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Abstract approved:

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David Bernell

Cities of the world today house more than half the world's population, contribute to 80 percent of the global GDP, consume approximately 70 percent of the global energy and produce 70 percent of the greenhouse gases produced worldwide (Floater et al., 2014; Intergovernmental Panel on Climate Change, 2014). City governments are critical players in reducing the global energy footprint. As a leading example, cities in the United States are passing legislation and taking actions to improve the sustainability of their jurisdictions and increasingly addressing renewable energy concerns.

Local government programs and plans along with municipal codes have a considerable impact on city energy use. Codification is a process of organizing and arranging all legislation of a general and permanent nature into a Code. This paper addresses the key question: Is codification used by municipal governments to promote renewable energy development? If yes, then how? The paper documents and forms a policy baseline of existing renewable energy references in municipal codes of U.S. cities. It further analyzes trends of renewable energy codification as of December 2015 across different regions, states, and cities of different populations. Codes addressing renewable energy in sample jurisdictions were collected and analyzed. From this research and findings, the conclusion argues that cities frequently use codification to promote renewable energy development. Population and location of a city are key factors that influence renewable energy codification. Zoning, permitting and development codes often address renewable energy in municipal codes. Codes referencing wind energy are more standardized than codes referencing solar energy.

The Missing Link: Use of Renewable Energy Codification in U.S. Cities

by

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1 Introduction

Cities of the world today house more than half the world's population, contribute to 80 percent of the global GDP, consume approximately 70 percent of the global energy and produce 70 percent of the greenhouse gases produced worldwide (Floater et al., 2014; Intergovernmental Panel on Climate Change, 2014). Urban areas are growing at a rate of 1.3 million people every week, and the urban population is expected to reach 60 percent of the global population by 2030, and 66 percent of the global population by 2050. (United Nations, 2014). From 2000 to 2010, the U.S. urban population increased 12 percent and accounted for 80 percent of the total population by 2012 (U.S. Census Bureau, 2012).

Local governments play a critical role in reducing the global energy footprint. The success of local climate programs across U.S. cities is attributed to strong government leadership (Busche, 2010). In the United States, local governments govern functions like land use, transportation, and building development which directly impact city energy use (Coenen and Menkveld 2002). Further, literature shows strong interest amongst local policy makers in clean energy solutions including renewable energy and energy efficiency technologies (The United States Conference of Mayors, 2014). They are a driving force to enforce renewable energy policy adoption, as they have legislative and purchasing power, and can form beneficial private sector partnerships (Busche, 2010). Local governments are the most important actor in "catalyzing investments" and addressing associated risks and costs of clean energy solutions (Riahi, 2015). They can also act as facilitators of change and raise environment sustainability awareness in businesses and communities (Busche, 2010).

In the past local policymakers have used a range of tools to achieve renewable energy development policy goals. The most common tools used include plans, programs, and codes. Strategic energy plans, climate action plans, sustainability plans, and environmental plans often address renewable energy. A study by United States Conference of Mayors (USCOM) surveying local policy makers of 288 cities, concluded that 36 percent of the surveyed cities had developed a broad-based energy plan, and the share of cities with such plans was expected to double in three years. Broad-based energy plans form the framework for cities to organize, prioritize, and track energy initiatives, while developing a comprehensive energy strategy for the city (Wheeler, 2008).

In addition, local governments address energy programmatically using sustainability, climate change, clean transportation, and "green" or "eco" programs. According to a study by USCOM, local policy makers expressed strong interests in developing programs for residents and businesses to reduce greenhouse gas (GHG) emissions as their priority (USCOM, 2014). For example, in Fort Collins, Colorado the ClimateWise program helps local businesses reduce their GHG emissions (City of Fort Collins, 2016).

Cities are increasingly using planning policy and local regulations to promote and accelerate clean energy solutions (Riahi, 2015). Local governments use codification as a tool to enact renewable energy policies within their jurisdictions. Federal, state, and local governments formally adopt codes through codification, to establish codes as a permanent and practical system of municipal law. Codification a "process of organizing and arranging all legislation of a general and permanent nature into a code" (Wight, 2000). A municipal code is "the end product of the process of research, review, revision, and organization of a town's local laws and ordinances into a comprehensive document”(Wight, 2000). They are either administrative or regulatory in nature.

Of the three tools used by municipal governments in policy making (plans, programs, and codes), the codification process is the most binding and carries the effect of law. Despite that, codification has received the least empirical attention in the literature. While plans and programs addressing renewable energy have been extensively studied in the academic literature, there is a lack of comprehensive literature and analysis of renewable energy codification by local governments.

The primary goal of this research is to bridge the existing gap in the literature and to develop a baseline analysis of renewable energy codification in cities with a population greater than 2,500 in the United States. Further, the paper researches the trends in renewable energy codification at a national and state level, and develops a better understanding of the nature of the codes. To answer these questions, this paper analyzes municipal codes for a sample of U.S. cities. Further, it analyzes trends of renewable energy codification across regions, states, and cities of different populations. Section 2 covers the literature review while section 3 explains the methodology, section 4 presents the results and analysis of the research, and section 5 is a conclusion and discussion of the results.

2 Literature Review

This section focusses on the literature studying renewable policies at the local level. Studies have often concluded that renewable energy policies are framed as part of a local climate change initiative (Busche, 2010) and seen as the natural continuation of sustainability polices (Martinot et al., 2011). However, while the two climate change and renewable energy are closely related and have implications on each other, they are distinct. The literature review also explores the policy diffusion theory, which has been used as a framework to analyze local renewable energy codification.

Increasing energy prices in the 1970s and early 1980s motivated local governments to prioritize energy efficiency and renewable energy policies. However, these policies lost priority as energy prices decreased. Energy costs, energy security, and urban sustainability again drove cities to promote clean energy policies in the 1990s. The Kyoto protocol in 1997 was a turning point in this movement. Due to the failure of the federal government to ratify the Kyoto Protocol, the role of local governments in addressing climate change was further emphasized. Climate change concerns led to the formation of organizations and city networks which promoted climate action plans and policies for reducing GHG emissions at the local level[1].

2.1 Renewable Energy and Cities

While there is a strong interest in renewable energy policies at all levels of governments (i.e. local, state, and national), past literature has focused on policy development and implementation largely at the state and national levels (Bird et al., 2005; Brown & Busche, 2008; Carley, 2009;

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[1] The initial networks created include three transnational city networks—Climate Alliance, Cities for Climate Protection (CCP), and Energie-Cite´s—with member cities across North America and Europe. Clinton Climate Initiative's C40 Cities Climate Leadership Group, Sierra Club's Cool Cities campaign, and, USCOM Climate Protection Agreement were launched in 2005. USCOM has 1,060 U.S. cities and counties which have signed its Climate Protection Agreement (CPA) (USCOM, 2016). In 2008 the Covenant of Mayors was formed to ensure EU's commitment to reduce GHG emissions beyond 2020, through local action.

Couture & Cory, 2009; Delmas & Montes-Sancho, 2011; Doris & Gelman, 2011; Doris, McLaren, Healey, & Hockett, 2009; Heeter et al., 2014; Lantz & Doris, 2009; Menz, 2005). Clean energy and climate policies at local governments can often be guided by state and national level energy policy frameworks (Busche, 2010; Martinot et al., 2011; Riahi, 2015; Steinhoff & Wei, 2015). Further, even different federal climate and energy programs encourage adoption of clean energy at the local level. For example, the President's State, Local, and Tribal Leaders Task Force on Climate Preparedness and Resilience assists local communities to be more resilient to climate change issues. Similarly, federal funding programs like the Energy Efficiency and Conservation Block Grant (EECBG) encourage action in local governments on clean energy issues[2].

Local clean energy policies and codes have been compiled, tracked and analyzed in various ways. Adoption of building energy codes at the state and local level has been captured, tracked and analyzed by different initiatives like Building Codes Assistance Project, organizations like International Code Council (ICC), and literature (Meres, 2016; Stellberg, 2013). Resources and databases developed by American Planning Association compile local renewable energy codes particularly providing examples of solar codes[3]. Similarly, the Database of State Incentives for Renewables & Efficiency (DSIRE) tracks over 2,665 state, federal, local, non-profit, and utility

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[2] The EECBG was a national program operated by the U.S. Department of Energy (DOE) from 2009 to 2015which provided over $2.7 billion in grants and technical assistance to over 2,187 cities, counties, states, territories, and Indian tribes to support clean energy activities. While seventy percent of the grants went directly to local governments the remainder mostly went to the States, which were obligated to fund local entities using a minimum of sixty percent of the funds (http://weatherization.ornl.gov/eecgbpdfs/EECBG_Report_Executive%20Summary_Final.pdf).

[3] See: https://www.planning.org/solar/data/.

clean energy policies. Of these there are 229 local clean energy policies. Of these policies tracked, 109 are financial policies while 120 are regulatory policies. One hundred and seventy-eight of these address renewable energy while 143 address energy efficiency, with some overlaps existing between the two (DSIRE 2016). Only 33 states have local governments clean energy policies in the DSIRE database.

Analysis of existing local clean energy policies in United States and around the world have been documented by the government and organizations like IEA, UNEP, OECD NREL, WWF-US, ICLEI USA, National League of Cities, and United States Conference of Mayors amongst others (Martinot et al., 2011; Riahi, 2015; Sims & others, 2009). These studies track climate inventories, clean energy priorities, and challenges, give policy recommendations and outline best practices. However, these are mostly restricted to qualitative research, case studies and comparative analysis of a small sample of cities. Empirical analysis of renewable energy policies at the local level is limited and there is a gap in the existing literature[4].

Reports by USCOM document data on energy technology, energy efficiency, conservation initiatives, priorities and challenges in clean energy for cities (The United States Conference of Mayors, 2014). These reports suggest that with the advent of a growing climate change movement and increasing energy costs, cities today are increasingly prioritizing energy and environment issues in local policy making (The United States Conference of Mayors, 2014; Farver & McFarland, 2015). Narrowing further they emphasize energy efficiency, building

[4] Energy efficiency policies at the local level are well covered in literature and are not included in this literature review.

retrofits and renewable energy as key priorities (Farver & McFarland, 2015; The United States Conference of Mayors, 2011). Within renewable energy, key technologies already demonstrated by cities include solar, geothermal, waste to energy, cogeneration, and biofuels (The United States Conference of Mayors, 2014). They have been addressed through target setting, urban planning, building codes, and tax exemptions in the past (Martinot et al., 2011).

The U.S. Department of Energy, the U.S. Environmental Protection Agency, NREL, and ICLEI have produced tools, guides, and best practices to aid cities in collecting and understanding energy data and GHG emissions data. They also provide important resources to policy makers on clean energy issues through different initiatives with cities across the U.S.

Key lessons are drawn from studies on local clean energy policy issues (Martinot et al., 2011; Riahi, 2015; Sims & others, 2009). Studies have also found awards and competitions, financial and fiscal incentives, and leveraging "city assets such as land and public buildings", to be good methods to promote local clean energy policy-making (Martinot et al., 2011; Riahi, 2015). The United Nations Environmental Program (UNEP) report also recommends local governments without "regulatory powers in the energy sector, a stake in a local utility, or the resources to undertake feasibility studies" to use planning and land-use policies (by encouraging mixed-use zoning and compact land use) as means to incorporate clean energy aspects (Riahi, 2015).

2.2 Policy Innovation and Diffusion Theory

The literature review indicates a developing understanding of why some governments adopt a policy while others do not? In the policy literature, such questions are explained by the policy innovation and diffusion theory developed by policy researchers. While a majority of the empirical research on this theory has been conducted on the state level, a growing number of studies have considered it for analyzing the local policies (Feiock & West, 1993; Godwin & Schroedel, 2000). According to Berry and Berry, policy innovation refers to a policy which is not necessarily a new idea but is one that was never utilized previously by a government entity which is adopting it. They also concluded that this adoption of a new policy can be explained using internal determinants and diffusion models (Berry & Berry, 1990, 1999).

Internal determinants are factors encouraging or restricting policy innovation i.e. political, economic, and/or social characteristics of a government or city. Diffusion models hold that policy innovation done by an entity is built on what has occurred in another government entity. One common definition of policy diffusion is "the process by which innovation is communicated through certain channels over time among the members of a social system" (Rogers, 1995).

Within the policy innovation and diffusion theory literature diffusion models have been developed to explain the process of policy diffusion. According to the regional diffusion model, a government entity is influenced by the actions of its neighbors within its geographic region and in this case neighbors often emulate policy actions. (Berry & Berry, 1999; Gray, 1994; Mooney & Lee, 1995; Walker, 1969). The national interaction model proposes that policy diffusion occurs as a result of continuous interactions among the adopting governments officials. Therefore, policy diffusion depends on the number of such interactions (Berry & Berry, 1999; Gray, 1973; Walker, 1969). As per the vertical influence model, the adopting government emulates policies of a higher level governing agency (Berry & Berry, 1999). For example, states emulating federal policies. In the leader-laggard model some adopting governments are leaders in policy implementation while others are followers (Berry & Berry, 1999).

Previous literature has found that often the size of a community determines their approach towards renewable energy policies (Martinot et al., 2011). Further, while smaller cities work towards achieving targets for 100 percent renewable energy, larger cities target specific renewable energy opportunities to "portray the city as progressive" and to "explore business ventures that will benefit the city." Mid-sized cities were found to be pioneers in the renewable energy space who initiated programs and policies more easily than large cities[5] (Martinot et al., 2011). This paper uses population as an internal determinant for understanding how cities with different population sizes codify renewable energy.

Existing literature shows sixty-three percent of the mayors (from 396 U.S. municipalities) indicated referring to successful clean energy technology adoption and best practices of other local governments, prior to adopting them in their own cities (The United States Conference of Mayors, 2011). Municipal governments often follow examples of leading cities or champion cities to promote adoption and implementation of renewable energy programs. This creates a "snowball effect" (Burr, Hallock, & Sargent, 2015; Judee, Tony, Schneider, & Sargent, 2014; Martinot et al., 2011). This clearly illustrates that while some cities are leading, the others are lagging in renewable energy policy implementation. Thus, the leaders and laggards model of policy innovation and diffusion theory is a good lens which is utilized in the paper to analyze renewable energy codification at the local level.

The success of local climate programs has been attributed to close involvement of a wide variety of stakeholders (Busche, 2010). Particularly successful programs involve funding and technical

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[5] Mid-sized cities are defined as cities with a population between 100,000 to 500,000 in the cited report (Martinot et al., 2011).

support from the federal and state level, engagement of local governments with the private sector, and well-rounded planning and execution processes (Steinhoff & Wei, 2015). Previous literature has found that states supporting more than three renewable energy market transformation policies (renewable portfolio standard, interconnection standards, and net-metering policies) tend to have local governments which are more likely to adopt climate change mitigation goals which broadly include renewable energy development goals (Busche, 2010). This shows the process of diffusing renewable energy policies at the local level. The vertical influence model is used in the paper to understand if cities emulate policies of a higher level governing agency as shown by existing literature, in the case of renewable energy codification.

3 Methodology

This study researched municipal codes of local governments in the United States to understand frequency of renewable energy codification in cities. Third party providers codify municipal codes in searchable online databases[6]. For a selected sample of cities, these online databases were searched for certain keywords which denote the presence of substantive renewable energy policies in the codes. The keywords used for this research include solar, geothermal, wind, biomass, co-generation, net-metering and waste to energy. The methodology section covers the sample dataset used, data limitations, and the process of data collection and analysis.

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[6] These third party providers include Municode, https://www.municode.com/; GeneralCode, http://www.generalcode.com/; Sterling Codifiers, http://www.sterlingcodifiers.com/; Code Publishing Company, http://www.codebook.com/; American Legal Publishing Corporation, http://www.amlegal.com/; and Conway Greene Company, http://www.conwaygreene.com/.

Municode database: Municode Corporation's MuniPRO is an online searchable database which includes over 3100 municipal, county and township government codes across the United States. A majority of codes 2300 within the database are associated with municipal governments while the remaining are for township governments. This total represents about 13 percent of all municipal governments in the United States. Local governments in the United States consist of 19,519 cities and towns (U.S. Census Bureau, 2014). The Municode data represents only 3 percent of the municipalities with populations below 2,500.

Sample: The sample used for this research uses cities in the Municode database. However, it does not include cities which have a population size smaller than 2,500, counties[7], or townships[8]. Removing these smaller cities, along with counties and towns from the Municode dataset increases the samples representation of the remaining cities to 30 percent. There are 2022 sample cities used in this research.

Table 1. Comparison of Cities by Population Size in the United States to those in Municode Database

Population	United States	Municode
<2,500	12789	394
2,500 – 4,999	2088	369
5,000 – 9,999	1667	456
10,000 – 24,999	1544	622
25,000 – 49,999	723	329
50,000 – 99,999	433	200
>100,000	275	203

[7] County codes also have overlaps with study sample cities, so to avoid double counting, county codes have not been considered in this study.
[8] Township or town, governments are located in 20 states and are differentiated from municipal governments because they vary widely in the public services they provide. See: http://www.census.gov/govs/go/state_townships.html and http://www.census.gov/govs/go/municipal_township_govs.html.

Table 2: Comparison of Cities by Population Size in the United States to those in the Sample

Population	United States	Sample
2,500 – 4,999	2088	364
5,000 – 9,999	1667	438
10,000 – 24,999	1544	580
25,000 – 49,999	723	300
50,000 – 99,999	433	178
>100,000	275	162

Limitations of sample: This sample has a few limitations. Firstly, almost 66 percent of municipal governments in the United States have populations below 2,500. These are not reflected in the research sample. Hence, this research is restricted to a sample of cities with a population over 2,500. But, initial keyword searches within the municode database illustrated that cities with a population over 2,500 accounted for more than 90 percent of the substantive uses of the renewable energy keyword searches, suggesting that the smallest cities are less likely to reference renewable energy. The dataset over represents larger cities (Figure 1). The sample also underrepresents cities from some regions of the country, particularly the mid-Atlantic[9] and west north central[10]. It overrepresents cities from other regions such as those in the west south central[11] and the south Atlantic[12] (Figure 2).

[9] New Jersey, New York, and Pennsylvania
[10] Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota
[11] Arkansas, Louisiana, Oklahoma, Texas
[12] Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, Washington D.C., and West Virginia

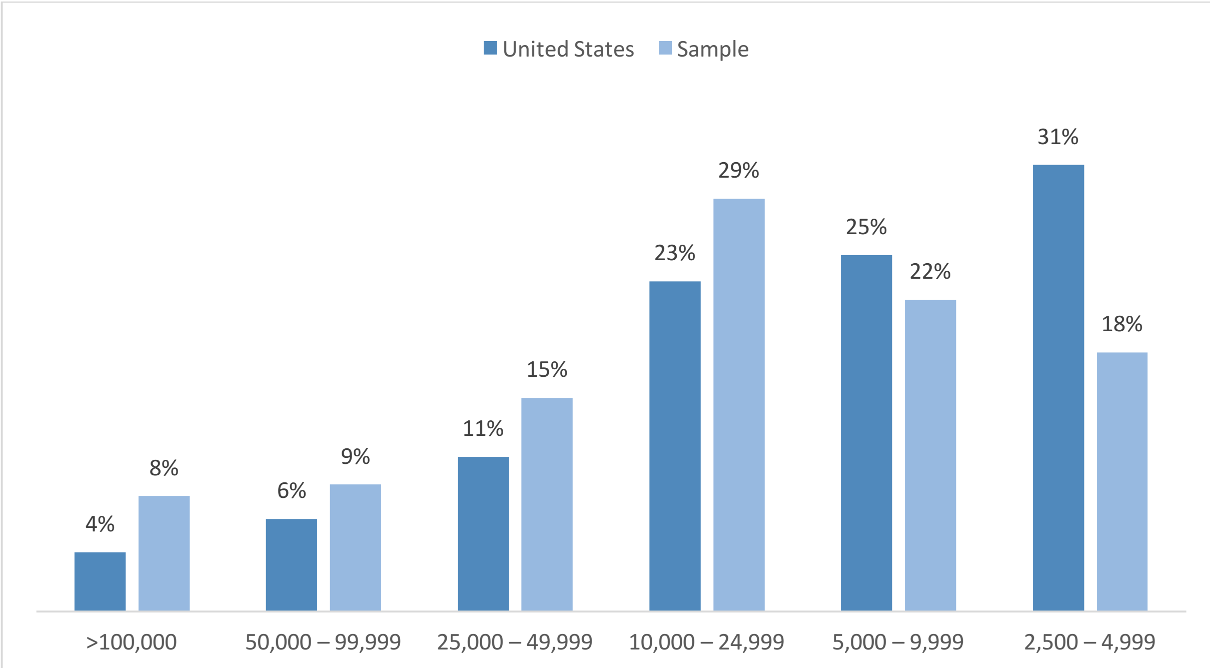

Figure 1: Sample Distribution across Cities with Different Populations

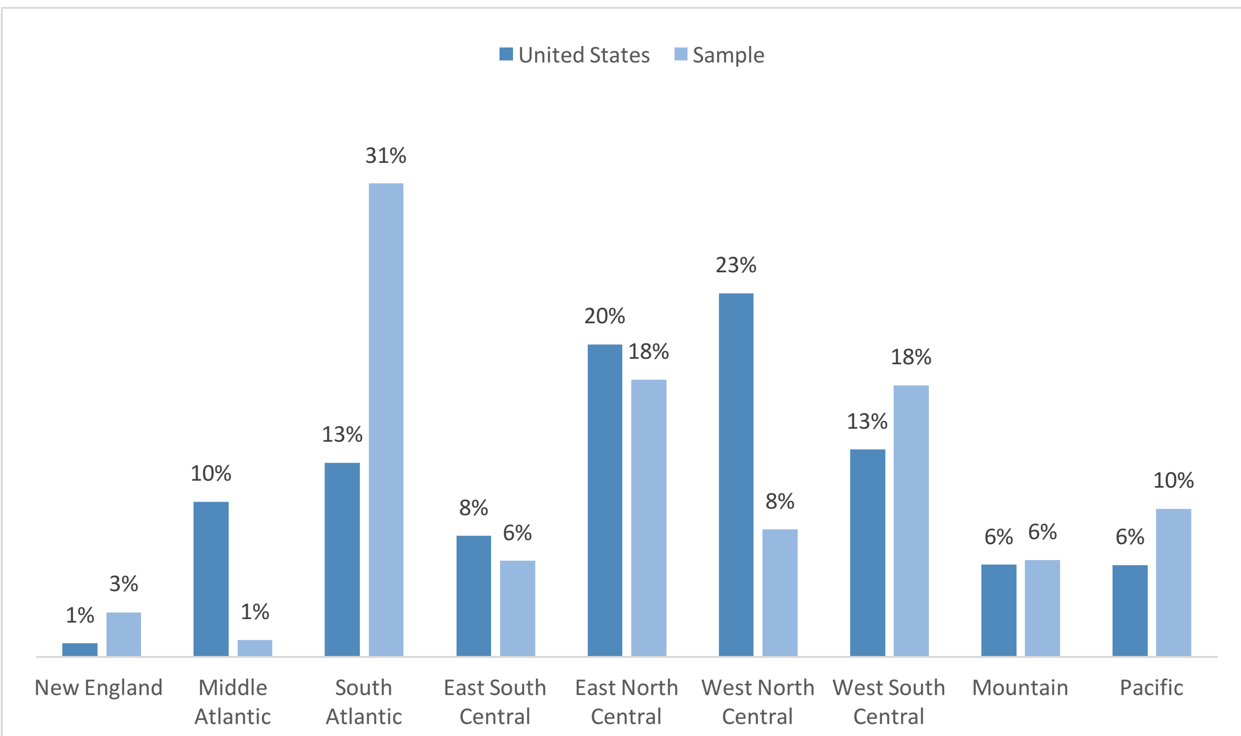

Figure 2: Sample Distribution across Census Regions

3.1 Data Collection and Analysis

3.1.1 Data Collection

The codes of these sample cities in the online searchable Municode database were searched by keywords. These keywords were chosen by an expert panel in the National Renewable Energy Laboratory. While a broader list of keywords was chosen by this panel, this thesis uses only keywords related to renewable energy and particularly solar, wind energy, geothermal, biomass, waste to energy, co-generation, and net-metering, to understand renewable energy codification. Other keywords such as renewable energy, alternative energy, distributed energy were also used initially. These were eventually eliminated because of duplicity and lack of producing substantive references.

Each reference[13] found in the keyword search was categorized as a substantive reference, non-substantive reference, or non-applicable. A substantive reference is the use of a keyword in a section of code that regulates a specific keyword. This reference could allow, prohibit, set requirements, standards, or rates for a particular keyword, amongst other things. A non-substantive reference is the use of a keyword in an intent, goal, purpose, or definition section of a code. If non substantive references are used in subsequent language or sections of the code substantively, it is considered a substantive reference. For example, if the keyword "solar" was used in the definition of alternative energy in a section with definitions, but the keyword was not

[13] In this research, a "keyword" refers to the word that was used for searching a database. For example, the solar keywords used in the research for searching the online database were solar, photovoltaics (PV). While a "reference" is the use of the keyword in a particular section of the code. For example, if the solar keyword was found 10 times in the permitting section of the municipal code, this would be called a reference. Typically, keywords were found in more than one section of the municipal code for a city and one keyword was referenced several times in the municipal code for one city.

used in any other municipal codes (permitting, zoning, taxation, development standards etc.) or in language which regulates solar, it was not considered a substantive reference[14]. On the other hand, if the solar keyword was used in the definition of alternative energy, and also in a zoning code to allow use of solar PV in a particular zone, then it was considered a substantive reference. Finally, a reference was considered non-applicable if the use of the term was not related to renewable energy. Non-applicable references were most common when searching for the term "solar." For example, references to the "solar time of day" or "solar flare" was considered non-applicable.

If it was determined that a city substantively referenced a particular keyword, no more references were reviewed for that keyword. For example, a substantive solar reference was found in the zoning code of Boulder, CO. The researcher does not check if there are other substantive solar references in the Boulder, CO municipal code. Other solar references might exist in the permitting or development standards code, but are not reviewed by the researcher. But it would be noted that Boulder, CO has solar references. If a non-substantive or non-applicable reference was found in a particular city, further references (from the same keyword) were reviewed until a substantive reference was identified, if any. Results from searches of six keyword references were populated in a spreadsheet, and the complete dataset consisted of 2022 sample cities and the six keyword references[15].

[14] Such examples were rare in our research.

[15] This analysis describes whether a city references a certain keyword, but not how many times or in how many different sections of code, the keyword has been referenced.

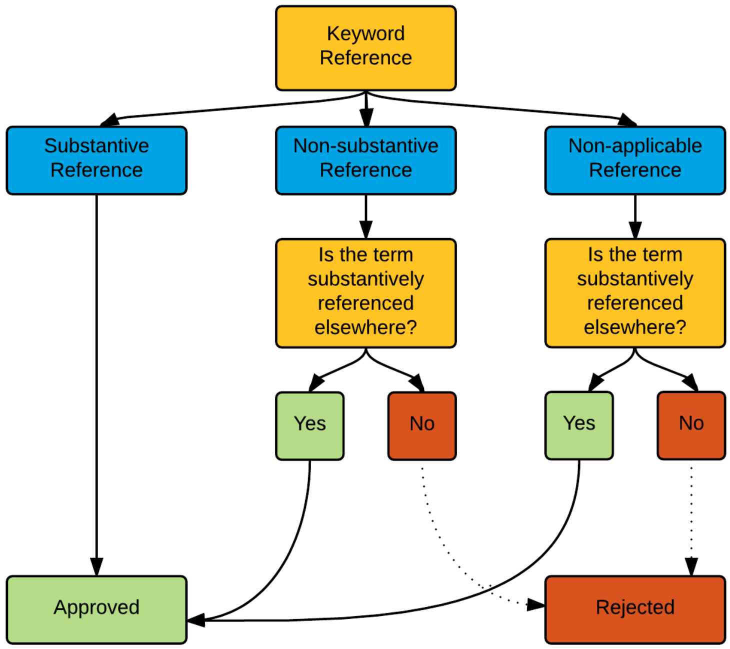

Figure 3: Methodology

3.1.2 Data analysis

Below is the methodology for the national and state analysis of the data. Further, an in-depth reference analysis is described below.

National analysis

The national data analysis uses a sample of 2022 cities and their respective municipal code references. The data was analyzed to detect regional trends and trends across cities with different population sizes.

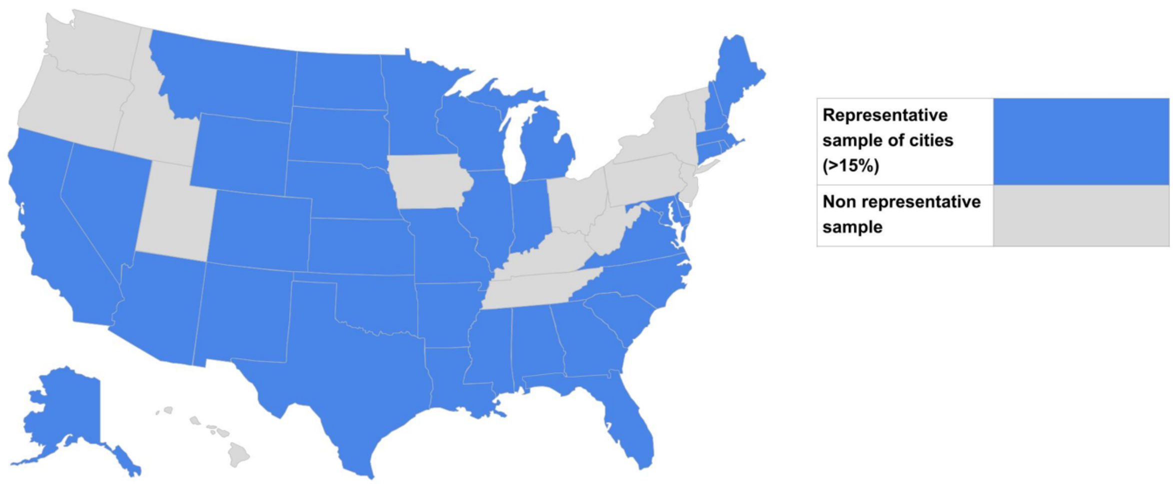

Figure 4: Sample for State Analysis

State analysis

This analysis uses two keywords (solar and wind energy) for cities across 34 states totaling 1933 sample cities, to understand what percentage of the sample cities in each state have referenced a particular keyword (solar and wind energy). A state was used in this state analysis if the state sample had 15 percent of the total local municipal governments. Sixteen states did not qualify this criterion since they were poorly represented in the sample (Figure 4). These states include Hawaii, Idaho, Iowa, Kentucky, New Jersey, New York, Ohio, Oregon, Pennsylvania, Tennessee, Utah, Vermont, Washington D.C., and West Virginia. Some states included in this analysis have a small number of local municipal governments which may affect our results. For example, Delaware has 17 local municipal governments which have a population more than 2,500 (U.S. Census Bureau, 2012). Of these, our sample considers five cities or 30 percent of the total, which passes the minimum 15 percent threshold. However, the study only considers five random cities in the state.

Reference analysis

This analysis uses 153 cities that have solar references, and 32 cities that have wind references. This helps us understand how cities are discussing these renewable energy sources in practice and their code classification.[16]

- *Solar reference analysis:* One hundred, fifty-three random cities were selected from Arizona, California, Florida, Georgia, Massachusetts, and Minnesota for the solar reference analysis. These states were selected since they captured the geographic diversity and have a high percentage of cities referencing solar. It was ensured that 10 percent of the total number of municipal governments in the state were included in our sample for reference analysis. These references were studied in detail to categorize solar energy references in different code categories (zoning, permitting, development code).
- *Wind reference analysis:* Thirty-two random cities were selected from Illinois, Wyoming, and South Dakota. These states were selected since they had a high percentage of cities referencing wind energy and hence form a good data set for analyzing different types of wind energy municipal codes. It was ensured that a minimum of 10 percent of the total number of municipal governments in the state were included in our sample for reference analysis. These references were studied in detail to categorize wind energy references in different code categories.

[16] Though this type of formal analysis was not completed for the other keywords, the common themes related to how each term is referenced across the United States is discussed in each keywords relevant section.

4 Results and Analysis

4.1 National Analysis

Of the 2022 sample cities studied, more than half the cities (53 percent) referenced at least one or more keywords. Thirty three percent of the cities used one keyword only and 20 percent of the cities used two keywords or more (Figure 5). From Figure 6 we can see, that the most commonly used keyword is solar. It is followed by wind energy and geothermal energy. References to net metering, cogeneration, biomass and waste to energy keywords were found to be very limited.

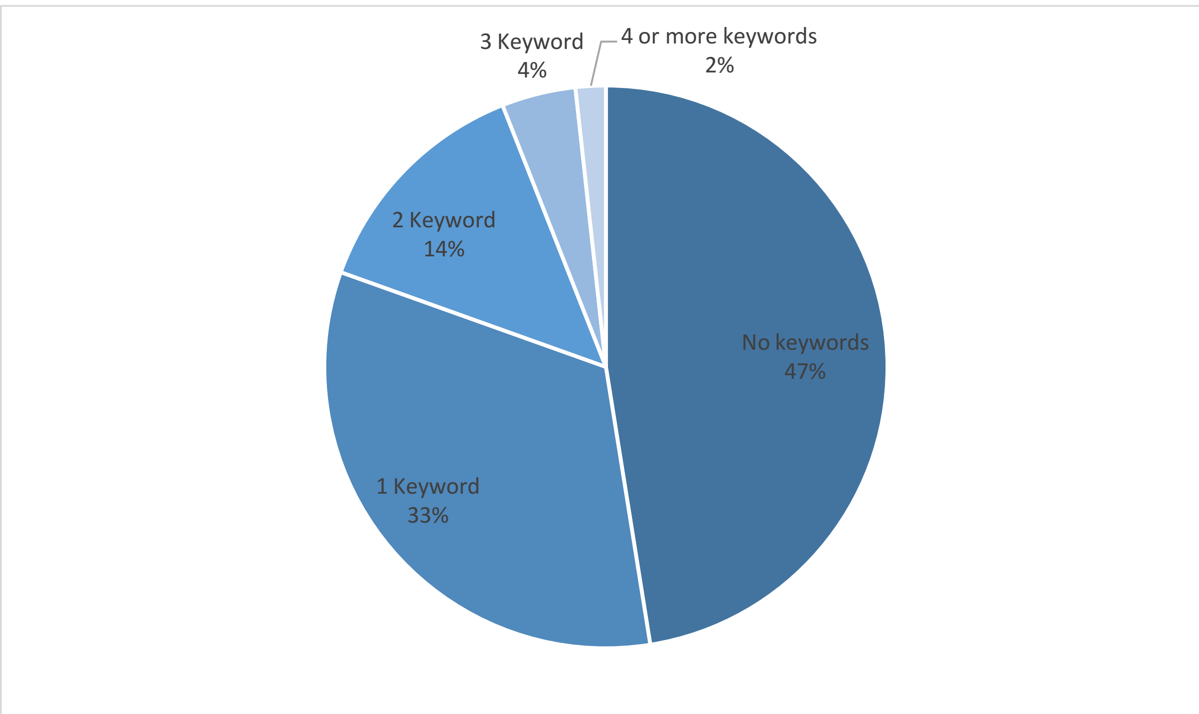

Figure 5: Percentage of Cities in the Sample by Total Substantive Keywords Referenced

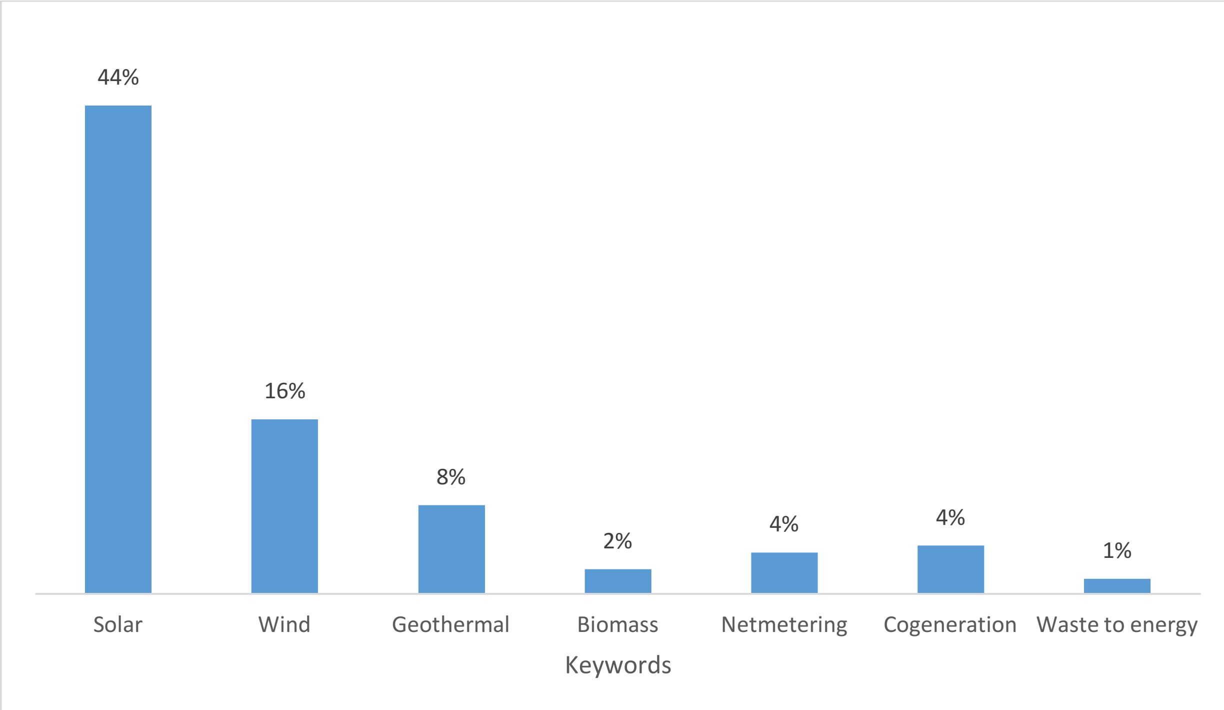

Figure 6: Percentage of Total Substantive References by Keyword Category

The regional variation of references reveals renewable energy codification is most prevalent in the west and least prevalent in the south. Approximately 20 percent of the sample cities in the west have referenced zero keywords while almost 60 percent of the sample cities in the south have referenced zero keywords (Figure 7). National trends of references were also reflected regionally, with solar being most commonly referenced followed by the wind and geothermal energy keywords by most regions. Almost 67 percent of cities sampled in the west had solar references while only 35 percent of cities sampled in the south had solar references. Almost 30 percent of the sample cities in the mid-west had wind energy references, but only eight percent of the sample cities in the south had wind energy references. Geothermal references were found in 23 percent of the sample cities in the west and only five percent of the sample cities in the south had geothermal references. Please refer to the graph and table below for further details.

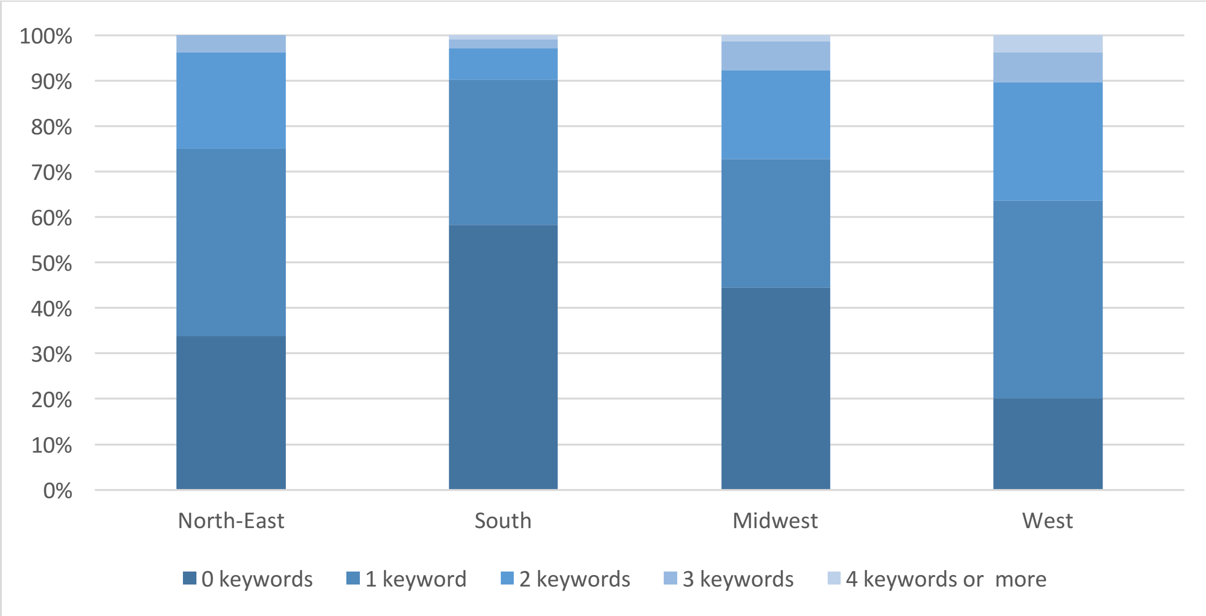

Figure 7: Percentage of Number of Keywords by Regions

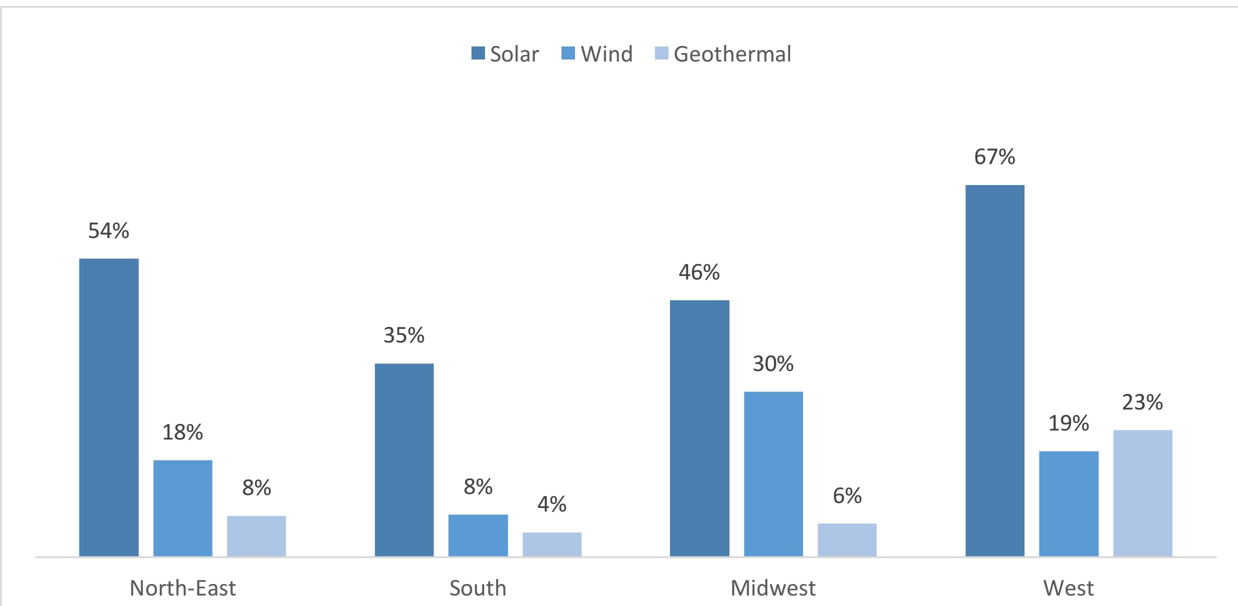

Figure 8: Reference Regional Analysis

Table 3: Percentage of Cities by Census Region for References

Census Region	Solar (%)	Wind (%)	Geothermal (%)	Biomass (%)	Net metering (%)	Cogeneration (%)	Waste to energy (%)
North-East	54	18	8	3	5	5	4

South	35	8	4	2	3	3	1
Midwest	46	30	6	2	5	2	1
West	67	19	23	3	5	12	3

The references based on population sizes of cities reveal interesting trends (Figure 9). Sample cities with a population greater than 100,000, reference solar and geothermal energy more than cities with a population between 2,500 to 4,999. Similarly, wind energy was referenced more by cities with a population greater than 25,000 as compared to cities with populations between 2,500 to 4,999 (Figure 9, Table 4).

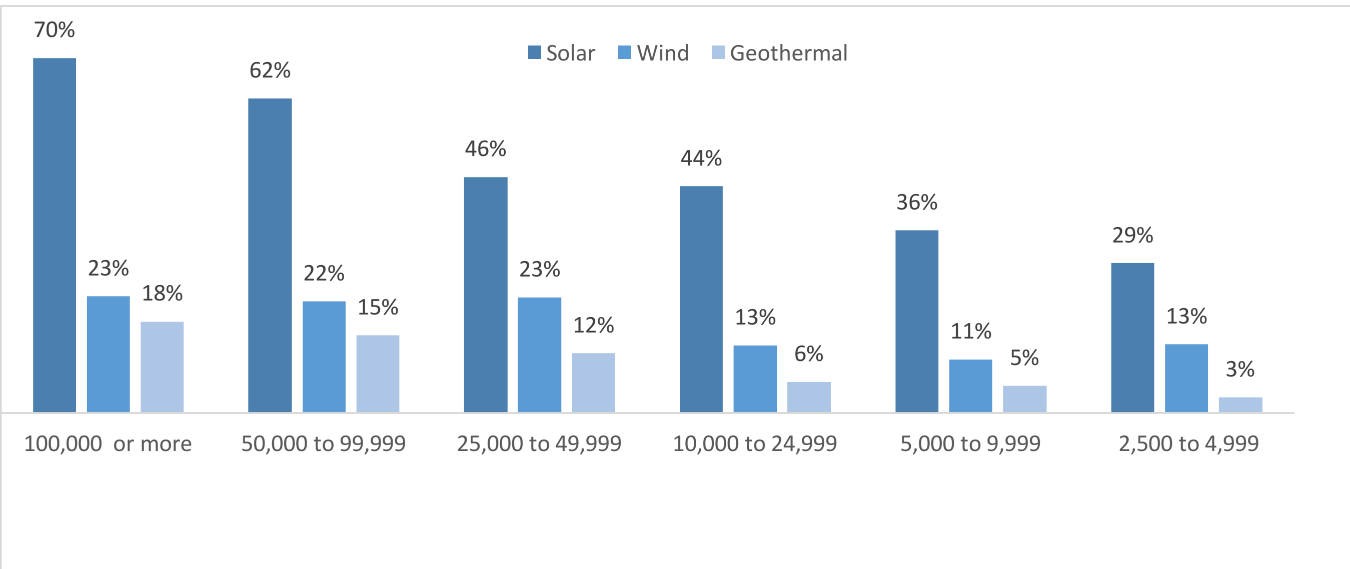

Figure 9: Reference Population Analysis

Table 4: Percentage of Cities by Population Distribution for References

Population distribution	Solar (%)	Wind (%)	Geothermal (%)	Biomass (%)	Net metering (%)	Cogeneration (%)	Waste to energy (%)
100,000 or more	70	23	18	6	7	13	6
50,000 to 99,999	62	22	15	4	6	4	3
25,000 to 49,999	46	23	12	1	2	2	1
10,000 to 24,999	44	13	6	2	3	4	1
5,000 to 9,999	36	11	5	2	3	4	1
2,500 to 4,999	29	13	3	2	4	2	0

A further analysis was conducted across each region for different population sized cities and references (solar, wind and geothermal). This revealed that trends seen nationally across cities with different populations (Figure 9) are translated regionally particularly for the western and southern regions (Figure 10). For example, cities sampled with a population greater than 100,000, reference solar and geothermal energy more than cities with a population between 2,500 to 4,999 in the southern and western region. The same was not found to be true for the north-eastern region. This can most likely be attributed to the sample limitations mentioned across these regions.

Figure 10: References by City Population Size for Different Regions

4.2 State Analysis

Despite these regional trends, there is significant variation in keyword references across states. Most frequently referenced keywords include solar (43 percent), and wind (16 percent). These keywords were used to conduct an in-depth state by state analysis to understand how local governments in different states across United States address renewable energy in their codes. Please refer to section 3.1.2 for a description of the methodology used for completing the state analysis.

Seventy seven percent of the sample cities in this state analysis have used one or more keywords in their codes[17].

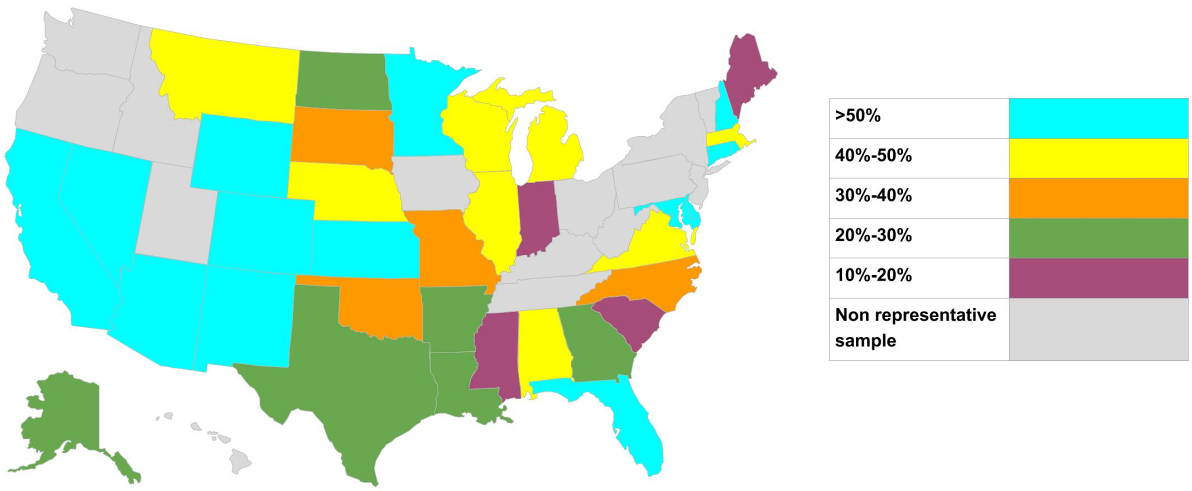

Figure 11:Percentage of Sample Cities in each State Referencing Solar Energy

Forty-three percent of the sample cities in these 34 states reference solar. The regional variation depicted in Figure 8 can be clearly visualized with our state-by-state break up in Figure 11. From our sample, we can conclude that the top states (amongst 34 states) which addressed solar energy at the local level were Arizona, California, Minnesota, and Wyoming. They had over 70 percent local municipal governments with solar energy references. Colorado, Connecticut, Delaware, Florida, Kansas, Maryland, New Mexico, and Rhode Island had 50-70 percent sample cities which addressed solar energy in their codes. Only 10-20 percent of the sample cities had solar energy references in Indiana, Alabama, Maine, and South Carolina.

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[17] This analysis uses 1933 sample cities in 34 states. It does not include Hawaii, Idaho, Iowa, Kentucky, New Jersey, New York, Ohio, Oregon, Pennsylvania, Tennessee, Utah, Vermont, Washington D.C., and West Virginia.

From our sample, we conclude that the top states addressing wind energy at the local level were Wyoming and South Dakota. They had over 50 percent local municipal governments with wind energy references. Alaska, Minnesota, and Wisconsin had 40-50 percent sample cities which referenced wind energy in their codes. Wind energy references in Alabama, Arkansas, Connecticut, Florida, Georgia, Louisiana, Maine, Missouri, New Hampshire, and Virginia accounted for only five percent or less local governments in the state (Figure 12).

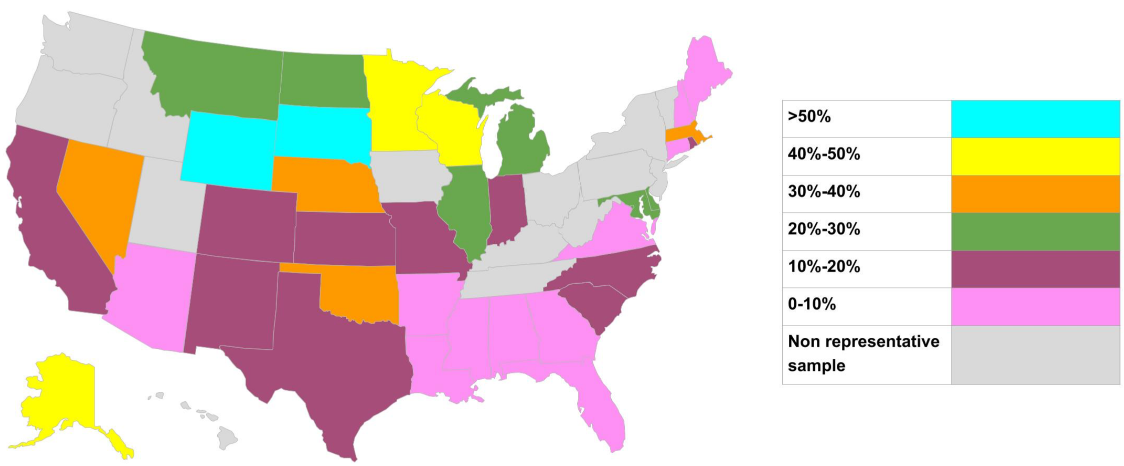

Figure 12: Percentage of Sample Cities in each State Referencing Wind Energy

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4.3 Reference Analysis

An in-depth reference analysis was completed for two keywords (solar and wind energy) in a small sample of cities (153 and 32 respectively). Each reference for the limited sample of cities was studied and categorized based on the nature of the code it was referring to. The references of the remaining keywords (i.e. geothermal, biomass, co-generation, waste to energy and net metering) were also researched, and an overview of their use in municipal codes has been described in this section. The detailed methodology of this analysis has been described in section 3.1.2.

4.3.1 Solar Reference Analysis

Solar related references of 153 random cities (from Arizona, California, Florida, Georgia, Massachusetts, and Minnesota) were studied in detail to classify them according to the municipal code sections in which the references were found[18]. Solar references were primarily in development and design standards, permitting, zoning, solar access, taxes, financing, and other municipal code sections (Figure 13).

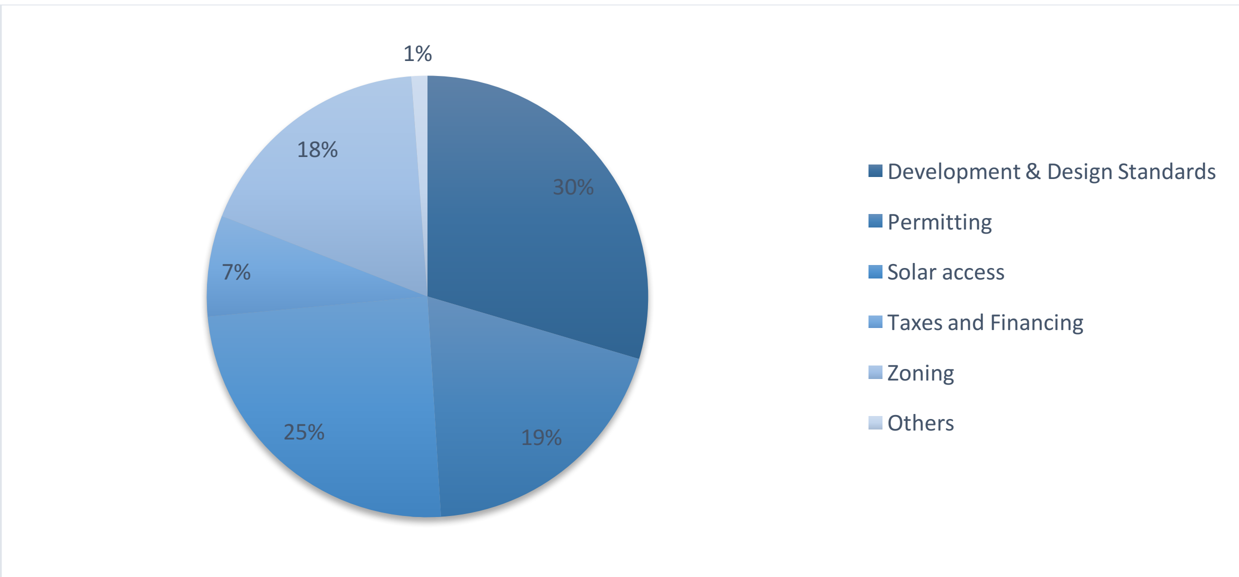

Figure 13: Solar Reference Analysis

Thirty percent of solar references were related to development and design standards. These included development standards for primary and secondary uses, along with a myriad of design requirements for construction and buildings. Several cities had guidelines and architectural design and development standards for solar panels and collectors which focused on aesthetics,

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[18] These states were selected since they captured geographic diversity and these were also states which have a high percentage of cities referencing solar.

landscaping, and orientation. These were specified for different building types and zones (i.e. for commercial districts, industrial districts, public open space, single family homes, wireless telecommunication facilities). Often the municipal codes excluded solar panels due to height, setback and lot coverage requirements. Some codes required screening of solar equipment from public view and others exempted solar equipment from such requirements. To promote adoption of solar, municipal codes contain rating and ranking systems encouraging projects with solar facilities. Solar water heating was also specifically promoted in municipal codes. Some codes specifically focused on safety and ensured that solar systems installed are in accordance with fire and electrical codes; many cities required their systems to meet the Uniform Solar Energy Code requirements[19].

Solar access-related references (25 percent) were the second most common. Existing codes protect solar access and recommend measures to improve solar access. Several cities had codes which required trees, major vegetation, and taller buildings to be placed in such a way that the shadowing of adjacent solar equipment would be minimized. This was often done by placing requirements and restrictions on different development aspects such as orientation, setbacks, siting, landscaping, height and lot density. Some codes required developers to make solar access easements that placed restrictions on intrusions in the solar skyspace, such as another building or trees.

Zoning and permitting were the third and fourth most referenced policy categories. The zoning references are largely similar across cities and typically allow solar PV, or solar water heating

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[19] The Uniform Solar Energy Code was prepared and published by the International Association of Plumbing and Mechanical Officials. The first edition was published in 1976, which has been revised and has new editions. It governs the installation and inspection of solar energy systems.

systems in particular zoning districts (i.e. agricultural, residential, or industrial) as accessory or secondary uses. There were also provisions which allowed the primary use of certain zones for solar energy in the form of solar farms and solar PV generation facilities. The permitting category includes municipal governments efforts to streamline solar permitting, set permit fees, exempt solar from certain permit requirements, and require contractors to hold licenses or certifications to be able to install solar systems.

The taxes and financing category account for seven percent of the references. These were references to financial incentives provided by municipal governments such as a reduction in inspection fees, discount and rebate programs, solar leasing programs, and tax exemptions. The remaining one percent of the references were others. These codes included a mandated solar and net metering category. For example, Fresno, California requires all new public buildings to incorporate solar. Lodi, California specified a net energy metering rider which established rates, terms, and conditions for net metering, particularly of solar systems.

4.3.2 Wind Energy Reference Analysis

To evaluate how cities reference wind energy, 32 cities from three states Illinois, Wyoming and South Dakota were selected for subsequent analysis[20]. Wind energy references for these cities were studied in detail to classify them according to the municipal code sections in which the references were found, similar to the solar reference classification. Also, an all-encompassing

[20] These states were selected since they had a high percentage of cities referencing wind energy and hence form a good data set for analyzing different types of wind energy municipal codes.

wind energy code which includes provisions on permitting, zoning and construction design was found in municipal codes.

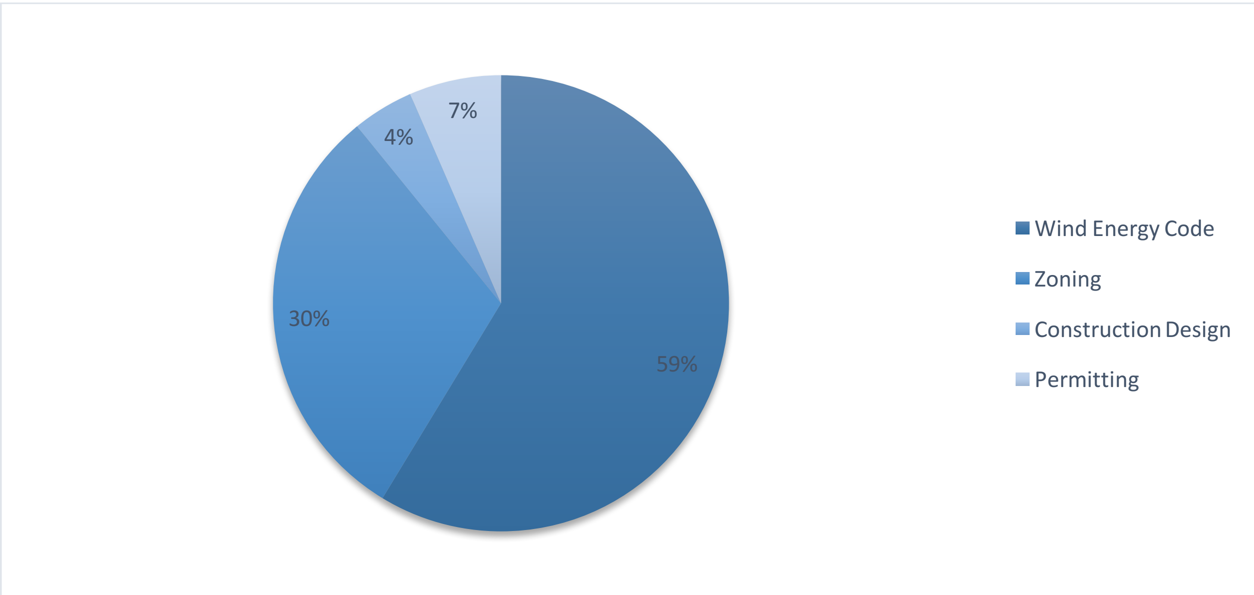

Figure 14: Wind Reference Analysis

Fifty-nine percent of the references to wind energy were associated with an all-encompassing wind energy code. These wind energy codes typically establish standards for wind energy systems and commonly cover standardized parameters such as access, appearance, electrical standards, equipment standards, height allowances, safety requirements for lightning, shadow flicker, noise standards, setbacks and decommissioning.

Some of the key parameters addressed in all-encompassing wind energy codes have been discussed below:

- Access codes ensure safety by limiting direct contact with wind energy generating equipment.

- Appearance codes ensure design uniformity and take into account aesthetic considerations.
- Electrical standards define equipment, wiring, and control requirements; while equipment standards further define requirements for equipment as stated by electrical standards.
- Height of a turbine for a ground mounted system is measured from the ground level. For a building mounted system, it is measured from the point where the system is attached to the building, to the rotor tip or any other part of the Wind Energy System. Codes generally define height allowances which may differ for different zones.
- Lighting must comply with minimum Federal Aviation Administration regulations and other state or local regulations.
- Shadow flicker referred to the visible flicker effect when rotating turbine blades cast shadows on the ground. Some ordinances required these to be included in setbacks while others required an in-depth analysis on these by developers. Others mentioned that their impact on neighboring properties needed to be prevented or mitigated.
- Setback requirements are defined between neighboring properties and the wind energy system. They are based on the zone in which they are present and as per local regulations.
- Decommissioning includes removal of wind turbines, buildings, cabling, electrical components, roads, and any other associated facilities. Ordinances define requirements and may require developers to restore the existing site.

Zoning references were the second most frequent and as was the case with solar, these references generally allow wind energy systems in certain zones as a special or conditional use. They also have specific requirements (setbacks, aesthetics, shadow flicker etc.) for the wind energy systems in particular zones. The remaining 11 percent of the references to wind energy were related to construction design and permitting. These were again similar to the ones in solar energy. The design standards typically addressed wind turbine height limitations and exceptions while the permitting references typically set application fees.

4.3.3 Other Renewable Energy References

Geothermal energy: One hundred and sixty cities used geothermal energy in their municipal codes substantively, accounting for eight percent of the sample cities. Geothermal energy codes were primarily related to geothermal heating and cooling systems. They often addressed permitting and zoning requirements for these systems. Permitting codes referred to the inclusion of geothermal in evaluation criteria for sustainable building regulations (Golden, Colorado) or as a preferred building material (Rifle, Colorado) or as a component to achieve "superior urban design" (Dover, Delaware). In this way, cities incentivized the use of geothermal systems. The remainder of the permitting references related to setting fees, and application processes.

Zoning references specified zones where geothermal wells were permitted to be used in different zones such as the source water protection overlay zone or corridor overlay zone (Dover, Delaware), or in agriculture, conservation reserve, public regional, public and industrial zones (Carson City, Nevada). In California, several cities excluded geothermal resources from definitions such as "Minerals" and "Well/Water Well", to ensure they do not require rigorous permits and processes similar to those which are required for drilling wells and mining. Instead, they were included in the definition of renewables which have different standards and regulations. Regulations and design standards for geothermal systems and power plants specify different aspects such as permitted locations, total height, setbacks, safety/access, easements, noise, permits, application processes etc.

Municipal governments also used tax and financial incentives to promote geothermal systems. For example, Belfast, Maine allows geothermal to qualify for its Property-Assessed Clean Energy (PACE) program and Fort Collins, Colorado includes geothermal as a qualifying resource in its net metering program. Finally, there are waste disposal references which relate to municipal prohibitions on discharging geothermal waters to public water treatment and waste management facilities (Sparks, Nevada).

Co-generation: Eighty seven cities use co-generation references in their municipal codes substantively, accounting for four percent of the total sample cities[21]. Different types of cogeneration references primarily included codes on zoning and permitting. Zoning ordinances define the use of co-generation in different zones, for example, in forest products overlay district (Darrington, Washington) or coastal zone general commercial district (Crescent City, California) or heavy manufacturing zone (Sutter Creek, California). Rates and taxes on co-generated electricity were also specified by certain municipal codes which varied. Some other examples of codes included some cities adopting federal guidelines on co-generation (Green Cove Springs, Florida). Other cities were innovative and ensured that different technologies, could be used well together, for example, Watertown, Minnesota required any solar equipment or device to be compliant with regulations of co-generation of energy.

Net-metering: Seventy-five cities use net-metering related terms in their municipal codes substantively, accounting for four percent of the total sample cities. Most net metering references

[21] Co-generation is often defined by cities as a process of producing power as a by-product of a manufacturing or power-producing process or a process of producing useful energy, by creating or converting waste disposal material to useable energy.

specify the net metering policy for the city which includes standards, procedures, costs, rates of net metering, billing, metering and interconnection in a city. There were also several codes for net metering requirements of specific forms of energy like wind and solar energy while other codes required renewable systems to comply with state and federal net metering requirements. Some codes also specify safety and emergency standards for net energy metering equipment in the city.

Biomass: Forty-four cities use biomass references in their municipal codes substantively, accounting for two percent of the total sample cities. The references are similar to other keywords and mostly used in zoning and permitting codes, to define development standards and regulations, and for defining rates, taxes and incentives. They are also used in a few cities as recommendations for sustainable building designs and some cities provide economic development incentives for facilities using biomass energy. They are often used in reference to ethanol, biofuel, alternative fuel, solid waste, furnaces, and bioenergy.

Waste to energy: Twenty-seven cities use waste to energy references in their municipal codes substantively, accounting for one percent of the total sample cities. These were references to waste to energy and energy recovery facilities, and the policies, procedures, standards and guidelines governing these facilities. There were also related zoning and permitting codes which defined permits, requirements, and uses for different zones.

4.4 Key Results

They key results of the study are discussed below:

A large number of municipal governments codify renewable energy across the United States. Municipal governments often address solar, wind energy, and geothermal energy in their codes.

Municipal governments across the United States frequently referenced renewable energy in their codes. More than half the sampled cities (53 percent) substantively refer solar, wind, geothermal, biomass, net metering, cogeneration or waste to energy at least once. This shows the growing importance of renewable energy in municipal codes. Municipal governments most frequently address solar, wind energy, and geothermal in their codes, with solar occurring with the highest frequency. Traction for wind energy at the local level has been lesser when compared to solar energy. This can be seen through our results and in other literature (Farver & McFarland, 2015; The United States Conference of Mayors, 2014). This can be attributed to various reasons including geography, resource potential, population size, community awareness, and economics.

The renewable energy references in municipal codes are primarily neutral or market supporting, and hence renewable energy codification can be described as a tool used by the municipal governments to promote renewable energy development in cities[22]. Previous literature established the use of strategic energy plans and energy programs by local governments to promote renewable energy development. This research has established that municipal codes are also used as another similar tool.

There were regional and state by state variations in renewable energy codification.

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[22] Data on renewable energy codification being market supporting, neutral or market barriers was not gathered in this research. However anecdotally the references studied by the researchers were found to be primarily market supporting or neutral.

A cities location within the United States is a critical factor in determining its likelihood of adopting renewable energy codification. From the national analysis results cities in the west more frequently referenced solar and geothermal energy. From a state by state analysis, all states of the west (California, Nevada, Arizona, New Mexico, Colorado, and Wyoming) have over 50 percent cities which reference solar energy. Cities in the mid-west most frequently reference wind energy. The Midwest states analyzed in the paper (North Dakota, South Dakota, Nebraska, Minnesota) have over 30 percent of cities which reference wind energy. The cities in the south reference renewable energy the least.

The highest concentrations of cities that reference solar were located in the southwest which aligns with the solar resource potential in the region.[23] According to wind resource potential mapped by NREL, South Dakota, and Wyoming both have high wind potential along with some other midwestern states and southern states[24]. While a high frequency of cities in South Dakota and Wyoming reference wind energy there were fewer wind energy references in southern states which have high wind potential like Texas and New Mexico.

As population size increases, the likeliness of a city to reference wind, solar and geothermal energy increases.

A city's energy use depends on geography, socioeconomics, built environment, and types of energy systems and markets. The population is another critical factor which determines the likeliness of a city to codify renewable energy. A large city is more likely to have substantial municipal codes referencing solar and geothermal energy as compared to a small city. As the

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[23] See: http://www.nrel.gov/gis/solar.html.
[24] See: http://apps2.eere.energy.gov/wind/windexchange/windmaps/resource_potential.asp

population of a city increases it is more likely to reference solar and geothermal energy. For wind energy, big and mid-sized cities reference wind energy in their codes with higher frequency than smaller cities with lesser populations. Thus large and mid-sized cities (cities with populations greater than 25,000) are more likely to reference and regulate renewable energy in local codes. This aligns and reinforces findings of ICLEI with quantitative data, where they emphasize that the community size determines approaches and possibilities for renewable energy in local policies (Martinot et al., 2011).

There is consistency while addressing renewable energy in municipal codes.

Cities codified renewable energy in sections of the municipal code pertaining to zoning, permitting, development and design standards, and taxes and financing. They also relied on comprehensive renewable energy codes particularly in the case of wind energy. Renewable energy codification includes regulations in infrastructural standards and requirements. Further, cities tailor policies and incentives in zoning and permitting processes to encourage renewables development. A few cities also use innovative mechanisms where they mandate the use of a renewable energy technology, provide tax exemptions and rebate programs, or initiate leasing programs.

Wind energy codes are more homogeneous than solar energy codes.

Most of the wind energy references (59 percent) found in codes were in a standardized format covering critical aspects of wind energy. On the other hand, solar energy references were found in varied sections of the codes (i.e. zoning, permitting, primary and secondary use development standards, design and construction requirements, solar access) instead of being in a comprehensive standard format. The language of solar and wind energy references in municipal codes also revealed higher standardization amongst wind energy references as compared to solar references.

5 Conclusions

The primary goal of this research was to develop a baseline of renewable energy codification in cities with a population greater than 2,500. Further, we analyzed trends across different regions, states and cities of different population sizes to understand better renewable energy codification in U.S. cities. With an in-depth reference analysis, the research provides an understanding of different ways in which renewable energy is codified by cities.

The policy innovation and diffusion theory and the literature on this subject help us understand why some cities adopt renewable energy codification while others do not? According to the vertical influence model often the government adopting a particular policy is seen to emulate policies of a higher level governing body (Berry & Berry, 1999). In this case, renewable energy codification at the local level is seen to be influenced by state level policies. Literature shows that state policies are broadly applicable across renewable energy technologies however, they are targeted to influence solar and wind technologies over biomass and geothermal technologies (Doris & Gelman, 2011). This trend is emulated across cities too. Solar (43 percent) and wind energy (16 percent) were the most referenced in sample municipal codes, which is much higher than biomass and geothermal technologies.

Another model of the policy innovation and diffusion theory explains that in policy adoption, some adopting governments are leaders while others are followers (Berry & Berry, 1999). This can evidently be seen in the case of local renewable energy codification. Arizona, California, Delaware, Minnesota, New Hampshire, South Dakota, and Wyoming can be identified as leaders in renewable energy codification at the local level. At least 80 percent of the cities in these states, reference renewable energy in their municipal codes. While Alabama, Arkansas, North Dakota, and South Carolina are laggards in renewable energy codification at the local level. Less than 30 percent of the cities in these states reference of renewable energy in their municipal codes.

Regional variations across renewable energy codification can be explained through the regional diffusion model. According to this model a government entity is influenced by the actions of its neighbors within its geographic region (Berry & Berry, 1992; 1999; Gray, 1994; Mooney & Lee, 1995; Walker, 1969). This influence is particularly strong amongst cities in the western states which widely reference solar and geothermal energy in their codes; and the mid-western states which widely reference wind energy in their municipal codes.

Consistency in renewable energy codification is another good example of the policy diffusion theory in practice. Often templates of model codes and ordinances are used by policy advocacy, lobbying, and interest groups to promote policy implementation on key issues at the local level. These groups and networks associated with wind and solar energy can influence implementation of solar and wind energy codes in cities. Thus, these codes, particularly wind energy codes show the high level of consistencies and standardization. The homogenous nature of the wind energy references could also be reflective of technology or market maturity.

Future work can be continued in three directions. Firstly, understanding the parameters influencing renewable energy codification at the municipal level is essential. Therefore, considering the influence of federal and state policies, demographics, geography, the political orientation of the constituents and municipal governments, the presence of peer city networks amongst other factors is critical for this research. Secondly, examining the role of renewable energy codification in renewable energy development at the municipal level i.e. evaluating the impact of these references. This can be done by evaluating renewable energy development in cities with and without codification. Particularly understanding the correlation between referencing renewable energy in codes and actual solar, wind or geothermal deployment in cities is important. Also understanding the effectiveness of using renewable energy codification as compared to using plans and programs in cities is an important consideration. Thirdly, researching the reasons for consistencies and standardization of renewable energy codification and its relevance can help us understand the policy diffusion process at the local level better.

Finally, this research establishes that municipal governments are using renewable energy codification. This paper thus provides a base to develop a more comprehensive understanding of how cities influence local renewable energy development in the United States.

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