'Business as Usual' scenario that considered increases in demand and mitigation initiatives the industry could keep within the IPCC recommendations of the 2 degrees (UNWTO 2008). However, it seems likely that the IPCC will be reducing the temperature increase target to 1.5 degrees (IPCC 2018). This is more in line with recommendations from over a hundred Small Island Developing States, Least Developed Countries and many others who have been calling for limiting global temperature rise to below 1.5°C above pre-industrial levels (Climate Analytics 2018). Thus if there continues to be the rate of growth that the UNWTO are forecasting and the IPCC reduce the target to 1.5 degrees the tourism industry would be out of kilter with the target and this could lead to a stronger public focus upon tourism strategies and policies with some uncomfortable questions for the industry to answer.

The Mauritius and Seychelles governments have both engaged with the United Nations Framework Convention on Climate Change and related negotiations to reduce greenhouse gas emissions. Notably both are signatories to the Paris Agreement, which entered into force on 4th November 2016. The Agreement commits both states to work towards keeping the increase in global average temperature well below 2°C above pre-industrial levels and to limit the increase to 1.5°C. Clearly, there is only so much individual governments can achieve, especially when they are not among the leading polluters. The international reporting of the CoP21 meeting tended to focus on aggregate global figures and targets. Whilst these are important, it is what is being legislated for and implemented at the national level that is more meaningful. Seychelles' Minister for the Environment, Didier Dogley, described the Paris meeting as a turning point in these negotiations and highlighted the need to address the extreme weather events that were negatively affecting Seychelles and other SIDS (Seychelles News Agency 2016). The Mauritian delegation to the signing of this Agreement echoed these sentiments. However, closer examination of the two states national planning towards sustainable development and converting to lower carbon economies show differing approaches. Both are working towards the same goals, but when comparing the Intended Nationally Determined Contribution (INDC) submissions to the Paris meeting there are some notable differences in terms of how each government lays out its approach, the level of coordination between Ministries and reference to partnerships with relevant stakeholders.

The INDC for Mauritius is notable in that it omits any direct reference to the tourism sector. Arguably this is implied but, given the importance of this sector to the Mauritian economy, it is surprising that it is not highlighted more explicitly. There are several references to a proposed transition to more renewable energy sources. Under a section on 'Mitigation contributions' there is reference to a proposed expansion of solar, wind and biomass energy production. Under 'Adaptation Measures' the sectors listed are 'Infrastructure; Disaster Risk Reduction

Strategy; Coastal Zone Management; Rainwater Harvesting; Desalination; Integrated Pest and Disease Management; Efficient Irrigation Techniques Development; Climate Smart Fisheries; Improve Marine and Terrestrial Biodiversity Resilience; Health Sector and Transportation'. Again, given the scope of the measures listed here, the tourism sector is noticeably absent from this list. In terms of means of implementation the government's focal point is its Ministry of Environment, Sustainable Development and Disaster and Beach Management (MOESDDBM). This does show a degree of cross-sector thinking and administration in dealing with these interconnected issues, but is also indicative of SIDS governments more generally where the limitations of the public sector means that Ministers often have responsibility for several portfolios.

In comparison the Seychelles INDC appears more comprehensive and makes numerous references to the centrality of the tourism sector in relation to energy usage and the consequences for climate change adaptation. In terms of governance the Seychelles has a designated Department of Energy and Climate Change (DECC) within its Ministry of Environment and Energy and Climate Change. The INDC lists a number of sectors with identifiable 'vulnerabilities'. These are 'Critical Infrastructure; Tourism; Food Security; Biodiversity; Water Security; Energy Security; Health and Waste'. Under the Adaptation section of this submission it is reported that 'The key economic sector is tourism and this sector requires nimble, adaptive responses, particularly where its success is predicated on proximity to the coastal and island areas. Tourism tends naturally to adapt to market forces and the suitability of the tourism offering for the future will need not only to recognise market pressures but also those driven by climate change' (Republic of Seychelles 2015). This is a far more explicit acknowledgement of the centrality of the tourism sector, and how it is impacted by climate change, than that presented by Mauritius. The Seychelles also have a more inclusive 'vision' which is to 'minimise impacts of climate change through sustained action at all levels of society' (Republic of Seychelles 2015). There are several components to this vision with, again, an explicit reference to the importance of the tourism sector. This goes further than simply recognising that tourism is a major source of income generation for the economy. As part of this vision there is a call for 'Training in climate change for hoteliers and the tourism students at the Seychelles Tourism Academy'. It is not made clear exactly what this training would involve but it is significant that this is something that is being acknowledged as necessary and resources are being committed to this training. It also demonstrates the need for governments to engage with the private sector to invest in sustainable adaptation policies and practices.

4. Energy policy in Mauritius

In 2007, the Mauritian government adopted an *Energy Policy 2007–2025. Towards a Coherent Energy Policy for the Development of the Energy Sector in Mauritius* (Republic of Mauritius 2009). The policy was developed with a consultative multi stakeholder perspective and recognises the importance of energy in the context of economic development and environmental sustainability. The key aim of the policy is to diversify the country's energy supply, improve energy efficiency, address environmental and climate changes and modernise the energy infrastructure in order to meet the challenges ahead. It recognised the issues of security of supply, affordability and the rapid shift to a low carbon, efficient and environmentally benign system of energy supply. A high barrier to effective implementation is identified as changing the habits of decision-makers who influence policy and it places great importance on the collaboration and participation of the private sector and other stakeholders.

As far as increasing renewable energy the Mauritian government is encouraging greater use of renewable and clean energy to reduce the country's dependence on fossil fuels and decrease greenhouse gas emissions. The aim is to increase the use of renewable sources of energy from the current 22% to 35% by 2025, through wind farms, solar energy, biomass and waste-to-energy projects. Progress towards this is difficult to assess as renewable energy has a capacity that is only obtainable in ideal conditions (solar is less efficient on hazy days), hence it is better to use country comparators to assess the potential impact. Given this, forecasts (CIA 2018) suggest that Mauritius could produce 14 % of total installed electricity capacity came from renewable sources.

Table 1. Mauritius production capacities per energy source

Energy source	total in Mauritius	percentage in Mauritius	percentage in Europe	per capita in Mauritius	per capita in Europe
Fossil fuels	6.19 bn kWh	79.0 %	49.2 %	4,892.28 kWh	8,120.79 kWh
Nuclear power	0.00 kWh	0.0 %	7.0 %	0.00 kWh	1,155.06 kWh
Water power	548.20 m kWh	7.0 %	24.1 %	433.49 kWh	3,979.85 kWh
Renewable energy	1.10 bn kWh	14.0 %	19.7 %	866.99 kWh	3,276.60 kWh
Total production capacity	7.83 bn kWh	100.0 %	100.0 %	6,192.76 kWh	16,500.88 kWh

Source: World Bank (2018a).

According to the World Bank data Mauritius can provide itself completely with self-produced energy. The total production of all electric energy producing facilities is 3 bn kWh per year (per capita this is an average of **2,156) which** is 107% of own requirements.

5. Energy and the tourism sector in Mauritius

The tourism sector is identified within the Mauritius Energy Policy 2007- 2025 (Republic of Mauritius 2009). Recognition is given to the economic benefits that tourism supplies and a target of 1.5 million tourists. This, coupled with the identification of higher fuel prices and a growing awareness of the negative environmental impacts of long-distance air travel, could reduce the number of tourists travelling to Mauritius. There is awareness of the competitiveness of the tourism market and an aspirational objective to promote zero-carbon-footprint holidays. Recognition is provided that energy efficiency and renewable energy solutions are a necessity to host additional tourists. The key strategies identified to support the tourism sector are:

- retrofitting of existing hotels with the latest energy efficient technologies and mandatory sustainable building design for new hotels
- mandatory use of solar hot water systems in hotels as far as practicable
- introduction of low-energy lighting/appliances/air-conditioning and cooling devices throughout the hotel industry
- promotion of low-energy and eco-friendly airport transfer policies
- encouraging hotels to provide facilities on optional basis to allow tourists to offset the carbon impact of their flights by investing in sustainable energy schemes in Mauritius
- incentive schemes to promote and develop an eco-friendly tourism industry.

6. Energy policy in Seychelles

The Seychelles energy policy was ratified slightly later than the Mauritian one, in 2010. The policy covers an ambitious 20 years and has a sustainable focus, emphasising energy efficiency, renewable energy and reducing the dependence on oil to improve energy security. The key aim is to diversify the energy supply, a 5% and 15% share of renewable energy is targeted for 2020 and 2030 respectively (Republic of Seychelles 2009). The Seychellois government intend to concentrate on four renewable technologies as they are deemed more appropriate in the country: solar PV, wind, micro-hydro, and biomass/municipal solid waste (Seychelles Energy Commission 2014).

Seychelles has a higher reliance than Mauritius (91%) compared to (79%) on imported fuels. Various petroleum fuels are imported every year, of which gas oil, fuel Oil and Jet A1 represent 94% by mass of imports. The Seychelles can provide themselves completely with self-produced energy. The total production of all electric energy-producing facilities is 325.5 m kWh (per capita this is an average **of** 3,396 kWh) 108% of own requirements, similar to Mauritius. There is no explicit link to energy within the tourism master plan. This contrasts with Mauritius that identifies tourism as a specific subsector in the energy policy document.

Table 2. Seychelles production capacities per energy source

Energy source	total on the Seychelles	percentage on the Seychelles	percentage in Europe	per capita on the Seychelles	per capita in Europe
Fossil fuels	701.50 m kWh	91.0 %	49.2 %	7,319.27 kWh	8,120.79 kWh
Nuclear power	0.00 kWh	0.0 %	7.0 %	0.00 kWh	1,155.06 kWh
Water power	0.00 kWh	0.0 %	24.1 %	0.00 kWh	3,979.85 kWh
Renewable energy	69.38 m kWh	9.0 %	19.7 %	723.88 kWh	3,276.60 kWh
Total production capacity	770.88 m kWh	100.0 %	100.0 %	8,043.15 kWh	16,500.88 kWh

Source: World Bank (2018b).

7. Energy and the tourism sector in Seychelles

The Seychelles energy policy does recognise that tourism alongside rapid economic growth has resulted in increased energy demand. The Principal Secretary for Tourism stated ‘being a Small Island Developing State we are vulnerable to external factors due to our size, location and exposure to global environmental challenges including the impact of climate change, hence finding the right balance for sustainable development in SIDS is imperative’ (Ministry of Tourism, Seychelles 2017). The Seychelles Tourism Department operate the Seychelles Sustainable Tourism Label (SSTL) certification for hotels and many of the strategies outlined in Mauritius are encouraged within the Seychellois tourism sector. An illustration of the proactive approach that has been undertaken was a specialist

Masters class on Sustainable tourism and energy efficiency (2017) and was attended by participants from the public and private sectors and graduate students.

8. Sustainability education policies in Mauritius and Seychelles

In looking at the nexus between energy, tourism and sustainable development, the role of education, both formal and informal, is crucial. To address issues of sustainability key messages need to be conveyed, understood and acted upon throughout all levels of a national community. This applies in both the public and private spheres. Valuing sustainability needs to be embedded within households, local and national government bodies and the business community. Of course, education is only as useful as the capacity allowed to make informed choices. Many people and communities who are fully aware that their actions may have short-term benefits but long-term costs, yet they may feel they have very restricted options. Environmental sensibilities and practices have often been portrayed as middle-class luxuries, which lower income households can simply not afford.

Both Mauritius and the Seychelles have well-developed education systems. Both have national universities and independent schools and colleges that focus on vocational training aimed at developing local capacity in the tourism sector. The University of Mauritius has a broad range of Faculties encompassing Agriculture, Engineering, Science, Law and Management, Social Sciences and Humanities (UoM 2019). Interestingly there is no specific Faculty or School focussing on either environmental issues or tourism. However, Mauritius does have a separate International School of Hospitality and Tourism Management (Vatel 2019), but this does not highlight adaptation to climate change or broader sustainability issues in its prospectus. In comparison the University of the Seychelles has a dedicated Department of Tourism and offers a Masters programme in Sustainable Tourism Management (UoS 2019). It is also home to the James Michel Blue Economy Research Institute (BERI 2019). BERI operates as an umbrella body for entities affiliated to the University, such as the Island Biodiversity & Conservation Centre (IBC centre) and the University Centre for Environmental Education

(UCEE). BERI's remit covers 'social and cultural related aspects of the Blue Economy; ocean governance; ecosystem change and modelling; ecosystem services; natural capital; renewable energy; biotechnology; sea-based products, fisheries and aquaculture; maritime transport and services; coastal and marine ecotourism; climate change; disaster risk reduction; pollution and waste management' (BERI 2019). Whist acknowledging the breadth and depth of this research it is clear that aspects of renewable energy and sustainable tourism strategies are key aspects of this institutes work.

In the Pacific region there have been innovative steps taken to integrate climate change adaptation measures into the formal education and training sector (Mcleod et al. 2019). This is something that could provide a model for similar approaches to be undertaken in Mauritius, Seychelles and the broader Indian Ocean region. The European Union-funded Pacific Technical and Vocational Education and Training in Sustainable Energy and Climate Change (PACVET 2019) project takes a regional approach with 15 SIDS governments accrediting climate change adaptation qualifications nationally and in tandem. Each of the governments involved maintain sovereign control over the accreditation process, but this is coordinated in such a way that these national qualifications are mutually recognised across the region. This facilitates the sharing of trainers and related resources and, crucially, the mobility of qualified professionals across the region. If these qualifications could be adopted in other regions, such as the Caribbean or the Indian Ocean, then this would enhance the sharing of good practice and upgrade the human capital capacity to address the challenges of climate change mitigation, resilience and adaptation.

The PACVET process began with a 'needs and gaps' analysis across the Pacific region and the creation of training materials and certification benchmarks in the fields of sustainable energy (SE), disaster risk reduction (DRR) and climate change adaptation (CAA). In line with the neo-functionalist approach of 'form follows function', as mentioned above, the 'function' required was to fill the identified gaps in SE, DRR and CAA. These extend beyond the formal education and training measures. This is a necessary platform upon which to build a comprehensive 'form' that involves all relevant stakeholders within each sovereign territory and across the region. The first intake for these new qualifications is only happening in 2018 so it will still be some time before the first graduates feed into the relevant fields of employment. What can be identified though is the type of skills that can be developed and the sectors where they can be most usefully deployed. For example, electrical engineers are now being trained with the specific intent of developing the solar power industry across the Pacific region. It is not the case that such electrical engineer training was not available previously, but now this is more strategically targeted with a focus on up-skilling and expanding the region's renewable energy capacity. Significantly this also ties in with the priority areas of donor countries and agencies that are now more willing to support such initiatives as they coincide with donor priority areas, in this case supporting the shift from reliance on imported fossil fuels to domestically produced and managed renewable energy sources. There is also an additional, positive impact of creating domestic employment opportunities and addressing the issue of out-migration, which is a serious issue among many SIDS, the extent of these approaches do not appear to be reflected within the Seychelles and Mauritius policies.

Seeking educational and employment opportunities outside of SIDS are among several issues impacting on the demographic composition of these island communities. Migration from these islands is often presented in the international media as escaping from low-lying territories at risk of inundation (Julca, Paddison 2010). Whilst there is some truth to this narrative it is also the case that many working-age people feel that their opportunities and life chances would be enhanced overseas, regardless of environmental degradation at home. Importantly it is the younger generation that are likely to feel this pull most strongly, as they are of an age where they are more readily accepted for training and to be offered skilled, professional employment. This is not to say that more 'traditional' skill sets, such as sustainable subsistence living in outer islands, should not be equally valued. However, a mobile workforce can be seen in both positive and negative terms. If this is a simple one-way process of 'brain drain' then this undermines the human capital capacity of societies and economies where the brightest and the best talents are siphoned off to core economies elsewhere. Alternatively, the PACVET project encourages mobility within the Pacific region but sees this as more of a circular process whereby skilled workers can move relatively freely across the region, facilitated by a region-wide recognition of their qualifications, and a collaborative approach to drawing on a shared pool of talent. As a model there is enormous potential for this type of formal training on a region-wide basis to be replicated in other regions of the world, notably the Indian Ocean.

For such an approach to be put in place in the Indian Ocean region several key elements need to be addressed. For PACVET the financial support of the European Union and the creation of a management structure to coordinate a region-wide framework for consultation and subsequent implantation was a key factor in the success of the project. This does not have to be an essential element for a similar project to be developed elsewhere, but there does need to be a recognition that some form of coordinating oversight has to be put in place, with at least 'start-up' funding to allow the initial 'needs and gaps' analysis to take place and to facilitate buy-in from the relevant governments and their Education Ministers. Beyond this the support of the private sector, not just the tourism industry, is important to ensure that meaningful job opportunities would be available for those qualified in SE, DDR and CCA. Although not directly part of the PACVET project there are several spin-off benefits from creating these employment opportunities. It will go some way towards tackling the issues of outmigration among SIDS' workforce (particularly within the tourism sector), it will generate additional wage income for domestic households, thereby reducing reliance of unreliable remittance payments. This increased household income also addressed many of the negative aspects of cycles of poverty, including health issues and enabling further educational opportunities. Whilst not wishing to present such projects as universal panaceas for all development needs in SIDS, the benefits of such vocational training extend far beyond the up-skilling of the individuals being trained.

9. Regional cooperation in a global context

As outlined above both Mauritius and Seychelles are well aware of the pressing need to move away from a damaging and unsustainable reliance on imported fossil fuels for energy security. Both governments have ambitious plans to transfer to greater production and consumption of renewable energy. This is to be undertaken in partnership with relevant domestic stakeholders in the private sector and civil society. The Regional Renewable Energy Forum provides an appropriate framework for the sharing of good practice across the broader Indian Ocean region. This analysis has highlighted the potential for regional cooperation among SIDS to engage with the issue of economies of scale and to undertake initiatives similar to the PACVET project. IRENA and the SIDS Lighthouses Initiative also demonstrate a willingness among these states, and related donor agencies, to promote renewable energy security policies and practices.

Despite these very positive initiatives and actions they do need to be viewed within the broader context of ongoing greenhouse gas emissions and related climate change. As mentioned earlier, the latest report from the Intergovernmental Panel on Climate Change indicates that in order to keep within the 1.5 degree target for global warming there will need to be massive investment in the renewable energy sector, in addition to carbon capture and other mitigation strategies (IPCC 2018). The IPCC Fifth Assessment Report (2014) report indicates the world's governments and industries have only twelve years to attempt to reverse current climate change trends or risk 'climate catastrophe'. Significantly such a catastrophe, should it occur, will have more profound impacts on some communities more than others. For example, although the United States has experienced an increased number of powerful hurricanes and other extreme weather events in recent years these have only devastated certain local areas and had, therefore, only a relatively minor impact on the national economy. This is not the case for SIDS, such as Mauritius and the Seychelles, where such events would have major consequences for the whole of these countries. The example of a major catastrophe devastating a whole island group would be dramatic and widely reported. However, the slow 'drip, drip, drip' of unsustainable energy policies and creeping sea-level rise making these low-lying communities increasingly insecure is no less concerning for those living on these SIDS.

The challenges of achieving sustainable development are particularly acute for low-lying SIDS. The tourism sector in these islands contributes both economically and also to greenhouse gas emissions; it is in this context that the scope of the industry could also be used as a vector to train the workforce about climate change. The direct educational benefits would be to upskill the tourism workforce and reduce outward migration of the population and improve the operational practises within the tourism industry to reduce GHG emissions. The indirect benefits would be the increased awareness of the local residents with the aim of transferring improved environmental behaviours into households. At a nation state level, the examples of CARICOM, Pacific Islands Forum and the over-arching AOSIS demonstrate that many SIDS recognise common causes and have become adept at sharing diplomatic resources and becoming impactful negotiators in relevant international bodies, such as the IPCC. The Indian Ocean Commission (IOC 2019) and the Indian Ocean Rim Association (IORA 2019) are appropriate bodies for the islands of the Southwest Indian Ocean to convene and collaborate to address SDG 7 (affordable and clean energy) there is also greater opportunity for collaboration within the tourism sector to overcome some of the perennial challenges of meeting the SDGs.

10. Conclusion

The conclusions of this study are twofold. First, within the tourism sector in Mauritius and the Seychelles, there is a recognition that reliance on fossil fuel imports is both unnecessarily costly and the resulting emissions contribute to climatic conditions that threaten the longer-term survival of these territories. As noted above, this awareness extends well beyond the tourism sector and informs both governments' priorities and sustainability education policies. Second, while the case study approach undertaken here has provided relevant data for these island states there are important lessons for other states. Island states, especially the lower-lying ones, are acutely aware of the threats posed by climate change and related extreme weather events. The fact that many such states are also significantly reliant on income generated by the tourism sector highlights the need to operate and promote this sector in a sustainable manner. Notwithstanding the specificities of these case studies, the issue of moving away from fossil fuel reliance to more sustainable, renewable sources of energy has much broader applicability.

Recent IPCC meetings have highlighted the vulnerability of small island states being on the 'front line' of climate change (IPCC 2020). They have been used as metaphors for much larger global patterns and processes to stimulate decarbonisation among industrialised economies. Whilst focusing on the tourism sector this study has also demonstrated the need for coordinated action between numerous public and private stakeholders and the importance of community engagement to implement sustainable practices. Some progress has been made with a growing awareness of the pressing need to decarbonise the global economy. A number of energy companies have taken on this challenge, albeit with a relatively small percentage of their overall businesses investing in the required research and development of renewables. There remain huge challenges to move away from fossil fuels to renewable forms of energy at the global level. However, this study demonstrates that with enough incentives, and political will, such transformations are both possible and practical.

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Evaluating the use of renewable energy and communal governance systems for climate change adaptation

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Abstract:

Aim: Renewable energy (RE) systems can be effective tools for rural communities for meeting goals for development and climate change mitigation and adaptation. RE systems provide small amounts of electricity fostering community development through improved energy access, livelihood opportunities, and improved quality of life. Communities in rural Guatemala are increasingly vulnerable to climate change impacts, due to increasingly extreme weather events. Distributed RE systems can be more effective than connection to national electric grids in providing power if community members have the agency and skill (technical and in governance) to maintain them. The goals of this study are to evaluate the performance of RE systems used in a rural Guatemalan community and the governance system created around, contribute to the literature on RE systems as a means for climate change adaptation, and identify further challenges in operation, monitoring, and evaluation of these projects.

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Design/Research methods: The specific RE systems were evaluated eight years ago; they had performed well especially after Hurricane Stan. Recommendations were made for further performance improvement. This study evaluates the subsequent performance given more intense rains, and the current state of related community governance on the basis of semi-structured interviews. The results of this study are compared to the ones obtained in the first evaluation carried out in 2009.

Conclusions/findings: This research highlights the need for enhanced and continuous monitoring and evaluation methods for both energy projects and their supporting institutional structures. Accountability, mediation mechanisms and transparency tools within these institutions can allow more open communication and equitable treatment with agents of power. The RE systems ultimately failed because of the arrival of the electrical grid and the failure of the governance system. Although users now enjoy more appliances, they indicate a desire to have the RE systems back as they are more reliable.

Originality/value of the article: The article provides original insights for project implementation and policy information. Strong trust bonds are necessary for community resilience in emergencies, and in the well-being and development of the community, independent of energy sources.

Keywords: renewable energy, adaptation, climate, resilience, institutions, governance, Guatemala
JEL: O10, Q20, Q42

1. Introduction

Investing in and implementing community-based renewable energy systems has been identified as a key solution to climate change as well as meeting Sustainable Development Goals (SDGs) (IRENA 2019, Ley 2017, Madriz-Vargas et al. 2018). While contributions of RE interventions for climate mitigation (through emissions reduction) and sustainable development (through improved energy access, poverty reduction, and cascading effects on education and quality of life) have been widely assessed, implications for climate change adaptation have received relatively less attention (Ley 2017, Venema and Rehman 2007). More recently, empirical evidence on the role of RE for adaptation is growing: for example, decentralized RE can facilitate disaster recovery by provision of electricity (Ley 2017), RE generation in communities can support local services such as health and water facilities, telecommunication, and enable livelihood diversification (Madriz-Vargas et al. 2018). What is less understood is how RE performance is mediated by local institutions and power dynamics and the implications of these governance structures and processes on adaptation to climate change.

While energy access across Central and South America is high relative to many developing countries, last-mile electricity delivery remains a challenge (IRENA

2018). This is where off-grid, decentralized energy systems have been identified as key to meeting energy access, mitigation of emissions, and adaptation concerns. Following global trends towards decentralized, community-based energy provision, national governments in the region have experimented with mini grids, solar energy, biogas etc. (Madriz-Vargas et al. 2018). In Guatemala, the site of this research, 67.4% of the country's energy comes from renewable sources (CEPAL 2017), with aim to raise this to 80% by 2027.[1] In the latest 'Policy for Rural Electrification 2019-2032' (MEM 2019), Guatemala's Ministry of Energy and Mines has announced a push for increasing renewable energy use, especially in rural areas, and instituting legal frameworks to integrate alternative sources of energy such as solar PV systems, wind power, small hydroelectric plants, and hybrid power plants. While this support of renewable energy is welcome, examining how existing RE interventions perform on the ground is critical to meeting these climate and sustainable development policy goals.

The adaptation literature has converged to argue that adaptation governance, i.e. the institutions, processes, agendas, and power dynamics involved in "steering action and processes" (Huang et al. 2018:223) towards local adaptation strongly mediate adaptation project functioning, performance, and sustainability (Vink et al. 2013, Huitema et al. 2016, Valdivieso et al. 2017). Moreover, the shift to renewable energy systems is not limited by technology alone but requires "collective involvement of a range of local actors and the penetration of low-carbon practices and technologies in […] physical, economic and social systems" (Huang et al. 2018:223). In practice, this strongly indicates that careful consideration of local power differentials, and institutional arrangements and functioning, is key to adaptation intervention outcomes.

From a six country study on micro-grids based on small-scale solar across Bangladesh, Brazil, India, Mozambique, Sri Lanka and South Africa, Kumar et al. (2019) demonstrate how technological and social factors such as the flexibility/fixity of the projects and the de-/centralisation of agency critically mediate solar energy project outcomes. Using the example of environmental disaster risk management in

[1]https://www.energia16.com/58-36-percent-of-guatemalas-electricity-comes-from-renewable-sources/?lang=en

Chile, Valdivieso et al. (2017) demonstrate how institutional dimensions such as management transparency, local government coordination, degree of public participation in decision-making processes, and vertical cooperation across governance scales can significantly improve adaptation outcomes. Assessing community renewable energy projects across Panama, Nicaragua, and Costa Rica, Madriz-Vargas et al. (2018) found that stable and long-lasting social structures to support governance of financial and non-financial benefits and shared maintenance responsibilities are vital to ensure long-term operation of RE systems. A four country study from Laos, Peru, India, and Tanzania also finds that the socio-economic context that sustainable energy projects operate within determine both project outcomes and longevity (Ortiz et al. 2012). Collectively, these studies highlight the importance of accounting for socio-institutional arrangements (in addition to technical aspects) when planning and implementing RE projects.

There is also a well-developed literature around governance of common property resources (CPR) which uses institutional theory to identify the conditions and processes through which users (individuals and groups) self-organize and govern the resources they depend upon (e.g. Wade 1987, Ostrom 1990, Agrawal 2001). Some authors have applied developments from this literature to the use and governance of RE systems (i.e. Wolsink 2012) where decentralized energy, often generated within communities, is likened to a common property resource, and its use and management, draws parallels with CPR governance.

In this paper, we use empirical evidence from four RE interventions and their related productive uses in one community in Guatemala, chosen because they explicitly aim to meet triple objectives of sustainable development, and climate mitigation and adaptation. We (1) trace how the projects evolved, with mixed outcomes for the community cohesion, and (2) identify factors that can hinder project functioning and outcomes, as well as their long-term sustainability. The paper makes three contributions. First, by examining the institutional barriers and enablers to sustaining community RE interventions, it adds to the literature on adaptation governance, specifically showcasing how community trust is critical to project functioning and outcomes. Second, by focusing on RE systems in rural Guatemala, it contributes to the empirical gap on adaptation implications of small-scale, rural RE interventions (de Coninck et al. 2018). Finally, the findings have implications for community RE implementation and policy by identifying key challenges in operations, and monitoring and evaluation, with specific lessons for Guatemala's 2019 Policy for Rural Electrification.

2. Methods

2.1 RE projects studied

The study was conducted in a community in El Palmar, Guatemala. Located between the Pacific coast and the Western highlands of Guatemala, the community was originally a privately owned *finca* (country estate) with commercial plantations of coffee and macadamia. Due to social conflicts with the owners, the community members abandoned the ranch. Later, when the *finca* was abandoned by the previous owner's son, the community secured a loan to buy it. They refurbished the *finca* and started processing coffee and macadamia nuts, as well as adding new projects such as pig and chicken farms, purified bottled water, and an ecotourism hotel. In 2005, the community was severely affected by Hurricane Stan but was nonetheless able to provide emergency relief to surrounding communities, especially by providing purified water, as emergency and rescue operations were slow in the days after the event because access to these remote locations was difficult. As a community member stated in retrospect 'We were not isolated, 'they' were isolated from us'.

The community studied had multiple RE projects in operation (

Table *1*) when first visited in 2009. The RE interventions were managed by the community and had a household-level monthly tariff system, a set of internal rules, and fines for late payment or using more electricity than allowed.

Table 1. Types of RE interventions in studied community in El Palmar, Guatemala in 2009

Type of RE intervention	Details
Micro-hydro	The original 16 kW micro-hydro plant was refurbished by the community using a grant from the UNDP Small Grants Program by installing two 8 kW Pelton turbines
Biodiesel	Average production of 48 gal biodiesel per 48 hours using recycled kitchen oil. This is was in a diesel generator to power 50 homes in the community, the finca offices, eco-hotel, and coffee, macadamia, and purified water projects. After Hurricane Stan, the biodiesel plant was supplied fuel for trucks and was especially useful to deliver potable water to nearby communities
Biogas	Piggeries, also for biogas generation which failed after rats chewed gas catchment system
Solar PV	Household solar PV which also supplied electricity for local eco-hotel
Water purifier	RE-powered water purifier for bottled drinking water from a community-owned spring sold within and outside the community
Coffee cacao and macadamia processing units	Coffee, cacao and macadamia plantations by the previous finca owners were refurbished and expanded, and coffee roasting and sorting were powered by RE

Source: Authors' own research

2.2 Research design

This research used semi-structured interviews with members of the committee that oversaw the RE systems and those who had left it. Interviews focused on the performance of the RE systems, the tariff structure and the functioning of the committee, and how micro-enterprises had evolved.

This research used a total of 23 semi-structured interviews with community members (15 in phase one and 8 interviews eight years later). The original aim was to interview the same people as in 2009 as well as those currently in charge of project management, as well as users and non-users, however, after the initial interviews it was clear there was fear amongst the community members to express their opinions. In the second phase of interviews, a particular focus was put on the performance of the RE systems in the most recent tropical storms and hurricanes, the losses the community has incurred, and other climate change adaptation mechanisms applied (early warning systems, communications during emergencies, use of shelters, use of purified water for themselves and other communities, amongst others).We aimed to assess the performance of RE systems through number of days with blackouts, extent and number of repairs done in a year, frequency of preventive maintenance, whether people were hurt due to operation and maintenance tasks, and number of days the RE systems failed to function during extreme weather events. However, given that the systems were defunct when the site was revisited during the second phase of interviews, we could not carry out an assessment using the above inspection protocol.

The first phase of this study took place in 2009 where the research team spent two weeks in the community conducting interviews with the community leaders, people in charge of each productive us project, a women's group, and RE users and non-users. We also undertook a technical inspection of the PV, hydro, biodiesel systems, and provided recommendations to potentially add to system and institutional robustness. A second visit in 2017 was then undertaken to assess the longer-term impacts of the RE projects, focusing on whether the community had been strengthened, the evolution of the governance mechanisms that had been institutionalized, and how the projects had evolved in terms of robustness during extreme weather events (following recommendations we had provided them), growth of other productive use projects, and expansion of hydro and solar PV systems. Interviews were conducted with the former community leadership, some of the workers of the micro-hydro and project managers and other community members. We also spoke to people external to the community who were familiar with or had formerly assisted with O&M of the micro-hydro project.

Data collection was challenging and interviewee selection purposive because many people were wary of discussing the performance of the RE projects. In many cases, respondents articulated feelings of fear when discussing the project, possibly because of not wanting to be seen as reporting negative impacts that might affect their relations within the community and fear of retaliation by former community leaders who were still influential.

3. Findings

The RE project studied began as externally funded but community governed interventions with careful attention paid to issues of participation, equity, and capacity building (
Table *2*).

Table 2 Governance characteristics of the RE project

Project characteristics	**Details**	
Roles	Funding entities	Various: Multilateral development organizations and local university
	Development entities	Community
Governance characteristics	Type of governance structure	Committee within the community, with well-defined roles and responsibilities that were followed
	Rules and regulations	Well-defined though not everybody followed energy usage regulations
	Community participation	Yes
	CPR management	No
	Training	Community received administrative, technical training
	Tariff structure	Yes, but not sustainable
	Equity	The project outcomes were equitable to an extent. Some elite capture by community leaders (e.g. over use beyond allotted energy quota) and women's group reported losing power when the UNDP project ended
Adaptation	✓ Energy provision for livelihood diversification ✓ More assured energy supply, especially during extreme events	
Mitigation	✓ Energy savings ✓ Emissions reductions	
Sustainable development	✓ Domestic uses ✓ Productive uses ✓ Communal uses ✓ Cost savings ✓ Social acceptance (for some time)	

Source: Authors' own research

However, the observations made during the second visit of the community and the statements taken by the different community members very clearly revealed a number of factors that contributed to the demise of the RE project. These are detailed in the subsequent sections.

3.1 Mismatches in community needs and RE project deliverables undermined operations and maintenance

With respect to energy access, the micro-hydro plant was observed to be poorly engineered and constructed during a technical inspection during the first phase of this study, and its capacity was insufficient to meet the community's demand for electricity. As a result, people had been eager to connect the community to the national electric grid in order to use more appliances in their respective households, and worked collectively towards that end. Eventually, community efforts to connect to the national grid succeeded. As a consequence, the community started paying the required tariff to the utility and there were no more payments to the community maintenance team for the upkeep of the hydro facility, which subsequently fell into disrepair. This was compounded by internal conflicts and mistrust within the community (detailed in Section 3.3).

During the first phase of the study, there were reports of some households consuming more electricity from the micro-hydro than allowed by the tariff and agreed-upon project rules, leading to conflicts within the community. Each home had a meter and a 'lock'; when a household exceeded its allotted consumption, the fuse would burn, cutting off electricity supply to the household, which would only be restored after paying a fine. Despite this, some people, typically community leaders, were using appliances specifically disallowed by project rules such as big color televisions and laptops that drew more electricity than was allotted.

Even during the first phase of the study, the community planned to connect to the national electric grid when available. The hydro facility would be kept as a back-up for grid electricity in case of disruptions due to extreme weather events (Ley 2013), which were evidently not factored in the community's decisions to abandon the RE projects as observed in the second phase of the study. Thus, community decision-making was seen to be dominated by "short-termism," a lack of awareness of or low value ascribed to the multiple benefits of the RE systems (e.g. improved resilience in the face of extreme weather events), and internal conflicts. Other studies have also noted that funded by international aid agencies, and lacking a broader enabling governance environment, community renewable energy projects across Central America have been plagued by issues of remaining functional for only a limited time (Madriz-Vargas et al. 2018).

3.2 Project failure exacerbated community vulnerability

In terms of adaptation to climate change and the community's conditions with respect to energy supply, our observations and the results of the interviews clearly demonstrate that the community's vulnerability to impacts has been greatly enhanced by the failure of these RE projects. As expected, as the community is situated within the last kilometer of a distribution line, people are subject to many blackouts. Further, the terminal portions of distribution lines tend to have more voltage fluctuations that can cause brown-outs or burn appliances. During the rainy season, when people most need electricity – especially in cases of emergency – they are actually cut off, sometimes remaining without electricity for up to four days continuously. Since the hydro facility does not function anymore as a back-up, there is no other way of acquiring electricity in this case, which means that there are no radio communications, means to charge cellular telephones, or other means of communication during emergencies. However, a few relatively wealthy (by community standards) households have solar photovoltaic installations that allow those individuals very basic levels of electric service.

From the interviews in the second phase, there was unanimous agreement that people would prefer to have the hydro facility, which people testified to having been more resilient. While they viewed the hydro as more resilient, they acknowledged its lack of capacity had been problematic before the arrival of the electric grid. Many homes have refrigerators to sell or store cold products including beer, soft drinks, meat, etc., and they lose products during these blackouts, which makes them lose income, exacerbating their vulnerability. Because of the lower capacity of the hydro, community members did not use refrigerators when the hydro provided all of the community's electricity. Thus, while the grid provided an increased opportunity for earned income (e.g., storing meat to sell), it has also increased their vulnerability due to the frequent and prolonged power failures.

3.3 Trust as key to community participation

Trust is paramount to effective communal governance of external interventions (Walker et al. 2010) and the lack thereof can lead to the deterioration of an RE system, independent of its technical robustness, as was the case in the community visited. When the RE systems were functional, community members faced loss of power only occasionally. A respondent emphasized, *"We used to be able to cope better during storms, with the grid, when the light goes off it takes at least 4 days before we get light again".* One woman respondent who owned a small shop selling ice creams and cold drinks added, *"The grid is very unreliable. I miss the hydro power...especially for my business...if there is no electricity, most of my popsicles just melt."*

One of the arenas where community conflicts played out was the coffee processing unit. Typically, members sold raw coffee beans to the community leader who oversaw bean roasting and grinding. However, the rates the leader offered were low and in parallel, some families found other middle men to buy their raw coffee beans, earning a bit more than what the community concession was paying for the communal product. This resulted in the general perception that the community leadership was keeping money for itself and cheating the community people. Subsequently, trust among the community began to erode and with that the motivation of maintaining the projects decreased, until they were ultimately abandoned and common property even became subject to looting. We found that conditions related to community cohesion but not directly related to the RE projects deteriorated in tandem with the institutional structures surrounding the projects. As an example, the community used to have a "communal fund" for celebrations, emergencies, and to help those in need. After the loss in trust over the coffee business described above, this practice was abandoned, leaving the poor and elderly on their own facing up to the impacts of extreme weather events.

These findings echo other studies that demonstrate that "trust (has) a necessary part to play in the contingencies and dynamics of community RE projects and in the outcomes they can achieve" (Walker et al. 2010: 2655).

4. Discussion and conclusion

This paper has added to the literature on adaptation governance by identifying community trust as a critical enabling factor of project functioning and outcomes. In particular, this research highlights the need for enhanced monitoring and evaluation methods and their continuous implementation for both the renewable energy projects and the institutional structures that surround them. It also emphasizes how including mechanisms for mediation in these institutional structures is necessary to ensure project sustainability. The renewable energy systems evaluated had been exemplars of the use of these systems to adapt to climate impacts but failed due to mistrust and unresolved disputes, highlighting the importance of having mediation mechanisms and transparency tools that will allow for more open communication and level the playing field with agents of power.

The findings point to the need for trust within individuals and institutions and the need for regular monitoring, evaluation, and mediation for projects to deliver their stated outcomes and increase resilience. Having these mechanisms will help ensure that problems are dealt with as they arise so the RE systems will work as expected during extreme weather events or other emergencies. First, developing and maintaining strong trust bonds are necessary for acceptance of the project in particular and community resilience during extreme weather events in general. Second, having robust, multi-scalar monitoring and evaluation processes can help identify potential negative or unintended impacts as well as plan for potential failures. As other research has pointed out (Ortiz et al. 2012), the lack of monitoring and evaluation have led to the failure of systems even in cases where there were small technical of social issues.

At first sight, these findings are difficult to reconcile with the literature on collective action theory, which spans the spectrum from Ostrom’s (1990) work on poly-centric governance of collective resources to Hardin’s (1968) call for state control. While initial project performance pointed more towards the success of community management, the subsequent performance might be interpreted to indicate that polycentric governance has not been sustainable and that project management should have been handled centrally. However, looking at some of the empirical work in this area, it quickly becomes clear that there is also a grey zone in between Ostrom and Hardin: In particular, Wade (1987) concludes from his work in India that users will fail to come up with effective rules of restrained access to collective resources if or when there are many users, when the boundaries of the common property resources are unclear, when the users live in groups scattered over a large area, and when undiscovered rule-breaking is easy. The research presented in this paper actually points to a variation of Wade's last item on rule-breaking as the reason for governance failure. In particular, the rule-breaking was not undiscovered, but it still undermined effective and sustainable governance, as there was no accountability once it was perceived. Thereby, this study's findings do not invalidate the case for polycentric governance, but rather specifies circumstances which have to be met in order for community management of common-pool resources to be effective and sustainable.

The paper has also contributed empirical work on adaptation implications of small-scale, rural RE interventions (de Coninck et al. 2018). The study shows how community RE can contribute to adaptive capacity through:

- building disaster resilience (as seen when energy supply helped during Hurricane Stan)
- diversifying livelihoods (e.g. into eco-hotels), which contribute to household incomes
- reducing community reliance on external energy sources thereby improving self-sufficiency (the grid was neither reliable nor robust and even though the hydro power plant had problems, it was more reliable than the grid and was under the control of the community).
- Improved communications (the RE energy also enabled charging cellphone batteries, particularly critical during extreme events)

Finally, the findings presented in this paper have implications for community RE implementation and policy by revealing challenges in operations, monitoring and evaluation, with specific lessons for Guatemala's 2019 Policy for Rural Electrification. Key to project implementation and sustainability, is reconciling community needs and demands with project deliverables. This also includes considering community expectations and their perceptions of RE projects *before* implementation. The study also found that following safety and quality codes and standards, as well as providing adequate training to ensure nobody gets hurt during O&M is critical for the technical functioning of the project. When safety protocols are breached, they can undermine human safety (through accidents) and the RE system's reliability, which, in the long-term, can erode community trust in and reliance upon the RE system. As the study showed, when investing in an RE system, setting up RE generation is not sufficient:. developing institutions that are transparent is key to effective community RE systems. While the project studied did ensure transparency in the early years (through proper records), these practices fell away and had completely eroded when we visited eight years later.

Table 3 Aspects of resource governance theory found in Guatemalen RE projects

	Aspects of resource governance	**Findings from community RE project in Guatemala**
Ostrom (1990)	Renewable energy resource system characteristics	✓ Well-defined boundaries
	User group characteristics	✓ Well-defined boundaries
	Relationship between resource system and users	✓ Energy consumption limits exceeded
	Institutional arrangements	✓ Locally devised access and management rules
		✓ Easily enforced rules
		✓ Graduated sanctions
		✓ Availability of low cost adjudication
		✓ Accountability of other officials to users
	Relationship between resource system characteristics and institutional arrangements	Good
	External environment	✓ Technology (RE) system helped meet development goals and strengthen management skills
		✓ Central governments should not undermine local authority
		✓ Nested levels of appropriation, provision, enforcement, governance
Wade	Low-cost exclusion technology	

(1987)	facilitates management of CPRs	

Source: Authors' own research

The main limitation of the study is that only one community was evaluated in this manner, so a comparative study with other communities with RE systems is desirable and an important area for future research. Further conditions that relate to the potential for transformational adaptation (such as behavioral or technological aspects of efficient use of energy) were excluded from this work but should also be considered. As with any communal project, the local contexts need to be taken into account.

Overall, community RE systems are a key strategy to meet climate mitigation, adaptation and sustainable development goals. Targeted at communities, decentralization and participation are core to the functioning of community RE. Using a case of Guatemala, we show RE project sustainability is strongly mediated by community dynamics and internal trust. Recognising how social dynamics interface with technical aspects to shape RE project outcomes is a necessary first step to effective community RE.

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Governance and decentralized energy transitions: a comparative case study of three medium sized cities in Sweden, Canada, and the United States

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Abstract:

Aim: This study aims to compare the sociotechnical conditions that contribute to innovative DE projects across five governance dimensions: (1) utility market structure, (2) multi-sector collaboration, (3) decision-making capacity and autonomy, (4) multilevel governance, and (5) public perceptions of climate change. Knowledge of how particular jurisdictions and their governance arrangements influence these transitions can help strengthen and contextualize divergent trajectories of decentralized energy transitions and – most importantly – reveal the role of geographical context in policy change. In particular, this study aims to draw from international comparisons of urban energy transitions.

Design: This paper compares the uptake of decentralized energy transitions in three cities in three different countries – Luleå (Sweden), Saskatoon (Canada), and Anchorage (United States). The jurisdictions in each city has unique governance contexts pertaining to electric utilities, regulations, public policy, and public acceptance. By comparing these transitions, this study highlights the governance considerations for decentralized energy transitions and asks how does governance impact the acceleration of decentralized energy transitions in cities? To answer this question, a total of 60 interviews were conducted with actors involved in decentralized energy projects (government, non-for-project, business, utility, academic, and environmental activism). Interview were thematically analyzed with the five governance dimensions.

Conclusion: The conclusions reveal that interactions between the five governance dimensions can partially explain the divergent trajectories of accelerated decentralized energy transitions. In addition to providing a more contextual understanding of these patterns of transitions in cities, the results show that multi-sector collaboration, broad public acceptance for climate change, state or national support for local projects, and local capacity serve as drivers for accelerating decentralized energy in cities. The results also suggest that regulated utility market structures, unstable political cycles, siloed integration of sectors, and decision-making autonomy serve a limited driving role.

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Originality: Much of the literature on decentralized energy and cities has focused on project and sectoral level analysis and hasn't considered the holistic nature of the energy system transition. A particular gap that would help inform a broader understanding is the jurisdictional governance impacts of decentralization energy transitions.

Implications of the research: In practical terms, the results could be used to inform interjurisdictional comparisons of decentralization energy projects. From a theoretical perspective, the results from this research suggest that there should be an elevated importance from the impacts of the interactions of the five governance dimensions.

Limitations of the research: Given that there were three case studies, it is not possible to make generalizable claims from the results.

Keywords: Sustainability transitions, comparative method, urban energy systems, decentralized energy, multilevel governance, energy transitions.
JEL: *O13,)16, Q01, R00*

1. Introduction

Innovative decentralized energy (DE) projects exist around the world – from solar co-ops with unique ownership structures and energy efficient and self-generating housing for low income residences to integrated combined heat and power (CHP) systems that also provide community district heating to ambitious wind projects in some of the harshest weather conditions; however, what determines the success of these projects is often unclear. To explain the drivers and challenges of DE transitions, researchers have developed theories, models, and various types of analysis. Some have argued that DE projects are successful because of a combination support in the form of subsidies, research and development, or regulations (Kemp et al. 1998). Others have argued that DE innovation works when competitive market forces are unleashed, government intervention is minimal, and public support is high.[1] Yet another view claims that it is sustainability networks that drive these unique local energy innovations (Seyfang et al. 2013). Motivated by the pursuit for sustainability, the environmental community takes on projects and pushes its agenda on the public and private sector.

[1] The academic literature generally does not support the idea that only market forces can be used to drive decentralized energy – there is a general consensus that government intervention at some level is required. This sentiment, however, more often prevails in mainstream discussions on energy transitions.

A robust interdisciplinary literature on sustainability transitions (Markard et al. 2012; Köhler et al. 2019), integrating expert knowledge from varied disciplines, has rapidly developed around these questions. This "socio-technical" approach has led to insights for pathways to overcome some of society's most contentious problems: overconsumption, GHG emissions, ocean acidification, social justice, and, of course, climate change. Despite these insights, most studies on sustainability transitions of DE have focused on single jurisdictions, with little research comparing how different cities in different countries handle transitions. Of the few comparative studies on multiple jurisdictions, even fewer have investigated the governance factors of integrating DE into their energy systems. Building on the literature on sustainability transition theories, governance, and urban local energy innovation, this current study compares three medium-sized cities. Often overlooked in the literature, medium-sized cities have unique constraints and opportunities that make them ideal for such an analysis. On this basis, the paper asks the question: How does governance impact the acceleration of decentralized energy transitions in cities? To investigate this question, stakeholders (n=60) involved with each city's local energy system and decentralized energy projects (government, non-for-project, business, utility, academic, and environmental activism) were interviewed. This paper compares these results using five governance dimensions: (1) utility market structure, (2) multi-sector collaboration, (3) decision-making capacity and autonomy, (4) multilevel governance, and (5) public perceptions of climate change. After a discussion on the theoretical implications of the results, this paper concludes with recommendations for further research.

2. Cities and energy

Half the world's population now live in urban spaces, a demographic trend that is predicted to continue (United Nations 2010, 2018; Jiang, O'Neill, 2017). By 2050 the world's population is expected to be 9.6 billion, 68% in cities (United Nations 2010, 2018). Although only 2% of the world's landmass is urban, these areas produce approximately two thirds of the GHGs (IEA 2009). According to the IPCC

(2007), half of all energy use and GHG emissions come from the built environment (IPCC 2007) as buildings consume substantial energy and emit high emissions (Akorede et al. 2010; Hughes et al. 2011). However, the projected increase in urbanization presents an opportunity to reduce energy demand (Lin, Ouyang 2014). For instance, the concentration of energy use intensity and public use of infrastructure creates opportunities to significantly reduce emissions.

Cities have potential to be drivers of innovation in the energy transition. Often centers of social progress, grassroots action, and experimentation, many cities are leading the fight against climate change (Bulkeley, Metsill 2003; Betsill, Bulkeley 2004, 2007; Wurzel et al. 2019). For cities, the energy transition is an opportunity to both reduce global emissions while creating opportunities of local autonomy and resiliency. National and international levels of government and policies have begun to recognize the importance of cities and their role in emissions reduction (Betsill, Bulkeley 2004; Chittum, Østergaard 2014; Compact of Mayors 2015). Instead of waiting for national and international signals for environmental action, they are often flexible enough to transition quickly to renewable energy (Droege 2002) and are seeking ways to augment their local and alternative energy portfolios, particularly DE (Mulugetta et al. 2010).

Despite these initiatives, developing and implementing local DE projects in cities is not a simple matter. A shift to DE is multidimensional, with intersecting social, economic, political, and technological factors to be considered (Hodson, Marvin 2009; Lesage et al. 2010). Although at all levels of government, energy is an increasingly challenging policy question, local entities, in particular, are often ill equipped to manage the challenge of energy governance (Florini, Sovacool 2009). Technical problems are also challenging. Engineers are building an understanding of urban energy system models and learning how to integrate a portfolio of energy options within an urban context (Keirstead et al. 2012). Urban issues and energy technologies, as a socio-technical system, should be the focus of further research (Hommels 2005). In particular, a focus on gaining insights from stakeholders within local energy systems will better expose the challenges and opportunities of these complex interactions.

3. The comparative method and case study selection

The comparative method is an established and growing research approach (Mill 1843; Tilly 1984; Rihoux et al. 2013; Ragin 2014). This method can unlock causal patterns within complex systems (Byrne 2005) necessary for comparative studies with few cases (Ragin 2014). The following cities were selected: Saskatoon (Canada), Luleå (Sweden), and Anchorage (United States). Table 1 compares key aspects of these cities relevant to the case study.

Table 1. Comparative case study city selection

	Saskatoon	Luleå	Anchorage
Country	Canada	Sweden	United States
Population (Urban)	246 376	75 832	291 538
Area	170.8 km^2	29 km^2	204 km^2
Density	1 3001/ km^2	2 619/ km^2	1 232/ km^2
Sunshine Hours in December	86.5	3	51.8
Average Temperature Range (Jan/July)[2]	-18.9 °C /25.7 °C	-12.9 °C /20.7 °C	-11.4 °C/18.6 °C
Latitude	52° 08’ N	64° 34’ 4” N	61° 13’ N
Local and Regional Electric Utility	Saskatoon Light and Power, SaskPower	Luleå Energi, Nordic Energy Market[3]	Anchorage Municipal Light and Power, Chugach Electric Association, Matanuska Electric Association
Electric Utility Ownership	Public/ GTD Provincial Monopoly[4]	Public	Public and Cooperative
Heat Type	Gas (minimal electric)	District CHP	Gas/Electric (minimal wood and oil)
Notable DE Projects	SES Solar Coop, Renewable Rides	LuleåKraft CHP, Biogas	Fire Island Wind, Low Income Housing Project

Notes:

1. Based on average low for January and average high for July.
2. The major companies are Vattenfall, Fortum, Statkraft, E.on, Elsam, and Pohjolan Voima.

Source: Statistics Canada (2016); United States Census Bureau (2019); Luleå Kummun (2020).

Several considerations informed the selection of these three cities: population size and density, location, experience with previous DE projects, language, and governance of local utilities. Medium sized cities of 50,000 to 300,000 from different countries were selected because cities of this size typically have the capacity to pursue innovative projects, lack the land use constraints of larger cities (Gargan 1981; Andrews et al. 2016) and are exposed to a similar range of DE technologies. By selecting cases that would presumably have the potential to pursue DE technologies in their city, a comparative approach can more precisely contrast the success and failures of projects. The cities chosen were in the north because northern cities have attributes that can be held constant in a comparative analysis such as the northern latitude, seasonal temperature variances, seasonal changes to sunlight hours, and cold temperatures. All the cities have predominately rural and low regional population densities and, because they are relatively isolated, are not influenced by the proximity of larger urban centres. Another consideration was commitment to reducing GHG emissions and experience with DE; all three cities selected had implemented at least two DE projects. For practical data collection purposes, English was spoken by all interviewees in the selected cities. Finally, the municipal governments of all three cities have public ownership in their local electric utilities.

In addition to similarities, differences among the cities enhanced their suitability for a comparative case study analysis. All have varied utility ownership structures, social cultural conditions, political systems, energy policies, and current implementation levels of DE. From a governance perspective, all three cities have highly different electricity systems. Saskatoon owns its own electricity distribution, although the province in which it is located – Saskatchewan – operates the majority of the generation, transmission, and distribution (Hurlbert et al.; Hurlbert et al. 2019). In Luleå, the electricity utility is integrated into a competitive Nordic energy market that includes Sweden, Demark, Finland, and Norway. In Sweden, the majority of electricity generation comes from hydro (44.1%) and nuclear (40.5%) (IEA 2013). Anchorage Municipality operates a local utility for the downtown core, while two regional cooperatively owned utilities serve the remaining portions of the city and surrounding area. Unlike Sweden and Saskatchewan, Alaska does not have an integrated and centralized electricity system that serves the entire region; instead, there are competing utilities with regional interconnections across the Alaska Railbelt.[2] The three utilities in Anchorage operate as independent, vertically-integrated utilities, each with its own generation, transmission, and distribution networks within their respective districts.

4. Data collection and interview methods

A total of 60 interviews were conducted with actors involved in DE projects (government, non-for-project, business, utility, academic, and environmental activism). Along these lines, stratified sampling was used to allow for intersecting perspectives from interviewees (Robinson 2014). To ensure interviewee participation and comfort, interviews remained anonymous (Tilley, Woodthorpe 2011; Saunders, Kitzinger 2015; Lancaster 2017). A non-probabilistic sample size was used for each of the city case studies based on achieving data saturation. (Glaser, Strauss 1999; Fossey et al. 2002; Hennink et al. 2017). Saturation is the point at which no additional insights are garnered from the data collection (Baker et al. 2018). Although saturation is essential in qualitative research (Moore, 1995), it is a subjective form of analysis; therefore, scholars have pointed out that research needs to be transparent and specific about what is meant by saturation (Morse 1995; Guest et al. 2006; Hennink et al. 2017) and operationalize the saturation process (Malterud et al. 2016; Aldiabat, Le Navenec 2018). This saturation method includes provisions such as aim, sample specificity, use of theory, quality of dialogue, and analysis strategy as factors in determining sample size (Malterud et al. 2016). Table 2 outlines the details of the information power analysis that was conducted to reach sample size saturation.

[2] The Railbelt is a regional electrical grid that connects seven utilities in the most population region in Alaska from Fairbanks, to Anchorage, and the Kenai Peninsula. Three of the seven utilities serve the City of Anchorage: MEA, ML&P, and Chugach.

Table 2. Information power sample size saturation

Criteria	Details related to study	Saturation metric
Aim	**Broad**: To compare the sociotechnical conditions that contribute to innovative DE projects	Enough interviews were conducted to inform the overall aim of the research[1]
Sample Specificity	**Dense**: Actors are limited to those with knowledge or connection with energy projects in their respective city.	Include actors from multiple sectors (political, business, advocacy, etc) that represent the major components of the energy system of each case study[2]
Use of Theory	**Applied**: Results will be used to develop theory	Enough interviews were conducted to answer the research question
Quality of Dialogue	**Strong**: Interviewer is very knowledgeable on topic and with conducting interviews. On-site face-to-face interviews to be used.	Individual interviewees have no additional comments to share on the topic[3, 4, 5]
Analysis Strategy	**Cross-case**: This is a comparative study with three cities.	Enough interviews so that thematic analysis could be conducted between the case studies.

Notes:

1. Selection of participants was based on background research on their involvement with the local energy system and their suitability for the study aim.
2. A semi-structured interview guide was development in accordance with quality qualitative semi-structured interview methods of "(1) identifying the prerequisites for using semi-structured interviews; (2) retrieving and using previous knowledge; (3) formulating the preliminary semi-structured interview guide; (4) pilot testing the interview guide; and (5) presenting the complete semi-structured interview guide" (Kallio et al. 2016: 2961).
3. In the case that more information was needed to be shared than an additional interview was conducted with that participant or follow up questions were asked.
4. Face-to-face hour-long dialogues were used for the majority of the interviews. As well the majority of the interviews were conducted at the interviewees' place of work. All interviewees were provided an information sheet on the project prior to the interview so they could be appropriately prepared for the interview.
5. Prior to conducting the interviews in each of the case study cities, thorough background research was conducted. This included in-depth documents analysis of academic and non-academic literature including books, reports, council minutes, official government website entries, and news articles.

Prior to starting the research, it was determined that a target of 15 interview participants for each city would meet the saturation requirements. Although an interview target was established, achieving information power saturation was the goal. For instance, in Anchorage (n=32) the sample size was double that in Saskatoon (n=12) and Luleå (n=16) because it was more difficult to achieve saturation. To buttress interview saturation, contemporaneous notes and journaling were also used during the interview process to ensure key insights and gaps in knowledge were accounted for (Janesick 1999; Watt 2007; Ortlipp 2008; Annink 2016). I conducted month-long site visits to better understand the cultural contexts that may have impacts on the institutions, norms, and organizations of the cities.[3] Face-to-face hour-long dialogues were used for the majority of the interviews. Where face-to-face interviews were not at option, telephone interviews were used instead. Research on telephone interviews has demonstrated that they are an effective alternative to face-to-face interviews for data collection (Watt 2007; Holt 2010; Block, Erskine 2012; Schober 2018).

6. Results and analysis

I conducted a thematic analysis specific to governance considerations from the interviews, journal entries, and city specific academic and grey literature. From this analysis, I selected five governance dimensions that impact DE transitions in cities: utility market structure, multi-sector collaboration, decision-making capacity and autonomy, multilevel governance, and public perceptions of climate change.

6.1. Utility market structure

Each of the cities operated within various utility ownership structures, regulated or deregulated electric utility markets, which had implications for DE transitions. Luleå's electric utility competes within the Nordic energy system. Anchorage has three vertically integrated electric utilities, two cooperatively owned and one municipally owned. Saskatoon has both a municipally owned utility for a portion of the city connected to a larger monolith vertically integrated crown corporation that serves the province of Saskatchewan. Interviewees in all of the cities noted a variety of opportunities and challenges with their jurisdiction's utility structures.

Of the three cities, Luleå is the only one that must compete within a deregulated market. Although Luleå owns its local electrical distribution utility, it is integrated into the broader Nordic energy market, or the Nordic Synchronized Area. For local energy in the city, the market structure provides an assortment of benefits, one of which is the potential for deregulated markets to better manage the challenge of intermittency. The ability to sell electricity in peak generation times when local

[3] The lead researcher and author of this paper resides in Saskatoon.

demand is low increases the value of DE to the grid. An energy expert in Luleå noted that, “The reason why we can do the CHP is maybe that we can […] sell electricity on the grid” (Luleå Interview #10). The same interviewee noted that “it’s not that the city balances the power grid. They care about the district heating. That one they have to supply because district heating is local, but the power they sell to the spot market” (Luleå Interview #10). By selling electricity to the spot market, Luleå is able benefit from its overproduced electricity, allowing projects like Luleå’s CHP system to be viable. Within the Nordic Synchronized Area, hydropower and pumped hydro storage, located in Norway and Sweden can serve as storage to balance local intermittent DE projects.

Saskatoon and Saskatchewan have a traditional regulated market. Although there are peaks and valleys in the demand profile in Saskatchewan, there is no spot market or capacity market within the system that local energy projects can leverage. In the Saskatchewan context with its regulated market, the financial justification for self-generation in community and roof-top solar is different.[4] From the perspective of the electrical utility, DE can be antagonistic to its profitability and business model (Dolter, Boucher 2018). An energy expert in Saskatoon noted that there is a fundamental business challenge to the local utility to sell electricity with the current net metering program.

There’s absolutely no benefit to Light and Power [SL&P]. So, for every kilowatt solar panels that are installed, Light and Power [SL&P] loses money. So, with the production it does mean, so whatever’s coming on, whatever’s not used onsite and comes onto the grid through the net meter that does offset bulk power purchases. But it also eliminates that revenue opportunity for Light and Power [SL&P]. If you take the loss revenue opportunity and you subtract the avoided bulk power purchase, it’s still a significant net loss for every kilowatt of solar that comes on the grid (Saskatoon Interview # 9).

Similarly, another energy expert mentioned that there is an economic challenge to local energy development from the perspective of SL&P.

[4] A forthcoming paper will provide an analysis of the policy landscape and decision-making challenges from the perspective of the utility of self-generation programs in Saskatchewan.

> [I]t's not quite as clearly defined as their [SL&P] mandate to make money. And the mandate to make money for the utilities is somewhat in conflict with the mandate to do renewable energy projects because… they buy most of their electricity from SaskPower for pretty cheap (Saskatoon Interview #2).

One of the major issues for intermittent renewable energy in a regulated market is cross-subsidization. In fact, a report to council in Saskatoon from the local utility noted that, "The financial impact for each kilowatt of solar installed is estimated to be a reduction in revenue of $185.25 per year. With these programs doubling in size every two years, the financial impact continues to grow proportionally. The loss of revenue opportunity from the existing programs in 2017 was estimated at $92,625" (City of Saskatoon 2017).[5] A deregulated market structure for DE can create an economic environment that better manages the issues of cross-subsidization.

The utility landscape in Anchorage and Alaska is disjointed and, in some instances, dysfunctional. Whereas Luleå's jurisdictions are deregulated and interconnected and Saskatoon's are interconnected and regulated, Anchorage's are neither. Discussed widely during the interviews in Anchorage was the lack of cooperation between the utilities along the Railbelt and the need to move towards a consolidated model that rationalizes the transmission system discrepancies. A government official discussing the seven Railbelt utilities noted that,

> Each organization [Railbelt utility] grew up as a standalone organization, right? And then you operate them together. You look at it, well that's nuts. Well you would never have designed it that way if you just designed it altogether (Anchorage Interviewee #7).

The interviewee continued by arguing that, "there are significant savings to be had by operating this unit as one" despite the "disagreement between utilities" (Anchorage Interviewee #7). Because of the lack of cooperation between the

[5] The issue of solar cross-subsidization in Saskatchewan was analyzed in more depth by Dolter and Boucher (2018).

Railbelt[6] utilities in Alaska, there is overcapacity embedded within the entire system. Interviewees emphasizes that this lack of integration has resulted in overcapacity buildup that would otherwise be required if there was greater integration between the utilities (Anchorage Interviewees #2, 6, 7, 13, 14 17, and 24).

As it pertains to DE in Anchorage, a lack of integration between the utilities creates obstacles.

For instance, according to the Committee on Railbelt Operating and Reliability Standards "to the extent practical, interconnecting entities should not be allowed to degrade the performance or reliability" (The Intertie Management 2017). Reliability is challenged by the uptake of DE on the grid. A business leader in Anchorage noted that,

> The utilities for the longest time were not particularly friendly to the idea of somebody undermining their business case by reducing the amount of energy that they're purchasing from the utility. Now they're trying to kind of thread the needle and they recognize that their consumers will not accept that. So now they're trying to figure out what new technologies, how to do net metering more effectively, and then how to balance that with the cost of their existing grid. Because again, you know […] now you've got the consumer electric grid, which is residential, commercial and some industrial in anchorage. Okay. So, who's paying to maintain that grid? (Anchorage Interview #2).

Similarly, a representative from one of the utilities in Anchorage noted that,

> If there's a dip in the availability of wind because of a gust or because the wind falls off, it's harder for our system to absorb those fluctuations. And so, we then have to have more reserve capacity online. We have to have

[6] As of February of 2019, four of the Railbelt utilities, included all of the Anchorage utilities made a request to the RCA for the formation of a transmission utility (Company 2019).

> more fossil generation. How we handle it, right now, we have more fossil generation spinning, which means that the economics aren't as good because we still have to be burning fuel (Anchorage Interview #13).

In response to the growing concern of the transmission system in Alaska, the Regulatory Commission of Alaska (RCA) has requested that the Railbelt develop a model in which the utilities increase cooperation. This is not a new discussion and there has been a longstanding debate between the seven utilities in Alaska connected in the Railbelt on models for integration. As early as 1998, a report prepared for the Alaska Public Utilities Commission highlighted the importance of power pooling and central dispatching (Alaska Public Utilities Commission 1998). Interviewees also emphasized that integration would allow Anchorage to sell its excess and relatively inexpensive electricity to Fairbanks, also connected to the Railbelt, which is experiencing higher electricity costs. Integration of the utilities would allow for greater penetration of DE on the gird in Anchorage.

6.2 Multi-sector Cooperation

Sweden, Saskatchewan, and Alaska have differing approaches to multi-sector cooperation and these differences impact local DE projects in Luleå, Saskatoon, and Anchorage. According to the interviewees, Luleå had a high level of multi-sector cooperation between public and private entities, whereas Anchorage and Saskatoon had a low level of integration.

The extent to which there was multi-sector cooperation was a source of success for projects in Luleå. Interviewees attributed their cooperation to the success of their DE projects. A political leader in Luleå emphasized that this integration has impacted the political scene in the city and opportunities for local energy innovation.

> The steel production is the backbone of the city [...] Everybody who lives in the city, and especially we who are in the ruling party, understands the importance of the industry and the need to find the collaboration with the industry in different ways. So I think that over the years, the solutions that have been made that are many of them, before I was born or before I

> was active in politics, they are made of the, of the mutual trust that the city and, and the industry has an extremely strong link between each other and the necessity to understand the work together (Luleå Interview #15).

A business leader in Luleå similarly emphasized how production processes are adapted to adjust to heating demand profiles in the city. As well, this business leader discussed the importance of maintaining steady production for the city during the coldest days in the winter to ensure that the city's district heating system has enough heat to continue operations.

> We have for many reasons to avoid [having] stops in production if it's very cold outside. But one of the reasons is that we really need energy to the heating system for the town [Luleå] for when it's cold outside. There are other reasons. […There is a] risk of freezing up parts of the plant here if it's too cold outside and we have a stop. We also have to think of […] supply[ing] the district heating (Luleå Interview #12).

Long-term agreements were often part of the multi-sector cooperation in Luleå. An energy expert in Luleå emphasized that long-term agreements between the public and private sector were important for the success of the existing district heating network that exists in the city.

> The fact that we did compile a really long-term agreement early on in the process when it comes to the price of the waste gas […] they put a very low price to begin with on the waste gas. Because [it is a] local energy company, we're supposed to be given the opportunity to invest in the district heating network. They had to allow this because there were no district heating network. There were small networks in the new built housing areas and perhaps here in there, but they had to build all those together and the steelworks found that reasonable (Luleå Interview #8).

Whereas Luleå had a managerial approach to its integration, Anchorage and Saskatoon had a more facilitation role. This is not to say that there are no partnerships in Saskatoon and Anchorage, but the breath and the long-term nature of the partnerships are not as prevalent. To this point, a business leader in Anchorage noted that, "the energy base of Anchorage and the region has kind of grown up organically over time without really any significant long-term planning until the last 20 years" (Anchorage Interview #2). What has resulted from this has been a more siloed approach. Similarly, in Saskatoon, the interconnections between the public and private sector are more limited. Recently, however, there have been notable projects Saskatoon and Anchorage – the Fire Island Wind project in Anchorage and the SES Community Solar project are both such examples.

Although Luleå has had much success with multi-sector cooperation, there was a perception amongst interviewees that there were few new actors entering the system. When asked if there were new actors in the energy system in their city in the last 10 years, interviewees in Saskatoon and Anchorage said that there were many new actors while most interviewees in Luleå mentioned that there were none in their city. In Saskatoon and Anchorage, interviews emphasized that there were many new businesses in all areas of the energy system. This contrasted Luleå where there was little mentioned of new businesses.

6.3. Decision making capacity and autonomy

Each of the cities have different levels of autonomy relative to their decision making. Anchorage has a strong mayoral form government, Saskatoon has less mayoral powers with a stronger council, and Luleå has a cabinet-based government, which operates as a party-based legislative municipal assembly.[7] Despite the strong mayoral form of government in Anchorage, local decision making on energy is spread among the three utilities through membership cooperative boards. This gives the cooperative utility board much autonomy to make decisions, which was highlighted as an opportunity. On the topic of this co-op system, a political leader in

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[7] The mayoral form distinction exists primarily in the United States. Cities in Sweden and Canada don't have this distinction.

Anchorage noted the following when comparing the ML&P (the municipally owned utility) and the utility co-ops:

> It [ML&P] is run like a separate individual utility and in fact it has profit requirements. It has to generate a certain amount of value for the municipality. The co-op model has a lower requirement and in fact the co-op model for energy production if it's done properly the intent there is to keep prices low. That's actually its core mission is to generate power as cost effectively as possible. So, it's that non-profit model but with a strong value on keeping the price proper […and] competitive (Anchorage Interview #1).

A business leader in Anchorage emphasized the decision-making autonomy of Anchorage and how the city is motivated to move forward with energy efficiency regulation.

> The state has no authority to any significant degree. They grant a broad set of brush stroke authorities that a city can adopt, but they leave it to the cities to choose what parts that they're going to adopt. Plus, there are national standards that are related to insurance that have to be adopted and finance that have to be adopted. So, you've got a fairly complex set of things that are influencing a city policy on building codes and energy efficiency. That's an interesting interaction. Well part of it is the city's got a motivation in this and the fact that they want their citizens to have more money in their pocket books so that there'll be a little more willing to. It also increases the value of the homes so your tax base goes up (Anchorage Interview #2).

Ownership over the local utility was emphasized as an opportunity for local DE project. A political leader in Saskatoon on the role of SL&P noted that,

> I think there's a risk by us not being out in front providing opportunities for people to do things like solar because we're moving in that way. And I think

> if we’re not part of that conversation, then we lose out on all of that revenue as well (Saskatoon Interview #3).

6.4. Multilevel governance

The impact of policies from state, provincial, federal, or national government was emphasized as important by the interviewees in each of the cities. In Saskatoon and Anchorage cities are creations of the province or state, respectively. Therefore, the federal governments in Canada and the United States have a limited direct impact on city autonomy. This contrasts with Luleå, where cities are with the jurisdiction of the national government. Therefore, the national government of Sweden has much greater impact on cities. There are a number of ways that higher level governments can support DE. However, supportive policies were perceived as less or more stable in each of the jurisdictions, which impacted decisions on DE projects.

Whereas Luleå has been a paragon of policy stability and support, the dynamic in Anchorage was one of a fluctuating policy environment. In the state of Alaska, a large portion of public revenues are from the natural resources sector. Since 2008, the price of oil has fallen and so to have the revenues associated with that support (Alaska Department of Revenue 2017).

In Anchorage for instance, there is financial support from higher level governments for tax credits. In particular, part of the justification for the energy efficiency and renewable energy projects for the Cook Inlet Housing Authority support through the Greater Opportunity for Affordable Living (GOAL) program. The GOAL program is applied based competitive process between developers of low to medium income housing that is administered by the Alaska Housing Finance Corporation (AHFC). As part of the selection process, points are allocated for the provisioning of conservation and renewable energy initiatives (Alaska Housing Finance Corporation 2018). An interviewee noted that, “One of the reasons why we do alternative energy is to get points to build these projects, right? Because our end goal in this whole thing is to create homes for people. So, to do that, we got a win money. And to do that we’ve got to do alternative energy because we get points for it” (Anchorage Interview #21). The same interviewee emphasized that the environment for funding has become increasingly competitive and funds are more difficult to receive.

6.5. Public perceptions of climate change

Public support for environmental initiatives and norms around climate change differed in the jurisdictions of each of the cities. At the city level, there were targets for emissions reductions under the Compact of Mayors. Public support for climate change within a jurisdiction can have positive impacts on the uptake of local DE projects. In the interviews, climate change was mentioned as a major driver in Luleå but not in Anchorage and Saskatoon.

When discussing the steel business and the CHP system in Luleå, a business leader emphasized that the steel industry is strongly motivated to reduce its emissions.

> Not only from the government but […] the climate discussions […] there is of course the pressure to reduce the climate impacts. And, as we are one of the major emitters of carbon dioxide in Sweden to reach the goals that are set up by the politicians we [the steel industry] have to do something (Luleå Interview #12).

A political leader in Luleå mentioned that there is political support for spending public funds on climate change, “I think that we have to take the tax money […] to help climate change so that our generations after us could stay [and] live here on this planet (Luleå Interview #7). These sentiments about the importance of climate change were heard throughout the interviews in Luleå. Nearly every interviewee mentioned the importance of climate change. This is also consistent with survey data in Sweden, which shows that there is widespread support for combating climate change (Gullers Grupp 2018).

In contrast, a lack of broad public support was mentioned as a major barrier to DE projects in Anchorage and Saskatoon. A representative from the environmental community in Saskatoon mentioned that a lack of leadership on climate change makes it difficult for the city to move forward with local energy initiatives.

> Unfortunately, none of the political parties are doing a ton, but in Saskatchewan in particular the need to oppose anything the federal government is doing, the need to […] deny climate change issues leads to no leadership from the province. And so, in terms of energy generation, energy conservation […] there's very little happening. And then from the municipal point of view, I think one of the resistances is the amount of work it could take for the city to do something on their own without the support from the province. So, for example, building code, the city municipalities can set their own building code, but Saskatoon's like, oh are you kidding me? The amount of work to have our own building codes separate from the province is just kind of too much. And then they also worry about things like people building outside of the city instead of in the city to save a few bucks on construction (Saskatoon Interview #2).

Climate change was minimally mentioned in Anchorage. Of the 32 interviews, only two talked about the attitudes towards and worries about climate change as impacting DE in the city. This contrasts with interviews in Luleå, where nearly all interviewees emphasized the importance of climate change. One interviewee from Anchorage, a representative for one of the utilities, discussed the importance of focusing on fuel savings instead of climate change to garner more support.

> There're definitely people in the state that don't agree with and believe climate change is happening. So, they don't want to pay more for their electricity around renewables. But if we can all agree burning less as is good, then everybody, no matter what their motivation is served. Whether it's cost, whether it's climate change, whether it's energy security, burning less fuel is good (Anchorage Interview #13).

7. Discussion

The purpose of this paper is to understand the governance challenges for DE transitions in cities. Based on interview data and grey literature review, the results below highlight the impacts of the five governance dimensions: utility market structure, multi-sector cooperation, decision-making autonomy and capacity, multilevel governance, and public perceptions on climate change. These governance dimensions and their impact on acceleration DE transitions will be explored in this section.

7.1. Utility market structure

Large technological systems like the electricity sector tend to move incrementally and are resistant to potentially disruptive innovations (Hughes 1983; Markard, Truffer 2006). However, the recent trend towards the liberalization and deregulation of electric markets have fundamentally restructured the operations of utilities, as in the case of Sweden. Market deregulation can be supportive to DE such as providing generation options and a market for selling local power (Carley 2009; Muratori et al. 2014). Deregulation of the energy markets has also been shown to reduce R&D funding for innovative energy technologies (Dooley 1998). Deregulated markets can permit new competition and differentiation of firms. Delmas et al have found that this differentiation can result in consumer preference for 'green' energy options, however this result is contingent a public preference for these energy options (Delmas et al. 2007). The results from the interviews also suggest that utility market structure can impact the opportunities for DE projects (see Table 3). Consistent with the literature, there are both opportunities and challenges with the deregulation of the electric market.

More important than the market type is the transmission functionality. In Anchorage, the lack coordination and oversight of the transmission system drew significant challenges for DE. Each electric utility in Anchorage is vertically integrated with their own transmission system. This creates a collective action problem known as a prisoner's dilemma (Hardin 1971). Voluntary cooperation of the transmission system between the utilities are disincentivized at the individual level to the detriment of all of the utilities on the Railbelt collectively. In other words, the benefits to act in one's economic self-interest are outweighed by the uncertainty that the other actors using this common pool, the transmission system, may defect and act in their perceived self-interest. This theory presumes that actors within this system operate solely within a rational economic cost-optimization model. Despite the clear logic of this theory, empirical and human evolutionary evidence suggests that actors are often inclined to cooperate and trust each other in such instances (Ostrom 2000). Although it would appear that the utilities operated only within their self-interest, there have been decades long attempt by the Railbelt utilities to voluntarily cooperate and otherwise create a framework that would more efficiently coordinate the transmission system. For instance, there are already utilities on the Railbelt engaged in a loose power pool arrangement and have shared purchased agreements, which are managed and governed by the intertie agreement and the intertie management committee (Amended and Restated Alaska Intertie Agreement 2011; The Intertie Management 2017). This agreement, among others, is a start but not enough to facilitate a sufficient coordination of the transmission system to support a broader transition to DE. Given the longstanding inability of the utilities to cooperate, a combination of oversight by the state and self-organization would be necessary.

Table 3. Competitive utility market structure

	Luleå	**Saskatoon**	**Anchorage**
Market type	Deregulated	Regulated	Regulated
Transmission functionality	Integrated	Integrated	Disjointed

7.2. Multi-sector cooperation

Emphasized by the interviewees in Luleå was that the success of their DE projects can be attributed to their cooperative approach (see Table 4). Long-term agreements and cooperation with the private sector, multiple levels of government, and the academy facilitated robust multi-sector cooperation. As a result, the system in Luleå is a large system of well entrenched institutional actors. This contrasted to Saskatoon and Anchorage where there was moderate multi-sector cooperation and siloed institutions. However, Saskatoon and Anchorage had many more new actors in the DE arena in the last 10 years. Perhaps an offset to the lack of cooperation in Anchorage and Saskatoon was a surge in activity of new actors. Largely non-existent in Luleå, these actors were motivated to solve the principal-agent collective action problem that existed within their siloed sectors. There was a perceived benefit to be garnered by cooperating between public-private and public-public entities, and these actors were motived to build this capacity within their city.

Table 4. Comparative institutional integration

	Luleå	**Saskatoon**	**Anchorage**
Multi-sector cooperation	High	Moderate	Moderate
New actors	Low	High	High

But what can explain the lack of new actors in Luleå and the emergence of new actors in Anchorage and Saskatoon? Actors within a highly cooperative system as with Luleå create co-dependence and have increased overall actors (Emerson 1962; Whetten, Rogers 1982). In fact, cooperation can create an institutional structure that affords opportunity and power to those within the cooperative network – and not to those outside (Moe 2005). The result of these interactions are stability of the system and a resistance to the emergence of new actors. Even facing failure, these interdependent actors persist (Klijn, Teisman 2003). This was seen in Luleå with the failure of their waste-to-gas project. Actors on the periphery as well as those directly involved with the project recognized that this project was a failure. This did not stop the project to continue despite revenue losses for a decade and alternatives (i.e. electric mobility) that would pose further risk to the project. This may explain the lack of actors in Luleå and the larger number of actors in Anchorage and Saskatoon.

Another explanation for the lack of new actors would be that the system in Luleå functions well and new actors may see less value in contributing in such a system – there is strong social self-organization in Luleå. My interviews and interactions with the environmental community in Luleå would support this claim. By virtue of their role in society, environmental activists are quick to point out flaws within systems and suggest alternatives. In Luleå, the environmental community spent little by way of critiquing Luleå's performance, which was a stark contrast to their counterparts in Saskatoon and Anchorage. The environmental community in Luleå focused their efforts on mining operations in the northern region of Sweden. When asked about the city of Luleå, they noted that the city was moving in the right direction. The perception that the city was progressing was supported by all interviewees in Luleå.

These two explanations can be mutually supportive. High levels of multi-sector cooperation could both facilitate the success of progress in the city while also leading to networks of interdependent actors resistant to new entrants. And the success of the network to achieve its goals leads in turn to new actors not seeing a benefit to disrupt the system. In this case, the success of the cooperative approach leads to an inherent weakness, albeit one that may not be overly concerning given the progress made in Luleå.

7.3. Decision-making capacity and autonomy

The three cities have varying degrees of decision-making capacity and autonomy. Swedish cities have considerable resources at their disposal, relative to their Canadian and American counterparts. Since the 1980s, the Swedish government has promoted increased local economic development which has afforded municipalities more responsibility over business development and innovation. The general differences of decision-making capacity and autonomy is summarized in Table 5. What can be said from this general comparison is that autonomy and capacity need to meet in order facilitate a DE transition. The Anchorage case demonstrates that autonomy alone without the underpinning capacity is not sufficient – which was evident from the interviewee's responses in Anchorage.

The ability for local entities to be involved in decision-making and have the capacity to execute DE projects is a strategy, purposeful or not, to mitigate the challenges of complexity. DE transitions are complex and how they emerge is diverse and locally specific. Local energy projects are a feature of their geography, infrastructure, and history. In Luleå, the district heating system is fed as a by-product from the local steel plant, the Swedish publicly owned company SSAB (Petrini et al. 2004). There are further efficiencies within the system through a CHP system that also provides electricity to the local electric utility, Luleå Energi. Actors within the city would likely be the most capable facilitators to leverage their local attributes of these complex system interactions. This analysis is also consistent with recent comparative work on local energy transitions in towns. Bayulgen has pointed that municipal government structure has limited impact as a driver but bureaucratic capacity is a determinative driver (Bayulgen 2020).

Table 5. Comparative decision-making capacity and autonomy

	Luleå	**Saskatoon**	**Anchorage**
Capacity	High	Moderate	Low
Autonomy	Moderate	Moderate	High

To be clear, decision-making capacity and autonomy are alone not enough – they are factors. It would be an over simplification to suggest otherwise. In fact, research on collaboration between industry and municipalities in Sweden emphasizes that their success relies heavily on the people involved in the projects (Grönkvist, Sandberg 2006), which was in particular the case in Luleå (Söderholm 2018). But again, the foundation of this success in contingent on having both autonomy and capacity in place.

7.4. Multilevel governance

With multilevel governance, the implications are somewhat counterintuitive. On the one hand, policy stability and support from higher level governments can create a foundation for DE transitions to occur. Actors and institutions can plan and build the necessary capacity to move objectives forward. On the other hand, a lack of policy stability and fluctuating support from higher level government can create a window of opportunity for DE transitions. The results from this study suggest that support from higher-level government is important but not essential. In Anchorage, actors respond quickly to policy windows because there is uncertainty on the stability of newly adopted policies in Alaska, given the natural resource market fluctuations and state level decision-making.

Table 6. Comparative multilevel governance

	Luleå	**Saskatoon**	**Anchorage**
Policy stability	High	Moderate	Low
Support from higher-level governments	High	Moderate	Moderate

A potential explanation is that windows of opportunity can create openings for disruptive innovations to occur (Geels 2002, 2014; Geels et al. 2017). These windows of opportunity need to be severe and urgent enough to create a focusing event amongst actors (Kingdon 1984; Brikland 1998). The policy instability in Anchorage created a response by groups of actors wanting to fill this gap. The Renewable Energy Alaska Project (REAP), for instance, is a highly innovative and prominent organization that has had strong impact on public policy in the city and state. These policy entrepreneurs[8] are often important actors in moving forward innovative policy (Roberts, King 1991; Mintrom 1997; Christopoulos 2015). Amongst other accomplishments, REAP played a key role with the establishment of Bill 162 (which established the Renewable Energy Grant Fund), Bill 289 (which provided $360 USD towards energy efficiency), and Bill 306 (which included a 50% by 2025 renewable energy target). These changes at the state level had impacts on Anchorage's energy system and were a function of the political and policy ebbs and flows.

7.5. Public perceptions on climate change

The interviewees concern on the public perception of climate change (see Table 7) and the impact this has on policy is consistent with the literature. Similar to the results, perceptions of climate change vary from country-to-country (Wolf, Moser

[8] Policy entrepreneurs, "use several activities to promote their ideas. These include identifying problems, shaping the terms of policy debates, networking in policy circles, and building coalitions" (Mintrom, Vergari 1996: 423).

2011). In Sweden, there is large public support for climate change (Wibeck 2014). In both Alaska and Saskatchewan public support is moderate to low (Mildenberger et al. 2016).

Table 7. Comparative public perceptions on climate chance

	Luleå	**Saskatoon**	**Anchorage**
Public perception	High	Moderate	Low

Public acceptance of climate change can impact the governance of DE transitions. In Anchorage in particular, there were attempts by project proponents to reframe projects in terms of economic benefits, which changed the justification for projects to move forward. Whereas in Luleå, great emphasis was placed on emissions reductions benefits of DE projects as well as economic considerations.

Public support for climate change can motivate support for climate policies. For instance, research suggests that support for climate policy varies with type of policy (Shwom et al. 2010; Rhodes et al. 2017) and how the issues of climate change are framed (Nisbet 2009; Shwom et al. 2010; Mccright et al. 2016; Feldman, Hart 2018; Stecula, Merkley 2019). Part of the reason this occurs is because people can psychologically resistant to climate change (Swim et al. 2011; Van Boven et al. 2018) and motivated by a particular political ideology (Mccright, Dunlap 2011; Van Boven et al. 2018).

8. Conclusion

Cities do not operate as silos or islands. They are integrated within a jurisdictional context that has governance implications, which impact how DE projects unfold and the dynamics in which they are situated. As the results of this study demonstrate, the success of DE projects care be impacted by cities' governance differences. The jurisdictions from which cities reside have political, cultural, legal, and policy practices and norms that can enable or hinder DE transitions. This paper asked the question: How does governance impact the acceleration of decentralized energy transitions in cities? To investigate this question, this paper compared five governance dimensions with their impact on DE transitions in cities: 1) utility market structure, (2) multi-sector collaboration, (3) decision-making capacity and autonomy, (4) multilevel governance, and (5) public perceptions of climate change. The results from this research showed that there are important determining factors within the governance dimensions. Public perception of climate change, supportive and stable government interventions, multi-sector collaboration, and local capacity are important determining factors to DE transitions. The results also showed that there are elements of the five governance dimensions that are not a determining factor in all cases, such as local autonomy, utility ownership structure, new actors.

This paper began by suggesting that governance hierarchies, markets, and networks have all been used to explain DE innovations and asked the question, "How does governance impact decentralized energy transitions in cities?". Upon starting this research project, it was hypothesized that networked governance would be the preferred arrangement to facilitate DE transitions. Given the stylized similarity of decentralization and networks, as well as the mainstream trend towards the "internet of things", I perceived that there may be alignment. However, my investigation into this topic has illuminated deeper and more nuanced insights. It is the case that networked governance is synergistic with DE transitions. The multi-sector collaboration in Luleå and the policy communities in Saskatoon and Anchorage show that these networks of actors can motivate DE transitions. It is also the case, though, that direct support from public institutions was important. In all cities, in fact, there was financial and managerial support for innovative DE projects and interviewees consistently emphasized that much of this support was necessary as it reduced the upfront financial burden of their projects. And finally, actors and organizations were able to capitalize on markets to move DE projects forward, the utility market structure in Luleå as the obvious example. Actors in Anchorage, particularly in the business and advocacy organizations, were able to deliver innovative DE projects despite a lack of direction from higher-level governments and weak actor networks.

In answering this question of governance and DE more precisely, I would bring this discussion back to the governance work from two decades ago. It was Powell who challenged the notion that governance falls within a continuum between a market and a hierarchy and suggested that governance can also fall within a third category: a network (Powell 1990). He observed that some sectors in society function well because of their network governance structure. His work laid the foundation for future research on network governance and a deeper appreciation of less formal organizational interactions and the power of human reciprocity. Powell's astute observation that we should consider a multitude of governance arrangements is correct. However, it could be expanded. His work focused on organizational sectors which is limited for an analysis involving multi-sector arenas like DE transitions. My observations have shown that interactions between governance dimensions may be just as relevant as the three categories of governance. There is a multiplicity of governance arrangements that can drive or hinder DE transitions. This work has outlined five governance dimensions but there are likely more. But the more promising insight is that the interactions of these governance dimensions may offer a more powerful explanation for DE transitions.

A revised focus on governance interactions can lead to further questioning. For instance, to what extent does the interaction between public perceptions of climate change and multi-sector collaboration facilitate DE transitions? Are policy communities more effective at facilitating DE transitions in regulated or deregulated utility markets? How much does city level autonomy and capacity impact DE transitions when there is strong support from higher-level governments? These questions, among others, that focus on the interactions of governance dimensions can be explored to offer further insights into the conditions that facilitate DE transitions.

I must end with a note on the limitations of this work. This research involved only three cases and therefore it is difficult to make generalizable claims. Ragin has presented a caveat for such instances, arguing that "case-oriented researchers are always open to the charge that their findings are specific to the few cases they examine, and when they do make broad comparisons and attempt to generalize, they often are accused of letting their favorite cases shape or at least color their generalizations” (Ragin 2014: ix). Although I was cautious not to fall victim to Ragin’s caveat of favouritism bias, there were a limited number of cases and therefore the major claims in this analysis leave it open to understandable scrutiny. The claims presented in this analysis should be considered a starting place for further inquiry on the question of comparative research on urban energy transitions and governance.

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Analyzing regulatory framework for carbon capture and storage (CCS) technology development: A case study approach

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Abstract:

Aim: This article provides insight into the portfolio of regulations advancing Carbon Capture and Storage (CCS) deployment. Using a taxonomy of policy portfolio tools adapted for regulations specific to CCS, this research identifies regulatory gaps as well as supports for CCS projects.

Design / Research methods: Through a case study approach, this article analyzes the regulatory provisions in six jurisdictions (Texas, North Dakota, the U.S, Saskatchewan, Alberta and Canada) which have a successful CCS facility. Analyzing the provisions and content of regulations in these jurisdictions, this article highlights regulatory supports or areas of gaps for CCS projects in each jurisdiction.

Conclusions / findings: There is no uniform definition or categorization of CO_2 as a hazard, waste, pollutant or commodity across jurisdictions. This has serious impact on CO_2 transport, especially across jurisdictions. It also impacts the administration of storage systems for CCS facilities. Regulations focusing primarily on technical aspects of CCS including capture, transport, and liability predominate while there are less regulatory provisions for the financial aspects of CCS technology as well as public engagement and support. While capital grants and emission and tax credits are the predominant financial issues covered in regulations, contract for differences, streamlining emission trading across borders and enhancing cooperation and multilevel engagement in CCS warrant more attention.

Originality / value of the article: Many scenarios to maintain global warming below 2 degrees Celsius require combinations of new technology including CCS. The focus on CCS cost as a barrier to deployment overshadows the needs for regulatory support as a means of reducing uncertainties and de-risking CCS investments.

Keywords: Carbon Capture and Storage (CCS), policy portfolio, regulatory framework, public engagement

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1. Introduction

In the last decade, carbon capture and storage (CCS) technology has evolved in several respects. In this period, in comparison with other greenhouse gas (GHG) emissions abatement technologies and options, CCS has emerged as one of few technologies capable of achieving GHG emissions abatement targets in the industrial sector as well as conventional fossil fuel power generation plants (Sawyer et al. 2008; US Department of Energy 2016; IEA 2019). But although it is now generally agreed that CCS technology can play a critical role in carbon abatement efforts in the industrial sector (Sawyer et al. 2008; US Department of Energy 2016; IEA 2019), the increase in the deployment of renewables have challenged its usefulness in the power sector. On this point, findings from the International Energy Agency (IEA) (2017) are instructive: while renewables have increased their share of global energy generation, increase in demand and consumption of fossil fuels, especially from the developing world, is eroding gains made in terms of GHG emissions reduction. In other words, dependence on fossil fuel will not slow down in the short term.

Four factors – global economic growth fueled by industrialization; an increase in global energy demand and consumption, lower fossil fuel prices and weaker energy efficiency outcomes; and the suitability of CCS technology in industrial applications – has made CCS an important tool in any effort to cut GHG emissions, especially at the rate and scale required (IEA 2018a, 2018b). Hence, many climate mitigation scenarios to limit our world to 450 ppm of carbon in the atmosphere and maintain global warming below 2 degrees Celsius now rely on a combination of new technologies including CCS (Edelenbosch et al. 2016; Popp et al. 2014, 2017; Koelbl 2014; Scott et al. 2004; den Elzen 2008), renewable, and to a lesser extent nuclear (Tavoni et al. 2012), although there are contrary opinions (de Coninck et al. 2014). Several authors argue that carbon emissions will have to be phased out at unprecedented levels unless CCS and bio-energy CCS (BECCS) are utilized (Blanford et al. 2014; Kanudia et al. 2014). BECCS utilizes biodegradable plant materials as feedstock in producing energy. Applying CCS technology to bioenergy production (BECCS) further reduces the level of emissions in the energy system. In the energy and transportation sectors, many future scenarios widely use BECCS (Edelenbosch et al. 2016; Riahi et al. 2017; van Vuuren et al. 2016). While conventional CCS technology (that is, CCS technology in fossil fuel plants) has been demonstrated at commercial scale, BECCS has had one small-scale demonstration facility (Kemper 2015).

Successful CCS development has been sparse, and its deployment far less than anticipated when the Intergovernmental Panel on Climate Change (IPCC) endorsed it as one of several technologies supporting a lower carbon future (Choptiany et al. 2014). Many consider CCS technology as an emerging, new technology of which public acceptance has been at issue (Markusson et al. 2011; Sanchez, Kammen 2016) and a barrier to implementation. Also, the cost of developing CCS technology at commercial scale has been seen by many as challenging the case for its use (World Resource Institute 2011; Napp et al. 2014; Budinis et al. 2018). CCS deployment may be advanced by policies establishing a carbon price and or market, but such policies need regulations as foundations. There has been little discussion of CCS regulations in the literature. Using a taxonomy of policy portfolio tools adapted for regulations specific to CCS, this research identifies regulatory gaps as well as supports for CCS projects.

1.1. Regulations – why important for CCS development

Regulations are grand statements providing contexts for action. Also, they define when and how to act; are often the spine and structure which ground action in relation to a defined objective. Without regulations, certainty becomes quite difficult to ascertain. Therefore, regulations provide some measure of guaranty by reducing uncertainty. As with other issues of social, economic and political relevance, CCS requires such solid foundations to guarantee certainty in action and in outcomes. Hence, in relation to CCS technology, the IRGC (2008) stated: "Large-scale CCS deployment will require the creation of a regime to manage risks and supporting policies to facilitate technology investment" and it believes that developing supporting regulations play an important role in that.

Further, regulations help to ensure that policies and actions on CCS technology development do not automatically follow the political circle. This is emphasized as important by the Global CCS Institute (2017: 36), saying: "securing policy certainty via a government commitment that has been demonstrated to extend beyond political cycles and to be resilient to conflicting political demands" is crucial for projects that have long term development timelines. This leads to yet another important point: regulations form the bedrock on which policies are built.[1]

Interestingly, in Saskatchewan for example, the deployment of CCS technology was advanced without a CCS specific regulation. This highlights the unique status of CCS as a technology in relation to regulations: as an integrated technology, it is new, but the various components making up the CCS technology chain currently exist and may already be covered by existing regulations. So, in Saskatchewan, the province deployed CCS technology by relying on regulations supporting its component parts rather than creating CCS specific technologies.

Saskatchewan was first-mover case, being the first commercial scale post-combustion CCS plant in the world. From a regulatory standpoint, Saskatchewan's first-mover CCS project provides useful context for gauging what is required, what works and how to improve current regulatory systems meant to accelerate CCS deployments in other places in the world. So, while the Saskatchewan case demonstrates one way to speed up CCS deployment by bypassing the perpetual winding legislative loops associated with developing new regulations, the novelty of CCS in its form as an integrated technology suggests that new challenges, risks, and uncertainties that old regulations do not adequately make provisions for may arise. Also, as CCS technology matures, the overall regulatory architecture underpinning it should understandably evolve, necessitating revisions. Thus, there is a need to review the current portfolio of regulations of CCS technology, especially now that its deployment needs to be increased. In this article, we have adapted the policy implementation taxonomy toolbox for reviewing policies as developed by Howlett (2019) as a framework for reviewing regulations governing CCS development.

[1] In the literature, 'regulations' and 'policies' are sometimes used interchangeably or even together. In this article, they are distinct. Regulations, as used in this article, are legally binding pieces of legislations advanced by state and its institutions to support specific goals. These are different from policies which are the means for achieving the objectives in the regulations.

1.2. Policy implementation tool taxonomy

The policy implementation tool taxonomy was developed to explain what types of policy instruments governments choose when tackling policy problems and why. The relevance of this question is in the fact that although there is usually a wider range of instrument options to choose from, governments always seem to choose from a limited set of options Howlett (2019). One reason for this is that the choice of policy instrument selected is related to the mode of governance in the state. Another, and closely related to this, is that the choice of policy instrument is a function of the "resources governments have at their disposal in developing the means to attain policy objectives" (Howlett 2009: 81). These resources which Howlett (2019) groups into the following categories: organization, authority, treasure and information form the policy implementation taxonomy (see Figure 1 below).

Figure 1. Policy portfolio implementation tool taxonomy

	Governing Resource			
	Information	Authority	Treasure	Organization
Substance	Advice	Licenses	Subsidies	Bureaucracies
	Training	User charges	Grants	Public enterprises
	Reporting	Regulation	Loans	Quangos
	Education	Self-regulation	Tax expenditures	
	Advertising Surveys	Vouchers Quotas	Program funding	
Purpose				
Process	Information-suppression (Censorship)	Advisory group creation	Interest-group funding	Administrative re-organization
	Information- release (Access to Information)	Interest group or party bans	Campaign funding	Administrative delay and obfuscation
		Denial of access	Denial of funding	

Source: Howlett (2019).

Although Howlett's policy implementation tool taxonomy was created in the context of policies and not regulations, in this study we have adapted it based on the argument advanced already that policies are developed based on regulations. For example, when governments develop policies that sanction certain actions or drive actions through coercion, they are using their *authority* as a resource. However, implicit in that process is the assumption that the policies are backed by regulations that spell out consequences for acting in support or in opposition to the government's ability to meet its expected objective. This underlying logic means therefore that regulations can very well be categorized along the same lines as the policy taxonomy. Thus, as shown in Table 1 below, this study adapts the policy implementation tool taxonomy by merging the authority and organizational categories. The authority category, according to Howlett (2019), involve the use of coercive force by government. This can be achieved by the government through compliance monitoring by its bureaucracy (according to Howlett, the bureaucracy represents the government's organizational resource). Therefore, we conclude that organizational resources work to enforce authority.

In the following section we discuss how CCS regulations and the issues they cover map into this framework.

2. Method

This study is explorative in scope and is based on a case study research design. Two states (in the United States), and two provinces (in Canada) with successful CCS plants, and their associated federal jurisdictions (United States and Canada) were examined, for a total of six jurisdictions.

The study was advanced in two stages. The first stage involved the identification of issues or challenges facing CCS technology in the literature. This stage relied on secondary data which it collected using a systematic literature review and then followed by a content analysis. Databases such as SCOPUS and Google Scholar were accessed and searched for published peer-reviewed articles. For this step, search phrases used included: “CCS regulation,” “CCS policy issues,” “CCS and Saskatchewan,” “CCS and Texas,” “CCS and North Dakota,” “CCS and Alberta,” “CCS policy,” and “future CCS development.” Once articles are found containing discussions of issues requiring regulation, they are included in a database on NVivo software (for qualitative analysis). A search of other relevant articles was done in the reference section of selected articles to find more articles. The International CCS Knowledge Centre provided access to grey literature from its own network of mostly transnational organizations involved with CCS technology, including the International Energy Agency (IEA), the Global CCS Institute, and the United Nations Framework Convention on Climate Change (UNFCCC). Together, a total of 117 articles discussing issues associated with CCS technology, including barriers and policy actions were found and included in the study database on NVivo. The articlesselected we analyzed on NVivo to identify key issues related to CCS technology requiring regulatory support. These issues were categorized following the policy implementation tool taxonomy framework by Howlett (2019).

The second stage involved a content analysis of existing regulations in the six jurisdictions (Canada (Federal), Alberta, Saskatchewan, the U.S (Federal), Texas and North Dakota). Some of the articles located in step one, referred to specific CCS regulations in different countries of the world, but most regulations were identified and collected by searching directly in parliamentary databases of the target jurisdictions. A total of 76 existing regulations were used for the analysis after exclusion criteria was applied. These regulations were thematically analyzed based on the developed policy implementation tool taxonomy framework to reveal aspects of CCS technology that are currently covered as well as areas where there is a gap in regulatory coverage.

All materials collected (both for the literature review and the analysis of regulations) were analyzed using NVivo software. The issues found in the literature were operationalized on NVivo as cases. Each case represents an aspect or activity in a typical CCS chain that has been identified in the literature as requiring some level of regulatory support (see Appendix I – Coding guide). Through an analysis of the content of these articles on NVivo, sixteen different issues were found in the literature (making sixteen case nodes on NVivo).

The next step involved coding[2] the regulations collected against each case. This way, this study identified which regulations make provisions for which CCS issue. This was done using NVivo software as well. Thus, the analysis of cases serves as

[2] Only regulations with direct bearing on the issues in the framework are coded. In fact, some regulations with only vague connection were excluded from the project.

the basis for developing insight into the portfolio of regulations advancing CCS deployment.

3. Results

A total of 76 regulations were collected from the six jurisdictions in the study. However, following coding on NVivo, 37 of those were excluded for being too remotely connected to CCS technology or components of it (such as EOR); being more connected to the environment in general; not being in force; and having amendments that nullify its provisions in a different regulation. Thus, in the end, 39 regulations from six jurisdictions were used (*n* = 49) (See Figure 2 below for distribution per jurisdiction).

Figure 2. Number of CCS regulations per jurisdiction

Source: Compiled by the author from NVivo analysis of regulations.

Issues related to CCS technology found in the literature were grouped into three core categories shown in Figure 3 below.

Figure 3. The three pillars in CCS technology development and acceleration

Source: Compiled by this author from literature review.[3]

Table 1. Taxonomy of regulations

	Regulatory Tools	
CCS Activities and Regulatory Issues	**Governing Resources Required (Howlett 2019)**	**Regulatory Tools Required**
CO_2 classification (hazardous material, pollutant, waste), transport, CCS capture, Post-closure and decommissioning, CO_2 injection, site selection, storage and long-term liability	Organization	Technical Authority
	Authority	
Capital grants, CCS certificate, contract for difference, emissions and tax credits, loan guarantees, price mechanism	Treasure	Financial
Public engagement and stakeholder involvement, benefit sharing	Informational	Information dissemination and public engagement

Source: Compiled by this author; adapted from Howlett (2019).

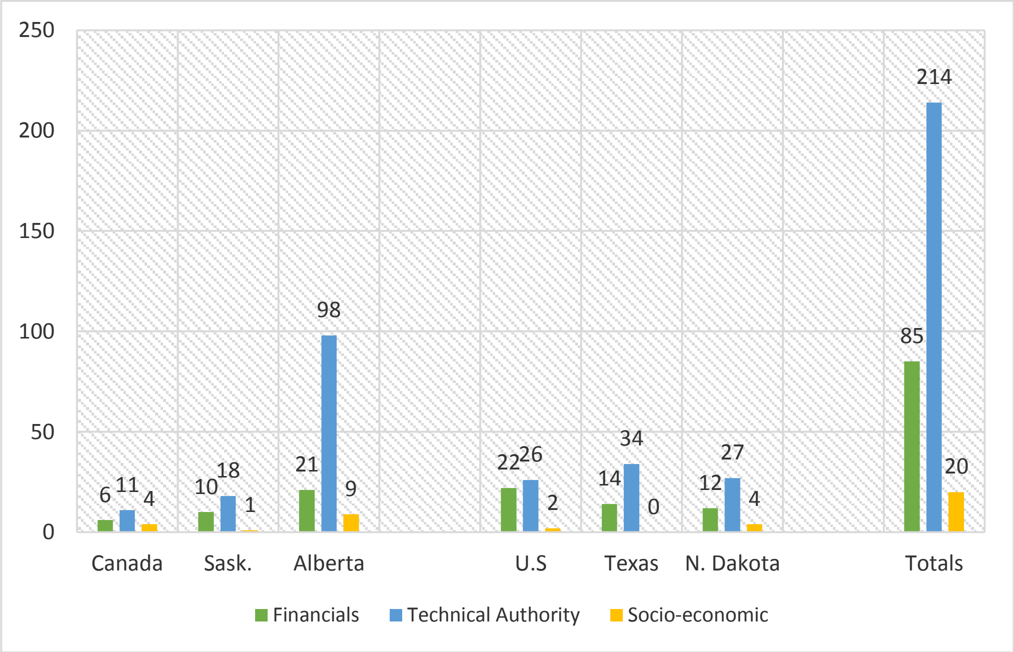
Through the process of coding the selected regulations, this study found that the technical issues required the use of *organizational* and *authoritative* resources to either define and set standards or monitor compliance. Hence, regulations covering these issues not only need to be authoritative but also technically sound. Therefore, these issues were mapped into our regulatory taxonomy framework as technical authority. The *treasure* related issues were covered by financial regulations while regulations with provisions for public engagement corresponded to *informational.*

[3] Please see Appendix VI for literature list.

Thus, as adapted here, and shown in Table 1, instead of four categories, there were three: technical authority, financial, and information dissemination / public engagement.

Based on the coding results shown in Figure 4, reference to technical issues dominate CCS regulations with CO_2 capture, storage and long-term liability and CO_2 injection having significant regulatory attention. The category to receive the least regulatory coverage is the informational category. In fact, in Texas, there is no reference to any public engagement and informational issues. In terms of financial or economic issues, tax credit, capital grants and capital grants dominated.

Figure 4. NVivo coding by location and regulatory taxonomy



Source: Compiled by the authors from NVivo analysis.

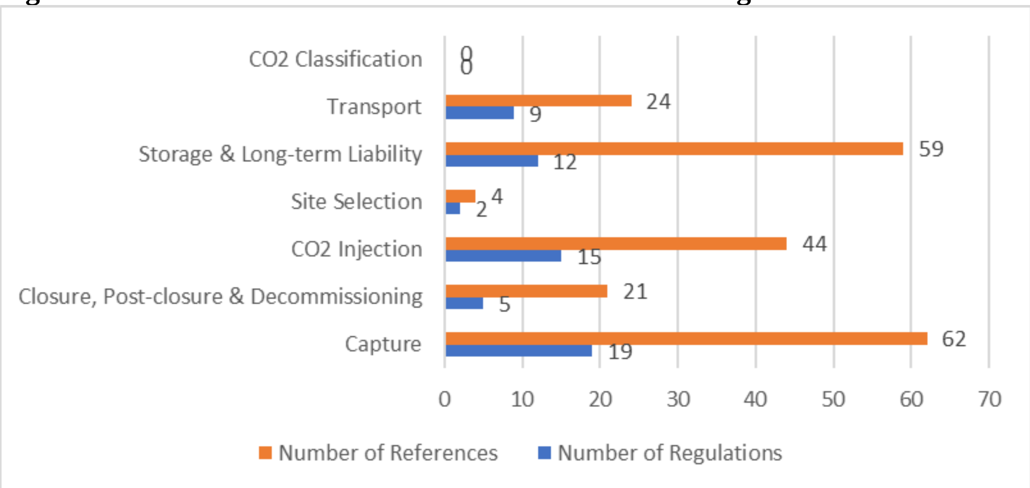
3. Discussion and analysis

The results of the analysis, using the adapted regulatory taxonomy tool framework shown in Table 1, are described subsequently. This analysis paints a picture of the regulatory portfolio supporting CCS technology and gaps that would need to be filled to provide more certainty for CCS stakeholders and accelerate deployment.

3.1. Technical authority

The taxonomy of 'technical authority' concerns defining, setting standards, and monitoring compliance. Thus, the issues under this taxonomy are mostly technical, requiring the government to use their authority to determine standards. Some of the earliest obstacles to developing CCS technology were of a technical nature, hence regulations focusing on technical issues including CO_2 classification, storage safety, CO_2 injection and transport, site closure, decommissioning, and long-term liability are described under this taxonomy. In Figure 3 below, we show the number of regulations making provisions for these technical issues across the six jurisdictions.

Figure 5. Distribution of references to technical issues in regulations



Source: Compiled by this author from NVivo analysis.

3.1.1. CO_2 classification

There is a regulatory gap in CO_2 classifications. Classifications challenge how we understand and define carbon at different points in the industrial process itself, or at various stages and state (liquid, gas or otherwise). The literature discusses several common classifications. Common classifications of CO_2 found in the literature (IEA 2010) include:

1. Hazardous pollutant: In its free state, without CCS processing CO_2 that leave the tailpipe of an industrial system, CO_2 may be classified as hazardous due to the presence of certain impurities and hydrocarbons that pose some danger to health and wellbeing of people and ecological systems. However, once captured in the CCS process, certain factors that may cause CO_2 to be classified as hazardous are its pressure, concentration, and the volume at which it is being stored. Thus, this classification emphasizes the harm that CO_2, either in its free state or when captured, can cause.
2. Waste: As a product of industrial processes, without applying CCS technology, CO_2 is one of several harmful greenhouse gases that leaves the tailpipe of an industrial system. Its potential to cause harm and the inability for it to be used in any meaningful way causes it to be classified as a waste. Thus, there is a growing emphasis on CO_2 utilization rather than just CO_2 capture and storage.
3. Commodity: In the context of carbon capture utilization and storage (CCUS) technology, it is difficult not to classify CO_2 as a commodity, especially when deployed in EOR or other industrial operations. Here, CO_2 becomes an input in an industrial process which transforms it from a waste to a commodity.

Therefore, the line between CO_2 being classified as a waste, hazard or dangerous pollutant, or as a commodity lies, for the most part, in whether it is considered an output or an input in an industrial process. Interestingly, no specific reference is made to CO_2 classification in all 6 jurisdictions. This would be an area of future regulatory attention. As existing large scale CCS projects in Saskatchewan (Boundary Dam 3) and Texas (Petra Nova) demonstrate, stakeholder involvement is critical to CCS success (Liang, Reiner 2013; Lipponen et al. 2017). Therefore, a common classification for CO_2 is critical in creating a clear understanding between multiple stakeholders and ensuring cooperation.

3.1.2. CCS capture

Regulations pertaining to CCS capture include provisions requiring capture, capture permits, approvals, risk assessment and safety requirements of capture sites. Although a few of the regulations discuss reporting, monitoring and evaluation (mostly by identifying roles and responsibilities), the focus was on CO_2 emissions limits. In Alberta, the Climate Change and Emissions Management Act and Oil Sands Emissions Limit Act, both provide for greenhouse gas emissions limits or targets. This is also the case in the Canada Reduction of Carbon Dioxide Emissions from Coal-fired Electricity Generation Regulation. Similar standards are also found in Texas and U.S regulations.

3.1.3. Closure, post-closure and decommissioning

Once CO_2 has been captured and then injected into a storage site, standards for post-injection monitoring, remediation, well plugging and abandonment, and site closure follows (Hart et al. 2012). One major factor limiting CCS deployment is storage capacity. Two common storage options are underground geologic sites and depleted oil and gas wells or reservoirs. The IPCC estimates around 2 trillion tones of worldwide capacity, that is, about 50 times the current emissions levels (GCCSI 2018a). Although only several countries are deemed to have mature storage capacity, the world's highest GHG emitters also have the best or near best storage capacity (GCCSI 2018a).

Regulations making provisions for CO_2 storage related activities discuss processes for acquiring storage site closure permits and certificates, set the standards and procedures for monitoring sites, conduct risk assessment, and determine the safety of CO_2 storage sites. Another important issue addressed by the regulations is determining criteria for transfer of liability of storage sites, especially after a CO_2 storage site is closed.

One significant regulation in this regard is the Alberta Mines and Minerals Act which created a post-closure stewardship fund that helps to cover cost of remediation. An area that requires some regulatory attention would be clarifying the potential for governments to assume more responsibility for storage sites.

3.1.4. CO_2 injection

The CO_2 injection process and activities are differentiated from those associated with CO_2 storage. Injection is primarily associated with the use of captured carbon in EOR activities, which involves the use of depleted oil and gas wells and reservoirs rather than geological formations for storage. The association with oil and gas exploration produces a set of issues that is unique from any other form of storage (in geologic sites). Hence, special regulatory attention to the use of captured carbon in industrial processes such as EOR is warranted. In the study, key provisions found in the regulations include: Monitoring, measurement and verification of CO_2 injection; CO_2 injection leases and permit/approval process; Health and safety, especially in relation to underground water formations; Pore space ownership and liability; Financial incentives for CO2 use in EOR (more on this later); Standards for CO_2 trading; All the jurisdictions studied had at least one reference to one or more of these issues except Canada (Federal regulations).

3.1.5. Site selection

Site selection is important to several CCS related activities such as, EOR, CO_2 storage, and transportation. The focus here is on procedures for determining the suitability of sites (on-shore or off-shore) in a CCS related activity. In the six jurisdictions studied, only four direct references are made regarding procedures for site selection and all four references are from Texas. The provisions highlight administrative steps regarding monitoring and evaluation of a site's mechanical integrity for various activities such as CO_2 injection and storage.

3.1.6. Storage and long-term liability

Permanent storage of CO_2 implies a long-terms sequestration of captured carbon. The extended time frame involved in CO_2 storage creates unique uncertainties as it is impractical to expect the responsible entities to exist for as long as the carbon is being stored. Therefore, sub-surface property rights and liability for storage over an extended period may become contentious if not managed by regulations.

The liability question also has a financial and ethical dimension that must be noted. Currently, an unabated emitter of CO_2 who fails to develop a CCS facility is free of any liability once the CO_2 leaves its facility into the atmosphere. Conversely, without adequate regulatory cover, the liability for captured carbon may become a disincentive for facilities who would first have to bear the cost of deploying CCS technology, and then assume liability in perpetuity for what could be considered an environmental good in capturing the carbon and safely storing them away in underground formations (Bui et al. 2018). This is one situation in which a clear classification of CO_2 is required because once captured and stored underground, if classified as a pollutant, waste or hazard, CO_2 capture and storage effectively becomes a disposal mechanism. This would have significant administrative and legal implications. Further, classifying CO_2 as a hazard, pollutant or waste creates a negative perception. Hence, securing storage sites for CO_2 storage may become extremely difficult, if not impossible, because of strong public opposition.

Five jurisdictions in the study (all except Canada (Federal)) had some form of provision for managing long-term liability of stored carbon. Of note is Alberta's approach which has been discussed extensively in the literature. In Alberta, the Crown (Government) recognizes that stakeholders are challenged by the daunting prospect of having to bear responsibility for stored carbon over its lifetime; in perpetuity. Therefore, the Crown assumes liability of storage and takes ownership of storage sites ones a closure certificate is issued to a CCS storage facility operator.

All provisions related to long-term liability in North Dakota are in North Dakota Senate Bill No. 2095, while in Alberta, several pieces of different legislations, including Alberta Mines and Minerals Act and the Oil and Gas Conservation Act, capture the issues. Alberta seems to have adjusted existing regulations to manage different aspect of CCS technology.

3.1.7. Transport

Transportation is considered of the most mature of all the activities in CCS technology chain (IEA 2013; CIAB 2016). Once captured, CO_2 is compressed and then transported typically by pipelines, but shipping is also a feasible option. Important issues under transport include pipeline ownership (common ownership to avoid monopolies in CO_2 pipeline infrastructure), cost of developing pipeline infrastructure/network, common carrier issues or hub-transport agreements, the safety requirements for different modes of transport, measurement, verification and reporting needed to obtain permits, site selection, and approvals for CO_2 transportation. CO_2 classification becomes relevant once more as it informs acceptable technical standards for pipes used or any other means adopted for transportation. Further, accelerating CCS deployment requires adequate CO_2 transport infrastructure to provide access to jurisdictions with adequate or sound geologic storage systems. This is one reason why the lack of streamlined regulatory systems for CO_2 classification is critical.

All but Canada (Federal regulation) have some provision for one or more of the issues. However, it is interesting that most of the regulations discuss liability for abandoned pipelines and they stipulate a requirement to carry CO_2 without discrimination (common carrier issues).

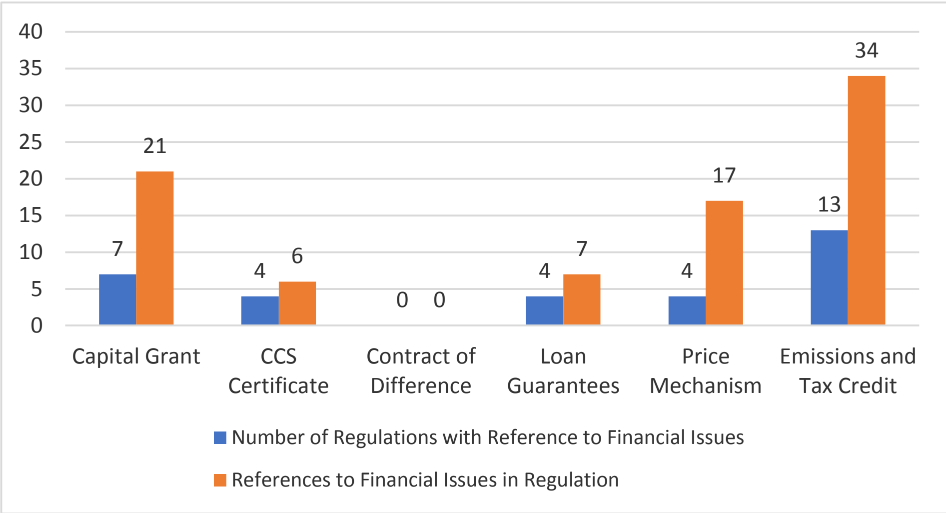
3.2. Financial issues

CCS technology, as with all innovative new technologies, is not cheap. The cost of CCS has been a major obstacle to development over the last two decades (World Resource Institute 2011; Napp et al. 2014; Budinis et al. 2018). That said, lessons can be learned from more mature technologies, especially renewable technologies such as wind and solar which were, not long ago, considered too expensive as well. Managing the cost of CCS can take any one or a combination of these three approaches:

1. Reduce the cost of developing a CCS project upfront. As much as 67% reduction in cost can be achieved for second-generation CCS designs under certain circumstances (CCS Knowledge Centre 2018).
2. Increase the economic value of CCS technology. This could involve developing innovative ways of using CO_2 beyond EOR; emphasizing CCUS (carbon capture, *utilization* and storage) rather than just CCS (carbon capture and storage) and leveraging private investments in CCS through initial public support and funding.
3. Creating a market-based system for trading CO_2 as a commodity to solidify the role of private capital and investment in CCS technology and further unlock the financial potentials in CCS technology.

In the literature, mechanisms for supporting the economics of CCS range from financial contributions by governments to the development of a market-based system. The most common mechanisms are highlighted in Figure 4 (below) which shows a distribution of regulatory provisions for various mechanisms meant to support CCS development. Based on the number of references to financial issues in the regulations, it can be said that regulatory provisions in the area of CCS finance are, at best, still growing when compared to what is obtainable for issues of technical relevance to CCS technology.

Figure 6. Distribution of references to financial issues in regulations



Source: Compiled by the authors from NVivo analysis.

Table 2. Mechanisms for financial support in early stage CCS development

	Stage of Project	Mechanism
Direct contribution or investment: Direct capital investments enlarge the pool of available capital for large scale projects. They unleash private investment available in the process	Research and Development	• Capital Grant • CCS Certificates • Contract of Difference
	Demonstration/First-mover Projects	
	Project Commission/Project Completion	
Risk mitigating instruments: These unleash private capital investments in large projects like CCS by reducing the risks in the projects and attracting private capital investments.	Project Operation and Maintenance	• Loan Guarantees • Emissions and Tax Credit
	Project Maturity	

Source: Compiled by authors.

Governments play a big role in reducing the risk in new technologies in their early stages, allowing private capital investments to flourish. This can be done through a variety of ways as shown in Table 2. These mechanisms are flexible and can be applied at different stages of a CCS project. Where possible, several mechanisms may be adopted and are discussed below (ADB et al. 2012).

3.2.1. Capital grants

Capital grants are direct financial supports provided by government in furthering a CCS project. Although regarded as useful in breaking down inertia due to uncertainties and risks in first-mover or demonstration projects, about 77% of total investment in CCS projects since 2005 have come from private interests (Anbumozhi et al. 2018). Ogihara (2018) asserts government investment in CCS facilities hurts the development of CCS technology.

Four jurisdictions (Alberta, Saskatchewan, Texas and the U.S) had provisions for government’s financial support of CCS projects through capital grants. For example, in Saskatchewan, a combination of direct capital grants from both the provincial and federal governments provided liquid cash which SaskPower (the province’s power generation and distribution company and owner of the CCS facility) used for the CCS project.

3.2.2. CCS certificate

A CCS certificate is a ‘quantity instruments’ that sets a baseline target for CO_2 capture. Solar and Wind technologies have benefited from certificates surrounding targeting quantity of GHG emissions reduced. When adapted for CCS technology, the objective can extend beyond a measurement of clean energy output by a CCS facility to include such things as amount of CO_2 stored. In the six jurisdictions studied, only in Canada (Federal), North Dakota and Texas are there regulatory provisions that highlight quantity measures for CCS facilities

3.2.3. Contracts of difference

Contracts of Difference (CfD) are important financial tools for signaling the potential for CCS technology and renewable technologies such as wind and solar to co-exist. The use of CfDs is based on two major premises: (1) CCS technology is the bridge between a fossil fuel based system and a renewables based system, and (2) over the longer term, as the use of renewables increases and conventional coal plants or those with CCS technology lose their share of generating capacity, the CfDs become a primary means of guaranteeing that these facilities do not become stranded assets and continue to provide base load generation.

The typical life cycle of a CCS project is at least 30 years. Thus, to attract the necessary investment, guarantees against potential losses through mechanisms such as CfDs are critical (Kapetaki et al. 2017; Sartor, Bataille 2019). This is clearly an area where some regulatory attention is needed as no jurisdiction in this study had direct provisions for developing or administering a CfD.

3.2.4. Emissions and tax credits

All six jurisdictions had references to a system of incentivizing CCS activities through credits, rebates or by other means although the level and strength of the credit system vary by jurisdiction. Emissions and tax credits work in nearly the same way as CCS certificates, except, emissions reduction is the major outcome being measured and rewarded through a tax credit, whereas in CCS certificates, other outcomes like power production (using clean or low carbon technology) may also be measured. The development of an emissions tax credit system can be a first step toward developing a carbon market.

Unlike capital grants that are upfront or may come at specific points in the life of a CCS project, emissions tax credits are ongoing and can cover some of the operational costs associated with a CSS facility. Since CCS technology is a chain of linked technologies, the credits could be issued for achieving different targets along the CCS chain. In the Saskatchewan case, due to the use of captured carbon in EOR activities, credits are used to reduce oil and gas royalty payments.

Emission credits may also be in the form of direct payments where transfers are made per ton of CO_2 captured, stored or utilized. A good example of this is the recent amendments made to section 45Q of the U.S Internal Revenue Code which allows substantial revisions of payments made for capturing, storing or utilizing CO_2.

3.2.5. Loan guarantees

North Dakota, Saskatchewan, Texas and the U.S federal level offer loan guarantees to banks and financial institutions funding a CCS project. The extension of a loan guarantee for CCS projects may never result in financial obligations, but serves as a critical buffer reducing financial risk exposure and uncertainty for financial institutions funding CCS projects. However, this study shows that it is not clear how such system works in cases where foreign, multinational or multilateral financing institutions are involved in financing a project. In the context of Article 6 of the Paris Agreement, this is a fundamental regulatory issue for the immediate future of CCS technology.

Loan guarantees thus function as a catalyst driving private investment in CCS projects as it did in the renewable energy sector (Brown, Jacobs 2011; IEA 2012). Unfortunately, in applying loan guarantees for CCS projects, the conditions have been notably stringent (Anbumozhi et al. 2018). Thus, there is a sense that more private capital could be leveraged if administrative burdens, including those in the application process, are eased (Jacobs, Craig 2017).

3.2.6. Price mechanism

The most common price mechanisms supporting CCS project development are the cap-and-trade and carbon tax. In the case of the carbon tax, its purpose is to make carbon intensive activities more expensive, and drive power generation towards a low carbon system. On the other hand, cap-and-trade follows a market model were a highly developed system of emissions trading or market is developed and emissions credits can be traded between parties. While both are touted as important tools for accelerating the deployment of innovative clean energy technologies like CCS, serious political-economy questions which have remained unresolved have hampered their use in many parts of the world.

Currently, more than sixty national and subnational pricing mechanisms exist around the world. In Canada, the Federal government has imposed a national carbon price which began by January of 2019 (Government of Canada 2016). However, this has been opposed by a number of provinces (CBC News 2019; Ljunggren 2019).

Generally, the application of a price mechanism varies widely because the pricing mechanism bridges quantity-based and price-based initiatives. Thus, different jurisdictions decide how far they will go. In Saskatchewan for example, the province set an emissions limit without a price system for trading carbon. Other jurisdictions in this study with regulatory provisions that refer to one or more aspects of carbon pricing include Alberta, Texas, and Canada. In Alberta, there is a price on carbon in the form of a carbon levy which is collected in a central fund used for climate change initiatives. In Texas, such payment may be charged for CO_2 storage.

3.3. Information

Public perception of innovative technologies can be an obstacle to accelerated deployment if it is negative (L'Orange Seigo et al. 2014; van Alphen et al. 2007; Wallquist et al. 2010; Bradbury et al. 2008; Bui et al. 2018). This regulatory area has received the least number of regulations. In the literature, public perception is often discussed in its context as a 'social good'; the Global CCS Institute argues that considering public perception of CCS technology as a 'non-commercial' issue is a mistake (GCCSI 2009). Public perception of CCS is difficult to manage because people's perception may not be a function of the technology itself (a combination of the technical and economic factor) as it may be a function of where they live, their politics, their knowledge of the technology in relation to the overall energy system, and their connection to fossil fuel industry (L'Orange Seigo et al. 2014; van Alphen et al. 2007; Wallquist et al. 2010; Bradbury et al. 2008; Bui et al. 2018).

To resolve challenges arising from negative public perception, public engagement has become a staple for major developmental projects in most part of the world and has been considered an opportunity to enlarge the community of stakeholders involved in a project, to co-create and co-own the project, and to develop lasting relationships needed to achieve the desired outcomes (Lash 2010). Public engagement strategies adopted must always include opportunities for all parties to adjust their goals and preferences in relation to the project (Breukers, Upham 2015). In that sense then, the goal should never be overcoming a barrier to deployment, instead, it should be expanding the stakeholder pool to include locals who will see value (both economic and social) in the project and become active advocates and participants in the development and sustainability of the project (GCCSI 2014).

CCS technology developers engage local public in different ways. In fact, regulations in Alberta, Canada (Federal), North Dakota, Saskatchewan and the U.S all have provisions that acknowledge the need to involve local publics in the decision-making processes that lead to siting of a CCS facility. Some of these regulations include dispute resolution procedure which requires members of the community to be part of an advisory committee to the government. Others have included benefit sharing as a way to galvanize support of local publics, particularly those within the immediate geographical location of a CCS facility. Benefit sharing schemes are meant to demonstrate the social value of a CCS facility for the community that hosts its, rather than pay to gain access to the community or their acceptance (ter Mors et al. 2014).

In a 2013 study, ERM (a global consulting company) and the CO_2 Capture Project (CPP), (a consortium of CCS technology stakeholders) conducted a study that revealed that benefit sharing can be achieved by:

1. Revenue sharing, especially when CO_2 is utilized for EOR or other industrial purposes
2. Direct investment in the community through investment in a local trust fund or other local initiatives
3. Community investment in CO_2 storage projects (perhaps through some sort of local content provision)
4. Shared commitment by government/developer/community in social management programs through education programs, on-site visits and learning centers

Still, the authors warn that benefits sharing should not be perceived as a "«silver bullet» when it comes to local acceptance" (ERM, CPP 2013), but be incorporated into a wider scheme that develops public trust in the projects by allowing the public to participate in taking ownership of the project (Bonham et al. 2014). In this study, it was found that the U.S Energy Independence and Security Act privileges projects that ensures local content in CCS development projects when making deciding between competing projects. No reference to issues related to benefit sharing was found in all other 5 jurisdictions.

4. Concluding remarks

Trends in energy consumption show that fossil fuel will continue to be consumed into the future and that emissions, particularly from developing countries, is still increasing which means that CCS will be needed at least in the short term (IEA 2018a; GCCSI 2017, 2018b). A growing appetite for CO_2 utilization fuels innovation in CCS technology and learning from existing CCS projects is driving down capital cost projections for future builds (International CCS Knowledge Centre 2018). However, policies are needed to support CCS project development, but policies don’t exist in a regulatory vacuum. Hence, more attention should be paid to development a regulatory regime or structure that supports CCS technology development.

Several gaps were identified in regulatory regimes. First, advancing public acceptance may benefit from socio-economic policies specifically relating to public engagement, providing information, and advancing societal benefits sharing (revenue sharing, investment in the community, shared social management). These regulations were found to be lacking. Second, although financial instruments were the second most predominant form of regulation, contracts for differences were missing as well as loan guarantees at the international, multinational and multilateral levels. Third, although many technical regulations exist there is a regulatory gap in the classification of CO_2. The literature describes it as a hazardous pollutant, waste or a commodity. Reconciling this would advance understanding of CCS. Lastly, not all jurisdictions have post CCS closure, stewardship and liability provisions.

This article provides a portfolio of regulations advancing CCS including technical regulations, pore space ownership, monitoring, enforcement and verification of CO_2 injection. Regulations focusing primarily on technical aspects of CCS including capture, transport, and liability predominate while there are less regulatory provisions for the financial aspects of CCS technology as well as public engagement and support. While capital grants and emission and tax credits are the predominant financial regulations, streamlining cap and trade provisions across borders warrants more attention.

Many scenarios to maintain global warming below 2 degrees Celsius require combinations of new technology including CCS. The focus on CCS cost as a barrier to deployment overshadows the needs for regulatory support as a means of reducing uncertainties and de-risking CCS investments.

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APPENDIX 1. Coding guide – CCS regulations project

This document describes what constitutes each case-node in this project.
This project has 49 regulations as its total universe. Specific provisions within those regulations are coded to each case-node as described below.

	A : Capture	B : Closure, Post-closure and Decommission	C : CO_2 Classification	D : CO_2 Injection	E : Site selection	F : Storage and Long-term Liabilities	G : Transport
1 : Alberta CARBON CAPTURE AND STORAGE ACT + Amendment Regulation	No	No	No	No	No	No	No
2 : Alberta CARBON SEQUESTRATION TENURE REGULATION	No	Yes	No	Yes	No	No	No
3 : Alberta CLIMATE CHANGE AND EMISSIONS MANAGEMENT ACT	Yes	No	No	No	No	No	No
4 : Alberta CLIMATE LEADERSHIP ACT	No	No	No	No	No	No	No
5 : Alberta ENVIRONMENTAL PROTECTION AND ENHANCEMENT ACT	Yes	Yes	No	Yes	No	No	Yes
6 : Alberta METALLIC AND INDUSTRIAL MINERALS TENURE REGULATION	No	No	No	No	No	No	No
7 : Alberta Mines and Minerals Act	No	Yes	No	Yes	No	Yes	No
8 : Alberta OIL AND GAS CONSERVATION ACT	No	Yes	No	Yes	No	Yes	Yes
9 : Alberta OIL SANDS EMISSIONS LIMIT ACT	Yes	No	No	No	No	No	No
10 : Alberta Pipeline Act	No	No	No	No	No	No	Yes
11 : Alberta RESPONSIBLE ENERGY DEVELOPMENT ACT	No	No	No	No	No	No	No
12 : Alberta Specified Gas Emitters Regulation	Yes	No	No	No	No	Yes	No
13 : Alberta SPECIFIED GAS REPORTING REGULATION	Yes	No	No	Yes	No	No	No
14 : Alberta Surface Rights Act	No	No	No	Yes	No	No	No
15 : Alberta WATER ACT	No	No	No	Yes	No	No	No
16 : Canada Emission Incentive Agency Act	No	No	No	No	No	No	No
17 : Canada Kyoto Protocol Implementation Act	Yes	No	No	No	No	No	No
18 : Canada Oil and Gas Operations Act	No	No	No	No	No	No	No
19 : Canada Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulation	Yes	No	No	No	No	No	No
20 : Canadian Environmental Assessment Act	Yes	No	No	No	No	No	No
21 : North Dakota Century Code 49-19- 01	No	No	No	No	No	No	Yes
22 : North Dakota Century Code 57 - 39.2	No	No	No	No	No	No	No
23 : North Dakota Century Code 57 - 60	No	No	No	No	No	No	No

24 : North Dakota Century Code 57-51.1	No	No	No	No	No	No	No
25 : North Dakota GEOLOGIC STORAGE OF CARBON DIOXIDE Article 43-05	No	No	No	Yes	No	Yes	No
26 : North Dakota SENATE BILL NO. 2034 Sub 5 + Amendment	No	No	No	Yes	No	No	No
27 : North Dakota SENATE BILL NO. 2095	Yes	No	No	Yes	No	Yes	No
28 : North Dakota SENATE BILL NO. 2139	No	No	No	No	No	No	No
29 : Saskatchewan Crown Minerals Act	No	No	No	No	No	No	No
30 : Saskatchewan Environmental Management and Protection Act	Yes	No	No	Yes	No	Yes	No
31 : Saskatchewan Management and Reduction of Greenhouse Gases Act	Yes	No	No	No	No	No	No
32 : Saskatchewan OIL AND GAS CONSERVATION REGULATIONS	Yes	No	No	Yes	No	No	No
33 : Saskatchewan Pipeline Act	No	No	No	No	No	No	Yes
34 : Saskatchewan -The Crown Oil and Gas Royalty Regulation	No	No	No	No	No	No	No
35 : Saskatchewan The Environmental Assessment Act	No	No	No	No	No	No	No
36 : Texas House Bill HB 149	Yes	No	No	Yes	No	Yes	No
37 : Texas House Bill HB 1796	Yes	No	No	No	Yes	Yes	Yes
38 : Texas House Bill HB 469	No	No	No	No	No	Yes	No
39 : Texas House Bill SB 1387	No	Yes	No	Yes	Yes	Yes	No
40 : U.S Accountable Pipeline Safety and Partnership Act of 1996	No	No	No	No	No	No	Yes
41 : U.S Carbon Pollution Emission Guidelines for Existing Stationary Sources-Electric Utility Generating Units 80 FR 205	Yes	No	No	No	No	No	No
42 : U.S Clean Air Act	Yes	No	No	No	No	No	No
43 : U.S Energy Improvement and Extension Act House Resolution H.R 6049	Yes	No	No	No	No	No	No
44 : U.S ENERGY IMPROVEMENT AND EXTENSION ACT OF 2008 +45Q Amendment	No	No	No	No	No	Yes	No
45 : U.S Energy Independence and Security Act	Yes	No	No	Yes	No	Yes	No
46 : U.S ENERGY POLICY ACT OF 2005	Yes	No	No	No	No	No	No
47 : U.S Energy Tax Incentive Act 2005	No	No	No	No	No	No	No
48 : U.S Hazardous Liquid Pipeline Safety Act of 1979	No	No	No	No	No	No	Yes
49 : U.S Pipeline Safety, Regulatory Certainty, And Job Creation Act - PUBLIC LAW 112–90	No	No	No	No	No	No	Yes

	A : Capital Grant	B : CCS Certificate	C : Contract for Diffrence	D : Emissions and Tax Credits	E : Loan Guarantees	F : Price Mechanism
1 : Alberta CARBON CAPTURE AND STORAGE ACT + Amendment Regulation	Yes	No	No	No	No	No
2 : Alberta CARBON SEQUESTRATION TENURE REGULATION	No	No	No	No	No	No
3 : Alberta CLIMATE CHANGE AND EMISSIONS MANAGEMENT ACT	Yes	No	No	Yes	No	No
4 : Alberta CLIMATE LEADERSHIP ACT	No	No	No	Yes	No	Yes
5 : Alberta ENVIRONMENTAL PROTECTION AND ENHANCEMENT ACT	No	No	No	No	No	No
6 : Alberta METALLIC AND INDUSTRIAL MINERALS TENURE REGULATION	No	No	No	No	No	No
7 : Alberta Mines and Minerals Act	No	No	No	No	No	No
8 : Alberta OIL AND GAS CONSERVATION ACT	No	No	No	No	No	No
9 : Alberta OIL SANDS EMISSIONS LIMIT ACT	No	No	No	No	No	No
10 : Alberta Pipeline Act	No	No	No	No	No	No
11 : Alberta RESPONSIBLE ENERGY DEVELOPMENT ACT	No	No	No	No	No	No
12 : Alberta Specified Gas Emitters Regulation	No	No	No	Yes	No	No
13 : Alberta SPECIFIED GAS REPORTING REGULATION	No	No	No	No	No	No
14 : Alberta Surface Rights Act	No	No	No	No	No	No
15 : Alberta WATER ACT	No	No	No	No	No	No
16 : Canada Emission Incentive Agency Act	No	Yes	No	Yes	No	No
17 : Canada Kyoto Protocol Implementation Act	No	No	No	No	No	Yes
18 : Canada Oil and Gas Operations Act	No	No	No	No	No	No
19 : Canada Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulation	No	No	No	No	No	No
20 : Canadian Environmental Assessment Act	No	No	No	No	No	No
21 : North Dakota Century Code 49-19- 01	No	No	No	No	No	No
22 : North Dakota Century Code 57 - 39.2	No	No	No	Yes	No	No
23 : North Dakota Century Code 57 - 60	Yes	No	No	Yes	No	No
24 : North Dakota Century Code 57-51.1	No	No	No	Yes	No	No
25 : North Dakota GEOLOGIC STORAGE OF CARBON DIOXIDE Article 43-05	No	No	No	No	Yes	No

26 : North Dakota SENATE BILL NO. 2034 Sub 5 + Amendment	No	No	No	No	No	No
27 : North Dakota SENATE BILL NO. 2095	No	Yes	No	No	No	No
28 : North Dakota SENATE BILL NO. 2139	No	No	No	No	No	No
29 : Saskatchewan Crown Minerals Act	No	No	No	No	No	No
30 : Saskatchewan Environmental Management and Protection Act	No	No	No	No	No	No
31 : Saskatchewan Management and Reduction of Greenhouse Gases Act	Yes	No	No	No	Yes	Yes
32 : Saskatchewan OIL AND GAS CONSERVATION REGULATIONS	No	No	No	No	No	No
33 : Saskatchewan Pipeline Act	No	No	No	No	No	No
34 : Saskatchewan -The Crown Oil and Gas Royalty Regulation	No	No	No	Yes	No	No
35 : Saskatchewan The Environmental Assessment Act	No	No	No	No	No	No
36 : Texas House Bill HB 149	No	No	No	No	No	No
37 : Texas House Bill HB 1796	Yes	Yes	No	Yes	No	Yes
38 : Texas House Bill HB 469	No	Yes	No	Yes	No	No
39 : Texas House Bill SB 1387	No	No	No	No	Yes	No
40 : U.S Accountable Pipeline Safety and Partnership Act of 1996	No	No	No	No	No	No
41 : U.S Carbon Pollution Emission Guidelines for Existing Stationary Sources- Electric Utility Generating Units 80 FR 205	No	No	No	No	No	No
42 : U.S Clean Air Act	No	No	No	No	No	No
43 : U.S Energy Improvement and Extension Act House Resolution H.R 6049	Yes	No	No	No	No	No
44 : U.S ENERGY IMPROVEMENT AND EXTENSION ACT OF 2008 +45Q Amendment	No	No	No	Yes	No	No
45 : U.S Energy Independence and Security Act	No	No	No	No	No	No
46 : U.S ENERGY POLICY ACT OF 2005	Yes	No	No	Yes	Yes	No
47 : U.S Energy Tax Incentive Act 2005	No	No	No	Yes	No	No
48 : U.S Hazardous Liquid Pipeline Safety Act of 1979	No	No	No	No	No	No
49 : U.S Pipeline Safety, Regulatory Certainty, And Job Creation Act - PUBLIC LAW 112–90	No	No	No	No	No	No

	A : Benefit Sharing	**B : Public Engagement and Stakeholder Involvement**
1 : Alberta CARBON CAPTURE AND STORAGE ACT + Amendment Regulation	No	Yes
2 : Alberta CARBON SEQUESTRATION TENURE REGULATION	No	No
3 : Alberta CLIMATE CHANGE AND EMISSIONS MANAGEMENT ACT	No	Yes
4 : Alberta CLIMATE LEADERSHIP ACT	No	No
5 : Alberta ENVIRONMENTAL PROTECTION AND ENHANCEMENT ACT	No	Yes
6 : Alberta METALLIC AND INDUSTRIAL MINERALS TENURE REGULATION	No	No
7 : Alberta Mines and Minerals Act	No	No
8 : Alberta OIL AND GAS CONSERVATION ACT	No	Yes
9 : Alberta OIL SANDS EMISSIONS LIMIT ACT	No	No
10 : Alberta Pipeline Act	No	No
11 : Alberta RESPONSIBLE ENERGY DEVELOPMENT ACT	No	Yes
12 : Alberta Specified Gas Emitters Regulation	No	No
13 : Alberta SPECIFIED GAS REPORTING REGULATION	No	No
14 : Alberta Surface Rights Act	No	No
15 : Alberta WATER ACT	No	No
16 : Canada Emission Incentive Agency Act	No	No
17 : Canada Kyoto Protocol Implementation Act	No	No
18 : Canada Oil and Gas Operations Act	No	No
19 : Canada Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulation	No	No
20 : Canadian Environmental Assessment Act	No	Yes
21 : North Dakota Century Code 49-19- 01	No	No
22 : North Dakota Century Code 57 - 39.2	No	No
23 : North Dakota Century Code 57 - 60	No	No
24 : North Dakota Century Code 57-51.1	No	No
25 : North Dakota GEOLOGIC STORAGE OF CARBON DIOXIDE Article 43-05	No	Yes
26 : North Dakota SENATE BILL NO. 2034 Sub 5 + Amendment	No	No
27 : North Dakota SENATE BILL NO. 2095	No	Yes
28 : North Dakota SENATE BILL NO. 2139	No	No

29 : Saskatchewan Crown Minerals Act	No	No
30 : Saskatchewan Environmental Management and Protection Act	No	No
31 : Saskatchewan Management and Reduction of Greenhouse Gases Act	No	No
32 : Saskatchewan OIL AND GAS CONSERVATION REGULATIONS	No	No
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46 : U.S ENERGY POLICY ACT OF 2005	No	No
47 : U.S Energy Tax Incentive Act 2005	No	No
48 : U.S Hazardous Liquid Pipeline Safety Act of 1979	No	No
49 : U.S Pipeline Safety, Regulatory Certainty, And Job Creation Act - PUBLIC LAW 112–90	No	No

Reference	**Legal Authority = Alberta (15)**	**Legal Authority = Canada (5)**	**Legal Authority = North Dakota (8)**	**Legal Authority = Saskatchewan (7)**	**Legal Authority = Texas (4)**	**Legal Authority = U.S (10)**	**Total (49)**
Capital Grant	3	0	1	3	4	10	21
CCS Certificate	0	1	1	0	4	0	6
Contract for Diffrence	0	0	0	0	0	0	0
Emissions and Tax Credit	7	3	9	1	4	10	34
Loan Guarantees	0	0	1	3	1	2	7
Price Mechanism	11	2	0	3	1	0	17
Capture	20	11	1	10	4	16	62
Closure, Post-closure and Decommission	20	0	0	0	1	0	21
CO_2 Classification	0	0	0	0	0	0	0
CO_2 Injection	32	0	6	3	2	1	44
Site selection	0	0	0	0	4	0	4
Storage and Long-term Liabilities	13	0	18	1	22	5	59
Transport	13	0	2	4	1	4	24
Benefit Sharing	0	0	0	0	0	1	1
Public Engagement and Stakeholder Involvement	9	4	4	1	0	1	19
Total	**128**	**21**	**43**	**29**	**48**	**50**	**319**

Financials

Provisions coded in this category are those that have some influence on the economics of CCS. This category has 6 case-node which are described below:

1. Capital Grant: When governments support for capital projects are enshrined in regulations, these provisions are coded to this case-node. Any type of direct funding, especially from government, which are aimed at supporting certain capital projects, of which CCS projects may qualify, are capital grants. These funds mostly support demonstrations and first-mover projects, supplement or match funding from other sources. When such funding is enshrined in regulation, that provision is coded to this case-node.

2. CCS Certificate: A CCS certificate is a contract that utilizes a 'quantity instrument' approach to drive action. In CCS, this can be a contract that guarantee certain payments would be made if parties involved generate certain amounts of power through clean coal, capture or store certain amounts of CO_2. It could also be tradeable certificates between parties in a carbon market. The key is the existence of contracts and the use of quantity instruments. Provisions that cover such issues or lay the framework on which such issues are carried are coded to this case-node.

3. Contract of Difference: Contracts of Difference (CfD) are incentive mechanisms aimed to cover for losses in income for fossil fuel power generators over a set period of time as jurisdictions ramp up their share of renewables or other sources. It ensures that conventional plants do not become stranded assets as these other sources are developed and provides certainty in investments. If provisions exist in the regulations that covers for such potential losses, those sections of the regulations are coded to this case-node.

4. Tax Credits and emissions trading: This is a fee-based system where an emissions baseline is set and organizations staying below this baseline receives some credit while those above the baseline are taxed or buy credits from others who are below the baseline. This case-node will also cover aspects such as green bonds, royalty relief, tax breaks and other forms of incentives that impacts a facility's tax burden or facilitate trading in emissions. Provisions in the regulation which recognizes or facilitates such arrangements are coded to this case.

5. Loan Guarantees: These arrangements basically mean government underwrite CCS projects. These cover financial risks arising from CCS projects. Governments acts as either a party to the project or as a third party, to cover for potential liabilities arising from CCS projects in cases of failures. This way, financial risk exposure is minimized, and certainty is provided to financial institutions funding CCS projects. All provisions in the regulations which deal with such arrangements are coded to this node.

6. Price Mechanisms: This node will cover regulations which make provisions for, facilitate, or support carbon trading through mechanisms or programs utilizing some form of price systems, including cap and trade and carbon tax.

Technical
Provisions coded in this category are those that have some influence on the technical and operational aspects of CCS. This category has 7 case-node which are described below:
1. Capture: Provisions which set guidelines for CCS capture activities including permits to capture and utilize CO_2, risk assessment and safety requirements are coded to this case-node. All provisions stimulating, facilitating and supporting CCS capture activities are coded to this case-node.

2. Closure, Post-closure and Decommissioning: This case-node relates to issues of liability for CO_2 storage systems, site remediation and reclamation, permits, monitoring, risk assessment and safety of CO_2 storage sites. Any regulation with provisions for actions to obtain a closure certificate or the criteria for transfer of responsibility after CO_2 storage site is closed is coded to this case-node.

3. CO_2 Classification: This case-node will cover all references to guidelines for how CO_2 in CCS processes, at various stages and states (liquid, gas or otherwise) are classified. Specific classification and references to issues which may arise from classification challenges, such as transboundary movement of CO_2 are covered by this case-node.

4. CO_2 Injection: This involves aspects of the CCS process including measures for obtaining permits for safe injection of CO_2 underground or for enhanced oil recovery (EOR). It also involves measurement and verification activities as well as stewardship/accountability for all processes pre-injection, during injection and post-injection of CO_2, including determination of storage capacity, leakage and other safety measures.

5. Transport: This case-node will cover issues related to how CO_2 is transported, including common carrier issues or hub-transport agreements, the safety requirements for different modes of transport, measurement, verification and reporting needed to obtain permits for transportation of CO_2.

6. Site selection: This involves issues that cut across the entire CCS chain, including siting of a capture plant, selecting storage site, and transport. Measurement and verification as well as research are critical to this node, so is public acceptance. Any reference to these issues is coded to this case-node.

7. Storage and Long-term Liability: The issue here has to do with the long-term liability for stored carbon, not just the process of storing carbon underground. The extended time frame involved in CO_2 storage creates unique uncertainties which most existing regulations may not cover, hence any provision with reference to these issues are coded to this node.

Socio-Economic

Provisions coded in this category are those that have some influence on the human, social and community/societal dimensions of CCS technology deployment. There are two case-nodes in this category. Suffice to say that both relate to improving public perception and acceptance of CCS. The two case-nodes in this category are described below:

1. Benefit Sharing: In cases where CCS projects involve EOR, revenues generated from any extra oil production can be shared in some agreeable ratio with the community. If regulations provide for such agreements or arrangements, these are coded to this sub-node.

2. Public Engagement and Stakeholder Involvement: This case-node will capture all provisions that mandate, facilitates or contributes to community involvement in CCS project, from planning to commissioning.

APPENDIX VI. Literature used for Figure 3

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COVID-19 – reflections on the surprise of both an expected and unexpected event[1]

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Abstract:

Aim: This paper reflects on the COVID-19 epidemic from the perspective of small probabilities and the difficulty of predicting similar events. Against the background of basic economic principles, the importance of the precautionary principle for crisis management is discussed, as well as potential consequences of this epidemic.

Findings: The authors argue that whilst the epidemic as such was unexpected, in future countries should be prepared for such stochastic events to happen. This requires a precautionary approach. When society is not prepared for such a calamity, or waits too long to implement measures to deal with it, the social and economic costs may be very high – much higher than 'hedging bets' and losing. The article reflects on different issues which are meant for further discussion on unpredictable future threats. One important issue is the uncertainty created by this event. This increases the likeliness that something unexpected can appear in the near future, creating the need for research and discussion on public and government responses to these events. Being aware of such challenges increases the likeliness of

[1] This paper is non-refereed, as it reflects on the actual situation. Authors are invited to contribute to the discussion and submit their reflections to this journal.

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society and people to be prepared for such developments. It is concluded that the current crisis brings forward the question whether the current political-economic system and globalization makes future pandemics more likely, and whether a radical change towards a more locally oriented economy provides solutions that minimize the likelihood or frequency of future pandemics.

Keywords: Black Swans Management, precautionary principle, non-linearity, crisis management, Coronavirus disease (COVID-19)

JEL: *F69, H12, Q56*

1. Introduction

The Covid-19 pandemic has created a crisis situation, in particular, in Europe and the USA. For many people, including scientists and politicians, the current epidemic appears to have come as a complete surprise. One could argue whether the current situation is a good example of a so-called Black Swan (Taleb 2007): an unexpected, very unlikely event that will have profoundly negative consequences for society and the global economy. However, there is a long and well-documented history of epidemics that have decimated earlier human populations (MPHonline 2020). And in the current process of globalization, it has been argued that the appearance of random events can pose greater threats due to the interconnectiveness of economic and political systems (Taleb 2012; Casti 2013). As Taleb wrote in his book "the Black Swan" in 2007:

> "As we travel more on this planet, epidemics will be more acute – we will have a germ population dominated by a few numbers, and the successful killer will spread vastly more effectively. … I see the risk of a very strange virus spreading throughout the planet" (Taleb 2007: 317).

As such, this event was an unexpected event, that could have been expected in one or the other form to appear one day. Ford (2020) states that the threats were already known in November 2019. In other words, we may talk about an unexpected event that could have been expected. It may be rather ignorance of the possibility of such events to happen that lead to lack of policy and preparation (spare capacity, buffers in health care).

As Taleb (2007) argues, small probability events with potentially high impacts are often ignored or downplayed, and considered to be a one in a hundred or thousand year event. Their stochasticity thus makes it very difficult for society to prepare for them., leading to responses that are reactive rather than proactive. Furthermore, a problem of dealing with such events is that it is very difficult or rather impossible to prove such an event has been prevented, despite efforts and costs that are clearly visible (Kahneman 2011). However, even when believing that such events can happen, there is a difference between being aware of this, and really feeling and experiencing such a situation. People having no experience with a war-like situation, or other types of crises, may have difficulties envisaging such a situation. This creates serious challenges in preparing for different types of threats, as well as an Early Warning System for potentially disastrous events (see Platje 2019; Platje, Zepeda Quintana 2019).

In this reflective paper, we provide some theoretical considerations for thought and further discussion. First, we will discuss the issue within an economic context. The main idea is that standard cost-benefit approaches do not catch the issue of preparation for potential disasters, as this approach may easily lead to the neglect of the potential threats of such an event, while, following Taleb (2007), awareness of such events is an important part of the solution. Afterwards, the importance of the precautionary principle is discussed on practical examples. Finally, some potential effects of the epidemic are discussed. While many effects are visible now or will become visible in the near future, the uncertainty created by the epidemic should make us aware that many different scenarios are possible. While many predictions probably will not become reality, also here awareness of the problem may make people and society more prepared for the new challenges.

2. Some general economic principles

A flaw of the cost-benefit approach in economics is that it does not provide political and economic systems with instruments that can handle rare, stochastic events. As a consequence, the cost of such an event can be substantial, and even lead to serious damage to political and economic systems (compare Taleb et al. 2014). This approach is strongly related to system theory, which can help to prevent negative side-effects of diffenent types of policy (Sterman 2000).

Standard economic theory states that there is no such a thing as a free lunch – by making choices, we need to sacrifice something else. This leads to a classic trade-off in prioritization. Now, the question becomes, whether this is a metaphorical choice between buying a steak or a hamburger, or between investing in a holiday resort or airports, or education and health care infrastructure. Or in case of an overcrowded hospital between treating one patient or another, either of whom might die without treatment. Investment policy, based on cost-benefit analysis, may try to catch the possibility of epidemics to appear. However, when such a situation has not happened for a longer time, policies for improving efficiency in health care may lead to different kinds of unseen fragilities, which become visible in the case of an unexpected event, e.g., an epidemic, which could have been expected to appear one or the other day. As Harari (2019) argues, the fact that we have managed many threats of epidemics does not happen they cannot appear in the future. However, this is easily forgotten in when health care is dealing with the many short-term or even immediate challenges.

As mentioned, epidemics are unexpected events, which consequently could be expected to appear unpredictably in space and time. The long-term impacts of epidemics are difficult to predict due to this high level of uncertainty. However, this is an example of when all is considered to be fine and that no threats exist (like economists believing in permanent growth and the idea of perfect markets), it is almost inevitable that a ‘rabbit will jump out of the hat’ sometime, somewhere. And this posits the question whether this is a reversible, manageable problem, or an irreversible, system-threatening issue. As such, this issue is related to the idea that non-linearity can threaten the sustainability of different types of socio-economic sytems.

As Taleb (2005, 2012) shows, there is a problem with unseen evidence. When providing aid for a disaster area, this reduces the funds, and in turn the physical resources, that could be allocated for other areas. For example, when a hospital is overcrowded, this reduces the possibility of treating other illnesses. This may be the case with people with a heart attack or after an accident, where the ambulance cannot come in due time. Or people who need surgery will be treated later when facilities are not available, which in turn can have negative health effects. Of course, the impact of such a situation depends on the period such a situation lasts. Furthermore, a question is how these experiences influence the mindset of people. We are not psychologists, but we can imagine that a traumatic situation experienced by many people may have a long-lasting impact. This may also change their risk perception, as with people who have experienced different financial crashes compared with people who have only experienced a growing economy and concomitant increase in welfare and well-being. Depending on the institutional and economic setting of particular countries, this can have impacts that are difficult to predict in the future.

As Tieleman et al. (2020) argue, in the early stages of the COVID-19 epidemic in Italy, The Netherlands adopted a rather lenient, lacklustre approach based on a ‘business as usual’ scenario. No travel restrictions were implemented with northern Italy only weeks before the spread of the pandemic, and pre-emptive warnings by some epidemiologists were ignored, until the ‘chickens came home to roost’. To be fair, the Dutch response was barely different from that of most other western industrialized nations in Europe and North America. For many weeks, COVID-19 was presented almost as a “normal flu” with a low death rate (<2%). However, it was rarely mentioned that the virus was novel, and thus that no-one had developed immunity to it, while the rapid spread of the virus wold inevitably lead to a large group of infected people, with a mortality rate that could lead to a large amount of deaths when taken cumulatively. Moreover, it glossed over the fact that a 2% death rate is up to 20 times higher than the 0.1% rate of a “normal flu in the USA” (Rettner 2020).

Tieleman et al. (2020) expect the epidemic to last at least another 7 weeks, which could lead to millions of people getting ill; some pessimistic estimates suggest that 60-70% of the populations of some countries could become infected by COVID-19 in the coming months before a vaccine is available if measures to contain it are unsuccessful (Smith 2020). If this in indeed true, then tens of millions of people, mostly vulnerable groups such as the elderly and those with pre-existing medical conditions, could die across the world. This shows that, in accordance with what Taleb (2007, 2012) argues, awareness of small probability, high impact events is essential in preparing for potential crises and proper crisis management.

3. Precautionary principle

Based on reading a wide variety of media sources, we get the impression that the mainstream and social media are currently full of COVID-19 commentaries from both experts and non-expert pundits alike: the range of opinions expressed is enormous. Some express optimism that measures implemented by most countries are working and that the virus can and will be contained in several months; others argue that current measures are an example of 'too little, too late', that we are in it for the long haul and that the future months are going to be be extremely grim. These opinions are nothing more than that, given the vast number of unknowns. There are so many variables that will determine how this all plays out. These not only involve the success of the current measures, but on the biology and ecology of the virus itself.

This brings us to the precautionary principle, which means that when there is uncertainty or lack of information on the impact of an event, which can lead to serious damage, measures should be taken to prevent such a situation to appear. In other words, itshould be applied when events associated with calamities can damage the functioning of a system seriously, or even destroy it. For example, when an innovation can lead to irreversible consequences for, e.g., human health or the ecosystem, scientific proof is needed of lack of harm. Here lack of action is the result (Taleb et al. 2014).

In the context of the current corona crisis, an important issue appears, namely which system is threatened. The health care system for sure, in the short run. But socio-economic systems can be threateded in the long-run. As Anderson et al. (2020) argue, there is in fact a trade-off between preventing deaths from COVID-19 and prevention of negative economic consequences. The authors argue that human life is most important for citizens. However, from the economic point of view, the question is, should human life be saved at any cost? For many this may sound horrible, but considering the example provided above on hospitals making choices whose life to save, this issue is relevant. When considering the unseen consequences of any kind of activity, preventing as many deaths as possible may have serious economic consequences.

While the spread of a virus may be considered a natural event, especially in a globalized world, the impact depends on how society deals with the threat.This is not only related to culture and good governance, but also, as Kelman (2020) argues in a blog, on "shoddily built infrastructure, breaking or not having planning regulations, not being able to afford or not having insurance, poor communication of warnings" as well as ignorance of advice and information from experts and poor information provision to society. Another factor that can limit the spread of the virus is general access to health care, as in case of a private health care system, and unpaid sick leave that allows people to remain at home in semi-quarantine. One of main problems in the United States is that millions have no health insurance (Gilmer et al. 2005), the poor not only may not try to find medical onsult, but also undertake activities to obtain a source of income, and many others are only paid when they working, forcing them to turn up to jobs when they are ill (Chen 2016) thus increasing the spread of the virus.

Other important elements of dealing with such a crisis situation are (Anderson et al. 2020): experience, like China, Singapore and Hong Kong, social distancing, isolation and quarantaine which can seriously enhance the containment of the epidemic. Also the number of tests carried out are important for obtaining reliable data and developing policy to deal with the epidemic (Karczmarewicz 2020). Indeed, several Asian countries that experienced the SARS COVID-1 infection in 2003 responded proactively by implementing measures before the viral outbreak in China had spread very far. Taiwan, for example, implemented severe travel restrictions to Chinese nationals as early as January (Chinazzi et al. 2020). If other nations around the world had taken similar measures, instead of maintaining a business-as-usual scenario, we might not be in the predicament that we are now. Public trust in government institutions may have been severely damaged by the lax response to the crisis. However, given that many people are highly skeptical of governments most of the time, it is hardly surprising that they place little faith in current measures to contain COVID-19. In fact, this may also explain why some people in Europe and North America are openly flouting government advice in containing the spread of the virus. Recent evidence shows groups of people meeting in bars, cafes, on beaches or in other public places even in Italy, where the effects of the pandemic have been most severe. The libertarian ethos that pervades much of western society may indeed hinder efforts to ‘dampen the pandemic curve’.

Another main reason for failure of the containment strategy is the limited capacity of health care systems. As discussed earlier, when too many patients are in the intensive care at any one moment, there will be a lack of beds, equipment, staff, etc. This leads to reduced health services for other ill, with all of its consequences. This problem is strengthened when there is a lack of co-operation between hospitals and regions, as regions with excess capacity can relief the troubles in the disaster area. However, this also creates the threat that when patients need intensive are in hospitals in non-infected regions, the capacity for delivering health care services to their patiens may also suffer there. Added to this, contact with patients increases the risk for health care staff to become infected, reducing the capacity of hospitals to deal effectively with the heavily ill (Pan et al. 2020). As the virus may be active for more than a year, and finding a vaccination may take 12-18 months (including medical testing) (Andersson et al. 2020), the strength of quick isolation, quarantaining and social distancing increases in importance, as it can significantly reduce the doubling time of the amount of infected people (Wilder-Smith, Freedman 2020).

4. Some (potential) consequences of the epidemic

The closure of many production facilities as well as shops, restaurants, etc., are likely to have a huge impact on the unemployment rate, cause negative economic growth, while the stock markets declined by about 30% (Amadeo 2020). The OECD has also predicted that the effects of the virus will be far greater than the financial crisis of 2008, and far more long-lasting (Sapovadia 2020). The decline in value on the financial market, declining national income and the increasing pressure on government budgets, will put also pressure on pensions and public goods and services. The dependency on tourism and exports may also lead to different scenarios for different countries.

Another example of a potential consequence is that highly developed countries may try to employ more specialists from other countries in order to deal with future short-term threats, creating a capacity problem in the countries “exporting” these specialists. This, except for the current negative impact on public health, also reduces the capacity of some countries to deal with possible future epidemics. Furthermore, as viruses do not recognize borders, this may increase the probability of future epidemics as well, exacerbated by globalized trade and increasing interconnectiveness (Taleb 2012).

The institutional consequences of the COVID-19 epidemic are hard to predict. The uncertainty may create a kind of institutional vacuum, where the existing institutions (rules of the game (North 1990)) do not apply completely and may be difficult to enforce (see Van de Mortel 2000; Platje 2004). Examples of a complete institutional vacuum are Arabic countries after the revolutions in 2011, where strong groups took over the power structures (Harari 2019). Naomi Klein (Vice 2020), in an interview on the current situation, argues that „These are the perfect conditions for governments and the global elite to implement political agendas that would otherwise be met with great opposition if we weren’t all so disoriented.” While limitations on different types of freedom are necessary in democratic societies in case of threats to the functioning of society, they should be withdrawn after the threats disappear, like in the case of 9/11 (Etzioni 2018). However, unpleasant surprises may increase in frequency in future. An issue that requires serious consideration is whether the existing uncertainty will not be used by the economically powerful to permanently change the rules in their own advantage, and/or to strenghten their economic position, which is turn contributes to increasing inequalities. As markets inherently are more random and rough than is often assumed (Mandelbrot, Hudson 2008), and extreme events with low probability will always appear at some time (Taleb 2007, 2012), this issue will always be relevant when assessing the stability and incentives for change in a capitalist society.

An interesting exercise is, what would happen in the short term when one of the following activities would disappear (compare Taleb 2012). For example, what would happen if university professors would suddenly stop working? Or researchers stopped working? Or garbage collectors stopped working? etc. In the last case, in the short term, the effects will become directly visible. When not teaching students, the effects on human capital become visible only in the longer term. When stopping broadscale scientific research, this reduces the capacity to deal with future epidemics and other unexpected events, The activities mentioned below cannot be removed without seriously damaging the functioning of society. They have what can be defined as good public functions, as their effects are beneficial for the whole of society. They are also intimately interconnected. For example, without transport, trade is impossible (Rydzkowski, Wojewódzka-Król 2000) and markets would stop functioning (compare Adam Smith, third chapter of his *Wealth of Nations* (1998 [1776]).

Examples of activities necessary for the functioning of a society in such a crisis are (Rijksoverheid 2020): health care, teachers providing distance education and taking care of children of parents working in the sectors mentioned here, public transport, the supply and distribution chain of food, energy supply and distribution, water supply, management of dangerous waste such as nuclear waste, waste management, child care, media and communication as an element of good governance (acess to information), police, military, fire brigade, government agencies involved in social services for the unemployed, ill etc., telecommunication, online banking services, internet services, etc. As Remuzzi and Remuzzi (2020) write, “[i]t is often the low paid providers of the public goods that have to keep the economy running.” Clearly, their role in economic recovery will be as vital as ever in the wake of the COVID-19 epidemic.

5. Concluding remarks

It is difficult to predict what is likely to happen in the future. The current COVID-epidemic may show the fragilities in the national and global economies. In other words, weakest links and vulnerabilities. This creates an opportunity to reflect on how to deal with such events in the future. The central point is that unexpected events can be expected (Taleb 2012). The random events, as mentiones, make vulnerabilities in political, social and economic systems visible. The high uncertainty appearing during and in the aftermath of such events may trigger off changes that can go into different directions.

For example, a question is whether the Schengen agreement may collapse due to the crisis. Maybe not, but a possible scenario is that when different countries in the EU have different policies of detecting infections, this may be used for continuing restrictions on free travel based on fears for public health. The crisis creates the threat of power enlargement for strong interest groups. To a global kind of oligarchic capitalism, accompanied by increasing nationalism and demise of democratic societies. However, there may also appear opportunities to galvanize society towards and more locally thinking, egalitarian economic system which can deal with other challenges to sustainable development such as climate change and resource depletion. Most important maybe is a discussion on whether the current political-economic system and globalization makes future pandemics more likely, and whether a radical change towards a more locally oriented economy provides solutions.

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