The potential of solar energy policy to transform the energy sector: three case studies from the Greater Boston Area

Innovative financial mechanisms, community participation, and decentralized governing structures accelerate the transition to a greener economy

by Stefi Mitova

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Abstract

Fast-paced urbanization contributes to more than 80% of global carbon emissions. More than 2/3 of this staggering number, however, can be traced back to suburban- rather than urban areas. Unlike compact cities, large, detached housing units in the outskirts construct a sprawling and energy-inefficient urban design. The very challenge they create, however, presents an interesting opportunity. Namely, large rooftop areas could be utilized for the installation of solar photovoltaic (PV) systems. *What is therefore the potential of solar energy policy to transform fossil fuel-dependent suburbs into self-reliant, PV-fueled centers?* In order to answer this research question, three case studies from the Boston area were analyzed. Data was collected from interviews, electronic surveys, site observations, statistical databases, governmental laws and reports, as well as scientific articles. Qualitative information was examined via a theoretical framework designed for this study. It builds on theories for adaptive, process, and transition management. Quantitative information, on the other hand, was analyzed with several types of software. It compares all thirty-one suburbs in order to extrapolate conclusions drawn from the three case studies to the entire Boston region. Results show how innovative governance structures disrupt and re-organize one of the oldest and most conservative industries: the energy sector. They transform a centralized, static, mono-disciplinary, and inflexible governance model into a decentralized, dynamic, multi-dimensional, and adaptive policy network. It introduces new actors, rules, and institutions, which accelerate the transition to a greener economy. Policy factors reminiscent of the older regime, on the other hand, impede the adoption of photovoltaic systems. The thesis ends with a list of recommendations that aim activating the full potential of solar energy policy.

Key words: residential photovoltaic systems, energy policy, Boston, urbanization, process and transition management.

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List of Abbreviations

CBGF	Community Block Grant Fund
CIPP	Context, Input, Process, Product
CO2	Carbon Dioxide
DG	Distributed Generation
DOER	Department of Energy Resources
GBA	Greater Boston Area
GC	Green Communities
HEET	Home Energy Efficiency Team
HMR	Hierarchical Multiple Regression Model
ITC	Investment Tax Credit
JEP	Jurisdiction, Economics, Politics
MA	Massachusetts
MAPC	Massachusetts Area Planning Council
MassCEC	Massachusetts Clean Energy Center
MCEC	Medford Clean Energy Committee
NGO	Non-Governmental Organization
PPA	Power Purchase Agreement
PV	Photovoltaic
RSI	Regional Solar Initiative
SREC	Solar Renewable Energy Certificate

Acknowledgments

I would like to acknowledge the support of many people around me. First of all, I would like to thank my supervisor, professor Tatenhove. His advice, wise recommendations, and encouragement inspired me to continuously improve my thesis. During my conversations with him, I was able to understand my role as an analyst and see the policy problem in perspective. Therefore, I learned a lot about scientific research as well as environmental issues in particular.

My thesis is also a product of all courses I took at Wageningen University. They taught me how to think critically and analyze complex problems. They also convinced me of the importance of policy in solving some of the most serious environmental challenges of our time.

Before I completed the interviews and field study, I had a rather theoretical understanding of the problem. That is why I was excited to speak to all interviewees and gain a real-life experience of the problem. They volunteered time from their busy schedule in order to help a student they had not even met. I owe them much gratitude for their help, engaging conversations, and insightful answers.

I am also grateful to my family and friends in the USA and Europe. Their emotional support helped me during my field research in Boston as well as later when I was overseas. Despite long distances and large time differences, they encouraged and inspired me. I thank all of these people for being a part of this six-month-long journey. They helped me discover an exciting field of study, which I would be grateful to visit in my future endeavors as well.

Chapter 1: Introduction to Solar Energy Policy

1. Problem description

1.1. Urbanization and suburbanization

Urbanization is one of the fastest-growing phenomena of modern times. While currently more than half of all people live in urban areas, it has been estimated that this number will grow up to 70% by 2050 (WHO, 2014). The intense urban growth has transformed cities into massive consumers of energy. Currently 80% of all carbon dioxide (CO2) emissions could be traced back to cities around the world (Hoornweg, 2011). However, these statistics should be considered carefully for they estimate the total amount of energy consumed in the *entire* metropolitan area: city centers as well as their suburbs. Hoornweg (2011), for example, shows that on average suburbs consume twice as much energy as their urban core. The contrast stems from the fact that cities are much more compact and densely populated than their surrounding areas (Marshall, 2011). Not only is urban density higher, however, buildings are much taller and therefore much more energy-efficient. Namely, attached housing units (such as those in apartment building blocks, office buildings, and skyscrapers) consume less energy than detached housing units (such as private residential houses in the suburbs) (See Figure 1). Furthermore, the size of the average home grows significantly as the distance from the city center increases. While people in the center live in compact apartments, those in the suburbs enjoy the spatial luxury of 2-3 story, private homes (Ewing and Rong, 2008; Madlener and Sunak, 2011).

Finally, the transportation system in cities is also much more energy-efficient than that in its outskirts. Namely, public transit such as buses, subways, and bikes are a much more sustainable means of transportation than individual automobiles: the main mode of transportation in the suburbs. Indeed, it is rare that suburbs are connected to the city core via an efficient, extensive, and timely railway system. Most suburban residents in the US, for example, commute on average 25 min to their workplace in the city core (US Census Bureau, 2014). Finally, city energy infrastructure is also more compact and therefore reduces the amount of energy wasted in transmission lines over large distances (Ewing and Rong, 2008; Marshall, 2011).

Figure 1 shows the contrast between compact cities (left)[1] and sprawling suburbs (right)[2] (Eriscon, 2011; Redfin, 2008)

The combination of inefficient transportation, inefficient housing, and inefficient infrastructure systems in the suburban zones creates one of the most challenging problems of modern times (Madlener and Sunak, 2011). Namely, as the world population continues to multiply, suburbs would sprawl even further away from the city core. In effect, energy consumption rates and carbon emissions would increase exponentially. Unfortunately, even if the compact nature of city planning manages to decrease some of these negative effects, their neighborhooding suburbs counter-act their sustainable efforts (Jones, 2014). It is therefore essential than suburban areas catch up with cities and implement their own local, sustainability efforts.

1.2. Suburban buildings and solar energy

Which sustainability efforts should take priority on municipal policy agendas though? How can suburbs continue growing without compromising the environmental and social health of their countries? To answer this question, it is important to zoom into arguably the most polluting sector today: the building sector. Indeed, buildings contribute to 40% of all carbon emissions in the world (excluding CO2 emitted while commuting from the suburbs to the city; therefore the total percentage is even higher) (IEA, 2014). It is namely due to the inefficient suburban planning (sprawling towns) and inefficient suburban architectural design (large, detached houses) that these neighborhoods output twice as much carbon dioxide as their core cities (Hoornweg, 2011).

Nevertheless, a study by Byrd (2013) has recently proved that urban and building design is the *problem* as well as the *solution* to the urban energy dilemma. The researcher estimates the solar energy potential of cities as a tentative solution to their energy needs. The article concludes that it is namely the sprawling nature of suburban houses that provides the largest rooftop area in the metropolitan area (tall buildings in the city have a much smaller rooftop area). If used effectively, residential as well as commercial buildings could fuel the energy needs of their towns and feed excess electricity to the city energy grid (See Figure 2 for a picture of residential rooftop installation).

Figure 2: Residential rooftop installation

Considering global dependence on fossil fuels, solar photovoltaic systems seem to hold great promise indeed. First of all, its carbon footprint is smaller than that of grey energy sources: its emission levels are considerably low both during the manufacturing process as well as later during its operation (Dutzik, 2012). Second of all, solar panels constitute an efficient, decentralized energy system, which eliminates the necessity of transmission lines. Coined as 'DG' (distributed generation), it is a convenient as well as price-effective method of supplying distant residential districts (such as suburbs) with green energy (Solangi et al, 2011).

Solar PV systems have several financial advantages, too. Once the system pays off the initial investment, the owner profits free energy generation for approximately 20 years- until the panel is retired. Solar owners, however, profit from any excess amount of energy that their panels produce as they feed it back to the electricity grid (Dutzik, 2012). Another financial advantage is the green job growth, which the industry ensures: hundreds of positions for PV installers, contractors, manufacturers, consultants, repair and technician workers, etc. Finally, solar energy ensures energy independence from foreign or out-of-state imports (Dutzik, 2012; Shrimali and Jenner, 2013).

In addition to the environmental benefits that come along with it, the green technology holds a great promise and virtually unlimited stream of energy. In fact, research shows that one hour of sunlight could power energy needs world-wide for an entire year (NREL, 2013). Unfortunately though, most of it is un-utilized: today only 11% of all energy consumed around the world is renewable- including solar, hydropower, wind, etc (US Energy Information Administration, 2014a). Power demands in urban and suburban areas are therefore predominantly supplied by fossil fuel sources of energy. These fuels, however, are associated with a long list of disadvantages: they are finite and geographically-dependent; their cost has been significantly unstable over the years; fossil fuel combustion releases large amounts of CO2, which has negative impact on environmental as well as public health; and finally- fossil fuels have been the subject of grave geopolitical disputes, such as those in the Middle East (Aldy, 2010; Carley and Browne, 2013; Sovacool and Brown, 2010).

Therefore, in the context of global energy needs, Byrd's (2013) proposition to focus on suburban solar panels presents great potential. Although proven technologically possible, it is important to evaluate the legislative, political, and social feasibility of this idea in the context of a particular area: the city of Boston in Massachusetts, USA.

2. Background Information: Solar energy in the USA, MA, and Boston

2.1. Solar Energy on a federal level

The case study in this paper is selected according to the following criteria: (1) Its location in the United States: a country that faces many energy policy challenges; (2) Its location in Massachusetts: a state with great solar potential (yet not fully utilized); and finally- (3) Its location in the Greater Boston Area, which represents the above-mentioned suburbanization dilemma (Coley, 2012; EPA, 2013) (See Figure 3). The three motivating factors are further explained below in order to provide background information to the main research question-which later ensues.

Why is the USA an important case study? The USA presents an important case study due to its high CO2 emissions; its low renewable energy capacity per capita; and its inadequate green energy legislation. Indeed, the USA is among the largest greenhouse gas polluters in the world- coming second only to China (EPA, 2013). It also ranks first in its carbon footprint on a per-capita basis- with 16,4 metric tons of carbon dioxide per person. By comparison, European countries output about half this amount- e.g. France emits 5,8 tons per person and the UK- 7,7. Thailand and India, on the other hand, rank much lower with barely 3,9 and 1,6 tons of CO2 (Oliver and Maenhout, 2013). As urban populations continue to grow, however, US energy demands will rise even beyond their current levels.

Unfortunately, the Obama administration has not yet signed the Kyoto protocol; neither have they passed a federal legislation that reduces fossil fuels or encourages renewable energy consumption. Therefore, most of the energy policies are implemented on a state or municipal level. Without a consistent legislation nation-wide, policies vary greatly across the country: while some states have impressive emission trading schemes

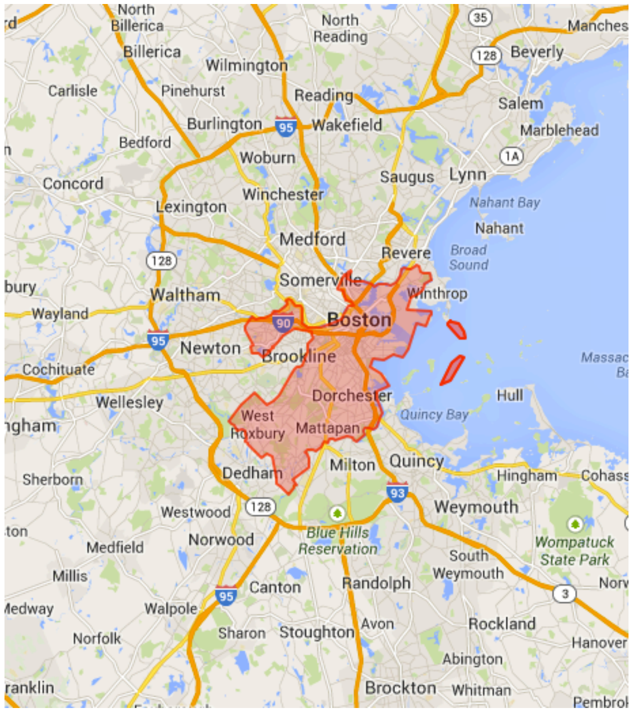


Figure 3: The case study for this research paper: Boston and its surrounding suburbs[3]

and climate targets, others have none or very few. In effect, the dissimilar energy policies create an uncertain and fluctuating energy market, which discourages risk-wary businessmen (Carley and Browne, 2013; Coley, 2012; Elliott, 2013). It is therefore not surprising that today the United States ranks at #20 in the world in its consumption of solar power per capita (Clean Technica, 2013a) (See Figure 4). Its total capacity installed in 2013 accumulated to 7,777 MW, or about 4.2 times less than that in Germany- a country that is 3,8 times smaller than the US (SEIA, 2013a). Finally, the US Energy Information Administration (2014c) estimates that in 2013 solar energy constituted 0.23% of all US energy generation *(Note: If compared on the basis of total solar power installed, the US ranks at #4 in the world. However, these rankings are not objective as they primarily reflect the large size of the country rather than their commitment to solar development. Therefore, countries in this paper have been compared on a per-capita basis: deemed a more objective and fair approach).*

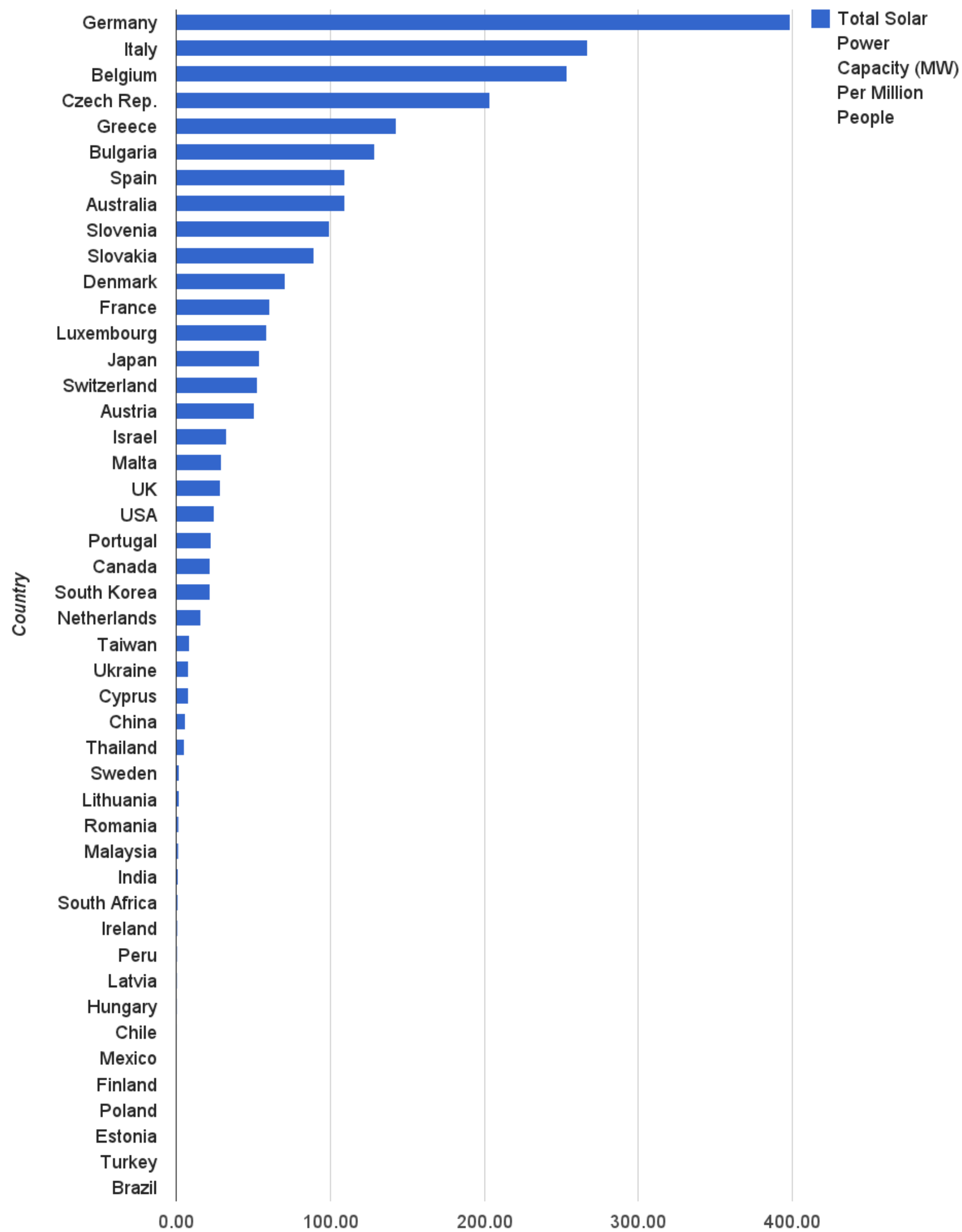


Figure 4: Solar power per capita- world rankings of top countries (Clean Technica, 2013a)

Despite its lower position in world rankings, the US has substantial social and market potential. If utilized well, it could significantly accelerate the adoption of solar PV's. The first potential is social: recent national polls reveal wide public acceptance of solar energy technology as well as solar policies. Conducted among 1,206 American citizens, it shows that 92% of them support solar development and consider it to be the most important source of renewable power; furthermore, 78% of them believe the federal government should implement a more thorough solar legislation (SEIA, 2013b). Unfortunately, popular recognition of green energy has not yet resonated with many American decision-makers. In effect, it lies as a dormant, un-activated potential.

The second potential is the market: PV energy has the ability to increase the employment rate in the US. The solar work force in the country is currently estimated at 119,000 jobs (SEIA, 2013a). It increases at a rate of 6.8% per year- a stark contrast to the average employment growth of the country of less than 1% (NARC). It is an impressive increase, achieved in the absence of consistent, federal policy. Therefore, if supported by the government, US solar power could achieve world-class success.

Despite public support for solar power (as revealed by the survey) and business support (as revealed by solar job growth), governmental support is the missing third element in the solar equation. Better solar policy is needed not only in order to realize the above-mentioned solar capacity though. It is also an essential means of achieving the government's own goal of receiving 10-15% of its energy mix from the sun by 2030, stimulating the solar market, and reducing financial obstacles (Solangi, 2011; White House, 2014). It remains unclear, however, how these goals will be accomplished in reality.

2.2. Solar energy on a state level

Why is Massachusetts an important case study? As previously mentioned, US solar policies vary from state to state. For example, only 28 of all 50 states have implemented Renewable Portfolio Standards (RPS)- widely considered to be the most efficient state solar policy (RPS is a law that obligates utilities to receive a proportion of their energy from photovoltaics in exchange for a certificate; certificates then become trade-able commodities among utility companies) (Solangi, 2011). States differ in the amount of solar capacity per capita, too. While Arizona, for example, ranks at #1 with 167W per person, Missouri takes the 25th position with only 1.7W (Clean Technica, 2013b) (Note: *solar energy per capita is not available for states ranking below the 25th position. However, the bottom 30 states have total capacity ranging between 0,01-8,89MW; the middle 10 states- between 15,74- 93,93MW; and the top 10 states- between 125 and 2055MW*) (NREL, 2014*)*. The contrast among states clearly demonstrates how inconsistent solar policies result in inconsistent solar achievements. However, it also shows that US solar underperformance is liable to change and subject to the influence of multiple factors. It is therefore the goal of this paper to explore those factors as a means of optimizing the US solar future.

One of the sustainability leaders in the USA has been the state of Massachusetts (MA). It ranks 2nd in total capacity and 10th on a per-capita basis; finally, there are 5,557 green companies and 79, 994 green collar employees (Clean Technica, 2013b; MassCEC, 2013a; NREL, 2014). Despite its reputation of a green state, Massachusetts has much untapped solar potential, too. Dutzik, for example, estimates that MA is currently utilizing barely 1.3% of its 8,7GW technical PV potential- the amount of energy the current solar infrastructure can endure (Dutzik, 2012).

However, the state is underperforming in its production of fossil fuels as well. In comparison to other parts of the country, Massachusetts *generates* only 0.14% of all US energy. Therefore, it ranks at #45 in terms of energy production. Specifically, in 2012 MA consumed 1382.7 trillion Btu and produced 128.1 trillion Btu (Calculations based on US Energy Information Administration, 2014b). Therefore, it consumes 11 times more than it produces. In fact, much of it is imported from other states and countries (IER, 2013; Union of Concerned Scientists, 2010). Considering those calculations, it becomes evident that on-site production of solar energy could significantly boost local energy independence as well as local economy. Finally, the North-East state should invest in solar also due to its uncommonly high electricity prices- the fourth highest among all 50 states or 15,53 cents per kWh (IER, 2013). With expensive fossil fuels, solar energy therefore has a favorable competitive advantage on the general energy market in Massachusetts.

2.3. Solar energy on a local level

Municipalities in the USA enjoy significant authority and influence over solar adoption policies. However, implementing solar ordinances remains a voluntary initiative on the part of the government. That is why today cities across the country demonstrate varying degrees of solar success- ranging from a full package of solar programs to (predominantly) deficient solar portfolios (APA, 2013). A recent survey conducted by the International City Management Association illustrates this pattern. 87% of the 2507 city halls participating in the survey have no solar goals whatsoever; 74% have no solar policies, and 50% have no appointed position (e.g. solar coordinator, department, committee, etc) either (ICMA, 2012).

Metropolitan areas best illustrate the above-mentioned contrast for two reasons. First of all, solar ordinances there are voluntary rather than obligatory. Second of all- metropolitan areas face serious urban planning and energy-related challenges, too (as explained in previous sections of this thesis). Therefore, American suburbs experience a dual challenge. The largest metropolitan area in Massachusetts is the capital Boston and its surrounding area- the Greater Boston Area (GBA). GBA is therefore chosen as the case study of this thesis.

The capital of Massachusetts, Boston, has been repeatedly ranked as one of the greenest cities in the nation. In 2013, for example, the city was ranked the most energy efficient city in the entire nation (ACEEE, 2013). Despite legislative efforts in the capital as well as Massachusetts, Boston's suburbs still present a bright contrast to their city core. Figure 5 below shows a map of emission levels in the Greater Boston Area: the red ring of suburbs contrasts the green area, which marks Boston (green designates low carbon emissions and red- high levels of emission). In addition to emitting on average 1.9 as much CO_2 as Boston, the same towns have about 12.3 smaller solar PV capacity than the capital (calculations based on Cool Climate Network, 2013; DOER, 2014a; NREL, 2013). Most of them have no solar energy policies/ ordinances either (See Appendix E, graph 3- only 18-64% of the survey participants have one of eight policy types). Therefore, suburbs contribute more the problem (CO_2 emissions) and less to the solution (kW of solar power).

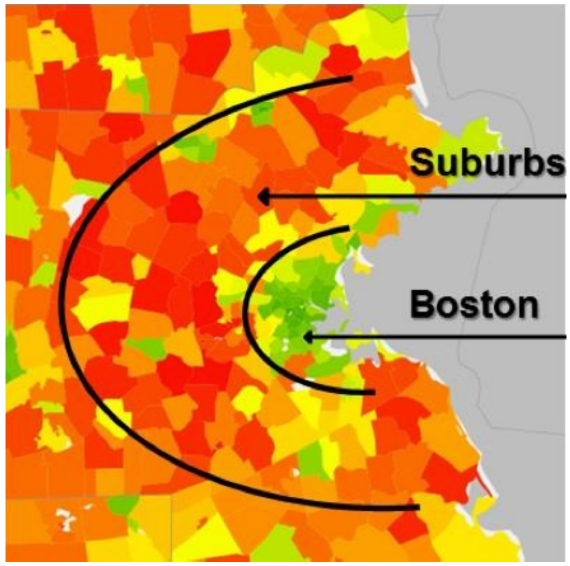


Figure 5 shows the contrast between CO2 levels in Boston and its suburbs. Green color signifies low level of emissions; yellow- medium; and red- high (Cool Climate Network, 2013).

The contrast between Boston and its suburbs is an important case study not only because it is representative of the world-wide suburbanization dilemma or the US local legislation challenge (non- compulsory ordinances). Considering the leading position of both Boston and Massachusetts, one would assume that its suburbs have a greater policy potential to increase their consumption of green energy and decrease local carbon footprint. Indeed, these suburbs are at a great legislative advantage in comparison with towns in lower-ranking states (e.g. Louisiana and Mississippi), where such energy policies simply lack (Carley and Browne, 2013). Nevertheless, the carbon footprint of Boston's suburbs is comparable to that of suburbs in the above-mentioned states. Considering that only 0.4% of all energy consumed in 2012 in MA was *renewable* (therefore *solar* constitutes an even smaller fraction), the similarity with Republican states is not surprising (calculations based on Cool Climate Network, 2013; US Energy Information Administration, 2014b). However, the statistics are disappointing in light of Massachusetts' and Boston's sustainability leadership.

Why have not these suburbs been able to develop their green energy sectors? Why have not the suburbs caught up with Boston’s green efforts? Furthermore, if towns in one of the most energy-efficient state in the USA have made no progress, what is to be expected of suburbs in Louisiana and Mississippi?

3. Past research and Research objectives

The issues of suburban and urban populations and their energy needs have been addressed in previous research to a different degree. Some authors, for example, focus on the problem of *suburbanization*, the disperse infrastructure of suburbs, and their inefficient consumption of energy (Diao, 2010; Ewing and Rong, 2008; Hoornweg, 2011; Jia, 2011; Jones et al, 2014; Madlener and Sunak, 2011; Marshall, 2011; Poumanyvong and Kaneko, 2010). Other researchers discuss *climate change* mitigation and adaptation as the solution (Aldy et al, 2010; Knuth, 2010; Krause, 2010; Pitt, 2009; Pitt, 2010a; Pitt, 2010b; Sharp, 2011). Another group of researchers *propose renewable energy* in general as the solution (Brown and Chandler, 2008; Carley and Browne, 2013; Denis and Parker, 2009; Coley, 2012; Doci et al; Elliott, 2013; Holburn, 2012; Negro, 2012; Sovacool, 2009; Sperling et al, 2011; White et al, 2013). There are articles that focus explicitly on *federal or state solar energy* (Drudy et al, 2012; Griffith, 2013; Hess, 2013; Huijben and Verbong, 2013; Sener and Fthenakis, 2014; Shrimali and Jenner, 2013; Smith, 2014; Solangi, 2011; Verhees et al, 2013; Zhai, 2013). Finally, some studies delve into *photovoltaic systems on a local level* (Dong and Wiser, 2013; Kellett, 2011; Kwan, 2012; Mills and Schleich, 2009).

It remains unclear, however, how city hall officials can connect the problem addressed in these articles (suburbanization) with the solution (local solar energy policy, rather than climate change or renewable energy policy in general). The first goal of this thesis is therefore to fill this gap. It will do so by framing (1) suburbanization and the building sector as the origin of the problem and (2) solar energy- as the proposed solution. Specifically, solar energy will be addressed on a municipal rather then state or federal level.

(3) The origin of the obstacles that impede renewable energy and climate change policy is also unclear. Some articles identify geographic, urban, and socio- demographic factors as the reason for the slow diffusion of clean tech systems and climate change

policies (Kwan, 2012; Mills and Pitt, 2010b; Schleich, 2009; Sharp, 2011). Those factors, however, are fixed and not subject to change. Yet other articles examine the decision-making process and its institutional characteristics- a much more malleable variable (Negro, 2012; Pitt, 2009; Pitt, 2010a; Pitt, 2010b; Sovacool, 2009). The third goal of this thesis is therefore (3) to examine both soft and hard factors. Furthermore, it will do so by considering factors pertaining to solar energy on a local level- rather that renewable energy or climate change on a federal or state level. Therefore, it will re-frame the problem in order to examine the feasibility of Byrd's proposition.

Each of the three objectives is analyzed in further detail below:

3.1 Energy problems in the building sector

Some researchers have argued that it is namely the suburbs (rather than the cities) that contribute to the staggering statistics of metropolitan CO2 consumption. Although much of the suburban CO2 emissions could be traced back to the transportation sector (rather than the building sector), residents spend long hours commuting namely because of the distant location of their home. Therefore, the private residence of suburban dwellers seems to be the origin of the problem (Byrd et al, 2013; Hoornweg, 2011). It is the goal of this thesis to analyze residential buildings in suburban Boston as the problem as well as the solution of rising carbon emissions. The choice of solar energy (rather than energy efficiency, wind, or urban planning policy) is motivated by the unfulfilled potential that the renewable source possesses in Massachusetts (as explained in Section 2: Background Information).

3.2. Suburban towns

Municipal energy problems differ from energy challenges experienced on a (higher) state or federal level. They could be more complicated due to the limited power and budget of small city halls. On the other hand, suburban towns have local resources, unavailable to other authorities (e.g. direct influence over their residents, power to tailor local policy to the specific needs and characteristics of the town, etc). Therefore, this paper aims to understand how municipal solar energy policy affects (and is affected by) other solar energy policies on a state level, as well as the energy policies of neighborhooding suburbs (Denis and Parker, 2009; Pitt, 2010b).

Considering the complex nature of solar energy problems- simultaneously pertaining to zoning, land, transportation, employment, etc, issues- it is important to understand them with regard to these sectors as well. Sectoral characteristics, however, differ across towns: each one has a unique social, political, business, and demographic composition (Kwan, 2012; Negro, 2012). A case study approach that focuses on a sample of suburbs is therefore important in order to gain insight into the specific energy needs of a town (and the specific socio-political resources available there to help tackle its problems).

Suburbs constitute an important case study also because of the specific energy problems they have. Namely, their populations are usually above-average income families whose carbon footprint is higher than that of city dwellers. Although their scarce population density is one of the causes of the energy problem, increasing suburban population density would only exacerbate the problem- namely, as more people pollute at high rates. As previously mentioned, the vast rooftop area and the uniform height of residential buildings (unlike the varying heights of city buildings) are yet another advantage to suburban houses (Kellett, 2011; Poumanyvong and Kaneko 2010). Therefore, suburbs constitute an attractive opportunity for states to increase their solar energy potential.

3.3. Policy instruments

This paper focuses on policy as the preferred tool for tackling the building energy dilemma in Massachusetts. Indeed, considering the solar energy capacity installed in locations such as Germany and California, it becomes evident that the problem is not of an engineering nature anymore. Instead, it could be assumed that the reason for the disparity in solar energy production is grounded in economics, politics, or legislation (Negro, 2012; Kwan, 2012). It is therefore the goal of this paper to explore the potential of both policy (soft factors) in its socio-demographic context (hard factors) to maximize the solar energy capacity of Boston's suburbs.

4. Research question

Despite the contrast between Boston and its suburbs, observations in 2013 showed that a couple of the other towns (e.g. Cambridge) have managed to significantly reduce their carbon emissions, increase the renewable energy in their portfolios, and initiate municipal energy programs. It therefore seems possible that a town of a considerably smaller size than Boston moves independently in a sustainable direction. Whether the driver of municipal green energy is of a social, political, legislative, or economic nature remains unclear though. It is therefore the aim of this paper to answer the following research question: *What factors contribute to the varying degrees of solar energy success across Boston's suburbs? In light of these factors, what is the policy potential of solar energy to transform fossil-fueled towns into self-reliant, PV-fueled centers?*

In order to answer these questions, the following sub-questions will be addressed:

- What solar policies are currently implemented in suburban Boston?
- What policy barriers and policy opportunities do they experience?
- In light of these factors, what is the policy potential of solar energy to reduce the carbon footprint of the suburbs? Why has (not) this potential been fully utilized?
- What recommendations could be given to the suburbs so that they can activate all opportunities?

5. Scope

The scope of this paper is limited to solar energy policy in the Greater Boston Area. Three towns were selected in order to analyze suburban obstacles and opportunities in depth. Suburbs, however, vary greatly in their contribution to the problem (CO2 emissions) as well as their contribution to its solution (PV capacity). Therefore, it is important that towns are selected in a way that ensures representatives with varying degrees of sustainability. In order to make such a selection, all 31 GBA towns have been categorized in Table 1. The table has two categories: (1) Tons of CO2 emitted (including transportation, housing, etc) and (2) Rank within the state of Massachusetts (according to capacity installed). MA rank was selected as a more objective means of measuring solar deployment across towns.

In order to differentiate between more sustainable and less sustainable towns, each of the

Town	CO2 (tons)	MA rank in 2012 (out of 353)
Arlington	49.1	81
Belmont	56.3	100
Boston	*26.8*	*1*
Brookline	50	130
Burlington	59.1	212
Cambridge	35.2	15
Canton	55.1	48
Chelsea	38	70
Dedham	53	61
Everett	42	19
Lexington	65	140
Lynnfield	64.2	323
Malden	42.5	98
Medford	**47**	**145**
Melrose	**51.8**	**196**
Milton	60.5	24
Needham	63.6	95
Newton	53	64
Norwood	49.6	353
Quincy	41.2	59
Revere	40.5	29
Somerville	**38.9**	**64**
Stoneham	50.6	280
Wakefied	55.4	320
Waltham	49.1	21
Watertown	47.2	36
Wellesley	63	156
Westwood	64	180
Wincheter	63.1	128
Winthrop	46	32
Woburn	49.9	54

CO2	
35.2	42.65
42.65	50.1
50.1	57.55
57.55	65

MA rank	
15	99.5
99.5	184
184	268.5
268.5	353

Table 1: Selecting three case studies according to two ranking criteria: tons of CO2 emitted and solar PV rank in the state of Massachusetts. The legend is shown below (Dutzik, 2012; Cool Climate Network, 2013).

two categories (excluding Boston) was split into 4 sub-sections. Each one was color-coded in blue, green, orange, and red (denoting respectively lowest through highest amounts of carbon pollution; as well as highest through lowest position in MA rankings). After all towns were color-coded, some of them received dissimilar colors for the two categories. However, others were entirely blue or entirely green. It is believed that these suburbs contribute to the problem and the solution to a similar degree. Therefore, this paper focuses only on suburbs, which have uniform, rather than different colors per category. Finally, one suburb was chosen from each color: one blue (Somerville); one green (Medford); and one orange (Melrose). (*No towns were selected from the last category. The reason is that they do not have any initiatives to be analyzed; they could not be reached for an interview and there was not enough time for four case studies*). The geographical location of the three towns has been rendered in Zeemaps (See Figure 6). The scope of this study is therefore limited to these three towns as samples of the larger pool of 31 suburban towns. (Melrose).

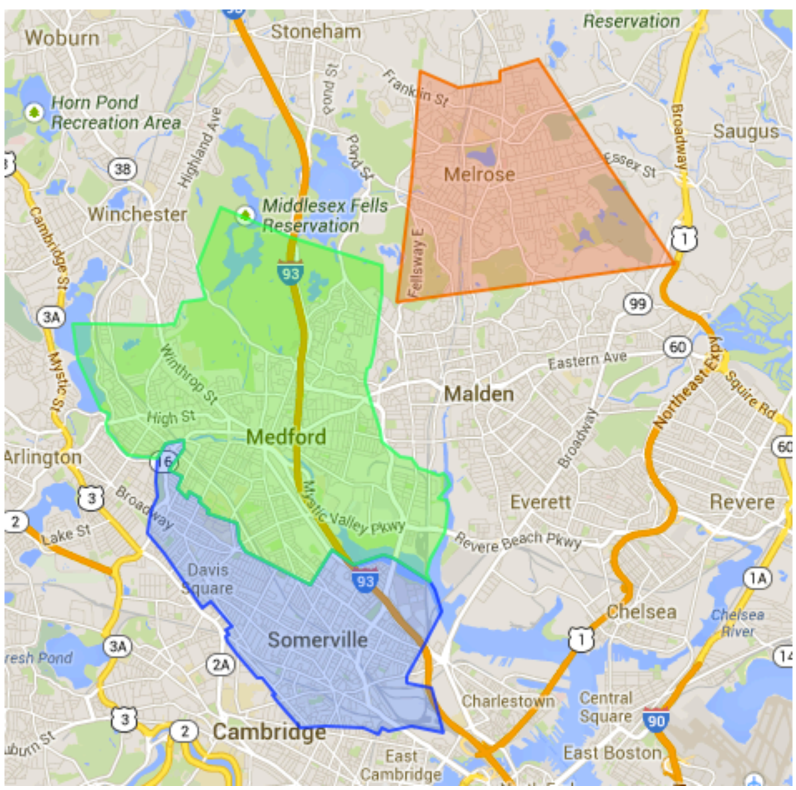


Figure 6: The three case studies in this thesis: Somerville (green), Medford, (yellow), and Melrose (orange) (Image rendered in Zeemaps; Google Maps, 2014).

Chapter 2. Methodology- data collection

The preferred research method for this paper is the case study. Longitudinal methodology, for example, is not suitable because it focuses on long-term data, rather than current challenges and opportunities that face the solar energy sector in Boston. Cross-sectional research design, on the other hand, emphasizes observational data from entire sections of the population. Large samples of this kind are not relevant here as this thesis aims to investigate in detail only a few sample suburbs. Finally, both quantitative and qualitative data has been collected and analyzed in this study. Quantitative data regards PV capacity, CO_2 emissions, as well as demographic and urban statistics for each case study. Qualitative data, on the other hand, pertains to solar energy stakeholders as well as the policies that define the interdependencies between them.

Data was collected from *primary* sources as well as *secondary sources*: (1) State laws and municipal ordinances; (2) Governmental and scientific reports regarding the progress of recently implemented polices; (3) Governmental databases of quantitative, city-specific information; (4) 23 participants from (non-) governmental and business sectors: 14 interviews and 9 electronic surveys; (5) Observations of city hall meetings; (6) Scientific articles; (7) Websites of local/state governments and solar energy companies.

Each of the methods is described in further detail below.

1. Laws, programs, and initiatives

The official websites of the state of Massachusetts and the three suburban towns were consulted for a list of their solar energy laws, ordinances, programs, and other initiatives. These websites also provide the original text of the policies. Therefore, they are an important primary source of information, which was analyzed. For example, policies across suburbs were compared in order to better understand differences and similarities across municipal legislation in Massachusetts. Finally, they were examined in the context of the state policies themselves, too. Examples of such policies are Green Communities, Community Development Block Grant Program, Solarize, etc

(Commonwealth of Massachusetts Executive Office of Energy and Environmental Affairs, 2013; DOER, 2013; DOER, 2014; Irvine, 2012).

2. Governmental and scientific reports

In addition to the original laws, energy reports were also consulted for this thesis. Published by governmental or scientific institutions, they track the progress of current energy policies. For instance, they summarize the outcome of specific solar initiatives, market trends, deployment statistics, energy prices, etc. These reports therefore provide preliminary impressions of the state of the solar industry in the USA. Examples of such institutions are the American Planning Association, International Capital Market Association, Institute for Energy Research, Massachusetts Clean Energy Center, National Association of Regional Councils, Solar Energy Industries Associations (APA, 2013; ICMA, 2012; IER, 2013; MassCEC, 2012-2014; NARC; SEIA, 2013a-b).

3. (Non-) governmental data bases

Federal, state, and local governments provide annual (or monthly) data sets and statistics regarding the following topics:

~ *Demographics*- Population size of the city, racial composition, employment rate, average income, political party affiliation, etc.

~*Urbanization*- Urban density, percent detached housing units, housing type and rent, percent of home-ownership, etc.

~*Energy*- Carbon emission levels, solar energy production and consumption, energy import and export, energy portfolio break-down, installed PV capacity (kW), installed number of panels, size and date of the PV installation.

Unlike the reports (section 2), these websites provide solely raw data: statistics, tables, or other interactive online tools. They serve as input for the contextual analysis of each suburb and quantitative evidence of the differences (or similarities) across suburbs. Finally, data-bases will help build a good town profile, which delineates the urban and energy character of each populated area. Some of these databases are: Cool Climate Network (2013), DSIRE USA (2014), DOER (2014a), Municode (2014), NREL (2014), US Census Bureau (2014).

4. Interviews and Surveys

The above-mentioned websites cover only preliminary information regarding the solar sector in Massachusetts. Stakeholders directly involved in the design or implementation of the policies, however, could give further insight into solar energy matters. Therefore, 23 stakeholders provided personal input into this thesis. 14 of them were contacted via Skype (40-60min phone calls). A sample of the questions asked during the interview is provided in Appendix A. Due to time limitations or stakeholder availability, 9 stakeholders were sent an electronic survey. The survey was prepared in www.SurveyMonkey.com and its web-link was emailed to participants in the USA. A screenshot of the survey is shown in Appendix B. Actors from several types of sectors were contacted: government, NGOs, and businesses. They represent all organizations, institutions, or companies later analyzed in the thesis. Therefore, data gathered represents multiple points of view in order to enhance the objectivity of the thesis. In effect, it was possible to juxtapose parallel or contrasting opinions regarding a single policy issue. A list of all thesis participants is provided in Appendix C.

4.1. Governmental actors: Governmental actors are an essential interviewee in this study. As the decision- making body in the solar energy context, they have the power and the means to initiate change and drive forth the renewable energy sector. Uniquely positioned in the center of the solar network, they have access to social, political, and business resources, too. Their key role, however, is undeniably characterized by multiple obstacles and opportunities as well. These factors (as well as other topics) were addressed during phone interviews.

4.2. NGOs- Governmental actors gave an insider's view into the policy-making process; non- governmental organizations, on the other hand, gave an external, objective evaluation of suburban solar policies. However, they also provided insight into the solar process as participants as well as observants. For example, some of them are active members of solar committees conferences, networks, campaigns, and other relevant events. Therefore, they offered valuable insight into solar problems in a particular suburb. Still others primarily assess solar activities rather than participate in them. These actors therefore gave critical input regarding solar failures or successes in a particular suburb.

4.3. Business actors: Business actors participate virtually at any end of the solar chain: manufacturing, retail, installation, operation, business associations, etc. Their experience with photovoltaic systems is therefore diverse and crucial for the proper understanding of solar problems. Furthermore, they are directly affected by most of the policies that govern the green sector: financial incentives, tax breaks, etc. They shared first-hand experience with these legislative instruments, their short-comings, and impacts on the production process.

5. Observations

Meetings of city hall committees are open to the public. Therefore, each resident is able to attend and witness how projects are designed and implemented. The author of this study attended the following meetings in July/August 2013 (See Table 1). Their purpose was to form a preliminary opinion and impression of the sustainability efforts of the suburbs. During those meetings it was interesting to observe the varying degrees of progress that each city hall had made in the past years. Their respective activities, programs, and initiatives were also considered. While some were clear leaders, others were lagging behind in their sustainability programs. It is this first impression of the contrast between neighborhooding towns that later inspired the research question of this thesis.

Many towns do not have a department dedicated to environmental affairs. That is why most of the projects are initiated by the committee. The second goal was therefore to get a first-hand impression of the committee is a form of governance. Namely, stakeholder participation and discussion dynamics were observed and later analyzed.

Table 1: A list of city hall meetings and observations

	Date	Town	Institution
1	07/24/13	Malden	Malden Town Hall -Planning Board
2	07/25/13	Cambridge	Cambridge Town Hall -Pedestrian Committee
3	07/26/13	Cambridge	Massachusetts Institute of Technology (MIT) -Rebuilding after Katrina
4	08/06/13	Cambridge	350 MA -Fossil fuel divestment movement
5	08/08/13	Boston	Boston City Hall -Environment Department
6	08/12/13	Malden	Malden Town Hall -Energy Efficiency Commission
7	08/13/13	Arlington	Arlington Town Hall -Storm Water Management
8	08/16/13	Boston	Boston City Hall -MassPort Transportation Forum
9	08/16/13	Boston	Boston City Hall - Water Forum
10	08/16/13	Boston	Boston City Hall -Green Entrepreneur
11	08/16/13	Boston	Boston City Hall -Mayoral Campaign for a Greener Boston

6. Literature review

Scientific articles were collected from journals such as Energy Policy, Environment and Planning, Journal of the American Planning Association, Urban Policy and Research, Environment and Urbanization, Renewable Energy, Renewable and Sustainable Energy Reviews, etc. These articles were referenced in order to gain insight into renewable energy problems on a federal, state, as well as local level. The focus of the papers falls into several categories: solar energy technology, policy, and municipal governance. They aim answering the following questions:

~Solar energy technology: How do solar panels work? What are their advantages/ disadvantages in comparison to fossil fuels? What is their adoption history in the US? What share of the US energy mix do they constitute? How does their price/ deployment vary over the course of the past decade?

~Solar energy policy: What kinds of solar energy policies are already in place internationally, in the USA, Massachusetts, and US municipalities? Which actors and processes constitute the solar chain (starting with manufacturing and progressing onto installment and operation)? What policy obstacles and opportunities does each one of them face? Are certain policy instruments better suited to a specific type of problem or population and if so- what kind?

~Political power: What is the political and legislative hierarchy in the USA? What political resources do municipalities have and how do they cooperate with the state/ federal government? What solar ordinances are they empowered to implement and which ones lie outside of their control?

7. (Non)-governmental websites

The websites of local, state, and federal governments have a library of current laws, bylaws, ordinances, etc. They also describe the roles of the Departments/ committees on energy, sustainability. These sources will be used as background information to other primary information. Finally, the official websites of other non-governmental stakeholders will also be consulted. Similarly, they describe the roles, projects, and activities of each of the parties analyzed in this thesis.

8. Videos of conferences and round tables

Interviews provide a useful one-on-one conversation with stakeholders from various institutions. Videos of conferences, on the other hand, constitute a platform where representatives of the same (or related) institutions debate amongst each other. Examples of such events are green technology or solar PV round-tables, public debates, conferences, etc. Sources of these videos are the Worchester Business Journal (2012), the White House (2014), GreenTech Media (2013a-b), and California Public Utilities Commission (2014).

The above-mentioned six types of data provide the basis of this research. The underlying goal of the data collection design is that it eliminates potential biases and information gaps. Data triangulation, for example, will help confirm or refute any uncertainty regarding a specific research question. For example, it is interesting whether information regarding the efficiency of municipal incentives is coherent across sources: interviewees, reports, observations, and articles. Therefore, multiple sources of data will help identify any contradiction or interrelation between the variables.

Chapter 3: Methodology- Case study analysis

The conceptual framework applied to this case study builds on several theories: the CIPP (Context, Input, Process, and Product) theory described by Crabbe and Leroy in *The Handbook of Environmental Policy Evaluation,* the JEP (Jurisdiction, Economics, and Politics) triangle, as well as the adaptive and transition management theories (Crabbe and Leroy, 2008; Folke et al, 2005; Loorbach, 2008; Patwardhan A. et al., 2012). Stufflebeam's publication on CIPP modeling has also been consulted in order to gain further insight into the specific features of the CIPP theory (Stufflebeam et al, 2000). However, these conceptual frameworks have not been applied in a straight-forward way. Instead, their features have been adopted to a new comprehensive theory that best addresses the problem of solar energy policy (See Figure 1). Key terms specific to the framework are emphasized in italics throughout the rest of the thesis.

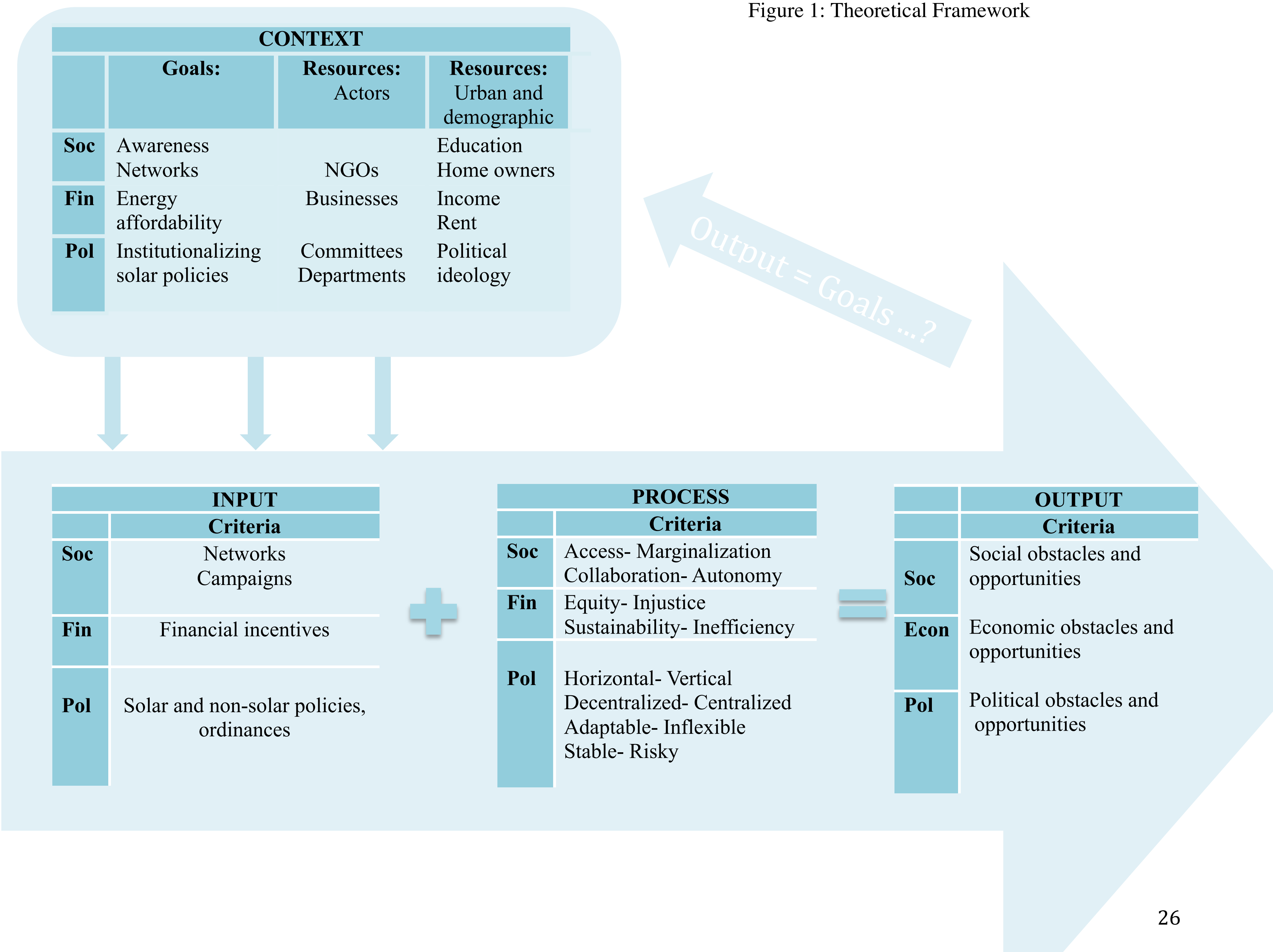
1. Structure of the theory

1.1. The CIPP framework

The new theory has been constructed as follows: the CIPP (Context, Input, Process, and Product) theory serves as the *skeleton* of the theory. Namely, it defines the main sections of Figure 1: *Context, Input, Process, and Product*. According to Crabbe and Leroy, the CIPP theory is a policy evaluation tool that allows a progressional analysis of the policy: (1) the *context* where the problem emerges, (2) the policies *input* into the system in order to solve the problem, (3) the *process* of the policy implementation stage, and finally- (4) its *output* or the final product of the policy (Crabbe and Leroy, 2008). While the first two stages are descriptive (i.e. the "Results" section of the thesis), the latter two are analytical (i.e. the "Discussion" section).

(1) *Policy Context*: While the overall structure of the CIPP framework has been preserved, some of the sub- sections of the four categories have been modified in order to best suit the needs of this thesis. For example, the *policy context* is here limited to the specific *resources* (demographic/ urban features; local actors) of each suburb as well as the generic *goals* of the solar policies in the USA. Other CIPP sections, such as *needs,* have been omitted as they are described earlier in the Introduction chapter of this thesis.

Figure 1: Theoretical Framework



(2) Policy Input comprises the policies implemented by each town. Other input criteria originally described by the CIPP framework (such as schedule and budget) are not relevant to solar policy and therefore they have been omitted, too.

(3) *Policy Process*- The third section of the CIPP framework is the policy *process*. Crabbe and Leroy describe it as an evaluation of the policy implementation stage and the effectiveness of its development *(*Crabbe and Leroy, 2008). Again, the *process* is analyzed through the prism of solar energy policy rather than environmental policy in general. Therefore, this section is characterized by the procedural characteristics of this sector in particular: e.g. solar adoption scope, solar affordability and equity, etc.

(4) *Policy Output*- Finally, the last stage of the CIPP framework is the *output*. This section aims answering the question, *What is the product of the environmental policy? What obstacles and opportunities does it entail for the local community? Finally, does it accomplish the goals set forth in the Policy Context?* The objective of this section is therefore to evaluate the efficiency of the policy in terms of the overarching goals of solar initiatives in the USA.

1.2. The JEP triangle

Each of the four CIPP sections is further classified into three *categories (social, political/ legal, and financial)* according to the JEP (jurisprudence- economics- politics) triangle. The JEP triangle has been chosen as it clearly delineates the three pillars of environmental policy: (1) *Jurisprudence:* legislative order and social rules as defined by law; (2) *Economics:* financial feasibility, management, and business efficiency; and finally- (3) *Politics:* power relations within the state as well as political values such as democracy, participation, and transparency *(*Crabbe and Leroy, 2008).

The three principles have been applied to each of the four sections of the CIPP framework (*Context, Input, Process, Output*). Therefore, each stage of the policy development has been analyzed from legal/political, economical, and social point of view. Structuring the analysis in this manner gives depth as well as breadth to the policy evaluation. Namely, the juxtaposition of the three pillars depicts a comprehensive (and objective) picture of suburban public life. The consequent analysis of each pillar in particular, on other hand, gives detailed (and subjective) insight into its political, economic, or legislative traits.

2. Content of the theory

Each of the four stages is here described in further detail:

2.1. Context:

The first stage of the theory describes the *context* of the solar energy problem in a particular suburb (See Figure 1). The goal of this section is that it 'sets the stage' and describes the circumstances where the policy later evolves. These circumstances refer to the generic *goals* of solar energy policies. They will be defined only once in this framework as they are the same for all US towns. The *context* also pertains to the *resources* a suburb will resort to in order to achieve these *goals*.

2.1.1. Goals can be further categorized into three levels of *variables: social, financial, and political/ legal.*

~**The social goals** are those that benefit civil society. For example, they aim increasing public awareness regarding solar panels (via websites, educational programs, brochures, and posters); creating a strong network of stakeholders (via local organizations, meetings, etc); and finally- democratizing the production of solar power (by empowering each citizen to produce their own electricity) (APA, 2013; US DOE, 2011).

~ **The economic goals** aim overcoming arguably the most challenging barriers to solar energy: the high cost of solar panels. Therefore, some of the economic goals that solar policies set are: providing an *affordable* and cost-competitive price for residential and commercial PV systems; decreasing the *up-front cost* of the panels; and stimulating the local PV market. An indirect yet important goal is increasing the solar employment rate of the suburb. Considering the nature of the industry (heavily dependent on installation, inspection, and maintenance technicians), solar systems indeed hold a great potential to increase the green employment rate of the suburbs (City of Tucson, 2009; US DOE, 2011).

~ **The political/ legal goals** aim improving the *institutionalization of solar energy into the municipal framework*. In other words, the objective is that solar energy policy becomes integrated into local ordinances, laws, bylaws, city plans, programs, provisions, etc. While some towns might choose to do so directly (i.e. implementing a solar bylaw that explicitly targets this particular renewable), other might incorporate solar goals into other municipal policies (building and electricity codes, sustainability plans, renewable energy targets and programs, etc) (APA, 2013). Yet another goal is strengthening the political solar networks. Participants in these networks could be state energy agencies, non-governmental organizations, educational institutions, business owners, as well as local residents (Denis and Parker, 2009; US DOE, 2011).

2.1.2. Resources: Actors

Local *actors* are stakeholders that the suburb relies on in order to achieve the above-mentioned goals. Again, *actors* could be of a *social, economic, or political/ legal origin*.

~ **Social actors** could be sought after certain social groups residing in the suburb. For example, environmentally conscious citizens, renewable energy educational projects, or green non- governmental organizations are a positive asset to the town. They could facilitate the deployment of solar panels by means of their green rationality, network connections, or future partnerships with the municipality (Denis and Parker, 2009; US DOE, 2011). These are key players whose position in the policy framework might not be yet activated. If so, they constitute a dormant potential whose utilization could accelerate the adoption of solar PV's (Pitt, 2010a).

~ Green businesses, on the other hand, constitute the **economic actors**. These are solar energy contractors, consultancy firms, installation or repair companies, manufacturers and retailers who are located in the suburb. The services these actors provide are essential to the wide- spread deployment of solar systems. Indeed, the above-mentioned businesses constitute key actors along the entire PV value chain: from production through installation. Therefore, they could ensure timely, low-cost, and convenient service to local residents. Solar businessmen could also form networks in order to better coordinate the solar industry of the suburb (US DOE, 2011). Lack of those resources, however, could be detrimental to the solar sector as customers would rely on out-of-town service providers. Not only would those companies be more expensive, however, they would prove a more un-sustainable choice, too (as they would inevitably travel large distances in order to reach local customers; hence, they would emit high levels of carbon dioxide). Finally, the availability of green businesses would stimulate local economy and increase the employment rate (Lehmer and Baker, 2012).

~ **Political/legal actors** are municipal departments, committees, and energy officers. Another type of legislative resource is the decision-making power that the municipality possesses: the ability to implement solar ordinances or building codes (US DOE, 2011). This is an important resource because it allows the city to unilaterally initiate a solar policy independently from the state. If the state of Massachusetts, for example, has not implemented a certain policy, it might be possible for a suburb to pursue the policy on its own terms. Finally, regional agencies will also be analyzed as they frequently collaborate with local towns (Pitt, 2014).

2.1.3. Resources: Urban and demographic features

Each town is characterized by a particular demographic/ urban profile. Scientific articles point to the fact that a number of variables influence renewable energy policies as well as the deployment rate of PV systems. These variables could be *social* (race, education), *financial* (income, employment rate), *political* (ideology), or *urban* (home-ownership, detached units, rent) (Ewing and Rong, 2008; Krause, 2010; Kwan, 2012; Mills B and Schleich J. 2009; Negro, 2012; Pitt, 2010b; Sharp, 2012; Sovacool, 2009; US DOE, 2011).

~**The social features** describe the racial composition of the town and percent college/university graduates. Racial minorities, for example, have limited access to education and/or lower income. Higher education is usually considered a predisposing factor to a green-minded community because of the highly technical nature of PV systems as well as its complex regulatory structures. Low income is also a barrier due to the high cost of solar energy systems- about $20,000-30,000 per home. Therefore, it is less likely that racial minorities opt for green technology, such as solar energy systems (Krause, 2010; Kwan, 2012; Mills and Schleich, 2009; Sharp, 2012; Pitt, 2010b; Sovacool, 2009).

~Financial features: The financial features that affect solar energy are average household income and average unemployment rate. As mentioned above, the average income directly affects the ability of a resident to purchase a PV system. A high unemployment rate, too, is an indication of a poorer community where residents would probably invest their savings in purchases other than solar energy panels (Kwan, 2012; Pitt, 2010b; Sharp, 2012; US DOE, 2011).

~The last feature is **political affiliation:** are the majority of the registered voters Republicans or Democrats? This is a very important variable because climate change and green energy affairs have historically spurred debates between the two parties. Republicans usually oppose sustainable energy and Democrats support it. It is therefore essential that each case study chapter considers the ideological lining of the local population (Coley, 2012; Kwan, 2012; Pitt, 2010b; Sharp, 2012).

~**Urban features**: Homeownership is another independent variable in this study. Residents who rent rather than own their house are not eligible for a PV system. Therefore, a community with a low percentage of homeowners would be assumed to have a lower PV deployment rate. The average rent is also an indicator of the financial affluence of a community. It is difficult to estimate, however, how a family spends their money. The third criterion therefore places rent and income in context. Namely, it is the percent of residents whose rent is more than 35% of their income. If a household spends more than 35% of their income on their rent, it is unlikely that they would be able to afford a solar system (US DOE, 2011; Ewing, 2008; Kwan, 2012; US DOE, 2011).

2.2. Input

The *Policy Context* describes the circumstances that affect the policy, not the policy itself (See Figure 1). The following three stages, on the other hand, explain the development of the solar policy: its *input, process, and output*. *Policy Input,* for instance, is a list of policy activities that a suburb undertakes in order to speed up the deployment of solar energy systems. The range and type of solar initiatives will vary from suburb to suburb: while some have implemented mostly financial incentives, other might have resorted to their business or political partners. Yet other suburbs might be lacking any solar activities at all. In the first case, the goal of the framework would be to find out why suburbs have opted for these particular solar policies and what factors enabled towns to implement them; whether they are effective and what other means are relevant (and available) in this particular local *context* (Stufflebeam, 2000). In the second case, on the other hand (no policies are implemented at all), the framework would aim identifying the barriers restricting the development of solar policies in this town.

There are several categories of initiatives that municipal officials could choose from: social, financial, and political/ legal.

2.2.1. Social input are networks that bring together actors from industry, civil society, or the government (Dennis and Parker, 2009). Their collaborative effort aims various profit and non-profit goals related to solar energy:

~Engaging the public in social activities- Many municipalities directly engage their residents in solar activities that train, educate, or inspire them to become solar leaders themselves. Solar campaigns, for example, are a community outreach strategy that aims raising awareness regarding the value, functionality, and practicality of installing solar panels. Campaigns are important because PV's are relatively unknown technology. It is therefore unlikely residents would consider a purchase unless a solar campaign informs them of the multiple benefits of the system (APA, 2013; US DOE, 2011).

~Mutual initiatives with non-governmental organizations (NGOs)- local environmental organizations often work on energy- related projects. Collaborating with NGOs could therefore benefit the government in several ways: they could share valuable knowledge of local challenges and opportunities; they could serve as consultants on energy-specific topics. Finally, town halls that lack the financial resources to hire a solar coordinator in a permanent position, could resort to environmental NGO's as needed (US DOE, 2011).

***~Workshops*,** on the other hand, are an active way of engaging citizens in the practical know-how of solar panels. During a series of meetings, different topics could be covered: PV operation and maintenance, incentives and permitting. As previously mentioned, these meetings could serve a dual purpose, too, as they (1) disprove commonly held myths regarding solar PV's and (2) bring new information to the table (US DOE, 2011).

2.2.2. Financial input are incentives, low-interest loans, rebates, tariffs, and tax reductions, which increase the affordability and improve the financial competitiveness of PV's on the larger energy market (US DOE, 2011).

~Low-interest loans- One of the most common drawbacks to solar photovoltaics is their high up-front cost. Therefore, low interest (and sometimes no interest) loans are an effective way of overcoming this barrier and attracting new customers (APA, 2013).

~Community Solar (CS)- As previously mentioned, solar systems are not affordable for most citizens. Community Solar models therefore allow residents to purchase shares of a large-scale project. This model has several advantages. First of all, it reduces the up-front cost per customer and makes solar energy a more attractive business investment. Second of all, many residents might not be able to purchase a solar panel due to technical rather than financial reasons. Examples are those who rent (rather than own) their home or whose house is not well-suited for solar PV's (due to poor location, orientation, shading, or roof slope) (APA, 2013; US DOE, 2011). As participants in Community Solar, however, they are able to join the solar market despite the short-comings of their property. CS projects could be installed on a wide range or public or private properties: for example brown fields, landfills, or un-used agricultural areas (US DOE, 2011).

~Third-party residential financing models- This option presents the reverse scenario where a resident does own a PV-appropriate roof, however, prefers to lease it out to a third-party entity. The latter could be an investor, a utility, or a company. This model is an attractive option for residents who would like to benefit from solar technology without incurring the high costs or the investment risk associated with solar energy in general (APA, 2013; US DOE, 2011). While the investor pays the upfront cost of the panel, residents consume the green electricity from the panel (Mass CEC, 2012c).

2.2.3. Political/ legal input are solar policies, which directly or indirectly address the solar planning process.

~Manufacturing and retail grants- Some municipalities provide a businesses grant (or other policy) that attracts innovative businesses to relocate to their area. It is a strategic tactic that not only stimulates technological innovation, however, it also increases the local employment rate. Finally, it also creates jobs in a suburban rather than urban area (therefore decreasing travel time of potential local employees) (US DOE, 2011).

~Zoning Bylaws- Zoning regulations define the areas where installation of solar PV's is allowed and those where it is not. Potentially restricted areas could be historical districts or urban redevelopment areas. Zoning regulations, however, could limit as well as encourage the installation of solar systems in certain regions- such as landfills or brown-fields (APA, 2013). Finally, zoning bylaws often specify the maximum height of roof-top panels. In order to encourage the deployment of the renewable energy systems though, some town halls explicitly set no limits to solar PV height at all (Ross, 2013; US DOE, 2011).

~Targets- Some municipalities set renewable energy (or specifically solar) targets in their overall energy plans. Similar to those implemented on a state or federal level, they set (higher) local goals and incorporate solar energy objectives into the every-day objectives of the municipality. Once integrated into the long-term legislature of the city, solar energy becomes a means of achieving other goals as well: economic growth, energy independence, environmental health etc (APA, 2013; US DOE, 2011).

~Sustainability/ Energy/ Renewable energy plans- Solar energy could be built into the general (renewable) energy plans of the city, too. These plans are a good starting point for the municipality to describe and prescribe the role of solar energy in the overall energy mix of the town. The plan could, for example, explain future strategies for expanding and strengthening the energy portfolio of the city and the significance of solar energy in particular (APA, 2013; US DOE, 2011).

~Solar/ Sustainability/ Environment/ Energy Department or Coordinator- Having a department or a coordinator- as a permanent part of the municipal hierarchy- is one of the best ways of mainstreaming solar energy into municipal legislature. The department (or coordinator) will be responsible for the organization of numerous energy-related projects, campaigns, policies, and programs as well as tracking their progress. Unlike the above-mentioned policies, which control a single solar initiative, the department head actively pursues a wide range of activities on a regular basis (US DOE, 2011).

~Solar/ Sustainability/ Environment/ Energy Committee- Committees or Advisory Councils are comprised of local volunteers appointed by the municipality to serve the community for a fixed amount of time. These are usually professionals working in the fields of energy, sustainability, or the environment (public as well as private institutions). Committees usually meet once a month in order to discuss projects and track progress (Pitt, 2010a; US DOE, 2011).

It is important to note that the above-mentioned list is only a provisional checklist of the majority of policies that have been implemented across the country. It is neither likely nor expected that a suburb will have all of them in place. In fact, the selected three suburbs only have a few of the above-mentioned items. Therefore, the full list will not be analyzed in its entire length but rather serve as a guiding framework: What policies could suburbs have opted for? Which ones could be recommended for future implementation? Which ones are irrelevant? Nevertheless, as policies are set on a voluntary basis, they do present an indicator of the degree of solar 'leadership' of the suburb.

2.3. Policy Process

Once the solar policies are *Input* or implemented, they enter the *Policy Process* stage (See Figure 1) (Crabbe and Leroy). Throughout this stage, the policy impacts a wide range of actors as they abide by it. Whereas policy *input* describes policies individually, the policy *process* analyzes the dynamics of their cumulative effect (Stufflebeam, 2000). Therefore, it examines how the policies *transform* the energy sector, how they affect stakeholder roles, as well as the relationships between them. The *Process* is once again evaluated against three types of variables: *social, financial, and political/legal*:

2.3.1. Social aspect of the process*:* The *social variable* measures the scope of PV adoption: Is the policy *inclusive* of all stakeholders (or does it *marginalize* certain actors from policy benefits- low income families, racial minorities, small businesses, etc?) What is their *position* within the policy framework and does it allow them to *participate* in the solar value chain? The goal of this section is then to analyze whether the policy framework gives equal *access* to solar PVs to all social and business groups (Crabbe and Leroy, 2008; Klijn and Koppenjan, 2006). However, it regards *participation* in the solar market rather than the decision-making process. *Participation* in the latter is described in *2.3.3 Political/legal aspect of the process*.

Once stakeholders have been granted access to the policy framework, their mutual *interdependencies* are evaluated. Stakeholders might depend on each other's financial, administrative, or legislative resources. In their *collaboration* together, they might exchange personnel, knowledge, or power. Collaboration will therefore be examined among towns as well as between city halls and regional agencies (Klijn and Koppenjan, 2006; Pitt, 2014). Finally, it is also possible that a certain actor has a *dominant* influence over the rest of the stakeholders. Rather than cooperating with them, this stakeholder enjoys an *autonomous* influence over the decision-making process. It is therefore essential that the power relations among all actors are examined carefully (Folke et al, 2005; Klijn and Koppenjan, 2006).

2.3.2. Financial aspect of the process- The financial dimension evaluates the *economic affordability* of the policy *process:* is it *financially equitable* for all stakeholders along the solar chain? An un- affordable process could be giving preference to certain solar beneficiaries over others. For example, citizens might be ineligible to apply for a certain low-interest loan that is normally available to business companies. In effect, the process distributes financial resources in an *unjust* manner that compromises the welfare of entire social groups (Crabbe and Leroy 2008; US DOE, 2011).

A financially sound policy should also utilize financial/ administrative resources *efficiently*. Efficient use is defined as optimizing stakeholder connections, resorting to prior experiences and partnerships, and effectively implementing available resources. A policy that regulates *sustainable* energy should therefore exhibit similar characteristics of *sustainable* and *efficient* use of policy tools (Verhees, 2013).

2.3.3. Political/ Legal aspect of the process- The first criterion differentiates between *vertically centralized* and *horizontally decentralized* governance models. The former is characterized by conservative, top-down political relations. It is rather linear and excludes non-governmental parties from participating in the decision-making process. Instead, a single actor (e.g. the state government) enjoys a greater power over the political process as well as the rest of the stakeholders. *Horizontally* oriented systems, on the other hand, involve a greater number and types of actors: NGOs, businesses, etc. They have equal access to the decision-making process and hence contribute to a much more *decentralized* policy process (Treib, 2007).

The second criterion distinguishes an *adaptive* process from an *inflexible* one. An *adaptive* process adjusts policy mechanisms to the policy context as well as the overarching policy environment (of the town itself or the state of Massachusetts) (Cumming and Olsson 2013; Folke, 2005). It is therefore important to ask two questions. The first one is, *Do policies successfully mobilize the resources described in the context-local socio-demographic conditions, local actors?* While many necessary resources might be lacking, policy-makers should utilize the ones that they do have access to. Therefore, local policies should not be generic: on the contrary, they should take those factors into account. The second question regards the ability of a local policy to adapt to the current programs on a state level. *Do they take advantage of them or not? Are they favorably synchronized or do they cumulatively create an unfavorable policy environment?* (Folke, 2005; Huijben and Verbong, 2013). As policy-makers attempt to integrate their efforts into the existing circumstances, they will craft new, creative policy tools. Therefore, this stage of the policy process entails a degree of *experimentation*, trial and error, as well as learning from past experiences. The process of *experimentation* and *adaptation* would then build a strong *resiliency* to socio-political vulnerabilities (Cumming and Olsson 2013).

The third and final criterion defines a *consistent* policy framework. Many authors have examined the import of a policy environment that does not *fluctuate* over time. As laws are terminated, they create an *uncertain* solar energy market. Therefore, it is essential that they are *predictable* and *stable* in order to encourage investments in renewable sources of energy. These are essential qualities also because they reduce *risk* and foster *trust* in the solar market (Brown and Chandler, 2008; Hess, 2014; Holburn, 2012; Sovacool, 2009; White W. et al, 2013).

The above-mentioned criteria have been selected as they are integral elements of a *transformative policy process*. Namely, in order that the policy potential of solar energy is activated, it needs to transform the conservative energy sector: from *horizontal to vertical; from centralized to decentralized, from risky to consistent,* etc (See pairs of opposites, Figure 1). The newly *emergent, vulnerable, and risky* renewable energy field, on the other hand, needs to also undergo a transition period as well. Therefore, it needs to become *institutionalized, resilient, and stable*. Only then would society be able to transition away from a fossil-fuel based economy (and governance) to a more sustainable future (Doci; Loorbach, 2008; Markard, 2012; Patwardhan A. et al, 2012).

2.4. Output

The product of the *Policy Process* is the last stage of the CIPP framework (See Figure 1). Namely, it is the *Policy Output:* the impact of process dynamics on public life. This section of the framework aims answering the following questions:

~ What is the policy output in each suburb? Does it fulfill the social, financial, and political goals as set forth by the policy context? In order to reach all three objectives, a product should ensure (1) An increased public awareness regarding solar energy (social goal); (2) Affordable PV systems and active PV market (financial goal); and (3) A resilient solar energy policy that is integrated into the decision making process (political goal). It might be the case that a few policies achieve many goals. However, it is also possible that many policies target the same goal, therefore failing to address other aspects of the problem (e.g. many policies reduce the upfront cost, however, there are no information campaigns or awareness programs).

~If the output fulfills the *social/ financial/political goals*, what factors enabled its success? If not, what factors impeded its progress? Therefore, this section describes the *obstacles and opportunities* in each town. It is the culmination of the analysis of each chapter, which ultimately answers the first research question for a particular suburb.

In its totality, the final framework is a combination of four theories, which are nested into each other in three hierarchical levels: *skeleton (CIPP), categories (JEP), and criteria* (See Figure 2). The criteria for the *context* is based on scientific articles (see references in 2.1); the criteria for the *input*- governmental reports (see references in 2.2); the criteria for the *process*- on scientific theoretical articles (see references in 2.3), and the criteria for the *output*- on the CIPP theory (see references in 2.4). The theoretical framework has been applied four times: three times to the case studies and once to the state of Massachusetts. Data collected from sources described in Chapter 2 has been entered into a data collection table (See Appendix D). It is based on this framework and hence facilitates data collection as well as data analysis.

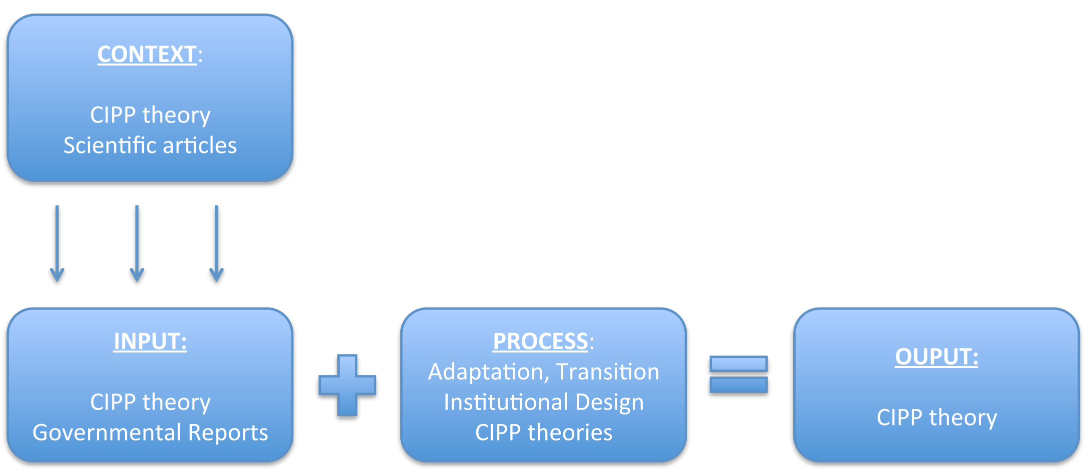


Figure 2: Summary of theoretical framework: each section is based on a different set of theories and sources

Chapter 4. Methodology- comparative analysis

In order to generalize conclusions later drawn to other towns, however, further analysis is needed. Namely, the independent variables considered in Chapters 5-8 should be examined for the rest of the suburbs as well. Therefore, Chapter 10 analyzes data for all 31 towns (PV capacity, CO_2 emissions, demographics, solar energy policies, and urban features of the towns). Three quantitative studies were performed using software StatPlus, StatKey, Esri GeoCommons, and Excel.

The methodology for each of the studies is described below:

1. Study #1: StatPlus

Using StatPlus to analyze the impact of demographic and urban data on PV capacity.

Scientific articles in the past have analyzed quantitatively the impact of a set of independent variables on a dependent variable (Ewing and Rong, 2008, Krause, 2010; Kwan, 2012; Pitt, 2010b; Sharp, 2011). This study takes a similar approach. The particular choice of variables in this thesis is explained in Chapter 3 (based on relevance to solar energy policy). It therefore measures the effect of 13 independent variables on three dependent variables: (1) Cumulative PV capacity for the periods of 2005-2010 (before solar policies) and 2010-2014 (after solar polices) and the entire period of 2005-2014. The independent variables are: percent white population; percent African-American population; percent Asian population; percent Latinos; percent of the population who own their home; percent of detached housing units; unemployment rate; average household income; average rent; percent of the population whose rent constitutes more than 35% of their income; percent registered Democrats; percent of the population who have a Bachelor degree; percent of the population who have a Masters degree. Namely, these are the variables whose effect on PV output is been considered for each of the three case studies: Somerville, Medford, and Melrose. The goal of this study is then to examine their impact on PV capacity in other towns as well.

Data regarding the independent variables has been collected from the database of the federal government, the US Census Bureau (2014). Data regarding the dependent variables has been collected from the database of the federal government- National

Renewable Energy Laboratory (PV output 2005- 2010) and the state government-Department of Energy and Environmental Affairs (PV output 2010-2014) (NREL, 2014; DOER, 2014a). Both PV datasets provide information on a project-basis (rather than cumulative per town). Therefore, all entries have been added in order to obtain the total amount. Non-residential projects (larger than 10kW) are outliers that would mar the objectivity of this study (and lie outside the scope of this thesis to find out the potential of *residential* installations to reduce carbon emissions from the built environment). Therefore, they have been excluded. Finally, independent variable data has been found from the profile of each town on the US Census Bureau website. 13 variables have been selected from a larger pool of information regarding each town.

StatPlus has then been used to analyze the impact of these 13 independent variables on each of the three dependent variables. In order to do so, the software builds a HMR model (hierarchical multiple regression model) of the two data sets. The model is an abstract representation of each town where categories of independent variables are tested against each dependent variable individually as well as cumulatively. In effect, the software creates a nested model of data layers, which impact each other as well as the final outcome of the test. The quantitative analysis examines whether there is correlation between the quantitative value of socio-demographic data and kW of electricity installed. Once again, correlation does not imply causation- it is a statistical method to see whether similar patterns are observed across towns. It is namely this ability of the HMR model to analyze data across levels that motivates its application to this thesis.

2. Study #2: Esri GeoCommons

Using Esri to analyze the impact of geographical location on PV output and socio-demographic factors.

Many studies and reports analyze data distribution on a map (Byrd, 2013; Dutzik, 2012; Kwan, 2012). It is a useful tool that allows the visualization of data patterns across space. The second test therefore measures the impact of geographical location on PV output. Unlike socio-demographic data, geographical location is not quantifiable. Using merely the coordinates of a town (latitude and longitude) would not account for its position with respect to Boston (North-South of it, etc). Therefore GIS (geographic information system) was used to visualize the impact of geographical location on the above-mentioned 13 variables as well as PV capacity. In order to perform the analysis, information regarding each town was geocoded (pv capacity, percent democrats, etc). In effect, each town area of the map is coded with its respective information. The software then divides each data string (e.g. percent of Democrats) into three quantile distribution sections. Each section is assigned one of three colors: light blue, medium blue, and dark blue. The goal is that the map color of a town represents the numerical percentage of democrats. In its totality, the map of the entire Boston region visualizes which suburban regions have more or less Democrats (or PV capacity, Latinos, etc). Therefore Esri analyzes the impact of geographical location on PV output and other socio-demographic factors.

Note: The software automatically splits each data set into quantile sections. Each data set, however, has a different highest and lowest value. Therefore, light blue in one map (e.g. distribution of Democrats) will not correspond to the value of light blue in another map (e.g. average income).

3. Study #3: StatKey

Using StatKey to analyze the impact of policy types on PV output.

The last study measures the impact of four policy types on solar PV output: having a department of energy/sustainability/ environment; a committee dedicated to the same issues; a Solarize Mass program or a Solar Challenge; a Municipal Ordinance (building bylaw; solar access ordinance; etc); as well as the combination of all 4 policies. Data regarding each town is collected from the federal database for municipal ordinances nation-wide, Municode (2014). Unlike the factors measured with StatPlus, these variables do not have numeric values. Therefore, two groups have been created for each policy: "0"- no department, committee, policy, or Solarize; and "1"- the town has a department, a committee, a policy, or Solarize. The research design therefore resembles a standard experiment setting where the control group ("0") does not have a solar policy/department/ committee/etc and the experimental group ("1") does have a solar policy/department/ committee/etc. The PV values for each town are then listed under group "0" or "1."

A randomization test is then performed using StatKey. The software takes 10,000 random samples. Each sample shuffles the values and re-assigns the PV-values to a different group. The goal of the analysis is to examine the probability (p-value) that a town belongs to a certain group ("0" or "1") due to chance rather than due to the solar policy/department/ committee/etc. In effect, StatKey analyzes the impact of policy types on PV output.

Software was chosen after research on other available programs. Their suitability to the needs of this thesis was tested. The best ones were selected and therefore used in this research. Tutorials and practice exercises were useful in order to gain expertise in using this software.

Thesis Roadmap

Thesis structure: The rest of the thesis is structured as follows (See Figure 1). Chapter 5 analyzes state solar energy policies in Massachusetts. Chapters 6-8 examine

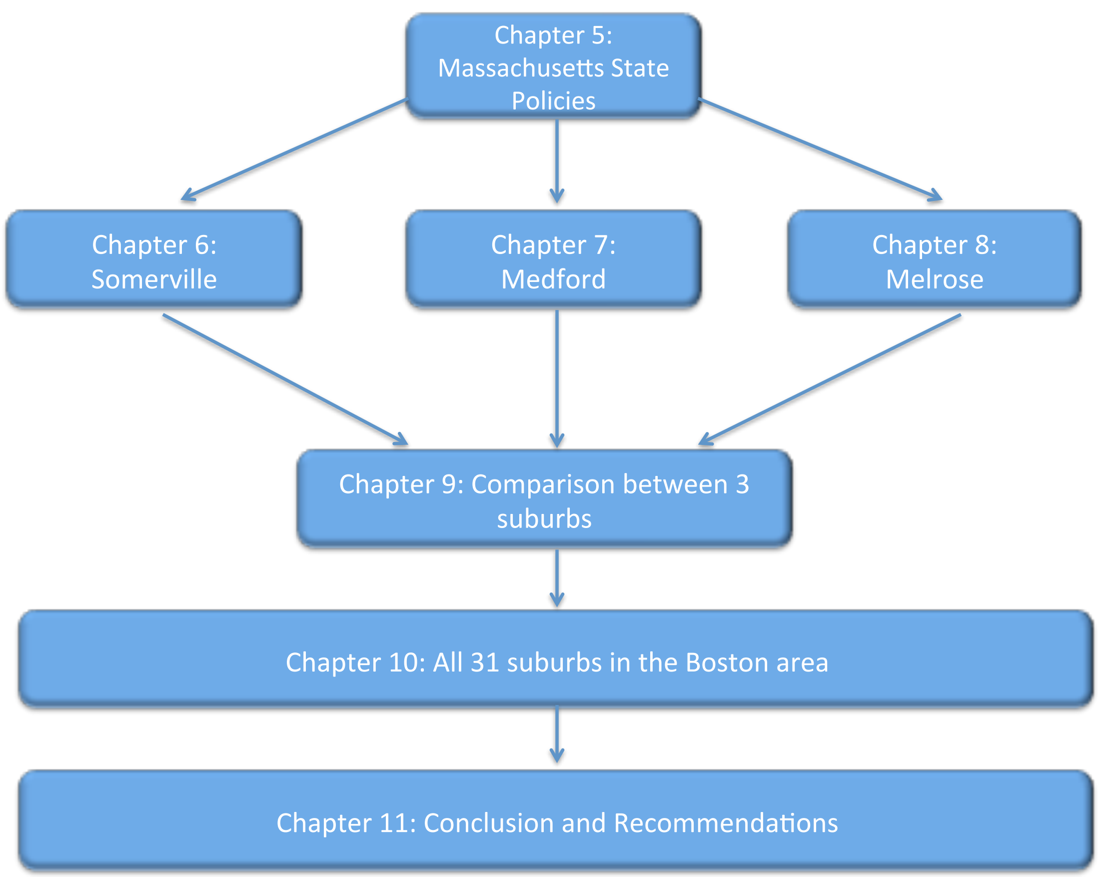


Figure 1: Overall research design of the thesis

municipal policies in Somerville, Medford, and Melrose respectively. All four chapters use the theoretical framework described in Chapter 3. Chapter 9 compares the three towns qualitatively as well as quantitatively. Chapter 10 performs quantitative analysis of all 31 towns in order to extrapolate conclusions drawn in Chapter 9 to all suburban towns. Lastly, Chapter 11 gives final conclusions and recommendations.

Thesis content: Each of Chapters 5-8 is structured according to the four sections of the CIPP theoretical framework. Namely, Sections 1 and 2 present the "Results" of the thesis and Sections 3 and 4- the "Discussion." Firstly, the *Policy Context* presents a statistical diagram of urban and demographic features specific to each town. Then, it introduces key stakeholders in the same town. Next, *Policy Input* describes the goals and functionality of each of the policies enacted by the local stakeholders. The next section analyzes the dynamics of the *Policy Process*, how it transforms the interdependencies among stakeholders as well as how it affects their participation in the solar market. While the prior two sections simply list stakeholders and policies, Section 3 reconstructs the policy process. Therefore, section 3 is based on a diagram that schematically represents the process chronologically in order to track the progression of the policy transformations (it is a reconstruction of the policy analyst, not a formal diagram by the government). Finally, the *Policy Output* analyzes the result of the process: has it achieved the policy goals by activating its contextual resources? If yes, what opportunities enabled its success? If not, what obstacles impeded it? In order to compare policy output with policy input, each chapter concludes with another diagram. It juxtaposes a policy timeline (input) with a timeline of PV installations (output). The final stage therefore loops back the policy cycle by visually comparing the impact of the policies on public life.

Chapter 5: Massachusetts State Policies

The goal of this thesis is to identify the factors, which *enable* or *constrain* the deployment of residential photovoltaic systems in suburban Boston. Local solar energy policy, however, is embedded in the wider context of state *legislation*, *stakeholders*, as well as the *interdependencies* between them. Massachusetts policy therefore affects suburban towns directly as well as indirectly. First of all, it influences municipalities indirectly as it determines which local policies can be enacted as well as what resources they have access to. Furthermore, state laws directly affect residents in the chosen three municipalities, as they are obliged to comply with them. Nevertheless, each town is characterized by a specific *political* and *social* composition and hence- state policies have dissimilar effect on local solar development, too.

Understanding these *interdependencies* would therefore shed light on the origin of local *obstacles* and *opportunities*, too. Therefore, the following chapter considers state solar energy policies. The CIPP framework is applied in order to derive a list of state *barriers* and *opportunities*. Each of these factors is then analyzed in order to determine the extent to which it influences a given local policy. An overview of the chapter is presented in Figure 1.

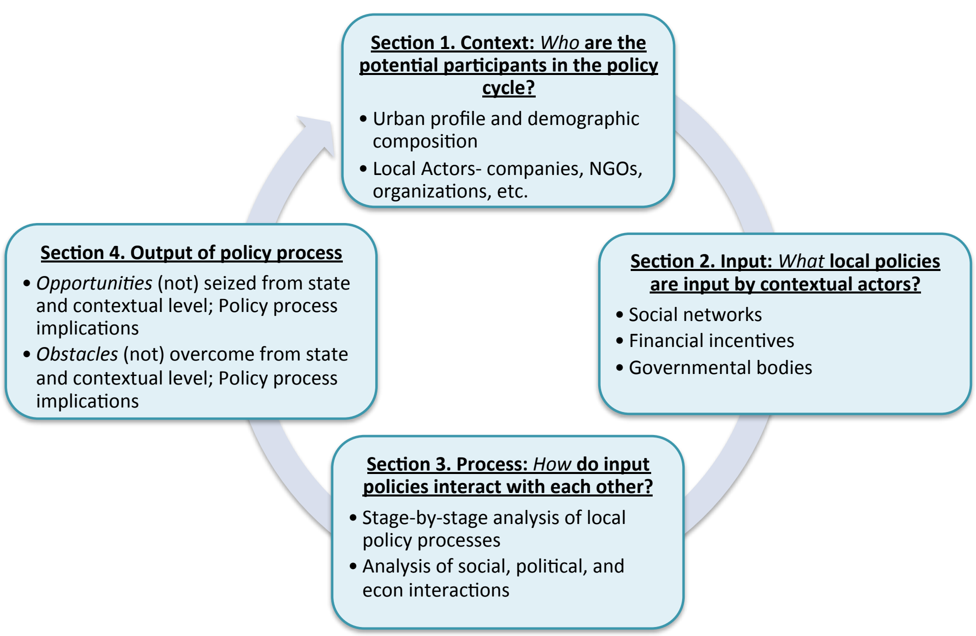


Figure 1: Chapter overview

1. Policy Context

The electricity sector is one of the oldest in the USA- dating back to early 19th century. Both electricity policy and electricity infrastructure are therefore grounded in a long history of established rules and traditions. A sector of a rather conservative nature, the grid has preserved its characteristic features in many American states today. Namely, it comprises the following stakeholders: electricity generation, transmission, and distribution bodies; the citizens and the government. They form a closed system where a central public or a private utility distributes energy to citizens across all sections of the country. US states with no policies related to climate change, renewable energy, or energy efficiency have preserved this traditional, vertical, and robust regulatory structure to a great extent (See Figure 2). Electric utilities in these states therefore enjoy a well-established monopoly over the energy sector, which has translated into financial gains worth billions of dollars (Carley and Browne, 2013; GreenTech Media, 2013a; Kind, 2013). In light of the long history of the electricity sector, it is interesting to consider how a young industry, such as solar photovoltaics, is disrupting the dominance of electrical utilities in Massachusetts (MA).

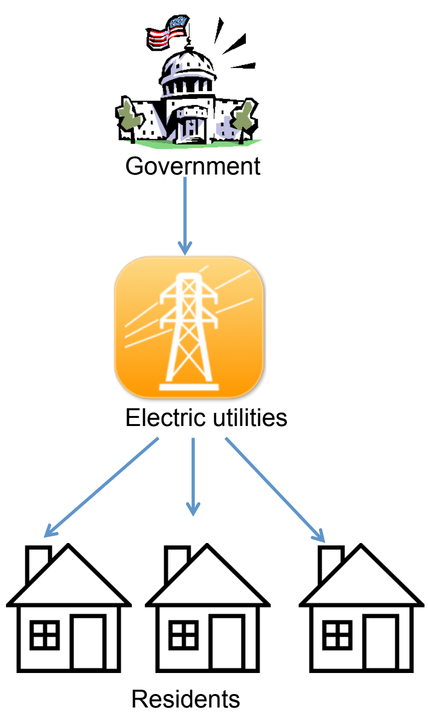


Figure 2: Visualizing the traditional governance model

1.1. Urban and demographic context

The urban factors in Massachusetts predispose a high deployment rate of solar panels. Figure 3 compares these factors with the rest of the USA (Data has been collected from US Census Bureau and statistically analyzed in Excel). Indeed, Massachusetts has a very low population density (829 people per square mile, lower than the US average of 991), relatively high percentage of detached units (52.5%, not substantially lower than the US average of 61.7%), and high percentage of homeownership (63.2%, almost as high as the national average of 66.5%). Therefore, its residents have the advantage to qualify for a PV installation by virtue of living in the Bay State (Massachusetts) (US Census Bureau, 2014).

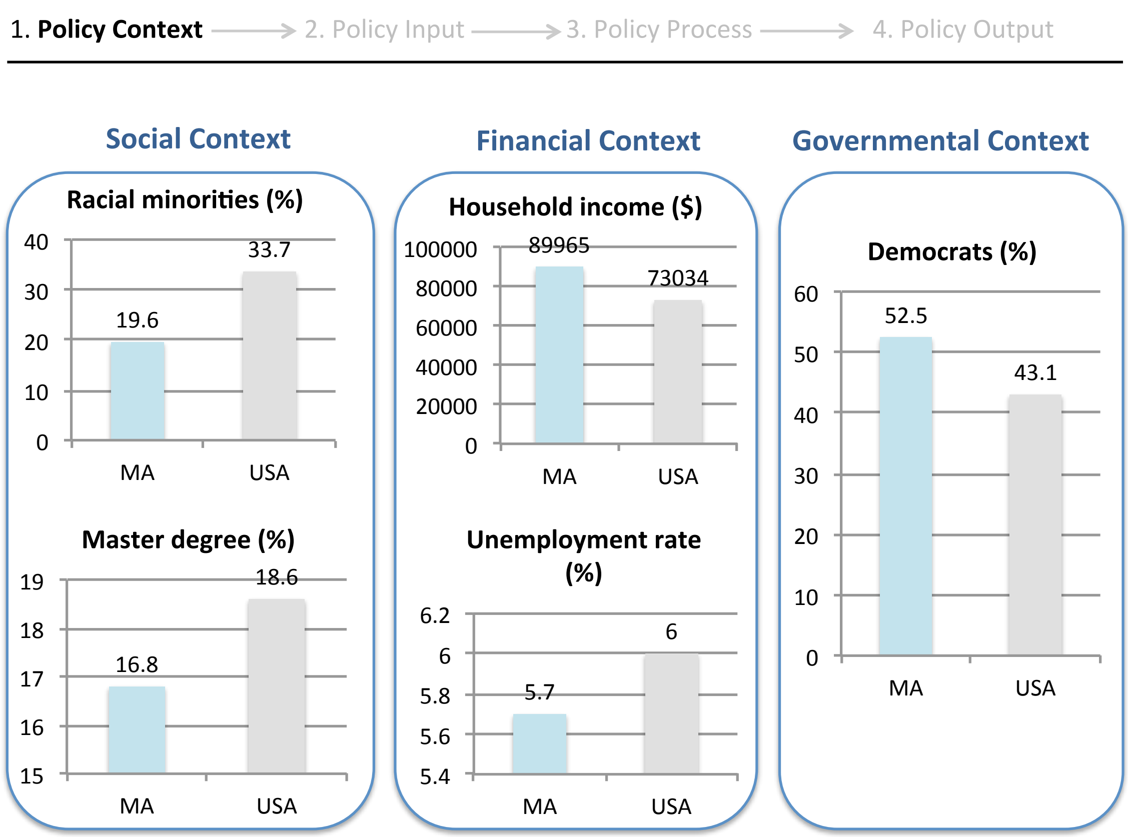


Figure 3: Urban factors in Massachusetts in comparison to the USA (US Census Bureau, 2014).

The demographic factors are similarly favorable (See Figure 4). For example, residents in the state have continuously been favoring carbon tax laws and renewable energy incentives. Surveys show their liberal ideology and hence- support for green energy, environmental sustainability, and conservation (Carley and Browne, 2013). Indeed, 52.5% of the population are registered *Democrats* (higher than the US average of 43.1%). Except for *percent of university graduates* (MA has 16.8% and the USA- 18.6%), MA leads USA across all other demographic factors as well. There are fewer racial minorities (19.6% compared to 33.7%); the average household income of $89,965 is higher than the US average of $73,034; and finally- the unemployment rate is relatively the same in MA (5.7%) and the USA (6%). Therefore, the overall demographic and urban profile of the state predisposes the deployment of PV systems. This is an important observation because these factors are fixed. Unlike other factors (enacting a policy) policy-makers cannot alter these built-in factors.

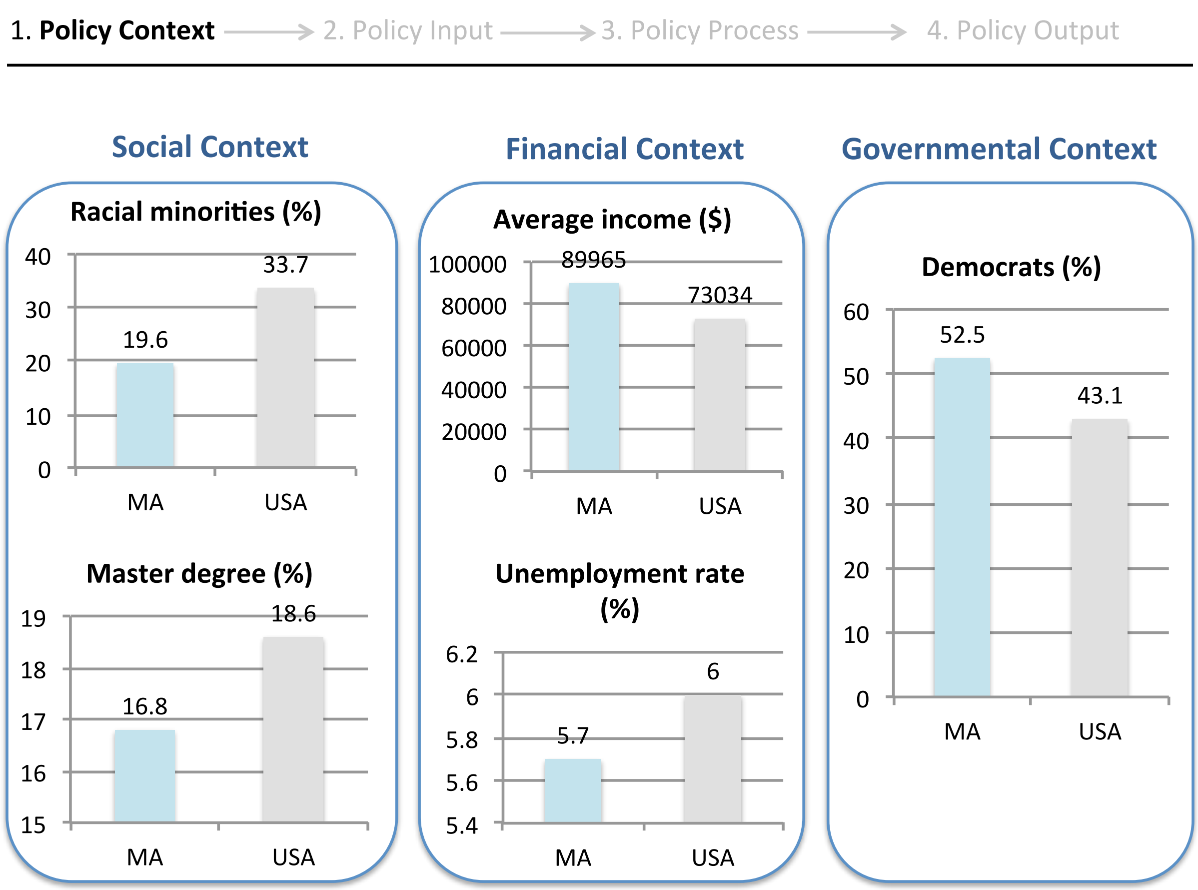


Figure 4: Demographic factors in Massachusetts in comparison to the USA (Saad, 2012; US Census Bureau, 2014).

1.2. State Actors

(See Figure 5)

1.2.1. Social Actors

~**Private developers** are residents, organizations, or companies interested in investing in solar energy. These could be solar energy companies (such as Solar City) as well as other corporations, such as Google. They usually choose to invest in order to obtain the profits from the purchase- e.g. the SRECs (see section 3.2 below), which are awarded to green electricity generators. While some developers buy the solar panels directly, others lease residential roofs and indirectly benefit from the investment (see section 3.2 for further explanation) (APA, 2013; US DOE, 2011).

1.2.2. Financial Actors

~**Electric utilities** produce and transmit electricity to residential and commercial users. Therefore, they are responsible for power generation as well as maintain the grid and transmission lines that connect the utility with the end users.

~**Solar energy companies** engage in one or all of the following: manufacturing, designing, and installing PV panels. Some companies also provide technical advice and consult clients on legal aspects of the process as well as compliance with the law.

1.2.3. Political Actors

~**State government**: The state department responsible for energy-related affairs is the Department of Energy Resources (DOER). They design, organize, implement, and monitor the development of various programs related to fossil fuel as well as green energy. Some examples are Solarize Massachusetts, SREC I and II, Solar Carve Out, etc. Finally, they also provide model bylaws for local municipalities (DOER, 2014c; Lusardi, 2014). They are described in more detail below.

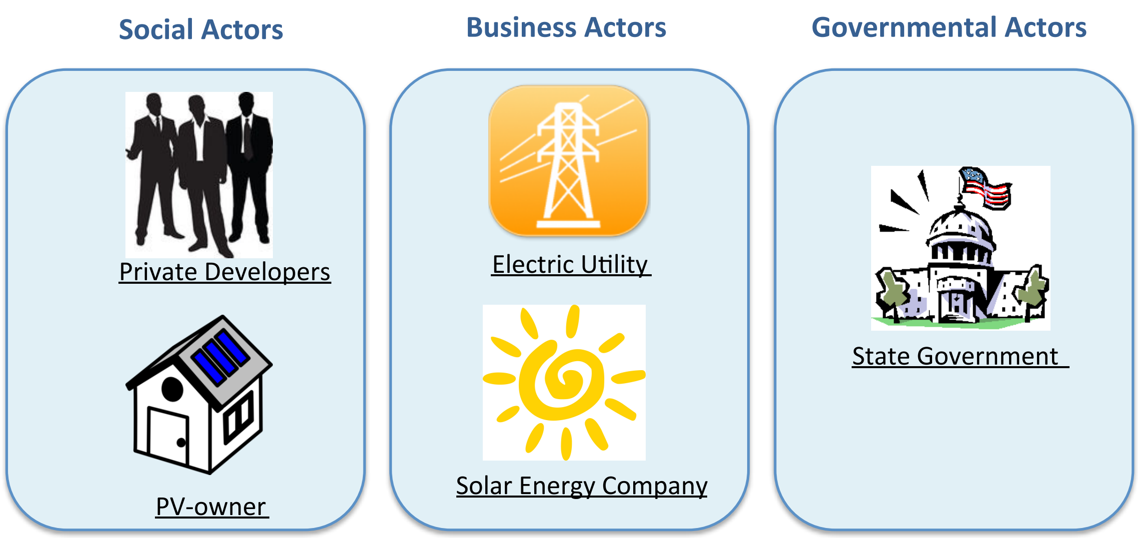


Figure 5: State actors in Massachusetts- key social, business, and governmental actors relevant to the field of solar energy

2. Policy Input

See Figure 6 for an overview of *social, financial, and governmental policy inputs*.

2.1. Social networks

None have been found

2.2. Financial incentives

2.2.1. Taxes and rebates: All residents in Massachusetts are rewarded a federal and a state tax incentive upon purchasing a solar energy system. The first one is called federal ITC (investment tax credit) and it is worth 30% of the value of the system. The state income tax credit, on the other hand, is worth 15% of the total value, or a maximum of up to $1000. Finally, residents in Massachusetts are also eligible for solar rebates- an upfront cash award, dependent on the size and capacity of the energy system (MassCEC, 2012c; MassCEC, 2014; DSIRE USA, 2014a).

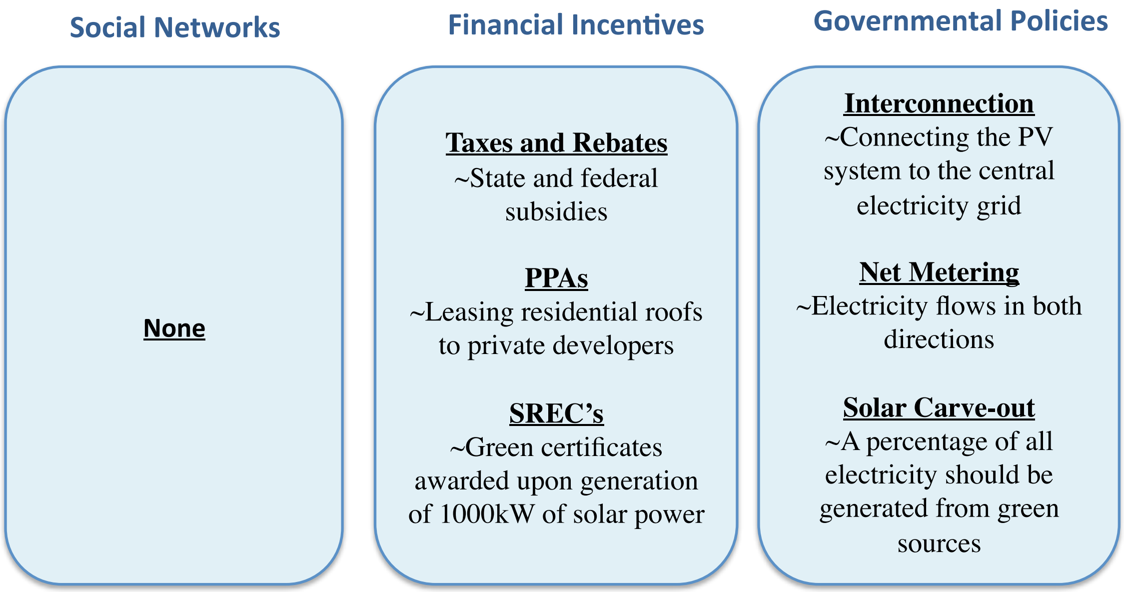


Figure 6: State Policy Input: key social, financial, and governmental policies relevant to the state of Massachusetts

2.2.2. PPAs: It is possible, however, that despite these incentives, citizens are still unable to purchase a PV system. In that case, the state allows them to lease out their roof to a third-party: usually a large corporation, such as any investment company or a solar manufacturer. The company rents the roof in order to install the panel, which they have bought. The contract, which binds the resident and the developer, is called a Power Purchase Agreement (PPA). Under such a contract, the resident buys green energy from the developer; however, the developer is the one who receives the state incentives- such as solar rebates, tax incentives, and SREC's (MassCEC, 2012c; MassCEC, 2014a).

2.2.3. Indeed, **SREC's (Solar Renewable Energy Certificate)** are the consequent section of the solar regulatory structure. A market-based policy mechanism, it is one of the main drivers of the state solar sector (Judge, 2014). Namely, they certify the production of 1000 kWh with one green certificate (2000 kWh= 2 green certificates, etc) (DOER, 2014b). The role of these green credits is to distinguish the production of one electron from fossil fuels from one electron from green energy. In return, the government is able track whether it is meeting the goal of 15% renewable energy by 2020 (DSIRE, 2014b). Therefore, once a residential PV system has generated electricity worth 1 SREC, its owner can sell this certificate to the electric utility at an auction. In effect, both parties benefit: the utility benefits as they acquire a certificate, which ensures that they comply with the Massachusetts law. The resident, on the other hand, benefits from the payment received in exchange for the certificate- usually between $200 and $300 per credit (DOER, 2012; DSIRE, 2014b).

2.3. Governmental policies

2.3.1. Once the electricity has been generated, it needs to be physically connected to the grid via the **Interconnection policy** (MassCEC, Interconnection Guide for Distributed Generation). **Net metering,** on the other hand, ensures that the panel can feed excess electricity back into the grid. While traditional electricity runs in a single direction, Net Metering allows that electricity flows both ways (Department of Public Utilities, 2013; DOER, 2014c). Once connected to the central grid, the policy cycle is completed.

3. Policy Process

The favorable state *policy context* has enabled the implementation of a complex solar energy framework. Currently, it comprises *actors* as well as *laws* unique to the state of Massachusetts alone. Figure 7 below shows the solar regulatory structure, the stakeholders who participate in it, as well as the policies, which define the interdependencies between them. The following section describes these policies in sequence, in order to track their progression from beginning to end.

3.1. Stage 1a and 1b: Taxes and Rebates The first section of the solar policy framework regards solar rebates and tax incentives. The design of the law resembles that of many other public policies- every citizen contributes to a solar fund as they pay their annual taxes or monthly electricity bills. While most other policies require that everybody

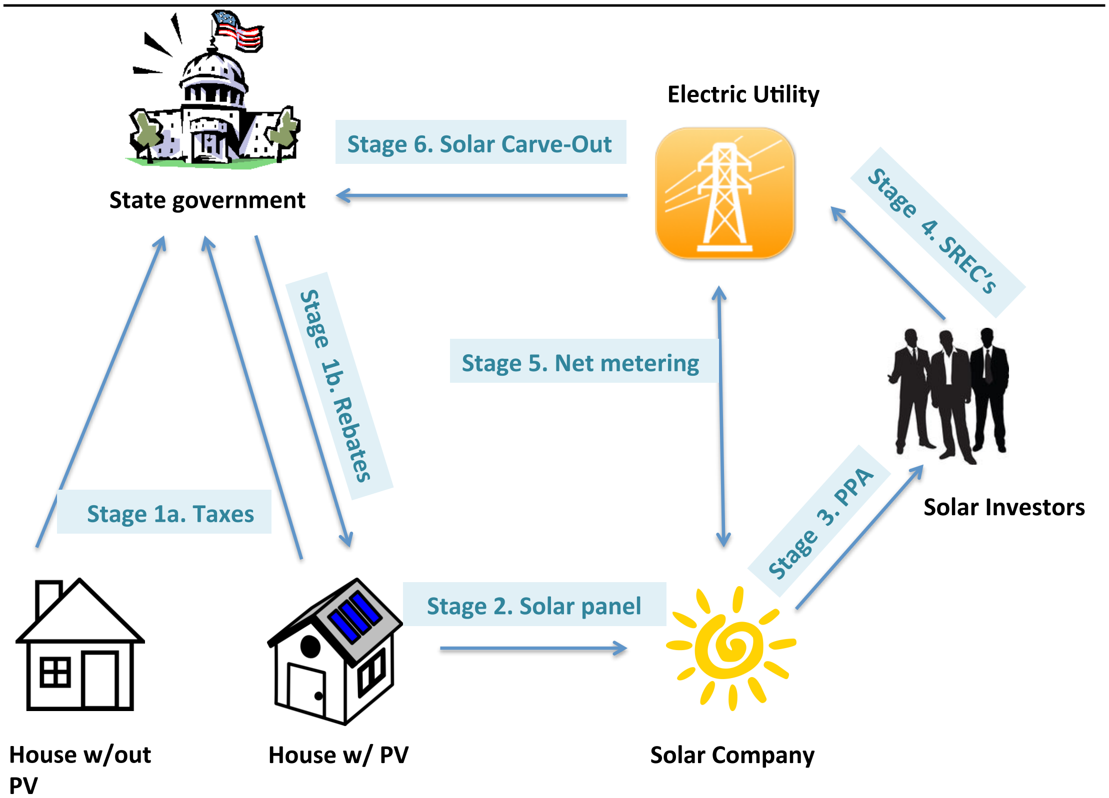


Figure 7: Policy Process in the state of Massachusetts- diagram constructed based on information regarding stakeholders (Policy Context) and the policies themselves (Policy Input)

contributes to the fund, they also ensure that everybody benefits from it, too. In the case of solar energy, however, it is arguable whether the costs and benefits are *equally distributed* among all stakeholders. The reason is that the fund is spent on financial awards, which citizens receive only upon the purchase of a solar panel. However, PV customers are usually mid- or high-income families and those who own their house. Low-income residents and those who rent their home are not able to benefit from the solar energy fund (Griffith, 2013).

Unfortunately, the unintended effect of the policy is reinforced over time. Namely, as demand for solar systems rises, their price inevitably drops. As more people leave the grid to generate their own solar power, however, fewer people are subsidizing the grid. Nevertheless, the cost of maintaining an infrastructure of such an expansive size remains the same. Therefore, the same cost of supporting and operating the grid would be divided among a smaller number of people (GreenTech Media, 2013a). As previously mentioned, however, these people would increasingly become mostly low-income families who cannot afford expensive panels. In effect, the policy creates a positive feedback loop between the number of panels sold and the *economical inequity* it inflicts upon poorer families: the more people buy panels, the more *unjustly* the system treats those residents. The policy therefore creates a situation that gives preference to residents of a certain income bracket over others. In effect, it becomes exclusive rather than *inclusive* and restrictive rather than *participatory*. Unfortunately, the unintended, negative effect of the rebate system is only reinforced as the number of PV users grows. Therefore, the policy is not sufficiently *sustainable* in the long term and does not ensure *affordable* green energy to all residents.

3.2. Stages 2 and 3: PPA's If residents cannot afford the upfront cost of the panels, they can choose to lease out their roof to a third party. The intent of the policy is to ensure *access* to solar energy for a wider section of the population- low income as well as wealthier citizens. Indeed, low-income families who opt for PPA's do not need to pay the high upfront cost of solar panels (which is usually the greatest barrier to PV deployment). Instead, a private investor buys the panels and rents the roof of a citizen.

The strategic design of the policy overcomes several obstacles to widespread adoption of solar systems. First of all, many people or businesses are interested in solar energy, however, they do not have an appropriate roof- due to its orientation, shape, slope, or access to sunlight (Shortsleeve 2014; Youngblood, 2014). Yet another group of citizens does own a suitable roof, however, they do not have the financial means to buy the PV system. The Power Purchase Agreement therefore simultaneously solves both problems as it creates a *partnership* between the citizen and a private investor. It bridges the gap between the two stakeholders and they are able to *share resources* and mutually benefit from the solar panel. Therefore, it *democratizes* energy generation and increases *participation* in the distributed generation of renewables.

This is an interesting *collaboration*, which is uncommon in states without solar energy legislation. Therefore it creates a new form of *collective ownership* and production of energy between stakeholders who otherwise would have very little in common. Furthermore, it creates a governance model where each stakeholder brings to the table their means an expertise and shares them with their partners. Namely, while the resident shares his roof with the business investors, the latter contribute their financial aptitude. Finally, a solar energy company serves as a facilitator between the two parties as they consult them throughout the process- and hence contribute their respective resources, too (knowledge, technical proficiency, experience, etc) (GreenTech Media, 2013b).

In the past several years, however, the proportion of third-party owned panels has been growing. Today 59% of all panels in Massachusetts are in fact property of a distant corporation. By comparison, this proportion is even higher in other US states: 91.3% in Arizona, 80.6% in Colorado, and 74.4.% in California (Drudy, 2013; Kann et al, 2014). The growing trend has several setbacks. First of all, large business companies have become a *prominent stakeholder* in this scenario. As PV ownership shifts to individual, large entities of this scale, the energy ownership model transforms back its previous, rather *centralized* character.

Not only do large corporations become a central owner of solar panels (as well as recipient of all the financial benefits that come with it), however, many of them have joined forces in order to multiply their financial benefits to an even greater extent. The largest US solar energy company, SolarCity (an installer as well as owner of PPA's), has recently partnered with the largest US manufacturer of electric cars and solar storage batteries, Tesla Motors. The partnership strategically combines SolarCity's leading position on the solar market with Tesla's prominent role in the development of cheap and compact solar energy batteries and electric vehicles (GreenTech Media, 2014). The partnership demonstrates an ingenuous vision of a future where widespread solar panels will urgently need convenient storage for any excess energy produced by the PV system. That same excess, on the other hand, will not go to waste as it could suitably fuel the electric car of the same household.

The growing share of PPA's therefore shows the dynamic character of the *policy process* in Massachusetts. Initially created to *decentralize* the market, it could eventually *concentrate* it in the hands of a few large companies. Although perceived as a threat to a *democratized* energy ownership model, however, corporate ownership could eventually prove beneficial, too. Namely, it shows that in the absence of governmental support, the private sector could quickly regain momentum and address the issue unilaterally. Therefore, it is an early indication of the *growing role* of the corporate sector and its potential role in *influencing state policy*- or simply initiating financial mechanisms of its own. The coagulation of green businesses might be the only power capable of balancing out the domineering position of fossil fuels on the market (Hess, 2013; Hess, 2014).

Finally, private companies could give weight to the *position of solar energy* on the larger energy market *financially* as well as *politically*. The former could be achieved as more companies of this size invest in PPA's and enable end-users to purchase a solar panel. As the number and influence of solar energy companies increases, on the other hand, the green employment rate will inevitably increase as well. In California, for example, green energy employment already outnumbers that of fossil fuel workers. It is an important fact that could shift political support towards the green sector. If solar industry continues to thrive in Massachusetts, it could possibly have the same implications in the Boston area as well (Hess, 2014; Lehmer and Baker, 2012).

3.3. Stage 4: SREC's The SREC market, in its original inception, is a creative, flexible, and smart policy tool. It introduces a system of trading green certificates between residents (or solar investors) and electric utilities. Therefore, it is yet another example of a *collaborative* consumption of energy: while residents benefit from on-site, green energy production and consumption, solar investors benefit $200-300 per certificate; finally, utilities benefit as the market allows them to comply with the law (SREC Trade, 2014). As each stakeholder shares their respective assets, they are able to *collectively* share resources and mutually navigate the energy regulatory structure.

The SREC system has successfully stimulated and accelerated the photovoltaic industry. It has created an incentive for all parties to engage in the solar industry as each party benefits from their *participation* in the auction. Similarly to other sections of the state solar framework, though, this one has experienced unfavorable outcomes as well. For example, theoretically it incentivizes electric utilities to invest in solar energy. In isolation of other policies and the interests of other stakeholders, it successfully fulfills this objective. In reality, however, the SREC policy does not exist in socio-political vacuum: it is intertwined in a *complex web of external variables, policies, and stakeholders*. In the case of the Massachusetts solar policy, this network of policies is even more intricate. As any market, for example, market demand drives down the cost of the photovoltaic system as more people purchase it. Ironically, however, a favorably high adoption rate of panels unfavorably reduces the value of the SREC's as well. Starting at about $500 per certificate in 2010, over the years their worth has dropped to about $250 in 2013 (US DOE, 2014). Its decreasing value could therefore discourage PV developers from future investments. app

The unfortunate outcome is reinforced by the low target set by the Solar Carve-Out policy- only 250 MW from solar energy by 2017. Therefore, utilities have been able to easily achieve the minimum share of solar energy four years early- well before the deadline (today the total capacity is 567 MW) (DOER, 2014d). The value of SREC's has been decreasing in the meantime, however. Therefore, utilities in the future could lose incentive to go beyond low target goals if SREC value is also decreasing.

The unfortunate result illustrates the complex *interdependency* between the Solar Carve-Out and the SREC policies. Although designed with a common goal- to accelerate PV adoption- their cumulative effect throughout the *policy process* stage has had positive as well as negative results. It shows the susceptibility of the young industry to *external influences* throughout the policy process stage. A beneficial financial mechanism in theory, it is *vulnerable* to the economical *fluctuation* of the market, as well as the *unpredictable* changes in PV demand and supply. A *resilient* policy tool, however, needs to be able to withstand the *variability* of the energy market.

Nevertheless, state officials have repeatedly *adapted* to the dynamics of the solar sector. Namely, they have raised the Solar Carve-Out target (from 250 MW by 2017 to 1600 MW by 2020) and hence attempted to once again trigger interest in solar investments (DOER, 2014d). Similarly, SREC-2 stimulates interest in residential and non-profit installations. Therefore, it shifts interest from predominantly large (and *centralized*) to smaller (and *decentralized*) projects (Sylvia, 2013).

Generally, these maneuvers show a mastered ability to withstand the unforeseen effects of the market as well as the individual interests and strategies of the stakeholders involved in it. Undeniably, the multiple editions and amendments to these laws have built *resiliency* and strong muscle that will enable the state government to navigate through future obstacles as well. As they react to market changes, PV *vulnerability* to future fluctuations should theoretically decrease, too. The very changes that allow the solar framework to continue thriving, however, discourages residents from participating in it in the future. The constant *changes* create an *uncertain* market where financial investments are *risky* and its outcomes- *unpredictable*.

3.4. Stage 5: Net metering and Interconnection Historically engineered to carry current that flows in a single direction, the grid is not suited to serve both traditional and solar energy generators (GreenTech Media, 2013a). That is why the state government has set a cap to the number of projects that can be connected to the grid. Similarly to the Solar Carve Out policy, the Net Metering cap of 3% has been reached unexpectedly soon- only to be raised to 6% in 2012 (SREC Trade, 2012). Considering the fluctuation of the policy over time, activists have been recently advocating for a favorable policy environment (Besser, 2014). Indeed, the *inconsistency* and frequent *changes* create an *uncertain* policy environment, which discourages investors in solar energy. Investments in the PV sector therefore become risky as the future outcome of the policy is *unpredictable* and *unstable*. In effect, the policy gives positive yet *temporary* advantage to solar companies over electric utilities (Sener and Fthenakis, 2014).

4. Policy Output

What is the result of the *Policy Process*? Does it affect the *Output* in a positive manner that reaches the *social, financial, and political goals* of the framework? If so, what factors enabled local actors to do so? Similarly, does it affect it in a negative manner that impedes the accomplishment of the goals? If so, what constraining factors played a role? Opportunities and obstacles are summarized in Figure 8.

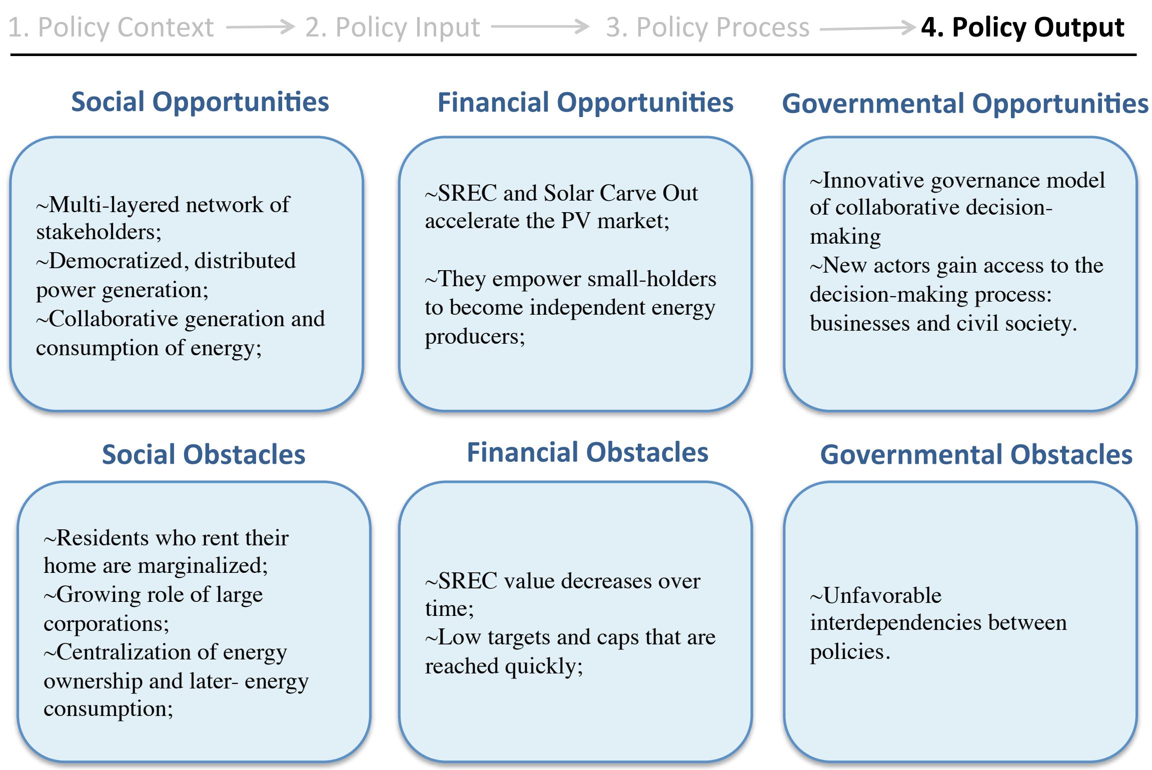


Figure 8: Summary of obstacles and opportunities in the state of Massachusetts

4.1. Social output

4.1.1. Opportunity- A multi-layered network of stakeholders

The *social goal* of the state energy framework is to raise awareness, build a strong stakeholder network, and *democratize* energy generation and consumption. Indeed, this objective is accomplished. Electricity produced by a given panel could be consumed by the same household, however, it could also be sent over the grid to distant residents. During night hours, on the other hand, the same household could be consuming electricity generated by a utility, which powers many other homes in the state. Therefore, the first objective is accomplished via a multi-layered network of stakeholders: residents, utilities, businesses, and state officials. It establishes a platform for *collaboration* that facilitates the policy process and hence- presents an important *opportunity*. In effect, they are able to *share resources* and jointly navigate the complex regulatory structure.

Although no state-wide awareness campaigns were found, each town organizes their own campaigns. These programs (e.g. Solarize Mass) are described in detail in the following chapters.

4.1.2. Obstacles: PPAs marginalize low-income families who rent their home; they centralize ownership to the benefit of large corporations

Nevertheless, the *dynamics* of the policy *process* disrupts some stakeholder *partnerships*. For example, PPAs unintentionally weaken the participation of families who rent their home. Furthermore, the policy attains a rather *centralized* ownership model. As more projects are developed by large corporations and project size increases, too, the governance model changes its shape. Namely, its initial inception is for multiple, small, *decentralized* installations; its final output, however, leans towards larger-scale projects and large corporate owners.

4.2.Financial output

4.2.1. Opportunity: SREC and Solar Carve Out accelerate the market by empowering small holders to become independent electricity generators.

The *financial goal* is to ensure an efficient solar energy market and affordable systems. Indeed, state policies initiated between 2008-2014 stimulate the market. Figure 9 shows a correlation between the financial incentives input into the system and PV capacity output by the system. Indeed, in 2008 there were a few kW of solar power installed. The *financial policies* implemented in the consequent years, however, have increased the capacity exponentially by 2014. The SREC and Solar Carve Out policies have therefore been an important *opportunity* in this regard. Namely, they have enabled multiple stakeholders to take part in the solar energy market. The policies have *empowered* them with the ability to generate their own energy onsite- *independently* from the utility and its billing mechanism. They have gained *access* to the solar market and in effect *collaboratively* driven forth the economic growth of the industry.

4.2.2. Obstacle- Low targets and low caps

The main *financial obstacle* is the low cost of the SREC's, the low target of the Carve-Out, and the low cap of the Net Metering policies. Set relatively low, they have been reached quickly. Before a higher cap or target is set, however, investors experience a risky PV market. Namely, they are not sure whether new incentives will be enacted. The uncertainty discourages investors and slows down the market (Worcester Business Journal, 2012). In effect, they compromise the *long-term viability* of the solar industry.

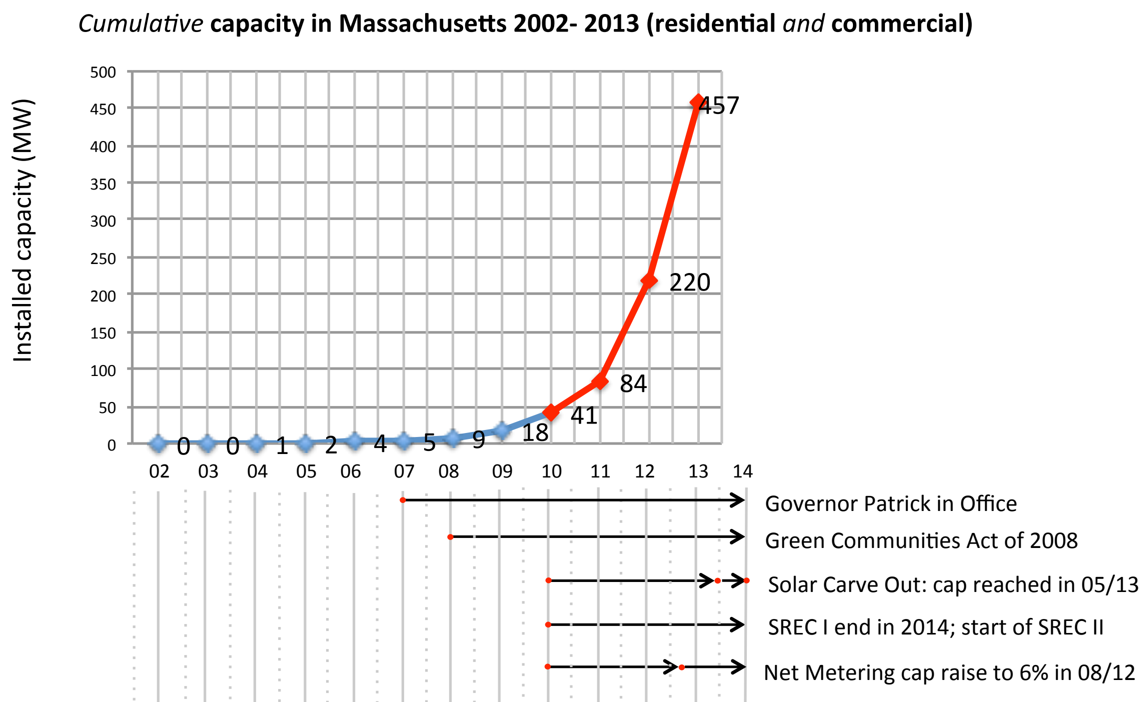


Figure 9: Policy timeline and deployment timeline: showing correlation between policy input and policy output (The graph is constructed based on data collected from: DOER, 2014d; DOER, 2014i; SREC Trade 2012; Commonwealth of Massachusetts Executive Office of Energy and Environmental Affairs, 2013)

4.3. Governmental outcome

4.3.1. Opportunity: Innovative and decentralized governance model; active community participation and public-private partnerships.

The main *political/ legal objective* is to create a stable and well-integrated solar energy framework. Indeed, the policies listed in the *policy input* create a unique regulatory environment in the state of Massachusetts. It comprises a mix of *interrelated* laws as well as a cluster of *interdependent* stakeholders. As previously mentioned, this network of policies and actors does not exist in most other states. In order to break away from the *traditional* and *centralized* energy governance model of these parts of the country, policy-makers in the Commonwealth have fundamentally re-organized the energy sector there. The factors that *enable* this transformation are partnerships with green businesses and active community participation. In effect, the new framework branches out a single governing body into a *horizontal* network of multiple actors (as opposed to a single, dominating electric utility); furthermore, it *decentralizes* a traditionally *centralized* energy governance model into *multiple policies* (rather than a single, *vertical* policy). The new model of *shared governance* has created an interesting system of policies and stakeholders. This *network* proposes a novel approach of *collaboratively* generating, *collaboratively* consuming, and *collaboratively* governing the electricity sector- a stark contrast to the historical model.

4.3.2. Obstacle: Interdependencies between policies in a fragmented framework

The state framework is characterized by a wide range of stakeholders, many programs, as well as multiple policy changes. That is why it is essential that all elements of the framework are synchronized into a coherent whole. *Uncertainty* in a particular section of the framework (e.g. reaching the net metering cap), however, could have an unfavorable impact on other sections (discouraging investors in SREC's, too). The *governmental obstacle* is therefore the unfortunate *interdependency* between policies. It is primarily caused by the fact that the state policy framework is quite complex. A better coordination between its disparate fragments could prove beneficial. As a single policy *adapts* to changes in other sections of the framework, for example, the overall system would also become more *resilient*.

5. Implications for local-level policies: *How do state-level obstacles and opportunities affect solar energy policy on a local level?*

Each of the above-mentioned policies affects cities directly. For example, they all have access to the SREC markets, they all need to comply with the Net Metering policy, etc. However, these are 'fixed' opportunities that affect municipalities uniformly and they cannot build on them- in order to expand their solar potential beyond the scope of the state policy.

Nevertheless, Massachusetts policies affect cities indirectly as well- therefore allowing them to advance independently, too. The main opportunity created by state policies is the ability for stakeholders to network with other agencies, organizations, governmental and non-governmental bodies. The following chapters therefore will show whether city halls have embraced this *opportunity* and whether it has enabled them to rank higher among their peer towns.

The main *obstacle* created by the Massachusetts solar energy framework is policy *inconsistency*. Therefore, the following analysis would also find out whether towns have attempted to overcome this *barrier*. For example, the autonomous power of each city allows it to enact its own ordinances and bylaws. Therefore, they could counter-act the state policy fluctuations with stable local ordinances. In effect, they could ultimately attract solar energy investors into their towns.

A key *opportunity,* on the other hand, is the newly implemented solar regulatory structure. It revolutionizes traditional electricity policy with a new set of rules as well as a wide range of new stakeholders. The Commonwealth has been able to depart from this conventional model largely due to its abundant and favorable *policy resources*: *social* capital, state *legislation*, and *financial* mechanisms. Indeed, the state of Massachusetts prides with one of the most environmentally conscious and progressive populations in the USA. Its state government has shown long-term commitment to renewables, which is yet another *enabling factor* for local governments (Judge, 2014).

Chapter 6: The City of Somerville

1. Policy Context

An overview of the chapter is provided in Figure 1.

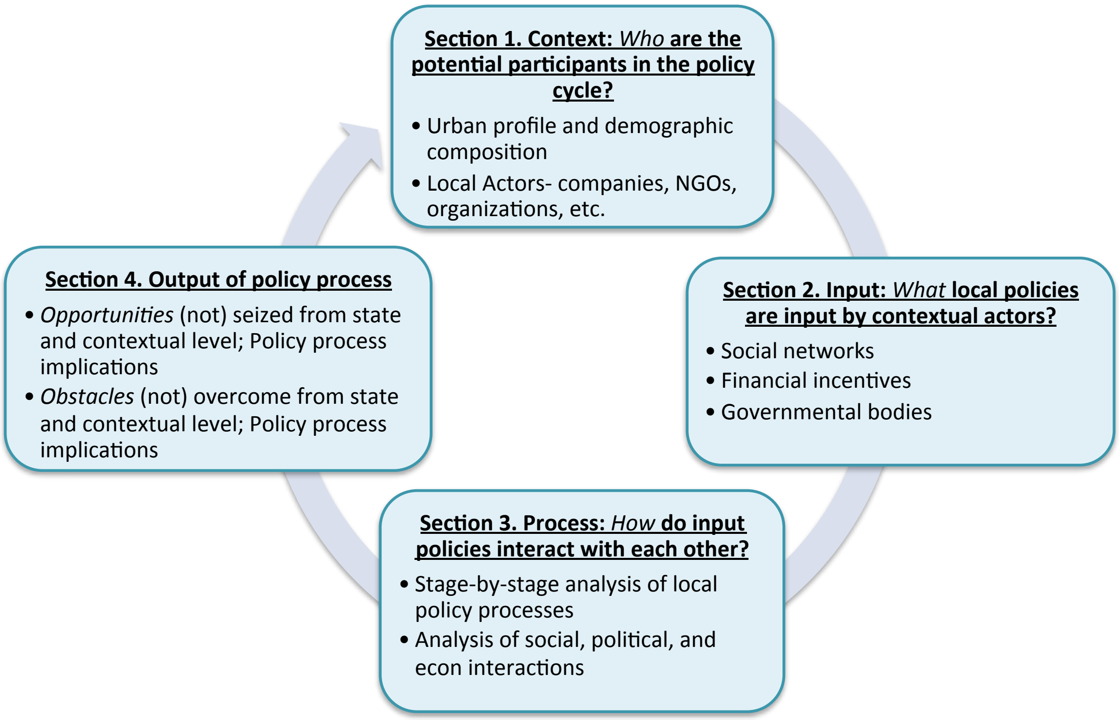


Figure 1: An overview of Chapter 6

1.1. Urban and demographic context

Figure 2 below shows Somerville's position within the Greater Boston Area. Situated almost immediately outside of the capital, it takes the innermost position of the suburban ring. While the rest of the towns have a rather suburban character, Somerville exemplifies urban as well as suburban qualities. A statistical survey of its urban composition testifies for the quasi-metropolitan features of the city (Figure 3). First of all, Somerville has the lowest percentage of detached housing units among the three case studies (11%). Second of all, only 33.2% of Somerville residents own their homes- once again, the lowest in this sample. Finally, the average rent is comparative to that in the rest of the cities (US Census Bureau, 2014).

The urban features of the city portray it as a densely populated environment, where most residents rent their house. Therefore, they indicate a potential *impediment* to the widespread adoption of solar photovoltaic panels. Namely, the high concentration of attached building units would accrue to a relatively small rooftop area. Finally, the fact that most residents do not own their home would later preclude their *participation* in the solar policy framework (APA, 2013; NARC; US DOE, 2011).

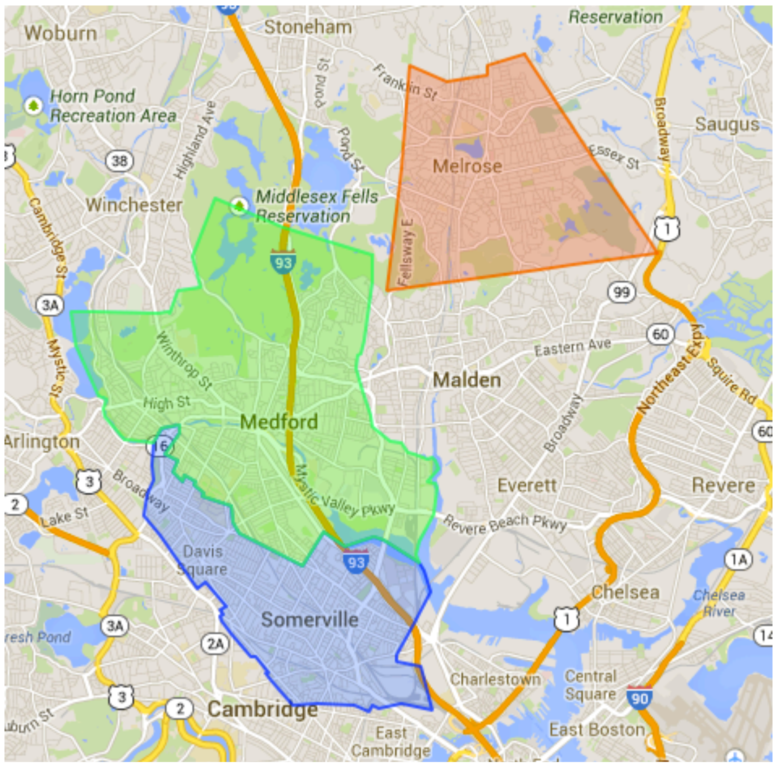


Figure 2: Visualizing Somerville's geographical location (blue region) (Image rendered in Zeemaps; Google Maps, 2014).

The *urban profile* of a town indicates whether a solar panel could be installed on its buildings; its *demographic indicators,* on the other hand, determine whether its residents are eligible to purchase a PV system. Demographic factors that could influence the ability of a resident to purchase a solar system are: *financial* (income level, unemployment rate), *political* (political ideology), and *social* (race and educational level). The statistical data in Figure 4 shows that once again the population of Somerville displays contrasting

Urban Context

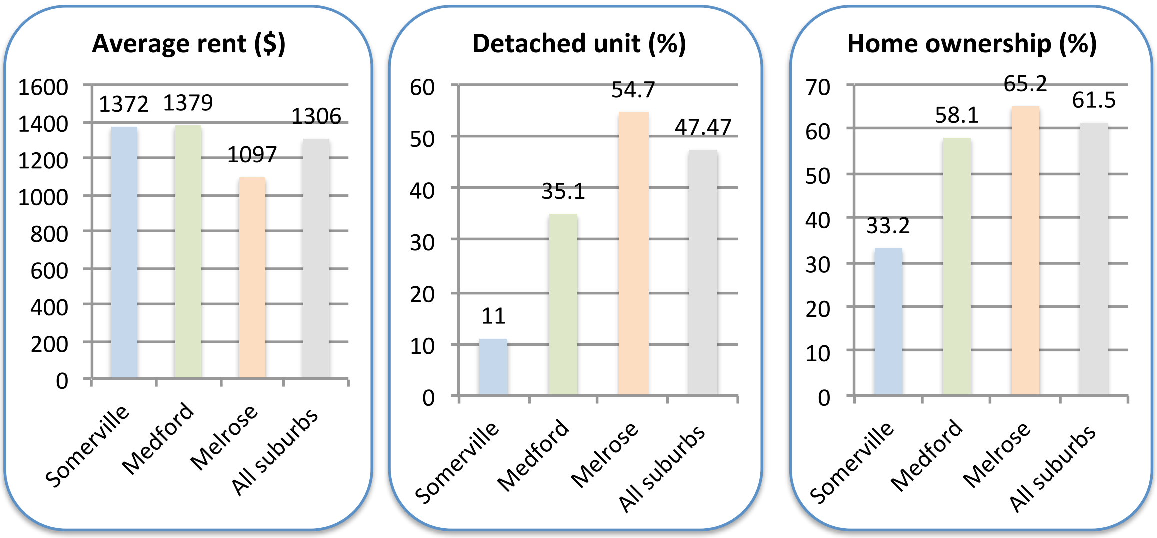


Figure 3: Statistical survey of Somerville's urban features (first bar in blue). Values for the rest of the case studies as well as the average for all 31 towns are also provided (US Census Bureau, 2014).

qualities to those of the rest of the three towns. For example, it has the highest percent of racial minorities (26.1%); as well as the highest percent of Master-level graduates (26%). While the former characteristic could potentially present an *obstacle* to PV deployment, the intellectual capacity of the town could *facilitate* popular reception of the high-tech systems.

The financial features of Somerville's demographics create unfavorable environment for PV deployment, too. With an average household income of $78, 530, the city stands below the rest of the case studies. The unemployment rate (5.4%) is also the highest in this group. In combination, the two financial factors suggest a potential *barrier* to PV deployment.

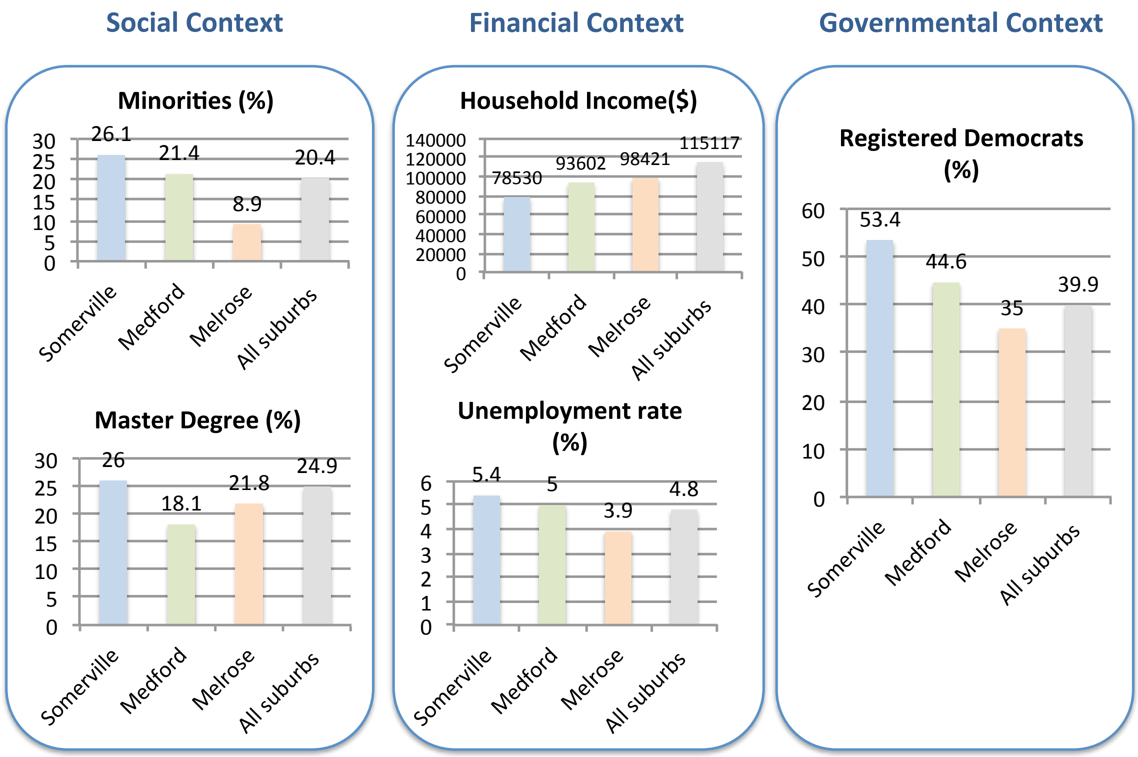


Figure 4: Statistical survey of Somerville's demographic context (first bar in blue). Values for the rest of the case studies as well as the average for all 31 towns are also provided (Boston, 2012; US Census Bureau, 2014).

The final characteristic is the political ideology of registered voters in Somerville. As shown in Figure 4, Somerville has the highest percentage of Democrats (53.4%). The liberal profile of the city creates a *favorable environment* for clean technology as well as the respective policies associated with it. The reason is that Republicans and Democrats have historically been polarized on a wide range of issues- including environmental legislation and green energy. While the majority of Democrats usually support progressive, green policies, Republicans have traditionally rejected their viability (Coley, 2012). A rather Democratic population, such as that in Somerville, is therefore an essential *opportunity* for solar PV's.

1.2. Local actors

There are three groups of stakeholders relevant to the city of Somerville: *social* (HEET, Somerville Climate Action, and MAPC), business (SunBug, GreenTown Labs, and NextStep Living), and governmental (Office of Sustainability and Environment and Commission on Energy Use and Climate Change) (See Figure 5). The following sections describe them in detail.

Figure 5: Key local actors in Somerville- identified social, business, and governmental actors relevant to Somerville's policies

1.2.1. Social Actors

~HEET- The Home Energy Efficiency Team (HEET) is a Cambridge-based, non-governmental organization, which develops projects in Cambridge, Somerville, and Boston. The mission of the organization is to educate local residents on practical means of reducing their monthly energy bills. The format of the projects takes various shapes: community outreach programs, campaigns, workshops, etc. Common themes throughout these initiatives are energy efficiency, renewable energy, and energy conservation. The organization therefore helps residents reduce the financial burden of their energy expenditures as well as facilitate their access to otherwise complex streams of information. Finally, in order to realize their projects, HEET has regularly partnered with local city halls (City of Somerville, City of Cambridge) as well as local businesses (such as NextStep Living) (HEET, 2014a; HEET, 2014b; Schulmann, 2014).

~Somerville Climate Action (SCA) is a local grass-roots organization, which promotes environmental sustainability and green lifestyle choices. Over the years, it has initiated campaigns advocating for renewable energy as well as public protests against fossil fuels. The overarching goal of SCA is to accelerate Massachusetts' divestment from coal and ultimately ensure the healthy wellbeing of its residents (Somerville Climate Action, 2014).

~Massachusetts Area Planning Council (MAPC)- The MAPC is a regional network that connects towns across the Commonwealth and provides them with administrative and technical resources. For example, its professional staff assists municipalities in designing sustainability ordinances, evaluating energy plans, or planning other endeavors related to environmental and energy conservation (MAPC, 2014a; MAPC, 2014b). Finally, member towns benefit from sharing their mutual resources, experience, and time. For example, MAPC organizes group PV-purchasing models for regional municipalities (Peterson, 2014).

~NGO's- Somerville is home to dozens of non-governmental organizations. Their work targets a variety of public sectors: education, agriculture, energy, etc. Some of the organizations are Eagle Eye Institute, Mass Farmers Market, and Green Streets Initiative (Somerville Solar, 2013a).

1.2.2. Business Actors

~**SunBug Solar** is a private company that provides a wide range of services in the field of solar energy. They cover many stages of the solar value chain: installation, education, maintenance, etc. Finally, the company serves private as well as residential customers (SunBug Solar, 2014). Over the years, SunBug has crafted a set of marketing tools, which have enabled its success. For example, their awareness campaigns have an educational rather than a merely commercial character. Their informative nature instructs the public on the environmental benefits of solar energy and its overall impact on socio-ecological systems. In effect, the company proposes more than merely a business deal (Mayer, 2014; SunBug Solar, 2014).

~GreenTown Labs is an incubator for clean-tech start-ups in Somerville. Founded in the summer of 2013, it hosts 24 companies and 92 employees. Some of the businesses focus on PV engineering and manufacturing; others provide sustainability consulting, financial and legal services (City of Somerville, 2013; GreenTown Labs, 2014). Collectively, they build a strong network of progressive, young businesses that drives forth innovation in the city of Somerville. While local residents benefit from GreenTown Lab's entrepreneurial services, member companies have the advantage of sharing common resources- such as prototyping spaces, electronics equipment, and support from regional sponsors. In effect, GreenTown Labs gives young entrepreneurs a solid foundation that helps them launch a successful, green-tech company (GreenTown Labs, 2014).

~NextStep Living- While SunBug focuses on solar energy alone, NextStep Living covers many energy types. For example, they provide weatherization, roofing, cooling, insulation, and PV-installation services. In effect, they help residents reduce their environmental footprint by optimizing virtually any aspect of their home energy system (NextStep Living, 2014).

1.2.3. Governmental Actors

~Office of Sustainability and Environment- The majority of the cities in the Greater Boston Area do not have a designated Department of Sustainability, Energy, or Environment. Instead, they have incorporated their environmental goals into the daily tasks of the rest of the offices (See Appendix E/ graph 1). The City of Somerville, on the other hand, has a well-established Office of Sustainability and Environment. Its goal is to plan and implement policies and programs that reduce energy needs and improve the overall sustainability in the city of Somerville. Some of its areas of expertise are recycling, green building, street lighting, and storm water management (City of Somerville, 2014a). Finally, its initiatives range from organizing community outreach campaigns to drafting a municipal Environmental Strategic Plan (Brandt et al, 2010; Mayor's Office of Sustainability and Environment, 2007).

~Commission on Energy Use and Climate Change- Members of the Office of Sustainability and Environment are city hall officials, employed by the municipality. Members of the Commission, on the other hand, are independent volunteers, appointed by the mayor to serve for a fixed period of time. They are professionals working full-time for private as well as public entities in the field of energy and sustainability in Somerville. Therefore, their commitment to the Commission is limited to monthly meetings and ongoing projects. Some of their past work includes energy efficiency projects, climate change initiatives, etc (City of Somerville, 2014b).

~Green Communities Green Communities (GC) is a governmental network of 123 communities in Massachusetts (out of a total of 351 towns) (DOER, 2014g). Membership and a Green Community status are granted on a competitive basis. In most cases, the local Department of Energy/Environment/ Sustainability (or committee in the absence of a department) applies on behalf of the entire community. In order to be accepted, the town needs to demonstrate sustainability leadership according to five criteria- green energy policies, energy plans, etc (Lusardi, 2014). In return, the town gains access to state funds, allocated for various environmental initiatives. In order to preserve its Green Community rank, a town needs to accomplish a number of goals in the future as well (Commonwealth of Massachusetts Executive Office of Energy and Environmental Affairs, 2013; DOER, 2014h). Therefore, GC serves as an incentive for the town to update its energy policies prior to its application- as well as maintain its green status post acceptance in the network, too.

~MassCEC (Massachusetts Clean Energy Center) MassCEC is a quasi-governmental organization that serves as a liaison between the Massachusetts Department of Energy Resources and civil society. Therefore, it provides both financial assistance and technical support for local towns. An example of financial assistance (in the field of solar energy) is Solarize Mass- a program co-produced by DOER, GC, the municipalities, and ENGO's (MassCEC, 2014b). The program spans about five months and offers a tired pricing structure for solar panels in a given town. Therefore, it is essentially a group-purchasing model where the cost of solar panels decreases proportionally to the number of residents who sign up for the program. In effect, it incentivizes citizens to join forces and encourage as many of their neighbors to sign up as possible (MassCEC, 2012a; MassCEC, 2012b).

2. Policy Input

While the *Policy Context* introduces the actors in the policy framework, the following section describes the specific solar policies, initiated by them (See Figure 6). The local policies in Somerville are divided into social networks (Solar Challenge), financial incentives (Green Community Grants and Community Block Grant Fund) and governmental ordinances (five GC policies).

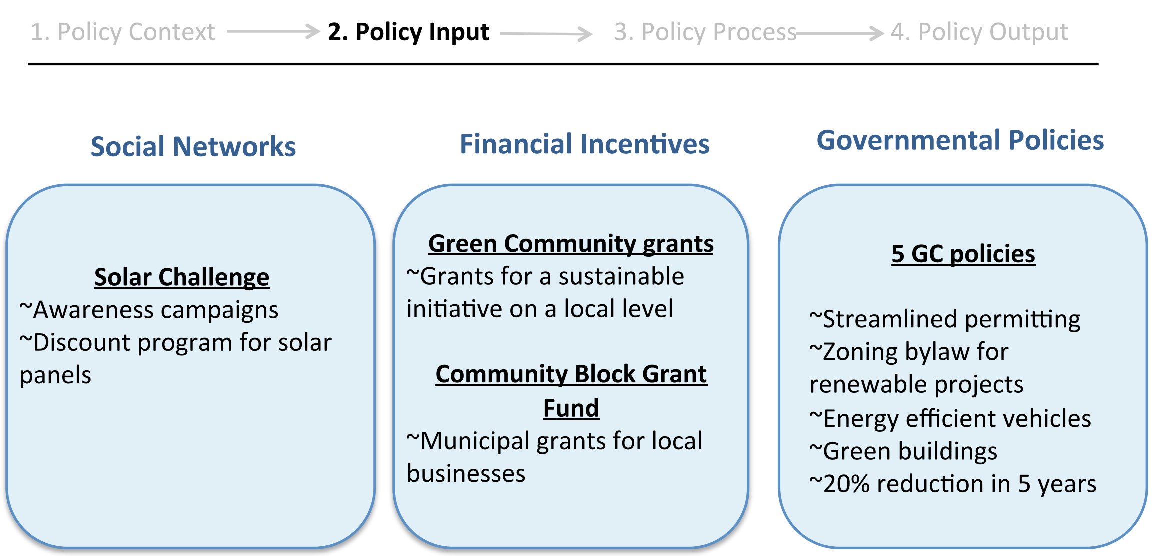


Figure 6: Policy input in Somerville- key social, financial, and governmental policies related to solar energy

2.1. Social Networks

2.1.1. Solar Challenge- The Solar Challenge is collaborative effort between public and private actors. Namely, together they plan a discount model for solar PV panels. Unlike Solarize Mass, however, the Solar Challenge is not funded and organized by MassCEC and the local city hall. Instead, it is a product of the cooperation between HEET, NextStep Living, Somerville Climate Action and local NGOs (MassCEC, 2012b; Somerville Solar, 2013b). Each of the participating actors contributes their respective resources to the program. HEET, Somerville Climate Action, and the NGOs help organize and publicize the Solar Challenge; NextStep Living, on the other hand, installs the solar systems later purchased. The second difference between Solarize Mass and the Somerville Solar Challenge stems from the financial structure of the collaborative model. Solarize Mass, on one hand, offers a tiered pricing agreement with its customers (the cost of the panels grows disproportionately to the number of residents who sign up for the program). Therefore, the final price is initially unknown as a resident joins the solar campaign. The Solar Challenge, on the other hand, offers a fixed discount of 20%. While the final price is originally disclosed, it cannot be reduced beyond this pre-determined threshold level (MassCEC, 2012b; Somerville Solar, 2013b).

The final stage of the program is signified by yet another interesting element of the program. $300 from each solar purchase is donated to one of the NGOs who have helped publicize the campaign. The donation serves to simultaneously (1) incentivize the non-profit to effectively advertise the program and (2) remunerate an organization, which might otherwise have limited budget and few funding sources (Somerville Solar, 2013b).

2.2. Financial Incentives

2.2.1. Green Communities Designation and Grant Program- The city had to fulfill five criteria in order to qualify for the designation: (1) Enact a renewable energy zoning bylaw; (2) Adopt an expedited permitting process; (3) Reduce municipal energy use by 20%; (4) Replace municipal vehicles with energy efficient automobiles; (5) Enact building regulation that minimizes energy expenditure at all new construction sites- residential, commercial, and industrial (DOER, 2013).

Somerville's application and acceptance to the state program was initiated by the local city hall. Unlike municipalities where energy efficiency efforts are not institutionalized, Somerville has a track record of environmental initiatives. Its past accomplishments were therefore recognized on a state level with its acceptance to GC (City of Somerville, 2011). On July 19, 2011, the city was granted a GC status and joined a select group of towns in Massachusetts. Indeed, only 123 of all 351 towns have distinguished themselves with green energy achievements. Somerville's first grant fund of $362,175 was invested in municipal solar energy installations, streetlight technology, electric vehicle charging stations, etc (DOER, 2014g). In the future, the city reserves its right to apply and receive for other municipal, energy upgrades.

2.2.2. Community Block Grant Fund- The Community Block Grant Fund is a state program initiated by the Department of Housing and Urban Development. It targets low- and mid-level income communities that seek to strengthen their economic development. While the average amount allocated is $741,000, it has been administered for a wide variety of purposes: social, housing, or economic (DHCD, 2014; HED, 2014).

In July 2013, Somerville received the Community Block Grant Fund in order to found GreenTown Labs. It was a deliberate strategy to attract new businesses and spur financial growth in the city. It is anticipated that the green-tech network would accrue approximately 140 new jobs to the local economy. At least 51% of them are allocated for low and mid-income families in Somerville (City of Somerville, 2013). In effect, the state grant accelerates innovation and stimulates community development.

2.3. Governmental policies

The City of Somerville has enacted the five GC policies described in 2.2.1.

3. Policy Process

What kind of interdependencies do policies from the *Input* stage create between actors from the *Policy Context*? How do policies themselves interrelate to create a municipal, governance network? Do they activate the local, demographical potentials? Do they target obstacles from the urban profile of the city?

These are only a few of the questions that the following section addresses. Its goal is therefore to analyze the demographics, actors, and policies in Somerville as a holistic system of interrelated components, which collectively aim the acceleration of PV deployment. While the previous sections describe these three policy elements individually, the following analysis brings them together in order to unveil the internal dynamics of the system they cumulatively compose. It depicts them as active– rather than static- elements that are subject to the synergetic effect of the policy system as a whole.

The progressional development of the system is illustrated in Figure 7 on a stage-by-stage basis. Concepts from the Theoretical Framework are highlighted in *italics*.

3.1. Stage 1: Green Communities (GC) Grant Fund

The GC is a key determinant of local solar deployment and affects consequent initiatives as well. It is important for Somerville's future because it acts as an external *impetus* that incentivizes the local government to enact five environmental policies. Therefore, it favorably supplements the city's prior sustainability efforts and energy

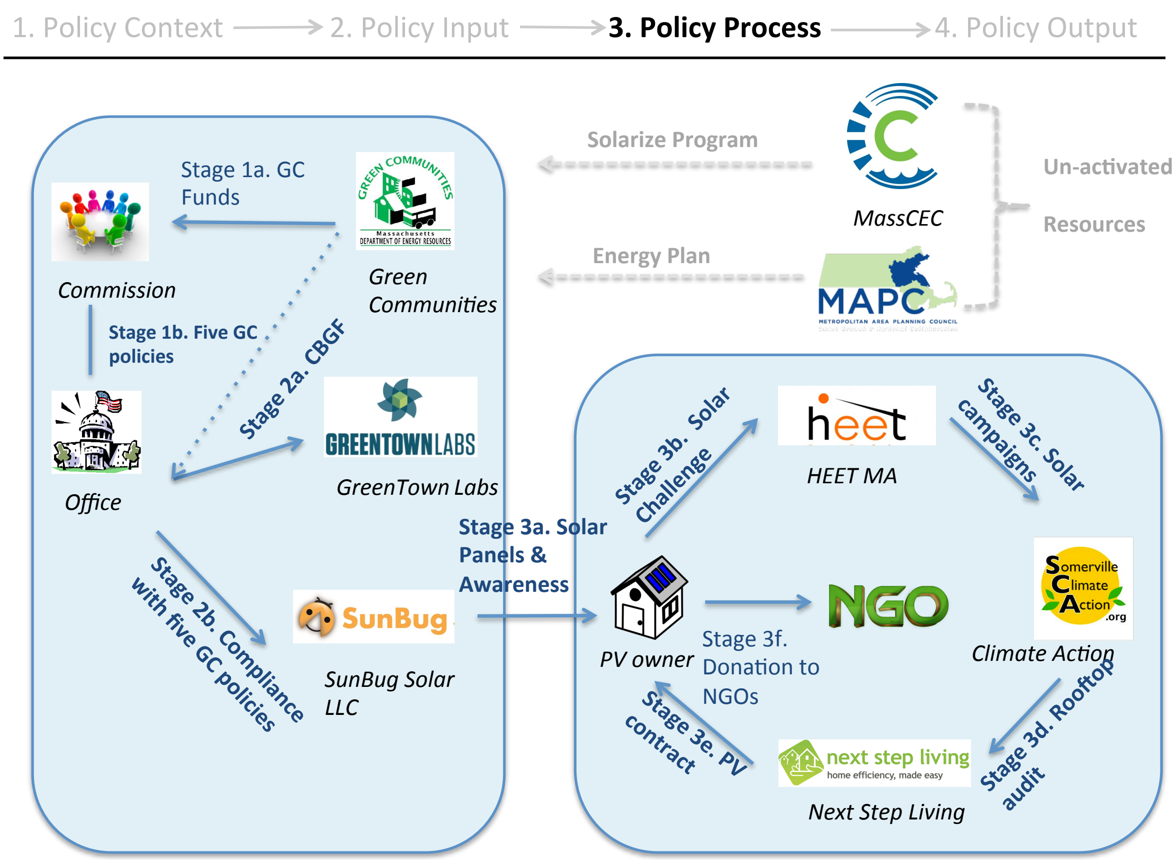


Figure 7: Visualization of the Policy Process in Somerville: the diagram is constructed based on data collected for stakeholders (Policy Context) and policies (Policy Input)

efficiency strategies. The state fund therefore acts as a key that *unlocks* the potential capability and legislative power of the municipality. The ability of the state government to *mobilize* local governmental *resources* is important for another reason, too. Namely, it commits the city to sustainable energy development and sets energy goals for the future, too. Any future endeavors are therefore rooted in its former experience with these five GC policy actions.

In its totality, the GC policies establish a network of *co-dependent* actors who mutually share *resources*. The state government grants a fund worth $362,175, which would otherwise be unavailable to city officials (DOER, 2014g). While it contributes *financial resources* to the network, the grant itself incentivizes the Somerville Office of Sustainability and Environment to enact five policies. In return, the department contributes its own, authoritative *power* and *resources* to the table as well. Lastly, the policy chain is completed as business actors utilize the policy benefits and execute the final action. Namely, they work in an environment that predisposes (rather than impedes) renewable energy projects.

Despite the beneficial impact of GC, it does create a rather *vertical interdependency* between the state and local government. Namely, the suburb is restricted to the programs and funds available at DOER. Therefore, Somerville will not be able to initiate projects that do not meet state requirements (unless local funds are available).

3.2. Stage 2: Community Block Grant Fund (CBGF)

The structure and functionality of CBGF bares close resemblance to the prior phase. Firstly, it is provided by the Massachusetts government; then, it is acquired by the Somerville municipality; and finally- it is utilized by GreenTown Labs (City of Somerville, 2013; DHDC, 2014; HED, 2014). The underlying principle behind this *interdependency* is reminiscent of stage 1. Furthermore, it (1) successfully adapts to the local context; (2) it counteracts the unfavorable effects of state polices; (3) it has a sustainable effect on the local, solar energy market.

(1) One of the challenges observed at the *Policy Context* level is the high unemployment rate (5.4%) and the below-average household income ($78, 530). Some of the opportunities, on the other hand, are the high percentage of Democrats (53.4%) and the high percentage of university graduates (26%) (US Census Bureau, 2014). The CBGF effectively targets all four of these factors. First of all, it facilitates GreenTown Lab's foundation in Somerville, which indirectly helps create over 92 local jobs (therefore decreasing the unemployment rate) (City of Somerville, 2013). Second of all, it ensures high-paying jobs in the green tech industry, which addresses the second challenge- low-

income levels. Finally, it *activates the social capital* in Somerville- a well-educated and liberal public. Indeed, a progressive network, such as GreenTown Labs, is true to the ideals of the left-wing party as well as the standards of an intellectual community. Therefore, it is perfectly suited for its local audience. Reminiscent of innovation hubs, such as the Silicon Valley in California, it could have hardly sprouted from a conservative environment (Coley, 2012).

(2) One of the unintended effects of state policies is their *inconsistency*. As described in previous chapters, their *unpredictable* support for the solar industry creates an *uncertain* policy environment. The CBGF policy, however, offsets this unfavorable outcome by stimulating local economy. It therefore bears fruits in the *present* as well as the *future*. Namely- it jump-starts a clean-tech network of companies, whose success feeds on its success and spurs growth in the upcoming years, too. In effect, the CBGF policy achieves *sustainable* solar development and inspires innovation in the city of Somerville.

While CBGF helps found the clean-tech network, the GC policy guarantees a favorable environment for its future development. Indeed, the five GC ordinances ensure sound zoning and building bylaws for green projects. It is interesting to note how CBGF in turn facilitates the subsequent, Stage 3 of the policy process: the Somerville Solar Challenge. First of all, the clean-tech network and SunBug's educative campaigns create a strong solar presence in the city. It is rare for a small suburban town to have 24 clean-tech companies on its territory. With predominantly local employees (as mandated by the policy), it fosters popular acceptance and improves public awareness of renewable energy. As discussed in the following section, the Solar Challenge relied namely on these social factors.

3.3. Stage 3: Somerville Solar Challenge

The Somerville Solar Challenge resembles Solarize Medford in the basic format of its program. It brings together actors from different public and private sectors who *collaboratively* campaign for five months in a single city. Unlike Solarize Mass, however, the Somerville Solar Challenge activates *local* rather than *regional* resources. Indeed, rather than organized by MassCEC and the state DOER, it is initiated by a local

NGO, publicized by local non-profit organizations. The local character of the program limits Somerville's *access* to the substantial resources of MassCEC and DOER. On the other hand, however, it ensures that the local *social capital* is *activated* and fully utilized, too. Namely, its capital is a well-educated and environmentally-conscious community. Indeed, Somerville is rich in green organizations, which play an important role throughout the campaign.

As described in Chapter 4, state policies tilt the playing field in favor of larger corporations and high-income families. It was therefore noted that it is the responsibility of the municipal policy to counteract this unfavorable effect by ensuring local financing options. Indeed, the Somerville Solar Challenge offers a 20% discount and hence strengthens their *position* and encourages their *participation* in the PV market. Therefore, it addresses another *contextual* factor- namely, the low household income.

Phases 3b and 3c of the Somerville framework illustrate the *collaboration* of two local organizations in their effort to *mobilize* the *social capital* of their city. The following two stages, however, do not address the challenges described in the *Policy Context* of the framework: low percentage of home ownership and low percent of detached housing units. These factors, however, are crucial to the successful outcome of the Solar Challenge. Even if people are environmentally conscious and well educated, they cannot purchase a solar panel unless their roof is suitable and their income is high enough. Those who rent a house or an apartment in a high-rise building, on the other hand, are also unable to take advantage of the PPAs (APA, 2013; NARC; US DOE, 2011).

The significance of the above-mentioned *inequity*, however, is undermined if only perceived as unrealized future *benefits*. In reality, it could be measured in terms of unequal distribution of *benefits* as well as unequal distribution of *costs*. Costs in this case are defined as high CO_2 levels, air pollution, urban heat island effect, etc. (Sub)urban towns are impacted by climate change more heavily than rural ones; therefore, they should be able to ensure healthier environmental conditions to their residents. Furthermore, (sub)urban towns contribute to the problem more than rural ones (residents commute larger distances and own larger houses). Their *position* on the solar market should therefore be strengthened by local programs. Unfortunately, the infrastructural and financial character of suburban towns (low percent of home ownership and low income) precludes their ability to engage in the solar market. If policies do not counter-balance this *inequality*, suburban towns would be *unjustly excluded* from the *benefits* of the program as well as *unjustly* subjugated to its *costs*.

4. Policy Output

Policies from the *Input* stage of the framework establish socio-political interdependencies between actors from the *Context*. These interdependencies as well as their transformations over time were analyzed in the *Policy Process* section of this thesis. The result of these policy processes is presented in the following section, *Policy Output* (See Figure 8). It aims to answer the following questions: (1) Does the *policy output* achieve the objective of the solar energy policy? (2) If yes- what *opportunities* enabled its success? (3) If not, what *obstacles* deterred its development?

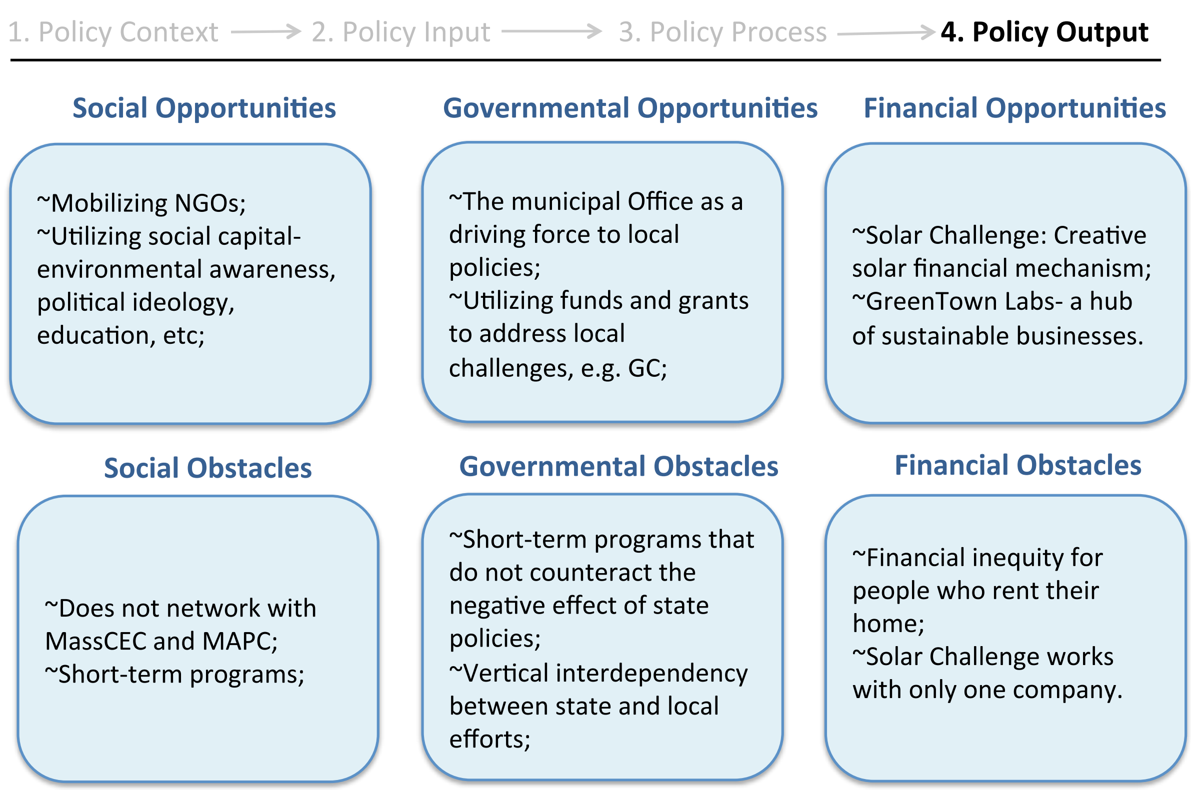


Figure 8: Summary of obstacles and opportunities in Somerville

4.1. Social Output

The *social goal* of solar policies is to increase *awareness* and improve public *reception* of solar photovoltaic panels. With a strong public presence, solar energy then gains attention and draws stakeholders into networks of collaborating partners. It acts as a *mobilizing* agent that activates the social capital of the city and builds strong partnerships. These partnerships would later serve as the vehicle that executes concrete solar energy actions (APA, 2013; NARC; US DOE, 2011).

4.1.1. Opportunity: Mobilizing the social potential of the city via the Solar Challenge and other campaigns

The Somerville solar policy framework achieves these *goals* to a certain degree. SunBug Solar, for example, pursues an active marketing campaign, which popularizes solar energy. It educates the public on the social and environmental benefits of renewables (Mayer, 2014). The Somerville Solar Challenge, too, results in a campaign, which raises awareness about solar energy (Somerville Solar, 2013). Unlike SunBug's ongoing efforts in this direction, however, the Solar Challenge has a short-term impact on the suburban town.

The factor that *enables* the realization of these two campaigns is the high social potential of the city. Indeed, Somerville prides in a *well-educated and liberal* community (See statistics in *Policy Context*). The company then employs an educative, marketing strategy that resonates with the high intellectual capital of the population. In return, residents then perceive of the product being advertised as a social good rather than as a business tactic. The instructing character of the campaign also leaves a deeper imprint on public life than standard business approaches do.

The Solar Challenge *activates the social potential* of the city in a similar manner. Namely, it *mobilizes* a large number of local NGOs in their community outreach program. As they join forces, they are better capable of tacking the problem, too. The last stage of the framework re-affirms this effect with an interesting finale: a percentage of each PV purchase is donated to a local non-profit organization. Therefore, it *strengthens* the *position* of a local organization in the social network in Somerville. The donation closes the loop of a chain of policy processes, which consequently consolidates the local *partnership* between HEET, the Somerville Climate Action, NextStep Living and the local NGOs. The key *enabling factor* is therefore the ability of stakeholders to raise *awareness* in a manner that echoes the demographic and institutional composition of a town.

4.1.2. Obstacle: Inability to tap onto regional resources

The primary *obstacles* that constrain the *social* impact of the policy are (1) their inability to utilize regional resources and (2) organize a program with a *long-term, social impact* on the local population. The former speaks to the fact that Somerville organizes its solar campaign unilaterally, rather than via MassCEC. Unable to tap onto the substantial resources of the regional player, Somerville's campaign is restricted to its own *power* and *capital*. Finally, the *social* impact of Somerville's policies is limited on a *temporal* scale, too. Indeed, the Solar Challenge only lasts a few months. Therefore, the effect of its educational campaigns is restricted by the tight schedule of the program.

4.2. Governmental Output

4.2.1. Opportunity: a Department that seizes regional/state opportunities

The *political/legal goal* of solar energy policy is two-fold. First of all, it aims to institutionalize solar energy objectives into the local governance framework. Departments, committees or permanent staff members in a given city hall are an indicator of a successful achievement of this goal. Second of all, a solar-friendly environment requires *stable* municipal ordinances that address the challenges in a particular town. These ordinances need to *effectively* pursue solar energy objectives and ensure higher PV deployment rates (Ross, 2013; US DOE, 2011).

The town of Somerville is among the few towns, which has an Environmental Office and dedicated staff. It accelerates local sustainability efforts as it enacts five GC policies. They set clear preferences for renewable energy projects (over fossil fuels) and hence- they give *impetus* to the green sector as a whole. The factor that *enables* this outcome is Somerville's membership in the Green Communities network. Unlike the rest of the state-wide or regional programs, GC ensures *long-term* support to local communities.

4.2.2. Obstacle: Short-term policies

One of the major challenges on a state level is the lack of *long-term* legislature that has a sustainable impact upon the PV market. The Somerville Solar Challenge, however, offers only a five-month-long financial incentive. Despite its generous discount of 20%, it therefore does not counter-act the effects of the state policies. Over time, however, multiple cities have organized similar programs. Cumulatively, they create an *inconsistent and unpredictable* PV market. Therefore, the state-level challenge is reinforced on a local level.

The final obstacle is reliance on state funds. DOER grants undoubtedly expand the potential of a small town to pursue energy initiatives. While regional institutions contribute to a *decentralized* network, dependence on governmental subsidy, however, creates a *vertical interdependency* between local and state governments. Therefore, a balance between local, regional, and state projects should be sought instead.

4.3. Economical Output

4.3.1. Opportunity: Creative financial model that drives down the cost of PV's

Considering the high upfront cost of solar panels is the main challenge facing the sector today, the policy framework has several *economical goals*. First of all, it needs to ensure *financial equity* on a local level: PV systems have to be *affordable* for all residents of the town. Second of all, it needs to establish a financial mechanism that is *sustainable* in the long term. Only when the policy steadily boosts the economic growth of the sector, would it be able to achieve the third goal, too. Namely, it should incentivize the solar industry in a way that gives it a competitive advantage to fossil fuels at the global energy market (APA, 2013; NARC; US DOE, 2011).

The solar policy achieves the first goal partially. The Solar Challenge offers a discount, which allows citizens to purchase a system that is otherwise unaffordable for them. Figure 9 shows the steep increase in deployment; it also illustrates the contrast between solar capacity before policy input (graph in blue) and after policy output (graph in red). The factor, which *enables* the success of the program is the partnership between

HEET and NextStep Living. Both parties design a model, which builds on the technical *capacity* of the NGO and the business *expertise* of the energy company.

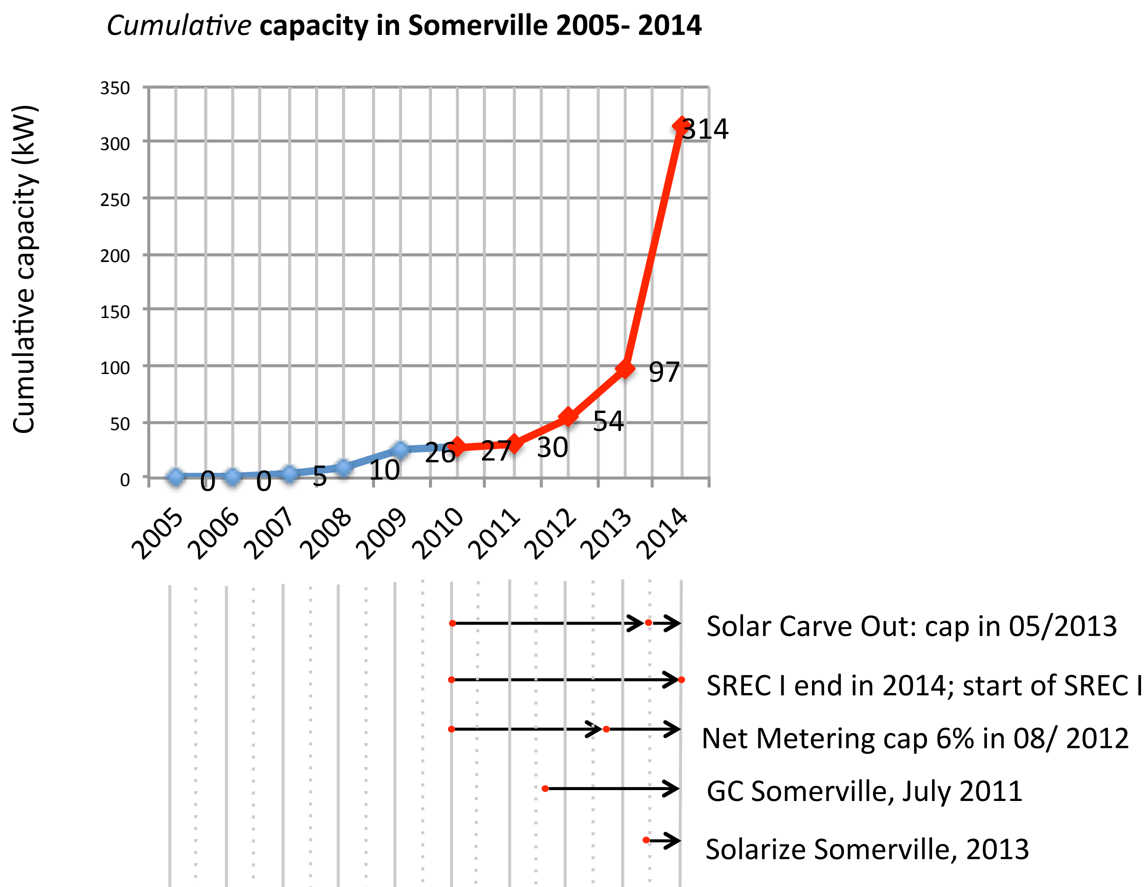


Figure 9: Policy timeline and deployment timeline in Somerville (graphs are constructed based on data from: DOER, 2014a; DOER, 2014d; DOER, 2014g; DOER, 2014i; NREL, 2014; SREC Trade 2012; Somerville Solar, 2013)

The innovative business network GreenTown Labs accomplishes the second goal of the solar framework. It brings together 24 clean-tech businesses, which *collaboratively* accelerate the solar industry in Somerville. The factors that *enabled* their success are the state grant, the environmentally conscious municipality, as well as the pre-existing progressive businesses in the area. Although the state grant only gives the initial *impetus* to the network, it jump-starts a green energy hub, which will benefit Somerville in the future as well.

4.3.2. Obstacle: Financial inequity for certain groups of citizens and companies

In order that solar deployment in Somerville gains *momentum*, policies should create *equal opportunity* to all participants. The reason is that *economical sustainability* in the long-term requires that all actors and resources are *mobilized*. However, the policy marginalizes solar companies, which do not participate in the Solar Challenge (only one company participates) (Somerville Solar, 2013b). Not only does this choice restrict competition, it also creates bias towards the same company in future campaigns (as well as upon individual purchases as customers prefer an already established business company). If the design of the model is changed (and mode companies participate), however, citizens would not be able to make an informed decision and choose an installer themselves. The program therefore poses a paradox. The only way to *accelerate* the market *today* is by *decelerating* its *future* development.

The financial *inequity* regards companies as well as citizens. Currently, most of the residents are unable to participate in the market by virtue of being residents of Somerville (lower percent of detached unites and percent of home ownership). The current financing model therefore favors residents in suburban rather than urban environments. As solar panels gain popularity in those areas, the adoption rate would become steeper. The deployment rate in urban towns, on the other hand, would either remain the same or even out. The reason is that most of the individuals interested in solar energy have an inappropriate roof and lower income.

Although the apparent *inequity* would exacerbate over time, it is a necessary evil. The preferential character of the policy is *unjust*, however, it ultimately results in a high deployment rate and it accelerates the solar economy (as wealthier citizens purchase the panels). Considering the issue on a larger scale, too, the policy would have positive environmental impact that benefits society as whole. Urban residents are therefore positioned in a situation where they have no choice but to compromise their welfare to the benefit of neighboring suburbs.

Chapter 7: City of Medford

1. Policy Context

1.1. Urban and demographic context

A solar-friendly town has the following urban features: low density, high percentage of homeowners, and high percentage of detached units. Unfortunately, Medford's social composition contrasts these criteria (See Figure 1). In comparison to the other two case studies (Somerville and Melrose), it has the second lowest percentage of detached housing units (35.1%). Therefore, very few of the buildings are actually

1. Policy Context → 2. Policy Input → 3. Policy Process → 4. Policy Output

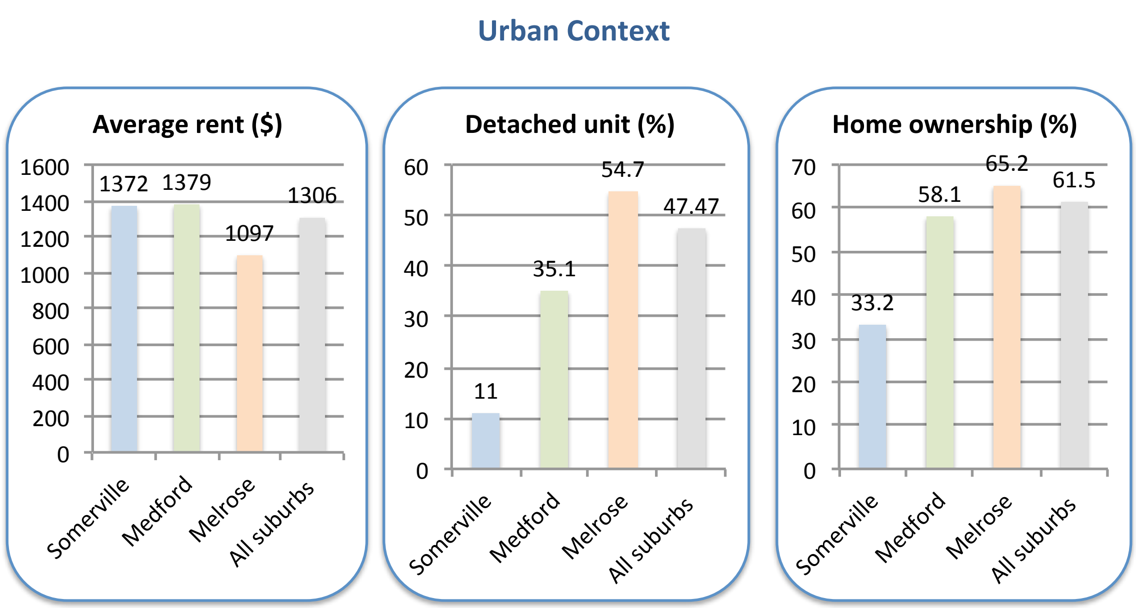


Figure 1 Medford's urban context (second bar in green) in comparison to the other case studies as well as all 31 suburbs (US Census Bureau, 2014)

appropriate for solar panels. Even if a building is suitable though, it is essential that its residents own, rather than rent it. Unfortunately, only 58.1% of the population in Medford owns its home- again, the second lowest percentage of homeowners among the three case studies. Finally, the average rent in Medford is $1,379 per year- comparable to the rest of the suburbs (US Census Bureau, 2014).

Medford's demographic context is summarized in Figure 2. Once again, Medford takes the second position among its peer towns. Namely, 21.4% of the population are racial minorities; the average income is $93,692, the unemployment rate is 5%, and finally- the 44.6% of the population are Democrats. The statistics show that Melrose contrasts Somerville; Medford's context, on the other hand, is intermediate and similar to the average of all 31 suburbs (grey bar in Figure 2). It is therefore expected that observations made in Medford- as well as conclusions later drawn- will be representative of the larger pool of towns (US Census Bureau, 2014).

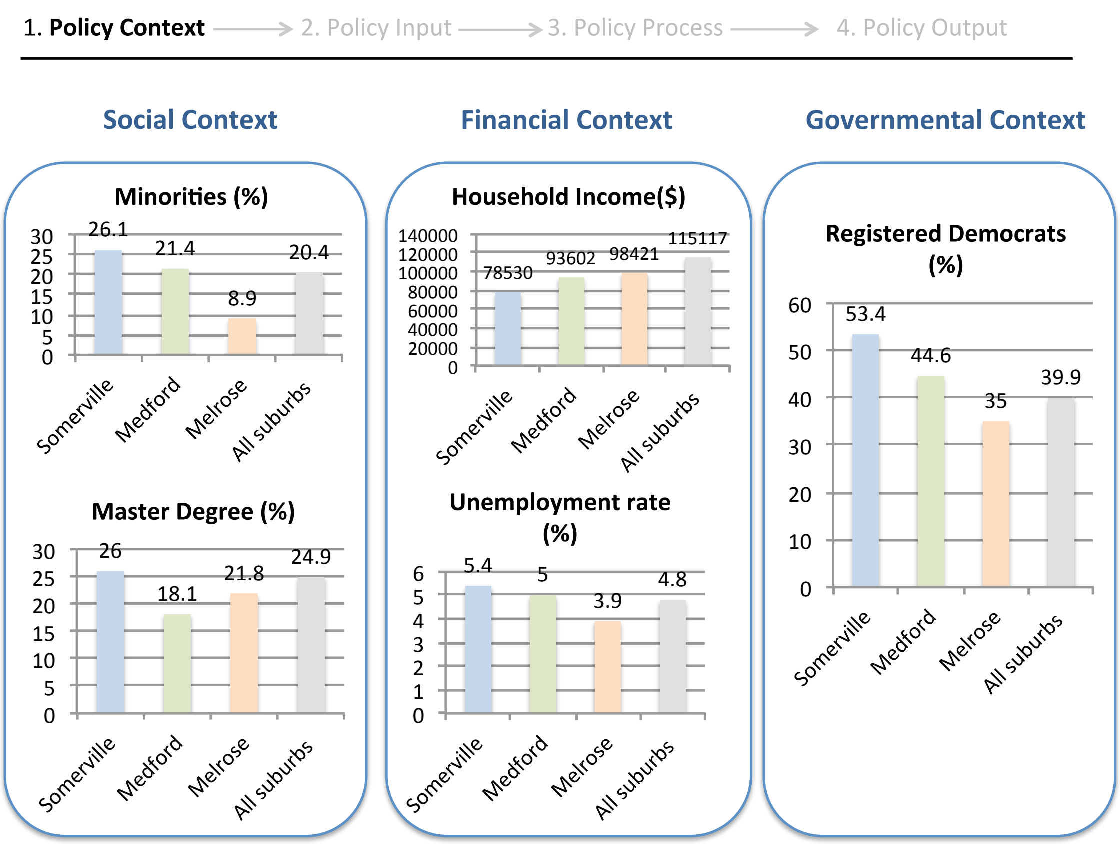


Figure 2: Medford's demographic context (second bar in green) in comparison to the other case studies as well as all 31 suburbs (US Census Bureau, 2014).

Medford's second position in the above-mentioned statistics is interesting with respect to its geographical position among its peer towns. Namely, they form an almost uniform line that extends from Somerville in the south, through Medford and Melrose in the north. Figure 3 shows this alignment and Medford's second position in the middle. It could hence be assumed that geographical location is correlated with the urban/contextual factors here described. These factors, however, determine whether a household can install a PV panel or not. The subsequent sections will therefore show whether geographical location is also correlated with PV adoption rates.

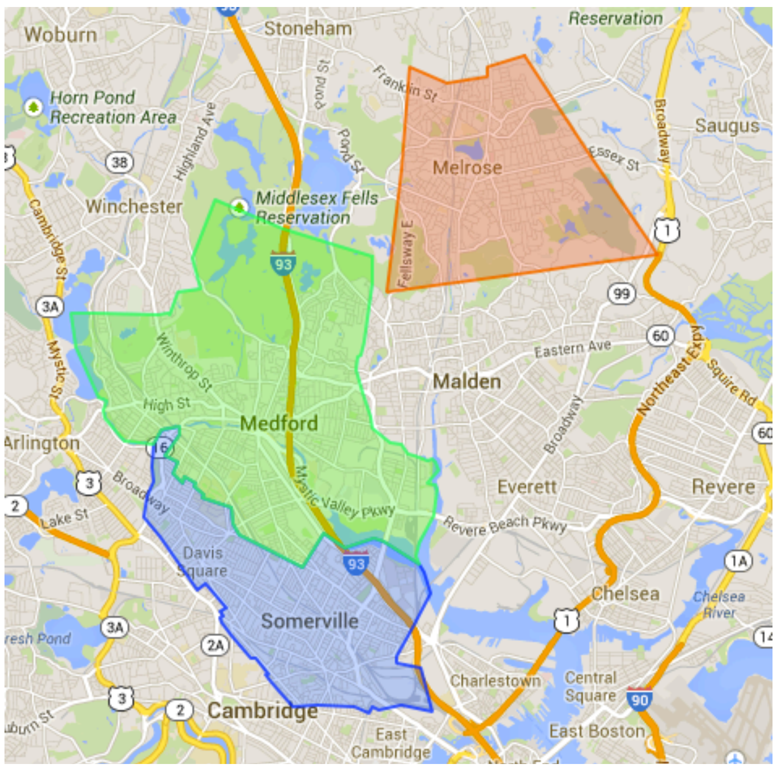


Figure 3: Medford is located between Somerville and Melrose (Image rendered in Zeemaps; Google Maps, 2014).

As the statistics above demonstrate, each town has unique demographic and infrastructural fabric. Therefore, each one calls for a specific set of policies that take into account the *challenges* and *opportunities* that its composition presents. Unfortunately, the building stock and social *context* in Medford present a *barrier* rather than an *opportunity*. Therefore, it is expected that the town hall addresses these difficulties with a relevant policy. Namely, such that facilitates the adoption of PV's for families who are currently denied access due to their income level or due to their housing occupancy arrangement. The *Policy Input* section, however, will show whether and how the City of Medford has addressed these barriers in its solar energy portfolio.

1.2. Local actors

Local actors are universities, solar energy companies, environmental organizations, and regional associations, which could influence the adoption rate of solar systems. Therefore, they are a dormant potential, which could be activated during the *Policy Input* stage. Failure to do so, on the other hand, indicates areas for improvement, which could be indicated later in the Recommendations section. Nevertheless, failure to utilize these resources could also be an indicator of additional obstacles on a higher level.

In the case of Medford, there are several institutions, which should be considered: MAPC, SunBug, Energy and Environmental Office, Clean Energy Committee, Green Communities, MassCEC (see Figure 4).

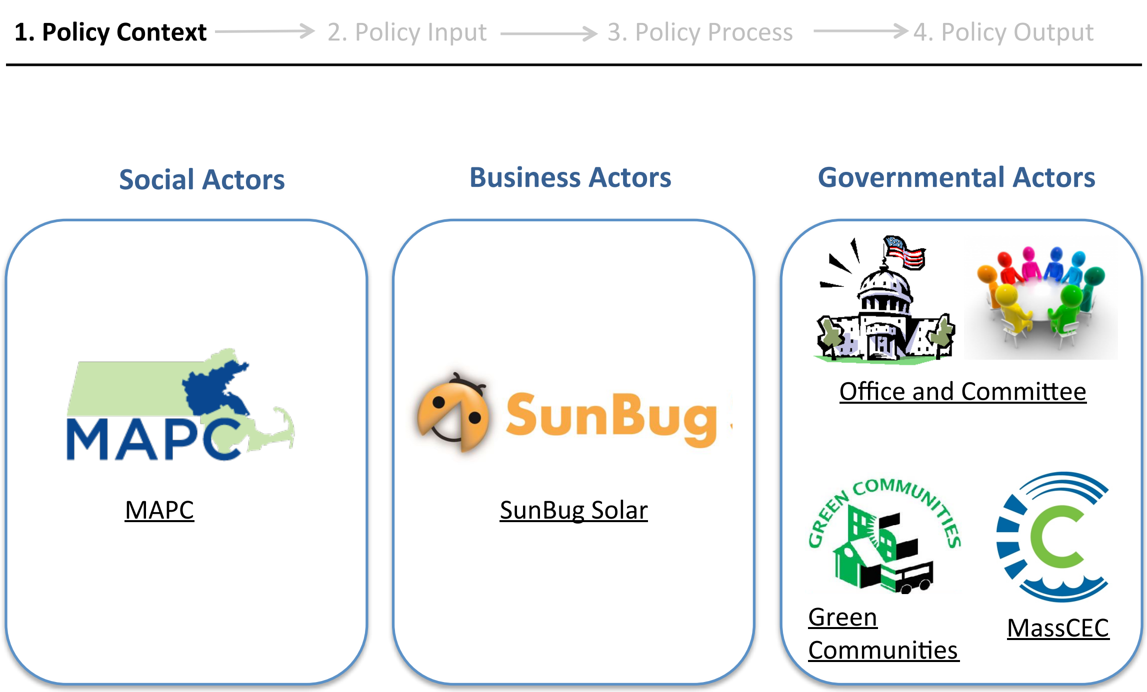


Figure 4: Stakeholders in Melrose: key social, business, and governmental actors relevant to the field of solar energy

1.2.1. Social Actors

~ MAPC: already described in Chapter 6: City of Somerville

1.2.2.Business Actors

~SunBug Solar: already described in Chapter 6: City of Somerville

1.2.3. Governmental Actors

~Medford Energy and Environment Office (E&E): Although not exclusively dedicated to solar energy per se, office staff works on a wide range of sustainability issues- environmental preservation, energy efficiency, renewables, recycling, etc. Some of its initiatives are the Climate Action Plan, Harvest Your Energy Festival, Medford Green Awards, etc (City of Medford, 2014). Furthermore, Medford is one of a few of the suburban towns, which has a department of sustainability/ energy. Therefore, by virtue of having both an office and a committee, it exemplifies environmental leadership and progressive thinking.

~Medford Clean Energy Committee (MCEC)- Like committees in all municipalities, MCEC is made up of local residents appointed by the Mayor to serve the Committee. These are professionals working in governmental, private, or educational institutions who volunteer their time. In their meetings, they discuss projects and plan future energy-related initiatives (Energy Commission, 2010). The advantage to having a committee is that it can independently initiate projects, which might otherwise be low on the municipal agenda. Considering its members are working professionals, they can contribute valuable first-had knowledge and experience regarding energy matters (Medford Energy, 2014; Paine, 2014). On the other hand, however, they are unpaid volunteers who are busy with their primary occupations. Therefore, their time and contribution to the municipality is limited.

~MassCEC: already described in Chapter 6: City of Somerville

~Green Communities: already described in Chapter 6: City of Somerville

2. Policy Input

The *Policy Input* comprises a set of solar energy initiatives, which differs greatly across towns (See Figure 5). Therefore, they are the direct result of the *contextual resources* available in a particular town: demographics, housing stock, and local actors.

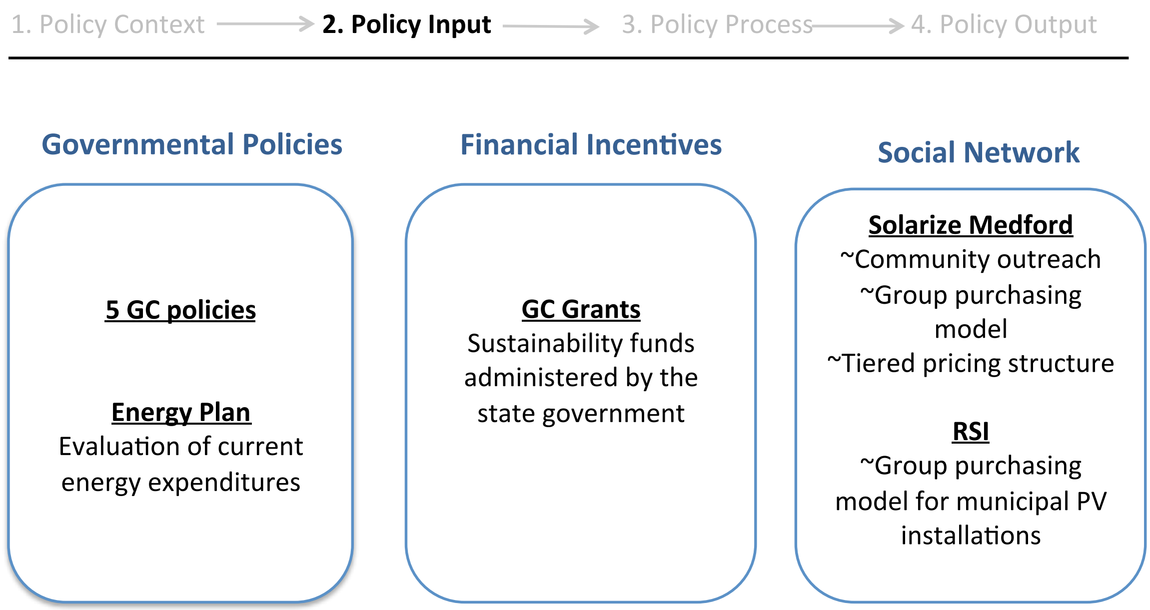


Figure 5: Policy input in Medford: key governmental, financial, and social initiatives relevant to solar energy

2.1. Governmental policies and financial incentives

2.1.1. Green Communities: In May 2010 the City of Medford became a member of the Green Communities of Massachusetts. In order to gain access to the network, the city had to fulfill five requirements: (1 and 2) Enact permitting and zoning bylaws that facilitate the installment of renewable energy projects; (3) Design a plan that reduces 20% of the municipal energy consumption; (4) Purchase only municipal vehicles that are energy efficient; (5) Implement energy efficiency ordinance for all new residential and commercial constructions in Medford (Commonwealth of Massachusetts Executive Office of Energy and Environmental Affairs, 2013).

Participation in this regional network therefore benefits Medford in two ways. First of all, the municipality is required to enact the above-mentioned initiatives prior to its acceptance. Upon admission to the network, on the other hand, the city gains access to a substantial fund (Commonwealth of Massachusetts Executive Office of Energy and Environmental Affairs, 2013). In the past years, Medford has received $271,651 for municipal energy efficiency projects (upgrading the school energy system, updating the Climate Action Plan, etc). They have also received $250,000 for the energy retrofit of the Chevailer Theater (DOER, 2014g).

2.2.2. Regional Solar Initiative (RSI). The overall design of the program is analogous to Solarize Mass: rather than mobilizing residents on a local level, however, RSI mobilizes municipal officials on a state level (MAPC, 2014b). The goal of the program is to bring regional municipalities together and hence increase the buying power of their cumulative solar purchase. So far RSI has partnered with 17 cities in Massachusetts, including Melrose (MAPC, 2013a; Peterson, 2014). Once participating cities have joined forces, the next step of the program is selecting a vendor- in this case Broadway Electrical. Much like residents throughout Solarize, cities then sign a PPA agreement with the company. Namely, the electricity provider installs solar panels on local city halls, which later lease out their roofs to the company. As Broadway Electrical becomes the owner of the solar panels, they sign a 20-year long contract with the municipality. Finally, the municipality agrees to purchase green power from the private developer for the entire duration of the contract (MAPC, 2013a).

~Energy Plan: The MAPC assisted Medford in designing the Local Energy Plan, too (Paine, 2014). The plan is an inventory of current energy consumption by sector. Therefore it identifies specific areas, which might require close attention and stricter energy regulation. Finally, it concludes with a set of strategic action steps that guide the municipality in improving those target areas (MAPC, 2013b). Therefore, it incentivizes the municipality to raise more initiatives on the agenda when an opportunity arises- such as Solarize Mass.

2.2. Social networks

2.2.1. Solarize Mass- Already a member of the Green Communities, Medford was qualified candidate for Solarize Mass. Solarize is a relatively young program and its pilot project was landed in 2011 (MassCEC, 2012b). At the time of its application, Medford was already a Green Community and had a Committee and an Office. Therefore, it had a stable foundation that facilitated the process.

The program itself lasted approximately five months and ended on October 31, 2013. It was organized and implemented by MassCEC, the Medford government (Office and Committee), and a group of local volunteers (Go Green Medford, 2013). During this time period all participants worked together to advertise and publicize the solar campaign. Indeed, the program takes the shape of a citywide campaign that aims to attract as many residents as possible (Paine, 2014). As their number increases, the price of the solar panels decreases proportionally. Therefore, the goal of the program developers is to design an attractive marketing and community outreach program that communicates to as many households as possible (Irvine, 2012).

Each participant had a key role. First of all, MassCEC developed the Solarize program model, which municipalities later simply had to adopt (MassCEC, 2012b). The ready-made model was an important factor that incentivized Medford's participation in the program. Considering the amount of time, resources, and financial capital required to design and later implement an energy program, it was only to Medford's benefit that Solarize Mass was already created and tested across other towns (Hunt, 2014).

The city hall was the second key stakeholder throughout the campaign. Its role was to coordinate the program and assist the volunteers with its staff and resources. For example, it helped citizens choose a vendor- a single solar energy company, which would later install the panels purchased during Solarize Mass. This step was crucial because it simultaneously tackles two main *challenges*. First of all, it eliminates the need for a customer to choose a vendor on his own or hire a consultancy company throughout the installation process (Youngblood, 2014). Indeed, most residents are often discouraged to buy a PV panel because of the complexity of the process itself. With a myriad of solar installers to choose from- and a myriad of federal, state, and local laws to comply with- it would be difficult for a non-specialist to make the right decision. Solarize therefore facilitated the process logistically.

Finally, it also *legitimized* the process and encouraged many residents to participate. Indeed, many of them would have been discouraged had they received the offer form a private body. Instead, they saw the campaign as an initiative of their own

City as well as their own neighbors (the volunteers who carried out the awareness campaigns) (Hunt, 2014).

The final piece of the Solarize puzzle are the program organizers and volunteers (MassCEC, 2012a). These are local residents who volunteered their time to popularize and organize the program locally. Once a resident expressed interest, he was sent forth to the solar company, which completed the process on his/her behalf. Throughout the five-month campaign, the contractor signed 48 deals, which accumulated to 387.6 MW of solar energy- almost twice as much as it previously had (Go Green Medford, 2013; MassCEC, 2014b).

3. Policy Process

3.1. Stage 1: Department and committee

The Massachusetts and Somerville solar policy frameworks transform traditional energy governance from a *vertical* to a predominantly *horizontal, collaborative* model. A similar trend takes place in the city of Medford as well (See Figure 6). Undeniably, the Office has initiated many projects beneficial to society and the environment (e.g. home energy assessment programs; wind power projects, etc) (City of Medford, 2014). Nevertheless, it is difficult for small departments to proceed unilaterally with any larger-scale, expensive projects. Hence, the Committee and the Office have engaged in a series of regional networks- such as Green Communities, MAPC, and MassCEC (Hunt, 2014). The two governmental bodies therefore serve as an essential *impetus* to all future solar energy projects/ policies. Their role is to *mobilize* regional resources in order to build the socio-political *capacity* of the local government. As the regional organizations gain *access* to the decision-making process, they contribute to a *collaborative and networked* governance.

3.2. Stages 2 and 3: Green Communities; Energy plan & RSI via MAPC

The *Policy Process* therefore strengthens the *position* of stakeholders who are external to the municipality- namely, citizens and ENGOs. Similarly to the state policy framework, a *collaborative* model of this kind has several advantages. First of all, it allows cities to communicate ideas, and share resources and experiences. For example,

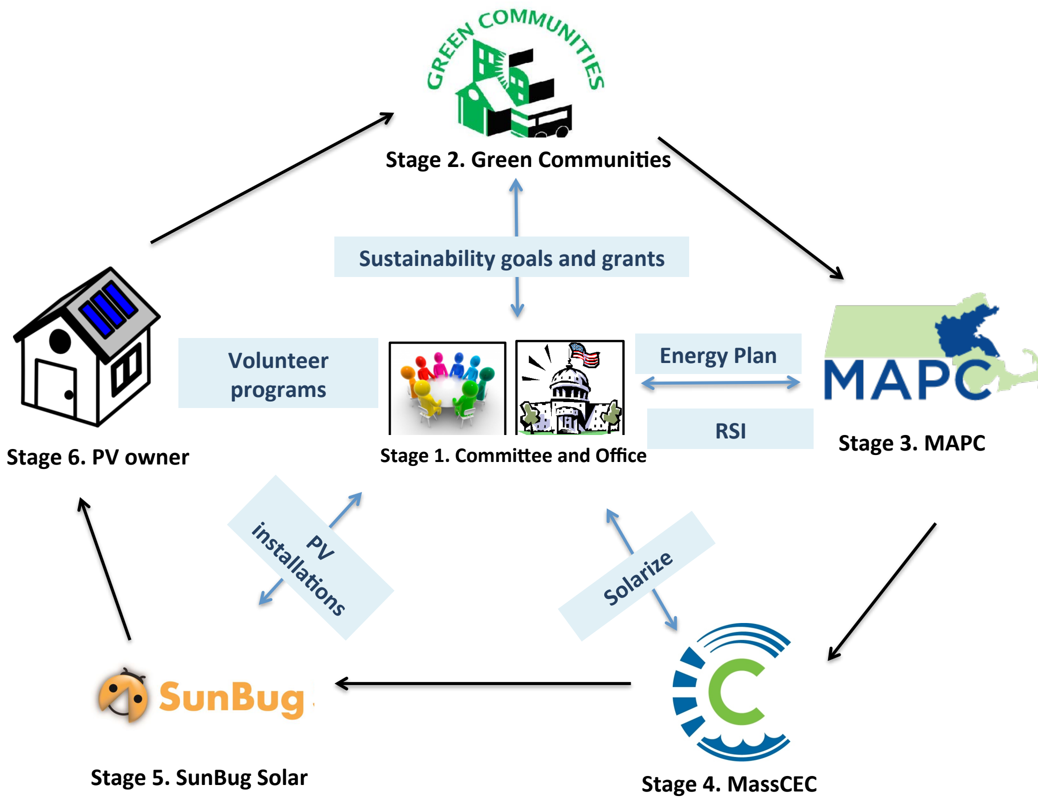


Figure 6: Medford's solar energy framework: diagram constructed chronologically based on data collected for stakeholders (Policy Context) and policies (Policy Input)

MAPC and GC enabled the Medford officers to meet energy managers from other cities and learn from their past programs (Hunt, 2014). Considering the legislative differences across towns, it is essential that towns are able to speak with each other. As mentioned earlier, synchronizing policies, such as solar permits, could save time, money, and drive down the soft costs of PV panels (Shrimali and Jenner, 2013).

In effect, the policy framework *democratizes* the governance model as it allows stakeholders from various NGO's to influence the political agenda. Consultants from the three organizations therefore gain *access* to the decision-making process in Medford; e.g. they advise city officials on ways to improve local sustainability management. The City, on the other hand, benefits from the professional experience of these organizations. Indeed, their regional expertise builds on work with many other suburban towns; hence-they are able to give Medford much more informed and holistic advice. Considering the nature of the sector being governed- distributed solar energy- it is essential that the newly emerging energy model is *networked* and *decentralized* as the one here described. Indeed, solar PVs grant each citizen the right to generate their own energy, independently from the grid. Therefore, it is only natural that these same stakeholders are able to come together- via channels of regional ENGO's- and participate in a *decentralized* decision-making process, too.

3.3. Stages 4 and 5: Solarize Medford with SunBug

Stages 1-3 build on Medford's municipal capacity and commitment to renewable energy. Therefore, they are an essential step in its application for yet another regional program- Solarize Mass. Having an *internal* department dedicated to energy matters (stage 1), therefore allowed them to respond to *external* opportunities, such as Green Communities. Membership in Green Communities, on the other hand, facilitated their participation in Solarize Medford.

Solarize Mass is a strategic tool that simultaneously targets two main challenges: the low deployment rate of PVs and their high upfront cost. In effect, it provides an effective pricing model, which allows low-income families to *participate* in the PV market. Traditionally *marginalized* due to the high costs of the panels, these families are given a valuable opportunity by the program.

While the program is *financially effective*, it is not necessarily *financially equitable*. The reason is that PV systems can be installed only if a number of conditions are met: (1) If residents owns rather than rent their home; (2) If the roof is un-shaded and un-obstructed by neighborhooding structures; (3) If the resident has the financial capacity and good credit history to make the payment (US DOE, 2011; APA, 2013). Many people would not be able to fulfill these requirements by virtue of being residents of Medford. Namely, the city is one of the most densely populated suburbs, many of its residents rent a room in a multifamily, attached- rather than detached- unit (see *Policy Context* statistics). Therefore, these stakeholders are denied *access* to the financial benefits of Solarize Mass.

Nevertheless, Stage 3 observes the strengthened *position* of yet another stakeholder, who is external to municipal politics- namely, volunteer residents. First of all, their unpaid *participation* in these endeavors demonstrates genuine interest in Medford's sustainability- and hence a guaranteed work quality. It is doubtful they would have participated in a long-term project of this kind if they did not truly wish to make a difference. The Medford policy framework therefore *empowers* citizens in a way uncommon in many other states. Namely, residents of a wide range of fields- energy businesses, sustainability organizations, university scholars- are able to take *part* in the solar campaign (or the energy committee) and independently stir local energy governance (Energy Commission, 2010; Go Green Medford, 2013). By virtue of being volunteers, however, their participation is temporarily limited. Therefore, the disadvantage of this governance feature is its short-term and *inconsistent* effect.

4. Policy Output

See Figure 7

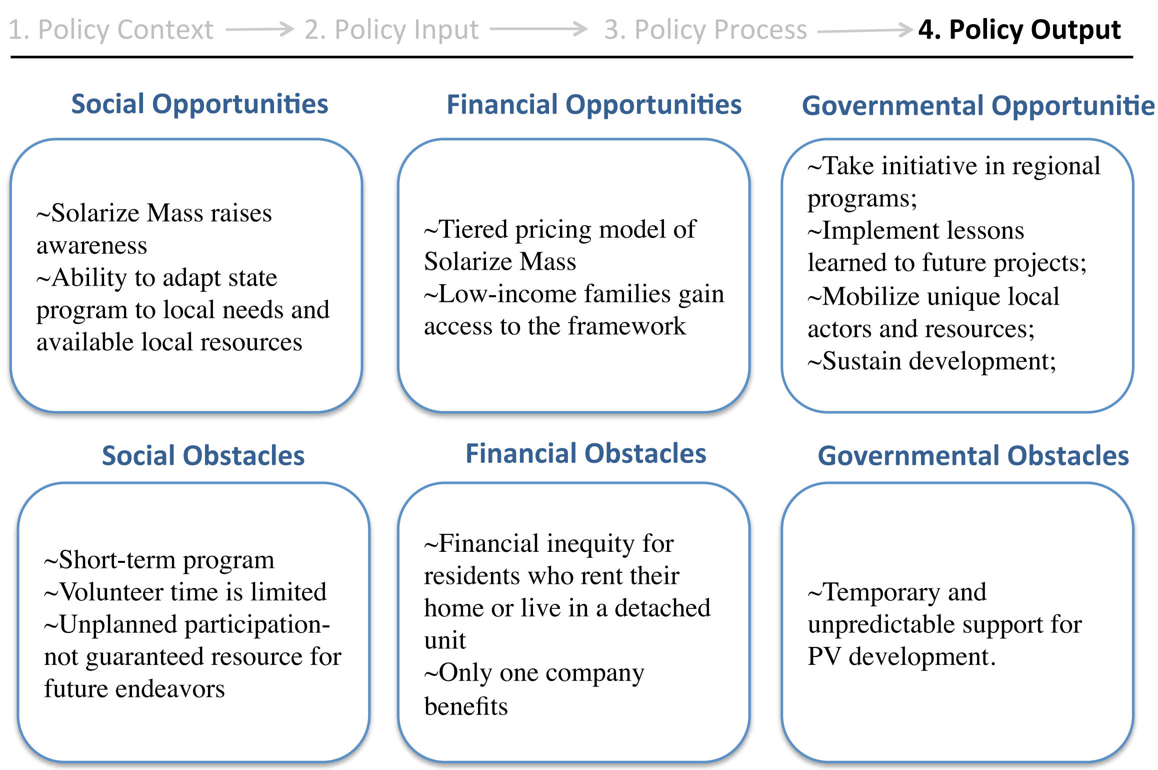


Figure 7: Policy output for the Medford case study

4.1. Social output

4.1.1. Opportunity: Customizing Solarize to local needs and resources

The social goal is to increase public awareness regarding solar energy and strengthen the local network of stakeholders. The Medford solar energy framework achieves these goals to a certain extend. Solarize Mass, for example, results in a massive campaign, which accomplishes goal #1: to educate the population on the advantages of solar energy, state incentives available, and other technological matters. Interested parties could share their knowledge with friends and neighbors as well. The enabling factor is therefore the state-wide program (Solarize), which towns were able customize according to *contextual* needs and resources. Namely, Medford mobilized their respective NGOs, volunteers, and utilized prior experience with regional networks, such as GC and MAPC. Therefore, the campaign resulted in a *decentralized* network of private as well as public stakeholders (goal #2).

4.1.2. Obstacle: short-term and unpredictable nature of the programs

The main obstacle is the short-term and unpredictable nature of these programs. Lasting only five months, it is unlikely whether Solarize would have a long-term effect throughout 2014 and the future as well. Volunteer time is also limited as participants are unpaid. Finally, participation in programs of this nature is *occasional and unpredictable*. Therefore, towns should not rely on them for future results. These programs serve as an add-on to the existing policy framework, however, they are not a constant policy effort. This is a considerable obstacle in light of the effects of state-level policies. Namely, they are also short-termed and create an *uncertain* environment. In effect, local-level efforts do not adapt favorably to state-level policies.

4.2. Financial output

4.2.1. Opportunity: a tiered pricing model that allows low-income families to gain access to the PV market

The *financial goal* is to ensure affordable panels and stimulate the PV market. Figure 8 below shows that the portfolio of policies indeed increases the capacity in the Medford exponentially. Before the policies were implemented in 2010 (graph in blue), there was barely any deployment. By the end of 2013, however, the policies output 503kW of solar power (graph in red). The past four years have therefore developed a much more matured PV market in Medford. Usually only high-income families are able to participate in this market. Solarize Medford, however, has ensured that its tiered pricing structure attracts families of a lower income bracket, too.

4.2.2. Obstacle: limited duration and limited access

Although Solarize Mass decreases the cost of solar energy substantially, the discount terminated in October 31, 2013. It has a limited duration as well as limited impact. Namely, Solarize (as well as the rest of the policies) do not explicitly address multi-family houses, detached, or rented units. Considering the policy *context* of the

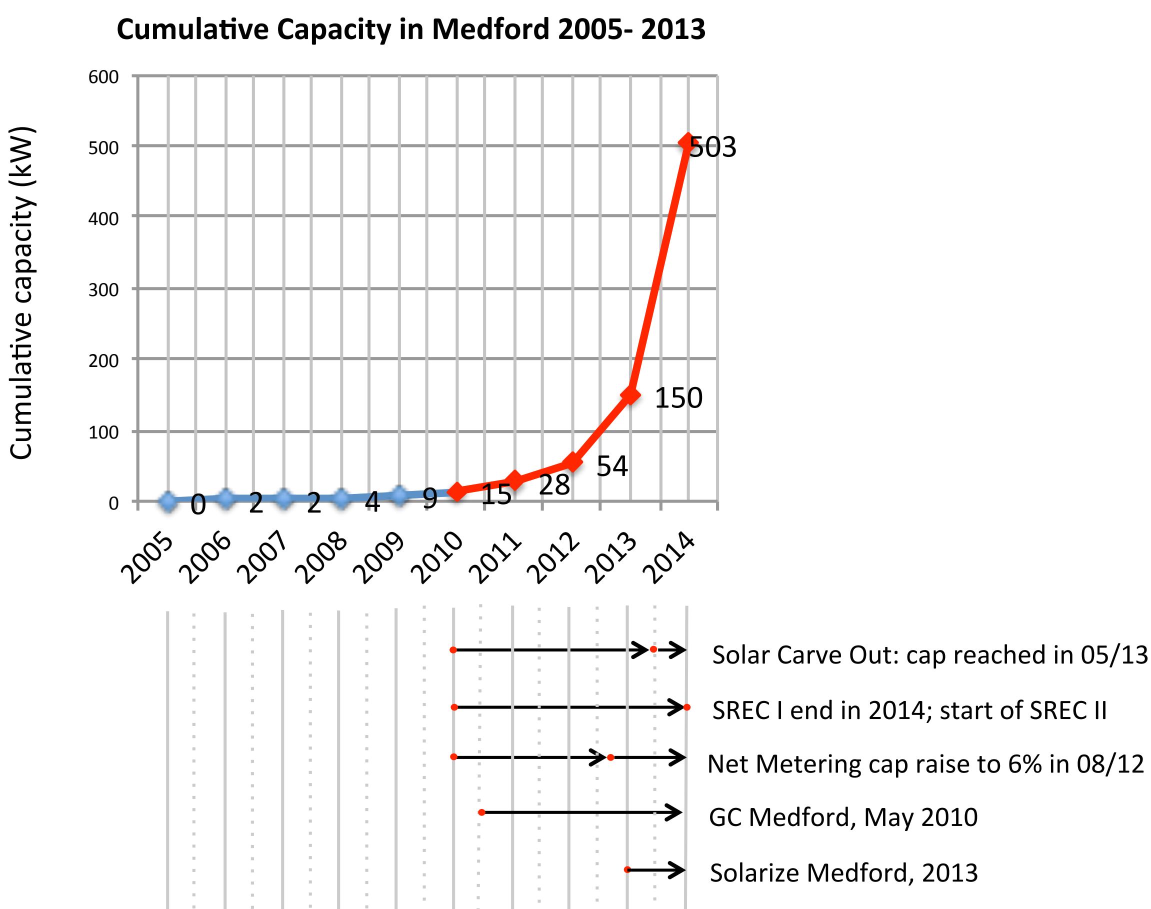


Figure 8: Timeline of policies and timeline of PV deployment in Medford (graphs are constructed based on data from: DOER, 2014a; *DOER, 2014d; DOER, 2014g; DOER, 2014i; NREL, 2014; SREC Trade 2012)*

town, a large percentage of the population would be denied *access* to the policy benefits. Moreover, only one company benefited from engaging in the tiered pricing model. Therefore, future customers would likely prefer the services of this contractor over other companies. This would be an unfavorable effect, which could slow down the solar market and adversely affect the competitive edge of other companies. It is interesting to note that a tactic that aims increasing *financial equity* to citizens (facilitating the choice of a contractor) results in *financial inequity* for businesses. Considering the solar industry is relatively young, it is not surprising that such trade-off's exist.

4.3.Political/legislative output

(See Figure 9)

4.3.1. Opportunities: continuous participation in regional networks that builds local resiliency

The *political/legislative* dimensions of the *Policy Process* measure whether solar goals are integrated into the local regulatory framework and whether they ensure a stable support for the PV market. Medford's participation in regional networks (MAPC, MassCEC, and GC) resulted respectively in a local energy plan, a solar campaign, and a number of GC projects. While regional collaboration built the local *capacity* of the city hall, regional stakeholders gained *access* to the decision-making process. Therefore, the policy goal was achieved via a multi-leveled governance model. It allowed actors to communicate across levels and mutually benefit form the decision-making process.

Solar success was enabled by three factors: (1) The *initiative* and *progressiveness* of the municipality to unilaterally and voluntarily seek those *external* opportunities outside of its own *internal*, institutional environment (e.g. GC, MAPC, MassCEC); (2) Once engaged in this regional/state program, the city should successfully implement any lessons learned from the past (acceptance to MassCEC depends on prior membership in GC); (3) It should *mobilize* local actors and unique contextual resources (partnering with ENGOs in Medford). (4) Arguably the most important step is the last one- the ability to *sustain* the solar growth once the regional program is over. A successful utilization of the sequence of factors builds the *resiliency* of the policy network. Local actors gain knowledge and expertise; in effect, their future *vulnerability* to market fluctuations and policy changes decreases.

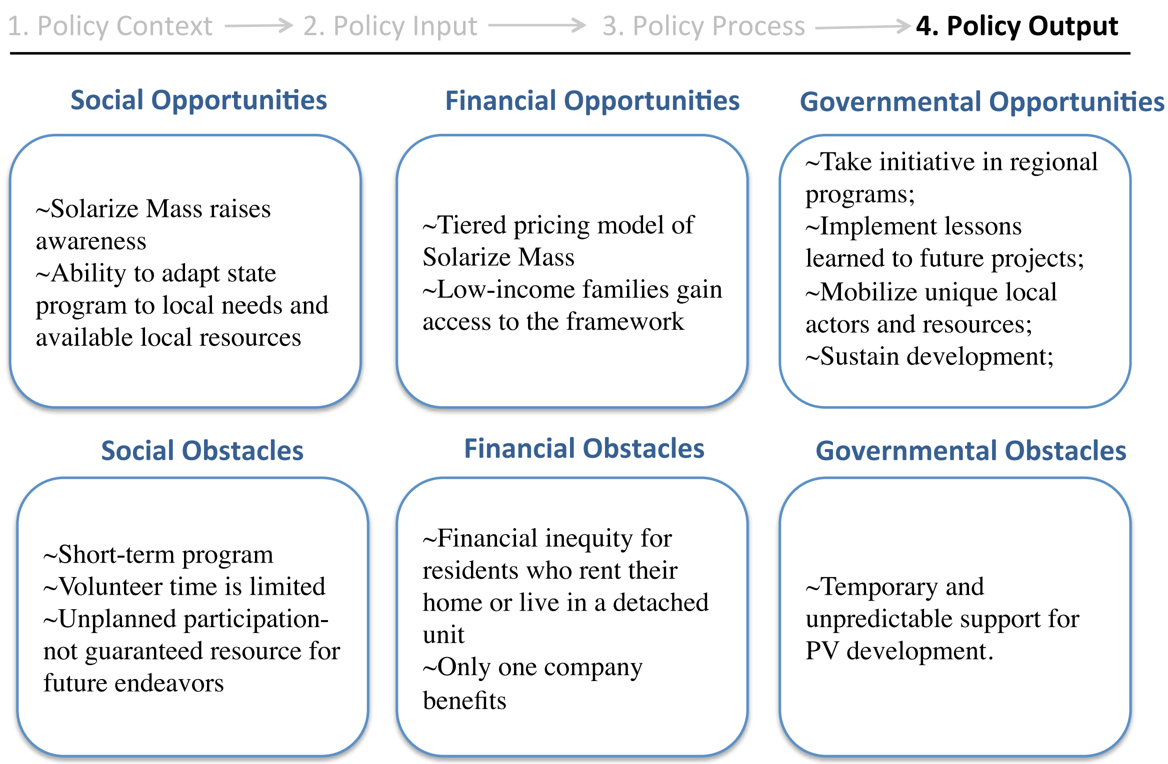


Figure 9: Summary of policy obstacles and opportunities in Medford

4.3.2. Obstacles: temporary support for solar energy projects

The main obstacle on a state level is the *unstable* and *unpredictable* nature of the laws. Therefore, it was suggested that in order to overcome this *barrier*, municipalities should respond with *regionally integrated, long-term, and predictable policies*. Only then would solar developers be incentivized to invest in an otherwise intermittent solar energy market.

Institutionalizing long-term goals is challenging on a local level however. The reason is that small towns have limited staff and budget. Participation in regional networks and state grants have undeniably helped overcome this barrier. External support from MAPC and GC, however, is similar to MassCEC. Namely, it provides *temporary and unplanned* programs, which might not be replicated in the future. The lack of a *stable* state policy framework is therefore magnified on a local level. It creates a vicious cycle where regional and local agencies counter-act the *inconsistency* of state policies with similarly *inconsistent* programs. In effect, a developer discouraged by state policies to invest in solar energy would unlikely be lured back to the solar market by such intermittent, local policy opportunities.

Chapter 8: The city of Melrose

1. Policy Context

1.1. Urban context

In comparison to the other two case studies, the city of Melrose is located the furthest away from the city of Boston (See Figure 1). While Somerville exhibits primarily urban features and Medford- semi-urban, Melrose has a predominantly suburban character. Not only its outermost location, however, its building stock testifies to this fact, too. Figure 2 displays a statistical comparison between all three towns across several housing factors. As the numbers indicate, Melrose has the lowest rent; the highest percent of detached units, 54.7%; and the highest percentage of home-owners, 65.2%.

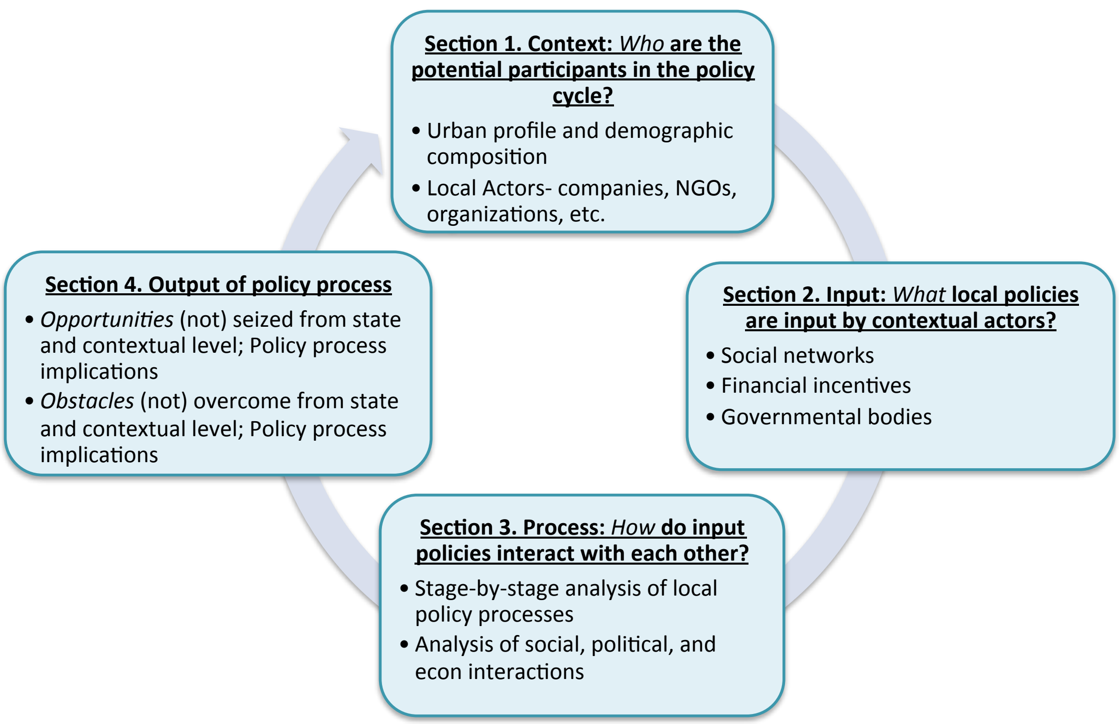


Figure 1: Chapter Overview

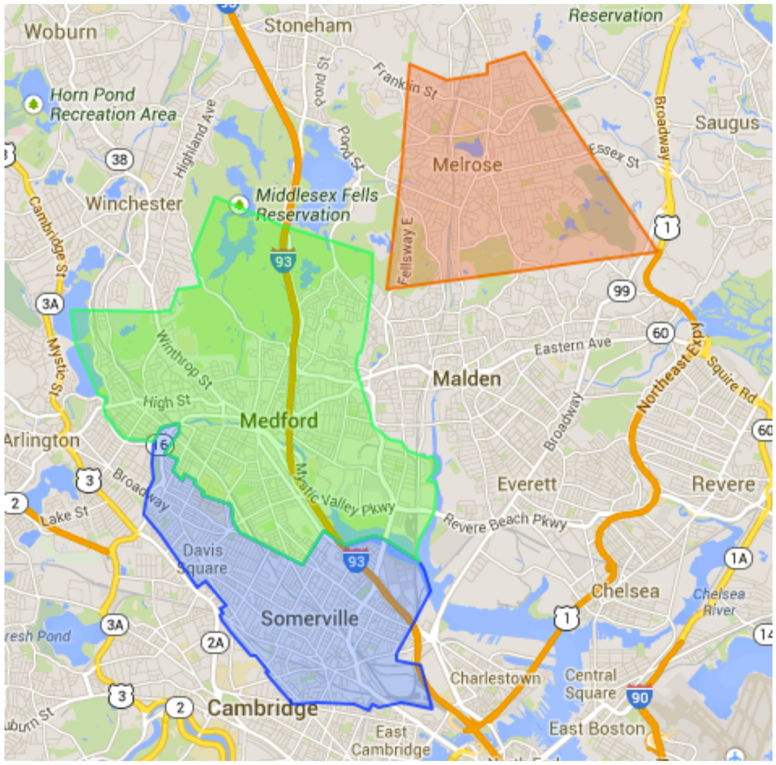


Figure 2: Melrose (highlighted in orange) is located the furthest away from Boston (Image rendered in Zeemaps; Google Maps, 2014)

Finally, the graphs also suggest that Melrose's overall character most closely resembles that of the average suburb (see fourth grey bar, "all 31 suburbs") (US Census Bureau, 2014).

The above-mentioned statistics delineate Melrose's clearly distinguished suburban character. They also imply a favorable environment for PV deployment. Low percent of detached units, for example, indicates a large rooftop area. Unlike high-rise buildings in densely populated cities, residents in Melrose do not face infrastructural impediments to PV installation. The high percent of homeowners, on the other hand, suggests that the majority of the population is eligible to install a solar system on their roof (those who rent their home are unable to do so).

Urban Context

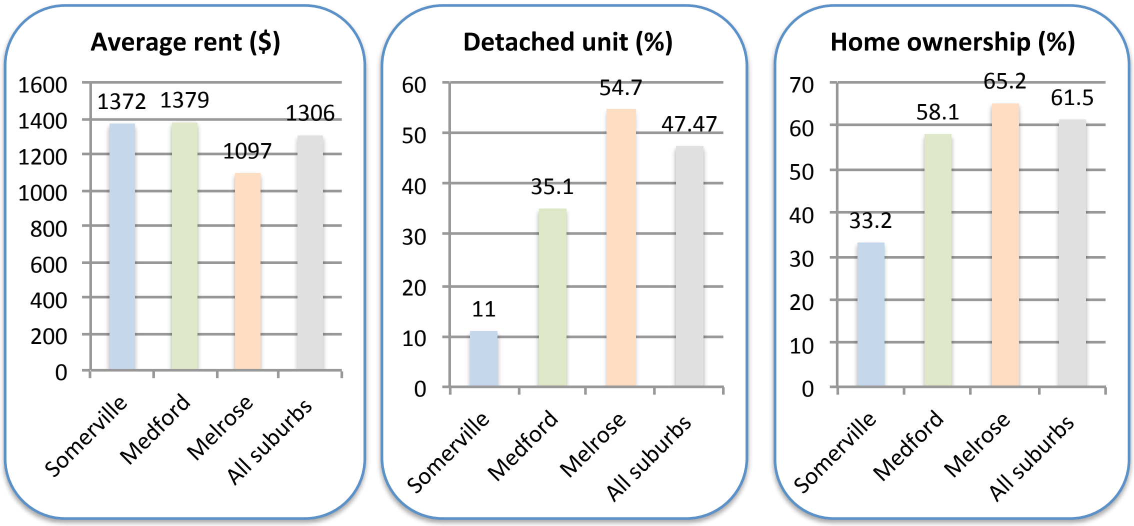


Figure 2: Summary of the urban features of Melrose (third bar in orange) in comparison with the other case studies as well as all 31 suburbs (grey bar) (US Census Bureau, 2014)

The urban composition of a city describes the building stock of a given town. Its demographical composition, on the other hand, is illustrated in Figure 3. Namely, it comprises the *social, financial, and governmental* factors, which distinguish Melrose from its neighbor-hooding towns. Much like the prior sections, the five demographical factors here described set Melrose apart from the other two cities. Indeed, once again the city located *furthest* away from Boston takes the *highest* values for all favorable factors and the *lowest*- for all unfavorable factors. The first graph, for example, shows that there are only 8.9% racial minorities; furthermore, 21.8% of its residents have obtained a Masters degree (value is comparable to the other towns) (US Census Bureau, 2014).

The first factor, racial minorities, has traditionally been identified as a potential obstacle to solar deployment. The reason is that ethnic groups usually fall into the lower income bracket of a town; furthermore, language barriers might impede their participation in solar awareness campaigns (Brant et al, 2010). With only 8.9% of racial minorities, however, it is not expected that Melrose would experience difficulties in this regard. Likewise, the educational level of the population also would not be an *obstacle* in

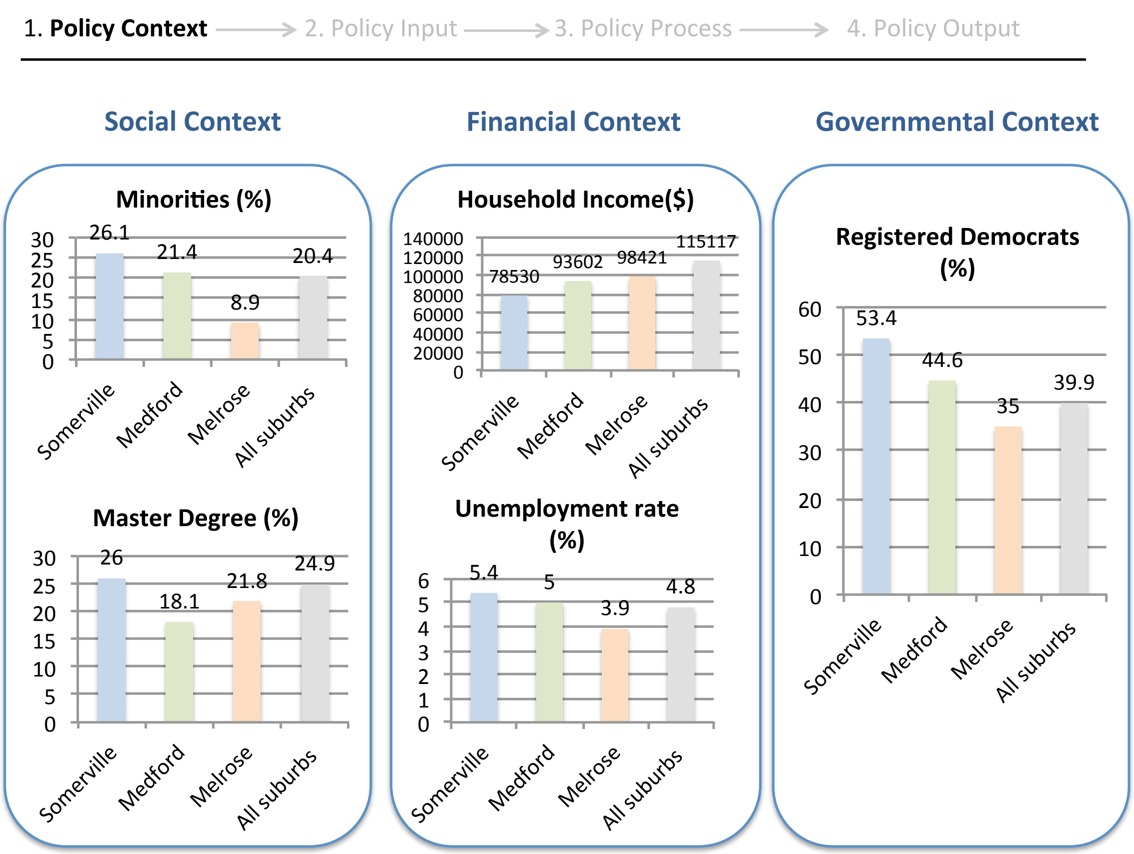


Figure 3: A summary of Melrose's demographic composition (third bar in orange) in comparison with the other case studies as well as all 31 suburbs (grey bar) (Boston, 2012; US Census Bureau, 2014)

this case study. With 21.8% of Master-level graduates, Melrose has a favorable social and intellectual capital. The town is the second highest in the sample, however, it stands lower than the average for all 31 suburbs (US Census Bureau, 2014).

The financial context in Melrose also predisposes the deployment of solar energy systems. The average household income is the highest among the three towns, $98,421. The average unemployment rate is also the lowest, 3.9%. Therefore, it is more likely that residents in Melrose could afford a PV system than those in Medford and Somerville (US Census Bureau, 2014).

The only unfavorable factor in this category is the low percent of registered Democrats, 35%. The conservative lining of the city might potentially impede the adoption of solar PVs in some households (US Census Bureau, 2014).

1.2. Local Actors

The following section lists key actors in Melrose: non-profit organizations, clean-tech businesses, and governmental bodies (See Figure 4). It is namely these stakeholders that later initiate the solar policies described in Section 2: Policy Input.

Figure 4: Summary of key stakeholders relevant to solar energy

1.2.1. Social Actors

~NGO's- Unlike Medford and Somerville, no environmental organizations were found in Melrose. The lack of ENGOs could be a potential impediment to solar deployment. As previous chapters have indicated, green institutions play an important role- especially throughout Solarize campaigns. For example, they raise awareness and organize community outreach programs. Nevertheless, there are other non-profits, such as Sally Frank's Farmers Market, the Melrose Family YMCA, and the Farm Direct Coop

(Melrose Patch 2012). The subsequent section of this chapter, *Policy Input*, describes how these actors take part in local solar initiatives, such as Solarize Melrose.

~**MAPC**: already described in Chapter 6: The city of Somerville

1.2.2. Business Actors

~**NextStep Living-** already described in Chapter 6: The city of Somerville

~**Broadway Electrical** is an electrical provider, which offers engineering, construction, and installation services to its clients. The company takes on public, private, as well as municipal projects. Finally, they specialize in conventional as well as alternative energy sources, such as solar PV design, interconnection, operation, maintenance, etc (Broadway Electrical, 2014).

1.2.3. Governmental Actors

~**Sustainable Melrose:** Sustainable Melrose is the governmental body responsible for environmental affairs in Melrose. Some of their duties are energy efficiency, water conservation, recycling, etc. Unlike other towns, they have an Energy Efficiency Manager, too, who is exclusively dedicated to energy matters (rather than one officer responsible for all issues related to sustainability). In cooperation with the commission, she has initiated many of the projects described in the *Policy Input* (City of Melrose, 2014; Grover, 2014).

~**Energy Commission**: The Melrose Energy Commission shares similar tasks and goals with the committees in Somerville and Medford. Namely, it is comprised of twelve working professionals who meet once a month to discuss progress on current projects. Appointed by the mayor, they volunteer their time to the city of Melrose (Energy Commission, 2014). Despite time restrictions, their diverse backgrounds benefit the commission- e.g. as they provide professional insight into ongoing projects. For example, while some of them are mechanical engineers or architects, others are energy consultants or economists. The range of projects completed in the past is also quite diverse: conservation, efficiency, and renewable energy programs. The goal of these projects is two-fold: decrease energy expenditure in Melrose and educate the public on environmentally-conscious living practices (Board of Aldermen, 2011; Melrose Energy Commission, 2010).

~**Green Communities**: already described in Chapter 6: The city of Somerville

~**MassCEC**: already described in Chapter 6: The city of Somerville

2. Policy Input

The following section presents a list of solar programs initiated by the actors described in the previous section (See Figure 5).

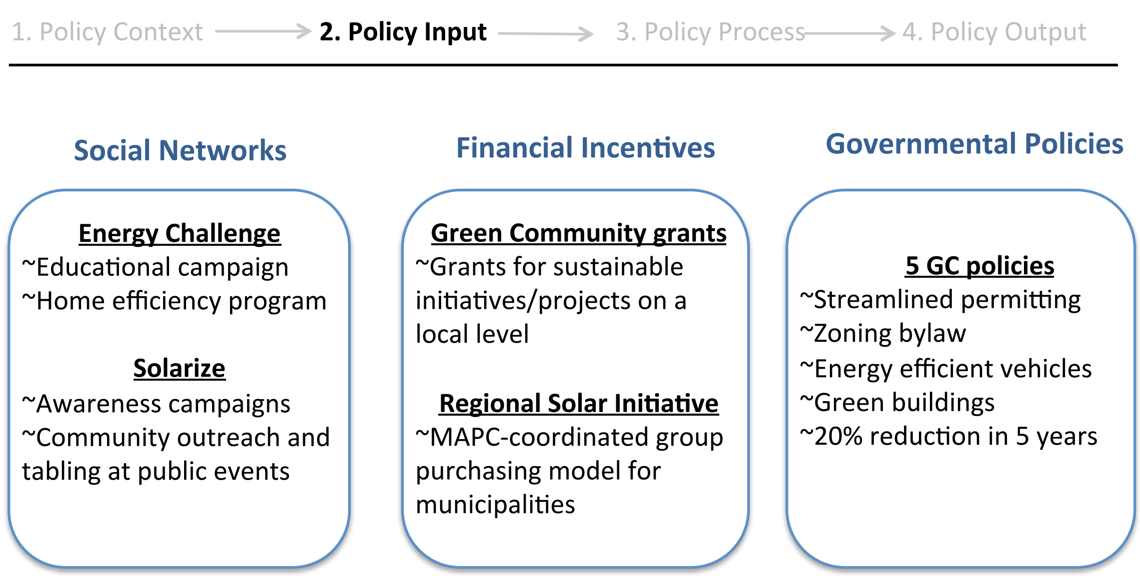


Figure 5: Summary of key policies relevant to solar energy

2.1. Social networks

2.1.1. The Energy Challenge is a collaborative effort between MassSave, NextStep Living, and the Energy Commission. The role of MassSave is to offer low-cost home energy assessment to Massachusetts residents. NextStep Living then executes all residential audits. Finally, the Melrose Energy Commission helps implement and publicize the program on a local level. They raise awareness and serve as a point of contact for any resident interested in it. In its totality, the Energy Challenge accomplishes two main goals: (1) it educates the public on various means of reducing their carbon footprint; and (2) it offers a no-cost home energy assessment to interested parties who take advantage of the program within a fixed period of time. Technical services provided by NextStep Living are limited to energy efficiency rather than renewables (hence, solar energy is not an alternative). Nevertheless, the collaborative initiative between the three stakeholders proved an important learning experience, which later positively affected Solarize Melrose, too (Energy Commission, 2014b; Grover, 2014).

2.1.2. Solarize Melrose is a sub-chapter of Solarize Mass: a statewide program, which piloted in 2011. Similar to Solarize Medford, it is organized by MassCEC, NextStep Living, Roof Diagnostics, the city hall (Melrose Energy Commission), local solar coaches, as well as local non-profit organizations. Therefore, the overarching goal of the program resembles Medford's. Namely, it aims incentivizing solar deployment by offering a five-month group-purchasing model with a tiered pricing structure (MassCEC, 2012a). In order to execute the project, each of the four participating stakeholders has a specific role and contributes their respective resources to the program. MassCEC, for example, designs and organizes the program, which participating cities (such as Medford and Melrose) later adopt. The city hall, on the other hand, has an intermediary role and facilitates the communication and collaboration between MassCEC, local residents, and the solar energy company. Finally, local solar coaches and non-profit organizations help publicize and organize Solarize locally (MassCEC, 2012a). In order to reach a variety of stakeholders, the following organizations also participated: Coffee, Tea, and Me; Whittemore Hardware, and Shaw's, Sally Frank's Farmers Market, the Melrose Family YMCA, and the Farm Direct Coop (Melrose Patch, 2012).

Unlike Medford, however, Melrose had the advantage to draw on resources and experience built throughout the Energy Challenge. First of all, they had already built skills related to community outreach, marketing, tabling, holding workshops, etc. In order to optimize the impact of the Energy Challenge, they offered it as an add-on to customers of Solarize as well. Secondly, they partnered with the same energy provider who was contracted for the Energy Challenge, too (NextStep Living). Finally, the city hired a solar coach who already had marketing experience from previous campaigns (Grover, 2014).

Nevertheless, Solarize Melrose faced a number of challenges. Although initially 672 residents expressed interest in solar PV, most of their roofs were not eligible for a system installation. In effect, only 178 site visits were completed and finally- 79 contracts were signed. Nevertheless, the program resulted in 425.6 kW of solar power, the highest of all three Solarize programs case-studied in this thesis. The amount of solar power installed more than tripled the existing solar capacity in the city of Melrose (MassCEC, 2012a).

Solarize Melrose differed from other Solarize programs financially as well. For example, 100% of all systems were leased through a PPA rather than a direct purchase agreement. Despite the high-income level of local residents, most of them opted for a much safer, cheaper, and less risky alternative to investing in solar energy directly. Namely, they entered the solar market indirectly as they leased their roof to a private developer (MassCEC, 2012a).

Nevertheless, the program had an interesting finale, which does incentivize future solar endeavors. Namely, they partnered once again with MAPC in order to participate in Energy Sage- an online platform for PV procurements. A database of solar contractors, it facilitates solar purchases as it outlines the process as well as potential contractors in the area. The goal of the partnership is to ensure that residents have practical means of contracting a solar developer post-Solarize as well (Grover, 2014; Melrose Solar Coach, 2014).

2.2. Financial incentives

2.2.1. Green Community (GC) Grants- The city of Melrose was granted a Green Community status on May 25, 2010. Considering the program was launched in 2010, Melrose was among the first towns to join the initiative and exemplify sustainability leadership on a local level (DOER, 2014g). As described in previous chapters, cities join the GC division on a voluntary basis. In order to be accepted, they need to implement five GC policies. Upon fulfillment of these criteria, towns become eligible for GC grants: state funds, which could be invested in municipal projects as well as programs and/or policies related to sustainability, energy, and the environment (Commonwealth of Massachusetts Executive Office of Energy and Environmental

Affairs, 2013). GC funds administered by the state department were invested in: (1) the position of the energy efficiency coordinator, (2) a consultant, and (3) several energy conservation projects (MassCEC, 2014g).

2.2.2. The Regional Solar Initiative (RSI)- already described in Chapter 7: the city of Medford

2.3. Governmental policies

Five GC policies have been identified: (1) Adopt a zoning by-law for designated locations, which removes any obstacles to the implementation of renewable energy projects; (2) Legislate a streamlined permitting process for renewable energy projects; (3) Ensure all municipal vehicles are energy efficient; (4) Enact a plan that reduces energy consumption in the next 5 years by 20%; (5) Implement new building regulations for energy efficient construction practices (DOER, 2013).

3. Policy Process

Policies from the Input stage create a number of *interdependencies* among actors from the Context stage. These interdependencies as well as the dynamics of the overall policy network are described in the following section (See Figure 6).

3.1. Stage 1: Green Communities

The city of Melrose became a GC member in 2010 (DOER, 2014g). The program marks the beginning of an inter-governmental *partnership* between the state of Massachusetts and the city of Melrose. Overall, the partnership resembles Medford's and Somerville's GC status. Namely, the state Department of Energy (DOER) requires that Melrose adopts five policies in order to become a Green Community (Commonwealth of Massachusetts Executive Office of Energy and Environmental Affairs, 2013). In effect, DOE *mobilizes* the *legislative and authoritative resources* of the local city hall.

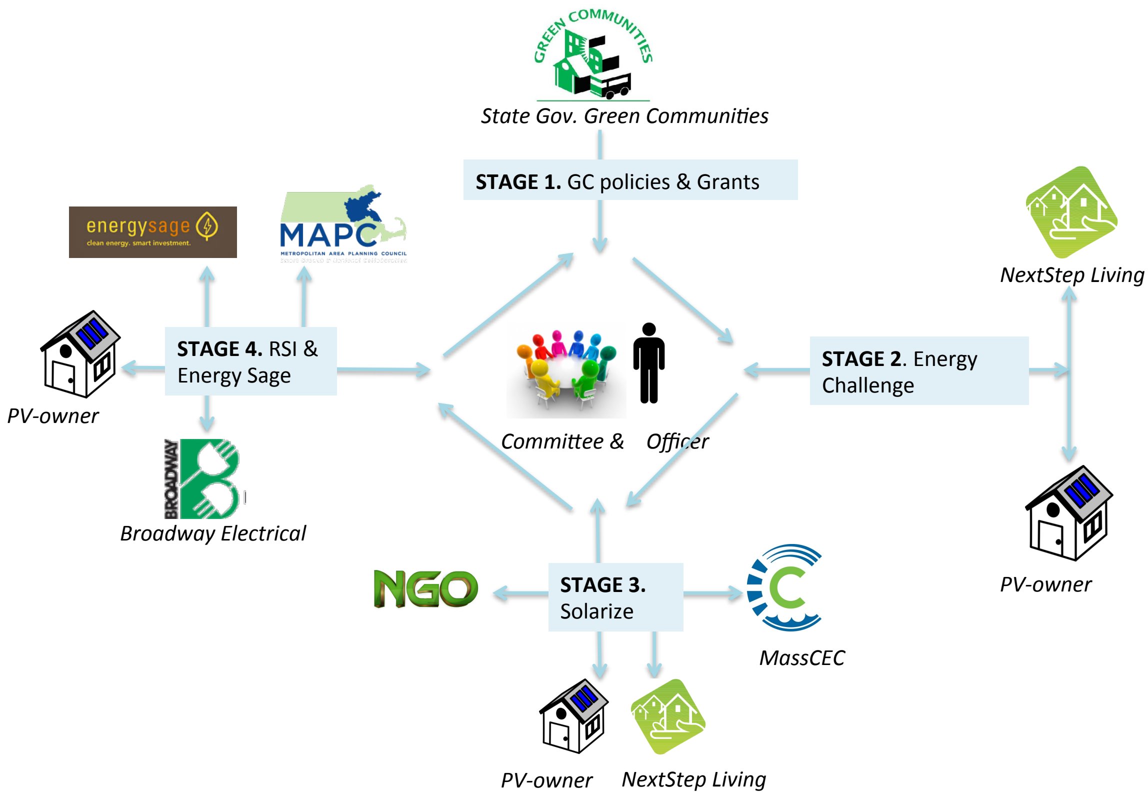


Figure 6: Visualizing the policy process in Melrose. The diagram is constructed chronologically based on data found in Policy Context and Policy Input.

Once Melrose has been accepted, it gains *access* to state grants, which are later invested in green energy. In effect, the GC status strengthens the *position* of the local renewable energy sector on the state market.

Despite similarities with Medford's and Somerville's participation in the Green Communities, Melrose later utilizes GC funds quite differently. Other cities, for example, choose to invest their money in singular, short-term projects: installation of a solar array, retrofitting the city theatre, or updating the energy system of another public building (DOER, 2014g). Although these projects improve the *present* energy efficiency of the respective buildings, they bear no significance to *future* solar projects. Therefore, the grant has a limited *effect* on the overall energy performance of local buildings.

Melrose, on the other hand, invests the sum in the position of the Energy Efficiency Manager and the Energy Performance Contract Consultant (DOER, 2014g). The GC grant hence has a much more *sustainable* and *long-term* effect on local energy use than those in other towns. As the following sections show, the Energy Efficiency Manager has a key role in initiating the future, solar programs. Therefore, the GC grant is integrated effectively into the *long-term* plans of the town.

3.2. Stage 2: The Energy Challenge

The second stage (the Energy Challenge) is related to solar energy indirectly. It pertains to home energy efficiency, rather than renewables. However it is a key link between the second and the third phases of the policy framework. Firstly, the city contracted the same company, NextStep Living, for both initiatives (Energy Commission, 2014b; MassCEC, 2012a). The participation of the company in two consecutive energy programs in Melrose *strengthens* the public-private *relations* between the city hall and the vendor. Furthermore, the company was able to familiarize itself well with the urban fabric of the city. A drawback to this strategy is the fact that other companies are marginalized. As customers become well familiar with a single company, they might not opt for other businesses.

The program was also offered as an add-on to Solarize Melrose (Melrose Solar Coach, 2014). Therefore, local officials incorporated it into other initiatives in order to optimize the impact of both programs. In effect, the policy framework became much more *integrated* as it had an *interdisciplinary* view of the problem.

Finally, the Energy Challenge allowed local stakeholders to improve their skills in marketing and public outreach. The events and campaigns they organize are key to publicizing Solarize Melrose, too. Therefore, the Energy Challenge serves as a platform for the city hall and other actors to develop their expertise and prepare for future solar endeavors as well. The *re-activation* of past experiences and *the re-mobilization* of past partnerships therefore important at stages 2 and 3. As a result, stage 2 of the framework was well adapted to the *contextual* needs and resources in Melrose.

3.3. Stage 3: Solarize Melrose

Solarize Melrose (phase #3) therefore activates the *social memory* of the town from the previous phase #2. In comparison to other case studies, the city of Melrose has the competitive advantage of building on previous experience, skills, as well as partnerships that are already established. In effect, the *collaboration* between the state (MassCEC and the municipality), society (NGOs and residents), and the market (NextStep Living) is much stronger and *efficient*. Nevertheless, the basic principle of their collaboration remains the same: MassCEC and the Melrose city hall contribute to the partnership with political *resources* (granting *authority* and *legitimacy* to the campaign); NGOs- with public *resources* (experience with civil engagement); and NextStep Living- with business *resources* (private-sector expertise). In effect, the four parties mutually benefit from the product of their *collaborative* effort- the installation of 425.6kW of solar power (MassCEC, 2012a).

Solarize Melrose owes its success to the favorable *contextual* factors. First of all, its population has the highest income and highest percent of home-owners/detached units in this study (See diagram in Policy Context). Therefore, they have the infrastructural and financial advantage that allows interested parties to install a PV system on their roof. Second of all, they had a financial strategy: PPAs (power-purchase agreements where a solar developer leases residential roofs) were emphasized as the preferred binding agreement between vendors and customers. Indeed, 100% of all 79 purchases are contracted through a PPA (MassCEC, 2012a). This strategy ensured the *financial equity* of the program as residents of more income brackets were able to buy a solar system.

The high interest in PPA's is a reflection of another interesting factor. Namely, it allowed residents to enter the solar market without claiming ownership of the system. In effect, they were able to avoid the unfavorable effects of state policies in 2012 and the *risky* economic environment they created. Indeed, Solarize Melrose (May- November 2012) coincided with the close termination of one of the state policies. Namely, the Net Metering policy reached its cap of 3% (SREC Trade, 2012). Before it was raised to 6%, the state policy environment was uncertain as investors did not know if they would be able to interconnect PV systems to the grid. 2012 was hence not an opportunistic time to invest in solar energy as it could have discouraged developers (Worchester Business Journal, 2012).

3.4. Stage 4: RSI and Energy Sage

Solarize Melrose *decentralizes* local governance as state and regional stakeholders *collaborate* locally in Melrose. Furthermore, they represent various social groups and public interests. The following phase of the framework, Regional Solar Initiative (RSI), takes this form of *decentralized* governance to the next level. As described in the *Policy Input*, RSI is a group-purchasing model- it allows municipalities to contract a common vendor and complete the process collaboratively. In effect, rather than working in a single city (as during Solarize), they target problems from all 17 towns simultaneously (MAPC, 2013a). For example, regional meetings allow officers to exchange experience with solar energy projects, share visions for the future, and discuss obstacles to solar deployment in their respective community. The ability to *network* with other city hall officials therefore improves Melrose's *access* to regional resources (knowledge and expertise of other officers) and strengthens their *position* on the state solar market (as they gain competence in tackling PV problems).

RSI therefore creates a platform for Melrose and other communities to *experiment* with new forms of governance, learn from each other, and improve local sustainability efforts. It provides them with ample space to manoeuvre in their efforts to improve local policies. In effect, participants find themselves in a new *position* and fulfilling new tasks, untypical for city hall officials from other cities. RSI enables a much more *democratized* form of governance where cities are given direct *access* to otherwise restricted *resources* (technical assistance, collaboration with other towns) (MAPC, 2014b). The ability to make decisions *independently* from the state also increases the *autonomy* of the town. Namely, municipalities are able to address issues that concern their problems in particular (rather than fulfil general state requirements that might or might not pertain to their problems).

The final stage of the solar energy framework is *collaboration* with Energy Sage and MAPC. It strategically builds on Melrose's past experience with MAPC in order to ensure its future solar success. Their partnership therefore culminates in Energy Sage- an online portal that facilitates bidding on PV projects (Energy Sage, 2014; Melrose Solar Coach, 2014). The project exemplifies a *consistent, sustainable, and efficient* finale to the framework that contrasts those in other towns (Note: finale is here used figuratively, a local policy framework is an on-going work in progress). First of all, the project is *consistent* because it *optimizes resources* and connections established in previous phases. Second of all, it is *sustainable* because it maximizes results from phases 2 and 3 in order to ensure continuous success in upcoming policy actions. Finally, it is *efficient* because none of the energy or resources input into the program are wasted.

4. Policy Output

(See Figure 10)

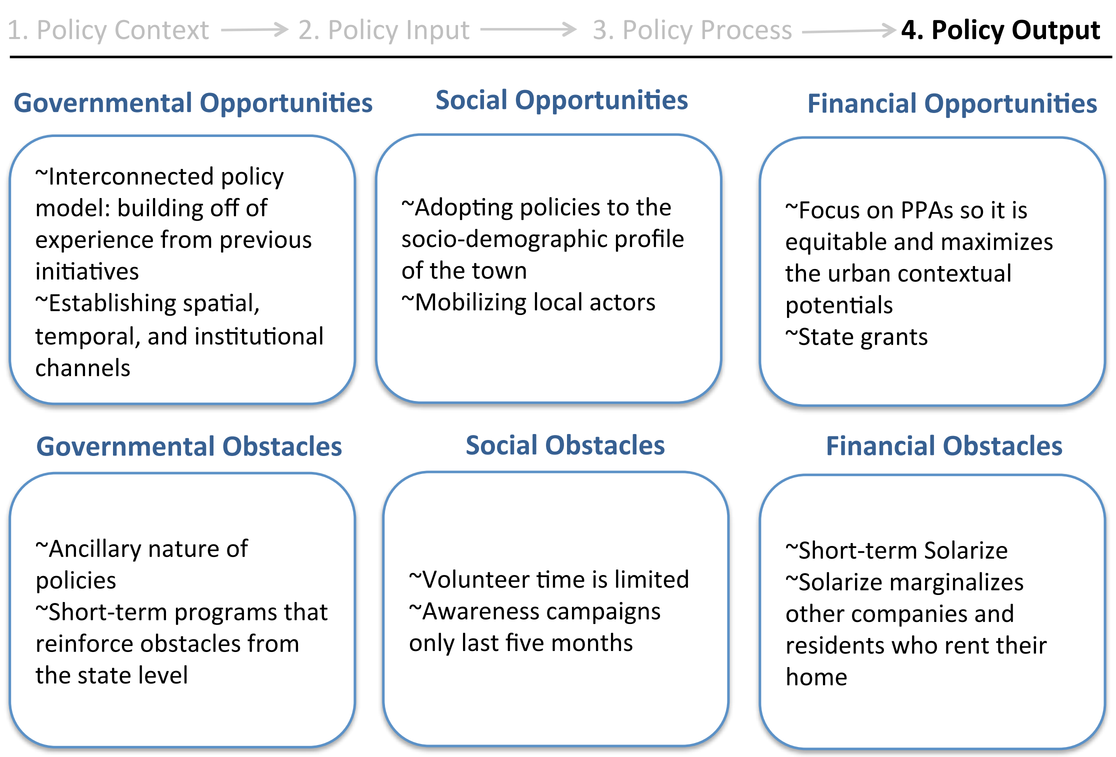


Figure 10: Policy output in Melrose change it

4.1. Governmental Outcome

4.1.1. Opportunity: interconnecting segments of the policy framework via channels that cross spatial, temporal, and institutional boundaries

The governmental goal is integrating solar energy into the municipal regulatory framework in a way that ensures stable support for the industry. Indeed, segments of the

Melrose policy framework are *interconnected* via channels that cross *spatial, temporal, and institutional* boundaries. As the *Policy Process* shows, actors from 17 towns cooperate on a single regional solar project and hence overcome *spatial* boundaries. Many of the actors (e.g. NextStep Living, MAPC) and policies (Energy Challenge), too, are re-introduced in subsequent stages of the policy framework and hence- cross *temporal* boundaries. Stakeholders from RSI, on the other hand, enable information flow across *institutional levels*: local, regional, and state governments. In effect, they ensure that officers from various administrative departments *coordinate* their work at every step of the process.

Melrose policies therefore transform a conventional governance model into an innovative solar energy policy (via the three types of channels described above). In this model, actors are aware that modifying one segment of the framework has multiple ripple effects on the rest of the system, too. Reminiscent of a live organism, its parts are *interconnected* and evolve simultaneously. The progression (or digression) of a given policy translates into positive (or negative) feedback loops across distant compartments of the system. The *systemic* nature of the Melrose policy framework therefore meets the governmental goal of solar energy policies. It ensures that actors from the Melrose City Hall, MAPC, and the private sector have a common platform and in effect their common projects and interests are coordinated. Namely, it ensures a governance model that is *sustainable and efficient*.

4.1.2. Obstacle: the complementary nature of the policies

Although Melrose seizes many opportunities, a number of obstacles impede the deployment of solar panels, too. The first *governmental obstacle* is the *ancillary* nature of the solar ordinances adopted: the five GC policies. Although they facilitate the installation and permitting of PV systems, they only do so once a resident has made the decision to purchase the panel. Unlike policy incentives, they do not trigger investments in solar energy. Therefore, they have a *complementary* effect on solar energy. Considering the character of the state energy polices, however, it seems unlikely that an ancillary policy would have a large-scale or a long-term effect on the local energy market. As described in Chapter 5: State Policies, the interrelation of the Net Metering, Solar Carve Out, and SREC policies results in a complex and *unstable* regulatory framework. It was therefore suggested that it is the responsibility of the cities to counter-act these negative effects with municipal ordinances.

Melrose does achieve this goal to a certain extend (e.g. adopting Solarize Mass to its contextual resources, initiating Energy Sage). Nevertheless, municipal policies do not *react* to the *inconsistent* impact of state policies. In fact, some of them are similarly short-term (e.g. Solarize only lasts five months). Despite their well-intended goals, they *reinforce* rather than *counteract* the unfavorable outcome on a state level. The only exception are the 5 GC policies, which have a long-term effect on local projects. As mentioned above, however, they facilitate the *finale* of the process rather than its beginning (which faces the most serious obstacles, e.g. high upfront cost, etc). Therefore, the *complementary* character of Melrose's policies is considered a governmental *obstacle* that impedes the city from reaching its policy goals.

4.2. Social Outcome

4.2.1. Opportunity: Adopting policies to the socio-demographic profile of the town

The social goals of the solar policies is raising awareness, building a strong network of local stakeholders, and *democratizing* the production of energy. Similarly to Somerville and Medford, Melrose achieves this goal via the Solarize campaigns (see analysis for previous chapters).

The second goal is accomplished by *adopting local policies* to the socio-demographic context of the city. For example, the campaigns *mobilize* key NGOs and volunteers throughout the campaign. The agricultural NGOs, for example, ensure communication pathways with local farmers and customers of organic food stores (Melrose Patch, 2012). Although professionally they do not work in the PV industry, their participation in Solarize expands the outreach potential of the campaign.

Finally, Melrose policies are well *adapted* to their contextual resources. Namely, actors opt for 100% PPA's during Solarize (MassCEC, 2012a). It was a good strategy because stakeholders could capture the high urban potential of the town (high percentage of home-owners and detached units). Considering the expiring policies on a state level, 100% PPAs were also a good choice. In effect, Solarize Melrose had a higher output rate than Medford (425.6kW vs. 387.6 kW) (MassCEC, 2012a; MassCEC, 2014b). The ability to *adopt* a policy to the current *context* (social and financial factors) as well as the current problems (variability in state solar policies)- is the second *social opportunity*. Ultimately, it allows Melrose to fulfil the socio-political goal of solar policies.

4.2.2. Obstacle: limited duration of programs and limited stakeholder participation

The obstacle in Melrose is similar to those in Medford and Somerville. Namely, awareness campaigns are short-term and therefore they raise awareness and strengthen stakeholder networks for a limited amount of time. Finally, they rely on volunteers whose participation is similarly limited.

4.3. Financial Outcome

4.3.1. Opportunity: Embedding state financial incentives into the local regulatory structure

The *financial goal* is to ensure affordable solar panels and stimulate the local market via sustainable financial incentives. Much like Medford, Melrose achieves the first goal via Solarize Mass. Figure 11 shows that the program multiplies the solar capacity in Melrose, too. Specifically, solar capacity before the policies were implemented is quite low (graph in blue), however afterward it rises sharply (graph in red). Therefore, it testifies to the fact that there are interested residents as well as suitable houses. It is only a matter of designing a creative financing mechanism (e.g. Solarize), which could capture this potential and output a significant number of projects.

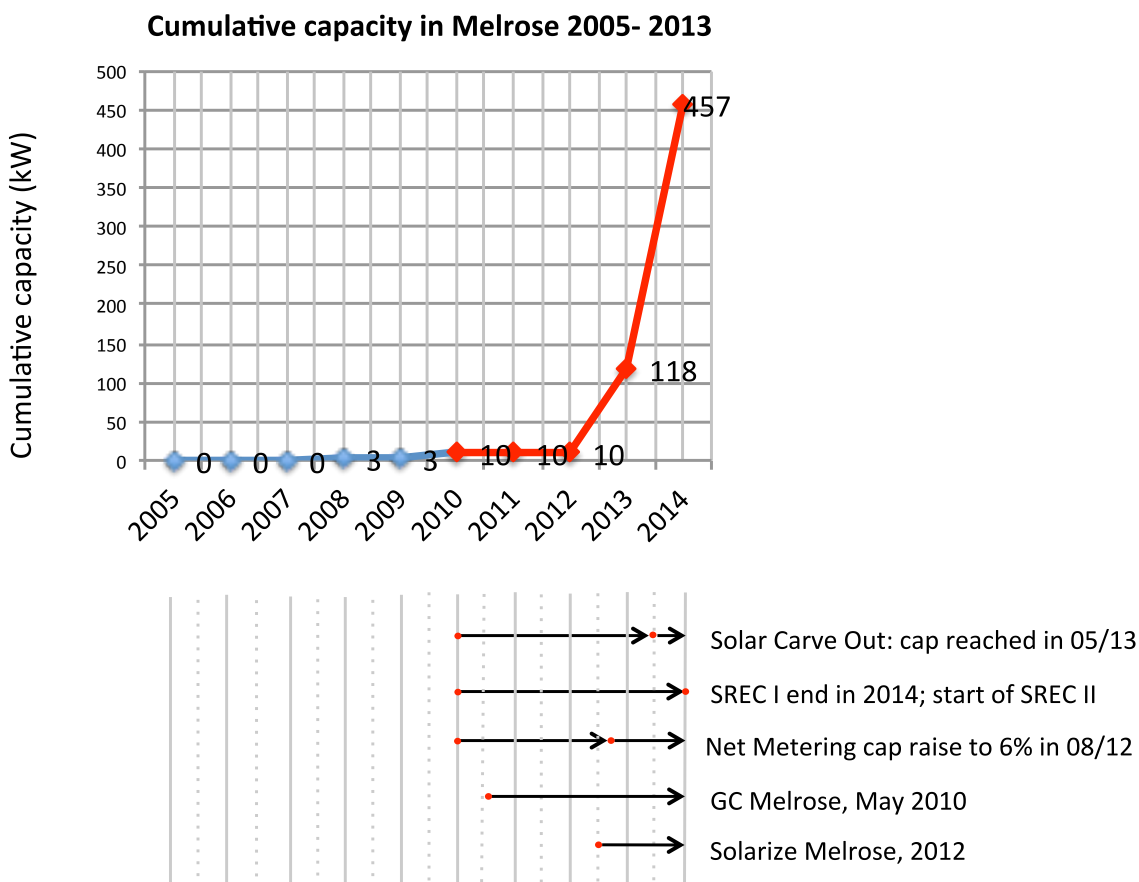


Figure 11: Timeline of policies and timeline of PV deployment in Melrose (graphs are constructed based on data from: DOER, 2014a; DOER, 2014d; DOER, 2014g; DOER, 2014i; MassCEC, 2012a; NREL, 2014; SREC Trade 2012)

The second goal is accomplished by successfully embedding its policies into the overarching state policy framework. Once again, Melrose exemplifies a *proactive* rather than *reactive* behaviour in this regard. Rather than reacting to Massachusetts policies, they actively pursue opportunities on a state level- e.g. applying for state grants (GC) and regional group-purchasing models (RSI). *Proactive* behaviour not only builds municipal *capacity* and fruitful experience with solar energy projects. It also shows that a creative policy format, such as Solarize Mass, is not a sufficient driving force for the PV industry. It also needs to innovatively establish relationships with already existing regulatory structures and business actors. Rather than *yielding* to the fragmented nature of US solar policies, Melrose builds bridges across its multiple segments and multiple *layers*. Finally, it ensures that collectively they construct a coherent solar framework.

The case study of Melrose proves that the PV sector faces a political rather than a technological challenge. Indeed, the obstacle is not a conflict of interests between two parties with opposing views (e.g. Republicans vs. Democrats; solar industry VS. fossil fuels). The conflict is between the *old* and the *new* governance systems. Actors have to therefore find new means of collaboration that re-defines the way they do their daily business. As mentioned above, Melrose is already home to some of these new modes of *networking across levels, space, time, and institutions*. Some examples are RSI, Energy Challenge, and Energy Sage- as well as the overarching policy framework that brings them together. Only after long-term and large-scale practice of these new patterns, however, would they be able to replace the old archetype (Smith, 2014; Pitt, 2008; Patwardhan, 2012).

4.3.2. Obstacle: Limited scope and duration

The financial obstacle is similar to that observed in the other case studies. Namely, Solarize is short-term and therefore it does not incentivize PV adoption in the subsequent months and years. Furthermore, residents who rent their home are not able to benefit from the program. Finally, only one company is hired for both campaigns (Energy Challenge and Solarize), therefore marginalizing other companies

Chapter 9: Comparison between Somerville, Medford, and Melrose

The following chapter compares solar energy policies in Somerville, Medford, and Melrose. It is divided into two sections: the first one compares the policy outputs *quantitatively* and the second one- *qualitatively*. The two approaches would then be combined in order to draw general conclusions about the case studies.

1. Quantitative comparison of the Policy Output of the three suburbs

Figure 1 shows the capacity of the three towns between 2005 and 2014 (2005 has been selected as a starting point because the first residential installation took place namely in that year). The arrows beneath the graph indicate the duration of the solar energy policies- on a state as well as local level. It is interesting to note that between 2005 and 2009 there is little deployment of solar photovoltaics. Similarly, no solar energy policies were found for this period either. The reason is likely the fact that the Republican Mitt Romney was a Governor during that time. With strong conservative believes, Republicans have rarely supported renewable energy legislation (Coley, 2012). Most of the state policies described in this thesis (SREC, Net Metering, Solar Carve Out) as well as local ones (Green Communities, Solarize Mass) took place after 2010. Aligning the graph with the arrows chronologically therefore shows a correlation between *policy input* (the laws/ programs themselves) and *policy output* (PV capacity installed). Indeed, the line grows gradually after 2010 and particularly steeper after 2012.

The timeline also shows that local policies are implemented approximately at the same time (2010-2014) in each of the three towns. The state policies also take effect simultaneously in all suburbs. The gradual rise in PV capacity after 2010, too, is observed simultaneously in all three towns. Therefore, the observation that Policy Input is correlated with Policy Output is confirmed by all three towns. As most scientific studies, however, *correlation* does not imply *causation*. Nevertheless, clean technology is strongly dependent on governmental subsidy in order to be competitive with fossil fuels on the energy market. Therefore, it is here assumed that the presence of state and local policies has directly influenced PV growth- as illustrated by the graph.

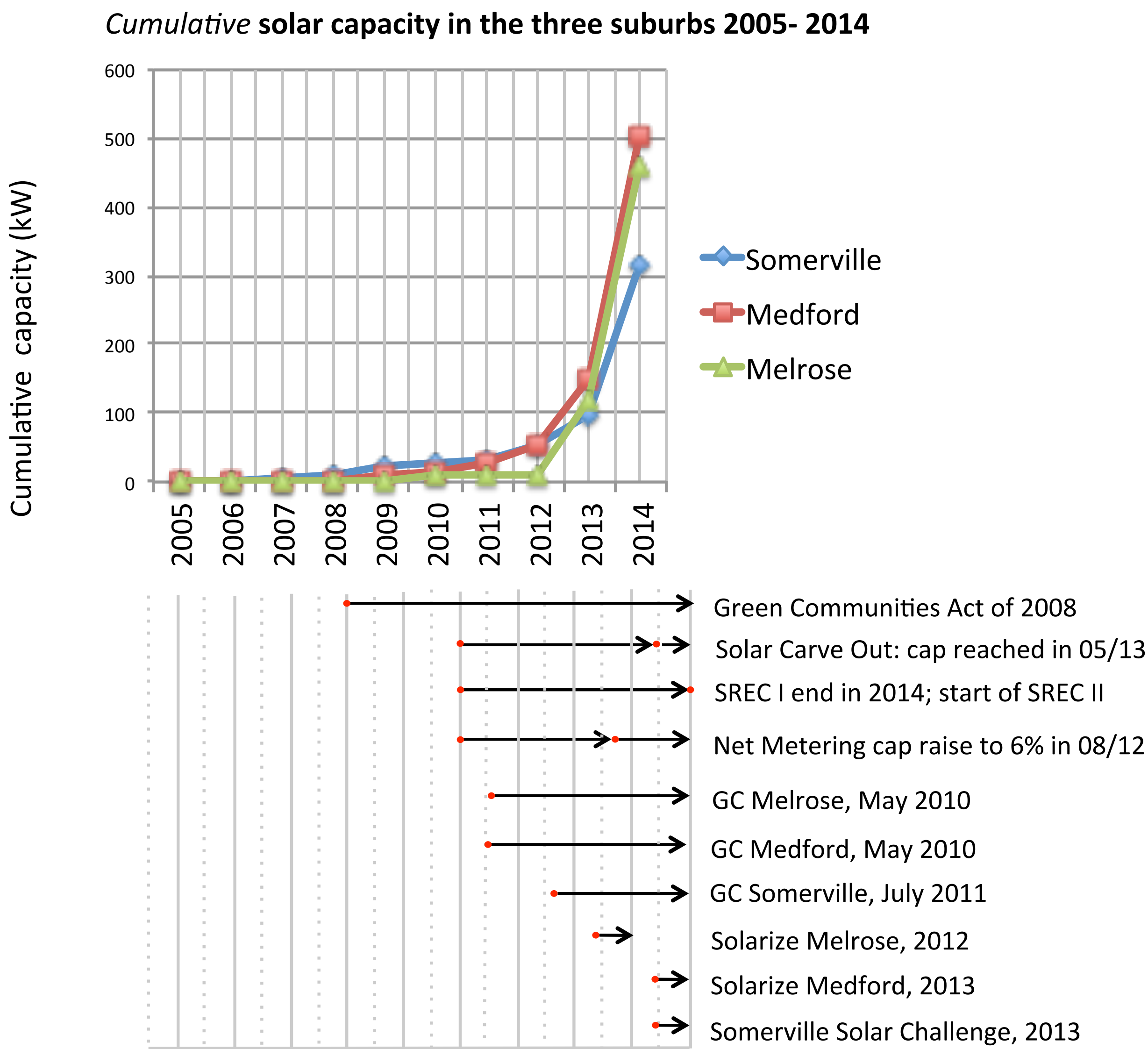


Figure 1: Comparing policy timelines with deployment timelines for Somerville, Medford, and Melrose (The timeline is constructed based on data from DOER, 2014a; DOER, 2014d; DOER, 2014g; DOER, 2014i; MassCEC, 2012a; MassCEC, 2014b; NREL, 2014; Somerville Solar, 2013; SREC Trade 2012)

Figure 2, on the other hand, compares the cumulative capacity of the towns. The first graph (blue bars) shows the capacity for the period 2005-2010. Namely, this is the period between the first residential installation in 2005 and 2010- when the first solar policy was implemented. The second graph (red bars) compares the three towns for the period between 2010 and 2014- after the policies took effect. Finally, the grey bars compare the towns throughout the

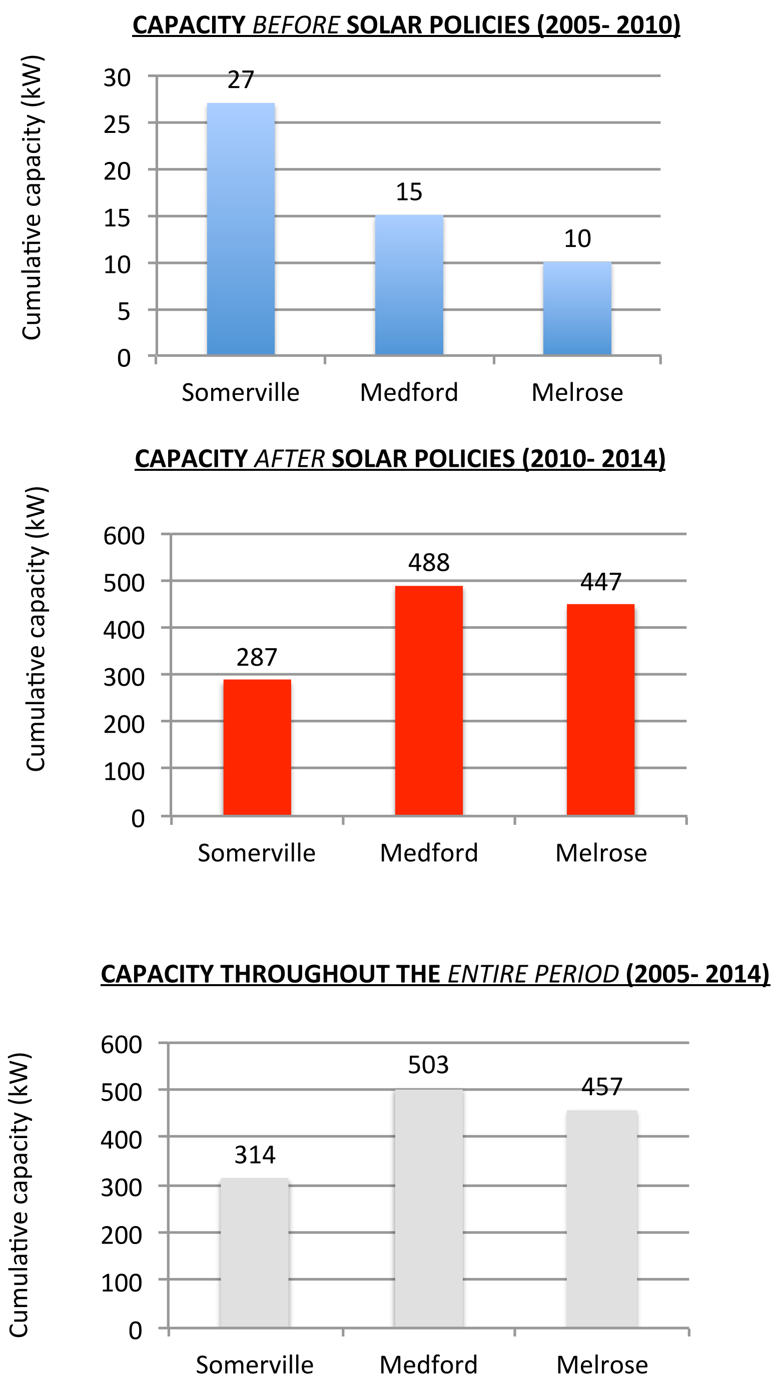


Figure 2: Comparing the capacity in the three towns: before the policies were implemented (blue bars), after they were implemented (red bars), and throughout the entire period (grey bars) (Calculations are based on data from DOER, 2014a; NREL, 2014).

entire period of 2005-2014. The figures show that before the policies were implemented, Somerville had the highest PV capacity and Melrose- the lowest. After 2010, however, Medford and Melrose took the lead and today Somerville ranks behind them. The same observation holds true for the entire period of 2005-2010 (DOER, 2014a; NREL, 2014).

Therefore, it could be concluded that the state and local solar energy policies (2010-2014) have had a much greater impact in Melrose and Medford than Somerville. Namely, the policies have increased the residential capacity in Melrose approximately 45.7 times; in Medford- about 33.5 times; and in Somerville- only 11.6 times. In order to explain the relatively similar success in Medford and Melrose- as well as the much weaker success in Somerville- the next section compares the policies *qualitatively*. It is believed that analyzing the Policy Output *qualitatively* would shed light on the *quantitative* output as well.

2. Qualitative comparison of the policy output of the three suburbs

Chapters 6, 7, and 8 analyzed the Policy Context, Input, Process, and Output in the three towns case studied in this thesis. The last section of each of the chapters, Policy Output, presented a list of local *obstacles* and *opportunities*. The goal of this section is to compare these *obstacles* and *opportunities*: (1) What are the common factors that have enabled or impeded the deployment of solar photovoltaics? (2) Do they have (dis)similar impact on each of the three towns? Why or why not? (3) Finally, the *qualitative* output of the three towns would be compared with the *quantitative* output already discussed in Section I.

Each of the three chapters ended with a diagram that categorizes obstacles and opportunities into *social, political, and economical*. In order to best compare them, the present section preserves the categorical structure of these chapters. Namely, it compares the most prominent policy factors according to their *social, political, and economic* criteria. Two main groups of opportunities have been classified into these three criteria: *external and internal*. *External* factors are pertinent to regional and state networks, policies, or funds. Alternatively, *internal* factors originate within the boundaries of the town itself (Pitt, 2010b). Tables 1 and 2 summarize the external and internal *opportunities* (column 3 of the tables) as well as the respective *obstacles* that they help overcome (column 2). Next, the tables describe how each of the suburbs has reacted to the *obstacles* and whether they have seized the *opportunities*. In effect, this section presents a total of six enabling and constraining factors, which have impacted solar deployment to the greatest extend.

2.1.External Policy Factors

Table 1 evaluates the ability of the suburbs to react to each of the three *external* policy factors. A town that has seized the *opportunity* is marked with one or more positive signs ("+"). Failure to do so is designated with one or more minuses ("-"). *Obstacles* and *opportunities* observed in this thesis are complex and they cannot be represented by a mere symbol. Nevertheless, the evaluation system simply aims to provide a coherent evaluation method across all six factors. Therefore, it would objectively compare the suburbs and rank their output qualitatively (In order to compare points received, pluses and minuses are summed up. One negative and one positive sign therefore cancel each other out).

2.1.1. Social opportunity: Participation in MAPC and MassCEC

The first obstacle is the limited administrative and technical capacity of small towns. With a staff of only a few people, municipal departments are unable to address all issues related to the environment, sustainability, and energy. The enabling factors, which have allowed suburbs to overcome this hurdle are the networks MAPC and MassCEC. Appendix E (graph 6) shows that it has been a key opportunity for about 80-90% of the survey participants. Chapters 6-8 observed, too, that these two organizations play a key role in facilitating the design and implementation of local solar projects and policies. MAPC, for example, provides technical support and assistance with clean energy ordinances as well as municipal purchasing models. MassCEC, on the other hand, specializes specifically in organizing Solarize Massachusetts throughout the five-month-long campaign. Both organizations constitute an important opportunity for solar growth: they offer financial and administrative resources, which are otherwise unavailable to small towns with a limited budget. Furthermore, they both present a platform where city hall officials collaborate with other local governments or private companies. Therefore, they share expertise, resources, and learn from each others' experience (MAPC, 2014a; MassCEC, 2014b).

While the ability to network with the above-mentioned stakeholders increases the regional character of a solar framework, its inability to do so fosters a rather localized governance model. Therefore, the former constitutes an opportunity and the latter- an obstacle. Somerville, Medford, and Melrose take advantage of this factor to a different extend. Medford, for example, uses MAPC's expertise in order to issue their municipal energy plan. Both Medford and Melrose, on

Table 1: Summary of *external* opportunities					
	Obstacle	**Opportunity**	**Somerville**	**Medford**	**Melrose**
Social opportunity	Limited administrative/ technical/ departmental resources of local governments	Collaboration with MassCEC and MAPC	-Does not collaborate with MAPC -Does not collaborate with MassCEC	-Collaborates with MAPC for energy plan -Collaborates with MAPC for RSI -Collaborates with MassCEC	-Collaborates with MAPC for RSI -Collaborates with MassCEC
Ranking			--	+++	++
Financial opportunity	High cost of implementing solar programs and policies, which are beyond the capacity of a small town	Funds from Green Communities (GC)	-Member of GC -Received GC fund for projects/ installations	-Member of GC -Received GC fund for projects/ installations	-Member of GC -Received GC fund for projects and a coordinator
Ranking			+	+	+
Political opportunity	Multiple state policies, which cumulatively have unfavorable, negative effects on a local level: inconsistency, uncertainty, complexity	Solarize Mass and Community Block Grant Fund to counteract negative effects of state policies	-Founding of GreenTown Labs -Solar Challenge initiated not via MassCEC	-Solarize Medford via MassCEC -No individual initiative like GreenTown Labs	-Emphasis of 100% PPAs -Solarize Melrose via MassCEC -No individual initiative like GreenTown Labs
Ranking			++	+-	+-
Total			+	++++	+++

the other hand, take part in the Regional Solar Initiative (organized by MAPC) and Solarize Mass (organized by MassCEC) (MAPC, 2014b; MassCEC, 2014b). Somerville, on the other hand, does not collaborate with MAPC and organized its Solar Challenge independently from MassCEC (Somerville Solar, 2013b). Its policies therefore attain a much more *localized* character, which limits its chance to tap onto valuable regional resources. Medford and Melrose, on the other hand, acquire a more *flexible* policy framework, which creates future *opportunities* as well. For example, they use their current membership in these *networks* as a starting point of subsequent *collaborations* and therefore maximize its value. An essential *opportunity*, it opens doors in an industry characterized primarily by *obstacles*. In effect, it contributes to a *decentralized* governance model, which aids small towns gain momentum in their solar energy efforts.

Table 1 evaluates and ranks Somerville, Medford, and Melrose according to criterion #1 (*social* factors). Somerville does not take advantage of either of the two initiatives and therefore it has been evaluated with two minuses. Medford collaborates with both organizations in order to execute three projects and therefore it receives three pluses. Finally, Melrose participates in both MassCEC and MAPC and hence- receives two positive points.

2.1.2. Financial opportunity: Applying for state funds from the Massachusetts Department of Energy: Green Communities and Community Block Grant Funds

The second *obstacle* is the high cost of solar energy projects and programs. Towns have been wary of investing too many funds into solar initiatives because of their relatively low output. Instead, it has been much more feasible to focus on energy efficiency rather than green energy. With small financial capacity, external funds are therefore key to the solar success of the towns. In addition to regional networks, state funds are therefore another *enabling* factor. The most prominent example of a state fund is the Green Communities. It acts as an *impetus*, which incentivizes towns to adopt five policies related to sustainability and renewable energy. In return, city halls gain access to state grants, which could be later spent on solar (or other) types of renewables (Commonwealth of Massachusetts Executive Office of Energy and Environmental Affairs, 2013).

All three towns are members of the Green Communities and all three have received funds from the state government. GC has therefore *mobilized* local officials in Somerville, Medford, and Melrose to prioritize renewable energy in their local ordinances. Without the state government, many of the green policies or solar installations would arguably not have happened. Considering only 123 of all 351 towns are GC members, all three case studies therefore exemplify *sustainability leadership* in this regard. Nevertheless, the city of Melrose applies the Massachusetts grants in the most *sustainable* manner. Namely, they invest the grant in the position of the Energy Efficiency Coordinator rather than a mere PV installation (DOER, 2014g). In effect, the GC grant bears fruits in the present as well as future. The GC funds in Medford and Somerville, on the other hand, have a much more limited impact as they affect only the project at hand (the Energy Efficiency Coordinator, however, could implement other projects in the future, too). Nevertheless, all three towns successfully activate a policy factor, which is merely a *dormant potential* in most other towns. Therefore all three suburbs are evaluated with one positive point in this category.

2.1.3. Political opportunity: Municipal ordinances to counteract the unfavorable effects of state policies

Despite their well-intended goals, the Massachusetts solar incentives cumulatively create an unfavorable policy environment. For example, they create an unpredictable and complex regulatory structure. It was therefore suggested that it is the responsibility of the local city hall to overcome this *obstacle* and counter-act the negative impact of the state policies. Somerville, Medford, and Melrose once again take advantage of this factor to a different degree. First of all, all three towns adopt Solarize Mass (Medford and Melrose) or the Solar Challenge (Somerville)– two important solar energy *opportunities*. The programs tackle two of the problems arising on a state level: inconsistent policy environment and high upfront cost. Solarize Mass counteracts the first one as it creates a streamlined and facilitated policy procedure; furthermore, its tiered pricing structure significantly reduces the cost of PV systems and hence- addresses the second *challenge*. Somerville, however, does not participate in Solarize Mass- instead, they organize their own Solar Challenge independently from the state. Nevertheless, the goals of the program are the same and hence- it targets the same *obstacles* created by state-level policies.

The three towns differ in some respects though. Somerville, for example, invests the CBGF fund in GreenTown Labs (City of Somerville, 2013). The clean-tech incubator arguably has the most long-lasting and far-reaching effect among all suburban policies. Namely, it creates many jobs, boosts the economy, and increases public awareness of green technologies. Unlike

Solarize Melrose and Solarize Medford (which terminate five months after their inception), GreenTown Labs will likely stay in business for years to come. Therefore, it will be able to offset negative externalities of state-level policies for a longer period of time.

The last difference is Melrose's clear emphasis on PPA's during Solarize. Unlike most other towns where PPAs constitute only a portion of all contracts, Melrose invests 100% in leasing contracts (MassCEC, 2012a). The strategy was successful on a local level as it had higher output rate than Solarize Medford and the Somerville Solar Challenge. It was successful on a state level, too, as the Net Metering policy reached its cap of 3% at approximately the same time in 2012 (SREC Trade, 2012). The Somerville Solar Challenge and Solarize Medford in 2013, on the other hand, coincided with the fulfillment of the Solar Carve-Out goal of 250 MW (DOER, 2014d). The town, however, did not implement any measures to counteract this effect. Therefore, the policies in Melrose interfered more favorably with state programs than those in Medford and Somerville.

Finally, all three towns receive one positive point for organizing a Solarize program. Somerville, however, stands out as it founds GreenTown Labs- an unusual undertaking for a small town. While it is awarded an additional mark for this achievement, the other two towns receive a minus. The reason is that they do not organize any similar ordinances, programs, or policies independently form the state (Solarize Mass is funded and organized by the state government and MassCEC).

Table 1 summarizes the rankings according to the criteria "external policy factors." Namely, Somerville, has one positive mark; Medford- four; and Melrose- three. Indeed, Medford and Melrose are much more active in regional and state initiatives. Their participation builds a *strong network, good partnerships, and a much more decentralized and horizontal governance model*. Somerville, on the other hand, pursues similar efforts, however, they choose to do so independently and locally. In effect, they are unable to transform the traditional energy governance model as the other two towns. Their transition towards an innovative energy future will likely be slower than that in Medford and Melrose, too.

2.2 Internal Policy Factors

2.2.1. Social opportunity: Addressing demographic/urban opportunities and challenges from the context

Suburbs are characterized by a set of demographic and urban features, which are described in the Policy Context section of each chapter (Figures 3 and 4). Policies that adapt to the local social/urban fabric allow towns to achieve greater solar success than others. Although it constitutes a valuable *opportunity*, failure to seize it has been an *obstacle*- and a likely reason for lower rates of PV adoption.

Some of the local policies in Somerville, for example, address key features of its context. For example, it has (1) the highest unemployment rate and (2) the highest percentage of Democrats. GreenTown Labs and the Solar Challenge effectively address the *obstacle* (#1 high unemployment rate) and utilize the *opportunity* (#2 high percentage of

1. Policy Context → 2. Policy Input → 3. Policy Process → 4. Policy Output

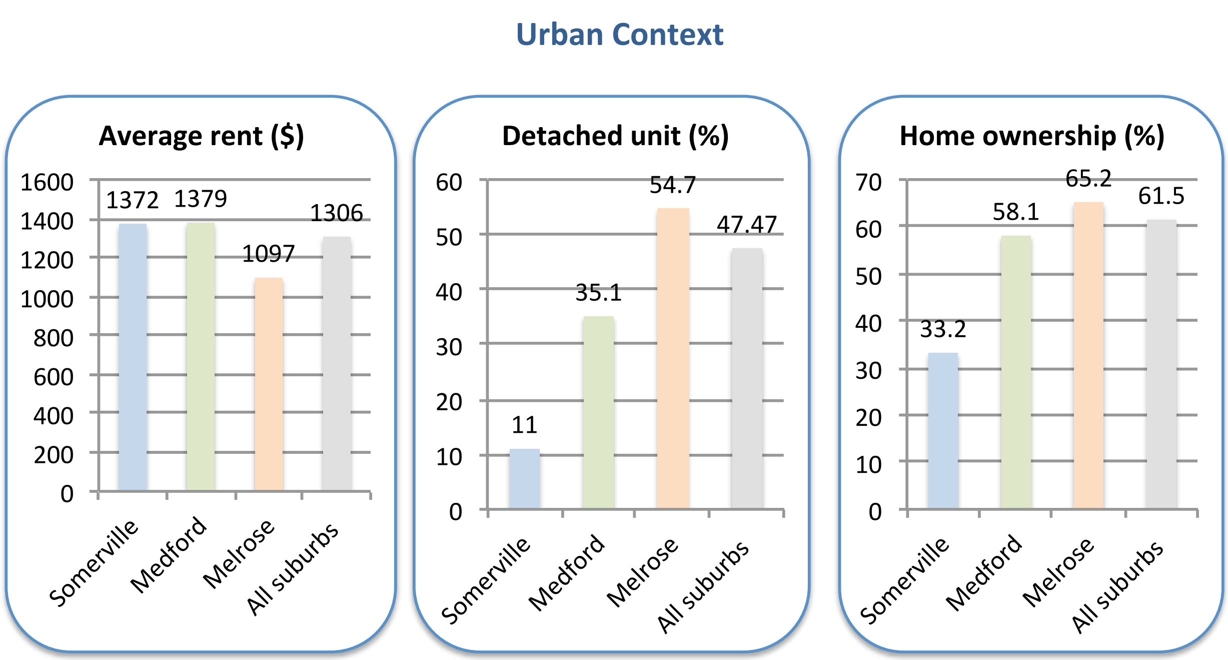


Figure 3: Urban context in the three towns (US Census Bureau, 2014).

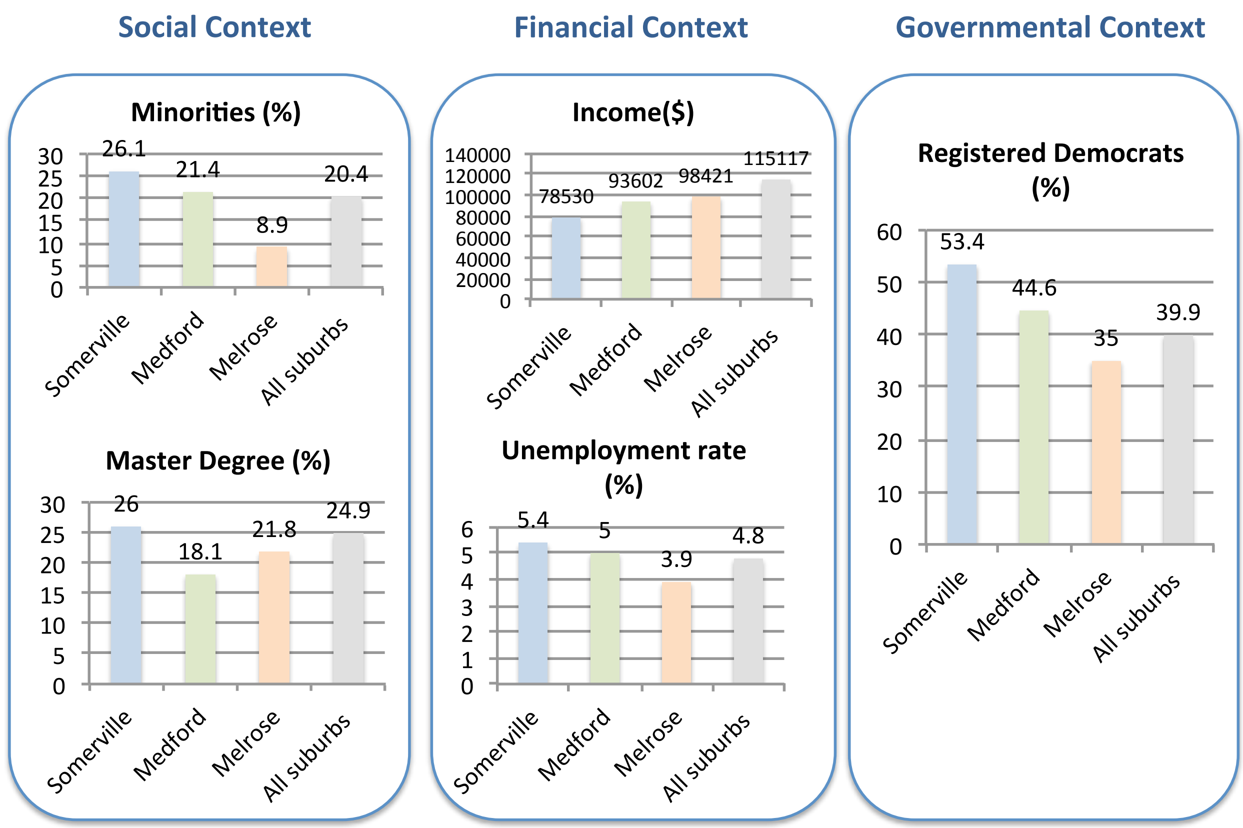


Figure 4: Demographic context of the three towns (Boston, 2012; US Census Bureau, 2014)

Democrats). Medford and Melrose, however, do not implement measures that directly or indirectly optimize their respective contextual resources. For example, none of the three towns addresses the issues of home ownership, average income, or density. Yet these are the most prominent factors for PV deployment, which are quite favorable in these two towns. It is therefore expected that they would maximize their potential in future programs. Considering the lack of initiative on the part of the latter two towns, they are assigned a negative point (see Table 2). Somerville, on the other hand, is evaluated with a positive sign "+."

2.2.2. Financial opportunity: financial programs that tackle the unequal cost-benefit distribution across towns as well as the high upfront cost of the panels.

Chapters 6-8 showed that the average household income increases as a town is located further away from Boston. Similarly, percentage of detached units and homeowners also increase in the same direction. Comparing the three towns, it is therefore evident that Melrose is more favorably situated than Somerville. Its residents have better opportunity to install solar PVs by virtue of being residents of this particular city. This fact, however, raises an important dilemma. Namely, the very families who need the financial benefits of solar PV (lower-income ones) are precluded from it for the benefit of wealthier ones. The *unfair distribution of benefits (favorable housing features)* is yet another *obstacle*, which should have been addressed by a program such as the Solar Challenge. It is further exacerbated by the fact that most residents cannot afford the high upfront cost of PV systems. Melrose's strategy to invest 100% of its contracts in PPAs, however, has *enabled* its residents to overcome these barriers. Nevertheless, this tactic better suits Somerville's needs than Melrose's (with a much higher income and more detached units, residents in Melrose do not benefit from it as much as those in Somerville would have). Therefore, the former (Somerville) has not been able to seize this window of *opportunity*.

Finally, *environmental costs* are also unequally distributed across towns. Namely, air quality is much poorer in densely populated areas with limited open spaces and green parks. Therefore, cities like Somerville arguably have a stronger right to clean-tech tools, such as PVs. The green technologies could help them offset the negative effect of their urban (rather than suburban) character. The three towns, however, have not addressed this *obstacle*. Practical means of dealing with the *unequal distribution of costs and benefits* (municipal loan and lease programs) will be later described in the Recommendations section.

High upfront cots and unequal cost-benefit distribution are some of the main *obstacles* to PV deployment. None of the three towns, however, has addressed this fact by a municipal loan or low-cost program. Therefore, Somerville and Medford are assigned a negative point "-" and Melrose- a positive one (due to its successful strategy with PPAs during Solarize).

Table 2: Summary of *internal* opportunities

	Obstacles	Opportunities	Somerville	Medford	Melrose
Social opportunity	Socio-demographic and urban/housing obstacles form the context of each town	Municipal programs or projects that utilize unique resources and tackle local challenges	-Addresses high unemployment rate, high % Democrats, high % educated population with GreenTown Labs	-Does not take advantage of favorable demographic profile	-Does not take advantage of favorable demographic profile
Ranking			+	-	-
Financial opportunity	Unequal cost-benefit distribution across towns; high upfront cost of solar PVs	Municipal loans and leases for solar panels; partnerships with financial actors/banks	None	None	-100% emphasis on PPAs
Ranking			-	-	+
Political opportunity	The old regime: vertical, centralized, rigid regulatory structure that limits actor participation in the decision-making process	Re-mobilizing and collaborating with local businesses, organizations, and volunteers to ensure a horizontal, decentralized, interdisciplinary, and flexible governance	-Mobilizing volunteers for the committee and volunteers during the Solar Challenge -GreenTown Labs -Using only one company for the Challenge	-Mobilizing volunteers for the committee and volunteers during Solarize -Using only one company during Solarize	-Mobilizing volunteers for the committee/ Solarize -Resorting to old partners throughout the policy process -Using only one company during Solarize
Ranking			++-	+-	++-
Total			++-	--	++-
FINAL			++	++	++++

2.2.3. Political opportunity: Re-mobilizing local partners and connections- committees, companies, NGOs, and volunteers- in order to ensure sustainable policy development

The last *constraint* is the old regulatory structure itself. It is predominantly *vertical, centralized, and un-flexible*. Towns that are still confined to this old regime have been unable to develop policies and install projects. The reason is that solar energy goals are not integrated into current municipal ordinances; means for realizing these goals, on the other hand, lie outside the capacity of the town hall. Furthermore, the current policy model limits key actors from participating in the solar market. Namely, these are the very residents who would later purchase the system. In order to accelerate PV adoption, suburbs should therefore *transform* the old regime to a much more *flexible, decentralized, and horizontal* model. In effect, they will be able to activate resources and build partnerships that fill the gap between the old regime and future goals.

Suburbs can overcome this *hurdle* by activating their institutional potential. Each town is home to various NGOs, businesses, and environmentally conscious residents. Cumulatively, they build the social fabric of the city, which can favorably (or unfavorably) predispose the deployment of PV systems. The ability to utilize these resources and re-mobilize them repeatedly over time is an important *opportunity*. It has allowed many towns to design and implement programs, which city hall staff has been unable to organize independently. Finally, it has created a much more *participatory* governance model where volunteers have *access* to the decision-making process (e.g. both energy committees and Solarize are driven by volunteers).

All three towns have seized this opportunity by forming a commission on energy or climate change. Members of the committees are volunteer residents who have been appointed by the mayor to work specifically on energy-related projects. The Departments of Environment/Sustainability have also played an important role, however, they are usually responsible for a wide range of issues: water management, recycling, etc. Therefore it has been difficult for solar energy to rise on the political agenda. Appendix E/ graph 5, for example, shows that in 91% of the cases, other issues take priority. A committee exclusively dedicated to energy matters alone, on the other hand, has been able to output a much more comprehensive body of work related to solar energy. Its members have proved to be key actors in various renewable energy projects, programs, and campaigns over the years. For example, they are the ones who apply for a Green Community status as well as Solarize Mass. In effect, they have been able to learn from past experiences, re-mobilize partner NGOs, recruit local volunteers, and strengthen existing network connections. In effect, committee members have built expertise and knowledge of the PV environment typical for their particular town. Cities where committees have chosen to specialize in different areas of public life, however, would likely lack the ability to tackle solar energy problems in their town (City of Somerville, 2014b; Energy Commission, 2014a; Medford Energy, 2014).

Finally, volunteers from the committees and Solarize have been an important *enabling* factor due to the '*interdisciplinary'* nature of their work. Drawn from various sectors and industries (solar engineering, academia, business, marketing), they have been able to tackle PV *obstacles* from multiple angles (City of Somerville, 2014b; Energy Commission, 2014a; Medford Energy, 2014). In effect, they have aided the *transition* from a much more mono-departmental energy governance (where one municipal department is responsible for all energy matters) to a much more diverse and *flexible* model.

Two towns where this *opportunity* is seized to the greatest extend are Somerville and Melrose. The city hall of Somerville, for example, helped found GreenTown Labs (City of Somerville, 2013). The clean-tech incubator raises public awareness of sustainability, stimulates acceptance of green technologies, and creates renewable energy jobs. Any subsequent solar energy programs of the committee (such as the Solar Challenge) are hence built on a firm foundation and increase the *resiliency* of the overall policy framework. A similar pattern was observed in the city of Melrose, too. Namely, city hall officials were resorting to old partners and network connections in order to optimize the little resources a small town has. In effect, they achieved the highest deployment rate throughout Solarize Mass. Finally, Melrose has resorted to MAPC in their past (RSI) and current (Energy Sage) solar initiative, too (MAPC, 2013a; Timmermann, 2014). A collaborative effort that maximizes lessons learned from RSI and the Energy Challenge, it shows *consistent* sustainability leadership on a municipal scale.

Undeniably, all three towns have activated and collaborated with a large number of local partners. In order to attain a truly *sustainable policy development* over time, however, city hall officials should not consider their policy actions in isolation. Instead, they should place them in the wider context of other actors and their circumstances. All three Solarize programs, for example, use only one vendor for PV installations during Solarize (MassCEC, 2014b; Somerville Solar, 2013b). Although it is a strategy that builds a strong partnership, it creates bias towards a particular solar company (NextStep Living and SunBug). In effect, it marginalizes other companies and limits their competitiveness on the energy market. This consequence is further magnified in Melrose where they hire the same company in two consecutive campaigns (Energy Challenge and Solarize Melrose) (Energy Commission, 2014b; MassCEC, 2012). Therefore, the potentially negative effect of the above-mentioned bias is here further amplified.

Each of the towns is awarded a positive sign for the work of their committee. Similarly, all three towns receive a negative point for their strategy regarding PV vendors. Somerville and Melrose stand out with their individual partnerships in organizing GreenTown Labs and Energy Sage, respectively. Therefore, they are awarded an additional point. All points are then summed up in Table 2. Somerville and Melrose are evaluated with two positive points and Medford- with two negative. Calculations of the total number of points for both *internal* and *external* policy factors are shown in the last row of the table. Namely, Somerville and Medford finish with two points and Melrose- with four. Indeed, the municipal policies in Melrose are much better *adapted* to their local context and local actors. Finally, they are *well-integrated* amongst each other and reinforce- rather than impede- their cumulative effect.

The *qualitative* analysis of *external* opportunities therefore shows both Melrose and Medford as the solar energy leaders. The analysis of *internal* opportunities, on the other hand, shows that Melrose and Somerville have the highest number of points. Finally, the *quantitative* analysis in Section II, shows that Medford and Melrose have more PV panels than Somerville. Therefore, the *qualitative* comparison of *external* opportunities confirms the *quantitative* comparison (where Medford and Melrose are the two leaders). This conclusion is in line with previous observations regarding the new and the old governance model. Namely, the policy potential of small towns lies outside of their immediate boundaries: it originates in continuous collaboration with regional partners and active participation in state programs. Therefore, the quantitative comparison is confirmed by the qualitative.

It should be noted that the analysis does not reject the importance of *internal* factors. On the contrary, they are an essential factor that allows towns to seize *external* opportunities. The reason they do not translate into high PV capacity is the nature of their impact. Committees, for example (internal opportunity), are the driver of most *external* programs. The committee itself, however, does not install panels. It is merely the trigger of future initiatives. Therefore, both *internal and external* factors should be maximized in the policy portfolio of a municipality.

Chapter 10: Quantitative comparison of all 31 towns in the Boston area

The comparative analysis in Chapter 9 is based on data collected for three case studies only. Therefore, *obstacles* and *opportunities* here described pertain to Somerville, Medford, and Melrose alone. Towns located in the suburban Boston area, however, have many features in common, which set them apart from other towns in the state of Massachusetts. For example, suburban residents are typically employees in the Boston area- an industrialized region with high concentration of Information Technology companies, clean-tech start-ups, diverse college campuses, and dynamic finance district. Unlike the predominantly rural Massachusetts, suburban residents usually represent white-collar employees of the urban center (MassCEC, 2013a; USDA, 2014). For the purposes of this thesis, the three case studies are samples of the entire pool of 31 towns. In order to generalize conclusions later drawn from these three towns to the other 29 suburbs, however, further analysis is needed. Namely, the data, which provides the basis of the thesis so far, should be extrapolated to the entire suburban region.

Three main sets of data have been analysed via the theoretical framework (See Figure 1): (1) Contextual data regarding the demographics and urban features of a town; (2) Geographical data rearding the location of a town; and (3) Policy data regarding specific ordinances, networks, and bylaws implemented in each town. In order to generalize findings from the three suburbs to the rest of the towns, information from each of the three categories has been collected for the other 29 suburbs as well. Then, it has been analyzed with the respective software tools (1) StatPlus, (2) Esri GeoCommons, and (3) StatKey. Each of the three programs has been used to compare the 31 towns quantitatively. Specifically, the softwares analyze: (1) The impact of 13 demographic/urban features on PV capacity in each town; (2) The impact of geographic location on PV capacity in each town; (3) The impact of 4 policy types on PV capacity in each town (The exact methodology for each of the three steps is described in Chapter 4). In order to ensure a parallel research design and consistent methodology for all three analytical studies, the following parameters have been chosen for each of them:

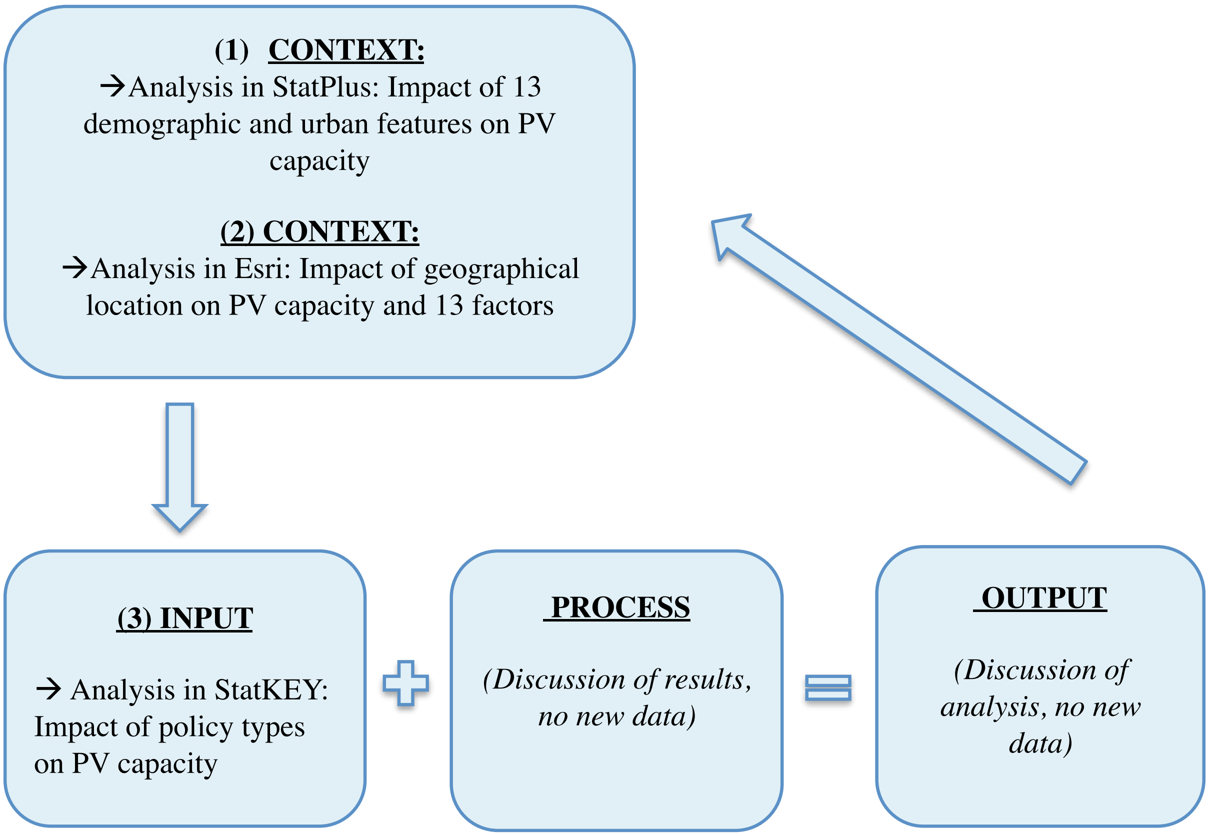


Figure 1: Overview of quantitative analysis of 31 suburbs

~Cumulative PV capacity installed for residential projects only (commercial projects have been excluded);

~The same set of 31 towns in the Boston area;

~Capacity installed for three periods of time: (1) 2005- 2010; (2) 2010- 2014; and (3) 2005-2014. The three periods of time are chosen in order to compare the impact of the independent variables on PV output *before* and *after* the policies were implemented. Finally, performing three tests gives a better indication about the strength of the correlation between the independent and dependent variables (i.e. even if there is dependency between the variables in 2005-2010, it might be due to chance; repeating the test for 2010-2014 and 2005-2010, however, eliminates chance results). That is why all three tests are perferomed three times: once for each period of time).

1. Policy Context Data (1)

Test 1: Using StatPlus to analyze the impact *of demographic and urban data* on PV output

Table 1: Using StatPlus to analyze the impact of demographic and urban data on PV output (*Calculations based on data from: Boston, 2012; DOER, 2014a; NREL, 2014; US Census Bureau, 2014*)

	city	PV in kW (05-10)	PV in kW (10-14)	PV in kW (05-14)	Black	Asian	Rent 35%> income	% democrats	% white
1	**Arlington**	55	1156	1211	2.4	8.3	29.8	46.6	85.7
2	**Belmont**	3	71	74	1.8	11.1	30.6	36.1	83.5
3	**Boston**	2500	2469	4969	53.9	24.4	12	54.7	53.9
4	**Brookline**	3	344	347	3.4	15.6	44.1	48.3	76.7
5	**Burlington**	17	448	465	3.3	13.4	37.4	29.8	80.8
6	**Cambridge**	214	650	864	11.7	15.1	38.8	57.9	66.6
7	**Canton**	15	189	204	6.3	6.1	33.1	33	84.8
8	**Chelsea**	13	166	179	8.5	3.1	47.3	53.4	47.8
9	**Dedham**	21	230	251	5.4	2.6	43.7	35.8	88.4
10	**Everett**	4	229	233	14.3	4.8	45.7	50.6	62.8
11	**Lexington**	77	725	802	1.5	19.9	43.4	38.7	75.5
12	**Lynnfield**	0	6	6	0.5	3.3	30.9	20.9	94.7
13	**Malden**	6	101	107	14.8	20.1	41.7	44.4	56.7
14	**Medford**	15	488	503	8.8	6.9	31.8	44.6	78.6
15	**Melrose**	10	447	457	2.4	3.8	29.3	35	91.1
16	**Milton**	17	211	228	14.3	4.1	39.8	45.4	77.4
17	**Needham**	22	426	448	1	6.1	38.4	33.7	90.8
18	**Newton**	11	860	871	2.5	11.5	35.6	45.3	82.3
19	**Norwood**	0	5	5	5.2	5.9	25.1	34.3	85.1
20	**Quincy**	65	270	335	4.6	24	37.1	41.2	67.3
21	**Revere**	44	400	444	12.6	4.8	52.9	47.8	74.1
22	**Somerville**	27	287	314	6.8	8.7	34.7	53.4	73.9
23	**Stoneham**	16	691	707	1.8	3.4	46.1	32.8	92.2
24	**Wakefied**	0	21	21	0.9	2.6	28.8	30.5	94.5
25	**Waltham**	93	445	538	6	9.7	37.8	35.2	75.4
26	**Watertown**	39	108	147	3	7.2	25.2	44.3	84.9
27	**Wellesley**	0	44	44	2	9.8	30.5	29.6	85.1
28	**Westwood**	40	257	297	0.9	5	60.5	26.3	92.7
29	**Wincheter**	10	528	538	1	9.3	46	29.9	87.1
30	**Winthrop**	5	99	104	2	1.2	42.8	40.7	91.8

31	Woburn	60	1366	1426	4.2	7.3	36.3	35.8	84.2
	City	Home owner	Detached	Unempl.	MS	BS	Income	Rent ($)	Latinos
1	Arlington	60.3	43	4.1	35.5	28.8	109,102	1324	3.3
2	Belmont	62.8	45.1	3.3	43.1	27.2	144,678	1606	3
3	Boston	34.2	12	7	23.9	17.5	79,538	19.5	8.9
4	Brookline	49.4	18.3	3.7	59	28.9	146,859	1756	5
5	Burlington	71.2	69.6	5.7	20.3	27.1	106,310	1599	2.4
6	Cambridge	36.1	9.3	3.7	26	27.3	109,212	1372	7.6
7	Canton	75.2	62.8	4.6	19.5	30	113,336	1338	2.8
8	Chelsea	29.8	9.3	8	5.9	7.8	56,264	1121	62.1
9	Dedham	73.2	66.8	4.5	18.5	26.9	195,470	1432	5.5
10	Everett	40.8	19.4	6.5	4.2	11.6	64,196	1164	21.1
11	Lexington	82.1	78.5	3.2	50.1	27	191,350	1898	2.3
12	Lynnfield	88.9	87.1	2.7	18.9	28.1	128,354	1206	1.7
13	Malden	43.3	26.5	8.5	12.9	18.2	67,686	1211	8.4
14	Medford	58.1	35.1	5	18.1	25.1	84,331	1379	4.4
15	Melrose	65.2	54.7	3.9	21.8	29.6	98,421	1097	2.5
16	Milton	83.4	82.8	4.2	28	31.4	110,506	1220	3.3
17	Needham	83.5	76.6	3.7	39.9	32.6	167,852	1433	2.1
18	Newton	69.8	53.7	3.3	47.8	27.2	161,881	1632	4.1
19	Norwood	58.5	46.4	4	15	26.2	89,011	1211	4.3
20	Quincy	49.4	33.6	6.6	13.4	24.2	74,616	1178	4.1
21	Revere	50.5	30	6.9	4.4	12.2.	63,345	1186	8.5
22	Somerville	33.2	11	5.4	26	27.3	78,530	1372	10.6
23	Stoneham	69.1	57.5	5	14.1	24	91,354	1204	3
24	Wakefied	77	63.3	5.2	15.4	28.7	100,055	1153	2.3
25	Waltham	48.4	38.1	3.5	20.2	26.3	87,915	1327	13.7
26	Watertown	52.3	23.1	4.9	25.1	30.6	96,956	1420	5.3
27	Wellesley	83	80.4	3.5	48.4	32.4	231,669	1431	3.6
28	Westwood	88	83.6	3.6	32.6	35.6	169,897	1278	1.6
29	Wincheter	83.4	69.5	3.6	40.2	30.1	181,124	1393	1.9
30	Winthrop	56.1	33.6	5.7	10.6	23.2	85,255	1272	6.1
31	Woburn	60.9	50.9	5.5	12.2	20.3	83,565	1240	4.5

Table 1 summarizes demographic and urban data collected for all 31 towns. StatPlus was then used to examine its impact on PV deployment. The results of the analysis are summarized in Tables 2-5. Table 2 shows the correlation coefficients for each of the 13 variables for the period between 2005 and 2010. Tables 3 and 4 then show the same correlation coefficients for the periods 2010- 2014 and 2005- 2014. Finally, Table 5 summarizes the cumulative effect of all 13 variables on PV output during each of the three periods.

As shown in Table 2, four variables have had the greatest impact on PV output between 2005 and 2010: percent of African-Americans, Asians, Whites, and Latinos. They all have p-values considerably less than 5% (0.00006, 0.00037, 0.00134, and 0.00048). Therefore, the probability that the outcome of the test is due to chance is very small and the test rejects the null hypothesis. The rest of the variables do not reject the null hypothesis and their p-values are much higher.

A similar outcome was observed for the periods of 2010-2014 (Figure 3) and 2005-2014 (Figure 4). The same four variables have the highest impact on PV deployment. Again, they all have small p-values. The only difference is the variable of percent of Democrats during 2010-2014. It has a small p-value and rejects the null hypothesis. This finding could be explained by the fact that political affiliation has traditionally been correlated with both environmental consciousness and income. Once again, however, the rest of the variables do not reject the null hypothesis.

The cumulative effect of all 13 variables on PV capacity is summarized in Table 5. R squared for the period (2005-2010) is 99.7%; during (2010-2014) it is 95.6% and during (2005-2014)- 98.3%. Therefore, the combination of all 13 variables explains respectively 99.7%, 95.6% and 98.3% of all data sets. Taking into account the number of variables tested, adjusted R-squared is considered next. Once again, the values are quite high- 99%%, 86% and 94.7%. With a p-value close to zero for all three tests, it could be concluded that the demographic and urban features of the 31 towns have a very strong effect on the deployment rate of PV systems.

Although the R-values are very high for the combined test, they are significantly lower for the individual tests. Tables 2-4 list them for each of the 13 independent variables. Except for "percentage of African-Americans," all variables have an R-value below 50% and p-value above 5%- for all three time periods. Therefore, it could be concluded that a single variable cannot

Table 2: Coefficient values for individual variables (2005-2010)

		Individual test		Group test			
#	**Independent variable**	**R**	**p-level**	**St. Error**	**t Stat**	**p-level**	**H0 (5%) rejected?**
1	**Black**	0.90006	0 (5.6E-12)	6.04449	9.86385	0.00006	**Yes**
2	**Asian**	0.48164	0.00608	8.43598	7.16918	0.00037	**Yes**
3	**Rent 35%>income**	0.49362	0.00477	4.63489	0.08842	0.93242	No
4	**Democrats**	0.33155	0.06844	4.26259	1.56517	0.16858	No
5	**White**	0.41323	0.02086	9.79165	5.63376	0.00134	**Yes**
6	**Home owner**	0.31806	0.08121	6.84908	0.09432	0.92792	No
7	**Detached**	0.29116	0.11203	4.1052	0.09177	0.92987	No
8	**Unemployment**	0.26218	0.15421	19.87033	-1.77434	0.12636	No
9	**MS**	0.01182	0.94968	2.42184	-1.09446	0.31573	No
10	**BS**	0.26725	0.25466	5.85188	-1.10111	0.31305	No
11	**Income**	0.15221	0.41368	0.00098	-0.39722	0.70495	No
12	**Rent**	0.77546	0 (3E-7)	0.13197	0.21709	0.83533	No
13	**Latino**	0.02948	0.87493	4.75985	6.84997	0.00048	**Yes**

Table 3: Coefficient values for individual variables (2010-2014)

		Individual test		Group test			
#	**Independent variable**	**R**	**p-level**	**St. Error**	**t Stat**	**p-level**	**H0 (5%) rejected?**
1	**Black**	0.64438	0.00007	23.45723	2.73577	0.03393	**Yes**
2	**Asian**	0.44043	0.01164	32.738	3.82757	0.00868	**Yes**
3	**Rent 35%>income**	0.33526	0.06069	17.98691	-0.22404	0.83016	No
4	**Democrats**	0.33095	0.06429	16.54208	4.92123	0.00265	**Yes**
5	**White**	0.2691	0.13641	37.99905	3.76164	0.00938	**Yes**
6	**Home owner**	0.22357	0.21869	26.57965	0.18464	0.85959	No
7	**Detached**	0.20448	0.2616	15.93129	0.74728	0.48314	No
8	**Unemployment**	0.11969	0.51409	77.11197	0.84055	0.43281	No
9	**MS**	0.10263	0.57621	9.39857	-0.71448	0.50177	No
10	**BS**	0.10077	0.67249	22.70973	-1.98324	0.0946	No
11	**Income**	0.10051	0.58416	0.00379	-1.15997	0.29013	No
12	**Rent**	0.09868	0.59739	0.51214	1.18433	0.28107	No
13	**Latino**	0.06791	0.7119	18.47185	3.12331	0.0205	**Yes**

Table 4: Coefficient values for individual variables (2005-2014)

		Individual test		Group test			
#	Independent variable	R	p-level	St. Error	t Stat	p-level	H0 (5%) rejected?
1	Black	0.81138	3.00E-08	27.99219	4.4225	0.00446	Yes
2	Asian	0.48769	0.00003	0.61115	1.03934	0.33871	No
3	Rent 35%>income	0.43483	0.00539	39.06721	4.75555	0.00314	Yes
4	Democrats	0.35202	0.0145	21.4643	-0.16865	0.87161	No
5	White	0.3578	0.05212	19.74014	4.46192	0.00427	Yes
6	Home owner	0.28552	0.04812	45.34537	4.36875	0.00473	Yes
7	Detached	0.26048	0.11947	31.71826	0.17509	0.86677	No
8	Unemployment	0.19919	0.15699	19.01126	0.64603	0.54217	No
9	MS	0.0516	0.2827	92.01995	0.32123	0.75893	No
10	BS	0.1906	0.78279	11.21559	-0.83506	0.43566	No
11	Income	0.13276	0.42086	27.10018	-1.89971	0.10621	No
12	Rent	0.67362	0.47649	0.00452	-1.05782	0.33086	No
13	Latino	0.02348	0.90023	22.04299	4.09645	0.00638	Yes

Table 5: Coefficients for all variables combined

	2005-2010	2010-2014	2005-2014
R	0.99854	0.97788	0.99159
R-square	0.99709	0.95624	0.98325
Adjusted R square	0.99078	0.86143	0.94697
S	53.25127	206.65534	246.60782
p-level	1.70E-06	0.00482	0.0003

explain the entire PV output on its own. This finding, however, does not mean that policy-makers should discount these contextual features. Instead, they should consider the entire group of factors in their totality. The reason is that almost 100% of all PV output is correlated to these 13 factors with a margin of error of almost 0%. Therefore, providing policies that optimize as many of the contextual variables as possible maximizes the effect of the solar policies in the future.

This observation is confirmed by the fact that variables change values in a particular direction across towns: e.g. towns that have higher populations of African-Americans usually tend to have lower incomes and higher unemployment rates. An example of two contrasting towns are Lexington and Everett. Respectively, they rank among the rest of the 31 towns as follows:

~Lexington- #3 income; #30 unemployment; #26 percentage of African- Americans; #2 Master graduates; #1 rent; etc.

~Everett- #28 income; #6 unemployment; #3 percentage of African-Americans; #31 Master graduates; #27 rent etc.

Therefore, the two towns stand on the opposite end of the spectrum along many of the socio-demographical factors that impact solar energy. For example, Lexington ranks the highest on the favorable factors and the lowest on the unfavorable factors. Conversely, Everett ranks the highest on the unfavorable factors and the lowest on the favorable factors. This example illustrates the fact that no single variable could explain why a town is lagging behind in its PV deployment rates. On the contrary, variables are mutually correlated and in effect- cumulatively impact the final outcome as well.

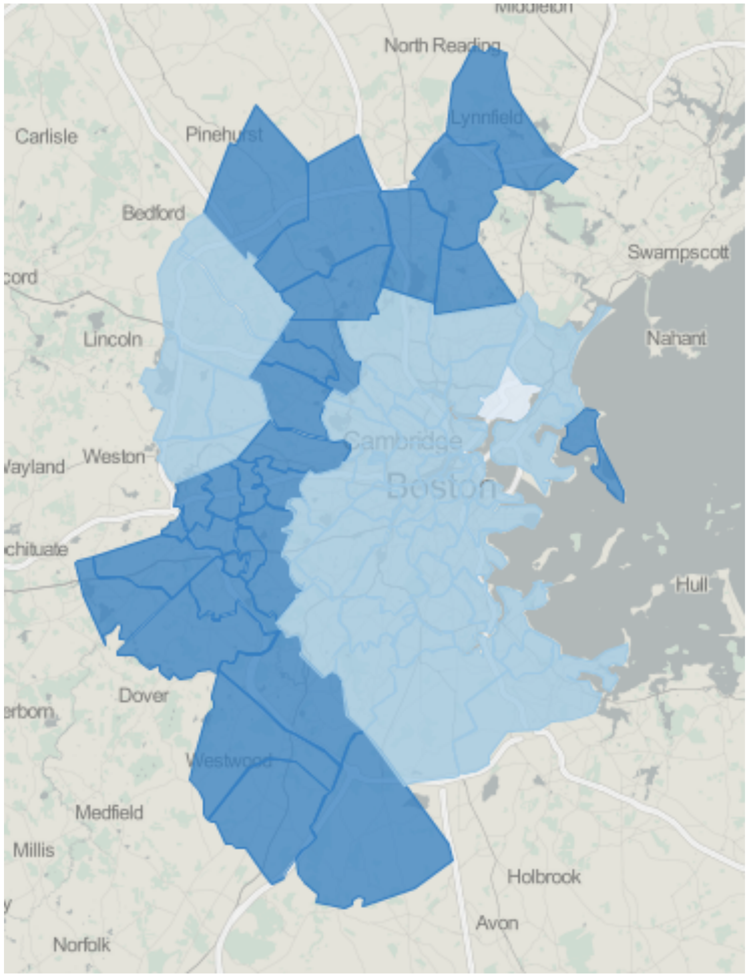
Findings from the first software test therefore confirm the observations from the case studies. Namely, the independent variables do affect the adoption rate of solar PV. Somerville (which has the lowest PV capacity) has three times higher percentage of racial minorities than Melrose (which has the highest PV capacity). Furthermore, Somerville has about $20,000 lower income; five times fewer detached units; and half the percentage of homeowners in Melrose. The test performed via StatPlus hence confirms the observations that the above-mentioned statistics are correlated with Somerville's poorer solar output than Melrose's.

2. Policy Context Data (2)

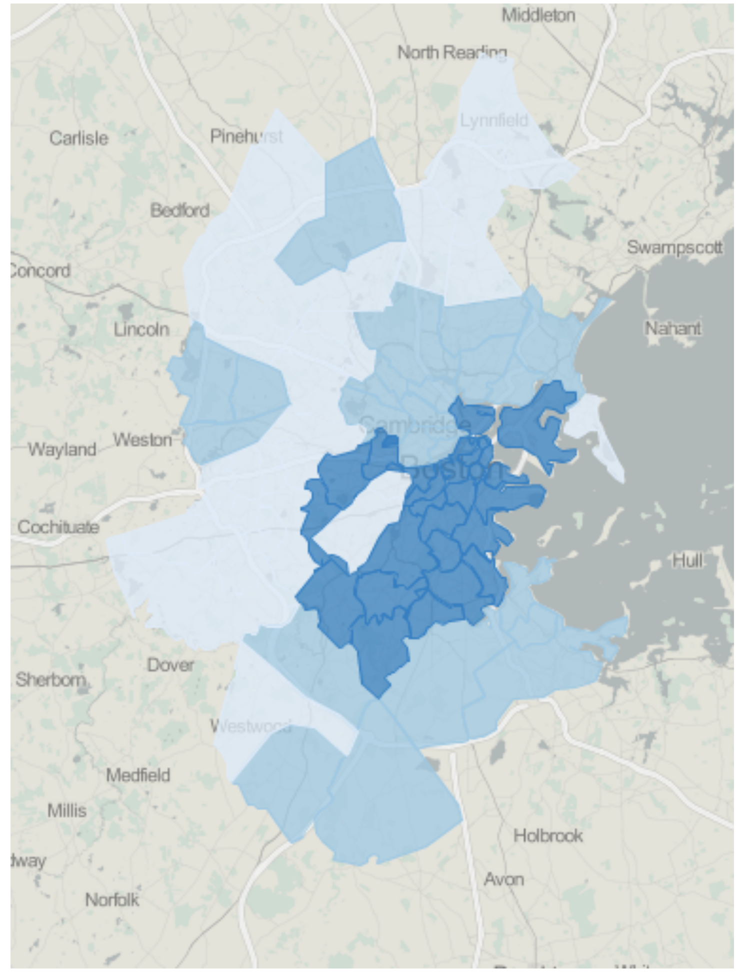
Test 2: Using Esri to analyze the impact of *geographical location* on PV output and socio-demographic factors.

Geocoding with Esri was performed for all thirteen variables. The results are displayed in Maps 1-16. The goal of these maps is to visually compare observed dependence between geographical location on one hand and the 13 variables and PV capacity on the other. Indeed, the pictures show an interesting pattern: the further away from Boston a town is located, the more favorable its features for PV installation are. For example, the ring of towns outside of Boston has: increasing percentage of white population (Map 1); lower percentage of African-Americans (Map 2); lower percentage of Latinos (Map 3); increasing percentage of home owners (Map 5); increasing percentage of detached units (Map 6); increasing income (Map 7); decreasing unemployment rate (Map 8); higher percentage of university graduates (Map 11), etc. The only figures, which show patterns in the opposite direction are percentage of Democrats and percentage of residents whose rent constitutes more than 35% of their income. The former finding could be attributed to the fact that political affiliation alone does not translate into high PV capacity. The higher income of Republican towns, on the other hand, in combination with favorable housing features, is a better predisposing factor. The latter finding (rent higher than 35% of income) could be explained by the fact that residents who generally have higher income are also able to afford more expensive housing. Despite the fact that the income itself is quite high, costly housing in the outskirts still represents a high portion of the income.

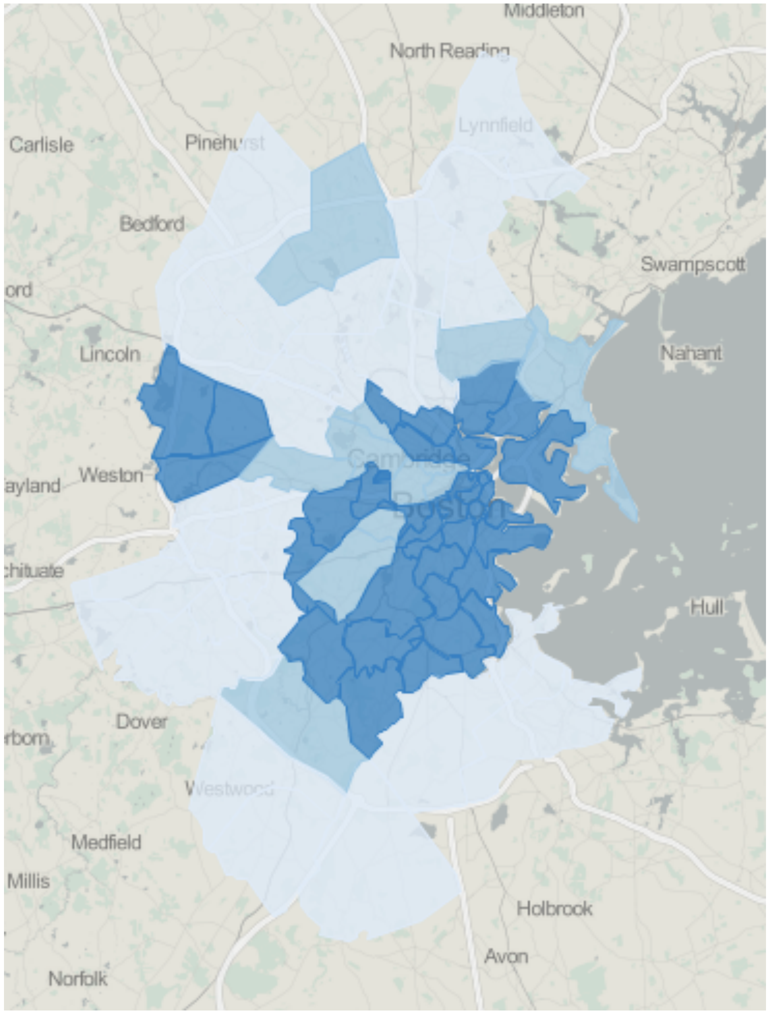
PV capacity increases as the distance from Boston increases, too (Maps 14- 17). However, the pattern is less clearly visible than that in the other maps. The first three maps show the corresponding PV capacity for 2005-2010; 2010-2014; and 2005-2014 (*Note: the three colors do not signify the same ranges of kW capacity- the software automatically splits the difference between the highest and the lowest value into three quantile ranges. These values are different for the three periods of time, however. Therefore, colors here are only used to signify a patter within a single dataset, rather than a numerical value across datasets*). Nevertheless, the



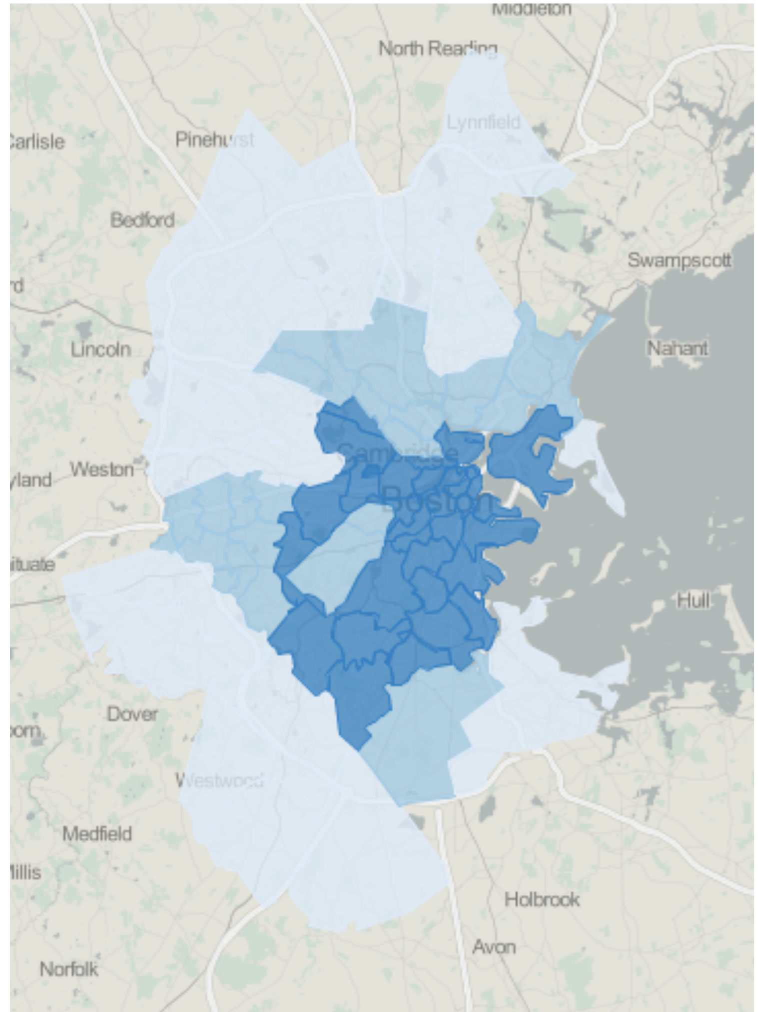
Map 1: Geographical distribution of **<u>white</u>** population
Quantile distribution: light blue (47.8-53.9); medium blue (53.9-80.8); dark blue (80.8-94.7);



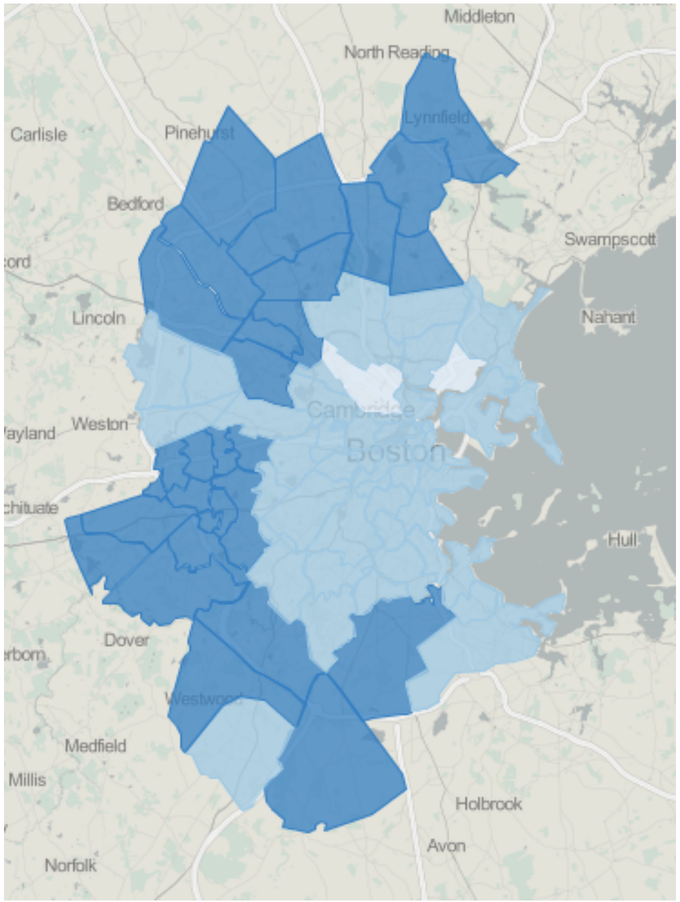
Map 2: Geographical distribution of **<u>African-American</u>** population
Quantile distribution: light blue (0.5-4.2); medium blue (4.2-53.9), dark blue (53.9-53.9)

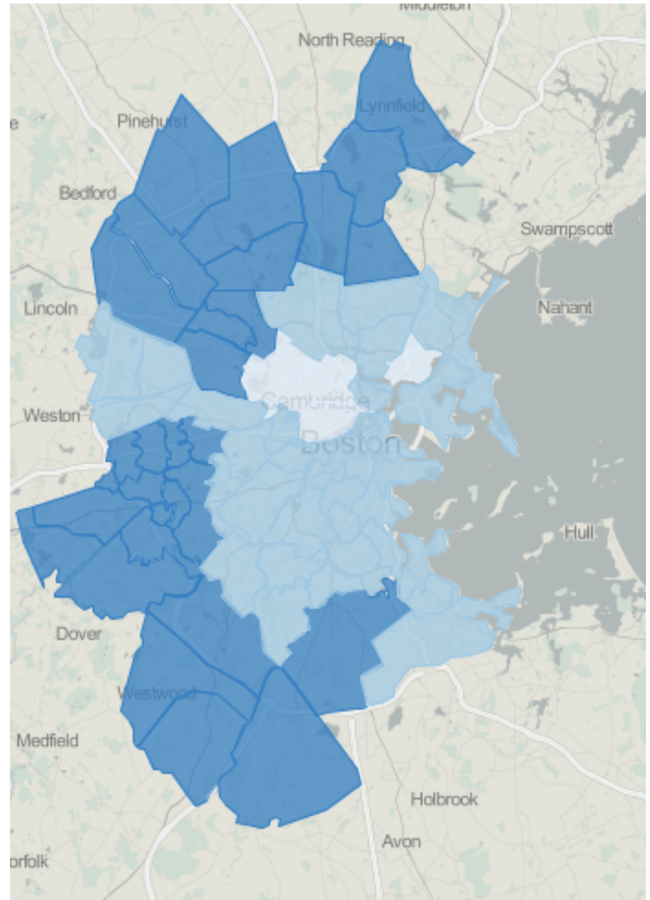


Map 3: Geographical distribution of **Latinos**
Quantile distribution: light blue (1.6-4.5); medium blue (4.5-8.9); dark blue (8.9-62.1);



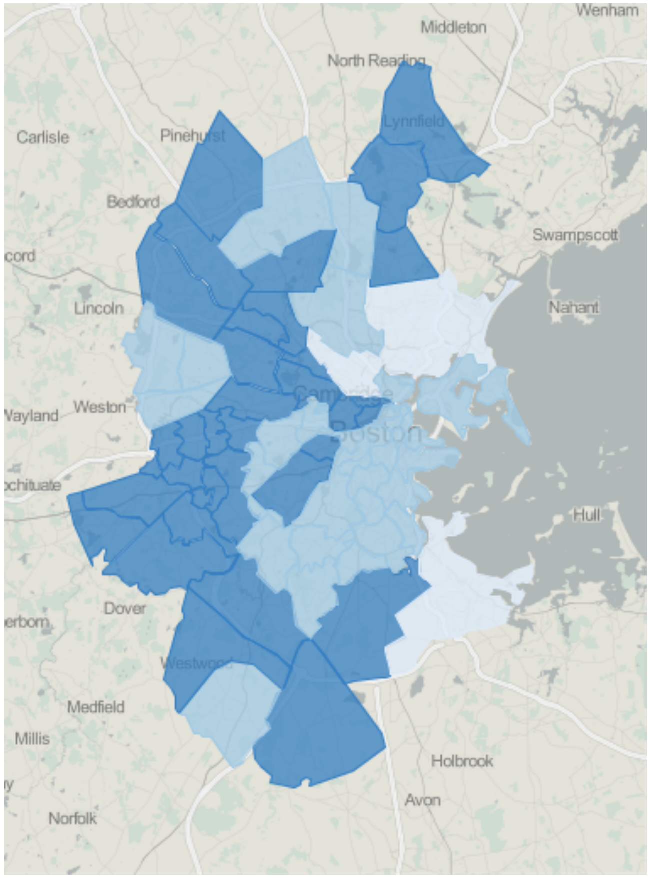
Map 4: Geographical distribution of **Democrats**
Quantile distribution: light blue (20.9-44.6); medium blue (44.6-54.7); dark blue (54.7-57.9);

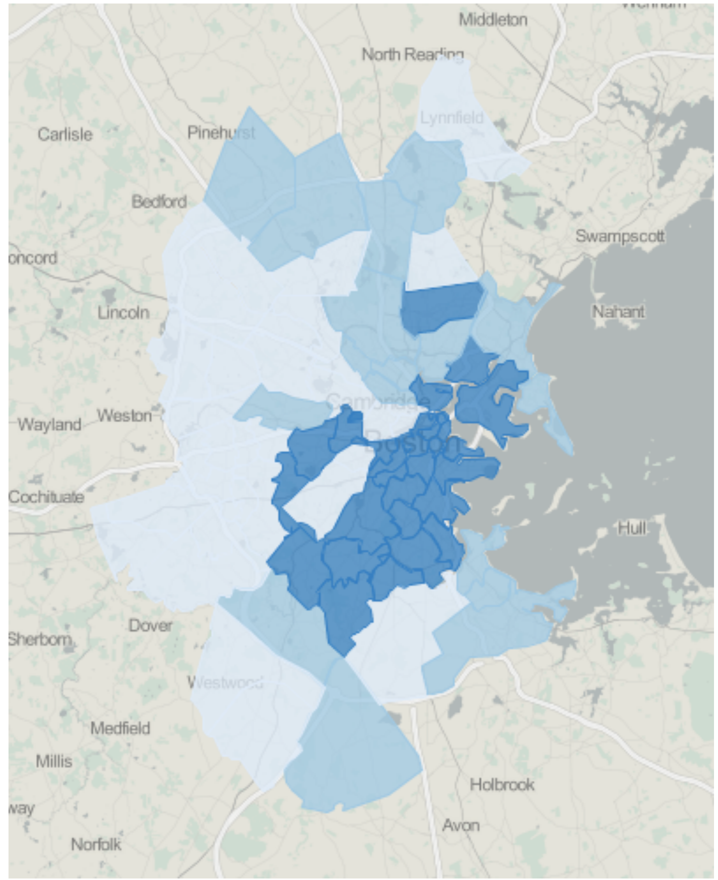




Map 5: Geographical distribution of **home owners**
Quantile distribution: light blue (29.8-34.2); medium blue (34.2-60.3); dark blue (60.3-88.9);

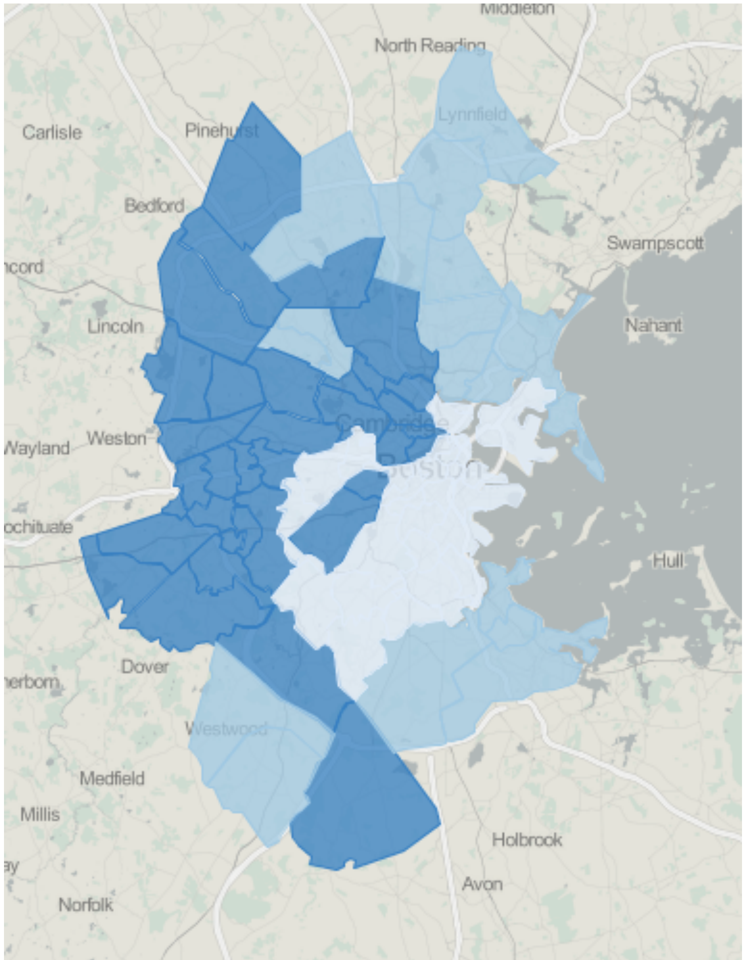
Map 6: Geographical distribution of **detached units**
Quantile distribution: light blue (9.3-12); medium blue (12-43); dark blue (43-87.1);

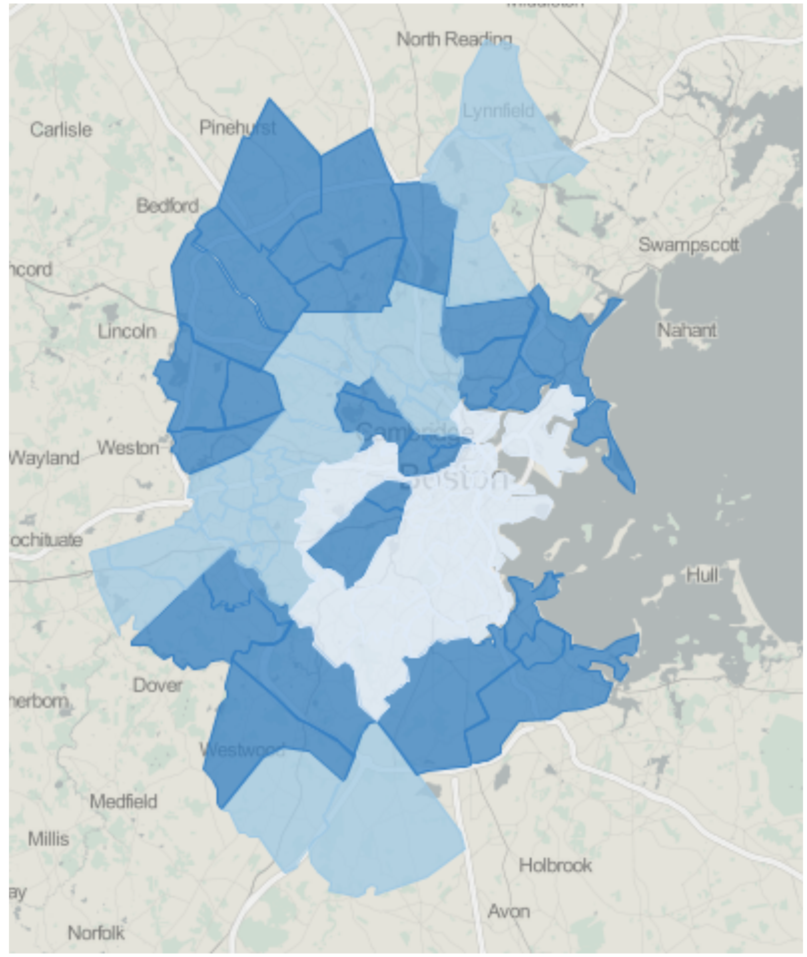




Map 7: Geographical distribution of **income**
Quantile distribution: light blue (56,264-79,538); medium blue (79,538-96,956); dark blue (96,956-231,669);

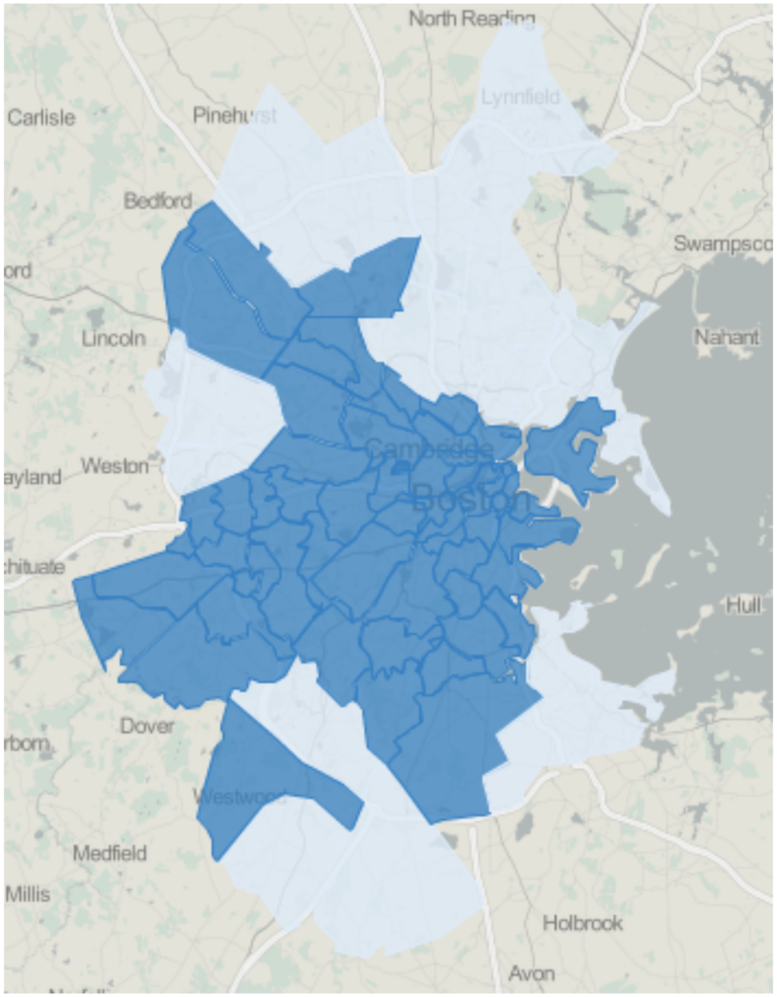
Map 8: Geographical distribution of **unemployment rate**
Quantile distribution: light blue (2.7-4.5); medium blue (4.5-7); dark blue (7-8.5);



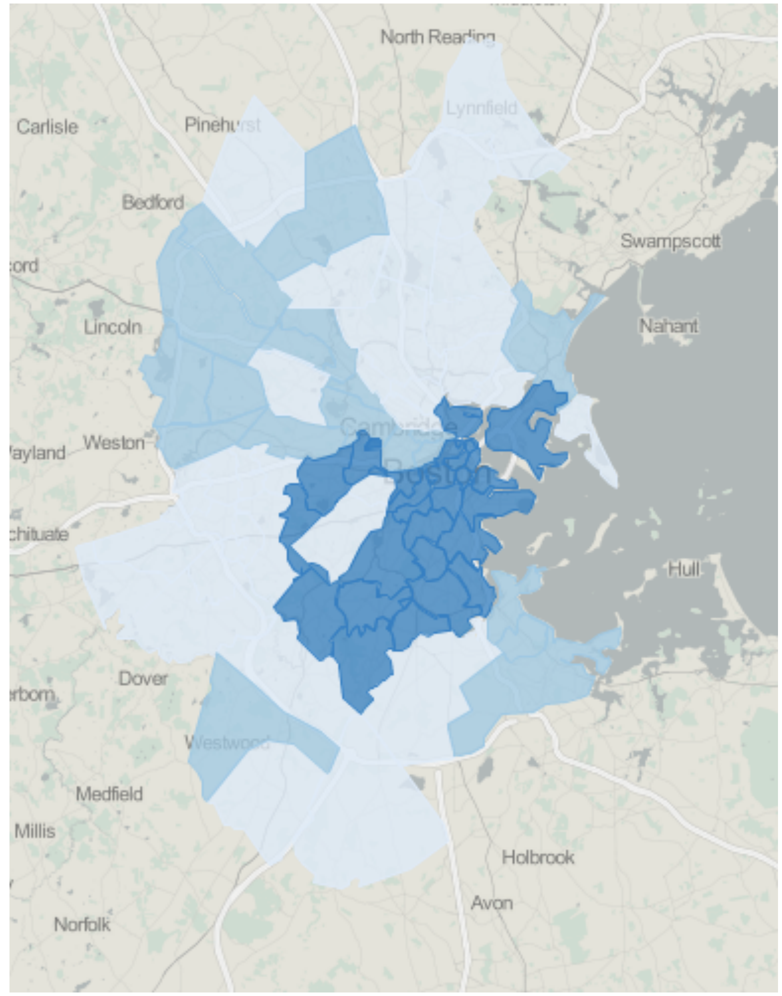


Map 9: Geographical distribution of **rent**
Quantile distribution: light blue (19.5-19.5); medium blue (19.5-1327); dark blue (1327-1898);

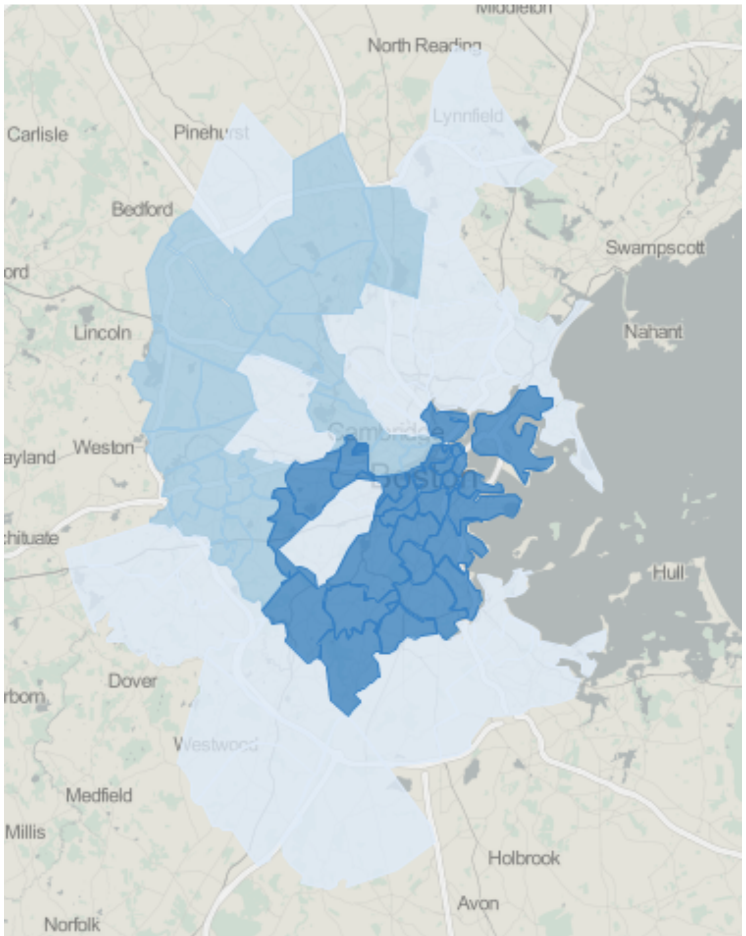
Map 10: Geographical distribution of residents whose **rent is more than 35% of their income**
Quantile distribution: light blue (12-12); medium blue (12-36.3); dark blue (36.3-60.5);



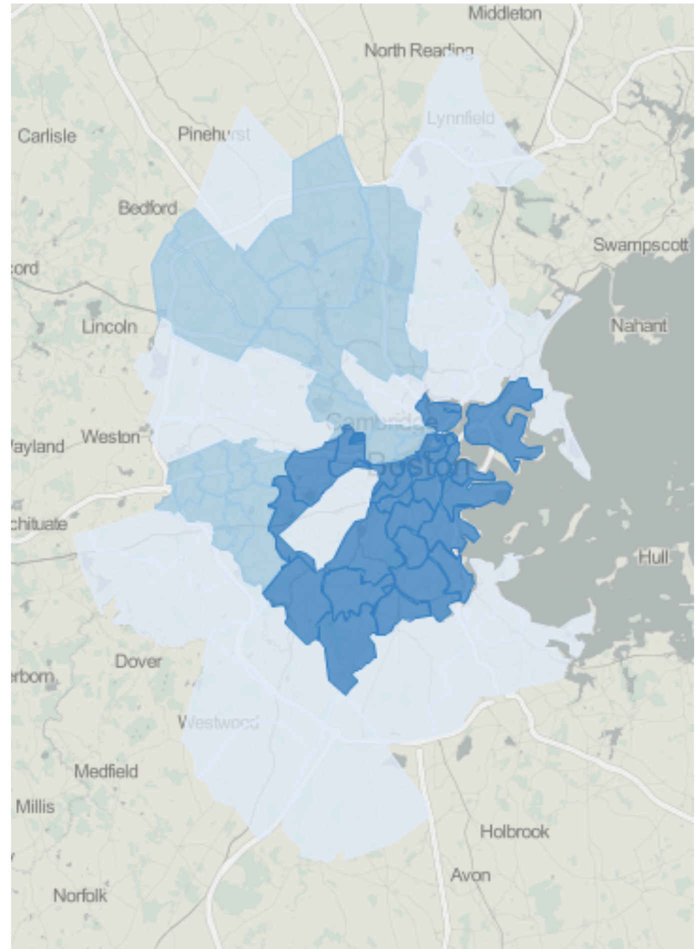
Map 11: Geographical distribution of **Master level graduates**
Quantile distribution: light blue (4.2-23.9); medium blue (23.9-23.9); dark blue (23.9-59);



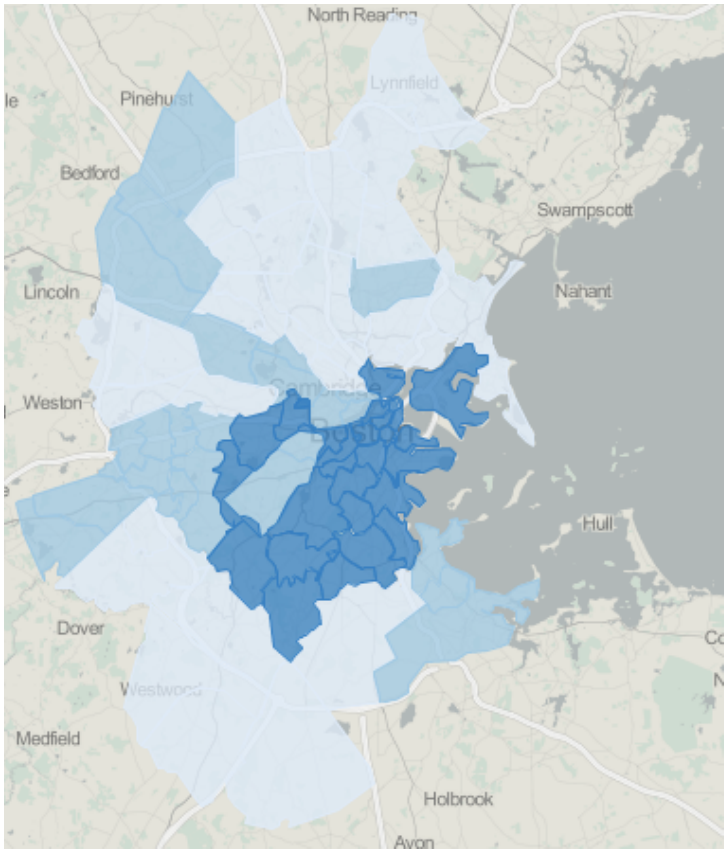
Map 12: PV capacity accumulated during **2005-2010**
Quantile distribution: light blue (0-39); medium blue (39-2500); dark blue (2500-2500);



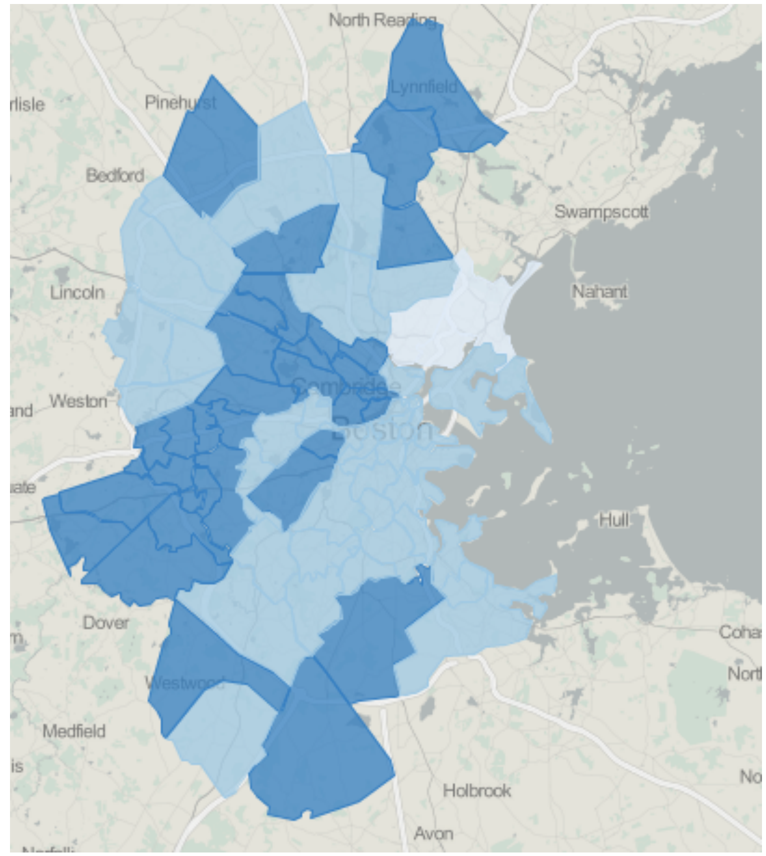
Map 13: PV capacity accumulated during **2005-2014**
Quantile distribution: light blue (5-538); medium blue (538-4969), dark blue (4969)



Map 14: PV capacity accumulated during **2010-2014**
Quantile distribution: light blue (5-488); medium blue (488-2469), dark blue (2469-2469)



Map 15: Geographical distribution of **<u>Asian population</u>**
Quantile distribution: light blue (1.2-9.8); medium blue (9.8-24.4), dark blue (24.4-24.4)



Map 16: Geographical distribution of **<u>Bachelor graduates</u>**
Quantile distribution: light blue (7.8-17.5); medium blue (17.5-27.1), dark blue (27.1-35.6)

region North of Boston does show that the second ring of towns has a larger capacity than the first ring. The reason the Southern region does not show this pattern is that it does not have a second ring (the official list of suburbs does not constitute a perfect circle of two rings of towns).

The conclusions derived via software Esri confirm the findings from the three case studies. Melrose, for example, is located the furthest away from Boston. Somerville, on the other hand, is located immediately outside of the capital. Not only does Melrose have much more favorable conditions for solar deployment (as already discussed in the previous section), however, it also has the highest PV capacity and Somerville- the lowest. Therefore, policy-makers should not design generic programs and apply them uniformly across suburbs (as it is the case with the state-wide program Solarize, which has the same format everywhere). Instead, city hall officials should take into consideration the specific socio-demographic composition and location of their town. In effect, they would be able to tailor a solar energy policy specific to their own context.

3. Policy Input Data

Test 3: Using StatKey to analyze the impact of *policy types* on PV output.

The third test examines the impact of four policy types on PV deployment. Data has been collected for the periods of 2010-2014 and 2005-2014 (The timeframe 2005-2010 has been excluded because it dates back to the period before the policies were implemented. Therefore they could not have had an impact on PV deployment. Considering the goal of this test is to examine the influence of policies on PV capacity, the timeframe 2005-2010 is irrelevant).

The results are summarized in Tables 6 and 7. Each table is split into two: “1”- towns that have a department, committee, etc. and “0”- towns that do not have a department, committee, etc. The respective PV capacity of each town is then entered into the table. For example, the first cell in Table 7 (section Department) shows “1156” in column “0.” Therefore, it indicates a town that does not have a department and its capacity is 1156kW. The cell next to it shows 650 in column “1.” It refers to a town that has a department and PV capacity of 650kW. The last section of Table 6, “Total,” designates the total number of policies. Towns that have no policies, departments, committees, etc, are entered into column “0.” Those that have at least one are entered into column “1.”

Table 6: Randomization results: testing the impact of four policy types on PV deployment between 2010 and 2014

Department	
0	1
1156	650
71	230
344	488
448	860
189	287
166	21
229	2469
725	
6	
101	
447	
211	
426	
5	
270	
400	
691	
445	
108	
44	
257	
528	
99	
1366	
# samples	10000
p	85.40%

Committee	
0	1
448	1156
189	71
166	344
229	725
6	101
5	447
270	211
400	426
691	445
99	108
1366	44
21	257
	528
	650
	230
	488
	860
	287
	2469
# samples	10000
p	68.50%

Solarize	
0	1
448	1156
189	725
166	101
229	447
6	445
5	108
270	650
400	488
691	860
99	287
1366	2469
21	
71	
344	
211	
426	
44	
257	
528	
230	
# samples	10000
p	96.60%

Ordinance	
0	1
189	448
229	166
6	270
5	1366
400	71
691	211
99	101
21	447
344	650
426	488
44	860
257	287
528	2469
230	
1156	
725	
445	
108	
# samples	10000
p	85.00%

Total	
0	1
189	21
229	344
6	426
5	44
400	257
691	528
99	448
	166
	270
	1366
	230
	725
	108
	71
	211
	1156
	445
	101
	447
	650
	488
	860
	287
	2469
# samples	10000
p	86.90%

Table 7: Randomization results: testing the impact of four policy types on PV deployment between 2005 and 2014

Department	
0	1
1211	4969
74	864
347	251
465	503
204	871
179	314
233	21
802	
6	
107	
457	
228	
448	
5	
335	
444	
707	
538	
147	
44	
297	
538	
104	
1426	
# samples	10000
p	86.30%

Committee	
0	1
465	1211
204	74
179	347
233	802
6	107
5	457
335	228
444	448
707	538
104	147
1426	44
21	297
	538
	4969
	864
	251
	503
	871
	314
# samples	10000
p	72.40%

Solarize	
0	1
465	1211
204	802
179	107
233	457
6	538
5	147
335	4969
444	864
707	503
104	871
1426	314
21	
74	
347	
228	
448	
44	
297	
538	
251	
# samples	10000
p	97.80%

Ordinance	
0	1
204	465
233	179
6	335
5	1426
444	4969
707	74
104	228
21	107
347	457
448	864
44	503
297	871
538	314
251	
802	
147	
1211	
538	
# samples	10000
p	86.10%

TOTAL	
0	1
204	465
233	179
6	335
5	1426
444	21
707	347
104	448
	44
	297
	538
	4969
	74
	228
	251
	802
	147
	1211
	538
	107
	457
	864
	503
	871
	314
# samples	10000
p	89.00%

Table 6 shows the result of the randomization test. The p-value for category "Department," for example, is 85.4%. It indicates that there is 85.4% chance that towns belong to group 0 or 1 due to their Department of Sustainability/ Energy/etc. rather than due to chance. The policy with the highest impact on solar capacity is Solarize (96.6%), followed by Total (86.9%), Department (85.4%), Ordinance (85%), and Committee (68.5%). It is not surprising that the policies with the strongest effect are Solarize and Total. As described in Chapters 6-8, Solarize programs double or triple the existing solar capacity of most towns. The last category, "Total" explains the results similarly to the combined StatPlus test (all 13 variables calculated simultaneously). Namely, it is the combination of all variables (rather than individual factors) that impact the final result to the greatest extend. The results for period 2005-2014 show a similar trend. Namely, the most effective policy is Solarize (97.8%), followed by Total (89%), Department (86.3%), Ordinance (86.1%), and Committee (72.4%).

The third tests also confirms observations from previous test as well as observations from the three case studies. A surprising observation is the fact the committee has the lowest score of 72.4%. The result could be explained by the fact that committees have indirect rather than direct impact on solar deployment. For example, they might facilitate the participation of their town in Green Communities. The GC program itself, however, does not guarantee adoption of solar systems. Another important finding is the strong role of municipal policies in driving solar deployment on a local level. It is commonly assumed that it is the responsibility of the state government to design and implement solar programs. Therefore, most towns have no programs, projects, policies, or initiatives regarding residential photovoltaics. This test, however, proves that there is strong correlation between local policy input and local policy output. This fact is further confirmed by the timeline figures that chronologically align policy input with PV output. In order to best seize the unique opportunities offered in each town, however, city hall officials should pay close attention to the contextual factors of their town- as proved by the previous two tests.

It is believed that the combination of these three tests confirms observations made in Chapters 5-8. Therefore, obstacles and opportunities listed in Chapter 8 are relevant to neighboring towns, too.

4. What do software results mean for the rest of the suburbs?

Test results show that PV deployment (dependent variable) is strongly influenced by innovative policies (test 3) that adapt to contextual (test 1) and geographical factors (test 2) (three groups of independent variables). These factors, however, depart from traditional forms of governance. Therefore, the reason PV systems diffuse so slowly is that **they challenge fundamental notions of energy**: the way it is produced, consumed, and governed. Indeed, solar energy actors find themselves in midst of a complex *transformation*, which interrupts public life spatially, temporarily, and socially (GreenTech Media, 2013a; Kind, 2013). Its impact breaks conventional modes of operation into a myriad of pieces, which no longer build a comprehensive picture. Actors today are therefore faced with a challenge: How can they put the pieces of the puzzle back together in order to construct a new reality?

Navigating this transformation successfully requires that **actors design new business and governance models** (test 3). Indeed, a modern energy system can hardly dwell in a world that still employs outdated working tools. Before a new, comprehensive system is established, however, stakeholders should re-evaluate old definitions for success. Namely, these rules measure success in MW; energy profits- in dollars per kWh; energy capacity- in Watts of electrons; energy emissions- in tons of $CO2$, etc. The solar energy sector, however, is rather new and its value cannot be measured against criteria for traditional energy systems. Instead, it requires a different set of measurement tools, which account for the complexity of the young energy market and its multiple benefits (GreenTech Media, 2013a; Griffith, 2013).

A better policy should therefore account for the **numerous additional advantages that solar energy brings to society** and its environment; it should also account for the numerous playing fields where it takes place (test 3). Unfortunately, the current legislation is only vaguely reminiscent of such qualities. It uses grey energy vocabulary to speak a green energy language. Therefore, it is unable to testify for its own successes and in return it is unable to win over the fossil fuel market.

Divesting away from fossil fuels therefore requires a fundamental change in popular rationality: a paradigm shift (Rifkin, 2012). Current rationalities can only discern a single piece of the puzzle mentioned earlier- and it can only solve isolated fragments of the problem it depicts. **A holistic approach**, on the other hand, envisions not only *decentralized, networked* technology, however, *networked* policies and *networked* stakeholders. Currently stakeholders are implementing individual policies without linking them into a comprehensive network of this kind.

Furthermore, these policies are universal and treat all towns similarly. However, not all cities are the created equal- just as not all residents, buildings, and economies are the same. As the quantitative analysis proved, towns differ significantly as their distance from Boston increases. Therefore, **policies should be adaptive** and take into account those contextual and geographical dissimilarities (test 1 and 2). Finally, residents as well as policies have multiple identities. If treated solely as tax-payers, residents would never be ensured their rights as foreigners, employees, or Democrats/ Republicans. Similarly, policies take many shapes and forms as stakeholders re-frame the issue to address other aspects the problem. The inability of the generic solar policies to envision the **multi-faceted nature of the problem** creates social, political, and economical gridlocks.

Only when actors acquire a holistic vision of the world, would they build resiliency to overcome any disturbance to the system. Unlike other technological revolutions, **solar energy will undergo many more transformations in the future**, too. Utilities and solar companies today are partners as a result of the Net Metering policy. The battery that Tesla Motors is currently designing, however, will be once again a game-changer. It will allow households to go off the grid as independent power producers (California Public Utilities Commission, 2014; Rifkin, 2012). The Net Metering and Interconnection policies will then become obsolete. The system therefore has many more strokes to absorb and unless it has the flexibility to re-organize itself afterward, it will collapse. A key component to future success would then be a transition away from a localized governance model that relies on vertical power relations and fragmented polices. Instead, it should re-orient itself towards networked governance, which connects stakeholders horizontally and drives technological innovation forward.

Chapter 11: Conclusion

The problem framed in this thesis is the high energy consumption in the Greater Boston Area (GBA). Indeed, GBA towns constitute a unique urban type and hence- they experience unique urban problems. Residents in these towns live in houses larger than the average urban unit; their homes are primarily detached; they travel longer distances to work; and they rely primarily on personal modes of transportation. Each of these factors contributes to high energy consumption and hence- high carbon emissions (See Contextual statistics, Chapter 9, Figure 4).

Solar energy was then proposed as a solution to this problem. As the study by Byrd (2013) proves, PV panels have the technical capacity to provide electricity to metropolitan areas. Therefore solar energy could turn the main obstacle in suburban towns (large, detached units) into a key opportunity (large rooftop area for PV installations). While Byrd's idea is proven technically, this thesis aims investigating its socio-political feasibility in Somerville, Medford, and Melrose. The three case studies therefore aim answering the following research questions, *What are the enabling and constraining factors facing the PV sector in suburban Boston? In light of these factors, what is the policy potential of solar energy to transform fossil-fueled towns into self-reliant, PV-fueled centers? What recommendations could be given to the suburbs so that they can activate this potential?*

Question 1: What factors (obstacles and opportunities) contribute to the varying degrees of solar success in suburban Boston?

Six main obstacles- and six respective opportunities that help overcome them- were examined in Chapter 9. Specifically, these are: (1) Limited administrative resources and staff in local governments- which could be overcome by collaborating with MassCEC and MAPC; (2) High cost of implementing solar programs and financial incentives- which could be counter-acted by obtaining funds from GC; (3) Unstable and unpredictable state-level policies- which could be balanced out by Solarize Mass; (4) Socio-demographic and urban features of the towns- which could be addressed by local projects, such as GreenTown Labs; (5) Unequal cost-benefit distribution across suburban rings- which could be overcome by municipal low interest loans for PV systems; (6) Limited actor participation in the decision-making process- which could be counter-acted by mobilizing local actors (NGOs, green businesses) and networking with regional players (environmental associations and organizations).

Question 2: In light of these factors, what is the policy potential of solar energy to transform fossil-fueled suburbs into energy-independent centers?

As shown in Chapter 9, each of the three towns has activated their potential to a different degree. Somerville, for example, initiates projects such as GreenTown Labs, the Somerville Solar Challenge, and Green Communities. Individually, these programs show sustainability leadership and environmental consciousness. Cumulatively, however, they create a policy framework that is still reminiscent of the old regime. Namely, it is *centralized* and *vertical*. For example, the Somerville municipality relies on *local* staff and *local* resources in order to organize the Somerville Solar Challenge. They rarely *collaborate* with other towns and regional organizations, such as MassCEC and MAPC. Programs and policies, on the other hand, are rather *universal* and do not *adapt* to the local features of the town or state-level programs. Finally, they are *short-term* and do not *re-mobilize* partners or skills from previous experiences. Somerville policies are therefore rather *static, centralized, and vertical*. Considering the grey energy sector is hundreds of years old, it is no surprise that it is rather *fixed* and undergoes *few transformations*.

Medford and Melrose, on the other hand, have been able to steer society away from this traditional model and towards a more *active, decentralized, and horizontal* system. Therefore, they seize the above-mentioned *opportunities* more successfully. Indeed, the *innovative* programs in these towns (e.g. Solarize Mass, Regional Solar Initiative) allow city hall officials to *collaborate* with other towns, *share* resources, and *experiment* with new policy tools. Rather than *universal*, they are much more *flexible* and *adaptive* to their own circumstances. Rather than *mono-disciplinary*, policy-makers in Medford and Melrose have a *multi-dimensional* outlook of the problem, too.

The Medford committee, for example, stands out with its *consistent* partnership with MAPC throughout several projects. Indeed, the committee has been the driver of most of the initiatives analyzed in this thesis. However, many local and state-level *obstacles* are not addressed- e.g. a small percentage of home-owners and the fulfillment several Massachusetts targets. These factors are present in Melrose, too, however, local stakeholders address them with a much more comprehensive and *sustainable* policy portfolio. For example, it *adapts* well to the socio-demographic features of the town as well as the un-intended effects of state programs. Rather than *short-term* and oblivious of past policy endeavors, it is *long-term* and *reminiscent* of lessons learnt in prior experiences as well. Rather than *standalone*, its programs are *well-integrated* into the overarching regulatory structure.

The three towns were then compared *qualitatively and quantitatively*. With unfavorable urban and demographic features and a localized governance model, Somerville was ranked third in this sample. Medford and Melrose, on the other hand, are comparable and rank higher. They have socio-demographic context that predisposes PV deployment as well as policies that take advantage of it. Nevertheless, Melrose exemplified the most *progressive* policy portfolio and it is the leader in this analysis. These observations were then confirmed by the *quantitative* comparison between the three towns. Until 2010, Medford and Melrose had lower PV capacity than Somerville. After their innovative policies were implemented, however, they caught up with Somerville and today they have higher capacity. Aligning a policy timeline with a deployment timeline showed the same results. Namely, adoption rates were rising steeper as the policies were implemented.

It can therefore be concluded that Medford and Melrose have been able to *transform* the traditional governance model to the greatest extent. The have been able to do so because (1) their innovative programs echo (2) the local features of their town and (3) its geographical location. These three factors were then tested for all 31 towns. *Quantitative* analysis with software proved with a very high certainty that namely these factors have a very strong impact on PV deployment. Therefore, it is essential that other suburbs learn from the experience of Somerville, Medford, and Melrose. Considering suburban towns are unique and unlike most towns in rural Massachusetts, it is important that they take the initiative and address local obstacles and opportunities.

Question 3: What recommendations could be given to the suburbs so they can activate their potential? What can neighboring towns learn from Somerville, Medford, and Melrose?

The *obstacles* listed above could be overcome by *opportunities* already described in this chapter. However, existing opportunities are not sufficient to fully seize the policy potential of solar PVs. In order to do so, the following recommendations are made to local, regional, and state stakeholders:

1. Institutionalization of solar energy: Energy coordinator/ officer

Most suburban towns do not have a department explicitly dedicated to energy/ sustainability/ the environment. Yet energy is an essential element of all public affairs and daily activities. Considering that departments are an expensive undertaking, it is here recommended that Somerville, Medford, and Melrose hire only one sustainable energy officer or coordinator (US DOE, 2011). His/ her role, however, would be central to all energy-related programs, projects, and policies on a local as well as regional scale. The reason is that all of the programs analyzed in this thesis required a central figure that initiates and drives them forward. Namely, this person applies for state grants, enters regional programs, and serves as a point of contact for future endeavors. Examples are private companies interested in pursuing a solar energy project; residents who would like to collectively undertake a Community Solar project, etc.

Without an energy coordinator, these stakeholders would not be able to pursue their projects in many towns. As the energy coordinator collaborates with local stakeholders and regional organizations, s/he would ensure that the governance model attains a more networked character. Indeed, it would be difficult for stakeholders from different towns and sectors to come together and realize a Community solar project, for example. While traditional energy governance relies primarily on its own efforts, solar energy requires that the municipality builds strong connections with its partners as well. The coordinator would therefore serve as the focal point that manages local and regional efforts.

3. Educating on solar energy: Staff training and awareness campaigns

Solar energy is different from fossil fuels in the way it is generated, consumed, and governed. Therefore, policy-makers in Somerville, Medford, and Melrose need to be educated on the values and specifics of solar energy. Staff training is also necessary in order that municipal officials are able to navigate the complex regulatory structure of solar panels as well as the technical aspects of PV installations (APA, 2013). Unless they are up to date with all technological innovations and legislative amendments, they will not be able to seize opportunities in this dynamic industry. As showed in the results though (See Appendix E, graph 4), only 11% of surveyed towns provide training. Solar energy therefore once again contrasts fossil fuel governance. Namely, city hall officials need to be continuously gaining new knowledge and adapting their current efforts to the continuous progress of the PV sector.

City halls should also organize on-going awareness campaigns. Public education is needed because a small percentage of all Massachusetts residents currently have a PV system on their roof. Therefore, PVs might lack visibility and public recognition. Awareness campaigns, newsletters, advertisements, as well as green fairs and festivals are all good ways of educating the population of the merits of renewables.

4. Solar Integration- incorporating it into other departments

Solar energy concerns the municipal department of energy (if existent). However, it also regards the departments of public works, employment, housing, etc. Therefore, municipal staff as well as municipal policies in Somerville, Medford, and Melrose should be well integrated into the mission and goals of other branches of the city hall (APA, 2013). This is important because currently many policies have unintended, negative effects. Incorporating solar goals into other programs, however, would eliminate unfavorable interdependencies and negative outcomes. Furthermore, solar energy might be low on the political agenda because city hall officials do not realize its beneficial effects on other sectors of public life. Integrating it into the municipal regulatory structure would therefore overcome these current barriers.

5. Platform for collaboration on solar energy projects

Many of the current challenges stem from the fact that towns do not have a platform for collaboration. This could be a regional, inter-governmental agency where local stakeholders can meet regularly and collectively pursue PV-related projects. For example, they can design community outreach programs or new business models. Once again, this is necessary in order to transform the traditional system of energy governance. Under this older system, city hall officials do not experiment with new policy tools and there is not need to share their respective experiences. Solar energy, however, requires a new regulatory approach. Therefore, it is important that energy coordinators are able to collectively navigate through this process. While the MAPC does bring them together, they are able to work on MAPC-initiated projects and schedule. A new platform would therefore allow them to customize projects to their own needs and schedule (therefore meeting more often than a few times a year). Finally, it is also recommended that Somerville takes part in already existing regional networks- such as MassCEC, MAPC, etc.

6. Adapting efforts to local needs

Unlike traditional energy policies, solar energy policies cannot be generic and universal for all towns. Towns with a high percentage of detached units or homeowners (such as Melrose), could design new ways of capturing their high PV potential. For example, they could emphasize awareness campaigns, contact owners directly, etc. Towns with a low potential, on the other hand, could organize a Community solar project. They could find a brownfield where ground-mounted PVs could be installed (US DOE, 2011). Without the initial stimulus of the government, however, it would be difficult for residents to independently organize such an initiative. Finally, towns with a low average income (such as Somerville) could provide a low-interest rate option for financially challenged families. It would be a strategic approach that simultaneously addresses one of the obstacles emerging on a local level (low average income) as well as state level (marginalization of poorer families).

Contributions and limitations of the research design

The slow deployment rate of solar panels has been the subject of investigation of many researchers in the USA. While most focus on the technical and financial aspects of solar energy policy, few have analyzed on socio-political matters alone (Byrd, 2013; Mills and Schleich, 2009; Sener and Fthenakis, 2014; Zhai, 2013). Similarly, most policy studies examine the PV sector on a federal or state rather than local level (Carley and Brown, 2013; Drudy et al, 2012; Griffith, 2013; Holburn, 2012; Seel, 2014;). Municipal studies, on the other hand, usually focus on climate change policy (Aldy et al, 2010; Knuth, 2010; Krause, 2010; Pitt, 2009; Pitt, 2010a; Pitt, 2010b; Sharp, 2011) or renewable energy in general (Brown and Chandler, 2008; Denis and Parker, 2009; Coley, 2012; Negro, 2012; Sovacool, 2009; Sperling et al, 2011; White et al, 2013), rather than municipal solar energy in particular.

The present thesis then makes the following contributions to the scientific field. Firstly, it fulfills three research objectives (stated in Chapter 1). For example, it focuses on the building sector as the primary cause of high CO2 emissions (objective 1). Indeed, data collected in the previous chapters show that suburbs emit more than Boston, yet they have fewer installed solar panels. Nevertheless, the results also show that there are many towns (e.g. Melrose) with abundance of detached housing units and homeowners. The building sector therefore has a great potential to solve the problems it has created in the first place (objective 2). Finally, the thesis zooms into municipal PV governance in order to describe and analyze how three suburban towns govern solar energy on their territory (objective 3). Therefore, it argues against popular assumptions that the origin of the problem is on a state-level. On the contrary, there are many challenges and opportunities on a local level, which municipalities (as well as society) have the freedom and flexibility to address as well. The thesis also challenges the conception that PVs cannot scale up due to technological reasons. On the contrary, policy has a great yet unfulfilled potential, which the three towns have been able to activate to a different extend. Therefore, the selection procedure of case studies (See Chapter 1), has shown various stages of policy transformation.

Secondly, the thesis also collects data from primary sources (interviews, electronic surveys, site observations, laws, governmental reports, databases, and websites) as well as secondary (scientific articles and reports). The wealth of data collected allows that observations made are confirmed or denied across sources.

Thirdly, the thesis constructs a theoretical framework that highlights the assets of multiple other theories: CIPP, adaptive governance, and transition management. It is developed in a way that adapts to the specific features of the PV sector. Therefore, it takes into consideration various aspects of the problem, which other theories might have ignored: for example, the impact of (1) state policies, (2) urban and socio-demographic features, and (3) local actors and policies on the dynamics of the policy process and its output. Previous studies have usually focused on the effect of only one of these three factors; furthermore, they usually examine climate change governance and rarely solar in particular.

Finally, the first part of the thesis examines policies qualitatively. In order to extrapolate conclusions to other suburban towns, it then conducts quantitative analysis. The three-tired software analysis then confirms the significance of the independent variables for the rest of the

31 towns, too. Therefore any short-comings of the qualitative examination are balanced out by the contribution of the quantitative analysis.

The limitations of the research design should be noted, too. Firstly, conclusions drawn are based solely on data found. It is therefore possible that actors that have not been interviewed would have given a different perspective on the problem. Additionally, data analysis is strongly influenced by the structure of the theoretical framework. Conclusions drawn are therefore tainted by the concepts and ideas integral to this theory alone. Furthermore, its goal is to reconstruct the policy process: starting with the context and input and proceeding with process and output. Framework re-construction therefore reflects the subjective perception of the policy analyst herself. It depicts her view of reality, not an objective picture of reality itself. Finally, time limitations should also be considered. Namely, analyzing more towns or conducting more surveys would have expanded the research scope of the thesis.

Considering these research contributions and limitations, it is suggested the topic is further investigated in future research. Questions that could be considered are, *How is the role of civil society growing in the diffusion of PV panels? What other power shifts are observed among stakeholders- businessmen, NGOs, governments? What are some innovative means of institutionalizing solar energy into municipal decision-making processes?* It is important that this research field is further examined also because of its fast-paced and dynamic nature. Namely, innovative collaborative models are continuously emerging. As they enter the playing field, they bring new actors, new rules, as well as new obstacles and opportunities. Therefore, only time will show what other transformations they will inflict on American society, businesses, and government.

Appendix A

<u>Interview Questions: City hall officials</u>

(Generic questions for the semi-structured interviews: more follow-up questions were asked depending on the course of the interview)

1. Solar Policy Overview: What solar policies do you have in place? When were they implemented? What stage are they at now? What was their goal and did they achieve it? What obstacles did they face?

2. Solarize Mass: When did the program start? How many people participated in the Solarize? How many solar kW were installed? Is the program still active? What challenges did you face in the process- lack of public interest, lack of political support form the state of MA, or lack of financial resources? Did the program increase demand/interest/kW capacity?

3. Institutionalizing Solar: What solar tasks/ projects is your department currently working on? What is their purpose? What stage are they at? Are they achieving their goal? What difficulties do they face?

4. Agenda-setting: Have you had other solar policies on the agenda/ implemented in the past? Which ones proved successful and which ones- not? Why?

5. Agenda-setting: How do you determine which solar policy gets on the agenda? Are you planning to raise new ones? What obstacles do you face in raising them on the agenda- financial, political, conflict of interest...? Lack of resources- if so, which ones?

6. Agenda-setting: Why are the following solar policies not on the agenda: community outreach campaigns, streamlined permitting, financial incentives, solar plans and goals? Have you experienced problems in the areas that are unregulated by them: lack of information and awareness; complex permitting process; ...? How do you plan to solve the problems that are not addressed by them?

7. Stakeholders: How do you currently collaborate with the following stakeholders: solar energy businesses, NGO's, universities, etc.

8. Stakeholders: A high percentage of the population in your town lives in multi-family housing units- rather than private houses. Do you have a special solar policy for people who rent rather than own their home?

9. **Stakeholders:** There is a large percent of unemployed people in your town. Do you offer special policies for them, too?

9. Interrelatedness: Have you considered interrelating the solar policies (e.g. permitting process) with that of other jurisdictions? If no- why not?

10. Interrelatedness: Have you experienced any conflict between various solar and non-solar policies? Any particular obstacles?

Interview Questions: Businesses

1. Customer Acquisition: What factors increase demand and trigger interest for customers? What discourages them the most?

2. Customer Education: Do you think citizens are well-educated: do they seem to be familiar with the process, etc? Which areas do you think should be emphasized in a tentative future campaign?

3. Customer Preference: Which form of solar contract are people most interested in: direct payment, third party, leasing, etc.?

4. Policy opportunities: Which state/ local policies accelerate and facilitate the process the most?

5. Policy obstacles: What obstacles have you faced: high price of PV's, lack of policy/support, lack of information?

6. Policy stages: Which stages of the solar chain is best and worst regulated: manufacturing, installation, training, permitting, etc?

7. Policy conflicts: Are there any policies which are in conflict with each other?

8. Policies: The following solar policies are missing in Somerville (financial incentives, awareness campaigns, etc). Have you experienced difficulties in those areas? If so, how do you deal with the problems that consequently arise?

9. Green business: Do you provide training for your employees? If yes- what kind? If no- why not?

10 Green business: Do you cooperate with the government, universities, utility companies, or NGOs? If so, what kind of projects do you collaborate in?

11. Green business: How much time does it take to install a PV? How long before it pays off its initial investment? How much does it cost?

Appendix B

A screenshot of the electronic survey that was sent to participants in this thesis

Solar Energy Survey

1. Which town do you represent?

2. What are the primary methods of carbon dioxide reduction in your municipality? (Please choose top 2-3 answers)

- [ ] Energy efficiency
- [ ] Conservation
- [ ] Renewable energy
- [ ] Transportation policies
- [ ] Urban planning
- [ ] Green buildings

Other (please specify)

3. Which of the following municipal offices is responsible for solar energy policies and projects? (Check all that apply)

- [ ] Department of Energy/Sustainability/Environment, etc
- [ ] Committee on Energy/Sustainability/Environment, etc
- [ ] Officer or Coordinator

Other (please specify)

4. Are the following municipal solar energy policies currently available in your town?

	Yes, it is	No, it is not	Planned for the future
Building bylaw (to facilitate solar projects)	○	○	○
Zoning bylaw (to facilitate solar projects)	○	○	○
Streamlined permitting for solar projects	○	○	○
Solar energy targets	○	○	○
Solar energy plan	○	○	○
Environmental/ Energy plan or targets	○	○	○
Low interest loans for solar projects	○	○	○
Solarize Massachusetts or Solar Challenge	○	○	○

Other (please specify)

5. Are the following community outreach programs for solar power available in your town?

	Yes, it is	No, it is not	Planned for the future
Awareness campaign	○	○	○
Survey	○	○	○
Workshops	○	○	○
Online solar map	○	○	○
Staff training	○	○	○

Other (please specify)

6. Are the following factors an obstacle to implementing a municipal, solar energy policy?

	Yes, it is	Somewhat	No, it is not
High cost of financing the policy/ project	◯	◯	◯
Not enough staffing personnel to coordinate the policies/ projects	◯	◯	◯
Other issues take priority on the municipal agenda	◯	◯	◯
Complexity of solar regulatory structure	◯	◯	◯
Difficulty finding support from regional networks	◯	◯	◯
Local opposition to solar/ renewable projects	◯	◯	◯
Likely expiration of the federal ITC in 2016	◯	◯	◯
Cap on net metering	◯	◯	◯
Decreasing cost of SREC's	◯	◯	◯

Other (please specify)

7. Have the following factors enabled your community to adopt solar energy policies?

	Yes, they have	Somewhat	No, they have not
Municipal department/ coordinator dedicated to energy matters	○	○	○
Environmental consciousness of residents	○	○	○
Favorable incentives in the state of Massachusetts	○	○	○
Cooperation with other governments	○	○	○
Participation in regional networks: MAPC	○	○	○
Participation in regional networks: Green Communities	○	○	○
Partnerships with local NGO's	○	○	○
Partnerships with local universities	○	○	○
Partnerships with local solar businesses	○	○	○

Other (please specify)

8. Please use this space for additional comments

Done

Appendix C

List of thesis participants

Interviews:

Besser J. (2014). VP Policy and Government Affairs, New England Clean Energy Council. Interviewed on March 28, 2014.

Grover M. (2014). Energy Efficiency Manager, Office of Planning and Community Development, City of Melrose. Interviewed on April 2, 2014.

Hess D J (2014). Director, Professor of Sociology, Vanderbilt University. Interviewed on March 21, 2014.

Hunt, A. (2014). Director of Energy and Environment, City of Medford. Interviewed on April 3, 2014.

Judge M (2014). Associate RPS Program Manager, Massachusetts Department of Energy Resources. Interviewed on March 31, 2014.

Lusardi M. (2014). Green Communities Division. Massachusetts Department of Energy Resources. Interviewed on May 9, 2014.

Mayer B. (2014). VP Residential Projects, SunBug Solar. Interviewed on March 14, 2014.

Melrose Solar Coach (2014). Interviewed on May 14, 2014.

Paine B. (2014). Medford Clean Energy Committee. Interviewed on March 24, 2014.

Peterson C. (2014). MAPC. Interviewed on April 2, 2014.

Pitt D. (2014). Assistant Professor Urban and Regional Planning, Virginia Commonwealth University. Interviewed on March 20, 2014.

Schulman A. (2014). HEET. Interviewed on March 20, 2014.

Shortsleeve M. (2014). Renewable Energy Executive, Regional Director with RGS Energy. Interviewed on April 3, 2014.

Youngblood E. (2014). Commonwealth Solar Programs. Massachusetts Clean Energy Center. Interviewed on March 24, 2014.

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Anonymous (2014). Town of Milton. Survey completed on May 5, 2014.

Anonymous (2014). City of Newton. Survey completed on May 5, 2014.

Anonymous (2014). Town of Wellesley. Survey completed on May 5, 2014.

Anonymous (2014). Town of Swampscott. Survey completed on June 16, 2014.

Energy Conservation Coordinator (2014). City of Winchester. Survey completed on May 6, 2014.

Environmental Department (2014), City of Dedham. Survey completed on May 20, 2014.

Luther, J. (2014). Building Department, Town of Carlisle. Survey completed on May 27, 2014.

Randel K. (2014). Waltham Energy Action Committee, Waltham. Survey completed on May 7, 2014.

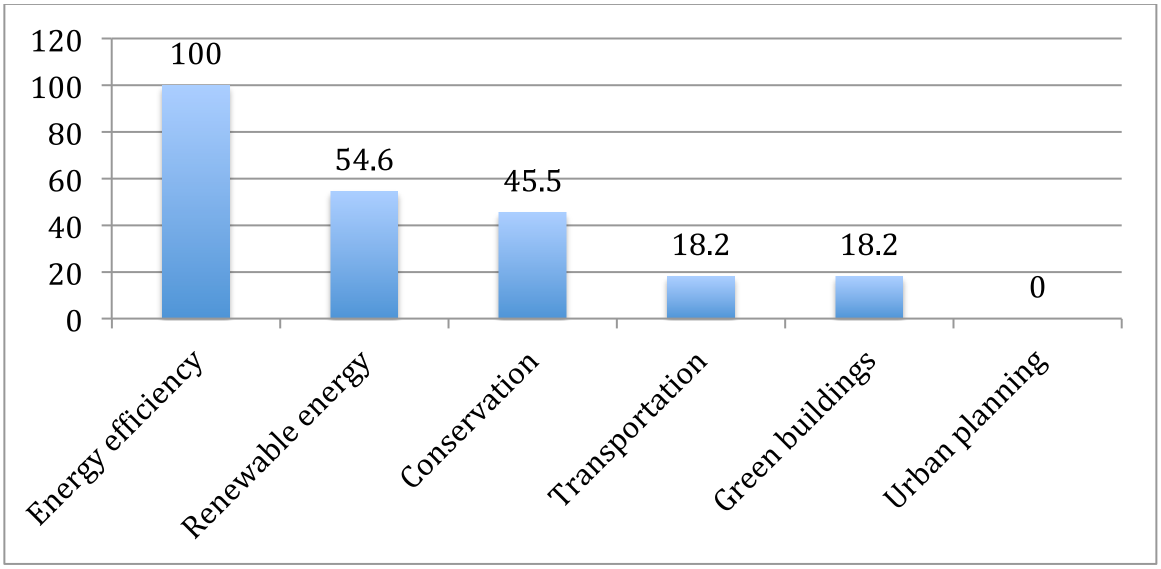
Appendix D

DATA COLLECTION SHEET			
Policy Context			
Variable	Indicator		Data collection space
Social Resources	-NGOs; racial minorities, college/ university graduates, home ownership, detached units		
Financial resources	-Businesses; average income, unemployment rate, average rent		
Political/ legal resources	-Department, committee; political affiliation of the residents		
Policy Input			
Variable	Indicator		Data collection space
Social networks	-Partnerships, collaborative projects, coalitions, campaigns, surveys		
Financial incentives	-Taxes, rebates, loans, subsidies, grants		
Political/ legal policies	-Ordinances, bylaws, programs, etc		
Policy Process			
	Indicator	Criteria	Data collection space
Social process	Changes in the social dynamics of the process	-Inclusiveness, participation, interdependency, collaboration	
Financial process	Changes in the financial dynamics of the process	-Affordability and equity, marginalization, sustainable and efficient finances	
Political/ legal process	Changes in the political dynamics of the process	-Horizontal, decentralized, flexible, adaptive, sustainable, and predictable	
Policy Output			
	Indicator	Criteria	Data collection space
Social output	-Fulfillment of social goals	-Obstacles that impeded the accomplishment of the goals and opportunities that enabled their achievement	
Financial output	-Fulfillment of financial goals		
Political/ legal output	-Fulfillment of political goals		

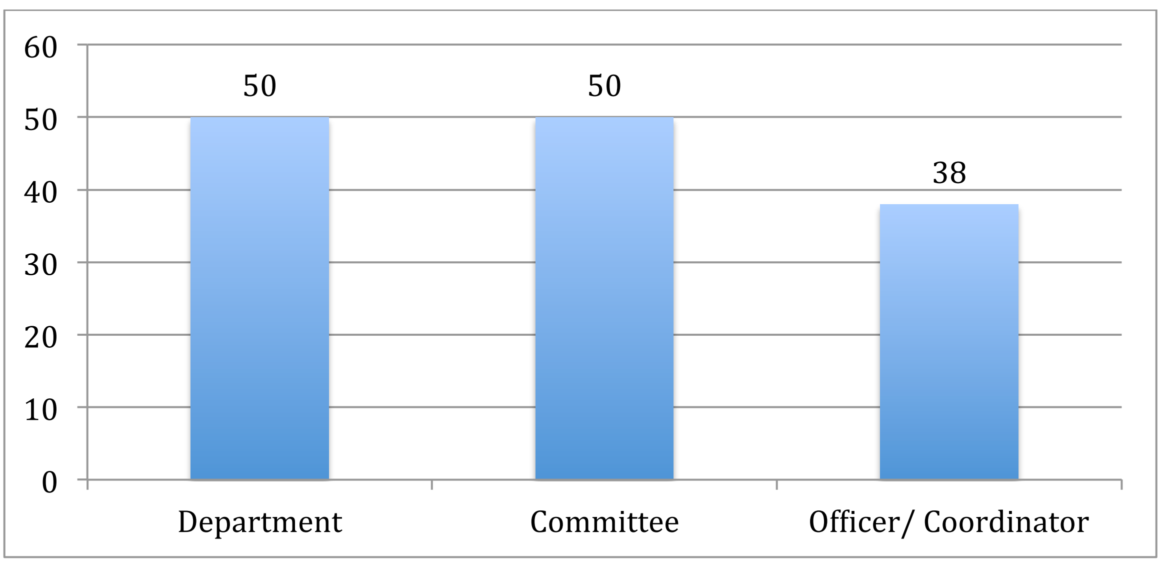
Appendix E

<u>Survey Results</u> (9 survey participants)

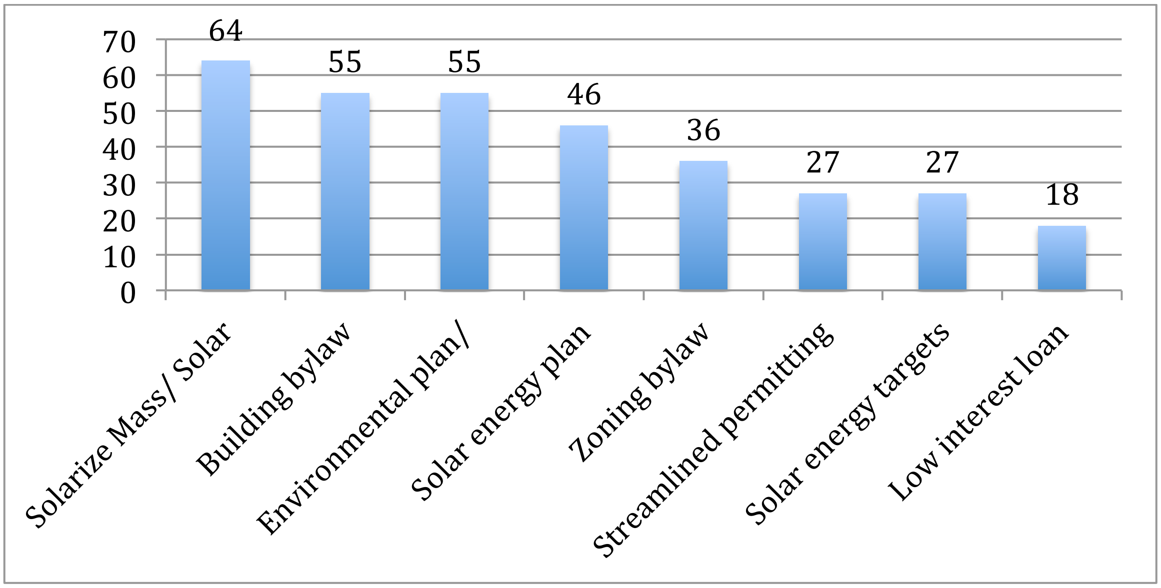
1. Percentage of towns that have the following carbon-reduction measures



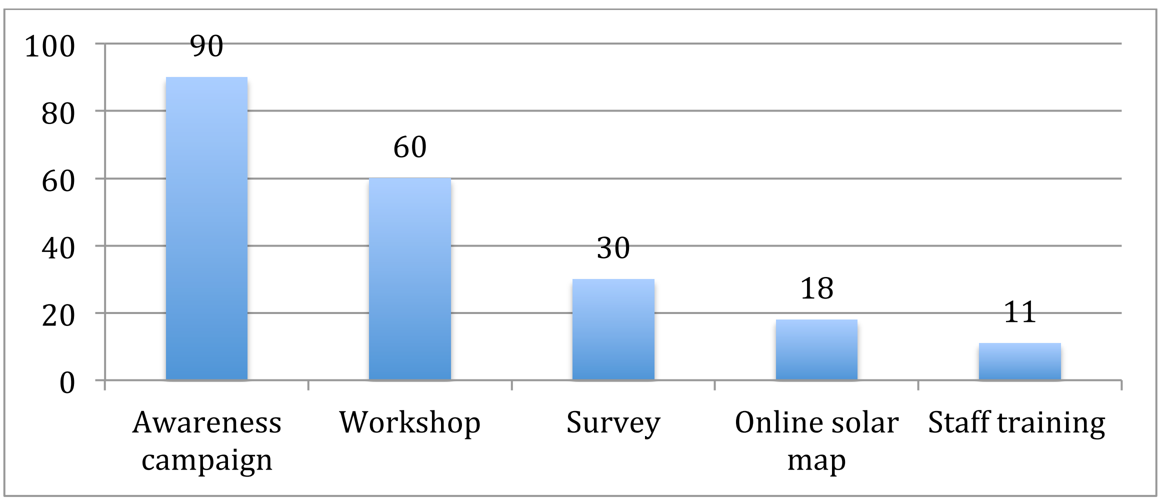
2. Percentage of towns that have a department/ committee/ officer:



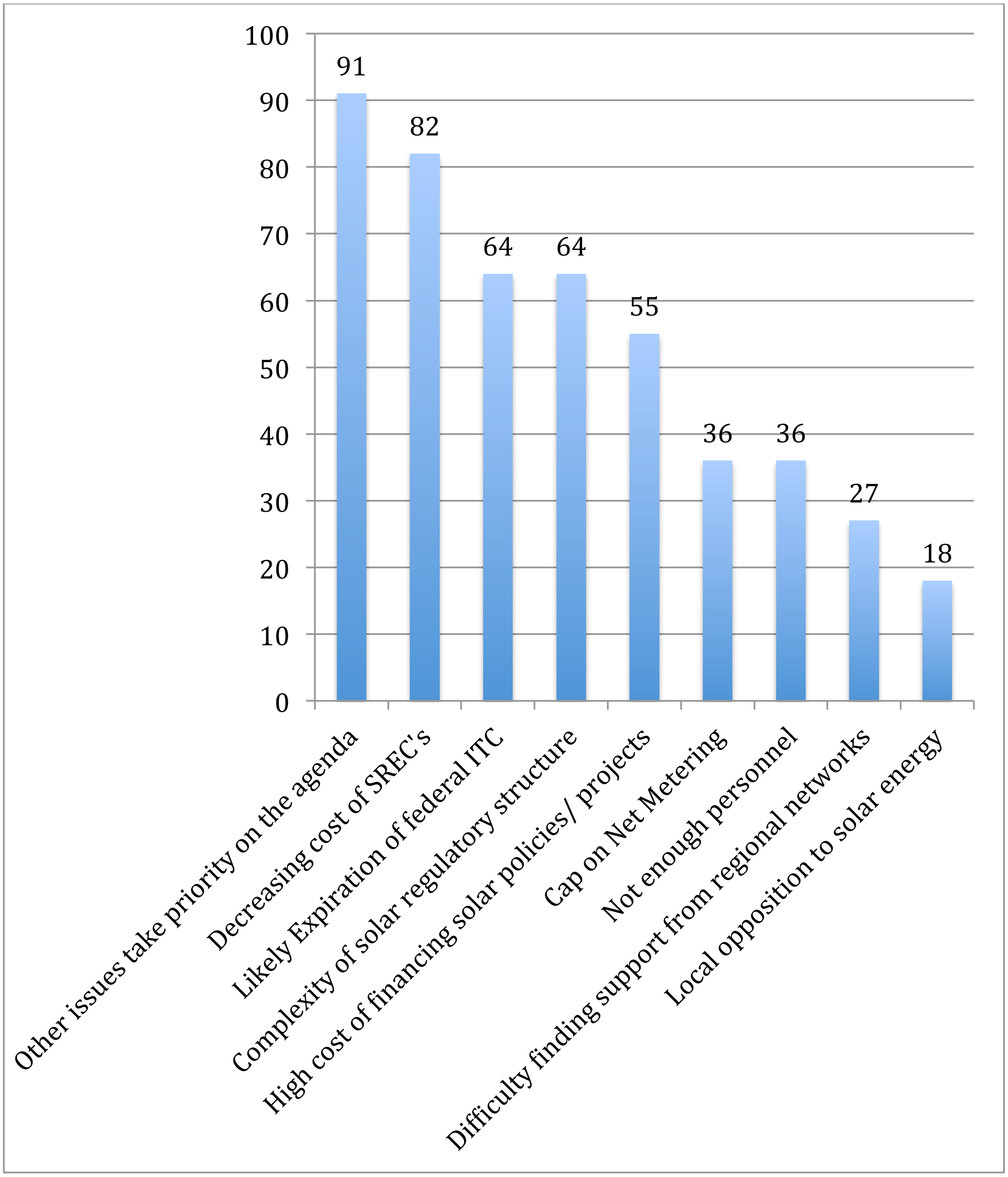
3. Percentage of towns that have the following policies



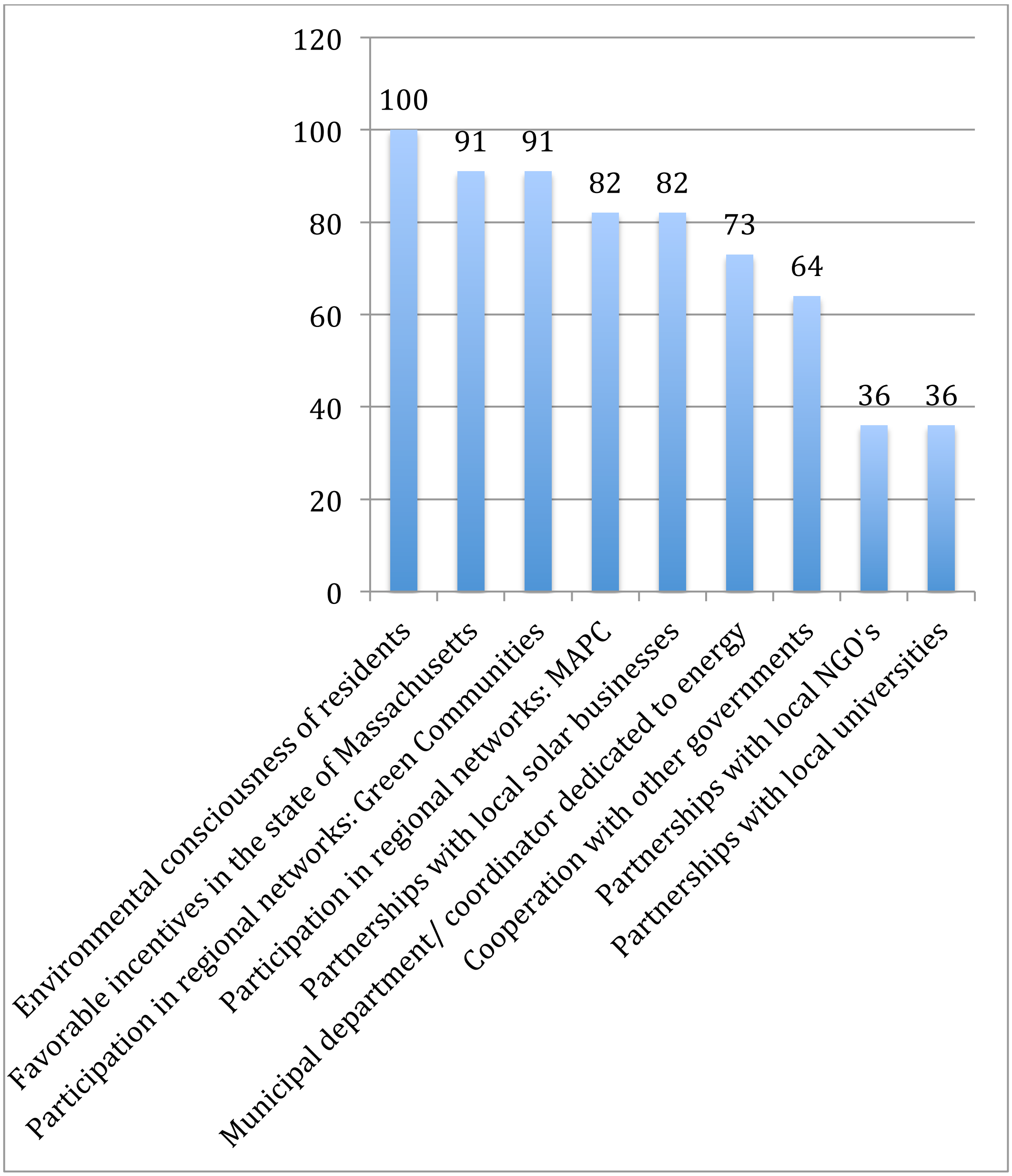
4. Percentage of towns that have the following community outreach programs



5. Ranking of obstacles
Percentage of towns where these factors are a (somewhat) significant obstacle



6. Ranking of opportunities
Percentage of towns where these factors are a (somewhat) significant opportunity



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