Center for American Progress

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Out of the Running?

How Germany, Spain, and China Are Seizing the Energy Opportunity and Why the United States Risks Getting Left Behind

Kate Gordon, Julian L. Wong, and JT McLain March 2010

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Introduction and summary

A clean-energy call to arms

As the United States debates comprehensive clean-energy legislation, it is confronted with a simple choice: come to the table and feast on the enormous economic opportunity that comes with reducing global warming pollution or be an item on the menu as our economic competitors forge ahead to build prosperity.

By 2020, clean energy will be one of the world's biggest industries, totaling as much as $2.3 trillion.[1] Over the past year, other countries made huge investments to seize the economic opportunity provided by the historic shift from fossil-based energy to renewable, low-waste electricity and fuel. These investments weren't made out of thin air, but were a result of intentional public policies, which in turn provided a strong stimulus for new public and private investment in new clean-energy markets, infrastructure, and human resources.

By 2020, clean energy will be one of the world's biggest industries, totaling as much as $2.3 trillion.

China, a country that in some ways is only now experiencing an industrial revolution, has made a serious commitment to building that revolution with low-carbon, low-waste technologies and infrastructure. Several European Union countries—notably Germany and Spain—have also turned from old energy policies to embrace the new. These three countries understand that the transformation to a low-carbon economy brings a range of strategic benefits, from climate stability to energy security to economic prosperity.

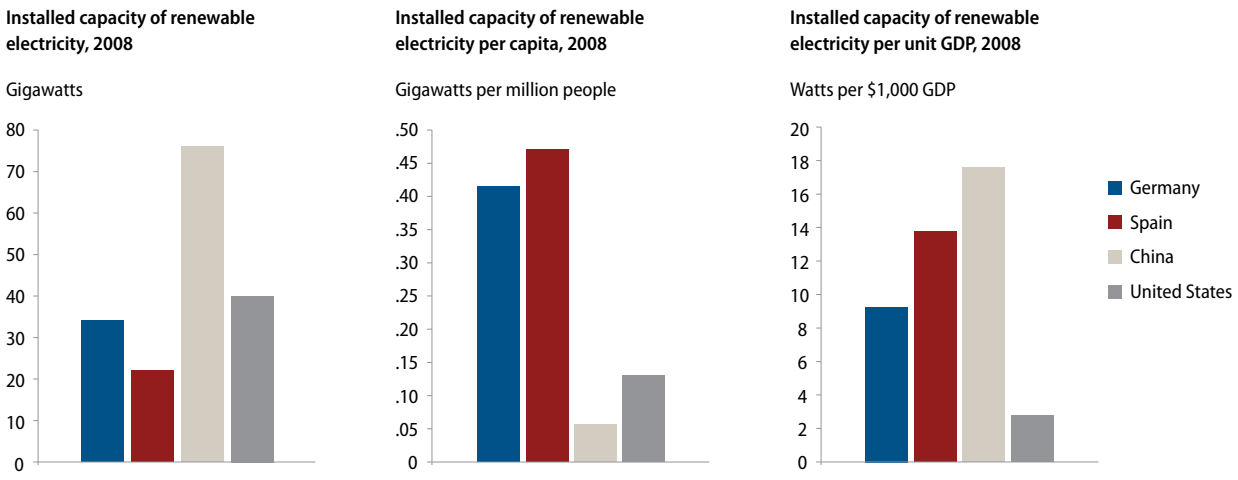
With that understanding, these countries are moving forward decisively. The United States came in second just behind Germany in absolute sales in a recent global country ranking of 2008 clean-energy technology product sales.[2] But when product sales were expressed as a proportion of respective gross domestic product, the United States was far down the list at 19th, compared to Germany at third, Spain at fourth, and China at sixth.[3] The United States also lags on installed renewable energy per capita as well as per unit of gross domestic product (see Figure 1).

These countries invested in clean energy for short-term benefits and laid a solid foundation for future sustainable economic growth by either setting a price on carbon or implementing strong national energy performance standards or both, thus spurring innovation in new technologies that lower carbon emissions. A 2009 study by the CERNA Research Program on Technology Transfer and Climate Change found clear evidence that

FIGURE 1

Comparison of renewable electric power capacity in Germany, Spain, China, and the United States

The United States trails these countries on capacity



Source: Center for American Progress, REN21, International Monetary Fund.

developed countries that ratified the Kyoto Protocol—each of which set a legally binding target to reduce its carbon emissions—saw a rise in green-tech innovation patents of more than 33 percent (see Figure 2).[4] Developed nations that didn't initially ratify Kyoto—the United States and Australia—saw no noticeable change in their share of total green tech patents over the same time period.

China, as a developing country, was not obligated to adopt mandatory carbon emission reductions targets under the Kyoto Protocol, but the country did embrace the treaty's clean development mechanism, or CDM. The CDM allows developed countries to offset their emissions at home by investing in clean-energy projects in developing countries, and China greatly benefitted from the resulting technology transfer, particularly in its wind industry.

Today's clean-tech innovations represent tomorrow's jobs and GDP growth. China, Germany, and Spain are well on their way to global competitiveness in the clean energy economy. Besides the clear advantage of having signed onto or directly benefitted from the Kyoto Protocol, these three countries have also benefitted from their early adoption of a truly comprehensive approach to energy and climate policy.

In a September 2009 report, "The Clean-Energy Investment Agenda," the Center for American Progress identified the need for a long-term, comprehensive approach to clean-energy policy that includes three core policy pillars:[5]

- **Markets:** Expanding markets and driving demand for new clean and efficient energy products and services

- **Financing:** Investing across the full value chain of clean-energy solutions—research, development, commercialization, production, and deployment—needed to meet demand

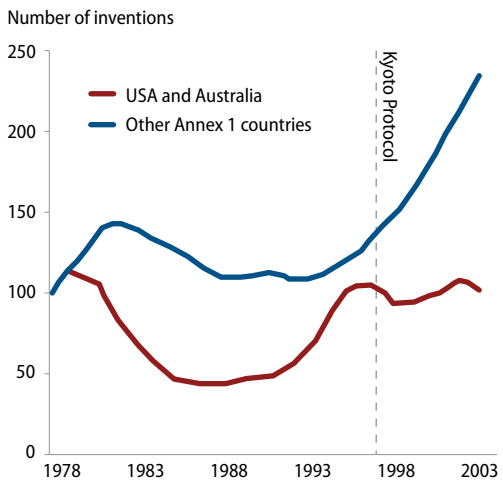
- **Infrastructure:** Revitalizing and reinvesting in the physical and human capital infrastructure upon which the clean-energy transformation—like all major industrial transformations in the past—will ultimately be built

When we researched Germany, Spain, and China's approach to the emerging clean energy economy, we found that all three countries have taken just such an approach. In this report, we will take a close look at the policies and programs that make up each country's approach to building a clean energy economy. We will examine how these policies are creating jobs, boosting industries, and spurring innovation in these three countries.

FIGURE 2

Innovation trends, by number of inventions, among Annex I developed countries under the Kyoto Protocol

Kyoto signatories saw more inventions



Source: CERNA, Mines ParisTech.

In addition we will use CAP's three-pillar framework to demonstrate the specific ways these countries are pursuing a broad range of smart policies to create new markets for clean-energy solutions, strategically channeling finances across the entire innovation and commercialization cycle, and building the necessary support infrastructure for new technologies and fuels.

Our purpose here is not to provide an exhaustive survey of the clean-energy policies of each of these countries. Rather, it is to show how they have become top competitors in the emerging global marketplace of clean energy by adopting a strategic policy approach—and to demonstrate what is at stake for the United States if we fail to learn from their example.

China, Germany, and Spain are early winners in the next great technological and industrial revolution. Many other countries such as Denmark, Japan, and South Korea that we do not discuss in this report are also forging ahead with ambitious clean energy economic strategies. The United States, which has yet to fully embrace a truly sustainable growth strategy for the low-carbon future, is not.

The United States has a clear moral imperative to join the worldwide effort to reverse climate change. But it also has an urgent economic imperative to become a clean-energy leader. The clean-energy achievements of China, Germany, and Spain represent a significant step in the fight against global warming pollution, but their driving motivation has been their own economic self-interest, through creating vibrant new industries, sustainable jobs, and international markets for clean-energy technologies.

We can do the same and we can do better, but not if we use the excuse—as opponents of passing comprehensive energy and climate legislation frequently do—of temporarily weak economic conditions to delay the transformation to a clean energy economy. It is through a failure to act that the United States will suffer economically.

American workers, business leaders, and policymakers struggling under the weight of a historic economic downturn may question the relevance of policies in European and Asian nations. But they should consider just one concrete result of the United States not having a similar policy focus: Less than two years after building a solar manufacturing plant in Devens, Massachusetts, Evergreen Solar—an early U.S. pioneer in solar photovoltaic technology—announced plans to move part of that operation to Wuhan, China.[6]

The race toward a clean-energy future is underway, and those nations that lead will reap enormous economic benefits. With the right investments and smart policies, the United States can be among them, a top player in the emerging global low-carbon economy.

Energy policies in Germany, Spain, China, and the United States

Germany, Spain, and China are pursuing national policies for markets, financing, and infrastructure

		Germany	Spain	China	United States
Markets	**Carbon pollution reduction commitment**	40 percent below 1990 by 2020	20 percent below 1990 by 2020	40 to 45 percent decrease in carbon intensity by 2020	No binding national policy, although a political commitment to 17 percent below 2005 by 2020
	National renewable electricity standard	20 percent by 2020	30 percent by 2020, with carveouts for specific technologies	15 percent nonfossil energy by 2020, with additional policies for specific technologies that effectively strengthen the goal	No comparable national policy, although 29 states have mandatory RES policies and six more states have goals for renewable energy use
	National energy efficiency plan	E.U. goal of reducing energy use to 20 percent below business-as-usual projections by 2020. Building codes have increased demand for low-energy houses 900 percent from 1999 to 2007.	E.U. goal of reducing energy use to 20 percent below business-as-usual projections by 2020. National plan has already reduced energy intensity by 11 percent from 2004.	20 percent decrease in energy intensity from 2005 to 2010	No comparable national policy, although 21 states have energy efficiency resource standards. The United States will invest $28 billion in efficiency programs as part of American Recovery and Reinvestment Act.
Financing	**Feed-in tariffs**	Tariff targets emerging technologies, with a total subsidy of $4.6 billion	Tariff amount tied to market growth for specific technologies	Tariff is 7 to 9 cents per kwh for wind, with solar moving toward a similar structure	No comparable national policy, although there are a few state and local feed-in tariff experiments
	Government-run "Green Bank"	Government-run KfW provides loans and other financing supports for renewable energy and energy efficiency	Multiple programs, including loan programs for specific technologies and support for strategic projects from government-run IDAE	Government-run CECIC will have a portfolio of roughly $15 billion in assets consisting of energy efficiency, renewable energy, and pollution control technologies by 2012	No comparable national policy, although DOE's loan guarantee program provides low-cost financing that leverages private capital and DOE-run ARPA-E supports earlier stage innovation
	Tax benefits	Tax incentives for bioenergy and fuel-efficient vehicles, in addition to a generally low corporate tax rate	Tax exemptions for biofuels	Value-added tax reduction for wind generators and value-added tax rebate for raw materials imports used in wind turbine manufacturing	Production Tax Credit for wind and Investment Tax Credit for solar
	Other government funds	Market Incentive Program provides $308 million annually in grants to renewable projects	Funding for energy R&D via multiple government institutions (ENCYT, CIEMAT, and CENER)	Multiple technology R&D programs and large equity investments from the state wealth fund	No permanent national policy, although ARRA has $6.3 billion for research, including advanced batteries, carbon capture and storage, and ARPA-E that develops new clean energy technologies
Infrastructure	**Workforce and manufacturing infrastructure**	Provides grants and interest-free loans with goal of reducing number of young adults without vocational training by half by 2015	National renewable energy job-training center has programs for all sectors and skill levels	Strong domestic content laws and incentives to use domestically produced inputs	No permanent national policy on green workforce development, but related programs include $500 million for clean-energy jobs training and "Buy America" provisions in ARRA, the Workforce Investment Act, and the Green Jobs Act
	Grid construction and improvements	Coordinating with neighboring countries to build a "supergrid" for offshore wind power	Upgrading grid with new technologies specifically for renewable energy, including use of electric vehicles as a stability tool	Mandates that grid companies must build interconnections for renewable projects and has plans for smart grid by 2020	No permanent national policy, but ARRA includes $17 billion for grants and loans for transmission and smart grid, which will leverage private capital

Germany

Germany, home to the world's fifth largest economy, is a key player in the global clean-energy arena. The country has a large industrial sector that makes up 30 percent of its GDP—agriculture is less than 1 percent and services make up the remaining 69 percent. It has emerged as a leader in wind and solar production because of this industrial infrastructure and the country's historic dominance in high-skill, precision manufacturing. At the same time, Germany has aggressively invested in domestic solar energy installation, making it the global leader in installed solar energy capacity.

Germany is unusual in the European Union in that its unemployment rate is below 10 percent, but even as the largest economy in the European Union it has been hit by the global recession and is struggling to find new products and markets. The German government has clearly picked renewable energy as one of these new potential global markets.

Clean-energy deployment in Germany

Germany is a world leader in clean and renewable energy generation. The country's strong focus on renewable energy is evident in DIW Berlin's recent finding that the price of renewable energy will become cost competitive with conventional energy in Germany by 2020.[7]

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Wind energy dominates the country's renewable electricity production, but other renewable sources such as hydropower and biomass are progressively gaining market share. Germany's installed wind capacity was 23,903 megawatts in 2008, making it second only to the United States. Wind energy generated 40,000 gigawatt hours, or GWh, in 2008, accounting for 6.6 percent of Germany's final energy consumption. Hydropower was second among renewable energy technologies with 3.5 percent, and biomass came in third with 2.5 percent.[8]

The solar photovoltaic sector receives the most public support of any renewable energy technology in Germany, and even though solar PV makes up a relatively small share of Germany's final energy consumption—2,220 GWh, or 0.7 percent, in 2006—the country is number one in the world in grid-connected installed PV.[9] Germany has attracted significant foreign investment in solar PV and is home to Q-cells, the world's largest manufacturer of PV cells.[10]

Renewable energy is also a strong contributor to Germany's fuel and heat sectors. Germany is the European Union leader in biofuel production. The volume of biofuel output increased from 86 kilotons of oil equivalent, or ktoe, in 1997 to 1,645 ktoe in 2005, which amounts to an average annual growth rate of 45 percent.[11] Solid biomass is the country's primary source of renewably generated heat and accounts for more than 5 percent of heat generation. Solar thermal heat, however, is quickly gaining market share, contributing more than 0.3 percent of total heat generated. Overall, renewable sources make up 7.4 percent of total heat generated in the country.

Clean-energy innovation

The Federal Ministry of Economics and Technology, or BMWi, established its High-Tech Strategy in 2006 to transition Germany to a sustainable energy future through innovation. The strategy commits about $1.67 billion in investments for 2009 and 2010. The program relies on strategic alliances with numerous government agencies and the private sector to create new and more efficient renewable energy technologies.

The High-Tech Strategy has led to many policy initiatives that promote innovation and create a friendlier environment for startups. Financing for the initiatives is often provided by Kreditanstalt für Wiederaufbau, or KfW, a federally owned financial institution. The High-Tech Start-Ups Fund is a public-private partnership that provides seed financing of up to $1.45 million of equity financing to promising technology companies. Altogether, the fund has $394 million in available funding. Since its inception in 2005, the fund has agreed to take stake in 177 budding technology companies, living up to its motto that "Technology is our future."[12]

Another major source for funding clean-tech innovation in Germany is the ERP Innovation Program, another public-private partnership that supports innovative small- to medium-sized businesses in research and development projects. Recipients are awarded up to $7.24 million, and the risk of default is assumed by KfW and the federal government. According to the Federal Ministry of Economics and Technology, each dollar of the more than $2.9 billion allocated annually stimulates more than two additional dollars in private investment, resulting in more than $14.5 billion in investment between 2006 and 2009.[13]

The High-Tech Strategy has already played a role in several large and innovative projects. Examples include:

- **Offshore wind farms:** The German federal government has begun a private-public collaboration to build 40 offshore wind farms off its northern shores. The *Federal Ministry of Transport, Building, and Urban Affairs, or BMVBS,* projects that the wind farms will generate 12,000 megawatts by 2030, which is enough to power 6.8 million homes. The private sector will finance around 70 percent of the $724 million to $1.45 billion project.[14]

- **Zuhausekraftwerke:** This innovative project combines renewable and smart grid technology into "home power plants." It aims to install 100,000 minipower plants driven by natural gas engines in private homes at a cost of $7,190. The ingenuity behind the concept lies in the amount of power generated when all the systems are linked together: 100,000 of these home power plants will be able to generate as much electricity—2,000 MW—as two full-scale nuclear power plants. The project is being promoted in an unusual alliance between Lichtblick—the biggest renewable energy supplier in Germany—and Volkswagen.[15]

- **Lithium Ion Battery LIB 2015:** LIB 2015, another public-private initiative, aims to develop highly efficient lithium-ion batteries for both automotive and energy storage by 2015. The German Ministry of Education and Research, or BMBF, is contributing $30.4 million, while a battery consortium headed by chemical company BASF will provide the remainder of the total sponsorship volume of $86.9 million.[16]

- **DESERTEC:** This German-led consortium to build a solar farm in North Africa using existing concentrating solar power or CSP technologies could provide around 15 percent of Europe's energy needs. Financing details for the estimated $555 billion infrastructure investment aren't clear, but Germany's Environment Ministry says the German government will play a major role.[17]

- **Organic photovoltaics:** This energy production project will use organic materials, such as phthalocyanine and polycyclic dyes, to develop solar cells with improved efficiency and durability. Its goal is to bring down the high current and projected costs of solar PV electricity.

The solar PV industry has become to Frankfurt/Oder what the automobile industry once was to Detroit.

Clean-energy manufacturing

As noted above, Germany has a historically strong industrial sector, and its attention to manufacturing technology and worker training has served it well as the country transitions to clean-energy system production.

Since implementing a suite of clean-energy policies—particularly the feed-in tariff described below—Germany has seen significant growth in clean-energy production and associated occupations. Notably, the poorest corners of Germany are benefiting the most from this growth.

The solar PV industry has become to Frankfurt/Oder what the automobile industry once was to Detroit. "Solar Valley," an area reminiscent of the rust belt, has given new opportunities to thousands of unemployed workers who previously relied on East Germany's semiconductor industry for income. It is a clean-energy hub that is home to more than a third of Germany's total solar PV production capacity, continually generates direct jobs,

and also provides a market for a supply chain made up of more traditional manufacturing industries in the area.[18]

Significantly, only 200 of the more than 15,000 firms in the German solar industry are involved in the manufacturing of modules. More jobs have been created in research and development, installation, and project management for domestic and international projects, as well as operations and maintenance of existing renewable plants.[19]

As Germany's renewable energy investments have grown, the country has found itself facing a labor shortage among skilled manufacturing workers with a technical focus.[20] This poses a particular problem for large businesses that rely on highly specialized staff. As a result, nearly half of Germany's clean-tech businesses with an international focus say they will open or expand existing foreign facilities as well as increase foreign recruitment.[21] Workforce training measures, as we discuss below, are being adopted to address this shortage.[22] Meanwhile, the renewable energy manufacturing sector keeps growing, largely due to strong innovation policies that have created thousands of new jobs. Between 2005 and 2007 Germany's overall manufacturing sector employment increased by 43,000 workers.[23]

Another major challenge for German manufacturers is the progressively higher cost of raw materials in a country with meager natural supplies. In the last four years, the prices of aluminum and copper have increased 80 and 300 percent, respectively. Dramatic increases in raw materials costs have a substantially negative effect in a market where raw materials account for 40 percent of production costs, while labor is only 25 percent. To address this challenge, Germany's Materials Innovations for Industry and Society, or WING program, develops efficiency measures that will reduce the country's use of raw materials 20 percent by 2016 for potential savings of $30.1 billion annually.

Clean-energy exports and jobs

Exports are paramount to German renewable energy markets. Germany was the number one renewable energy system exporter in the world from 2003 to 2008. In 2008, exports accounted for 47.2 percent of its GDP. Germany's most lucrative renewable energy export, wind towers and turbines, had a staggering global export share above 70 percent in 2006. The PV sector export share in 2006 was 30 percent.[24]

Germany's renewable energy industries are also proven and strong job creators. More people work in the combined renewable energy industries than in the combined coal and nuclear sectors. In 2008, 278,000 workers were employed in renewable energy industries compared to 238,000 in conventional energy.[25] This represents a 12 percent increase in renewable energy jobs from 2007 and a 73 percent increase from 2004.[26]

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A large share of these new renewable energy jobs—about 82,000—are in the wind industry, followed by solar PV (27,000), bioenergy power generation (22,000), and hydropower (3,000).[27] The concentrated solar thermal industry in Germany also has huge overall growth and job-creation potential. German solar thermal industries employed 17,400 workers in 2008—a 44 percent increase from 2007.[28] By 2020, the number of workers in the renewable energy sector could grow to between 353,500 and 400,000, including at least 162,093 in wind, 29,159 in solar PV, and 54,240 in biomass-biogas.

Clean-energy policy tools

The vast strides Germany made to become a leader in clean-energy production and export were no accident. The country used intentional and strategic policymaking based on the understanding that every part of the clean-energy value chain—from innovation to installation—influences and affects every other part. Cultivating this chain requires a comprehensive policy approach that invests in every part of our three-pillar model: markets, financing, and infrastructure.

Expanding markets and driving demand

The key to successfully restoring markets is to send clear policy signals that create investment certainty. A commitment to reducing carbon emissions is the first and best signal that a country is serious about moving toward low-carbon electricity and fuel solutions. Germany recently strengthened its commitment by announcing a target of reducing emissions levels to 40 percent of 1990 levels by 2020.[30] The E.U. commitment, by comparison, is just a 20 percent reduction of 1990 levels by 2020. And Germany's national commitments to specific targets for renewable energy and energy efficiency have been instrumental in accelerating the deployment of clean-energy technologies.

There's no doubt that Germany's clean-energy development has been driven by European Union policy. In 2007 the E.U. Commission adopted an agreement binding E.U. countries to a renewable energy target of 20 percent of total energy consumption by 2020. The next year the commission set specific goals for each country. In 2007 Germany met its 2012 goal of generating 12.5 percent of its electricity from renewable sources, and the country will likely exceed its 20 percent by 2020 goal as early as 2011. In fact, even conservative estimates indicate that by 2020 Germany will be getting 47 percent of its electricity from renewable sources.[31]

Germany also passed strong building codes containing robust energy efficiency standards tied to financial supports for implementation. These codes have proven highly successful not only in creating a new green building market, but also in measurably reducing energy consumption and carbon emissions in the housing and construction

sector. The impact has been impressive: The German market for low-energy houses grew nine-fold from 1999 to 2007.[32]

Financing research, development, and deployment

Spurring the clean-energy market is not enough, however. Countries must also dedicate tangible resources to financing—either directly or indirectly through loan guarantees and other risk-reduction tools—new low-carbon technologies and enterprises. Germany has assertively developed a combination of public and private financing tools to build its clean-energy industries.

The feed-in tariff is the most successful policy tool in stimulating the deployment of clean energy infrastructure across Europe, and it is especially effective in Germany and Spain.[33] Though variations exist, a feed-in tariff typically requires a regional or national utility to buy electricity generated from a predetermined menu of clean energy source—such as solar thermal, solar photovoltaic, wind, wave, hydropower, and geothermal—in the form of long-term contracts and at prices that reflect the relatively higher cost of generating that electricity. As new technologies grow closer to achieving cost parity with traditional sources, the tariffs are typically lowered accordingly so that the market is not distorted by overinvestment.

The law also guarantees access to the power grid for clean-energy producers, meaning they do not have to negotiate with the grid operator but can simply "feed in" their clean-energy electricity. The combination of fixed prices and guaranteed access provides investment certainty for renewable energy generators and creates a market for new and better technologies to supply those generators.

Germany adopted its first feed-in tariff in 1991. Subsidies from the government to renewable electricity generators ranged from 65 to 80 percent of the average retail rate depending on the source of the energy and amount. The EEG established the ambitious goal of doubling Germany's 1997 renewable energy share to 12.5 percent by 2010, and it expanded the scope of renewable sources covered.

The law also introduced financial mechanisms to reduce cost differentials between various sources of energy and level the playing field between renewables and conventional energy sources such as coal and oil.[34] The result of this effort is less expensive energy. A 2007 Ministry of the Environment study concluded that while the subsidies for renewable electricity cost the government $4.63 billion, the savings from taking conventional plants off the grid were $7.24 billion, resulting in $2.61 billion in net savings.[35]

The German tariff system and the Spanish tariff system—which we will discuss later—have been criticized for establishing an initial rate that was too high, particularly for solar power, resulting in an inefficient allocation of public resources. Although as a partial result of such

criticisms feed-in tariffs for solar are expected to be reduced by 15 percent to 17 percent this spring,[36] the modified starting tariff level will still be well over $0.40 per kilowatt hour, which is at least five times higher than wholesale electricity rates in the United States.[37]

Germany provides several other policy and financing tools for clean-energy developers and consumers in addition to the feed-in tariff. Specifically:

- A 1997 tax on fuel-inefficient vehicles combined with a 1999 ecological tax reform resulted in higher purchases of fuel-efficient diesel cars and a corresponding decrease in fuel consumption. Germany now has the world's largest market share of diesel cars.[38]

- In 1999 a revenue-neutral ecological tax reform was introduced to promote energy savings. Energy taxes on fuel, electricity, natural gas, and heating oil were increased yearly from 1999 to 2005. The revenue was used to lower employers' social security contributions, making labor cheaper for German businesses.

- Pure liquid and solid biofuels used for heat and transportation benefit from tax exemptions.

- In 1999 the government introduced the 100,000 Solar Roofs Program, or HTDP, to increase photovoltaic electricity generation by subsidizing the installation of new solar panels. The government invested $738 million and expects to generate $1.88 billion in private investment.[39] HDTP helped Germany's installed PV capacity grow from 50 MW in 1998 to 350 MW in 2003.

- Recycling is critical to German industry, which spends 45 percent of its production costs on materials and less than 20 percent on labor. In 1994, Germany introduced a waste management program that aimed to increase resource productivity by 100 percent between 1994 and 2020. The policy's results included increased recycling rates, a decoupling of gross national product growth and waste generation, and 40 metric tons of avoided CO_2 equivalents. It also reaped substantial economic co-benefits for the waste and recycling sector, including $72.5 billion in growth and the creation of 250,000 new jobs between 2002 and 2006. At the same time, Germany avoided $5.37 billion in raw material import costs as a result of these policies.[40]

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Germany takes a comprehensive approach to financing energy efficiency projects in its building sector, too. In fact, Germany's approach to conserving energy in this sector is a model of comprehensive legislative and fiscal policy that is shaped to achieve a defined outcome. The greatest energy savings in buildings can be tapped by insulating roofs and external walls, replacing windows, and installing heat recovery systems and low-temperature boilers or gas condensing boilers. For this reason, the federal government's "On Location Consultation Service" assistance program targets homeowners and provides them with competent information about suitable, cost-effective energy conservation measures. The federal government covers part of the consultation costs.

Germany's best-in-class financial support and workforce training

The Kreditanstalt für Wiederaufbau, or KfW, a government-owned financial institution, provides necessary financing for developing and implementing clean-energy technologies and infrastructure. KfW has effectively and efficiently supported the expansion of industries that improve economic and social conditions since its creation in 1948.

KfW was part of the Marshall Plan, which aimed to restructure the German economy after World War II. This progressive banking institution adapted to provide pivotal support after the fall of the Berlin Wall, and has embraced the renewable energy industry as a key driver of economic vitality going forward. KfW invests 20 percent of its entire financing volume in domestic and international environmental projects, and it even surpassed the World Bank in renewable energy financing in developing countries.

That economic foundation is complemented by Germany's unparalleled workforce training, which has long positioned it as a global leader in high-tech manufacturing. This training is now proving indispensible as the country moves to more aggressively produce and export advanced technologies in the clean-energy sector.

To complement that program, KfW established the "Housing, Environment, Growth" initiative in 2006 to provide loans to homeowners for rehabilitations that lead to energy savings and for the construction of new low-energy homes. In 2006 and 2007 the program loaned more than $47.6 billion. Carbon dioxide emissions were reduced by 1.6 million tons annually as a result of the measure.

Germany uses a similarly all-encompassing approach to reducing emissions from heat generation. It introduced a policy in 1998 to reduce heating energy use 20 percent by 2005 through energy efficiency standards and financial mechanisms, including a 1999 eco-tax and a Market Incentive Program.[41] The program met its goal, and by 2007 it had increased the use of renewables for heating by 40 percent since 1997.[42] The Market Incentive Program, instituted by the German government and financed by KfW, supports heat-generation technologies by underwriting specific research, development, and deployment projects in this sector.

Between 1999 and 2005 this program underwrote more than 485,000 projects. The combination of $1.2 billion in subsidies and $1.3 billion in loans led to investments exceeding $9.4 billion for more than 623,900 projects. With an average volume of $308 million per year, the Market Incentive Program is the largest renewable energy subsidy program in Europe.

Building physical and economic infrastructure

As impressive as Germany's clean-energy sector is, its full potential will not be realized without a strong clean-energy infrastructure—including a modern transmission grid and a strong and skilled workforce. Germany acknowledges it cannot efficiently capitalize on its growing clean energy supply without modernizing its existing grid.[43]

E-Energy, Germany's "ICT-based energy system of the future"—ICT meaning information and communication technologies—is an energy supply project that will oversee and optimize Germany's energy distribution network as well as facilitate secure energy transactions between the supply, demand, and other players in the energy marketplace. An optimized transmission grid will decentralize power generation and distribution, which will increase competition between suppliers and diversify the sources of energy delivered to users. The result is reduced transaction costs, better use of existing grid capacities, and increased use of clean sources of energy.[44]

E-energy is a public-private cooperative that consists of six pilot programs representing different geographical regions with different energy supply and demand profiles. The projects that complement one another while presenting a range of supply options. The program also has an "electromobility" component that seeks to lay the framework for integrating electric vehicles into the overall supply system.[45] The German government, between the BMWi and BMU, will provide $86.9 million of the $202.7 million in total equity capital needed to mobilize the project.[46] In 2012, the projects will be fully implemented in the six model regions.[47] A successful program will result in subsequent follow-up investments and widescale implementation.

Physical infrastructure is critical to maximizing a booming clean-energy sector, but so is economic and human capital infrastructure. High-quality workforce training produces the high-skilled laborers necessary to compete in advanced industries such as the clean-energy sector. Germany is the standard bearer for workforce training.

Its "dual" system of standard education and vocational training equip youth with the necessary skills to excel upon entering the workforce. Workforce training programs are subsidized by federal and local governments in addition to private industries. This cooperation between government and industry shows a unique appreciation on Germany's part for developing a highly-skilled workforce that's well prepared for the specific jobs emerging in growth industries.

The German government's Act for Investment in the Future, or Zukunftsinvestitionsgesetz, reinforced its commitment to job training and education across various industries, including the clean-energy sector. The program will invest more than $12.5 billion in fiscal year 2009-2010 in education infrastructure. Two of the program's key priorities are improving students' transitions from school to vocational training and promoting programs that help

incumbent workers find careers with advancement opportunities. The environmental technology sector workforce is increasing at a rate of 10 percent annually, which means strong workforce and education investments such as these are imperative.[48]

At the same time, the German government mitigates the cost of education through the Federal Training Assistance Act, or BAföG. This program ensures that school students receive all necessary financing as a straight grant, while college and vocational students receive half of the money in the form of a grant and the other half as an interest-free state loan. One in four students is financed by BAföG to some degree.[49]

Germany is also easing restrictions on foreign labor to combat its low birth rate and subsequently declining workforce, as well as a deficit of science and technology experts. "The contribution of labor migration to securing the necessary pool of qualified workers in Germany" action program increases job market access for highly qualified foreign workers and eases requirements on German employers to prove that there are no equally qualified candidates domestically. The government also lowered the income threshold for workers to qualify for the program from $125,115 to $93,836 for highly qualified foreign workers.[50]

Over the past three decades, Germany expanded its share of the clean-energy industry by instituting comprehensive and long-term policies with concrete targets and the requisite financial mechanisms to realize them. And it is taking deliberate steps to address its particular challenges, which include a skilled labor shortage, an aging electricity grid infrastructure, and a deficit of natural resources. Germany's overarching approach and staggering success in wind and solar energy technologies prove that the country is a dedicated and capable leader in the clean-energy arena.

Spain, another European counterpart to the United States, is providing fierce competition in the clean-energy space through a similarly comprehensive domestic policy approach.

Germany expanded its share of the clean-energy industry by instituting comprehensive and long-term policies with concrete targets and the requisite financial mechanisms to realize them.

Spain

Like the United States, Spain recently experienced the bursting of a major real estate bubble, which left the country with unemployment rates over 13 percent. But even as Spain's housing economy falters, the country is emerging as a renewable energy powerhouse, particularly in wind and solar technologies. Spain is investing in a mix of innovation, manufacturing, deployment, and basic worker training strategies, and it clearly views clean-energy technology as its ticket out of the old economy and into the new.

Spain's economy is a mix of agriculture (3.4 percent), industry (29 percent), and services (67.6 percent). It is firmly in the top 10 economies worldwide with a GDP of $1.6 trillion.[51]

Clean-energy deployment in Spain

Since 2004, Spain's energy policy has focused on three objectives: sustainability, competitiveness, and supply security. The Spanish government has paid particular attention to energy efficiency and renewable energy.

There is no question that Spain has surged ahead in the clean-energy race. In 2008, renewable energy sources covered about 7.6 percent of its primary energy and 20.5 percent of its net power generation. Provisional figures for the first part of 2009 point to higher numbers: about 9 percent of primary energy and more than 27 percent of net power generation.

Wind is by far the most common renewable source used in Spain's power sector. Over 16,546 megawatts were installed at the end of 2008 and at least another 1,500 MW were installed in 2009, making Spain fourth in the world in wind energy. Incredibly, high winds in November 2009 led to Spain's wind farms producing a staggering 53 percent of the country's power for more than five hours. The same winds caused maximum simultaneous wind power of about 11.5 GW, or around two-thirds of the wind farms' theoretical maximum capacity.[52] A combination of good wind speeds and strong government policies to support wind has led to a number of wind manufacturing companies springing up in Spain, most notably Iberdrola and Acciona.

Solar is the next largest piece of Spain's renewable electricity mix (3,270 MW for PV and 61 MW for concentrated solar power at the end of 2008), followed by small hydropower

(1,872 MW), and biomass, municipal solid wastes, and biogas (374 MW, 189 MW, and 149 MW respectively at the end of 2008). Altogether nearly 26 percent of Spain's electricity comes from renewable power, not including cogeneration. Several regions want to reach 100 percent renewable power, and two—Castilla y León and Galicia—are already pushing 70 percent.[53]

Biomass is one of the main renewable energy sources in Spain, which is perhaps not surprising for an economy with a strong agricultural sector. The country has set ambitious targets for the use of biofuels and bio-based heating as well as for bio-based power. Spain was the third largest bioethanol producer in the European Union in 2008, and the seventh largest biodiesel producer. That same year, more than 1.9 percent of Spain's transport energy needs were covered by biofuels. The country is also known for its biofuel innovations in fields such as barley-based, Jerusalem artichoke-based, and cellulosic ethanol.

While Spain has met its biofuel objectives, it still lags behind other EU countries in the use of bio-based heat. However, the country is committed to stepping up production of bio-based heat in the coming decade. Spain is also focused on increasing solar thermal and geothermal heat production. Currently about 2.5 percent of total primary energy in the country is met using these three technologies.

But Spain's energy policy goes beyond renewable energy generation, and the country is also serious about energy efficiency and conservation. The Spanish Energy Efficiency Strategy 2004-2012, implemented through several different action plans—the most recent being the Energy Savings and Efficiency Action Plan 2008-2012 and the Energy Saving and Efficiency Activation Plan 2008-2011—has reduced Spain's energy consumption per unit of GDP, or energy intensity, by more than 11.3 percent in the last four years—2005 through 2008—after a long period with increased consumption.[54]

Spain has surged ahead in the clean-energy race. In 2008, renewable energy sources covered about 7.6 percent of its primary energy and 20.5 percent of its net power generation.

Clean-energy innovation

Spain's public investment in research and development, or R&D, of alternative energy has fallen from historic highs in the late 1970s, when the oil crisis spurred both government and private industry to aggressively seek alternatives to fossil fuels. This is true of most other developed countries including the United States. However, public spending on clean-energy R&D has steadily increased each year since 2004 and rose to nearly $128.5 million in 2008.

Spain's government approved in 2006 a National Strategy for Science and Technology, or ENCYT, which sets out medium-term goals through 2015 for the country's science and technology. The program, implemented through the National Plan for Scientific Research, Development and Technological Innovation—which runs from 2008 to 2011—includes energy and climate change as one of its five strategic actions.

Under ENCYT, public funding—in the form of loans and subsidies—covers the energy R&D path from basic and applied research to pilot and demonstration projects to market entry and commercialization. The loans are interest free with a maximum payback period of 15 years. Subsidy levels are limited by EU state aid rules and they vary according to the size and type of project.

Publicly funded energy R&D is also conducted by research institutions, universities, technology centers, and private entities. The government directly funds several public research institutions that focus on applied research and pilot and demonstration projects, and these institutions often receive private sector funding. Two of the most important are the National Research Centre for Energy, Environment and Technology, or CIEMAT, and the National Renewable Energy Centre of Spain, or CENER.

CIEMAT is the major publicly funded energy research institution in Spain. It primarily carries out energy R&D and demonstration projects, but it also researches the environment and other technology areas. CIEMAT had a budget of $208.5 million in 2007 and a staff of 280 working on energy R&D projects.

The CIEMAT Plataforma Solar de Almería, or PSA, located in the southeastern Almería region, has been a world leader in concentrated solar power research since 1977. The program works on improving concentrated solar power technologies such as parabolic troughs, central receivers, dishes, and Fresnel collectors. In 2007, PSA received $28.6 million—almost half of CIEMAT's total funding for renewable energy.

CENER was founded in 2001 by the Navarre regional government, the national Ministry for Science and Innovation, and CIEMAT. CENER carries out applied research and technology transfer in clean energy. The center has around 200 staff and an annual budget of $32.8 million, of which 60 percent is self-financing.

CENER is more focused on the commercialization and marketability of clean-energy technologies and CIEMAT focuses mostly on early-stage R&D. CENER's main activities center on wind energy, and it operates a major wind turbine test facility that's become a hub for testing turbines for the entire EU community. The facility costs more than $71.4 million and includes test laboratories for blades and power trains, an aerodynamic tunnel, a laboratory for composite materials, and an experimental wind farm. CENER has invested an additional $47.1 million in a new demonstration plant for second-generation biofuels.[55]

A third important government institution is the Instituto para la Diversificación y Ahorro de la Energía, or Institute for Diversification and Saving of Energy. It is a state-owned business entity that reports to the Ministry of Industry, Tourism and Trade through the State Secretary for Energy, and it is responsible for managing the funds of the National Renewable Energies Plans, which grant incentives for investments in technological innovation in the renewable energy field using government funds.[56] Since IDAE's creation in

Spain is a renewable electricity powerhouse

An aggressive feed-in tariff helped Spain become one of the largest and most assertive installers of renewable energy. By the end of 2008, the country boasted 3.3 gigawatts of installed solar photovoltaic capacity—second in the world to Germany. By the end of 2009, it was fourth in the world in wind power capacity with 18 GW.

More than 25 percent of Spain's electricity now comes from renewable power. Several regions have the goal of reaching 100 percent renewable power, and two—Castilla y León and Galicia—are already pushing 70 percent. Spain also boasts of some of the world's leading renewable energy companies such as Gamesa, Acciona, and Iberdrola Renewables.

1974 it has been an active player in stimulating the renewable energy market by providing technical and financial services for innovative projects suitable for replication.

Spain's private sector is also a major investor in clean-energy R&D. The renewable energy sector invested about 6.6 percent of its overall GDP in 2007, or $450 million, in R&D—in contrast to other sectors, which invested only about 1.3 percent in R&D activities.[57]

Clean-energy manufacturing

Spain's strong renewable energy policies work in tandem with its solid natural wind and solar resources to make it a bastion of clean-energy manufacturing both at home and abroad.

The country is home to Iberdrola and Acciona, the world's two largest renewable energy companies. Both of them have a special focus on wind energy development. The presence of these large wind developers guarantees a market for wind turbine manufacturing, and two Spanish companies—Gamesa and Acciona—are among the top 10 global wind turbine manufacturers. Gamesa has 30 manufacturing facilities in Spain that make all aspects of turbines including towers, nacelles, and blades.[58]

Spain is also the solar thermal power manufacturing capital of the world with more than 2 GW under construction or at an advanced planning stage. More than 800 MW will be in operation in Spain in 2010.[59] In the solar thermal sector for heating applications, there are more than 1,300 companies and 35 manufacturers with a production capacity of more than 1.9 million of square meters.[60]

Most observers credit the country's strong renewable energy standard and other supportive policies for this manufacturing growth. These policies create a stable and predict-

able regulatory framework and act as a clear signal for investors. They also create market demand for renewable energy products.

Local policies have played an important role, too. There is no national incentive to use locally produced renewable energy systems, but some regional governments have put these incentives in place. Wind project developers in the Galicia region, for example, must use at least 70 percent locally manufactured equipment. Navarre has a similar requirement that recently led the region to install 700 MW of locally produced wind energy systems, creating 4,000 local jobs. Altogether, three-quarters of Spain's installed wind energy systems come from domestic manufacturing facilities.[61]

All this manufacturing strengthens Spain's position in the global clean-energy marketplace. Overall, the Spanish renewable energy sector exports about $5.3 billion each year.[62] The country exports wind energy equipment worth $3.6 billion every year, according to the Global Wind Energy Council, and it exports 80 percent of its solar technology to Germany. However, Spain's solar PV market may become more competitive since it is beginning to import more of this technology from Taiwan, which is becoming a powerhouse in solar exports in its own right due to its manufacturing prowess, as we shall explore later below.[63]

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Clean-energy jobs

Spain's total number of clean-energy jobs has been debated over the past year. A controversial paper released in 2009 argued that the country's "green jobs" growth was entirely due to government subsidy and had displaced a corresponding number of private-sector jobs that would otherwise have been created.[64] The paper, written by Gabriel Calzada Alvarez—the founder and president of the Instituto Juan de Mariana, a libertarian think tank founded in 2005, and also a fellow of the Center for New Europe, a Brussels-based libertarian think tank that in recent years apparently accepted funding from Exxon Mobil—has been roundly criticized and discredited since its publication.[65]

In fact, the Labour Union Institute of Work, Environment and Health, or ISTAS, found that Spain's renewable energy sector had 89,000 direct jobs at the end of 2007, along with another 90,000 or so indirect jobs.[66] And Spain's aggressive renewable energy policies will ensure future job growth: The ISTAS study indicates the country will host over 270,000 direct jobs in renewable energy industries by 2020.

What's more, these clean-energy jobs have helped stabilize Spain's economy after its housing bubble collapse in 2008. At the same time, it's important to remember that clean-energy investment does more than create jobs—it reduces emissions and improves public health and environmental quality.

Clean-energy policy tools

Spain's progress in innovating, manufacturing, and developing clean-energy systems is largely due to a comprehensive clean-energy investment and policy approach. Spain worked hard to create the markets and financial incentives necessary to develop this sector, and it fostered the important infrastructure supports—including workforce training—that underlie all sustainable economic development.

Expanding markets and driving demand

Spain committed to reduce its carbon emissions by 20 percent of 1990 levels by 2020 in line with the EU target. And it committed to achieving 20 percent of its own final consumption and 10 percent of its transport energy needs from renewable sources by 2020 under the EU Directive that promoted the use of renewable energy.[67] In Spain's own 2005-2010 Renewable Energy Plan, it committed to using renewable energy to meet 12.1 percent of its primary energy needs, 30.3 percent of electricity needs, and 5.83 percent of transportation fuel.

The Renewable Energy Plan further established specific targets for different technologies in order to meet the more general overall targets. Spain has already met its solar PV target and is on track to meet wind and solar CSP targets during 2010. Spain also met the intermediate annual target for biofuels in 2008 and has covered 75 percent of the overall target for biofuels production capacity for 2010. Spain is not performing as well in other areas, including bio-based electricity and heat, but both areas are expected to grow significantly in the next decade.

Further, Spain sought to create a solar installation market through its groundbreaking 2005 Technical Building Code, which requires installing solar hot water systems in all new buildings and in some refurbished buildings. Spain is also the first European country—and only the second in the world after Israel—to make solar thermal energy mandatory in new and refurbished buildings.[68]

Finally, the Spanish Energy Efficiency Strategy 2004-2012—which sets a goal of reducing energy intensity in Spain by 7.2 percent by 2012—together with its implementing regulations helped create a market for energy efficiency technologies and services.

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Financing research, development, and deployment

Spain's government R&D programs described above such as the ENCYT, CMEIT, and CENER channel public finances into energy R&D.

The European Union's renewable energy standard created a market for renewable projects in Spain, and the country's feed-in tariff system plays a major role in creating the necessary financial conditions to bring the private sector on board. Spain's feed-in tariff was enacted in 1997 through the Electric Power Act and has since evolved through different royal decrees. The feed-in tariff's primary goals are to help Spain accelerate renewable energy deployment and achieve its national renewable energy target.

Spain reduced its feed-in tariff for solar PV systems in 2008 due to the rapid growth of PV installations under the original tariff. The new royal decree for solar PV in 2008 reduced the tariffs and implemented a 500 MW solar PV capacity annual cap. The cap will increase each year—depending on the development of the market—up to a 10 percent annual growth rate, and tariffs will simultaneously decrease annually.[69]

One important recent policy guarantees that targets are actually measured and met. The parliament passed a new royal decree in 2009 creating a renewable energy register for electricity production. This system turns Spain's indicative energy targets into mandatory ones by tracking actual installation of different renewable technologies.

Spain provides a number of financing tools for renewable energy developers and consumers besides the feed-in tariff. These tools are used not only in the power sector but also for heat and transportation:

- A variety of soft loans and direct support—nonrecoverable funds—for a number of renewable energy projects, including standalone PV installations, certain types of standalone combined wind and PV installations, production installations for domestic or industrial renewable heat use, and solar thermal applications (installations not covered by obligations in the technical building code)

- Fuel tax exemptions for biofuels along with a minimum mandatory blend of 5.83 percent of bioethanol and biodiesel in automotive use by 2010—with an indicative target of 3.4 percent bio-blend in 2009

- Public support for developing storage facilities such as pumping systems and electric vehicles that can capture off-peak renewable energy production

- Other financial supports through IDAE for specific strategic projects that focus on early-stage plants and technologies

Building physical and economic infrastructure

Spain's government has invested in the infrastructure that ensures renewable power can get to market as part of its comprehensive approach to clean energy. Two critical pieces of

this infrastructure investment include power grid upgrades and strategic support for the workforce training and education system.

Spain's National Investment Plan, the national power system plan, was last updated for 2008-2016. The plan takes the Spanish Renewable Energy Plan 2005-2010 into account, which establishes a target of 30.3 percent renewable energy. It also considers that the objective for 2020 could be as high as 45 percent, with 40 GW generated from wind projects alone.

The plan recognizes that using more renewable electricity requires much more than building and reinforcing grid systems. The variability of wind and solar power and the fact that Spain is a semi-isolated electric zone—the interconnection capacity with France is only about 3 percent of peak demand—pose significant challenges to the power system's reliable operation. Spain coped with these challenges and achieved impressive renewable electricity penetration rates by implementing traditional solutions such as strong interconnection standards, grid upgrades, and pumping storage, and by introducing innovative ideas such as:

- Enacting technology performance requirements to keep wind turbines from disconnecting during recovery periods after voltage dips
- Creating the Control Centre for Renewable Energy, or CECRE, to supervise and control renewable energy generators. The CECRE collects detailed information from wind production units every 12 seconds. Based on this information, the system calculates how much wind power can be fed into the power system at any given time. This calculation is broken down by individual wind farm and transmission grid node, and is then sent to generation control centers, which in turn communicate it to the producers so they can control the volume and quality of electricity supplied to the grid. Spain is the first country worldwide to have a control center for every wind farms over 10 MW
- Improving forecasting tools and models—Spain's transmission system operator tools can forecast renewable generation with error rates lower than 5 percent as much as four hours in advance

In another important move, Spain set an ambitious target of producing 1 million plug-in hybrid and electric vehicles, or PHEVs, by 2014. Spain's objective in passing this target—beyond slashing oil dependence—is to use the PHEV vehicle fleet as a way to manage variable energy in the power grid system. A pilot project known as Movele will introduce 2,000 electric cars to the market mainly in urban and suburban areas. At the same time, the country plans to build a network of 500 public charging stations in some of its major cities by the end of 2010. The Movele project will monitor electric vehicle energy consumption in real time and provide data to regulators in hopes of eventually widening deployment of these vehicles.

Spain's government has invested in the infrastructure that ensures renewable power can get to market as part of its comprehensive approach to clean energy.

Spain also knows that its labor force is a critical piece of its clean-energy infrastructure. The Navarre government created the Centro Nacional Integrado de Formación en Energías Renovables, or CENIFER, in 2001, a national center dedicated to renewable energy job training. The center provides all levels of training, from entry-level skill development to retraining for unemployed workers to technical training for high-level incumbent workers. CENIFER also constantly researches developments in a variety of renewable energy sectors so that its training is always relevant to the industries it serves.

Like Germany, Spain is adopting a comprehensive approach to renewable energy innovation, manufacturing, and deployment, particularly through its progressive feed-in tariff. This approach and Spain's abundant natural wind and solar resources have all been key to the country's transition to a powerhouse in the clean-energy industry.

Finally, a look at China shows how a major developing country is growing its own clean-energy industries while dealing with the challenges of economic development.

Continentwide coordination spurs new clean-energy markets

The European Union's experience with clean-energy policy provides a useful lesson on the importance of broad, continentwide standards. While the policies of individual countries ultimately drive clean-energy investments in such countries, these policies or mechanisms exist largely because of a European Union-wide agenda. So while Germany and Spain are shining examples of clean-energy policy and development, the impetus for their actions stems mostly from continentwide directives on emissions reduction, renewable energy deployment, and energy efficiency.

The European Union set 2020 targets for reducing carbon emissions by 20 percent of 1990 levels, obtaining 20 percent of its electricity from renewable sources, and increasing energy efficiency by 20 percent. The "20-20-20 by '20" vision spurred countries like Germany and Spain to adopt domestic targets that are as strong as or even stronger than these EU targets.

A European Union-wide cap on emissions also sparked a European Union-wide carbon market, which is the first and now the largest carbon market in the world, totaling almost $100 billion in transactions in 2008.[70] Such transcontinental alignment on clean energy prompted various collaborations across EU countries, including a recently announced $43 billion effort by nine countries to build high-voltage cables under the North Sea to boost the transmission of renewable energy power.[71]

There are clear lessons here for the United States. Progressive states have led the way toward the clean-energy transformation by passing state renewable portfolio and efficiency standards, but only federal standards can pull in states that wouldn't otherwise act while also spurring interstate markets and infrastructure to accelerate the national transition to a clean energy economy.

China

China is commonly viewed as pursuing an uncompromising economic growth model without consideration for the environment or public health. But China's leaders fully grasp climate change's threat to the country's water and food security and the strategic economic and energy security benefits provided by deploying clean-energy solutions at a massive scale.

China's GDP in 2008 was $4.3 trillion—less than one-third that of the United States in absolute terms and just 7 percent of U.S. GDP in per capita terms. China's economy comprises three primary sectors: industry, services, and agriculture. Industry makes up the largest share of China's GDP at 48.6 percent.[72] Services follow close behind at 40.1 percent, and agriculture is third at 11.3 percent. China's strong manufacturing and industry sectors, aided by what some believe to be a deliberately undervalued currency, drive its robust global trading position and resulted in a global trade surplus of more than $400 billion in 2008.[73]

China eclipsed Germany in 2009 as the world's largest exporter. But the economic downturn that began in 2008 caused a temporary but dramatic dip in its exports. This dip prompted China to seriously consider rebalancing its growth with increased domestic consumption. This rebalancing would also diminish China's global trade surplus.[74]

China's leaders fully grasp climate change's threat to the country's water and food security and the strategic economic and energy security benefits provided by deploying clean-energy solutions at a massive scale.

Clean-energy deployment in China

China boasts the most installed renewable electricity capacity of any country in the world. At the end of 2008, its 76 GW of installed capacity of renewable electricity—which excludes large hydropower for environmental impact reasons—was nearly twice the amount installed in the United States.[75] While the European Union is aiming to produce 20 percent of its energy from renewable sources by 2020, and the U.S. Congress considers adopting a 20 percent renewable electricity standard by the same year, China produced fully 16 percent of its electricity from hydropower and wind power alone by the end of 2009—numbers that will certainly increase over the next decade.[76]

In fact, nonfossil fuel sources are expected to account for as much as 30 percent of China's overall power supply by 2020. The country expects to meet a big portion of this new market by building seven wind megabases of at least 10 GW each strategically sited across the country.

Wind power is definitely China's current favorite in its renewable energy race. The country possesses more than 20 GW of wind capacity, which gives it the third-largest installed wind power fleet behind the United States and Germany. Solar PV, in contrast, accounts for only about 0.3 GW of installed capacity, compared to a total installed capacity—renewable or nonrenewable—just over 800 GW. The solar sector, however, is poised to grow exponentially to a targeted 20 GW by 2020 as a result of new major incentives announced in 2009 for domestic deployment.

One caveat worth pointing out: Installed capacity, especially in China's case, is not necessarily the best way to measure the success of a country's renewable energy development. As many as one-third of China's wind farms are not connected to the transmission grid due to the lack of incentives for grid companies to build out transmission lines to interconnect with clean-energy projects in remote areas. At the same time, the capacity factors of domestically made wind turbines—typically in the 20 to 30 percent range—are generally inferior to those of leading foreign-made turbines, which are above 30 percent.

The good news is that policymakers recognize these problems and have introduced new measures to address them. They have clarified rules and offered incentives that require grid companies to connect to renewable energy projects, and they have removed domestic content requirements to allow increased penetration of foreign-made wind turbines into the Chinese wind market.

Clean-energy innovation

> *"We should see scientific and technological innovation as an important pillar and make greater effort to develop new industries of strategic importance. Science and technology is a powerful engine of economic growth . . . We will make China a country of innovation. . . We will accelerate the development of a low-carbon economy and green economy so as to gain an advantageous position in the international industrial competition."*
>
> *– China's Premier Wen Jiabao at the World Economic Forum, September 10, 2009.*

Fostering "indigenous innovation" is a long-term strategy of China's economic planners.

Innovation and R&D have not been traditional strengths of Chinese industry, which is better known for its ruthless efficiency in cost cutting and manufacturing productivity. However, the central government views science and technology as key drivers of social progress as China develops a more modern economy. Fostering "indigenous innovation" is a long-term strategy of China's economic planners.

The Medium-to-Long-Term Science and Technology National Plan, unveiled in 2006, established the Chinese government's strategic role in innovation activities through 2020. The plan includes tangible benchmarks such as achieving global top-five rankings in

patents generated and citations in international science publications. It also identifies five more general targeted growth industries with top priority given to technologies relating to "energy, water resources, and environmental protection."

Even more specifically, the Ministry of Science and Technology, or MOST, has identified three priority clean-energy technologies to target with policies and investment for the five-year period ending in 2010: energy-saving technologies, 2-3 MW wind turbines, and high-voltage electricity transmission technologies.

China's most noteworthy government-funded clean-energy R&D initiatives include:

- **Key Technology R&D Program:** This is China's first national R&D program to support innovation in a broad range of socioeconomic sectors including environmental pollution control and efficient resource utilization for energy and water. Over the five-year period of 2001 to 2005 almost $1 billion in funds have been invested programwide, making it the third-largest source of national government R&D funding over that period—just behind the 863 Program (discussed below) and the National Natural Science Fund.[77]

- **863 Program:** The 863 Program is more formally known as the State High-Tech Development Plan, and it is the most well-funded government innovation program, receiving some $3 billion from 2001 to 2005. Managed by MOST, the 863 Program was created in March 1986—hence the name—to stimulate development of a wide range of technological fields. China's current national Five-Year Plan—2006 to 2010—identifies energy technologies as a focus area of the 863 Program, and it further identifies hydrogen and fuel cells, energy efficiency, clean coal, and renewable energy as targeted beneficiaries of some $172 million in funding.

- **973 Program:** This program is also known as the National Basic Research Program and focuses on more fundamental basic research. It complements the 863 Program, whose focus is more on the commercialization of high-technology applications. Sustainable development and energy have been key areas of the 973 Program since its founding at the third meeting of the National Science and Technology Committee in 1997. Between 1998 and 2008 the program funded 382 projects for a total investment of $1.3 billion—with 30 percent of the funding going toward energy and resource protection projects.[78]

The absolute dollar amount invested through these programs is not by itself impressive given the scale of investment needed to truly transform China to a clean energy economy, and it isn't clear after—in some cases—more than two decades of existence that these programs are yielding the hoped-for results.[79] What is clear, however, is China's long-term commitment to innovation through sustained programmatic funding rather than an ad hoc approach such as providing funding through legislation that is subject to annual unpredictable appropriations. As an example, China announced in December 2009 the establishment

of 16 new energy R&D centers that will work in key sectors such as nuclear power, wind power, high-efficiency power generation and transmission, and facility materials.[80]

But innovation does not originate in a vacuum. One of the historical features of China's technology innovation is the role of foreign technology in the innovation chain. To achieve its goals of indigenous innovation, China's government has adopted a model of "import/assimilate/re-innovation." Thus, the early stages of all technology development include heavy reliance on foreign technologies.

These technology transfer opportunities sometimes result from intergovernmental cooperation—as was the case with energy conservation technologies made available to China through the auspices of the Japanese Green Aid Plan to China between 1992 and 2003. They can also result from purely commercial negotiations, as in the case of Goldwind, a Chinese wind company that acquired much of its intellectual property and know-how by licensing foreign technologies and ultimately outright acquiring a German wind company.[81] Goldwind was virtually unheard of two years ago. Now it has gone public and is the eighth largest wind turbine manufacturer in the world.

Today, China continues to increase its R&D capacity by welcoming international expertise. Applied Materials, the world's biggest supplier of solar manufacturing equipment, is opening a new major R& D facility in China and is relocating its chief technology officer from Silicon Valley to China.[82] Applied Materials's move follows on the heels of DuPont, another American company that expanded its solar R&D facilities in Shanghai last summer.[83]

The relocation of innovation activities to where the manufacturing and market are growing makes sense because of the synergistic benefits of co-locating activities from different links of the value chain. But it also represents a potential threat to American innovation because clean-energy manufacturing activities and the clean-energy market are growing more rapidly abroad.

China's reputation as the "factory of the world" holds true in the clean-energy technology sector.

Clean-energy manufacturing

China's reputation as the "factory of the world" holds true in the clean-energy technology sector. It is currently the world's leading supplier of solar PV panels and solar hot water heaters, and until recently more than 90 percent of Chinese-made solar PV panels were shipped overseas for export markets.

Altogether, China produces a third of the world's solar panels. Almost all of these are exported to countries or regions with strong incentives for solar deployment, especially Germany, Spain, and California. China had just 0.3 megawatts of installed solar PV capacity at the end of 2009. In the same year, however, two major policies—the Solar Roofs Program and Golden Sun Program—were adopted to spur the domestic market, which will

further support the solar manufacturing sector. Suntech, China's largest solar manufacturer with an annual production capacity of 1 GW, is poised to overtake Germany's Q-Cells as the world's largest manufacturer of silicon-based solar panels**.** Its domestic competitors, Yingli and Trina, are also among the world's largest solar PV producers. All three are publicly traded global companies that are listed on the New York Stock Exchange or NASDAQ.

The wind manufacturing sector has grown as well, tracking the domestic wind power market's growth. China had few major wind manufacturers just five or six years ago, but it was home to 70 of these firms by the end of 2008.[84] China's top three wind turbine makers have combined annual production capacities of 4 GW, and total annual manufacturing capacity by Chinese makers may reach as high as 20 GW by 2010.[85]

This upward trend is the result of a concerted and comprehensive policy to develop China's domestic capacity to manufacture wind components for its own burgeoning wind energy market. The domestic market is vast. In 2007, China set a national target of 10 GW and 30 GW of installed wind capacity for 2010 and 2020, respectively. By the end of 2009 approximately 20 GW were already installed. As a result, China's National Development and Reform Commission is reportedly revising these targets to 35 GW by 2011 and 150 GW by 2020—truly staggering numbers by international standards.

The leadership of local, city, and provincial governments in creating low-carbon development zones has been another catalyst for clean-energy technology manufacturing. In these regions, clean-energy industries are the backbone of economic development, creating jobs through innovation, manufacturing, and assembly activities. There are many examples of publicly supported low-carbon economic clusters, including Baoding in Hebei province, Tianjin municipality, Wuhan city in Hubei province, and the "solar belt" of cities found throughout Jiangsu province.[86] Growing academic and real world evidence demonstrate that this type of cluster-based approach to economic development can lead to higher rates of innovation and entrepreneurship and better wages.[87]

The leadership of local, city, and provincial governments in creating low-carbon development zones has been another catalyst for clean-energy technology manufacturing.

A closer look at China's wind power sector provides a useful illustration of its manufacturing policy at work. It adopted several measures in recent years to promote a manufacturing infrastructure of wind energy components that has transformed the sector from one heavily dependent on foreign technology to one where China is becoming increasingly self-reliant and ultimately export oriented. The government enacted targeted policies to promote the domestic manufacture of wind technologies, including:

- A mandatory requirement that all wind power projects have 70 percent of the equipment manufactured domestically (This requirement has recently been lifted to address international concerns of trade protectionism, but has nonetheless served its purpose.)

- A tariff and value-added tax rebate on imports of parts and raw materials used in manufacturing wind turbines

- The elimination of tariff-free importation of wind turbines less than 2.5 megawatts in capacity

- Strong market demand created by ambitious national targets for installed wind capacity supported by robust financial and tax incentives, as described above

Clean-energy exports and jobs

As Chinese investment in innovation begins to bear fruit, the "Made in China" label is slowly losing any stigma of inferior quality. Chinese clean-energy hardware is increasingly receiving warm reviews. At the same time, the Chinese commitment to manufacturing, stimulated by a market both at home and abroad, is becoming a job creation engine throughout the country.

The poster child for China's clean-energy exports is undoubtedly its solar sector. As mentioned earlier, Chinese solar PV panels account for 30 percent of the world's global production, with almost all of that—until recently—targeting overseas markets. Top Chinese solar manufacturers have established sales offices in lucrative European markets as well as targeted American markets like California. China's Suntech has gone one step further by announcing it will open a manufacturing facility in Arizona with an annual capacity of 30 MW—able to fully serve 8 percent of the United States' solar market.[88]

The poster child for China's clean-energy exports is undoubtedly its solar sector.

China's large domestic demand for wind power means that most manufactured turbines are installed in China. But with Chinese manufacturers rapidly increasing their annual production capacities, there are now concerns of wind manufacturing overcapacity. So Chinese wind firms such as Sinovel, Goldwind, and A-Power are now starting to flex their global muscles by aggressively seeking overseas markets for their wares.[89]

The relatively more mature hydropower sector is becoming a strategic export sector as well. State-owned Sinohydro is building hydropower dams in other developing countries such as Cambodia, Laos, Ecuador, and Botswana. China's technology leadership position in advanced coal combustion, electric vehicles, and high-speed rail are also starting to win orders from overseas.

Employment in the Chinese renewable energy sector reportedly numbered 1.12 million by the end of 2008, with that figure increasing by 100,000 a year.[90] A recent report by the Global Climate Network concluded that by 2020 the fulfillment of China's domestic renewable energy targets will lead to an additional 1 million new jobs in hydropower, between 670,000 and 1 million jobs in wind power, and between 860,000 and 880,000 jobs in solar PV.[91] Together, these three sectors alone could create up to 2.88 million jobs by 2020 solely by meeting domestic demand. Any concerted clean-energy export strategy will lead to even more new jobs in China's clean-energy industries.

Clean-energy policy tools

Expanding markets and driving demand

Recently, China announced that it would reduce its carbon dioxide emissions as a proportion of each unit of GDP produced by 40 to 45 percent of 2005 levels by 2020. But this is just the latest in a vast array of national-level, clean-energy targets that China has set for itself.

All the countries discussed in this report engage in some level of national economic development planning, but China does so to an extreme. It develops its future economic growth strategies through a series of five-year plans. Its current five-year plan (2006-2010) contains the country's most ambitious environmental targets to date, including reducing energy consumption per unit of GDP by 20 percent from 2005 levels. Each provincial-level jurisdiction must meet a share of the national energy intensity target, and provincial governors are promoted in part based on their fulfillment of these goals.

In support of this five-year target, the Medium- and Long-Term Energy Conservation Plan released in 2004 sets extensive targets for energy and resource efficiency across two dozen specific industrial sectors and equipment types and identifies 10 priority energy conservation projects in coal, petroleum, buildings, lighting, transportation, and other areas. These energy conservation targets have attracted major government and private sector investment, and preliminary studies indicate that China will achieve or come close to achieving most of its energy conservation goals.[92]

One major national energy conservation program that sets energy efficiency standards for the top 1,000 energy consuming enterprises in China achieved its stated goal of reducing energy use by 100 million tons of coal equivalent two years ahead of its 2010 target date. In the process of fulfilling this target, some $7.3 billion in energy efficiency technologies and measures was invested in 2007, and another $13.2 billion was invested in 2008.[93]

The Medium- and Long-Term Development Plan for Renewable Energy sets out medium (2010) and long-term (2020) targets for renewable energy. China aims to generate 15 percent of its primary energy from nonfossil fuel sources by 2020. While it is unclear whether this share includes nuclear power—various government investments indicate that it probably does—the hydropower, wind, and solar sectors are expected to benefit as well.

A range of complementary policies support these national goals. The Renewable Energy Law of 2006 requires grid companies to purchase electricity from renewable sources, and other policy initiatives require those companies to clarify how the additional costs of producing and connecting renewable energy is to be shared across all power consumers. Similar policies require power generators to supply a certain percentage of their power from renewable energy sources.

In a program called the mandated market share, or MMS, power generators with an installed capacity of more than 5 GW must produce 3 percent of their electricity from nonhydro renewable sources by 2010 and 8 percent by 2020. Because the MMS is binding, it is more similar to the "renewable portfolio standard" common in the European Union and the United States than the 2020 nonfossil fuel target.

All these national standards and policies were not driven by climate change considerations, but by a national focus on domestic energy security. But with climate change rising in importance in its socioeconomic agenda, and armed with a new goal to reduce carbon intensity, China is poised to enact new domestic legislation that curbs the growth of carbon emissions and will spur further growth of China's clean-energy industries.

China is also embarking on a gradual yet indispensible initiative to reform energy prices. Traditionally, energy prices have been artificially suppressed to promote universal access to electricity and fuel. But the environmental and public health consequences of unfettered fossil fuel use have proven unsustainable. Through a combination of easing price controls, taxation, differential pricing, and standards setting, oil and coal have been made steadily more expensive for consumers, thereby increasing the competitiveness of traditionally more expensive nonfossil fuel counterparts.

A good illustration of these policies' impact on consumption is the evolution of transportation fuel and energy-efficient vehicle use by Chinese consumers. In 2008 Chinese authorities doubled the tax rate on engines above 4 liters from 20 percent to 40 percent while lowering the tax rate from 3 percent to just 1 percent for cars with engines less than 1 liter.[94] These tax policies were combined with an automobile fuel economy standard that is one-third higher than the United States, the linking of gasoline prices to global crude oil prices, and the implementation of China's first gasoline taxes in 2009.[95] The result: In the first three quarters of 2009, cars with engine sizes of less than 1.6 liters accounted for 70 percent of new car sales—up from 62 percent for all of 2008.[96]

And in its efforts to manage its heavy reliance on coal, China is now beginning to address the pricing of electricity by, for instance, recently raising electricity rates for nonresidential customers.[97]

Financing research, development, and deployment

The Chinese government understands that creating a new clean energy economy requires a decisive and strategic mobilization of finance for innovation, infrastructure, manufacturing, and deployment. Government investments are made through various channels, including state-owned investment vehicles and financial institutions, economic stimulus programs, and financial and tax policies.

Central government leadership has certainly recognized that "scientific development" requires a public investment in clean-energy technologies. The aforementioned 863, 973, and Key Technologies R&D Programs represent significant public investment in clean-energy innovation. And China has employed a comprehensive suite of government policies to grow the low-carbon energy sector.

A look at the range of policies promoting China's wind sector is instructive:

- **Concession programs.** Through a bidding process, renewable energy developers are awarded project concessions at a preferential tariff rate

- **Feed-in tariffs.** In the wind sectors, concession programs have evolved to feed-in tariffs ranging from $0.07 to $0.09 per kilowatt-hour, depending on the region. Solar concessions, which started this year, are similarly moving to a feed-in tariff system

- **Carbon markets.** The clean development mechanism under the Kyoto Protocol has been instrumental to the wind sector's growth. Carbon credits generated under the CDM enable returns on investment, which make wind projects attractive to broad private sector participants

- **Mandatory grid connection and electricity purchase.** Grid operators are required to build transmission lines that connect renewable energy sites and purchase electricity generated from these sites. This requirement is supplemented by a subsidy to grid operators—varying by distance—for the build out of transmission lines

- **Cost sharing.** The national government set up a renewable energy fund by levying a 0.015 to 0.03 cents per kwh surcharge on all electricity users. The funds are disbursed periodically to renewable energy developers as a financial incentive. From 2006 through 2008, some $320 million was channeled to renewable energy developers under the cost-sharing program

- **Mandated market share**. Power generators with an installed capacity of more than five gigagwatts must produce three percent of their electricity from non-hydro renewable sources by 2010 and eight percent by 2020

- **VAT reduction**. Wind power generators are entitled to a 50 percent discount on their value-added taxes

On top of these national-level incentives additional carrots are dangled at the provincial and local levels in the form of added tariffs, tax breaks, and favorable land pricing, among others.

State-owned enterprises are another critical driver of clean-energy deployment.

State-owned enterprises are another critical driver of clean-energy deployment. China's "Big Five" electric utility companies—Huaneng, Datang, Guodian, Huadian, and China

Power Investment—are all major investors in renewable energy projects. They accounted for 55 percent of all domestic installed wind capacity as of the end of 2008.[98]

China Investment Corporation, or CIC, a recently formed state wealth fund with $300 billion of managed assets, is now making major investments in Chinese clean-energy companies. In November 2009, it announced investments of $400 million in China Longyuan Power, China's largest wind energy generator, and $700 million in GCL-Poly, a diversified energy company specializing in cogeneration, wind, and polysilicon production. In the same month CIC also invested $1.6 billion in AES, a U.S.-headquartered global utility with one of the largest foreign operations in China, including investments in hydro and wind power projects.

The China Energy Conservation Investment Corporation, a state holding company in operation since 1988, invests widely across a broad range of energy conservation, pollution control, and renewable energy businesses. Partnering with Suntech, the CECIC recently completed China's first 10 megawatt solar PV power plant project in Ningxia Autonomous Region. CECIC now has more than 90 subsidiaries and employs more than 20,000 workers. By 2012 it plans to reach $15 billion in total assets, $7 billion in total revenue, and $750 million in total profits. In the same time frame, the company projects an annual energy conservation capacity of 4.25 million tons of coal equivalent and annual reduction of carbon dioxide of 12 million tons.[99] It also aims to install 1.4 GW of grid-connected solar power capacity and is now beginning to set its sights on overseas utility-scale solar projects in Europe in alliance with several other Chinese companies.[100]

China invests big in power grid and high-speed rail infrastructure

Approximately $100 billion of the $586 billion economic stimulus package China implemented in 2008 is dedicated to building transmission lines and railways. China already leads the world in ultrahigh-voltage grid transmission technology—its line between Shanxi and Hubei boasts the highest capacity in the world and is able to transmit 1,000 kilovolts over 400 miles.

China is also embarking on the largest railway expansion in history and plans to spend almost $300 billion expanding its railway network from 48,000 miles today to 75,000 miles in 2020.[101] Of this, 8,000 miles will be comprised of high-speed, long-distance rail. What's more, China is poised to have the world's largest network for intracity urban rail transit. Eleven cities currently have urban rail routes totaling 520 miles, and by 2015 approximately 1,300 miles of railway lines will be laid and operational in 19 cities.

Building physical and economic infrastructure

China's government announced a $586 billion economic stimulus plan in November 2008. Some $100 billion of this will be allocated to infrastructure, particularly to the country's rail and transmission grid systems. These systems will serve as the backbone to China's emerging clean energy economy.

China, like the United States, must modernize its national grid infrastructure to accelerate its uptake of renewable energy. It is an emerging world leader in ultrahigh-voltage, or UHV, transmission technology, with more than 100 domestic manufacturers and suppliers participating in the manufacture and supply of UHV equipment.[102] A transmission line from Shanxi to Hubei boasts the highest capacity in the world and is able to transmit 1,000 kilovolts over 400 miles. The State Grid Corporation will invest $44 billion through 2012 and $88 billion through 2020 in building UHV transmission lines.[103] And in the coming months, China will unveil new plans to build an extensive smart grid by 2020.[104]

But its infrastructure investments are not confined to the power sector. As American economic history shows, transportation links are the backbone of a nation's economy. Cars will probably remain out of reach for the majority of Chinese households for the foreseeable future despite the country's rapidly growing automotive market, which is now the biggest in the world. Mass transit—particularly intracity subways and long-distance, high-speed rail—will remain the mobility solution of choice for many Chinese.

Recognizing this, China is embarking on the largest railway expansion in history and plans to spend almost $300 billion expanding its railway network from 48,000 miles today to 75,000 miles in 2020.[105] Of this, 8,000 miles will be comprised of high-speed rail. The 800 mile Beijing-Shanghai line is under construction and will reduce travel time between those destinations by nearly two-thirds—from 14 to 5 hours—when it opens in 2011.[106] This will attract an estimated 220,000 daily passengers and should dramatically offset air travel between the metropolises.

China is second in the world in electrified railways with a reported 16,000 miles. This figure accounts for an impressive 32 percent of China's total railways, and electrified rail is responsible for 50 percent of overall passenger and cargo volume.[107] What's more, China is poised to have the world's largest network for intracity urban rail transit. Eleven cities currently have urban rail routes totaling 520 miles, and by 2015 approximately 1,300 miles of railway lines will be laid and operational in 19 cities.[108]

There's little doubt that China is an emerging leader in clean-energy solutions. The more interesting question is how they got here. While the conventional wisdom is that China is able to produce low-carbon technologies primarily on the strength of its low-cost manufacturing prowess, it is equally true that the central government recognizes the need for a comprehensive approach to developing the clean energy economy.

China is proving to be a quick learner of international best practices, too. It has adapted successful policies from Europe such as clean-energy standards and feed-in tariffs to the Chinese situation while creating unique policies of its own, thereby creating the market signals and channeling the finance necessary to spur long-term innovation and deploy clean-energy installations on a mass scale.

Conclusion: Lessons for the United States

China, Germany, and Spain are forging ahead on the path to a clean-energy future while the United States lollygags. Each of these countries has a vastly different political economy—China is an authoritarian developing economy, Germany a long-established industrialized democracy, and Spain is a new industrialized democracy. But each is seizing the clean-energy opportunity with a truly comprehensive approach. All three countries have promoted intentional and interrelated policies to simultaneously:

- Enlarge their clean-energy markets
- Channel necessary finance for clean-energy innovation, manufacturing, and deployment
- Build supporting infrastructure

Every year the United States fails to chart similar strategies is a year it falls further behind.

This is not to say that the clean-energy "space race" is entirely about competition among countries. There is also an important role for bilateral and multilateral cooperation that can speed global deployment of cutting-edge clean-energy solutions while accelerating domestic economic benefits. A recent study by CAP and the Asia Society found that U.S.-China cooperation on carbon capture-and-storage technology, or CCS, could speed up CCS deployment by 10 years, create as many as 940,000 new U.S. jobs by 2022, and cut the cost of deploying CCS in the United States by as much as $18 billion.[109]

Even so, our overarching point is that the United States is missing out on important innovation and development opportunities and ceding overall technological leadership, with costly consequences for our economy and national prosperity.

CAP's "Clean-Energy Investment Agenda" outlined a set of comprehensive, concrete policy actions that will propel the United States toward a prosperous low-carbon economy including setting a price on carbon, limiting emissions, and establishing renewable energy and energy efficiency standards (see box).

Aside from the benefits of reducing global warming pollution and enhancing energy security, the drive to develop domestic clean-energy sources can be a powerful job-creation engine at home. We can revitalize our manufacturing industries, bolster exports, and strengthen the technology sector in ways that will pay economic dividends for decades to come.

The clean-energy investment agenda for the United States

As outlined in CAP's "Clean-Energy Investment Agenda," a comprehensive approach to developing a low-carbon economy would include three major elements: expanding markets and driving demand, providing financing, and investing in physical and economic infrastructure. Below are some of the important policies the United States should consider under each of these three elements:

1. Expanding markets and driving demand

- Set a price for carbon and limit the emissions of global warming pollution
- Enact an renewable electricity standard requiring utilities to meet a set percentage of its power needs through renewable generation
- Enact an energy efficiency resource standard requiring utilities to decrease its energy consumption through efficiency measures
- Updated codes to increase home appliance efficiency
- Updated codes to increase residential, commercial, and industrial building efficiency
- Provide rebates for building owners who invest in efficiency improvements
- Provide performance-based incentives to reduce carbon emissions from existing fossil fuel resources through technologies such as carbon capture and sequestration

2. Providing secure financing for research, development, and deployment

- Provide production and investment tax credits for renewable energy
- Ramp up investment in innovation through existing channels such as the National Science Foundation, national energy laboratories, land-grant universities, and federal programs such as Advanced Research Projects Agency – Energy, or ARPA-E
- Set up a new Clean Energy Deployment Administration, or Green Bank, to provide up front capital or credit enhancements for emerging clean-energy projects
- Provide incentives for states and cities to pass Property Assessed Clean Energy bonds, or PACE bonds, proceeds of which are lent to commercial and residential property owners to finance energy retrofits; property owners then repay their loans to PACE bond investors over time via an annual assessment on their property tax bill

3. Revitalizing and reinvesting in our physical and economic infrastructure

- Rewire the electrical grid by resolving the gridlock over planning, siting, and cost allocation; providing incentives for the deployment of "smart grid" components; taking measures to increase the physical and cybersecurity of the grid; and providing the conditions necessary to ensure that new grid investments help lower emissions from the electricity sector
- Shift the focus of federal transportation spending away from new roads and toward mass transit options and the repair and maintenance of existing roadways
- Develop a mix of incentives and standards to encourage investment in alternative-fuel vehicles and fuel distribution infrastructure, including electric vehicles, the use of natural gas in the heavy-duty fleet, and increasing production of high-yield, low-carbon biomass feedstocks for ethanol and biodiesel
- Strengthen public funding support for the Workforce Investment Act
- Provide tax credits or low-cost loans to help manufacturers retool to produce clean-energy technologies

A study by CAP and the University of Massachusetts found that a combination of comprehensive clean-energy and climate change legislation and the American Recovery and Reinvestment Act of 2009 would lead to $150 billion in new clean-energy investments and would create 1.7 million new net jobs in the United States.[110] Another study by the University of Illinois, Yale University, and the University of California similarly concluded that 1.9 million new jobs could be created as a result of comprehensive clean-energy and climate change legislation.[111]

The United States retains a global advantage in science and technology education and research, innovation capacity, and private financial markets. But only a truly comprehensive approach that recognizes the value of every stage of technology development including manufacturing and underlying infrastructure—both physical and economic—will help the United States create a vibrant and sustainable future characterized by lower emissions, greater energy security, and millions of new middle-class jobs.

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About the authors

Kate Gordon is the Vice President for Energy Policy at American Progress. Most recently, Kate was the co-director of the national Apollo Alliance, where she still serves as senior policy advisor. Most recently, she co-authored CAP's report on "The Clean-Energy Investment Agenda."

Julian L. Wong is a Senior Policy Analyst with the Energy Opportunity team at American Progress. Prior to joining American Progress, Julian was a Fulbright scholar in Beijing researching China's renewable energy policies, and a corporate lawyer at the international law firm of Paul, Weiss, Rifkind, Wharton & Garrison LLP in New York and Hong Kong. Julian is the founder and author of The Green Leap Forward, a leading blog on China's energy and environmental issues.

JT McLain is a contributing author for the Energy Opportunity team at American Progress. He recently graduated as a public policy and law major from Trinity College in Hartford, Connecticut with both academic and faculty honors. He also received honors for his senior thesis, "Generating a Climate for the Adoption of Solar Electricity."

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