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Policy Implications for the Clean Energy Transition: The Case of the Boston Area

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Abstract: In this paper, we investigate the transition to clean energy technologies in the Boston area, as perceived through the lens of strategic niche management. The main goal of the study was to assess the role of policy in fostering/hindering the development of the clean energy niche and the complete deployment of clean energy technologies in this area. Using argumentative discourse analysis, our research showed that the clean energy niche in the Boston area is generally perceived as strong and dynamic. However, the public de-legitimizing narrative identified gaps at the policy level that include, among others, the limited engagement of the local and federal government in breaking through well-established practices and regulatory frameworks, funding, and infrastructure. These gaps are likely to delay the market uptake of clean energies in this area.

Keywords: socio-technical transition; strategic niche management; clean energy technologies; argumentative discourse analysis; innovation policy

1. Introduction

Clean technologies are defined as "all the techniques, processes, and products that are of importance in preventing or reducing the burden on the environment" [1]. They compete directly with the older and more traditional technologies employed in existing infrastructures, which are often less expensive (due to scale economies), more stable, and more widespread in the market. These rivalry aspects are detrimental to the market uptake of clean technologies and must therefore be mitigated by policies that incentivize the shift to a more sustainable society. Moreover, many older infrastructures are associated with significant sunk costs that cannot be recovered by incentives alone. For this reason, infrastructural restoration for clean technologies requires public support [2,3]. Furthermore, as clean technologies lack long-term research support, they are frequently considered risky and unattractive to private investors. Finally, public investment in sustainable innovations is a strategic policy decision that might be undermined by short-sighted political actions [4].

Against this background, the main goal of the present study was to map policies and assess their role in fostering or hindering the emergence of the clean energy niche and the deployment of clean energy technologies in the Boston area. (Note: The Boston area comprises the city of Boston, the city of Cambridge, the city of Somerville, neighboring cities and surrounding suburbs—all of which are home to numerous universities, research centers and firms. The Boston area is neither a statistical nor an administrative unit; rather, it is a delimitation of eastern Massachusetts (US) that is commonly used in scientific papers and thus suitable for the present study. In accordance with Berry et al. [5] and Owen-Smith and Powell [6], we define the Boston area as a functional economic area with a certain gravitational and commuting influence on its surrounding areas. With this geographical focus in mind, we attempt here to illustrate the historical evolution of the development of the area's clean energy niche.)We selected the Boston area because it is considered a leading region in research

and innovation relating to clean energy technologies (classified as second in the US) [7]. Nonetheless, this area generates only 10.5% of its net electricity from renewable energy resources; this is less than the US average (15.9%) [7], showing a mismatch (or incomplete transition) between technological development and deeper societal changes.

In our study, we investigated the transition process to clean energy technologies in the Boston area using the lens of strategic niche management (SNM). This perspective links the emergence and empowerment of technological niches to interactive learning processes and institutional changes [8,9] (Note: Bearing in mind the regional dimension of the case study, the Boston area clean energy transition could be equally understood through the framework of regional innovation systems (RIS), as this area possesses "significant supralocal governance capacity and cohesiveness," which differentiates it from the national context and that of other regions [10] (p. 480). RIS "opened up the way to exploring the extent to which innovation processes at regional level could be defined as systemic" [10] (p. 489) and, in this sense, is associated with both innovation research and regional science. However, RIS falls short in capturing the broader perspective of transition from an incumbent system to a more sustainable one by means of socio-technological change [11,12]. In fact, innovation systems provide only a narrow definition of socio-economic factors, disregarding the fulfillment of societal functions as a driver of innovation processes [11,13]). In socio-technical transitions, the emergence of a technological niche is not conceived as a technology push process, but one that is triggered by the interactions between technology, user practices, societal needs, and regulatory structures [14]. In the successful evolution of a niche, SNM involves three internal mechanisms [9,14,15]:

(i) the convergence of future expectations, in order to overcome the initial lack of confidence in innovation and to attract attention, thus legitimating niche development;
(ii) learning processes, which reduce uncertainties around innovations by increasing formal and informal knowledge on several dimensions (i.e., technical, social and environmental, cultural, economic, regulatory); and
(iii) networking, in order to build a community of supporters, facilitate stakeholder interactions and bring in (financial, human, physical) resources for niche development.

The destabilization of incumbent socio-technical systems and associated institutional structures is generated by the emergence of innovative and sustainable socio-technical configurations that receive increasing political support [16]. Furthermore, the process of creating legitimacy plays a pivotal role in boosting the maturity of socio-technical niches [17,18] by expanding the network of supportive actors.

Socio-technical transitions are not simple and linear, but complex and long-term transformations of socio-technical systems influenced by numerous dimensions at different levels of development [19], guided by sustainability goals and policies [16]. In these uncertain transitional environments, policy plays an important role in providing direct infrastructural support and building economic and regulatory framing conditions for the development and diffusion of sustainability innovations [17]. The transition to sustainable socio-technical systems can only be accomplished with the support of innovation policy (see, e.g., [20–22]). However, policy interventions maintain a conflicting position: on the one hand, they are crucial for building favorable conditions for niche maturity by boosting niche internal mechanisms; on the other hand, they are affected by path-dependent institutions and incumbent lobbies.

According to Markard et al. [16] policy affects socio-technical systems and their sustainability transitions in different ways. First, policy contributes to the development of innovations and technologies by means of knowledge generation and diffusion. From a deployment and diffusion perspective, policy plays a crucial role in market formation, regulation and the up-scaling of emergent socio-technical systems. Second, policy can contribute to destabilizing established socio-technical systems by removing subsidies and/or increasing taxes on traditional technologies.

In a study examining the role of policy in supporting energy democracy in the US, Burke and Stephens [23] identified four policy categories pertaining to socio-technical transitions. The first

category, *regulatory context*, lays the ground for the implementation of further ad hoc policies boosting the diffusion of renewable energies. This category includes renewable energy standards, green public procurement and community benefit agreements, among other regulatory instruments. An additional policy category concerns *financial inclusion measures*, or financial instruments and monetary incentives that promote energy system changes. The most important instrument in this category is the feed-in tariff (FIT), which guarantees a long-term minimum fixed purchasing price for renewable energy. Other instruments may relate to green subsidies, on-bill financing and repayment programs, public bonds, carbon tax-and-invest programs and cooperative financing. A third policy category pertains to *economic institutions*, in the form of new socio-economic institutions and economic opportunities for communities. This category focuses on communities' and/or public actors' ownership of renewable energy systems. Policy instruments in this category include renewable energy cooperatives and the re-municipalization of public assets, such as water, sewage and electricity systems. Finally, the fourth policy category consists of *new energy system institutions*, which support and facilitate institutional change in the energy system. This category includes policy instruments concerning microgrids and democratized grid management, energy regions and sustainable energy utilities.

The necessity of and commitment to a transition to sustainable innovation has dominated the discourses of global and local actors; this is particularly true in the US, where industrial production still depends to a very large extent on non-renewable energy resources. Socio-technical transitions entail political negotiation [24,25] between stakeholders with conflicting positions and opinions; such negotiation depends on the framing and definition of the institutionalizing process of innovation [26]. Indeed, the sustainability transition is shaped by social values and political discourse, and further nuanced by stakeholders' differing perceptions of sustainability issues, goals and policies. Accordingly, in the present study, we used argumentative discourse analysis (ADA) to examine the discourse of key actors concerning the role of policy in the development and deployment of clean energy technologies in the Boston area.

The research investigated the way in which constellations of actors legitimized or delegitimized innovations within transition episodes in terms of multi-dimensional discursive interactions. The aim was not to provide a deterministic view of the transition dynamics, but to explain the differing perspectives of the conflicting actors and to link narratives at the micro level to discourse at the macro level, which influences collective knowledge and discursive events. To this end, our investigation: scrutinized dominant discourses relating to the clean energy transition in the Boston area; framed innovations within discrete narratives (with a particular focus on narratives about the role of policy interventions); and assessed any enduring narratives that could obstruct the sustainable transition to clean energy technologies in the Boston area.

2. Materials and Methods

Moving within this framework, we investigated the transition process to clean technologies in the Boston area by applying argumentative discourse analysis (ADA), as proposed by Hajer [26] and subsequently developed by Hajer and Versteeg [27]. This analysis of discourse and narratives has been applied by many scholars to describe a problem, identify solutions and mediate between actors' positions in the transition process [28–35].

ADA is a valuable methodology for critically examining the environmental discourse embedded in the analysis of energy policies. For instance, by examining the discourses of key actors, ADA exposes contradictory narratives and conflicts formed around particular opinions. The main component of ADA is the storyline, which is a narrative sustained by a socio-political coalition that plays a crucial role in "clustering of knowledge, positioning of actors, and ultimately, in the creation of coalitions amongst the actors of a given domain" [26]. Storylines within an environmental discourse are characterized by specific emblems or "issues that dominate the perception of the ecological dilemma in a specified period" [26]. Since storylines emerge between and within political boundaries and do not conform to

specific political and institutional settings, they are very helpful in investigating the influence of policy on niche maturation, by revealing the hegemonic ways in which environmental conflicts are argued.

Hajer [26] defines 10 tasks of ADA, which are generally summarized in three main steps. The first step consists of making a preliminary assessment of the context and its development by analyzing written documents and official communications. This provides an overview of the developmental process, which is later enriched with further information or reframed by the interviews conducted in the second step [26]. In the present study, to explore the context of clean energy technologies in the Boston area, we reviewed reports, industry roadmaps, empirical studies and analyses [36–44], as well as official websites [45–55]. This enabled us to identify concepts and ideas that structured the discourse.

The second step of ADA consists of interviewing key players in order to collect more information on specific events. In our case, the relevant event involved the sustainability transition towards a clean energy sector. As a result of the preliminary assessment, we identified five key actors involved in clean energy technologies in the Boston area. Each actor was asked to provide at least two names of other relevant actors. After examining the suggested actors' profiles, we identified seven additional actors. In this way, we built a final list of 12 key actors, with whom we conducted formal interviews using a qualitative, semi-structured questionnaire (see Appendix A). The interviews were conducted between June and July 2016. Figure 1 presents a graphic representation of the types of actors interviewed in this step, differentiated between core and peripheral actors. Table 1 provides the full list of the interviewed actors.

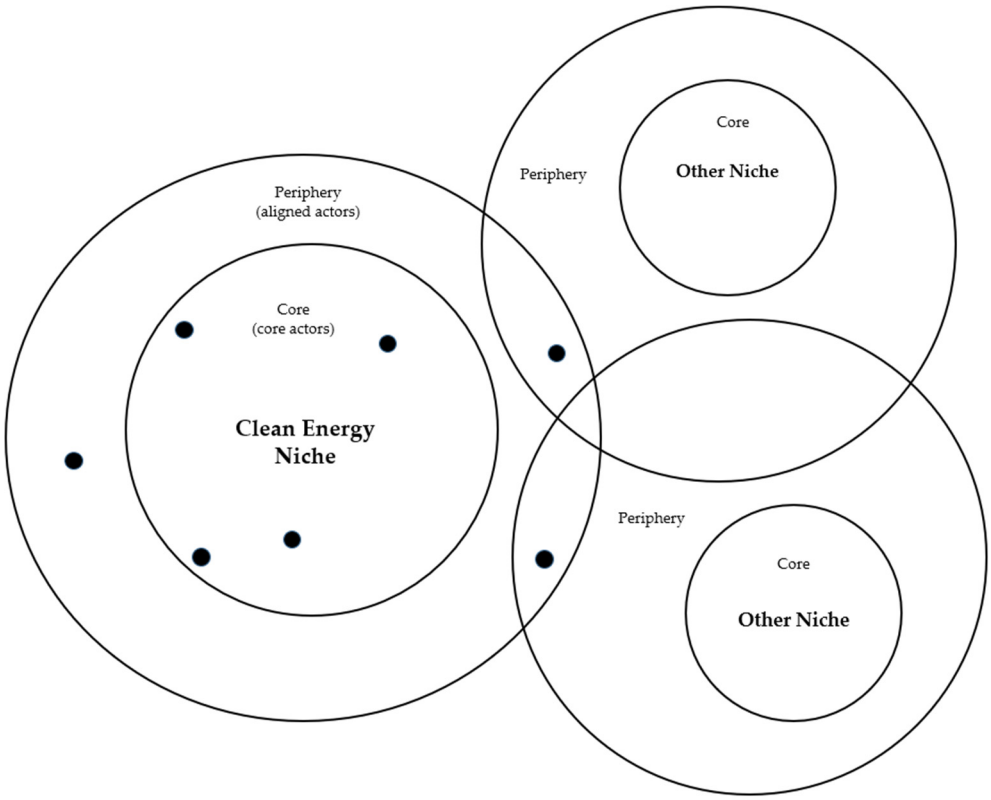

Figure 1. Core and peripheral actors. *Source:* Authors, based on Rosenbloom et al. [28].

Table 1. List of key actors' organizations.

Niche Actors	Peripheral Actors	Policy Actors
Clean-Tech Officer—Technology Licensing Office, MIT	Clean-Tech Officer—Massachusetts Technology Transfer Center	Manager of Grant Programs—Massachusetts Clean Energy Center
Clean-Tech Officer—Center for Research Innovation, Northeastern University	Board Member—Venture Café Foundation	Senior Cluster Development Specialist—EPA Office of Research and Development
Clean-Tech Officer—Harvard Office of Technology Development	Board Member—New England Water Innovation Network	Program and Research Analyst—Innovation Institute (Massachusetts Technology Collaborative)
Manager of Projects in Innovation and Industry Support—Greentown Labs		Director of OTA—Executive Office of Energy and Environmental Affairs Director of Real Estate—Boston Redevelopment Authority

Source: Authors.

As shown in both Figure 1 and Table 1, four of the selected actors were classified as part of the "core" of the clean energy niche, given their role in developing and diffusing the innovative technology. This group was composed of actors from three technology transfer offices (Harvard University, MIT, Northeastern University) and one clean technology business accelerator (Greentown Labs). The second column of Table 1 indicates three peripheral actors at the "fringe" of the niche [28] (p. 1279); these actors participated in initiatives promoting the development and deployment of clean technologies, but were not directly involved in either the niche or relevant policy (New England Water Innovation Network, Venture Café Foundation, Massachusetts Technology Transfer Centre). For instance, some of these actors engaged in technology transfer and the promotion of new technologies and start-ups in support of other niches. The third and final group of interviewees, who are not reflected in Figure 1 because they operate outside of the niche, was composed of five actors at the policy level (Massachusetts Clean Energy Centre, Environmental Protection Agency (EPA), Massachusetts Technology Collaborative: Innovation Institute, Executive Office of Energy and Environmental Affairs: Office of Technical Assistance and Technology (OTA); Boston Redevelopment Authority); these actors are grouped in the third column of Table 1. Within each organization, the selection of interviewees was made on the basis of interviewees' strategic role (e.g., manager of grant programs, innovation projects, industry support, clean technology, etc.).

To complete the ADA, a third and final step was undertaken, involving the analysis of particular events or incidents that emerged from the reviews and interviews. The aim of this step was to validate the reliability of the storylines, given the controversial opinions and experiences they contained. To this end, we analyzed the interviews and documents, querying all relevant discourse elements and events.

By following these three steps, we identified a dominant storyline concerning the flourishing dynamics of the clean energy niche. We also identified two struggling storylines: one legitimizing the crucial role and commitment of public intervention in the development of the clean energy niche, and another delegitimizing the engagement of public bodies, showing a lack of niche power to break through the incumbent market. In Section 3, we present the identified storylines along with illustrative quotes from the interviews.

3. Results

Building on the theoretical and empirical framework depicted in the previous sections, we will now illustrate the identified discourse surrounding clean energy technologies in the Boston area. The storylines that emerged in the research highlighted two specific trajectories:

1. How actors recognize the presence of a clean technology niche; and
2. How actors frame the policy context in which this niche innovation is developed and deployed.

We placed the main storyline within the first trajectory. Within the second discourse trajectory, we placed two other storylines: one legitimizing the role of public intervention and another delegitimizing its commitment. In the following subsections, we discuss these three storylines in some detail.

3.1. Dominant Storyline

Overall, most actors expressed the need to shift to a cleaner energy system, and thereby commit to more sustainable production. As emerged from the discourse analysis, the adoption of the Green Community Act in 2008 was considered the breaking point with traditional energy production. This event was found to significantly influence the development of this dominant storyline, regarding the current development of clean technologies.

STORYLINE 1: Clean energy technologies are central to a thick network that exchanges knowledge and engages for a cleaner common future.

In this storyline, we identified all three mechanisms characterizing the development of the clean energy niche in the Boston area (Table 2). According to SNM, one of the main mechanisms for the development of an innovative niche is building a common vision through shared expectations. On the one hand, universities use the commercialization of research and patents to encourage social use of their inventions; on the other hand, the state adopts environmentally friendly laws and incentives for more energy efficient and cleaner production (e.g., the Commonwealth's 2016–2018 Three-Year Energy Efficiency Plan, the Affordable Access to Clean and Efficient Energy Initiative, etc.) [46]. The annual Industry Report of the Massachusetts Clean Energy Centre (MassCEC) [36] mentions specific goals: "In August 2008, Massachusetts required all economic sectors to reach a 25% reduction in GHG emissions by 2020 and an 80% reduction by 2050 under the Global Warming Solutions Act," becoming "one of the first States in the Nation to move forward with a comprehensive regulatory program to address climate change." Moreover, the private sector "continues the trend of becoming more 'pure-play', meaning that all of their activities are clean energy related" [55].

The achievement of this goal at all levels is driven by knowledge creation and sharing, which consists of local learning processes and investment in human capital and a specialized labor force. The interviewed actors focused particularly on research and innovation, for two reasons: first, the development of clean energy technologies requires intense research to generates radical innovation; and second, as mentioned above, the Boston area is characterized by a high number of academic research institutions conducting theoretical and applied clean energy research. More specifically, since the US government adopted the Bayh-Dole Act in 1980, universities have become key actors of innovation by commercializing their research to firms operating in the market. MIT's Technology Licensing Office files approximately 200 patents each year, but only a quarter of these relate to clean technology. Both MIT and Northeastern University license half of their filed patents to existing companies, and 20–25% of these result in spin-offs. These institutions have engaged in an intense transfer of mature technology, amounting to 147 patents awarded to 36 companies working with pre-commercial products, 229 patents awarded to firms focusing on energy efficiency and 25 patents awarded to firms working exclusively with energy goods and services [36]. Grentown Labs, a clean technology accelerator, has filed 32 innovative patents and supported nine university-born companies. On the other hand, according to Venture Café, there remains a dire need for technology transfer: "Clean energy in the Boston area is composed by small companies; there are no large companies yet. Therefore, technology transfer is really important because all the research and innovation comes from universities. Small companies don't have budget for research."

Indeed, knowledge sharing and technology transfer in the Boston area represent a regional competitive advantage that is disseminated through networked actors. Collaboration and networking

are quoted as incentives, either for the location of clean energy companies in Boston or the success of clean energy development. Indeed, one-third of the patents filed at MIT are developed in collaboration with other universities or companies at which their students are likely to find employment. Also, according to the respondent at Greentown Labs, their success depends on their dense network, composed of 102 host start-ups and mature and specialized companies, with expertise in topics ranging from IP to tax filings, fundraising and clean energy technology.

Table 2. Overview of the dominant storyline.

Dominant Storyline	**Clean Energy Technologies Are Central to a Thick Network that Exchanges Knowledge and Engages for a Cleaner Common Future**		
Key narratives	Universities, industry and public bodies share common expectations and work for a cleaner future	Knowledge creation, local learning processes and technology transfer are unique to the Boston area	Networking is an asset for the location of clean energy companies in the Boston area

Source: Authors.

3.2. Legitimizing and Delegitimizing the Role of Policy

The core message of the dominant storyline pertains to the existence of a dynamic and sufficiently mature clean energy niche with a thick network of actors engaged in learning processes and knowledge exchanges. Moreover, a common thread throughout this storyline is the need for public institutions and actors to proactively exert pressure upon the incumbent energy regime, prompting the deployment of clean energy technologies. We investigated this aspect further by identifying two additional storylines about the role of policy in niche development.

STORYLINE 2: Public intervention is everywhere.

The second storyline is based on three key narratives relating to policy intervention areas in support of the clean energy niche: the regulatory framework, funding for knowledge creation and sharing, and infrastructures for a collaborative environment. Such policy interventions, which aim at developing an environmentally friendly regulatory framework in the Boston area, account for a significant number of laws and regulations concerning air quality, toxic and hazardous substances, waste and recycling. One particular example is the Toxics Use Reduction Act (TURA), which receives support from both industry and environmental groups. This Act requires companies to analyze and report their annual chemical use, quantifying the chemical content in the final product, the chemical content released into the environment at the end of the production process and any waste treatment performed. Furthermore, it requires companies to draw up long-term pollution reduction plans.

The TUR Institute, located on the Lowell Campus of the University of Massachusetts, is tasked with meeting TURA's goal of developing innovative techniques for cleaner production. As stated by the OTA interviewee: "the Institute is engaged in alternative assessments, in research developing alternative chemistries and in evaluation of alternative technologies in order to complete their program of technology transfer."

Moreover, following the Green Communities Act of 2008, the Massachusetts government now promotes the development of renewable energy, energy efficiency and conservation, "green communities" and the implementation of Regional Greenhouse Gas Initiatives. This Act aims at reducing the costs of renewable energies for consumers and "increase[ing] generation from low or zero-carbon resources within Massachusetts" [43]. The Green Communities Program, instituted by this Act, provides incentives to municipalities that engage in energy efficient and renewable technology. Furthermore, the Pioneer Valley Planning Commission Sustainability Toolkit mentions that the Green Communities Division of the Department of Energy Resources shall provide "up to 10 million dollars per year state-wide in technical and financial help to the communities involved." A portion of this money is raised by the Regional Greenhouse Gas Initiative (enacted under the same Act), which draws on market-based cap-and-trade CO_2 emissions. The emission allowances

issued under this initiative are auctioned, and the generated funds are used for zero-interest loans for municipal energy-efficiency projects.

With respect to knowledge creation and sharing, the Green Jobs Act, adopted in 2008, designated "125 million dollars to train about 30,000 people in green collar jobs" [47]. In order to achieve this goal, the Act instituted the MassCEC, which became "the most important quasi-public agency in job creation and for the economic development of the clean energy industry."(Interviewee from the MTTC.) Indeed, both the MassCEC and the Innovation Institute have programs in place to support students who are transitioning to the labor market, "because Boston has a high rate of international students who would chose to work in the Boston area only if there is a good work environment."(Interviewee from the Innovation Institute.) Similarly, the MassCEC Workforce Development Programs aim at increasing awareness of clean energy job opportunities and placing job seekers in clean energy jobs in Massachusetts [36]. Since 2011, this organization has placed "more than 1300 interns at over 250 companies which have received a reimbursement of $14/h for the internships." (Interviewee from the MassCEC.)

Moreover, according to technology officers from MIT, Harvard University and Northeastern University, 80–90% of the research at these universities is publicly funded, with most of the funds granted by the NSF and NIH for basic research. However, the MassCEC and SBIR are key actors in placing their students in green collar jobs, commercializing their staff's clean patents and funding their inventors' spin-offs.

Considering that Massachusetts's basic research at universities, research institutes and hospitals is worth $4.5 billion, in 2003, the state legislature created and funded the Massachusetts Technology Transfer Centre (MTTC). The MTTC aims at improving knowledge generation and the diffusion of innovative technologies. While it does not provide funding, it supports universities' technology transfer offices, assists institutions that do not have their own technology transfer office and develops programs in collaboration with the MassCEC and the Massachusetts Technology Collaborative (MassTech)—both quasi-public agencies that provide financial support for MTTC programs.

The MassTech provides capital funding grants with a co-participation of one-third (up to $5 million) on projects relating to innovation development. It generally funds non-profit institutions—especially universities—that collaborate with private companies or for-profit institutions (Interviewee from the Innovation Institute). To confirm its role in the up-scaling of the emergent clean energy system, the MassCEC implements many grant programs, targeting university innovators and start-ups as well as growing companies, and provides pilot test areas for GTL companies. Table 3 summarizes the MassCEC grant programs that support the development of new clean energy technologies.

Table 3. MassCEC grant programs.

Grant Program	Target	Grant Amount
Catalyst	To help researchers and young companies develop prototypes and proof-of-concept studies	$2.1 million to 55 companies
AmplifyMass	To support Massachusetts-based awardees of ARPA-E (Advanced Research Projects Agency-Energy)	$3 million to 14 awardees
AccelerateMass	To support graduates in transitioning out of accelerator programs	$50,000 in phase 1, $100,000 in phase 2
InnovateMass	To help young clean energy and water companies overcome financial barriers to commercializing products and technologies	$2.2 million to 19 companies
DeployMass	To help companies seeking a first or early customer to validate the commercial readiness of their technology	up to $160,000
Direct Equity Convertible Debt Investment	To help early stage companies	average investment of $500,000
Venture Debt Investment Program	To fill funding gaps for clean-tech companies seeking venture debts but unable to attract private venture capital	$100,000 to $1 million

Source: Authors, based on data from MassCEC [54].

At the federal level, Small Business Innovation Research (SBIR) is a special program of the Small Business Association (SBA), which supports the creation of spin-offs. In particular, the SBA funds small companies that collaborate with universities, with funding also provided for the universities.

Public intervention also targets infrastructure in support of a collaborative environment. At the local level, the city of Somerville is building fabrication laboratories that are small makerspaces in high schools. Also, to stimulate innovation, Somerville is providing physical connections, in addition to economic ones. As highlighted by MIT and stated by Harvard representatives in Cambridge: "the State of Massachusetts and the municipalities of Boston and Cambridge have an economic development project for the creation of an innovation district and their engagement focusses particularly in infrastructural works of connecting Kendall Square with the rest of the area by the bridge and the red line."

Incubators and accelerators represent important infrastructure for start-ups and innovative companies in the Boston area. Some examples include the Cambridge Innovation Center (hosting 600 new companies), the Roxbury Innovation Center (situated in a marginalized neighborhood), Venture Café, MassChallenge and the Boston Innovation Center, which are all supported by the state of Massachusetts as well as local municipalities, as part of their innovation policy initiatives. All of these co-working spaces support start-ups in preparing business plans and networking with strategic partners, mainly for mentorship and resources. Furthermore, in 2015, the city of Boston launched an initiative involving a "startup czar." This czar, named by the municipality, has a background in planning and is tasked with analyzing the city's opportunities for welcoming start-ups and providing them with, in particular, physical connections (Interviewee from the Greentown Labs).

Table 4 summarizes the three key narratives of Storyline 2 related to policy intervention areas in support of the clean energy niche.

Table 4. Overview of Storyline 2 on legitimizing public engagement.

Storyline 2	**Public Intervention Is Everywhere**		
Key narratives	Adoption of significant number of environmentally friendly laws and regulations	Availability of (public) funds for knowledge creation and sharing in clean energy	Public intervention also targets infrastructures for a collaborative environment

Source: Authors.

Most actors perceived the general framework of public engagement in the development of innovative technologies as rather positive and supportive of the emergence of the clean energy niche. However, the discourse analysis uncovered some hurdles in the maturation of the clean energy niche and the deployment of these technologies in the Boston area, as reflected in the third storyline.

STORYLINE 3: diffusion of clean energy technologies in the Boston area is limited by incumbent barriers.

This final storyline represents the interviewees' discourse in response to the questions: "In your opinion, which is the level of diffusion of clean energy technologies stemming from research in this field, as used by companies and households, respectively? For what reason(s)?" The concepts and ideas that emerged in the discourse mainly concerned the limited policy commitment to break through well-established practices and regulatory frameworks, the lack of public programs and policy support for attracting venture capital to up-scale innovations and the lack of infrastructural interventions for the commercialization of clean energy technologies (Table 5). Accordingly, this storyline significantly reframes the role of policy in the clean energy transition in the Boston area.

Table 5. Overview of Storyline 3 on delegitimizing public engagement.

Storyline 3	**Diffusion of Clean Energy Technologies in the Boston Area Is Limited by Incumbent Barriers**		
Key narratives	Scarce commitment of policy to break through well-established practices and regulatory framework	Lack of public programs and policy support to attract venture capital for the market uptake of clean energy technologies	Lack of infrastructural interventions for the commercialization of clean energy technologies

Source: Authors.

The storyline rightly assumes that clean energy technologies are based on radical innovations that demand change in well-established practices and regulatory frameworks. The interviewed actors perceived limited policy commitment to increasing awareness and improving regulations to support a trustworthy and long-term transition in the Boston area. Indeed, the adoption of the Energy Policy Act in 2005 by the US government intended to extend federal production tax credit to renewable energies. The creation of this policy involved varying public and private stakeholders concerned with environmental regulation and incentives. However, although initially promising, the Act had no real effects (regulatory or otherwise) on the energy sector. In fact, according to the Union of Concerned Scientists [56], the $14.5 billion provided for the implementation of the bill was spent mainly on nuclear and fossil fuel; only 9% was spent on renewable energy and 21% on energy efficiency. Moreover, community-driven innovations such as Greenovate (which promotes bike sharing and solar panels) are not necessarily attractive and struggle to establish shared practices. Consequently, these innovations are unlikely to become established in the market, unless policy intervenes with regulations aimed at raising awareness and forming new markets, for example through State purchasing and procurement. This is the main reason why only 30–50% of university patents are commercialized (Interviewee from the OTA).

Lack of resources also limits the up scaling of clean energy technologies, thereby hindering their ability to gain purchase in the market. Policy has failed to build long-lasting public–private partnerships and to financially plan innovative activities: "15 years ago, there was a program called the Strategic Technology Environmental Partnership (STEP). Its purpose was to take new clean technologies and make the proof-of-concept for commercialization. Once the technology was ready to be deployed, we proposed it to the companies. The program no longer exists, mainly because of lack of resources and change of administration." (Interviewee from the OTA.) Indeed, incentives that support the clean energy sector in the Boston area depend heavily on the governing party. However, there is a mismatch between the horizon of clean energy development and the horizon of political turnover; this increases the uncertainty of clean energy, making it less attractive for venture capitalists (Technology officer from MIT). Although venture capitalists are key for the flourishing of innovation activities in the US private sector, they are not particularly attracted to and active in the clean energy market due to its risky nature [2]. US states (with the exception of California) tend to be conservative with venture capital, due to the long-time horizons involved. In particular, the transition to clean energy technologies cannot occur in the short term (Interviewee from the EPA). This is one of the reasons why companies are afraid of investing in clean energy technologies, as they are unsure whether such technologies will prove sound investments over the long term.

With respect to infrastructural interventions for the commercialization of clean energy, the interviewed actors recognized a lack of policy. Massachusetts is highly dependent on external sources, considering that the state's energy consumption exceeds its production. The state does not produce any petroleum, coal or natural gas, yet its net electricity generation is 73.3% dependent on natural gas, 0.3% dependent on petroleum, 3.7% dependent on coal, 14.5% dependent on nuclear energy, and only 5.7% dependent on renewables (mainly hydroelectric and biomass) [7]. Moreover, Boston—the largest city in the state—has the oldest active port in the US; this port has petroleum product terminals

and the only liquefied natural gas (LNG) import terminals. In addition, Massachusetts is home to the largest coal-fired power plant in New England. This shows that state policy has mainly engaged in infrastructure for economic development (see storyline 2), rather than infrastructure that could boost the deployment of clean energy technologies (e.g., the MassCEC funding programs neither supply testing areas nor build infrastructural facilities for start-ups in the clean energy technologies niche).

All of these elements, which emerged from the discourse analysis, substantially undermine the belief that policy has embarked on a flourishing path to a clean energy transition in the Boston area.

Overall, storylines 2 and 3 seem to confirm what emerged in storyline 1—that the clean energy niche in the Boston area is dynamic and potentially able to achieve maturity. However, these two storylines provide two rather contrasting perspectives on this potential. On the one hand, storyline 2 stresses the role of public policy in supporting the emergence of the niche. On the other hand, storyline 3 suggests that policy has failed to support the deployment of clean energy technologies in the Boston area due to a lack of pressure on the incumbent energy regime; thus, breakthrough of the clean energy niche has been impeded.

4. Discussion and Concluding Remarks

Overall, our investigation showed that the clean energy niche in the Boston area is characterized by a fast growing and dynamic innovation environment. In particular, important actors in the quickly evolving clean energy niche are: (i) local research institutions and universities that provide innovation, a specialized workforce, laboratories, and equipment; and (ii) technology business incubators (e.g., Greentown Labs) and clean technology business accelerators (e.g., Cleantech Open Northeast, Venture Café, MassChallenge), which support start-ups in developing innovative business plans and networking with strategic partners, mainly for mentorship and resources. The activity of these actors lays the groundwork for the emergence of an innovative niche, by means of knowledge generation and networking. However, these actors are failing to up-scale clean energy technologies into innovative systems and to fully penetrate the market. In addition, they are lacking in long-term financial resources, as they are dependent on private funds and/or affected by instable political support.

Given the importance that the literature attributes to policy intervention for the development of clean technologies, we further tested the engagement of public agencies in the Boston area in relation to the three niche mechanisms determined through SNM. We identified a legitimizing public engagement storyline (storyline 2) grounded on three key narratives, each reflecting a policy intervention affecting niche mechanisms. The first policy intervention emerged from interviewees' discourse concerning the adoption of a significant number of environmentally friendly laws and regulations, paving the way to a common expectation of clean energy technologies development. The second policy regarded the availability of public funding for knowledge creation and sharing, in order to trigger actors' learning processes. Finally, the third policy targeted infrastructures for a collaborative environment to support networking among actors—both within and beyond the niche.

However, the narratives in the public delegitimizing storyline (storyline 3) identified gaps at the policy level that, according to the respondents, hindered the upscale of clean energy technologies, and thus the development of the clean energy niche in the Boston area. These gaps related generally to three major pitfalls in the public strategy for developing the clean energy niche: (i) state policy engaged more in adopting new laws rather than harmonizing regulation to destabilize well-established practices; (ii) policy intervention had not yet succeeded in attracting private investment to the clean energy sector, resulting in a dependent relation between (unstable) public funding and the market uptake of clean energy technologies; and (iii) by only occasionally providing key infrastructures (e.g., facilities for market-level technology deployment), policy had not yet succeeded in building an effective commercialization program, resulting in the limited deployment of clean energy technologies in the Boston area and hindering the clean energy niche breakthrough.

Overall, until policy designs and implements focused interventions, the emerging clean energy niche in the Boston area, though significantly dynamic, will struggle to overturn the incumbent regime.

This explains why, although the government has invested significantly in clean technologies research and development, the Boston area remains at an early stage of deployment of clean energy technologies.

As a final remark, we shall suggest a possible action to overcome these pitfalls and speed up the transition process. As noted, the clean energy sector in the Boston area is largely composed of small companies—particularly start-ups—that are dispersed across the state. This industrial structure has struggled to develop and, for this reason, is not attractive for venture capital investment, which is "focused on some of the safer bets rather than on the radical innovation that is required to allow the sector to transform society so as to meet the double objective of promoting economic growth and mitigating climate change" [2] (p. 136). Therefore, larger amounts of public resources must be invested to stimulate the growth of small companies. This will attract private investments, facilitating a fruitful entrepreneurial environment and stimulating the development of dedicated infrastructures for the deployment of innovative clean energy technologies.

One limitation of the methodological approach we have applied in this work regards the inclusion of only local actors in the niche, while according to the socio technical transition literature, niches can be defined as networks of both local and global actors [57–60]. In that respect, it could be important to investigate learning processes that aggregate niches' actors in networks generating global structures. However, exploring global (knowledge) spillovers of the Boston area clean energy niche goes beyond the scope of this paper—whose purpose is to assess the role of policy in fostering/hindering the emergence of the clean energy niche and the deployment of clean energy technologies in the Boston area—and would represent a very fertile line for future research.

Furthermore, although the policy gaps and shortfalls identified in this paper are context-specific—grounded in the discourse of local actors—the analysis has highlighted divergent policy needs in the different phases of niche emergence and maturation. Considering the role of actors' perceptions and needs in transition studies, ADA could be a suitable methodology for pinpointing context-specific needs in the energy transition process. For this reason, as an interesting and important further line of research, we suggest that ADA be applied in developing countries that have only recently begun to engage in energy transition pathways.

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Appendix A Outline of the Semi-Structured Interviews

- Describe your organization and the role it plays in the clean energy sector.
- What are the main drivers of your presence in the Boston area (MA)?
- Have you introduced innovative technologies and/or processes in the market, and/or filed any patent related to clean energy technologies?
    - Did you develop the innovation/patent on your own or in collaboration?
    - What percentage of your R&D/innovation activity has been funded by public financial support/private organizations?
    - Have you received any other support from private or public organizations?
- Has your organization developed any kind of collaboration with other public or private organizations?
    - What kind of collaboration?
- Has public policy supported the development of clean energy technologies?

  - Through which correlated or direct activities?
- In your opinion, what is the level of development of clean energy technologies in the Boston area (as compared to other places)?
  - For what reason(s)?
- In your opinion, what is the level of diffusion of clean energy technologies in the Boston area (compared to the R&D in this field)?
  - For what reason(s)?
- Please rate the following statements on a scale from 1 (strongly disagree) to 5 (strongly agree):
  (a) The legislation supports innovative activities.
  (b) Special aid is available from the government for innovations.
  (c) Starting up one's own business is encouraged in Massachusetts.

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