Act locally, transition globally: grassroots resilience, local politics, and five municipalities in the United States with 100% renewable electricity

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Title: Act locally, transition globally: Grassroots resilience, local politics, and five municipalities in the United States with 100% renewable electricity

Abstract

This paper examines five communities in the United States (U.S.) that have transitioned to 100% use of renewable resources for electricity. The paper describes and compares social, political and economic similarities and differences among these communities to improve understanding of the factors that support successful renewable energy (RE) transitions. The analysis builds on Geels' multi-level perspective theory in assessing sustainable energy transitions and the energy transition process based on these five case studies. Main variables of interest considered for 100% renewable energy transition in these municipalities are renewable energy resource availability (solar, wind and hydro), utility ownership, partisanship of municipal leadership, population size, and supporting energy legislation at state level renewable portfolio standard (RPS). Findings from this paper show that utility ownership appears to play a critical role in the transition process, as most of the municipalities have municipally owned utilities. State RPS programs are also prominent among all the states in which these the municipalities are located, indicating the importance of state legislation. Further, RE resource availability may not be required, as possibilities for hybridization of energy technologies are evident in the studied places. The most common pathway typology in these 100% RE transitions is reconfiguration. This typology results from technological innovations fuelled by development in RE technologies and stakeholder advocacy. Identified drivers from this research provide helpful parameters of consideration for energy transitions in other places in the U.S. and beyond.

Keywords: 100% RE transition, municipalities; United States; multi-level perspective; driver matrix.

1. Introduction

It is no longer news that renewable energy (RE), specifically electricity generated from renewable sources, is becoming more appealing globally. At local levels, municipalities are already benefitting from lower energy costs associated with RE resources such as solar, wind, and hydro (Gearino, 2019; Sierra Club-a; U.S. Climate Alliance) while also achieving GHG reduction, better air quality, and new job opportunities (Martinez, et.al. 2018; Banerjee, et.al. 2017; Bunker, et. al. 2015). RE is also appealing because of the degree of financial security it offers due to the non-volatility of prices relative to fossil fuels (Martinez, et. al. 2018; Branker et.al, 2011). This is especially advantageous to community members who are retired or are for other reasons supported by a fixed income (Martinez, et.al 2018). The economics of RE compared to conventional fossil fuel resources make RE a better investment choice for electricity production at a local level (Prehoda et.al, 2019; Kantemneni et.al, 2016).

RE is becoming increasingly popular in the United States. Data from the U.S. Energy Information Administration (EIA, 2019) reveals a gradual and steady increase in the penetration of RE, at 17% in 2017, ranking 4th among other sources for electrical power generation in U.S. electrical power mix. EIA forecasts

also show that by 2050, RE will rank second highest, reaching about 31% behind natural gas with 39% (EIA, 2019). This RE transition will likely be propelled by the development in renewable technologies, especially through the deployment of storage to balance the intermittencies of solar and wind power plants, as well as the continuous decline in costs and improvement in performance of RE technologies (EIA, 2019). Simultaneously, use of coal and nuclear sources are expected to experience corresponding decline. The International Renewable Energy Agency (IRENA) appears to be more optimistic regarding the country's potential for RE adoption, predicting that RE will comprise 78% of U.S. electricity generation by 2050 (IRENA, 2018).

If all current assumptions regarding geophysical and technological variables such as increase in efficiency of solar, wind, etc. remain constant, the U.S. is capable of meeting 80% of current nationwide electricity demand with solar and/or wind at any given time (Shaner et.al. 2018). This implies that as far as technical feasibility is concerned, 100% RE transition for electricity production in many places in the U.S. is beyond just an ambition. Furthermore, (Shaner et.al. 2018) argue that the country has 100% RE transition capability with the right storage technology, policy, and planning. In the face of grid parity, price performance, market competition, and cost-benefit analyses of RE electric generation technologies, different energy agencies or regime actors in the energy sector can easily exhibit a trajectory of transition (Geels and Schot 2007).

Another important trend is people's perceptions and increasing interest in RE (Sierra Club-a). In one national survey, 90% of respondents supports government intervention to encourage the development of RE (Martinez et.al, 2018). Various coalitions of cities, including the Global Covenant of Mayors for Climate and Energy, C40 Cities Climate Leadership Group, and ICLEI Local Governments for Sustainability, are moving toward 100% RE targets, with over 250 US Mayors showing strong commitments (Sierra Club-a; Martinez, et.al. 2018). This reveal growing grassroots commitments on climate and energy issues (Stephens et.al, 2018) despite the current U.S. federal administration's announcement to withdraw from the Paris Agreement (Carley et.al, 2018; Martinez, et.al 2018). At the state level, at least five municipalities in U.S states have achieved their 100% RE goals by May 2019 (Sierra Club-b). This is an indication of small but growing interest in transitioning from dominant incumbent energy sources.

Sierra Club is a U.S. based environmental advocacy organization that has created its own campaign for government commitments to 100% electricity from RE. This study draws on Sierra Club's campaign and focuses on five U.S. municipalities that have already achieved this goal: Burlington, Vermont; Aspen, Colorado; Greensburg, Kansas; Georgetown, Texas; and Rock Port, Missouri (Sierra Club-a).¹ This study examines 100% RE transitions with attentiveness to the role of various actors and their interactions at different level in these five pioneering municipalities. This analysis utilizes the Multi-level Perspective (MLP) of

¹ For the purposes of this article any references to 100% commitment to RE mean commitment to 100% electricity from renewable sources.

sociotechnical transitions (Geels and Schot, 2007) as well as drawing from existing literature on energy transitions to examine the successful energy transitions in these five municipalities.

1.1 Research Problem

Prior research on 100% RE in the five municipalities (Martinez et.al 2018; Sierra Club Sierra Club-a and b; Hess and Gentry, 2019) approaches the topic from different perspectives, with little framework that could be replicated by other U.S. municipalities. As municipalities and their mayors that have pledged their commitment to transitioning prepare to achieve this feat, there is a need for a framework of what to learn from. This is especially for other municipalities within the same state of those five municipalities; Georgetown, Burlington, Aspen, Rock Port and Greensburg, who have achieved the 100% RE transition. Although the five cases appear to be small sample size to generalize for the thousands of municipalities in the U.S., they equally provide geographical diversity (social, economic and political) based on states where they are located. As such, having a transition framework that can be useful for other U.S. grassroots and communities who are interested in low-carbon electricity to consider is needed.

Another shortcoming with existing literature is limited reference to how the driving factors interact in such transition process. The knowledge of various interactions of driving factors in the transition process can inform typologies in those places and allows for better understanding of the MLP. As the MLP has gained much attentions among scholars of sociotechnical transition, there is still limited work that operationalizes the various typologies, in particular 100% renewable electricity context. This is perhaps due to the fact that not so many of such transition to zero carbo electricity has been achieved globally.

1.2 Research Objectives

This review paper aims to develop a framework of factors that should be considered while assessing the socio-technical feasibility of 100% RE transitions at the local level in the U.S. In this paper, a comparative analysis is carried out on contributing factors at the three levels of socio-technical transition. The levels based on MLP are the niche innovations, socio-technical landscape and socio-technical regime. Qualitative Comparative Analysis (QCA) is used to develop a driver matrix of observed factors and their role in these five municipalities.

Further, we aim to provide a descriptive analysis of the energy transitions and observed typologies in each of the five communities that are being powered by 100% RE. With this, we strive to identify some of the important factors to consider through the multi-level perspective (MLP) as framework in researching transition to 100% RE in other U.S. municipalities. This paper contributes to bridging the gap in existing literature, which is currently lacking detailed and comparative accounts on pathways for 100% RE transition in U.S. municipalities. Developing a framework for understanding RE transitions through a comparative analysis of successful case studies is intended to contribute to both further refinement of MLP as a conceptual model and to developing practical guidance for communities seeking to move toward 100% RE.

2. Conceptual Lens: Energy Transitions and the MLP

The use of energy for meeting human needs has involved several evolutions in sources, from the use of human power to the adoption of animal like oxen and then the development of machinery for productivity improvement with steam engines produced by wood and coal, and then by liquid fossil fuels (Smil, 2017). Markard et.al (2012) highlights a need for future empirical research to elaborate and specify such conceptual frameworks like the MLP. This is because there is limited research on transitions in practice and everyday life (Kohler et.al, 2019; Markard, 2012). This is the aim of this work – to deploy a conceptual framework in a comparative analysis of the empirical realities of energy transitions at the municipal level in order to refine the framework and provide enhanced understandings of transitions in practice.

Based on the MLP of sociotechnical transition, energy transitions are presumed to be dependent on the interactions and process alignment of three levels: niche innovation, socio-technical regimes, and socio-technical landscapes (Geels and Schot, 2007; Geels 2014; Geels 2018). This review revealed what previous research found as drivers to RE transitions in the U.S. in addition to the MLP theoretical framework. Bayulgen (2020) recently found that clean energy transition in local town of Connecticut, hangs on government-society synergy. Regime actors appears to be the main drivers analysed in the paper. The research was done using a combination of public documents (secondary data) and semi-structured interviews (primary data).

In similar research by Lee et.al (2020), regime level policies (state RPS) and niche-level actions are found to contribute significantly to Hawaii's transition. Other drivers include energy resource endowment (Zhu and Wang, 2020; Martinez et.al, 2018;), energy cost, and experience of climate change effects (Martinez et.al, 2018). Public engagement through environmental organizations and community advocacy in the planning process has been critical in establishment of some documented 100% RE goals (Hess and Gentry, 2019), especially in Lake City, Park City and Moab, Utah (Skill, 2019).

2.1 Re-introducing and operationalizing the MLP in energy transition

The socio-technical regime involves structural and social agencies including markets, users and their preferences, policy makers, scientists and industry actors that dictate the how, when, and what of energy systems and their transitions (Geels and Schot 2007). The MLP argues that every form of technological transition is strongly influenced by overlapping activities in two or all three levels at different times (Geels and Schot 2007; Geels 2014; Araujo, 2014; Kohler, 2019). Figure 1 presents the MLP transition curve, showing the interplay among processes in bringing about technological transitions. Transitions take place through the interaction of multiple scales, within and across hybrid agencies, and based on rational, interpretative, routine, and power-based actions (Geels and Schot 2007). The MLP as a global model takes into consideration the activities of different actors as transitions occur through contest and struggles (Geels and Schot 2007).

In other words, in energy transitions, the dynamics surrounding the interactions of multiple entities such as consumers, policy makers, utility structures, and technological novelty as well as the multilevel interactions among various actors are critical prerequisites. Energy systems are characterised as socio-technical systems involving several elements fulfilling societal energy functions (Kern and Smith, 2008). Because the MLP discusses socio-technical transitions in general, it is expedient to operationalize it in the context of energy transition in the U.S. This paper attempts to match the actors involved in energy transitions in the U.S. to those described in general in the MLP framework and to document characteristics and interactions that correspond to successful RE transitions in municipal settings.

The socio-technical landscape also includes external factors (e.g. climate change) beyond control of regime members, affecting the development of energy system (Kern and Smith, 2008). From the MLP transition typology curve, form of ownership and structure of the electricity provider, resource availability, and other external factors can be assumed to operate at the level of the sociotechnical landscape. Also, central to achieving such trajectory as in the case of the U.S., is the type and role of electricity provider. By electricity provider, this review refers to electric utilities. including investor owned utilities (IOUs), cooperatively owned utilities (co-ops) or municipally owned utilities (MOUs) (Bluvas, 2006; Hess, 2013; Hess, 2016). IOUs are required to maintain a certain level of electricity service to their customers while maximizing profit for their shareholders. In contrast, MOUs and co-ops are supposed to serve in the best interest of their customer-residents and customer-members, respectively. (Bluvas, 2006; Prehoda et.al, 2019). In the U.S., the majority of customers are served by a small number of IOUs (Hess, 2016). Communities that are served by IOUs are reported to experience higher resistance to 100% RE transition goals (Hess and Gentry, 2019). Understanding the role utilities play in successful transitions is therefore necessary.

Scientists, public authorities such policy makers and energy regulators at all levels, consumers, energy markets, civil and special interest groups such as the Sierra Club, Greenpeace, and the media (Geels, 2004) all contribute to the patterning of technological development, and they constitute part of the sociotechnical regime (Geels, 2014). Within the MLP, they represent various techno-institutions complex similar to that which is described by Unruh (2000; 2002). The complexity of formal and informal institutions in this web include preferences and identities of individuals, community, leadership and policy makers. An example is the role of partisanship in energy technology choices. Previous research examining the relationship between political affiliation of Americans and their perception towards alternative energy development has resulted in conflicting findings.

Mildenberger et.al (2017) provide a background for understanding the effect of partisanship on the perception of climate change and corresponding degree of heterogeneity in policy preferences. Their research establishes that among the members of the Republican Party, there is heterogeneous climate policy preferences including renewable energy funding and carbon controls. In addition, according to Carlister et.al (2015), political ideology proves insignificant in terms of support for solar energy development in the U.S.. meaning

that there may be differences in views on climate and energy policies within the same political party. However, Mayer (2019) and Karapın (2019) found that local policy actors who identify as Republicans were less likely to support the Clean Power Plan, a signature initiative of the Obama Democrat administration. It is thus unclear how individual or community level political affiliation identities may affect support and ultimate achievement of 100% RE transitions.

The niche innovation level is the point where technology is developed and introduced to the market for price or performance improvements (Geels, 2014); the evolution of technologies and innovations usually bring about a shift via adoption. Niche-innovations describe various energy technologies such as solar, wind, hydro, and fossil fuels (coal, oil and natural gas), available to the U.S. market. Geels (2018) defines them as social or technological innovations with sharp contrast from prevailing sociotechnical system and regime. They are also the level that accounts for preferences regarding one technology or another for the purpose of power generation. At this level, the contest is between well-established incumbent fossil fuel and the renewables for electricity generation. However, most adoption decision activities lie at the socio-technical regime and the socio-technical landscape levels (also referred to as the incumbents).

Figure 1: MLP on socio-technical transition and main actors and interactions in each pathways (adapted by authors from Geels and Schot 2007)

2.2 100% Renewable Electricity and Transition Typologies

The MLP organizes transitions into typologies depending on the types of interactions. Geels and Schot (2007) describe four different transition pathways, based on the interaction of actors in the MLP curve: 1) Transformation, 2) Technological Substitution, 3) Reconfiguration and De-alignment, and 4) Re-alignment. The major difference between these pathways is the level of involvement of main actors, leading to such

transition. In other words, all of these pathways have common elements and agency who play roles in various degrees. So, in this section, efforts are made to give a clearer view of each pathways with respect to transition to low-carbon electricity.

In the ***Transformation*** pathway, main actors involve actions and voices of players such as policy makers, policy regulators (e.g. public service commissions), customers, researchers, special interest groups (e.g. Sierra Club), and other stakeholders. These regime and niche actors lead to the creation of new plans or goals for innovation (Geels and Schot 2007). Specifically, instability and changes in the socio-technical regime precipitate adoption of new solutions. Current 100% RE goals, adoption and implementation of low carbon electricity in many places fall into this category.

Technological Substitution is described as a situation of technological push sequel to the emergence of radical innovations in the niche and simultaneous landscape pressure on existing regime (Geels, 2004). In other words, as changes begin to occur via technological innovation, demand for better solutions compels a change in the market, consumer behaviour, user culture as well as in policy. Unlike in the transformation with stakeholders, some of which maybe external to the community (e.g. Sierra Club), cultural adjustment of internal stakeholders and market power tussle play key role in technological substitution. However, this takes time before the pressure yields substantial change in a dynamically stable regime.

Reconfiguration involves hybridization and interaction across multiple innovations (Geels, 2018). The key concept here is co-existence of technologies leading to hybridization to foster learning process and gradual development of new goals and visions. Transition in electricity to low-carbon technologies in many places such as The Netherlands (Kern and Smith, 2008) has been achieved through hybrid energy technologies of coal, gas, nuclear, and renewables as well as social interactions while the incumbent regime experiences gradual weakening or phasing out (Geels, 2014). Reconfiguration often involves formal pressures in the landscape and regime level that create niche level innovation.

In the ***De-alignment and Re-alignment*** typology, increased niche momentum facilitates multiple innovations, allowing one dominant design to stabilize. In other words, the peculiarity of this transition typology is based on loss of confidence in the existing regime and landscape levels (energy resources, structures, technologies, policies, etc.), due to the emergence of a new paradigm. This may lead to a shift to decentralised technologies and management (Stephens et.al, 2018).

As the MLP is a generalized broad framework for different sociotechnical transitions, it is necessary to place it in juxtaposition with existing energy contexts. This research intends to identify the specific transition pathway typology involved in each of the five municipalities that have achieved 100% RE and account for the factors that contributed to these successful energy transitions. This is necessary for further recognition of dependent variables that must be considered in other municipalities and cities for possible replication of achieving 100% RE transitions.

To put the MLP pathways typology in the context of 100% RE transitions in the U.S., Table 1 below was created by extrapolating descriptions from (Geels and Schot, 2017). As demonstrated in the table, each pathway involves a transition with main actors, interactions, and concepts that vary. This table also signals the key features this paper interrogates in each municipal case study in order to conduct the comparative analysis of successful transitions.

Transition pathways	Main Actors	Types of (inter)actions	Key Concepts
1. Transformation	Scientists, policy makers and state legislation (RPS), resource availability, utility structure, special interest groups (Sierra club, etc.)	Criticism leading to formation of new goals and plans	External energy advocacy, Mayor negotiations, rule adjustment, and statutory formation, changes in structure or landscape
2. Technological substitution	Conventional and RE producers and suppliers, (utilities and power generating firms), political affiliation of mayors, consumers, electricity prices, interest group, state legislation etc.	Novel RE solutions that compete with current fossil fuel-based energy producers	Price determinism, rationalism, market power tussles between the old and new energy producers. High market entrance of new technologies, retirements of old, re-establishment of new winner.
3. Reconfiguration	Niche-innovation entrants and energy resources (RE), small regime actors such as utility, policy makers, community members, institutions etc	Energy technology adoption by small regime actors, changes in utility structure leading to new energy plans and goals. Interplay of regime actors with energy technology and suppliers	Co-existence of technologies leading to hybridization to foster learning process. Gradual development of new goals and visions.
4. De-alignment and Re-alignment	A segment of industries and small users of RE and EE technologies, incumbent technologies e.g. coal and their actors	Energy technological innovations poses pressure on regime, incumbents lose power, giving way for new technologies	Market competition and new versus old firm power struggles, culture change etc. Gradual loss of trust in incumbent

Table 1: Main actors and interactions in MLP transition typology (Source: Author based on interpretation of Geels and Schot 2007)

3. Methodology

This study is based on review of peer-reviewed academic literature, online documentation such as relevant information from webpage of the case study communities and variable data regarding the energy transition in the five municipalities. In the absence of enough previous research works that systematically account for 100% RE transition in these five municipalities, it is pertinent to seek direct information from these places. Each municipality's website divulges useful information for investigating factors leading to the transition. Data from Sierra Club on advocacy for RE is used as foundation to this research. This advocacy comes in three different forms. Sierra Club distinguishes three types of calls for RE adoption: 100% RE Campaign, 100% RE Commitment, and 100% RE Powered. The ready for 100% RE Campaign indicates interest and calling for achieving 100% RE but without specific temporal commitments to targets. Because these pledges do not usually come in the form of legislative acts, they are susceptible to being discarded with changes in mayoral or municipal leadership.

The 100% RE Commitment involves pledges made by municipal leaders, which are made for ambitious targets. In the U.S., the main municipal governments forms include Mayor-Council, Commission, Council-Manager, Town Meeting, and Representative Town Meeting (MASC, 2017; Moulder, 2008). The two prevalent forms are Council Manager and Mayor-Council (Moulder, 2008). While the first three mentioned forms involve election of the local government leaders in the municipalities, Town Meeting and Representative Town Meeting officials are selected by voting citizens (Moulder, 2008). A mayor is a common elected official at the municipal level, charged with overseeing and managing affairs in cities, towns, and other sovereign units (Bae and Feiock, 2013; City Mayors). Mayors also have capability to veto ordinances passed by a city council, which serves as the legislative body (City Mayors; Moulder, 2008).

In total, mayors from 121 different cities have indicated their committed to reaching RE targets by a specific year (Sierra Club, 2018). States with the most mayors making such commitments to 100% RE are California, Colorado and New Mexico, with fifteen, seven and six municipalities respectively (Martinez et.al. 2018). Of these 121 mayoral level commitments, five municipalities have already achieved 100% RE Powered. The five municipalities Rock Port, Burlington, Greensburg, Georgetown and Aspen are the members of this category, and they are the objects of this study. These commitments and actions have been accumulating at the same time as the U.S. announced its withdrawal from the 2015 Paris Agreement (White house briefings, 2019; Sierra Club 2018). In addition, the current administration under President Trump is showing more interest in supporting fossil fuels and their use in electricity generation U.S. (White house briefings 2019).

Although our analysis of factors in sociotechnical transition are built through the MLP framework, we also incorporate more literature review to strengthen and analysis with the MLP. The variables of the study are RE technology utilization, RE resource availability (solar, wind and hydro), utility ownership and supply source, supporting energy legislation at state level (renewable portfolio standard, RPS), municipality size (population), partisanship of municipal leadership, time to reach accomplishment sequel to initial decision, and other unique corresponding factors including municipal energy programs and stakeholder involvement in

the process. While RE technology relates to development of niche innovation on the MLP, population, leadership partisanship, supporting legislation and stakeholder involvement pertains to activities in the socio-technical regime. Socio-technical landscape thus involves RE resource availability outlook and utility ownership. The varying interactions of these variables yield four different pathways to the energy transition based on the MLP.

Data on the different combinations of RE technology utilized in each municipality and utility ownership in each municipality were checked from their webpages and other published data. In the U.S., three forms of utility ownership generally exist; investor owned utilities (IOU) are a profit-making corporation, municipal utilities are controlled by the municipality as the name suggests, and rural electric cooperative utilities are owned by utility ratepayers. National Renewable Energy Laboratory (NREL) data was used to assess RE potential in the municipalities that have achieved 100% RE. For solar potential, NREL's published National Solar Radiation Database map (Appendix 1-1) was used. Wind potential was assessed using Land-based and Offshore Annual Average Wind Speed at 100 meter above ground level, also published online by NREL (Appendix 1-2). The U.S. National Hydropower Map of Oak Ridge National Laboratory provided the information of operational hydro plants in the country (Appendix 1-3).

NCSL data was used to obtain supporting energy legislation, specifically state RPS. RPS is a statutory requirement on utilities to ensure a certain percentage of the electricity sold by them comes from RE resources (Klass and Wiseman, 2017; Wiser et.al 2007). Previous research has shown that there is a significant and positive relationship between state RPS and adoption of renewable energy (Yin and Powers, 2010). Data on municipality size, partisanship of mayors, and time of accomplishment were gathered from Sierra Club and other published information. The MLP transition typology (Geels and Schot, 2007) was used to identify what variables may matter for successful energy transitions and the kinds of transitions identified in each case based on the associated variables in each municipality.

Each of these variables – energy technologies, resource mix, utility ownership, municipality size, mayor's political affiliation and state legislation exists in one or more of the multi-levels, that is the innovation niche, sociotechnical regime, and sociotechnical landscape. From data collected on these variables, a qualitative comparative analysis (QCA) on the RE transition was carried on the five municipalities. QCA is one of the most suitable and widely used research strategies in social sciences for multiple case studies, designed to address small-*N* and intermediate-*N* research situations (Rihoux, 2006). In doing this, a matrix table (Table 2) was created for the description of results of the research. QCA is also gaining ground as a method in investigating and uncovering complex patterns like the MLP (Kohler et.al, 2019).

Municipality, Transition Typology and Year	Renewable Energy Mix	Utility Ownership & Supply Source	City size & Mayor's Affiliation	State Legislation on RE (RPS)
Georgetown, TX				
Burlington, VT				

Aspen, CO				
Rock Port, MO				
Greensburg, KS				

Table 2: Driver Matrix

4. Results: Review of transition drivers in the five municipalities

There are a diverse set of motivations for the RE transition among the five municipalities. In accounting for these drivers, this section serves as a checklist in assessing some prominent factors of each energy transition based on the driver matrix provided in section 3. It also interprets the transition pathway typology that is evident in each municipality based on key actors, levels, and their interactions. The three prominent RE resources that are common to these municipalities for electricity generation are hydro, solar and wind. However, achieving 100% electricity delivery from RE sources is possible even without resource availability either within the municipality or others in proximity. Factors other than resource availability that appear to drive these successful municipal RE transitions are identified. A summary of all the identified driving factors is presented in Figure 2 of driver matrix at the end of this section.

4.1 Georgetown, Texas

In 2018, Georgetown achieved its goal of 100% powered by RE resources. The municipality's energy mix comprises 150 MW solar with NGR Energy Inc. (a renewable energy company) and 144 MW wind with Électricité de France (EDF) RE, serving its municipally owned utility, Georgetown Utility System (GUS) (Foster, 2017; Motyka et.al, 2019). Resulting generation mix shows approximately 50% solar and 50% wind resources, imported from power stations located about 500 miles away from the municipality. The utility, GUS, is municipally owned and not for profit. Georgetown and its utility are developing solutions to long transmission distance (500 miles) from its solar and wind power sources in Fort Stockton and Amarillo respectively despite locally available resources.

Georgetown has the highest population among the examined five municipalities , with 54,898 residents (Sierra Club, 2018). The local government is headed by an elected mayor, who is a democrat (Long et.al, 2018; Yang, 2019). On RE resource availability, global horizontal solar irradiance in this place is higher than average in the US, within the range of 5.00-5.25 kWh/m²/day based on NREL data map (supplemental material 1). Further, at 100 meters above ground level the wind speed in Georgetown is about 7m/s (supplemental material 2), while the hydrography shows average annual run off approximately 250mm/year of hydropower potential (supplemental material 3). This shows an indication of locally available renewable energy resources that can support the community's RE transition goal.

Furthermore, the state of Texas is well endowed both in conventional sources and renewable energy resources (Long et.al, 2018). The state of Texas had its RPS legislation first enacted in 1999 (Garbose, 2016) and currently has a renewable generation requirement of 10 GW RE capacity target by 2025 (NCSL, 2018).

As the RE usage in Georgetown is counted as part of the state's RPS, the legislation is considered another support for achieving 100% RE transition in the city. Texas also leads the nation in RE installed capacity of over 23 GW from combined solar and wind (Long et.al, 2018). To support transmission infrastructure for RE, Texas state has shown significant support by investing \$7 billion in a competitive Renewable Energy Zone program (Sierra Club, 2018).

GUS engages community members, energy partners, and stakeholders in the development of distributed generation such as rooftop solar and batteries, which reduce the technical and economic challenges of using centralized systems to meet the 100% RE target (Georgetown, Texas). The attempt is also geared towards harnessing local resources to continuously meet demand without interruption. This public engagement is increasing perception and willingness of the people, especially homeowners to participate in the rooftop solar power project if approached. This is also very instrumental to Georgetown winning a \$1 million grant from Bloomberg Philanthropies in the U.S. Mayors Challenge in 2018 to install 400 solar panels on about 15 city rooftops (Linan, 2018).

Environmental reasons such as drought, as well as the falling prices of RE are among main drivers in Georgetown (Sierra Club, 2018). Other drivers of 100% RE in Georgetown are long-term contracts with fixed energy prices and financial and regulatory risk mitigation (Sierra Club, 2018; Foster, 2017). Thus, a pathway typology observed in this place is de-alignment and re-alignment, with the regime level spearheading the energy transition due to loss of faith in the incumbent system (refer to figure 1 and table 1). This is partly due to fuel price volatility leading to electricity costs unpredictability, scientific consensus on climate change and a match in resources to meet electricity supply from renewables (Long et.al, 2018).

4.2 Burlington, Vermont

Burlington, under the leadership of a democratic mayor (The City of Burlington, 2019; Drier and Clavel, 2015), achieved the 100% RE goal in 2014. Its energy mix is comprised of 50% hydro, 30% wood chip (biomass) and 20% for combined solar, wind, and landfill methane (Sierra Club, 2018). Its municipal utility, Burlington electric department (BED) (Stephens et.al, 2018), also outsources part of its supply from renewable electricity retailers such as NextEra Energy Power Marketing, Sheffield Wind, Georgia Mountain Community Wind, New York Power Authority (NYPA), Hydro Quebec, Vermont Electric Power Producers Inc., Vermont Standard Offer, ISO-NE Exchange and Hancock Wind (Burlington Electric Department). The net metering available in Burlington allows for distributed generation of electricity from solar and wind resources by privately owned systems to feed into the grid.

The city of Burlington in Vermont has been acknowledged internationally as being the first U.S. city to transition to 100% RE (Stephens et.al, 2018). Among the list of these five municipalities, Burlington is the second biggest in terms of population, with 42,282 people (Sierra Club, 2018). The city's GHI is among the lowest in the country, ranging between 4.00-4.25 kWh/m²/day and wind speed of 6.0 m/s (supplemental

materials 1 and 2). However, it also ranks among the highest on hydro power potential and resources (supplemental material 3). The average annual run off is about 2800 mm/year.

The state of Vermont also has a renewable energy standard (RES) of 75% RE by 2032, which is enforceable on investor, municipal and cooperative utilities as well as retail suppliers (NCSL, 2018). Under title 30 V.S.A. § 8004 on Vermont's RES, no electricity retailer in the state shall sell or provide electricity without enough RE capacity or tradeable RE credits (The Vermont Statutes). The public-private partnership (PPA) in place encourages community solar (NCSL, 2018). However, the state's RPS was first enacted in 2015 (Garbose, 2016), a year after Burlington's 100% RE achievement. Vermont also exemplifies citizens involvement and activism for transition (Clegg, 2013) in energy planning process due to the state's commitment to RE through participatory approaches (Stephens et.al, 2018). This includes a town energy committee set up in over 100 communities, various community solar projects developments, and establishment of energy action networks (EAN), among others (Stephens et.al, 2018).

Here, the transition pathway corresponds to the technological substitution typology, due to price determinism and market power tussles existing between energy producers. However, Stephens et.al. (2018) and Burke and Stephens (2017) in previous research interpret the transition typology in this place as being de-alignment and re-alignment. On the one hand, the eventual interplay of regimes led the way to a democratically accepted paradigm shift to the deployed energy source. On the other hand, the root cause is laden in technological innovation. Innovation in renewable energy technologies resulted in low LCOE opened room to demand for more affordable and just energy systems. This is also coupled with the net metering and energy efficiency programs in the region. The utility company influenced this transition as a socio-technical regime actor. It may also suffice to say, if the main actors in these two typologies evolved simultaneously, then this is a combined typology, as there is thin line differentiating them (refer to table 1).

4.3 Aspen, Colorado

In 2004, the city of Aspen began to embark on the journey of 100% RE transition, which was achieved in the year 2015 (NREL 2015; City of Aspen-a; McLaren, 2018). The electricity mix in Aspen now is approximately 53% wind, 46% hydropower, and 1% land-fill gas through COA-utilities (City of Aspen-b). A review of the RE resources in this location shows that the city has average solar irradiance between 4.75-5.00 kWh/m²/day, low wind speed of 4.0m/s 100 meters above ground level, and average annual run off rivers around 250 mm/year (supplemental material 1-3). COA-utilities is a municipal utility that provides electric and water services to the residents of Aspen. One of the core missions of this utility company is to deliver safe, reliable and 100% RE electricity to customers (City of Aspen-b). These must have played a key role in the transitioning of the city to 100% RE. The driver that seemed most important for Aspen is the environmental factor, because of the historical mining activities in the region (Martinez, et.al. 2018). Within a decade (2004-2014), the city had reduced emissions by as much as 42% and had developed a future goal of 30% reduction by 2030 (2004 benchmark) and 80% reduction by 2050 for the same reference (Sierra Club, 2018).

Aspen is a small city with a total population of 6,658 under the governance of elected city council (City of Aspen-a), headed by a mayor politically affiliated to the Libertarian party. The city established the "Canary Initiative" in 2005 in acknowledgement of the impact of climate change on the city, prioritizing sustainability with quality of life (City of Aspen-b). The Canary Action Plan was a collaborative work of the City of Aspen utilities (COA-utilities), Global Warming Alliance, city and county staff, and other stakeholders. From the Canary Action Plan, policy decisions and education at all levels of government prioritized significant reductions in GHG emissions. This represents a form of legislative commitment support to RE. To meet its 100% RE target in the face of deficient local renewable resources, Aspen entered a PPA with wind energy producers in neighbouring states – the Municipal Energy Agency of Nebraska and South Dakota (Martinez, et.al. 2018). The city also utilizes its hydro resources for power generation based on available run of rivers (Supplemental material 3), having two generating hydro power plants of 5 MW and 0.5 MW (City of Aspen-b). Furthermore, Holy Cross Energy (HCE), a co-operatively owned utility company in Colorado, is collaborating with COA-utilities to serve 70% of energy demand in Aspen to achieve 100% RE goal (Sierra Club, 2018; City of Aspen-a; City of Aspen-b). These, together with the state of Colorado's RPS under Act Colo. Rev. Stat. §40-2-124 (supplemental material 4) of up to 20% by 2020, which applies to all utilities (investor, cooperative and municipal) (NSCL, 2018), is considered to have facilitated the achievement of the clean energy goal.

The observed energy transition pathway typology in this city is reconfiguration, where regime actors (here city council) interplay with energy technology suppliers (COA-utilities, HCE). These actors played principal roles in the process and achievement of the target. It should also be noted that the time difference between when the decision or plan for 100% RE target was made and when it was achieved is within 11 years. This shows that time is a factor for maturity, as planning processes in this municipality were required to experience a successful energy transition. As indicated in the MLP analysis (Figure 1), the adjustment that occurred in the socio-technical regime of City of Aspen led to breakthrough of new technology. Also, in line with this is the fact that RE went through tremendous development in efficiency, component costs, and research between 2004 and 2015.

4.4 Rock Port, Missouri

Located in the state of Missouri, Rock Port is the first community in the U.S. to be 100% wind powered, achieving 100% RE in the year 2008 (University of Missouri Extension; Johnson, 2008). The small town generates 125% of its energy demand through public-private partnerships (Hart, 2009) from a total installed capacity of 5 MW (Morris, 2008). It has its power generating wind farm financed through partnership with Wind Capital Group and John Deere. Due to generation excess, the community is also able to sell electricity, serving as a means of income.

The energy resource maps show a very high wind and average solar resources of 10m/s and 4.25-5.00 kWh/m²/day respectively in this area (supplementary material 1-2). The amount of energy generated from

wind resource shows how much the resource availability contributes to the transition process. Recounting the transition, resource availability and technological innovation in wind power inspired one of the community members, which resulted in further research (Morris, 2008; Rock Port). With the wind turbines supplying electricity (Morris, 2008; Rock Port), Rock Port enjoys lower annual energy costs per capita compared to others, with an average of \$3000 per household (Cohen, 2010). Another economic benefit considered in transitioning to 100% RE is that it fosters stakeholder-ship in the communities, as in the case of Rock Port, where landowners can lease their properties for renewable infrastructures (Martinez, et.al 2018; University of Missouri Extension).

Rock Port is a small community with a total population of 1300 (University of Missouri Extension; Johnson, 2008; Morris, 2008) and under the leadership of a non-partisan mayor. The state of Missouri has an RPS established in 2007 to achieve 15% RE share by 2021 (NCSL, 2018). Furthermore, this small town is the only one among the list of five communities served by an investor owned utility (NCSL, 2018). The profit driven nature of such type of utility did not however deter the city from achieving this target amidst stiff challenges from incumbent regime and technology. According to the narrative of how this community transitioned, one of its residents, Eric Chamberlain who was the brainchild of this transition, saw a wind turbine in a nearby town and thereafter made a case for its consideration by the community (Morris, 2008). This narrative provides two learning points, first is the importance of knowledge and information about the capabilities of various energy technologies, and second is the role of a small group individuals and local leaders in the community who are willing to share their knowledge for community benefits (Simpson, 2018). The reconfiguration pathway typology is evident in this town's transition process, seeing the interplay between small regime actors, community leadership, energy suppliers and investors for energy transition.

4.5 Greensburg, Kansas

In 2013, Greensburg achieved transitioning to 100% RE amidst different socioeconomic challenges it was facing. The city houses the 12.5 MW Greensburg Wind Farm, which produces a 66% of energy demand, which is sold back for Renewable Energy Credits (Sierra Club, 2018). One of the ways Greensburg is achieving its goal is by having a contractual private partnership agreement (PPA) with Kansas Power Pool (Martinez, et.al. 2018). The whole city of Greensburg's electricity comes from wind energy (Greensburg, KS, 2019). Greensburg also created Sustainable Comprehensive Master Plan as a means of keeping the city's vision for their sociotechnical landscape in transition (Martinez, et.al. 2018).

Greensburg has the smallest population among the studied municipalities with a population of 778 (World Population Review) and is under the leadership of a republican mayor and city council executives (Greensburg, KS, 2019). Greensburg was affected by the massive tornado in May 2007 (NREL; Stones, 2013), leading to outmigration and a population reduction from 1400 to 785 (Sierra Club, 2018). Mayor Bob Dixon argued the environment got over-politicized and his administration decided to put an end to it while rebuilding Greensburg (Newsy, 2016). Reviewing minutes of the Greensburg council from December 2007, the impacts

of regime actors in the city's energy transition is evident. Records show Mid-Kansas Electric Corporation (MKEC) instigating the city council into greening Greensburg and their support for it during the executive session meeting in December 17, 2007 executive session (Executive Session, 2007). MKEC is a cooperative owned utility in the generation and transmission of electricity in Kansas (Mid-Kansas Electric Company, Inc.). The proposal submitted during this meeting by MKEC was greeted by unanimous support by all executives in attendance with a 4-0 motion passed under the leadership of Mayor John Janssen and city administrator Steve Hewitt. This marks the beginning of the city's journey to transitioning into 100% RE.

On resource availability, map shows very high speed of 9.0m/s at 100m height above ground level and good solar irradiation ranging between 5.25 to 5.0 kWh/m²/day (supplementary document 1-2). The state of Kansas does not have RPS, but a renewable energy goal of 20% by 2020 which was established in 2015 under Kansas Stat. Ann. §66-1256 et seq. (NCSL, 2018). The main difference between RPS and renewable goals is that while the former is mandatory or legally binding on utilities, the latter is not (SEIA, 2019; Li and Yi, 2014; Adelaja, et.al, 2010). RE investment is supported by Google and Kansas City (Newsy, 2016). There is municipal ownership of the local utility, which works in collaboration with the community on their goal.

The previous natural disaster that left a devastating impact on the community must be considered as one driver in the community's successful RE transition. The transition typology pathway that is evident here is transformation, as actions and voices of regime players including policy makers, special interest and community-based groups such as Greensburg Green Town (NREL, 2015; Stones, 2013), and other stakeholders were involved, due to landscape pressure, leading to the creation of new plans or goals for innovation.

Municipality, Transition Typology and Year	Renewable Energy Mix	Utility Ownership & Supply Source	City size & Mayor's Affiliation	State Legislation on RE
Georgetown, TX De-alignment and Re-alignment (achieved in 2018)	50% solar & 50% wind.	GUS – Municipally owned utility. All supply imported from EDF RE	Population of 54,898 Mayor is affiliated to Democratic party	Texas has 10 GW RE capacity target by 2025
Burlington, VT Technology substitution (achieved in 2014)	50% hydro, 30% wood chip, 20% from solar, wind & landfill methane.	BED – Municipally owned utility. Outsource part from RE retailers e.g. Hydro Quebec, NYPA etc.	Population of 42,282. Democratic Mayor's support	Vermont also has renewable energy standard (RES) of 75% RE by 2032 enforceable on MOU, IOU and Cooperative utility
Aspen, CO Reconfiguration (achieved in 2015)	53% wind, 46% hydropower, and 1% land-fill gas.	COA Utility – Municipally owned utility. Imports 70% supply from Holy Cross Energy	Population of 6,658 Mayor is politically affiliated to Libertarian party	The state of Colorado has of up to 20% by 2020 which applies to all utility type
Rock Port, MO Reconfiguration (achieved in 2008)	Over 125% wind energy.	Investor owned utility (public-private partnership) Imports if need be	Population of 1,300 Non-partisan Mayor	Missouri has RES established to achieve 15% RE share by 2021
Greensburg, KS Transformation (achieved in 2013)	166% RE from Greensburg wind farm. Excess 2/3 sold as REC.	MKEC – Co-operative owned utility with PPA with Kansas Power Pool	Population of 778 Republican Mayor	Kansas has renewable energy goal of 20% by 2020

Figure 2: Driver Matrix - Comparative analysis of socio-technical actors and energy transition typology in the 5 municipalities already in 100% RE.

5. Discussion

Most of these municipalities relied solely on fossil fuel for electricity supply prior to shifting to 100% RE (McLaren, 2018; Yang 2019). This is due partly to the stability of incumbent energy technologies and the sociotechnical landscape. This research finds that community members, social groups, existing energy legislation, and utility type or ownership are all critical in the transitioning of these five municipalities to 100% RE (Figure 2). These municipalities have shown resilience in achieving this feat amidst unpredictable political terrains, resource availability, and demographic challenges associated with small population size.

Furthermore, the research results show that these socio-technical transitions were achieved irrespective of political affiliation of their local leadership. Although two of the five local leaders who were responsible for the RE transition commitment are affiliated with the Democratic party, the study shows involvement from a mix of other political parties (Figure 2). For example, the mayor of Greenburg is affiliated with the Republican party, whose current national leadership tends to deny climate change or the need to prioritize climate change issues. Some previous scholarship suggests that political party affiliation of local leaders in U.S. with Republican party identity may hinder this transition. The current findings, however, though with a small sample, contradicts this suggestion, finding that 100% RE transition at U.S. grassroots levels is also evident in places with politically conservative mayors, city council managers, etc.

State level legislation such as RPS is a key factor, considering that all the states, except Kansas, of the five municipalities have it. An RPS can further strengthen previous arguments as a driver in energy transition. However, in the case of Vermont, it may be argued that the RPS cannot be considered as a driving factor because the achievement was prior to the state's RPS enactment. As policy processes (bill conceptualization, proposals, and passages) usually start much earlier than enactment, the effect of the RPS proposition could have played a role; given that the majority of US states not have RPS policies, these may be necessary but not alone sufficient for successful 100% RE transitions.

Another observation is the role of resource availability in these municipalities to produce electricity. As critical as the availability of these energy resources are, these municipalities have been able to achieve their target in the absence of it locally. Three out of the five municipalities – Aspen, Burlington and Georgetown – import some or all their electricity from renewable energy generating utilities in proximity to meet demand. These municipalities have been able to leverage the market instrument of renewable energy credits (RECs) for renewable energy trading and credit certification. This is fostered by the utility type in these places, which is predominantly municipally owned. Greensburg and Rock Port do not engage in importation like the other three. While Greensburg is served by a cooperative owned utility, Rock Port is served by an investor owned utility. Even then, they are engaging the public in public-private partnerships to develop RE generating power plants to meet the 100% RE goal.

The role of the public, civic groups, external pressures, and clean energy advocates is invaluable to the achievement of 100% RE transitions, even or perhaps especially in places where there is less support from the top leadership. Sierra Club's campaign and activities on energy transition is gaining more attraction by local leaders. Such attraction has led to exponential increase in the number of mayors that have signed up for 100% RE transition between 2016 and 2019 (Sierra Club-a and b). It thus makes this civil groups an important external actor in the sociotechnical landscape and regime of the transition process. This group is acting as advocacy and information provider for low-carbon electricity transition in the U.S.

From the conceptual stage as in the case of Rock Port and Greensburg to achievement and continuous supply of affordable electricity from RE resource as in the case of Georgetown, public participation is evident. Greensburg was able to bring about changes in its energy landscape as they rebuilt the city following previous natural disaster. This change was the collective decision of the small but resilient members and leaders of the community. The Canary Initiative of policy makers and stakeholders in Aspen also exemplifies the roles of the public and small advocacy groups in the transition process. Energy efficiency programs and net metering for privately owned RE systems in Burlington further demonstrate the importance of the public and public engagement in energy transitions.

All of the five municipalities possess a relatively small population. Two of the municipalities, Rock Port and Greensburg, have a population that is less than 2,000. Georgetown and Burlington both have over 40,000 population, although this is also considered small in the U.S. context. More so, the two communities with the smallest populations are the ones with excess electricity generation and with a single renewable energy technology – wind turbine. While there is not much of surprise that municipalities such as Georgetown and Burlington could achieve this transition, Rock Port and Greensburg present amazing cases of communities with extremely small populations yet with capability to achieve such a feat.

In the transition process, we observe that different key actors across the three level of MLP played significant role in each municipality. The different roles of those key actors help identifying four pathways from Geels' framework on sociotechnical transition. While Aspen and Rock Port are reconfiguration, Georgetown, Burlington and Greensburg are alignment/de-alignment, technological substitution and transformation respectively. We also observed closeness between key actors in technological substitution and alignment/de-alignment as defined by Geels. This bring about a thin line difference between the two typologies and need for more empirical data from the five communities to clarity.

6. Conclusion and Recommendations

This research highlights common factors and significant variables that matter in the RE transition processes of the five municipalities in the U.S. that have met the Sierra Club challenge for 100% RE. An established RPS in some of the states where these municipalities are located, indicating the importance of state legislation. RE resource availability (within or in proxy) and possibilities for hybridization of energy technologies are evident in the studied places. Locally available RE resource is a factor, however,

municipalities and their utilities can import electrical power from neighbouring RE retailers with abundant resources.

However, innovations in energy technologies, especially battery and other electrical storage, can further facilitate the sociotechnical transition. As resources in proxy are crucial to the transition process, future research should further examine the technical feasibility of achieving such transitions. This will include comprehensive year-round resource assessment to match hourly electricity demand and identification of potential relationships between cities or municipalities for RE. Average wind speed as given by the resource map, for instance, is not enough to know if granular load can be met all year-round. Technical assessment of resource and infrastructure availability is often limited by proprietary information kept by utilities reluctant share their load data or to identify the capacity of their interconnection infrastructure, but this information is necessary for a full assessment of the technical capabilities and needs for supporting RE transitions. Yet technical capabilities and the proximity to RE sources do not necessarily benefit surrounding communities. This underscores the need for further interdisciplinary analysis for which this study serves as the initial step.

The different transition typologies that these communities underwent are identified in this work, with reconfiguration being most common but without any clear emergence of one typical transition pathway for these 100% RE transitions at the municipal level. The reconfiguration pathway offers an effective bottom-up and gradual approach to achievement of 100% RE transitions by allowing learning in the process of replacing the incumbent technology. This typology is the result of technological innovation fuelled by development in RE technologies combined with small stakeholder advocacy for the RE transition.

100% RE transitions in the U.S., which is stemming from grassroots and local levels, is occurring independently of the political affiliations of mayor or other types of local leaderships, as demonstrated by the variety in political affiliations of local leaders in the five municipalities. What is unknown is the probability of termination of transition goals or plans in the face of changing leadership at local levels in the U.S. That, in turn, requires further research attention on the effect of leadership change within or between political party on transition commitment and achievement. This is necessary because many other mayors have pledged to 100% RE transition (Sierra Club-a) and it is not known if such pledges will be sustained if a new regime comes into power before the goals are achieved.

Utility ownership type is a vital factor to transitioning, as the majority of the municipalities have MOUs. This suggests that MOUs have the greater flexibility to transition to 100% RE and could facilitate such sociotechnical change. On the other hand, IOU resistance to energy transition is evident through lobbying and political campaigns (Prehoda et. al, 2019). As such, other municipalities as well as scholars looking towards grassroot 100% renewable electricity must pay cognizant to the ownership type of the utility serving them.

Civic engagement cannot be overlooked; this is especially important for the energy efficiency and conservation programs that utilities are incorporating into the 100% RE transition. These variables, therefore,

provide helpful parameters of consideration for future research on energy transitions in other places in the US and beyond. They also demonstrate mechanisms for promoting transition pathways for 100% RE at localized levels. However, our review could not substantiate the level of participation of the public and civil groups. It is also important to know how the research support or differs from some theoretical framework of public participations such as (Marquart-Pyatt et.al, 2008; Cornwall, 2008 and Kantemneni et.al, 2019).

Future research may further investigate the transition process by obtaining data from the main actors and stakeholders who were involved in the process. Surveys, interviews, and focus group meetings are some of the ways to obtain direct information that may be excluded from cities' or communities' websites, news articles, and available peer-reviewed and grey article publications. Such information could help to uncover all that transpired in the process including level of community participation, setbacks and challenges that confront communities in transition.

Scholars of MLP on any other forms of socio-technical transition (e.g. 100% clean mobility) can borrow a cue from this review. An in-depth case by case future work will be needed to provide a fuller explanatory framework about pressures on existing regimes, the role of other external factors and other elements of the socio-technical regime. By other elements of the regime, we refer to specificity of individuals actors along the transition process and their contributions. Municipalities and other mayors in the U.S. who are yet to achieve their 100% RE target, will find this comparative analysis very useful in knowing what to consider along the way. Lastly, other case study would facilitate further understanding of transition typologies in the U.S.

Supplemental Material

Appendix 1 – Renewable Energy Resources in U.S

a. Global Horizontal Irradiance for U.S.

The National Hydropower Map

U.S. Operational Plants in 2018

ENERGY | Energy Efficiency & Renewable Energy

LOWER 48 STATES MAP - June 1, 2018/2019
 North American Datum 1983
 USA Contiguous Landmass Contour Data (2018) Projection

ALASKA MAP - June 1, 2018/2019
 North American Datum 1983
 Alaska Albers Projection

HAWAII MAP - June 1, 2018/2019
 North American Datum 1983
 Hawaii Albers Equal Area Conic Projection

Plant Type by Capacity (MW)

Hydropower	Mixed Capabilities	Pumped Storage
○ 0-50	△ 0-50	□ 0-50
○ 50-300	△ 50-300	□ 50-300
○ 300-1,000	△ 300-1,000	□ 300-1,000
○ 1,000-2,500	△ 1,000-2,500	□ 1,000+
○ 2,500+	△ 2,500+	

Plant Ownership

- U.S. Army Corps of Engineers
- U.S. Bureau of Reclamation
- Tennessee Valley Authority
- Non-Federal on Army Corps
- Non-Federal on Reclamation
- Non-Federal

Hydrography

Avg. Annu. Runoff (mm/yr.)

2,800+ 250 0

— River Network
 — Major Lake

Continental Divides

- Great
- Laurentian
- St. Lawrence
- Eastern
- Great Basin

Source: Energy Information Administration, Environmental Systems Research Institute, Federal Energy Regulatory Commission, the National Atlas of the United States, National Hydrography Dataset, National Hydrologic Asset Assessment Program, National Inventory of Dams, National Earth, Soil, and Water Survey, U.S. Army Corps of Engineers, U.S. Bureau of Reclamation, U.S. Geological Survey, U.S. Forest Service, U.S. National Oceanic and Atmospheric Administration, U.S. National Weather Service, U.S. National Water Research Institute.

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OAK RIDGE
National Laboratory

Cartographer: Nicole Sano - June 2018

State Renewable Portfolio Standards 2018 (Source: NCSL 2018)

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