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

Sustainability of Large Photovoltaic Deployment: Environmental Research

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Presentation at the

Northeast Solar Energy Research Center (NSERC) Planning Workshop

March 8-9, 2011

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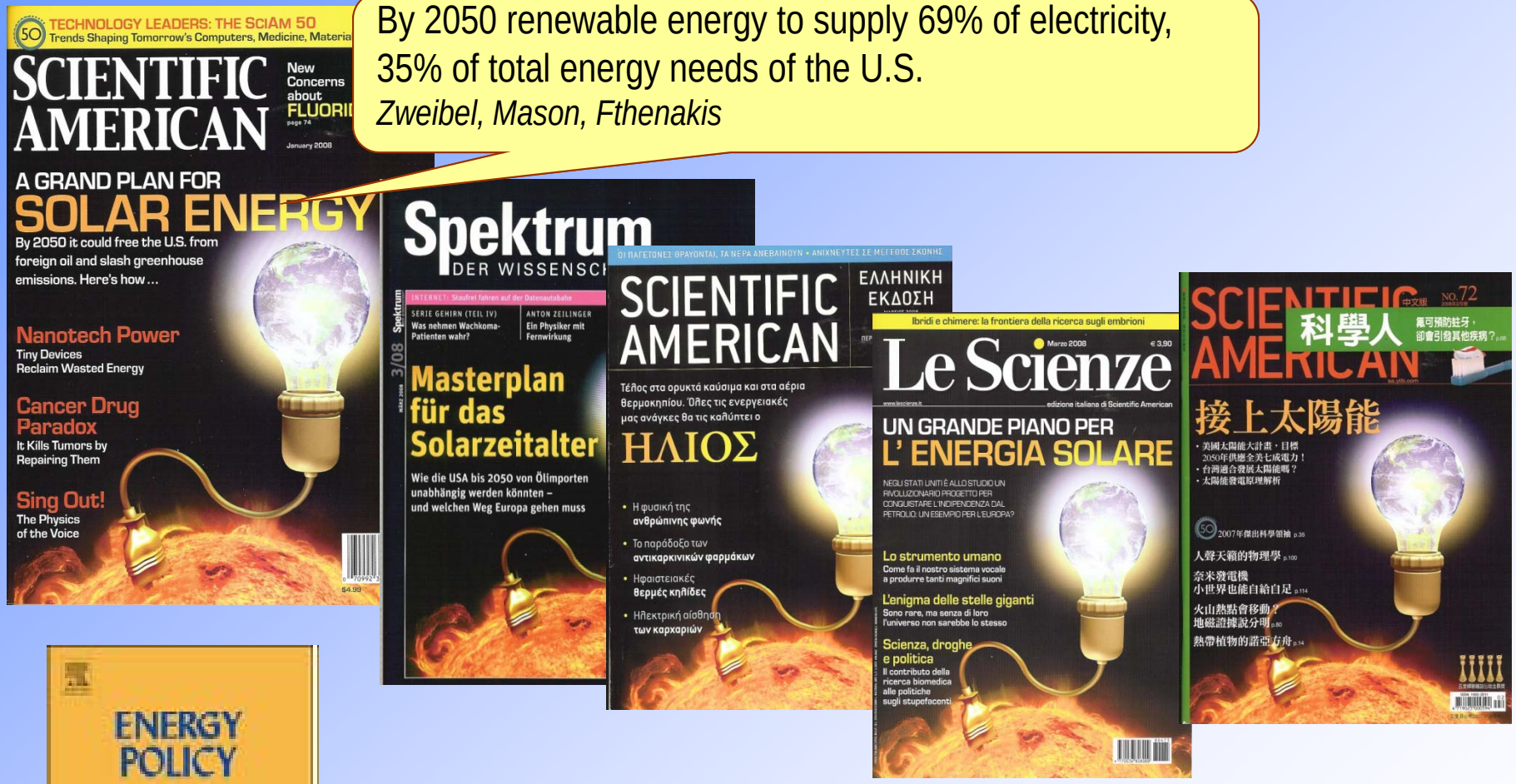
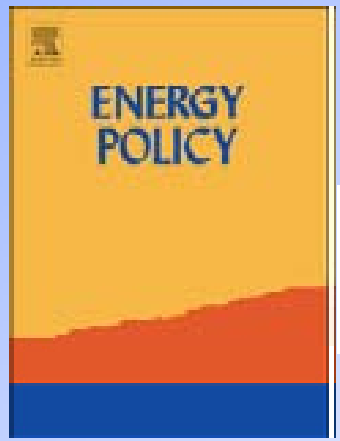
BROOKHAVEN NATIONAL LABORATORY

A Solar Grand Plan

By 2050 renewable energy to supply 69% of electricity, 35% of total energy needs of the U.S.
Zweibel, Mason, Fthenakis

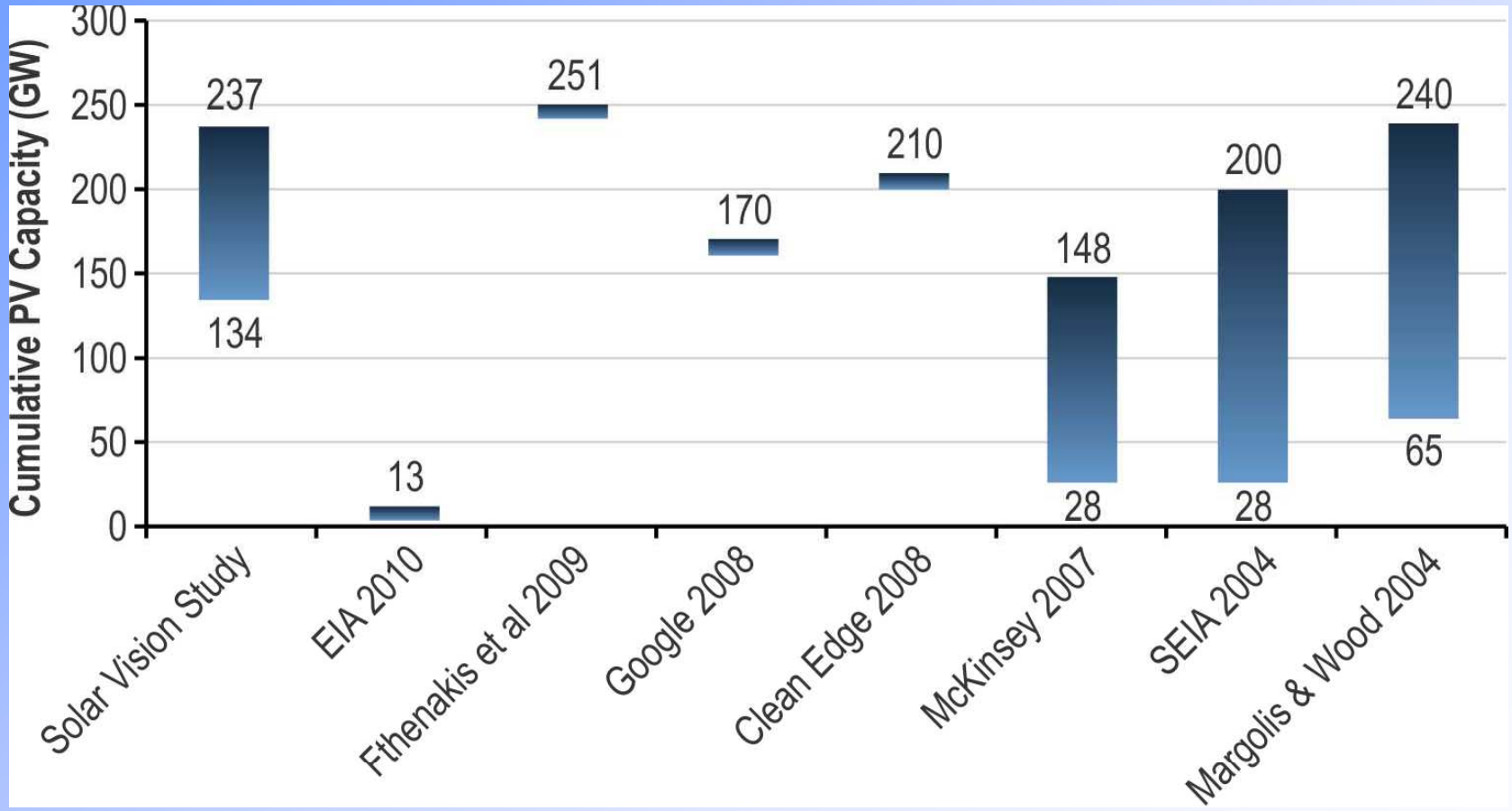




The technical, geographical, and economic feasibility for solar energy to supply the energy needs of the US

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

DOE-EERE Solar Vision Feasibility Study 10-20% Penetration by 2030



PV market projections for the United States by 2030

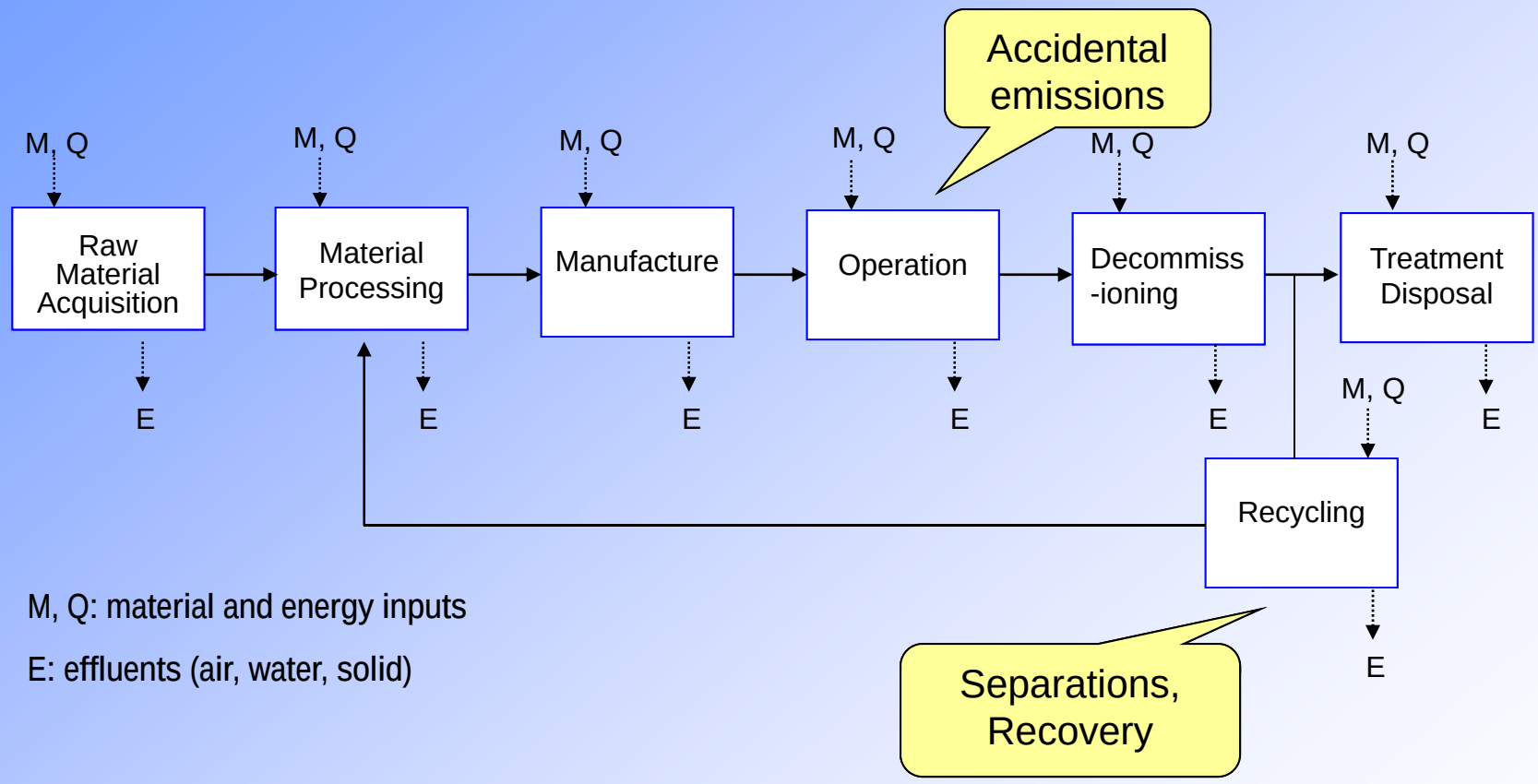
Report in review, not to be cited

PV Environmental Research Topics

- Life Cycle Analysis
  - Energy Pay-Back Times
  - Greenhouse Gas Emissions
  - Toxic Gas Emissions
- Recycling
  - Separation Technologies
  - Resource Assessment
  - Collection Infrastructure Modeling
  - International activities PVCYCLE, EPIA, IEA
- Risk Analysis
  - Hazardous Materials in Manufacturing
  - Emissions during Fires

Life Cycle Environmental Impacts

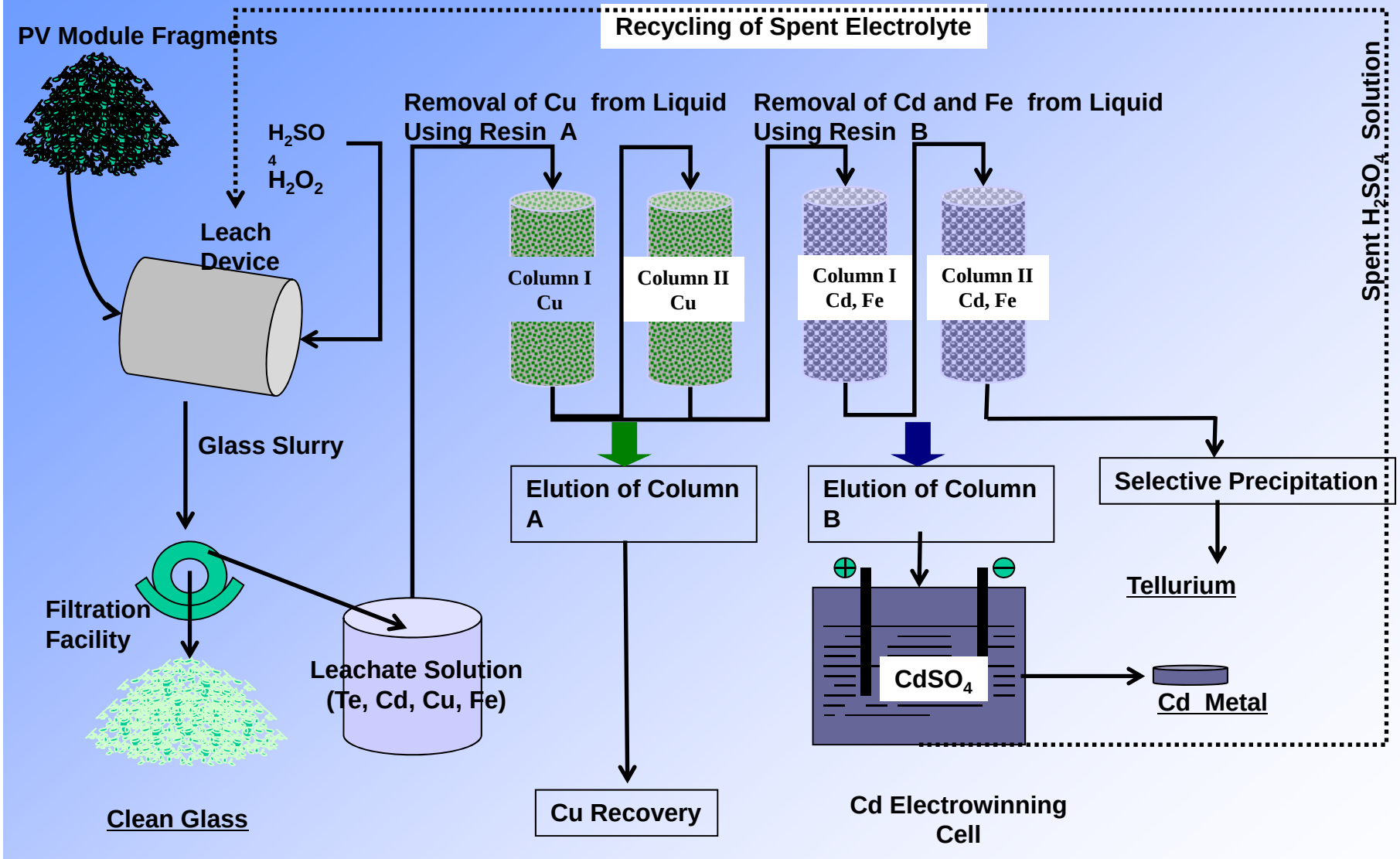
Experimental Research at BNL



M, Q: material and energy inputs

E: effluents (air, water, solid)

Recycling R&D at BNL: CdTe and CIGS PV Modules

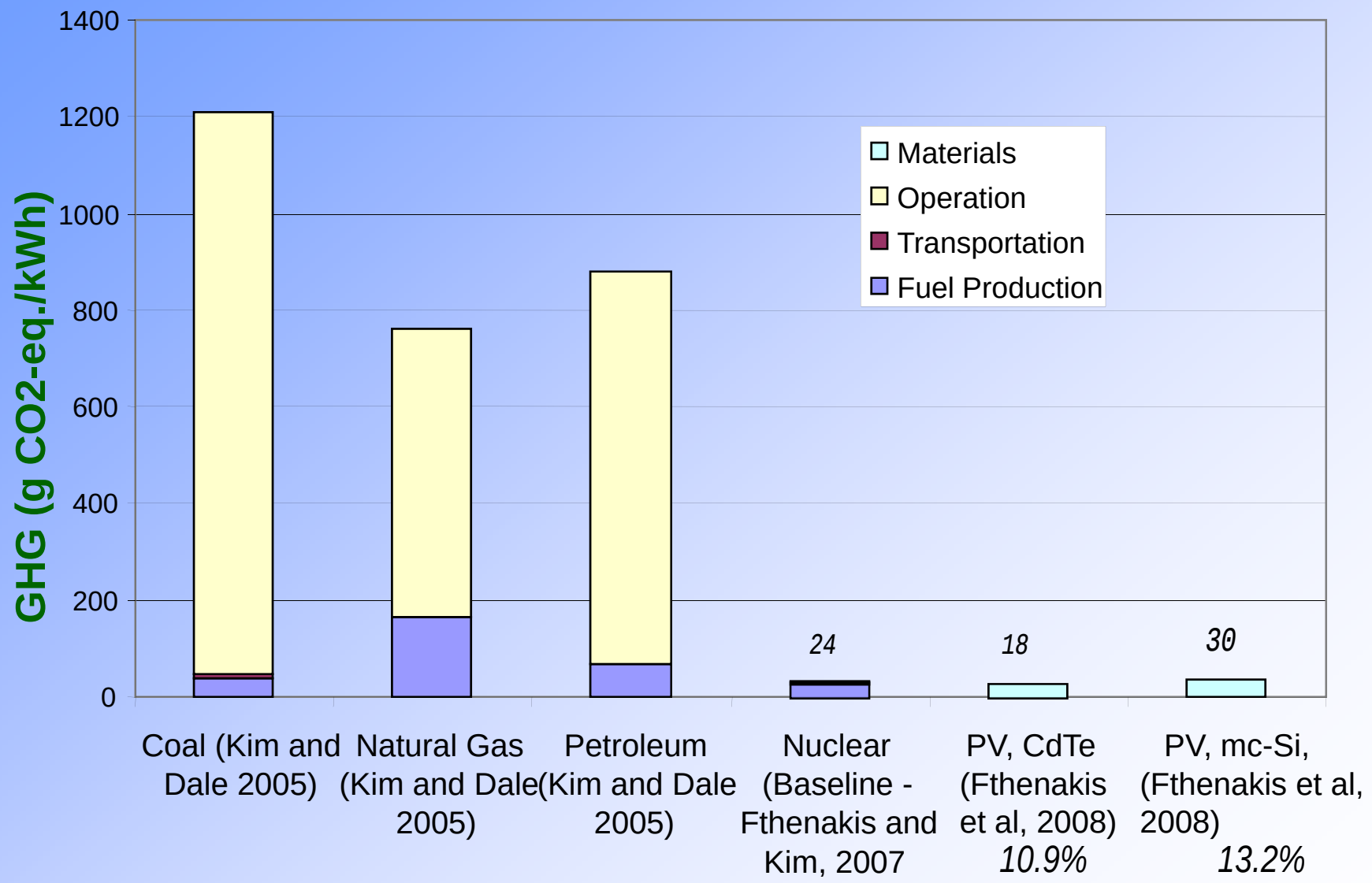


Te Separation from Cd waste: Patent # 7,731,920

Wang and Fthenakis, Kinetics Study on Separation of Cadmium from Tellurium in Acidic Solution Media Using Cation Exchange Resin, Journal of Hazardous Materials, B125, 80-88, 2005

Fthenakis and Wang, Extraction and Separation of Cd and Te from Cadmium Telluride Photovoltaic Manufacturing Scrap, Progress in Photovoltaics: Research and Applications, 14:363-371, 2006.

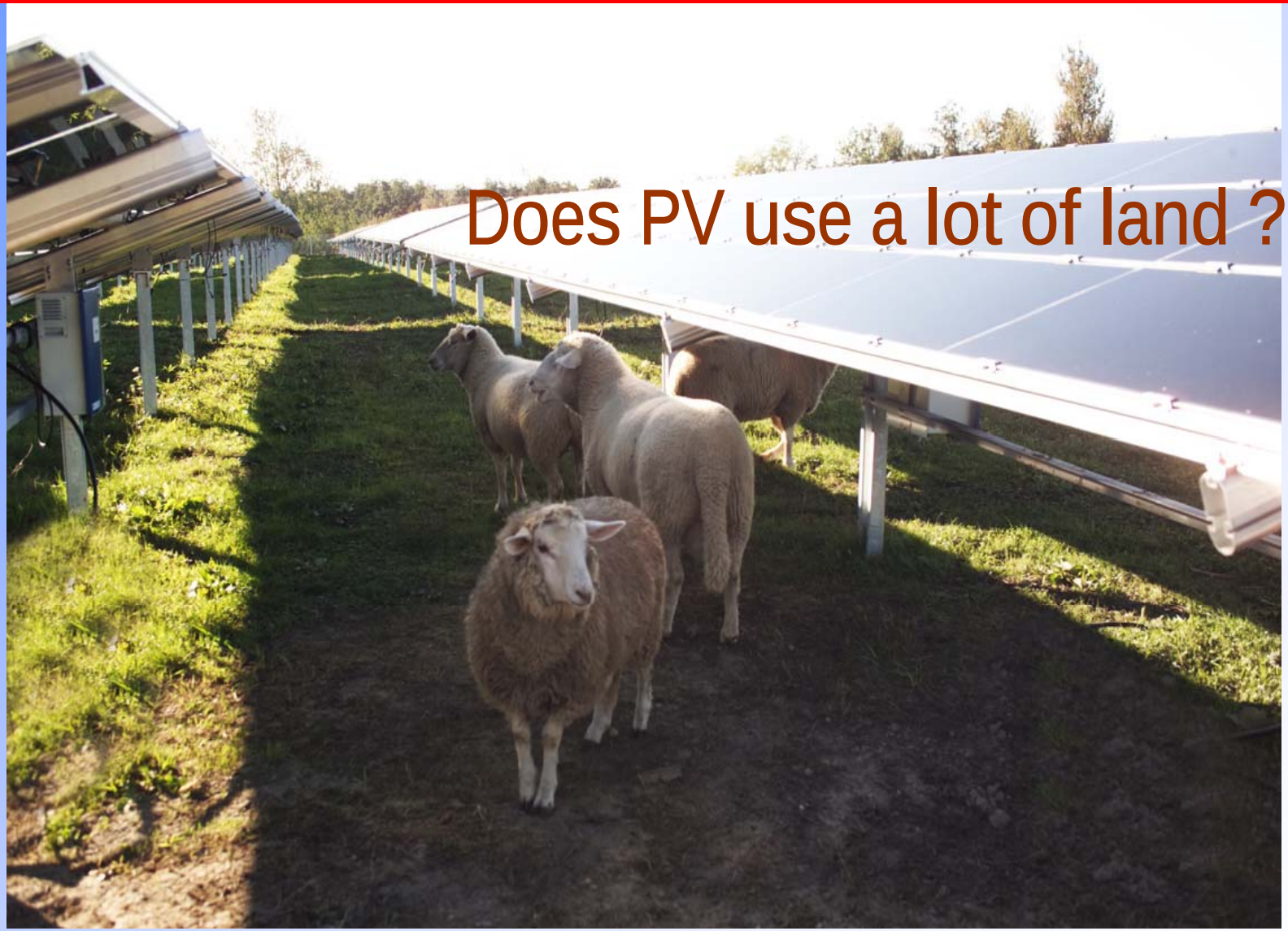
GHG Emissions from Life Cycle of Electricity Production



California Energy Commission, *Nuclear Issues Workshop*, June 2007
Fthenakis & Kim, Life Cycle Emissions…, *Energy Policy, 35, 2549, 2007*
Fthenakis & Kim, *ES&T, 42, 2168, 2008*

Land Use & Potential Impacts on Wild Life

Dual and Ecological-friendly Use of Land



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

More Land is used by the Coal Life Cycle than PV

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

The PV Industry is Proactive on Environmental Protection

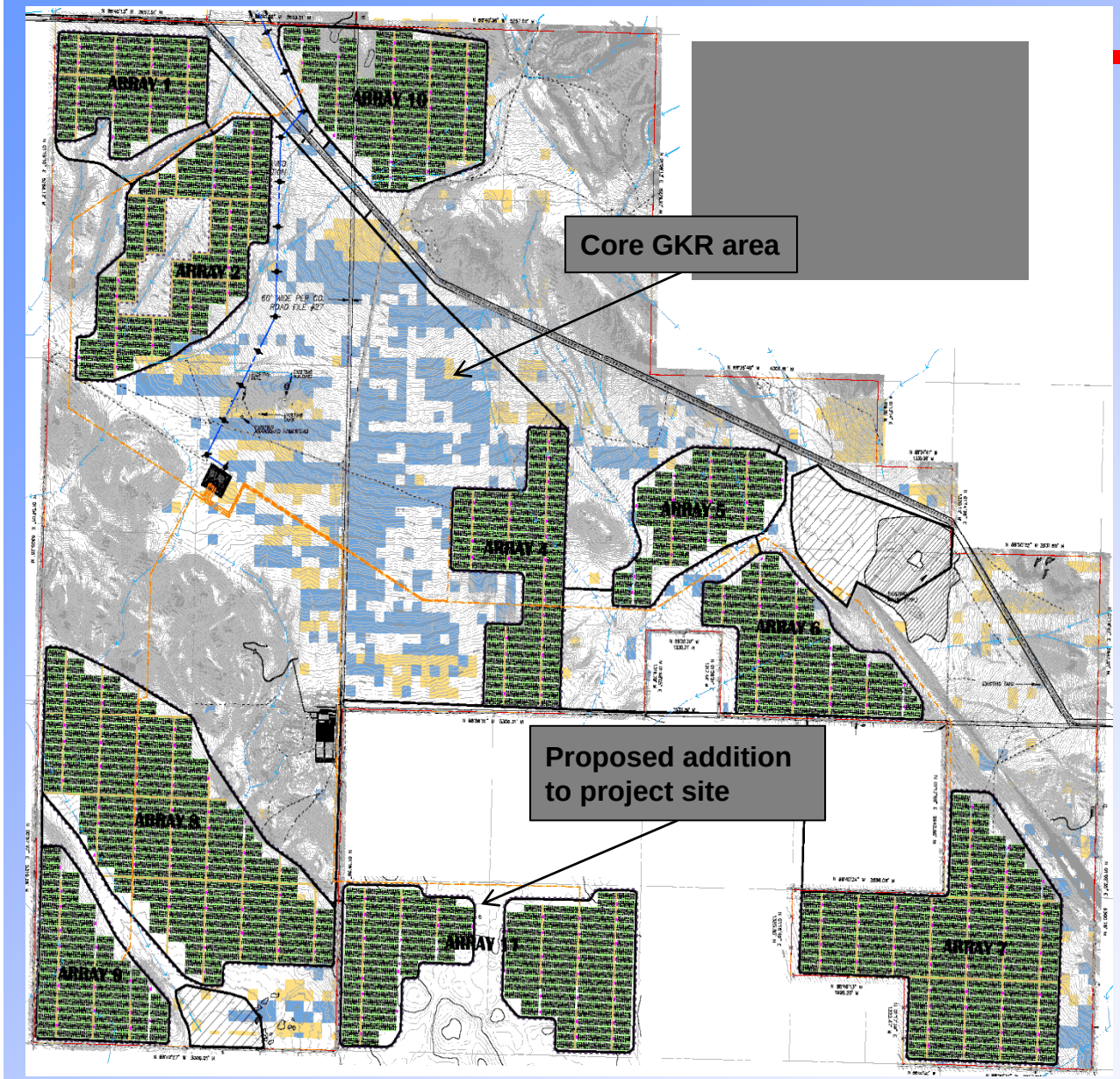
- PV continuous improvement on energy and resources utilization
- PV end-of-life Recycling
- PV industry minimizing impacts on Wild-life from large installations

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

Fthenakis et al., *Wild-Life Society Conference*, Snowbird, UT, Oct. 2010
with contributions from Julie Blunden, *SunPower* , and Lisa Krueger, *FirstSolar*

Redesign to Avoid GKR - Alternative #3



Date: Q2 2010

Design emphasis:

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

Source: SunPower

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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

BNL Environmental Research- LISF Plant

- Estimate CO2 emissions from cut vegetation at the LISF
- Record air temperature, soil temperature, air humidity, soil moisture, and infiltration rate between the LISF and nearby land
- Quantify air movements created by surface temperature differences between the LISF and nearby land
- Quantify the difference in thermal radiation at LISF
- Compare the animal population/migration within the LISF with surrounding land and previous surveys.
- Record response of vegetation to conditions within the LISF.

Current Research Topics

- Utility RE Power Plant Assessments
  - Environmental /Land & Water Use/Wild Life
  - Modeling PV-Wind integration
  - Modeling of CAES & other storage systems
  - GIS-based optimization of wind & solar site selection

Future R&D Directions

We would welcome your comments & suggestions related to Future Directions

Thank you