Testimony

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Summary

Chairman Bingaman, Senator Murkowski, and other members of the Committee, thank you very much for inviting me to testify before you today on the topic of global investment trends in clean energy technologies[1], and the impact of domestic policies on that investment. I am Kelly Sims Gallagher, a professor of energy and environmental policy at The Fletcher School, at Tufts University. I direct our program on Energy, Climate, and Innovation, and concurrently serve as a Senior Research Associate at the Belfer Center in the Harvard Kennedy School. I served as a Visiting Professor at Tsinghua University's School of Public Policy and Management last summer where I conducted research on global energy commercialization, with emphasis on the role of China.

The United States is undoubtedly a leader in clean energy innovation in many dimensions. Other countries like Germany, Denmark, Iceland, Brazil, the United Kingdom, and Japan have also become leaders in clean and efficient energy technologies and industries. New contenders, most notably China, have recently emerged as well.

In order for the United States to remain competitive in clean energy, it must strengthen its energy innovation system, and ensure its firms are not operating at a competitive disadvantage in the global marketplace. As my testimony will reveal, U.S. strategies, policies, and investments for clean energy innovation are significantly different from the efforts of many of our major competitors in clean energy technologies, and I believe we could do better.

The United States needs to set clear and measurable goals, determine and articulate strategies to achieve these goals, and then implement practical energy policies that are stable, credible, aligned, and consistent to realize the deep and currently unrivaled potential of the U.S. energy innovation system. Such policies are likely to catalyze the creation of new firms,

[1] I define "clean energy technologies" to include solar, wind, nuclear, energy efficiency technologies, coal with carbon capture and storage, geothermal, and hydroelectric electricity. None of these technologies is without liability, but all can be considered cleaner than conventional fossil-fuel based alternatives.

strengthen others, generate new jobs, capture growing markets, improve energy security, and address important environmental challenges, as they have in other countries.

What do we know about how energy innovation works?

Research and development (R&D) is often used as shorthand for energy innovation. But, research and development are only one component of the energy innovation system (see Appendix A for a visual depiction of the energy innovation system). In the linear growth model of innovation, we used to think technologies were invented in the R&D stage, before they proceeded to demonstration, and eventually were "diffused" in the marketplace. This model is still a useful one to consider, but I would emphasize that the diffusion "stage" is not so simple. If and when a new technology is successfully demonstrated, it must somehow gain entry into the market, and this can be difficult because:

- New technologies are unfamiliar and seemingly risky,
- They are often initially more expensive,
- They usually do not have equivalent government support, and,
- The incumbents will try to prevent them from entering.

Clean and efficient energy technologies face an even bigger hurdle because their benefits are not fully valued by the market. In other words, even though they may offer significant advantages in terms of reduced pollution, improved public health, or greater energy security, the market will not naturally reward these advantages. We can see, then, that there is an important intermediate stage between demonstration and diffusion that is "market formation." In the market formation stage, government can help to reduce the barriers to cleaner technologies (and indeed, these can be barriers once created by governments), provide niche markets, and incentivize firms to reduce the costs of advanced technologies. Once a technology is sufficiently competitive, it can freely enjoy widespread commercial diffusion.

While the linear model is helpful conceptually, we now know that there needs to be coherence to the entire system, encouragement of feedbacks, with a balance of effort on "pushing" and "pulling" new technologies into the market. We know that there are at least two important "valleys of death", one between R&D and demonstration, and another between demonstration and commercialization.[2]

How does the United States compare?

Around the world, governments are engaged in substantial market formation activities, some more successfully than others. I will provide some examples.

Denmark has achieved its remarkable success in the development and deployment of wind technology (now 20% of electricity generation) through a mixture of many policy instruments. It established a goal for wind generation, required utilities to achieve the goal, permitted the formation of local co-ops to own and operate turbines of many sizes, provided testing stations and certification, established a feed-in tariff for wind, guaranteed loans for

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[2] Grubler A., Aguayo F., Gallagher K.S., Hekkert M., Jiang, K., Mytelka L., Neij L., Nemet G., Wilson C. 2011, "Energy Technology Innovation Systems," in, Nakicenovic et al., eds., *The Global Energy Assessment*, Cambridge University Press.

turbine exporters, and joined the EU emissions-trading regime. Denmark now has established a more far-reaching goal of 50 percent of generation. Danish wind firm, Vestas has a 13% market share of the global wind market, the largest of any single firm.[3]

Like Denmark, Germany participates in the EU emissions trading regime. It established renewables targets far into the future 18% by 2020 and 50% by 2050. It also established a feed-in tariff system for renewable energy technologies, which guaranteed a price at which renewables would be bought for a certain period of time. While this program proved to be expensive, it was also effective. Germany accounts for nearly half of solar PV capacity today. Its firms are leading renewable equipment suppliers around the world. Indeed, during one visit to a Chinese solar PV factory last summer, I noticed that most of the manufacturing equipment came from Germany and Japan, and was startled to discover dozens of German technicians in the company cafeteria at lunch, all of whom were there to install their equipment in the new assembly line. German feed-in tariffs created market demand upon which Chinese solar PV firms capitalized, based on equipment sold to them by German equipment suppliers.[4]

The UK government created a renewables obligation, similar to a renewable portfolio standard in 2002. This standard was initially set at 3 percent and is scheduled to ramp up through 2037. The current obligation is 11 percent. The UK also imposed a climate change levy in 2001, which taxes fossil fuels and nuclear energy. The British government also created the Carbon Trust in 2001. This not-for-profit organization provides services to firms and local governments including zero-interest loans, tax relief, energy management advice, certification labels, educational materials, and direct support for advanced technology development in firms.

Brazil is well known for improving its energy security and decarbonizing its transportation system by shifting to sugarcane-based ethanol beginning in 1975. This shift was achieved through the combination of many policy measures, including guaranteed purchases by Petrobras, taxing gasoline to make ethanol more attractive at the pump to consumers, mandates to achieve a certain percentage of its fuel from ethanol, and low-interest loans for farmers and agribusinesses to produce sugarcane. Brazil is the largest ethanol exporter in the world.

China recently codified its commitment to support a low-carbon, energy-efficient growth strategy in its 12th Five Year Plan. The plan sets clear goals adding 70 gigawatts of additional wind generation capacity and 40 additional gigawatts of new nuclear power by 2015, sending strong positive signals to investors in low-carbon energy. China also had a renewable portfolio standard of 10% by 2010, which has been revised to 15% by 2020. It has established feed-in tariffs for wind energy. It has supported the deployment of high-efficiency ultra-supercritical coal plants, and approved the construction of GreenGen, an integrated gasification combined cycle plant capable of capturing and storing carbon dioxide, which is now anticipated to be in operation well before the U.S. equivalent, FutureGen. The Chinese government set fuel-efficiency standards more stringent than even the most recent U.S. corporate average fuel-economy standards for its motor vehicle fleet. Extensive procurement policies are used to encourage the development of clean and efficient energy technologies, and it ensures that

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[3] REN21. 2010. *Renewables 2010 Global Status Report*, Paris: REN21 Secretariat.
[4] Ibid.

capable clean tech firms have relatively easy access to finance on favorable terms. [5] Chinese firms now hold 23% of the global market in solar PV, and 23% of the global wind market.

The policies of these countries are far from perfect, but there is much to be learned from their and our experience experimenting with different types of policies, over different time horizons, in different places. Common features include the setting of long-term goals, establishment of stable and credible policies that are aligned to achieve the goals, provision of consistent signals to the marketplace, and support of firms.

The topic for today is current investment trends in clean energy technologies, and findings from a recent paper with colleagues on global trends in government investments in energy research, development, and demonstration (RD&D) are striking.[6] This analysis includes *all* public investments in energy innovation (including, but not limited to, investments in clean energy technologies). We found that six major emerging economies are together are investing slightly more than all of the OECD countries combined (see Appendix B for a table with country-by-country breakdowns). The six countries studied were Brazil, Russia, India, Mexico, China, and South Africa (BRIMCS). These BRIMCS countries spent $13.8 billion in 2008 compared with the OECD total of $12.7 billion for a global total of approximately $26.5 billion that year. I note that these BRIMCS figures include state-owned enterprise investments in these BRIMCS countries, and are adjusted for purchasing power parity. For reference, the U.S. total was $4.1 billion in 2008. The line between public and private investments in energy innovation in these countries is hard to draw due to the dominance of state-owned energy companies. The data underlying these figures is not standardized or complete; rather, this picture of current investment levels should be considered a rough sketch. As an important aside, it would be wise to expand the International Energy Agency's data collection efforts to include these BRIMCS countries so more accurate statistics are available.

The volatility of investments in both industrialized and developing countries is striking. Within the OECD, nuclear fission and fusion RD&D have been the single largest type of investment since 1974. Japan, and more recently China, are the only two countries that have historically steadily increased their investments in real terms. By contrast, in the United States, there has been a one-in-three chance that any given program will receive a funding change (increase or decrease) greater than 27% each year between 1978 and 2009.[7] Sharp jumps and declines in energy RD&D funding are also evident in Brazil, India, and Mexico. Like energy RD&D in the United States and other OECD countries, BRIMCS country energy RD&D appears to mainly be devoted to fossil fuel and nuclear technologies. In general, the large emerging economies appear to be ramping up support for energy RD&D, with the exception of Mexico. It was not possible to complete a similar survey of market formation and other deployment activities due to the lack of systematic and long-term data, even in industrialized countries.

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[5] For more on this subject, see Hout, T. and P. Ghemawat 2010, "China vs. the World: Who's Technology Is It?," *Harvard Business Review*, December.
[6] Gallagher, K.S., Anadon, L.D., Kempener, R. and C. Wilson 2011, "Trends in investments in global energy research, development, and demonstration," *Wiley Interdisciplinary Reviews: Climate Change*, Vol. 1, *in press.*
[7] Narayanamurti, V., L. D. Anadon, and A. D. Sagar 2009, "Institutions for Energy Innovation: A Transformational Challenge." Paper, Energy Technology Innovation Policy research group, Belfer Center for Science and International Affairs, Harvard Kennedy School, September.

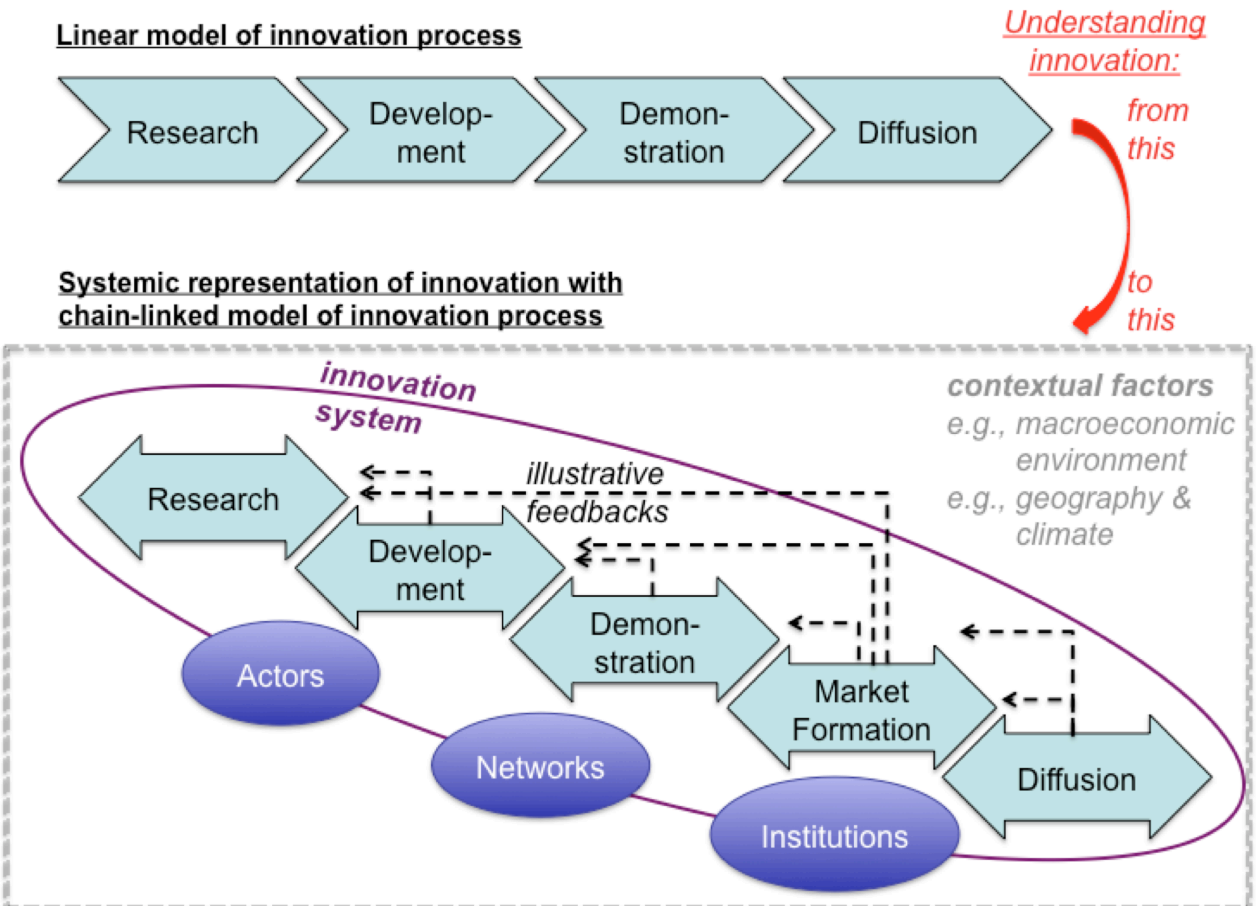
A related important question is how successful the United States currently is in penetrating global markets for clean and efficient energy technologies through trade, licensing, and foreign direct investment. I believe other witnesses will address this issue, but I want to note that the largest energy market is now China, which became the largest consumer of energy last year. The International Energy Agency's 2010 World Energy Outlook forecasts that 36% of the growth in energy demand for the next two decades will be from China. As such, China is a key export opportunity for American energy products and services. Expanding access to China's market for energy goods and services should therefore be a major concern for the U.S. government.

In terms of the market for clean energy, HSBC has projected that the global clean energy market will triple to $2.2 trillion by 2020.[8] Such figures depend greatly on whether or not governments around the world put create the incentives for clean energy technologies to be used, so again, we should be doing all we can to secure a competitive position for U.S. firms to take advantage of opportunities in these markets.

The global trends I presented here are intended to support your decision-making about U.S. government investments in clean and efficient energy technologies and industries, and the policy tools that can be employed to create incentives for more rapid and greater deployment of advanced energy technologies. Ideally, the U.S. government will adopt a portfolio approach to investing in energy technologies, taking into account the different stages of technology development, which technologies are likely to be substitutes or complements to existing technologies, and knowledge about private-sector investments to avoid duplication of effort and to better design public-private partnerships. Of course, it is also critical to take into account the investments made by other governments, not only to understand the "competition" and determine one's strategic interests, but also to identify potential areas for technology cooperation. In theory, governments might be able to better pool resources and share risks in pre-commercial collaborative activities, as well as learn from each other's endeavors. Policy support during the market formation stages can strongly affect energy markets around the world, and in turn, energy RD&D needs. The United States must therefore carefully monitor investment trends and policy developments in other countries, as they will strongly affect market conditions for U.S. firms and workers.

[8] HSBC 2010, "Sizing the climate economy", available for download from http://www.research.hsbc.com/midas/Res/RDV?ao=20&key=wU4BbdyRmz&n=276049.PDF

Appendix A: The Evolution of Thinking about the Energy Innovation Process



Source: Grubler A., Aguayo F., Gallagher K.S., Hekkert M., Jiang, K., Mytelka L., Neij L., Nemet G., Wilson C. 2011, "Energy Technology Innovation Systems," in, Nakicenovic et al., eds., *The Global Energy Assessment*, Cambridge University Press.

Appendix B: Energy RD&D Investments in Major Emerging Economies

TABLE 3 | Snapshot of Direct Government Support and Related Other Sources of Funding for Energy RD&D in the BRIMCS in Latest Year Available[41]

in Million 2008 PPP $int[1]	Fossil (incl. CCS)	Nuclear (incl. fusion)	Electricity, transmission, distribution & storage	Renewable energy sources	Energy Efficiency	Energy technologies (not specified)	*Total*
United States—Government	659	770	319	699	525	1160	*4132*
United States—Other ∼	1162	*34*	*No data*	*No data*	*No data*	1350	*2545*
Brazil—Government	79	8	122	46	46	12	*313*
Brazil–Other	1167	*No data*	*No data*	*No data*	*No data*	184	*1351*
Russia—Government	20	*No data*	22	14	25	45	*126*
Russia—Other	411	*No data*	*No data*	*No data*	*No data*	*508*	*918*
India—Government	106	965	35	57	*No data*	*No data*	*1163*
India—Other	694	*No data*	*No data*	*No data*	*No data*	*No data*	*694*
Mexico—Government	140	32	79	*No data*	*No data*	*No data*	*252*
Mexico—Other	0.11	*No data*	*No data*	*No data*	2633	194	*282*
China—Government	6755	12	*No data*	*No data*	136	4900	*11803*
China—Other	289	7	*No data*	*No data*	26	985	*1307*
South Africa—Government	*No data*	133	*No data*	*No data*	*No data*	9	*142*
South Africa—Other	164	312	26	7	*No data*	*No data*	*229*
BRIMCS—Government	7100	1149	>259	>117	>208	>4966	>*13,799*
BRIMCS—Other	2724	≫38	≫26	≫7	≫289	>1696	>*4781*
BRIMCS—Grand total	9824	>1187	>285	>124	>497	>6662	>18, 580

[1]Data from United States, Brazil, Russia, India, China, and South Africa based on 2008, Mexico on 2007. 'Other' includes (whenever available) funding from state and local governments, partially state-owned enterprises, NGOs, and industry. ∼ US data on industry expenditure is from 2004.[44] > These cumulative values are based on data from only three to four BRIMCS countries, so actual expectedditures are likely to be higher. ≫These cumulative values are based on data from two BRIMCS countries or less, so actual expenditures are expected to be much higher.

[2]•On the basis of PEMEX's fund for Scientific and Technological Research on Energy.

[3]On the basis of total nongovernmental investments into PBMR Ltd.

[4]On the basis of 2005 R&D expenditure in car manufacturing industry.[45]

[5]On the basis of 2005 R&D expenditure in utilities sector.[45]

Source: Gallagher, K.S., Anadon, L.D., Kempener, R. and C. Wilson 2011, "Trends in investments in global energy research, development, and demonstration," *Wiley Interdisciplinary Reviews: Climate Change*, Vol. 1, *in press.*