



Patenting invention

Clean energy innovation trends and priorities for the Trump administration and Congress

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Introduction

President Trump has been right to say that energy industries are important to “making America great again.”¹ And Energy Secretary Rick Perry and Secretary of State Rex Tillerson have likewise been on target when they have stressed the importance of energy innovation.

“Energy innovation, it’s the quickest way to make our anemic economy very powerful,” Perry declared in 2014, referring to recent breakthroughs in renewables, energy storage, and electric vehicles. And for his part Tillerson insisted in 2015: “We must recognize the role of investment and innovation in helping unlock new supplies of energy,” including from renewables.²

Tillerson especially has shown himself alert to the economic importance of innovation in keeping the United States relevant in the \$1.4 trillion worldwide advanced energy sector.³

Play it right, Perry and Tillerson have seemed to suggest, and clean energy innovation holds great potential to spark job creation in U.S. regions, support the manufacturing sector, and improve the trade balance by improving American competitiveness.

And yet, there is a problem. At a moment when signs indicate the U.S. clean energy innovation enterprise could be flagging, the Trump administration has proposed draconian federal budget cuts that raise new concerns about the future of the nation’s long-term commitment to low-carbon economic development.

Under Trump’s proposed “skinny budget,” the Office of Science within the Department of Energy (DOE) would lose \$900 million of its \$5 billion annual appropriation, affecting DOE offices supervising early-stage research into solar, wind, nuclear, battery, and carbon-capture technologies.⁴ Additional cuts would

affect all of the department’s applied energy offices. The Trump framework also proposes eliminating the Advanced Research Projects Agency-Energy (ARPA-E), which supports early stage “moon shots” that are too risky for private investment, and axing build-out loan programs like the Advanced Technology Vehicle Manufacturing Program, which provided early support to Tesla.

Making this even more untimely is the fact that several indicators of the competitiveness of U.S. cleantech innovation are raising warning lights. Eleven countries around the world now spend more on energy research and development (R&D) as a percentage of their economies than the United States does; China spends three times as much.⁵ Likewise, flows of the venture capital (VC) needed to help cleantech entrepreneurs build companies peaked in 2011 and have since dwindled.⁶ What is more, there is a perception problem: while energy innovation is a matter of broad national interest, too few Americans understand that the research, invention, testing, and commercialization that goes into it extends far beyond the usual short list of elite, green coastal tech centers in California and Massachusetts and actually reaches across the country.

So, as Congress considers the Trump budget proposals and develops its own plan, it is appropriate to assess the status of the U.S. cleantech innovation enterprise, both nationally and regionally. To that end, this

brief and a forthcoming one undertake to look closely at trends and issues involving two key aspects of U.S. cleantech innovation—technology patenting and VC investment—as they are playing out across 14 clean technology areas and the nation’s diverse metropolitan areas.

Patenting matters, because patenting—a measure of new technology invention—is an intermediate step toward innovation, and patent data provide indirect and partial indicators of innovation. Patenting activity has been shown to be positively correlated with regional economic health, as high rates of patent creation are geographically associated with higher-than-average wages, lower regional unemployment, and more startup company activities.⁷ VC is important because it is a key form of the early-stage financing that is frequently necessary to allow innovative new energy companies to grow.⁸ VC has also been shown to play a key role in advancing key segments of the innovation economy of the United States over the last several decades.⁹

This brief

In keeping with that, this first brief of two on cleantech innovation—a forthcoming brief will examine VC dynamics—looks at dynamics, emphases, and patterns in clean-technology patenting since 2001 for the nation and its diverse metropolitan areas. In doing so, the post provides a baseline look at the pace and geography of cleantech innovation, with an eye to informing decisionmaking.

What do these data show? Overall, even as cleantech invention has grown over the years, patenting may be slowing, and it tends to be concentrated in relatively few technology domains such as advanced green materials,

energy efficiency, and transportation. Likewise, while many U.S. firms are patenting extensively, more and more U.S. patents are being obtained by foreign companies, raising questions about the nation’s commitment to profiting domestically from its inventions. Each of these findings raises questions about the competitiveness of the U.S. innovation scene. However, there are also signs of vibrancy across the map. Notably, while much of America’s patenting takes place in a relatively few large metropolitan areas, low-carbon energy innovation activity extends into all regions of the country, ensuring that energy innovation is far from a monopoly of coastal cities. That breadth provides grounds for optimism.

Cleantech patenting: what and where

Patents matter as an indicator of U.S. energy-sector innovation vitality because, while imperfect, they are a useful measure of the ability of individuals, firms, industries, and places to develop and implement new ideas that create business value.¹⁰ Patents, which grant their claimants temporary monopolies on the use of inventions, play an important role in the entire technology lifecycle, from basic research, development, and demonstration (RD&D) to commercialization. It is not surprising, therefore, that patents are one of the most frequently employed indicators for monitoring the emergence of new technologies, processes, and products wherein the rate of invention is represented by the volume of new patents resulting from public and private funded research.

For the purposes of this analysis, patents remain the best available source of data on innovation that is readily available and comparable across regions. Patent information can be used to assess RD&D trends, emerging technologies, “whitespace,” innovation patterns, and the technology competitiveness of firms, industries, and regions.¹¹

And so this brief uses IP Checkups’ Cleantech PatentEdge database to analyze patenting trends for 14 cleantech energy innovation categories (ranging from solar and wind to nuclear and conventional fuels) between 2001

and 2016, with a focus on the period after 2011, for the United States and its metropolitan regions.¹² This discussion focuses only on patent activity at the U.S. Patent and Trademark Office (USPTO), one of the largest patent offices in the world and the recipient of a significant share of applications and grants from foreign inventors because of the size and openness of the U.S. market.¹³ Overall, the resulting analysis reveals a mixed picture of U.S. cleantech innovation.

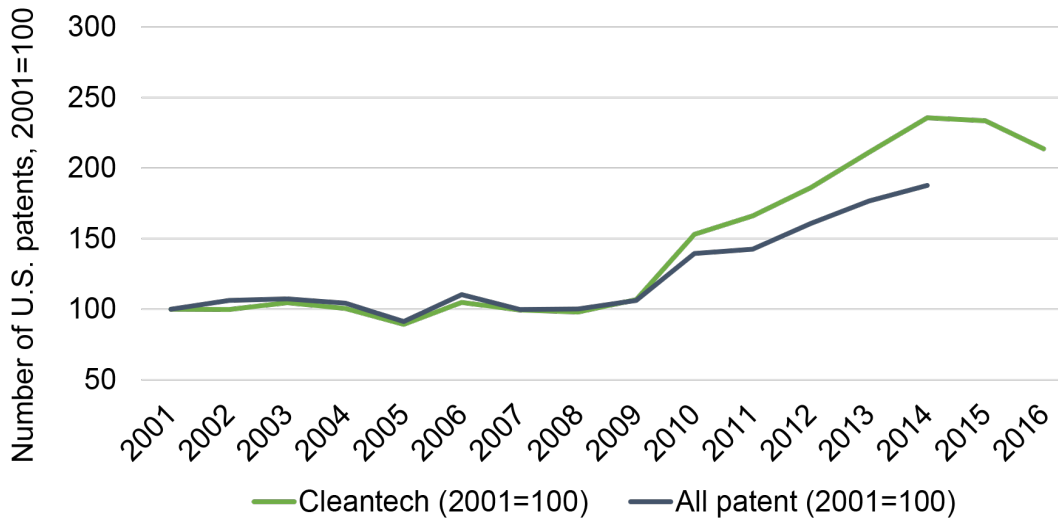
Five major findings stand out:

1. U.S. Cleantech patenting has grown significantly since 2001, outpacing growth in all U.S. patents, but may now be flagging

Patent filing and granting has generally increased since the early 2000s, and the cleantech sector is no exception.¹⁴ Since 2001, the total number of granted patents in cleantech has more than doubled—from a little less than 15,000 in 2001 to approximately

32,000 in 2016. U.S. cleantech patents reached an all-time high of 35,271 in 2014. Moreover, patenting in cleantech has been growing faster than in many other important innovation industries.

Figure 1: After years of growth the number of cleantech patents granted by USPTO has declined since 2014
(2001-2016)



Source: Brookings analysis of IP Checkups' Cleantech PatentEdge database

During the years 2001–2014, for example, patenting across all technology areas rose at a 5 percent compound annual growth rate (CAGR), but in cleantech the rate was 7 percent (for the period 2011–2014 the rate was 12 percent growth).¹⁵ In fact, during these years cleantech patenting grew at a faster pace than patenting in such celebrated innovation industries as medical technology (which grew at 6 percent CAGR), semiconductors (5 percent), biotechnology (3 percent), and pharmaceuticals (4 percent). Only digital communications and computer technology (14 percent and 12 percent a year growth) saw faster patenting than cleantech. Likely contributing to strong patenting in the years prior to 2015 has been the cumulative impact of investment in research—by both government and industry—and growth in the market for clean technologies globally. A strong

surge in the years 2011–2014 may also reflect recovery from the global recession, along with USPTO efforts to decrease its backlog of patent applications.¹⁶

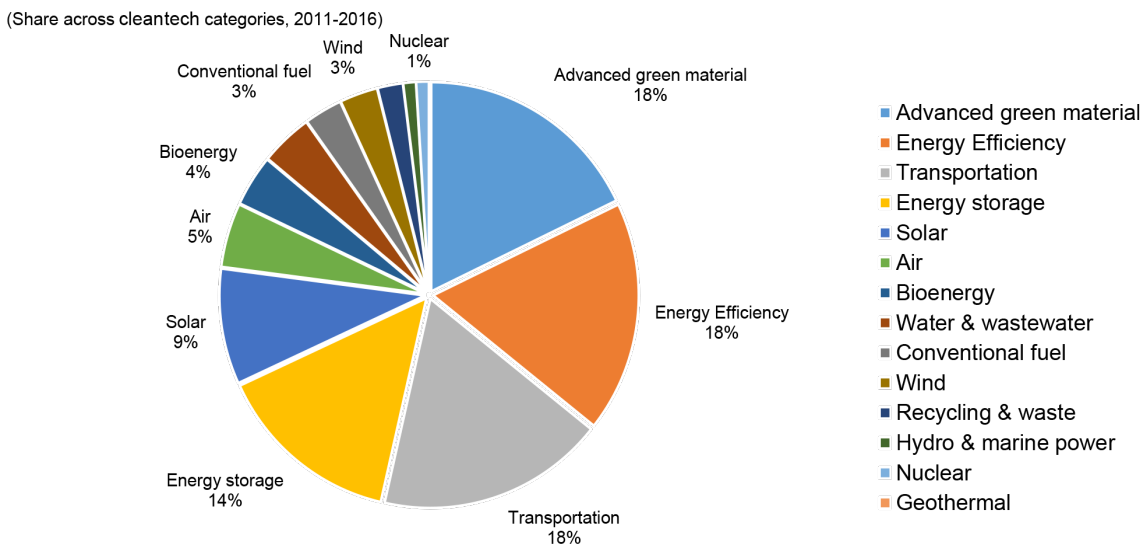
However, between 2014 and 2016 the number of cleantech patents granted in the country has declined by 9 percent (Figure 1). While most cleantech categories saw a downward trend in the number of patents granted since 2014, the decline has been most pronounced in energy efficiency, hydro and marine power, solar, bioenergy, and nuclear. It is too early to say whether the downward trend is just a blip or here to stay. In 2015, for instance, patents granted by the USPTO decreased 2 percent, the first decline in granted patents since 2008.¹⁷ But the recent overall slump bears watching.

2. Cleantech patenting is quite concentrated in relatively few categories

While cleantech patenting appears vibrant and extensive in some technology areas, it remains modest in others (Figure 2). Overall, a total of 186,500 patents have been granted in the United States since 2011 across 14 cleantech categories. Of this activity, advanced green materials, energy efficiency, and transportation each accounted for 18 percent of the total patenting, while energy storage accounted for another 15 percent. This extensive activity reflects that these are broad categories encompassing a wide range of technologies addressing large sectors of the economy. Energy efficiency, for instance, includes technologies related to heating, ventilation, and air conditioning (HVAC); water heating; appliances; windows and building envelope; lighting; sensors and controls; and smart meters.

However, drastically fewer patents are being granted in such areas as geothermal energy, hydro and marine power, and nuclear generation. None of these technology areas accounted for more than 1 percent of post-2010 total cleantech patenting. All of which means that little innovation has been occurring in two clean energy categories that play a large role in the U.S. electricity mix: hydro and nuclear.¹⁸ The low patenting rate in the nuclear power industry is especially concerning. Without improved reactor technologies—advances yielding cost reductions, shorter cycle times, smaller sizes, and greater safety—nuclear power will be unable to play an expanded role as a source of zero-carbon power.¹⁹ Advances in wave and tidal power generation are also lagging behind despite their vast global potential to generate new sources of clean and renewable electricity.²⁰

Figure 2: Cleantech patenting is disproportionately concentrated in a few categories



Source: Brookings analysis of IP Checkups' Cleantech PatentEdge database.

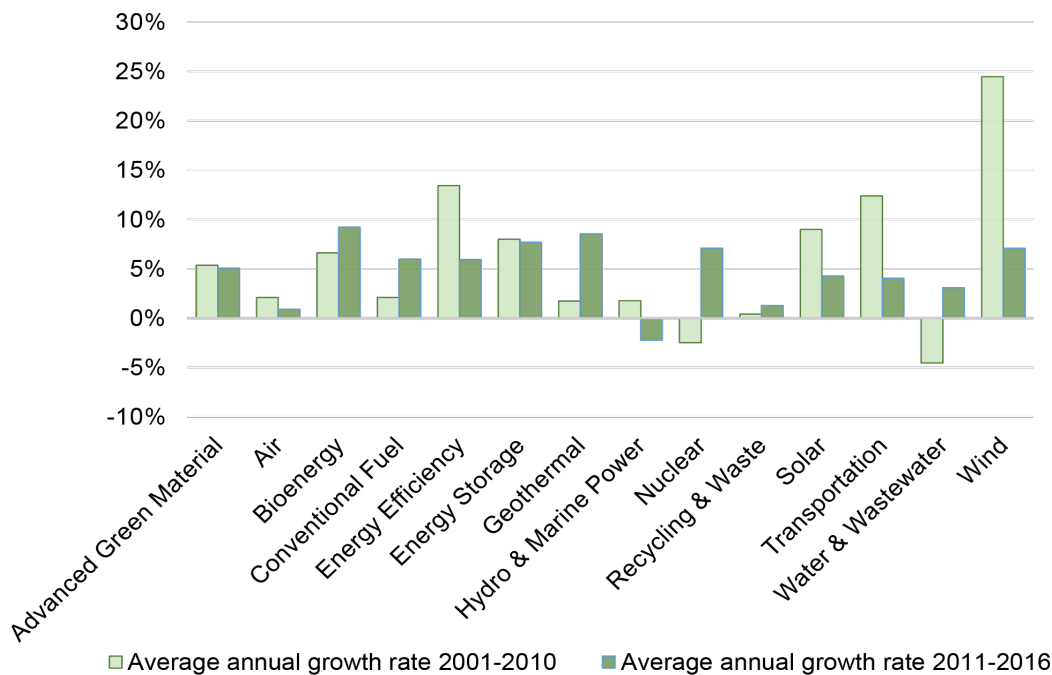
A look at patenting growth rates reveals more variation—and questions about the future (Figure 3). On the upside, patenting has picked up since 2011 in such categories as nuclear (albeit from a low base), geothermal, transportation, and water and wastewater. Most notably, while patenting in the nuclear power industry contracted 3 percent per year between 2001 to 2010, the industry has posted a solid 7 percent a year patenting surge (again, on a small base) since 2011. Apparently rising interest in nuclear energy is moving the industry toward innovation.²¹ Similarly, the negligible patenting rates exhibited by the transportation and water/wastewater industries prior to the recession have given way to more respectable patenting rates of 4 percent and

3 percent CAGR since then. This bodes well.

With that said, patenting is slowing in other categories. Patenting rates for wind and solar, for example, surged before the crisis but have slowed since 2011. Wind tech patenting, for instance, expanded by 25 percent a year between 2001 and 2010 but has been growing at a more modest 7 percent CAGR since then, perhaps reflecting the natural maturation of the industry. A similar slowdown has affected the solar and energy-efficiency industries.

In short, variable patenting rates across categories and over time are beginning to raise questions about the nation’s ability to compete and win in the burgeoning global clean energy market.

Figure 3: The pace of patenting varies greatly across the different cleantech categories
(Average annual growth rate for 2001-2010 and 2011-2016)



Source: Brookings analysis of IP Checkups’ Cleantech PatentEdge database

3. Large metropolitan areas host a disproportionate share of cleantech patenting but do not monopolize it; overall, cleantech patenting is widely distributed across the nation²²

Cleantech patenting, in terms of absolute patent issuance, is highly concentrated in a relatively small number of larger metropolitan areas. This is not surprising given that metropolitan areas are home to the productive drivers of the U.S. economy. Metros aggregate the productive assets—skilled workers, capital investment, advanced technologies, infrastructure, and relationship networks—that matter for economic growth and competitiveness. Indeed, the 100 largest metro areas, which are home to 35 percent of the U.S. population, accounted for 73 percent of granted cleantech patents, developed by one or more U.S.-based inventors, since 2011.

Patenting data suggest that cleantech innovation—far from solely the province of “blue America”—is occurring in metros in both red and blue states.

Along these lines, just 10 metro areas ranging from Boston and Detroit to Houston, Minneapolis, San Francisco, and San Jose accounted for 38 percent of the cleantech patents developed by U.S. inventors since 2011, while 20 metro areas accounted for 52 percent.

These metro areas are more likely to have a

large number of highly specialized researchers, engineers, and entrepreneurs who are coming up with breakthrough clean technologies.

Table 1 lists the 20 metro areas with the highest number of granted patents over the five-year period ending in 2016. The top three cleantech patenting subcategories are also listed for each metro to provide a sense of the metros’ most prominent cleantech sectors. The list in Table 1 suggests that there is a degree of truth in the common assumption that cleantech is primarily the province of a few large high-tech cities.

And yet the patent data make clear that cleantech innovation is also widely distributed across diverse regions of the country—in red and blue states, in big and small metros. To begin with, while 20 large metro areas generate half of the nation’s cleantech patents developed by U.S. inventors, another half of the nation’s patents emanates from a set of farther-flung, highly inventive cities. Such highly inventive metros—identified by the density of their patenting as measured by their cleantech patents per million residents—can be found in every region of the country, from Albany and Rochester, N.Y. in the Northeast to Albuquerque, N.M. and Boise City, Idaho in the West, Greenville, S.C. and Palm Bay, Fla. in the South, and Detroit and Madison, Wis. in the Midwest (Table 2).

The patenting data, in this regard, suggest that cleantech innovation—far from solely the province of “blue” America—is occurring in metros in both red and blue states. Greenville and Boise City in solidly Republican South Carolina and Idaho, for instance, are ranked 6th

and 7th (among the top 100 large metro areas) in cleantech patents per million residents. Provo, Utah and Knoxville, Tenn. also boast high cleantech patenting rates in Republican-leaning states. This runs counter to the popular perception that innovative activity in the United States is predominantly concentrated on the east and west coasts with very few pockets of activity in the remainder of the country.

Equally important is the fact that cleantech patenting occurs in many smaller metro areas and not just in the largest 100 metro areas. Smaller metros—including both college towns like Ann Arbor, Mich., Boulder, Colo., Durham-Chapel Hill, N.C., and Ithaca, N.Y. as well as other places like Bay City, Mich., Columbus, Ind., Corvallis, Ore., and Peoria, Ill.—account for smaller shares of the nation's total cleantech patents, but they punch well above their weight in terms of patents per capita. Ann Arbor, for instance, with 564 cleantech patents per million residents in any given year from 2011 to 2016, is the most inventive metro area by intensity. It even beats San Jose, which has 538 cleantech patents per million residents and is top metro in terms of sheer patent volume. The cleantech patenting intensity of seven small metro areas including Columbus (499 patents per million residents), Durham-Chapel Hill (313), and Boulder (249) is higher than that of San Francisco (174), which ranks second in patenting intensity among the top 100 metros.

Table 1: Total granted cleantech patents and patenting rate by metropolitan area of inventor, 2011-2016 (top 20 of 100 largest metropolitan areas, ranked by average granted patents)

	Average granted patents per year, 2011-2016	Patents per million residents, 2011-2016	Top three cleantech categories
San Jose-Sunnyvale-Santa Clara, CA	1,036	538	Advanced green materials, energy efficiency, solar
San Francisco-Oakland-Hayward, CA	789	174	Advanced green materials, solar, energy efficiency
Detroit-Warren-Dearborn, MI	708	165	Transportation, energy storage, energy efficiency
Houston-The Woodlands-Sugar Land, TX	642	101	Conventional fuel, advanced green materials, bioenergy
Los Angeles-Long Beach-Anaheim, CA	631	48	Advanced green materials, transportation, energy efficiency
New York-Newark-Jersey City, NY-NJ-PA	575	29	Advanced green materials, solar, energy efficiency
Boston-Cambridge-Newton, MA-NH	492	105	Advanced green materials, energy storage, energy efficiency
Chicago-Naperville-Elgin, IL-IN-WI	452	47	Transportation, advanced green materials, energy efficiency
Minneapolis-St. Paul-Bloomington, MN-WI	368	106	Advanced green materials, energy storage, transportation
Seattle-Tacoma-Bellevue, WA	334	92	Transportation, advanced green materials, energy efficiency
San Diego-Carlsbad, CA	309	96	Advanced green materials, bioenergy, energy storage
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	288	48	Advanced green materials, bioenergy, energy efficiency
Dallas-Fort Worth-Arlington, TX	232	34	Energy efficiency, advanced green materials, transportation
Atlanta-Sandy Springs-Roswell, GA	223	40	Energy efficiency, advanced green materials, transportation
Phoenix-Mesa-Scottsdale, AZ	215	49	Transportation, advanced green materials, energy efficiency
Washington-Arlington-Alexandria, DC-VA-MD-WV	200	34	Advanced green materials, transportation, energy efficiency
Austin-Round Rock, TX	200	106	Advanced green materials, energy efficiency, energy storage
Denver-Aurora-Lakewood, CO	171	63	Solar, bioenergy, advanced green materials
Rochester, NY	171	157	Energy storage, advanced green materials, energy efficiency
Portland-Vancouver-Hillsboro, OR-WA	169	73	Advanced green materials, energy efficiency, transportation

Source: Brookings analysis of IP Checkups' Cleantech PatentEdge database.

Table 2: Total granted cleantech patents and patenting rate by metropolitan area of inventor, 2011-2016 (for all metropolitan areas, ranked by patents per million residents)

	Average granted patents per year, 2011-2016	Patents per million residents, 2011-2016	Top two cleantech categories
Ann Arbor, MI	200	564	Transportation, energy storage
San Jose-Sunnyvale-Santa Clara, CA	1,036	538	Advanced green materials, energy efficiency
Columbus, IN	40	499	Transportation, air
Bay City, MI	46	430	Advanced green materials, solar
Durham-Chapel Hill, NC	167	313	Energy efficiency, advanced green materials
Boulder, CO	77	249	Energy efficiency, advanced green materials
Ithaca, NY	21	203	Advanced green materials, energy storage
Corvallis, OR	17	202	Advanced green materials, solar
Santa Maria-Santa Barbara, CA	79	182	Advanced green materials, energy efficiency
Albany-Schenectady-Troy, NY	156	177	Advanced green materials, transportation
San Francisco-Oakland-Hayward, CA	789	174	Advanced green materials, solar
Detroit-Warren-Dearborn, MI	708	165	Transportation, energy storage
Santa Cruz-Watsonville, CA	44	162	Transportation, energy efficiency
Champaign-Urbana, IL	37	158	Advanced green materials, bioenergy
Rochester, NY	171	157	Energy storage, advanced green materials
Peoria, IL	58	152	Transportation, energy storage
Elmira, NY	12	141	Advanced green materials, transportation
Ames, IA	13	137	Bioenergy, advanced green materials
Trenton, NJ	51	137	Advanced green materials, solar
Greenville-Anderson-Mauldin, SC	115	135	Transportation, wind
<i>Source: Brookings analysis of IP Checkups' Cleantech PatentEdge database.</i>			

4. The nation's metro areas, both big and small, display distinctive profiles in cleantech patenting

The nation's most inventive metros in terms of low-carbon energy patenting vary in their specializations, meaning that different regions with distinctive industry clusters are functioning as globally significant innovation hubs that convene local business, academia, and government to drive American competitiveness (Figure 4).

America's metros stand out as regionally differentiated platforms for cleantech innovation.

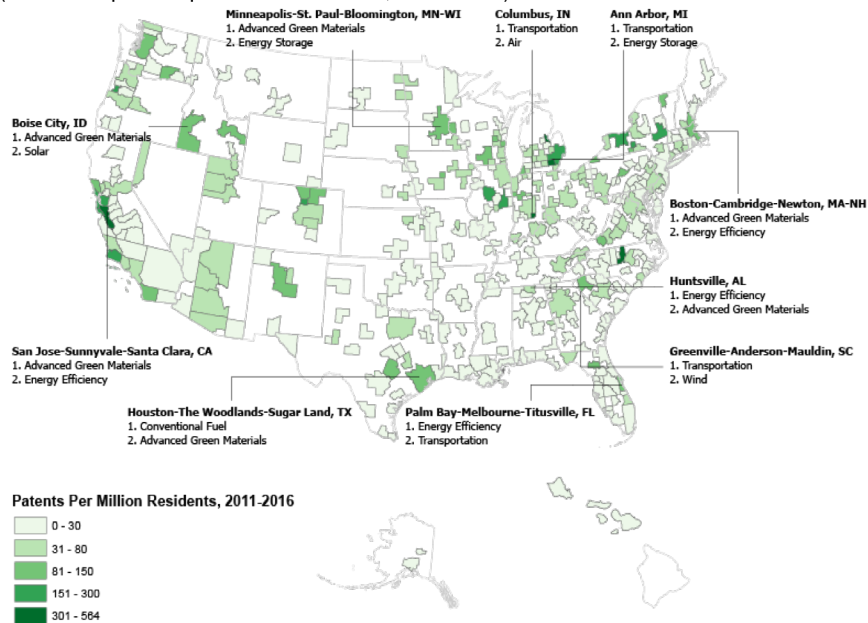
Among the top hubs for cleantech patenting, San Jose, San Francisco, Detroit, Houston, and Los Angeles demonstrate the point. San Jose excels at advanced green materials, energy efficiency, and solar innovation, while also having significant presence in energy storage and transportation patenting. San Francisco has a similar profile, with advanced green materials, energy efficiency, and solar as its top three patenting technology areas. Detroit, Houston, and Los Angeles round out the top five metro areas with the highest number of granted cleantech patents every year since 2011. Not surprisingly, transportation is the dominant cleantech category for Detroit, accounting for 61 percent of total patents; Ford Motor Company drives a good number of patents every year. Energy storage accounts for another 18 percent of Detroit's patenting activity. Houston—the energy capital of the

world—saw significant patenting activity (42 percent) in conventional fuels, led by companies like Baker Hughes, Halliburton, and Schlumberger Technology Corporation. Houston also has the highest number of geothermal patents among all metros. And for its part, Los Angeles is focusing on energy efficiency, transportation, and advanced green materials. Both Broadcom Corporation and the University of Southern California own several of Los Angeles' energy-efficiency patents, while AeroVironment—involved in electric vehicle systems and unmanned aerial vehicles—and Boeing dominate in transportation patenting and the California Institute of Technology in advanced green materials.

A few other distinctive large-metro concentrations include Greenville's focus on transportation and wind patents, led by General Electric in both categories; Boise City's concentration in advanced green materials and solar, led by Micron Technology in both technology areas; Knoxville's specialization in advanced green materials and air, led by UT-Battelle—which manages the Oak Ridge National Laboratory for the Department of Energy—and Alstom Technology, respectively; and Cleveland's focus on energy efficiency and energy, led by General Electric and Eveready Battery Company, respectively.

Figure 4: A few large metropolitan areas anchor the U.S. cleantech innovation map, but activity extends to many diverse locations

(Cleantech patents per million residents, 2011-2016)



Source: Brookings analysis of IP Checkups' Cleantech PatentEdge database

At the same time, many smaller metro areas that develop cleantech patents at high rates display significant specialization in one or two categories. Nearly 70 percent of Ann Arbor's cleantech patents are in transportation and energy storage, with transportation alone accounting for half of the metro's patenting activity. While Ford Motor Company owns the majority of patents in transportation, other carmakers like Chrysler, BMW, and Daimler also have significant presence. In a similar fashion, 78 percent of Columbus, Ind.'s cleantech patents are in transportation, owned by Cummins. Bay City's cleantech patents are disproportionately concentrated in advanced green materials (51 percent), led by Dow Corning; Durham-Chapel Hill's in energy efficiency (43 percent), led by Cree; Peoria's in transportation (76 percent), led by Caterpillar; Ames, Iowa's in bioenergy (27 percent) and

advanced green materials (26 percent), led by Iowa State University in both categories; and Wilmington, N.C.'s in nuclear (80 percent), led by GE Hitachi Nuclear Energy.

A casual look at the data suggests that access to research infrastructure housed in universities and research institutions matters significantly for both the rate of patenting and the total level of patents. This appears to be true for both the nation's large metros—San Jose has Stanford, Los Angeles has Cal Tech, San Francisco has University of California, Berkeley, and Boston has MIT and Harvard—as well as for the smaller metros like Ames, Ann Arbor, Boulder, Durham-Chapel Hill, and Ithaca. Not surprisingly, the University of Michigan is a leading cleantech patent assignee in Ann Arbor, as are North Carolina State University in Durham-Chapel Hill, Cornell University in Ithaca, the University of Illinois in Champaign-Urbana, Ill., and

Princeton University in Trenton, N.J. In a similar fashion, the U.S. national energy labs, including Argonne in Chicago, the National Renewable Energy Laboratory in Golden, Colo., and the four national labs in the San Francisco Bay Area, serve as regional hubs of energy innovation and emerge as leading patent assignees in their regions.

In short, a large number of America’s metropolitan areas stand out as regionally differentiated platforms for cleantech innovation. Each of them is a specific, distinct location in a distributed network for cleantech invention, commercialization, and economic growth.

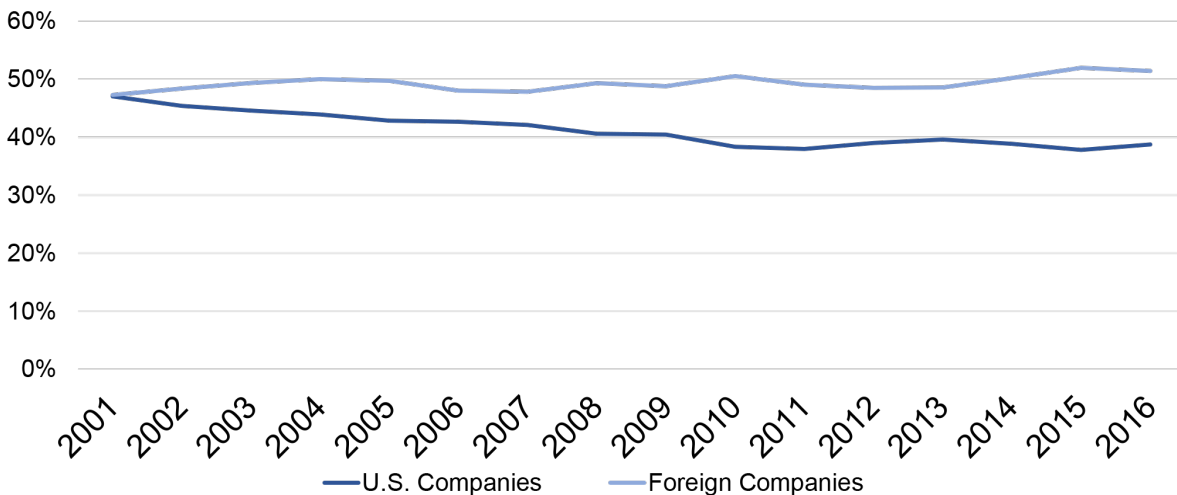
5. The share of U.S. cleantech patents owned by foreign companies has grown over the years, raising concerns about global competitiveness of U.S. companies²³

Even while cleantech innovation holds out the promise of regional and national economic gain in the U.S., cleantech patenting is increasingly being led by foreign companies. Foreign multinationals own a significant number of the cleantech patents that are granted by the USPTO every year, reflecting the globalization of cleantech industries, particularly in developed and developing Asian economies urgent about reducing carbon emissions and cornering growing markets for

cleantech. More importantly, though, foreign companies collectively have begun to capture a larger share of U.S. cleantech patents awarded to corporations over the years. In 2001, both U.S. and foreign-owned companies generated about 47 percent of cleantech patents each. By 2016, 51 percent of all cleantech patents were owned by large foreign multinationals, while only 39 percent were generated by U.S. companies.

Figure 5: U.S. cleantech patenting is increasingly being led by foreign companies

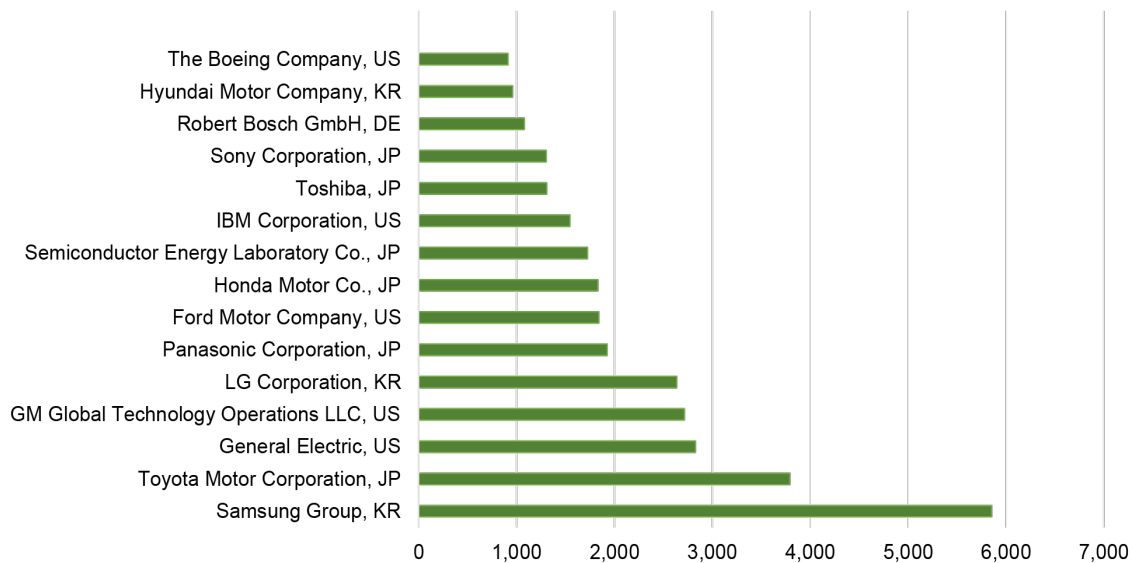
(Share of USPTO granted cleantech patents owned by U.S. and foreign companies, 2001-2016)



Source: Brookings analysis of IP Checkups’ Cleantech PatentEdge database

Figure 6: Majority of the top 15 cleantech patent assignees are from outside the United States

(Top 15 USPTO cleantech patent assignees, 2011-16)



Source: Brookings analysis of IP Checkups' Cleantech PatentEdge database.

Some of this may reflect foreign acquisitions of innovative U.S. companies by foreign ones, but in any event patent-quantity supremacy may be shifting away from corporate America to companies based overseas, especially in Asia.²⁵ Such shifts could in time challenge the assumption that the United States is a global innovation leader in the cleantech sector.

In this regard, while patenting by U.S. startups and venture-backed firms has become more widespread in the last decade, large incumbent firms—often foreign-owned—are increasingly dominating patenting in the cleantech sector. For instance, the top 15 companies—led by Samsung, Toyota, Honda, General Motors, and General Electric—have accounted for 21 percent of cleantech patents owned by corporations since 2011 (Figure 6).

Who are the big players? Japanese, South

Korean, and German companies dominate patenting across several cleantech categories, with shares of 20 percent, 7 percent, and 6 percent respectively for the period between 2011 and 2016.

The leading nations appear to have particular priorities. About 27 percent of Japanese companies owned patents in the transportation sector—including popular automotive companies like Toyota, Honda, Nissan, and Mitsubishi—while another 35 percent owned patents in energy storage. Roughly one-third of all South Korean companies, including Samsung and LG Electronics, owned patents in the energy-efficiency sector, while another quarter of these companies were focusing in advanced green materials. Finally, while half of all German companies owned a patent in

transportation and energy storage, many German companies, including Siemens, Areva Wind, and Maritime Offshore Group, are also investing heavily in the wind sector.

In short, while American firms and individuals

continue to innovate in key cleantech sectors, formidable and well-funded corporations from around the world are competing aggressively with them to invent and commercialize new ways to make clean energy cheap.

Defending progress

So how should the nation and its regions respond to changing patenting trends and coming budget decisions in Congress? It is important to remember that the transition to a clean economy is well under way globally. China's National Energy Administration recently announced that the country will invest \$361 billion in renewable power generation alone by 2020, creating an additional 3 million jobs in the process.²⁶ The European Union has also pledged to stick to its environmental policies and climate targets—reducing emissions by at least 40 percent in 2030 from 1990 levels—regardless of what the United States does.²⁷

Given the high stakes, the United States cannot afford to relinquish its lead on innovation in the burgeoning global cleantech market to China or any other country. Doing so would mean withdrawing from the global race—not just to slow climate change, but to lay hold of the sector's burgeoning job creation, exports, and investment opportunities.

And yet, instead of making cleantech innovation a high priority and looking at ways to accelerate the development and deployment of new technologies, the Trump administration has proposed to shut down or slash resources for virtually all of the DOE programs most important to cleantech innovation.²⁸ Basic and applied research funded through DOE and conducted at U.S. national labs, universities, and research institutions

has long supported the development of new cleantech technologies, while the department's commercialization initiatives such as the Loan Guarantee Program help ensure that new technology makes it out of the lab and into the marketplace where it can drive job creation and economic development. All of this is in danger now.

However, Trump's proposed cuts are in no way a foregone conclusion. In fact, while the White House has had its say, it is far from clear that Congress will go along with Trump's skinny budget—especially given the degree of bipartisan support that energy innovation has tended to enjoy among members.

Congress

In this regard, Congress has the opportunity now to come together around a short list of minimum viable supports for cleantech innovation and growth, keeping in mind that federal government involvement in RD&D provides a high return on investment and creates significant economic returns for taxpayers.²⁹

Little hope remains, for example, that the United States will double its clean energy R&D funding over the next five years, consistent with the international Mission Innovation commitment.³⁰ And yet, clean energy R&D remains a point of possible convergence in Congress, given that government-funded R&D has long been recognized for playing a critical role in innovation.³¹

Accordingly, it is appropriate to challenge members to maintain clean energy R&D appropriations at their current level. Such a commitment would set right one of the skinny budget's most troubling threats to the ability of firms, industries, and regions to maintain their competitive advantages and develop new ones. The commitment to clean energy R&D should be understood as a matter of national competitiveness at a time of possible slippage.

Beyond that, though, Congress will surely want to set aside Trump's wholesale budget cuts in favor of an approach that reforms programs that do not work effectively and scales up those that have shown promise.³² There are several priorities for triage.

For one thing, Congress should move to maximize the economic impact of the nation's 17 national laboratories, which are a critical part of America's clean energy ecosystem, as

recent Brookings work has shown.³³ On this front, preserving the DOE Office of Science budget, which supports work at the labs, will be a starting point. But it will also be important to support greater lab autonomy, more collaboration with external small and medium-sized businesses, and better connections with local industrial clusters, including on cleantech deployment.³⁴ Such adjustments will be important both to contribute to and leverage the power of local strengths and clusters. In a similar fashion, Congress should also support DOE's Office of Technology Transitions and Lab to Market initiative, which seeks to amplify the national labs' impact by supporting the transition of innovative clean technologies into the market. These programs support cost-effective development of next-generation technologies, from conventional to nuclear to renewables, and fit in well with the Trump administration's "all of the above" energy strategy. But they also will leverage the bottom-up commercial power of local business concentrations.

In addition, Congress should preserve other programs at DOE that have proved effective at accelerating the deployment and commercialization of technology—again with an eye toward seeding national and local energy innovation networks. Most notably, Congress should preserve the Advanced Research Projects Agency-Energy, which funds long-shot research with a potential for major commercial impact. ARPA-E has supported entrepreneurs who have gone on to raise more than \$1.25 billion in follow-on funding from private investors and create hundreds of jobs. Similarly, Congress should maintain and scale up the energy-focused institutes within the Manufacturing USA network. These programs are helping to move new technologies into the economy, often by ushering them into

local low-carbon energy clusters, and support a broader manufacturing competitiveness agenda.³⁵

States and regions

For their part, states and regions—and companies—that want to benefit from the bright future of cleantech growth will all need to step up. To be sure, the main locus of cleantech innovation policy remains federal, but states and regions play a sizable role—and can do more.

Among the states, the larger, more committed ones must continue to invest robustly on their own.³⁶ For example, California, Massachusetts, and New York have all been able to invest directly and sizably in low-carbon energy innovation, and have geared systematic state investment toward the entire innovation spectrum—everything from R&D, testing, demonstration, and commercialization. More states will need to engage this way.

At the same time, states with smaller energy innovation budgets can support cleantech innovation in several ways. First, they can adopt or strengthen state-level clean energy standards. These standards have proven to work well in increasing clean energy deployment and creating demand for innovation—and should be expanded. Second, grid modernization and utility regulatory reform, as is happening in New York, Hawaii, Minnesota, Rhode Island, Massachusetts, and California can play an important role in urging utilities to open their networks to emerging technologies that can improve electric service for all ratepayers. Finally, states should focus on local strengths and foster regional partnerships, whether among local research institutions, with local utilities, or with nearby states. In 2015, for

example, Ohio, West Virginia, and Pennsylvania entered into a three-year agreement to pool their resources on shale gas issues, including through a cross-state research collaboration of the states' academic institutions.³⁷ Likewise, Colorado leveraged its relationship with Xcel Energy, its utility, to support the demonstration and testing of emerging technologies, while Tennessee partnered with Oak Ridge National Laboratory to establish an "innovation voucher" program to help smaller companies access the lab's expertise.³⁸ In this fashion, states can play a meaningful role in supporting cleantech innovation and fostering associated economic development.

Similarly, cities and regions have a role to play. Most notably, local cleantech "ecosystems" have become forums for unleashing the progress that can result when local government, business, civic, philanthropic, university, and community institutions and leaders work collaboratively.³⁹ Successful regional cluster organizations in places like Austin, Texas; Boston; Chicago; Knoxville; Portland, Ore.; San Diego; and Silicon Valley, for example, have worked to link energy decision makers, industry, and investors with the capabilities at nearby universities and research institutions. Likewise, clean energy incubators and accelerators including Greentown Labs, NYC ACRE, and the Los Angeles Cleantech Incubator (LACI) have emerged across the country to help their regions' entrepreneurs bring new technologies to market.⁴⁰ In short, cities and metros have been forging ambitious, bottom-up solutions. More of such problem solving will now be necessary.

Private sector

As for the private sector, cleantech industry is going to need to engage in new ways to preserve its access to critical innovation and grow.

Not for a while, apparently, will cleantech corporations be able to rely on federal clean energy research funding to seed their innovations. Instead, industry itself will now need to argue more forcefully for what investments it can preserve even as it moves to shoulder more of the burden itself. What might this look like? Recent initiatives suggest elements of an outline.

Bill Gates, for example, recently announced the creation of a \$1 billion fund, called Breakthrough Energy Ventures, capitalized by 20 like-minded investors, that will invest systematically in new energy technologies.⁴¹ Similarly, 10 of the

world's largest oil and gas companies launched the Oil and Gas Climate Initiative, which plans to invest in carbon capture and storage technology, among other things.⁴² Going forward, more of such initiatives will be necessary. Yet these may be one-offs. More broadly, the private sector is going to need to step up its funding of academic R&D if federal support of basic and applied work in public universities and research institutions further declines. Others have proposed that groups of companies come together to create private energy innovation entities, each one focused on a specific technology area and supported by approximately 10 companies, with each contributing \$10 million a year for 10 years.⁴³ Perhaps such collaboration is not wishful thinking. In any event, rethinking the funding of clean energy innovation from the bottom up is going to be essential.

Summing up

Congress especially, but also the private sector and states and regions, stand at a critical juncture this spring. With the economic potential for workers and regions of cleantech innovation widely acknowledged, the question has become: will the U.S. compete?

Endnotes

¹ In the White House's America First Energy Plan, President Trump pledged to make the United States energy independent, create millions of new jobs, and unleash new U.S. wealth through an energy revolution. For more details, see www.whitehouse.gov/america-first-energy. Elsewhere President Trump has emphasized the need to encourage innovation and investment in R&D. For more details, see <http://sciencedebate.org/20answers>.

² See Rick Perry, "Energy Independence in America," remarks at the Commonwealth Club of California, June 11 2015, <https://climateone.org/node/9870/#transcript>. At the confirmation hearing for his appointment as energy secretary, Perry maintained his support for the Department of Energy's energy research programs; see Julia Pyper, "Rick Perry Pledges Support for DOE Research, Renewables, as Trump Plans Drastic Agency Cuts," *Greentech Media*, January 19, 2017. See also Rex Tillerson, "Unleashing Innovation to Meet our Energy and Environmental Needs," remarks at the 36th Annual Oil and Money Conference, London, October 7, 2015, www.corporate.exxonmobil.com/en/company/news-and-updates/speeches/unleashing-innovation-to-meet-our-energy-and-environmental-needs.

³ Advanced Energy Economy (AEE), "Advanced Energy Now: 2016 Market Report" (Washington: AEE, 2017). Advanced energy represented a \$1.4 trillion global market in 2016, which was almost twice the size of the global airline industry and nearly equal to the revenue in worldwide apparel. The U.S. advanced energy industry alone generated \$200 billion in revenue last year.

⁴ Office of Management and Budget, "America First: A Budget Blueprint to Make America Great Again" (Washington: OMB, 2017), www.budget.gov.

⁵ Virum Sivaram, Teryn Norris, Colin McCormick, and David Hart, "Energy Innovation Policy: Priorities for the Trump Administration and Congress" (Washington: Information Technology and Innovation Foundation, 2016).

⁶ Forthcoming Brookings research will show trends in cleantech venture capital investment across 14 technology areas for the United States and its regions.

⁷ Jonathan Rothwell et al., "Patenting Prosperity: Invention and Economic Performance in the United States and Its Metropolitan Areas" (Washington: Brookings Institution, 2013).

⁸ Shikhar Ghosh and Ramana Nanda, "Venture Capital Investment in the Clean Energy Sector," Working Paper 11-020 (Cambridge, Mass.: Harvard Business School, 2010).

⁹ Several papers have examined the key role of venture capital in advancing the innovation economy of the United States over the last several decades. See Richard Florida and Donald Smith, "Venture Capital, Innovation, and Economic Development," *Economic Development Quarterly*, 1990; Rudra Pradhan et al., "Venture Capital, Innovation Activities, and Economic Growth: Are Feedback Effects at Work?" *Innovation Organization and Management*, 2017; Will Gornell and Ilya Strebulaev, "The Economic Impact of Venture Capital: Evidence From Public Companies," Working Paper No. 3362 (Stanford, Calif.: Stanford Graduate School of Business, 2015).

¹⁰ Patents, both generally and in cleantech, play a key role throughout the technology life cycle as a record and instrument of technology invention and development. See International Renewable Energy Agency (IRENA), "Intellectual Property Rights: The Role of Patents in Renewable Energy Technology Innovation" (Bonn, Germany: IRENA, 2013). It is important to note, though, that patents remain imperfect indicators when used as information sources on innovation activity. One of the criticisms is that patents are a measure of invention and not innovation, and do not contain all economically significant innovations. Not all inventions are patented, and the propensity to patent differs by industry and technology area. Not all patents are of equal value, moreover, and not all foster innovation. Most notably, several scholars have noted a general rise of patenting often motivated by companies' desire to block rivals, negotiate with competitors, or help in infringement lawsuits. See Wesley Cohen, Richard Nelson, and John Walsh, "Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not)," Working Paper No. 7552 (Cambridge, Mass.: National Bureau of Economic Research, 2000), www.nber.org/papers/w7552.

¹¹ IRENA, “Intellectual Property Rights.”

¹² The Cleantech PatentEdge database is dedicated to addressing cleantech industry patent developments. The database filters more than 1.5 million worldwide patents in more than 150 cleantech market sectors and includes technologies as diverse as, but not limited to, ethanol biofuels, solar thin films, energy storage, and desalination. For more information, see www.cleantechpatentedge.com/.

¹³ Although U.S. patents are naturally skewed toward U.S. inventions, these market attributes make U.S. patent data useful for identifying trends in global inventiveness, too.

¹⁴ A total of 344,609 patents were granted in the United States across 14 cleantech categories from 2001 to 2016. These patents have both U.S.-based as well as foreign inventors. According to the patent laws of the United States, any inventor regardless of his/her citizenship can apply for a patent in the United States. In that sense, trends in the volume of patents granted in the country should be treated with caution and not solely attributed to the health of the U.S. innovation ecosystem.

¹⁵ Data for all U.S. patents and for some of the technology areas have been obtained from National Science Board, “Science and Engineering Indicators 2016.” The comparison of cleantech to other technology areas should be interpreted with some caution. Cleantech, unlike other technology areas, does not have an assigned class at the USPTO or for that matter in any other country’s patent offices. Moreover, cleantech patents can cross several disciplines. For all these reasons, the comparisons are not exact and are only intended to provide some general understanding of trends across different technology areas.

¹⁶ The United States enacted a new patent law in 2011 that was aimed in part at reducing the backlog of USPTO patent applications. For more information, see the White House Press Release, “President Obama Signs America Invents Act, Overhauling the Patent System to Stimulate Economic Growth, and Announces New Steps to Help Entrepreneurs Create Jobs,” September 16, 2011, <https://obamawhitehouse.archives.gov/the-press-office/2011/09/16/president-obama-signs-america-invents-act-overhauling-patent-system-stim>.

¹⁷ Chris Barry et al., “2016 Patent Litigation Study: Are We at an Inflection Point?” (New York: PricewaterhouseCoopers, 2016).

¹⁸ Nuclear and hydroelectric power generation, for instance, account for 20 percent and 6 percent of U.S. electricity generation, respectively.

¹⁹ For a strong discussion of the importance of innovation in the nuclear industry, see Ted Nordhaus, Loren King, and Jessica Lovering, “How to Make Nuclear Innovative: Lessons From Other Advanced Industries” (Oakland, Calif.: Breakthrough Institute, 2017). See also Richard Lester, “A Roadmap for U.S. Nuclear Energy Innovation,” *Issues in Science and Technology*, Vol. 32, no. 2 (2016).

²⁰ For more details, see Christa Marshall, “2016—The End or Beginning of an Era for Marine Energy?” *E&E News*, November 28, 2016.

²¹ A report by Third Way found that there are nearly 50 companies in the United States and Canada developing next-generation technology, armed with \$1.3 billion of private capital. There is significant activity in small modular reactors based on the current light water technology, and this technology could see a surge in commercial activity in the next five to 10 years before more advanced reactor designs are introduced. The report includes the most comprehensive set of details about who is working on these reactor designs and where. For more details, see Samuel Brinton, “The Advanced Nuclear Industry” (Washington: Third Way, 2015).

²² This part of the data analysis relies on 330,100 cleantech patents between 2001 and 2016 for which inventor country location information is available. There are a total of 910,272 inventors, out of which 409,347 are U.S.-based inventors, associated with the 330,100 patents. The U.S.-based inventors are associated with 160,840 cleantech patents. Approximately 1,000 U.S.-based inventors have missing city and state information and, therefore, have been taken out of the analysis. We ended up with 408,261 U.S.-based inventors with full location information, associated with 154,288 cleantech patents for the period between 2001 to 2016, which is our sample for the metro analysis. Since 2011, there are 79,192 patents with 218,180 U.S.-based inventors. If a patent has more than one inventor, each location gets a weighted share, adding up to 1 for that patent. There are several patents that have both foreign and U.S.-based inventors.

²³ This section of data analysis relies on 313,829 cleantech patents between 2001 and 2016 for which owner information is available. A majority of the patents had one owner but some have more than one, in which case each patent was assigned an ownership share. For instance, if a patent had four owners, each owner got a 0.25 share, adding up to 1 for that patent. The categories of owners are as follow: U.S. companies, foreign companies, government, national laboratories/universities/research institutions, and individuals.

²⁴ Among the remaining cleantech patents, 0.5 percent were owned by U.S. and foreign governments, 3 percent by U.S. and foreign individuals, and 6 percent by U.S. national laboratories and U.S. and foreign universities/research institutions collectively. In other words, cleantech patenting is disproportionately a private-sector affair. Indeed, the share of cleantech patents owned by companies has grown from 87 percent in 2011 to 91 percent in 2016.

²⁵ At the same time, it is important to note that patent quantity should not be confused with quality, and additional research should be undertaken to examine patent quality by ownership.

²⁶ "China to Plow \$361 Billion Into Renewable Fuel by 2020," Reuters, January 5, 2017, www.reuters.com/article/us-china-energy-renewables-idUSKBN14P06P.

²⁷ Ewa Krukowska, "EU Ready to Resist Trump on Climate as Kerry Offers Assurance," Bloomberg, November 16, 2016.

²⁸ Brad Plumer, "Trump's Budget Would Hammer Climate Programs at EPA, NASA, NOAA, and Energy," Vox, March 16, 2017.

²⁹ It has been estimated that R&D investments totaling \$12 billion between 1976 and 2012 at the Office of Energy Efficiency and Renewable Energy (EERE) yielded net economic benefits to the United States of \$230 billion (in inflation-adjusted dollars) with an annual return on investment of 20 percent. See Jeff Dowd, "Aggregate Return on Investment for R&D Investments in the U.S. DOE Office of Energy Efficiency and Renewable Energy," (Washington: U.S. DOE, 2016). Available at <https://energy.gov/sites/prod/files/2016/10/f33/Aggregate%20ROI%20impact%20for%20>

[EERE%20RD%20-%202010-5-16.pdf](https://energy.gov/sites/prod/files/2016/10/f33/Aggregate%20ROI%20impact%20for%20EERE%20RD%20-%202010-5-16.pdf)

³⁰ For more details on Mission Innovation, see its website at <http://mission-innovation.net/>.

³¹ For instance, in 2016 the Senate passed the Energy Policy Modernization Act, which was a comprehensive and bipartisan omnibus energy policy bill. It is the first energy policy bill the Senate has passed since the Energy Independence and Security Act in 2007. See Mike Henry, "Senate Passes Bipartisan Energy Bill Loaded With Science Provisions," American Institute of Physics, April 22, 2016, www.aip.org/fyi/2016/senate-passes-bipartisan-energy-policy-bill-loaded-science-provisions.

³² Sivaram et al., "Energy Innovation Policy."

³³ Mark Muro, Matthew Stepp, and Scott Andes, "Going Local: Connecting the National Labs to Their Regions to Maximize Innovation and Growth" (Washington: Brookings Institution and ITIF, 2014).

³⁴ See Muro et al., "Going Local," as well as Scott Andes and Stephen Ezell, "Localizing the Economic Impact of Research and Development: Fifty Policy Proposals for the Trump Administration and Congress" (Washington: Brookings Institution, 2017). See also Sivaram et al., "Energy Innovation Policy."

³⁵ An independent study conducted by Deloitte has found that Manufacturing USA is spurring R&D innovation needed to develop new products and markets, helping alleviate a shortage of technically trained manufacturing workers, and building a sustainable national manufacturing research infrastructure. Deloitte, "Manufacturing USA: A Third-Party Evaluation of Program Design and Progress," (New York: Deloitte, 2017).

³⁶ Daniel Cusick, "Mass. Poised to Join Calif. Among Clean Energy Elite," E&E News, September 27, 2016; Jayant Kairam, "The Future Is California: How the State Is Charting a Path Forward on Clean Energy," EDF blog, January 19, 2017; and Katie Fehrenbacher, "New York Governor Unveils \$5B Clean Energy Fund," Fortune, January 21, 2016.

³⁷ Douglas Guth, "Fracking Research Collaborative Cuts Across

State Lines,” *Midwest Energy News*, December 17, 2015.

³⁸ Xcel’s Innovative Clean Technology program in Colorado enables the testing of emerging energy technologies. Since the Colorado public utility commission approved the program in 2009, it has funded a limited number of projects, giving Xcel the ability to test new technologies and evaluate their cost, reliability, and environmental performance on a small demonstration scale before determining whether to deploy them more widely for customers. For more details, see [www.xcelenergy.com/staticfiles/xe/PDF/Marketing/CO-Innovative-Clean-Technology-Info-Sheet.pdf](http://www.xcelenergy.com/staticfiles/xcelenergy.com/staticfiles/xe/PDF/Marketing/CO-Innovative-Clean-Technology-Info-Sheet.pdf). Tennessee’s Revv vouchers, which are awarded competitively to promising small and medium-sized companies, allow selected companies to consult with Oak Ridge National Laboratory experts on manufacturing and cleantech issues, for purposes of advancing innovation. See www.ornl.gov/programs/revv.

³⁹ Jonathan Rothwell, Mark Muro, and Devashree Saha, “Sizing the Clean Economy: A National and Regional Green Jobs Assessment” (Washington: Brookings Institution, 2011); Bruce Katz and Mark Muro, “The New ‘Cluster Moment’: How Regional Innovation Clusters Can Foster the Next Economy” (Washington: Brookings Institution, 2010).

⁴⁰ David Ferris, “An Investor Lemon Starts to Squeeze Some Lemonade,” *E&E News*, November 14, 2016. Recognizing the critical role played by incubator and accelerator resources, DOE launched Incubatenergy, the first nationwide network connecting incubators and accelerators to each other across the country. Several dozen such programs around the country have been identified. For more details, see <https://incubatenergy.org/>.

⁴¹ For more details see the Breakthrough Energy Ventures website at www.b-t.energy/ventures/. See also Bill Gates, “A New Model for Investing in Energy Innovation,” Bill Gates blog, December 12, 2016, www.gatesnotes.com/Energy/Breakthrough-Energy-Ventures.

⁴² Damian Carrington, “Oil Firms Announce \$1bn Climate Fund to Clean Up Gas,” *The Guardian*, November 4, 2016.

⁴³ Arun Majumdar et al., “Energy Innovation Needs New Private-Sector Push,” *Bloomberg*, February 11, 2016.

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