RISING TIGERS, SLEEPING GIANT II:
Asian Nations Outpacing the United States in Clean Energy

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INTRODUCTION

In 2009 the Information Technology and Innovation Foundation (ITIF) and the Breakthrough Institute collaborated to complete the report, *Rising Tigers, Sleeping Giant*, which benchmarked the clean energy competitiveness of China, Japan, South Korea, and the United States in order to emphasize the importance of innovation as a driver of economic competitiveness.[1] The report analyzed clean energy investments and policy support for research, manufacturing, and domestic demand, focusing on wind, solar, nuclear, carbon capture and storage, hybrid and electric vehicles, advanced batteries, and high speed rail.

This follow-up report examines the competitive economic position of those same four nations—China, Japan, South Korea, and the United States—in the global clean energy technology sector as of 2015. Exploring competitiveness in the clean technology industry as measured by research, development, and demonstration (RD&D), and new developments in infrastructure deployment, it focuses on three low-carbon energy generation technologies: solar, wind, and nuclear power. Finally, it discusses policy conclusions for the United States, including reasons why the United States cannot count on current policies and private incentives to address climate change and remain competitive.

COMPARING RESEARCH AND INNOVATION IN THE CLEAN ENERGY SECTOR

The international energy landscape has changed considerably since 2009. Large stimulus packages following the Great Recession gave way to significant adjustments in public and private RD&D and investment, with austerity measures in the United States and large reallocations in Japan out of the nuclear sector. Perhaps the most prominent shift, however, has been the rise of the Chinese clean energy sector. Driven by strong domestic demand, low manufacturing costs, and protectionist local content requirements, China's clean manufacturing output has surged. Chinese companies top the list of largest solar panel producers and are making significant inroads in wind turbine production.[2] As this report shows, this is not simply because China is a convenient low-cost producer of technologies developed in other nations: The Chinese government now spends more on renewable energy RD&D than any other nation.

For many years, Japan was the United States' only serious clean energy industry competitor in Asia. Both nations significantly ramped up energy RD&D spending after the 1970s' oil price shocks, but from the 1980s onward Japan maintained high levels of investment as a percent of GDP, while the United States quickly reduced its investment. (Figure 1) In the past 15 years Korea and China have increased their energy innovation spending as well. Korean government energy-related RD&D spending peaked in 2007 but has remained above the United States except for 2009, the year of the U.S. stimulus package. Data for overall energy RD&D is unavailable for China.

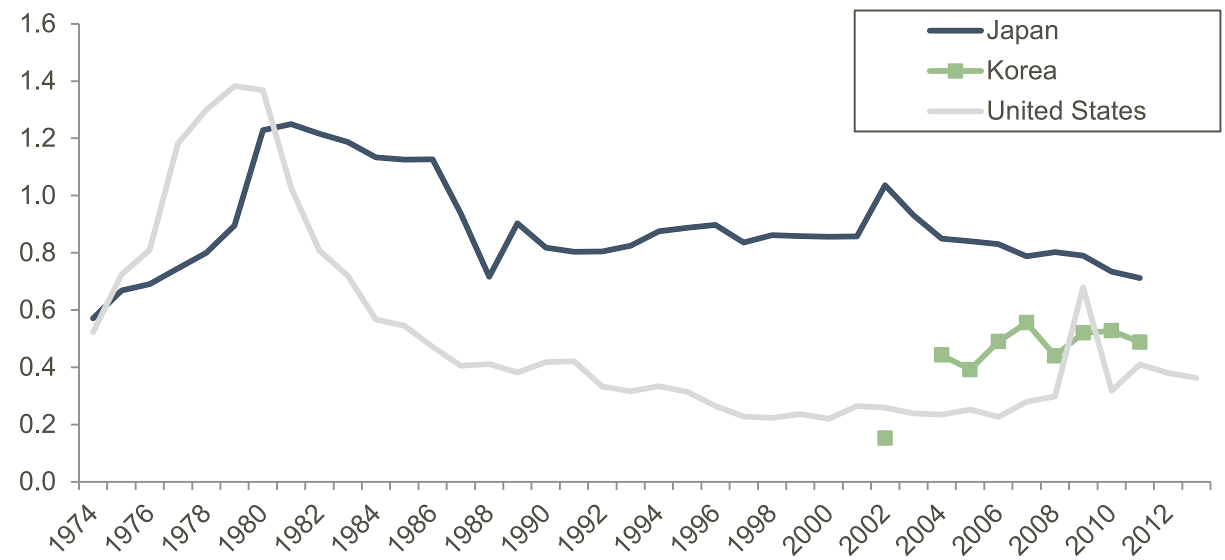

Figure 1: Total government energy RD&D budgets per thousand units of GDP[3]

The effects of these RD&D inputs can be seen in patent output. U.S. companies have filed roughly half the number of triadic energy patents that Japanese companies have since the turn of the millennium (triadic patents are patents filed in the United States, Japan, and Europe).[4] However, stable output rates mean that U.S. energy patent output is falling relative to GDP. As a share of GDP, energy-related triadic patents are on average four to five times higher in Japan than in the United States, and about 50 percent higher in Korea. (Figure 2) China was below the United States as of 2011, the last year for which data was available, but it has undoubtedly made progress since then in terms of patenting.

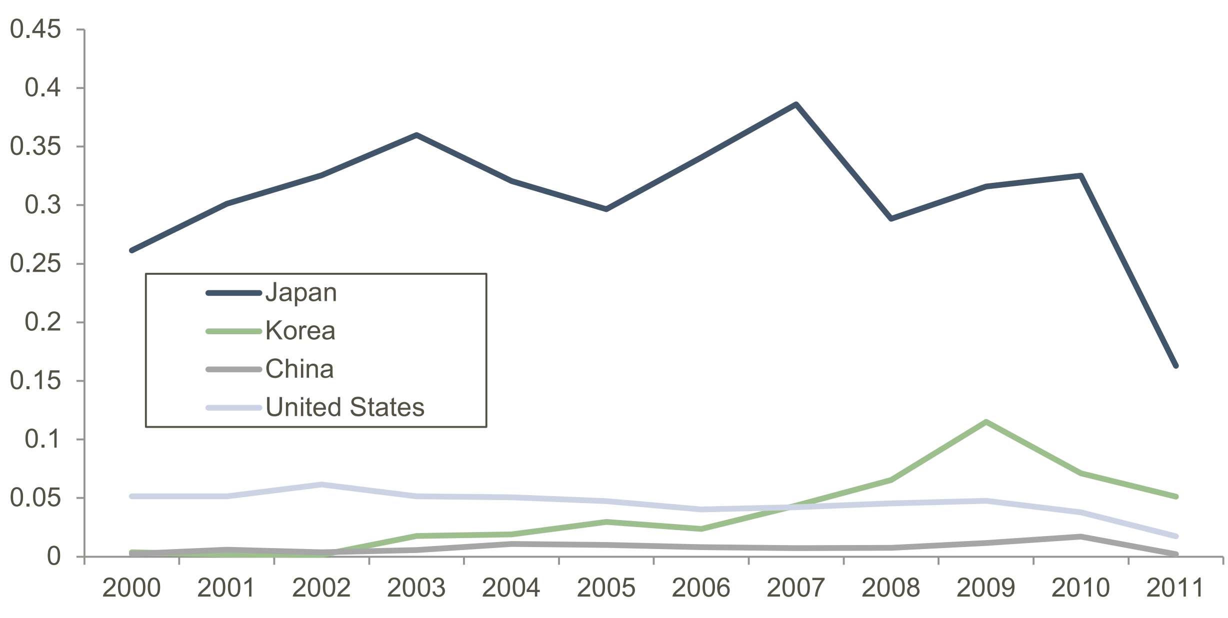

Figure 2: Total energy-related triadic patents (relative to GDP in billions current USD)[5]

Separating renewable energy RD&D from total energy RD&D provides a different picture. The long-term trend has been a large increase from 10 years ago in all four countries, although government renewable energy RD&D in the United States has remained low relative to the stimulus-induced funding of 2009-2010. (Figure 3) Although it was on a downward trajectory before, Japanese investment shot up in 2011. Korean investment has increased by a factor of four, even controlling for GDP growth. And China now leads the United States not only in expenditure as a percentage of GDP—which is also true of Japan and Korea—but in absolute terms as well.

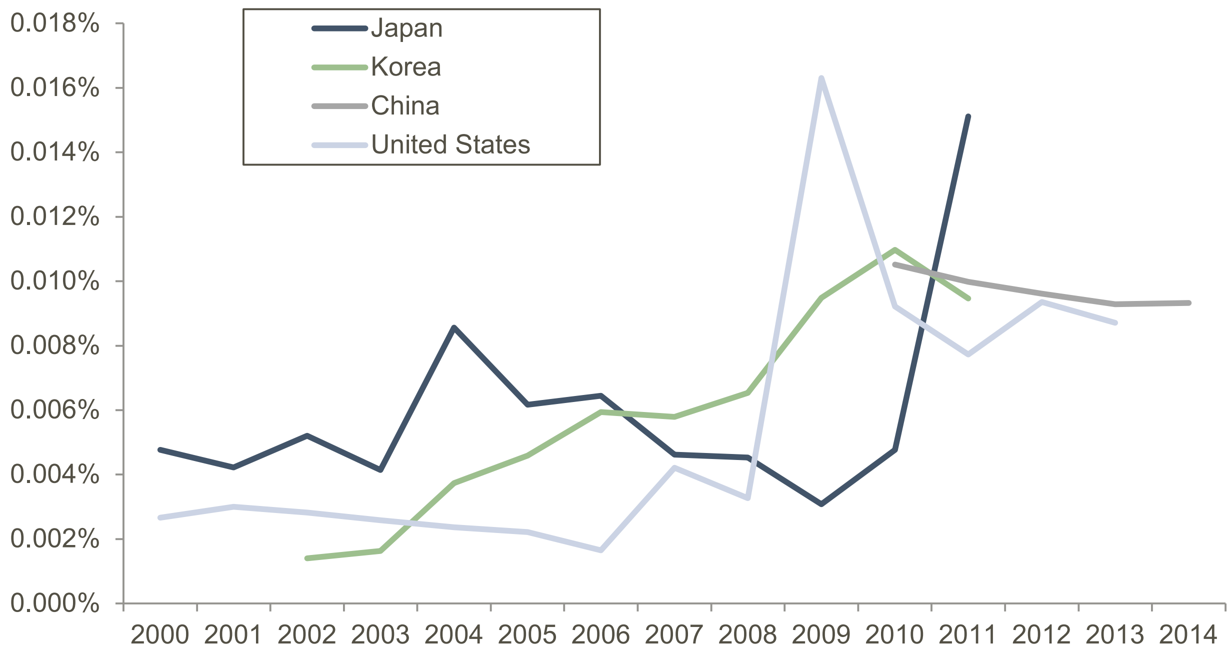

Figure 3: Government spending on renewable energy RD&D as percent of total GDP (IEA, BNEF)[6]

Renewable energy patents have increased in all four countries since the beginning of the millennium, particularly in Korea. (Figure 4) However, the United States again lags in third place behind Japan and Korea in relative terms. In absolute terms (not pictured) the United States and Japan are more evenly matched, and far ahead of China and Korea: While Japan filed for 352 renewable energy-related patents in 2009 and the United States filed for 310, Korea and China filed for only 103 and 26 that year, respectively.

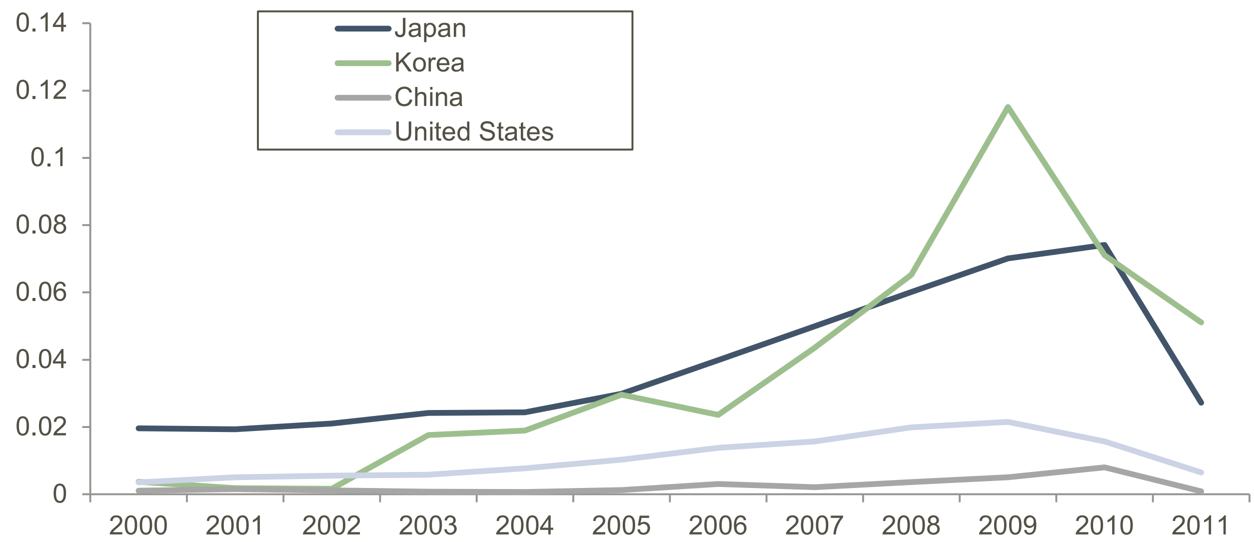

Figure 4: Triadic patents for energy generation from renewable and non-fossil sources (relative to GDP in billions current USD)[7]

China

Despite large increases, government investment in RD&D for renewables has actually fallen in proportion to GDP due to the fast growth of China's economy. (Figure 5) Still, these absolute levels of investment are substantial. In 2014 China's government funding for clean energy research and development accounted for nearly a third of total public support around the world—more than double that of the United States.[8] Public support worldwide made up slightly less than half of total public and private support, which means that the Chinese government provided almost 15 percent of total funding for clean energy R&D around the world. China's public R&D appears to compensate for a relative lack of private R&D within China: Chinese companies spend just half of what U.S. companies spend, or what Japanese and Korean companies together spend.[9]

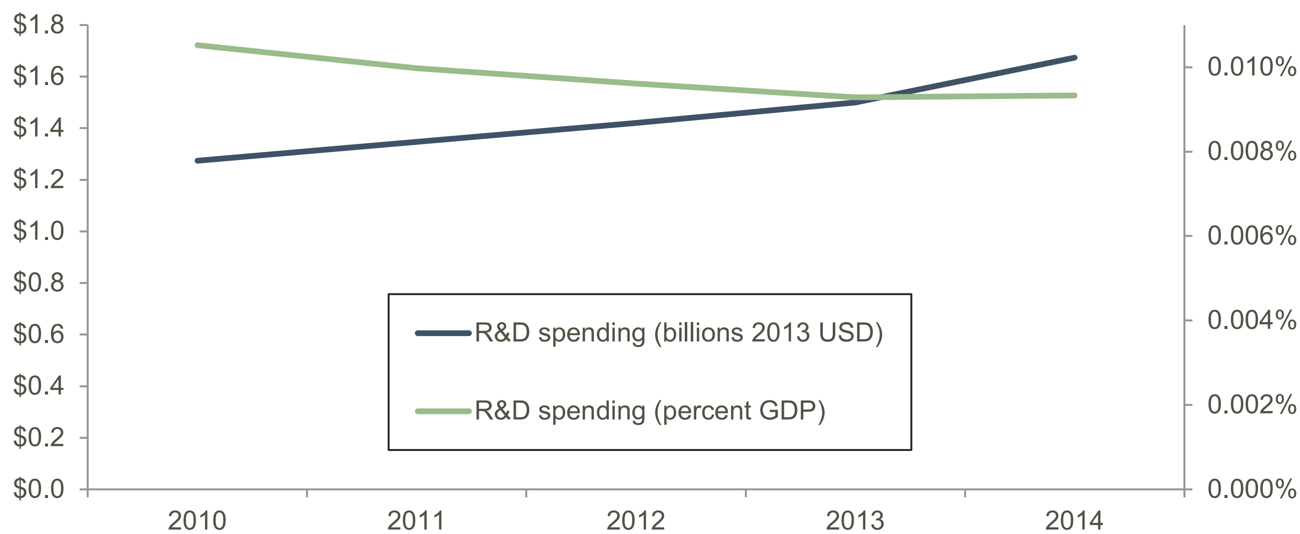

Figure 5: Chinese government spending on renewable energy R&D (millions 2013 USD and percent GDP)[10]

While Chinese R&D expenditures have increased significantly, it is likely that most of these funds are allocated to development and applied research with little allocated to basic research In aggregate, including not only energy but all other areas of research, China spent only 4.6 percent of total public and private research funding on basic research.[11] This compares with an average among developed nations of 15 percent to 20 percent.[12] Patenting in China remains significantly below the United States and Japan, at least for the most recent available years (2010 and 2011). (Figure 2) Data quality here is somewhat problematic, however. Triadic patents are those that are filed in the United States, Japan, and Europe, so numbers may be naturally biased against Chinese companies that are only filing in China. There were more than 1.3 million patents authorized in China in 2013, compared with 6,000 filed by Chinese companies in the United States, for example.[13] On the other hand, official Chinese sources have noted that many Chinese patents are of very poor quality and few Chinese companies are engaging in substantial R&D.[14]

Two thirds of Chinese government R&D expenditures ($1.1 billion) have gone toward solar energy.[15] This amount is more than the total government R&D expenditure for all types of renewable energy in both Japan and Korea combined, or in the total government expenditure on renewable R&D in the United States. These large investments appear to have played a role in assisting Chinese businesses to significantly increase global market share in the sector.

Japan

Japan's public spending on energy RD&D remains very high, at 0.07 percent of GDP.[16] Japan's large amount of funding has translated into an impressive amount of energy-related patents, more than double the amount in the United States.

Japan's public RD&D budget was heavily focused on nuclear through 2010, receiving nearly 70 percent of total funding that year.[17] Since the Fukushima disaster, however, the role of nuclear power in Japan's future has been less clear. Japan shut down all of its 50 nuclear plants and cut nuclear RD&D significantly in 2011, although it still made up more than half of overall funding that year. (Figure 6) Renewable funding increased in its place, as Figure 3 shows above.

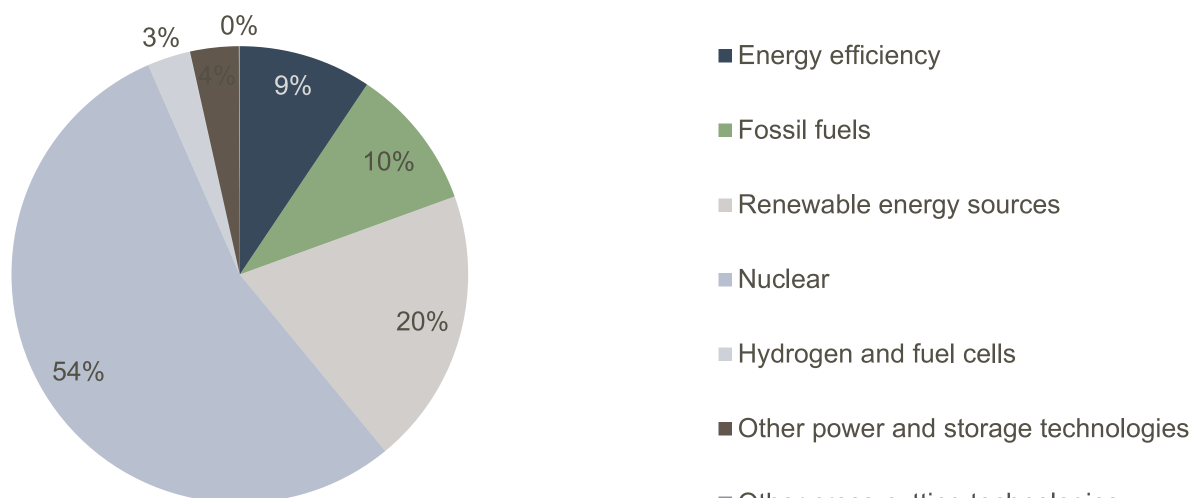

Figure 6: Japanese government spending on energy RD&D, 2011[18]

Solar has traditionally occupied the largest portion of Japan's funding for renewables, but Japan has diversified in recent years. Wind and biofuels have grown since 2009 to 20 percent of renewable RD&D funding, while large investments in "other renewable energy sources" were allocated 62 percent of total renewables funding in 2011, the latest year with available data. (Figure 7) Even though the level of government funding of renewable RD&D is high, government funding makes up a smaller percentage of Japan's overall RD&D funding because Japanese firms tend to invest more in RD&D than their counterparts in other countries. Overall, Japanese government funding made up only 16.4 percent of total RD&D, with industry providing the rest of the funds.[19] This helps account for the high levels of energy patents despite lower levels of absolute spending than the United States.

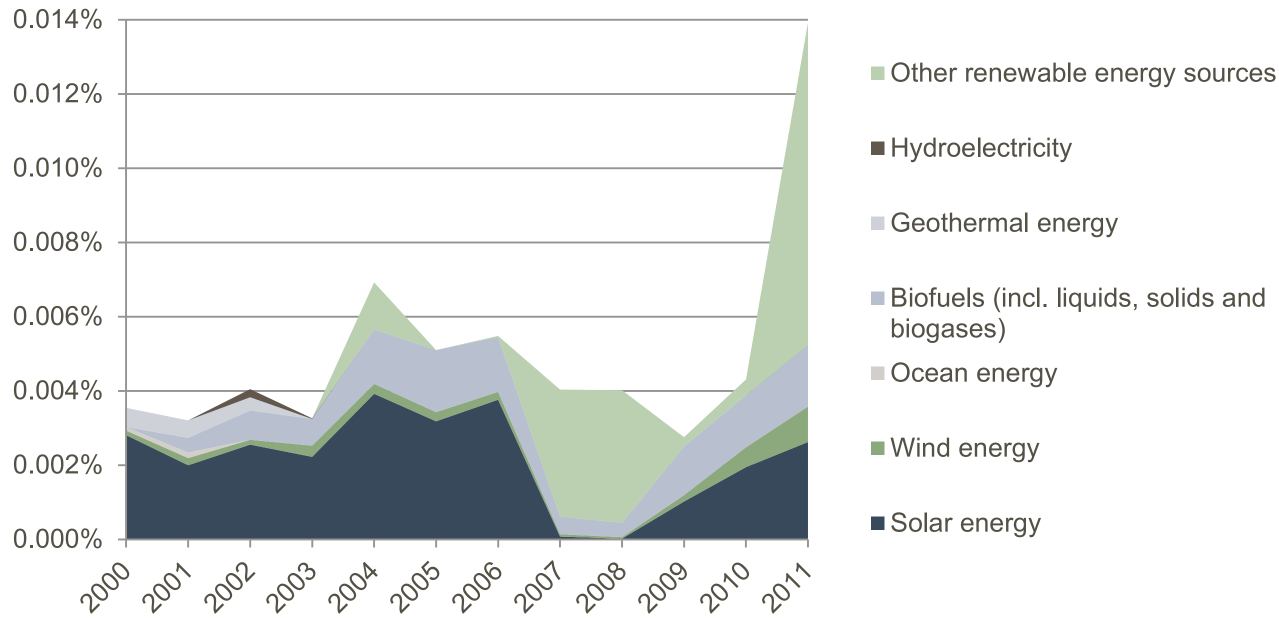

Figure 7: Japanese government spending on renewable energy RD&D by technology (percent GDP)[20]

South Korea

Korea's public spending on all types of energy RD&D is well diversified, with renewables claiming the largest proportion at just over a quarter of expenditure. (Figure 8) Nuclear is the second largest at 20 percent, with energy efficiency, fossil fuels, and other sources claiming about 15 percent each.

Like Japan and China, Korea allocates the bulk of its renewable funding to solar energy projects. (Figure 9) No Korean company has managed to break into the top 10 solar companies by shipment size, however. This is perhaps not surprising, as Korea's overall public RD&D on clean energy technology has not reached the levels of its Asian neighbors. Korea did significantly outpace China in triadic patents through 2011, the latest year with available data.

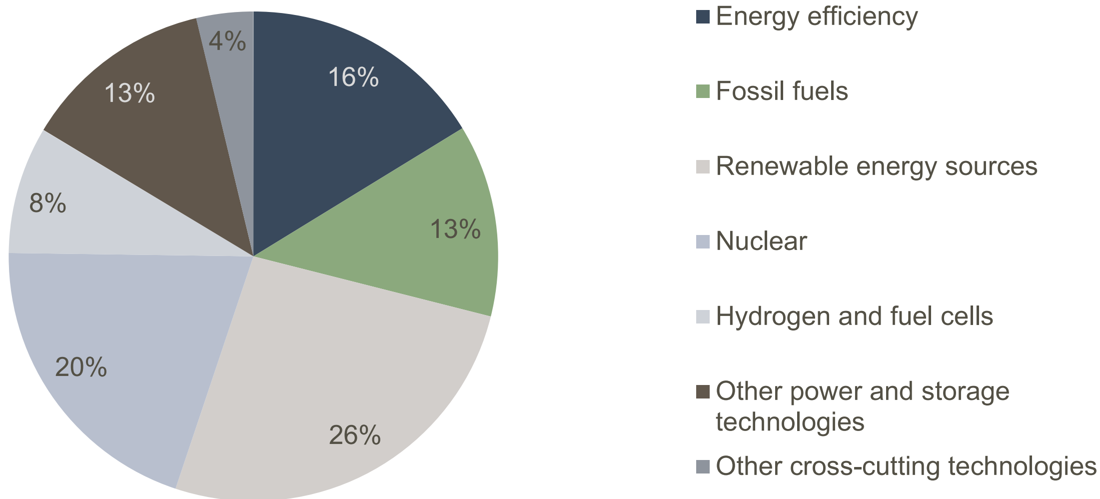

Figure 8: Korean government spending on energy RD&D, 2011[21]

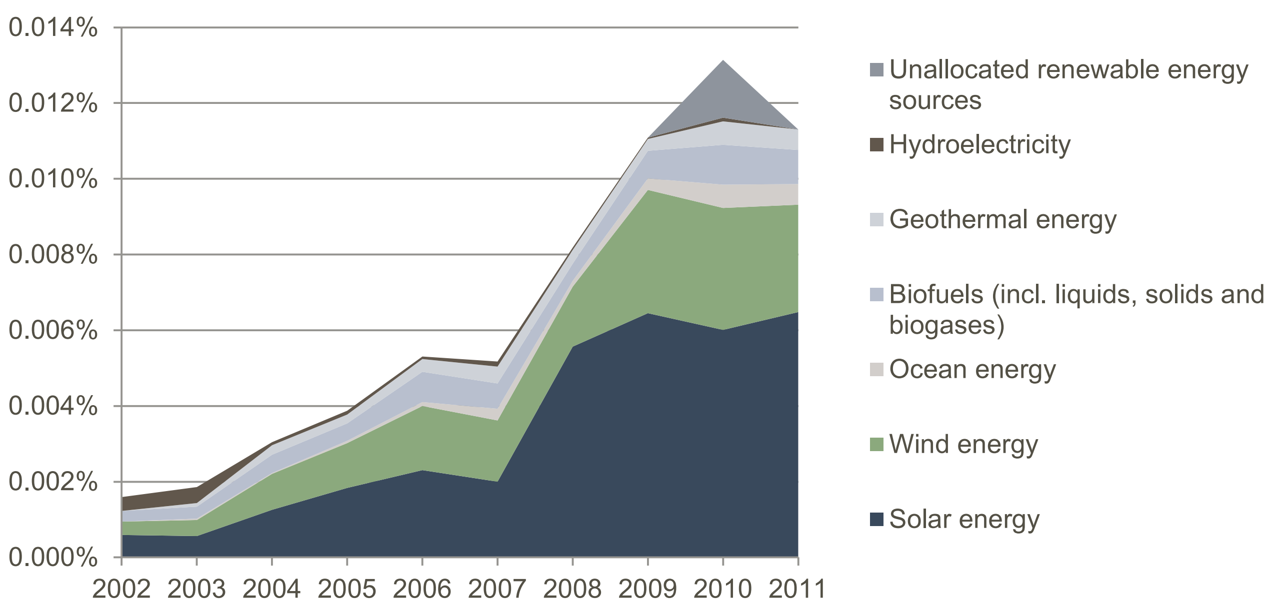

Figure 9: Korean government spending on renewable energy RD&D by technology (percent GDP)[22]

United States

Other than a brief period after the 1970s' oil crises, the U.S. government has long invested less as a share of GDP on energy RD&D than Japan, the leader since then. Even the U.S. fiscal stimulus package in 2009 only brought expenditure levels up to around half of the 1981 peak, and still failed to match Japan's percentage. The stimulus program also marked the last time the United States allocated a larger amount of money in absolute terms toward renewable energy R&D than China did. Since then, China has increased its renewable energy R&D budget significantly while the U.S. budget has fallen due to the sequester and other austerity measures. According to Bloomberg New Energy Finance and the United Nations Environmental Program, the United States renewable energy R&D budget is now less than half of China's.[23]

Moreover, since 2008, U.S. RD&D spending on renewables has been dominated by biofuels, despite the uncertainty surrounding their ability to reduce carbon emissions and tendency to crowd out food production and raise food prices.[24] As recently as 2013, biofuels made up 57 percent of renewable energy RD&D funding, with over half a billion dollars of support. (Figure 11) Solar and wind energy came in second and third with 22 percent and 10 percent of total renewable energy RD&D funding, or $200 million and $93 million.

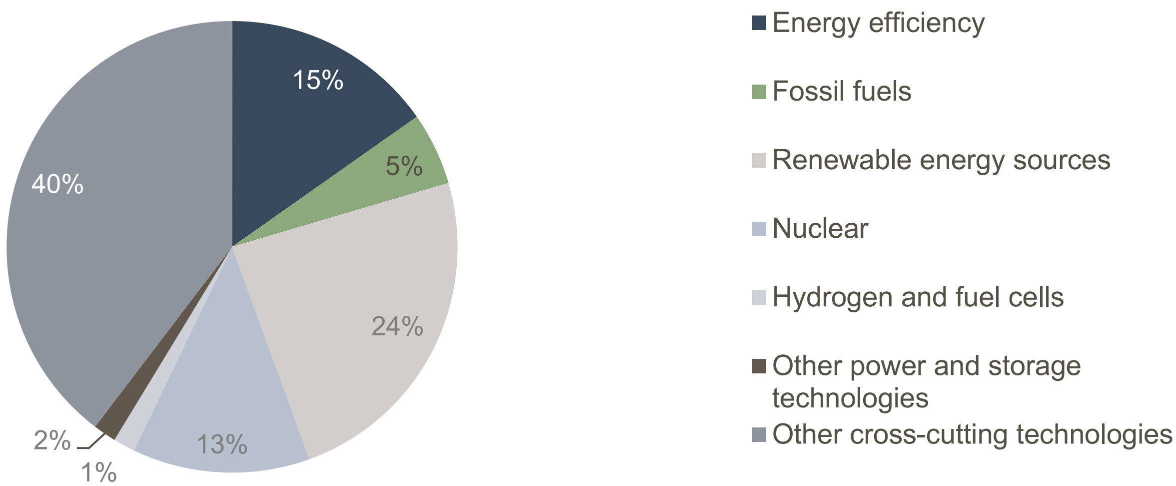

Figure 10: U.S. government spending on energy RD&D, 2013[25]

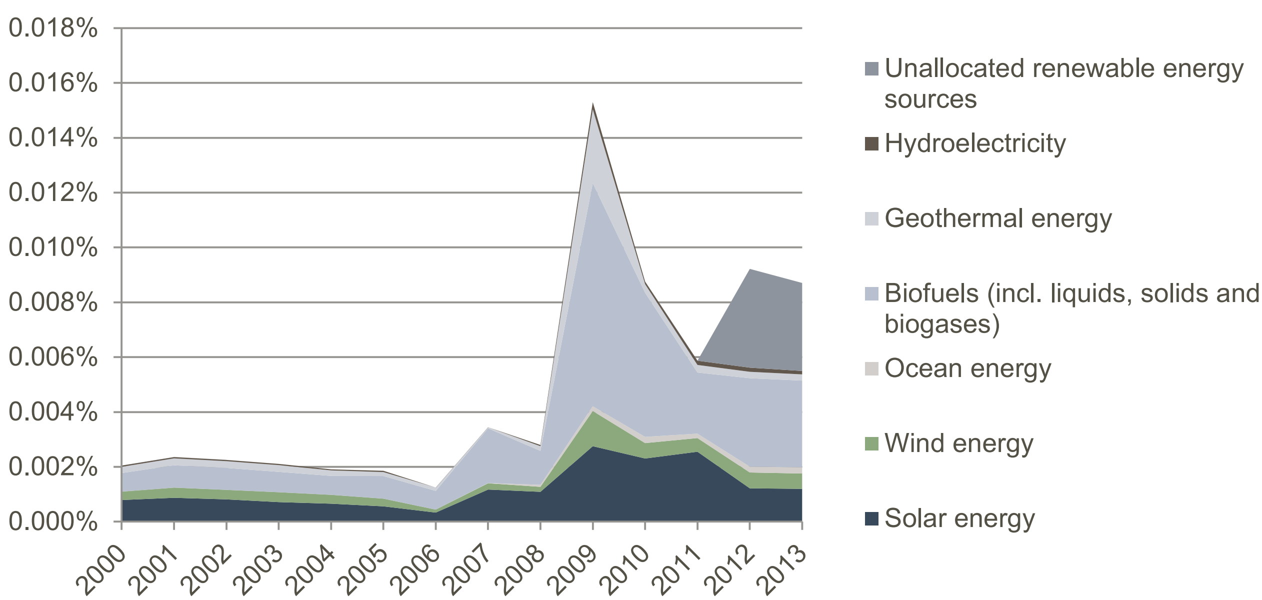

Figure 11: U.S. government spending on renewable energy RD&D by technology (percent GDP)[26]

TRENDS IN CLEAN ENERGY GENERATION

Research, development, and demonstration expenditures for clean energy technologies are a key part of addressing climate change, but ultimately the question is whether they can supplant fossil fuels for use in power generation. This section focuses on solar, wind, and nuclear power generation. Hydroelectric and biomass also make large contributions to the grid, but they are unlikely to expand their roles going forward as dynamically as solar, wind, and nuclear.

While this section focuses on capacity, the “capacity factor” of different technologies (which translates into the amount of energy they are able to generate) varies widely: Nuclear ranges from 60-90 percent; wind farms range between 20 percent and 40 percent; and photovoltaics range between 15 percent and 30 percent. Technologies with higher capacity factors tend to generate a larger percentage of total electricity than their headline capacity would suggest (and vice versa), because over time they average more output as a percent of capacity. For example, nuclear energy provided roughly 20 percent of U.S. electricity in 2012, even though it made up less than 10 percent of total capacity. Likewise, solar energy in Japan powered only 0.7 percent of electricity in 2012 even though it made up more than 2 percent of total capacity.

Until recently solar production was quite small. Falling costs in solar, however, have spurred far more adoption than analysts predicted even three years ago.[27] All four countries more than tripled their solar capacity between 2010 and 2014, with China increasing solar capacity by 35 times and Japan and the United States increasing capacity 6- and 7-fold, respectively.[28] However, such increases are easier when the initial level is low. As seen in Figure 12, solar makes up about 2 percent of capacity in the United States, China, and Korea for 2014, which likely represents approximately 0.5 percent of electricity generation.[29] In Japan the percentage of capacity has risen quickly as overall capacity growth slowed.

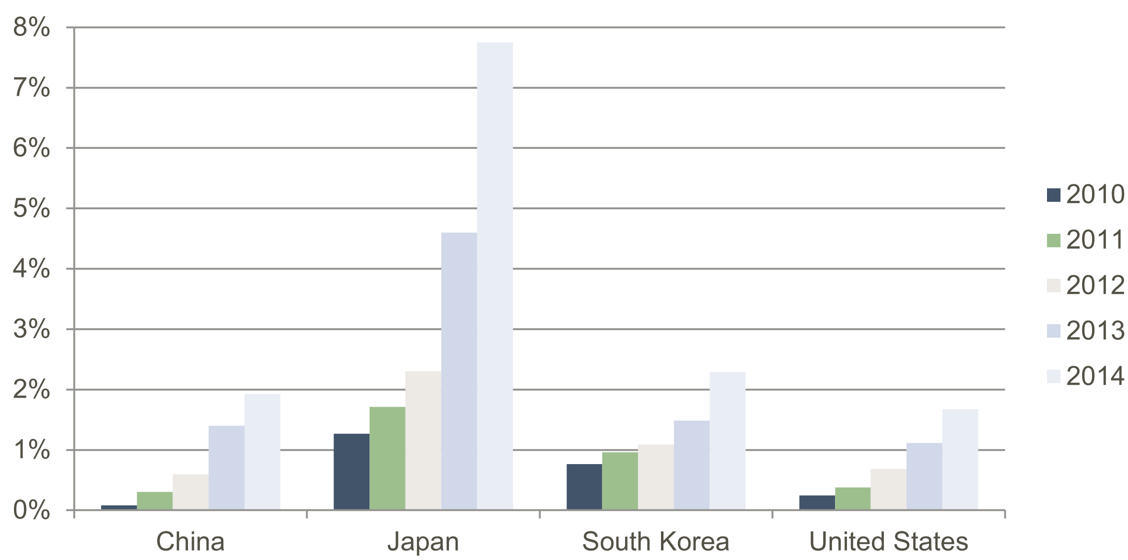

Figure 12: Solar energy production capacity (percent total electrical generation capacity)[30]

In China and the United States wind capacity is growing as well, albeit less dramatically. (Figure 13) China, after starting from roughly the same capacity level as the United States in 2010, nearly tripled absolute capacity by 2014, with wind power reaching nearly 8 percent of total generation capacity or approximately 2.5 percent of generated electricity. The United States generated nearly 3.5 percent of total electricity from wind in 2012, and has increased capacity share by 7 percent since then.

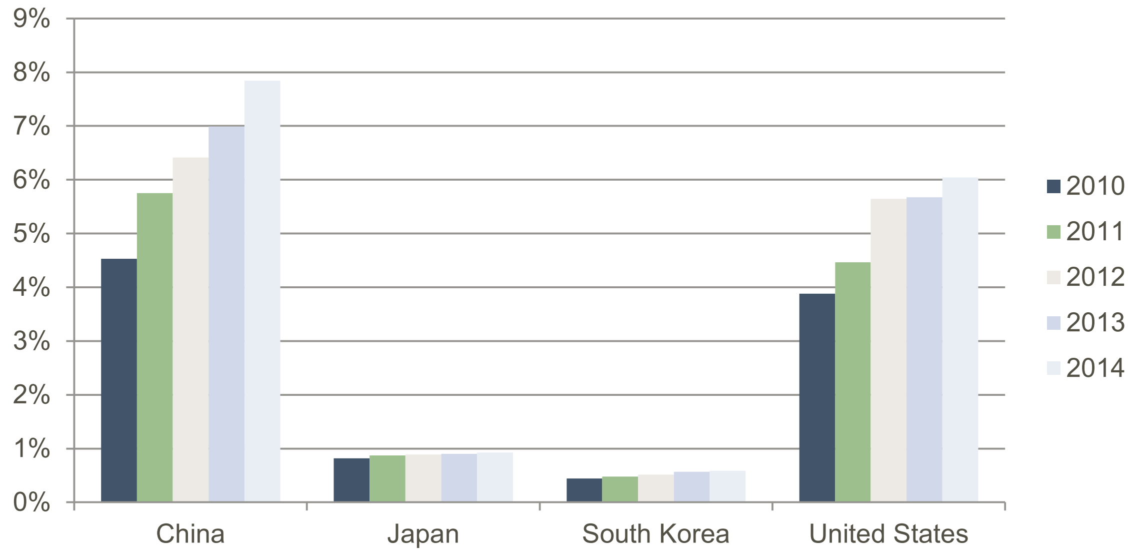

Figure 13: Wind energy production capacity (percent total electrical generation capacity)[31]

Nuclear still plays a larger role than renewables in the United States and South Korea. Figure 14 shows trends in nuclear capacity. As nuclear generates electricity at a level much closer to maximum capacity than solar or wind, Figure 14 understates nuclear's role in power generation: In 2012 nuclear energy made up 20 percent of total electricity generation in the United States, even though nuclear made up less than 10 percent of total capacity.[32] Likewise, South Korea obtained nearly 30 percent of electricity from nuclear power (and in the long term plans to generate 70 percent), despite nuclear power making up only about 20 percent of capacity. Japan, which previously relied heavily on nuclear and had planned for expansion, shut down all of its reactors, and it is unclear whether existing capacity will be put back in use. In China, nuclear capacity is growing slowly from a low level, although it will likely accelerate as plants that are now under construction come online.

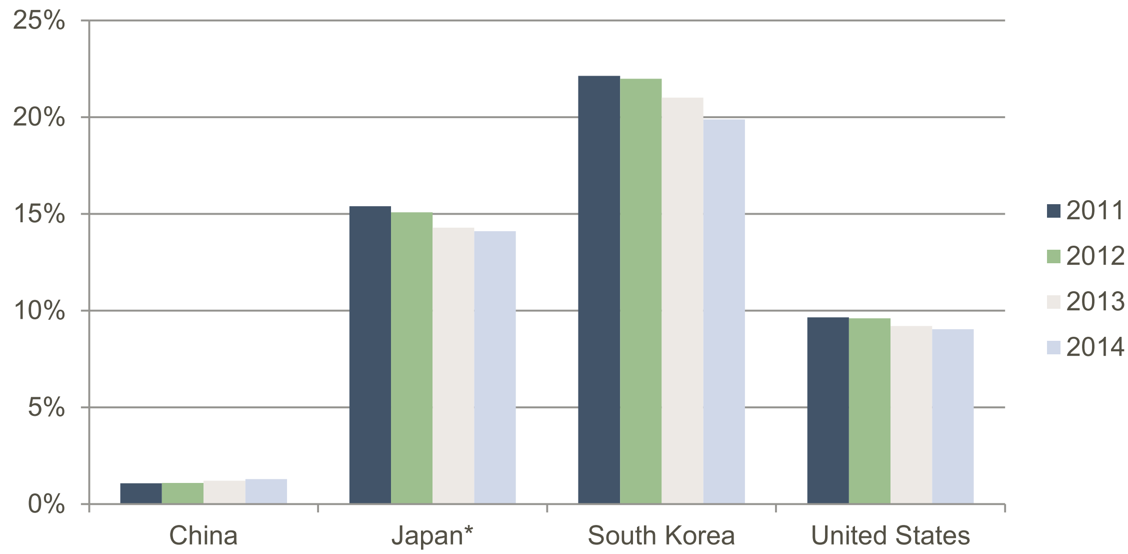

Figure 14: Nuclear energy production capacity (percent total electrical generation capacity)[33]
***Note that Japan's full nuclear capacity is included despite having gone largely unused since 2011.**

BARRIERS TO WIDESPREAD CLEAN ENERGY ADOPTION AND THE PUBLIC INVESTMENT IMPERATIVE

As the Center for Clean Energy Innovation (CCEI) has shown previously, clean energy is still not price competitive with fossil fuels in most situations, especially in levelized terms (e.g., addressing the issue that most renewable energy is intermittent whereas demand is not).[34] This means that cheaper and better clean energy technologies are needed. Public support for clean energy RD&D is a key part of that solution. However, some oppose expanded public investment in clean energy RD&D because they believe the incentives of private markets will guide our economy into a clean energy future, or that current policies are sufficient. Neither of these hopes can be counted on, for a number of reasons.

Price Differential Between Clean Energy and Fossil Fuels

While there is a strong case that the full societal costs of fossil fuel use (e.g. carbon emissions) are not incorporated into their price, governments have been unwilling to raise the price of fossil fuels high enough for most clean energy technologies to become cost competitive. As a result, without public policy support, the costs of these newer technologies are too high relative to well-established fossil fuels, and their performance and expected rate of return are too low to justify significant private sector investment in their widespread deployment.

Spillovers Discourage Firms From Making Large Investments in RD&D

Individual firms are discouraged from making large investments in RD&D because the knowledge created by such investments may leak out to other firms. In these cases of "knowledge spillover," firms are unable to fully capture the benefits of their investments, and therefore lack the incentives to make them. This leads to underinvestment by private firms in basic and applied research.

Extended Time Horizons and Large Scale of Clean Energy Projects Complicate Rate of Return Calculations

The scale and long time horizon of many clean energy projects, combined with considerable market and technology uncertainty, makes it extremely difficult for firms to assess expected rates of return on investments. This high level of uncertainty discourages high-risk, high-reward research in favor of short-term research and incremental product development, while simultaneously inhibiting the commercialization and adoption of technologies that require capital-intensive projects to demonstrate technological and financial performance at commercial scale.

Current Infrastructure Supports Incumbent Rather Than Emerging Energy Technologies

Current energy infrastructure has been established to accommodate and support incumbent technologies, not emerging challengers. For example, national electricity grids are tailored for large centralized thermal power plants, while renewable energy generation facilities are generally smaller, must be located near resource-rich areas, and frequently require new transmission capacity to reach markets. The lack of enabling infrastructure for emerging clean energy technologies therefore inhibits their widespread diffusion and large-scale deployment.

The standard solution to spurring more clean energy is a carbon tax. But there is little political will to implement the high carbon prices needed to truly change the market, because absent innovation to lower the price of low-carbon energy, carbon pricing simply raises the price of energy writ large, which elicits political and consumer resistance. Countries are constrained by unwillingness to pay higher energy prices or place limits on the economy. In other words, the so-called "Iron Law of Climate Policy" holds true—consumers and industry in high-income countries may be willing to take on small costs for mitigating climate change, but higher costs are politically difficult in high-income countries and economically impossible for low-income countries. Moreover, even if a carbon tax were implemented in most nations, it's not clear it would spur the kind of technological breakthroughs needed.[35]

As a result, to address climate change, nations will need to increase funding for clean energy RD&D. This is why CCEI proposed its $100 billion campaign, advocating for nations around the world to collectively invest $100 billion in clean energy innovation. This would amount to more than four times current investment, but still only 0.15 percent of GDP.[36] A major boost in RD&D funding is necessary to improve the price and performance of clean energy technologies and help the clean energy industry gain a competitive advantage in the marketplace. Failing to prioritize support for clean energy RD&D in the United States means risking the national potential to invent and commercialize the next major energy breakthrough. Failing to prioritize support for clean energy RD&D around the world means we must choose between raising taxes and slowing economic growth, and climate catastrophe.

ENDNOTES

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ABOUT CCEI

The Center for Clean Energy Innovation is a Washington, D.C.-based think tank dedicated to designing, advocating, and advancing cutting edge energy innovation policies to address global climate change, increase economic growth, and provide universal energy access. Founded in 2014, CCEI is a nonpartisan organization that accepts climate change as an innovation challenge at heart, focusing on energy RD&D policy, smart deployment, clean technology trade policy, STEM education and training, and advanced manufacturing at the state, national, and international levels.

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