Fast-Tracking Solar Development in the Desert

by Howard Wilshire

> The greatest challenge we, as a species, face right now is to create a way of life based on the energy flow of sunlight, not fossil or nuclear energy, [and] to do so without destroying our soils.- Jason Bradford interview with Kelpie Wilson, September 2006

Since solar power is believed to be a prime solution to U.S. dependence on foreign energy sources, a rapidly growing U.S. solar industry is supporting grand proposals for utility-scale solar power plant developments on essentially free public lands in the southwestern deserts. With blessings from assorted environmental groups, the U.S. Department of the Interior (DOI) is accelerating the process for approving solar development.

The targeted southwest has both the nation's highest concentration of public lands, and also receives the nation's highest average solar radiation (Fig. 1). Public lands thus can provide industry with essentially free land and free access to groundwater resources, along with free sunshine energy. Any utility-scale solar project that gets underway by December 2010 also will get free money from the American Recovery and Reinvestment Act, in the form of loan guarantees and up front cash payments in lieu of tax credits.

Of the 250,000 square miles of southwestern deserts deemed suitable, the grand planners call for 49,000 to be developed by 2050 and 173,000 (equal to the total area of California, Maryland, and Massachusetts) by 2100. The desired land must have slopes no greater than 3%, because the dominant technologies have very low tolerance for land surface irregularities, such as ephemeral washes. But the solar developers typically grade even gently sloping land surfaces to less than 1%, eradicating existing ecosystems

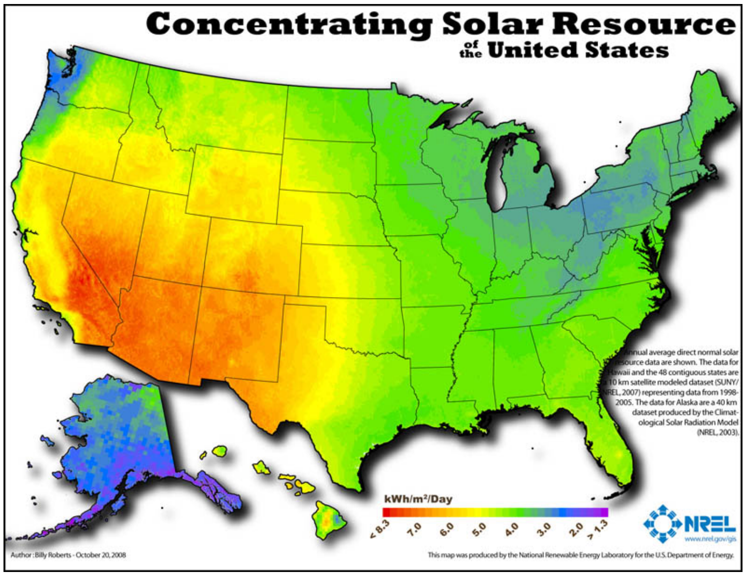

Figure 1. U.S. potential for generating solar thermal (Concentrating) power

The power generated does not feed directly into the old transmission system, so a new national high-voltage direct current transmission system needs to be built along with energy storage facilities to provide power during cloudy or nighttime conditions.

All of these plans ignore less disruptive alternatives that would avoid destruction of large expanses of largely-undisturbed desert land. Alternatives include locating solar developments in blighted and abandoned urban settings (brownfields), incentives for using widespread commercial and residential rooftops for solar generation, supporting building conversions to add passive solar features, and more intensive concentration on energy conservation.

Rush to Build

Three basic motivations drive the rush to build solar power plants on public lands in southwestern deserts:

- hope that such renewable energy sources as solar power can provide most or all of the nation's energy demands, reducing or largely eliminating U.S. dependence on foreign energy imports;
- hope of avoiding climate catastrophe by meeting energy demands with non-polluting "renewable" sources; and
- stimulus money—any project approved by December 2010 qualifies can obtain enough stimulus funds to cover nearly one third of development costs.

Solar Tech

Solar photovoltaic and solar thermal designs are the most amenable for development as utility-scale power plants. As discussed below, each of these technologies poses significant problems of land requirements.

Figure 2. Single axis tracking photovoltaic array, Nellis Air Force Base, Nevada

Figure 3. Model of parabolic mirror solar thermal array

Whether the fast-track time tables allow realistic assessment of the environmental impacts of such developments and whether the less damaging alternatives should be bypassed in the rush to the centralized power plant "solution" are the most important questions facing the public—the owners of the lands targeted for development.

Photovoltaic facilities consist of arrays of fixed or sun-tracking collector panels, with or without concentrating capability, which directly generate electricity (Fig. 2).

Solar-thermal (also called concentrating solar) technologies consist of either:

- parabolic troughs (Fig. 3), central power-towers (Fig. 4), and linear fresnel lenses, which heat a fluid to create steam for running conventional electricity-generating turbines, or
- parabolic or flat mirror devices that heat a gas whose expansion drives a piston generator (Fig. 5).

Figure 4. Aerial view of central power-tower solar thermal array, Daggett, California

Figure 5. Stirling heat engine devices

Life-cycle analysis of utility-scale solar power plants show that they are not "non-polluting" as generally proclaimed: photovoltaic panels yield toxic waste during production and at the end of their useful life, and solar energy does release some greenhouse gases (GHG).[1] The trough and power-tower technologies also require adequate water supplies, which are problematic in desert areas.

Grand, Grander, Grandiose

A Grand Solar Plan advanced in 2008[2] proposed a three-stage program of heavy federal investment in solar power plants, supposed to carry the nation through 2100 and beyond ($400 billion through 2050, more following). Including projected growth in energy demand, this level of solar development is designed to avoid the rigors of energy conservation, and allow continued high U.S. levels of energy consumption per person.

The 2008 plan calls for installing solar photovoltaic and solar thermal plants on 46,000 square miles of southwestern public lands by 2050—enough to provide 69% of anticipated electricity consumption and 35% of total energy consumption.[3] Projecting expansion of solar power plants to 2100 to reach the goal of providing 100% of electricity consumption from solar sources, and more than 90% of total energy consumption, would require 165,000 square miles of land—an area the size of California plus Maryland. To reach these goals the plan requires only modest contributions from distributed solar (e.g. rooftop photovoltaics), wind farms, geothermal, hydroelectric and other electricity-generating sources.

In 2009 some of the Grand Solar Plan, authors published an essentially identical paper, but in a more scientifically rigorous journal.[4] The 2009 plan accounts for a previously overlooked issue, the progressive loss of photovoltaic panel efficiency over time. To compensate for efficiency losses and achieve the 2008 Grand Plan goals for electricity and total power production, the 2009 publication requires periodic additions to the power plants' solar arrays, requiring additional land—a total of about 49,000 square miles by 2050 and 173,000 by 2100.

All these land use estimates are based on an assumed panel degradation rate of 0.5% per year. In fact, the actual rate of panel degradation is not known.[5]

The locations of southwestern lands suitable for utility-scale solar (and wind) developments are commonly far distant from existing power transmission lines. The extensive plans for developing solar power plants on southwestern U.S. lands thus require constructing an extensive system of connections, and add road-building projects to the Grand Plans' proposed consumptive land uses.[6] Unfortunately, solar power generates direct current (DC) electricity while the existing transmission grid dominantly carries high-voltage alternating current (AC). Conversion of DC to AC current in photovoltaic plants results in large energy losses, as much as 16%.[7] Transmitting high-voltage AC current over large distances incurs double the energy loss (22% or more) of high-voltage DC transmission (about 10% energy loss).

The age of existing transmission lines and power transformers—70% of are 25 years old or older is another major concern. In addition, 60% of circuit breakers are more than 30 years old. Lines, transformers, and circuit breakers—all are in imminent need of replacement. Not surprisingly, the grand plan visionaries also propose construction of a new nation-wide high-voltage DC transmission system, gobbling even more land.

A third very grand plan[8] calls for weaning the entire world from fossil fuels and replacing them with power produced from millions of large wind turbines, billions of rooftop photovoltaics, hundreds of thousands of tidal turbines, tens of thousands of solar power plants, thousands of geothermal plants, and hundreds of huge hydroelectric plants. This fantasy does not address the land use and political problems it would create.

The (Less) Grand Fast-Track Plan

The U.S Department of the Interior (DOI) has opened the door to accelerated development of renewable energy projects on public lands, even creating four new Bureau of Land Management offices (Renewable Energy Coordinating Offices) to fast-track development proposals.[9] A special initiative will study 24 Solar Energy Study Areas in six western states to establish their environmental suitability for large-scale solar energy production. The developments would occupy about 670,000 acres of mostly public lands, said to exclude "sensitive lands, wilderness, and other high-conservation-value lands."[10] The terms "sensitive" and "high-conservation-value" lands are not defined, but projects already in process of approval suggests the terms are applied very loosely.[11]

Figure 6. Nevada Solar One, parabolic mirror array, which truncates ephemeral drainages, including a large wash visible at nearest corner of array. Note that surface features and vegetation were eradicated within the array's footprint

Anyone familiar with desert topography and vegetation will quickly note that most depictions of proposed power plants are doctored photographs of the facility-to-be. In many such "artists' conceptions" the well-vegetated, stable landscape is air-brushed and colored to appear barren and lifeless, or is an artificial landscape made of cardboard. These depictions indicate that nothing living depends on these lands—they are not "sensitive" or "high-value". What better use than a power plant?

Two significant benefits accrue to developers who apply for projects on lands in any of the BLM's 24 Solar Energy Study Areas. The DOI and Department of Energy (DOE) will spend $22 million on the evaluations, making public funds pay for much of the work required for an EIS, which normally would be paid by a project proponent. Priority will be accorded to projects proposed for those lands. With the December 2010 deadline for obtaining stimulus funds rapidly approaching, BLM Director Bob Abbey affirmed the agency's guarantee of full environmental analysis and public review for fast-track projects.

The first large fast-track solar project proposal submitted is the Ivanpah Solar Electric Generating System, intended for a site on the east-facing flanks of Clark Mountain, California. If the draft EIS is any indication, the BLM's fast-track process guarantees superficial and incomplete analysis of the proposed developments' environmental consequences and their mitigations.

Because solar power plants require sites with less than three percent slope, alluvial valleys are the principal target areas in western deserts. The complex computer programs that continually reorient the sun-tracking mirror systems of photovoltaic arrays, and constantly refocus sun rays to heat the fluid containers of solar thermal plants, have a low tolerance for surface irregularities. Hence, surfaces corrugated by ephemeral washes on low-dipping and coalescing alluvial fans, are typically graded as closely as possible to a flat surface (Fig. 6). The results include destruction of the local ecosystems, and high increases of the risks from flooding and airborne dust and sand.[12]

Water Issues

Solar thermal power plants run conventional steam turbines to generate electricity. Steam is produced by concentrating solar radiation on water containers to heat water directly, or by heat exchange after super-heating special fluids with solar radiation. After passing through the turbines, the steam evaporative towers cool the steam, a process that loses 80% or more of the water to the atmosphere.[13] The remaining 20% or so of water may be recycled through the system.

Water for desert solar power plants will generally be pumped from groundwater. As a result, evaporated cooling water is not returned to the groundwater resource and is therefore consumed, like a mined metal. The amount of water consumed by solar-thermal systems using recirculating cooling systems (measured in gallons per million watt hours of electricity generated: g/MWh), is quite large. For example, plants that heat water with parabolic troughs use 760 to 920 gallons/MWh/year.

The 64 MW Nevada Solar One plant, a parabolic trough plant using water cooling, is said to produce 134,000 MWh/year. It would require between 300 and 400 acre feet of cooling water/year, and would consume more than 80% of that water. The nine SEGS parabolic trough power plants (total capacity 354 MW) consume between 1,840 and 2,230 acre feet of water/year or more to generate about 987,000 MWh/year in the Mojave Desert.[14] These plants use natural gas for generating electricity at night, so their solar efficiency is substantially lower than implied by the amount of power they produce annually.

BLM has rightfully expressed concern over the potentially high water consumption of power generating plants in desert locations. Assessing the availability of groundwater for cooling will likely be needed for most solar thermal projects in the southwest, but the agency promises only that "It will be analyzed closely to the extent that we have information available to us." Adequate information on long-term groundwater sufficiency is rarely available, and there is no guarantee that this critical information will really be obtained, and no information about who would pay for it.

If groundwater information is not now in hand, due to the short time frame for completing the process it's highly likely that a credible assessment will be made for any Fast-Track project that requires groundwater for cooling. This challenges BLM Director Bob Abbey's assertion of appropriate environmental review and adequate time for public review of fast-track projects; clearly the time, funds, and staff to perform adequate analysis of potential impacts all are insufficient and the agency is running on empty when it comes to knowledge of water supply and consumption.

Rather than using fresh water, where proximity to waste water treatment plants allow it, some solar projects propose using municipal treated wastewaters for cooling. This alternative has a significant problem: evaporative cooling is a distilling process, so the low volatility contaminants remaining in treated waste water will become concentrated in the residual cooling water. When this water is reused in the plant steam cycle, its contamination levels will progressively increase, possibly reducing cooling efficiency.

Dry cooling is an option, but it costs 5 to 10% more than wet cooling. Dry cooling also reduces plant efficiency of power tower plants by as much as 3%, and of trough plants by as much as 5%. Ambient conditions also affect the costs, such that dry cooling is more expensive under drier local climatic conditions.

Deceptive Performance Reports

Estimates of required acreage for the various grand solar plans are based on assumptions about the nature of collector arrays, and the efficiencies of various collector devices and arrangements. The simplest type of array is flat panel PV fixed in orientation to maximize solar radiation input at one (short) daytime period. The only unused spaces (in terms of receiving solar radiation) are access routes for maintenance. The total array efficiency includes the amount of available solar radiation in the entire power plant operational area. Sun tracking by collector arrays makes more efficient use of the sun striking the panels, but has more unused space between panels, to prevent the shading effects of closely adjacent panels.

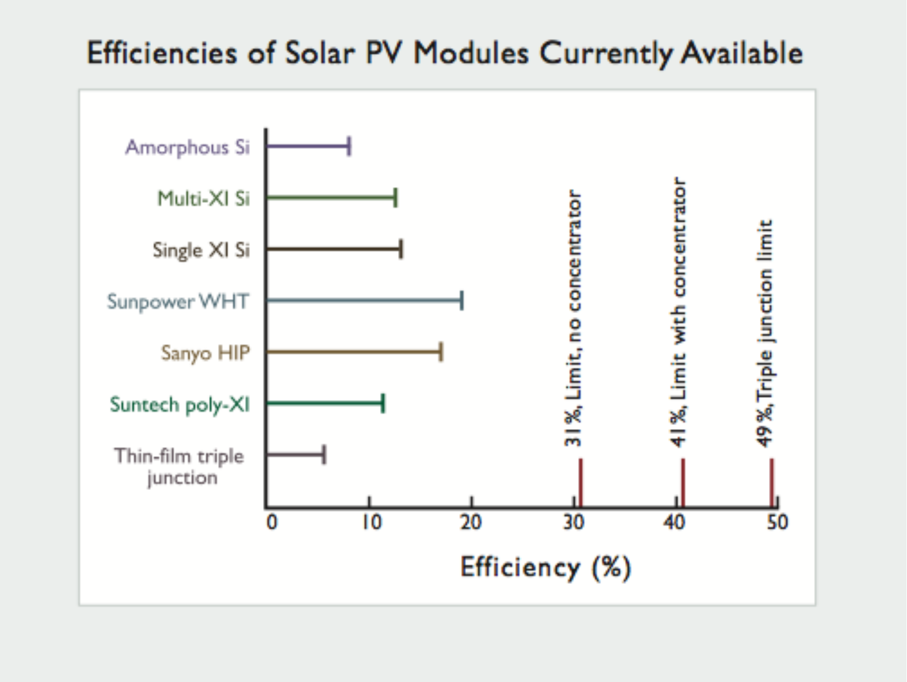

Figure 7. Modified from David JC MacKay, Endnote 7.

A plant is assigned a "nameplate" capacity for generating electricity, given in millions of watts (megawatts, or MW). The nameplate (optimum) capacity is routinely reported by government agencies and the media, translated as numbers of homes the facility can provide with electricity. Estimates of plant efficiencies, usually from a site proponent, convert the misleading capacity figures into deliberate deception.

But the capacity rating emphatically is not the level of power that the plant is capable of producing on a daily basis for a year—including nights, cloudy days, shutdowns for maintenance, and the like. It represents only the optimum level of power that the system can produce at "high noon" on a sunny day (sometimes at the equator).

The assumed efficiency, expressed as a percentage of nameplate capacity, supposedly accounts for all those awkward times (noted above) when the system is producing little or no electricity. A believable number has to come from actual production, not undocumented models, but actual data are hard to come by. The same applies to actual water consumption by solar thermal power plants. For the actual annual production of a solar power plant to meaningfully apply to the solar benefit, it must exclude power produced at night with fossil energy sources (natural gas).

The efficiencies of various commercially available panels of PV cells are shown in Fig. 7.[15] The industry's hopes for greater efficiencies are invested in technological improvements to enhance the use of solar radiation by fixed and tracking panels. Much research is underway using exotic materials, of low abundance in the Earth, to boost cell efficiency. In spite of their rarity, these materials are supposedly available for the long term.

Another arm of research hopes to reduce the cost of PV panels. Thin-film technology using cadmium-telluride cells is leading the commercial field. The Cd-Te formula is much cheaper than silicon-based cells, but is also less efficient by a substantial factor. It also and depends on supply of tellurium and cadmium, both rare in the Earth's crust.[16]

Alternatives to Utility-Scale Solar

Several imperatives support a range of alternatives for increasing solar-generated electricity and avoid the enormous environmental costs of remote power plant and transmission line construction on and across little-disturbed land in the southwestern deserts. Alternatives include: distributed solar power on rooftops throughout southwestern cities, siting solar plants in decayed urban settings, supporting passive solar building and retrofitting, and other incentives for reducing per capita energy use. All can accomplish the goals of grand solar plans—reducing consumption of fossil fuels and GHG emissions—with less recourse to bureaucratic contortion or technical deceptions.

The economics of full rooftop development can be greatly eased by fast-growing innovative financing that makes it easy for property owners to tap into clean distributed energy.[17] Distributed solar thermal, mainly for hot water, has been used for many years and is expanding. It can also be used as a means of storing energy for times of low solar availability. PV on commercial and residential rooftops is underway on a relatively small scale, but a national study of commercial and residential rooftop availability for grid-connected solar PV found ample potential to supplant a major portion of current and anticipated electricity consumption in the U.S.[18]

A review of this study, as presented to the DOE by the Energy Foundation (March 1, 2005), states "Rooftop space is not a constraining factor for solar development. Residential and commercial rooftop space in the U.S. could accommodate up to 710,000 MW of solar electric power (if all rooftops were fully utilized, taking into account proper orientation of buildings, shading from trees, HVAC equipment and other solar access factors). For comparison, total electricity-generating capacity in the U.S. today is about 950,000 MW."

Brownfields—lands in and close to urban areas that are contaminated by previous industrial uses, closed landfills, or other under utilized lands—could provide additional distributed solar power development opportunities. In 2005 The Government Accountability Office estimated 450,000 to 1 million brownfields in the U.S.[19] Unfortunately the size of those areas are not known, but the DOI has estimated that 22% of current electricity demand can be generated on brownfields.

Such lands could be used for small solar thermal or PV power plants, needing only short distance transmission to industrial and residential users.

Wind farms, if placed in Midwestern farmlands of gentle terrain, can add substantially to a renewable, low-impacting energy mix, but will not ameliorate transmission problems.

Of 218 industrially developed countries, the U.S. ranks #9 in per capita consumption of electricity, using twice the electricity per person of residents of the EU. These figures show a major opportunity for reducing consumption along with lessening the need for additional power plants.

In the U.S., buildings account for 72% of electricity consumption and 39% of total energy use. Energy consumption by buildings coughs up 38% of the nation's CO_2 emissions, uses 42% of raw materials, puts out 30% of our huge waste product, and uses 14% of potable water. Significant advances have been made in understanding how to construct buildings to consume much less energy. Proper building and refitting of these structures can go far to meeting the goals of solar grand planners.[20]

Better Ways

Americans yearning for alternatives to coal, oil, and nuclear power, really know very little about the performance of solar power plants in our southwestern deserts, because credible information is difficult to come by. Most serious is the scanty amount of believable information on existing power plant performance. A Google search on the internet readily demonstrates the paucity of information sources.

The ecosystem damage and soil loss caused by grading desert surfaces to build solar plants in the western deserts will be very long lasting. Long-term desert re-vegetation studies, based on well-described plots, show that surface stabilizing plant growth may be reestablished in several decades, but reestablishing plant diversity and soil, if even possible, will likely take millennia.[21] Eliminating ephemeral drainages on portions of alluvial fans will cause progressive long-term deterioration of downslope vegetation outside of the power plant limits.[22]

Additional downsides come from manufacturing PV cells and panels, employing a great variety of toxic materials. Some of them inevitably are released into the soil, water and air supply. A larger problem arises from the toxics in PV plant components. The solar collectors can constitute a witches brew of toxins, such as arsenic, cadmium telluride, hexafluorethane, lead, chromium-VI, selenium compounds, gallium arsenides, polyvinal fluoride, and bromated flame retardants.

The problems of PV efficiency degradation and contribution to the nation's enormous waste problems apply equally to utility-scale solar power plants and rooftop solar. Potential pollution from carelessly disposing of waste PV panels may be worsened by the growing use of nanoparticle technologies.[23] The EU is apparently well ahead of the U.S. in eliminating toxic materials from PV construction, to ameliorate waste disposal problems. But of the millions of tons of electronic waste that the U.S. generates annually, only 10 to 15% is recycled The remaining 85 to 95%, with all the toxic components, is mostly buried in landfills, incinerated, or shipped overseas for salvaging, where environmental laws are less stringent.

From shame alone, our per capita electricity consumption should make us find ways to reduce demand. EU residents use less than half the electricity of U.S. citizens, but appear to have standards of living that do not look poor in comparison. Improving our consumption takes only the will to do so. For residential rooftop PV, the slow progressive loss of efficiency might even have the salutary effect of allowing adaptation to reduced energy availability.

There is no doubt that implementing a major distributed solar program would be difficult politically, but should not be difficult economically. Political obstacles come from bypassing the control of utilities over electricity distribution. The main questions are whether such approaches are feasible and timely.

Acknowledgments

John Rosenblum and Jane Nielson provided helpful reviews

Endnotes

1. Solar and wind energy are commonly called non-polluting because their electricity producing operations do not release GHG. But the plants' entire lifecycle, including extraction, transport, and processing of materials for manufacturing solar collectors and ancillary equipment and processing and disposal of wastes, certainly does produce GHG. The same is true for wind turbines and towers. Although the level of GHG emissions from solar PV are much smaller than those of fossil fuel generation, there is no real gain without reducing electricity consumption (V. M. Fthenakis and H. C. Kim, Greenhouse-Gas Emissions from Solar-Electric and Nuclear Power: A Life-Cycle Study, *Energy Policy* 35:2549-2557, 2007)

2. Ken Zweibel et al., A Solar Grand Plan, *Scientific American*, January 2008, 64-73

3. The article referenced gives confusing figures on land demands for reaching 2050 goals, first saying 30,000 square miles of photovoltaic plants, then 46,000 square miles of PV and concentrated solar plants.

4. Vasilis Pthenakis et al., The Technical, Geographical, and Economic Feasibility for Solar Energy to Supply the Energy Needs of the US, Energy Policy 37:387-399 (2009)

5. C. R. Osterwald and T. J. McMahon, History of Accelerated and Qualification Testing of Terrestrial Photovoltaic Modules: A Literature Review, *Progress in Photovoltaics Research and Application*, 17:11-33 (2009); see also C.R., Osterwald, et al., Degradation Analysis of Weathered Crystalline-Silicon PV Modules, *Proceedings of the 29th IEEE PV Specialists Conference*, New Orleans, Louisiana, USA, p. 1392–1395 (2002)

6. The BLM Fast-Track Renewable Energy Projects has approved seven such transmission line projects. A project not on this list but addressing the same goals, the Sunrise Powerlink Transmission Project, is already well on its way to approval. This is a 70-mile long high-voltage line linking potential solar plants in Imperial Valley to San Diego. Powerlines involve extensive road and tower pad construction with environmental impacts extending well beyond the road limits (H. G. Wilshire et al., *The American West at Risk: Science, Myths, and Politics of Land Abuse and Recovery* (New York, Oxford University Press, 2008), Chapter 5.); the roads remain permanent fixtures for maintenance purposes such as periodic washing of insulators for dust removal.

7. David JC MacKay, *Sustainable Energy – Without the Hot Air* (Cambridge, England, UIT Cambridge Ltd., 2009), p. 40

8. M. Z. Jacobson and M. A. Delucchi, A Path to Sustainable Energy By 2030, *Scientific American*, November 2009, 58-65

9. The BLM Fast-Track Renewable Energy Projects: http://www.blm.gov/wo/st/en/prog/energy/renewable_energy/fast-track_renewable.html lists 14 solar power plants occupying 60,289 acres of public lands; 7 wind projects occupying 53,575 acres of public lands; 6 geothermal projects, 3 of which will occupy 19,912 acres of public lands, and 7 interconnect transmission lines with total length of 1,076 miles occupying 26,085 acres of public lands (ROW 200 feet wide). The total public land area for these projects is 250 square miles.

10. BLM News Release, Secretary Salazar, Senator Reid Announce 'Fast-Track' Initiatives for Solar Energy Development on Western Lands.

11. For example, the Ivanpah Solar Electric Generating System, Draft Final Staff Assessment and Draft Environmental Impact Statement. The Final Staff Assessment is by the California Energy Commission, lead agency for the California Environmental Quality Act. Excellent descriptions and photographs of the Ivanpah site and many other proposed solar power plants and wind farms in the desert are provided by Basin and Range Watch, http://www.basinandrangewatch.org/

12. A USGS study of a 15,000 square mile strip in the central Mojave Desert found that about 48% has slopes less than 5%, and 8.3% (about 1,300 sq. mi.) has slopes of less than 1%, the most desired topography for solar power plants. However, deposits underlying 98% of this land are prone to yield airborne sand and dust, especially when disturbed, and 89% are susceptible to flooding (D. R. Bedford and D. M. Miller, Assessing the Geology and Geography of Large-Footprint Energy Installations in the Mojave Desert, California and Nevada, in Natural Resouirce Needs Related to Climate Change in the Great Basin & Mojave Desert: Research, Adaptation, Mitigation, *U.S. Geological Survey* Workshop, April 20-22, 2010, Las Vegas, Nevada, Poster)

13. John Rosenblum, "Solar Cogeneration Systems for Industry: Design and Investment Analysis," Ph.D. thesis, Stanford University, 1986

14. Water use data from U.S. Department of Energy, Interdependency of Energy and Water, Report to Congress, December 2006, Table V-1; Nevada Solar One generation data from Natural Resources Defense Council, Energy Facts: Solar Trough, 2008; generation data for SEGS I-IX plants from Solar Paces, http://www.solarpaces.org//csp_Technology/docs/solar/_trough.pdf

15. MacKay, Sustainable Energy, Technical Chapter D

16. Tellurium is extremely scarce now and cadmium very scarce. Demand for both is nearly certain to exceed supply by 2030 (Chris Clugston, Increasing Global Nonrenewable Natural Resource Scarcity: An Analysis, *The Oil Drum*, April 6, 2010)

17. Cisco DeVries, Everything You Need to Know About Berkeley's Innovative Rooftop Solar Program, *Grist*, 3 November 2009; Cisco DeVries, How Innovative Financing Is Changing Energy in America, *Grist*, 27 January 2010; see also Christopher Mims, The No-Money-Down Solar Plan, *Scientific American*, December 2009, 50-51

18. J. Paidipati, et al, Rooftop Photovoltaics Market Penetration Scenarios, *National Renewable Energy Laboratory*, Subcontract Report NREL/SR-581-42306, 2008

19. U.S. Government Accountability Office, *Brownfields Redevelopment: Stakeholders Report That EPA's Program Helps to Redevelop Sites, but Additional Measures Could Complement Agency Efforts*, GAO-05-94 (Washington, D.C.: December 2, 2004)

20. U.S. Green Building Council, Green Building Research, 2010. http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1718

21. R. H. Webb et al., Perennial Vegetation Data From Permanent Plots on The Nevada Test Site, Nye County, Nevada, U. S. Geological Survey Open-File Report 03-336 (2003)

22. W. H. Schlesinger, and C. S. Jones. 1984. The Comparative Importance of Overland Runoff and Mean Annual Rainfall to Shrub Communities of the Mojave Desert. *Botanical Gazetteer* 145:116-124, W. H. Schlesinger, et al. 1990. Biological Feedbacks in Global Desertification. *Science* 247: 1043-1048, Wilshire et al. The American West at Risk, Chapter 5

23. Dustin Mulvaney et al., Toward a Just and Sustainable Solar Energy Industry, *Silicon Valley Toxics Coalition*, White Paper, January 14, 2009