Chapter Seven
Trading the Sun

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While solar power has enormous potential, it faces serious challenges. Heliophiles never cease to remind us that "within six hours deserts receive more energy from the sun than humankind consumes within a year,"[1] and throughout human history, engineers and researchers have attempted to utilize the sun's energy by turning solar irradiation into a medium that provides heating, cooling, and lighting services. However, today direct solar energy accounts for only about 0.1% of total primary energy supply world-wide, and the international community still speaks of solar energy as the "new energy" to power the world tomorrow. Is it time to give up?

This chapter argues that the obdurate challenges are socio-political, not technological. In the past decade, solar energy returned to the front pages, particularly with growing concerns about climate change, sustainable development, as well as the most recent oil price spike in 2006. At the same time, the solar industry is on the verge of achieving its long-predicted potential. Alas, history has shown that interest in solar energy arrives in waves, often linked to energy price shocks, and that these waves crest and their momentum dissipates. The EU and U.S. should make use of the momentum as well as newest technological advances and adopt a new joint approach to solar energy research while simultaneously opening global markets to solar energy. In the midst of a prolonged, global economic slump, as public interest in climate change wanes,[2] this task will be difficult, but the economic and environmental returns warrant the investment.

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[1] Dr. Gerhard Kies, DESERTEC Foundation, quoted on DESERTEC website homepage. Accessed September 8, 2011 at http://www.desertec.org/.

[2] "Global Concern for Climate Change Dips Amid Other Environmental and Economic Concerns," Nielsen Company (New York: August 29, 2011). Available at

The environment, energy security and economy—these are the three key considerations that drive public support for renewable energy technologies. For many years, politicians and advocates of green energy included the economic benefits of solar technology as an additional factor. Introducing the 2007 bill in the United States Senate on climate change, U.S. Senators Lieberman and Warner "presented their new bill as the core of a new federal program that Congress should pass to avert catastrophic global climate change while enhancing America's energy security," and only once mentioned jobs.[3] Since 2008, worsening economic conditions globally have strengthened and juiced the economic argument. In 2010, Senator Lieberman released a new bill, stating that the "comprehensive energy and climate change legislation will create jobs, strengthen America's energy independence, safeguard our national security, and restore our global economic leadership for decades to come."[4] Europe underwent the same transformation, from its Climate and Energy package of 2008 to the 2010 State of the Union address, in which European Commission President José Manuel Barroso said the EU must continue "to deliver on climate and energy package, as a core driver for change [...] this will not only strengthen our economy tomorrow: it will provide new openings today."[5] Politicians today have changed the order of importance, and rank the economic objectives of renewable energy development first.

The international climate and domestic economy dimensions can contradict each other. On one hand, the rapid and broad deployment

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http://blog.nielsen.com/nielsenwire/consumer/global-concern-for-climate-change-dips-amid-other-environmental-and-economic-concerns/.

[3] "Lieberman and Warner Introduce Bipartisan Climate Legislation," Press Release, Office of Senator Joe Lieberman (Washington, DC: October 18, 2007). Available at http://lieberman.senate.gov/index.cfm/news-events/news/2007/10/lieberman-and-warner-introduce-bipartisan-climate-legislation.

[4] "Kerry, Lieberman: American Power Act Bill Will Secure America's Energy, Climate Future," Press Release, Office of Senator Joe Lieberman (Washington, DC: May 12, 2010). Available at http://lieberman.senate.gov/index.cfm/news-events/news/2010/5/kerry-lieberman-american-power-act-bill-will-secure-americas-energy-climate-future.

[5] José Manuel Durão Barroso (President of the European Commission), *State of the Union 2010*, European Commission (Strasbourg: September 7, 2010). Available at http://europa.eu/rapid/pressReleasesAction.do?reference=SPEECH/10/411.

of low-carbon technologies requires low barriers and liberalized trade. On the other hand, maintaining clean-energy technology manufacturing creates temptations for protection. Governments face strong political pressure to ensure that the budget expended on subsidies and support for renewable energy goes to domestic producers. If there is to be conflict across the Atlantic Ocean, it will be on the protection of these industries against international trade. The first salvo hit the transatlantic relationship in August 2011. The European Commission requested consultations with the government of Canada under the auspices of the WTO regarding the feed-in-tariff (FIT) program in Ottawa, which included local content requirements of 50% for wind projects and 60% for solar projects by 2012, arguing that this weakened the ability of European exporters to sell equipment in Ottawa.[6] These squabbles signal a perilous path into trade conflicts.

This chapter argues in favor of a coordinated approach to solar energy research and trade. Section one describes the status of the solar energy technology. Section two describes common policy approaches in the United States and Europe regarding solar power and renewable energy. Section three examines the rise of the 'green growth' and 'green jobs' objectives to the top of the agenda and section four reveals contentious points between the U.S., EU and global partners, as they balance environmental objectives and economic objectives. These sections support the argument for increased collaboration across the Atlantic for solar energy and solar power development.

Solar Energy Technological Status

In the modern era, it is too short-sighted to look back to climate change awareness resulting in the 1997 Kyoto Protocol, or President Carter's installation of solar panels on the White House roof in 1978 as the beginning of the solar energy era. Public support of solar technology moves in waves of interest and apathy.

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6 "The EU requests WTO consultations with Canada over Ontario's renewable energy policy," *European Commission*, *Trade Directorate-General* (Brussels, Belgium: August 11, 2011). Available at http://trade.ec.europa.eu/doclib/press/index.cfm?id=732 . WTO Dispute record for Dispute DS412, "Canada—Certain Measures Affecting the Renewable Energy Generation Sector, available here: http://www.wto.org/english/tratop_e/dispu_e/cases_e/ds412_e.htm.

Following World War II, the first modern age of global interest in solar energy involved a host of new international organizations. The United Nations accredited the International Solar Energy Society (ISES) in 1954 to support the advancement of solar energy, and in 1958 the UN's Department of Economic and Social Affairs published a study about solar power, *New Sources of Energy and Economic Development*. From the 1950s onwards, UNESCO organized conferences about solar power in the United States, India and France. In the mid-1950s, at a Solar Energy Laboratory in the French Pyrenees, a parabolic mirror was used to generate 30 kW of power.[7] Despite this activity, interest faded; oil cost little and nuclear grew fashionable.

The 1973 and 1978 oil shocks, as well as growing discomfort with nuclear power, changed the situation. Tam Dalyell, a Member of the European Parliament and the rapporteur of its energy budget, wrote in *New Scientist* in October 1978 that "the most serious work is being done in Europe, probably in the world, on solar energy" at the European Community's research facility in Ispra, Italy.[8] In 1977, the U.S. government established a short-lived Solar Energy Research Institute (SERI), and respected research groups such as the Worldwatch Institute predicted that, by the year 2000, solar energy would provide a quarter of energy.[9] Nevertheless, for a second time, oil prices decreased and postponed this event.

In the past decade, solar energy returned to the front pages. The UN's Department of Economic and Social Affairs states that "New and renewable sources of energy have received a great deal of attention since the World Summit on Sustainable Development was held in Johannesburg in 2002."[10] Others would argue that attention returned

[7] *UNESCO Courier*, UNESCO, XI, 9 (Paris: 1958). Daniel Berhman, "The Sun at Work around the World," *The UNESCO Courier: a window open on the world*; XI, 9 (Paris: 1958), pp. 1-17. Available http://www.unesco.org/new/en/unesco-courier/archives/.

[8] Tom Dalyell, "Westminster Scene," *New Scientist*, Vol. 80, No. 1125 (October 19, 1978), p. 211.

[9] Denis Hayes, *Worldwatch Paper #11: Energy: The Solar Prospect*, Worldwatch Institute (Washington: 1977).

[10] United Nations Department of Economic and Social Affairs, Renewable Energy website. Accessed October 21, 2011 at http://www.un.org/en/development/desa/climate-change/renewable-energy.shtml.

in earnest with concern about climate change in the mid-1990s, or the oil price spike of 2006. Solar energy technology rides a supportive wave, but the political controversy over the bankruptcy in August 2011 of a U.S. firm, Solyndra, which received a loan from the U.S. Department of Energy, hints that the momentum of the wave is dissipating.

This chapter largely focuses on efforts to generate electricity from solar power because energy analysts and national and international energy statistics bureaus anticipate the sector to play a role in meeting future electricity demand. Today, coal, gas and oil fired power plants provide 67% of electricity worldwide (nearly 70% in the United States, and 48% in the eurozone).[11] Consumers in advanced economies use more electricity, and rural and universal electrification projects increase access to people in developing regions, so the demand for new power plants and electricity generation capacity is increasing.

Unlike other types of thermal power generation, solar power applications, especially PV, can be used in many configurations. Some are small enough to provide energy to one appliance, such as a handheld calculate, or just one household. Off-grid systems operate well in remote areas to provide electricity for specified, limited services, such as medical clinics or schools. Large centralized solar PV and CSP power stations function as full scale utilities, providing many megawatts of power.

Three technological pathways exist to convert the sun's rays into energy: photovoltaic (PV) cells, which directly convert solar energy into electricity; concentrating solar power (CSP), which uses mirrors to reflects the sun's rays and heat medium, making steam to turn turbines and generate electricity; and solar fuels, in the early stages of basic research, which apply solar energy to chemicals or other compounds to produce fuel.

[11]Electricity production from oil, gas and coal sources (% of total), World Bank Data (series EG.ELC.FOSL.ZS). Available at http://data.worldbank.org/topic/energy-and-mining.

Solar Energy Technologies

Concentrating Solar Power (CSP)

Concentrating Solar Power utilizes an array of mirrors to reflect and concentrate the sun's rays at one point, rapidly creating temperatures in the thousands of degrees. A heat transfer medium, such as water, molten salt, or oil, produces steam to turn a traditional turbine and generate electricity. Scientists and researchers have developed CSP technologies for well over a century. Today, four categories account for all CSP systems: parabolic trough, liner Fresnel mirrors, central tower, and dish systems. California installed the first modern commercial CSP plant for electricity generation from 1985 to 1991. Concentrating solar power electricity generation is best suited in areas with clear skies and direct sun—the "Sun Belt" across southwestern United States, southern Europe, North Africa and the Middle East, and Australia.

Photovoltaic (PV)

Photovoltaic cells exploit the properties of semiconducting materials, such as silicon, to generate a voltage as solar irradiance crosses the semiconductor. A wide-range of photovoltaic technologies exists, with silicon cells dominating the market. The U.S. government utilized solar cells in satellites and defense applications in the 1950s. RCA Laboratories introduced the first commercially successfully photovoltaic cell, the a-Si solar cell, in 1976. Today, emerging PV technologies at the basic research phase include dye-sensitized solar cells, organic PV cells, advanced semiconductors and spectrum converters. The best PV cells achieve efficiencies around 25 percent.

Solar Fuels

The third and most immature solar energy technology is solar fuel. Using either electricity generated from PV/CSP or direct solar heat and a chemical or biological process, scientists have been able to produce fuels, such as methanol, diesel, hydrogen and mixed gases. Most research is still in the basic phase, so this paper focuses on commercial solar technologies.

Source: Many papers discuss the types of solar energy in far more detail. The best, most comprehensive source is the IPCC's Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN).[1]

[1]Arvizu, D., P. Balaya, L. Cabeza, T. Hollands, A. Jäger-Waldau, M. Kondo, C. Konseibo, V. Meleshko, W. Stein, Y. Tamaura, H. Xu, R. Zilles, Direct Solar Energy in O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. v. Stechow (eds), IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation, (Cambridge University Press, Cambridge, UK, 2011).

Policies to Promote Solar Power

A well-developed literature on innovation economics demonstrates the importance of government support for invention and innovation.[12] Governments and private investors have many options to support new technologies along the simple and effective model of the innovation process below. At the front-end, or initial stages of basic research, economists have demonstrated that markets invest below the equilibrium level for optimal social gain because of factors including risk, uncertainty, increasing returns to scale and failure to capture all gains. As a result, governments should fund laboratories and academic institutions to fill the investment gap.

Innovation Process

At the back-end of the innovation sequence—commercialization and deployment—governments play an important role in market regulation and creating or subsidizing markets. Amongst the many back-end policies that serve to promote renewable energy, two policy families have driven the deployment of solar electricity generation. Renewable portfolio standards (RPS) mandate that renewable energy sources comprise a certain share of the total energy mix. A renewable portfolio standard is technology-neutral in theory, though rarely in implementation. Some RPS policies specify that a certain share must come from solar power. The second category, feed-in tariff (FIT) policies, provide a fixed, long-term and guaranteed tariff or a subsidy per kWh to a producer of solar

[12]See Richard R. Nelson, *National Systems of Innovation* (Oxford, England: Oxford University Press, 1993); Lewis Branscomb and Phillip Auerswald, *Between Invention and Innovation, An Analysis of Funding for Early-State Technology Development* NIST GCR 02-841 (Washington: National Institute of Standards and Technology, 2002); George S. Ford, Thomas M. Koutsky and Lawrence J. Spiway, *A Valley Of Death In The Innovation Sequence: An Economic Investigation*, Discussion Paper prepared for the Commerce Department, Technology Administration (Washington, DC: Phoenix Center for Legal and Economic Public Policy Studies, 2007).

electricity. Feed-in tariffs necessarily require a qualification or certifications of facilities to receive the tariff.[13]

Europe

The European Union (EU) provides front-end support to assist researchers in solving technological challenges, as well as back-end incentives to level the playing field between solar electricity and carbon-based generation. EU member states have pursued independent energy policies for many years, working on solar and other renewable technologies, and national agencies retain strong control over research priorities and budgets. Italy, Spain and Germany accounted for 95% of member state spending, and companies in those countries also invested the most in R&D, reflecting a correlation between research activity and government support. Spain's Center for Energy, Environment and Technological Research operates a solar power prototype site at Almeria, which is the largest European center for research, development and testing of concentrating solar power. Germany, another example, directs research through its Federal Program on Energy Research and Energy Technology's New Energy area. Multiple ministries, including the Ministry for Environment and of Education and Research, provide funding to activities all along the innovation pathway, from basic research to deployment of prototypes, advancing German industry's technological leadership.[14]

While member states continue to maintain autonomy over their research priorities, the European Commission, especially since the creation of a Directorate for Innovation in 2009, aims to streamline and enhance energy research. The EU's research flagship is the Seventh Framework Programme for Research and Technological Development (FP7), which runs from 2007 to 2013 in this iteration. FP7 is funding 29 PV research projects for a total of €106 and six CSP proj-

[13]Toby D. Couture, Karlynn Cory, Claire Kreycik and Emily William. *A Policymaker's Guide to Feed-in Tariff Policy Design*, Technical Paper NREL/TP-6A2-44849 (Golden, Colorado: National Renewable Energy Laboratory, US Department of Energy, 2010).

[14]*Photovoltaic Power Systems Programme (PVPS) Trends Report 2009*, (Paris: International Energy Agency, 2009), p. 21. Available at http://www.iea-pvps.org/index.php?id=32.

ects for a total of €21 million, as of October 2011.[15] In the previous Framework Programme from 2002 to 2006, the EU dedicated €110 million to 30 solar projects, covering a range of technologies and processes. Member states and the private sector funded another €350 million of research into photovoltaics, with corporate R&D accounting for nearly 60% of the total.[16] The EU dedicated much less funding to CSP research, a total of €86 million in 2007. The EU provided about one-quarter of the funding in 2007 (€20 million), member states a little less, and corporations funded 56% of total R&D in CSP.[17]

The European Commission's Directorate-General for Energy in 2009 created the Strategic Energy Technology Plan (SET-Plan), to reduce redundant activity, combine expertise, and share costs across many member states. Under the SET-Plan, the European Commission created the *Solar Europe Industrial Initiative* in 2008, an opportunity for European companies to increase their innovation base and improve their competitiveness. The Solar Europe Industrial Initiative exists to "focus and align the efforts of the Community, member states and industry in order to achieve common goals and to create a critical mass of activities and actors, thereby strengthening industrial energy research and innovation on technologies for which working at the Community level will add most value."[18] Specifically, the SEII designed the technology roadmap and guides progress towards milestones for demonstration and deployment of both solar photovoltaic (PV)[19] and concentrating solar power (CSP).[20]

[15] "EU Energy Research Projects," Directorate General for Research & Innovation, database (Brussels: European Commission, 2011). http://ec.europa.eu/research/energy/eu/projects/index_en.cfm#results, accessed on October 20, 2011.

[16] "Photovoltaics," Strategic Energy Technologies Information System (Brussels: European Commission, 2011). http://setis.ec. europa.eu/newsroom-items-folder/capacities-map-photovoltaics, accessed on October 20, 2011.

[17] *Concentrated Solar Power*, Strategic Energy Technologies Information System (Brussels: European Commission, 2011). http://setis.ec. europa.eu/newsroom-items-folder/concentrated-solar-power, accessed on October 20, 2011.

[18] *Industrial Initiatives*, Strategic Energy Technologies Information System (Brussels: European Commission, 2011). http://setis.ec.europa.eu/activities/initiatives, accessed on October 20, 2011.

[19] *Solar Europe Industry Initiative Implementation Plan 2010-2012*, Solar Europe Initiative (Brussels: European Photovoltaic Industry Association (EPIA) and PhotoVoltaic Technology Platform, May 2010). Available at http://ec.europa.eu/energy/technol-

Up to 2020, the EU plans to invest €16 billion in solar energy research, leveraging public funds to attract private financing in public-private partnerships that share risks, and rewards, in the development of solar energy technologies.[21] Surprisingly, the EU did not fund a single solar energy project in the €3.8 billion European Economic Recovery Programme, though it is not clear if this is because solar was seen as unproductive for investment, or already sufficiently supported through other programs.[22]

On the back-end, the EU leads the world in meaningful policy action. The EU and its member states are using market-pull policies to support the development of solar energy, notably generous FIT policies, a RPS and a greenhouse gas reduction mandate. The EU adopted in 2009 a comprehensive energy and environment plan (20-20-20), which includes an effort-sharing decision for the EU collectively to reduce carbon dioxide (CO_2) 20% by 2020 compared to 1990 levels, a binding target for collective use of 20% renewable energy, also by 2020, and a strengthened and expanded emissions trading scheme (ETS) emissions to account for the climate cost. Though the EU's RPS is largely technology-neutral, the European Commission forecasts envision solar power providing up to 20 percent of the portfolio standards.

Spain, Germany, France, Italy and the Czech Republic implemented FIT policies. For example, Spain's 1997 electricity law created a feed-in tariff of 80-90% of the market price, Percentage-based FIT models did not always support solar because until recently, solar

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ogy/initiatives/doc/pv_implementation_plan_final.pdf.

[20]*Solar Thermal Electricity European Industrial Initiative (STE-EII) Implementing Plan 2010-2012*, Solar Europe Initiative (Brussels: European Solar Thermal Electricity Association, May 2010). Available at http://ec.europa.eu/energy/technology/initiatives/doc/csp_implementation_plan_final.pdf .

[21]"Joint Statement on the launch of the European Wind, Solar, Electricity Grids and Carbon Capture and Storage Industrial Initiatives" (Brussels: European Commission, Presidency of the European Union, SET-Plan Steering Group, June 3, 2010). Available at http://ec.europa.eu/research/energy/eu/policy/set-plan/joint_statement_for_the_eiis_launch.pdf .

[22]"EU Energy Projects Funded Under The European Economic Recovery Programme," European Commission. Available at http://ec.europa.eu/europe2020/pdf/energy_project_en.pdf.

energy cost 100% more than market prices, so even with a 100% feed-in tariff, the solar power producer could not reach cost recovery. Consequently, Spain revised its FIT 2006 to create a fixed price above retail, or a sliding premium.[23] Responding to rapid subscription and large costs, estimated at $26.4 billion in solar energy FIT payments for 2008 alone, the Spanish government capped the program, and the market collapsed. New legislation in 2010 removed premium options for CSP, and adds a cap to the number of hours per year that existing solar projects receive FIT payments, weakening these projects financial position. The boom and bust of Spain's solar energy industry due to the FIT policy provides important lessons for designers of FIT policies in the future.

The United States

The United States has deliberately supported science and technology at the federal level since the end of World War II, guided by Vannevar Bush's call to President Truman for the United States to maintain the vigorous "pioneer spirit" in the realm of science.[24] For solar power, the United States built a complex and comprehensive system of front-end, or technology-push, but has failed to enact market measures to develop demand for solar power.

The U.S. government provides the majority of its support for solar power through front-end policies, providing sixteen financial incentives to solar power, at least three regulatory incentives, and research funding through the Departments of Energy, Defense, Agriculture and Commerce. The DOE's Solar Program provided $247 million for solar energy technology in 2010.[25] The National Renewable Energy Laboratory, the doyenne of the Department of Energy's national laboratories, conducts and directs substantial research in solar energy. A host of other institutions conduct basic research, partner with universities and private companies, or provide loan guarantees and federal

[23]Couture, et. al., *A Policymaker's Guide to Feed-in Tariff Policy Design*, p. 20.

[24]Vannevar Bush, *Science: The Endless Frontier* (Washington, DC: Government Printing Office, 1945). Available at http://www.nsf.gov/od/lpa/nsf50/vbush1945.htm.

[25] "Solar Energy Technologies Program," U.S. Department of Energy, Energy Efficiency & Renewable Energy (EERE). http://www1. eere.energy.gov/office_eere/pdfs/51841.pdf, accessed on October 20, 2011.

investments in solar power research.[26] The most recent is the Advanced Research Projects Agency—Energy (ARPA-E), which provides funding for high-risk, high-reward projects, with the objective of filling the under-investment gap discussed above. In February 2011, the Department restructured solar research under the "SunShot Initiative" which aims to "drive widespread, large-scale adoption of this renewable energy technology and restore U.S. leadership in the global clean energy race." SunShot is analogous to the EU's Solar Industrial Initiative, focusing on the commercialization of solar energy technologies. It primarily aims to bridge the 'valley of death' in the innovation process between basic research and deployment.

The only back-end, market-based measure in the United States at the federal level to support the deployment of renewable energy and solar power is a performance-based incentive, the Renewable Energy Production Incentive (REPI), in force since 1992, which provides a maximum of 2.2¢/kWh to qualifying renewable energy producers, though it frequently pays less because of fiscal constraints. The United States enacted the first major feed-in tariff policy in the world, in the 1978 Public Utility Regulatory Policies Act (PURPA), which encouraged renewable energy in response to the oil price shock, and required utilities to purchase power from other independent power providers. Power sector deregulation and lower primary energy source prices diminished the impact of PURPA. U.S. legislators proposed bills over the past five years to enact a federal RPS or carbon market, notably the Lieberman-Warner 2007 (America's Climate Security Act) and the Lieberman-Kerry 2010 (American Power Act), yet the government has not passed any form of national legislation to mandate greenhouse gas emission decreases, require renewable energy use, or place a price on carbon.

In the absence of federal action, U.S. states, led from the West by California, have enacted back-end policies of their own to create the marginal markets for solar energy, primarily Feed-In Tariffs and Renewable Portfolio Standards. As of September 2011, California, Hawaii, Maine, Oregon, Rhode Island and Vermont, in addition to

[26] "Fact Sheet: Department of Energy Investments in Solar Energy," U.S. Department of Energy, Energy Efficiency & Renewable Energy (EERE). http://www.eere.energy.gov/pdfs/fact_sheet_doe_investments_in_solar.pdf, accessed on October 20, 2011.

municipalities in California, Florida, Indiana and Texas have enacted FIT legislation.[27] 38 states, Guam, the Northern Mariana Islands and the District of Columbia enacted mandatory renewables portfolio standards, joined by four municipalities or cities.[28] Unlike in Europe, where member state level legislation applies EU law, in the U.S state laws often lead federal law.

Industry Development

Relative to other sources of energy, solar power is practically invisible. Globally, all forms of solar energy accounted for 0.1% of total primary energy supply in 2008. Even among renewable energy sources, which provide 12.9% of the world's primary energy supply, solar power accounts for about 0.8% (biomass provides the lion's share, over 80%).[29] Solar energy remains extremely limited compared to other energy sources.

Solar power is growing as PV and CSP costs decrease and government policies support the sectors' commercialization, however, solar power is still more expensive than any other form of electricity generation; the levelized cost of electricity calculated by the IEA still exceeds the high-end cost estimates for coal, gas and nuclear, even when including a carbon price of $30/ton, a price which exceeds the average market price in Europe.

[27] "Database of State Incentives for Renewables & Efficiency, Solar (DSIRESOLAR)," N.C. Solar Center, N.C. State University and the Interstate Renewable Energy Council. http://www.dsireusa.org/incentives/ index. cfm?EE=1&RE=1&SPV=0&ST=0&searchtype=RPS&technology=all_solar&sh=1, accessed on October 21, 2011.

[28] DSIRE Solar.

[29] *Summary for Policy Makers* in: O. Edenhofer, R. Pichs_Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. von Stechow (eds), *IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation* (Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2011), p. 6. Available at http://srren.ipcc-wg3.de/report/IPCC_SRREN_SPM.

Table 1. Levelised Cost of Electricity (US$ per MWh)

Technology	Low-end	High-end	Investment costs (%)	Fuel costs (%)	O & M (%)	Carbon costs (%)
Coal	67	142	42	23	8	27
Gas	76	120	16	67	5	11
Nuclear	42	137	75	9	15	0
Wind (onshore)	70	234	87	0	13	0
Wind (offshore)	146	261	80	0	20	0
Solar (CSP)	136	243	n/a	0	n/a	0
Solar (PV)	215	600	n/a	0	n/a	0

Assumptions: 10% discount rate for all technologies. Coal prices of 20 USD/ton, gas price of USD 10.3/MMBtu in OECD Europe and USD 11.7/MMBtu in OECD Asia. Carbon price of 30 USD/ton.
Source: *Projected Costs of Generating Electricity* (2010). International Energy Agency (Organisation for Economic Co-operation and Development/International Energy Agency, 9 rue de la Fédération, 75739 Paris Cedex 15, France).

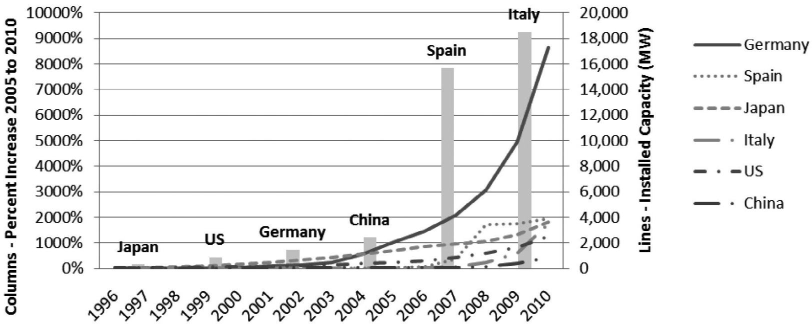
PV Industry

PV power production reached 40 GW at the end of 2010, after installers added 16.7 GW, a 73 percent increase over 2009. Four countries dominate the PV solar power sector: Germany, which alone accounts for 43% of installed global capacity; Spain, accounting for another 10%; Japan and Italy, both around 9%; and the United States at 6%. Spain, Italy, France and the Czech Republic recently joined the exclusive group of countries with more than 1 GW of installed solar capacity, all increasing their installed capacity many thousand-fold between 2005 and 2010.[30]

Germany is the leader in absolute terms of installed PV capacity, but other countries rapidly increased their capacity. However, growth rates for this sector are misleading. For example, Italy in 2010 had only 20% of Germany's total installed capacity, Italy's astronomical growth rate of 9239% from 2005 to 2010 increased capacity from only 37.5 MW to 3502 MW, whereas Germany's more sedate 742% increase over the same period added four times more cumulative installed capacity (15.3 GW compared to 3.5 GW for Italy). The chart

[30] "Renewable Energy—Solar (Installed capacity)," *BP Statistical Review of World Energy 2011*. Available at http://www.bp.com/sectionbodycopy.do?categoryId= 7500&contentId=7068481.

Figure 2. PV Solar Power—Cumulative Installed Capacity (MW) and Increase 2005–2010



Source: *BP Statistical Review of World Energy*, June 2011.

above demonstrates the sky-high growth rates and also the absolute numbers to provide perspective.

The United States increased total installed PV capacity by 426% since 2005, and Asia's growth of installed solar capacity averaged 633% from 2005, with South Korea increasing PV capacity by 4144% and China by 1213%.[31]

The PV sector is developing into a global industry, with competition for resources and markets, especially the PV sector. The largest Solar PV manufacturers by market share are First Solar (USA, 10%), Suntech Power (China, 7%), Sharp (Japan, 6%), Q-Cells (Germany, 5%).[32] Consolidation of small players and vertical integration is increasing economies of scale and weeding-out the least-efficient production systems. Governments make the market with their generous feed-in-tariffs (FITs). In 2008 and 2009, the industry responded to generous FIT policies and expanded production capacity, but demand declined after Spain revised FITs in 2010, resulting in a surplus of PV

[31]Ibid.

[32]*Renewable Energy and Energy Efficiency Export Initiative*, National Export Initiative (Washington, DC: U.S. Department of Commerce, Trade Promotion Coordinating Committee, 2010), citing 'Renewable Energy Policy Network for the 21st Century, "Renewables 2010 Global Status Report." Available at http://export.gov/reee/.

modules. Factories in the U.S. had to slow production or delay planned expansions.[33]

Over the past ten years, the center of gravity of the global PV industry shifted west and then back east as the industry moved to the countries with the strongest political programs to support domestic construction of solar PV. In 2004, Japan was the leader in cell production (830 MW), followed by Europe (470 MW), China (200 MW), and the United States (150 MW).[34] In 2007 and 2008, Germany produced more solar PV cells and modules than any other country. During this period, China, Taiwan and the Philippines entered the industry as low-cost exporters. Today China is the world's largest producer of PV solar cells, manufacturing a vast 3,800 MW of PV cells in 2009, though it has almost no domestic demand at present.[35] One analysis predicts that "the production of cell, modules, and BOS components will likely continue to shift toward countries in Asia and other low-cost production centers that possess a comparative advantage in flexible light manufacturing of tradable goods."[36]

The price of PV panels decreased over the past decade, despite volatility in the PV supply chain. PV modules consist of many parts, the PV panel, system components and mounting material. The silicon market, a key component of the PV panel, generated much of this this volatility. A pricing oligopoly, with only ten firms supplying silicon and accelerating demand from solar cell producers, increased the spot price of silicon from $30 to $400 per kilogram in 2008, before new capacity created oversupply and reduced prices $60 to $80 per kilogram.[37] The "balance-of-system" components, or all the parts in a

[33] "U.S. Solar Market Insight, 2nd Quarter 2022: Executive Summary" (Washington, DC: Solar Energies Industry Association, 2011). Available at http://www.seia.org/galleries/pdf/SMI-Q2-2011-ES.pdf.

[34]World Bank, *International Trade and Climate Change: Economic, Legal and Institutional Perspectives* (Washington, DC: World Bank Environment and Development, 2007), p. 62.

[35]*Photovoltaic Power Systems Programme (PVPS) Trends Report 2009*, (Paris: International Energy Agency, 2009), p. 25. Available at http://www.iea-pvps.org/index.php?id=32

[36]Jacob Funk Kirkegaard, Thilo Hanemann, Lutz Weischer and Matt Miller, "Toward a Sunny Future? Global Integration in the Solar PV Industry," Working Paper Series 10-6 (Washington, DC: Peterson Institute for International Economics, May 2010), p. 30.

[37]Ibid., p. 18.

solar module other than the PV panel itself, account for 20-70% of the cost. These components include inverters (DC to AC), mounting hardware, cables, batteries, controllers and also non-hardware costs such as shipping, taxes, permitting fees and labor when calculating final installed costs. Balance-of-system costs decreased by the same level as the module between 1998 and 2007, about 40%. However, as module costs continued to decrease, between 2008 and 2009 balance-of-system costs exhibited a slight increase, according to the "Tracking the Sun III" report.[38] Installation of solar PV and CSP is necessarily conducted on site, and naturally dominated by local contractors.

Between 1998 and 2009, manufacturers reduced costs for final, installed PV systems by 30%, about 3.2% annually.[39] Thus, photovoltaic systems are expensive but becoming cheaper, whereas the opposite could be said of fossil-fuel and nuclear generation sources.

Concentrating Solar Power Industry

CSP installed capacity is much smaller than PV, totaling 1 GW in 2010. Aiming to take advantage of supportive policies and new technological advances, developers are planning 15 GW of CSP.[40] CSP reflects the optimism of PV. The IEA's Energy Technology Perspectives 2008 (ETP 2008) forecasts under one scenario that CSP could produce 5% of global electricity production by 2050.[41] Policymakers in the U.S. and EU view CSP as a feasible, cost-effective technology and direct research funding and subsidies towards the sector.

The concentrating solar power (CSP) sector is emergent; 37 CSP plants, at 24 sites, operate today world-wide. Only a handful of companies construct and operate CSP plants, including Spain's Abengoa Solar and Acciona Energy, France's Areva, US firms BrightSource, Luz, eSolar and others. CSP development stalled from the late 1980s

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[38]Galen Barbose, Naïm Darghouth and Ryan Wiser, *Tracking the Sun III: The Installed Cost of Photovoltaics in the US from 1998-2009* (Berkeley, California: Lawrence Berkeley National Laboratory, Environmental Energy Technologies Division, December 2010).

[39]Ibid., p. 1.

[40]*Technology Roadmap: Concentrating Solar Power* (Paris: International Energy Agency, 2010), p. 9.

[41]Ibid., p. 19.

to 2005. The Saguaro Solar Power Plant in Arizona came online in 2005 after a fifteen year hiatus of any CSP development. Nine new CSP plants have entered operation in the United States since 2005.[42] In Europe, specific feed-in tariff policies (discussed above), resulted in the PS10 CSP plant, the first grid-connect central receiver CSP plant. In Spain, and the United States and some North African countries, governments and companies are planning more than 50 CSP plants.[43]

CSP plants are capital intensive and initial investments costs range from $4.2/W to $8.4/W depending on labor and land costs, technologies, the amount and distribution of solar irradiance and the size of the solar field.

For both PV and CSP, reducing generation costs will require further support to improve technology, cheaper manufacturing and economies of scale. These dynamics draw attention to the central role of socio-political concerns.

Trade Policy for Solar Energy Goods

The solar energy sector developed into a globally traded industry, with countries exporting and importing PV panels, CSP heliostats, generators, thermostats and solar water heaters. As described above, low-cost manufacturers in Asia produce more and more solar equipment. The U.S. and EU subsidize the sector, and consequently face increasing political and popular pressure to protect domestic solar energy production capacity, ensuring that subsidy dollars remain in the domestic economy. These measures could hinder the development of a global solar energy industry and prevent wide-spread deployment of low-carbon solar energy electricity generation.

If anything, since 2007, the U.S. and EU have followed similar strategies, which puts the two economies at odds with each other as they compete for exports. The White House stated in its March 2011 Secure Energy Future strategy that "we must focus on expanding cleaner

[42] Utility_Scale Solar Projects in the United States, Operating, Under Construction, or Under Development, website, Solar Energy Industries Association. Accessed October 21, 2011 at http://www.seia.org/galleries/pdf/Major%20Solar%20Projects.pdf.

[43] Arvizu, et. al., *Direct Solar Energy* in: *IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation*, pp. 37–38.

sources of electricity, including renewables like wind and solar, as well as clean coal, natural gas, and nuclear power—keeping America on the cutting edge of clean energy technology so that we can build a 21st century clean energy economy and win the future."[44] The European Commission's March 2, 2010 *Europe 2020 Strategy* stated that "The EU should maintain its lead in the market for green technologies as a means of ensuring resource efficiency throughout the economy, while removing bottlenecks in key network infrastructures, thereby boosting our industrial competitiveness."[45] And the EU's *Roadmap for moving to a competitive low-carbon economy in 2050* stated that "By stepping up climate action 1.5 million additional jobs could be created by 2020."[46] According to a report from Senator Ron Wyden and the Department of Commerce, the U.S. is running a trade deficit in environmental goods (defined as the World Bank 43) of $4.3 billion in 2009. In light of this report, Senator Wyden suggested that the U.S. take action to increase its exports of renewable energy goods and reduce the trade deficit. Both the U.S. and EU aim to export to a limited marketplace, and have focused efforts on reducing non-tariff barriers.

Indeed, tariffs on solar energy goods remain quite low. Though a few countries have tariffs above 10%, the most solar-energy importing markets have no import tariffs on solar power equipment.[47] For the large number of developing countries with tariffs on solar energy goods, the World Bank estimates that eliminating tariffs on environmental goods and services (EGS) in a set of developing countries would increase trade in solar power goods 6.4%. Further eliminating non-tariff barriers would result in a total increase in trade of 13.5%.[48]

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[44]*Blueprint for a Secure Energy Future*, White House (Washington, DC: The Executive Office of the President, March 30, 2011). Available at http://www.whitehouse.gov/sites/default/files/blueprint_secure_energy_future.pdf.

[45]*Europe 2020: A strategy for smart, sustainable and inclusive growth*, European Commission (Brussels, Belgium: Presidency of the European Commission, March 3, 2010), p. 15. Available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:2020:FIN:EN:PDF.

[46]*Roadmap for moving to a low-carbon economy in 2050*, website, European Commission, Directorate-General for Climate Action. http://ec.europa.eu/clima/policies/roadmap/index_en.htm, accessed on October 21, 2011.

[47]Kirkegaard, et. al, op. cit., p. 32.

[48]World Bank, *International Trade and Climate Change: Economic, Legal and Institutional Perspectives* (Washington, DC: World Bank Environment and Development, 2007).

The discussion about facilitation of trade in EGS reached prominence in 2001, when trade ministers at the World Trade Organization's Doha meeting adopted a declaration calling for inter alia "the reduction or as appropriate elimination of tariff and non-tariff barriers to environmental goods and services."[49] Six years later, a group of "Friends of Environmental Goods and Services" developed a grocery list of 153 potential items in 2007, and the World Bank refined this list to 43 environmental goods, suggesting facilitating trade of these goods as a way of easing countries' work towards implementing a low-carbon economy.[50]

The U.S. and EU have followed a cooperative approach in regards to trade in EGS. In an op-ed about the proposed EGS agreement in 2007, the EU Trade Commissioner Peter Mandelson and U.S. Trade Representative Susan Schwab advocated for rapid global adoption of a joint proposal for trade in environmental goods' inclusion in the final Doha trade talks, reducing tariffs on certain environmental goods and services to zero, using the World Bank's list.[51] Subsequently, the international community has stumbled at the level of implementing a system that reduces tariffs on environmental goods. In the turmoil of the global economic recession, progress in this area, and other areas of liberalized trade, has slowed.

In all fairness, it is not a simple lack of political will. Data problems hinder progress. The international trade system of coding goods for the purposes of applying tariffs (HS or SITC system) aggregates related goods, and as result does not differentiate between, for example, mirrors used for CSP or mirrors for other industrial use. Likewise, photovoltaic panels fit into the same category as Light-Emitting Diodes (LEDs), many which are not used as environmental goods. Data for the materials and goods used in the construction of CSP is

[49] *Doha Ministerial Declaration* WT/MIN(01)/DEC/1, World Trade Organization (Doha, Qatar: WTO, November 14, 2001).

[50] World Bank. *International Trade and Climate Change: Economic, Legal and Institutional Perspectives*. Washington, DC: World Bank Environment and Development, 2007), p. 79.

[51] Susan Schwab (U.S. Trade Representative) and Peter Mandelson (EU Trade Commissioner), "Working towards an open global market in green technology," *Wall Street Journal*, December 7, 2007.

much more difficult to aggregate, because the harmonized system of custom codes does not differentiate between the final use of the mirror or pipes that carry the steam.[52] Countries, especially developing countries that collect significant customs revenues, hesitate to reduce or eliminate tariffs on an overly-large group of goods just to attempt to increase trade in EGS. Therefore, EU and U.S. efforts have targeted non-tariff barriers.

One example of the non-tariff barriers that the EU and U.S. are confronting are domestic content requirements (DCR) or local content requirements (LCR). In August 2011, the EU filed a WTO complaint against the Canadian province of Ottawa for its DCR for solar and wind projects. In October 2011, U.S. solar companies, alleging dumping, asked the U.S. government to consider placing import tariffs of 100% Chinese solar panels. These actions both indicate commitment to maintain liberalized trade, but also the potential for conflict between the EU and U.S. as they seek to increase their international market share in the face of growing competition from Asia.

The second area of trade is the actual export of electricity that is generated from solar energy. Unlike oil or gas, which can be contained and piped, electricity is fugitive and expensive to store or transmit. In a few cases, such as the transmission of hydropower from Canadian hydroelectric dams to the United States, "renewable electricity" itself is actually the traded commodity. This area of solar energy trade is especially important for CSP, which is most effective in desert areas, far from population centers. Many industrialists envision the generation of electricity in areas with clear skies and high solar irradiance, such as North Africa, Australia or Southwestern United States, and the transmission of this electricity across long-distance high-voltage lines. For example, North African countries could directly deliver power to the European Union, Australia to Indonesia, or Arizona to California.

[52] Two papers discuss the problems with identifying environmental goods and services: Senator Ron Wyden, "US Trade in Environmental Goods. Follow-Up Report To Major Opportunities And Challenges To US Exports Of Environmental Goods," (Washington, DC: Office of Senator Ron Wyden. US Senate, May 20, 2010), p. 3; Kirkegaard, et. al, op. cit., p. 28.

DESERTEC

The DESERTEC initiative demonstrates many of the issues discussed in this chapter. DESERTEC aims to generate electricity for Africa and Europe from the installation of CSP, PV and wind facilities across the Middle East and North Africa (MENA).

The DESERTEC Foundation and Industrial Initiative is promoting the establishment of giant solar fields in the Sahara Desert that will be able to supply about 17% of Europe's electricity usage by 2050. The Industrial Initiative has attracted 17 shareholders from eight countries, including many of the major players. Many other European and international organizations are looking at the southern coast of the Mediterranean as one huge green electricity generation site. The World Bank's project on concentrated solar power in the MENA region aims to co-finance commercial-scale power plants to help MENA countries become suppliers and consumer of solar-generated electricity. The EU's Union of the Mediterranean Solar energy plan, while quieter in the publicity front, is also working to develop projects in Morocco and Tunisia.

An examination of the demographic and energy data for the MENA region should cause reason for doubt. There are technological challenges—cost-competitive generation, maintenance and transmission—and political challenges, as governments across North Africa undergo difficult transitions. The largest challenges arise from growing populations and their related increasing demands for energy, which will utilize the full capacity of any electrification projects, and the inefficient use of energy resources in North Africa.

The demand for electricity exists. In North Africa alone, the demand challenge is chilling. The youth cohort is the largest in the world, and increasing development has increased electricity demands. Oil and gas, which North Africa exports, is now being used domestically as industry develops. The European Union anticipates increasing energy imports from North Africa for a different reason: it wants to obtain 'green energy.' The EU's "20-20-20" energy package provides a legislative requirement for the use of renewables and targets for member countries to reduce their overall greenhouse gas emissions. European countries have limited capacity for domestic renewable energy generation, but the desert of North Africa provides a rich "Sun Belt" for concentrating solar power (CSP) and sustained winds for aeolian power.

Beyond the technological challenges to design and build the projects, the successful implementation of a solar energy system across North Africa is dependent on two initial steps. First, the industrial groups working in North Africa must collectively agree that the top priority is providing energy for North Africans. This is a developmental goal, and also a regional requirement. Second, on the demand side, North African countries must increase energy efficiency. While all other regions decreased their energy use per $1,000 GDP, in North Africa energy use has increased more than 100% in the past twenty years. If these initial steps are taken, solar-generated electricity can provide for North Africa's development while also benefitting the EU market.

Sources: DESERTEC Foundation. Website. http://www.desertec.org/. World Development Indicators, from International Energy Agency (IEA Statistics © OECD/IEA, http://www.iea.org/stats/index.asp) and United Nations, Energy Statistics Yearbook.

The Way Forward

The European Union and the United States followed remarkably similar paths towards the development of solar energy policy, regardless of substantial differences in the details. Both countries face the problem of competition from countries with lower labor costs and environmental standards. The U.S. and EU could use this area to reinvigorate cooperation and indicate that the transatlantic relationship today is about more than simply stopping financial market contagion; it is also about taking on constructive projects.

First, the U.S. and EU should maintain the momentum of the current wave of solar energy innovation. This requires the political assuredness to continue costly front-end financing of research and prototype development so that nascent solar energy technologies cross the 'innovation valley of death'. A joint effort, possibly as the marquee initiative of the EU-U.S. Transatlantic Energy Council, could provide both with the mutual confidence. It requires even more political assuredness to develop long-term feasible market measures. National feed-in-tariff policies provide flawed incentives for the development of solar energy, as demonstrated in Spain, but they are the best option when well-designed. Work, such as the U.S. National Renewable Laboratory's "Policymaker's Guide to Feed-in Tariff Policy Design" should be continued at the transatlantic level to enhance systems. The United States especially has lost the resolve for climate change measures, such as Renewable Portfolio Standards, or a carbon system, so a transatlantic market-based measure is unlikely.

Therefore, as a second step, to build a global market, the EU must forge ties with Asia to maintain the growth of PV and CSP deployment. These regions have the largest current installations of solar power capacity, and with China's ambitions to build a domestic market in addition to exporting solar equipment, the EU-Asia partnership will be the future solar market.

Thirdly, the U.S. and EU must renew the stalled efforts to reduce tariffs and non-tariff barriers on environmental goods and services. The U.S. and EU will continue to maintain the lead in the development and innovation of solar energy technologies. Corporations based in the U.S. and EU will lead in the design and installation of systems, profiting from upstream innovative activity, as well as down-stream local activity.

Despite the rise and fall of previous waves of solar energy innovation, this moment is unique. Solar energy technology is mature. Systems in operation today come tantalizing close to cost recovery without subsidies. Countries, politicians and societies desire renewable energy, including solar, for many mixed motives. Current efforts recall the optimism about solar power from earlier in this decade, when researchers and policymakers believed that solar power could help poor countries develop and mitigate greenhouse gas emissions. The case for solar energy is stronger than ever.