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Here Comes the Sun: Solar Power Parity with Fossil Fuels

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HERE COMES THE SUN: SOLAR POWER PARITY WITH FOSSIL FUELS

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ABSTRACT

There is wide agreement across the political spectrum that the United States should develop domestic, renewable sources of energy. There are many ways to describe the challenges of a transition from a fossil fuel economy to one fueled by atoms, the sun, or the wind, but in a nutshell, the problem is said to be cost: the basic reason the United States continues overwhelmingly to rely on fossil fuels is that they are comparatively cheap, and alternative energy is relatively expensive.

Or so it seems. This Article is intended to encourage more open discussion about real energy costs. To keep the discussion short and focused, we concentrate on solar energy. We look at solar energy through the lens of some simple and conservative assumptions about the cost of one input—water, and the cost of one externality—carbon.

Our goal is to illustrate the kind of analysis that would move public discussion and policies towards "truer" energy cost assessments. The bottom line: fundamental shifts in energy sources from fossil fuels (or at least coal and oil) to large-scale commercial solar may be closer than suggested by headlines and widely held popular and political beliefs.

INTRODUCTION

There is wide agreement across the political spectrum that the United States should develop domestic, renewable, sources of energy.[1]

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[1] *See, e.g.*, George Altman, *Wicker: Middle East Unrest Shows Need for Domestic Energy Production*, GULFLIVE (Mar. 5, 2011), http://blog.gulflive.com/mississippi-press-news/2011/03/wicker_middle_east_unrest_show.html (Republican Senator arguing for increased

This widespread understanding has recently been strengthened by the BP Deepwater Horizon oil spill in the Gulf of Mexico and by the ongoing transformation and instability throughout the Middle East.[2]

There are many ways to describe the challenges of a transition from a fossil fuel economy to one fueled by atoms, the sun, or the wind, but in a nutshell, the problem is said to be cost: the basic reason the United States continues overwhelmingly to rely on fossil fuels is that they are comparatively cheap, and alternative energy comparatively expensive.[3]

All claims about the relative costs of any source of energy, however, must be viewed skeptically. There are few goods or services that have seen as much regulation and subsidy (explicit and implicit) as energy markets.[4] Every current assertion about the relative costs of energy, therefore, is a product of past and present non-market decisions.

Consumers today see lower prices for electricity from coal, natural gas, or nuclear fission because of these subsidies.[5] Taxpayers make fossil fuel and nuclear energy appear cheaper through tax breaks on oil and gas exploration, military expenditures to protect petrochemical wells and transportation, and government-subsidized insurance.[6]

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domestic energy production); Helene Cooper, *Obama Says He'll Push for Clean Energy Bill*, N.Y. TIMES (June 2, 2010), http://www.nytimes.com/2010/06/03/us/politics/03obama.html (Democratic President pushing for the same).

[2] *See* Altman, *supra* note 1; Lisa Mascaro, *Gulf Spill Helps Revive Left-for-Dead Energy Legislation*, L.A. TIMES, (June 13, 2010), http://articles.latimes.com/2010/jun/13/nation/la-na-energy-congress-20100613.

[3] *See, e.g.*, Fiona Harvey, *Cheap Gas Will Overtake Renewables, Energy Chief Warns*, THE GUARDIAN (May 30, 2011), http://www.guardian.co.uk/environment/2011/may/30/renewables-overtaken-cheap-gas-energy; S.M. Enzler, *Fossil Fuels*, Lenntech, http://www.lenntech.com/greenhouse-effect/fossil-fuels (last visited Nov. 8, 2011).

[4] *See, e.g.*, David Kocieniewski, *As Oil Industry Fights a Tax, It Reaps Subsidies*, N.Y. TIMES (July 4, 2010), http://www.nytimes.com/2010/07/04/business/04bptax.html; Jonathan Rothwell, *How Electricity Market Regulations Affect Clean Energy Development*, THE NEW REPUBLIC (Dec. 8, 2010, 10:40 AM), http://www.tnr.com/blog/the-avenue/79732/how-electricity-market-regulations-affect-clean-energy-development; *What We Do*, OFFICE OF ENERGY MARKET REGULATION, FED. ENERGY REGULATORY COMM'N, http://www.ferc.gov/about/offices/oemr.asp (last visited Nov. 8, 2011).

[5] *See, e.g.*, Kocieniewski, *supra* note 4; Matthew Wald, *U.S. Supports New Nuclear Reactors in Georgia*, N.Y. TIMES (Feb. 16, 2010), http://www.nytimes.com/2010/02/17/business/energy-environment/17nukes.html; *Energy Subsidies and External Costs*, WORLD NUCLEAR ASS'N, http://www.world-nuclear.org/info/inf68.html (last visited Nov. 8, 2011).

[6] *See, e.g.*, ANITA DANCS, NAT'L PRIORITIES PROJECT, THE MILITARY COST OF SECURING ENERGY 4 (2008), *available at* http://rethinkamerica.net/wp-content/uploads/2010/02/nppenergycost.pdf; Mark A. Delucchi & James J. Murphey, *U.S. Military Expenditures to Protect the Use of Persian Gulf Oil for Motor Vehicles*, 36 ENERGY POL'Y 2253, 2256 (2008); Kocieniewski, *supra* note 4; Stephen Mufson, *Talk of Raising Gas Tax is Just That—Analysts Cite Advantages but Concede Its Political Improbability*, WASH. POST, Oct. 18, 2006,

The history of highly subsidized and regulated energy markets invites analysis of costs and benefits that are not currently captured by apparent energy prices. One goal of this Article is to encourage more open public discussion about real energy costs. This Article is part of a longstanding effort to focus the attention of policymakers and the public on truer costs and benefits of alternative energy. To keep the discussion short and focused, we concentrate on solar energy.

Current energy prices do not include the full cost of harm to the environment from either workaday energy operations or the extraordinary harms from spills, wars, and other disasters.[7] Nor do current energy prices capture the burden to current and future generations of national security expenditures tied to non-U.S. energy sources, and the costs of climate change.[8]

While attention has been drawn by the BP Deepwater Horizon oil spill, the Fukushima Daiichi nuclear crisis, and geopolitical instability to the costs of rare but extraordinary events (and the policies that limit or spread liability for such events), we focus here on more pervasive and cumulative costs. We look at solar energy through the lens of some simple and conservative assumptions about the cost of one input—water—that is increasingly subject to market pricing. We take note of the cost of one externality—carbon—even in the absence of short-term political or market mechanisms to internalize that cost. Extreme weather events may induce markets, including risk-spreading institutions such as insurance companies and banks, to take account of carbon long before national and global political institutions do so.[9] And the relevant time frame for the construction and operation of energy facilities makes a discussion of carbon pricing realistic.[10]

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at D1 (citing Senator Richard Lugar's estimate that "the U.S. military cost of protecting Middle East oil supplies runs around $50 billion a year."); *Fact Sheet on Nuclear Insurance and Disaster Relief Funds*, NUCLEAR REGULATORY COMM'N, http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/funds-fs.html (last visited Nov. 8, 2011).

[7] *The Hidden Costs of Fossil Fuels*, UNION OF CONCERNED SCIENTISTS, http://www.ucsusa.org/clean_energy/technology_and_impacts/impacts/the-hidden-cost-of-fossil.html (last visited Nov. 8, 2011).

[8] *Id.*

[9] *See, e.g.*, EVAN MILLS, A GLOBAL REVIEW OF INSURANCE INDUSTRY RESPONSES TO CLIMATE CHANGE 1 (2009), *available at* http://evanmills.lbl.gov/pubs/pdf/gpp200914a.pdf (discussing insurance industry response to climate change).

[10] *See* DAVID BERRY, INVESTMENT RISK OF NEW COAL-FIRED POWER PLANTS 3, 5, 9, 13 (2008), *available at* http://iowa.sierraclub.org/Energy/western-resource-advocates-coal-investment-risk-report.pdf (discussing the long life of coal plants, the costs associated with building and operating coal plants, and the prospect of future carbon emissions regulations).

Our goal is to illustrate the kind of analysis that would move public discussion and policies towards truer energy cost assessments. But even within alternative energy sources there is a lack of recognition of the sum of the actual costs. Popular discussion, at least, often suggests that "solar energy" is a single technology, with a single cost across different settings. To drive home the goal of better cost accounting across energy sources, this Article focuses on the current water needs of solar electric generation. It then looks at the price challenges facing current technologies and reviews low-water-use alternatives. Finally it presents a rough economic analysis suggesting that some forms of low-water-use solar energy are among the lowest real-cost sources of energy available if even part of the actual cost of water is taken into account. Any regulatory or market changes to reflect the externalities produced from industrial carbon dioxide ("CO_2") emissions would only make the cost comparison more favorable to solar energy (and to other low carbon sources).[11]

The bottom line: the direct energy and energy policy impacts of the BP oil spill, the Fukushima crisis, the instability in the Middle East, and increasing attention to extreme weather events and their impacts should serve as a reminder that energy costs are fluid and reflective of a host of policy choices. From this perspective the economic catalyst to fundamental shifts in energy sources and uses may be closer than suggested by headlines and widely held popular and political beliefs.

I. H_2O AND CO_2: CAPTURING THE COST OF INPUTS AND EXTERNALITIES

Every president since Richard Nixon has pledged to reduce our country's dependence on foreign oil, primarily because our consumption of fossil fuels funds countries and people who, to put it mildly, do not have the best interests of the United States at heart.[12] A climate change skeptic could rationally support alternative energy simply on the basis of national and economic security. Prices should in some way account for the cost of

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[11] *See* JONATHAN KOOMEY & FLORENTIN KRAUSE, INTRODUCTION TO ENVIRONMENTAL EXTERNALITY COSTS 1 (1997), *available at* http://siteresources.worldbank.org/EXTRENENERGYTK/Resources/5138246-1237906527727/Introduction_to_Environmental_Externality_Costs.pdf (noting that pollution is an externality that is not reflected in market transactions).

[12] *See* Gus Lubin, *Obama Joins The Long Line of Presidents Who Promised to Reduce Foreign Oil Dependence and Failed*, BUS. INSIDER (Mar. 30, 2011, 11:35 AM), http://www.businessinsider.com/american-foreign-oil-dependence-2011-3?op=1; *see also* Gregory White, *The 12 Oil Leaders Who Have the US On Its Knees*, BUS. INSIDER (Apr. 7, 2010, 10:45 AM), http://www.businessinsider.com/oil-price-america-2010-4?op=1.

the transfer of wealth to the Middle East, and for the expense of securing the sources and channels of petroleum from there, which, excluding the expenses for the Iraq war, amounts to at least $50 billion, and as much as $103 billion a year.[13]

Indeed, there is a long list of inputs and externalities that are not fully or fairly included in either apparent energy pricing (the prices consumers and businesses pay) or even in many of the economic and policy assessments of current and future energy pricing.[14] But for the purpose of clarity, in this section we focus on only one major input—water—and one high profile externality—carbon.

A. Water

In 2005, approximately forty-nine percent of the 410 billion gallons of water withdrawn each day in the United States was for thermoelectric power generation.[15] About seventy percent of that was fresh water.[16] Approximately forty percent of that water was consumed, and the rest was returned to rivers, lakes, and oceans.[17]

Though energy plants that pass water through for cooling and return it to large bodies consume much less water, the water that they return is at a higher temperature.[18] Environmental concerns about heat altering the marine environment, and harm to aquatic life sucked into the plant, have been given teeth through the Clean Water Act and the Endangered Species Act.[19] Thus plants that rely on such water cycles are becoming increasingly costly and difficult to construct.[20]

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[13] *See* Mufson, *supra* note 6.

[14] *See generally* KOOMEY & KRAUSE, *supra* note 11, at 1–4.

[15] J.F. KENNY ET AL., U.S. GEOLOGICAL SURVEY, U.S. DEP'T OF THE INTERIOR, ESTIMATED USE OF WATER IN THE UNITED STATES IN 2005 4, 5, 44, *available at* http://pubs.usgs.gov/circ/1344/.

[16] *Id.* at 7.

[17] *Id.* at 38.

[18] *See* Allen Bellas et al., *Technological Advance in Cooling Systems at U.S. Power Plants* 1 (Stirling Economics Discussion Paper No. 2011-05, March 2011), *available at* http://www.management.stir.ac.uk/research/economics/?a=24688; David W. Dunlap, *Using the Hudson to Cool the Trade Center*, CITY ROOM BLOG, N.Y. TIMES (Apr. 6, 2009, 12:27 PM), http://cityroom.blogs.nytimes.com/2009/04/06/using-the-hudson-to-cool-the-trade-center (showing that returned water was heated and subjected to state regulation).

[19] *See* Bellas, *supra* note 18, at 1; UNION OF CONCERNED SCIENTISTS, THE ENERGY-WATER COLLISION, POWER AND WATER AT RISK 1 (2011), *available at* http://www.ucsusa.org/assets/documents/clean_energy/ew3/power-and-water-at-risk-with-endnotes.pdf.

[20] *See* Robert H. Abrams & Noah D. Hall, Framing Water Policy in a Carbon Affected and Carbon Constrained Environment, 50 NAT. RESOURCES J. 3, 16, 31–32. Even smaller-scale versions of the shoreline cooling mechanisms have been scaled back. The HVAC system

Water is a limited and precious resource, notwithstanding policies that often fail to recognize this fact.[21] The combination of water shortages and a high proposed volume of water consumption caused several power plant projects to fail to receive permits in Idaho, Arizona, and Montana in recent years.[22] Permit rejections on similar grounds are likely to increase given increasingly short supplies of water, particularly in high-growth regions such as the desert southwest.[23]

Even though water prices in most locations reflect only delivery cost (or only some fraction of delivery cost), the price and availability of adequate water is nonetheless one of the most critical cost and resource components for most large-scale electric generation facilities.[24] As a result, conventional power plants using water cooling systems (or solar plants with similar water requirements) cannot meet new electricity needs unless sites with abundant water can be found.[25] This point holds true even where water is available at well below market prices.

Those who need no convincing about the need to shift to lower or no-carbon sources of energy often neglect to put all of the costs of the cleaner alternatives on the table. Specifically, champions of various alternative energy sources fail to recognize the huge amount of water required for many types of electric power generation. The intimate connection between water and energy is often referred to as the water-energy nexus.[26] As a prominent proponent of alternative energy, Al Gore seemed to simply ignore this fact in a 2008 op-ed, printed just days after Barack Obama was elected President.[27]

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at the new World Trade Center will use Hudson river water to cool the facility, but not nearly to the extent in the past, because of concerns about harm to fish in the river. *See* Dunlap, *supra* note 18.

[21] *See generally* ROBERT J. GLENNON, UNQUENCHABLE: AMERICA'S WATER CRISIS AND WHAT TO DO ABOUT IT (2009).

[22] *See id.* at 61.

[23] *See id.* (noting the potential for increased energy demand and growth in the Southwest, where water supplies are limited, while water shortages are beginning to affect nuclear power plants).

[24] U.S. GOV'T ACCOUNTABILITY OFFICE, ENERGY-WATER NEXUS: IMPROVEMENTS TO FEDERAL WATER USE DATA WOULD INCREASE UNDERSTANDING OF TRENDS IN POWER PLANT WATER USE 5–6 (2009), *available at* http://www.gao.gov/new.items/d1023.pdf.

[25] *See, e.g.*, *Cooling Power Plants*, WORLD NUCLEAR ASS'N, http://www.world-nuclear.org/info/cooling_power_plants_inf121.html (last visited Nov. 8, 2011).

[26] *See* SARAH GAGNON-TURCOTTE & VICTORIA PEBBLES, THE ENERGY-WATER NEXUS: IMPLICATIONS FOR THE GREAT LAKES 1 (2009), *available at* http://www.glc.org/energy/pdf/GLCIssue-01-EnergyWaterNexus-Final-20100204.pdf.

[27] Al Gore, Editorial, *The Climate for Change*, N.Y. TIMES, Nov. 9, 2008, at WK10.

B. Carbon

For most of the last century, the main concern of environmentalists regarding energy generation has been air pollution. Since the Industrial Revolution, manufacturing and power plants have spewed a variety of toxins into the air that are harmful to humans, plants, and animals and cause acid rain, smog, and a host of other problems.[28] Over the last century this pollution has been reduced largely by restricting the amounts of toxins that polluters could emit and requiring them to place filters and scrubbers on their smokestacks.[29] Until the 1990s, environmentalists made only occasional mention in mainstream publications of the emission of CO_2,[30] a gas that is harmless when inhaled by humans.[31]

In the past two decades, scientific consensus on the reality of human-caused climate change has broadened.[32] With the huge and growing scientific focus, and clarity on threats to the human and natural environment from climate change, the attention of environmental groups, politicians, and the public has turned to the production of "greenhouse gases," and in particular to CO_2.[33]

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[28] *See* Robin Kundis Craig, *The Public Health Aspects of Environmental Enforcement*, 4 PITT. J. ENVTL. PUB. HEALTH L. 1, 1, 5, 11 (2010); *Air*, EUR. COMM'N, http://ec.europa.eu/environment/air/index_en.htm (last visited Nov. 8, 2011); *Air Pollution Effects*, ENVTL. PROT. AGENCY, http://www.epa.gov/ebtpages/airairpollutioneffects.html (last visited Nov. 8, 2011); *Ecosystems Impact of Air Pollution*, ENVTL. PROT. AGENCY AIR RES. BD., http://www.arb.ca.gov/research/ecosys/ecosys.htm (last visited Nov. 8, 2011).

[29] *Cf. Reducing Acid Rain*, ENVTL. PROT. AGENCY, http://www.epa.gov/acidrain/reducing/index.html (last visited Nov. 8, 2011) (noting the use of emissions caps and scrubbers to reduce sulfur dioxide pollution).

[30] The first Intergovernmental Panel on Climate Change ("IPCC") assessment was published in 1990. *See* SPENCER WEART, THE DISCOVERY OF GLOBAL WARMING 162 (2003).

[31] *Health Effects of Carbon Dioxide Gas*, CAN. CENTRE FOR OCCUPATIONAL HEALTH & SAFETY, http://www.ccohs.ca/oshanswers/chemicals/chem_profiles/carbon_dioxide/health_cd.html (last visited Nov. 8, 2011).

[32] *See* THOMAS R. KARL ET AL., GLOBAL CLIMATE CHANGE IMPACTS IN THE UNITED STATES 9, 12 (2009), *available at* http://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf; S.D. SOLOMON ET AL., CONTRIBUTION OF WORKING GROUP I TO THE FOURTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE 100, 103 (2007).

[33] Whatever its other virtues or vices, the United States Supreme Court decision in *Massachusetts v. Envtl. Prot. Agency*, and subsequent Environmental Protection Agency ("EPA") action, confirmed that the official stance of the U.S. government is that CO_2 is a pollutant. Massachusetts v. Envtl. Prot. Agency, 549 U.S. 497 (2007) (holding that greenhouse gases fall within EPA's regulatory authority under the Clean Air Act; EPA must make a determination as to whether such gases require regulation under the Act). Following the case, in 2009 the EPA declared CO_2 a pollutant under the Clean Air Act. John M.

CO_2 has proven a much more difficult pollutant to deal with than the particulates and toxins that are the traditional focus of clear air laws.[34] Even the "cleanest" coal plant emits approximately two pounds of CO_2 per kilowatt hour ("kWh").[35] Increasing energy demand in the United States, and exponentially increasing demand in China, India, and other parts of the developing world, means that more and more CO_2 is being emitted due to power generation each day.[36]

Approximately forty percent of human-caused CO_2 emissions are from electricity generation.[37] But power generation is not the only source of CO_2: almost as much comes from transportation, and most of the rest comes from industry and climate control of homes and offices.[38]

Climate change is happening, as even most critics of more aggressive climate policy admit.[39] And the risks from both the likely and predictable, as well as less likely and less predictable, consequences of climate change suggest the wisdom of developing and employing sources of energy that emit little or no greenhouse gas.[40]

Broder, *E.P.A. Clears Way for Greenhouse Gas Rules*, N.Y. TIMES (Apr. 17, 2009), http://www.nytimes.com/2009/04/18/science/earth/18endanger.html.

[34] *See* ENVTL. PROT. AGENCY, EXECUTIVE SUMMARY OF INVENTORY OF U.S. GREENHOUSE GAS EMISSIONS AND SINKS: 1990–2009 7–8 (2011), *available at* http://epa.gov/climatechange/emissions/downloads11/US-GHG-Inventory-2011-Executive-Summary.pdf (noting the variety of sources and pressures leading to increased carbon dioxide emissions and the historical trend of increased emissions). Many fossil-based energy sources also emit greenhouse gases other than CO_2, such as methane, that have a dramatically more powerful greenhouse effect when combusted. *Methane*, ENVTL. PROT. AGENCY, http://www.epa.gov/methane/ (last visited Nov. 8, 2011). For purposes of this Article, we refer to CO_2, or greenhouse gases, interchangeably, since fossil-based sources emit multiple greenhouse gases, and the solar ones we discuss emit none.

[35] U.S. DEP'T OF ENERGY, CARBON DIOXIDE EMISSIONS FROM THE GENERATION OF ELECTRIC POWER IN THE UNITED STATES 3 (2000), *available at* http://www.eia.doe.gov/cneaf/electricity/page/co2_report/co2emiss.pdf; *see also* NAT'L MINING ASS'N, CLEAN COAL TECHNOLOGY 1 (2011), *available at* http://www.nma.org/pdf/fact_sheets/cct.pdf (noting that even clean coal technology could only produce a ten to fifteen percent reduction on current emissions).

[36] Grant Smith & Christian Schmollinger, *China Passes U.S. as World's Biggest Energy Consumer, IEA Says*, BLOOMBERG NEWS (July 20, 2010), http://www.bloomberg.com/news/2010-07-19/china-passes-u-s-as-biggest-energy-consumer-as-oil-imports-jump-iea-says.html.

[37] *Human-Related Sources and Sinks of Carbon Dioxide*, ENVTL. PROT. AGENCY (Apr. 15, 2011), http://www.epa.gov/climatechange/emissions/co2_human.html.

[38] *See id.*

[39] Maggie Astor, *Tea Party is Alone in Denying Climate Change, Poll Finds*, INT'L BUS. TIMES (Sept. 9, 2011), http://www.ibtimes.com/articles/211559/20110909/climate-change-global-warming-tea-party-republicans-democrats-campaign-2012.htm.

[40] *The Current and Future Consequences of Climate Change*, NAT'L AERONAUTICS AND SPACE ADMIN., http://climate.nasa.gov/effects/ (last visited Nov. 8, 2011).

As recently as 2008, domestic and international policies seemed inclined towards regulatory regimes that would have increased the price of CO_2 emissions.[41] Since 2008, it has become much less likely that carbon pricing legislation will become law in the United States in the near term, or that new active carbon markets will emerge in other major world economies.[42]

The time frame for assessing the full cost of a power plant, including potential costs for CO_2 emissions, is not the next few years, but the useful life of a newly constructed power plant, which is at least twenty, and often over sixty years.[43] So, for purposes of this Article we work from a very modest assumption: some climate policies at state, national, and international levels, and pressure from various market actors (businesses, consumers, insurers, and banks), are likely to raise the cost of CO_2 emissions by some amount over much of the life of newly constructed power plants. Even a modest increase could be transformative.

To the extent that industrial policy and consumer demand moves cars in the direction of part- or full-time electric vehicles, and the recently released models from Chevrolet and Nissan have shown that electric cars are no longer just a concept,[44] such a change will require substantial amounts of electricity.[45] The implications for climate change should be positive, but that will depend in part on the energy sources that power these new cars.

The real cost and scarcity of water, the need (if not the short-term likelihood) for CO_2 regulation, the environmental risks from ongoing energy production and extreme events, and the implicit costs of protecting oil suppliers and supply routes around the world, all support the conclusion that there is a serious need for domestic, non-greenhouse gas-producing sources of electricity.

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[41] *Putting a Price on Carbon: An Emissions Cap or Tax?*, YALE ENV'T 360 (May 7, 2009), http://e360.yale.edu/content/feature.msp?id=2148.

[42] *See, e.g.*, American Clean Energy and Security Act of 2009, H.R. 2454, 111th Cong. § 727 (2009). This bill focused on a cap and trade program but never became law. *See H.R. 2454: American Clean Energy and Security Act of 2009*, GOVTRACK, http://www.govtrack.us/congress/bill.xpd?bill=h111-2454 (last visited Nov. 8, 2011).

[43] *See, e.g.*, BERRY, *supra* note 10, at 3, 5, 9, 13.

[44] Jerry Edgerton, *Electric Cars: Chevy Volt and Nissan Leaf Get Top Safety Ratings*, CBS NEWS (Apr. 26, 2011), http://moneywatch.bnet.com/spending/blog/cars-money/electric-cars-chevy-volt-and-nissan-leaf-get-top-safety-ratings/2841/.

[45] *See Will Electric Cars Increase Reliance on Coal?*, BUS. ETHICS (Mar. 13, 2010), http://business-ethics.com/2010/03/13/1438-will-electric-cars-increase-reliance-on-coal/.

Many alternatives exist. These include wind, biofuels, nuclear, and solar energy sources.[46] But each of these sources has its drawbacks. Wind energy requires large amounts of space that is often in picturesque locations or on coastlines where people oppose it.[47] It can be far from the current locations of energy use, raising transmission challenges, and it is intermittent and difficult to store.[48] Wind energy can threaten avian populations, raising concerns with wildlife advocates and facing potential legal barriers under the Endangered Species Act.[49]

Biofuels in the form of ethanol have strong political support, but scientific analysis overwhelmingly indicates that corn ethanol, the primary biofuel source in the United States, is not an efficient source of energy and may not even produce more energy than is required to make it.[50] Other consequences of corn ethanol production, such as increased food prices and deforestation, make it even less attractive.[51] Other biofuels, such as biodiesel from algae or grass ethanol, show more promise from an energy efficiency standpoint, but are not yet industrially viable.[52]

Nuclear power is plentiful and proven, but current technologies require large amounts of water and produce radioactive waste for which no safe storage system is available.[53] Furthermore, as recently demonstrated

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[46] In the case of biofuels, certain alternatives are greenhouse gas neutral because though they emit CO_2 when combusted, they act as a carbon sink when grown (like algae), and the only net gain in atmospheric CO_2 is from any fossil-fuel source energy expended in their production. Alan Zarembo, *Biofuels May Raise Carbon Emissions*, L.A. TIMES (Feb. 8, 2008), http://articles.latimes.com/2008/feb/08/science/sci-biofuel8.

[47] *See, e.g.*, ETHAN GOFFMAN, CAPTURING THE WIND: POWER FOR THE 21ST CENTURY 9, 10 (2008).

[48] *Id.* at 2, 9, 10.

[49] *Id.* at 8; News Release, U.S. Fish & Wildlife Service, Draft Habitat Conservation Plan for Kawailoa Wind Power Facility Available for Public Comment (Aug. 24, 2011), *available at* http://www.fws.gov/pacific/news/news.cfm?id=2144374861.

[50] Zachary Wallen, *Far From A Can of Corn: A Case for Reforming Federal Ethanol Policy*, 52 ARIZ. L. REV. 129, 154–55 (2010).

[51] *See* John Roach, *Ethanol Not So Green After All?*, NAT'L GEOGRAPHIC NEWS, (Jul. 11, 2006), http://news.nationalgeographic.com/news/2006/07/060711-ethanol-gas.html; Gina Lappe, *Corn Ethanol is Inefficient and Drives Food Prices Higher*, PENINSULA PRESS (Apr. 26, 2011), http://peninsulapress.com/2011/04/26/corn-ethanol-is-inefficient-and-drives-food-prices-higher/.

[52] *See* Will Thurmond, *Biofuels' Bright Future*, FORBES CUSTOM, http://www.forbescustom.com/EnvironmentPgs/BiofuelsP1.html (last visited Nov. 8, 2011).

[53] *See* Justin Gundlach, Note, *What's the Cost of a New Nuclear Power Plant? The Answer's Gonna Cost You: A Risk-Based Approach to Estimating the Cost of New Nuclear Plant*, 18 N.Y.U. ENVTL. L.J. 600, 601–02 (2010); DEP'T OF PARLIAMENTARY SERVICES, WATER REQUIREMENTS OF NUCLEAR POWER STATIONS (Dec. 4, 2006), *available at* http://www.aph.gov.au/library/pubs/rn/2006-07/07rn12.pdf.

by the meltdown precipitated by a tsunami at the Fukushima Daiichi nuclear power plant, which may make parts of that region impassable for decades, the consequences of a malfunction at a nuclear facility can be disastrous.[54] Nuclear plants are also very capital-intensive and place energy production in a smaller number of high-production facilities at a time when security needs and transmission infrastructure suggest the value of more distributed energy sources.[55] The cumulative impact of the financial and regulatory hurdles to the construction of a new nuclear generation facility means that, at least in the current economic environment, nuclear energy is not financially competitive.[56]

While there may be multiple paths to wiser energy production, solar energy again and again seems to come to the fore. Solar energy is virtually limitless and the operation of solar plants produces no or little carbon emissions.[57] By one widely quoted estimate, a photovoltaic installation of only 100 square miles in the Nevada desert could meet all the electric power needs of the entire United States.[58]

However, the resources needed to move to increased use of solar energy in the Southwest are often understated, since many of the current solar technologies require substantial amounts of water.[59] Fortunately, there are existing solar technologies that can operate with very little water.[60]

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[54] *See* Martin Fackler, *Large Zone Near Japanese Reactors to Be Off Limits*, N.Y. TIMES, Aug. 22, 2011, at A6. This is only the most recent example of an uncommon, but by no means unheard of, event, such as those at Three Mile Island or Chernobyl.
[55] *See* Rebecca Johnson, *After Fukushima*, OPEN DEMOCRACY (Mar. 24, 2011), http://www.opendemocracy.net/5050/rebecca-johnson/after-fukushima; *Policies that Support New Nuclear Power Plant*, DEVELOPMENT NUCLEAR ENERGY INSTITUTE (Oct. 2009), http://www.nei.org/resourcesandstats/documentlibrary/newplants/factsheet/policiessupportnewplantdevelopment/.
[56] LARRY PARKER & MARK HOLT, CONG. RESEARCH SERV., RL33442, NUCLEAR POWER: OUTLOOK FOR NEW U.S. REACTORS 14 (2007).
[57] Of course there would likely be carbon emissions associated with the construction, and perhaps maintenance of a solar plant—here we refer to the emissions associated with generating electricity. *See* Ken Zweibel et al., *A Solar Grand Plan*, SCIENTIFIC AMERICAN (Dec. 16, 2007), http://www.cce-mt.org/Links/past%20articles/files/A_Solar_Grand_Plan.pdf.
[58] SOLAR ENERGIES TECHNOLOGY PROGRAM, U.S. DEP'T OF ENERGY, MYTHS ABOUT SOLAR ELECTRICITY (2008), *available at* http://www1.eere.energy.gov/solar/pdfs/32529.pdf. It is important to remember that this catchy statistic was calculated using 2008 technology that has been substantially improved upon.
[59] *Solar Energy*, NATURE, http://www.nature.com/scitable/spotlight/solar-energy-8731061 (last visited Nov. 8, 2011).
[60] *See, e.g.*, David Rotman, *Praying for an Energy Miracle*, TECH. REVIEW (Mar./Apr. 2011), *available at* http://www.technologyreview.com/energy/32383/ (detailing solar plants that use molten salt in place of water).

Market-based shifts that include some of the true cost of water—not just the cost of its delivery—and some conservative estimates of the externalities generated by CO_2 in energy prices would make some low-carbon energy sources as cheap, *if not cheaper*, than fossil fuel or nuclear power.[61]

The remainder of this Article hones in on this point. Our goal is to help nudge even general energy policy debates into a more economic framework, while at the same time reminding those who assume that all markets speak the truth that any discussion of energy economics and markets must take account of the distorting effect of government interventions in energy markets and production. Government subsidies, and other policies in the energy arena that distort or obscure real prices, make any discussion about costs necessarily rough. But even rough calculations of only a handful of inputs and externalities can, we believe, shift the debate over alternative energy sources.

What this Article adds to the debate is a reminder about how much of energy "markets" are constructed, and therefore how much energy policy has been (and will likely continue to be) a major subject of government policy. We also hope to show how close we may be to fully economic solar power generation when even conservative estimates of the true costs of water and even marginal calculations for carbon are taken into account.

II. GET MORE REAL: ILLUMINATING THE ROUGH ECONOMICS OF SOLAR POWER

In this section we confront current published cost estimates of solar against conventional sources and try to take account of only a few of the critical real costs associated with each. Making even conservative assumptions, our rough economic analysis suggests that solar energy may, in some common settings, be one of the lowest real-cost sources of energy available today.[62]

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[61] *See id.* (noting that while renewables like solar may be approaching price parity with fossil fuels, more needs to be done to make the costs equivalent).

[62] Largely ignored in this work is the issue of where to get energy from at night, when the sun isn't shining. This is a real concern in the future of solar power, although storage technologies have been developed for other energy sources that are intermittent. With regard to solar power, at present there is substantial demand for solar energy in daylight hours when energy demand is at its peak. *See, e.g.*, David Biello, *How to Use Solar Energy at Night*, SCI. AM. (Feb. 18, 2009), http://www.scientificamerican.com/article.cfm?id=how-to-use-solar-energy-at-night.

A. *Fossil/Solar Cost Differential*

The primary and widely acknowledged advantage of fossil fuel and nuclear electric generation over solar power is price.[63] At present, according to the U.S. Department of Energy ("DOE"), solar electric power costs between twelve and fourteen cents per kWh.[64] By contrast, coal power, currently the cheapest and most common source of power, costs about two to three cents per kWh, and natural gas about five to six cents per kWh.[65] The DOE believes that available technological innovations and scaling could reasonably bring the cost of solar power to five to seven cents per kWh, but that still represents a substantial premium over current coal-generated electricity prices.[66]

Natural gas, though, is also much cleaner and less carbon-intensive than coal and is becoming a more common choice for new electricity generation facilities.[67] Recent advances in natural gas extraction technology, primarily hydraulic fracturing or "fracking," have increased the supply of natural gas available in the United States.[68] Natural gas prices have fallen since 2008, however they are still up sharply since 1995.[69] Fracking is fiercely opposed by some environmentalists, and the EPA recently found that major extractors were in violation of the Safe Drinking Water Act as a result of injecting diesel fuel into the ground that can then find its way to drinking water.[70]

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[63] Since all of these forms generally face the same cost issues with respect to water as coolant, the price of water does not affect the competitiveness of one versus the other. *See* Ralph E.H. Sims et al., *Carbon Emission and Mitigation Cost Comparisons Between Fossil Fuel, Nuclear and Renewable Energy Resources for Electricity Generation*, 31 ENERGY POL'Y 1315, 1321–22 (2003).

[64] SOLAR ENERGY TECH. PROGRAM, U.S. DEP'T OF ENERGY, DOE CONCENTRATING SOLAR POWER 2007 FUNDING OPPORTUNITY PROJECT PROSPECTUS 2 (2007), *available at* http://www1.eere.energy.gov/solar/pdfs/csp_prospectus_112807.pdf [hereinafter SOLAR ENERGY TECH. PROGRAM].

[65] *The Cost of Coal*, NOW WITH BILL MOYERS (Aug. 2, 2002), http://www.pbs.org/now/science/coal.html.

[66] SOLAR ENERGY TECH. PROGRAM, *supra* note 64.

[67] Bryan Walsh, *Natural Gas Can Save the Climate? Not Exactly*, TIME ECOCENTRIC BLOG (Sept. 9, 2011, 12:16 PM), http://ecocentric.blogs.time.com/2011/09/09/natural-gas-can-save-the-climate-not-exactly/.

[68] Bob Shively, *The Natural Gas Fracking Debate: What is Fracking and Why Does it Matter? Part I*, ENERDYNAMICS BLOG (Sept. 1, 2011), http://blog.enerdynamics.com/2011/09/01/the-natural-gas-fracking-debate-what-is-fracking-and-why-does-it-matter-part-I/.

[69] *Annual U.S. Natural Gas Citygate Price*, U.S. ENERGY INFO. ADMIN. (Aug. 29, 2011), http://www.eia.gov/dnav/ng/hist/n3050us3a.htm. Though there was a recent drop in prices to pre-2005 levels, this was likely due, in large part, to the economic downturn.

[70] *See, e.g.*, Tom Zeller, Jr., *Gas Drilling Technique is Labeled Violation*, N.Y. TIMES, Jan. 31, 2011, http://www.nytimes.com/2011/02/01/business/energy-environment/01gas.html; Ian

Adding to this complexity is the fact that there is a "laboratory" cost, what it takes to produce a watt if you hold everything else constant, and what it takes to produce a watt at the end of a plug in the real world. That difference depends not on financing costs, fluctuating commodity prices, exchange rates, and global demand for the materials used to construct plants, as well as the constantly changing maze of regulations and incentives, and the somewhat more slow but ongoing changes to the electric grid and storage options that vary from state to state.

The financial and regulatory complexity of big energy projects notwithstanding, we believe that current price comparisons between solar and conventional sources of energy are misleading. Only part of the full cost of conventional sources is included in its price,[71] whereas most of the cost of solar energy is included in its price.[72] In other words, solar only loses in a rigged game. A truer market where prices reflected even some of the externalities created by conventional sources—even without taking into account past and current subsidies for fossil fuels—would find certain types of commercial solar energy to be price competitive.

Attempts to address some of the difficulty in comparing one energy source to another by producing "levelized" comparisons tend to be rife with problems. Many studies, like the one conducted by the State of California's Energy Commission, do not include the cost of externalities but do include subsidies that apply inconsistently, for example to some, but not all, forms of solar—or better put, to some, but not all, sources of zero-carbon emission energy.[73] Generally studies appear not to take into account the value of water above the cost currently paid by producers.

Perhaps most significantly—and a problem shared with attempts to price the effects of climate change—is the fact that the decisive input in many models is the cost of capital.[74] As a consequence, the models' prediction of the cost of a watt of energy from capital-intensive solar plants could change well in excess of 100% depending on interest rates at the

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Urbin, *A Tainted Water Well, and Concern That There May be More*, N.Y. TIMES, Aug. 3, 2011, http://www.nytimes.com/2011/08/04/us/04natgas.html?pagewanted=all.

[71] *See supra* note 13 and accompanying text.

[72] *See generally* RICHARD PEREZ ET AL., SOLAR POWER GENERATION IN THE US: TOO EXPENSIVE OR A BARGAIN? (2011), *available at* http://www.asrc.cestm.albany.edu/perez/2011/solval.pdf (discussing the various components included in the cost of solar energy).

[73] *See, e.g.*, JOEL KLEIN ET AL., CAL. ENERGY COMM'N, COMPARATIVE COSTS OF CALIFORNIA CENTRAL STATION ELECTRICITY GENERATION 39 (2009), *available at* http://www.energy.ca.gov/2009publications/CEC-200-2009-017/CEC-200-2009-017-SD.PDF.

[74] *Id.* at 12–13 (noting that capital costs include total costs of construction, land purchase, development, permitting, equipment, interconnection, environmental control equipment, and financing).

time the plant is constructed.[75] This is an essential consideration when a company is choosing what type of facility to construct, but it mistakes a discussion of corporate financial planning for a comparison of renewable energy to fossil fuel energy.

1. Unpaid Costs in Conventional Energy Sources

Many of the environmental externalities of current energy sources go largely unpaid by producers and consumers, and are instead borne by society at large and by future generations.[76] The environmental harms from energy production include those that are ongoing, cumulative, and widespread (climate change), and those that are regional or site-specific (spills).[77]

The military and geopolitical cost of importing billions of barrels of oil from far-flung places, as well as the resulting transfer of wealth to hostile regimes, is difficult to estimate, but it is safe to say that some portion of the United States' military activity in the Middle East in particular is attributable to the need to protect energy sources.[78] Estimates of this cost range from $50 to $103 billion annually, not including the expenses for the Iraq war.[79] If even a fraction of that cost were paid by energy users it would cause a marked rise in the price of oil-based energy.[80] Furthermore, some portion of the costs arising from terrorism-related security efforts is a consequence of funding that terrorists receive from individuals and governments enriched by selling oil to the West.[81]

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[75] *See* STAN KAPLAN, CONG. RESEARCH SERV., RL 34746, POWER PLANTS: CHARACTERISTICS AND COSTS 17–23 (2008). This distortion is even more acute today, with interest rates at historic lows. Jennifer Aversa & Scott Lanman, *Fed to Keep Key Rates at Record Lows Through Mid-2013 Amid Weaker Economy*, BLOOMBERG (Aug. 9, 2011, 4:36 PM), http://www.bloomberg.com/news/2011-08-09/fed-to-keep-rates-at-record-lows-at-least-through-mid-2013.html.

[76] EUROPEAN WIND ENERGY ASS'N, WIND ENERGY—THE FACTS: A GUIDE TO THE TECHNOLOGY, ECONOMICS, AND FUTURE OF WIND POWER 365 (2009).

[77] *Id.*

[78] *See, e.g.*, Graham Paterson, *Alan Greenspan Claims Iraq War was Really for Oil*, SUNDAY TIMES (Sept. 16, 2007), http://www.timesonline.co.uk/tol/news/world/article2461214.ece (noting the alleged connection between the Iraq War and oil); *see also supra* note 13 and accompanying text.

[79] *See supra* note 13 and accompanying text.

[80] According to the Congressional Budget Office, in 2007 over $280 billion was spent on gasoline. Incorporating these costs into gas/diesel prices would cause a seventeen to thirty-six percent increase. CONG. BUDGET OFFICE, EFFECTS OF GASOLINE PRICES ON DRIVING BEHAVIOR AND VEHICLE MARKETS, at x (2008), *available at* http://www.cbo.gov/ftpdocs/88xx/doc8893/SUmmary.4.1.shtml.

[81] *See* David E. Kaplan, *The Saudi Connection: How Billions in Oil Money Spawned a Global Terror Network*, US NEWS (Dec. 7, 2003), http://www.usnews.com/usnews/news/articles/031215/15terror.htm.

That the full environmental and geopolitical cost of oil is not included in gas prices makes it an indirect government subsidy. More direct subsidies exist as well. For oil and gas development those direct subsidies, typically through tax breaks, total many billions of dollars each year.[82] For nuclear power, the federal government provides catastrophic loss insurance that amounts to a multimillion to billion dollar annual subsidy to the nuclear power industry.[83] Further, government loan guarantees for new plant construction[84] and expenditures to develop long-term storage for spent fuel are additional costs not paid by energy consumers but instead by taxpayers.[85]

The true cost of the water used as a coolant by coal, oil, natural gas, and nuclear power plants is either completely put off to society as an externality, or directly subsidized by local or federal governments.[86]

A discussion of the unpaid costs of electricity could fill several books. This Article again takes a simple but revealing path: in the next part we look at the implications of more fluid water markets and a modest carbon price on the relative cost of solar versus fossil power.

B. Better Markets for Carbon and Water

We endorse a more market-oriented solution to new energy even as we recognize how far from free all energy markets are. Taking even minimal account of the externalities of different energy sources will allow businesses and individuals to make more rational choices about their energy needs and will give the least costly (in real terms) technology a better chance to succeed. That these costs are not included in current energy prices is a fact not lost on politicians, even if they do not do anything about it.[87] In June 2010, remarking on the Gulf spill, President Obama said "If

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[82] *See* Kocieniewski, *supra* note 4.

[83] The U.S. government provides catastrophic loss insurance to nuclear power plants under the Price-Anderson Act. 42 U.S.C. § 2210 (2006). Under the act, amounts exceeding an individual operator's liability insurance would be paid first by an industry pool of all operators, then by the federal government. *See* Michael Faure & Karine Fiore, *An Economic Analysis of the Nuclear Liability Subsidy*, 26 PACE ENVTL. L. REV. 419, 430–31 (2009).

[84] *See* Wald, *supra* note 5.

[85] *High-Level Waste Disposal*, U.S. NUCLEAR REGULATORY COMM'N, http://www.nrc.gov/waste/hlw-disposal.html (last visited Nov. 8, 2011).

[86] *Structure of the U.S. Energy Sector*, SUBSIDYSCOPE, http://subsidyscope.org/energy/summary/structure/ (last visited Nov. 8, 2011) (noting that water use in power generation may cause contamination and is the recipient of government subsidies).

[87] *See* Cooper, *supra* note 1.

we refuse to take into account the full cost of our fossil fuel addiction—if we don't factor in the environmental costs and national security costs and true economic costs—we will have missed our best chance."[88]

We limit our discussion below to two measures to illustrate the impact of making a "more real" cost-benefit analysis: 1) using water markets to allow for the proper pricing of hydrologic resources; and 2) establishing a carbon price that begins to include the costs of climate change in energy prices.

1. Taking Account of the Water-Energy Nexus

Coal, natural gas, and nuclear power generation stations consume up to 500 gallons per megawatt hour ("mWh") of water to cool the steam that runs their turbines.[89] They pay an average of just over one dollar per 1000 gallons for this water.[90] This cost often does not even cover the full cost of delivery and provides users with little incentive to conserve or direct water to its best uses.

Some states and localities have moved towards the creation of water markets.[91] The idea of a water market is actually quite simple: willing owners can sell to willing buyers.[92]

Does that sound radical? It is if being radical means a rejection of widely established and long-standing policy. But it is exactly such policies that lead farmers to grow low-value crops like alfalfa using flood irrigation, and waste billions of gallons of water in the process.[93] When water is free, why use it wisely? Situations where you can't sell what you own—and especially in western water systems where if you don't use water you might

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[88] *Id.*

[89] U.S. DEP'T OF ENERGY, CONCENTRATING SOLAR POWER COMMERCIAL APPLICATION STUDY: REDUCING WATER CONSUMPTION OF CONCENTRATING SOLAR POWER ELECTRICITY GENERATION 4 (2010), *available at* http://www1.eere.energy.gov/solar/pdfs/csp_water_study.pdf.

[90] *See* John S. Maulbetsch & Kent D. Zammit, *Cost/Performance Comparisons of Alternative Cooling Systems*, Presentation at the California Energy Commission/Electrical Power Research Institute Advanced Cooling Strategies/Technologies Conference (June 2, 2005), *available at* http://www.energy.ca.gov/pier/conferences+seminars/2005-06_advanced_cooling_conference/presentations/G _National_Study_Slides.pdf.

[91] *See, e.g.*, Jedediah Brewer et al., *Water Markets in the West: Prices, Trading, and Contractual Farms*, 46 ECON. INQUIRY 91, 94–98 (2008) (discussing the operation and economics of several state and regional water markets).

[92] *See id.* at 94.

[93] *See, e.g.*, *id.* at 91, 94.

lose the right to it—encourage truly (economically and socially) odd uses of water.[94]

Creating water markets does not require the rejection of all preferred uses. Proponents of water markets have suggested that all persons receive a grant of a minimum amount of water—roughly a generous calculation of how much is required to meet basic human needs.[95] Furthermore, markets can be structured to provide price breaks to preferred uses, whether for farming or simply leaving water in rivers ("in-stream flows") to create fish and bird habitat.[96]

How does the emerging trend towards more open water markets relate to electricity? If transferrable and marketable property rights are granted in water, we believe its price, on average, will go up. This is not a logical consequence of increasingly freer markets, which often lead to lower prices; it is instead a reflection of the disconnect between the actual scarcity of water and the existing system that allocates it based on political and historical, rather than economic, forces. The evidence of severely distorted water markets comes in multiple ways. One simple example would be the phenomenon of drought measures in cities occurring at the same time, and in the same water system, as flood irrigation of low-value crops.[97] Initial information from fledgling water markets, where economic forces exert greater control over distribution, suggests that the multiple competing demands for water and its scarcity tend to generate higher real prices.[98]

For the average homeowner, freer water markets would not mean much. The price we pay for municipal water today—an essential element of human life—is often exceeded by expenditures on cable television or premium coffee.[99] What will it mean for a water-cooled power plant? Probably a lot. In the next section, we consider the implications of market prices for water and solar energy.

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[94] *See id.* at 94.

[95] *Cf.* Robert Glennon, *Water Scarcity, Marketing, and Privatization*, 83 TEX. L. REV. 1873, 1895–96 (2005) (discussing various proposals regarding the basic right to water and impediments to water privatization).

[96] *See* Robert C. Griffon & Shih-Hsun Hsu, *The Potential for Water Market Efficiency When Instream Flows Have Value*, 75 AM. J. AGRIC. ECON. 292, 292–93 (1993).

[97] *See, e.g.*, Kelly Zito, *Worst Drought Ever Expected After Mild January*, S.F. CHRONICLE (Jan. 30, 2009), http://articles.sfgate.com/2009-01-30/news/17198620_1_sierra-nevada-snowpack-rationing-snow-s-water-content.

[98] *See* Brewer et al., *supra* note 91, at 109 (largely attributing this effect to the sale of water rights from farmers to urban users willing to pay much higher prices).

[99] Glennon, *supra* note 95, at 1873.

2. Solar Energy and Water Consumption

When most people think of solar energy, they do not think of water consumption. That disjunction is a critical error in assessing the true cost of solar energy.[100]

All solar facilities use small amounts of water for washing mirrors and panels.[101] It is solar thermal systems that can have large water needs for cooling.[102] The most common type of solar thermal facility is the parabolic trough system, which uses long, curved mirrors that focus light on a pipe filled with a heat transfer liquid.[103] This heated liquid is used to make steam and drive a turbine to generate electricity in the same way a coal, gas, or nuclear plant would.[104] Most existing parabolic trough systems use water-evaporation cooling systems and consume a similar amount of water to that needed for coal, natural gas, and nuclear, though newer systems have proven effective with dry and hybrid cooling as well.[105]

A different system, which has been deployed in large-scale commercial plants in Spain, is called a "power tower."[106] This system uses a field of mirrors that direct concentrated sunlight at a heat exchanger on a tower.[107] This heats a fluid (often molten salt) that then uses a steam turbine to generate electricity, just as the parabolic trough system does.[108] Power towers operate at substantially higher temperatures than parabolic troughs, which permit efficiency gains over most parabolic trough systems in translating solar radiation into electricity.[109] Power towers are among the most capital intensive of solar power technologies, though at large scale they can be economically attractive.[110]

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[100] *See* Robert Glennon & Andrew M. Reeves, *Solar Energy's Cloudy Future*, 1 ARIZ. J. ENVTL. L. & POL'Y 91, 95 (2010) (noting the need for water as an element limiting solar energy's availability). While this paper concurs with Glennon and Reeves regarding the importance of water in meeting energy needs, we argue that dry and hybrid cooled systems are viable alternatives in places where water scarcity would or should be a barrier to development of a solar generation facility. Furthermore, ultra-low water use technologies like photovoltaic panels are ideal for locations where even limited water use would preclude fossil fuel powered plants.

[101] U.S. DEP'T OF ENERGY, *supra* note 89, at 7.

[102] *Id.*

[103] *Id.* at 8.

[104] *Id.* at 7.

[105] *Id.* at 4, 12.

[106] *Id.* at 9–10.

[107] U.S. DEP'T OF ENERGY, *supra* note 89, at 9.

[108] *Id.* at 9–10.

[109] *Id.* at 10.

[110] SUN LAB, SOLAR POWER TOWERS 1–2 (1998), *available at* http://www.nrel.gov/docs/fy99osti/23100.pdf.

Another solar technology currently deployed at two facilities in California is a dish Stirling system.[111] This system uses a large parabolic dish that focuses light on a heat exchanger connected to a Stirling engine.[112] The Stirling engine, contained on each dish unit, converts the heat into electricity in a closed cycle.[113] Stirling dish generators are completely air-cooled and require water only for cleaning.[114] They are highly scalable: each dish is a self-contained generator, and a generation facility could be comprised of a few dishes, or a few thousand dishes.[115] Stirling dishes suffer from high capital costs, and currently suffer from reliability and maintenance issues.[116]

The most familiar source of solar electricity is from photovoltaic ("PV") sources, most commonly in the form of the PV panel.[117] An emerging technology is concentrated PV ("CPV"), which uses mirrors or lenses to focus sunlight on very high-efficiency PV cells.[118] PV installations require water only for cleaning, and use very little.[119] PV panel installations are far less capital-intensive than most solar thermal technologies, however a similar-sized solar thermal facility is likely to have a greater energy output because ordinary PV panels are the least efficient of the major current solar technologies at converting solar radiation into electricity, with a conversion efficiency at the low end, near eleven percent, for low cost industrial-use cells.[120] Laboratory models have achieved nearly twenty-nine percent efficiency, but are not presently commercially viable.[121] CPV,

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[111] U.S. DEP'T OF ENERGY, *supra* note 89, at 10.
[112] *Id.*
[113] *Solar Energy System Descriptions*, TRIBAL ENERGY & ENVTL. INFO. CLEARINGHOUSE, http://teeic.anl.gov/er/solar/restech/desc/index.cfm (last visited Nov. 8, 2011).
[114] U.S. DEP'T OF ENERGY, *supra* note 89, at 11.
[115] The facilities being developed in California will have approximately 30,000 dishes. *See Imperial Valley Solar (Formerly called SES Solar Two Project)*, CAL. ENERGY COMM'N, http://www.energy.ca.gov/sitingcases/solartwo/index.html (last visited Nov. 8, 2011).
[116] *See* L. STODDARD ET AL., NAT'L RENEWABLE ENERGY LAB., ECONOMIC, ENERGY, AND ENVIRONMENTAL BENEFITS OF CONCENTRATING SOLAR POWER IN CALIFORNIA 2–3 (Apr. 2006), *available at* http://www.nrel.gov/csp/pdfs/39291.pdf.
[117] *See Solar Energy System Descriptions*, *supra* note 113.
[118] *See id*.
[119] *See id*.
[120] *See id.*; *see also* Tom Cheyney, *NREL Confirms 11% Conversion Efficiency for SoloPower Flexible CIGS PV Modules*, PV TECH (Apr. 27, 2011), http://www.pv-tech.org/news/nrel_confirms_11_conversion_efficiency_for_solopower_flexible_cigs_pv_modul.
[121] *PV Producer XSunX Reaches 15.1 Percent Conversion Efficiency with its CIGS Thin-Film Solar Technology*, SOLAR SERVER (Oct. 11, 2010), http://www.solarserver.com/solar-magazine/solar-news/current/kw45/pv-producer-xsunx-reaches-151-percent-conversion-efficiency-with-its-CIGS-thin-film-solar-technology.html.

on the other hand, has shown the ability to generate electricity at very high conversion efficiencies, in excess of twenty-five percent, in more scalable forms.[122]

PV's drawbacks can often be overcome, however, for small-scale installations at the point of use because the elimination of transmission infrastructure and loss can balance out the negatives.[123] Because a small to mid-scale application can be installed with minimal capital, without changes in transmission infrastructure, and often without the environmental impact assessments and regulatory hurdles of utility-scale applications, they can be attractive to businesses and investors.[124]

Current water costs for electric generation facilities generally range from $1 to $8 per thousand gallons, with prices closer to $1 being most common.[125] The point at which the lower performance of dry-cooling solar energy systems is overcome by the cost of water for wet-cooled systems is only in the $3.50 to $4.50 per thousand gallons range.[126]

The notable conclusion from a look at water prices is that wet-cooled systems (for solar or fossil-fuel sources of electricity) are only economical in a world where water is cheap in the extreme—at a price that only reflects delivery cost, if even that. Consequently, virtually any system that includes some of the true value of water in its price will be transformative for the competitiveness of dry-cooled energy sources.

PV and dry-cooled solar thermal technologies that use water only for mirror washing consume approximately twenty gallons per MWh, down from approximately 800 gallons per MWh for a wet-cooled parabolic trough plant.[127] Dry-cooling systems are less efficient at converting solar radiation to electricity than wet, but these "inefficiencies" would actually generate cost savings where water prices are higher or, more importantly, would allow a plant to exist where water may be legally unavailable.[128] Even in places like coastlines where water is abundant, hybrid wet/dry systems can be used that reduce water use eighty to ninety percent over what existing coal or nuclear plants use, with a cost effect on the electricity produced as small as two percent.[129]

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[122] *See Proven Results*, REHNU, http://www.rehnu.com/proven-results (last visited Nov. 8, 2011).
[123] *See* Glennon & Reeves, *supra* note 100, at 96, 124–25.
[124] *See id.* at 124–25.
[125] Maulbetsch & Zammit, *supra* note 90, at 17.
[126] *Id.* at 23.
[127] U.S. DEP'T OF ENERGY, *supra* note 89, at 17.
[128] *See id.* at 13.
[129] *See id.* at 15–16.

Dry and hybrid cooling systems are generally more capital intensive to construct, but costs have fallen as the systems become more common.[130] Of course, whether they are a net gain or loss in the long run depends on the cost of water.

What the equilibrium price of water in a market system would be is highly speculative, and will depend on region.[131] That it would rise above $3 per thousand gallons, however, is quite likely.[132] Even without a fully open water market, wet-cooled electric generation only makes economic sense where the true value and scarcity of water are ignored. As a result, we do not believe that wet-cooling systems make sense for any electric generation method, but they are a particularly poor choice for solar power facilities located in the parched deserts where the sun's energy is most prevalent.[133]

3. Costing Carbon

We have discussed the implications of taking account of water in energy production because it is often left out of policy analysis.[134] It should and will have to be considered, however, if the trend towards water markets continues. This trend is likely to continue because water scarcity is a critical issue not just in the desert Southwest, but in areas such as the Southeast, which might seem to have abundant water supplies, but face serious shortages as well.[135]

But any discussion of the real cost of energy must at least recognize the issue of greenhouse gases.[136] The massive size and dramatic character of the BP oil spill notwithstanding, the largest single externality

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[130] *See, e.g.*, SOLAR ENERGIES INDUS. ASS'N, UTILITY-SCALE SOLAR POWER 1 (2010), *available at* http://seia.org/galleries/pdf/factsheet_usp.pdf; Andrew Williams, *Cooling: Cost-efficiency vs Water-usage*, CSP TODAY (May 14, 2010), http://social.csptoday.com/industry-insight/cooling-cost-efficiency-vs-water-usage.
[131] *See* Abrams & Hall, *supra* note 20, at 10–11.
[132] *See id.* at 7; Maulbetsch & Zammit, *supra* note 90, at 17.
[133] It should be noted that the price of water, even in a completely open market, would be location sensitive. If you are on the shore of Lake Michigan, you would pay only for the cost of the unit of water, which would be based on its relative abundance in that site, and some negligible amount for delivery. If, on the other hand, you are in the California desert, you will either pay the cost of transport from the Colorado or Sacramento rivers, plus a high price for the water that reflects its relative scarcity, or you will pay a much higher price for scarce groundwater, and a lower cost for delivery since you need only pump it out of the ground. *See* Abrams & Hall, *supra* note 20, at 10–11.
[134] *See* Glennon & Reeves, *supra* note 100, at 95.
[135] Abrams & Hall, *supra* note 20, at 24–25.
[136] *See* SERGEY PALTSEV ET AL., ASSESSMENT OF U.S. CAP-AND-TRADE PROPOSALS 19 (2007), *available at* http://web.mit.edu/globalchange/www/MITJPSPGC_Rpt146.pdf.

created by energy from fossil fuels is global climate change caused by the emission of greenhouse gases, chiefly CO_2.[137] Though there are a number of externalities associated with energy, including air pollution, mercury poisoning, land despoiled for coal and tar sands mining and fracking for natural gas, spilled oil and defense spending,[138] a big step toward making the price of energy reflect its true cost would be to include some modest portion of the cost of carbon emission.[139]

Though there are several ways to begin internalizing the cost of carbon, the best among them is a carbon tax. Such a tax would allow the market to "sort" energy sources by all relevant cost measures and minimize government interference in that market.[140] Further, a carbon tax is in theory less susceptible than subsidies or cap-and-trade to lobbying and parochial political interests, is administratively simpler, and would not interfere with other legal or regulatory efforts, including state regulation.[141]

For the purposes of this discussion, however, virtually any mechanism that begins to price the cost of carbon emissions would suffice, be it a carbon tax, the cap-and-trade system sometimes considered by Congress, something as unusual as a temperature tax, or any of the myriad of other proposals. That is because any system that places a non-zero price on carbon would begin to lower the subsidy that makes energy from fossil-fuel sources artificially cheap. On the even slightly more level playing field that would result, solar power can compete.

The difficulty of predicting the precise effects of climate change is part of the challenge of developing the most appropriate policy responses. Climate and environmental scientists tasked with predicting the effects of a dramatic realignment of Earth's environmental chemistry, including the effects of events that have never been observed, have understandably arrived at a broad range of conclusions.[142] But the uncertainty over the

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[137] *Greenhouse Gases, Climate Change, and Energy*, U.S. ENERGY INFO. ADMIN., U.S. DEP'T OF ENERGY (May 2003), http://www.eia.gov/oiaf/1605/ggccebro/chapter1.html.

[138] *See, e.g.*, Daniel M. Kammen & Sergio Pacca, *Assessing the Costs of Electricity*, 29 ANN. REV. ENVTL. RESOURCES 301, 302 (2004).

[139] *See* PALTSEV ET AL., *supra* note 136, at 19.

[140] *See generally* SHI-LING HSU, THE CASE FOR CARBON TAX: GETTING PAST OUR HANG-UPS TO EFFECTIVE CLIMATE POLICY (2011) (arguing that market forces, not government planning, is the best way to make determinations about the cost and efficiency of the various available energy sources).

[141] *See id.*

[142] *See, e.g.*, Timothy R. Carter et al., *New Assessment Methods and the Characterisation of Future Conditions*, *in* CLIMATE CHANGE 2007: IMPACTS, ADAPTATION AND VULNERABILITY 133, 144 (2007), *available at* http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-chapter2.pdf; Jonathan T. Overpeck et al., *Paleoclimatic Evidence for Future Ice-Sheet*

precise impacts of climate change at different time periods and scales, and in different natural and human systems, does not reflect any serious doubt about the basic facts of human-caused climate change.[143] Nor does it conflict with increasingly good models (and actual observations) identifying degrees of risk with regard to ranges of potential change—ranges that often include possibilities for "worst case scenarios" that are dismissed from public discourse the way that worst-case deep water oil spills were dismissed until April 20, 2010.[144]

A different, and less certain, issue is how to price the harm from the greenhouse gases that are a primary cause of human-induced climate change.[145] Some of the more prominent studies have addressed the qualitative effects of climate change, but have not attempted to put a cost on today's carbon emissions.[146] We survey several of the most prominent studies that try to arrive at a level of clarity sufficient to make the point about fossil-solar tradeoffs.

William Nordhaus, using his "DICE" model, evaluated a cost of $30 per ton of carbon.[147] The Stern Review arrived at a much higher rate of $350 per ton.[148] Richard S.J. Tol, in a 2005 survey of peer-reviewed studies,

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Instability and Rapid Sea-Level Rise, 311 SCIENCE 1747 (2006) (noting that various models and predictions have come to different conclusions on possible amounts of sea level rise).

[143] KARL ET AL., *supra* note 32, at 9.

[144] For example, there has been widespread discussion of the consequences of one meter of sea level rise over the next century, and some commentary about revised models suggestions as much as a two meter sea level rise over the same period. *See* Overpeck et al., *supra* note 142, at 1747. But research also suggests a chance of a ten meter rise. Richard Z. Poore et al., *Sea Level and Climate*, USGS, http://pubs.usgs.gov/fs/fs2-00/ (last visited Nov. 8, 2011). Worst-case scenarios and current policy discussions should take account of these smaller risks of much greater harms, as well as of the risk of sudden changes in systems. J.T. Overpeck & J.E. Cole, *Abrupt Change In Earth's Climate System*, 31 ANN. REV. OF ENV'T & RESOURCES 1, 2–3 (2006); *see also* Oliver A. Houck, *Worst Case and the Deepwater Horizon Blowout*, 40 ENVTL. L. REP. 11033 (2010).

[145] *See* Richard S.J. Tol, *The Marginal Damage Costs of Carbon Dioxide Emissions: An Assessment of the Uncertainties*, 33 ENERGY POL'Y 2064, 2064, 2067, 2069 (2005).

[146] *See, e.g.*, KARL ET AL., *supra* note 32, at 8.

[147] WILLIAM NORDHAUS, A QUESTION OF BALANCE 12–13 (2008).

[148] NICHOLAS STERN, THE ECONOMICS OF CLIMATE CHANGE: THE STERN REVIEW 344 (2007). This stark difference is mostly explained, however, not through a radical difference in climate models, but through a philosophical difference of opinion over the discount rate used. If the same discount rates were used in Nordhaus's DICE model that were used in the Stern Review, it yields nearly the same result. Consequently, the difference between the two boils down to something of a policy argument over the level of cost that we should endure today relative to the benefit of future generations. NORDHAUS, *supra* note 147, at 186. *But see* Kari Lundgren & Stefan Nicola, *Green Europe Imperiled as Crisis Triggers Carbon Collapse*, Bloomberg News (Oct. 10, 2011, 6:43 AM), http://mobile.bloomberg.com

arrived at a mean of $43 per ton.[149] The United Nations Intergovernmental Panel on Climate Change survey also found a mean cost of $43 per metric ton.[150]

Different methods to calculate the cost abound as well. Kammen and Pacca estimated the marginal cost of the emission of a metric ton of carbon based on the number of deaths in tropical regions attributed to climate change multiplied by the (also highly contested) actuarial value of a life, finding it to be $33.60 per ton.[151] Another method is to look at the cost of removing CO_2 from the atmosphere through planting trees or other natural captures, which the United States Energy Information Administration estimates at approximately $54 per ton.[152] Those studies and surveys arrive at a mean cost per ton of approximately $92. An average of these studies that excludes the Stern Review, or rather, uses the Stern numbers with a discount rate closer in line to what other studies use, arrives at a result of approximately $40.

Though we will likely not know what the precise effects of climate change will be until they occur, and much of what occurs will depend on our actions over the coming years, we can make the following conclusions with a reasonable degree of certainty: 1) the Earth's atmospheric concentrations of greenhouse gases have dramatically increased since the preindustrial era;[153] 2) as a result of that increase, the Earth's temperature is rising;[154] 3) that change in temperature is likely to have a substantial impact on climate;[155] and 4) there is at least a small chance of catastrophic effects that will fundamentally disrupt the way we live today.[156] Ultimately, it may be impossible to arrive at an accurate marginal cost per ton of carbon emitted, but the chance that it may be very high suggests we should

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/news/2011-10-09/green-europe-imperiled-as-debt-crisis-triggers-46-carbon-market-collapse (noting the decline in carbon prices in Europe in response to the European and global economic crisis).

[149] Tol, *supra* note 145, at 2070.

[150] Gary W. Yohe et al., *Perspectives on Climate Change and Sustainability*, *in* THE FOURTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE 811, 813 (2007).

[151] Kammen & Pacca, *supra* note 138, at 336 (surveying Cline, Fankhauser, Nordhaus, Titus, and Tol).

[152] U.S. ENERGY INFO. ADMIN., U.S. DEP'T OF ENERGY, ELECTRICITY GENERATION AND ENVIRONMENTAL EXTERNALITIES: CASE STUDIES (1995) (converted to 2010 dollars by authors).

[153] *Greenhouse Gases, Climate Change, and Energy*, *supra* note 137.

[154] KARL ET AL., *supra* note 32, at 9.

[155] *Id.*

[156] *Id.*

buy some insurance. The good news is that we can have that insurance for just pennies per kWh, and at a price likely to decrease over time.

The cap-and-trade system implemented in Europe, where emitting a ton of carbon costs around $19, may increase over time as the European Union shifts from predominantly free carbon allowances to predominantly auctioned ones.[157] The European system has seen the price of electricity from carbon-emitting sources increase by six to eleven percent.[158] Energy bills considered by Congress in 2009 and 2010 would have created a price for carbon emissions estimated to be between $12 and $93 per ton in 2020, with the floor and ceiling rising at a rate three to five percent above the CPI.[159] This translates to roughly nine cents per kWh in 2020, and increasing thereafter.[160]

Where the price eventually settles is less important than the fact that there should be some non-zero price, one that would put some applications of solar power, even at current prices, within range of hydrocarbon energy.[161] It is also important to keep in mind that the relevant comparison against new sources of solar electricity is *new* conventional plants, not existing capacity. Ideally, old coal plants would be replaced by cleaner alternatives, but in the short term increasing demand for electricity means that new capacity will still be necessary.[162]

A modest carbon price together with some movement towards water markets would push the cost of coal, natural gas, and nuclear energy up—even if existing plants could be retrofitted with dry-cooling and carbon sequestration systems.[163] And though a coal plant in a North Dakota winter

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[157] SETH KERSCHNER ET AL., CLIMATE LAW UPDATE 4 (2010), *available at* http://www.shearman.com/Climate-Law-Update-05-26-2010/; Claire Milhench, *Analysis: EU Carbon Cost May Force Refiners to Relocate, Close*, REUTERS (Oct. 3, 2011, 6:15 AM), http://www.reuters.com/article/2011/10/03/us-refineries-regulation-idUSTRE79216L20111003.

[158] Kevin Bullis, *The Real Price of Obama's Cap-and-Trade Plan*, MIT TECH. REV. (Mar. 4, 2009), http://www.technologyreview.com/business/22247/.

[159] KERSCHNER ET AL., *supra* note 157; Loise Radnofsky & Jean Spencer, *Public Still Backs Offshore Drilling*, WALL ST. J., May 13, 2010, at A4; U.S. ENERGY INFO. ADMIN., U.S. DEP'T OF ENERGY, ENERGY MARKET AND ECONOMIC IMPACTS OF H.R. 2454, THE AMERICAN CLEAN ENERGY AND SECURITY ACT OF 2009 1 (2009); U.S. CONG. BUDGET OFFICE, COST ESTIMATE OF H.R. 2454: AMERICAN CLEAN ENERGY AND SECURITY ACT OF 2009 12–13 (2009); SERGEY PALTSEV ET AL., *supra* note 136, at 16.

[160] U.S. ENERGY INFO. ADMIN., *supra* note 159, at 2–27.

[161] *Good Policy, and Bad*, ECONOMIST, Dec. 5, 2009, at 12.

[162] U.S. ENERGY INFO. ADMIN., INTERNATIONAL ENERGY OUTLOOK 2011 85 (2011), *available at* http://205.254.135.24/forecasts/ieo/pdf/0484(2011).pdf.

[163] *See Competitiveness of Solar Energy*, NITOL SOLAR, http://www.nitolsolar.com/encompetitiveness/ (last visited Nov. 8, 2011) (Conversely, "[b]ased on the current technological advances, materials pricing trends and installation volumes, the cost of solar

should be able to take advantage of dry-cooling, recent advances in dry and hybrid cooling have made it workable[164] even in hot climates.[165]

The comparison to energy from new plants, which tend to be more expensive than energy from existing facilities, further demonstrates that the real gap between conventional sources and the better renewable alternatives is smaller than generally thought.

III. "SUNNY DAYS" AND DEEP PONDS: SOLAR TECHNOLOGICAL OPTIMISM

The decreasing cost of existing solar technologies may suggest a potential flood of technological advances that could more radically and quickly change the alternative energy equation.[166] Technological innovation comes from many sources, but among the sources of innovation are government investments in both basic and applied research. Alternative energy in general and solar energy in particular have seen relatively modest government research funding compared to the amounts spent on oil, gas, and nuclear development and technology.[167]

There is some momentum behind increasing research and development ("R&D") expenditure on renewables. The Obama Administration has signaled a strong intent to invest in R&D and in infrastructure, both as evidenced in the 2011 State of the Union speech, as well as in more concrete acts such as the commitment of $1.85 billion of the American Recovery and Reinvestment Act (the stimulus bill) funds to "applied" solar energy.[168] Other incentives under the American Recovery and

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electricity is expected to decrease by 8% each year or by over 50% every 8 years.").

[164] *See* U.S. DEP'T OF ENERGY, *supra* note 89, at 13–14 (showing that dry-cooling was workable but resulted in a loss of efficiency).

[165] STACY TELLINGHUISEN & JANA MILFORD, PROTECTING THE LIFELINE OF THE WEST: HOW CLIMATE AND CLEAN ENERGY POLICIES CAN SAFEGUARD WATER 10, *available at* http://www.westernresourceadvocates.org/water/lifeline/lifeline.pdf.

[166] *See Competitiveness of Solar Energy*, *supra* note 163.

[167] Between 1978 and 2007, "federal spending for renewable energy R&D amounted to about 16% of the energy R&D total, compared with 15% for energy efficiency, 25% for fossil, and 41% for nuclear." FRED SISSINE, CONG. RESEARCH SERV., RS22858, RENEWABLE ENERGY R&D FUNDING HISTORY: A COMPARISON WITH FUNDING FOR NUCLEAR ENERGY, FOSSIL ENERGY, AND ENERGY EFFICIENCY R&D 1 (2008), *available at* http://www.nationalaglawcenter.org/assets/crs/RS22858.pdf.

[168] *See Obama Pledges $2B In Stimulus Funds to Solar Firms*, GREENBIZ (July 10, 2010), http://www.greenbiz.com/news/2010/07/06/obama-pledges-2b-stimulus-funds-solar-firms. Other stimulus funds support a range of energy policy activities. Loan guarantees for energy projects could have a larger financial impact. *See Executive Summary*, *Key Provisions Benefitting the Solar Energy Industry in H.R. 1, the American Recovery and Reinvestment Act of 2009*, SOLAR ENERGY INDUS. ASS'N (Feb. 17, 2009), *available at* http://www.seia.org

Reinvestment Act that have had a significant impact on the development of solar electricity generation facilities include the thirty percent investment tax credit for solar and other renewable technologies,[169] a controversial treasury grant program for certain types of installations,[170] and the loan guarantee program, which, for example, is helping with the development of one of the largest solar thermal facilities in the world by Abengoa Solar in Arizona.[171]

Though, as a recent investigation by the New York Times has indicated, government investment in renewable energy saw a spike in connection with the stimulus bill, these were one-time expenditures, and do not significantly affect the level of spending over the long term, compared to fossil fuel sources that receive billions of dollars in subsidies through multiple mechanisms year after year.[172] By comparison, during the period of 2002 to 2008, government support (largely through subsidies written into the tax code) to the developed and profitable fossil fuel industry averaged over ten billion dollars annually, whereas support for renewables averaged approximately four billion.[173] In the "spike" year of the $700 billion stimulus bill, subsidies to renewables peaked at a one-time high of $14.7 billion, but that program will end in December 2011.[174]

Implicit in any direct subsidy or loan-guarantee regime, however, is the possibility that the project will fail. The recent collapse of Solyndra is a classic example.[175] This is one of the primary benefits of a carbon tax

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/galleries/pdf/guide_to_recovery_act_3_18_09.pdf.

[169] *Executive Summary, Key Provisions Benefitting the Solar Energy Industry in the American Recovery and Reinvestment Act*, *supra* note 168.

[170] *Id.*

[171] *See 1603 Program: Payments for Specified Energy Property in Lieu of Tax Credits*, U.S. TREASURY (Aug. 26, 2011), http://www.treasury.gov/initiatives/recovery/Pages/1603.aspx; *Introducing Solana: Arizona's Largest Solar Generation Station*, APS, http://www.aps.com/main/green/Solana/default.html (last visited Nov. 8, 2011); *Program Overview: Business Energy Investment Tax Credit*, N.C. STATE UNIV. DATABASE OF STATE INCENTIVES FOR RENEWABLES & EFFICIENCY (June 15, 2011), http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US02F; *Abengoa Closes $1.2 Billion Financing for the Mojave Solar Project and Starts Construction*, ABENGOA SOLAR (Sept. 14, 2011), http://www.abengoasolar.com/corp/web/en/acerca_de_nosotros/sala_de_prensa/noticias/2011/solar_20110913.html.

[172] *See* Paul Krugman, *Here Comes the Sun*, N.Y. TIMES (Nov. 6, 2011), http://www.nytimes.com/2011/11/07/opinion/krugman-here-comes-solar-energy.html?ref=paulkrugman.

[173] ENVTL. LAW INST., ESTIMATING U.S. GOVERNMENT SUBSIDIES TO ENERGY SOURCES: 2002–2008 11-12 (2009), *available at* http://www.elistore.org/Data/products/d19_07.pdf.

[174] *See* Krugman, *supra* note 172.

[175] *See* Eric Lipton & Matthew L. Wald, *E-mails Reveal Early White House Worries Over Solyndra*, N.Y. TIMES (Oct. 3, 2011), http://www.nytimes.com/2011/10/04/us/politics/e-mails-reveal-white-house-concerns-over-solyndra.html?ref=solyndra.

or other carbon-pricing system over direct subsidies—it makes it much harder for governments to pick lousy technologies to fund.[176] There may be a silver lining to the Solyndra story, however. As Paul Krugman, the Princeton economist and New York Times columnist, recently observed, one of the main causes of Solyndra's failure was the precipitous drop in the cost of the solar panels that were in their competition.[177]

Private investment in solar energy research has increased as well. Companies, academic researchers, foundations, and investors are paying increasing attention to the many externalities of an energy system built largely around oil, gas, and coal, and to a lesser extent hydro and nuclear energy.[178] Corporations and various sources of private capital are also attentive to the increasing costs in existing markets, which are affected by the enormous fluctuations in energy input prices and the huge role of regulation and subsidy in this area.[179] An initiative lead by business leaders including Bill Gates and General Electric Chief Executive Officer Jeffrey Immelt has called for a tripling of government spending on energy research.[180]

As just one example of the kind of emerging solar technological solutions, a start-up company in Arizona called REhnu has proposed the use of mass-produced mirrors and especially high efficiency solar cells.[181] Among the notable aspects of the REhnu technology is that the company explicitly addresses some of the challenges of resources (water, materials, capital), direct impact of installations (footprint), and questions about how to scale up should the technology prove as feasible and cost-competitive

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[176] *See supra* note 140 and accompanying text.
[177] *See* Krugman, *supra* note 172.
[178] *See, e.g.*, AUSTL. ACAD. OF TECHNOLOGICAL SCI. & ENG'G, THE HIDDEN COSTS OF ELECTRICITY: EXTERNALITIES OF POWER GENERATION IN AUSTRALIA (2009), *available at* http://zunia.org/uploads/media/knowledge/ATSEHiddenCostsElecreport1262168477.pdf; ATOMIC ENERGY SOCIETY OF JAPAN, EXTERNALITIES OF ENERGY AND NUCLEAR POWER (2010), *available at* http://www.aesj.or.jp/en/about_us/ps/AESJ-PS002e.pdf; ORG. FOR ECON. COOPERATION & DEV., NUCLEAR ENERGY AGENCY, EXTERNALITIES AND ENERGY POLICY: THE LIFE CYCLE ANALYSIS APPROACH (2011), *available at* http://www.oecd-nea.org/ndd/reports/2002/nea3676-externalities.pdf.
[179] Among the clearest evidence of the role of government regulation is that Germany is the world leader in solar energy—though far from a world competitor in having clear, sunny skies. Craig Whitlock, *Cloudy Germany a Powerhouse in Solar Energy*, WASH. POST, May 5, 2007, at A1.
[180] John M. Broder, *A Call to Triple U.S. Spending on Energy Research*, N.Y. TIMES, June 10, 2010, at B3.
[181] *See A Solar Revolution*, REHNU, http://www.rehnu.com/technology/rehnus-solution (last visited Nov. 8, 2011).

as its designers hope.[182] And REhnu is just one of more than 200 startup companies currently in the solar energy arena.[183]

One huge advantage to solar electricity over coal, nuclear, natural gas, or hydroelectric is its variety.[184] Solar electricity can be generated in the form of a few panels atop a freeway sign to power its lights,[185] to a mid-sized installation connected to an industrial plant to lessen its draw on the grid,[186] to a 1000 megawatt solar trough plant providing base-load support for the power grid.[187] Given all the problems associated with transmission and grid reliability, many small-to-mid size uses may become more prevalent, particularly in locations that have expensive grid power.[188]

Though there is enormous capacity for solar power to meet peak electricity demand, if it is to become a major source of electricity, questions of transmission and storage must be addressed. Issues of modernizing the electric grid are common to all energy sources, traditional and alternative, and to the energy "source" of conservation.[189] Storage is a particular challenge for solar sources because demand for electricity occurs when it is dark and when it is cloudy.[190] Storage options, however, are available. Though

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[182] *See id.*; *Local Sustainability*, REHNU, http://www.rehnu.com/sustainability/local (last visited Nov. 8, 2011). Our natural fondness for ideas from the University of Arizona—where one of the authors recently graduated with a law degree (Mee) and where the other teaches (Miller) led us to use REhnu—a start-up with the central innovative participation of University of Arizona physicist and optical expert Roger Angel. We should note that we have not done a systematic survey of new solar technologies, nor, for the record, do we have any kind of investment or personal involvement in the work of REhnu.

[183] Eric Wesoff, *150 Solar Startups: The Sequel*, GREENTECH MEDIA (May 26, 2009), http://www.greentechmedia.com/articles/read/the-master-list-of-early-stage-solar-startups-the-sequel/.

[184] *See, e.g.*, Partha Das Sharma, *Solar Power—Sustainable Green Energy to Protect our Economy and Environment*, SAFERENVIRONMENT BLOG (Feb. 2, 2009), http://saferenvironment.wordpress.com/2009/02/02/solar-power-%E2%80%93-sustainable-green-energy-to-protect-our-economy-and-environment/.

[185] *See, e.g.*, STARCOM SOLAR, http://www.starcomsolar.com/ (last visited Nov. 8, 2011).

[186] *See, e.g.*, *Solar and Wind Powered Systems*, SAFT, http://www.saftbatteries.com/MarketSegments/Buildingandindustrialplants/Solarwindpoweredsystems/tabid/227/Language/en-US/Default.aspx (last visited Nov. 8, 2011).

[187] *E.g.*, *Blythe Solar Power Project*, CAL. ENERGY COMM'N, http://www.energy.ca.gov/sitingcases/solar_millennium_blythe/index.html (last visited Nov. 8, 2011).

[188] *See, e.g.*, Lauren Sommer, *Midsize Solar Installations Grow at Light Speed*, NPR (March 16, 2011), http://www.npr.org/2011/03/16/134341220/midsize-solar-installations-grow-at-light-speed.

[189] *See* Paul Davidson, *Buzz Grows For Modernizing Energy Grid*, USA TODAY (Jan. 30, 2009), http://www.usatoday.com/money/industries/energy/2009-01-29-smart-grid-energy_N.htm.

[190] *See* Biello, *supra* note 62.

batteries are prohibitively expensive, both parabolic troughs and power towers can effectively store heat using molten salt, which can run turbines when sunlight is insufficient or at night.[191]

Another important storage alternative, and one that is already in use on a substantial scale, is pumped hydro.[192] Pumped hydro energy storage is accomplished by pumping water uphill (using off-peak electricity, as it often is now, or using excess solar power generated during peak sunlight) and then running the water through electricity-generating turbines when it is needed.[193]

Pumped storage is already used on a large scale to balance generation (constant) with demand (variable).[194] For example, in Arizona, water is pumped upriver into the lakes behind hydroelectric-equipped dams during periods of off-peak demand, then released through the turbines during periods of peak demand.[195] This prevents utilities from having to run more expensive small generators during peak demand.[196] The full potential of the solar-water-pumped storage connection, however, has not been explored. Consider Las Vegas, Nevada. Some of the sources of electricity for Las Vegas are the turbines below Hoover Dam that are fed by the waters of the Colorado River held in Lake Mead.[197] There is substantial capacity in those turbines to generate additional electricity.[198] The amount

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[191] *Id.*

[192] *See, e.g.*, J.P. Deane et al., *Techno-Economic Review of Existing and New Pumped Hydro Energy Storage Plant*, 14 RENEWABLE & SUSTAINABLE ENERGY REVS. 1293, 1294 (2009); Jure Margeta & Zvonimir Glasnovic, *Feasibility of the Green Energy Production by Hybrid Solar + Hydro Power System in Europe and Similar Climate Areas*, 14 RENEWABLE & SUSTAINABLE ENERGY REV. 1580, 1580–81 (2009).

[193] Deane et al., *supra* note 192, at 1294.

[194] One example that suggests the global reach of this energy storage approach is a large facility recently completed in China with a 1836 MW capacity. *See Tianhuangping Pumped-Storage Hydro* Plant, POWER-TECHNOLOGY, http://www.power-technology.com/projects/tianhuangping/ (last visited Nov. 8, 2011).

[195] In the period from October 2009 to October 2010, over 7000 net MwH of electricity were produced in this manner in Arizona. U.S. ENERGY INFO. ADMIN., ELECTRIC POWER MONTHLY: JANUARY 2011 40 (2011), *available at* http://www.eia.gov/electricity/monthly/current_year/january2011.pdf. Other states' statistics are also available from this source.

[196] Deane et al., *supra* note 192, at 1294.

[197] John G. Edwards, *Hoover Dam's Reduced Output Having Little Impact on Nevada Power*, LAS VEGAS REVIEW-JOURNAL (July 10, 2004), http://www.reviewjournal.com/lvrj_home/2004/Jul-10-Sat-2004/business/24275179.html; Dylan Scott, *Boulder City Dumping NV Energy for Cheaper Power*, LAS VEGAS SUN, (Feb. 17, 2011, 2:01 AM), http://www.lasvegassun.com/news/2011/feb/17/costly-dry-spell/.

[198] *See* CAL. ENERGY COMM'N, SUMMER 2011 ELECTRICITY SUPPLY AND DEMAND OUTLOOK B-4, B-5 (2005), *available at* http://www.energy.ca.gov/2011publications/CEC-200-2011

generated now is determined by the amount of water scheduled to be released into the river, not by demand for electricity.[199]

Imagine a large solar generation plant in the Nevada desert nearby—an area with ample sunshine.[200] This plant could send some portion of the electricity it generates into Las Vegas during sunlight hours, and could use any excess to pump Colorado River water from below the dam back into Lake Mead.[201] This water could then be released back through the turbines after dark to generate electricity for Las Vegas.[202]

Beyond technical feasibility, there are a number of more subtle reasons why an idea like this makes sense. Clark County, where Las Vegas is located, used over nine billion gallons of water in 2005 to generate electricity.[203] Power generated in Clark County is only about half of the electricity used there, so the amount of water used to generate the electricity used in the county is actually much greater.[204] Las Vegas is located in the desert, and relies primarily on groundwater and Colorado River water to meet its needs.[205] Due to heavy withdrawals and drought conditions, the groundwater table is dropping, and for the same reasons, the level of Lake Mead is dropping.[206] If the level drops too much, Nevada

-004/CEC-200-2011-004.pdf (discussing the limiting effect of levels in Lake Mead and the flow of the Colorado River for summer 2011); *see also Hoover Dam: No Water Without Power*, GROWINGBLUE (2011), http://growingblue.com/case-studies/hoover-dam-no-power-without-water/.

[199] *See* CAL. ENERGY COMM'N, *supra* note 198, at B-4, B-5 (showing that energy generation is determined more by water needs than demand).

[200] *General Climactic Summary for Las Vegas, Nevada*, NAT'L OCEANIC & ATMOSPHERIC ADMIN., http://www.wrh.noaa.gov/vef/lassum.php (last visited Nov. 8, 2011) ("Las Vegas is commonly noted for its abundant sunshine throughout the year.").

[201] There is no issue with sufficient water below the dam to do this—any amount pumped would be a fraction of the flow in the Colorado, there are multiple reservoirs below Lake Mead (Lake Havasu, for example) that could easily buffer any variability in flow.

[202] *See* Margeta & Glasnovic, *supra* note 192, at 1580–81.

[203] *Estimated Use of Water in the United States County-Level Data for 2005*, USGS, http://water.usgs.gov/watuse/data/2005/ (click "Nevada" link to access county-level data). Clark County used 25.21 million gallons of water per day for thermoelectric generation in 2005. When that is extrapolated over a year, it adds up to over 9.1 billion gallons.

[204] *Where Our Power Comes From*, NV ENERGY, http://www.nvenergy.com/company/energytopics/where.cfm (last visited Nov. 8, 2011) (noting that Southern Nevada, where Clark County is located, receives about 70% of its power from NV Energy generation in Southern Nevada).

[205] Phoebe Sweet, *Quenching Las Vegas' Thirst*, LAS VEGAS SUN, http://www.lasvegassun.com/news/topics/water/ (last visited Nov. 8, 2011).

[206] *See Averages by Year, Lake Mead Water Database*, LAKEMEAD.WATER-DATA, http://lakemead.water-data.com/index2.php (last visited Nov. 8, 2011); *see also* John McChesney,

will see restrictions on the water it can withdraw, and if the lake drops far enough, water will no longer flow through the turbines.[207]

If some of the electricity generated for Las Vegas by water-cooled coal and natural gas plants can be replaced by dry-cooled (or low water use wet/dry hybrid cooled) solar, some of those nine billion gallons can be used by households or casinos, or left in the ground (which helps keep the lake from dropping, among other things).[208] Through the use of pumped hydro storage, the variability of generation from solar power can be smoothed, and solar-generated power can be used for base-load generation.[209]

CONCLUSION

To a cynical reader it may look like the unstated purpose of this Article is to advocate for higher electric bills. Assuming the current array of real costs, this is true. When the true *current* costs of energy are included in the price of *current* sources, the real price of energy will go up. The benefit is that these costs will now be borne by the energy consumer, and will factor into a more efficient evaluation of inputs, rather than being borne by taxpayers, society, and future generations.[210]

It is worth restating two critical points. First, any "increase" in prices is not new—we pay it today. We simply join forces with the many observers of energy policy who believe that some portion of the cost in our energy bill should recognize some portion of these real externalities—so we can see it for what it is and change our behavior appropriately, rather than pushing the cost off to other places where we do not recognize it.[211]

Nevada Water Maven: "I Would Not Declare the Drought Over on the Colorado River,*"* RURAL WEST INITIATIVE (July 4, 2011), http://www.stanford.edu/group/ruralwest/cgi-bin/drupal/content/pat-mulroy-interview.

[207] McChesney, *supra* note 206; *Hoover Dam: No Power Without Water*, *supra* note 198.

[208] *See supra* note 203 and accompanying text.

[209] *See* Margeta & Glasnovic, *supra* note 192, at 1580–81.

[210] As even conservative economists such as N. Gregory Mankiw have argued, the additional revenue generated by Pigovian taxes on carbon, gas, or water can be used to offset taxes that are more economically distortionary and harmful to growth such as income or sales taxes. N. Gregory Mankiw, *Raise the Gas Tax*, WALL ST. J., Oct. 20, 2006, at A12.

[211] To show the power of simple economic incentives, take the case of California. Starting in 1978, the state implemented a system whereby its utilities, after a certain level designed to cover capital costs and a reasonable return, made the same amount of money regardless of their customer's energy use. In 2007, this system was shifted so that the utilities actually made more money when their customers used less energy. As a consequence the biggest proponents of energy efficiency in the state are the utilities. In part because of that rule, Californians use about forty percent less electricity than the national average, "preempting the need [to build] twenty-four large-scale power plants" since 1978

Second, we do not believe that a significant increase—and perhaps any increase in real terms—in energy costs is a necessity. Currently, solar accounts for a small fraction of the electricity produced in the United States.[212] Increases in the scale of solar generation facilities, the volume of production of the goods used to build those facilities, the operational knowledge of the utilities, and technological innovation in the systems utilized to generate solar power will all serve to reduce the cost of that electricity.[213]

No one thing—be it a policy, a technology, or an attitude—will solve our energy problems. We will need all of these and more. We need not succumb, however, to the naysayers about renewable energy: it costs too much, the technology is not ready, it cannot replace conventional sources for base load, and so on. Only by ignoring the true cost of the energy we use, and exploiting natural resources unsustainably, have we had such "cheap" energy. As the real cost becomes clear, and if sound policies begin to incorporate it into the price of energy, sustainable energy sources like dry-cooled solar will be available to meet our needs.

Our analysis suggests that relatively dramatic policy impacts could come from relatively modest policy changes that are well within practical and economic reach. Our conclusion becomes even more powerful if modest technological improvements in solar energy generation continue on their current trend, or increase to reflect increased government and private investment, a transforming political and economic culture, and new market-based incentives.

So much of the policy debate generated by climate change, including energy policy, turns on whether radical policy changes or shifts in markets will occur. For some areas that may be true. The thought experiment conducted in this Article leads us to believe that we are far closer to sustainable electric power than both solar skeptics and solar champions believe.

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despite dramatic growth. Ronald Brownstein, *The California Experiment*, THE ATLANTIC, Oct. 2009, at 67, 69, 70.

[212] *Renewable Energy Sources in the United States*, NATIONAL ATLAS, http://nationalatlas.gov/articles/people/a_energy.html#three (last visited Nov. 8, 2011).

[213] *See* Matthew J. Wald, *What's So Bad About Big?*, N.Y. TIMES (Mar. 7, 2007), http://www.nytimes.com/2007/03/07/business/businessspecial2/07big.html?pagewanted=all (discussing the benefits of economies of scale in renewable energy).