By Breakthrough Institute and the Information Technology and Innovation Foundation

RISING TIGERS SLEEPING GIANT

ASIAN NATIONS SET TO DOMINATE THE CLEAN ENERGY RACE BY OUT-INVESTING THE UNITED STATES

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Overview

This report provides the first comprehensive comparison of public investments by the United States and key Asian competitors in core clean energy technologies, including solar, wind, and nuclear power, carbon capture and storage, advanced vehicles and batteries, and high-speed rail. Core findings include:

1. **Asia's rising "clean technology tigers" – China, Japan, and South Korea – have already passed the United States in the production of virtually all clean energy technologies, and over the next five years, the government's of these nations will out-invest the United States three-to-one in these sectors.** This **public** investment gap will allow these Asian nations to attract a significant share of **private** sector investments in clean energy technology, estimated to total in the trillions of dollars over the next decade. While some U.S. firms will benefit from the establishment of joint ventures overseas, the jobs, tax revenues, and other benefits of clean tech growth will overwhelmingly accrue to Asia's clean tech tigers.

2. **Large, direct and sustained public investments will solidify the competitive advantage of China, Japan, and South Korea.** Government investments in research and development, clean energy manufacturing capacity, the deployment of clean energy technologies, and the establishment of enabling infrastructure, will allow these Asian nations to capture economies of scale, learning-by-doing, and innovation advantages before the United States, where public investments are smaller, less direct, and less targeted.

3. **Should the investment gap persist, the United States will import the overwhelming majority of clean energy technologies it deploys.** Current U.S. energy and climate policies focus on stimulating domestic demand primarily through indirect demand-side incentives and regulations. Should these policies succeed in creating demand without providing robust support for U.S. clean energy technology manufacturing and innovation, the United States will rely on foreign-manufactured clean technology products. This could jeopardize America's economic recovery and its long-term competitiveness while making it even more difficult to reduce the U.S. trade deficit.

4. **Proposed U.S. climate and energy legislation, as currently formulated, is not yet sufficient to close the clean tech investment gap.** In contrast to more direct investments by Asia's clean tech tigers, current U.S. policies rely overwhelmingly on modest market incentives that are viewed by the private sector as more indirect, create more risks for private market investors, and do less to overcome the many barriers to clean energy adoption. The American Clean Energy and Security Act, passed by the U.S. House of Representative in June 2009, includes too few proactive policy initiatives and allocates relatively little funding to support research and development, commercialization and production of clean energy technologies within the United States. Including investments in clean energy R&D, demonstration, manufacturing and deployment in both U.S. economic recovery packages and the House-passed climate and energy bill, the United States is poised to invest $172 billion over the next five years, which compares to investments of $397 billion in China alone, a more than four-to-one ratio on a per-GDP basis.

5. **If the United States hopes to compete for new clean energy industries it must close the widening gap between government investments in the United States and Asia's clean tech tigers and provide more robust support for U.S. clean tech research and innovation, manufacturing, and domestic market demand.** Small, indirect and uncoordinated incentives are not sufficient to outcompete China, Japan, and South Korea. To regain economic leadership in the global clean energy industry, U.S. energy policy must include large, direct and coordinated investments in clean technology R&D, manufacturing, deployment, and infrastructure.

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Executive Summary

Asia's rising "clean technology tigers"—China, Japan, and South Korea—are poised to out-compete the United States for dominance of clean energy markets* due to their substantially larger government investments to support clean technology research and innovation, manufacturing capacity, and domestic markets, as well as critical related infrastructure. Government investment in each of these Asian nations will do more to reduce investor risk and stimulate business confidence than America's currently proposed climate and energy legislation, which includes too few aggressive policy initiatives and allocates relatively little funding to directly support U.S. clean energy industries. Even if climate and energy legislation passed by the U.S. House of Representatives becomes law, China, Japan and South Korea will out-invest the United States by a margin of three-to-one over the next five years, attracting much if not most of the future private investment in the industry. Global private investment in renewable energy and energy efficient technologies alone is estimated to reach $450 billion annually by 2012 and $600 billion by 2020,[1] and could be much larger if recent market opportunity estimates are realized.[2] For the United States to regain economic leadership in the global clean energy industry, U.S. energy policy must include more significant, direct and coordinated investment in clean energy R&D, manufacturing, deployment, and infrastructure.

Asia's clean tech tigers are already on the cusp of establishing a "first-mover advantage" over the United States in the global clean tech industry. This year China will export the first wind turbines destined for use in an American wind farm, for a project valued at $1.5 billion.[3] With no domestic manufacturers of high-speed rail technology, the United States will rely on companies in Japan or other foreign countries to provide rolling stock for any planned high-speed rail lines. And all three Asian nations lead the United States in the deployment of new nuclear power plants. The United States relies on foreign-owned companies to manufacture the majority of its wind turbines, produces less than 10 percent of the world's solar cells, and is losing ground on hybrid and electric vehicle technology and manufacturing.[4] As this report demonstrates, the United States lags far behind its economic competitors in clean technology manufacturing. Should this gap persist, the United States risks importing the majority of the clean energy technologies necessary to meet growing domestic demand.

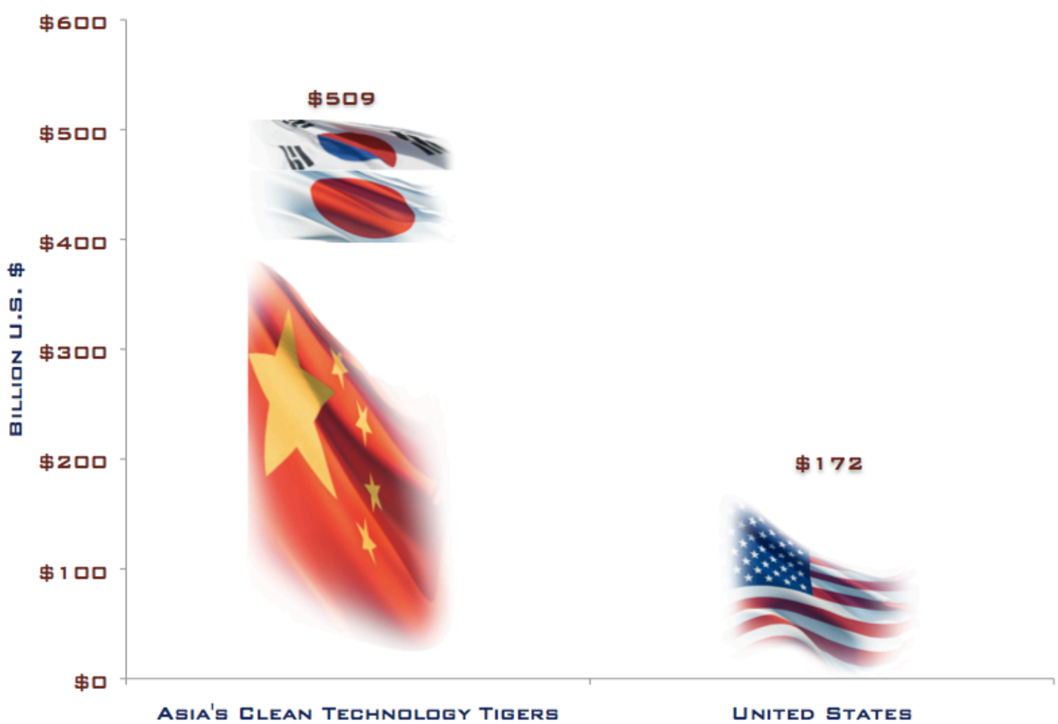
While the United States has traditionally attracted the bulk of available private investment in clean energy, capital flows are increasingly being directed towards Asia's clean tech tigers, and these nations' greater public investments are likely to capture much of the future private investment in clean energy technologies. Between 2000 and 2008, the United States attracted $52 billion in private capital for renewable energy technologies, while China attracted $41

* The term "clean energy technologies" can be variously defined. Throughout this document, unless otherwise specified, we refer to zero- or low-carbon energy generation and transportation technologies and efficient end-use energy technologies.

billion. China's share of global clean tech investment is rising each year, surpassing the United States for the first time in 2008.[5] According to a recent study by Deutsche Bank,[6] "generous and well-targeted [clean energy] incentives" in China and Japan will create a low-risk environment for investors and stimulate high levels of private investment in clean energy. These nations rely on a "comprehensive and integrated government plan, supported by strong incentives." In contrast, the investment firm notes, the United States is a "moderate-risk" country since it relies on "a more volatile market incentive approach and has suffered from a start-stop approach in some areas."

China, South Korea and Japan will invest a total of $509 billion in clean technology over the next five years (2009-2013) while the United States will invest $172 billion, a sum that assumes the passage of the proposed American Clean Energy and Security Act (ACESA) and includes current budget appropriations and recently enacted economic stimulus measures (both figures include investments in clean energy generation and advanced vehicle technologies, as well as rail, grid, and efficiency investments; see Appendix A for more).

Figure 1. Competing Public Investments in Clean Energy Technology, 2009-2013



Source: See Appendix B for breakdown of investments by nation.

The largest investments are being made by China, which is planning new direct investments totaling at least $440[7] to $660[8] billion over ten years. This investment is expected to focus primarily on low-carbon power, and is in addition to the $177 billion in stimulus funds China has already invested in clean technology, including rail and public transit.[9] South Korea recently announced it will invest $46 billion over five years in clean technology sectors – over one percent of the nation's gross domestic product (GDP) – with the explicit goal of increasing Korean firms' share of the global clean tech export market by eight percentage points. This "Green New Deal" investment program will focus in particular on solar, LED lighting, nuclear, and hybrid car technologies.[10] Japan will provide $33 billion in targeted deployment incentives for a number of clean energy technologies, including solar, hybrid-electric vehicles, and energy efficiency technologies, and plans to invest an additional $30 billion over the next five years to implement technological roadmaps that focus on achieving price and performance improvements in a suite of low-carbon technologies.[11]

Beyond their greater size, the direct and coordinated nature of these Asian nations' public investments will confer significant advantages by developing each of the areas necessary to achieve a competitive economic advantage in the clean energy industry: research and innovation, manufacturing, and domestic market demand, as well as supportive infrastructure. China is poised to replicate many of the same successful strategies that Japanese and South Korean governments used to establish a technological lead in electronics and automobiles. Those governments supported nascent companies with low-interest loans, industry-wide R&D, government procurement, and subsidies for private firms to drive the purchase of advanced technologies. China is now employing similar tactics in emerging clean technology industries such as electric cars and low-carbon power generation.[12]

Many of these investments are directed at growing domestic clean technology industries in order to meet aggressive technology deployment targets. By 2012, China, Japan, and South Korea plan to produce 1.6 million hybrid gas-electric or electric vehicles annually compared to North America, which is projected to produce 267,000, less than a fifth as many, according to industry forecasts.[13] Japan has unveiled a plan to boost domestic solar power capacity by a factor of 20 by 2020. The nation also plans to generate 20 percent of its electricity from renewable sources by 2020. Both objectives are backed up by targeted R&D investments, technology-specific deployment incentives, and government procurement programs. China plans to deploy up to 86 GW of new nuclear capacity by 2020, and is rapidly deploying wind and solar power spurred by guaranteed preferential tariff prices and, in many cases, low-interest financing. The country expected to generate between 15 to 18 percent of its electricity from renewable sources by 2020; Chinese officials have recently indicated this amount could reach 20 percent.

As Asia's clean tech tigers solidify their lead, they will capture economies of scale, learning-by-doing experience, supply chain efficiencies, and greater market power advantages. These "first-mover" advantages are likely to create significant challenges for late-to-market entrants. National investments in the deployment and procurement of new technologies will be used to help emerging domestic industries solve technology problems, improve manufacturing efficiency and product performance, and reduce price, providing a lasting competitive advantage over other firms and nations. Japan, for example, is using government procurement and other incentives to buy down the price of solar power and is engaging in targeted R&D efforts to drive price and performance improvements that could help it retain its status as a leading global producer of solar technology.[14]

Nations that establish an early lead in key industries can more easily retain that advantage at a lower cost over the long-term. Direct government investments by Asia's clean tech tigers will help them form industry clusters, like Silicon Valley in the United States, where investors, manufacturers, suppliers and others can establish dense networks of relationships that can provide cost and innovation advantages for participating firms, and for the nation as a whole.[15]

In order to avoid ceding first-mover advantage to Asia's clean tech tigers, U.S. support for the nation's already lagging domestic industries must be robust. Unfortunately, according to the Environmental Protection Agency (EPA), the climate and energy bill passed by the U.S. House of Representatives in June 2009 is not sufficiently aggressive to significantly increase the deployment of renewable and other low-carbon energy generation technologies or advanced vehicle technologies, particularly in the near-term.[16] When compared to investments made by the Asian competitors examined in this report, ACESA directs relatively little public funding to support research and development, commercialization and production of clean energy technologies within the United States. Furthermore, the legislation is unlikely to trigger significant private investments in clean energy development and deployment before 2020, if not much later, largely because carbon prices established by the bill's cap and trade program are projected to remain relatively low over this period and firms are expected to rely significantly on offsets for compliance with the legislation.[17] Renewable energy deployment standards contained in ACESA are also insufficient to require additional deployment beyond business-as-usual projections.[18]

Large government investments in China, Japan and South Korea are significant because, in contrast to many other industries, there are large barriers to the widespread commercialization of clean energy technologies.[19] These barriers include: high capital costs; significant uncertainty and risk; a lack of enabling infrastructure (e.g. transmission lines and storage for solar and wind); historically low levels of publicly funded R&D; low levels of privately funded R&D due to intellectual property concerns and spillover risks; and low to nonexistent competitive product differentiation in the energy sector, leaving emerging technologies to compete with well established incumbent technologies primarily on the basis of price alone.[20] As a result, the energy industry has remained one of the least innovative industries, with several of the dominant core technologies over a century old.

Public sector investments in new technologies have traditionally played a pivotal role in supporting emerging industries and catalyzing further private sector investment.[21] The U.S. Defense Department's procurement of microchips in the 1950s facilitated the technology's market penetration and dramatically reduced its cost. Today's vibrant information technology sector exists in large part because of early and sustained public investments in R&D, computer science, infrastructure, and the procurement of new technologies. Government investment was also crucial for the development of agriculture, railroads, radios, the Internet, aerospace, and pharmaceuticals.

Public investments have spurred the creation of clean technologies in past decades. Prior U.S. investments resulted in the invention of nuclear, wind, and solar energy technologies. Further price and performance improvements in wind turbines occurred in Denmark, where the government guaranteed its market for wind energy in the 1980s and 1990s and offered both targeted deployment incentives and supportive industrial R&D programs.[22] Today, Denmark's Vestas remains the world's top wind turbine manufacturer by capacity.

Since emerging clean energy technologies both remain more expensive than conventional alternatives and face a variety of non-price barriers, public sector investments in clean energy will be a key factor in determining the location of clean energy investments made by the private sector. Dollar for dollar, the direct and targeted public investments of China, Japan, and South Korea are likely to attract substantial private investment to clean energy industries in each country, perhaps more so than the market-based and indirect policies of the United States.[23]

As trillions of dollars are invested in the global clean energy sector over the next decade, clean tech firms and investors will invest more in those countries that offer support for infrastructure, R&D, a trained workforce, guaranteed government purchases, deployment incentives, lower tax burdens, and other incentives. In China, for example, local governments are offering firms free land and R&D money, and state-owned banks are offering loans to clean tech firms at much lower interest rates than those available in the United States.[24]

History offers examples of the United States catching up to competitors who have surged ahead. The United States raced past Europe in aerospace through sustained federal military-related support for aviation technology innovation and deployment, and was able to become a world leader in civil and military aviation after trailing Europe for years.[25] During the space race, the United States quickly met and then surpassed the Soviet Union after it launched the Sputnik satellite, putting a man on the moon twelve years later after a sustained program of direct investment in innovation and technology. The United States has consistently been a leader in inventing new technologies and creating new industries and economic opportunities. It remains one of the most innovative economies in the world, and is home to the world's best research institutions and most entrepreneurial workforce. The challenge will be for the United States to aggressively build on these strengths with robust public policy and government investment capable of establishing leadership in clean technology development, manufacturing, and deployment, and to do so before China, Japan and South Korea fully establish and cement their emerging competitive advantages.

Summary of Implications for U.S. Economic Competitiveness

Restoring America's competitiveness and ensuring U.S. leadership in the burgeoning clean energy sector will require a direct and sustained effort by the federal government to strengthen U.S. clean technology research and innovation, manufacturing capacity, and domestic markets. Establishing a price on carbon emissions, new energy standards, and other indirect incentives are necessary but are not sufficiently robust to support the growth of the U.S. clean energy sector and outcompete Asia's clean technology tigers. As China, Japan and South Korea all launch proactive and aggressive strategies to achieve technological and economic leadership in the clean energy sector, the United States will find it difficult to catch up without direct and targeted public investments of a similar scale. More aggressive measures will be required for the United States to regain the lead in the global clean energy race. The policy actions of these Asian competitors have important implications for U.S. policy and the steps that the U.S. government should take to strengthen the nation's competitive position:

| 1 |

The U.S. government should significantly increase investment in clean energy innovation by making a sustained commitment to research, development, and demonstration (RD&D).

A major boost in RD&D funding is necessary to improve the price and performance of clean energy technologies and gain a competitive advantage in the clean energy industry. Furthermore, without much greater investment in innovation, the United States risks seeing the next generation of clean technologies invented and commercialized overseas. The government of South Korea is poised to double its investment in clean energy R&D, and Japan plans to invest $30 billion over five years on research and development in low-carbon energy. Both Japan and South Korea have developed technology roadmaps that direct resources to technology R&D based on a thorough analysis of the economic and environmental potential of each technology and current institutional capacity to achieve technological leadership. The United States currently has no such strategy, and its investment in energy R&D has stagnated at low levels for years.[26] Along with increasing its commitment to clean energy research and development, the United States should explore new institutional structures to strengthen and augment the federal energy R&D system.[27] Furthermore, to ensure the timely commercialization of emerging technologies, the U.S. government should provide much greater funding to accelerate the commercial-scale demonstration of promising clean energy technologies, particularly in situations where the private sector is reluctant to commit funding to commercialize these nascent technologies.[28] A substantial and sustained increase of federal investment in clean energy RD&D will be necessary to regain economic leadership in the clean energy sector and to match the aggressive policies of our competitors.

| 2 |

The United States government should spur the adoption of innovative manufacturing processes and accelerate economies of scale in U.S. clean energy manufacturing.

Currently, China, Japan and South Korea are far outpacing the United States in manufacturing and producing the clean energy technologies that will underpin a new wave of economic growth. While low-carbon technology development benefits the entire world, real economic advantages are at stake for particular nations in the form of increased tax revenues, jobs, and the emergence of related industries and businesses along the clean energy technology value chain. The Chinese government is actively supporting the development of clean energy manufacturing centers in the country and is linking them with supporting financial and research institutions. To establish a competitive clean energy manufacturing industry in the United States, the government should provide or secure low-cost financing,[29] incentives,[30] and technical assistance[31] to retool the nation's industrial base and ensure that U.S. factories are commercializing and building the clean, cheap energy technologies to power America's economy and export abroad. Furthermore, a significant portion of U.S. research and development efforts should be located close to regional industry clusters and targeted to address manufacturing challenges and improve the design and production of clean technologies at scale.[32]

| 3 |

The United States government should actively support, through targeted public policy and investment, the acceleration of clean energy deployment and market creation in order to reduce the price of promising clean energy technologies and encourage their widespread adoption.

The U.S. government should provide sustained and targeted investments to spur a full suite of promising clean energy technologies, with a particular emphasis on closing the price gap between clean energy and incumbent fossil fuel energy sources. Pricing carbon can play a role here, but raising the costs of carbon-intensive energy sources through an economy-wide carbon price will not by itself provide the targeted support necessary to overcome technology-specific price gaps and other key barriers that inhibit the deployment of a full suite of clean energy technologies at scale. Asia's clean tech tigers are supporting clean energy technology adoption through a variety of targeted public policies, including technology-specific production incentives, government procurement offers and sustained and long-term lines of credit in the form of low-cost financing and credit guarantees. The U.S. government should similarly provide sustained financial and policy support for the deployment of clean energy at scale. Such incentives must be considered integral to any U.S. clean technology development and economic competitiveness strategy.[33]

Asia Seeks First-Mover Advantage Through Investments in Clusters

Government investments will be crucial to helping China, Japan, and South Korea gain a "first-mover" advantage over the United States in key clean energy sectors. Firms that can establish economies of scale and capture learning-by-doing and experience effects ahead of competitors can achieve lower cost production and/or higher quality products, effectively limiting their competitors market share and making it hard for new entrants to break into the market. This first-mover advantage accrues to nations as well as firms. While firms gain a first-mover advantage by being the quickest to develop, commercialize, and widely produce emerging technologies, nations can gain first-mover advantages by making investments to attract and grow leading firms, by fostering relationships between local firms, research labs, and universities, and by developing the associated infrastructure, human capital, and expertise that help firms become more competitive.

Direct government investments will help Asia's clean tech tigers form industry clusters, like Silicon Valley in the United States, where inventors, investors, manufacturers, suppliers, universities, and others can establish a dense network of relationships. Even in an era of increasingly globalized commerce, enduring competitive advantages lie increasingly in the structure of these regional economies.[34]

The governments of Asia's clean tech tigers are investing heavily to develop clean technology manufacturing and innovation clusters. In China, national, regional, and local governments are offering clean energy companies generous subsidies to establish operations in their localities, including free land, low-cost financing, tax incentives, and money for research and development. In just over three years, the Chinese city of Baoding has transformed from an automobile and textile town into the fastest growing hub of wind and solar energy equipment makers in China.[35] The city is home to "Electricity Valley," an industrial cluster modeled after Silicon Valley, composed of nearly 200 renewable energy companies focusing on wind power, solar photovoltaics (PV), solar thermal, biomass, and energy efficiency technologies. Baoding is the center of clean energy development in China, and operates as a platform that links China's clean energy manufacturing industry with policy support, research institutions, and other social systems.[36]

In Jiangsu, a province on the eastern coast of China, local government officials have enacted aggressive solar subsidies to reach a target of 260 MW of installed capacity by 2011. Jiangsu already houses many of China's major solar PV manufacturers, and the new policy is targeted to create substantial market demand and attract a cluster of polysilicon suppliers and solar technology manufacturers.[37] Another Chinese city, Tianjin, is now home to Vestas' largest wind energy equipment production base. The base will not only enhance the company's production capacity, but will also increase the localization of wind turbine equipment and help component suppliers develop expertise with the company's advanced wind power technology.[38]

Japan has an explicit industrial cluster program to strengthen the competitiveness of its domestic industries.[39] The Japanese government is funding R&D collaborations between government, academia, and industry while offering coordinated deployment incentives in order to achieve price and performance improvements in a suite of technologies that can improve the productivity of domestic industry. Likewise, South Korea is providing billions in R&D funding and credit guarantees to drive private investment in clean energy technologies.

Clusters provide cost and innovation advantages, including access to specialized labor, materials, and equipment at lower operating costs, as well as lower search costs, economies of scale, and price competition.[40] Clusters provide members with preferred access to market, technical, and competitive information, creating knowledge spillovers that can accelerate the pace of innovation. Relationships between companies are leveraged to help them learn about evolving technologies as well as new market opportunities. Workforce mobility further facilitates knowledge spillovers that can enhance the rate of innovation for the whole cluster. These clusters can provide an attractive business environment for particular industries; if one or two companies fail or move out of the area, others can quickly replace them.

Notable examples of competitive economic clusters include Detroit's historic leadership in auto technology, Silicon Valley's long dominance in successive waves of information technology, and biotechnology and pharmaceutical firms clustered around the Philadelphia area. The United States established strong first-mover advantages in each of these industries by developing clusters that fostered relationships among related organizations and value-added industries, which enhanced overall industry productivity. These advantages made it costly for other nations to catch up.

Establishing industrial clusters does not guarantee continued market dominance. In the case of the automotive industry, U.S. firms eventually lost market dominance after East Asian nations spent years implementing an industrial policy that sheltered their nascent auto industry from competition and invested billions in direct subsidies to support the industry's growth and technological progress. In the face of this dedicated international competition, and its own failure to innovate and adapt, the U.S. auto industry faltered.

Continual investment in innovation is also critical. New technologies disrupt existing markets, and new technology clusters can likewise disrupt the established geographic concentration of industry dominance. Such was the case when, in the 1980s, the transformation of the computer industry away from mainframes and then minicomputers led to a shift of dominance from the northeastern United States to Silicon Valley.[41] This could likely prove true for clean energy as well, as major investments in emerging technologies form new geographic concentrations of industrial and technological leadership.

The United States has natural innovation advantages, including a skilled workforce, world-class universities and research institutes, fluid capital markets, an open society and vibrant creative culture. However, given the dynamics of first-mover national advantage and the aggressive measures now being taken by Asian competitors in the clean energy sector, these advantages will by no means be sufficient for the United States to retain its innovative edge. A recent report by the Information Technology and Innovation Foundation (ITIF) ranked the United States sixth out of 40 leading industrialized nations in innovation competitiveness, and last in the rate of improvement in national innovation competitiveness over the last decade — America's economic competitors are surging ahead while U.S. innovation capacity stagnates.[42] Particularly in this new 21st century growth industry, many nations are starting from a more even position. Ultimately, economic success in the clean energy race will be determined in large part by the public investments made by competing nations. Without much larger public investments in clean technology, the United States risks being out-innovated by its economic competitors.

Barriers to Widespread Clean Energy Adoption and the Public Investment Imperative

Financial and non-financial barriers prevent the widespread deployment and commercialization of clean energy technologies. The persistence of such barriers leads private investors to under-invest in clean energy deployment and innovation, and they are often referred to as "market failures," a term that implies that these barriers can be corrected through market mechanisms. However, many of the pervasive barriers that inhibit the widespread adoption of clean energy technologies cannot be solved by market signals alone.

Four barriers, in particular, are indicative of the challenges to large-scale clean energy deployment, and along with other obstacles are major reasons why the energy sector has remained one of the least innovative sectors of the global economy.[43] **First,** a significant price differential exists 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.[44] 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 too low, to justify significant private sector investments in their widespread deployment.

Second, individual firms are discouraged from making large investments in research and development because the knowledge created by such investments may spill over to other firms. In these cases of "knowledge spillover," firms are unable to fully capture the benefits of their investments, leading to under-investment by private firms in basic and applied research.[45] There are strong indications that these risks are particularly challenging for the energy sector. The U.S. energy sector invests less than one quarter of one percent of annual revenues in R&D activities,[46] just one-tenth of the average across all U.S. industries (2.6 percent of revenues).[47] As a portion of annual revenues, U.S. energy sector R&D investments are two orders of magnitude lower than leading innovation-intensive sectors such as biomedical technology (10-20 percent of annual revenues invested in R&D each year), semiconductors (16%), and information technology (10-15%).[48]

Third, 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.[49]

Fourth, 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.[50] New transmission lines must typically serve multiple energy projects to secure financing and to be profitable, and individual clean energy project developers and investors are unlikely to shoulder the cost of network expansion on their own. Coordination between project developers could help to solve this problem, but such coordination has proven difficult, since each project depends on its own funding, planning, and energy contract processes that can be uncertain and unpredictable.[51] Similarly, a ubiquitous refueling infrastructure exists for conventional gasoline vehicles, while electric or alternative fuel vehicles require the establishment of new refueling systems. The lack of enabling infrastructure for emerging clean energy technologies therefore inhibits their widespread diffusion and large-scale deployment.

The dominant policy approach to improving U.S. economic competitiveness in clean energy has been focused on establishing a price on emissions of carbon dioxide and other global warming pollutants along with new efficiency and renewable energy regulations, but these efforts cannot succeed on their own for several reasons. **First,** for many clean energy technologies to be competitive with fossil fuels, governments would have to set very high prices for carbon pollution, and typically governments face stiff political resistance to doing so.[52] Thus, political considerations mean that any carbon price established will be relatively low, as in currently pending U.S. climate and energy legislation, which would establish a price averaging roughly $15 per ton of CO2-equivalent for the first decade of the program (2012-2021) – the equivalent of a roughly 15 cent increase in the price of a gallon of gasoline.[53]

Second, an economy-wide carbon price would not overcome specific barriers to the adoption of particular technologies. While a modest carbon price may help some lower-cost and more mature clean energy technologies (e.g., wind power) become more competitive with fossil fuels, it will do little for less mature and currently more expensive technologies such as solar energy or carbon capture and storage. Furthermore, carbon prices clearly cannot solve the many non-price barriers specific to the adoption of emerging clean technologies.[54]

Third, even a high carbon price will not solve the problem of knowledge spillover and the long-term risks associated with large private investments in technology development and deployment. Nor will it facilitate the establishment of critical infrastructure, such as new transmission lines, grid upgrades, or storage for intermittent sources like wind and solar.[55]

Given each of these limitations, there is wide expert consensus[56] around the need for significant, targeted public investment to overcome these key barriers, particularly to boost the performance of current clean energy technologies and decrease the cost of deploying them. Governments can help remove or overcome barriers to clean energy adoption by making investments that private investors are unable or unwilling to make and by shifting the incentive structure faced by private firms in order to encourage greater private investment in clean energy technologies. Public investments in research and development can help fill the innovation gap that results from a private sector constrained by risks of knowledge spillover and other market failures.[57] These investments are necessary to both accelerate the invention of new technologies and improve the price and performance of existing technologies, increasing their appeal to market adopters.

Public investment can similarly bridge the initial price differential between clean energy technologies and their incumbent competitors. Unlike economy-wide carbon prices or market mechanisms, these public investments and incentives can be targeted to address the varying price differentials for a full suite of clean technologies at various stages of maturity and development. These investments in turn accelerate reductions in the real, unsubsidized cost of emerging clean technologies over time. New technologies routinely become less expensive with increasing experience and scale, as supply chain and production efficiencies are captured and economy of scale effects are realized. This "learning-by-doing" effect, brought about through operational market experience, also feeds back into the research process to guide future research and improvements in product performance and price.[58]

Public investments in enabling infrastructure, such as electricity grid expansion or electric car charging stations, lower barriers to clean technology adoption by offering greater market access for private firms. Similarly, public support for clean energy financing, in the form of low-cost loans, credit guarantees, tax incentives, and direct project grants, reduces private sector project risk. Given the persistence of the multiple barriers to clean energy technology adoption discussed above, public investment will be a key determinant of future private sector investment in the industry and the resulting pace and scale of market growth for emerging clean energy technologies.

Methodology

This report examines the competitive economic position of each of four nations—China, Japan, South Korea, and the United States—in the global clean energy technology sector. The report examines three core metrics of competitiveness in the clean technology industry: research and innovation capabilities, domestic manufacturing capacity, and domestic clean energy market development. While different firms and countries may specialize in one or more of these areas, nations that progress in all three areas will see the greatest economic gains and strengthen their competitive positions vis-à-vis their economic competitors.

In examining the competitive position of each country in the clean technology sector, we focus on six technologies in particular, including solar, wind and nuclear power, carbon capture and storage (CCS) technology for fossil-fueled power plants, advanced vehicle and battery technology, and high-speed rail. Each of these technologies is either a low-carbon energy generation technology or a more efficient transportation technology that can be powered by low-carbon electricity sources. Furthermore, each of these technologies is the subject of intense international competition and will provide increasing opportunities for international export. While this not an exhaustive list of technologies in the clean energy sector, the analysis provides an overall indication of the competitive position of each nation in major clean technology industries that are expanding or set to expand at a rapid pace.

This report then provides an analysis of the relative trajectories of each country's future competitiveness in a suite of clean energy technologies. Projections of future competitiveness are made based on an examination of the respective public investments and financial incentives provided or planned by each nation to support the development, manufacturing, and deployment of clean energy technologies. Wherever possible, we also examine infrastructure investments that support the growth of clean energy industries, such as electricity grid expansion, and electric vehicle charging stations. In this section we focus particularly on public strategies to grow clean energy industries because as long as multiple persistent barriers inhibit the widespread adoption of clean energy technologies, the overall pace and scale of investment in clean energy will continue to be driven largely by public policy.

Competing Industries: A Comparison of Current Positions in the Clean Energy Sector

This section examines the current state of economic competitiveness among China, South Korea, Japan, and the United States in the global clean energy technology industry. While there are a number of possible indicators that could measure economic competitiveness in this industry, this report focuses on three in particular: research and innovation related to the clean energy sector, clean energy technology manufacturing, and domestic clean energy market development. All three areas are critical components of a comprehensive domestic strategy to establish economic leadership in the global clean energy industry.

In each of these three categories, we use different metrics to assess the relative competitive positions of each nation. These metrics are described in Table 1 on the following page. The importance of each indicator to a competitive position in the clean energy sector is described in this section, along with a snapshot of the current state of competitiveness in each country, including recent developments and growth trends. While this assessment does not provide a full market analysis, its findings suggest that Asia's "clean tech tigers"—China, Japan, and South Korea—are already gaining an increasingly competitive position in the industry, presenting a significant economic challenge to the United States.

Table 1. Metrics for Assessing Economic Competitiveness in Clean Energy Technologies

	Clean Energy Research and Innovation	Clean Energy Manufacturing	Domestic Clean Energy Markets
Quantitative Measures	• Government Spending on Energy R&D • Clean Energy Patents	• Clean Energy Production and Manufacturing Capacity (Wind and Solar) • Heavy Forging Capacity (Nuclear)	• Total and New Installed Clean Energy Generating Capacity (Wind, Solar, Nuclear) • Track Length (High-Speed Rail) • Current and Planned Demonstration Plants (CCS)
Qualitative Measures	• Structure of Energy Innovation System	• Indigenous Technology (Nuclear, CCS, and High-speed rail) • Current or announced advanced vehicle or battery production (Advanced Vehicles)	• Market Introduction Dates (Advanced Vehicles)

Research and Innovation

Achieving leadership in clean energy research and development is critical to establish and maintain a sustainable competitive advantage in the clean energy technology industry. Energy R&D is necessary to both invent new technologies and reduce the cost and improve the performance of existing clean energy technologies in order to make them more competitive with conventional energy sources, as well as to reduce the costs of climate change mitigation. Substantial funding for R&D is necessary because scientific and technical progress is crucial to quickly making clean energy sources cheaper in unsubsidized terms relative to fossil fuels. Equally important to the level of investment in R&D is the structure of national R&D and innovation systems. National R&D systems that coordinate activities between industry, academia, and government, will be more effective at leveraging the expertise of each, as well as designing more effective policies to move technologies from their research stage through to commercialization.

While investing in R&D is necessary, it is not sufficient to establish leadership in the global clean energy industry. Countries that focus solely on R&D may be at the forefront of developing new technologies, but risk seeing those technologies manufactured and commercialized elsewhere without a similar commitment to clean technology manufacturing and domestic deployment. The United States, for example, pioneered many of today's clean energy technologies, such as solar PV, wind, and nuclear power, only to see the geographic centers of manufacturing and deployment for each technology shift to places like Japan, China, and much of Europe. A comprehensive strategy to lead the clean energy race must also include investment to develop domestic manufacturing capacity, as well as to create domestic market demand for clean energy products. Indeed, such policies can actually strengthen the innovation process and make R&D activities more effective. The innovation process entails various feedback loops between research activities and market experience,[59] and the innovative capacity of nations is enhanced when the links between research and the market application of emerging technologies are strengthened.

This section examines the state of clean energy innovation in China, Japan, South Korea, and the United States. Innovative capacity is measured by public spending on clean energy research and development (R&D) and by patents awarded in the clean energy sector. The section then examines the structure of clean energy innovation in each country. As this section shows, investments in clean energy R&D are low in each nation relative to the overall size of the energy industry, and while the United States and Japan continue to vie for a leading position in clean energy innovation, South Korea and China are moving quickly to fill the innovation gap.

China

Over the past 30 years, China has instituted a number of reforms that have helped to strengthen its innovation system, with mixed success. China has historically invested little in R&D, and for decades most research was carried out through direction of the central government, and isolated from industrial sectors. As China began to embrace institutional and market reforms, efforts were made to wean research institutes from heavy government influence and foster relationships with enterprises based on market supply and demand.[60] Two government programs in particular marked a departure from the older heavy-handed system. The "863 Program", created in 1986, awarded competitive grants for applied research in a number of priority sectors, including energy. China also created a National Basic Research Program (the "973 Program") to increase basic research and help meet the nation's strategic needs.[61] In 2008 the government invested $585 million (RMB4 billion) in these two programs, as well as a further $290 million (RMB2 billion) for R&D and demonstration of biofuels.[62] These reforms have led to some decentralization of the R&D process in China's energy sector, and overall increases in energy R&D. Between 1996 and 2003, China's R&D to GDP ratio rose from 0.6 to 1.3 percent and the industry share of R&D spending has grown from less than 30 percent to approximately 60 percent.[63]

Notwithstanding the measurable gains in the innovative capacity of China's energy sector, investments in R&D, particularly from the private sector, remain low. China does not yet achieve a significant number of patents in the clean energy sector and many institutions are still adapting to the changing system. In June 2009, Chinese renewable energy experts identified key shortcomings in China's clean technology innovation system, including the lack of a coordinated public research platform, clear technological roadmaps, and long-term financial and institutional support for clean energy R&D.[64]

The government has begun to address these remaining challenges, and has recently announced plans to significantly boost targeted R&D support for a number of clean energy technologies. For solar energy, the Chinese Academy of Sciences will set up a platform to support scientific innovations and implement an action plan to provide support at each stage of the technology development pipeline, including basic research, applied research, and market commercialization.[65] China is already home to Suntech, one of the most innovative solar cell companies and the number two global solar cell producer in the world. Suntech has constructed a leading global R&D facility that is working on second and third generation technologies,[66] and recently broke industry efficiency records for multicrystalline solar cell modules, at 15.6 percent.[67] Businesses outside of China have taken notice of the development of China's innovative capacity around solar energy, and plan to build on it over the coming years. Applied Materials, an American company and the world's leading producer of solar manufacturing equipment, opened the world's largest solar R&D facility in Xian, China in October 2009.[68]

China has made technological progress in nuclear energy that will allow the nation's nuclear energy industry—set for a large expansion in the next few decades—to rely on indigenous technologies to support Chinese nuclear power development. The head of China's National Energy Administration recently noted, "China has made major breakthroughs in the research and development of some key nuclear power equipment."[69] As a result, 13 of the 17 nuclear power facilities currently under construction apply CPR-1000, a China-developed second-generation technology based on a design by French company Areva.[70]

China has also turned to the international community for support in financing research and development in a suite of low-carbon technologies and has sought out opportunities to collaborate with scientists from other countries. In 2007, China and the United Kingdom launched the Near Zero Emissions Coal (NZEC) research and piloting initiative as part of the China-EU Partnership on Climate Change. The two-year initial phase runs through late 2009, aiming to build capacity for CCS technology in China and study options for early demonstration.[71] CCS technology, along with energy efficiency and low carbon vehicles, will be a main focus of R&D efforts at the joint US-China energy research center announced in July 2009.[72] Funding for these initiatives are relatively low, however. The U.S.-China joint partnership has at this point committed only $15 million toward the effort.

Japan

In 2008 Japan spent $3.9 billion on energy R&D, according to the International Energy Agency (IEA), ranking it just behind the United States.[73] Japan's level of energy R&D investment has remained relatively constant over the past four years. The majority of public funds for energy R&D went to nuclear power, which received 65 percent of the total. Energy efficiency received 12 percent and renewable energy received five percent. As a percentage of GDP, Japan's public energy R&D investment was greater than South Korea's and well over twice the level of the United States.

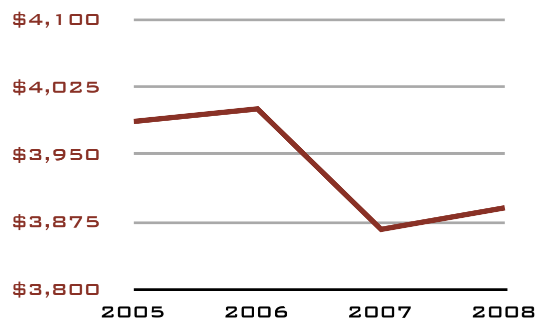
In order to help the nation achieve ambitious clean energy development objectives, the Japanese government is significantly ramping up public investments in clean energy R&D. The government has proposed to invest $30 billion over five years in energy research and development in order to develop new, innovative technologies and to improve existing technologies over the short-term. This includes using new materials and structures that may significantly improve solar cell efficiencies, with a goal of improving generating efficiency by over 40 percent and achieving a generating cost of only 7 cents /kWh (7¥/kWh) by 2030, close to the cost of conventional energy sources.[74]

In 2008, Japan's "Cool Earth Innovative Energy Technology Program" identified 21 key innovative energy technologies based on a set of criteria including innovative technologies that can deliver substantial reductions in carbon dioxide, technologies that are expected to deliver substantial performance improvements and cost reductions, and technologies that Japan can lead the world in developing—gaining global market share and boosting economic growth.[75] The low carbon technologies selected include CCS, innovative solar PV, and advanced nuclear power generation. Japan's New Energy and Industrial Technology Development Organization (NEDO) is tasked with enhancing Japan's industrial competitiveness through targeted R&D and support for new technology commercialization.[76]

For each of the selected technologies, the government has created a technology development roadmap that spans from now until 2050, outlining a diffusion scenario over the long-term, the current level of international economic competitiveness in the technology, and the prospects for international expansion.[77] The roadmap also identifies technical hurdles in the development of each technology and suggests the specific areas of research needed to address them. Japan's explicit goal of driving cost reductions and increasing technology performance through direct investments will help foster the continuous competitive advantage of Japanese industry in targeted clean energy technologies.

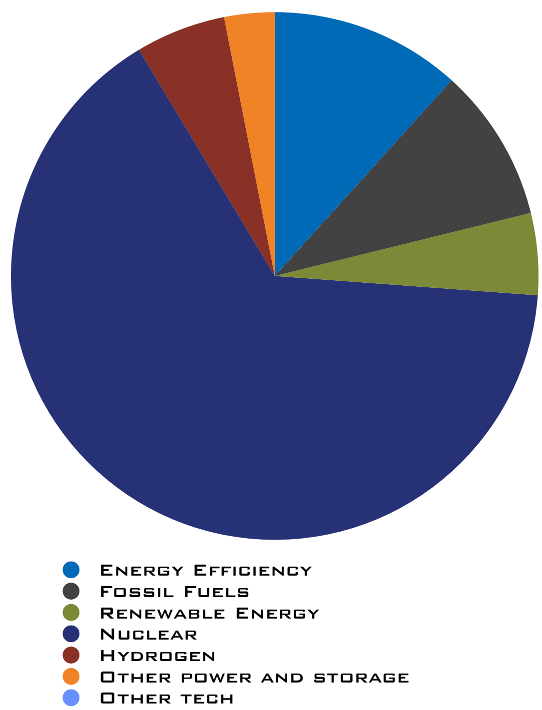
Japan's Council for Science and Technology Policy recently recommended the creation of a national R&D system in order to centralize the management of R&D activities. The council recommended that the government put in place a national process to evaluate R&D activities with respect to their contribution to the technology development roadmap, as well as a process to continuously evaluate international R&D trends and Japan's competitive position in each targeted technology.[78]

Figure 2. Japanese Public Investment in Energy R&D (million US $, 2005-2008)



Source: IEA Energy R&D Statistics, Author's Analysis

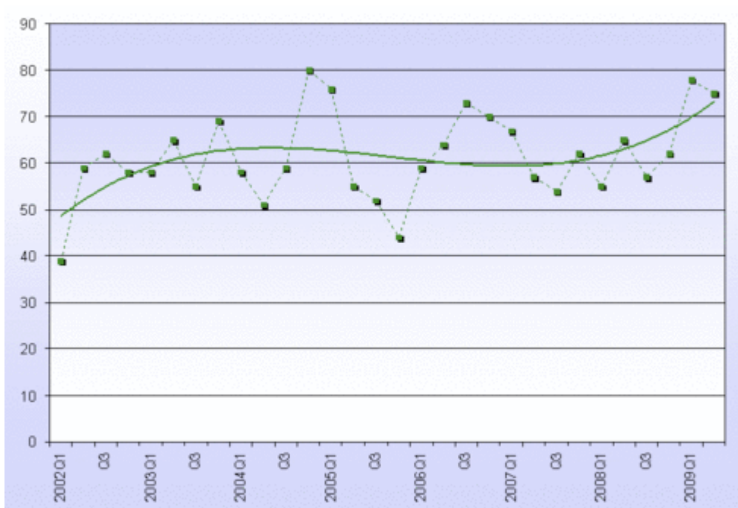
Figure 3. Japanese Energy R&D Budgets, 2008 - Total: $3.9 billion



Source: IEA Energy R&D Statistics, Author's Analysis

Japan has historically been one of the world's most innovative economies in a variety of fields, including clean energy technology. Over the past decade, Japan has consistently rivaled the United States in the invention of new clean energy technology products. In 2005, Japanese companies were awarded nearly 20% of international patents in renewable energy technologies, nearly equivalent to the United States.[79] In the first quarter of 2009, Japanese companies secured 75 of the 274 patents granted by the United States Patent and Trademark Office (USPTO).[80] Honda, the Japanese auto company, has secured the most clean energy patents granted by the USPTO of any company in the world since 2002.[81]

Figure 4. Japanese Clean Energy Patents, 2002-2009



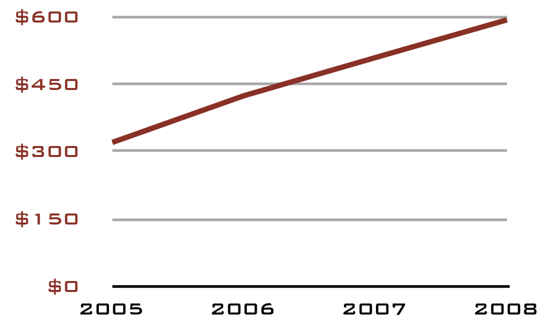
Source: Cleantech Group LLC

South Korea

Over the past few decades, South Korea has steadily increased investments in clean energy R&D, and worked to structure a national energy innovation system to provide targeted support to develop and improve a variety of clean energy technologies. In the 1990s the government established the "Five-year National Plan for Energy Conservation Technology Development (1992-1996)" to develop technologies with large energy saving potential. In 2003, weary of the country's reliance on imported sources of energy, the government established a new "Ten-year Basic Plan for New and Renewable Energy RD&D (2003-2012)," to diversify its energy mix by increasing the contribution of domestic clean energy technologies to overall primary energy supply.[82] The plan establishes goals for different clean energy technologies, designates priority areas for R&D and promotes the commercialization and widespread deployment of different technologies.

The government of South Korea provides targeted R&D support for "core energy technologies" that it deems important to achieving its energy, environment, and economic goals. In 2006, the Korea Institute of Energy Research (KIER), a government agency, created a long-term strategic energy technology roadmap (ETRM) to advance the development and diffusion of clean energy technologies with specific attention to technologies with widespread commercial potential. The major purpose of the technology roadmaps, according to government officials, is to provide policymakers with insight into what direction the country's strategic development of energy technologies should take, given national priorities.[83]

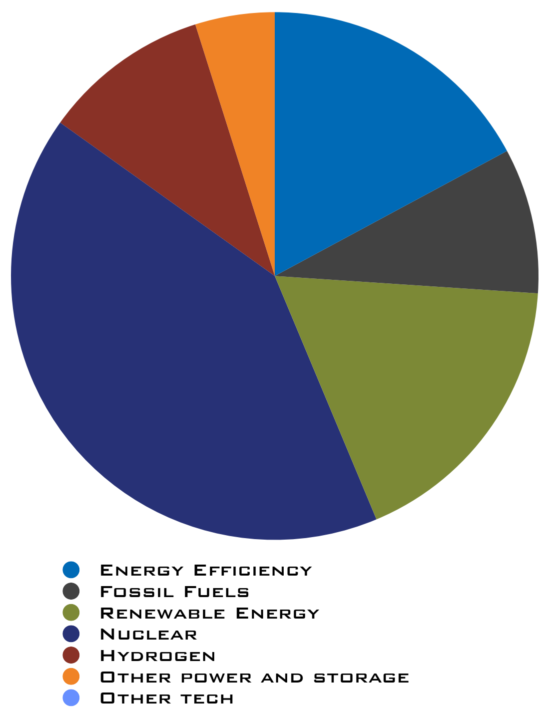
Figure 5. South Korean Public Investment in Energy R&D (million US $, 2005-2008)



Source: IEA Energy R&D Statistics, Author's Analysis

The comprehensive technology roadmaps evaluate both the economic and environmental potential of each technology, as well as the national institutional capacity to develop and advance the technology over time. Using these detailed analyses, the government can provide targeted support for technologies that will contribute the most to energy and climate objectives, as well as those that may provide a competitive advantage for Korean industries. By creating technology roadmaps for each energy technology, the government can benchmark progress toward technology performance improvements and market penetration over time.

Figure 6. South Korean Energy R&D Budgets, 2008 - Total: $595 million



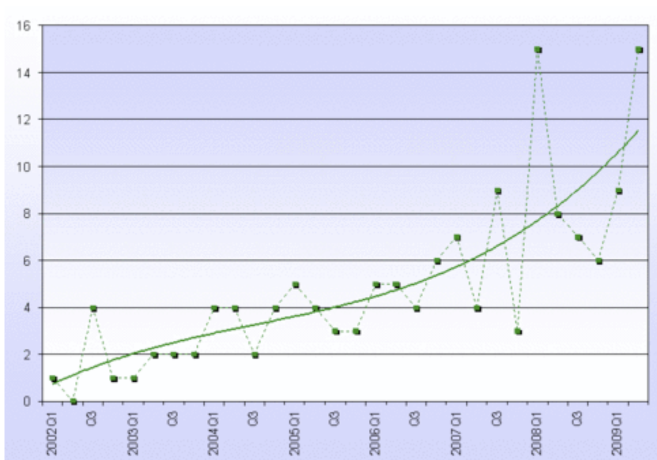
Source: IEA Energy R&D Statistics, Author's Analysis

South Korea's public expenditures on energy R&D have grown by more than 16 percent each year over the last four years, according to the International Energy Agency. In 2008, public investment in energy R&D was $595 million.[84] A majority of the energy R&D investment went to nuclear power (41%), with renewable energy and energy efficiency making up the second and third largest portions of spending, respectively. When South Korea's public expenditures on energy R&D are measured in absolute terms, they are small compared to investment levels in Japan and the United States. However, as a percentage of each nation's GDP, South Korea commits twice as much of its national resources to energy research as the United States.

The government has plans to significantly boost energy R&D spending over the next five years. The South Korean government has embarked on an explicit strategy of "green growth", aiming to link the development of the nation's clean energy technology industries to its long-term economic prosperity. In order to encourage technological innovation, industrial R&D features prominently in this new strategy. As part of South Korea's five-year "Green New Deal" initiative, discussed in "Clean Energy Race" section of this report, the government plans to spend approximately $6.6 billion on clean energy R&D to advance 27 core green technologies, including high-efficiency LEDs, high-efficiency solar batteries, and hybrid vehicles.[85] This investment, amounting to $1.3 billion per year, would double South Korea's current energy R&D investment.

South Korea achieves a sizable number of patents in the clean energy sector, relative to the size of its economy. South Korean companies generated about 2.5% of the 700 renewable energy patent applications that were filed in 2005, placing it 12th in the world, according to the OECD international patent database.[86] South Korean companies have been successful in securing U.S. patents as well. In the second quarter of 2009, South Korea had 15 of the 274 clean energy patents granted by the United States Patent and Trademark Office, placing it fourth behind companies in the United States, Japan, and Germany.[87] The majority of patents filed by Korean companies were for hybrid and electric vehicle technologies.

Figure 7. South Korean Clean Energy Patents, 2002-2009



Source: Cleantech Group LLC

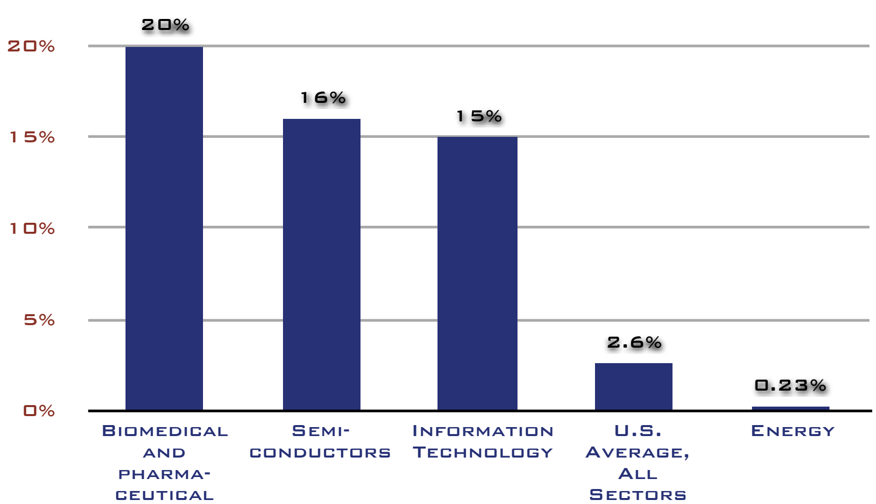
United States

Historically, the United States has been a world leader with respect to innovation in clean energy technologies. The United States invented and commercialized many of the low-carbon technologies currently in wide use today, including solar PV, wind turbines, and nuclear technologies. But over the past two decades, public and private energy R&D spending has dramatically declined, and other nations have largely capitalized on earlier U.S. clean energy innovations.

The United States still leads the world in clean energy patents and maintains some of the world's top research institutions, many of which are becoming increasingly focused on clean energy technology research. In 2005, according to the OECD, the United States was issued 20.2% of international renewable energy patents, the most in the world –although just slightly ahead of Japan.[88] Currently, however, the United States lacks a coordinated and well-funded national clean energy innovation strategy that could sustain or accelerate its current innovation advantage, and both private and public sector investments in energy R&D have remained at historically low levels for decades.

Private firms in the United States spend well under $3 billion annually on energy R&D in an industry with well over a trillion dollars in annual revenue.[89] This is less than one quarter of one percent of revenues (0.25%), and is significantly less than innovation-intensive growth industries such as biotechnology and information technology, which routinely invest 5 to 15 percent of revenue in R&D,[90] and even dwarfed by well established industries such as electronics (8%) and automobiles (3.3%).[91] Despite an expanding energy industry and growing demand for clean energy, private sector investment in energy R&D has fallen by more

Figure 8. Innovation Intensity of U.S. Industrial Sectors (R&D investment as percentage of annual revenues)

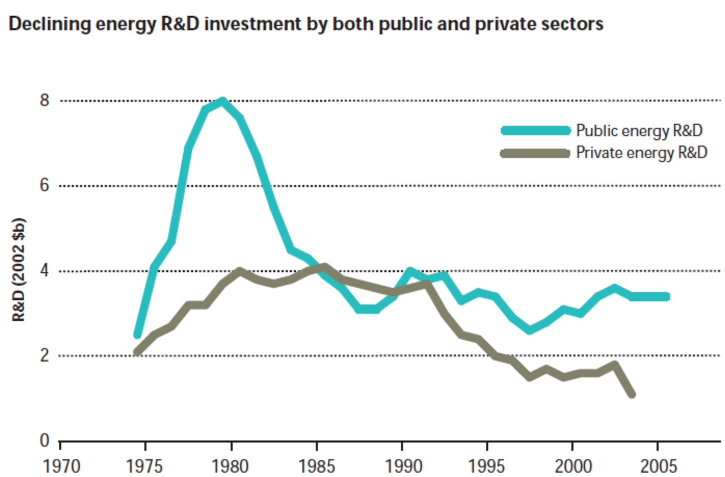


Source: See in-text notes on this page. All values approximate.

than half in recent decades.[92] Private sector investment is now so low that the R&D budgets of individual biotechnology companies now exceed the combined total of private sector investment in energy R&D.[93]

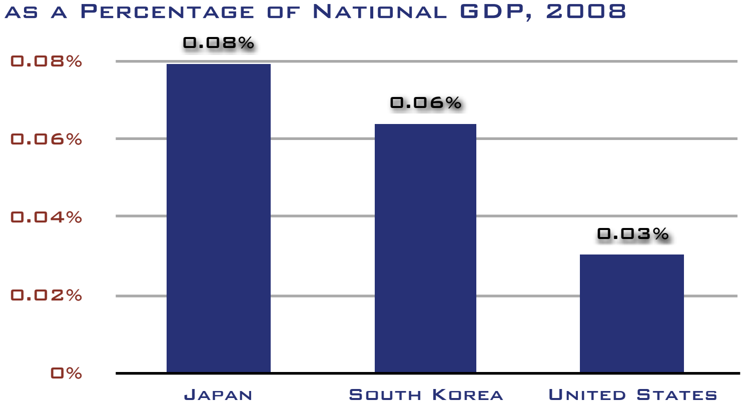
The federal government has failed to sufficiently invest in clean energy research and development to fill the hole left by the lack of private sector investment.[94] Federal funding for energy R&D has fallen to half of peak levels reached during the late 1970s and in 2008, the federal government invested just $4.3 billion in energy-related R&D programs, comprising 0.03 percent of U.S. GDP.[95] As a percentage of GDP, the U.S. government invests less than half as much in energy R&D as South Korea and Japan.[96]

Figure 9. United States Public and Private Energy R&D Investments, 1970-2005



Source: Kammen, Daniel M. and Gregory F. Nemet. "Reversing the Incredible Shrinking Energy R&D Budget." Issues in Science and Technology:, 84 (Sep 2005) at 84-88. p. 85.

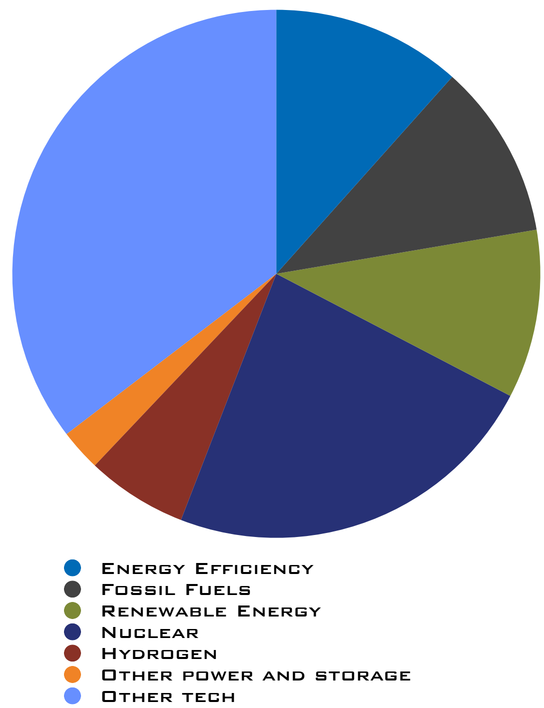
Figure 10. Government Energy R&D Investments as a Percentage of National GDP, 2008



Source: IEA Energy R&D Statistics, Author's Analysis

Federal spending for energy R&D has increased somewhat in recent budget cycles to roughly $5.3 billion in FY2009[97] but remains far lower then federal spending on other key national innovation priorities, including health care research ($30 billion annually) and defense-related research (over $80 billion annually).[98] Federal energy R&D budgets were temporarily augmented by the American Recovery and Reinvestment Act (ARRA), which provided an extra $6 billion to the Department of Energy (DOE) for energy R&D on top of the FY2009 funding request.[99] Many observers worry that the increase in funding will not be sustained;[100] the DOE's energy R&D budget request is $5.4 billion for FY2010, less than 2 percent higher than regular appropriations in FY2009, and less than half of the total 2009 R&D funding under both ARRA and the FY2009 budget.[101] Furthermore, the American Clean Energy and Security Act (ACESA) would channel only an estimated $1.2 billion per year on average to energy R&D at EPA-projected emissions allowance prices, 1.5 percent of the total value of emissions allowances created under the legislation.[102] The potential impacts of ACESA for the clean energy sector in the United States are discussed at length in the "Clean Energy Race" section of this report.

Figure 11. United States Energy R&D Budgets, 2008 - Total: $4.32 billion



Source: IEA Energy R&D Statistics, Author's Analysis

Finally, the United States lacks a coordinated energy innovation strategy and optimal institutional structures to effectively catalyze industrial R&D in clean technologies.[103] Until the establishment of the Advanced Research Projects Agency for Energy (ARPA-E)—initially funded at $400 million in FY2009—the U.S. government has lacked any institution or agency singularly focused on energy research. The U.S. Department of Energy was not created to pursue the types of innovation that can lead to new commercial applications of energy technologies. Originally created from a collection of nuclear weapons-related departments, the majority of the Department's funding and attention still remains focused on managing – and cleaning up after – the nation's nuclear weapons arsenal.[104] The majority of DOE-funded energy research that does exist is primarily centered on the national laboratories, which are not designed to pursue commercial technology applications and have their focus similarly split between a wide range of basic science activities, much of which are not directly energy related, including high-energy particle physics and non-energy related nuclear science.[105] Other DOE offices managing applied R&D programs are responsible for everything from actual research to technology deployment, home weatherization programs, and other loosely related tasks. Organized around individual fuel sources – e.g. the Office of Nuclear Energy or Office of Fossil Energy – these DOE offices also end up overly stovepiped, fragmented and uncoordinated.[106] Unlike competing Asian nations, the United States lacks an agency or ministry directly responsible for industrial technology policy and research, such as the New Energy and Industrial Technology Development Organization (NEDO) in Japan or Korea Institute of Energy Research (KIER) in South Korea.

Clean Energy Manufacturing

As the global clean energy market continues to grow at a rapid pace, economic benefits will accrue to those nations that establish dominance in manufacturing the technologies that underpin the expanding industry. Manufacturing is a traditional engine of wealth creation and jobs growth, and the expanding clean energy sector's demand for manufactured goods will provide a key economic opportunity in coming decades. Manufacturing is especially critical for nations to achieve sustainable job creation objectives; a number of studies have shown that most clean energy jobs are created at the manufacturing level. For example, a 2004 study from the Renewable Energy Policy Project found that every 1 GW of installed wind capacity could potentially create as many as 4,300 jobs, 3,000 of which would be in manufacturing.[107] Companies that are able to manufacture at the highest volume and the lowest cost will be able to achieve economies of scale and capture learning-by-doing advantages, reducing the prices of clean tech products and securing greater industry market share.

While leadership in manufacturing is a necessary component of a comprehensive strategy to lead the global clean energy industry, it is not sufficient. Countries that focus their efforts solely on clean energy manufacturing and lack domestic market demand will likely be overly dependent on clean tech export markets, which are still largely policy driven and therefore unpredictable. This is one reason that China, for example, is building domestic demand for solar photovoltaics after relying heavily on exports to foreign clean energy markets that are now shrinking as a result of the recession, as well as a corresponding drop in public subsidies for solar deployment. Likewise, countries that excel in manufacturing but do not invest sufficiently in R&D will also face the risk of being out-innovated by other nations; a new generation of technologies with better performance may be developed and manufactured elsewhere, taking market share from nations that manufacture only the current generation of technologies.

This section examines the current manufacturing capacity of China, Japan, South Korea, and the United States with respect to the six clean energy technologies surveyed in this report. As this section shows, the United States lags behind its international competitors in clean energy manufacturing. China currently produces the most solar cells of any country in the world, is a leading and rapidly expanding producer of wind turbines, and is emerging as a world leader in developing advanced CCS technology. All three Asian nations have a greater heavy engineering capacity to manufacture components for nuclear reactors than the United States, and the United States is the only of the four nations with no capacity to manufacture high-speed rolling stock. The United States is also playing catch-up in the race to manufacture plug-in hybrid and electric vehicles, and the advanced batteries that will power them.

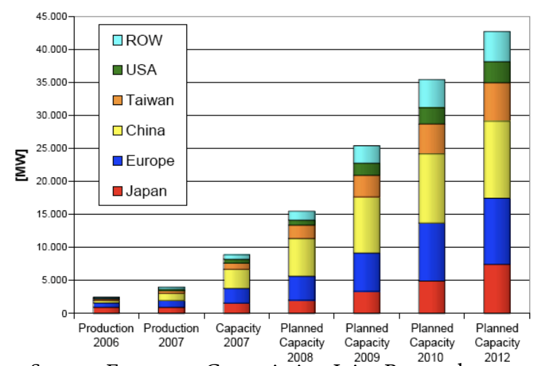
China

China commands an increasingly large share of global clean energy manufacturing, with the world's largest solar manufacturing capacity, a leading wind manufacturing industry, and new efforts underway to take a leading position in plug-in hybrid and electric vehicles and the advanced batteries required to power them. China is also quickly developing the capacity to domestically construct its own nuclear power plants, and is heavily engaged in the development of carbon capture and storage technology (CCS). Finally, China has recently become a leading manufacturer of high-speed rail technology after localizing several designs.

Solar Power

With over 400 solar PV companies and the largest manufacturing capacity in the world, China is already a global leader in low-cost solar manufacturing.[108] In 2008, its solar photovoltaic (PV) production volume was 1.8 GW,[109] rising from 820 MW of production in 2007.[110] Currently, China has one-third of global solar manufacturing capacity[111] and supplies 30 percent of the global PV market.[112] China's largest producer of photovoltaic cells, Suntech, is currently on track to pass Q-cells of Germany to become the second largest PV supplier in the world,[113] with American thin-film company First Solar ranked number one. China is expected to lead worldwide growth in manufacturing capacity.[114]

Figure 12. World Solar Production Capacity and Planned Additions, 2006-2012



Source: European Commission Joint Research Center.

China's solar manufacturing growth to date has been primarily driven by increasing international demand from countries like Spain, Germany, and the United States—China currently exports 98 percent of its manufactured PV output, and is the leading solar exporter in the world.[115] Domestic demand is expected to drive much of the future growth as China turns to more public procurement and puts in place domestic solar PV incentives to reach its domestic renewable energy targets.[116]

Wind Power

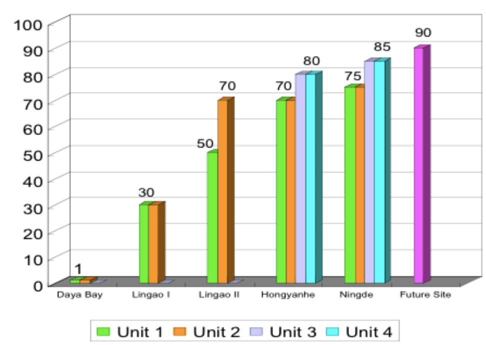
China manufactured 8 GW of wind turbines in 2007,[117] and its domestic manufacturing capacity is expected to reach between 12 GW[118] and 20 GW[119] by 2010. Only five years ago, there was almost no Chinese presence in the wind manufacturing industry. Today, China has at least 70 wind turbine manufacturers, and the top three companies have an annual manufacturing capacity of 4 GW.[120] China's domestic wind manufacturers, two of which are ranked in the top ten globally, were poised to start exporting turbines in 2008.[121] Chinese wind turbine makers and joint-venture manufacturers have also boosted domestic market share from 25 percent in 2004 to 62 percent by the end of 2008, according to the Chinese Wind Energy Association.[122] In 2008, for the first time, domestic wind turbine manufacturers supplied a majority of the domestic market.[123]

Nuclear Power

Of China's 11 currently installed nuclear power plants, three are indigenously designed and constructed and each uses a two-loop Generation II Pressurized Water Reactor (PWR) technology.[124] China's first indigenous power plant, the Qinshan Phase I in Zhejiang province, was completed in 1991 at a capacity of 279 MW. The latter two (Qinshan Phase II, units 1&2) are essentially scaled up versions of the first reactor, and each has a capacity of 600 MW. Of China's eight remaining currently installed nuclear power plants, four apply French reactor technology, two use Canadian technology, and two Russian reactor technology.[125]

The Chinese government recognizes the value of importing foreign technology, but is also keen to achieve self-reliance in nuclear design and construction. China's nuclear manufacturing strategy involves licensing foreign nuclear technology and developing the experience and expertise to domestically source the technology and components for future reactors. China's indigenous reactor focus has been on the Chinese Pressurized Reactor (CPR-1000), a three-loop indigenous Generation II+ PWR design based on a French reactor technology. The first such reactor, completed in 1994 at Daya Bay, was built almost exclusively using foreign parts and labor, with only one percent local content. Since then, however, the localization of CPR-1000 reactors has increased and recently reached 75 percent in 2008, with the construction of the first two Ningde reactors (see Figure 13 at right).[126] The CPR-1000 reactor is being widely deployed for domestic use; of the 17 new nuclear reactors currently under construction, 13 are CPR-1000. The second reactor technology that will figure prominently in China's nuclear future is the AP1000, a Generation III+ passively safe PWR design supplied by the American firm, Westinghouse. Westinghouse has agreed to transfer its technology to China's State Nuclear Power Technology Corporation (SNPTC) after the first four AP1000 reactors are built so that the SNPTC can build the following ones on its own. Two of the reactors currently under construction in China, along with many reactors still in the planning stages, will employ the AP1000 design. Westinghouse also announced in 2008 that it was working with the SNPTC and another Chinese research organization to jointly develop a larger Generation III design

Figure 13. Progressive Locailization of CPR-1000 (Percent of Reactor Components Manufactured in China)



Source: World Nuclear Association

(around 1,400 MW) for large-scale deployment, and possibly for export. Construction of this new reactor type is expected to begin in 2013.[127]

As massive engineering and construction projects, most new nuclear power plants are constructed from parts that come from many different international suppliers, specializing in areas including design, engineering, and project management. One critical issue for accelerating nuclear power plant construction around the world is the availability of heavy forging capacity—plants capable of producing the very large reactor components needed to construct nuclear reactors.

Two Chinese companies currently have the largest forging presses in the world, at 15,000 tons of capacity. Today, China's heavy manufacturing plants can produce about seven sets of pressure vessels and steam generators per year, double its production capacity in 2007. This manufacturing capacity is projected to rise to 20 sets per year by 2015.[128] China is also becoming more advanced in making components for larger reactors. In June 2009, Dongfang Heavy Machinery Co., a Chinese heavy engineering and manufacturing firm, produced the first Chinese-made reactor pressure vessel for a 1000 MW reactor.[129]

Carbon Capture and Storage

Many Chinese companies are involved in CCS projects in China and around the world, and are gaining technical competency in the industry through their participation in international CCS projects. China is already a world leader in CCS technology. American firm GE, itself a CCS leader, recently noted that China is currently more advanced in developing CCS technology than the United States and European countries.[130] A CCS technology developed by China's Thermal Power Research Institute is being licensed for use in the FutureGen project, a 275 MW CCS demonstration plant in the United States and the first commercial-scale plant to use the technology.[131] The same technology is also being used in China's first CCS power plant, GreenGen, which is expected to be operational by 2011. Almost all of the components for that plant are being manufactured domestically.[132]

Advanced Vehicles and Batteries

China has already taken the lead in commercializing plug-in hybrid and electric vehicles. Chinese firm BYD introduced the world's first plug-in hybrid vehicle, the F3DM, at the end of 2008, at least a full year ahead of its competitors in the United States and Japan.[133] BYD plans to introduce the F3DM in the American and European markets sometime in 2010. BYD is also releasing a fully electric car model, the E6, which is targeted for release in China in 2009, Europe in 2010, and the United States in 2011.[134] Another Chinese car company, Chery Automobile Co., will introduce a plug-in hybrid in June 2010, with a sales forecast of 30,000 units over the first three years.[135] Both BYD and Chery are poised to introduce mass-market electric vehicles ahead of their competitors in other countries and all of China's major state-owned and joint-venture automotive companies have announced that they will launch electric vehicle models.[136] Overall, China wants to raise its annual hybrid or electric vehicle production to 500,000 units by the end of 2011, up from 2,100 units in 2008.[137]

The Chinese are also taking a leading position in advanced battery manufacturing. According to 2008 research by the Argonne National Laboratory, the number of battery companies in China increased from 455 to 613 between 2001 and 2004. Between 2000 and 2003, the lithium ion battery industry in China grew at a rate of 140 percent per year, and in 2003, four of the top ten global battery manufacturers were Chinese.[138] By 2008, China's production of lithium ion batteries had accounted for 41 percent of the global market.[139]

High-Speed Rail

As China begins a major expansion of high-speed rail (HSR) networks, the nation has initially relied on technologies licensed and imported from international technology companies. However, China is quickly employing a localization strategy similar to those implemented for other non-indigenous technologies, including nuclear power and carbon capture and storage technology, in an effort to achieve largely domestic manufacturing and production of HSR technologies and components.

China currently operates four high-speed train designs based on technology licensed from Canada's Bombardier, Germany's Siemens, France's Alstom and a consortium of Japanese firms led by Kawasaki Heavy Industries. These designs, now designated China Railway High-speed (CRH) models, are produced by joint ventures between Chinese firms and foreign technology companies or have been entirely transferred to Chinese firms via technology licensing agreements.

A joint venture between Bombardier and China's Sifang Locomotive Co. now produces the CRH1 family of HSR trains, which have been in service on China's railways since 2007. The current generation of the CRH1 design, based on Bombardier technology, is capable of maximum speeds of 155 mph (250 km/h) and is built in Qingdao, in Shandong Province.[140] In 2009, the Chinese Ministry of Rail (MoR) selected the Bombardier-Sifang joint venture to supply 80 next-generation train sets capable of traveling at speeds up to 236 mph (380 km/h) in a contract worth $4 billion (RMB27.4 billion), half of which is expected to accrue to China's Sifang Co. These new trains will also be manufactured in Qingdao with engineering work conducted in Quingdao and at Bombardier centers in Europe.[141]

Sifang is also the manufacturer of the CRH2, a 155 mph (250 km/h) design based on Japanese Shinkansen, or "bullet train" technology licensed from a consortium of firms led by Kawasaki Heavy Industries and including Hitachi, Itochu Corp, Mitsubishi Corp, Mitsubishi Electric, and Marubeni Corp. While the first nine CRH2 train sets were produced in Japan, the technology is now produced entirely in China by Sifang under the terms of a technology transfer deal with the Japanese firms.[142] In October 2009, China's MoR awarded a $6.6 billion (RMB45 billion) contract to Sifang Co. to produce 140 next generation CRH2 train sets capable of 217 mph (350 km/h) speeds, also licensed under a technology transfer agreement with Kawasaski Heavy Industries.[143]

CRH3 trains, used on the Beijing-Tianjin HSR line since 2008, are produced via a joint venture between Germany's Siemens and China's Tangshan Locomotive Works. While the first three CRH3 train sets were produced in Germany by Siemens, the trains have been produced in China by Tangshan since April 2008 with Siemens supplying some components under a technology transfer arrangement. The CRH3 is the first Chinese-built train designed to operate at the current world-standard HSR speed of 217 mph (350 km/h).[144]

Finally, a joint venture between the French firm Alstom and Changchun Railway Vehicles Co. Ltd produces the CRH5, a 155 mph (250 km/h) design based on Alstom's Pendolino line of trains. The trains have been in use since 2007 on Beijing and Harbin routes.[145] Changchun Co., a subsidiary of China CNR Corporation, is investing $366 million (RMB2.5 billion) to establish what will soon become China's largest manufacturing center for high-speed rolling stock (train cars) in the northeastern Jilin province. Changchun will establish a major HSR manufacturing center in the Jilin provincial capital, scheduled for completion in 2010. Once operating, CRC's manufacturing center should be able to reach a production capacity of 800 CRH train cars per year, in addition to ordinary passenger and intra-city train cars, and will play an important role in achieving the 11th Five Year Plan's objective of 1000 CRH trains in use by 2010.[146]

Japan

Japan is a historic leader in solar photovoltaic manufacturing and has long dominated high-speed rail technology. Japan is also a world leader in the production of heavy forged components for nuclear reactors and the preeminent nation in hybrid-electric vehicle technology and the batteries that power them. The nation has a relatively small, export-oriented wind manufacturing industry. Japan is actively developing CCS technology, also with aims for global export.

Solar Power

Japan ranks third in the world in PV cell manufacturing capacity, behind China and Germany and its cumulative solar cell manufacturing capacity was approximately 1,768 MW in 2008, accounting for 13 percent of global manufacturing capacity. Japan added approximately 350 MW of manufacturing capacity over its 2007 total. In 2008, Japan produced 1,172 MW of solar cells, accounting for 17 percent of the global total, and an increase of approximately 280 MW from 2007 production levels.[147] Japan's domestic cell production has steadily increased each year, and until 2007 the country was the leading solar cell manufacturer in the world. In recent years, however, Japan's share of world PV production has declined—falling from a dominant 48 percent of global production in 2004—as China has dramatically boosted solar cell production and become the dominant PV exporter in the world.[148]

Wind Power

Japan does not supply a large portion of the world's wind turbines, in part because Japan's domestic wind market is small compared to other nations. As a result of the lagging domestic market for wind turbines, Japan's largest manufacturers have begun expanding overseas. The majority of sales for Japan's wind energy companies come from turbines that are deployed in other countries.[149] Japan now has four wind turbine manufacturers; Mitsubishi Heavy Industry, Fuji Heavy Industry, Japan Steel Works (JSW), and Komai Tekko.[150] Mitsubishi, Fuji, and JSW each manufacture 2-MW class turbines. The largest manufacturer is Mitsubishi, which currently supplies 19 percent of Japan's domestic market.[151]

Nuclear Power

Japan is a leader in nuclear technology development. After importing its first nuclear reactor from the UK in the 1960s, the country began to adopt a strategy whereby Japanese utilities purchased designs from U.S. companies and built reactors with the co-operation of Japanese companies, who later licensed the technology to build subsequent nuclear power plants in Japan on their own.[152] Through this system, companies like Hitachi, Toshiba, and Mitsubishi Heavy Industries—some of Japan's nuclear heavyweights today—developed the technical competency to design and construct light water reactors (LWRs) on their own. By the early 1980s Japan had established a domestic nuclear industry and today it exports nuclear power plants to countries in East Asia and Europe.

The majority of nuclear power plants constructed in Japan have featured a standard PWR or BWR Generation II design, but Japanese firm Hitachi (jointly with American firm General Electric) has also developed a Generation III reactor, the Advanced Boiling Water Reactor (ABWR), which has been operating in Japan since 1996. Mitsubishi is also developing an Advanced Pressurized Water Reactor (APWR) technology for reactors that is expected to be ready for commercial application in the next few years.[153]

Japan has the largest heavy forging capacity in the world. The largest and most well-known heavy forging supplier is Japan Steel Works (JSW), which produces large forgings for reactor pressure vessels, steam generators, and turbine shafts, and holds 80 percent of the world market for large forged components for nuclear power plants. At present, JSW has the capacity to produce four reactor pressure vessels and associated components each year. In December 2008, however, it announced that it would triple its capacity by 2012, buoyed by new agreements to supply the many new nuclear power plants that will be deployed around the world in the coming decade.[154]

Carbon Capture and Storage

A number of Japanese firms are engaged in international CCS projects, and supply technology for CCS demonstration plants. Mitsubishi Heavy Industries (MHI) is one CCS technology leader in Japan, and has developed a carbon capture technology, known as the KM-CDR process, which will soon be demonstrated at a coal-fired power plant in Alabama to capture carbon dioxide emissions from the equivalent of 25 MW of generating capacity.[155] MHI's technology is also being provided for use in the 530 MW ZeroGen project in Australia which, when completed in 2015, aims to be the world's first commercial-scale Integrated Gasification Combined Cycle (IGCC) plant equipped with CCS technology.[156] Toshiba, the well-known Japanese electronics company, recently entered the CCS market and is testing a post-combustion technology on a pilot plant in Japan, which aims to eventually trap up to 90 percent of the plants pollutants.[157] Other Japanese CCS technology leaders are IHI Corporation and JGC Corporation.

Advanced Vehicles and Batteries

Japan dominates global manufacturing of hybrid-electric vehicles. The Toyota Prius accounted for 73 percent of world hybrid sales through 2007,[158] and cumulative sales of hybrid vehicles manufactured by Japan's largest auto company, Toyota, topped 2 million in 2009.[159] Due to recent surges in worldwide demand this year, Japanese factories have implemented overtime in order to produce 50,000 Priuses per month.[160]

Japanese car firm Mitsubishi began selling the i-MiEV, the first mass-produced fully electric vehicle in the world, on the Japanese market in July 2009.[161] Japan's other major car companies will soon produce electric vehicles as well. Nissan plans to sell electric vehicles in Japan, the United States, and Europe around the end of 2010. Toyota is looking to begin sales in 2012, and Honda has announced that it plans to manufacture and sell electric vehicles in the United States by 2015.[162]

Japan is also a world leader in vehicle battery manufacturing and is the world's top producer of the nickel-metal-hydride batteries used in current-generation hybrid vehicles. Panasonic alone accounts for 83 percent of the world's nickel-metal hydride batteries used in vehicles. By the early 2010s, it plans to make enough batteries for 1 million hybrids annually.[163] Japan is also a leader in the production of advanced lithium-ion batteries—a technology that many market analysts expect to dominate in the emerging plug-in hybrid and electric vehicle industry. Currently, Japan is home to eight of the world's ten leading battery manufacturers.[164] Japan, China, and South Korea collectively manufacture 87 percent of the world's lithium-ion batteries.[165]

High-Speed Rail

As the first country to deploy high-speed rail technology in 1964, Japan is a world leader in HSR technology and has a significant and established HSR manufacturing sector. Fourteen different domestic HSR designs currently operate on Japan's well-established high speed network, and Kawasaki Heavy Industries, Mitsubishi Heavy Industries, and Hitachi all dominate domestic manufacturing of HSR rolling stock.[166]

Japan intends to dominate global market share of HSR technology and the nation's HSR manufacturers play a significant international role, as its technology experience and manufacturing services are contracted for high-speed rail projects all over the world. Japan has been working to reap profits from its long-time HSR technology experience by implementing a campaign to license and export Japanese Shinkansen, or "bullet train" HSR technology and components to countries around the world.

Japanese firms have already been a major beneficiary of China's rapid expansion of HSR lines. Kawasaki Heavy Industries has licensed its HSR technology to China's Sifang Locomotive Co., the recent recipient of a $6.6 billion contract to build train sets under a technology transfer arrangement with the Japanese industrial conglomerate.[167] Mitsubishi is similarly playing an instrumental role in bringing HSR to India, who aims to create a bullet train line connecting Mumbai and Delhi. Towards this end, the Japanese government has plans to extend India $4.5 billion in loans for the project.[168] In 2007, Kawasaki, Mitsubishi, and Hitachi formed a consortium to supply the trains for Taiwan's bullet train service as well.[169] In February 2009 the British government gave a Hitachi-led consortium of companies preferred bidding status for a $10 billion dollar contract to build and maintain potentially 1,400 train cars over the next two decades.[170] The first UK high-speed commuter line began limited operation in June 2009 using Hitachi's Javelin train cars. The line will offer full service beginning in December 2009.[171]

Japanese Shinkansen, or "bullet trains" may even appear on future U.S. high-speed rail lines. Today, many of Japan's own lines use N700 technology, a model the chairman of Japan's primary railway operator, JR Tokai, has been working hard to convince U.S. Transportation Secretary Ray LaHood, to adopt in planned HSR projects.[172]

South Korea

South Korea's clean energy manufacturing industry is at an early stage of development but is expected to grow rapidly in the near future, with new efforts to increase capacity and market share in solar, wind, and advanced vehicle manufacturing. South Korea does not currently manufacture carbon capture and storage technology but is a leading global manufacturer of nuclear power plants and high-speed rail.

Solar Power

South Korea's domestic solar cell manufacturing is relatively small but is growing quickly. Total solar cell production by domestic firms reached 60 MW in 2008.[173] In 2008, two of South Korea's largest flat-panel display companies, Samsung Electronics and LG Electronics, announced that they would begin making solar photovoltaic cells in 2009.[174] Korean market analyst DisplayBank projects that South Korea's solar cell manufacturing capacity will grow to 4.5 GW of solar modules by 2012, a dramatic increase from a production capacity of less than 200 MW in 2008.[175]

Wind Power

As with solar manufacturing, South Korea's wind turbine manufacturing sector is nascent but growing quickly, and several domestic firms have started producing wind turbines over the past few years, a trend that is expected to grow. In one recently signed deal, South Korean company Unison will supply 2 GW of wind turbines over the next five years to Liaoning, a Chinese province.[176] Notably, two of the largest shipbuilding firms in the world—Hyundai Heavy Industries (HHI) and Samsung Heavy Industries (SHI)—have recently decided to manufacture wind turbines. SHI plans to build a production plant with an initial production capacity of over 500 MW,[177] and HHI will enter the wind turbine manufacturing market with a $710 million dollar facility that is expected to have an annual output of 800 MW in 2010. The facility will initially target the U.S. export market while the government implements policies to drive domestic market creation and reach targets for domestic renewable energy deployment.[178]

Nuclear Power

South Korea relied on imported technology from American firm Westinghouse and French firm Areva for its first ten Generation II pressurized water reactors (PWRs), the last of which went into commercial operation in 1996. In 1987, the Korean nuclear industry initiated a long-term plan to standardize the design of its nuclear plants and achieve technical self-sufficiency. Since then, the Korean Standard Nuclear Power Plant (KSNP), later re-branded Generation II OPR-1000, has become a recognized design throughout the world, and the domestically designed and constructed power plants were used for the last six power plants constructed in South Korea.[179] South Korea is also constructing four reactors using a domestic Generation III technology, the APR-1400, which offers reduced costs of about 20 percent and an enhanced design life of 60 years. The first of these 1450 MW reactors is under construction and expected to begin operation in 2013.[180]

Doosan Heavy Industries is South Korea's largest heavy forger, and one of the largest in the world. It currently operates a 13,000 ton press, and is undertaking a major investment in forging capacity, including a 17,000-ton press that will be the largest in the world and is expected to be operational 2010.[181]

Carbon Capture and Storage

South Korea does not currently have any companies substantially engaged in CCS projects, but the government has recently announced plans to develop domestic CCS technology and construct a CCS power plant in the country (See "Clean Energy Race" section below).

Advanced Vehicles and Batteries

South Korea is also aiming to strengthen its competitive position in advanced vehicle production. Korean automaker Hyundai entered the hybrid-electric market in July with the release of the Elantra Avante liquid petroleum gas (LPG)-electric model car. The Elantra Avante hybrid is the world's first LPG-electric hybrid to be manufactured and the world's first hybrid to feature advanced lithium-ion polymer battery technology.[182] Hyundai aims to produce 7,500 vehicles in 2009 and 15,000 in 2010 for the domestic market.[183] Hyundai also plans to introduce a gasoline-electric hybrid in the U.S. in 2010 using the same battery technology,[184] as well as a plug-in hybrid and electric vehicle model, both available globally by 2012.[185]

South Korea is a player in the global advanced battery market as well. Most notably, Korean company LG Chemical was chosen by American company General Motors to supply the lithium-ion batteries for the forthcoming Chevrolet Volt plug-in hybrid.[186] One market research firm estimates that the two largest Korean battery makers, LG Chem and Samsung SDI, may seize more than 30 percent of the electric car battery market by 2020, a market that is projected to be valued at $36 billion.[187]

High-Speed Rail

When South Korea became the second Asian nation to deploy high-speed rail in 2004,[188] it also insisted on developing the capabilities to manufacture its own rolling stock. Like China, South Korea licensed technology for use on its Korea Rail eXpress (KTX) HSR line from foreign companies – in this case French firm Alstom's TGV trains – but quickly localized production through a technology transfer arrangement. While the first twelve train sets in use on the KTX were manufactured by Alstom, the next 34 were produced in South Korea by Hyundai Rotem using 58 percent domestic technology.[189]

Hyundai Rotem launched the KTX-II in November 2008, a 205 mph (330 km/h) rated design based on the Korean-designed HSR-350X prototype, the result of a decade-long government-led R&D effort to develop indigenous HSR technology. The KTX-II earns South Korea the distinction of being on the fourth nation in the world to develop HSR technology rated for operating speeds greater than 300 km/h. According to Hyundai Rotem, the trains use 87 percent South Korean technology, with additional components supplied by overseas technology vendors. Hyundai Rotem aims to export the KTX-II to HSR projects in Turkey, Brazil and Australia.[190] Hyundai Rotem is now producing at least 19 KTX-II train sets for deliver to Korail, the operator of the Korea Train Express, in 2009 and 2010.[191]

United States

U.S. manufacturing of clean energy technologies lags behind its international competitors on almost all fronts. The United States is outpaced by at least one of its Asian competitors in the production of solar cells, wind turbines, and components for nuclear power plants, and currently has no domestic high-speed rail manufacturing capacity. The United States is also in danger of falling behind in the development of CCS and advanced vehicle technology and is already a laggard in the production of advance batteries for hybrid and electric vehicles.

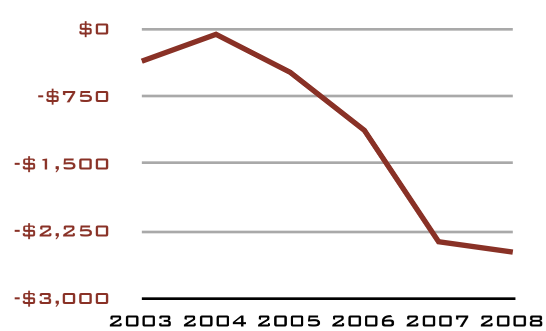
Solar Power

At the end of 2008, the United States had 952 MW of cumulative solar PV manufacturing capacity, accounting for nearly 7 percent of the global total.[192] The U.S. production of solar cells was far lower, amounting to only 5 percent of the global total, a new low. At 375 MW of cells produced in 2008, the United States remained behind China (1.8 GW),[193] Taiwan, Japan, and a number of European countries in the global marketplace.[194] While U.S. total manufacturing share of solar PV has declined, thin film solar technology remains the United States competitive strength. The thin film segment grew to 13 percent of the overall solar market in 2008.[195] While U.S. thin-film company First Solar is the leading thin-film producer globally, and is expected to be the number one solar PV producer in 2009, the large majority of its cell production occurs overseas; of the 1.2 GW of cell production capacity operating or announced by First Solar, less than 20 percent exists in the United States.[196]

Wind Power

In 2007, the United States manufactured 2.4 GW of wind turbines,[197] compared to 8 GW of wind turbines in China.[198] The value of U.S. imports of wind-powered generating sets has increased from $365 million in 2003 to $2.5 billion in 2008, while the United States has never exported more than $84 million of wind turbines in any year during that period.[199] In 2008, the United States imported roughly 50% of the components for the 8.5 GW of wind turbines it installed in 2008, a share that is expected to shrink as foreign manufacturers build more plants in

Figure 14. U.S. Trade Deficit in Wind Turbine Components (million US $, 2003-2008)



Source: U.S. Department of Commerce, Author's Analysis the United States to cut down on transportation costs.[200] Even though the United States has the largest wind market in the world, only one of the top ten wind turbine manufacturers in the world is American.[201]

Nuclear Power

Virtually all of the 104 nuclear reactors operating in the United States employ American technology. There are 69 Pressurized Water Reactors (PWRs) and 35 Boiling Water Reactors, all of which became operational in the 1970s.[202] The United States was an early pioneer of nuclear power development. American firm Westinghouse designed its first fully commercial PWR in 1960. Though there have been no new construction starts in the United States since 1977, some U.S. firms are still involved in developing new reactor technology for deployment elsewhere. The Department of Energy and the U.S. nuclear industry developed four advanced reactor types.[203] One is an advanced boiling water reactor (ABWR) derived from an earlier GE design. These reactors are already operating in Japan. A second is the Generation III System 80+, the design features of which have largely been adopted by South Korea for their domestic APR-1400 reactors, which will be marketed around the world soon. A third American reactor type is the Westinghouse designed AP-1000 reactor, a Generation III+ passively safe design, the first of which is under construction in China. U.S. company GE Hitachi Nuclear Energy has also developed a Generation III+ reactor, the Economic Simplified Boiling Water Reactor (ESBWR), which is still awaiting design certification.[204]

The United States has seen a decline in nuclear engineering facilities.[205] In the mid 1980s there were 440 U.S. facilities accredited to produce components for nuclear power plants. In 2008, there were 255 such facilities.[206] The United States currently has only one manufacturer with heavy forging capacity to produce nuclear reactor pressure vessels. Lehigh Heavy Forge, in Bethlehem, Pennsylvania, has been operating for more than a century and has the largest press in North America at 10,000 tons, but there are currently no plans for expansion of heavy forging capacity in the United States.[207]

While the United States does not have the capacity to produce ultra heavy forgings, a recent study of the domestic nuclear energy industry concluded that, of the hundreds of components that make up a nuclear plant, only two cannot currently be produced in the United States.[208] According to a recent analysis, there is an adequate supply of other key components for the construction of four to eight nuclear power plants, but more aggressive plant construction rates would create constraints in the U.S. manufacturing supply chain.[209]

Carbon Capture and Storage

The United States was an early leader in carbon capture and storage (CCS) technology, and is one of the leading nations in the world in CCS development. The U.S. government has been investing in CCS R&D since the early 1990s.[210] Several U.S. engineering and oil and gas exploration companies are developing products and services for various components of the CCS process. American company GE is an industry leader in developing integrated combined cycle gasification (IGCC) technology, which enables pre-combustion capture of carbon dioxide for storage. GE built a full-scale 250 MW project in 1994 in Tampa, Florida.[211] Battelle Memorial Institute, based in Ohio, is one of the world's leaders in the development of CCS technology. They are involved in the U.S. FutureGen project and are currently consulting for Japan's largest CCS consortium, the Japan CCS Company Limited, to help demonstrate CCS technology in Japan.[212] A number of other firms are developing technologies to enable pre- and post-combustion capture of carbon dioxide, as well as geologic sequestration processes.

Advanced Vehicles and Batteries

The United States lags behind Asia in both advanced battery development and hybrid and electric vehicles. Of the more than 1 million hybrid vehicles sold in the United States through 2007, over 93 percent were manufactured by foreign companies.[213] The United States is playing catch-up in the race to develop and commercialize plug-in hybrid and electric vehicles as well. One market research firm estimates that while China has plans to produce 500,000 hybrid or all-electric vehicles in 2011, Japan and South Korea will produce 1.1 million hybrid or all-electric vehicles by the end of 2011, and North America is expected to produce just 276,000.[214] The first American company to manufacture electric vehicles in serial production for commercial sale (as opposed to fleet evaluation or prototyping) is Tesla Motors. Tesla manufactures 25 vehicles per week, with components sourced from Europe (UK and France), Asia (Taiwan), and the United States.[215] The first American plug-in hybrid, the Chevrolet Volt, is scheduled for release in 2010 and will compete with a plug-in version of the Toyota Prius, which will be introduced a full year earlier,[216] as well as BYD's mass-produced plug-in hybrid, already on the market in China. BYD has plans to sell this model in the United States in 2010.[217] Ford is also developing both a plug-in hybrid and electric vehicle model, but will likely not introduce either until 2011 or 2012.[218]

With respect to advanced battery manufacturing capacity, the United States is currently in a poor position to compete in what is expected to be a lucrative new industry. As most hybrids sold to date have come from Asian manufacturers, most of the batteries used for new generation vehicles have been developed in Asia. The United States is home to only two of the top ten battery manufacturers in the world.[219] Domestic companies entering the hybrid-electric business like Ford and GM are purchasing batteries from Asian suppliers.[220]

High-Speed Rail

The United States ceded its place in the heavy manufacturing of rolling stock by choosing not to compete when Japan first introduced high-speed rail in the 1960s. Today, the United States does not manufacture any high-speed rolling stock and all future high-speed rail plans will require international imports, although the United States could alternatively pursue domestic technology development or technology transfer arrangements similar to the strategies successfully employed to localize HSR technology manufacturing by China and South Korea. While negotiations are still underway, at this point Japan appears to be leading the pack to win a deal to provide the rolling stock for the planned California HSR line, likely the first HSR line to be constructed in the U.S.[221]

Domestic Clean Energy Markets

Developing and deploying domestic clean energy generating capacity is critical to competitiveness in the clean energy sector. Large domestic demand can help attract leading clean energy companies to do business within the country and may lead firms to relocate parts of their manufacturing and supply chain operations to areas where domestic demand is greatest.

As with R&D and manufacturing-focused strategies, however, domestic clean energy market demand is only one critical component of a comprehensive strategy to achieve economic leadership in the global clean technology sector. Nations lacking a strategy to develop and manufacture clean technologies domestically will be highly dependent on clean tech imports to meet domestic demand, widening the nation's trade deficit. Furthermore, such nations will lose out on creating and attracting new value-added industries along the technology value chain and the future engines of economic growth that emerge from a strong domestic manufacturing base. Finally, without pioneering their own R&D efforts, nations with strong domestic demand for clean energy will be reliant on other countries to improve the price and performance of the technologies they increasingly rely on.

This section examines the current state of domestic clean technology markets in China, Japan, South Korea, and the United States, as well as its implications for overall economic competitiveness in the clean energy sector. Domestic market development is measured by new installed clean energy generating capacity, as well as total cumulative installed capacity. For the advanced vehicle sector, market development is measured by the expected introduction dates of mass-market hybrid and electric vehicles. CCS market development is measured by the number of demonstration sites active within each nation and high-speed rail is measured by the amount of track laid in each nation. As this section shows, the United States lags behind its competitors in domestic market development for nuclear power and high-speed rail. The United States leads each of its three Asian competitors in market size for wind power, solar PV, and CCS, but other nations are quickly catching up. China will soon surpass the United States as the world's largest market for wind power, and is expected to be one of the largest markets for solar PV in the near future.

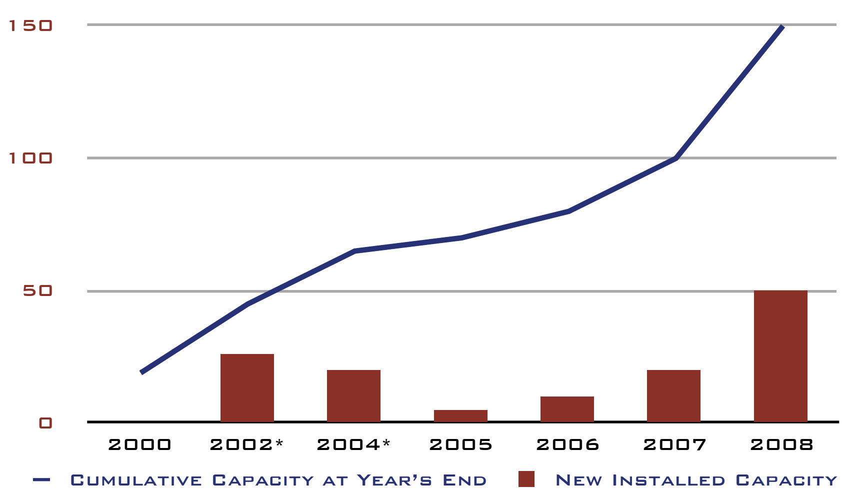
China

In 2008, China had a total installed electric power capacity of 792 GW.[222] Since then, total capacity has been increasing at a rapid rate, and is projected to reach about 1400 GW by 2020, according to the International Energy Agency.[223] China continues to meet its growing energy demand largely through the use of fossil fuels, but its renewable energy sector is expanding rapidly as well, and it is on pace to lead the world in deployment of many clean energy technologies. In 2008, China for the first time attracted more renewable energy capital investment than the United States.[224] China is rapidly increasing its deployment of new nuclear power plants, and is viewed internationally as a major market for the demonstration and deployment of CCS technology. China's automobile market has grown to the largest in the world, but higher-cost advanced vehicles currently have difficulty selling in the Chinese market. China is also in the midst of the expanding the nation's high-speed rail network to become the largest in the world, with plans to link all connect all major Chinese cities.

Solar Power

In 2008, China's domestic market (new installed capacity) was 50 MW, bringing cumulative deployed capacity of solar PV to 150 MW, a relatively modest size, given China's manufacturing prowess in solar PV technology. China's domestic PV market is growing rapidly, however, with 2008 installations growing 200 percent over new installations in 2007.[225] China's solar PV market, though relatively small compared to solar heavyweights such as Spain and Germany, still ranked seventh in the world.[226] China's domestic market is set for substantial and sustained growth due to recently enacted policies to support the development of the industry, and may soon become one of the largest in the world due to new solar incentives, discussed in the "Clean Energy Race" section of this report.

Figure 15. Chinese Installed Solar Power Capacity, 2000-2008 (Megawatts Capacity)

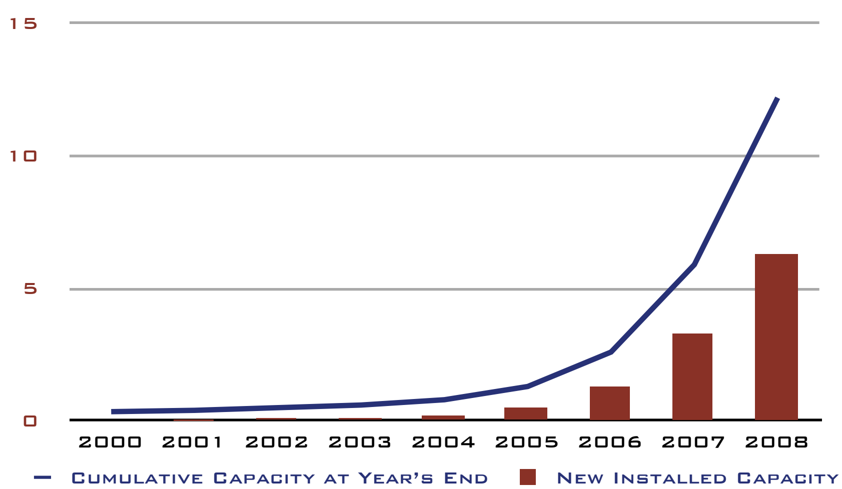


Source: China Greentech Initiative;
* New installed capacity for two-year period in 2000-2002 and 2002-2004

Wind Power

After beginning from a low base of 350 MW of installed wind power generating capacity in 2000, China has doubled its wind energy capacity in each of the last four years and is expected to nearly double its capacity again this year, according to the Global Wind Energy Council (GWEC). China's cumulative installed capacity at the end of 2008 was 12.2 GW, ranking it fourth in the world behind the United States, Spain, and Germany. China had a newly installed wind capacity of 6.3 GW in 2008, making its market for wind power second only to the United States, which installed 8.4 GW.[227] The GWEC predicts that in 2009 China will surpass the United States and lead the global market for wind power.[228] In the first half of 2009, China had already installed 4.4 GW of new capacity.[229] Notably, there have been some problems with grid connection that have hampered the effective development of China's wind sector. In 2008, more than 20 percent of China's installed wind turbines were not connected to the electrical grid, and thus did not generate any electricity.[230] The Chinese government is currently investing heavily in grid network expansion with hopes of addressing this issue in the future.

Figure 16. Chinese Installed Wind Power Capacity, 2000-2008 (Gigawatts Capacity)



Source: Global Wind Energy Council, "Global Wind 2008 Report"

Nuclear Power

With 11 nuclear power plants in operation, China's installed nuclear capacity stands at approximately 9 GW, which places it 11th in the world in deployed nuclear capacity. China's first three nuclear power plants began commercial operation in 1991, with a total net capacity of 1.23 GW. No new reactors were built until 2002, as a result of the dominant belief that cheap and abundant coal obviated the need for further nuclear development.[231] In recent years, domestic concerns over pollution and climate change have led to a higher prioritization of nuclear power as a source of electricity. From 2002-2004, six new nuclear power plants totaling 4.4 GW were built. The last two nuclear plants were completed in 2007, and at 1 GW each, are the largest plants currently in operation in the country. Although China's deployed nuclear power capacity amounts to only 1.2% of the country's total electric capacity, it has recently put in place a number of policy provisions, discussed in the "Clean Energy Race" section of this report, which will dramatically boost nuclear power generation and make China one of the largest markets for the technology worldwide. China currently has 17 additional reactors under construction, and many more in the planning stages.[232]

Carbon Capture and Storage

China has two major domestic CCS efforts currently underway. The first is GreenGen, an integrated gasification combined cycle plant (IGCC), approved for construction in June 2009. GreenGen will be China's first commercial-scale IGCC facility equipped with CCS technology.[233] The first stage, to be completed by 2011, is to build a 250 MW IGCC power plant with a domestic gasifier. A 400 MW demonstration plant equipped with CCS technology will be completed by 2016, as part of the last stage of the project.[234] The aim is to capture 25,000 to 35,000 tons of CO2 per year starting in 2012.[235]

There have also been a number of joint international partnerships established to explore regional opportunities for carbon capture and storage in China. One of the key initiatives is the Cooperation Action within CCS China-EU (COACH), jointly managed by China and the European Union. The goal of the project is to develop and demonstrate advanced, near-zero coal emissions technology in China and the EU. Phase II of the project, started in 2008, is a site-specific design of a demonstration plant, and Phase III (to be completed by 2020), will be the construction and operation of a full-scale coal-fired demonstration plant with near-zero emissions CCS technology.[236]

Advanced Vehicles and Batteries

Automobile sales in China have been surging over the past few years, and sales in China hit a monthly record of 1.1 million vehicles in March 2009, exceeding U.S. sales for the third month in a row. However, hybrids and electric vehicles account for only 0.01 percent of Chinese passenger-vehicle sales.[237] Hybrid vehicles do not sell well in China relative to their conventional competitors. Since Toyota entered the Chinese market in the beginning of 2006 with its Prius hybrid, the most popular in the world, it has only sold 2,500 vehicles and only 558 vehicles were sold in 2008. The higher price for hybrid vehicles is the main factor limiting their penetration of the Chinese market; the Toyota Prius sells for two to three times the cost of gas-powered alternatives in China.[238]

The story is much the same thus far in the emerging plug-in hybrid and electric vehicles sector. Since Chinese battery firm BYD introduced the first mass-market plug-in hybrid in China in 2008, the firms sold fewer than 100 units in China over the first eight months.[239] Priced at about $22,000, the cost of the plug-in hybrid is still prohibitively high for many Chinese consumers. BYD and other car firms in China are eagerly awaiting the announcement of government subsidies for private buyers to purchase "new energy vehicles," which many firms hope will boost their sales.[240] China will also have an electric car, BYD's E6 model, on the market by the end of 2009.

High-Speed Rail

China's current high-speed rail capacity includes 115 miles (185 km) of high-speed lines[241] as well as 19 miles (30 km) of high-speed magnetic levitation railway (Maglev), the world's first and only commercial Maglev line deployed in 2004 to connect Shanghai airport with the city center.[242] The Maglev system uses magnets to propel the train at speeds of up to 270 miles per hour (430 km/hr).

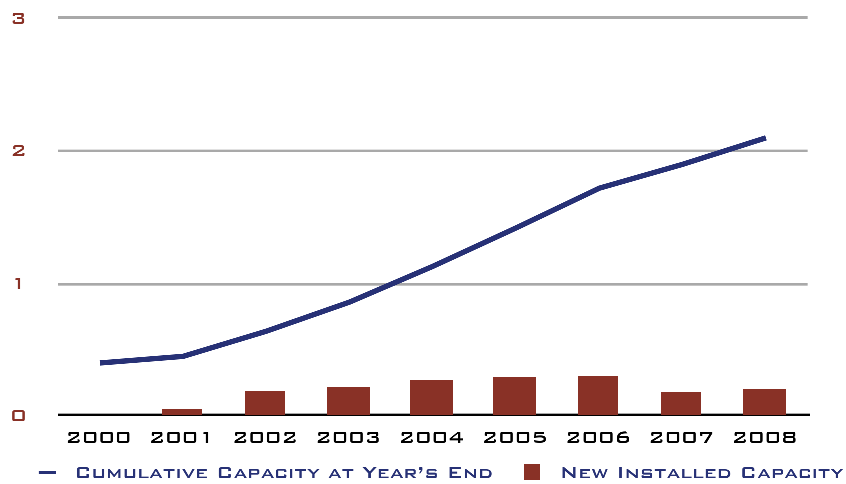
Japan

Japan ranks third behind the United States and China in total electricity generation with 262 GW of capacity.[243] Nuclear power accounts for around 30 percent of Japan's electricity generation.[244] Hydro accounts for close to 8 percent, and other renewable energy sources still contribute little to the nation's electricity mix. Japan does not currently have a large market for wind power. Japan will continue to rely on nuclear power for the foreseeable future, and has many new plants either under construction or planned. Japan has just recently commenced domestic projects to demonstrate CCS technology. The country is expected to be one of the world's largest markets for advanced vehicles, and a number of auto companies are gearing up production for the Japanese market. For more than 30 years, Japan has operated a fully integrated national high-speed rail system.

Solar Power

Japan has historically been a world leader in the development and deployment of solar photovoltaic technology. Japan's cumulative installed solar PV capacity was 2.1 GW at the end of 2008, ranking it third in the world behind Spain and Germany. Japan's newly installed PV capacity was 230 MW, accounting for 4 percent of total additional global capacity, and ranking it sixth in PV capacity additions. While cumulative deployed PV capacity grew at a rate of 28 percent annually from 2000 to 2006, it has grown only 6 percent annually over the past two years. Japan's domestic market peaked in 2006 at 300 MW, and new additional capacity has stagnated since.[245] The decline in new capacity growth is due primarily to a government decision to discontinue a residential PV installation subsidy in 2005. The Japanese government has since redoubled its efforts to grow its domestic solar energy industry, and is aiming for a twenty-fold expansion in solar over the next decade (See the "Clean Energy Race" section of this report).

Figure 17. Japanese Installed Solar Power Capacity, 2000-2008 (Gigawatts Capacity)

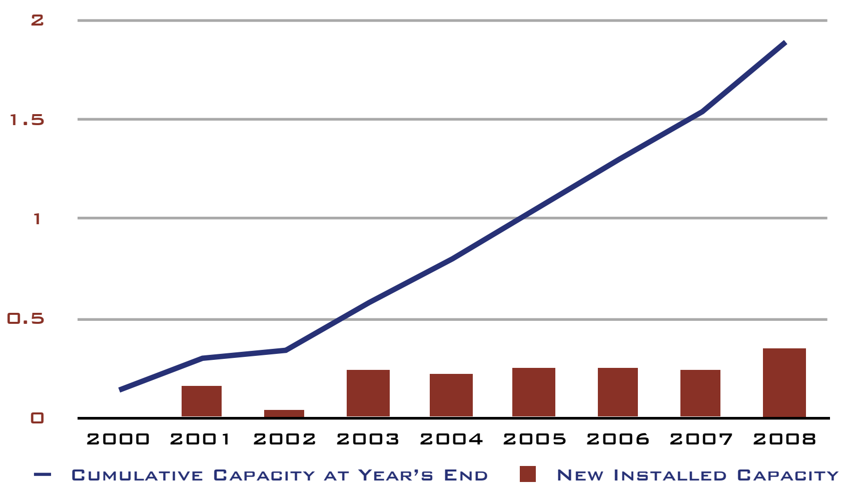


Source: 1) Robert Foster, "Solar PV Market Overview"
2) SolarBuzz, "Annual Solar PV Market Report"

Wind Power

Japan's cumulative installed wind energy capacity grew from 136 MW in 2000 to 1.88 GW in 2008, an annual increase of about 39 percent per year.[246] Japan added 346 MW of new wind capacity in 2008, the largest single year capacity addition to date. And while its market has surged ahead in recent years, it is still relatively small. Japan ranks 13th in the world in total installed wind power capacity, and its current capacity comprises just 1.6% of the global total.[247] The expansion of Japan's wind energy sector has been limited by severe weather and grid constraints, among other things. According to the Global Wind Energy Council, Japan has a history of extreme weather events, including typhoons and lightning incidents, that have damaged deployed wind turbines in the past. Grid capacity also remains a major constraint, as most of the wind resource availability is in remote areas where grid capacity is relatively small, while energy demand is greatest in populated cities near the center of the country.[248] Wind energy will be a component of Japan's plans to increase renewable electricity generation, but will likely play a more minor role relative to solar and nuclear power technologies.

Figure 18. Japanese Installed Wind Power Capacity, 2000-2008 (Gigawatts Capacity)



Source: Global Wind Energy Council, "Global Wind 2008 Report"

Nuclear Power

Japan has had an active nuclear power program since nuclear research began in the country in 1954, and its first nuclear reactor went into commercial operation in 1970. Nuclear energy figures prominently into Japan's national electricity mix, and its role in Japan's energy future will increase in the coming decade. Japan currently has 53 nuclear power plants in operation with a total generating capacity of 46 GW.[249] Nuclear power currently represents 18 percent of the country's total electric capacity and provides 30 percent of the country's electricity generation.[250] It has two more plants under construction and 13 more planned. Japan has the third largest installed nuclear capacity in the world, behind the United States and France.

Carbon Capture and Storage

Japan currently has no major commercial scale CCS projects underway within the country, but it does have two commercial scale projects in their planning stages, which are expected be operational in 2017 and 2020. In May 2008, 29 major Japanese power companies launched Japan CCS Company Ltd. to jointly develop CCS technologies. The corporation is conducting feasibility studies for the government in order to progress on a national goal to capture and store 100 million tons of C02 per year starting in 2020. CCS demonstration projects in Japan are currently done for aquifer sequestration and post-combustion capture on a small-scale. However, Japanese companies are engaged in larger CCS demonstration projects internationally, most of which are supported by the Japanese government.[251]

Advanced Vehicles and Batteries

The market share of advanced vehicles in Japan is high relative to other countries around the world. In May 2009, 21,601 units were sold, representing 12 percent of new light-duty vehicle sales, the first time the monthly new vehicle share of hybrids topped 10 percent.[252] In July 2009, more than 30,000 hybrids were sold in Japan, making it the number one market globally for the product, passing the United States.[253] Japan is expected to be a large market for of plug-in hybrid and electric vehicles. Mitsubishi's iMiEV was the first electric car to enter the market in July 2009, mainly for the Japanese government and domestic companies. Mitsubishi has an initial sales goal of 1,400 units in Japan in 2009.[254] Japanese company Nissan will also have an electric vehicle model, the Leaf, ready for mass production and release in Japan by 2010. Toyota, Japan's leading hybrid manufacturer, will mass-produce a plug-in hybrid version of its Prius model, set for a 2012 domestic release.

High-Speed Rail

Japan became the first nation to create and deploy HSR infrastructure in 1964, just prior to the Tokyo Olympic Games, by introducing the innovative Shinkansen "bullet train." Today, the entire Shinkansen network, operated by Japan Railways (also known as JR Tokai), runs on 1,550 miles of high-speed track.

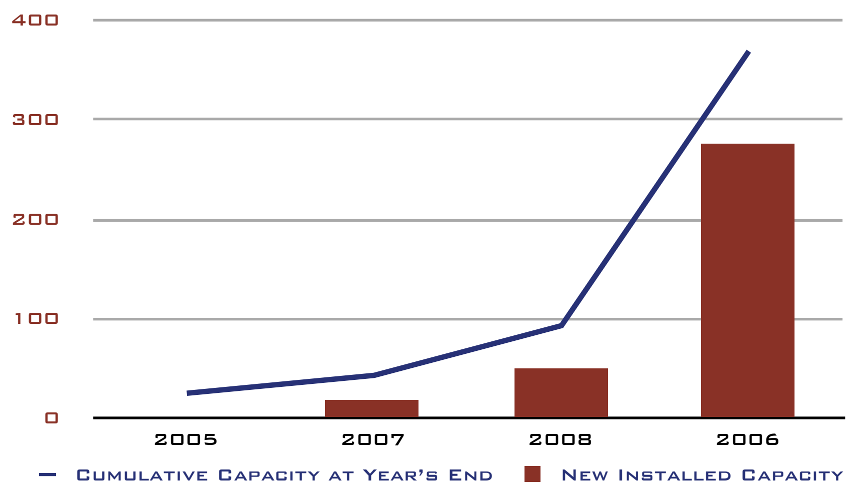
South Korea

South Korea had a total installed electric capacity of 66 GW in 2007, and it currently generates less than 1 percent of its electricity from renewable sources, including hydropower. Nuclear power is South Korea's most developed source of low-carbon energy, and contributes 37 percent of the nation's electricity generation.[255] South Korea's utilization of solar and wind energy are still relatively low, but the contribution of renewable sources to power generation, and solar PV in particular, is growing. There are no major CCS projects underway in South Korea, and the domestic market for advanced vehicles is still nascent. The nation is, however, developing a national high-speed rail network, expected to be completed in the next few years.

Solar Power

South Korea's domestic solar PV industry experienced substantial growth in 2008, and its domestic market now ranks fourth in the world after emerging from relative obscurity just a few years earlier. South Korea's newly installed solar PV capacity soared to 276 MW, an almost six-fold increase over the 50 MW added in 2007.[256] South Korea has ambitious PV market development programs that have underpinned the growth of its domestic industry. The industry is poised for a take-off as a result of generous government support. South Korea has a goal for a 1.3 GW cumulative PV capacity by 2012.[257]

Figure 19. South Korean Installed Solar Power Capacity, 2005-2008 (Megawatts Capacity)

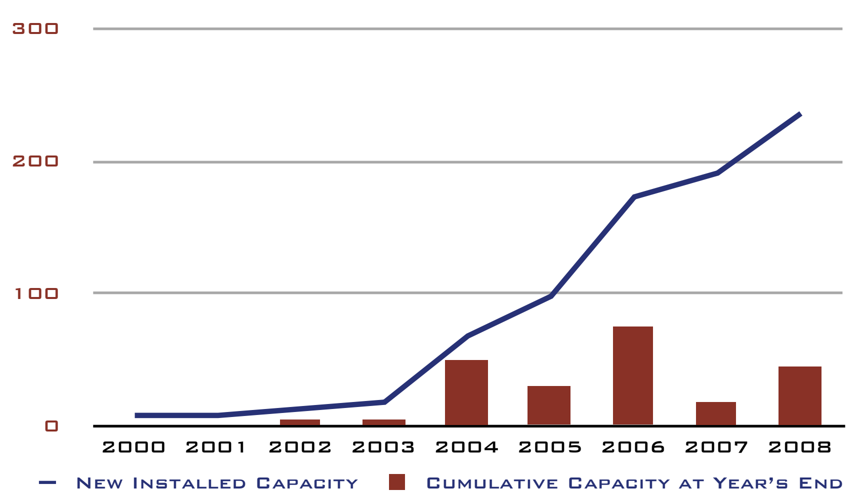


Source: SolarBuzz, "Annual Solar PV Market Report"

Wind Power

South Korea added 43 MW of new wind energy capacity in 2008, bringing its cumulative total to 236 MW.[258] South Korea's wind energy sector has grown at an average annual rate of 52 percent since 2001. The country's wind market was largest in 2006, when it added 75 MW of wind power capacity. South Korea's domestic wind sector is still in an early stage of development relative to many countries around the world; the country's installed capacity ranks just 26th in the world. According to the Global Wind Energy Council, South Korea has

Figure 20. South Korean Installed Wind Power Capacity, 2000-2008 (Megawatts Capacity)



Source: Global Wind Energy Council, "Global Wind 2008 Report" a large wind resource potential, but there are a number of constraints to the development of the domestic wind market, including a relative scarcity of suitable siting locations and difficulty of grid expansion; most of its resource rich areas are mountainous regions far outside of major population centers.[259] A recent feasibility study conducted by the Korean Institute of Energy Research (KIER) estimates the maximum potential for on-shore wind power development in South Korea at 7.8 GW.[260] Nevertheless, wind energy has been designated a priority area for South Korea's plans to increase the share of renewable energy in the nation's primary energy supply.

Nuclear Power

Nuclear power plays a large role in South Korea's electricity sector. South Korea currently has 20 nuclear reactors that supply 40 percent of South Korea's electricity. South Korea has 17.7 GW[261] of deployed nuclear capacity, representing a sizable 26 percent of the nation's generating capacity and the world's fourth-largest installed nuclear capacity.[262] Currently there are six nuclear power plants under construction and a further six ordered or planned in the future. By 2014, when the last plant under construction is scheduled to be completed, South Korea will have added a further 6.7 GW of nuclear generating capacity.

Carbon Capture and Storage

There are currently no major CCS projects currently underway in South Korea, but the government has announced a major future effort to invest directly in a number of pilot projects in the country. This plan is discussed in the following section of the report.

Advanced Vehicles and Batteries

South Korea does not currently have a large domestic market for hybrid and electric vehicles. South Korea's two largest automakers, Hyundai and Kia, control 75 percent of the domestic market. Hyundai just recently launched first hybrid (the LPG Elantra) for the domestic market in July of 2009.[263]

High-Speed Rail

The first stretch of HSR track in South Korea welcomed traffic in April 2004, linking Seoul with the city of Daegu and, via transfer to a normal rail line, to the southern port city of Busan. Work will be completed in 2010 on the remainder of the full 412 km route to Busan.[264]

Korea's Seoul-Mokpo plan has been under construction since 2006 and is scheduled to be fully operational in 2017. HSR trains on the Seoul-Mokpo line will begin traveling on the existing Seoul-Busan route to Osong, but the line will require 143 miles (230 km) of new high-speed track and will be a total of 199 miles (320 km) upon completion. Total expenditures on the line are predicted to be approximate $11 billion. This project is a component of the South Korea National Rail Network construction plan for 2006-2015.[265]

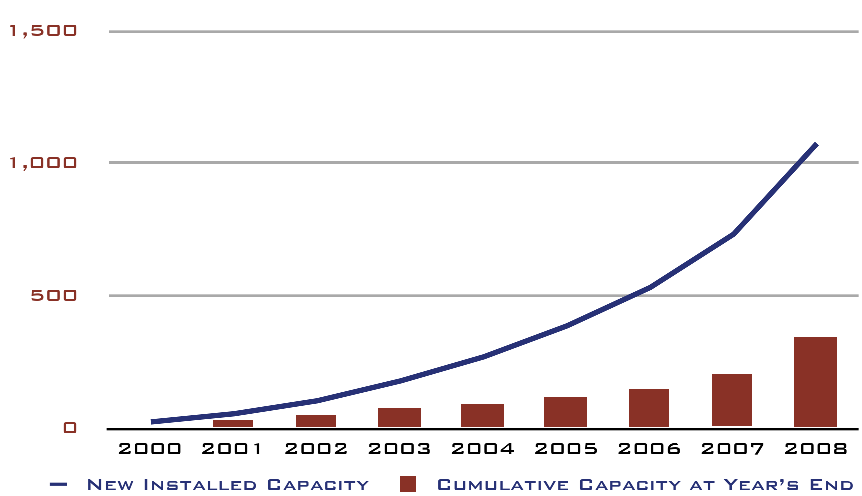
United States

In 2007, low carbon energy sources (including hydropower and nuclear), accounted for 22 percent of total installed electric capacity in the United States, which stood at 968 GW.[266] Nuclear power, with an installed capacity of 100 GW, is the largest low-carbon U.S. energy source. Some clean energy sectors have been expanding rapidly in the United States, particularly solar and wind.[267] Some clean energy sectors have been expanding rapidly in the United States, particularly solar and wind. The United States is currently the largest market for wind power in the world, although China is expected to take the top spot in 2009. The United States currently has no new nuclear power plants under construction, and hasn't completed a new plant since the 1970s. The nation also has no high-speed rail capacity to speak of. The nation is a major site for CCS demonstration projects, many of which involve international companies, and the United States, along with China, is expected to be one of the largest future markets for advanced vehicles in the world.

Solar Power

The U.S. solar market experienced impressive growth in the last decade, especially in 2008, when new capacity additions totaled 342 MW, a 70 percent increase compared to new additions in 2007.[268] In 2008 the U.S. solar market, measured by new capacity additions, ranked third in the world behind Germany and Spain. The United States has a cumulative

Figure 21. United States Installed Solar Power Capacity, 2000-2008 (Megawatts Capacity)



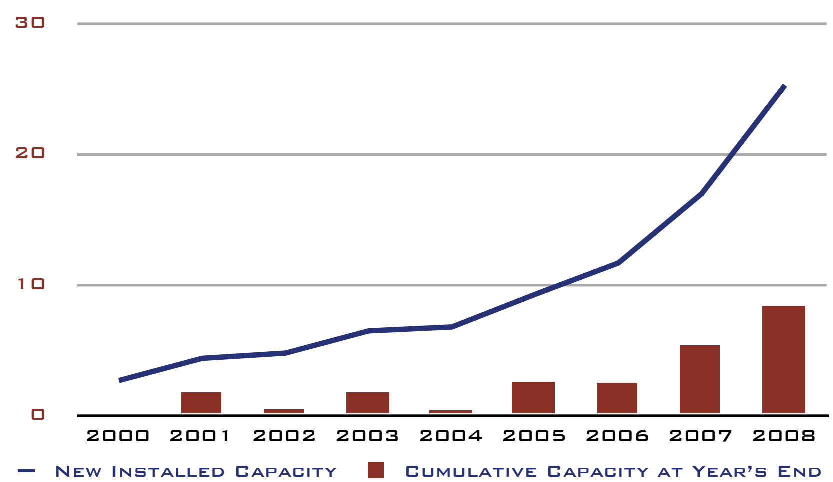
Source: Solar Energy Industries Association, "U.S. Solar Industry Year in Review 2008" total of approximately 1,138 MW of installed solar PV capacity, which is eight percent of global capacity and ranks the United States fourth behind Japan, Spain, and Germany.[269] Much of the national growth in solar PV installations is driven by the policies of individual states. California continued to far outpace other states in the deployment of solar PV capacity in 2008 with 178 MW of grid-tied PV capacity. New Jersey, the second ranked state, installed 22.5 MW.[270]

Wind Power

The U.S. wind sector has experienced substantial growth over the past few years, expanding from a cumulative installed capacity of 2.5 GW in 2000 to 25 GW at the end of 2008, an annual increase of 33 percent.[271] In the midst of a deep economic recession, the United States still added 4 GW of wind generating capacity in the first two quarters of 2009, bringing current cumulative installed capacity to 29 GW.[272] Due to the rapid growth of domestic wind power production, the United States is currently the global leader in installed wind energy, with capacity at 21 percent of the global total, besting Germany for the top spot at the end of 2008.[273] China, however, is expected to overtake the United States in 2009 as the largest domestic market for wind.[274]

The road to the top of the wind market has not been smooth for the United States, and annual additional wind energy capacity has been periodically inhibited by inconsistent government support. Wind energy deployment is highly correlated with the availability of the wind Production Tax Credit (PTC), which has lapsed on three occasions before eventually being renewed.[275] In each of the three years during which the PTC lapsed (2000, 2002 and 2004), the level of additional deployed wind capacity fell far below the previous year's total. The recently passed stimulus bill extended the PTC through the end of 2012.

Figure 22. United States Installed Wind Power Capacity, 2000-2008 (Gigawatts Capacity)



Source: Global Wind Energy Council, "Global Wind 2008 Report"

Nuclear Power

The United States is the world's largest generator of nuclear power, and accounts for more than 30 percent of global nuclear electricity generation. There are 104 nuclear reactors currently in operation in the United States, which produce 20 percent of all U.S. electricity. Current nuclear capacity stands at 100.5 GW, the most in the world. Nearly all of the nuclear generating capacity that exists in the United States today comes from reactors that were built between 1967 and 1990. No new nuclear power plants have begun construction in over 30 years due to safety concerns arising after the Three Mile Island accident in 1979. At the same time as construction of new nuclear power plants has halted, U.S. reliance on nuclear power has increased markedly due to increases in the output of existing plants. In 1980, output from nuclear power accounted for 11 percent of the country's electricity generation, while in 2008 it accounted for 20 percent, as average capacity factors were boosted from 56.3 percent in 1980 to 91.1 percent in 2008.[276]

In recent years, largely because of concern over air pollution and climate change, interest in new nuclear power plant construction has grown. Currently, 13 applications for 22 new reactors are under active review by the U.S. Nuclear Regulatory Commission. Over $4 billion has been spent on new nuclear power plant development over the last several years and the industry plans to invest nearly $8 billion in the coming years in order to start new reactor construction by around 2012.[277]

Carbon Capture and Storage

The United States currently has three operational CCS projects and a further 16 planned.[278] One major project is the FutureGen Clean Coal Project in Matoon, Illinois. In 2008, the project was cancelled by the Bush Administration for cost overruns but has since been revived with funding from the recent economic stimulus package passed in February 2009. The 275 MW plant would be designed to capture 90 percent of its emissions in the third year of operation, but it is currently still in the design stage.[279]

A second major project is the 1,300 MW Mountaineer Plant in West Virginia. In October 2009, the plant successfully completed a first-ever test of capturing coal plant carbon emissions and injecting carbon dioxide underground.[280] The demonstration-scale project uses a "chilled ammonia" technology developed by the French firm Alstom to capture carbon dioxide. The project aims to store about 1.5 percent of the plants yearly emissions underground.

Advanced Vehicles and Batteries

The market for hybrid vehicles in the United States has been expanding and hybrids have outperformed the wider market this year, growing to 2.8 percent of overall sales.[281] In the first nine months of 2009, 221,000 hybrid vehicles were sold in the United States. Japanese company Toyota supplied over 65 percent of the U.S. hybrid market.[282] A number of new plug-in hybrid (PHEV) and electric vehicle models will be introduced in the U.S. market over the next three years. China's BYD plans to introduce it's F3DM hybrid-electric vehicle in 2010, and its electric vehicle, the E6, in 2011. Japanese company Nissan is expecting a limited release of its electric model, the Leaf, in 2010. Ford will introduce PHEV and EV models around 2011, and GM is targeting the Chevy Volt PHEV for introduction in November of 2010.

High-Speed Rail

The United States currently has no internationally recognized HSR. Although the Northeast Corridor's Acela Express is sometimes referred to as high-speed, the technology reaches maximum speed at 110 mph and only averages about 68 mph in actual practice, well below the international standards for high-speed rail.[283]

A Summary of Competing Clean Energy Industries

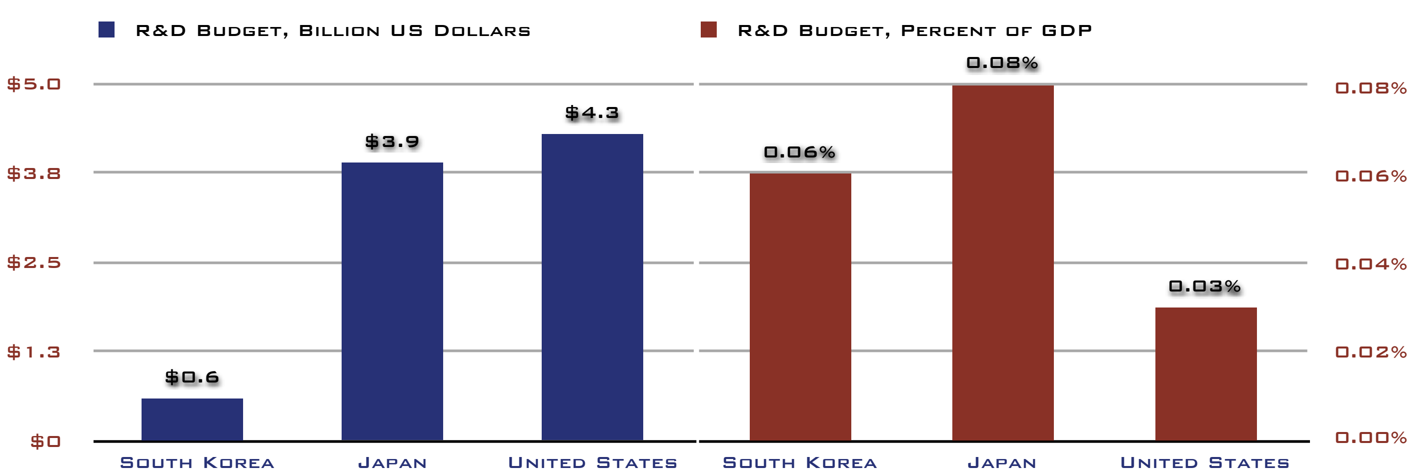
Asia's "clean technology tigers" – China, Japan, and South Korea – are aggressively challenging the United States for economic dominance in the global clean technology industry. A comprehensive national strategy to achieve economic leadership in clean energy technology involves three critical components: clean technology **research and innovation**, **manufacturing** capacity, and the development of **domestic markets**. In each of these three critical areas, the United States is either behind, or is being aggressively challenged by its economic competitors.

The United States only slightly edges out Japan in clean energy research and innovation capacity, and South Korea and China are moving quickly to fill the innovation gap. The United States lags behind at least one of its economic competitors in the production and manufacturing of each of the six technologies examined in this report: solar, wind, nuclear, carbon capture and storage (CCS), advanced vehicles and battery technology, and high-speed rail. With respect to domestic market development, the United States leads its economic competitors in solar, wind, and CCS market development (although China is quickly gaining ground in each), is currently neck and neck in advanced vehicles, and is falling far behind its economic competitors in nuclear power and high-speed rail.

Research and Innovation

The United States currently invests slightly more money in research and development than Japan and has an advantage over China and South Korea. However, each Asian competitor is moving to close the innovation funding gap. Furthermore, as a percentage of each nation's gross domestic product (GDP), Japan and South Korea out-invest the United States on energy innovation by a factor of two-to-one. The United States secures 20.2 percent of the world's clean energy patents—a measure of innovation in the clean energy sector—more than any country in the world. Japan is close on America's heels, however. In addition to almost matching U.S. energy R&D spending in 2008, Japan achieves a nearly equivalent number of international clean energy patents.

Figure 23. Comparative Government Energy R&D Investments, 2008



Source: IEA Energy R&D Statistics, Author's Analysis; Data not available for China.

Clean Energy Manufacturing

The United States has fallen behind its economic competitors, especially China, in the capability to manufacture and produce clean energy technologies on a large scale. The United States is behind both China and Japan in the production of solar PV cells, and China now manufactures twice the amount of wind turbine components as the United States. All three Asian nations have the heavy engineering and manufacturing capacity to produce full component sets for new nuclear reactors, and all now have their own domestic nuclear reactor designs. While the United States was an early pioneer in nuclear reactor technology and retains domestic production of some nuclear components, it has seen a decline in nuclear engineering facilities and does not have the large heavy forging capacity necessary to produce full nuclear reactor sets, especially those necessary for the large advanced nuclear power plants being developed today.

The United States is currently being aggressively challenged by its Asian competitors in the race to develop the next generation of advanced vehicles—plug-in hybrid and electric cars—as well as the lithium-ion batteries that will power them. China, Japan, and South Korea collectively manufacture over 80 percent of the world's lithium-ion batteries as storage devices, and all four nations are moving quickly to release or scale-up manufacturing of their first mass-market electric and plug-in hybrid vehicle models. Asia's clean tech tigers are also far ahead of the United States in the development of high-speed rail technology. Japan has long been a technological leader in HSR, and both South Korea and China are engaging in successful strategies to localize production and develop domestic HSR technologies. The United States, by contrast, does not manufacture any high-speed rolling stock, and all future plans for high-speed rail deployment may require international imports.

Table 2. Comparative Domestic Manufacturing Capacity by Clean Energy Technology

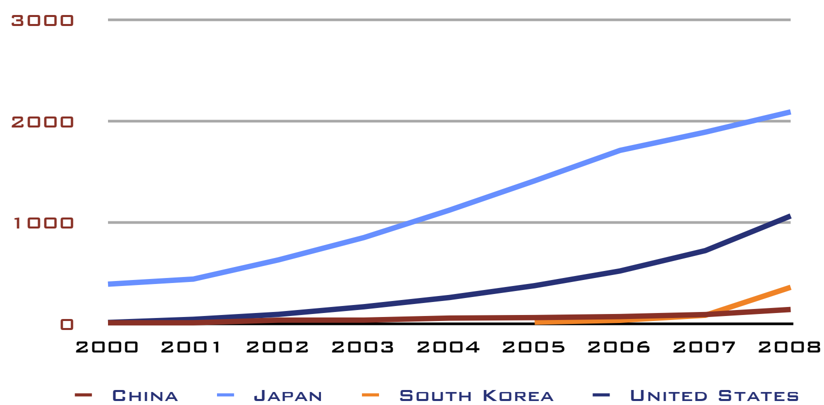
	Solar PV (Manufacutring Capacity)	Wind Power (Manufacturing Capacity)	Nuclear (Manufacturing Capacity)	Advanced Vehicles (Initial Produciton Date)	High-Speed Rail (Number of Domestic Designs)
China	1,800 MW	8 GW*	7 reactor sets (15,000 ton max heavy forging capacity)	EV: BYD E6 (2010) PHEV: BYD F3DM (2009)	4
South Korea	60 MW	Data not available (see Korea section above)	Data not available for reactor sets (13,000 ton max heaving forging capacity)	EV: Hyundai i10 (2010) PHEV: Hyundai Blue-Will (2012)	2
Japan	1,200 MW	Data not available (see Japan section above)	4+ reactor sets (two 14,000 ton heaving forging presses)	EV: i-MiEV (2009) PHEV: Toyota Prius (2012)	14
United States	375 MW	4.2 GW	No full sets (10,000 ton max heavy forging capacity)	EV: Tesla Roadster (2009) PHEV: Chevy Volt (2010)	0

Note: *2007 figure, data for 2008 unavailable.

Domestic Clean Energy Markets

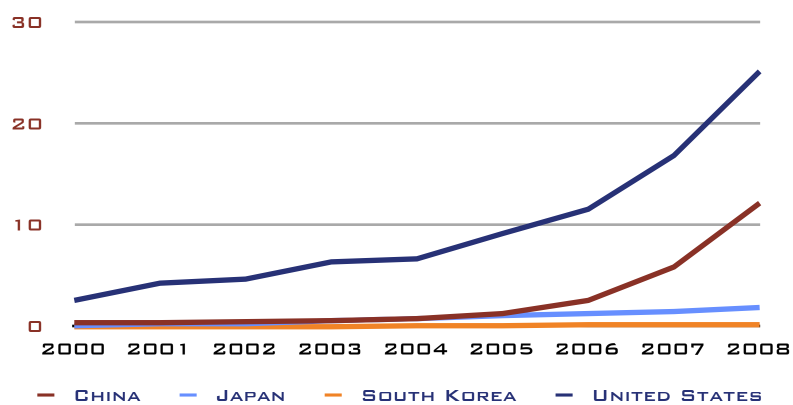
The United States currently leads China, Japan, and South Korea, in the domestic market development of three of the six technologies surveyed in this report, including solar PV, wind power, and the nascent market for CCS technology. The United States has experienced strong growth in the deployment of solar PV and wind power, but other nations are quickly catching up. The United States was the largest market for wind in 2008 and surpassed Germany as the leader in total installed capacity at the end of that year. China's wind market, however, was not far behind in 2008, and China is expected to surpass the United States as the largest market for wind in 2009. The United States also led each of the three Asian nations in annual solar PV capacity in 2008, although Japan continues to be the leader of the pack with respect to total installed solar PV capacity. There are currently more CCS demonstration sites being developed throughout the United States than anywhere in Asia. The United States has three such sites operational now, and a further 16 planned.

Figure 24. Comparative Domestic Solar Markets, 2000-2008 (Cumulative Installed Megawatts)



With respect to advanced vehicles, all four nations are vying for leadership in domestic market development. China has introduced the world's first mass-market plug-in hybrid vehicle to its domestic market. The other three nations will introduce plug-in hybrids to their respective markets by 2012. Japan and the United States each have serially-produced electric cars on their roads right now (albeit in small numbers). Markets for each of these technologies are still nascent, and a clear world leader has yet to emerge.

Figure 25. Comparative Domestic Wind Markets, 2000-2008 (Cumulative Installed Gigawatts)



The United States currently lags behind its competition in market development for two of the six technologies surveyed in this report: nuclear power and high-speed rail. Despite having the world's largest installed nuclear power capacity, the United States has no new nuclear power plants under construction, while China leads the pack with seventeen. While the United States has no high-speed rail (HSR) capacity to speak of and is still years away from breaking ground on the nation's first true high-speed line, each of its three Asian competitors has a large and growing domestic market for this clean technology. Japan has been a historic leader in HSR since the 1960s and has a fully developed domestic network spanning more than 1,500 miles. South Korea, the second nation in Asia to deploy HSR, is in the midst of constructing a nationwide network of high-speed lines. China's market for HSR technology is poised to become the largest among the four nations examined, however, as the country moves rapidly to construct a nationwide high-speed rail network with plans to ultimately connect all major Chinese cities with HSR service.

Figure 26. Comparative Domestic Nuclear Markets

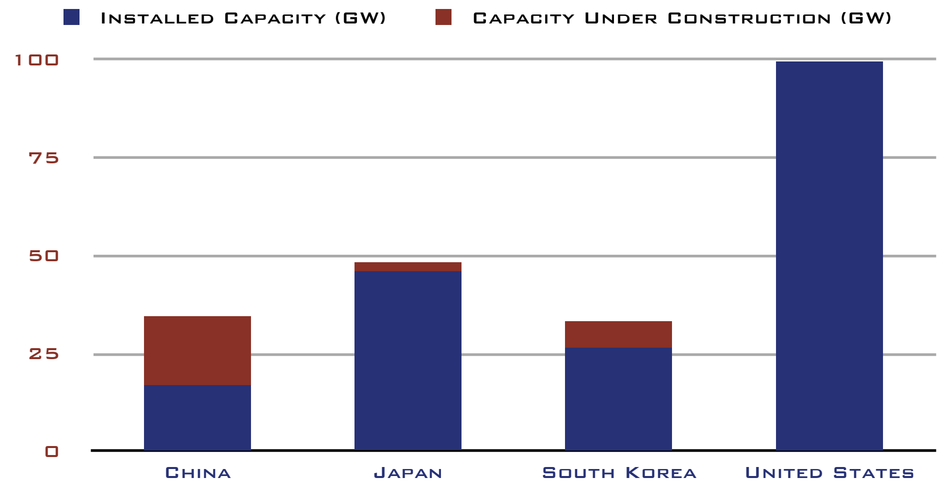


Figure 27. Comparative Domestic CCS Markets (Number of Pilot Projects)

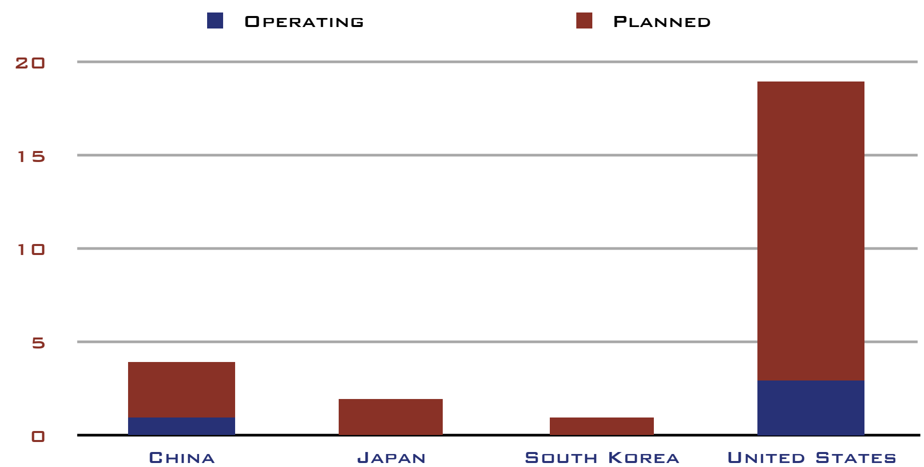
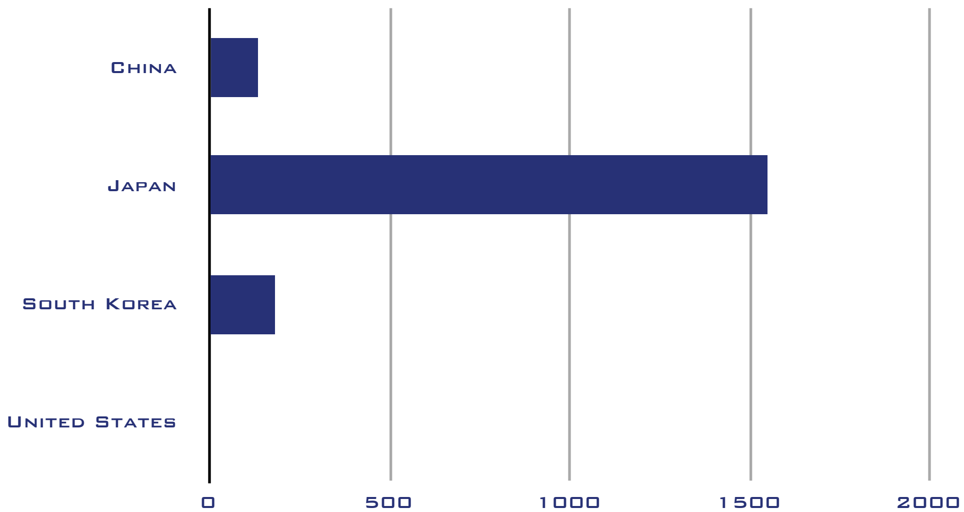


Figure 28. Comparative High-Speed Rail Markets (Miles of Track Installed)

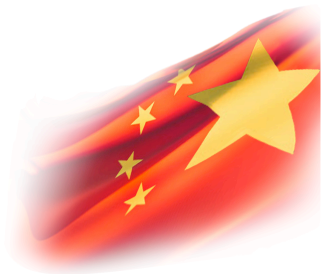


The Clean Energy Race: Government Strategies to Secure Clean Tech Leadership

As long as emerging clean energy technologies remain more expensive than conventional alternatives or face a variety of persistent barriers to adoption, domestic clean energy development and deployment will continue to be determined largely by public policy. Governments employ a diverse array of policy mechanisms to reduce the many existing barriers to clean energy adoption and to drive deployment. Such policies include direct subsidies for clean energy installation, subsidies for clean power generation (e.g. feed-in tariffs and production incentives), government procurement contracts, tax credits, capital subsidies, preferential financing and loan guarantees, and renewable portfolio standards or other deployment requirements. Governments also routinely support the growth of their domestic clean energy industries by investing in research and development to improve clean technologies and related manufacturing processes and to spark the next generation of innovations. Finally, public investments in enabling infrastructure, such as electricity grid expansion, can increase access to clean energy resources or make clean energy technologies more attractive to private-market adopters.

This section details the clean energy strategies of the governments of China, Japan, South Korea, and the United States. We examine relevant existing policies that have helped to catalyze clean energy research and development, manufacturing, and deployment in each country, paying particular attention to recently passed economic stimulus measures. We then examine the policies and investments that each nation has proposed to develop their clean energy industries in the near future. When relevant, we also describe each nation's targets for clean energy deployment, broken out by technology where possible.

As this section shows, the governments of China, Japan, and South Korea will out-invest the United States in clean energy technologies by more than three-to-one over the next five years. Furthermore, policy mechanisms in these three Asian nations are more targeted and direct than those currently planned or relied upon in the United States, and will likely provide a more attractive, lower risk environment for private investment in clean energy technologies.



China Quick Facts:

Popluation (2009)
1,338.6 million

GDP PPP (2008 est)
$7.973 trillion

GDP PPP per Capita (2008 est)
$6,000

Electr. Generation (2007 est)
347.1 ave. GW

Total Primary Energy Supply (2007)
1,955.8 Million tons oil-equivalent

Source: CIA World Factbook and International Energy Agency

China

China has only recently offered sustained and substantial policy support for its clean energy industries, after recognizing the need to address mounting pollution problems, the threat of climate change and the immense economic opportunities provided by the burgeoning global clean energy industry.

In 2005, China passed the Renewable Energy Law, which imposed a national renewable energy requirement to boost the share of renewable energy capacity to 10 percent of total electricity capacity by 2020.[284] The legislation was the first in China to implement a national framework for developing the domestic clean energy industry, and included a number of provisions to spur renewable energy deployment, including requiring grid operators to purchase electricity from registered renewable energy producers, as well as offering discounted lending, tax breaks, and other financial incentives for renewable energy.[285]

In 2007, the Chinese National Development and Reform Commission (NDRC) created a "Medium and Long-Term Development Plan for Renewable Energy", which raised the previously established renewable energy target to 10 percent by 2010 and 15 percent by the year 2020. It was also the first Chinese policy to set technology specific targets for renewable energy deployment, including targets of 30 GW of wind power, 300 GW of hydropower, and 1.8 GW of solar PV by 2020.[286] China also created a Medium and Long-Term Development Plan for Nuclear Power (2005-2020), which called for a major acceleration in domestic nuclear power development and deployment and set a target for 40 GW of installed nuclear capacity by the year 2020.[287]

In June 2009, Zhang Xiaoqiang, the NDRC vice minister in charge of climate policy, expressed confidence that China could exceed these targets and produce 18 to 20 percent of its energy from clean energy sources by 2020.[288] Indeed, as a result of the rapid development of many of China's clean technology industries, government officials have officially revised China's earlier targets, established in 2007, for clean energy technology deployment. Specifically, the government more than tripled its early target for wind to 100 GW by 2020,[289] as well increased its 2020 solar PV target more than ten times from 1.8 GW to 20 GW.[290] Some reports have suggested that the government is planning to more than double its original nuclear deployment target, aiming to have 86 GW of nuclear power installed by 2020.[291]

In order to reach these ambitious deployment targets, the government has employed a number of policy mechanisms and financial incentives to support its clean energy industries. Most policies are targeted toward individual technologies, and are described in detail below. Perhaps the largest boost to China's clean energy sector will come from an economic stimulus package enacted in December 2008, as well as a planned new energy stimulus package that China will likely announce by the end of 2009.

China's 2008 stimulus package invested close to $177 billion in clean energy technologies and enabling infrastructure, according to HSBC. The large majority of the investments were directed toward rail and grid projects, with only $8 billion going to energy efficiency technologies and low-carbon vehicles.[292] While low-carbon power technologies did not get a major boost under the 2008 stimulus package, the government will soon announce a new investment package specifically for clean power technologies.

In May 2009, the state-run Xinhua news agency reported that the Chinese government is developing a massive and sustained renewable energy investment package,[293] reported to be on the scale of $440[294] to $660 billion[295] over ten years. With this new plan, China is positioning itself to outpace the United States and other competitors and establish itself as a global leader in the manufacturing and deployment of clean energy technologies.

As this report goes to press, the details of China's new renewable energy stimulus have yet to be announced, but some reports have emerged that indicate the shape the future investment package may take. A draft amendment to China's 2005 Renewable Energy Law, proposed in August 2009, would set a minimum target for the amount of renewable electricity that power grid companies must purchase.[296] Xinhua wrote that the amendment would guarantee the direct purchase by the central government of an annual minimum of renewable energy for the state grid.[297]

Research and Innovation

It is unclear how much of China's 2008 stimulus package or planned energy stimulus will be directed towards energy R&D, but there are signs that the government is making a concerted effort to boost research and development of key technologies. A draft amendment to China's 2005 Renewable Energy Law, recently reviewed by the National People's Congress, will set up a new fund to support renewable energy research and development. The fund will be financed by a small surcharge on electricity end users, who are charged a rate of $0.00014 (RMB0.001) per kWh, as well as financing from the Ministry of Finance.[298] Under the current charging standard the fund would generate $659 million (RMB4.5 billion) this year, according to government estimates, plus any amount the central government decides to contribute directly.

In the solar energy industry, the Chinese Academy of Sciences is also working to set up a platform to support scientific innovations and provide support for solar energy at each stage, including basic research, applied research, and market commercialization.[299] In October 2009, American company Applied Materials—the largest solar equipment manufacturer in the world—built the world's largest non-government solar energy R&D center in Xian, China.[300]

The Chinese government has also allocated $1.5 billion in R&D subsidies to help domestic automakers upgrade their technologies and develop low-carbon vehicles.[301]

Manufacturing and Markets

Solar Power

In 2008, China had a cumulative PV capacity of just 140 MW, but substantial policy support for the domestic solar sector is expected to dramatically boost the industry, and China's PV deployment target has been significantly upgraded. China is now planning to increase its solar deployment targets to over 20 GW, more than ten times its original target established in 2007.[302]

The Chinese central government has announced two recent plans to incentivize and support the development of its domestic solar energy industry. In March 2009, the Chinese Ministry of Finance announced the "Solar Roofs Program," which will offer a subsidy for large-scale roof-mounted solar PV installations that are greater than 50 KW in size. At $2.93 per watt, the building-integrated solar subsidy is one of the most generous of its kind in the world, covering half the costs of PV installation.[303] In July 2009, the government announced a second major subsidy program—the Golden Sun program—for utility scale solar projects. The Golden Sun Program stipulates that the government will subsidize 50 percent of the investment of solar power projects, as well as transmission and distribution systems that connect to grid networks.[304] The subsidy will be 70 percent for projects in remote regions. In order to qualify for the subsidy, each project would have to have a minimum generating capacity of 300 KW, and the project must be in operation for at least 20 years. Under the program, the government will also install more than 500 MW of solar power pilot projects over the next two to three years. With these deployment incentives and procurement policies, China is expected to reach 2 GW of deployed capacity by 2011.[305]

There are further reports that China's robust policy support for its solar industry will not end any time soon. China is currently developing a proposal for a feed-in tariff of between $0.16 to $0.22 per kWh for utility-scale solar projects.[306] The prospect of a guaranteed premium rate for solar generated electricity has already induced American thin-film solar company First Solar to announce that it will build a 2 GW solar power plant, the world's largest, in China. According to the memorandum of understanding between First Solar and the Chinese municipality of Ordos in Inner Mongolia, First Solar will actively participate in the expansion of supply chains in China for thin film module production, creating many manufacturing jobs in China and localizing technology production.[307]

Wind Power

The Chinese government announced in May 2009 that it would pursue a 100 GW target for deployed wind capacity by 2020, more than triple the 30 GW target established by China's 2005 Renewable Energy Law.[308] En route to this goal, China is planning to build seven wind power "mega projects" with a minimum capacity of 10 GW each.[309]

China has provided consistent support for wind power deployment and has enacted a number of different policies to spur the development of the sector. In 2001, it cut value-added taxes on wind power production by half, and between October 2007-June 2008, the government provided $205 million in financial subsidies to the wind power sector, including an $88 per kW subsidy for domestic wind turbine and component manufacturers for the first 50 MW of turbines produced.[310] This year, China significantly boosted its support for wind deployment when the government instated feed-in tariffs set to correspond with available wind resources in different regions. Tariff levels range from about $0.07 (RMB0.51) to $0.09 (RMB0.61) per kWh, roughly 1.5 to two times higher than the average rate for coal-fired electricity ($0.05, or RMB.034). The tariffs will replace the public bidding process that currently governs wind projects in China after a government agency identified low tariffs and grid connection problems as barriers to profitability for wind projects.

China has also taken steps to build out its domestic manufacturing capacity for wind power, in part by shielding domestic component manufacturers from international competition. In recent years, the Chinese government has mandated that 70 percent of the equipment needed for installed wind power plants must be sourced domestically. By 2007, these policies led to the creation of over 50 local wind power technology companies, and China now controls over 60 percent of the domestic market, historically dominated by imports.[311] In late October 2009, Chinese officials announced that they were dropping the local content requirement for wind turbines after diplomatic meetings with U.S. officials. The move should allow foreign wind power technology companies to more readily compete in China's rapidly expanding market.[312] The decision comes on the heels of a major announcement that a young Chinese wind company—buoyed by low-financing from state-owned Chinese banks as well as a 30 percent project grant provided by the U.S. economic stimulus program—will supply 600 MW for a large wind farm in Texas. The project will create nearly 2,000 jobs in China, compared to around 300 in the United States, and is the first major instance of a Chinese firm gaining a foothold in the U.S. wind market.[313]

Nuclear Power

China's Medium and Long-Term Development Plan for Nuclear Power (2005-2020) called for a major acceleration of nuclear power development. The plan originally set a target for nuclear power capacity to reach 20 GW by 2010 and 40 GW by 2020.[314] The 2020 target was later revised to 60 GW, and then revised upward again to 70 GW in 2008.[315] Recent government projections and news reports suggest China may reach a nuclear power capacity in the range of 75 GW[316] to 86 GW[317] by 2020, more than double the original target set in 2005. Longer-term plans for nuclear power to comprise 16 percent of China's power generation in 2030[318] would require 250 GW of nuclear power to be installed by that time.

China currently has 22 new nuclear reactors under construction and 50-100 additional reactors planned or proposed. The government has made large advances in its own nuclear power technological capacity; 20 of the 22 reactors under construction use CPR-1000, the China-developed Generation II reactor technology.[319] Chinese companies are now also building the majority of the components necessary for their nuclear power stations, including building 90 percent of the Yanjiang plants that started construction in 2008. The government hopes to completely localize production by 2009 and to develop China's own nuclear technology patent, both of which will cut construction costs.[320] Achieving the original government target of 40 GW of installed nuclear generating capacity by 2020 was estimated to require a total investment of $66.2 billion, but additional significant investment would likely be needed to reach its more ambitious targets.

Carbon Capture and Storage

In the past two years, carbon capture and storage technology has garnered the attention of Chinese government officials. Many governments in the developed world view CCS as integral to reducing carbon emissions in China, as China is expected to construct many new coal fired power plants in the future. CCS was integrated into the "Outline for National Medium and Long-term S&T Development Plan towards 2020" as a leading edge technology. China's "National Climate Change Program of 2007 included CCS as a key to reducing greenhouse gases."[321] Early reports have indicated that CCS technology will feature prominently in China's new renewable energy stimulus.[322]

Advanced Vehicles and Batteries

In the electric vehicle sector, the Chinese government has developed a robust strategy to lead the emerging world market in electric vehicles. The Chinese government released an "Automobile Industry Adjustment and Stimulus Plan" in March 2009 which stated a goal of expanding the production and sale of hybrid or all-electric vehicles to 500,000 per year by 2011[323]. A plan from China's Ministry of Science and Technology states that 10 percent of all new vehicles will have to be energy-efficient or low-carbon models by 2012. According to the Climate Group, the requirement could lead to 1 million new electric vehicles on the road in China over that span.[324] The Climate Group also estimates that "if EVs and other low carbon vehicles account for 20-30% of China's auto sales [by 2030], the domestic market for low carbon vehicles could be worth between 700 billion and 1.5 trillion Yuan [between $102 billion and 220 billion]." China's advanced battery market would also benefit tremendously from such an expansion, and is expected to be worth between $22 billion and $58 billion under such a scenario.[325]

To boost the development of its electric vehicle sector, which is still in its early stages, the government has launched an EV demonstration project that will put 10,000 EVs on the road (1,000 in each of ten different cities around the country) before the end of 2009.[326] The Chinese government is also implementing procurement policies to drive EV deployment, providing generous subsidies to help local government agencies purchase electric buses, taxis, and other public service vehicles.[327] Subsidies will be up to $7,300 (RMB50,000) for hybrid vehicles and $8,800 (RMB60,000) for electric vehicles. Hybrid buses will receive up to $61,456 (RMB420,000) and electric buses will enjoy a subsidy of over $73,000 (RMB 500,000).[328]

High-Speed Rail

Today, China has aggressive plans to expand the nation's high-speed rail network to 8,077 miles (13,000 km) by 2012[329] and further to 16,000 miles (25,750 km) by 2020.[330] The Beijing-Tianjin high-speed commuter link is expected to be fully operational in 2009 and will run on 72 miles (115 km) of track.[331] The more extensive Beijing-Shanghai line is scheduled to stretch for 819 miles (1,318 km) and should be ready for passenger traffic by 2013.[332] Construction of the line employed 110,000 workers in 2009, according to the Chinese Ministry of Railways.[333] The Ministry is contributing nearly 80 percent of the estimated cost of the $23.4 billion (RMB 160 billion) project, with the rest of the financing to be supplied by private capital, including foreign investors.[334] China has plans to install a total of eight high-speed trunk lines to form the core of an HSR network connecting major city centers across the nation,[335] each likely to receive major funding from the Ministry of Railways. This massive expansion of high speed rail capacity has already been a major recipient of funding from China's $586 billion (RMB4 trillion) stimulus package and China has invested or plans to invest $50 billion in high speed rail in 2009, more than double what it spent in 2008. The government plans to invest $300 billion dollars to fully build out the nation's HSR network by 2020.[336]

Enabling Infrastructure

China is simultaneously making large investments in enabling infrastructure to support the massive increase in renewable electricity generation that is expected to come on-line over the next decade, as well as to accelerate the growth of its low-carbon vehicle sector. New grid infrastructure is critical in order for investments in clean energy technologies to remain productive. In 2008, more than 20 percent of Chinese wind turbines did not generate electricity because they were not yet connected to the grid, according to the China Wind Energy Association.[337] In order to ensure the effective operation of new renewable energy projects, China's $586 billion stimulus, launched in November 2008, will spend $161 billion over three years on grid infrastructure such as expanding power lines and building out transmission.[338] Already an emerging world leader in ultra high voltage (UHV transmission technology), China's State Grid Corporation will invest $44 billion in UHV power lines through 2012.[339] This year, China will also begin work on an extensive smart-grid development project that will be capable of integrating and managing the variable output of renewable energy sources more effectively. The project is slated be completed by 2020.[340]

To supplement procurement policies and further support the growth of the plug-in hybrid and electric vehicle industry, the government is also setting regulations to develop electric vehicle charging infrastructure. In February 2009, for instance, it began requiring local governments in 13 pilot cities to provide funding for the construction and maintenance of charging stations.[341] One market research firm estimates that by 2015, nearly one half of all electric vehicle-charging stations in the world will be in China.[342] The government has allocated $2.9 billion over the next three years to develop its electric vehicle sector with a focus on battery charging stations and grid construction.[343]

Japan Quick Facts:

Popluation (2009)
127.1 million

GDP PPP (2008 est)
$4.329 trillion

GDP PPP per Capita (2008 est)
$34,000

Electr. Generation (2007 est)
120.8 ave. GW

Total Primary Energy Supply (2007)
513.5 Million tons oil-equivalent

Source: CIA World Factbook and International Energy Agency

Japan

The Japanese government has announced a number of measures since May 2008 to support its clean energy sector and bring about a "low carbon society," including a "Low Carbon Technology Plan,"[344] an "Action Plan for Achieving a Low-Carbon Society,"[345] and "The Innovation for Green Economy and Society Program."[346] Taken together, these represent a comprehensive strategy to make Japan a global leader in the development and diffusion of core clean energy technologies.

The two economic stimulus measured passed by Japan in 2008 and 2009 contained $36 billion for investment in clean energy technologies, including $18.3 billion for energy efficiency and $3.7 billion for low-carbon vehicles.[347]

Japan will invest approximately $66 billion over the next five years in clean energy technologies, broadly defined. Of this total, $36 billion will be invested to support the deployment of clean energy and energy efficiency technologies, and the government plans to spend $30 billion over the next five years on clean technology R&D (both measure are discussed below).

Given the change of government in August 2009, there is some uncertainty about particular investments the government will make going forward. However, Japan's new governing party, the Democratic Party of Japan (DPJ), voted into power for the first time on August 30, 2009, has announced ambitious plans to support the development and deployment of clean energy including new climate and clean energy targets more ambitious than their predecessors. A DPJ policy paper called for 50 percent subsidies to customers for installing solar panels, up from 10 percent under the previous government. The DPJ has also called for expanding the solar feed-in-tariff set to begin in November to require utilities to purchase all solar electricity, rather than just surplus electricity, and may extend the tariff to cover all forms of renewable electricity, which will provide a large boost to Japan's wind energy industry, as well.[348] The new ruling party also pledges steeper cuts in Japan's greenhouse gas emissions, which could spur more demand for clean energy if backed by commensurate policies.[349] Japan's domestic clean energy sector may thus be poised for is set for resurgence as new policies are put in place to spur domestic demand for clean energy and cut greenhouse gas emissions.

Research and Innovation

To gain a greater competitive advantage in clean technology markets, Japan has developed technology roadmaps for several low-carbon energy supply and transportation technologies that spell out cost and performance improvement targets for each technology. These roadmaps are part of an overarching strategy to lay a new foundation of economic growth through "green" innovation in all areas of society, including investment, consumption, technology, and international relations.[350] The Japanese government plans to spend $30 billion over five years to implement these technological roadmaps, with particular attention to solar energy, low-emission vehicles, and energy efficiency technologies.[351]

The government's long-term technology roadmap for plug-in hybrid vehicles and electric vehicles aims to increase the capacity of advanced lithium-ion batteries to seven times today's level while reducing the cost of each battery to one-fortieth of today's cost by 2030. Recently, Japan's New Energy and Industrial Technology Development Organization (NEDO) formed a research consortium to develop advanced batteries. NEDO will spend $214 million over seven years on developing a battery with three times the current capacity of lithium-ion batteries.[352] Japan's emphasis on technology development may already be paying dividends. Japanese car company Toyota, in collaboration with Japan's Tohoku University, have reportedly achieved a technology breakthrough that could eventually improve the storage capacity of its lithium-ion batteries and vehicle range by up to ten times the current level.[353]

Japan's direct investment in the deployment of emerging technologies will help create market demand that fosters economies of scale and captures the critical market experience that informs further research and development efforts. To facilitate this process, Japan is investing directly in strengthening the link between R&D efforts and market commercialization. Recently, the government created the "Innovation Network Corporation of Japan" (INCJ) to accelerate technology innovation and the commercialization of new and emerging technologies. The new public-private partnership, co-funded by the Japanese government and 16 leading private corporations, including the American company GE, is capitalized at $1 billion in equity and will provide loan guarantees of up to $8.5 billion.[354] The new organization seeks to leverage private sector expertise to achieve sustainable growth through technology innovation.

Manufacturing and Markets

Apart from increasing investment in clean energy R&D, Japan has plans to rapidly scale up the deployment of both existing and emerging clean energy technologies. Former Prime Minister Taro Aso recently announced a goal for 20 percent of the nation's energy consumption to come from renewable energy in 2020, double today's level.[355] In order to help meet this goal, Japan currently plans to install 28 GW of solar generating capacity by 2020; install 5 GW of wind power capacity; construct 9 new nuclear power plants while increasing utilized nuclear capacity to 80 percent (up from the current 60%); and increase the share of next generation vehicles in total vehicle sales from four percent to 50 percent in 2020.[356] Overall, the government aims to increase the proportion of zero-carbon energy in electricity generation from 40 percent to 50 percent by 2020.[357]

Solar Power

Japan has been a long-time world leader in solar energy, primarily due to its highly successful "New Sunshine Program", which enacted targeted policies to grow its solar PV industry and funded the installations of over 930 MW from 1992 to 2005.[358] The program included long-term R&D, deployment policies, such as net-metering standards that require utilities to purchase surplus solar power, low-interest loans, and rebates for grid-connected residential systems, as well as direct government procurement.[359] The government-initiated program was so successful that authorities were able to reduce the solar PV installation subsidy from $10/Watt (¥900/Watt) in 1994 to $0.22/Watt (¥20/Watt) in 2005.[360] The government discontinued solar installation subsidies in 2005, however, and the PV market has stagnated since. As a result, Japan lost its solar market dominance to European nations like Germany and Spain, which have instituted generous price support mechanisms for their domestic PV industries.

Japan's leaders have since recognized that boosting their domestic solar PV industry is an important step to increasing economic competitiveness in the burgeoning industry and the government has moved swiftly to regain its position as a leader in solar PV. In 2009, former Prime Minister Taro Aso declared Japan's intention to become "the number one solar power nation in the world" with a national goal of increasing solar power generating capacity to twenty times 2005 levels by 2020, and 40 times by 2040.[361] This would amount to a deployment of 28 GW in 2020, and 56 GW in 2040. Mr. Aso suggested that Japan must make solar energy cheaper through widespread deployment that could drive down the costs of solar power systems by "one half over the next 3 to 5 years."[362] The government aims to eventually make unsubsidized solar energy as cheap as conventional energy sources.[363]

To drive down the price of solar energy, the government will implement three key policy measures. First, it plans to procure solar power generation units to install at tens of thousands of school across the nation over the next three years.[364] Second, the Japanese government has reinstated the solar PV installation subsidy that was discontinued in 2005.[365] The government has budgeted $222 million (¥20 billion) for a $700/kW (¥700,000/kW) PV installation subsidy available through 2009, and aims to have 70 percent of new homes equipped with solar panels by 2020.[366] For non-residential solar, the government has provided several hundred million dollars over the past two years to subsidize installation costs (1/3 of project costs for the commercial sector, 1/2 for the public sector).[367] The public sector installation subsidy extends to utility-scale "mega solar" power generation facilities, and Japan has established a target for each of the country's ten utilities to build a large-scale solar plant by 2020, for a total of nearly 140 MW.[368] Lastly, the government will implement a new feed-in tariff for solar electricity production that is expected to dramatically increase solar energy adoption. The "new purchasing system" would require utilities to purchase excess solar PV electricity at about twice the current (voluntary) price, or close to 50 cents/kWh.[369]

Wind Power

As a result of the many barriers to widespread wind energy adoption in Japan (discussed in the "Competing Industries Section" above), Japan does not currently offer significant incentives for domestic wind energy deployment. Many of the existing policies for the development of the domestic wind industry focus on solving grid and energy storage issues and developing turbines that meet certain national safety standards (for example, those that can withstand extreme wind speeds).[370]

Nuclear Power

Japan currently has two nuclear reactors under construction and a further 13 planned for construction over the next ten years, with the first to begin construction at the end of 2009. The Japanese government plans to increase reliance on nuclear power to achieve its greenhouse gas reduction goals. In 2008, the Ministry of Economy, Trade and Industry (METI) released an electricity supply plan showing nuclear capacity growing to 61.5 GW by 2017 (up from 47.5 GW today) and the share of nuclear electricity generation growing to 41 percent of total generation in 2017, up from 30 percent today.[371] While some specifics of future nuclear policy are uncertain due to the election of the Democratic Party of Japan (DPJ) in August 2009, the DPJ remains supportive of increasing domestic reliance on nuclear power.[372]

Carbon Capture and Storage

In 2008, Japan set a goal to capture and store 100 million tons of carbon dioxide per year by 2020. Government officials believe that there is potential to store up to 150 billion tons of CO2 in the country.[373] As part of Japan's "Cool Earth" initiative—a push to develop innovative energy technologies—the government aims to reduce the cost of carbon capture from around $40 (¥4,200) per ton today to $11 (¥1,000) per ton in 2020.[374] Japan currently has two CCS test facilities planned in the country. The first is the Coolgen project, a $1.1 billion project that aims to demonstrate an oxygen-blown IGCC process to eventually bring plant emissions down to zero. The facility is expected to be operational in 2017.[375] A location within Japan has yet to be selected for the second plant.

Advanced Vehicles and Batteries

Japan's "Action Plan for Achieving a Low-Carbon Society" sets an ambitious goal for the development of low-emission vehicles. The government aims for one out of every two new cars sold to be a next-generation vehicle by the year 2020, up from the current proportion of one in 50.[376] In April 2009, former Prime Minister Aso proposed an initiative to make Japan "the first nation to popularize eco-cars." He set a goal to begin mass production and mass sales of electric cars in three years' time on the way to achieving the 2020 target. To help boost domestic sales of hybrid and electric cars, Japan is providing a $2,500 subsidy for low-emission vehicles to replace older cars and a $1,000 subsidy for customers to purchase a newer, efficient car.[377] Japan is also providing a major subsidy in FY2009 to encourage the early adoption of electric vehicles. The subsidies are currently implemented by METI, and would offer a maximum of $14,201 (¥1,390,000) for the purchase of a new electric vehicle.[378] The government hopes that subsidies will help create initial demand for the vehicles, but it also plans to improve price and performance through R&D and the provision of electric vehicle charging infrastructure.

High-Speed Rail

While Japan does not have major plans to expand its already well-established high-speed rail network, Japan has consistently modernized its technology, creating demand for new HSR rolling stock. Japan will release the new E5 series trains in 2011 and plans to launch next generation maglev bullet trains, currently in the testing phase, in 2025 on a line that will connect Tokyo and Nagoya in approximately 40 minutes.[379]

Other Clean Technologies

As part of Japan's economic stimulus packages, the government allocated $18 billion for building energy efficiency improvements.[380] Japan also leads the world in the production of high-efficiency lighting, and contributes 45 percent of the world's supply of high-brightness light-emitting diodes (LEDs) as well as 37 percent of global market demand.[381] It is home to the world's largest LED manufacturer and five of the world's top ten LED suppliers.[382] LEDs are an important part of Japan's strategy to improve energy efficiency and reduce its CO2 emissions.

South Korea
Quick Facts:

Popluation (2009)
48.5 million

GDP PPP (2008 est)
$1.335 trillion

GDP PPP per Capita (2008 est)
$27,600

Electr. Generation (2008 est)
50.2 ave. GW

Total Primary Energy Supply (2007)
222.2 Million tons oil-equivalent

Source: CIA World Factbook and International Energy Agency

South Korea

The South Korean government is quickly ramping up efforts to increase domestic deployment of clean energy technologies and its share of global clean tech markets. In December 2008, the government passed the Third Basic Plan for New and Renewable Energy (NRE) Technology Development and Deployment, which set medium to long-term targets for renewable energy development and deployment and laid out action plans and strategies to achieve them.[383] The plan set a target for the renewable energy share of the primary energy supply to reach 4.3 percent in 2015, 6.1 percent in 2020, and 11 percent in 2030, up from 2.4 percent today. The government is targeting a number of technologies to reach its goal, including solar PV, wind power, bioenergy, and waste energy, with the latter two making the largest contribution toward the governments renewable energy objective.

While the Korean government has offered renewable energy subsidies for a number of years, the most substantial policy support to date came in the form of South Korea's $38 billion economic stimulus package passed in 2008. The package, called "the Green New Deal", invested $31 billion in energy and environment related sectors. While much of that investment is set aside for environmental restoration projects, approximately $17 billion dollars is allocated to clean energy technologies, including renewable energy, low-carbon vehicles, high-speed rail, and energy efficiency technologies.[384]

Recently, the Korean government announced that it is turning its "Green New Deal" into a five-year $84 billion (107 trillion won) investment program to reduce the nation's reliance on fossil fuels.[385] Of this total, about $46 billion[386]—fully one percent of the nation's GDP each year—will be directed toward clean energy technologies, such as renewable energy, LEDs, hybrid vehicles, and new smart grid infrastructure.[387]

South Korea's new investment plan is the centerpiece of a larger strategy of "green growth" that seeks to address the challenges of the global economic downturn while simultaneously increasing energy security and reducing the nation's contribution to global climate change. The government seeks to create a "green growth engine" to create jobs and bolster continued economic development. South Korea's "green growth" strategy has been praised by organizations including the United Nations Environmental Program (UNEP), which will soon release a report hailing South Korea's new development strategy as a model for the rest of the world.[388]

Research and Innovation

The "Green New Deal" investment program provides direct support for South Korea's domestic clean energy industries at each stage of development.[389] To support technologies in early research and development stages, the government will launch a "Comprehensive R&D Plan on Green Technology," increasing public investment in clean energy R&D to $6.7 billion over five years, or $1.3 billion annually, sufficient to double current funding levels. The funds will be used for R&D targeting a suite of 27 core energy technologies, including high-efficiency solar batteries, hybrid vehicles, and CCS technology.[390,391] The Korean Development Bank will also establish additional $237 million fund to support R&D activities of private sector "green industries."[392]

In September 2009, South Korea's largest utility, the state-run Korean Electric Power Corporation (KEPCO), announced that it would spend $2.4 billion (2.8 trillion won) through 2020 on clean technology development. Funds will be disbursed beginning in 2010, and KEPCO will allocate its investment to eight sectors in particular, including CCS, nuclear, smart grid development, and electric charging infrastructure for plug-in hybrid and electric vehicles.[393]

Manufacturing and Markets

With the "Green New Deal", South Korea aims to establish itself as one of the world's top seven "green powers" by 2020, and one of the top five by 2050.[394] In addition to the overall renewable targets established in late 2008, the government has also set technology-specific deployment targets. The government is aiming for 2.25 GW generated from wind[395] and 1.3 GW from solar PV by 2012.[396] It has also set a goal to completely localize nuclear power technology and export its first nuclear power plant by 2012.[397] Overall, the government seeks to increase its market share in the overseas green technology market by 8 percentage points, with a focus on solar, LED, nuclear, and hybrid car technologies.[398]

To support small and medium size enterprises in clean technology sectors, the government will offer preferential financing, which will be increased to approximately $900 million in 2013. Loan guarantees to "green enterprises" will be increased to $5.6 billion in 2013 from $2.2 billion today. The government will also expand export financing of clean tech products from $800 million today to $2.3 billion in 2013.[399] Some private companies are already taking advantage of these new incentives and South Korea's direct investments to grow its clean technology market. In June, American investment bank JP Morgan announced plans to set up funds of more than $1 billion to invest in South Korea's alternative energy industry.[400]

Overall, the market for clean technologies in South Korea will see a major boost over the next five years. The forthcoming UNEP report estimates that South Korea's five-year investment program will induce production worth between $141.7 billion (182 trillion won) and $160.3 billion (206 trillion won) over that time period.[401] The government estimates that through investments in the program, the export and domestic sales of green technologies could increase to $410 billion in 2020.[402]

Solar Power

South Korea's solar PV industry is poised for take-off after experiencing its best year to date in 2008. Due to the expansion of a generous solar feed-in tariff, the domestic market became the fourth largest globally in 2008. The government first introduced a generous feed-in tariff for solar electricity in 2002; the tariff was set about 8 times higher than the average residential electricity price. Until 2007, however, the program was capped at 20 MW of cumulative capacity. In 2007 the cap was elevated to 100 MW, and in 2008, despite increasing budgetary concerns, the government raised the cap even further, to 500 MW, helping to drive a six-fold increase in the deployment of solar energy in 2008, and making South Korea's solar market 4th in the world.[403]

South Korea's feed-in tariff is financed by the federal budget (unlike many other nation's feed-in tariffs which are financed by electricity ratepayers), and policymakers have since become concerned about the strain that the generous solar policy could place on the national budget. In October 2008, the government decided to cut the feed-in tariff by 8 percent for systems less than 30 kW and 37 percent for large solar parks of over 3 MW.[404] The differentiated rates reflect a decision by the government to concentrate on developing building-integrated and residential PV systems. New government proposals have also suggested that the feed-in tariff be capped each year at 98 MW of new capacity in 2009, 132 MW in 2010 and 162 MW for 2011, which are all below previous market growth projections.[405] As the result of the feed-in tariff cut, South Korea's PV market is expected to decline in 2009. In addition, the government announced in July 2009 that it plans to introduce a federal Renewable Portfolio Standard (RPS) and phase-out the current feed-in tariff policy by 2012.[406] As a result of this phase-out and the more indirect incentive provided by the new RPS, South Korea market analyst DisplayBank projects that annual installed PV capacity would be 200 MW in 2012, well below the current pace of installation under the feed-in tariff policy.[407]

The government has also become acutely aware of the need to boost market share of its domestic solar companies and has been focusing its efforts on developing a domestic, low-cost solar manufacturing industry, with a goal of capturing 10 percent of the global PV manufacturing market. South Korea has recently partnered with Germany, an established veteran of the solar energy industry, for assistance it in developing its own domestic manufacturing capacity.[408]

Wind Power

To help achieve South Korea's national goal for wind power, the government is providing attractive incentives such as a guaranteed feed-in tariff and other subsidies for the domestic wind market. Wind generation is eligible for a tariff of $.09/kWh (107.29 Won/kWh) for the first 15 years of plant operation. The tariff rate offered to new wind projects is scheduled to decline 2% per year each year after October 2009. The government also offers subsidized loans to help renewable project developers secure long-term financing at attractive rates.[409]

To boost domestic manufacturing capacity, the Korean Energy Management Corporation (KEMCO) provides maximum loans of $8.4 million (10 billion Won) per facility for renewable energy manufacturing facilities that are repayable over ten years with no payments necessary for the first five years.[410]

Nuclear Power

South Korea has plans to dramatically expand its nuclear power capacity. With 20 nuclear power plants already in operation, the nation has another six under construction and six on order or planned for construction, totaling 14.8 GW of new capacity. A majority of the new reactors use Generation III technology, and major components will be supplied and manufactured primarily by Korean companies, as the country seeks to completely localize the technology for its booming nuclear power industry. Korea plans substantial investments in order to make its nuclear industry a global leader, with the goal of exporting a nuclear power plant by 2012. In total, KEPCO plans to complete 18 new nuclear power plants by 2030, at a cost of $32 billion to $40 billion.[411]

Carbon Capture and Storage

South Korea has not been a major player in the CCS technology market in recent years, but the government plans to change that with a new multi-billion dollar investment in a major CCS demonstration project in the country. In October 2009 the Ministry of Knowledge Economy announced that it would spend $85.5 million by 2013 on R&D to develop domestic technology, as well as create a business consortium to build a pilot 500 MW power plant equipped with CCS technology, intending to make it operational by 2015. The government will also provide a further $1.1 billion over the next ten years to state-run KEPCO for CCS RD&D.[412]

Advanced Vehicles and Batteries

South Korea has boosted its low-carbon vehicle industry with public investments from its recent economic stimulus package. As part of its "Green New Deal" stimulus, the government allocated $1.8 billion to the development of fuel-efficient vehicles, such as electric and hybrid cars, by Korean automakers Hyundai and Kia.[413] In a plan outlined in October 2009, the Korean government called for the full-scale production of electric vehicles in the second half of 2011, two years ahead of the original target date of 2013. In order to speed production, the government will reduce legal and regulatory hurdles that have thus far impeded electric vehicle adoption.[414] For example, the government currently prohibits the use of pure-electric cars, citing a number of administrative issues. The government said that it is reviewing steps to spur sales of EVs, including tax breaks and direct subsidies, and will offer incentives to public organizations that use electric vehicles for official purposes. Overall the government aims to capture 10 percent of the global EV market by 2015, as well as ensure that 10 percent of all vehicles sold in South Korea by 2020 are electric-powered. Such production capabilities would make South Korea the fourth largest EV manufacturer in the world.[415]

High-Speed Rail

Currently, the South Korean government has committed to providing Korail (the operator of the high-speed Korea Train Express) with about $170 million (200 billion won) every year for the next five years. The subsidies are meant to finance interest payments on the $3.7 billion (4.5 trillion won) Korail owes from its expenditures.[416]

Other Clean Technologies

As countries around the world turn an eye to energy saving technologies, South Korea's LED industry looks poised to shine. South Korea is quickly becoming a leading world manufacturer of LED technologies. In 2007, Korea's Seoul Semiconductors ranked fourth in the world, and analysts predict that market growth forecasts combined with the aggressive growth of the company could soon propel South Korea to the top of the industry.[417] According to market research firm Strategies Unlimited the world market for LEDs will grow at an annual rate of 20 percent over the next five years, and will reach $11.4 billion by 2012.[418] The Korean government has taken proactive steps to grow its domestic LED industry and boost the economic competitiveness of its companies, primarily through direct government procurement of the technology. The government plans to replace all incandescent light bulbs at public facilities with LEDs by 2012, a move that is sure to boost the domestic industry and help reduce the cost of LEDs.[419]

Enabling Infrastructure

South Korea has long-term plans to build out electricity grid infrastructure and charging infrastructure for advanced vehicles, in order to make clean energy technologies more attractive to private market adopters. In June 2009, the government announced its intention to build the world's first nation-wide smart grid by 2030. KEPCO plans to set up a $65 million smart grid pilot project on one of South Korea's islands by 2011.[420] South Korea has also signed cooperative agreements with the United States to collaborate on the development of smart grid technologies.[421] The government will also provide $343 million (400 billion won) through 2014 for the development of electric car batteries and battery charging infrastructure. KEPCO has said that it will spend a portion of a ten-year $2.36 billion clean energy R&D investment on smart-grid technology and electric car infrastructure to enable the growth of the industry.[422]

United States Quick Facts:

Popluation (2009)
48.5 million

GDP PPP (2008 est)
$1.335 trillion

GDP PPP per Capita (2008 est)
$27,600

Electr. Generation (2008 est)
50.2 ave. GW

Total Primary Energy Supply (2007)
222.2 Million tons oil-equivalent

Source: CIA World Factbook and International Energy Agency

United States

The United States has historically lacked substantial and sustained policy to promote the development of its clean energy industry. However, the Obama administration and the current Congress have signaled a new intention to develop these industries through the recent economic stimulus package and as part of climate and energy legislation currently under consideration in Congress. The United States will publicly invest around $172 billion in clean energy technologies over the next five years, if the American Clean Energy and Security Act (ACESA) passed by the U.S. House of Representatives in June 2009 becomes law.

In October 2008, the United States enacted the Emergency Economic Stabilization Act (EESA), which included clean energy tax credits and incentives valued at $9.1 billion over five years.[423] The February 2009 American Recovery and Reinvestment Act (ARRA) includes public investments in clean energy sectors totaling approximately $62 billion, the majority of which will be spent in 2009 and 2010,[424] and further clean energy tax credits and incentives valued at approximately $10 billion over five years.[425] Normal U.S. budget appropriations direct roughly $62 billion to clean energy over the next five years if current budget levels are sustained over this period. These are primarily investments in U.S. rail infrastructure and clean energy research and technology programs at the U.S. Department of Energy. Finally, if the House-passed ACESA climate and energy bill becomes law, the United States will invest an additional $29 billion over the next five years in clean energy sectors. (See Appendix A for a detailed breakdown of U.S. clean technology investments)

Table 3: U.S. Public Investment in Clean Technology by Source, 2009-2013

Source	Current Budget Appropriations	U.S. Stimulus Measures	American Clean Energy and Security Act
Amount (Billions US $)	$62.3	$81.1	$28.7

As these numbers indicate, after a substantial amount of clean energy investment in U.S. stimulus measures, American public investment in clean technology is set to decrease as stimulus funding is phased out and replaced by the ACESA climate and energy bill, which scales back public investment in U.S. clean energy industries by nearly two-thirds relative to levels established under ARRA and EESA.

ACESA would also create a nationwide cap and trade program to establish a price on carbon dioxide emissions and other greenhouse gases, a measure intended to incentivize adoption of clean and efficient energy technologies. However, due to a number of measures in the bill to contain the cost of compliance with the cap and trade program (most notably the permitted use of offsets to cover up to two billion tons of emissions annually), as well as the potential over-allocation of emissions allowances in early years due to the current economic recession and associated drop in U.S. emissions,[426] the carbon price established by ACESA is expected to be relatively low. The U.S. Environmental Protection Agency (EPA) projects that the ACESA cap and trade program will establish a carbon price of $12.70 per ton of CO2-equivalent in 2012 – the equivalent of an increase in gasoline prices of roughly 12 cents per gallon – rising to $14.38 per ton in 2015 and $17.69 in 2020 (all values in constant 2009 dollars).[427]

The EPA expects that a carbon price in this range is not likely to significantly increase demand for clean energy technologies in the near-term, especially new low-carbon electricity and advanced vehicle technologies. EPA analysts concludes that under ACESA, "electricity demand is reduced significantly," primarily through the legislation's energy efficiency regulations, "and allowance prices are not high enough to drive a significant amount of additional low- or zero-carbon energy (including nuclear, renewables, and CCS) in the shorter-term, excluding the technologies with specific financial incentives (e.g. CCS)."[428] Furthermore, the agency concludes, "The increase in gasoline prices that results from the carbon price … is not sufficient to substantially change consumer behavior in their vehicle miles traveled or vehicle purchases at the prices at which low GHG emitting automotive technologies can be produced."[429]

Finally, ACESA includes a combined efficiency and renewable electricity standard (CERES), which establishes a nominal requirement that 20 percent of U.S. electricity be generated by renewable energy sources by the year 2020. Up to one quarter of this requirement may be met through energy efficiency savings, rather than new renewable electricity generation and as a result of several other exemptions included in the legislation, the CERES will only require between 8 percent and 12 percent of U.S. electricity generation from renewable sources in 2020, limiting the provisions impact on new renewable energy deployment.[430] The U.S. Energy Information Administration (EIA) projects renewable electricity generation will reach 10 percent of total U.S. electricity use in 2020 in the absence of any new policies, and an analysis by the Union of Concerned Scientists concludes, "The Waxman-Markey (ACESA) RES [Renewable Electricity Standard] does not ensure that any new renewable electricity will be developed beyond the renewables that are already projected to occur under the business as usual forecast by the [EIA]."[431] The standard may incrementally increase the use of energy efficient technologies and practices, but will have little to no impact on U.S. renewable electricity deployment.

Research and Innovation

Fiscal Year (FY) 2009 and 2010 U.S. energy research, development and demonstration (RD&D) budgets subject to normal Congressional appropriations total just over $5 billion annually, up somewhat from FY2008 levels of $4.2 billion.[432] These funds include both basic science and research and applied technology RD&D programs at the U.S. Department of Energy, the primary U.S. agency involved in energy research. Other agencies, including the U.S. Department of Agriculture, National Science Foundation and Department of Defense fund some energy-related research, but exact levels are difficult to discern from published budget documents, and overall energy R&D funding from these agencies is relatively small.

The American Recovery and Reinvestment Act (ARRA) provides a significant temporary boost to U.S. energy RD&D budgets constituting the largest increase in energy innovation funding in decades. The stimulus package includes $7.4 billion for clean energy RD&D including $2.5 billion for renewable energy research and development and around $2.4 billion to develop and demonstrate CCS technology (see Appendix A for more).[433] Most of this funding will be allocated in 2009 and 2010.[434]

Should the American Clean Energy and Security Act (ACESA) become law, however, it will significantly reduce funding levels established through ARRA, dedicating cap and trade allowances estimated to be worth just under $900 million per year to clean energy research and development in 2012 and 2013.[435] This funding would augment budgets at the newly established Advanced Research Projects Agency for Energy (ARPA-E) and fund the creation of several new regional Clean Energy Innovation Centers. ACESA R&D investments would increase somewhat beyond 2013, averaging $1.2 billion per year between 2012 and 2021, still well below budget levels under ARRA.[436] In contrast, President Obama has called for new clean energy R&D investments averaging $15 billion per year over the next ten years,[437] a funding level supported by a variety of energy innovation experts.[438]

Table 4. U.S. Public Energy RD&D Funding By Source, 2009-2013

Source (in millions of US $)	2009	2010	2011	2012	2013	Five-year total, 2009-2013
DOE budget appropriations*	$5,269	$5,237	$5,237^	$5,237^	$5,237^	$26,217
ARRA funding	$3,700#	$3,700#	$0	$0	$0	$7,400
ACESA allowance allocations	$0	$0	$0	$873	$893	$1,766
Total (in billions of US $)	**$9.0**	**$8.9**	**$5.2**	**$6.1**	**$6.1**	**$35.4**

* Includes DOE Advanced Research Projects Agency for Energy (ARPA-E), the Office of Science's Office of Basic Energy Science, Fusion Energy Sciences Program, and Biological and Environmental Research program, technology budgets at the Office of Fossil Energy, Office of Energy Efficiency and Renewable Energy, Office of Nuclear Energy and Office of Electricity Delivery and Energy Reliability, and DOE-funding for the Small Business Innovation Research (SBIR) program.

Assumes ARRA RD&D funding spent in FY 2009 and FY 2010. Approximately $6 billion of $7.4 billion total ARRA RD&D funding is listed as appropriated for FY 2009 in DOE budget documents. Some of this funding will likely be carried over into FY 2010, so total funding level is split evenly between the two years.

^ Assumes FY2010 budget levels continued in subsequent years. Actual funding levels subject to future Administration budget requests and Congressional appropriation.

Manufacturing and Markets

In October 2008, the United States passed EESA to help stem the effects of the U.S. financial crisis. Tucked in the $700 billion bill were approximately $18.2 billion worth of tax credits intended to spur demand for clean energy technologies. In February 2009, the United States passed ARRA to boost the ailing economy. The $787 billion stimulus package included $54.1 billion in public spending for clean energy manufacturing and deployment, broadly defined, with the majority to be spent in 2009 and 2010. It also included tax incentives, credits, and bonds to spur the deployment of various clean energy technologies valued at $20 billion over ten years.[439] According to the EIA, these public investments will help double U.S. non-hydro renewable energy generation between 2009 and 2012, increasing electricity generation from these sources to over 300 billion kilowatt-hours in 2012.[440]

The House-passed ACESA legislation would generate an average of approximately $78 billion worth of revenue each year over the first decade of the program (2012-2021) at allowance prices projected by the EPA. Of that revenue, an average of approximately $9.5 billion annually will be invested in clean energy technology manufacturing and deployment. However, just $7.6 billion and $7.8 billion in clean technology deployment and manufacturing funding will be provided in 2012 and 2013, respectively.[441] The following table details the clean technology programs funded through ACESA allowance allocations.

Table 5. ACESA Allowance Allocations for Clean Energy Technology Manufacturing and Deployment

Allocation (in million constant 2009 US $ at EPA-projected allowance prices)	2012 Allocation Value	2013 Allocation Value	Average Annual Allocation Value, 2012-2021
Carbon Capture and Sequestration Deployment Incentives	$0	$0	$2,234
Advanced Automotive Technology Manufacturing and Deployment	$1,745	$1,786	$1,452
Renewable Energy & Energy Efficiency Deployment (state, local govt. programs)	$5,526	$5,657	$5,443
Building Code and Building Efficiency Retrofit Programs	$320	$328	$416
Total	**$7,591**	**$7,771**	**$9,544**

ACESA contain additional measures likely to boost the manufacturing and deployment of clean energy technologies in the United States. Notably, the House bill creates a new Clean Energy Deployment Administration (CEDA), initially capitalized with $7.5 billion. The new administration would leverage these federal funds to provide direct loans, loan guarantees, insurance products and other credit enhancement mechanisms to support and accelerate the commercialization, improvement and deployment of emerging clean energy technologies.

ACESA also authorizes the creation of a revolving loan program to support the construction of U.S. clean energy manufacturing facilities or retooling of existing plants to manufacture clean energy technologies. ACESA authorizes $15 billion in each of 2010 and 2011 for this purpose. ACESA also doubles the aggregate amount of loans that the Department of Energy is authorized to make under the Advanced Technology Vehicle Manufacturing Loan Program, from $25 billion to $50 billion. However, these two manufacturing loan provisions are not provided with a dedicated source of revenue in the legislation and are subject to further appropriations. Due to current U.S. budgetary constraints, it is unclear whether these provisions will be funded in part or in full. Therefore, these programs are not included in the overall investment figures calculated in this report.

The United States lacks a comprehensive federal clean energy technology policy that provides targeted support for individual technologies (i.e. a feed-in tariff with specific rates for different energy technologies), and the primary incentive mechanism under pending legislation—an economy-wide carbon price—would likely incentivize the adoption of only the lowest-cost clean energy technologies, such as energy efficiency, or simple fuel switching to natural gas. There are, however, some technology-specific investments in EESA and ARRA, discussed below, which will increase the deployment of targeted technologies. Likewise, a portion of the revenue from allowances under ACESA will be directed towards particular technologies.

Solar Power

In recent years, the most substantial solar incentive at the federal level has been the Investment Tax Credit (ITC). The ITC provides a credit equal to 30 percent of a project's qualifying costs, which is realized in the year in which the project begins commercial operation. While the ITC was intended to give greater investor certainty for the renewable projects it covered, it has historically faced continual threat of expiration in Congress and has had to be extended numerous times, creating investor uncertainty and delaying renewable projects. In October 2008, as part of the EESA, the ITC was extended until the end of 2016, a previous $2,000 cap on the tax credit was removed for residential solar PV systems, and utilities were for the first time allowed to qualify as tax credit recipients. The federal ITC has been ineffective at driving renewable deployment in 2009, however, because tax equity investors, such as large investment banks, typically provide the bulk of financing for renewable projects, as they have generally been able to make the large initial investments necessary to eventually claim the 30 percent tax credit. The current financial crisis has reduced the number of such investors and limited the efficacy of the ITC at the same time that the costs of project financing have increased.[442]

In order to address this issue, ARRA included a provision that allowed, for a limited time, ITC-eligible projects to instead receive a cash grant to cover 30 percent of project costs.

ARRA authorized the program, which has no funding cap but is expected to cost $3 billion through October 2011, when the program is due to end. Projects that begin construction before the end of 2010 are eligible for the grant. To date, over $1 billion in cash grants have already been distributed.[443] However, thus far, most of the cash grant money has gone to wind power projects, and only a fraction to solar, creating doubt as to how large an effect the new program will have on solar PV deployment.[444]

ACESA, if passed into law, would provide some direct investments that could be used to support solar PV deployment. Just over $5.5 billion in allowance revenue would be provided to state, local, and tribal governments for renewable energy and energy efficiency in 2012 and 2013. However, because the money will be divided among many parties, it will be used predominantly for end-use energy efficiency and distributed renewable generation, rather than large-scale renewable deployment. Small-scale, distributed solar PV may therefore benefit under this program, but prospects for large, utility-scale solar projects are less certain under ACESA.

Wind Power

Similar to the incentives for solar power, tax credits have been the major policy support mechanism for wind power deployment. Specifically, wind power projects are eligible for the federal Production Tax Credit (PTC), which was originally authorized by the Energy Policy Act of 1992.[445] As discussed earlier in this report, the federal PTC was perpetually at risk of expiration over the past decade, and did in fact expire on three occasions. In each of the years following the expiration of the tax credit, the level of deployed wind power capacity was substantially lower than it was in the previous year. For example, in 2003 the United States deployed close to 1.7 GW of wind power, while in 2004, the year after the PTC expired, its domestic market fell 82% to just 300 MW.[446] The PTC has been active, though still at risk of expiration, since 2005 and was recently extended again until the end of 2012 through ARRA. The PTC currently provides a $.021/kWh benefit for the first ten years of an eligible renewable energy facility's operation.

The efficacy of the PTC, like that of the ITC, also requires large investors with a sufficient tax appetite to provide financing for wind power projects in order to claim the credit. Therefore, the impact of the PTC on wind deployment has also been blunted by the financial crisis. For a limited time under ARRA, PTC-eligible projects are also eligible to receive a cash grant equal to 30 percent of eligible project costs instead of claiming the PTC. Recent evidence suggests that the cash grant program is providing a big boost for wind power deployment and attracting significant additional private investment. Just four weeks into the program, $800 million in grants had already been submitted, and analysts predict that the number would reach as high as $10 billion by the end of 2010, although Treasury Department estimates initially expected the grant program to total $3 billion.[447]

Wind power may also gain some benefit from the roughly $5.5 billion annual allowance revenue that ACESA provides to state, local, and tribal governments for renewable energy and energy efficiency. The effects of these annual investments on wind power deployment are uncertain, however, as much of the investments are expected to go to end-use energy efficiency and distributed renewable generation.

Nuclear Power

The United States currently provides $18.5 billion in loan guarantees for nuclear power projects, originally authorized under the Energy Policy Act of 2005. Those working in the domestic nuclear industry do not believe that the program is sufficient to jump-start the dormant U.S. industry, and the government is currently reviewing options for expanding the loan-guarantee program or offering other incentives.[448]

The ACESA legislation does not provide direct support for nuclear power. The legislation would establish the Clean Energy Deployment Administration to provide financial incentives and loan guarantees for eligible advanced technologies, including nuclear, but limits the amount of funding going toward any one energy source to 30 percent of the loan guarantees, which could reduce its impact on nuclear power expansion.[449]

Carbon Capture and Storage

The United States is planning an expansion of its support for CCS technology in pending climate and energy legislation. ACESA would invest allowances valued at an average of $2.2 billion per year from 2012-2021 to create deployment incentives for commercial-scale CCS projects, although these incentives do not begin until 2014. The legislation also creates a Carbon Capture and Sequestration Demonstration and Early Deployment Program, which would create a private Carbon Storage Research Corporation managed by the utility industry's Electric Power and Research Institute (EPRI) but publicly financed by a small carbon fee on all electricity sold in the United States. The fee would generate $10 billion over ten years dedicated to promote the commercialization and large-scale demonstration of CCS technologies.[450]

Advanced Vehicles and Batteries

ARRA contained $3 billion in direct spending for efficient vehicles, advanced batteries and transportation electrification. Of that amount, $2 billion was directed towards the Advanced Battery Manufacturing grant program to support the production of advanced batteries for hybrids, plug-ins, and electric vehicles. ARRA allocates $400 million for transportation electrification activities, $300 million to facilitate the use of alternative fuel vehicles, and $300 million for the acquisition of efficient vehicles for the federal fleet.[451] In August 2009, President Barack Obama announced that the $2.4 billion would be split between 48 different projects throughout the country. He announced that $1.5 billion would go to U.S.-based manufacturers producing advanced batteries, $500 million to producers of electric-drive components, and $400 million for grants to purchase thousands of plug-in hybrid or all-electric vehicles for test demonstration in different locations around the country.[452]

ACESA allocates allowances valued at approximately $1.8 billion per year in 2012 and 2013 to support the deployment and manufacturing of advanced vehicles; this allocation decreases in value over time, averaging under $1.5 billion between 2012-2021. ACESA also contains a number of programs aimed at supporting advanced vehicles, such as expanding the Advanced Technology Vehicle Manufacturing Incentive loan program by $25 billion. A revenue source for this funding is not specified, however, and the funding has yet to be appropriated.

High-Speed Rail

The United States does have plans to implement high-speed rail (HSR) although none are shovel-ready as this report goes to press. Under the economic stimulus package, ARRA, $8 billion is allocated to developing HSR in the United States and the money has been meted out to 10 potential high-speed intercity corridors via a grant process that accepted applications through August 2009. In addition to the stimulus dollars, President Obama's budget outline allocates $5 billion over the next five years for HSR development.[453] The House of Representatives increased that to $4 billion per year in their appropriations for FY2010[454] while the Senate appropriations, passed in September 2009, allotted $1.2 billion for FY2010.[455] The two bills have not gone to conference as this report goes to press.

Part of the reason that the United States lacks high speed rail infrastructure, is that there are many obstacles to installing nation-wide, or even regional, networks that smaller nations do not face. In addition to topographical challenges, high-density suburbs, essentially the phenomenon of the American town, makes it challenging to find the space to construct brand new HSR infrastructure.[456] Furthermore, the predicted cost to establish a national HSR network—one estimate places the cost at $600 billion dollars over the next two decades[457]—has kept many projects from securing the necessary funding to advance. Yet, as Japan gains increasing dominance in the global export market, and China continues to grow its HSR infrastructure and technology knowledge, the cost of neglecting high-speed rail technology could grow for the United States, especially if the nation does not develop the capacity to localize HSR manufacturing.[458]

Currently, California has a $42 billion plan to deploy an 800-mile line that would connect San Diego and Los Angeles in the south with Sacramento and San Francisco. Although this is by far the most advanced HSR proposal in the United States, it is still far from "shovel-ready."[459] Advocates of the plan are still seeking local approvals and construction is not expected to begin until 2011 at the earliest. A significant portion of the funding for the California HSR line has been secured however. In 2008, California voters approved a ballot proposition authorizing $9.5 billion in bonds as well as $950 million to finance improvements to the conventional transportation infrastructure that will service the high-speed line. The federal government is expected to provide 25-33 percent of construction costs and an additional $4.5-7 billion will be financed by a public-private partnership.[460] The project is expected to generate $1 billion in annual profits and plans to operate without any additional government subsidy.[461]

Enabling Infrastructure

ARRA provided a major investment for the development and deployment of infrastructure to support the adoption of clean energy technologies. The legislation provides $11 billion to modernize the U.S. electrical grid, including funds for the development of smart-grid infrastructure. In October 2009 President Obama announced the distribution of $3.4 billion of this funding for grid-modernization, including smart grid development and "smart meters" to boost energy efficiency.[462]

Conclusions and Implications

As this report documents, Asia's "clean technology tigers" plan to build on their current advantages in the global clean technology sector by making large and sustained investments to support clean technology research and innovation, manufacturing, domestic markets, and the establishment of critical infrastructure. Over the next five years, the governments of China, Japan, and South Korea plan to invest a total of $509 billion in domestic clean technology industries. By contrast, the United States government will invest just $172 billion over the same period.

The largest investments will be made by China, which will soon announce a renewable energy stimulus package reported to be valued at $440 to $660 billion over ten years. Japan plans to invest $66 billion over the next five years in clean energy technology, with a focus on improving the current generation of clean technology and reducing their costs while scaling up domestic industries. South Korea will invest $46 billion on clean energy technology over the next five years, a full one percent of its GDP; were the United States to invest an equivalent portion of the nation's resources in clean technology, it would spend nearly $140 billion annually.

In addition to the larger scale of clean energy investments in China, Japan, and South Korea, the clean technology policies of the United States' Asian competitors are more long-term and more directly formulated to overcome barriers to individual technologies. These targeted policies, such as national feed-in tariffs and technology installation subsidies, as well as support for clean tech manufacturers and major investments in clean energy infrastructure, are likely to offer a lower risk environment for private investors, attracting the bulk of future private investment in clean technologies, expected to be in the trillions of dollars over the next decade.

There are a number of barriers that prevent the widespread adoption of clean energy technologies by private market adopters, and four in particular are described in this report. The first major barrier is the significant price differential that exists between clean energy and fossil fuels. The costs of these new technologies are too high, and their return on investment too low, to justify large-scale private investment in their widespread deployment. Second, firms are discouraged from making large investments in clean energy research and development because of technology spillover risks that prevent them from capturing the full value of their investments. Third, the scale and long time horizon of most clean technology projects makes it difficult to assess expected rates of return on investments, creating unacceptable levels of financial risk and inhibiting private investment. Lastly, new clean energy technologies frequently require the establishment of new enabling infrastructure, as current energy systems are designed to accommodate incumbent technologies, not emerging challengers.

The long-term and targeted clean energy public policies of Asia's clean tech tigers will help address many if not most of these barriers, generating greater private market investment in domestic clean technology industries. In order to bridge the price gap between clean energy technologies and fossil fuels, and to provide greater investor certainty in domestic clean technology markets, these three nations are enacting clean energy procurement policies and long-term policies to buy down the costs of clean energy generation.

China has implemented feed-in tariffs for wind power generation set to correspond to variable wind resources. China will soon adopt a new feed-in tariff policy for utility-scale PV plants, a plan that has already helped secure a deal to construct the world's largest solar power plant within the country. China is adopting procurement policies to drive the widespread adoption of electric vehicles, and the government is financing the majority of the nation's major expansion of high-voltage electrical transmission and high-speed rail networks. South Korea has targeted feed-in tariffs policies that offer premiums on electricity generated by a suite of low-carbon energy technologies, including solar PV and wind. Japan has enacted installation subsidies and procurement policies to increase solar PV adoption, and in November 2009 instated a new feed-in tariff for solar electricity.

To overcome barriers to research and innovation, all three Asian nations are extending their public commitments to energy research and development. The Japanese government plans to spend $30 billion over five years implementing low-carbon technology roadmaps to reduce the cost and improve the performance of emerging clean energy technologies. South Korea is doubling its investment in energy R&D over the next five years and China is strengthening its nascent energy innovation capacity.

These nations are also investing heavily in new energy infrastructure to help accelerate the deployment of new clean technologies. Each nation is investing in the construction of new electric-vehicle charging infrastructure to enable greater adoption of plug-in hybrid and electric vehicles. To accelerate the deployment of clean energy generation technologies, China is investing $44 billion through 2012 in new ultra high voltage (UHV) power lines, while South Korea is funding the construction of a nationwide smart grid by 2030.

Proposed climate and energy policy in the United States, by contrast, is less targeted, more volatile, and may create a higher risk environment for investors. While the direct technology investments and other incentives in the U.S. Emergency Economic Stabilization Act (EESA) and the American Recovery and Reinvestment Act (ARRA) have provided a major boost for domestic clean technology industries—the two stimulus measures will provide just over $81 billion for clean technology over the next five years—a level of direct support that is not sustained under the American Clean Energy and Security Act (ACESA) passed by the U.S. House of Representatives in June 2009. The ACESA climate and energy bill would invest just $29 billion to support U.S. clean energy industries over the next five years, a step backwards from funding levels begun under U.S. economic stimulus measures and far short of investments planned by Asia's clean tech tigers.

Moreover, as the primary mechanism to incentivize clean technology adoption, the ACESA legislation would establish an economy-wide carbon price that is expected to remain low (an average of $15 per ton CO2-equivalent) for at least the next decade, a level insufficient to provide a significant near-term boost to U.S. competitiveness in clean energy technology. This market-incentive based policy is likely to create more risks for private clean technology investors because the incentive is not sufficiently strong (i.e. the carbon price is low), it is not targeted to the requirements of individual technologies, and because it does little to address the many non-economic barriers to clean technology adoption, including grid access, energy storage, and spillover risks from investments in energy innovation.

Implications for U.S. Economic Competitiveness

The clean energy race may become one of the defining global economic competitions of the 21st century. The latest trends in the global clean technology industry suggest that Asia's rising clean tech tigers are positioning themselves to gain first-mover advantages and capture market share in the burgeoning clean energy sector.

Fortunately, not all the indicators portend a loss of dominance for the United States and the nation retains an entrepreneurial spirit and world-class innovative capacity. Historic examples of U.S. action offer models for how the nation can regain the lead in clean energy. One of the most salient examples is early aviation and aerospace. In the early 20th century, the United States, through sustained federal support for aviation technology development and deployment, became a world leader in civil and military aviation, after trailing its European counterparts for years.[463] Likewise, during the space race, the United States quickly met and then surpassed the Soviet Union after it launched the Sputnik satellite, putting a man on the moon twelve years later with the support of a sustained program of direct investment in innovation and technology. This era of large-scale public investment in technology supported successive waves of innovation, paving the way for the information technology revolution and decades of U.S. economic growth.

Restoring America's competitiveness and ensuring U.S. leadership in the burgeoning clean energy sector will require a direct and sustained effort by the federal government to strengthen U.S. clean technology research and innovation, manufacturing capacity, and domestic markets.

Establishing a price on carbon emissions, new energy standards, and other indirect incentives are necessary but are not sufficiently robust to support the growth of the U.S. clean energy sector and outcompete Asia's clean technology tigers.

As China, Japan, and South Korea all launch proactive and aggressive strategies to achieve technological and economic leadership in the clean energy sector, the United States will find it difficult to catch up without direct and targeted public investments of a similar scale. More aggressive measures will be required for the United States to regain the lead in the global clean energy race. The policy actions of China, Japan, and South Korea have important implications for U.S. policy and the steps that the U.S. government should take to strengthen the nation's competitive position:

| 1 |

The U.S. government should significantly increase investment in clean energy innovation by making a sustained commitment to research, development, and demonstration (RD&D).

A major boost in RD&D funding is necessary to improve the price and performance of clean energy technologies and gain a competitive advantage in the clean energy industry. Furthermore, without much greater investment in innovation, the United States risks seeing the next generation of clean technologies invented and commercialized overseas. The government of South Korea is poised to double its investment in clean energy R&D, and Japan plans to invest $30 billion over five years on research and development in low-carbon energy. Both Japan and South Korea have developed technology roadmaps that direct resources to technology R&D based on a thorough analysis of the economic and environmental potential of each technology and current institutional capacity to achieve technological leadership. The United States currently has no such strategy, and its investment in energy R&D has stagnated at low levels for years.[464] Along with increasing its commitment to clean energy research and development, the United States should explore new institutional structures to strengthen and augment the federal energy R&D system.[465] Furthermore, to ensure the timely commercialization of emerging technologies, the U.S. government should provide much greater funding to accelerate the commercial-scale demonstration of promising clean energy technologies, particularly in situations where the private sector is reluctant to commit funding to commercialize these nascent technologies.[466] A substantial and sustained increase of federal investment in clean energy RD&D will be necessary to regain economic leadership in the clean energy sector and to match the aggressive policies of our competitors.

| 2 |

The United States government should spur the adoption of innovative manufacturing processes and accelerate economies of scale in U.S. clean energy manufacturing.

Currently, China, Japan and South Korea are far outpacing the United States in manufacturing and producing the clean energy technologies that will underpin a new wave of economic growth. While low-carbon technology development benefits the entire world, real economic advantages are at stake for particular nations in the form of increased tax revenues, jobs, and the emergence of related industries and businesses along the clean energy technology value chain. The Chinese government is actively supporting the development of clean energy manufacturing centers in the country and is linking them with supporting financial and research institutions. To establish a competitive clean energy manufacturing industry in the United States, the government should provide or secure low-cost financing,[467] incentives,[468] and technical assistance[469] to retool the nation's industrial base and ensure that U.S. factories are commercializing and building the clean, cheap energy technologies to power America's economy and export abroad. Furthermore, a significant portion of U.S. research and development efforts should be located close to regional industry clusters and targeted to address manufacturing challenges and improve the design and production of clean technologies at scale.[470]

| 3 |

The United States government should actively support, through targeted public policy and investment, the acceleration of clean energy deployment and market creation in order to reduce the price of promising clean energy technologies and encourage their widespread adoption.

The U.S. government should provide sustained and targeted investments to spur a full suite of promising clean energy technologies, with a particular emphasis on closing the price gap between clean energy and incumbent fossil fuel energy sources. Pricing carbon can play a role here, but raising the costs of carbon-intensive energy sources through an economy-wide carbon price will not by itself provide the targeted support necessary to overcome technology-specific price gaps and other key barriers that inhibit the deployment of a full suite of clean energy technologies at scale. Asia's clean tech tigers are supporting clean energy technology adoption through a variety of targeted public policies, including technology-specific production incentives, government procurement offers and sustained and long-term lines of credit in the form of low-cost financing and credit guarantees. The U.S. government should similarly provide sustained financial and policy support for the deployment of clean energy at scale. Such incentives must be considered integral to any U.S. clean technology development and economic competitiveness strategy.[471]

Appendices and Endnotes

Appendix A: Summary of U.S. Government Clean Technology Investments

In October 2008, the United States enacted the Emergency Economic Stabilization Act (EESA), which included clean energy tax credits and incentives valued at $9.1 billion over five years. The February 2009 American Recovery and Reinvestment Act includes investments and direct spending totaling approximately $62 billion in clean energy sectors, the majority of which will be spent in 2009 and 2010, and further clean energy tax credits and incentives valued at approximately $10 billion over five years (see Table A2 below). Normal U.S. budget appropriations direct roughly $47 billion to clean energy over the next five years if current budget levels are sustained, primarily for investments in U.S. rail infrastructure and energy technology programs at the U.S. Department of Energy. Finally, if climate and energy legislation passed by the House in June 2009 (American Clean Energy & Security Act, ACESA) becomes law, the United States will invest an additional $34.5 billion over the next five years in clean energy sectors. Table A1 below summarizes U.S. investments in clean energy technologies and provides sources and notes. Table A2 provides a detailed summary of clean technology investments in the American Recovery and Reinvestment Act.

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About the Breakthrough Institute

The Breakthrough institute is one of America's leading think tanks developing climate and energy policy solutions. Since 2002, Breakthrough has been a pioneering advocate of an innovation-centered approach to the nation's energy and climate challenges, calling for major federal investments to make clean and low-carbon energy technologies cheap and abundant, strengthen America's economic competitiveness and energy security, and slow global warming. For more information about the Breakthrough Institute, please visit http://thebreakthrough.org.

About the Information Technology and Innovation Institute

The Information Technology and Innovation Institute (ITIF) is a non-partisan research and educational institute – a think tank – whose mission is to formulate and promote public policies to advance technological innovation and productivity internationally, in Washington, and in the states. Recognizing the vital role of technology in ensuring prosperity, ITIF focuses on innovation, productivity, and digital economy issues. For more information about ITIF, please visit: http://itif.org

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Table A1. U.S. Government Investment in Clean Energy Technology, 2009-2013

	2009	2010	2011	2012	2013	Total, 2009-2013
Investment Source	(Billion U.S. $)					
Department of Energy Appropriations (total - energy technology)[I]	14.1	6.5	6.5*	6.5*	6.5*	40.1
Office of Science - Energy-related Research Programs[II]	2.6	2.7	2.7*	2.7*	2.7*	13.3
Applied Energy Technology Offices[III]	4.0	3.9	3.9*	3.9*	3.9*	19.5
Advanced Vehicle Manufacturing Loan Program	7.5	0.0	0.0	0.0	0.0	7.5
Transportation Appropriations (total – rail investments)[IV]	1.8	7.3	4.3*	4.3*	4.3*	22.2
High-speed Rail[V]	0.0	4.0	1.0	1.0	1.0	7.0
Other rail[VI]	1.8	3.3	3.3*	3.3*	3.3*	15.2
Emergency Economic Stabilization Act of 2008 (clean energy tax credits & bonds)[VII]	1.8^	1.8^	1.8^	1.8^	1.8^	9.1
American Recovery and Reinvestment Act of 2009 (clean energy tax credits & bonds)[VIII]	2.0^	2.0^	2.0^	2.0^	2.0^	10.0
American Recovery and Reinvestment Act of 2009 (direct spending and investment)[VIII]	30.8#	30.8#	0.0	0.0	0.0	61.5
American Clean Energy and Security Act of 2009 (total - allowance allocations)[IX]	0.0	0.0	0.0	8.5	8.7	17.2
Clean Energy R&D[X]	0.0	0.0	0.0	0.9	0.9	1.8
Other Clean Energy Technology Investment[XI]	0.0	0.0	0.0	7.6	7.8	15.4
American Clean Energy And Security Act of 2009 (total - other clean technology funding)[XII]	0.0	8.5	1.0	1.0	1.0	11.5
Clean Energy Deployment Admin. (capitalization)	0.0	7.5	0.0	0.0	0.0	7.5
CCS Demonstration and Early Deployment	0.0	1.0	1.0	1.0	1.0	4.0
Total	**50.8**	**57.2**	**15.7**	**24.2**	**24.4**	**172.1**

Sources and Notes, Table A1:

*. Assumes budget appropriations levels continue at FY 2010 levels.

^. Average annual value of ten year budget score for tax credits and incentives.

#. Assumes majority of stimulus spending allocated in 2009 and 2010. A portion of funds may be distributed in later years.

i. Source: "Department of Energy Congressional Action on R&D in the FY 2010 Budget." American Association for the Advancement of Science (10/5/09). http://www.aaas.org/spp/rd/fy2010/doe10c.pdf

ii Includes control area budgets for DOE Office of Science's Offices of Basic Energy Science, Fusion Energy Sciences, and Biological and Environmental Research (operator of the Bioenergy Research Centers) as well as DOE-funded Small Business Innovative Research (SBIR) grants and the Advanced Research Projects Agency-Energy (ARPA-E).

iii. Includes control-area budgets for DOE Offices of Energy Efficiency and Renewable Energy, Fossil Energy, Nuclear Energy, and Electricity Delivery and Reliability.

iv. Source: H.R. 1105. Omnibus Appropriations Act, 2009. Transportation, Housing, and Urban Development Appropriations. Passed March 11, 2009; U.S. House of Representatives Committee on Appropriations. 2010 Transportation, Housing, and Urban Development Appropriations Bill. Passed by the House on July 17, 2009; United States Office of Management and Budget. Budget Overview: "A New Era of Responsibility." February 26, 2009. http://www.whitehouse.gov/omb/budget/Overview/

v Assumes House Appropriations funding level in FY 2010 (see source above) and continued funding at Presidential budget request levels FY 2011-2013 (see source above).

vi. Includes appropriations for Amtrak, commuter rail and public rail transit. FY 2009 funding level from Omnibus Appropriations Act of 2009 (see source above) and FY 2010 funding level from 2010 Transportation, Housing, and Urban Development Bill (see source above). Assumes FY 2011-2013 continued at FY 2010 budget levels.

vii. Source: "A Climate for Recovery: The Colour of Stimulus Goes Green." HSBC Global Research (February 25, 2009). p. 2 http://www.globaldashboard.org/wp-content/uploads/2009/HSBC_Green_New_Deal.pdf

viii. Source: "Conference Report to Accompany H.R. 1 - The American Recovery and Reinvestment Act of 2009." U.S. House of Representatives Committee on Rules (February 2009). http://rules.house.gov/bills_details.aspx?NewsID=4149. See also Table A2 below.

ix. Source: Jenkins, Jesse. "Kerry-Boxer Climate Bill Allowance Allocation Breakdown." Breakthrough Institute (10/26/09). http://thebreakthrough.org/blog/2009/10/kerryboxer_climate_bill_allowa.shtml. See in particular detailed spreadsheet: http://thebreakthrough.org/blog/BTI_Allowance_Allocations_2012-2032.xlsx. Assumes allowances prices of $12.70 per ton CO2-e in 2011, $13.24 per ton CO2-e in 2012 (in 2009 dollars) consistent with values reported in U.S. EPA Analysis of HR.2454: http://www.epa.gov/climatechange/economics/pdfs/HR2454_Analysis.pdf

x. Includes funding for the Advanced Research Projects Agency for Energy (ARPA-E) and new regional Clean Energy Innovation Centers.

xi. Includes $3.5 billion for advanced automotive technology deployment and manufacturing, $11.2 billion for renewable energy and energy efficiency deployment, and $0.6 billion for building codes and building efficiency retrofits, all figures over 2012-2013 at EPA-projected allowance prices.

xii. Source: H.R. 2454. American Clean Energy and Security Act. Passed by the House on July 26, 2009. See Title 1, Subtitle B, Sec. 114 and Subtitle I.

Note: This total investment figure excludes clean energy public investments at the state-wide level. Public clean energy investment funds are relatively small, however, and do not substantially impact the overall U.S. investment figure. Public state-wide clean energy investments were only $1.5 billion from 1998 to 2007.[472]

Table A2. Detailed Summary of Clean Energy Technology Investments in American Recovery and Reinvestment Act of 2009 (ARRA)

	Public Investment and Direct Spending (Billion US $)		Tax Credits, Incentives and Bonds[IV] (Billion US $)
RD&D – total	7.4	Clean Energy Deployment - total	7.5
ARPA-E	0.4	Renewable Energy Production Tax Credit (PTC) extension	6.6
Office of Science Energy R&D[I]	0.8	Temporary Investment Tax Credit (ITC) for projects eligible for PTC	0.1
Applied Renewable Energy and Energy Efficiency R&D	2.5	Adjustments to ITC	0.4
Applied Fossil Energy RD&D	3.4	Clean Renewable Energy Bonds	0.3
Dept. of Defense Energy R&D	0.3	Energy Efficiency Deployment - total	1.4
Clean Energy Deployment - total	7.0	Qualified Energy Conservation Bonds	0.4
Innovative Technology Loan Guarantee Program[II]	4.0	Extension of tax credits for efficient home improvements	1.0
DOE Temporary Cash Grant Incentive for Renewable Energy Deployment[III]	3.0	Advanced Transportation - total	1.0
Advanced Transportation Deployment - total	3.0	Extension of tax credits for alternative fueling infrastructure	**
Advanced Battery Manufacturing grant program	2.0	Increased tax credit for purchase of plug-in hybrid electric vehicles	1.0
Transportation electrification grants	0.4	Rail - total	0.1
Alternative Fuel Vehicles Pilot Grant Program	0.3	Employee transit incentives	0.1
Federal fleet purchases of efficient and advanced vehicles	0.3		
Energy Efficiency Deployment - total	16.9		
"High performance" federal buildings	4.5		
Energy Efficiency and Conservation Block Grants	3.2		
Weatherization Assistance Program	5.0		
State Energy Program	3.1		
Energy Efficiency Rebate Program	0.3		
Efficient building upgrades – low income and Native American housing	0.8		
Electricity Grid Modernization	11.0		
DOE Office of Electricity Delivery and Reliability	4.5		
Borrowing authority increase for federal power marketers – grid expansion	6.5		
Rail	16.2		
High-speed rail	8.0		
Amtrak	1.3		
Public transit	6.9		
Total – Public Investment and Government Spending	**61.5**	Total – Tax Credits, Incentives and Bonds	**10.0**

Sources and Notes, Table A2:

**. figure totals less than $0.1 billion.

Unless otherwise noted, source is "Conference Report to Accompany H.R. 1 - The American Recovery and Reinvestment Act of 2009." U.S. House of Representatives Committee on Rules (February 2009). http://rules.house.gov/bills_details.aspx?NewsID=4149.

i. Includes ARRA funding allocated to FY2009 control area budgets for DOE Office of Science's Offices of Basic Energy Science, Fusion Energy Sciences, and Biological and Environmental Research (operator of the Bioenergy Research Centers), as well as DOE-funded Small Business Innovative Research (SBIR) grants and remaining unallocated ARRA funds for Office of Science. See: "U.S. Department of Energy FY 2010 Control Table by Appropriation." U.S. Department of Energy (5/6/2009). http://www.cfo.doe.gov/budget/10budget/Content/AppControl.pdf

ii. ARRA originally authorized $6 billion for the Innovative Technology Loan Guarantee Program, but $2 billion was taken from it to extend the U.S. "Cash for Clunkers" Program. See: "President Obama Approves a $2 Billion Extension for "Cash for Clunkers." U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy (8/12/2009). http://www1.eere.energy.gov/vehiclesandfuels/news/news_detail.html?news_id=12709

iii. The Treasury Department and Department of Energy has allotted $3 billion for this program through the end of 2010, but some market analysts believe $10 billion could be distributed if the government decides to extend the program. See: Borofksy, Yael and Jesse Jenkins. "Wind in Wall Street's Sails: Investment Rushes into Wind, But Can We Make it Last?" Breakthrough Institute (9/3/2009). http://www.thebreakthrough.org/blog/2009/09/wall_street_rushes_into_wind.shtml

iv. Tax credits, incentives and bonds scored as expected cost over 10 years. Values here assume even annual distribution of total score, and includes first five years only.

Appendix B: Comparison of Public Investments in Clean Energy Technology, United States vs. Asia's Clean Technology Tigers

Table A3: Cumulative Prospective Public Investments in Clean Energy Technology by Nation, 2009-2013

	Investment in clean energy technologies	Investment in clean energy technologies, excluding rail	Investment in clean energy technologies, excluding rail, grid, and efficiency
China	$397 billion	$293 billion	$209 billion
South Korea	$46 billion	$39 billion	$33 billion
Japan	$66 billion	$66 billion	$48 billion
Asia Total	$509 billion	$398 billion	$290 billion
United States	$172 billion	$150 billion	$93 billion
Investment Ratio, Asia:U.S.	**3:1**	**2.7:1**	**3.1:1**

Sources and Notes, Table A3:

1. "A Climate for Recovery: The Colour of Stimulus Goes Green." HSBC Global Research (February 25, 2009). p. 2 Available at: http://www.globaldashboard.org/wp-content/uploads/2009/HSBC_Green_New_Deal.pdf

2. Robins, Nick; Clover, Robert and Charanjit Singh. "A Global Green Recovery? Yes, but in 2010." HSBC Global Research (August 6, 2009). p.2.

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4. See Appendix A for United States figures.

Endnotes

Executive Summar and Introductory Sections

1 Mark World Economic Forum, "Green Investing: Toward a Clean Energy Infrastructure,," (Geneva, Switzerland: WEF, January 2009), http://www.weforum.org/pdf/climate/Green.pdf.

For example, a recent opportunity estimate for China alone predicted a maximum market opportunity of $500 billion to $1 trillion by 2013. China Green Tech Initiative, "The China Greentech Report 2009," (September 10, 2009) 16, http://www.china-greentech.com/report

2 For example, a recent opportunity estimate for China alone predicted a maximum market opportunity of $500 billion to $1 trillion by 2013. "The China Greentech Report 2009." China Green Tech Initiative (September 10, 2009), 16, http://www.china-greentech.com/report.

3 John Collins Rudolf, "China-U.S. Group Plans to Build Texas Wind Farm," The New York Times, (New York, New York), October 29, 2009, http://www.nytimes.com/2009/10/30/business/energy-environment/30wind.html

4 Wind: Through the 3rd quarter of 2009, 55 percent of installed turbines were manufactured from foreign companies, as well as 67 percent of the turbines slated for projects currently under construction. Source: Russ Choma, "Overseas Firms Collecting Most Green Energy Money," Investigative Reporting Workshop, (Washington, D.C.: American University School of Communications, 2009), http://investigativereportingworkshop.org/investigations/wind-energy-funds-going-overseas/; Solar: Marketbuzz 2009, "Annual World Photo Voltaic Industry Report," Solarbuzz (San Francisco, California: March, 2009), 130, http://www.solarbuzz.com/Marketbuzz2009-intro.htm .

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5 Deutsche Bank Climate Change Advisors, "Global Climate Change Tracker: An Investor's Assessment," (Frankfurt, Germany: Deutsche Bank Group, October 2009), http://www.dbcca.com/dbcca/EN/investment-research/investment_research_1780.jsp See also: United Nations Environmental Program, "Global Trends in Sustainable Energy Investment," (London, United Kingdom: UNEP, 2009), http://sefi.unep.org/english/globaltrends1.html#c2322.

6 Deutsche Bank Climate Change Advisors, October 2009.

7 "China Plans 440-bln dlr stimulus for Green Energy." Agence France Press, May 24, 2009, http://www.google.com/hostednews/afp/article/ALeqM5i7wWkoCABy_Y7poh8ym0TI7CjJjA.

8 "The scale of the total investment planed for new energy may reach 4.5 Wan Yi," translated by Gang Lin, http://money.163.com/09/0526/16/5A8JM34S00252G50.html.

9 Nick Robins, Robert Clover, and Charanjit Singh, "A Climate for Recovery: The Colour of Stimulus Goes Green," (London, United Kingdom: HSBC Global Research, February 2009), 2, http://www.globaldashboard.org/wp-content/uploads/2009/HSBC_Green_New_Deal.pdf.

10 A number of reports have put South Korea's investment figure at around $84 billion, but this includes a number of investments that are unrelated to clean energy technology. While details of South Korea's investment package have not been completely specified, a preliminary accounting of the investment package puts the clean energy total at $46 billion. This figure excludes investments in water and waste management. Nick Robins, Robert Clover, and Charanjit Singh, "A Global Green Recovery? Yes, but in 2010," (London, United Kingdom: HSBC Global Research, August 6, 2009), 2.

See also: Kim Hee-Sung, "Gov't Unveils Plan to be Among the Top Green Nations," Korea.net: Korea's Official Website, (South Korea: Government of South Korea) July 7, 2009, http://www.korea.net/news/issues/issueDetailView.asp?board_no=20963.

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15 See "Asia Seeks First-Mover Advantage Through Investments in Clusters" in this report.

16 U.S. Environmental Protection Agency, "Analysis of H.R. 2454 in the 111th Congress, the American Clean Energy and Security Act of 2009." (Washington, D.C.: EPA, June 2009), http://www.epa.gov/climatechange/economics/pdfs/HR2454_Analysis.pdf.

17 The U.S. Environmental Protection Agency projects carbon prices under the House-passed American Clean Energy and Security Act (ACESA) would rise to just $13 per ton of CO2-equivalent (CO2-e) by 2015, while the Congressional Budget Office projects a price of $16 per ton CO2-e in 2012, rising to $17 per ton in 2013 and $19 per ton in 2015. See U.S. Environmental Protection Agency, June 2009; U.S. Congressional Budget Office, "H.R. 2454, American Clean Energy and Security Act of 2009," (Washington, D.C.: June 2009), http://www.cbo.gov/ftpdocs/102xx/doc10262/hr2454.pdf.

In contrast, CO2 permit prices in the European Union's Emissions Trading Scheme (ETS) have regularly traded at above $30 per ton CO2-e during the current compliance phase (Phase II) and preferential production incentives for solar power, for example, offered in China, Japan, the EU and elsewhere routinely top the CO2 price equivalent of $200-500 per ton (roughly equivalent to production incentives or tariff prices of $0.20-0.50 per kilowatt-hour).

Furthermore, both of the EPA and CBO forecasts were published prior to revised emissions projections for 2009 taking into account the impacts of the global economic recession and resulting significant drop in U.S. CO2 emissions. Analysts now project a potential over-allocation of emissions permits in the early years of the ACESA cap and trade program, which may collapse carbon prices down to the $10 per ton CO2-e floor price for primary auction markets established by the legislation, with secondary markets potentially trading below this nominal floor. See Jesse Jenkins, Ted Nordhaus, and Michael Shellenberger, "Over-Allocation of Pollution Permits Would Result in No Emissions Reduction Requirement during Early Years of Climate Program." (Oakland, California: Breakthrough Institute), September 23, 2009, http://thebreakthrough.org/blog/2009/09/climate_bill_analysis_part_20.shtml.

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Conclusions and Appendices

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