U.S. DEPARTMENT OF ENERGY
Energy Efficiency & Renewable Energy

Solar Energy: Impacts & Management Measures

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Wildlife Society 17th Annual Conference, October 4, 1010, Snowbird, UT

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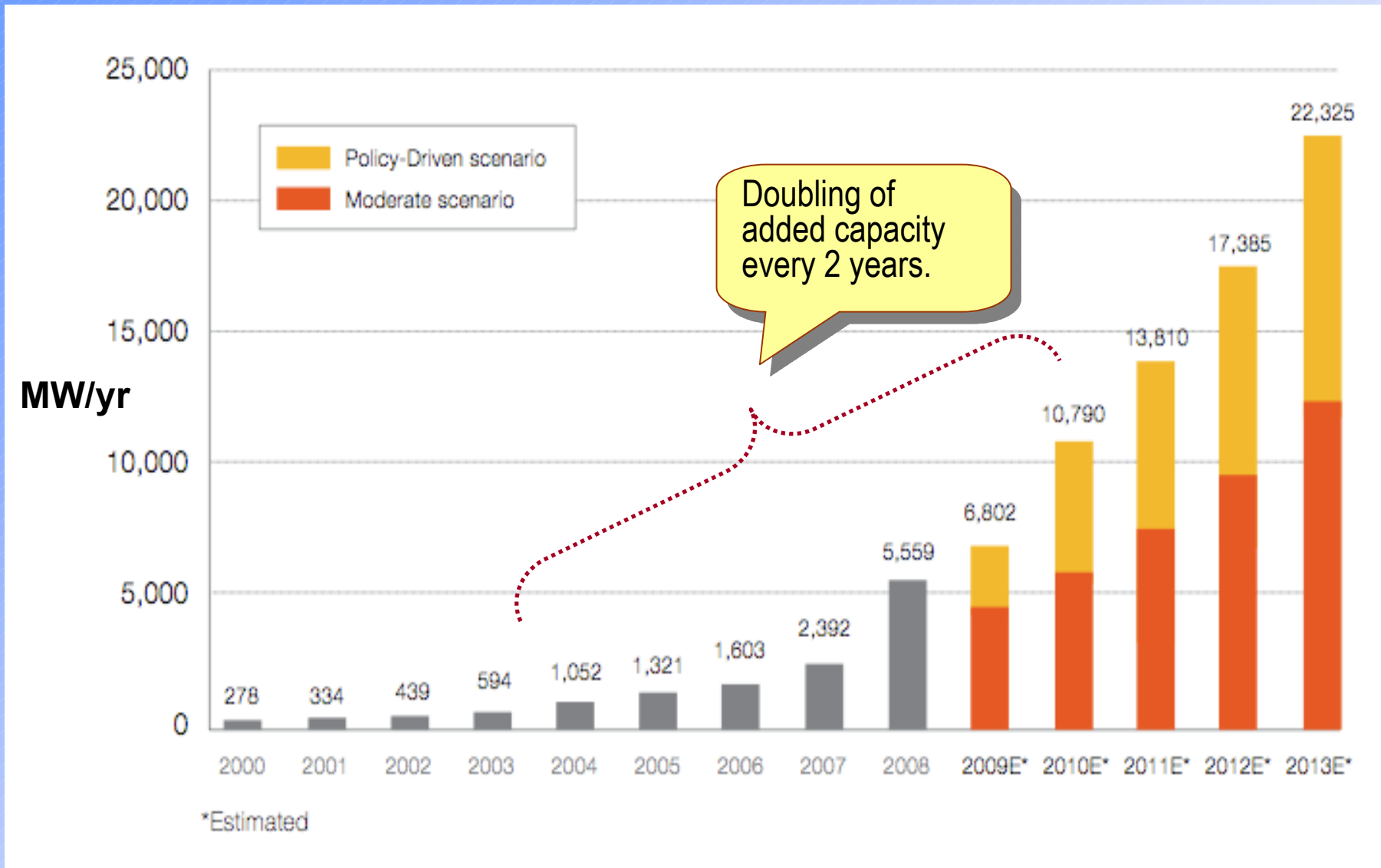
BROOKHAVEN NATIONAL LABORATORY

Outline

- Photovoltaics status & potential
- Life-cycle environmental impacts & comparisons with other power generation
  - Energy use
  - Emissions
  - Land use
  - Endangered species protection

Photovoltaic Global Sales and Projections



Source: PV Market Outlook European Photovoltaic Industry Association 2009

Projected PV Growth and Electricity Price Targets

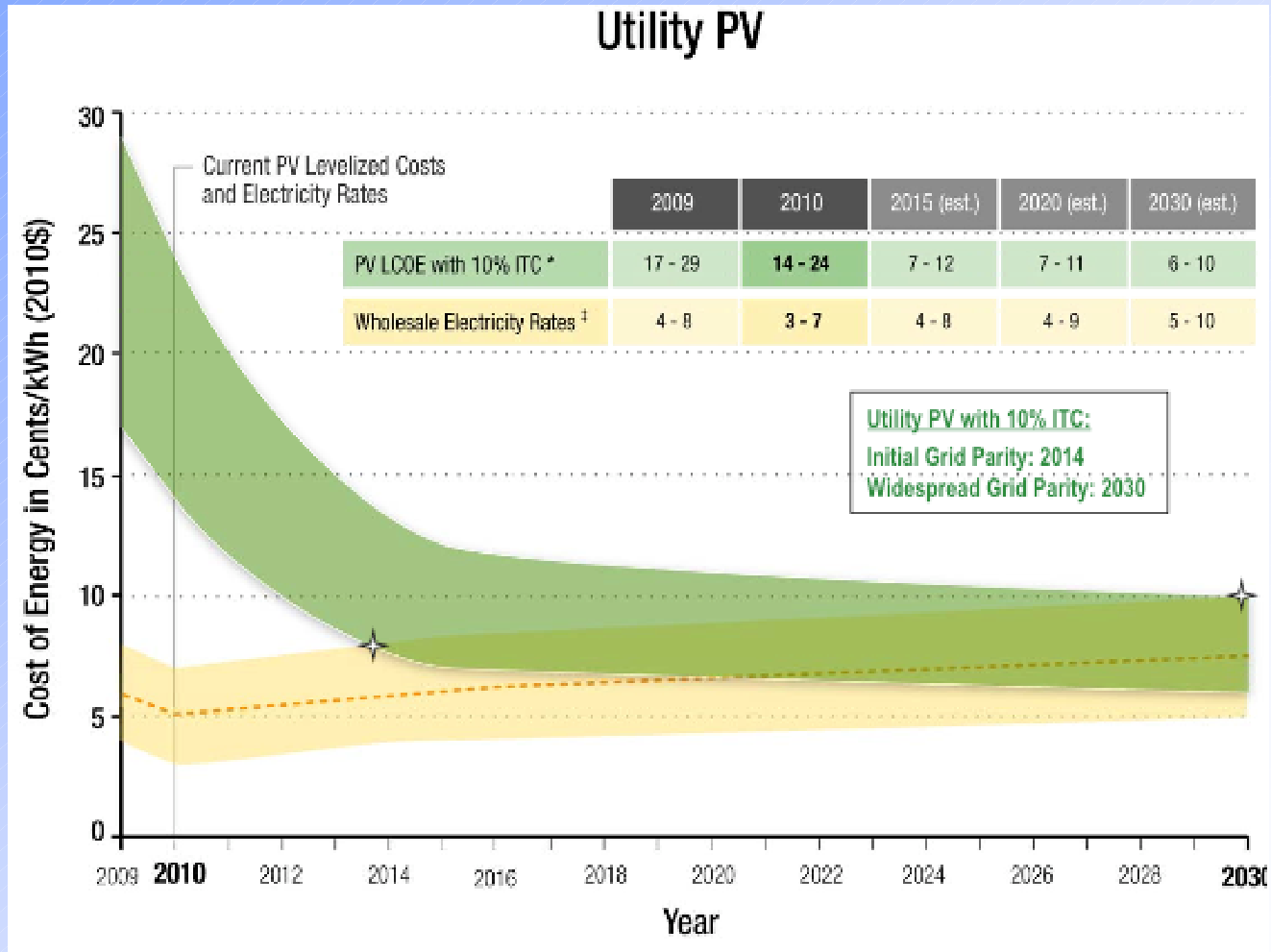
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Geographic Locations

Phoenix, AZ
Kansas City, MO
New York, NY

Financing Conditions

Low: 8.2% after-tax WACC
High: 9.9% after-tax WACC



•Assumes IOU or IPP ownership of PV, and thus the LCOE includes the taxes paid on electricity generated. Includes 5-yr MACRS but not state or local incentives.

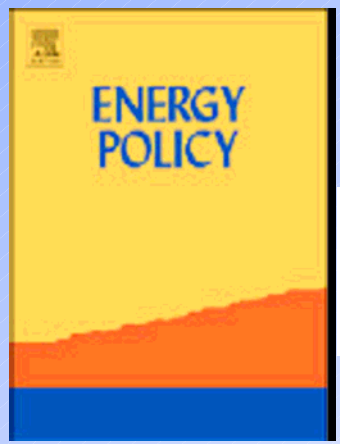
For a complete list of assumptions see DOE Solar Cost Targets (2009-2030), in process.

Source: J. Lushetsky, Solar Technologies Program, DOE, 25th EUPV, Valencia, Spain, Sept. 2010

A Solar Grand Plan beyond 2030

By 2050 solar power could free the U.S. from foreign oil and slash greenhouse emissions.

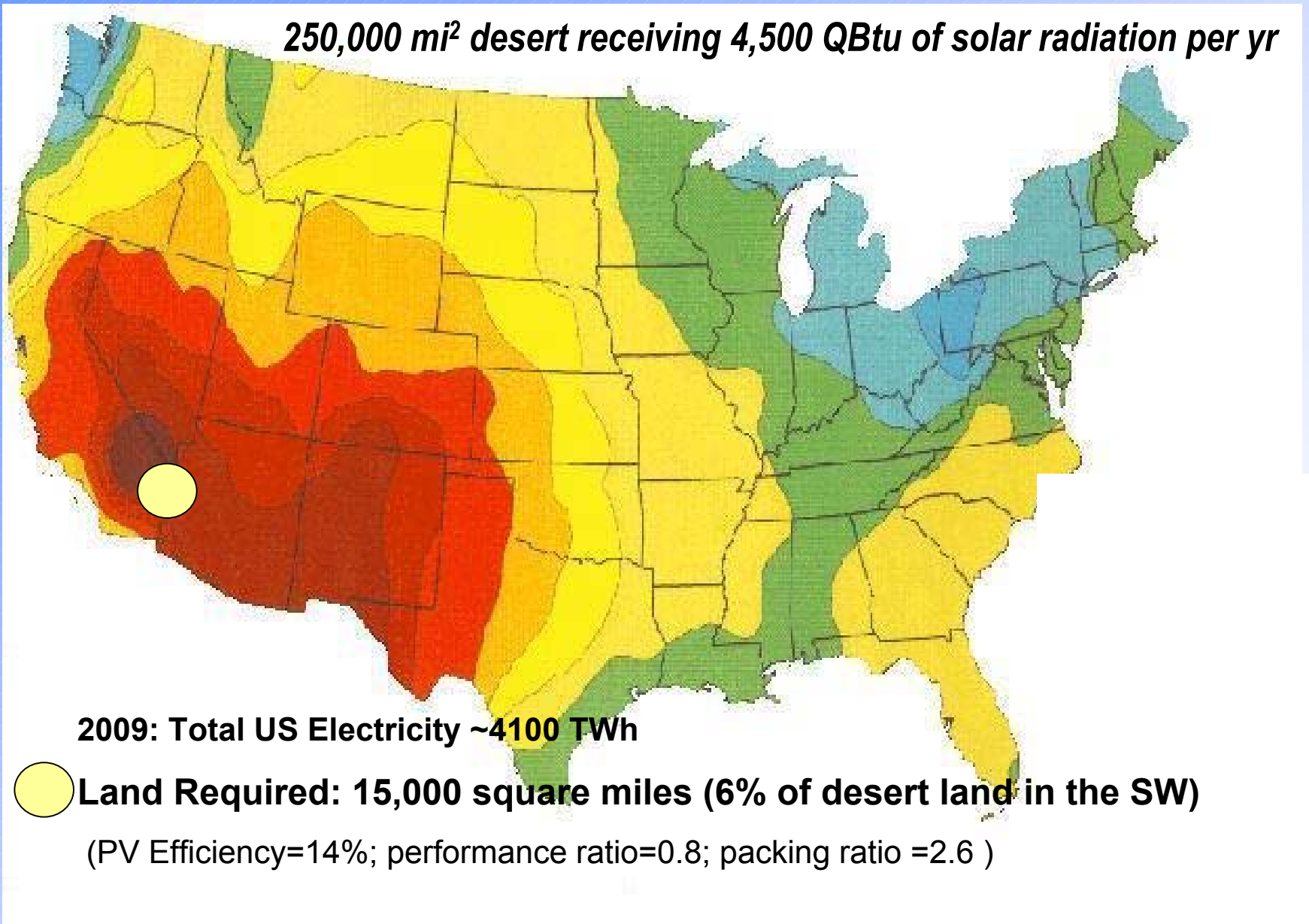
Renewable energy to supply 69% of U.S. Needs



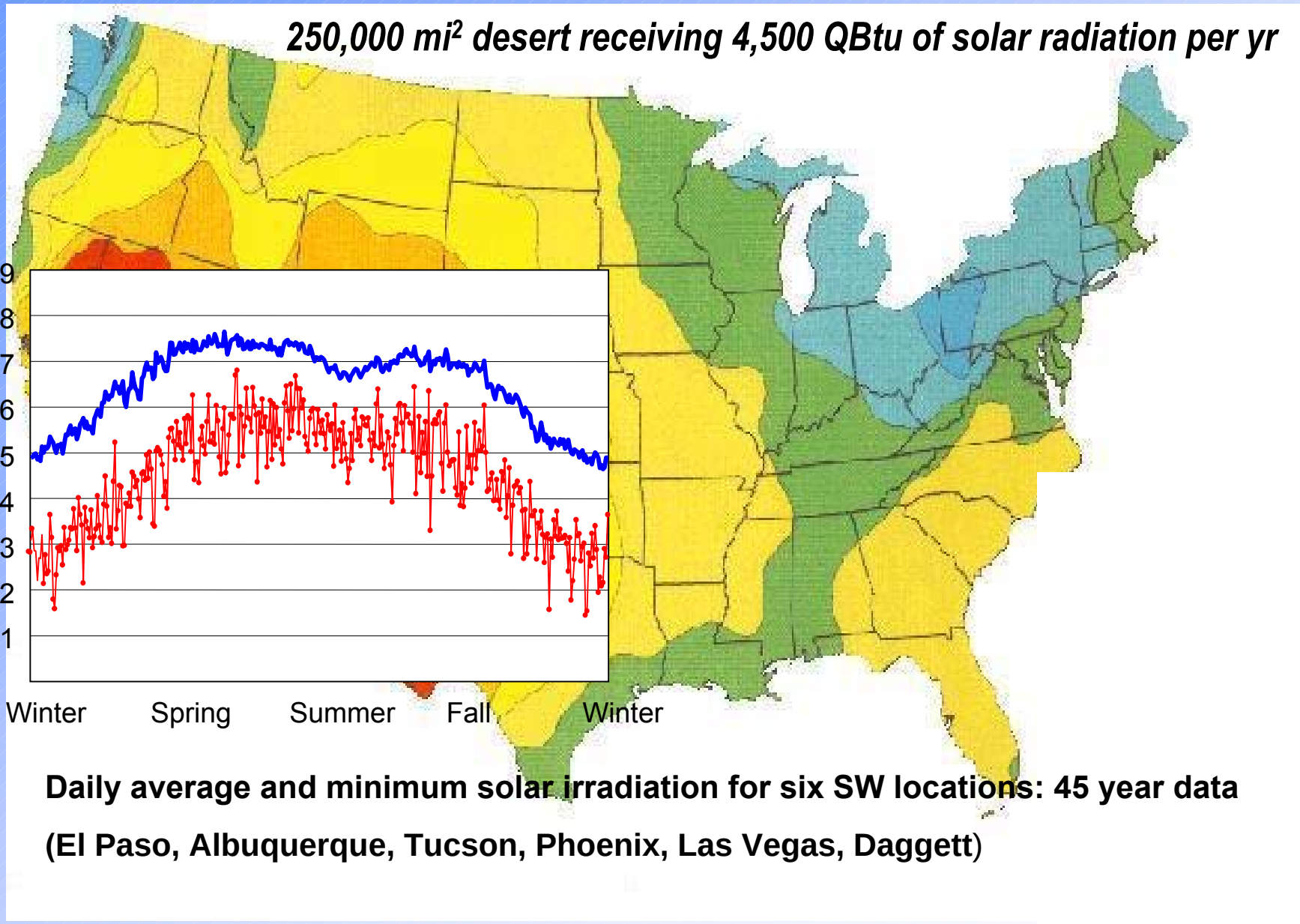
The technical, geographical, and economic feasibility for solar energy to supply the energy needs of the US

Vasilis Fthenakis James E. Mason Ken Zweibel *Energy Policy* 37 (2009)

Solar Irradiation and Desert Lands are Abundant



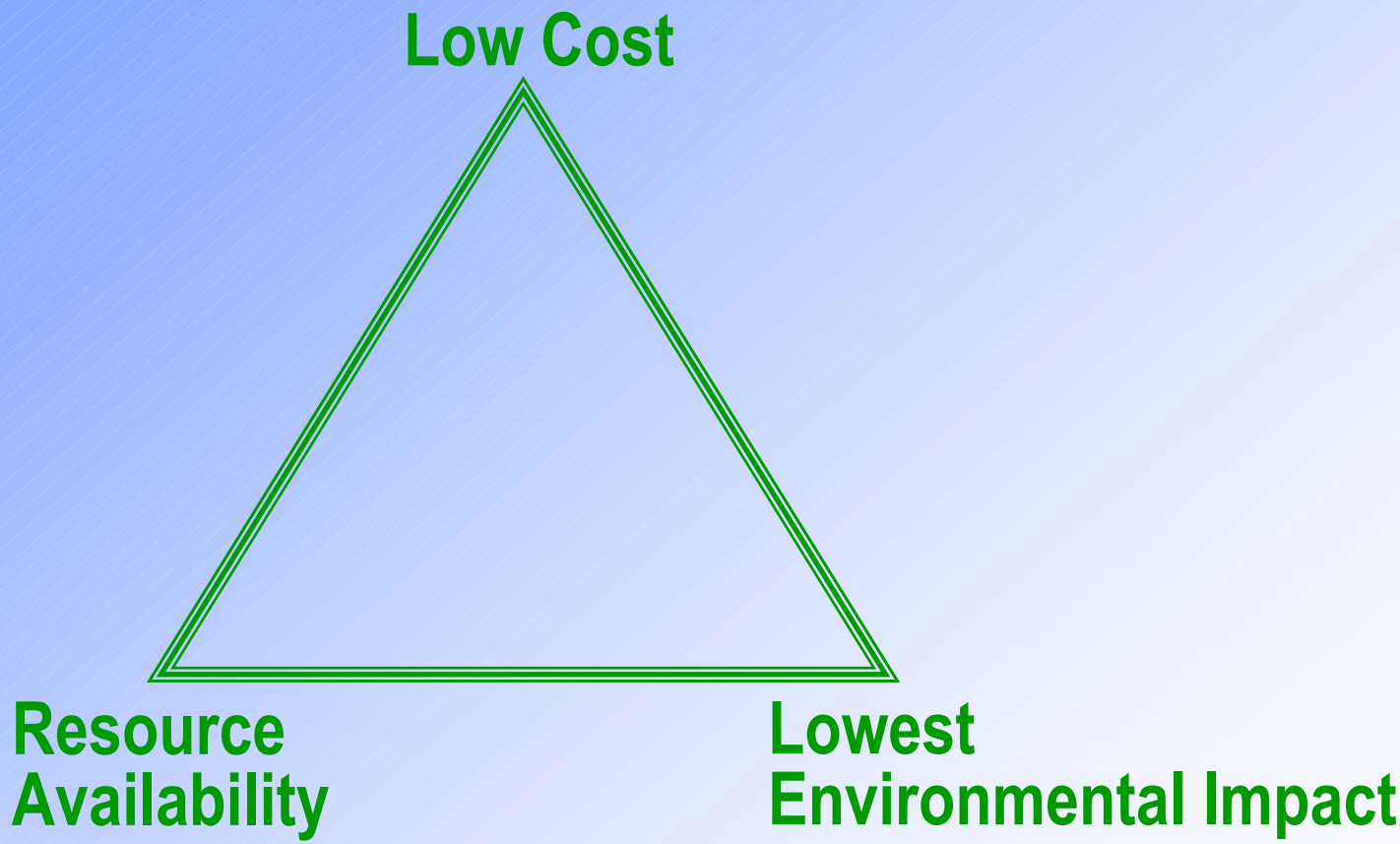
Consistent Solar Energy from SW in the Winter



Daily average and minimum solar irradiation for six SW locations: 45 year data

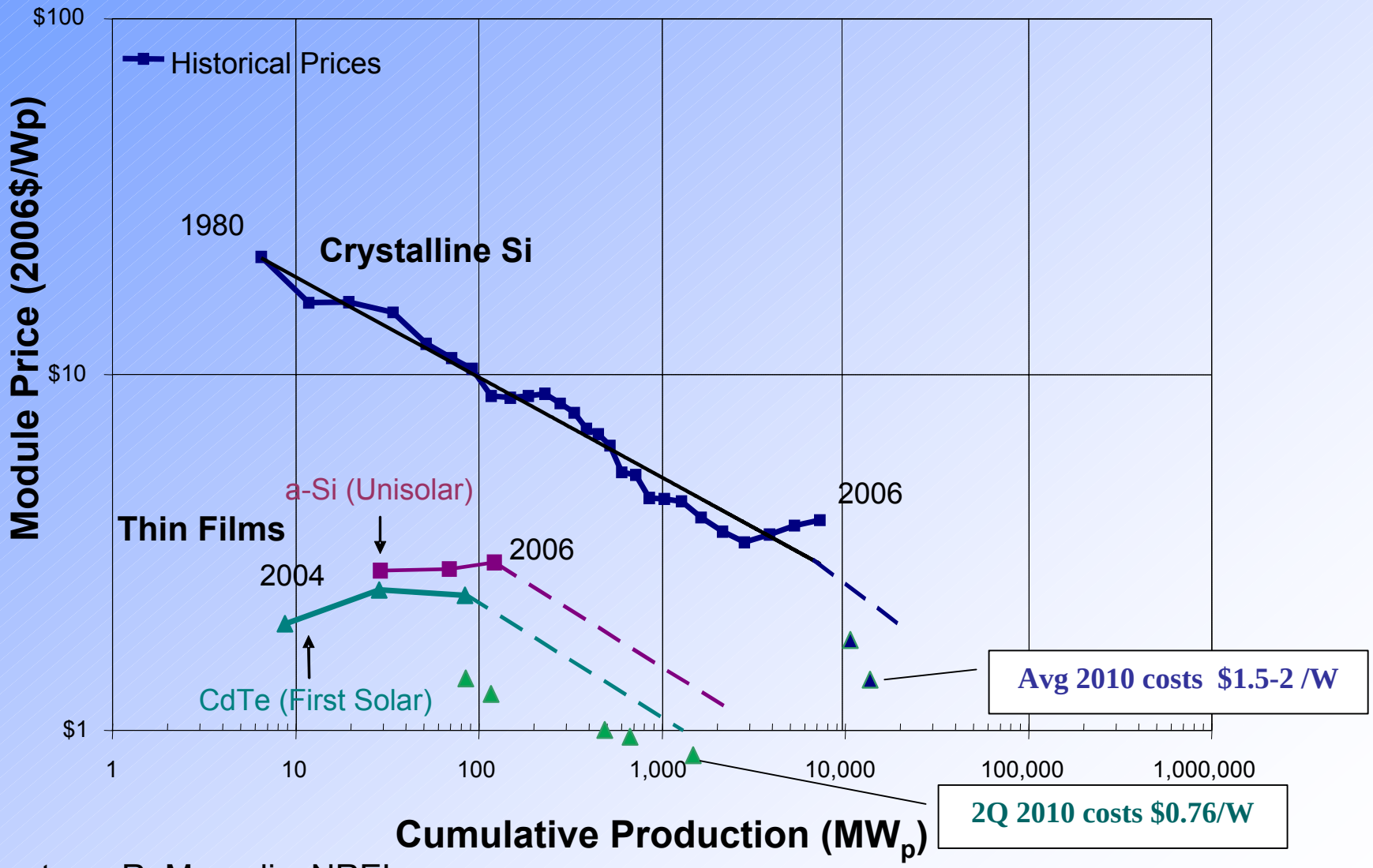
(El Paso, Albuquerque, Tucson, Phoenix, Las Vegas, Daggett)

Photovoltaics –Sustainability Criteria



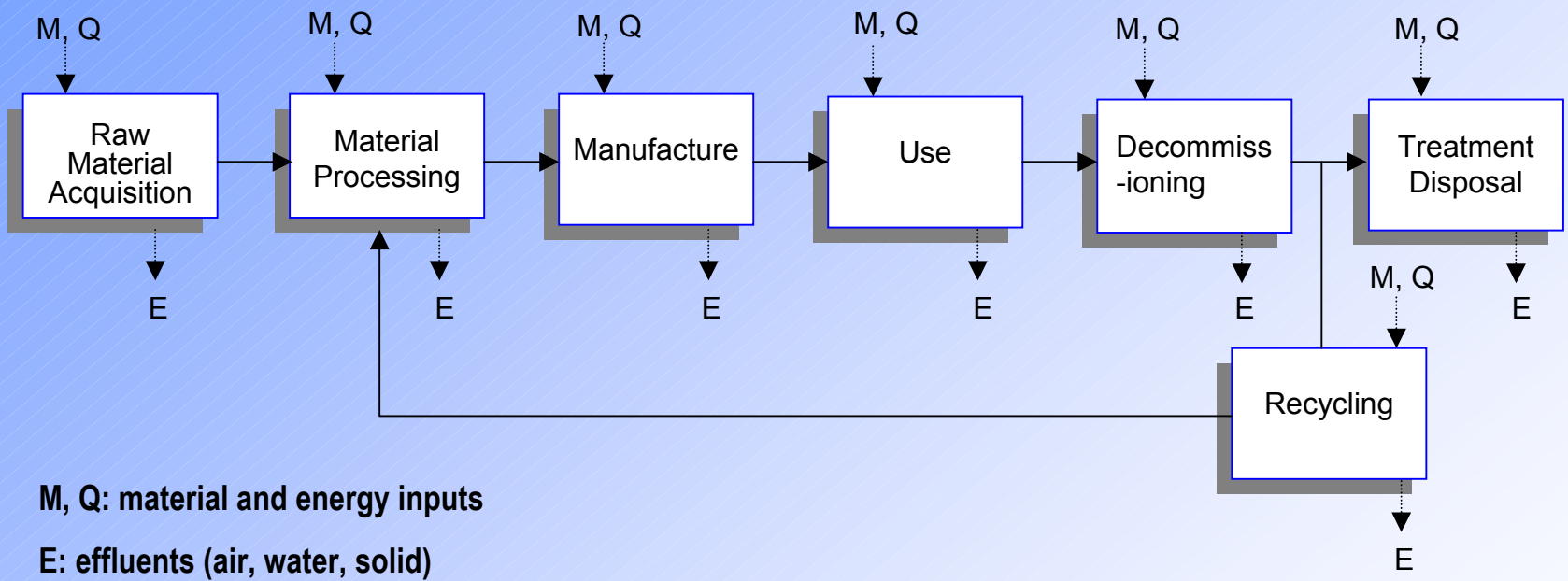
Affordability - Cost Reductions

Prices and Production Costs of PV Modules



Courtesy R. Margolis, NREL
Update V. Fthenakis

Life Cycle Environmental Impacts

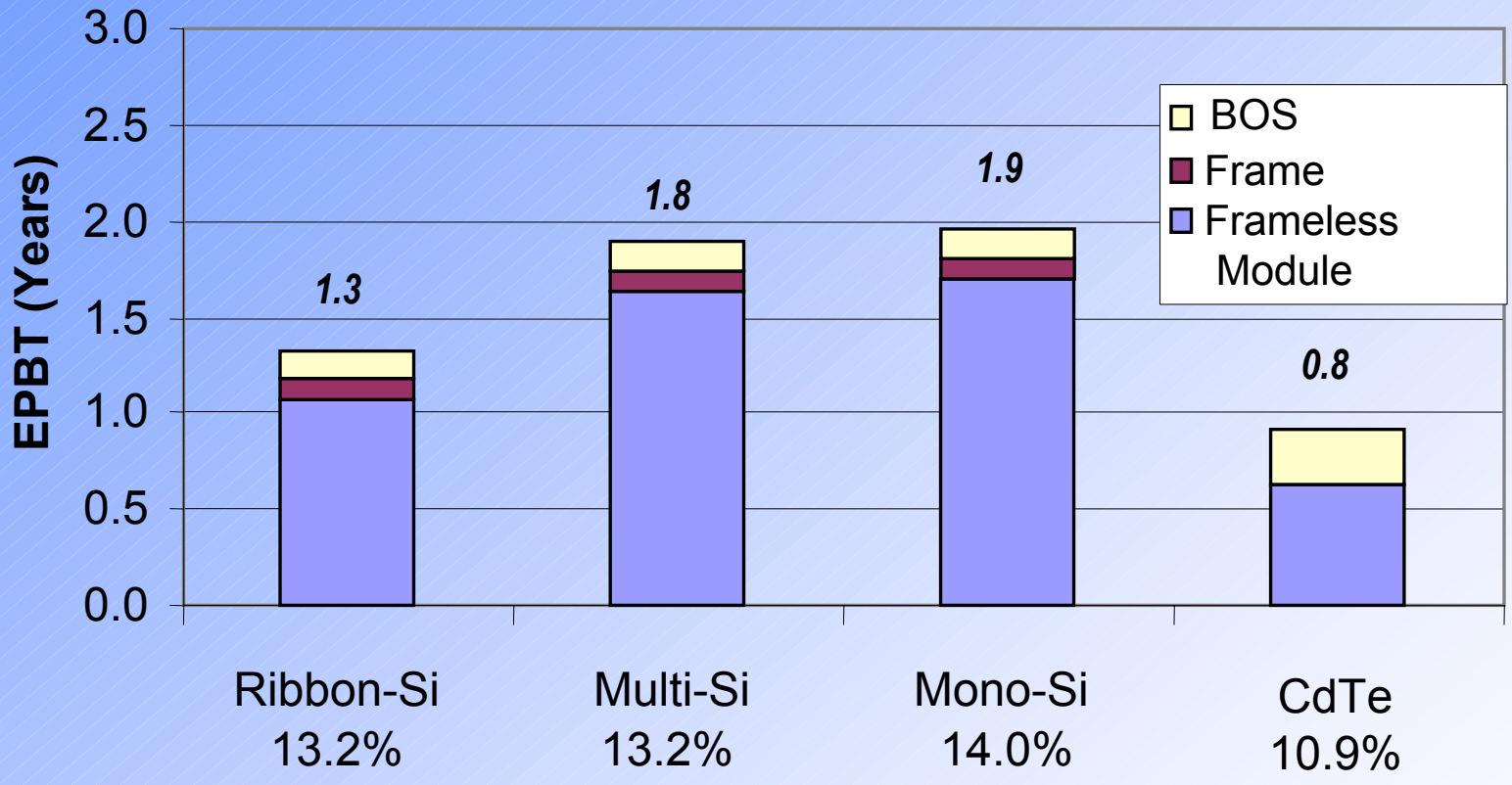


M, Q: material and energy inputs

E: effluents (air, water, solid)

Energy Payback Times (EPBT)

Insolation: 1700 kWh/m2-yr

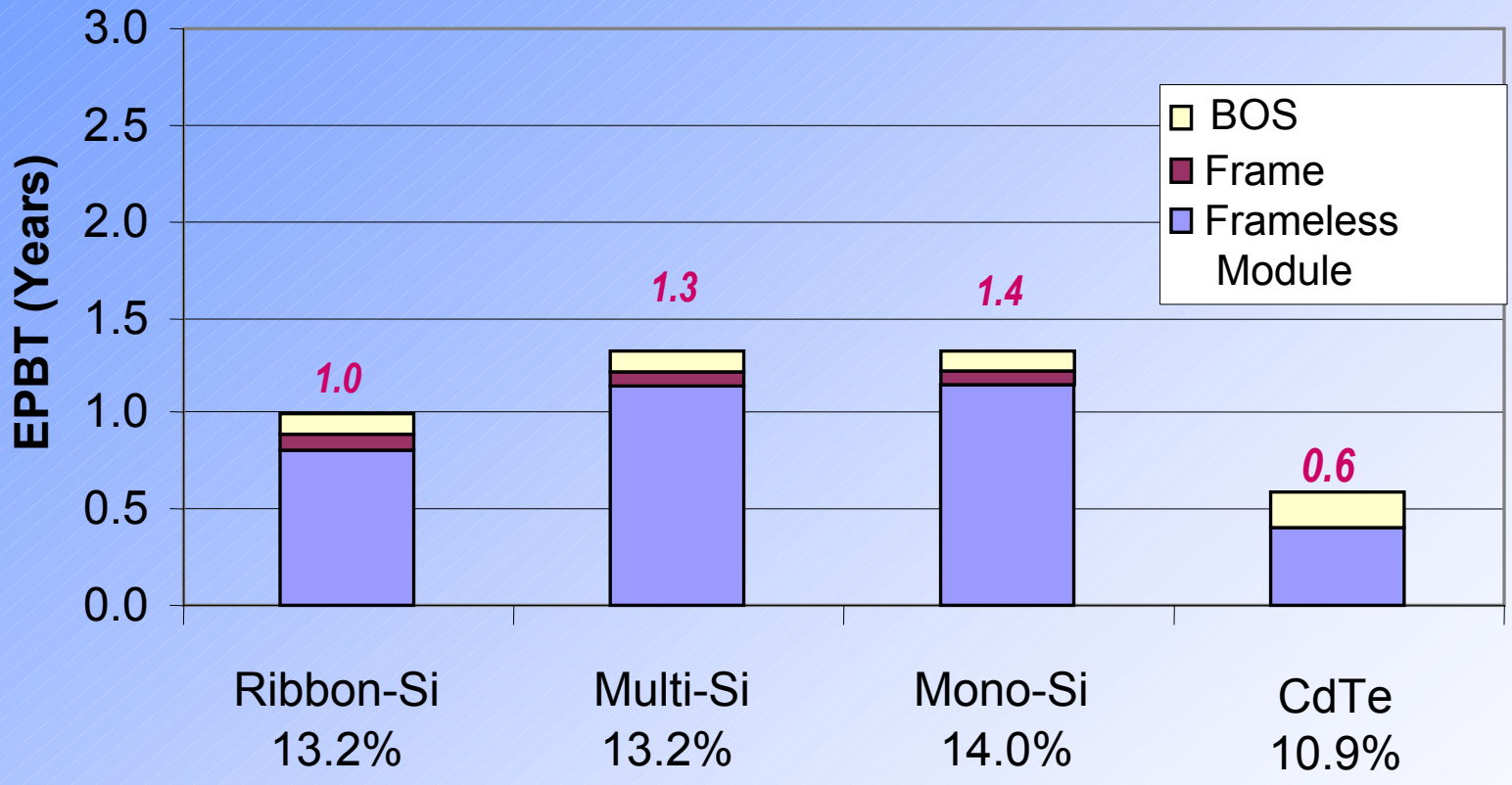


Based on data from 13 US and European PV manufacturers

deWild 2009, *EUPV, 2009*
Fthenakis et al., *EUPV, 2009*

Energy Payback Times in the US-SW

Insolation: 2300 kWh/m2-yr

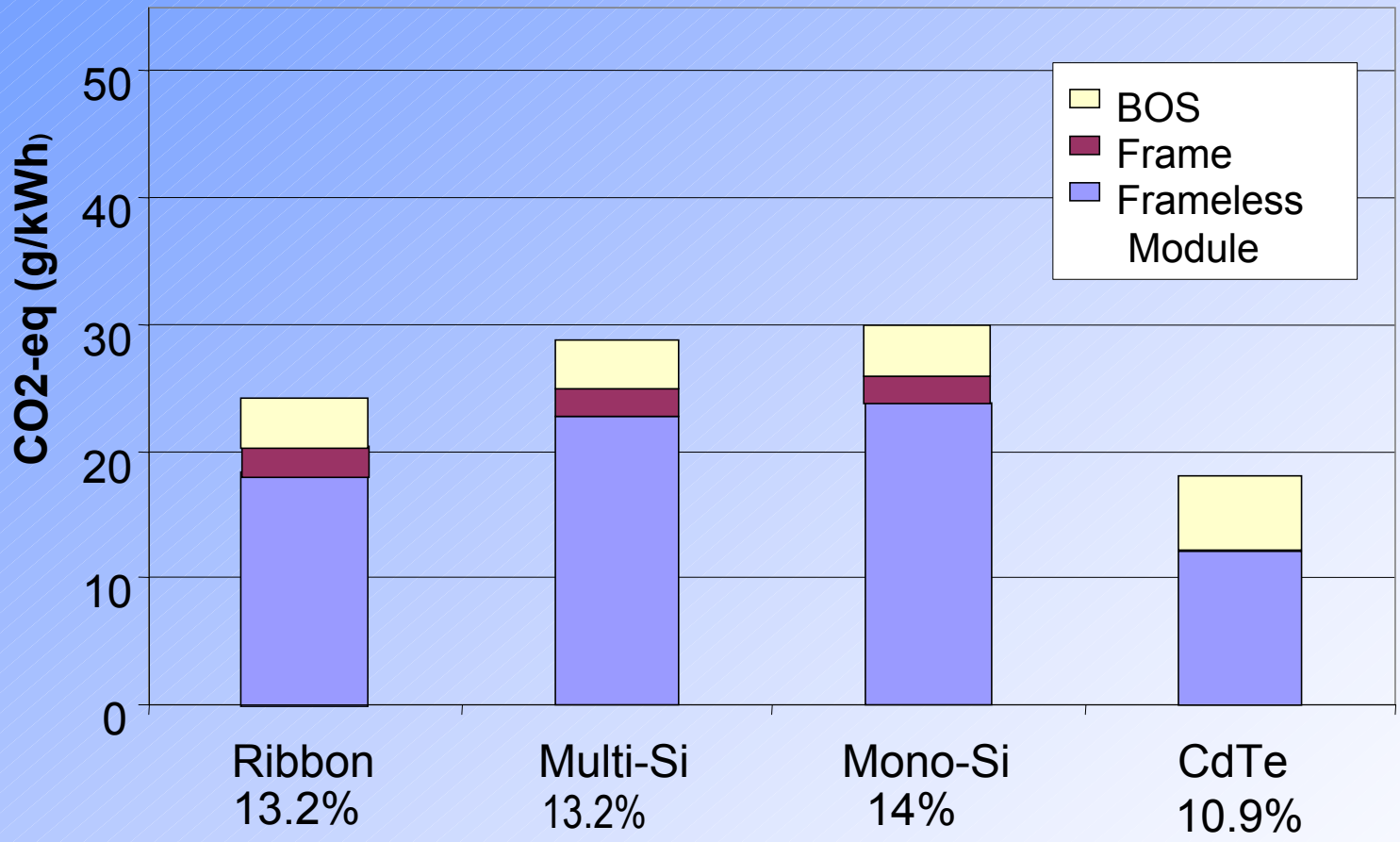


deWild 2009, *EUPV, 2009*
Fthenakis et al., *EUPV, 2009*

Greenhouse Gas (GHG) Emissions

Crystal Clear & BNL LCAs
GHG Emissions –U.S. and Southern Europe

Insolation: 1700 kWh/m2-yr



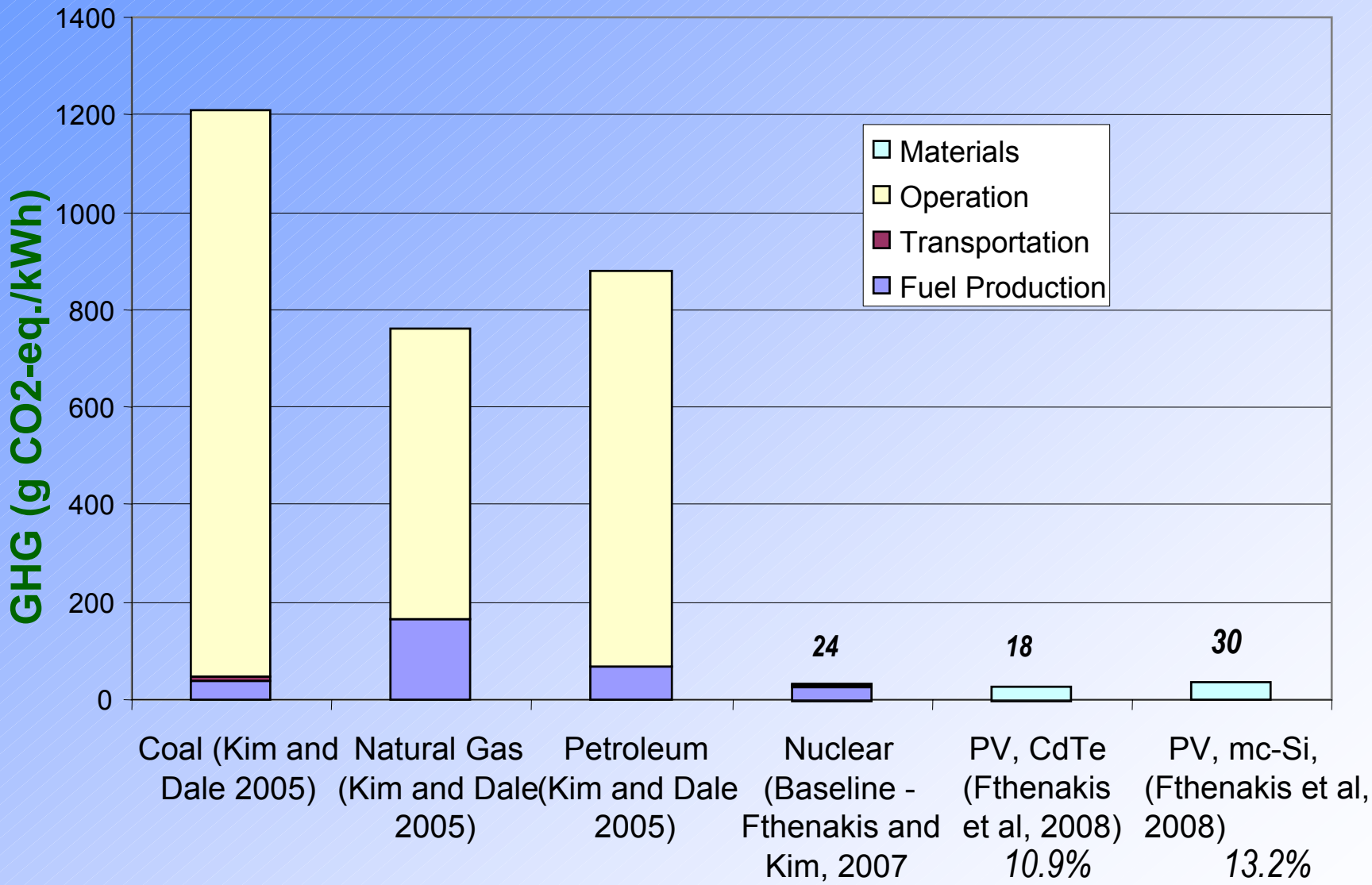
deWild 2009, *EUPV, 2009*
Fthenakis et al., *EUPV, 2009*

PV Total Life-Cycle GHG Emissions

Activity	Emission g $CO_{2\text{-eq}}$ / kWh
Power plant life-cycle	18 to 30
Deforestation (if applicable)	10 to 20
Loss of natural forest sequestration (if applicable)	0 to 10
Total:	18 to 60

1700 kWh/m^2/yr, 30 yr life time

GHG Emissions from Life Cycle of Electricity Production



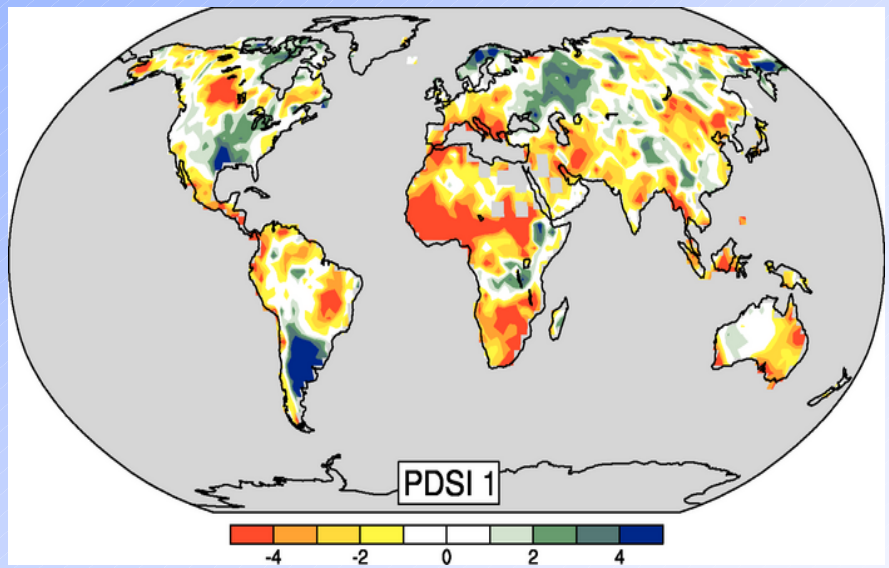
California Energy Commission, *Nuclear Issues Workshop*, June 2007

Fthenakis & Kim, Life Cycle Emissions…, *Energy Policy, 35, 2549, 2007*

Effect of Greenhouse Gas Emissions on Habitat

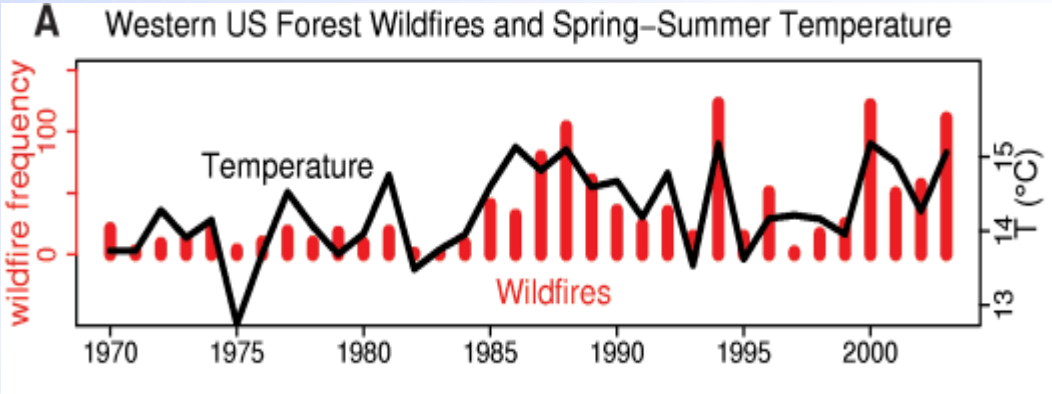
"The evidence suggests that both terrestrial and marine biological systems are now being strongly influenced by observed recent warming. " (IPCC, 2007).

- Precipitation and temperature patterns have changed.
  IPCC (2007) WG1 FAQ 3.2



Palmer Drought Severity Index 1900-2002

- Fires are occurring more frequently.
  (Westerling et al. 2006)



Extinction & Risks from Climate Change

Terrestrial Examples:

- Species of frog and toad in the mountains of Costa Rica have gone extinct. (Pounds et al. 2005)
- Possums and pikas populations in mountains have disappeared, or are seriously threatened. (Beever et al.; Ainley et al. 2003)
- Populations of polar bears in the Arctic and penguins in the Antartic are crashing. (Derocher et al. 2004)
- Habitat boundaries are moving towards the Earth's poles (e.g. coastal fisheries, butterfly habitats) and to higher elevations (e.g. mountain pikas).

  (Parmesan et al. 1999, Holbrook et al. 1997, Beever et al. 2003)

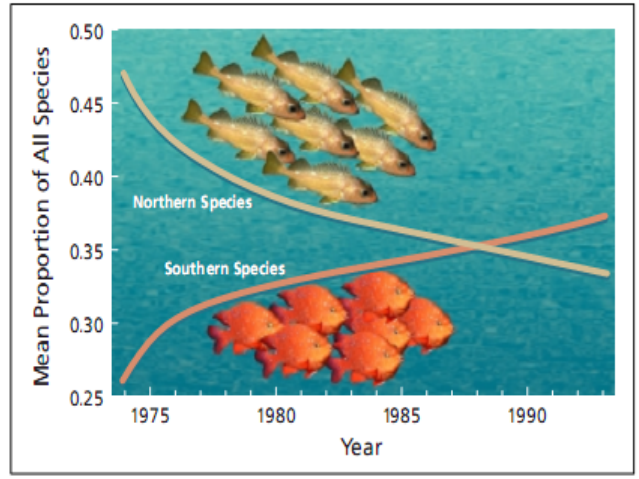
http://ecopreservationsociety.wordpress.com/category/wildlife-conservation/

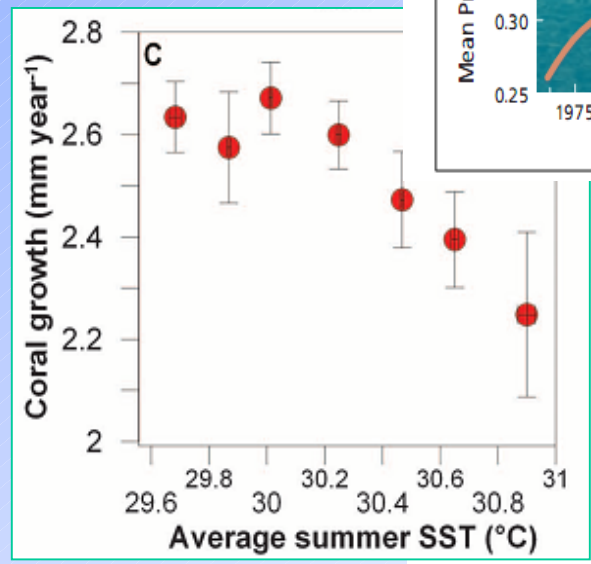
http://www.sciencedaily.com/releases/2009/02/090212171936.htm

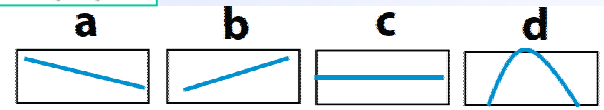
Extinction & Risks from Climate Change

Marine Examples:

- Cold-water fish in coastal CA waters have given way to warm-water fish. (Confronting Climate Change California, 1999)
- Coral bleaching become more common. Coral growth is slowing. (Cantin et al. 2010)
- Marine life vitality decreases in response to ocean acidification. (Doney et al. 2009)







Physiological response	Major group	Species studied	a	b	c	d
Calcification						
	Coccolithophores[1]	4	2	1	1	1
	Planktonic Foraminifera	2	2	–	–	–
	Molluscs	4	4	–	–	–
	Echinoderms[1]	3	2	1	–	–
	Tropical corals	11	11	–	–	–
	Coralline red algae	1	1	–	–	–

Environmental Impacts of PV Power Plants

- **Zero emissions under normal conditions**

  (testing in thermal cycles of –80 C to +80 C)

- **Potential accidental emissions**

  (low potential for fire emissions or metal leaching)

- **Land use issues**

Dual and Ecological-friendly Use of Land

Sinzheim, Germany, with permission from Juwi, 2006
1.4MW

Dual and Ecological-friendly Use of Land

Does PV use a lot of land ?

More Land is used by the Coal Life Cycle than PV

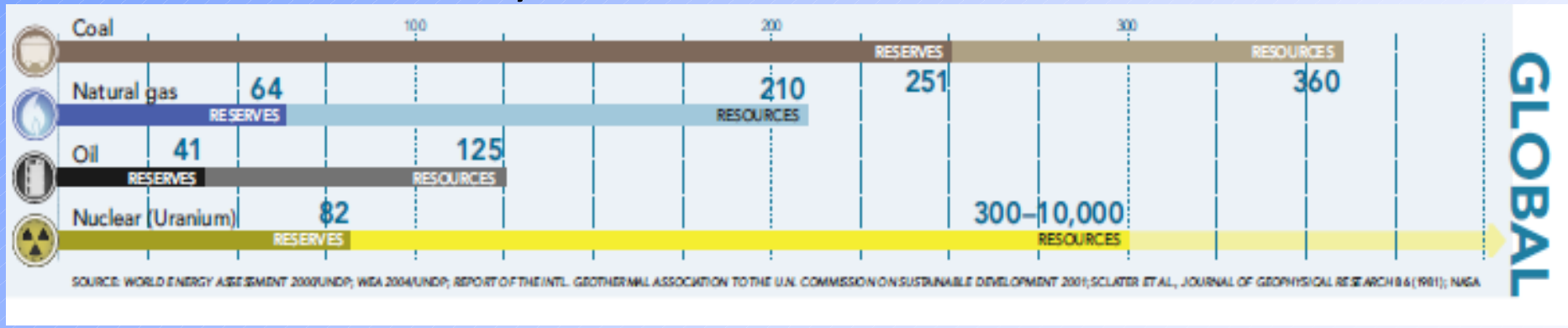
Fthenakis V. and Kim H.C., *Sustainable and Renewable Energy Reviews*, 2009

Coal Mining also Damages the Land. Oil Drilling Pollutes and Kills Habitat

Conventional Energy Resources: How much is left?

- Oil: 40 – 125 years (Hubbert's Peak ~ 2015?)
- Natural Gas: 65 - 210 years
- Coal: 250 – 360 years
- Nuclear: 80 – 300 years

Science **329**, 786 (2010)

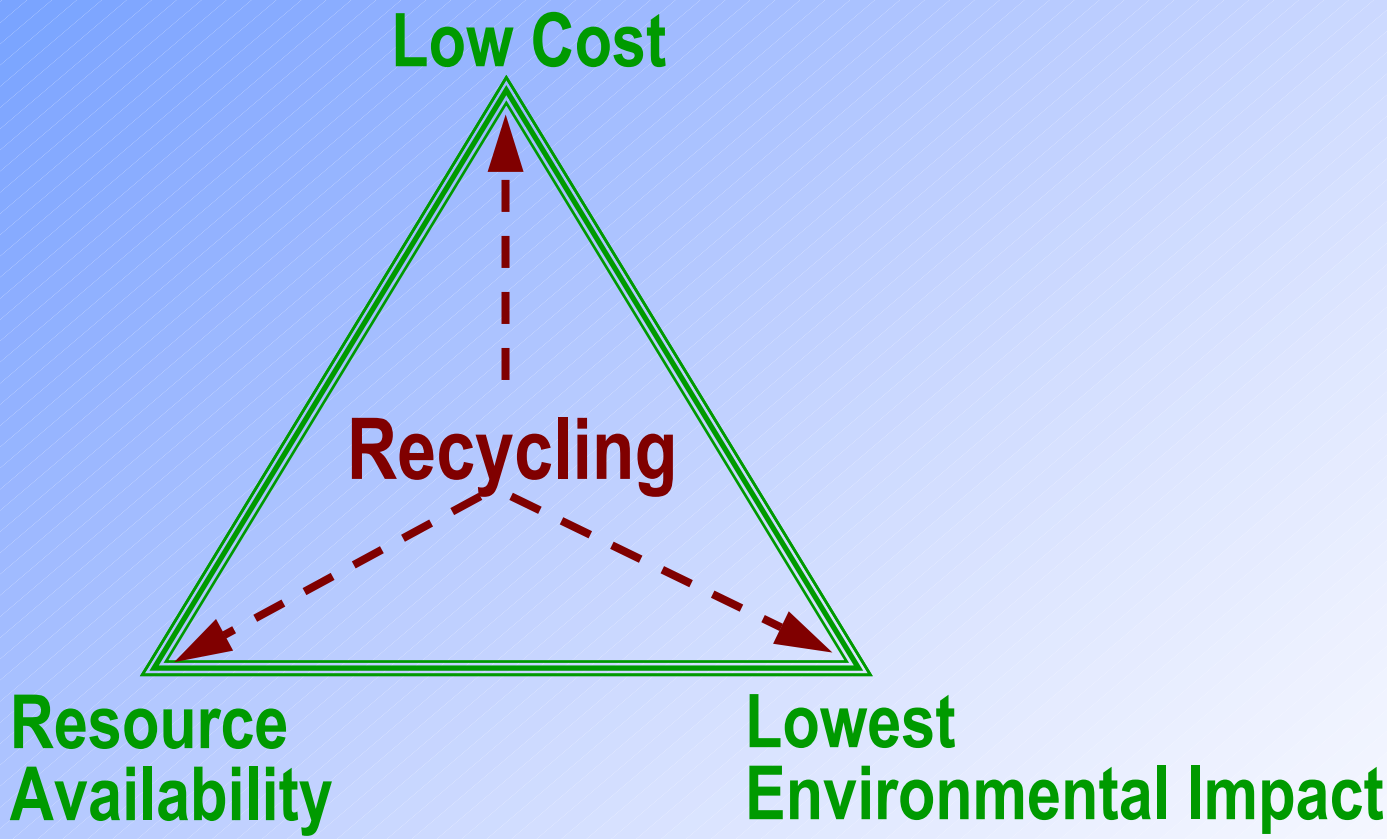


More Difficult/Costly/Risky

The PV Industry is Proactive on Environmental Protection

- PV continuous improvement on energy and resources utilization
- PV end-of-life Recycling

Photovoltaics –Sustainability Criteria



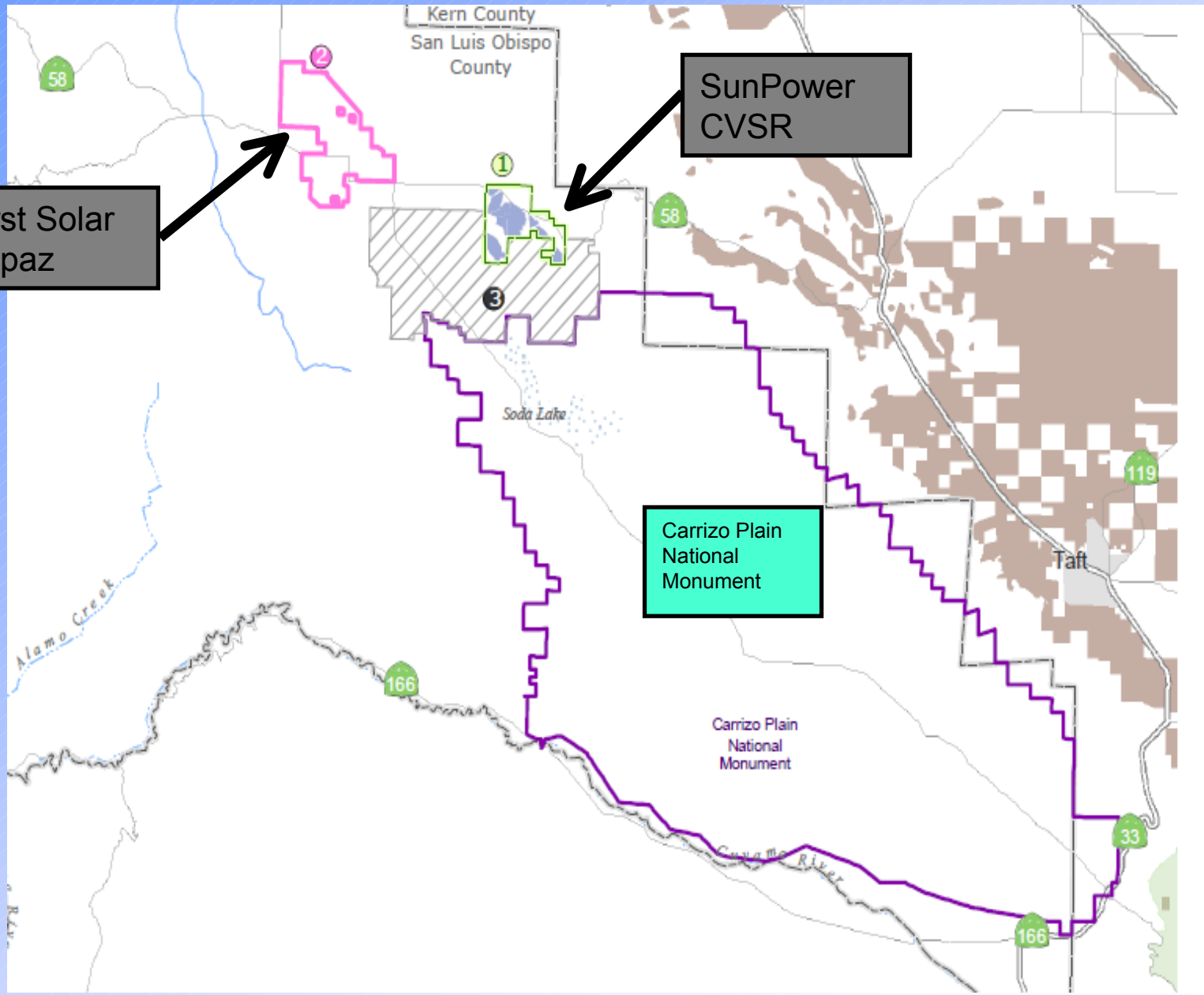
PVCYCLE:

Voluntary Industry Program in Europe with 90% Industry Subscription

Industry Measures for Protecting Wild Life in our South West

- San Luis Obispo County (Carrizo Plain) Projects
  - First Solar 550 MW plant
  - Sun Power 250 MW plant
- Protect Sensitive Species
  - Desert Kit Fox
  - Giant Kangaroo Rat (GKR)
  - Desert Tortoise
- Avoid Sensitive Areas
- Minimize Impact on Ground
- Maintain Vegetation

CA Carrizo Plain PV Plant Sites



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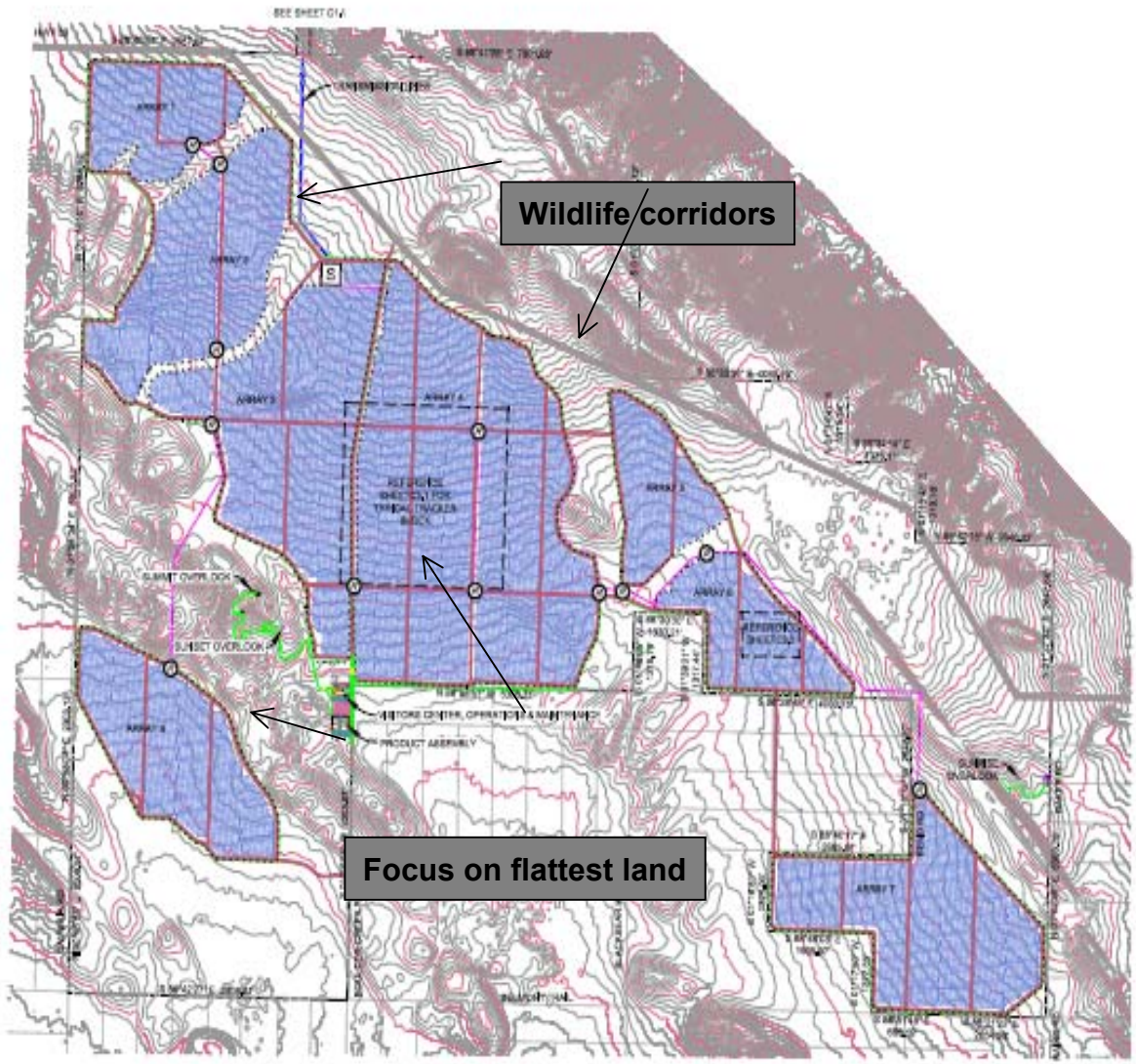
Sun Power Original Design with T20 Trackers



Date: Q1 2009

Design emphasis:

- Maximize use of flat areas
- Minimize grading
- Incorporate wildlife corridors

GKR impacts:

- Not measured
- Not known to be present at the time

Source: Sun Power

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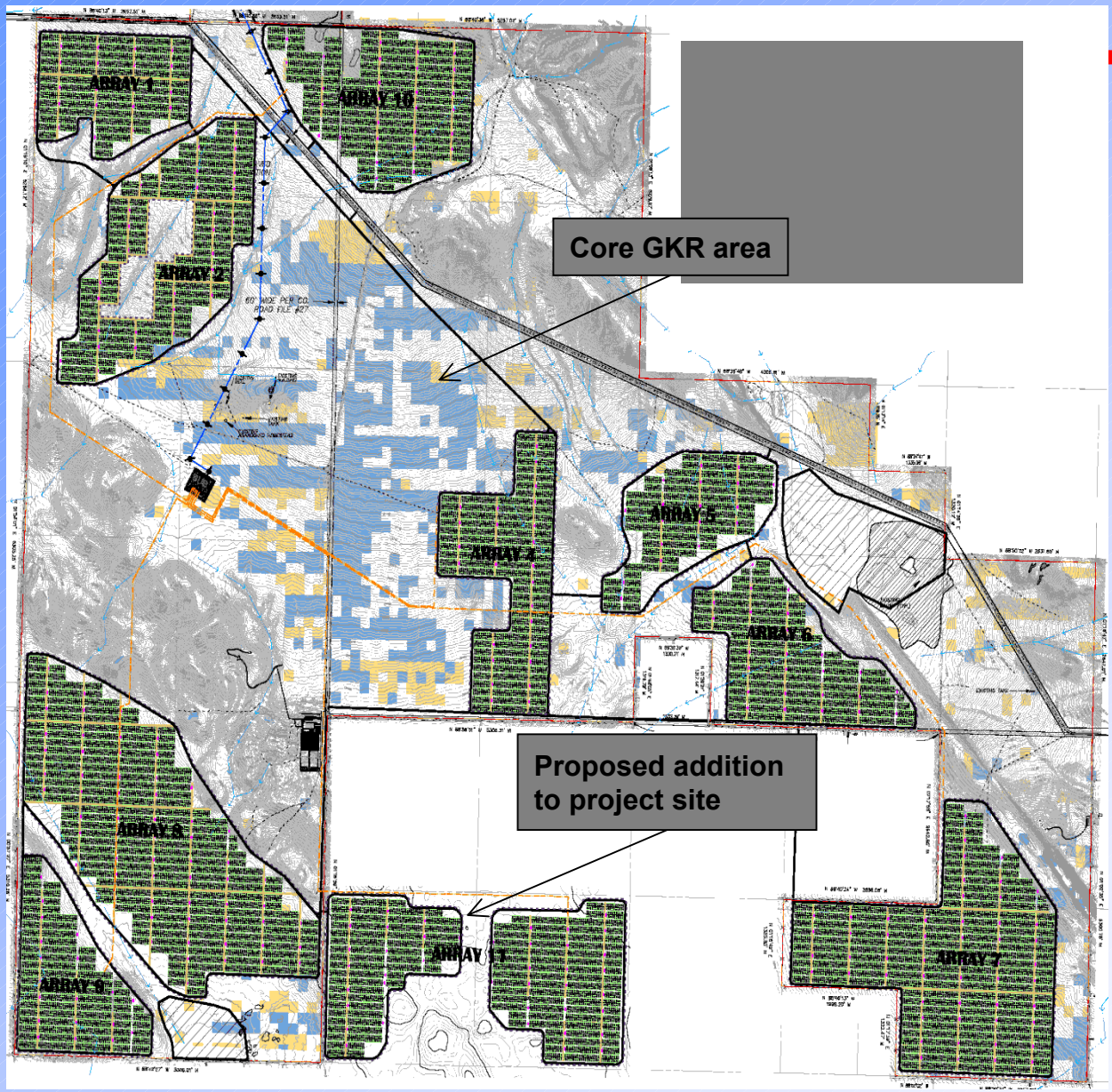
Redesign to Avoid GKR - Alternative #3



Date: Q2 2010

Design emphasis:

- Consider acquisition of more land to minimize impact on presence of GKR

Source: Sun Power

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Sun Power Project Revisions due to Environmental Feedback

1. Wild life access corridors
2. Low impact penetrating foundation vs. concrete pedestals
3. Changed type of trackers to reduce visual impact

Source: Sun Power

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Sun Power Project Revisions due to Environmental Feedback

1. Wild life access corridors
2. Low Impact Penetrating Foundation vs. Concrete Pedestals
3. Changed Type of Trackers to reduce visual impact

4. Changed fencing to allow kit fox movement
5. Coordinated wildlife mitigation measures
6. Redesigned array layouts to substantially avoid sensitive biological resources
7. Utilize existing on-site surface gravel mine to reduce truck traffic
8. Reduced water use by 20% per year
9. Ensured project will not use water suitable for domestic use
10. Large water tank located near SR 58 for community firefighting access

Source: Sun Power

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First Solar Key Elements of Wild Life Protection Plans

1. Design Kit Fox friendly project

- Re-vegetate to promote habitat for kit fox and small rodent prey
- Arrays mounted 18” above ground on steel posts to limit ground coverage and provide line of site beneath arrays
- Allow for passage through project with kit fox culverts in perimeter fence
- Provide separately-fenced wildlife corridors, up to one mile in width
- No perimeter lighting

2. Implement Kit Fox Protection Plan during construction

3. Monitor Kit Fox use of project site on an ongoing basis

4. Onsite habitat enhancement

- Fencing would allow site access by kit fox but exclude coyotes, a primary predator
- Install artificial escape dens

Source: First Solar

Topaz: Improved Wildlife Habitability

- Steel-post panel mountings instead of concrete ballasts
  - Reduced impermeable surface
  - 18-inch ground clearance provides unencumbered line of sight for Kit Fox
  - Leading Kit Fox experts retained
  - Fence for permeability of endangered species
  - Improved vegetation growth

Source: First Solar

Carrizo Plain Projects Environmental Benefits

(2 projects -800 MW)

- Generate **clean, renewable, secure, domestic energy**
- **Emissions Avoidance** (from US avg grid over 30 yrs)
  - Carbon Dioxide (CO_2) greenhouse gas — 70 billion pounds
  - Nitrogen Oxide (NO_x) — 235 million pounds
  - Sulfur Dioxide (SO_2) — 517 million pounds
  - Particulates — 75 million pounds
- **Resource Conservation** (project lifetime, based on CO_2 emissions offsets)
  - Equivalent to NOT driving — 70 billion miles
  - Equivalent to planting trees — 15 million acres
- Contributes to a broader **conservation strategy** for the Carrizo region
  - Permanently protect and properly manage both on-site and off-site land as habitat
  - Protect and restore species while increasing population density

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DOE Activities to Identify and Address Potential Environmental Impacts

- Co-funding a Programmatic Environmental Impact Statement (PEIS) with the Bureau of Land Management. (http://solareis.anl.gov)
- 24 Solar Energy Study Areas in 6 states (Arizona, California, Colorado, Nevada, New Mexico and Utah)
  - Draft scheduled for release in December 2010
- Supporting the development of a Solar Information Clearinghouse to serve as a "one-stop shop" for solar resource, technology, environmental and project information for solar developers, decisionmakers and stakeholders.
- Supporting the development of LCAs for CSP power tower and parabolic trough technologies and a comparison of LCAs across generating technologies.
- Develop a comprehensive GIS siting tool to inform the siting of new solar projects to include resource, environmental, land ownership, land quality, water availability and other relevant data layers.

Conclusion

- Large PV power systems (PVPS) are necessary for significant displacement of fossil fuel power generation and mitigation of global warming impacts.
- The potential environmental impacts and risks of large PVPS are very small in comparison to the impacts and risks of fossil fuel life-cycles.
- The PV industry and the DOE put great efforts in minimizing conflicts, preventing impacts to biodiversity and preserving endangered species.

Email: VMF@BNL.GOV

www.pv.bnl.gov

California Valley Solar Ranch Community Meeting

San Luis Obispo, CA

September 15, 2010

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Site Selection – Why California Valley?

- Balance between technical, environmental, and policy considerations
- Best solar resource in PG&E service territory
  - 315 sunny days/yr / higher elevation / lower temps
  - Protected from coastal and valley fog / low humidity
- Flat, remote site, sufficient for large scale PV
- Existing transmission & highway infrastructure
  - Previously tilled, heavily grazed ag land
  - – Insufficient water for irrigation
- Restoration of 2 abandoned gypsum mines
- Identified in County General Plan Energy Element as “crucial location of high solar potential”

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California Valley Solar Ranch

- 250 Megawatt Solar Photovoltaic Power Plant
- Southeastern San Luis Obispo County
  - Previously tilled, heavily grazed land
- Adjacent to existing high voltage transmission
- 1,935 acres – solar arrays and support facilities
  - 4,365 acre total project
  - 2,400 acres (55%) permanently managed to meet conservation objectives
- 714,000 MWh/yr of clean, renewable solar energy
  - Equivalent to needs of ~100,000 homes
- ~350 local construction jobs at peak over 2.5 years, 15 permanent jobs
- Power Purchase Agreement with PG&E approved by the California Public Utilities Commission

SunPower project, Germany

California Valley Solar Ranch (rendering)

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Biological Resource Assessment

- Comprehensive, ongoing coordination with CDFG and USFWS
- Completed biological surveys and analysesc:
  - Literature and database research (CNDDB, CNPS, CDFG, ESRP, USFWS) 2008
  - Species expert and resource agency coordination and involvement 2008
  - Aerial and reconnaissance surveys to inform assessment and planning 2008
  - Vegetation mapping and rare plant surveys, 2009
  - Wetland/jurisdictional waters delineation, 2008 & 2009
  - Vernal pool habitat assessment, 2009
  - Wintering and special-status bird surveys, 2009
  - Small mammal live trapping surveys, 2008
  - San Joaquin antelope squirrel surveys, 2009
  - Blunt-nosed leopard lizard surveys, 2009
  - Giant kangaroo rat distribution surveys, 2009
  - San Joaquin Kit Fox surveys (spotlight, burrows, cameras), 2009

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Extended Biological Assessments

- Branchiopod surveys, spring 2010
- Rare plant survey, spring & summer 2010
- Blunt-nosed leopard lizard protocol-level surveys, spring & summer 2010
- Giant kangaroo rat precinct survey, summer 2010
- Golden eagle survey per USFWS interim guideline protocols, spring 2010
- San Joaquin antelope squirrel visual & live-trapping survey, spring & summer 2010
- Additional CEQA level surveys – alternate switchyard & CEQA alternative #3, summer 2010

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Biological Resource Assessment Key Findings

- No federally-listed vernal pool branchiopods
- No federally or state-listed plant species
- No Blunt nosed leopard lizards (adults or juveniles)
- Confirmed utilization of the site by San Joaquin kit fox, giant kangaroo rat, burrowing owl, San Joaquin antelope ground squirrel
- Determined that conservation objectives can be achieved

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Project Permitting Schedule – What's Next

CUP Application filed and CEQA process – Commenced January 2009

- Draft EIR prepared by County and Aspen Environmental –
- Comments August 24th through October 12, 2010
- County Workshop on September 22, 2010
- Planning Commission hearings commence in Winter 2010

Biological Surveys and Agency Coordination – Commenced December 2009

- Extensive biological surveys submitted, December 2009 – August 2010
- Ongoing consultation with USFWS and CDFG – Regular meetings with agencies
- Cooperatively developing a comprehensive conservation approach – Winter to Present 2010
- CDFG Permits (2081 and 1603) pending approval of CEQA document

Federal Permits in Progress

- Jurisdictional Delineation and Draft Biological Assessment - Submitted January 2010, Revised in August 2010 -
- USFWS, Section 7 consultation and Biological Opinion prep ongoing
- Participants include agencies, scientists, conservation groups, and conservation-minded industry groups
- Environmental and biological resource impacts will be mitigated

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