Atlantic Council
GLOBAL ENERGY CENTER

ISSUE BRIEF

Mapping Green Innovation Ecosystems:

Evaluating the Success Factors for the World's Leading Greentech-Innovation Centers

JANUARY 2021 PETER ENGELKE, MARGARET JACKSON, AND RANDOLPH BELL

I. Introduction

Climate change is driving an innovation revolution in the energy sector, as well as in other carbon-intensive sectors, in order to reduce emissions and mitigate environmental impact. Provocative examples of such "green" technologies ("greentech" for short) fall into two main categories: those directly related to energy production and consumption, and those that mitigate environmental and climate impact in industries other than energy. Tesla's cutting-edge electric vehicles (EVs) that are upending the automobile industry, LONGi's solar photovoltaic panels that are dramatically reducing rooftop solar prices, Ecobee's and Nest's smart-home devices that allow individual consumers to manage their own energy consumption, and Vestas' massive wind turbines that are generating energy around the world are all examples of technologies in the former category that are transforming the energy system and driving the economy toward net-zero carbon emissions. In the latter category, technologies like Netafim's drip-irrigation system that enable crops to be grown in water-starved regions, and Beyond Meat and Impossible Foods' alternative foods that could revolutionize the world's meat industry, have achieved commercial scale and marketability because producers and consumers in the agricultural industry are adapting to the realities of climate change impact.

This issue brief is an initial foray into researching the blend of policies, funding, and stakeholders that make up ecosystems that encourage this type of greentech innovation, in order to gain a better understanding of these ecosystems and facilitate more of them throughout the world, as humanity confronts and seeks to mitigate the environmental impacts of the energy system and other carbon-intensive sectors.

The world risks devastating ecological and social impacts like sea-level rise, biodiversity loss, and climate migration if global warming exceeds 1.5 degrees

The **Global Energy Center** promotes energy security by working alongside government, industry, civil society, and public stakeholders to devise pragmatic solutions to the geopolitical, sustainability, and economic challenges of the changing global energy landscape.

Smart-home devices, like the Nest, allow individuals control over their energy consumption. *Source:* Unsplash/Dan LeFebvre (@danlefeb)

Celsius above preindustrial levels. The Intergovernmental Panel on Climate Change (IPCC) Special Report from 2018 states that, to meet the 1.5-degree target, greenhouse gas emissions must decrease by half from a 2010 baseline by 2030 and reach net zero by 2050. Countries such as Chile, the United Kingdom, and China have committed to mitigating these impacts by aligning with IPCC goals for mid-century, and more than 1,300 businesses are partners in the United Nations "Race to Zero" Campaign. The challenge for policymakers is that the technologies that will enable net-zero carbon emissions either have not reached commercial scale or do not exist yet. Therefore, investment in energy and climate technology research and development (R&D) and the nurturing of greentech-innovation ecosystems are integral to prolonging human life on the planet.

Additionally, the localities, companies, and innovators who are first moving on new technologies in this field will reap the economic and geopolitical benefits of a reimagined low-carbon global economy. The energy transition's biggest geopolitical winners will be the countries that "emerge as industrial leaders, exporting [green] technologies and services."[1] For decades, the United States has enjoyed a position atop the global technology development pyramid. Yet now, the United States risks losing this position, owing to underinvestment in science and innovation and rising competition in Asia and other parts of the world.[2]

Greentech-innovation ecosystems, the subject of this report, are places—cities and regions—wherein entrepreneurs, firms, researchers, and investors successfully commercialize new green technologies in the marketplace. These cities and regions possess the right mix of talent, financing, infrastructure, scientific research capabilities, institutional resources, supportive public policies, and creative culture to produce cutting-edge, disruptive, and commercially viable green technologies. And, they are places that are designed to overcome several important challenges that are unique to greentech development. For greentech entrepreneurs and investors, such challenges include solving thorny science problems, working through complex engineering processes, and breaking into marketplaces that are often highly resistant to change. Representative ecosystems include Los Angeles, London, Beijing, Berlin, Tel Aviv, and Silicon Valley.

Although there is no single formula, greentech-innovation ecosystems combine visionary political leadership, robust support for greentech startups, and coordinated public policies and investments that are designed to boost green-technology deployment on a commercial scale. Promising interventions range from local public support for startup-friendly intermediary institutions (for example, Boston's Greentown Labs and Toronto's MaRS incubator), to pro-deployment policies such as the national feed-in tariffs that have helped make Germany, Denmark, and China world leaders in renewable energy production and consumption. Successful ecosystems most often benefit from complementary policies that are implemented at local, state, regional, and national levels, as is the case with Los Angeles, which has benefited from its own interventions as well as the state of California's (see Box 2).

"Greentech" is one of several terms used to describe the technologies that provide economic value while minimizing

1 Roman Vakulchuk, Indra Overland, and Daniel Scholten, "Renewable energy and geopolitics: A review," *Renewable and Sustainable Energy Reviews* 122 (2020), 109547.

2 Peter Engelke and Robert A. Manning, *Keeping America's Innovative Edge: A Strategic Framework*, Atlantic Council, 2017, https://www.atlanticcouncil.org/in-depth-research-reports/report/keeping-america-s-innovative-edge-2/.

Box 1: What's in a name? Greentech, Cleantech, and Climate Tech

There is no one word or phrase that organizes all green technologies under a single linguistic roof. Three common, but competing, terms are often used to group such technologies together: "climate tech," "cleantech," and "greentech." Although subtle differences exist in these terms, they are often used interchangeably. Beyond these three are many other, narrower terms. The energy field, for example, uses "green energy" and "clean energy," as well as specific descriptors ranging from "energy storage" to "smart grids." Transportation features a lengthy list of terms including "electric vehicles," "hydrogen-powered vehicles," and others. Similarly, food and agriculture industries offer an array of terms ranging from "FoodTech" to "AgTech" and more.

Moreover, there is an overlap among technologies that are created to solve environmental problems and those created to serve other market needs. Few believe that automobile manufacturers are developing autonomous vehicles for environmental reasons. Yet, these vehicles might have important environmental impacts, including carbon-emissions reductions. (Advocates believe that autonomous vehicle fleets would reduce congestion and therefore fuel/energy waste; critics argue otherwise.)

Investment trends explain much of this confusion. Both "cleantech" and "greentech" became common parlance in the 2000s, when the fundamentals of investment in the sector were strong (for example, high oil and gas prices incentivized the search for substitutes). After the 2008 financial crisis struck the sector especially hard, owing to particularly difficult challenges facing startups in this space, investors backed away. Now, "climate tech" is the latest green-technology investment term, perhaps as an attempt to wipe the linguistic slate clean to help regain investors' trust in the sector. However, this report uses "greentech" as an umbrella term to encompass technologies that are specific to the energy sector, as well as technologies that work to mitigate climate impacts in other sectors (especially food and agriculture). In our view, "greentech" is the most inclusive of these various terms.

Sources: "Innovation Landscape for a Renewable-Powered Future: Solutions to Integrate Variable Renewables," International Renewable Energy Agency (2019), https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Feb/IRENA_Innovation_Landscape_2019_report.pdf; "What is FoodTech?" Digital Food Lab, https://www.digitalfoodlab.com/foodtech/; Timo Moeller, et al., "The Future of Mobility is at Our Doorstep," McKinsey & Company, December 19, 2019, https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/the-future-of-mobility-is-at-our-doorstep; Pantelis Kopelias, et al., "Connected and Autonomous Vehicles—Environmental Impacts—A Review," *Science of The Total Environment* 712 (2020), https://www.sciencedirect.com/science/article/abs/pii/S0048969719352295; Ted Dillon, "Climate Tech vs. Cleantech: Does Cleantech Need a Rebrand?" *Clean Energy Ventures*, February 19, 2020, https://cleanenergyventures.com/clean-energy-venture-capital/climatetech-is-cleantech-in-need-of-a-rebrand/; Katie Fehrenbacher, "Why 'climate tech' is the new cleantech," *Greenbiz*, February 5, 2020, https://www.greenbiz.com/article/why-climate-tech-new-cleantech; "A brief history of cleantech," *Leonard*, December 12, 2019, https://leonard.vinci.com/en/a-brief-history-of-cleantech/; Neal Dikeman, "Defining an industry: Cleantech vs. Greentech" *Seeking Alpha*, July 16, 2007, https://seekingalpha.com/article/41150-defining-an-industry-cleantech-vs-greentech.

environmental impact. Although there are many definitions of greentech and similar terms that are used to describe it (see Box 1 for a discussion of "greentech," "cleantech," and "climate tech"), these terms encompass disruptive technologies that can reduce the environmental footprint of the world's biggest and most impactful sectors, such as energy, transportation, food and agriculture, buildings, materials, and consumer goods. Investors, entrepreneurs, scientists, researchers, "Big Tech" firms, and government agencies at local, state, regional, and national levels all participate, in one fashion or another, in the invention, incubation, and scaling of these technologies.

Because greentech-innovation ecosystems have not been examined in detail at a global level and data availability is limited, this report is not exhaustive. Specifically, the data referenced in this report have noticeable gaps in regions of the world outside of Europe and North America. Yet, the findings of this report suggest answers to several important questions, including why these ecosystems matter, how they work, which ecosystems are global leaders, and what should be done by stakeholders going forward. Section II draws a tentative map of the world's leading greentech-innovation ecosystems. Section III examines ecosystem characteristics, including their core qualities and the cen-

tral obstacles that make greentech development and commercialization particularly difficult relative to other types of technologies. Finally, the conclusion offers recommendations regarding what researchers, policymakers, the private sector, philanthropists, and civil-society organizations such as the Atlantic Council should do in the months and years to come, given the importance of this subject.

II. Mapping the World's Greentech-Innovation Ecosystems

One of the challenges involved in assessing the state of greentech innovation is that there is incomplete information about the world's leading ecosystems, in terms of both geography and performance. Most indexes assess national ecosystems rather than local (city) ecosystems, where innovative activity occurs, because systematized—and, hence, comparable—data are collected most often at the national, rather than local, level. In large part for this reason, only a few organizations attempt to measure the performance of tech-innovation ecosystems at the local level. Few, if any, attempt to measure performance of the entire universe of local tech-innovation ecosystems, again due to data-availability constraints.

Many institutions create indexes and other measurement tools that map global innovation ecosystems in general terms. Among the most well-known and highly rated annual rankings are produced by the World Intellectual Property Organization (WIPO) and the World Bank. The WIPO index, produced with partners at Cornell University and INSEAD, measures innovation as a mix of inputs (including human capital and research and infrastructure quality) and outputs (including knowledge creation and creative goods and services). Other specialist indexes attempt to measure pieces of this larger system. The US Chamber of Commerce produces an index focusing solely on how ecosystems perform in protecting intellectual property.[3]

Only a tiny number of all indexes are focused on measuring greentech innovation-ecosystem performance, whether at national or local level. For example, Atomico, a European venture capital firm, has a highly respected annual "State of European Tech" index that examines only European ecosystems, and does not measure greentech performance at the local-ecosystem level.[4] Cleantech Group, a clean-technology consulting firm, and the World Wildlife Fund (WWF), an international conservation organization, partner to publish the biennial "Global Cleantech Innovation Index" to measure potential for startup greentech companies at the national level only (with the most recent version published in 2017), while Startup Genome, an innovation policy advisory and research firm, has a well-regarded index of local (city) startup ecosystems that considers greentech as a subcategory of analysis.[5]

To augment these findings, the authors performed an exploratory analysis of startup data using Crunchbase, a database that enables analysts to identify trends and patterns in venture capital investment, startup activity, and other innovation-relevant performance metrics and at local, regional, and national geographic levels (Dealroom and Pitchbook are also often used to assess such metrics).[6] To explore innovative activity, the authors assessed the number of greentech startups by location, defined as locale (city level), region or US state, and nation. Although the results do not constitute an index variable that measures ecosystem performance as a whole, greentech startup count is nonetheless a proxy for the amount of innovative activity within any given geographic boundary. This analysis assessed a sample of startups (defined as pre-Series C funding) that self-identified within one or more greentech categories; for example, listing their industry affiliation as "GreenTech," "CleanTech," "Renewable Energy," "Electric Vehicle," "Green Building," and other categories.[7] The findings are presented in Table 1, alongside findings from two published indexes, one by Startup Genome and the other by the Cleantech Group.

There are several takeaways of note from this short analysis. The first is to stress that there is an imperfect overlap

3 Robert A. Manning and Peter Engelke, *The Global Innovation Sweepstakes: A Quest to Win the Future*, Atlantic Council, 2018, https://www.atlanticcouncil.org/in-depth-research-reports/report/the-global-innovation-sweepstakes-a-quest-to-win-the-future-2/. For a review of the WIPO methodology, see "Global Innovation Index 2020: Who Will Finance Innovation?" Cornell University, INSEAD, and WIPO, 2020, Appendix I, Figure A-I.1, 205.

4 The latest is "The State of European Tech 2020," Atomico in partnership with Slush and Orrick, 2020, https://2020.stateofeuropeantech.com/chapter/state-european-tech-2020/.

5 Chris Sworder et al., *The Global Cleantech Innovation Index 2017: Which countries look set to produce the next generation of start-ups?* Cleantech Group and WWF, 2017; "Global Startup Ecosystem Report 2020: The New Normal for the Global Startup Economy and the Impact of COVID-19," 2020; "Global Startup Economy Spotlight: Top Ecosystem Rankings for Female Founders, Agtech, and Cleantech," Startup Genome, 2019.

6 Each can be found at: crunchbase.com; dealroom.com; pitchbook.com.

7 Startups were defined as pre-Series C only. "Greentech" firms were defined as those self-identifying within one or more of the following categories: greentech, cleantech, renewable energy, solar, wind energy, battery, clean energy, electric distribution, biofuel, environmental consulting, environmental engineering, energy efficiency, energy storage, electric vehicle, green building, energy management, power grid, and fuel cell.

Table 1: Greentech-Innovation Ecosystem Rankings (Sample)

Startup Genome Cleantech Rankings	Cleantech Group / WWF	Crunchbase Pro Analysis (Number of greentech startups; authors' analysis)		
Ranks local cleantech ecosystems	Global ranking (national-level only)	City-level ranking	Region / US state-level ranking	National-level ranking
Top 10 (2020) 1. Silicon Valley 2. Amsterdam 3. Houston 4. London 5. New York City 6. Los Angeles 7. Boston 8. Tel Aviv 9. Boulder-Denver 10. Paris	Top 10 (2017) 1. Denmark 2. Finland 3. Sweden 4. Canada 5. USA 6. Israel 7. UK 8. Germany 9. Norway 10. Switzerland	Top 10 (2020) 1. London 2. New York City 3. San Francisco 4. Beijing* 5. Berlin 6. Vancouver 7. Los Angeles 8. Singapore** 9. Boston 10. Amsterdam	Top 10 (2020) 1. California 2. England 3. New York 4. Massachusetts 5. Ontario 6. Beijing* 7. Texas 8. British Columbia 9. Colorado 10. Pennsylvania	Top 10 (2020) 1. United States 2. China 3. United Kingdom 4. Canada 5. India 6. Germany 7. France 8. Netherlands 9. Israel 10. Australia

* Beijing in the city ranking includes the central districts Xicheng and Dongcheng. The regional ranking includes all Beijing districts.

** Singapore is both a city and sovereign nation-state. In the country-level findings using Crunchbase data, Singapore ranks fifteenth.

Sources: "Global Startup Ecosystem Report 2020: The New Normal for the Global Startup Economy and the Impact of COVID-19"; "Global Startup Economy Spotlight: Top Ecosystem Rankings for Female Founders, Agtech, and Cleantech," 20; Sworder et al., *The Global Cleantech Innovation Index 2017*, 13; Crunchbase Pro database.

across these different attempts to rank greentech-innovation ecosystems and both the local and national levels. This lack of perfect overlap is expected, as the rankings utilize different methodologies and data sources. Moreover, the authors' Crunchbase analysis is not based on an index of variables but a single proxy variable—startup activity—and, hence, measures volume of output for this one metric only.

Six common cities appear on both the Startup Genome and Crunchbase lists of city-level ecosystems (Silicon Valley and the San Francisco Bay Area, New York City, Los Angeles, Boston, Amsterdam, and London), with another eight appearing on either list (Houston, Tel Aviv, Boulder-Denver, Paris, Beijing, Berlin, Vancouver, and Singapore). There is less overlap at the national level, with the United States, United Kingdom, Germany, Israel, and Canada appearing on both the Cleantech Group/WWF and Crunchbase lists and another ten appearing on either list, but not both. Of note are the four Nordic countries that appear on the Cleantech Group/WWF national-level ranking (Denmark, Finland, Sweden, and Norway); these countries tend to score high on innovation indexes that measure inputs as well as outputs, including good governance metrics, infrastructure, education, R&D, and more.

The second takeaway is to emphasize that although the United States' competitive edge remains, whether measured on local, state, regional, or national grounds, there

Box 2: Los Angeles Ecosystem

Los Angeles is one of several US cities with a global reputation in greentech development and commercialization, and its success is the result of visionary leadership, smart policymaking, and strong public-private investment into core institutions that support greentech development.

California's state government has long been a global leader in pro-deployment legislation, setting statewide greenhouse gas limits via a cap-and-trade program, a renewables portfolio standard, a low-carbon fuel standard, energy-efficiency standards, and more. The state invests public money, including funds generated by its cap-and-trade program, into other pro-deployment channels (for example, zero-carbon transportation). California also has a significant advantage over other US states in terms of private (venture capital) investment in greentech startups.

Los Angeles's trajectory mirrors the state's growth in greentech expansion. In the 2000s, then-Mayor Antonio Villaraigosa launched an ambitious program to accelerate the city's greentech ecosystem. Although the city had to pare back its goal to refurbish an entire green-technology-focused district (to be called the LA Cleantech Corridor), it did launch the world-leading Los Angeles Cleantech Incubator (LACI). LACI sits within the La Kretz Innovation Campus, a state-of-the-art facility opened in 2015 that houses startups, features a full advanced-prototyping center, and hosts public events and exhibits.

The current mayor, Eric Garcetti, continues efforts along these lines. LA's Green New Deal aspires to achieve a "zero carbon grid, zero carbon transportation, zero carbon buildings, zero waste, and zero wasted water" by 2050. It embraces the environment-economy linkage, placing emphasis upon the economic and employment gains to be had from investing in environmental protection.

Los Angeles's greentech-innovation ecosystem builds upon the city's considerable advantages. These include its trade infrastructure (e.g., two major commercial ports), research institutions and universities, huge skilled-labor pool, a massive creative class arising from the entertainment industry, and a lengthy history as an industrial center. Los Angeles, for decades a center of the global aerospace industry, still generates cutting-edge startups in that sector (for example, SpaceX).

Sources: Stakeholder interviews; "2017 U.S. Clean Tech Leadership Index. State & Metro," CleanEdge, May 2017; Busch, et al., "The California Climate and Clean Energy Policy Story;" "La Kretz Innovation Campus," https://lkic.la/; "L.A.'s Green New Deal Plan," https://plan.lamayor.org/; David Greene, Sonari Glinton, and Shereen Marisol Meraji, "What Gets Made in LA is Way More than Movies," National Public Radio, November 30, 2015, https://www.npr.org/2015/11/30/455886225/what-gets-made-in-la-is-way-more-than-movies; Lynnette Woo, "The Relationship of Art and New Technology in LA's Clean Tech Corridor," untapped cities, October 15, 2012, https://untappedcities.com/2012/10/15/the-relationship-of-art-and-new-technology-in-las-clean-tech-corridor/; Shana Rappaport, "The next-gen cleantech entrepreneurs," February 4, 2019, https://www.latimes.com/archives/la-xpm-2010-may-22-la-fi-clean-district-20100522-story.html.

is no guarantee that it will remain the top greentech innovator in the future. Over the past several years, numerous studies have concluded that the geography of tech-driven innovation is evolving.[8] While the lists shown in Table 1 contain several American cities and states, the lists also include European, Asian, North American (non-US) and, to a lesser extent, Middle Eastern cities and regions. Not only are other places and governments figuring out the formulas to create thriving tech-innovation ecosystems, access to ecosystems anywhere in the world is far easier than it used to be. The digital landscape, now including cloud computing, high-speed Internet access, and increasingly

8 Richard Florida and Ian Hathaway, "How the geography of startups and innovation is changing," *Harvard Business Review*, November 27, 2018, https://hbr.org/2018/11/how-the-geography-of-startups-and-innovation-is-changing; Manning and Engelke, *Sweepstakes*, 10; *Global Startup Ecosystem Report 2020.*

Bicycles in Amsterdam, Netherlands, demonstrate an emphasis on environmentally-friendly personal transportation options. *Source:* Unsplash/Jace & Afsoon (@jacegrandinetti)

ubiquitous artificial-intelligence-enabled tools, appears to be accelerating this expansionary process, making it easier for entrepreneurs and investors to engage over longer distances and acting as a spur to the globalization of entrepreneurial activity.[9] This research also underscores that, while the richest and most well-established places have an enormous advantage, emerging economies can, with time, build successful ecosystems from scratch. Many leading cities only recently developed a global reputation for tech-focused and startup-centered innovation, such as Shenzhen, Singapore, Beijing, and Paris. Behind them are even more places that aspire for entry into these ranks, many of which are in the Global South, ranging from Kigali to Santiago.

A third takeaway involves the overlap between tech-innovation ecosystems in general, and those that have reputations for producing green technologies. Although there is no widely accepted metric or metrics for distinguishing between these two categories, one can draw some inferences. It is not surprising that the world's most

9 Several interviewees emphasized the last point, including the ease with which investors now can identify and fund entrepreneurs located anywhere in the world. See also Robert D. Atkinson and Caleb Foote, "The 2020 State New Economy Index: Benchmarking Economic Transformation in the States," Information Technology & Innovation Foundation, October 2020, 4.

vibrant tech-innovation ecosystems, such as Silicon Valley and London, also are producing much of the world's new greentech. The biggest tech-innovation ecosystems have an enormous built-in advantage over smaller ones. They are home to high-quality research institutions, large and wealthy tech companies, and numerous venture capital firms, all of which facilitate greentech development. But, the interesting finding is that other ecosystems also perform well in greentech, including Amsterdam, Vancouver, Ontario (Toronto), and Houston, among others. Their high performance suggests that there are critical additional factors at play, many of which are outlined in this next section, such as pro-deployment policies, that enable some places to become world-leading ecosystems for greentech development.

A final takeaway involves the symbiotic relationships that can, and should, exist between local tech-innovation ecosystems and higher levels of government. Los Angeles and San Francisco, both California cities that rank high in greentech innovation, are important examples because of this complementarity. As also discussed in Box 2, state and local government officials alike embrace tech-driven innovation and craft policies and make appropriate investments toward this end. California's state government has long been recognized as one of the United States'—if not the world's—foremost leaders in pro-deployment legislation, setting economy-wide greenhouse gas emissions limits, establishing rigorous energy and end-use technology environmental performance standards (e.g., automobile and lighting standards, a renewable portfolio standard), and more.[10] Los Angeles and Silicon Valley (or the San Francisco Bay Area writ large) have very different economic histories that lead to divergences in ecosystem size and performance (the valley's is the world's largest by far). With respect to greentech development, however, both ecosystems benefit from the state government's environmental leadership.

III. Success Factors of Greentech-Innovation Ecosystems

World-leading greentech-innovation ecosystems feature several common characteristics that enable them to cultivate a thriving innovation community and overcome funding and resource hurdles. The ideal ecosystem has strong local leadership, in both the public and private sectors, that commits to the long-term success of entrepreneurial ecosystem development and coordinates policies and investments for maximum advantage, including providing support to vulnerable greentech startups. Multiple stakeholders, including governments, visionaries, investors, entrepreneurs, researchers and scientists, intermediary institutions such as incubators and accelerators, corporations and utilities, and workers all have mutually reinforcing roles to play in this equation (see Box 3 for a stakeholder summary). Based on the findings of the data in section II, and supplemented by analysis of existing literature and personal interviews, the authors of this report identified four main categories of factors that determine whether a city or region will be able to build a successful greentech-innovation ecosystem: vision and coordination; research and startup support; pro-deployment context; and place and flow.[11]

A. Vision and coordination

Often, the origins of successful innovation centers involve pioneering visionaries who strive for years, if not decades, to put an ecosystem on the map. These individuals frequently sit at the intersection of several stakeholder groups. Brad Feld, an entrepreneur, author, and co-founder of the Techstars accelerator behind the innovation ecosystem in Boulder and Denver is an important example. Feld insists that local leadership—government, universities, community builders, and corporations—must have a decades-long commitment if their tech-innovation ecosystems are to succeed.[12] Governments, in particular, play an indispensable role at all levels. Both Silicon Valley and Los Angeles are leaders in greentech innovation, in part, because the state of California has been at the global forefront of environmental policymaking for more than half a century. The California Air Resources Board (CARB) was created in 1967 to improve the state's air quality through regulation. Since then, California has often been ahead of the policymaking curve, even relative to the US federal government, on a range of environmental questions, including greenhouse gas emissions and automobile and appliance efficiency standards. Although not the only state agency involved in California's

10 Chris Busch, Hal Harvey, and Lili Pike, "The California Climate and Clean Energy Policy Story," Energy Innovation Policy & Technology, December 2015, https://energyinnovation.org/wp-content/uploads/2016/11/CA_LowCarbonStory.pdf.

11 Dan Dowling et al., "Cleantech Cities: Accelerating Climate Action through Startup and Corporate innovation," LACI and C40 Cities in collaboration with PricewaterhouseCoopers, 2019.

12 Brad Feld and Ian Hathaway, *The Startup Community Way: Evolving an Entrepreneurial Ecosystem* (Hoboken: John Wiley & Sons, 2020).

Box 3: Stakeholders in greentech-innovation ecosystems

Multiple stakeholders are involved in making greentech-innovation ecosystems work:

1. **Governments**: Sub-national (local, state, and regional), national, and supranational governments (e.g., the European Union) have multiple indispensable functions. They create long-term strategies, craft public policies, invest in public goods such as infrastructure and institutions (universities, etc.), levy harmful or helpful taxes, provide harmful or helpful subsidies and incentives, and generally create the conditions within which ecosystems succeed or fail.

2. **Pioneers**: Individuals form an initial cadre of local leaders who can be critical to ecosystem formation. Brad Feld, a notable example, was critical to formation of the Boulder/Denver ecosystem and was co-founder of the Techstars accelerator.

3. **Scientists and Researchers**: Every world-leading ecosystem has at least one, and often several, research universities and laboratories that conduct basic scientific discovery. Ecosystems frequently orbit around discoveries made in these institutions. For a variety of institutional and cultural reasons, universities and government research laboratories often struggle to bring promising lab-based research to the commercial marketplace, hence the need for other actors (entrepreneurs, investors, incubators, accelerators) to fill the gap.

4. **Entrepreneurs**: Create startups based on technologies produced in laboratories. These are not always the technologies' inventor(s), but are ecosystem linchpins because of their willingness to risk failure to bring nascent greentech to market. Successful startups "exit" through two pathways, through either acquisition by a larger firm or an initial public offering.

5. **Investors**: Critical players provide capital to startups at various stages. Different investor categories fund early, middle, and late startup stages with different time horizons for payoff. Greentech startups can struggle to attract investors with shorter time horizons, hence the need for "patient" capital from individual and philanthropic donors, governments, and large institutions. As investment capital is concentrated in the largest ecosystems (e.g., Silicon Valley), with investors often wanting startups to locate in these locations, smaller ecosystems face an obstacle to their growth. In countries with nationalized industries, it may be somewhat less crucial to raise private capital for greentech innovation.

6. **Corporations and Utilities**: These can play critical roles in ecosystems, including conducting in-house scientific and engineering research, providing or withdrawing investment capital, and making strategic business decisions that accelerate or hinder greentech development and commercialization.

7. **Incubators and Accelerators**: Provide services to startups (management training, investor access, legal advice, peer networking, etc.), in return for financial stakes in startup companies. Their intermediary services are elevated in importance given the specific obstacles facing greentech startups. Incubators have particular importance owing to longer gestation periods that early-stage greentech startups often require for their technologies to be proven viable in the marketplace.

8. **Workers**: Skilled labor (coders, lab technicians, data analysts, engineers, etc.) required for both startups and large technology firms to compete at the world-class level. Farsighted policies in education, immigration, worker retraining, and more are required to ensure ecosystems can attract and retain sufficient numbers of high-skilled workers.

environmental leadership, CARB features prominently in this history, setting tailpipe and greenhouse gas emissions standards across a range of pollutants, among other important regulatory interventions.[13]

Such long-term commitments, coupled with sustained public policies and investments, signal to other stakeholders the seriousness of political leadership's intentions to provide regulatory certainty and a durable ecosystem. Private investors and entrepreneurs are more willing to take risks in developing and scaling new green technologies when they believe that an investment climate is stable. Other actors, including talented individuals who live elsewhere (entrepreneurs, investors, skilled workers, scientists and researchers, and environmental advocates), also find such commitment attractive and are more willing to move to a rising city in order to be a part of a dynamic, exciting, and engaging ecosystem.

Successful leadership examples demonstrate an appreciation for the intersections between economic development, environmental protection, and spurring innovation. For example, local governments now embrace city-planning strategies that promise a lower climate impact, increased quality of life, and a stronger local economy all at once. Climate action strategies at the local (city) level stress this intersection; for example, asserting that shifting travel behavior toward EVs (cars, buses, trams) and personal mobility (bicycles, e-bikes, walking, and more) will result in healthier and happier residents while reducing carbon emissions and facilitating local economic development. It is not accidental that cities that have crafted the most ambitious, robust, and forward-leaning climate action plans, like New York, London, Berlin, Singapore, and Toronto, are many of the same places that are known for development of their greentech sector.[14] Amsterdam, a city with an underappreciated, but important and growing, presence on the greentech innovation landscape, the result of a now-familiar confluence of factors (high quality of life, world-class infrastructure, dynamic local culture, migrant-friendly context, and a network of organizations dedicated to building the city's tech sector).[15]

Ideally, government policies and investments should maximize the opportunity to support greentech development and innovation at the same time. A 2020 University of Maryland study compared the US states of Colorado and Maryland in terms of clean energy innovation outcomes (numbers of firms and levels of employment in the sector). It found that although both states had similarly robust clean energy policies, only Colorado integrated its clean energy and economic programs, having defined clean energy as a strategic economic sector from the outset. Colorado has incubated far more cleantech firms than has Maryland over roughly the same time period.[16]

B. Research and startup support

The thorniest problem in the entire greentech-development equation involves moving promising new technologies into successful commercialization. The linchpins are entrepreneurs, who come from different backgrounds (academics, engineering, business, etc.) and attempt to create commercially viable greentech startups. Their pathways are strewn with a number of obstacles from technology-transfer opportunities to access to capital.

Successful tech-innovation ecosystems are founded upon strong R&D platforms at local universities and research labs. Government funding of fundamental science at these institutions is especially critical for many areas of greentech development (e.g., supporting the advanced chemistry behind battery development). The US government has long poured billions of dollars into basic science, technology, engineer-

13 "History," California Air Resources Board, https://ww2.arb.ca.gov/about/history.

14 Rachel Cooper, "Mayor of London unveils 1.5C climate action plan," *Climate Action*, December 14, 2018, https://www.climateaction.org/news/mayor-of-london-unveils-1.5c-climate-action-plan; "Paris Climate Action Plan: Towards a Carbon Neutral City and 100% Renewable Energy, City of Paris," May 2018, https://cdn.paris.fr/paris/2019/07/24/1a706797eac9982aec6b767c56449240.pdf; "1.5°C: Aligning New York City with the Paris Climate Agreement," New York City Mayor's Office of Sustainability, September 2017, https://www1.nyc.gov/assets/sustainability/downloads/pdf/publications/1point5-AligningNYCwithParisAgrmtFORWEB.pdf; "Berlin Energy and Climate Protection Programme 2030," Berlin Senate Department for the Environment, Transport and Climate Protection, April 2019, https://www.berlin.de/sen/uvk/en/climate-protection/publications/; "TransformTO: Climate Action for a Healthy, Equitable & Prosperous Toronto. Implementation Update 2017 and 2018," City of Toronto Environment and Energy Division, 2018, https://www.toronto.ca/wp-content/uploads/2020/02/92f8-TransformTO-Climate-Action-for-a-Healthy-Equitable-Prosperous-Toronto-Implementation-Update-2017-and-2018.pdf; "L.A.'s Green New Deal: Sustainability City pLAn 2019," Office of Mayor Eric Garcetti, 2019, https://plan.lamayor.org/sites/default/files/pLAn_2019_final.pdf.

15 Conrad Egusa, "An Entrepreneur's Guide to Amsterdam's Tech Ecosystem," *Next Web*, October 23, 2019, https://thenextweb.com/podium/2019/10/23/an-entrepreneurs-guide-to-amsterdams-tech-ecosystem/; Lester Isaac Simon, "Behind Amsterdam's Strong Ecosystem and the Organizations that Got It There," *Startup Guide*, December 29, 2019, https://startupguide.com/behind-amsterdam-strong-ecosystem-and-the-organizations-that-got-it-there.

16 K. Surana et al., "Regional Clean Energy Innovation: Regional Factors for Accelerating the Development and Deployment of Climate Mitigation Technologies," Energy Futures Initiative with University of Maryland Global Sustainability Initiative, 2020, 15–17.

A row of electric vehicle chargers is seen at Strathclyde Park, United Kingdom. *Source:* Unsplash/Colin D. (@ccbotanic)

ing, and mathematics (STEM) education, spread across the nation's first-rate public and private universities. However, universities and research laboratories the world over struggle to take lab-based research and bring it into the marketplace, in large part because academic cultures often regard entrepreneurialism with suspicion.[17] Although universities now recognize this problem, with many creating tech-transfer offices focused on incentivizing faculty, staff, and students to commercialize their inventions, there has proven no easy solution to this challenge.[18]

For those entrepreneurs who create greentech startups, their primary obstacle is finding the right amount and type of capital to develop their nascent technologies and prove market viability. Unfortunately, as green technologies are often based in hard science—and frequently involve new materials, processes, and systems—greentech startups are more expensive to fund in early stages and take longer to achieve commercial maturity compared with software and digital startups. They need greater amounts of capital for prototyping (e.g., funds for expensive testing and hard-

17 Engelke and Manning, *Innovative Edge*.

18 Ibid.

ware) and longer time horizons to demonstrate effectiveness—frequently a decade, if not longer—compared with three to five years for software and digital startups.[19]

After the 2008 financial crisis, public finance flows (so-called "green stimulus programs") in the European Union, China, Japan, South Korea, and the United States provided significant capital to develop greentech—specifically, renewable energy technologies—as one way to stimulate the economy. China, for example, focused on green industrial policy, laying the path for future dominance in solar-panel, wind-turbine, and battery manufacturing.[20] However, private investors (venture capitalists, in particular) assessed greentech startups as too risky, leading to their temporary withdrawal from this sector. Major corporations also appeared to withdraw their investments in greentech startups more than in other research-heavy sectors (e.g., pharmaceuticals and medical technology), reflecting the unique scaling problems facing greentech startups (for example, the transformation of massive systems such as power grids).[21]

For these reasons, entrepreneurs benefit from programs that attempt to bridge the "valleys of death" that is particularly challenging to greentech startups. There is a great need for alternative sources of startup financing in this space, particularly from sources that have a longer time horizon for investment returns. Some types of private-sector institutional funders are more appropriate; for example, individual and philanthropic investors. But, as the previous paragraph shows, the public sector has an important bridging role to play as well. A widely cited example of such public financing is the US Department of Energy's Advanced Research Projects Agency-Energy (ARPA-E) program, which provides seed funding for promising greentech startups focusing on building efficiency, agriculture, transport, advanced batteries, power generation and conversion, and new materials.[22]

Green banks—institutions that are dedicated to financing low- or zero-carbon solutions—are a growing presence in the investor landscape. Green banks are designed with the greentech-startup challenge uppermost in mind; hence, creating new financial instruments that are intended to reduce risk, real or perceived, for investment in these startups. There are a rising number of green banks the world over. Among the best known is Australia's Clean Energy Finance Corporation.[23]

Intermediary institutions such as incubators and accelerators play an important role in the lives of many startups. These institutions provide core services, access to investor networks, training, peer support, and more. Regarding greentech development, these institutions play an outsized role, given the particular challenges facing startups in this space, as outlined above. Boston's Greentown Labs (soon to include a Houston affiliation) is but one of many prominent incubators focusing on this space. Box 4 examines the roles played by incubators and accelerators in greater detail.

C. Pro-deployment context

Pro-deployment policies, taxes, incentives, and constructive regulation can help to overcome the scaling problem that green technologies often face. Marketplaces may not be ready to accept promising greentech for a variety of reasons (for example, early EV adoption was limited not only by EV prices and lack of range, but also, and critically, by the lack of charging infrastructure). Public-sector activities can address these constraints through fueling consumer demand, sending price signals, and otherwise incentivizing the market uptake of promising green technologies, which influence both the supply and demand sides of the marketplace. To return to the EV example, Norway has become the world's leader in EV adoption, despite the fact that the country does not make EVs, because the country has

19 Jesse Jenkins and Sara Mansur argue that greentech startups frequently face two "valleys of death," one technological and one commercial, at different stages. Jesse Jenkins and Sara Mansur, "Bridging the Clean Energy Valleys of Death: Helping American Entrepreneurs Meet the Nation's Energy Innovation Imperative," Breakthrough Institute, 2011, https://s3.us-east-2.amazonaws.com/uploads.thebreakthrough.org/legacy/blog/Valleys_of_Death.pdf.

20 Laszlo Varro, et al., "Green Stimulus After the 2008 Financial Crisis Learning from Successes and Failures," International Energy Agency, June 29, 2020, https://www.iea.org/articles/green-stimulus-after-the-2008-crisis.

21 Benjamin Gaddy, Varun Sivaram, and Francis O'Sullivan, "Venture Capital and Cleantech: The Wrong Model for Energy Innovation?" MIT Energy Initiative, July 2016, http://energy.mit.edu/wp-content/uploads/2016/07/MITEI-WP-2016-06.pdf.

22 Jenkins and Mansur, "Bridging the Clean Energy Valleys of Death;" Gaddy, Sivaram, and O'Sullivan, "Venture Capital and Cleantech."

23 Tamara Grbusic and Laurie Stone, "Green Banks 101," Rocky Mountain Institute, May 28, 2020, https://rmi.org/green-banks-101/; Angela Whitney et al., "State of Green Banks 2020," Rocky Mountain Institute, 2020, 23, https://rmi.org/insight/state-ofgreen-banks/.

Box 4: Greentech Incubators and Accelerators

Incubators and accelerators are essential intermediary institutions within tech-innovation ecosystems. Incubators generally support startups' earlier stages and accelerators their later stages (hence the two terms: to "incubate" a startup before commercialization; to "accelerate" a startup's growth after commercialization begins).

Incubators are particularly important for greentech development given the more difficult science, expensive testing, and long gestation times involved in moving many startups from infancy to commercial maturity. In exchange for monthly fees and/or equity stakes, incubators provide mentoring, access to business networks, structured exposure to interested investors, grants and low-interest loans, peer-to-peer contacts, collaborative workspaces, and more.

There is a long list of greentech incubators and accelerators. Prominent examples in North America include Greentown Labs (Boston, and soon also Houston), Techstars (multiple locations, originally Boulder), Plug and Play (Silicon Valley), the MaRS Discovery District (Toronto), and the Los Angeles Cleantech Incubator (LACI). There are many incubators elsewhere. Israel's InNegev, for example, incubates AgTech, FoodTech, and Cleantech startups in the dry Negev region, while the EIT Climate-KIC Accelerator manages a network of partnering organizations across Europe.

Local, state, and national governments frequently play a role in the founding and ongoing support of such institutions (for example, InNegev is backed by the world-renowned Israeli Innovation Authority, a publicly funded agency). Very often, incubators are founded as partnerships between public, private, and academic institutions, as was true in the case of Toronto's MaRS Discovery District.

Incubators routinely recruit talented entrepreneurs from around the world in an attempt to bring in house the most promising startups. LACI, as an example, has co-hosted the annual LA Co-Mobility Challenge, a global competition for green transportation startups, and the California Climate Cup, a global competition for climate tech startups.

Sources: "What is the Difference between a Startup Accelerator and a Business Incubator?" *Brex*, April 13, 2013, https://www.brex.com/blog/startup-accelerator-vs-business-incubator/; Los Angeles Cleantech Incubator, https://laincubator.org/our-strategy/; MaRS Discovery District, https://www.marsdd.com/about/; Greentown Labs, https://greentownlabs.com/about/; Techstars, https://www.techstars.com/mission; Plug and Play, https://www.plugandplaytechcenter.com/about/; InNegev, https://innegev.com/#about-us; EIT Climate-KIC Accelerator, https://www.climate-kic.org/programmes/entrepreneurship/accelerator/; "California Climate Cup," Empower Innovation, https://www.empowerinnovation.net/en/custom/funding/view/1341; "The LA New Mobility Challenge," *NewCities*, https://newcities.org/the-la-new-mobility-challenge/.

employed a coordinated mix of pro-deployment policies and incentives that include tax breaks, discounted parking fees, exemptions to driving regulations, and investment in charging infrastructure.[24]

As Table 1 shows, even a non-exhaustive list of pro-deployment policies, taxes, regulations, and incentives is a lengthy one. They include carbon taxes, cap-and-trade programs, renewable portfolio standards and feed-in tariffs, energy-efficiency regulations, infrastructure investment, deployment financing, and certificate programs.

Many pro-deployment activities have had real consequences around the world, helping to accelerate marketplace transitions to more readily adopt green technologies. The United Kingdom's carbon tax, called the Carbon Price Support, is credited with accelerating the country's transition from coal-fired electricity generation to gas and re-

24 Jake Richardson, "The Incentives Stimulating Norway's Electric Vehicle Success," *CleanTechnica*, January 28, 2020, https://cleantechnica.com/2020/01/28/the-incentives-stimulating-norways-electric-vehicle-success/; David Nikel, "Electric Cars: Why Little Norway Leads the World in EV Usage," *Forbes*, June 18, 2019, https://www.forbes.com/sites/davidnikel/2019/06/18/electric-cars-why-little-norway-leads-the-world-in-ev-usage/?sh=4a86d34513e3.

newable sources (from an estimated 40 percent share to 3 percent over six years after its 2013 introduction).[25] Germany famously created the world's first national feed-in tariff for renewable energy (principally solar), helping the country dramatically scale its renewable energy consumption.[26] Multiple actors—for example, Chinese utilities—are expanding their EV infrastructure to encourage EV ownership and use.[27] New York's Sustainable Roof Laws require major real-estate owners to install "sustainable" roofs (either solar photovoltaic panel systems or green roofs consisting of plants and other soft elements). Designed to accelerate a small but thriving niche market, the laws attempt to reduce energy consumption in New York City's enormous building stock (buildings are among the largest consumers of energy and producers of carbon dioxide in the world in general, and in New York in particular).[28] Finally, Japan improved the energy intensity of its economy by more than 40 percent since 1979 through the regulation of energy consumption by law and energy-saving campaigns. In the process, it developed one of the largest markets for energy-efficient appliances, among other technologies.[29]

D. Place and flow

Successful ecosystems score high in terms of place and flow. "Place" refers to appropriate local conditions, while "flow" refers to degree of integration within global flows of capital, information, and people.[30] The world's best ecosystems are attractive places to live, work, and invest, while also being fully integrated into a heavily networked global economy. This place-flow interaction is the lifeblood of every high-performing ecosystem, including ecosystems that encourage greentech innovation.

Mayors and other elected officials generally have an intuitive understanding of this equation, knowing that if their cities are to create a viable tech sector and attract the required human capital, then they must craft the right policies and make the right investments: supporting scientific and engineering research institutions that do lab-based research; investing in high-quality infrastructure such as airports, so as to ensure connectivity to the rest of the world; providing city-planning amenities (parks, walkable neighborhoods, sufficient quality housing, etc.) to support a high standard of living for tech-sector workers; and more. For any ecosystem to succeed, moreover, state, regional, and national governments must support these local features through investments and policies ranging from education and worker training to intellectual property protection.[31]

The best public policies boost place and flow simultaneously. For instance, supportive immigration policies (a power possessed by national governments) attract world-class talent to a country and encourage migrants to put down roots and become citizens. Immigration has been foundational to the United States' world-leading status in technology innovation (Apple, Amazon, Google, Tesla, Uber, Palantir, and SpaceX are among many US tech giants that were founded by first- or second-generation immigrants).[32] Other countries have taken notice. Canada, as an example, in 2017 crafted an aggressive policy titled the "Global Skills Strategy" that focuses on skilled-migrant labor, created in part to take advantage of the United States' hostility to such immigration under the Donald Trump administration. Although preliminary, results have been promising, with Canada's tech sector booming in cities such as Toronto.[33]

---

25 Figures from a 2019 University College London study: University College London, "British Carbon Tax Leads to 93% Drop in Coal-Fired Electricity," *phys.org*, January 7, 2020, https://phys.org/news/2020-01-british-carbon-tax-coal-fired-electricity.html.

26 Germany famously created the world's first national feed-in tariff in 1991—one much copied since. History briefly outlined in Toby D. Couture, et al., "A Policymaker's Guide to Feed-in Tariff Policy Design," National Renewable Energy Laboratory, June 2010, 9–11.

27 Anders Hove and David Sandalow, "Electric Vehicle Charging in China and the United States," Columbia University CGEP/SIPA, February 2019, 26–29.

28 Chris Teale, "NYC Passes Sweeping 'Climate Mobilization Act,'" *Smart Cities Dive*, April 22, 2019, https://www.smartcitiesdive.com//news/new-york-city-climate-mobilization-act/553134/; Cailley LaPara, "NYC's Roofs are Getting a Sustainable Makeover," *Smart Cities Dive*, January 22, 2020, https://www.smartcitiesdive.com/news/nycs-roofs-are-getting-a-sustainable-makeover/570620/; Kelly DiNardo, "The Green Revolution Spreading Across Our Rooftops," *New York Times*, October 9, 2019, https://www.nytimes.com/2019/10/09/realestate/the-green-roof-revolution.html.

29 "Top Runner Program: Developing the World's Best Energy-Efficient Appliance and More," Ministry of Trade, Environment, and Industry, March 2015, https://www.enecho.meti.go.jp/category/saving_and_new/saving/data/toprunner2015e.pdf

30 Manning and Engelke, *Sweepstakes*, 59.

31 Manning and Engelke, *Sweepstakes*; Engelke and Manning, *Innovative Edge*.

32 Rani Molla, "More than Half of the Most Valuable U.S. Tech Companies Were Founded by First- or Second-Generation Immigrants," *Vox*, May 30, 2018, https://www.vox.com/2018/5/30/17385226/kleiner-perkins-mary-meeker-immigration-tech-founders-jobs-slides-code-conference.

33 Randi Druzin, "Canada's Tech Sector Benefits from U.S. Visa Policy," *US News & World Report*, July 20, 2020, https://www.usnews.com/news/best-countries/articles/2020-07-20/how-canadas-tech-sector-benefits-from-us-visa-policy.

Table 2: Selected Pro-deployment Policies, Taxes, Regulations, and Incentives

Policy Domain	**Sample Policies, Taxes, and Incentives**
Carbon taxes	Canada's Greenhouse Gas Pollution Pricing Act (GGPPA), United Kingdom's Carbon Price Support*
Cap-and-trade programs	Regional Greenhouse Gas Initiative (RGGI), California Cap and Trade, European Union Emission Trading Scheme (EU ETS)
Renewable portfolio standards and feed-in tariffs	Germany's feed-in tariff for renewable power sources
Green-building policies and building-efficiency programs	Singapore's Green Building Masterplans;** New York's Sustainable Roof Laws
Low-/zero-emission and electric-vehicle incentives	Norway's pro-EV policy basket***
Direct and indirect support for greentech infrastructure	Chinese public utilities' investments in EV charging-station networks
Direct and indirect financing for deployment	IRENA/ADFD Project Facility geared toward financing clean energy deployment projects in developing countries****
Replacement certificates	Danish wind power replacement certificate program*****
Regulation	Japan's Energy Conservation Law and Top Runner Program******

Unless otherwise indicated, sources include: interviews; Dowling et al., "Cleantech Cities;" Surana et al., "Regional Factors;" CleanEdge, "Leadership."

* Brad Plumer and Nadja Popovich, "These Countries Have Prices on Carbon. Are They Working?" *New York Times*, April 2, 2019, https://www.nytimes.com/interactive/2019/04/02/climate/pricing-carbon-emissions.html.

** "Green Building Masterplans," Building and Construction Authority (Singapore), https://www1.bca.gov.sg/buildsg/sustainability/green-building-masterplans.

*** Richardson, "The Incentives Stimulating Norway's Electric Vehicle Success."

**** The facility is jointly administered by the International Renewable Energy Agency (IRENA) and the Abu Dhabi Fund for Development (ADFD), https://www.irena.org/ADFD.

***** James Dean, "Policy, Not Tech, Spurred Danish Dominance in Wind Energy," *Cornell Chronicle*, November 5, 2020, https://news.cornell.edu/stories/2020/11/policy-not-tech-spurred-danish-dominance-wind-energy.

****** "Top Runner Program: Developing the World's Best Energy-Efficient Appliance and More," Ministry of Trade, Environment, and Industry, March 2015, https://www.enecho.meti.go.jp/category/saving_and_new/saving/data/toprunner2015e.pdf.

IV. Opportunities and Recommendations

This issue brief makes the following recommendations for action and further research to drive the expansion of greentech-innovation ecosystems and help the global community tackle the most difficult climate and environmental challenges.

1. *Shape public policy to attract more greentech innovators.* Local government leaders can use social and economic policy to create attractive environments for technology innovators and foster the development of a larger ecosystem. This report provides a checklist for the building blocks of an effective greentech ecosystem: provide clear, visionary leadership; leverage and improve existing R&D capacity in local educational institutions, companies, and community organizations; invest in talent and startup funds; and establish investment certainty through regulatory and pro-deployment policies.

2. *Focus technology innovation on mitigation of climate and environmental impacts.* Government and industry leaders can take action to promote innovation in greentech or risk getting left behind in an economic race for market share in the emerging low-carbon economy. Technologies related to fast-growing sectors such as clean energy, sustainable agriculture, and environmentally friendly consumer products are worthy of investment for economic gain, and for the health of humanity and the planet.

3. *Develop robust place-specific greentech-innovation ecosystem indexes focused on measuring ecosystem performance in greentech development.* Without a comprehensive landscape analysis of ecosystems and stakeholder networks, it is difficult to know where the world's dynamic centers of innovation are located, to assess who is responsible for their performance, and to generate an understanding of how they operate. Developing more accurate maps would also allow policy researchers to assess trends, to gauge how different cities, regions, and countries are moving up or down the global balance sheet.

4. *Expand best-practice policy learning and transfer.* Much transfer of practice happens organically. Investors and executives who run incubators and accelerators scan the global horizon constantly, looking for investment opportunities and guarding against competitors finding an edge. However, it is not clear that best-practice policy learning and transfer happens as easily. Although governments do learn and adopt policies borrowed from elsewhere, the diversity and inconsistency of policy across greentech-innovation ecosystems suggest much opportunity for improvement.

5. *Build global networks of stakeholders.* Think tanks and academic institutions can provide valuable platforms to facilitate learning and the socialization of findings among stakeholders for building a more robust and productive dialogue on how to strengthen greentech-innovation ecosystems. They can create the conditions for sustained engagement with policymakers at all levels of governance (local, state/regional, national, supranational) to address best practices in policy design and execution, as well as leading industry players and entrepreneurs to exchange new ideas.

The Atlantic Council is grateful to the MacArthur Foundation for its support of this project. The authors would like to thank numerous experts from different ecosystems around the world who took the time to share their thoughts. The interviews were off the record and not for attribution. The authors also thank Frank Willey, who conducted the Crunchbase analysis.

About the Authors

Peter Engelke is a Deputy Director and Senior Fellow within the Atlantic Council's Scowcroft Center on Strategy and Security. His diverse work portfolio at the Center's Foresight, Strategy, and Risks Initiative spans global and regional futures, innovation and technological disruption, geopolitics, climate change and natural resources, and urbanization among other topics. Dr. Engelke has managed numerous projects on these subjects, resulting in a lengthy list of Atlantic Council publications. His work has appeared in the Washington Post, Los Angeles Times, The Hill, The National Interest, Citiscope, Meeting of the Minds, the World Economic Forum's Agenda platform, and other outlets. Dr. Engelke's professional experience includes stints at other think tanks and foundations in Europe and the United States, including as an Executive-in-Residence at the Geneva Centre for Security Policy, a Bosch Fellow with the Robert Bosch Foundation in Stuttgart, Germany, and a Visiting Fellow at the Stimson Center in Washington, DC. His most recent co-authored book, The Great Acceleration, is a global environmental history from 1945 to 2016. His first, Health and Community Design, was penned while he was on the research faculty at Georgia Tech and is a study of public health and urban form. Dr. Engelke holds a Ph.D. in history from Georgetown University and has master's degrees from Georgetown's Walsh School of Foreign Service, the University of Maryland, and Indiana University. He currently is on the adjunct faculty at Georgetown's School of Continuing Studies.

Margaret Jackson is the deputy director for climate and advanced energy in the Atlantic Council's Global Energy Center. From 2019 to 2020, Ms. Jackson was a Council on Foreign Relations-Hitachi International Affairs fellow at the Institute of Economics, Japan, where she researched US-Japan energy security cooperation. Prior to working in Tokyo, she was a Fulbright scholar at the Institute of Energy, Environment, and Economy at Tsinghua University in Beijing, studying implications for Chinese overseas renewable energy investment. Ms. Jackson is also a former US Navy Surface Warfare Officer and served in Japan and on multiple deployments to the Western Pacific. During her time in Washington, DC, she briefed senior leaders on US-China affairs and worked in operations and plans related to East Asia under the Chief of Naval Operations. Early in her career, she interned under the US Military Representative at the North Atlantic Treaty Organization (NATO).

Ms. Jackson earned an MA from Georgetown University with a focus on energy and climate policy, and a BS with honors in Political Science and a minor in Mandarin Chinese from the United States Naval Academy.

Randolph Bell is the director of the Atlantic Council's Global Energy Center (GEC), where he oversees the center's research and programs in Washington and elsewhere, including the annual Atlantic Council Global Energy Forum in Abu Dhabi. He is the Richard Morningstar chair for global energy security. He joined the Global Energy Center in 2017 as its director of business strategies. From 2014–2016, Mr. Bell led the launch of the center in his capacity as director of business development and new ventures for the Atlantic Council.

From 2011–2014, Mr. Bell was managing director at the International Institute for Strategic Studies (IISS)–US, where in addition to holding overall responsibility for the operations and programming of the IISS's Washington, DC office he published extensively on African, South Asian, and cyber security issues. From 2010–2011, he was manager of national security at the Markle Foundation, where he worked on cyber security, intelligence community information sharing, and technology policy issues.

Mr. Bell has an MPP from the John F. Kennedy School of Government at Harvard University, where he was a Public Service and Belfer International and Global Affairs fellow, and graduated *magna cum laude* from Harvard College.

Atlantic Council

Board of Directors

CHAIRMAN
*John F.W. Rogers

EXECUTIVE CHAIRMAN EMERITUS
*James L. Jones

PRESIDENT AND CEO
*Frederick Kempe

EXECUTIVE VICE CHAIRS
*Adrienne Arsht
*Stephen J. Hadley

VICE CHAIRS
*Robert J. Abernethy
*Richard W. Edelman
*C. Boyden Gray
*Alexander V. Mirtchev
*John J. Studzinski

TREASURER
*George Lund

DIRECTORS
Stéphane Abrial
Todd Achilles
*Peter Ackerman
Timothy D. Adams
*Michael Andersson
David D. Aufhauser
Colleen Bell
*Rafic A. Bizri
*Linden P. Blue
Philip M. Breedlove
Myron Brilliant
*Esther Brimmer
R. Nicholas Burns
*Richard R. Burt
Michael Calvey
Teresa Carlson
James E. Cartwright
John E. Chapoton
Ahmed Charai
Melanie Chen
Michael Chertoff
*George Chopivsky
Wesley K. Clark
*Helima Croft
Ralph D. Crosby, Jr.
*Ankit N. Desai
Dario Deste
*Paula J. Dobriansky
Joseph F. Dunford, Jr.
Thomas J. Egan, Jr.
Stuart E. Eizenstat
Thomas R. Eldridge
*Alan H. Fleischmann
Jendayi E. Frazer
Courtney Geduldig
Robert S. Gelbard
Thomas H. Glocer
John B. Goodman
*Sherri W. Goodman
Murathan Günal
Amir A. Handjani
Katie Harbath
Frank Haun
Michael V. Hayden
Amos Hochstein
*Karl V. Hopkins
Andrew Hove
Mary L. Howell
Ian Ihnatowycz
Wolfgang F. Ischinger
Deborah Lee James
Joia M. Johnson
*Maria Pica Karp
Andre Kelleners
Astri Kimball Van Dyke
Henry A. Kissinger
*C. Jeffrey Knittel
Franklin D. Kramer
Laura Lane
Jan M. Lodal
Douglas Lute
Jane Holl Lute
William J. Lynn
Mark Machin
Mian M. Mansha
Marco Margheri
Chris Marlin
William Marron
Neil Masterson
Gerardo Mato
Timothy McBride
Erin McGrain
John M. McHugh
H.R. McMaster
Eric D.K. Melby
*Judith A. Miller
Dariusz Mioduski
*Michael J. Morell
*Richard Morningstar
Virginia A. Mulberger
Mary Claire Murphy
Edward J. Newberry
Thomas R. Nides
Franco Nuschese
Joseph S. Nye
Ahmet M. Ören
Sally A. Painter
Ana I. Palacio
*Kostas Pantazopoulos
Alan Pellegrini
David H. Petraeus
W. DeVier Pierson
Lisa Pollina
Daniel B. Poneman
*Dina H. Powell McCormick
Robert Rangel
Thomas J. Ridge
Lawrence Di Rita
Michael J. Rogers
Charles O. Rossotti
Harry Sachinis
C. Michael Scaparrotti
Rajiv Shah
Wendy Sherman
Kris Singh
Walter Slocombe
Christopher Smith
James G. Stavridis
Michael S. Steele
Richard J.A. Steele
Mary Streett
*Frances M. Townsend
Clyde C. Tuggle
Melanne Verveer
Charles F. Wald
Michael F. Walsh
Gine Wang-Reese
Ronald Weiser
Olin Wethington
Maciej Witucki
Neal S. Wolin
*Jenny Wood
Guang Yang
Mary C. Yates
Dov S. Zakheim

HONORARY DIRECTORS
James A. Baker, III
Ashton B. Carter
Robert M. Gates
James N. Mattis
Michael G. Mullen
Leon E. Panetta
William J. Perry
Colin L. Powell
Condoleezza Rice
George P. Shultz
Horst Teltschik
John W. Warner
William H. Webster

*Executive Committee Members

List as of December 16, 2020

The Atlantic Council is a nonpartisan organization that promotes constructive US leadership and engagement in international affairs based on the central role of the Atlantic community in meeting today's global challenges.

Atlantic Council

1030 15th Street, NW, 12th Floor,
Washington, DC 20005

(202) 463-7226, www.AtlanticCouncil.org