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Fostering Innovative Growth in Regions Exposed to Low Carbon Transition

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Abstract:

Sources of innovative growth have the potential to mitigate the localized adverse impacts of a low-carbon energy transition. Transitions themselves may contribute new activities related to clean energy. To explore this potential, we examine the relationship between transition exposure and regional innovation in the United States. We find that innovative activity is generally weak in areas exposed to transition, especially in those places with high shares of fossil fuel extractive industry employment. Using case studies, we evaluate the experiences of diverse efforts to systematically strengthen regional innovation systems, with a focus on clean energy and manufacturing. In each case, we look for evidence of five entrepreneurial competencies, and characterize the number and criticality of the gaps in these competencies. We then examine the ways that each case intervention has addressed these gaps. We find that interventions that address *critical*, but not necessarily *more*, gaps are effective. Buy-in from multiple stakeholders who share an interest in sustaining an intervention, and building on existing local capabilities are also antecedents of success.

The costs of transitioning to a low carbon economy in the United States will be concentrated in regional economies heavily dependent on fossil fuel extraction and its downstream uses. A transition to low carbon energy is poised to displace jobs within these industries, many of which still underpin regional economic viability. While public programs and other forms of aid may be provided to compensate those affected, they are largely aimed at alleviating dislocation and do not translate into new sources of durable economic growth. It is therefore important to examine whether and how transition regions can generate new sources of local economic activity.

Existing literature on regional economic development focus on two competing forces: convergence and agglomeration. Barro and Sala-i-Martin (1995) define convergence as growth of a focal industry declining in the level of economic activity due to diminishing returns. Glaeser, et al. (1992) describe agglomeration as a countervailing force in which growth accelerates in the level of a focal industry's economic activity. Delgado, Porter, and Stern, (2012) find that agglomeration dominates in a co-located set of similar industries, or cluster, in which businesses supply complementary functions.

The context of deep decarbonization could be particularly painful for transition regions because it unravels the benefits of agglomeration. Consider for example, economic activity in Youngstown, Ohio: agglomeration occurred across closely related industries including mining (primarily coal), associated combustion processes for electric power and high quality heat, and then downstream consumption of inexpensive electricity and heat, especially but not exclusively in steel production. In a transition, particularly one that removes access to low prices for energy and high-quality process heat, the economic unraveling could be devastating.

However, unlike recent past industrial transitions, where communities have been affected by the wholesale decline of certain industries often as a result of international competition, e.g. steel manufacturing in Appalachia, the energy transition is two-sided: electricity generated from coal and natural gas will decline and be replaced by new clean generating technologies. While this transition will a shift away from carbon-intensive processes, there is plausible optimism that new technology and new firms could take their place locally.

For regions in transition, there are two challenges to capturing the value of these opportunities. First, the new industries are likely to form in orthogonal technological spaces relative to existing industries. For example, the technological basis, workforces and supply chain for solar photovoltaic technology has little overlap with that of coal mining and coal-fired power production. As a result, regions facing transition may be at a disadvantage with respect to existing assets and competencies to be able to take advantage of new technological opportunities, particularly in comparison to traditional, and booming, entrepreneurial ecosystems, such as Silicon Valley or Cambridge. The academic literature highlights many reasons for these dynamics including the effects of agglomeration, intellectual spillovers from academic institutions, and co-location with risk-capital, among others. Moreover, solar PV is an imperfect substitute for a coal plant, as it is less amenable to producing high-quality process heat and will require innovations in storage and grid management to handle its intermittent availability. Figure 1 shows how a clean energy transition undermines the agglomeration advantages enjoyed by fossil fueled local economies.

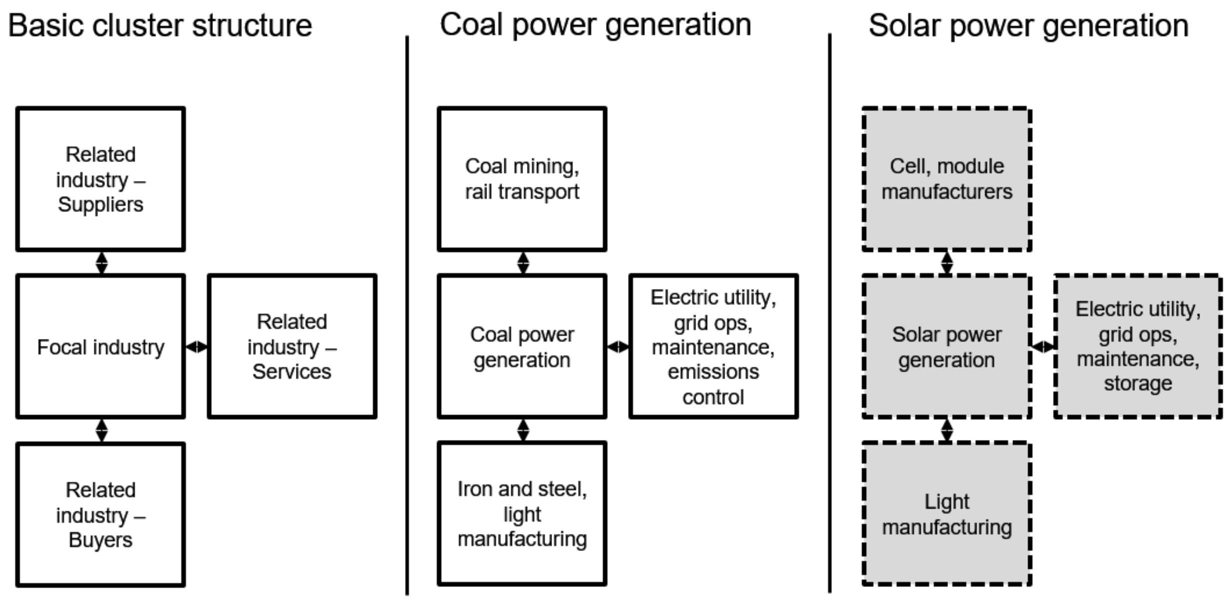


Figure 1 *How the transition to clean energy (in this case from coal power to solar power) undermines agglomeration economics in a region. Left panel: basic structure of an industry cluster, Middle panel: agglomeration economies enabled by low-cost electricity and heat, Right panel: implications of shifting from coal to solar PV electricity in a cluster during low carbon transition. Changes indicated by dash lines and grey background.*

Second, and building on the first, the returns to innovative sources of economic growth are increasingly concentrated in the hands of specific socio-economic groups, and unequally distributed across geographies. The concentrated nature of entrepreneurship and innovation on the coasts of the United States bodes poorly for those communities in between that are poised to endure the negative effects of transition without enjoying the fruits of the transition related to new technologies, firms and growth.

For that reason, we focus on how at-risk communities can build sources of innovative economic growth locally, acknowledging that each region faces unique circumstances. We are particularly interested in activities that have the potential to match the scale of existing energy-related industries. The subset of these activities that are compatible with transition aims of carbon reduction are our primary focus. These activities include developing substitutes for fossil energy locally, but also tangential industries such as advanced manufacturing, information technology, and construction.

This paper begins by examining the relationship between regional exposure to transition and indicators of innovative activity (Section 1). This analysis shows quantitatively what we have alluded to above: regions vulnerable to transition lag on innovation. Section 2 motivates our focus on five innovation competencies, which we use as a starting point for our case analysis. Section 3 introduces our hypotheses and discusses case selection. Section 4 uses the cases to test our hypotheses. Section 5 summarizes our main findings and concludes.

1. Localizing the challenge

We define transition regions using employment shares in the extractive industries, which include coal mining and processing as well as oil and natural gas drilling, and in the energy-intensive, export exposed (EITE) manufacturing industries (fossil power generation plus refining, petrochemicals, and plastics manufacturing), which are directly exposed to prices of primary fuels or energy carries (e.g., electricity and heat). Employment shares are sourced from the Bureau of Economic Analysis.

We plot these shares against regional innovation metrics (see Table 1) and show correlations for all metrics in Table 2. Some metrics vary with the extent of new business activity (entrepreneurial quality, VC funding, and federal R&D support), while others are scale-independent (patenting and publications by individuals engaged in science and engineering occupations). All metrics will not be equally important in every context, and some—such as VC funding—reflect resources leveraged across state lines. Here, we focus on total venture capital provided from any origin to businesses located within a state. Similarly, we focus on patents registered to, and papers published by, researchers in the state, but collaborating teams spanning multiple locations may have been involved.

Table 1 *Measures of entrepreneurial activity.*

Measure	Description
Entrepreneurial quality	Likelihood that a startup in a region achieves high growth (Guzman & Stern, 2015)
Patents	Patents per 1,000 individuals in science and engineering occupations
Federal R&D	Federal R&D spending as a share of state regional product
Publications	Publications per 1,000 individuals in science and engineering occupations
Venture capital funding	Seed, early, and late-stage funding received during 2017

1.1 Exposure to fossil extractive industry job losses

We find that four out of five regional innovation metrics correlated negatively with extractive industry share, while for the fifth metric, publications, the correlation is weakly positive. Figure 2 shows the relationship between extractive industry share and entrepreneurial quality. With the exception of Oklahoma, states with shares of extractive industry employment shares above 2% rank in the bottom half of the state distribution (New Mexico, West Virginia, Alaska, North Dakota, and Wyoming). The negative correlation is the strongest for our venture capital funding measure. Figure 3 shows the relationship between extractive industry employment shares and venture capital funding received in 2017, again with select states labeled. The sharp negative relationship is perhaps unsurprising, in that venture capitalists are basing funding decisions on a range of competencies, e.g. composition and strengths of the founding team, intellectual property, and market access to suppliers and customers. Again, states with the highest extractive industry exposure rank in the lower half of the distribution. North Dakota raised no venture capital in 2017. Data on entrepreneurial quality were obtained from the Startup Cartography Project (Andrews, et al., 2019), while data on patents, federal R&D spending, publications, and venture capital funding are from the National Science Foundation's Science & Engineering State Indicators (National Science Board, 2018).

Table 2 *Correlations between transition-affected industry employment shares and the log of entrepreneurship metrics.*

Industry	Entrepreneurial Quality	Patents	Federal R&D	Publications	VC Funding
Extractive industry share	-0.269	-0.276	-0.232	0.052	-0.525
Energy-intensive manufacturing industry share	-0.130	0.294	-0.155	0.294	0.015

Figure 2 *Relationship between share of extractive industry jobs and the log of entrepreneurial quality. The mean of log(EQ) is -3.31.*

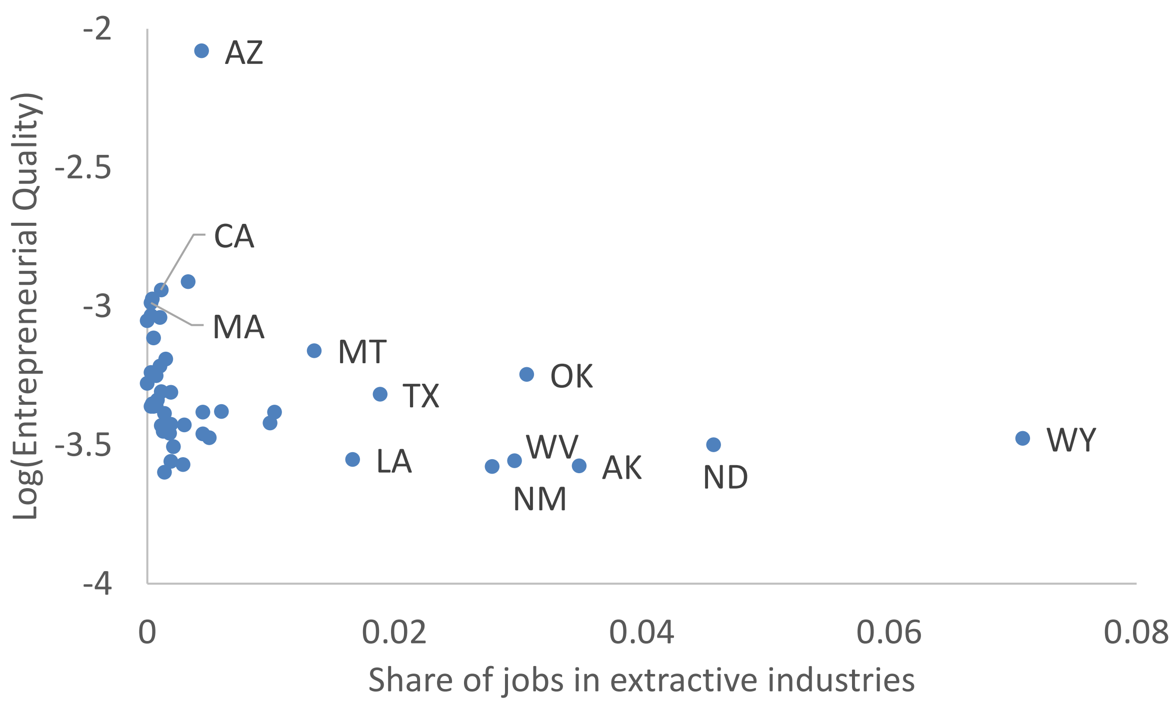
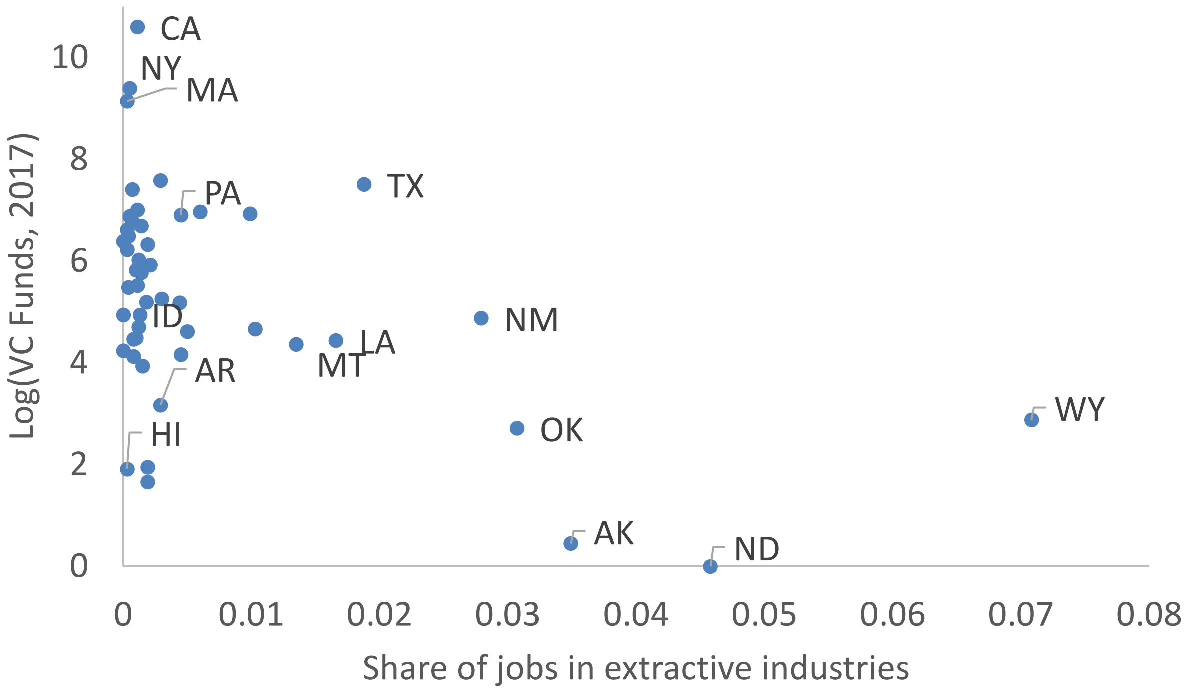


Figure 3 *Relationship between share of extractive industry jobs and the log of venture capital funding (millions) raised in 2017. The mean of log(VC funding) is 5.04.*



1.2 Exposure to energy intensive manufacturing job losses

Compared to the extractive industries, correlations between EITE manufacturing employment shares and entrepreneurship/innovation measures (shown in Table 2) tell a somewhat different story. Here, EITE manufacturing is positively associated with both intensity measures, patents and publications. This is perhaps not surprising given that EITE manufacturing may be co-located with applied research facilities. EITE manufacturing employment shares negatively associate with the scale-dependent measures of entrepreneurial quality and federal R&D, but these correlations are less strong compared to those with extractive industry share. We find no relationship between EITE manufacturing share and our VC funding measure. It may be that VC funding in states with high EITE manufacturing shares targets capital-intensive investments with larger ticket sizes. The challenges of attracting inputs needed for scaling early-stage, high-growth entrepreneurship may nevertheless remain in states with high EITE manufacturing shares, but the conditions seem fundamentally more favorable, compared to areas with high extractive industry shares. We emphasize that these correlations should *not* be interpreted as causal. They draw attention to general patterns.

If alternative sources of growth cannot be readily cultivated in exposed areas, social spending may need to be larger and longer lasting, and will not translate into self-sustaining activity. Therefore, explicit consideration of how to invigorate entrepreneurship in transition areas, if done well, may reduce the need for government outlays while kindling local economic growth.

2. Competencies related to innovative growth

2.1 What underpins innovative growth?

Prior studies have identified competencies that influence the pace and direction of innovative growth in a region. Workforce skill is frequently ranked highly as a precondition for innovative growth, regardless of whether the nature of innovation is incremental or more radical (Toner, 2011). Mason, et al. (2017) further emphasizes the contribution of different skill types, finding important roles for both high-level skills and upper intermediate technician-level skills in the generation of innovative outputs. When combined to produce final goods, uncertified skills (such as on-the-job training) further become important.

Access to risk capital is another important competency for building new entrepreneurial activity, and may pose the greatest challenge to new venture creation (Gompers & Lerner, 2001; Tian, 2011). Established players, by contrast, may have established creditworthiness or be able to finance new activities internally.

The literature on regional innovation systems emphasizes the cultivation of tacit knowledge among locally-interacting organizations and individuals as an important source of competitive advantage (Asheim and Gertler, 2009). Regional economic organization can impact survival and success: Saxenian (1994) attributes the success of Silicon Valley to its decentralized, cooperative industrial system and the decline of Route 128 in Massachusetts to its siloed, self-sufficient organizations. Guzman and Stern (2015) develop a new measure of entrepreneurial quality (used above) across the United States and find evidence that location and institutional quality influence firm outcomes, above and beyond a set of early firm decisions such as where to register and patent filings. The proximity to users or customers can also be important for firms that engage in open innovation (von Hippel, 2005).

A related issue for the health of an entrepreneurial ecosystem is the circulation of ideas. There is a well-established literature relating the importance of geography to the circulation of ideas. Jaffe, et al. (1993) capture the presence of geographic knowledge spillovers comparing the location of patent citations with that of the cited patent. Saxenian (1994) articulates the importance of engaging with complementary firms, e.g. suppliers, and Porter (1998) expands on the importance of established firms in an entrepreneurial environment. Carlino and Kerr (2015), among other contributions, highlight that geographic concentration enables the spread of tacit knowledge, which can be fundamental to product and process innovation. Building off of this literature, Hellmann and Perotti (2011) focus on the nature of idea circulation within a market as an important input for idea completion. The authors predict that an efficient system for idea circulation involves diverse organizational forms participating in a mutually beneficial idea completion process.

The literature shows that local institutions are an important component of the environment that shape the interplay between idea generator and incumbents (Hellmann & Perotti, 2011; Porter, 1998; Saxenian, 1994). Strong IP protection is an important mediator of this interplay, reducing frictions in engagement between new entrants and competitive incumbents (Gans, Hsu, &

Stern, 2008), particularly in environments with high capital intensity for complementary assets (Gans & Stern, 2003). Second, the actors within the market need to be committed to the new incentive regime (Gans & Stern, 2010).

Culture, defined as the largely unchanging beliefs and values that ethnic, religious, and social groups transmit from generation to generation, also shapes innovativeness (Guiso, Sapienza, & Zingales, 2006). Of all of the competencies important for innovative growth, culture is perhaps the most difficult to change among the regional competencies listed here. The propensity to engage in risky new ventures, to form industry associations, to unionize, and to pursue or switch occupations may be influenced by these beliefs and values.

2.2 What interventions can help entrepreneurs succeed?

Studies on which interventions help entrepreneurs succeed focus largely on public policy and programs (Lerner, 2010, 2013). Lerner (2013) illustrates how government intervention is neither uniformly good nor bad, but can suffer from mistakes or regulatory capture. For example, the Small Business Investment Company (SBIC) laid the foundation for the modern venture capital industry in the U.S., with abundant analogs in other countries, but even the SBIC supported corrupt fund managers. This literature emphasizes the importance of nuanced and contextual understanding of regions and entrepreneurs, including the conditions that make entrepreneurship attractive, as well as the need for extended support horizons and ongoing evaluation to realize success.

Combining insights from these literatures, we arrive at the following (non-exhaustive) list of competencies that are important to building local entrepreneurship. These competencies include:

(1) A well-trained pool of human and managerial capital;

(2) Risk-tolerant sources of financing;

(3) A proximate or accessible base of suppliers and/or knowledge inputs for the focal activity;

(4) Channels for exchanging information, including coordinating with local stakeholders and marketing to or innovating with prospective customers;

(5) Prevailing rules and cultural norms that support and reward new business creation.

The dependencies and complementarities among these competencies are no doubt complex, and may differ across contexts. The first three competencies are relatively straightforward to characterize and potentially influence, while the fourth and fifth are recognized as important but involve elements of systems that tend to be less observable and mutable, especially on short time frames.

3. Empirical approach: categorizing interventions and hypotheses

The remainder of this paper asks what makes an intervention to strengthen a region's innovative economic activity successful. We focus mainly on interventions that are directly related to, or at least consistent with, the objective of low carbon energy transition. The eight cases we present are not intended to be fully representative or exhaustive, but instead to allow initial exploration of our hypothesis within our sample. The insights that emerge are intended to provide a starting point for designing interventions in the focal regions of the broader Roosevelt project.

First, we are interested in the extent to which the interventions we study overcome gaps in regional innovation competencies. Therefore, for each case discussed in this section, we focus on how an intervention targeted and closed one or more gaps. Prior literature suggests that filling in these gaps will support agglomeration economies in the innovative activity by enabling complementarity across competencies. Our first hypothesis is:

H1: Individual interventions that cultivate multiple competencies in a given region will be more effective, relative to interventions that cultivate fewer competencies.

Second, we focus on how the breadth of stakeholder support matters to the longevity and success of an intervention. We see two reasons why this should be the case. Connections to multiple stakeholders suggest that an intervention is effectively "plugging in" to an innovative ecosystem, potentially tapping into the upsides of agglomeration. The second reason is political: stakeholders invested in an intervention are more likely to defend it as policy priorities change. For instance, if an intervention focuses not on creating a single start-up company, but on workforce training and networking across a start-up community, it would be considered as having a larger breadth of stakeholder support. Therefore, our second hypothesis is:

H2: An intervention that targets multiple institutional structures in a local ecosystem will be more effective by stimulating the potential for spillovers and agglomeration through related but not competitive activities.

Third, we focus on the relationship between the intervention and the preexisting industrial base. An important question for transition communities is whether to abandon the high carbon activities in which they currently enjoy agglomeration benefits and develop new industries, or instead to evolve existing industries in ways that support a low carbon transition. The latter strategy may have short-term benefits, but could increase the transition costs over the long term. To explore these tensions, we hypothesize the following:

H3: Focusing on activities that are adjacent to the preexisting industrial base will be easier in the short term, but may make it more difficult to transition in the long term.

In selecting cases, we face "survival bias"—all of our interventions were successfully established and most are still in existence. We recognize that we are excluding interventions did not initiate successfully. Therefore, we can only draw conclusions about the relationship between the characteristics and the degree of success, but about how characteristics may have affected inception.

To relate the attributes of cases discussed above to outcomes, we adopt a process tracing approach. As shown in Table 3 below, our cases represent variation along the main dimensions that the hypotheses focus on: the number of competencies addressed (single vs. multi competency), the breadth of stakeholder support (few vs. many), and the extent to which the focus of an intervention is new to a region's industrial base (existing vs. *de novo*).

We collect information for our cases from archival sources as well as over 50 interviews with program administrators, startup executives and ecosystem partners covering the various stages of the interventions we study.

A summary of our cases characterized along the four dimensions is provided in Table 3 below:

Table 3 *Summary of cases along four dimensions.*

<table>
<tr><th>Case</th><th>Single vs. Multi Competency</th><th>Few vs. Many Stakeholders</th><th>Existing vs. de novo activities</th><th>Hypothesis</th></tr>
<tr><td>Greentown Labs</td><td>Multi</td><td>Few</td><td>de novo</td><td rowspan="4">H1</td></tr>
<tr><td>Innovation Crossroads/LEEP</td><td>Single</td><td>Few</td><td>de novo</td></tr>
<tr><td>Elemental Excelerator</td><td>Multi</td><td>Few</td><td>de novo</td></tr>
<tr><td>Connecticut Green Bank</td><td>Single</td><td>Few</td><td>existing & de novo</td></tr>
<tr><td>Alaska Center for Energy and Power</td><td>Multi</td><td>Few</td><td>existing & de novo</td><td rowspan="2">H2</td></tr>
<tr><td>Center for Advanced Energy Studies (Idaho)</td><td>Multi</td><td>Many</td><td>existing</td></tr>
<tr><td>Kentucky REAP</td><td>Multi</td><td>Many</td><td>de novo</td><td rowspan="2">H3</td></tr>
<tr><td>Auburn University + GE</td><td>Multi</td><td>Many</td><td>existing</td></tr>
</table>

While each case inevitably has many idiosyncratic features, we attempt to focus on the influence of various dimensions, accounting for interactions among them and differences in the existence of competencies across locations.

4. Case Analysis

4.1 Single vs. Multi-Competency Interventions

To evaluate our first hypothesis, we compare four cases. Three are incubators (Greentown Labs, Innovation Crossroads/LEEP, and Elemental Excelerator) and one is a financing source (Connecticut Green Bank). We provide two scorecards for each case. The first scorecard qualitatively captures how the intervention supplied or strengthened innovation competencies in a region. The second scorecard evaluates the viability of the organization on several dimensions: portfolio growth, funding sources, funding volume, and the intervention's longevity.

4.1.1 Greentown Labs

Greentown Labs is a cleantech startup incubator located in Somerville, MA. By the time it was founded in 2011, the Greater Boston region had emerged as a major hub for entrepreneurship, strong and growing stronger on the five competencies described earlier, which provided fertile ground for the incubator to develop. In just under a decade, Greentown has gone from four startups sharing space in a Cambridge warehouse, to the largest cleantech startup incubator in North America. At the same time, it has become a cornerstone of the Greater Boston region's increasingly vibrant cleantech innovation system.

The incubator's focus is on providing early-stage startups that are developing clean energy and sustainability technologies with physical space and infrastructure, as well as a robust community of fellow entrepreneurs and resources from across the Greater Boston cleantech innovation community. Greentown is built around three key competencies: providing tangible resources to startups (in the form of work space, labs, and equipment), helping them build connections with industry and suppliers (through a network of partners, an in-house accelerator program, and a supply chain initiative), and building a vibrant community of clean-energy entrepreneurs.

The gaps filled by the incubator, and its overall performance over the past decade, are summarized in Table 4. Since its founding in 2011, Greentown Labs has incubated over 230 startups, 88% of which remain operational to date and six of which have been successfully acquired. Collectively, those startups have raised over $750 million in investments, and generated $232 million in revenue (along with 430 patents). As of December 2019, there were 110 startups in residence at Greentown's campus in Somerville (Greentown Labs, 2019a).

Table 4 *Scorecard for Greentown Labs. Ecosystem attributes coding: Green – not a barrier; Yellow – a partial or emerging barrier; Red – a major barrier. Performance measures coding: Green – strong performance; Yellow – some weaknesses in performance; Red – intervention severely challenged or discontinued.*

a)

Ecosystem attributes addressed by the intervention	**T1**	**T2**
Well-trained pool of human and managerial capital	Green	Green
Risk-tolerant sources of financing	Green	Green
Proximate base of suppliers and/or knowledge inputs	Yellow	Green
Channels for exchanging information with prospective customers	Yellow	Green
Prevailing rules and cultural norms that reward business creation	Green	Green

b)

Measure of performance	**T1**	**T2**
Portfolio Growth	Yellow	Green
Funding Sources	Red	Green
Funding Volume	Red	Green
Longevity	Red	Green

Greentown Labs traces its origins to a warehouse just outside MIT's campus in Cambridge, MA. A number of recent MIT graduates working on energy startups — off-grid refrigeration, efficient compressors for oil & gas, airborne wind turbines, building energy management — found themselves in search of an affordable space where they could engage in the messy work of prototyping their products, while also remaining close to the relationships they'd built at MIT (Winn, 2019).

The warehouse they rented together in late 2010 quickly became more than just a shared workspace, with the four startups regularly swapping business advice, and introducing each other to potential employees and investors. When the warehouse was demolished in 2011, the four startups once again banded together and moved to a larger facility in South Boston. Turning the collaborative element of the shared workspace into a formal organization, they ultimately would add another sixteen startups. Greentown Labs quickly became a core element of what Boston Mayor Tom Menino dubbed the "Innovation District" — an effort to rebrand South Boston by positioning it as a regional hub for innovation and entrepreneurship (City of Boston, 2013; Farrell, 2012). By 2013, Greentown once again faced rising rents, and moved to a new 33,000 square-foot facility across the Charles River, in Somerville. The move was aided by $330,000 in tax incentives offered by Somerville Mayor Joseph Curtatone, who said at the time that "[Greentown] bring[s] us everything we hope for in the type of companies we need to build our locally-sustainable economy" (Shemkus, 2015). In 2015, Greentown's continued expansion into a full-fledged incubator led it to begin construction on a 60,000 ft^2 expansion, completed in 2018, to give it the 100,000 square-foot campus it currently calls home.

Greentown's roots in the practical needs of early-stage energy startups continue to inform the key competencies it fulfills today, as a key component of the Greater Boston region's innovation system. Startups in residence at Greentown (for two years on average), can expect to benefit from the various resources it provides, the partnerships it allows them to draw on, and its vibrant community of cleantech entrepreneurs. For a monthly fee, Greentown offers startups work and lab space, and access to prototyping and machining facilities. It also gives them access to technical software and specialized equipment (Greentown Labs, 2019a).

While Greentown does not provide direct funding or investments to startups that are part of its entrepreneurial community, it has developed an expansive network of partners across the Greater Boston region's innovation system that startups are encouraged to draw on. These partners range from multinational industrial corporations like Shell and BASF (chosen for their "science-based climate commitments"), to local universities and energy firms, to a network of investors with a strong interest in funding those startups (Greentown Labs). A number of Greentown's major partners, such as the innovation arm of multinational utility Enel, have actually opened their own "regional innovation hubs" in the form of desks and dedicated staff located at the incubator, giving them prime access to the startup community (Chesto, 2019).

Greentown has further helped startups achieve economic impact beyond its immediate vicinity by developing a number of cross-cutting initiatives, which bring startups together with other components of the Greater Boston region's innovation system. Chief among these is the Launch startup accelerator, which brings startups together with large corporations to tackle specific sustainability challenges over a six-month period. BASF is currently sponsoring an effort focused on startups that could play a role in a circular supply chain for plastics (Greentown Labs). In 2015, Greentown launched its Manufacturing Initiative, which was rebranded as Forge in 2019 and spun off into an independent, but allied, non-profit. Forge seeks to help Greentown startups build connections with regional suppliers and manufacturers, with a particular emphasis on building "East-West" connections between the entrepreneurial community in the Greater Boston area and the manufacturing base in Western Massachusetts (FORGE). To date, Forge has produced over 120 contracts and what Greentown estimates at $10.8m in known economic impact (Greentown Labs, 2019, p.35).

Greentown's vibrant startup community draws in no small part from the existing academic and innovation infrastructure of Greater Boston — Emily Reichert, Greentown Labs' CEO, is quick to note that the incubator sits in the middle of a triangle bounded by Tufts University, Harvard University, and MIT (Jacobs, 2019). Around 24% of Greentown startups are directly spun out of universities, while 71% have employees who hail from major local universities (Greentown Labs, 2019, p.15). Hearkening back to its roots, 60% of Greentown's startups also have some kind of tie to MIT (Winn, 2019). Looking to state agencies, the incubator notes that 89% of startups received support from Massachusetts' clean-energy agency, Mass CEC, totaling over $11 million in financial support (Greentown Labs, 2019, p.15). The relationship between Greentown and Mass CEC is an example of the complementarities available to regions: Greentown focuses on helping startups in attracting human capital, facilitating knowledge/supplier links, and channeling information exchange among a pre-existing local talent pool, while Mass CEC assists on funding.

Greentown has played a role in community-driven efforts to build a regional cleantech innovation system in the Greater Boston area. As has been discussed, it was a key element first of the South Boston "Innovation District," and later to an effort to grow Somerville's innovation-centric economy. Per its own statistics, Greentown's startup have had a $1.56 billion economic impact in the region, creating 6,500 jobs and over $550 million in labor income. Notably, Greentown's impact on the Greater Boston regional innovation system appears to operate on a timescale well beyond the average startup's two-year tenure in the incubator — 66% of its 135 alumni companies remain based in the Greater Boston region, today (Greentown Labs, 2019, pp. 5, 42).

As a result of these successes, Greentown Labs has been hailed over the years as an exemplar of Boston's thriving regional cleantech innovation system. It has been highlighted by the mayors of Boston and Somerville, Senator Elizabeth Warren, and Governor Charlie Baker — who presided over its 2018 ribbon-cutting. It has also become a regular feature in high-profile climate and energy policy announcements in Massachusetts. In February 2019, State House Speaker Tom DeLeo announced Greenworks, a $1 billion commitment to municipal renewable energy, energy efficiency, and climate resilience, at Greentown's Somerville Campus (LeBlanc, 2019). The same month, Senator Ed Markey launched the Green New Deal from Greentown, a day after formally introducing the bill in Washington (Massachusetts Jobs with Justice, 2019).

The case of Greentown Labs reveals that it is not the number of gaps an intervention addresses that makes it successful. Instead, it is the extent to which an intervention address critical or region-specific gaps that matters. Given that human capital, technology, and an entrepreneur-friendly culture were at hand, perhaps one of the most critical gaps Greentown addressed was in facilitating information exchange and collaboration between the members of young companies, potential follow-on funders, and large industrials interested in gaining exposure to their technologies and business models. No doubt, progressive state energy policies and support for programs like Mass CEC also helped Greentown to succeed. Transition contexts may be very different, but the insight that context and intervention must combine in ways that address critical gaps still holds.

4.1.2 Chain Reaction Innovations/Lab Embedded Entrepreneurship Program: Innovation Crossroads

Since their origins in the massive science and engineering investments of the Second World War, the national labs have played important roles in major technological advances: from the nuclear weapons project to the space program to the computing revolution. Today, they are centers of clean energy research, focusing on photovoltaics and nuclear reactors, advanced grid technologies, and electric vehicles, among a wide array of other technologies. They are also regional hubs of knowledge, expertise, and resources. The Laboratory Embedded Entrepreneurship Program (LEEP) is one prominent example of how the labs support innovative sources of regional growth (U.S. Department of Energy, 2018). The program aims to create regional innovation hubs that offer budding startups financial support and entrepreneurship training, as well as access to the resources, personnel, and networks of a national lab.

Instead of focusing on “spinning out” technologies developed in national labs, LEEP focuses on catalyzing regional innovation by “spinning in” outside ideas and would-be entrepreneurs into the national lab system, providing them with access to facilities for technology development and entrepreneurial training (Satell, 2019). LEEP traces its origins to Cyclotron Road, an incubator for clean energy startups launched in 2015 at Lawrence Berkeley National Laboratory. In 2016, Cyclotron Road was expanded into LEEP, in an effort to replicate its model across the country, housed in the Advanced Manufacturing Office of the Department of Energy's Energy Efficiency and Renewable Energy division. LEEP subsequently added two new sites: Innovation Crossroads at Oak Ridge National Laboratory (ORNL) in Tennessee, and one outside Chicago, Chain Reaction Innovations (CRI) at Argonne National Laboratory.

We focus here on Oak Ridge’s Innovation Crossroads because it is located in the transition context of the southern Appalachian region. Launched in September 2016, Innovation Crossroads is a two-year fellowship, intended to give researchers with hard-science startups access to ORNL resources, researchers, and networks, as well as a fellowship to support them during the process. It also provides them with a customized entrepreneurship training program, designed to help teach the skills needed to turn a research idea into a viable, commercializable business. To date, Innovation Crossroads has hosted fifteen startups across three cohorts — with two currently underway and applicants for a fourth currently being evaluated. The program began as a standard LEEP effort with funding from DOE’s Advanced Manufacturing Office, and gained the backing of the Tennessee Valley Authority, beginning with the third cohort. Innovation Crossroads offers prospective entrepreneurs a personal fellowship, Cooperative Research and Development Agreement (CRADA)-based funding for work conducted at ORNL, entrepreneurial training, and access to a broad network across the lab. However, its efforts have been carefully aligned with ORNL’s overall mission and capabilities. Prime examples of this are the multiple nuclear energy/isotope startups in its cohorts, which rely on the lab’s world-class nuclear research facilities, or the multiple data science-driven startups in its cohort drawing on the lab’s SUMMIT supercomputer — the fastest in the world.

Table 5 *Scorecard for Innovation Crossroads. Ecosystem attributes coding: Green – not a barrier; Yellow – a partial or emerging barrier; Red – a major barrier. Performance measures coding: Green – strong performance; Yellow – some weaknesses in performance; Red – intervention severely challenged or discontinued.*

a)

Ecosystem attributes addressed by the intervention	**T1**	**T2**
Well-trained pool of human and managerial capital	Green	Green
Risk-tolerant sources of financing	Red	Red
Proximate base of suppliers and/or knowledge inputs	Yellow	Green
Channels for exchanging information with prospective customers	Red	Yellow
Prevailing rules and cultural norms that reward business creation	Red	Yellow

b)

Measure of performance	**T1**	**T2**
Portfolio Growth	Red	Red
Funding Sources	Red	Yellow
Funding Volume	Yellow	Yellow
Longevity	Yellow	Yellow

The LEEP approach offers regional innovation systems a distinct model for overcoming critical gaps to startup formation: bring entrepreneurs into national labs and leverage internal and external networks of expertise. The direct benefits from Innovation Crossroads are just beginning to emerge. We summarize our findings from the case in the scorecards in Table 5.

Based on an examination of ORNL's public profiles of the cohort firms, the fifteen Innovation Crossroads startups have created 34 jobs in the region, to date, including the twelve currently being supported by the program's fellowships (Oak Ridge National Laboratory, n.d.). Per Innovation Crossroads's own documents, the twelve current cohort members have raised a total of just under $3 million in funding, while the four alumni companies alone have raised just over $3 million (Innovation Crossroads, n.d.) — though it's worth noting that $2.6 million came from a single ARPA-E grant to one of the four (ARPA-E, 2018). While these numbers are relatively small, it is important to bear in mind the fact LEEP startups are usually in the very early stages of commercialization — just making the leap from lab bench to product. In addition to jobs created and funding raised, eleven patents have been granted to cohort members, with seven more in various stages of the patent grant and application process (Oak Ridge National Laboratory, n.d.). In addition, the ability of LEEP to leverage a national network of expertise in support of a regional innovation system is compelling, and should be considered as a model for drawing expertise to regions, helping to fill critical gaps in competencies.

However, the LEEP approach has some drawbacks. These programs rely on a match between entrepreneurs that are proximate (or willing to relocate) and their counterparts within the lab. It may also not address critical gaps in financing and supplier access, since lab personnel may be less well positioned to direct entrepreneurs to resources in the private sector. Finally, the companies that LEEP entrepreneurs create are not likely to locate their companies in transition regions if conditions are more attractive elsewhere, and the LEEP program is not designed to improve these underlying conditions. This case suggests that the labs may be able to function as catalysts for innovative entrepreneurial activity, but without attention to *critical* gaps in regional competencies, the impact of the entrepreneurs incubated may be felt far from the region where a lab is located. Differing from our hypothesis, it seems that the number of gaps addressed is less important than whether or not the critical gaps are addressed.

There are indications that the LEEP model is relatively transferable across regional contexts. As we have discussed, over the past five years, LEEP has expanded substantially from its origins at Cyclotron Road, to CRI and Innovation Crossroads. Based on publicly-released proposal documents, Los Alamos National Laboratory (LANL) is also in the process of creating its own LEEP-inspired initiative, known as the “Manhattan District.” Calling back to LANL’s origins in the Manhattan Project, the proposed initiative could be summed up as “LEEP for national security” — an effort to bring talented early-career researchers with promising ideas for tackling national security challenges into the LANL ecosystem, and provide them with the support, resources, connections, and entrepreneurial training they will need to succeed (Cernicek & Mcbranch, 2019). The proposal for the Manhattan District explicitly calls back to “successful Lab-Embedded Entrepreneurship Programs” like Cyclotron Road, Innovation Crossroads, and CRI by name — citing them as exemplars of how to use lab-based support for entrepreneurship to drive local, regional, and national economic growth. It will be interesting to understand the effectiveness with and extent to which this model can be applied across different regional innovation systems.

4.1.3 Elemental Excelerator

Incubation initiatives can also emerge from local partnerships between government and business interests, enabling them to leverage external inputs. The Elemental Excelerator was born of Hawaii’s late-2000s drive to begin decarbonizing the state. The Hawaii Department of Business, Economic Development and Tourism’s Strategic Industries Division, working with the U.S. Department of Energy and contractors from BoozAllenHamilton created the Hawaii Clean Energy Initiative in 2008, as a focal point for realizing this goal. However, those involved with the project recognized that building a community-based effort around decarbonization would also require developing a components of a broader regional system — one with the capacity to support cleantech innovation and entrepreneurship efforts over a longer timeframe. This led to the creation, in 2009, of what would become the Elemental Excelerator (Hrushka, 2018).

Originally named the Energy Excelerator, this Hawaii-based nonprofit “growth accelerator” funds and supports startups primarily focused on developing and deploying clean energy technologies in Hawaii (Elemental Excelerator, 2018a). The Energy Excelerator (EEx) was born of the Hawaii Clean Energy Initiative, which was created with Department of Energy funding in 2008, to help the state develop the innovation and entrepreneurial infrastructure it would need to meet its ambitious RPS target. It got its start as a project of the Pacific International Center for High-Tech Research (PICHTR). Dawn Lippert was part of a BoozAllenHamilton team that helped bring the effort into being, and was tapped to run it. Its first incarnation was as the Hawaii Renewable Energy Development Vehicle, which began competitively awarding project-based grants in 2009, much like a traditional R&D agency (Elemental Excelerator, 2018b).

Around the same time, the U.S. Department of Defense — not primarily known for its environmental progressivism — was becoming increasingly concerned about *operational energy*: US military's reliance on energy for its day-to-day and combat operations. It was also becoming concerned about the implications of climate change — not only on its readiness/ability to carry out its duties, but also as a "threat multiplier" on the kinds of challenges it would be called upon to confront at home and abroad. The Department of Defense has a long-standing and sizable presence in Hawaii, with 11 bases across the state, including the famous Joint Base Pearl Harbor-Hickam — headquarters for the U.S military's Pacific operations (Klare, 2019).

Thus, in 2013, the Department of Defense decided to make a major commitment to accelerating the deployment of technologies that could alleviate its operational energy challenges (beginning in the Hawaii region, and scaling from there), by backing the Energy Excelerator. The Department of the Navy, through the Office of Naval Research, decided to make a $30 million commitment to the Excelerator — which it later doubled down on, by committing another $30 million in 2018 (O'Brien, 2018).

In 2017, the Energy Excelerator merged with the Emerson Collective's energy-focused Elemental arm, becoming the Elemental Excelerator, and began an expansion into supporting California-based startups as well as further project deployments across the Asia-Pacific region (O'Brien, 2018). The Emerson Collective is believed to provide the Excelerator with funding comparable to that provided by the Department of Defense (Hrushka, 2018).

As in the case of Greentown, the Excelerator's development is intertwined with the rise of a broader regional cleantech innocation system in the state — driven partially, in Hawaii's case, by increasingly ambitious clean energy policies. In the decade since the founding of the Excelerator, Hawaii has gone all-in on its commitment to decarbonization. In 2015, the state government adopted a new renewable portfolio standard that mandates 100% renewable electric generation by 2045 (St. John, 2017). Combined with Hawaii's isolated island geography, and the accompanying constraints and opportunities, this has helped the state develop a vibrant regional innovation system for proving and deploying clean energy technologies.

Each year, the Excelerator selects 15-20 startups from over 400 applicants, and provides each with up to $1 million in funding. The Excelerator's core investment activities take place along three tracks: a Go-to-Market track, which provides a $75,000 grant for customer discovery and validating a scalable business model; a Demonstration track, which provides a grant of up to $1 million for project deployments in Hawaii or Asia Pacific, and an Equity & Access track, which provides up to $750,000 investment for companies increasing access to innovation for low-to-moderate income communities in California (Elemental Excelerator).

Table 6 *Scorecard for Elemental Excelerator. Ecosystem attributes coding: Green – not a barrier; Yellow – a partial or emerging barrier; Red – a major barrier. Performance measures coding: Green – strong performance; Yellow – some weaknesses in performance; Red – intervention severely challenged or discontinued.*

a)

Ecosystem attributes addressed by the intervention	**T1**	**T2**
Well-trained pool of human and managerial capital		
Risk-tolerant sources of financing		
Proximate base of suppliers and/or knowledge inputs		
Channels for exchanging information with prospective customers		
Prevailing rules and cultural norms that reward business creation		

b)

Measure of performance	**T1**	**T2**
Portfolio Growth		
Funding Sources		
Funding Volume		
Longevity		

Geographically speaking, the Excelerator sources potential portfolio companies from across the world. However, its ultimate choice of companies is fundamentally driven by its role in regional innovation systems. Each company has some degree of regional focus, whether by addressing a sustainability challenge in the context that Hawaii faces it; conducting sizable demonstrations of its technology in Hawaii or across the broader Asia/Pacific region; or addressing challenges of equity and access to resources in underprivileged communities in California. As of January 2020, the Excelerator has 99 portfolio companies, 10 of which have been successfully acquired. It has awarded $36 million in funding grants to its portfolio companies, which have gone on to raise a total of $1.1 billion in funding (Lippert, 2020).

The scorecard for Elemental Excelerator is shown in Table 6. The Excelerator is example of how an incubator can channel resources and interest from the outside in hastening regional energy transition. It serves as a bridge, and like a bridge, it has benefited both ends — driving clean energy job creation in Hawaii, across the U.S., and globally. The Excelerator benefits from its savvy and well-connected leadership and its ability to access capital from diverse sources: the military, Emerson, and local utilities, in order to help support cleantech innovation and entrepreneurship in Hawaii. In addition to providing funding, these partnerships with other players in Hawaii's regional cleantech innovation system have also enabled the Excelerator's efforts to accelerate the pace at which its portfolio companies' technologies are deployed, allowing them to pair up with utilities to build demonstration projects across Hawaii. This focus on matching the startups with customers was especially critical in this case, underscoring the importance of addressing the right gaps. In addition, its multiple tracks allow it to address market opportunity as well as social needs, which may prove relevant in regional transition contexts that face even more severe dislocation.

4.1.4 Connecticut Green Bank

The Connecticut Green Bank (CGB), created by the state legislature in 2011, from the state's existing green financing initiatives, is a quasi-public corporation focused on investing in the expansion of energy efficiency and clean energy development initiatives across the state, and expanding state economic development in the process. As such, it one cog in Connecticut's cleantech innovation system.

Since it began operations in 2012, the CGB has provided a wide range of grant, loan, tax benefit, and subsidy funding aimed at energy-efficient upgrades to residential, commercial, and municipal buildings, and has served as the operational entity for Connecticut's incentive programs subsidizing PV solar at various scales (Connecticut Green Bank). By generating demand for PV solar, the program has stimulated the solar energy industry in Connecticut.

In 2018, the CGB's annual report states: "By using $260.1 million of ratepayer funds, we have helped attract $1,427.9 million of private investment in green energy for a total investment of $1.7 billion in Connecticut's economy. In addition, $87.2 million in estimated tax revenues have been generated from this investment. This is supporting the deployment of 358.2 MW of renewable energy, producing and saving an estimated 48.5 million MMBtu and 12.3 million MWh of green energy and reducing an estimated 5.8 million tons of CO2 emissions over the life of the projects, while creating over 20,000 job-years, and improving public health benefits by $206.7 to $466.8 million as a result of cleaner air" (Connecticut Green Bank, 2019).

The CGB essentially addressed only one gap in the regional innovation system: its aim was to stimulate private investment in clean energy and efficiency. The scorecard for the CT Green Bank is shown in Table 7. The CGB has played a role in creating jobs and economic activity in Connecticut that are consistent with a clean energy transition. However, it did not start from scratch: Connecticut has a skilled labor force available for jobs, households and businesses that can afford and are willing to adopt clean power or efficiency measures, and readily available pools of private capital for investment. Against this backdrop, the CGB's provisions were sufficient to prompt an infusion of private capital. Though it lacks system-wide breadth, the CGB has served as something of a national model: New York, Rhode Island, and Nevada, among others, have also followed in creating similar institutions (National Renewable Energy Laboratory).

The CGB case also demonstrates why single-competency interventions can be fragile, and the importance of pre-existing complementary competencies in the location. The scorecard for the CT Green Bank is shown in Table 7. The CT Green Bank faced a challenge in recent years from a shift in the political landscape. In 2017, the CT General Assembly shifted $33 million from the CGB to the state's general treasury, in order to help deal with a statewide budget shortfall. However, meeting this obligation would have required transferring out essentially all of the

Bank's remaining funds in 2019, bankrupting it. Instead, the Bank issued a green bond worth $35.5 million up-front and $18 million over the next 15 years, in exchange for allowing the purchasers to claim the solar energy credits from 14,000 rooftop solar systems across Connecticut. While this is less than the expected direct market value of the credits over 15 years ($71 million), it allowed the Bank to remain solvent and operational (Pilon, 2019). The integrated organization and (apparent) short support horizon for the project may have made it a more coherent target for the legislature. The CGB was saved in part because it could draw on local competencies, including the influence of beneficiaries of and key players in the state's cleantech innovation system.

Table 7 *Scorecard for Connecticut Green Bank. Ecosystem attributes coding: Green – not a barrier; Yellow – a partial or emerging barrier; Red – a major barrier. Performance measures coding: Green – strong performance; Yellow – some weaknesses in performance; Red – intervention severely challenged or discontinued.*

a)

Ecosystem attributes addressed by the intervention	**T1**	**T2**
Well-trained pool of human and managerial capital	Yellow	Yellow
Risk-tolerant sources of financing	Red	Yellow
Proximate base of suppliers and/or knowledge inputs	Yellow	Yellow
Channels for exchanging information with prospective customers	Yellow	Green
Prevailing rules and cultural norms that reward business creation	Green	Green

b)

Measure of performance	**T1**	**T2**
Portfolio Growth	Yellow	Yellow
Funding Sources	Yellow	Yellow
Funding Volume	Red	Yellow
Longevity	Yellow	Yellow

4.2 Few vs. Many Stakeholders: Alaska Center for Energy and Power

Whether competencies are built on the support of few or many stakeholders in a regional innovation system can affect the longevity of an intervention. The Alaska Center for Energy and Power (ACEP) is an applied energy research program based at the University of Alaska, Fairbanks. Its primary focus is on the development of technological and policy solutions that can ensure clean, reliable, affordable energy for communities relying on islanded microgrid systems, commonly found across rural Alaska.

Since its inception, ACEP has come to take on the role of a regional innovation hub, serving as a "one-stop-shop" for Alaskan/Arctic energy research and development. Its R&D investments, test facilities, and research programs address a wide range of technologies and topics including advanced microgrids, waste heat, hydropower, biomass, geothermal energy, grid modeling, energy policy analysis, and small modular nuclear reactors — all in the context of the role they might play in helping alleviate Alaska's evolving energy needs. It has also played a key role in outreach and coordination, bringing stakeholders from across Alaska and across the country to consider novel approaches to tackling the state's energy challenges.

From 2010-2015, ACEP invested $29.2 million in energy research and development efforts across Alaska, which it notes is nine times the direct state investment in the program. In particular, it notes that 82% of its funding came from external funding sources outside the UAF budget (Alaska Center for Energy and Power, 2015). However, ACEP's relative financial independence and prominent role in Alaska's regional innovation system did not fully immunize it from broader political and economic shocks.

As a single, coherent entity that relies on funding authorizations from the state legislature, ACEP was targeted for budget cuts in the midst of a revenue decline for the Alaska Permanent Fund, the state's sovereign wealth fund. Since early 2019, the University of Alaska system — and, by association, ACEP — have found themselves caught in the midst of a political budget battle between the state's newly-elected Governor and the state legislature. Governor Dunleavy campaigned on nearly doubling the Alaska Permanent Fund dividend — the annual share of the state oil royalties that each Alaska resident receives — to $3,000. However, Alaskan oil production has been steadily declining since peaking in the 1990s (Alaska Department of Revenue, 2017), leading to a significant drop-off in state oil royalties. As a result, Dunleavy's proposal was expected to cost $1.9 billion, necessitating $1.6 billion in cuts to the state budget. In response, Dunleavy line-item vetoed roughly $135 million allocated to the University of Alaska as part of the state budget earlier this year — a cut that university officials said would have required emergency financial measures including closing various degree program, and potentially laying off staff and tenured faculty.

While intensive negotiations held amidst a state- and nation-wide outcry (Goldman, 2019) reduced the cuts to $25 million this year, and $45 million over the next two years, the incident still serves as a telling example of how promising regional cleantech innovation and development efforts that reside in a single, highly visible entity can run headlong against powerful political and economic forces in a rapidly-changing policy landscape (Hanlon, 2019).

A counterpoint to the ACEP case is Idaho, where the state's clean energy innovation system is distributed across a much larger number of entities that share a shared broader agenda —often making it difficult to assign a single label to efforts that have significantly expanded the state's entrepreneurial competencies in renewable energy, in recent years. Idaho is a national leader in renewable energy production — over 80% of electricity generated in-state comes from renewables (roughly 60% hydropower, 17% wind, and 3% each from solar and biomass) (U.S. Energy Information Administration (EIA), 2019).

The anchor of the state's clean energy innovation system is the Department of Energy's Idaho National Laboratory (INL). INL traces its origins back to 1949, when it was created as a nuclear reactor test site — it was where electricity was first generated from a nuclear reaction, in 1951. The lab's focus on energy has continued to this day. In addition to a homeland security mission focused on protecting electric infrastructure, the lab remains the heart of the Department of Energy's advanced nuclear energy research program, and is expected to serve as a proving ground for the emerging class of small modular nuclear reactors.

In recent years, INL has also developed a mission focus on clean energy integration, with research streams centered on clean transportation technologies, advanced manufacturing, biomass energy, and the development of hybrid electrical systems that integrate variable and baseload emissions-free generation technologies with novel transmission and distribution technologies (Idaho National Laboratory).

INL also serves as a core member of the Center for Advanced Energy Studies (CAES), a regional consortium that unifies the energy R&D and education efforts of INL, Boise State University, Idaho State University, the University of Idaho, and the University of Wyoming. In addition to a stand-alone research facility in Idaho Falls comprised of eight laboratories, CAES also includes an effort to train workers for clean energy careers, numerous vehicles for industry collaboration on research/development/testing, and an energy policy institute (Boise State University; Center for Advanced Energy Studies).

Idaho has a fairly well-developed clean energy innovation system. It largely revolves around the research and development work at INL, and the state's energy industry — which has been driven by a backbone of abundant hydroelectric generation that dates back to the 1960s. Idaho Power, the state's largest electric utility (Idaho Public Utilities Commission, 2014), has committed to 100% clean energy by 2045. It has also announced plans to shut down two of its three coal-fired power plants by 2025, to be replaced in part by a 120 MW solar farm scheduled to come online in 2022 (Chappell, 2019).

However, the state's clean energy innovation system also serves to support smaller, emerging players. Idaho has a number of small, homegrown renewable energy firms spanning solar, wind, and geothermal energy. Working in tandem through the Idaho Clean Energy Association, they have often taken unified stances in support of issues critical to the development of clean energy enterprises (notably a recent debate over net metering of solar energy)(Idaho Clean Energy Association).

Idaho's clean energy sector appears to have a bonafide regional innovation system — strong research and educational institutions with a history of leading energy work in partnership with industry, climate-conscious utilities, a number of small renewable firms, and a policy environment that is increasingly being shaped with an eye towards promoting the growth of clean energy enterprises. The Center for Advanced Energy Studies, the focal intervention in this case, has thrived because of its support from many stakeholders and its interactions with the state's growing clean energy innovation system.

The comparison in the outcomes achieved over time in the two cases is show qualitatively in Table 8.

Table 8 *Outcomes scorecard for ACEP and CAES. Performance measures coding: Green – strong performance; Yellow – some weaknesses in performance; Red – intervention severely challenged or discontinued.*

Measure of performance	**ACEP**		**CAES**	
	T1	**T2**	**T1**	**T2**
Portfolio Growth	Red	Yellow	Red	Yellow
Funding Sources	Green	Red	Green	Green
Funding Volume	Yellow	Yellow	Yellow	Green
Longevity	Yellow	Red	Yellow	Green

4.3 Existing vs. *de novo* activities: Kentucky REAP program and GE/Auburn University

The length of support horizon can affect the viability of an intervention. A short horizon can work if the intervention is catalytic, but requires that stakeholders be aware of local competencies and shortcomings and have strong incentives to work together to patch in missing elements. An example of a program that can make strides in this context is the MIT Innovation Initiative's REAP Program, which worked with the state of Kentucky catalyze a series of conversations over a year among industrial, academic, startup, and governmental entities on how to build a regional innovation system capable of supporting high-growth entrepreneurship (MIT Regional Entrepreneurship Acceleration Program (REAP)). Much of this effort has been driven by the work of the Kentucky Cabinet for Economic Development, a state agency charged with promoting economic growth and jobs development (Kentucky Cabinet for Economic Development).

One of the early foci of the effort has been creating tech jobs in the region, as exemplified by Rusty Justice's Bitsource — which has received national attention for "teaching coal miners how to code," and creating "blue-collar coders" (Rosenblum, 2017). The effort has led to the creation of a number of startup accelerators and incubators across the region, particularly in the Louisville area, where Google has estimated over 100 software jobs are being created every 90 days. Google also partnered with a tech skills training organization, sponsoring a $100,000 expansion of their work (Bethea, 2018). All of this is occurring against the backdrop of the rapid decline of the coal industry across Appalachia, embodied by closures of mines that have sustained towns for decades, and a spate of corporate bankruptcies. Media reports suggest that the jump to tech jobs has partially been driven by an over-saturation of more closely aligned fields, like construction. We believe that the long-term scalability of these efforts is not yet clear, and remains a question meriting further investigation.

Long-term viability aside, the REAP team has already had to grapple with the reality that the activities they were trying to establish were very distant from the region's traditional industrial base. While the program provided valuable information and facilitated communication among key stakeholders during the year-long cycle of interactions mediated by the MIT REAP team, its short time horizon required that much of the buy-in and receptivity to the information delivered by the team already be in place. Thus, for transition contexts such as Kentucky, substantial groundwork must be laid for REAP-style interventions to catalyze growth, especially at a scale that would offset regional job losses associated with a transition. Even if losses could be offset, it is not clear that the basic ingredients for growth in these high tech industries exist regionally. Implemented at the right time, such programs are likely to be important, but must ultimately be complemented by an enrichment of the underlying soil on which new business growth is being cultivated.

An alternative approach involves building on the strengths of a region's incumbent industries and universities, to develop adjacent activities that are compatible with a low carbon transition. These interventions could include a focus on advanced manufacturing, which is aligned with a transition if clean and affordable energy sources are available in the region. We focus here on the case of the ongoing relationship between General Electric and Auburn University, Alabama's land grant university. Since 2017, GE has been expanding its advanced manufacturing/additive manufacturing presence in Auburn, AL. This began in 2017, with a grant to Auburn University of a $250,000 3D metal printer, one of 50 donated worldwide as part of its GE Additive Education Program. The university was selected off the merits of its existing additive manufacturing program and its engineering school. In coordination with the gift, the university announced the establishment of a Center for Industrialized Additive Manufacturing, the renovation of an engineering lab to include dedicated additive manufacturing space, and the intended hiring of several faculty with related expertise (Anthony, 2017).

GE's presence in the Auburn region was nothing new: the conglomerate was already using "additive manufacturing to mass produce fuel nozzle injectors for jet engines at its plant in the city of Auburn's Technology Park West." This collaboration was also part of a sustained investment in developing a highly-skilled workforce in the region. The plant was opened in 2013, and designated as a hub of GE Aviation's 3D printing/additive manufacturing efforts in 2014. The plant currently makes injection nozzles for GE's LEAP engine for narrow body aircraft, and employs ~240 people. In March 2019, GE announced a $50 million expansion of additive manufacturing efforts at the Auburn site, which will involve hiring 60 more workers and expanding the plant's production to a second kind of nozzle, which will be used in GE's flagship GEnx-2B engine for widebody aircraft (EETV Web Team, 2019; Metal AM, 2019; Palczewski, 2019).

In this case, we see two well-established institutions — Auburn University and GE — partnering to not only build a new regional industry on the foundation of an existing manufacturing base, but also create a robust training pipeline that would allow local students to gain the skills needed to take advantage of this emerging opportunity. It highlights the short-term benefits of being able to build on proximate activities, but also points to the inherent dependencies: electric power will need to decarbonize, and in the short term, electricity prices may rise.

The comparison in the outcomes achieved over time in the two cases is show qualitatively in Table 9.

Table 9 *Outcomes scorecard for Kentucky REAP and GE/Auburn University.*

Measure of performance	**Kentucky REAP**		**GE/Auburn University**	
	T1	**T2**	**T1**	**T2**
Portfolio Growth	[yellow]	[yellow]	[red]	[yellow]
Funding Sources	[yellow]	[yellow]	[yellow]	[green]
Funding Volume	[red]	[yellow]	[yellow]	[green]
Longevity	[red]	[red]	[yellow]	[green]

5. Conclusions

The cases presented in this chapter focus on interventions that create regional economic opportunity and are compatible with transition aims. One striking observation from our correlational analysis is the differences it reveals in conditions available to support innovative activity in transition regions compared with the existing entrepreneurial hubs along both coasts. We therefore included among our cases models outside of software and information technology, which thrive in urban areas with a high density of computer science graduates. Suggestions that these models transfer seamlessly to transition contexts are probably wrong, and have prompted backlash. Efforts to “teach miners to code” have drawn scorn, while some initiatives have been discredited (Robertson, 2019). We therefore focus on a set of activities that may overlap more strongly with existing local competencies and transition needs.

The preliminary recommendations we reach are as follows, building on our earlier findings with respect to each of the three hypotheses:

Recommendation #1: Interventions must address “critical” gaps—not necessarily more gaps—in regional entrepreneurial competencies. This can be done either by focusing on building those competencies locally or building and leveraging the relationships needed to access competencies in distant locations.

We originally hypothesized that interventions that addressed a larger relative number of gaps would be more effective, because of the complementary nature of competencies in local agglomeration economies (H1). We find some supportive evidence of this in the case of Greentown Labs, which address three competencies: infrastructure, connectivity, and building a community of entrepreneurs and financiers, which were arguably critical catalysts in building a regional cleantech innovation system in Boston. However, looking across all cases, we found instead evidence that it is not the number of competencies addressed, but instead how critical these competencies are, that affected intervention success. Attention to the way that the gap addressed will contribute to the intervention’s changes of seeding regional innovation. The gap addressed by the CT Green Bank, financing, was not critical in that context, which was already teeming with clean energy service providers (many from neighboring states), and may have led policymakers to reduce priority assigned to the program. Interventions like the Elemental Excelerator closed many gaps in competencies, but included among them was the critical gap of connecting startups with customers. Initiatives that focus on single or one-size-fits-all competencies may bypass transition areas because they fail understand the missing competencies that may be hindering progress. Therefore, it is extremely important to understand a region’s pre-existing competencies, and identify any critical gaps. Our cases further suggest that competencies must not necessarily be developed locally, but can be extended or leveraged from distant locations, which we see to varying degrees in the cases of Innovation Crossroads, CT Green Bank, and Elemental Excelerator.

Recommendation #2: Interventions that involve many stakeholders will be more durable in the face of political and/or decision-making cycles than those that rely on the support of only a few stakeholders.

We find support for our second hypothesis, which states that more stakeholder support increases the success of interventions (H2). In our cases, regional innovation system interventions that generate buy-in from multiple institutions and local initiatives appear to create greater momentum for entrepreneurial growth, as each becomes dependent on, and reaps the rewards of, others' successes. The example of Idaho Center for Advanced Energy Studies, which is supported by multiple organizations that emerged simultaneously and symbiotically, has enjoyed ongoing support and buy in from local stakeholders who gain recognition and benefit from its activities. By contrast, the Alaska Center for Clean Energy and Power was impacted by severe cuts in state funding for the University of Alaska, and lacked influential champions in other parts of the relatively small clean energy innovation system across the state. The dominance of oil and gas in Alaskan energy, compared to the growing emphasis on clean and renewable electricity in Idaho, may have further affected support. In transition contexts, making new activities independent of fossil energy funding and tapping into a broad base of stakeholder support is likely to help communities sustain regional clean energy innovation initiatives.

Recommendation #3: Interventions should carefully evaluate the opportunities and tradeoffs in focusing on preexisting versus *de novo* entrepreneurial activities.

The third hypothesis states that focusing on preexisting innovation may make it easier to transition in the short term, but harder in the long term (H3). While our cases support this idea, they also suggest that the appropriate strategy likely depends on the nature of a region's transition exposure. The selection of focus may depend on the extent to which local industries are exposed to a low carbon transition. If primary fuel delivery and electricity carriers can be shifted to low carbon sources without altering core regional economic advantages, it may make more sense to focus on existing activities, such as manufacturing. However, if a region's advantage is rooted in carbon-intensive energy (for instance, in the case of the oil industry and its derivatives along the gulf coast), a system-wide rethink may be in order. In our cases, we saw in the case of the Kentucky REAP program how challenging it may be at first to seed certain forms of high-growth entrepreneurship in transition regions. If initiatives that build on preexisting industrial and academic strengths—as in the case of the GE/Auburn University partnership—can help maintain a region's advantage in the face of low-carbon transition, such paths may offer less resistance. Each transition region will be different, and the recommendations above are designed to offer general principles for improving interventions that can smooth the path ahead.

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