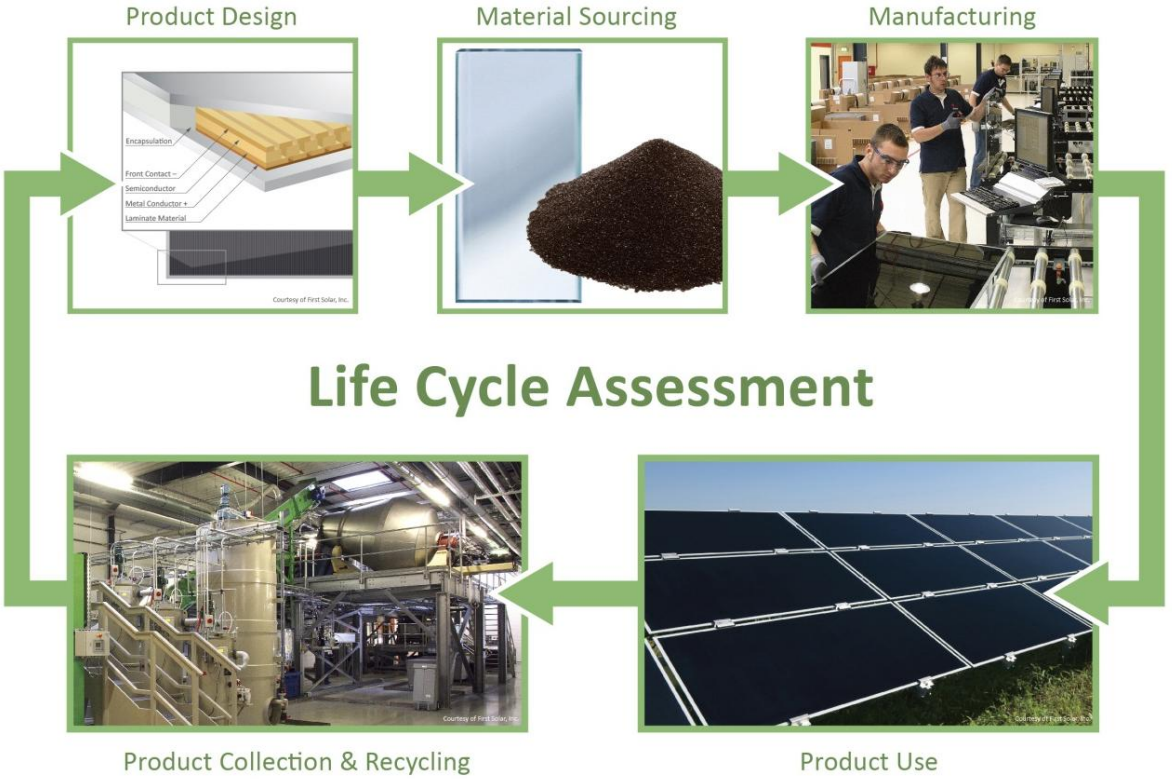
Environmental aspects of PV: contribution to sustainable energy and water supply

Dii conference
Cairo, November 2011

What is Life Cycle Assessment (LCA)?

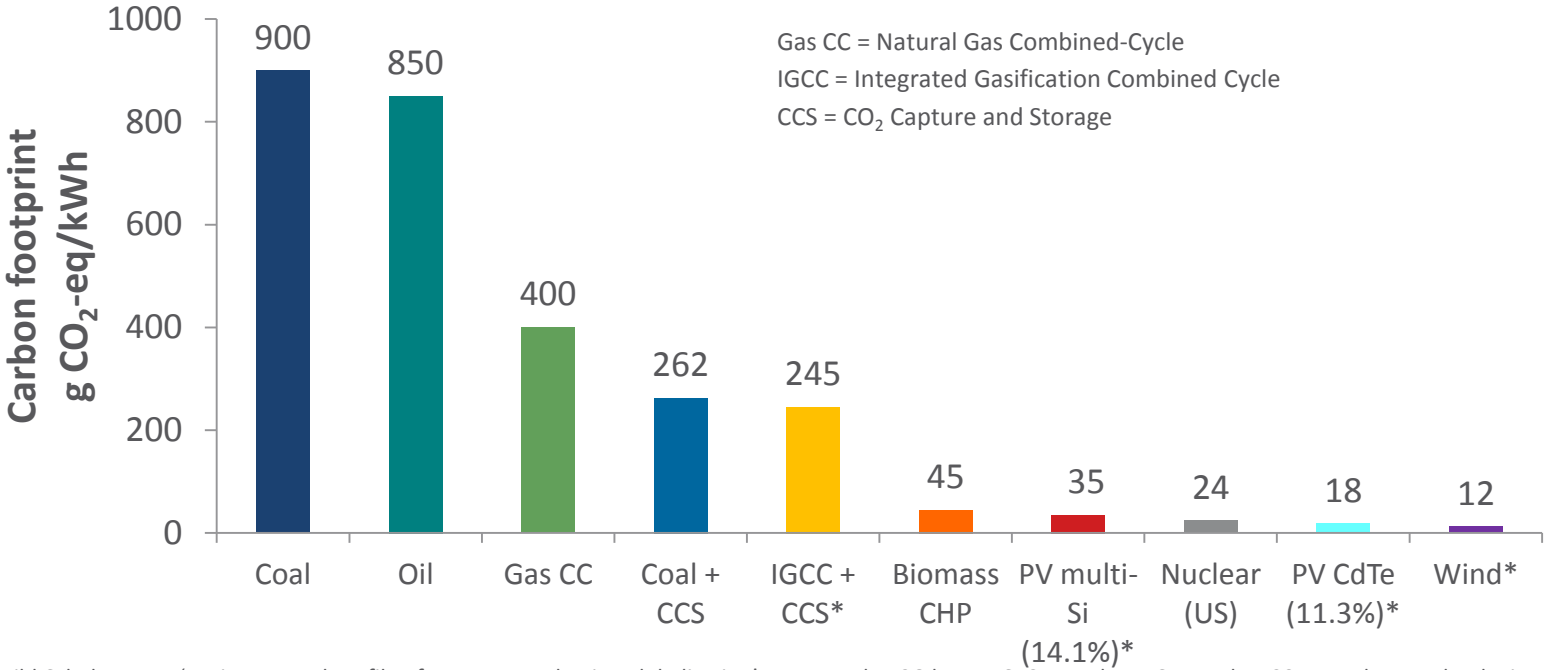
- Quantitative, cradle-to-grave assessment of environmental impacts of a product.
- Allows the comparison of the environmental attributes of competing alternatives with a systematic, quantitative, comprehensive methodology.
- Takes into account the transfer of environmental impacts from one medium to another and from one life cycle stage to another.

The case of PV



Sustainable Environmental Profile

PV Carbon Footprint a Fraction of Conventional Sources



*de Wild-Scholten, M., 'Environmental profile of PV mass production globalization', presented at 26th EUPVSEC, Hamburg, September 2011. Both PV technologies assume rooftop installation, 1700 kWh/m2/yr irradiance, UCTE grid, and 20% module degradation in 30yrs. All other data from ExternE project, 2003; Kim and Dale, 2005; Fthenakis and Kim, 2006: Fthenakis and Alsema, 2006; Fthenakis and Kim

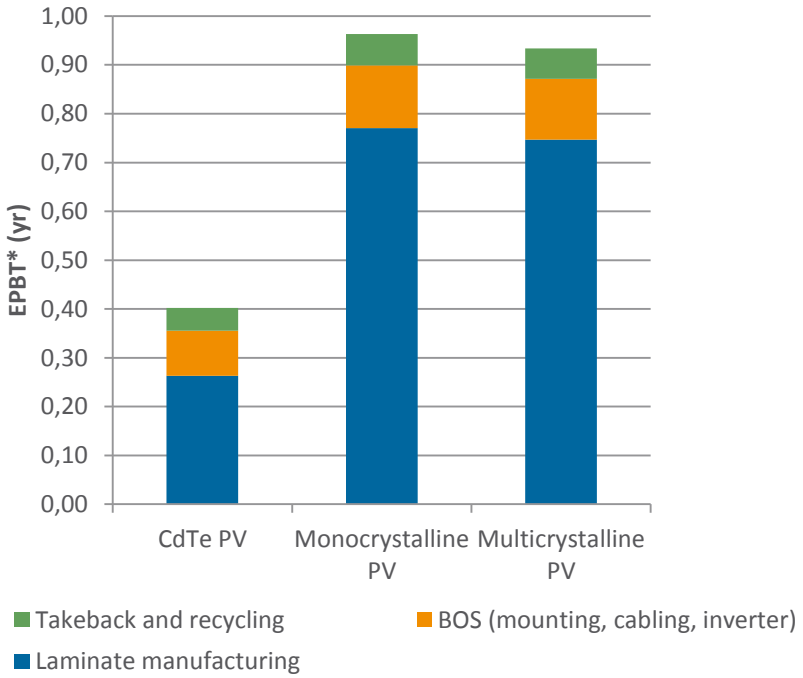
Life Cycle Energy Payback Time (ex. Saudi Arabia)

$EPBT = E_{input}/(E_{output}/yr)$

The amount of time a system must operate to recover the energy that was required to fabricate the system.

The higher the irradiance, the higher the output energy, the lower the EPBT.

Allows rapid expansion of PV while achieving carbon reductions

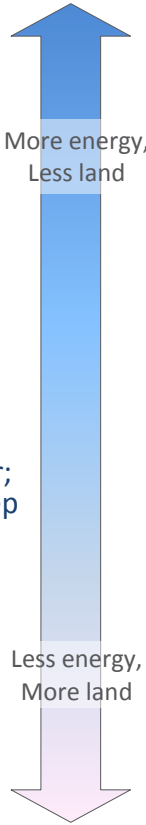


EBPT: de Wild-Scholten, M., 'Energy Payback and Carbon Footprint of PV Technologies', Energy Research Center of the Netherlands, presented at 20th Workshop on Crystalline Silicon Solar Cells & Modules: Materials and Processes, Breckenridge, 3 August 2010. Updated to reflect solar irradiance and electricity generation mix for Saudi Arabia , and 2011 module conversion efficiencies for Si PV and CdTe PV.

Land use life cycle analysis

Renewable Electricity Generation

- Solar
  - Power plant footprint
  - Power plant materials production
- Wind
  - Power plant footprint
  - Power plant materials production
- Hydro
  - Water reservoir
    - Varies widely: reservoir vs. run-of-river; wide/shallow reservoir vs. narrow/deep reservoir
  - Power plant
- Biomass
  - Crop land
  - Fuel conversion refinery (ethanol)
  - Power plant

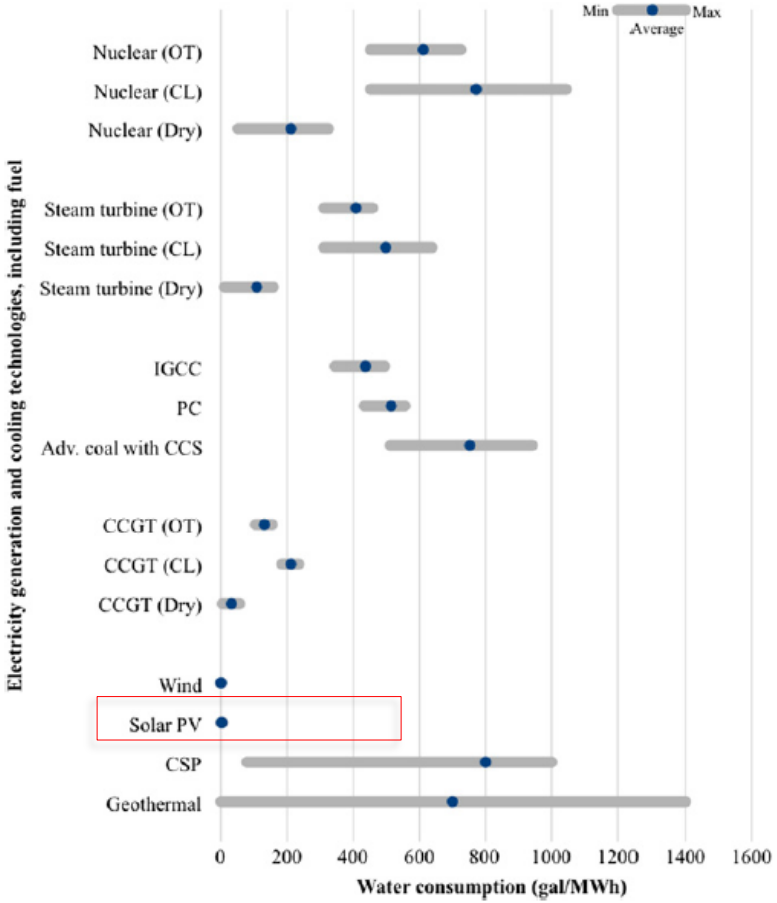


Non-renewable Electricity Generation

- Nuclear
  - Power plant + perimeter safety buffer
  - Nuclear waste disposal
  - Fuel extraction, milling, enrichment
- Natural gas
  - Fuel transport
  - Fuel extraction
  - Fuel storage
  - Power plant
- Coal
  - Mining/Fuel extraction
    - Strip/surface vs. underground
  - Fuel transport
  - Solid waste disposal
  - Power plant

Source: Fthenakis, V., Kim, H.C., Land use and electricity generation: A life-cycle analysis. Renew Sustain Energy Rev (2008)

Water Consumption for Electricity Generation



Technology	Water Consumption in Wet Cooling[a] (gal/MWh)	Other Water Consumed in Generation (gal/MWh)
Nuclear	400-720	30
CSP – Parabolic Trough	760-920 78 (dry cooling)	8
CSP – Power Tower	~750 90 (dry cooling)	8
PV	0	5[b]

a: Data is for cooling tower technology and unless otherwise stated is from DOE, *Energy Demands on Water Resources: Report to Congress on the Interdependency of Energy and Water*, Dec. 2006, available at http://www.sandia.gov/energy-water/docs/121-RptToCongress-EWwEIAcomments-FINAL.pdf.
b: NREL, *Fuel from the Sky: Solar Power's Potential for Western Energy Supply*, NREL/SR-550-32160, July 2002, p.99.

Mielke, E., et al., 'Water Consumption of Energy Resource Extraction, Processing, and Conversion', Energy Technology Innovation Policy Research Group, Harvard Kennedy School, Belfer Center, October 2010

Environmental profile of FSLR thin film technology (CdTe)

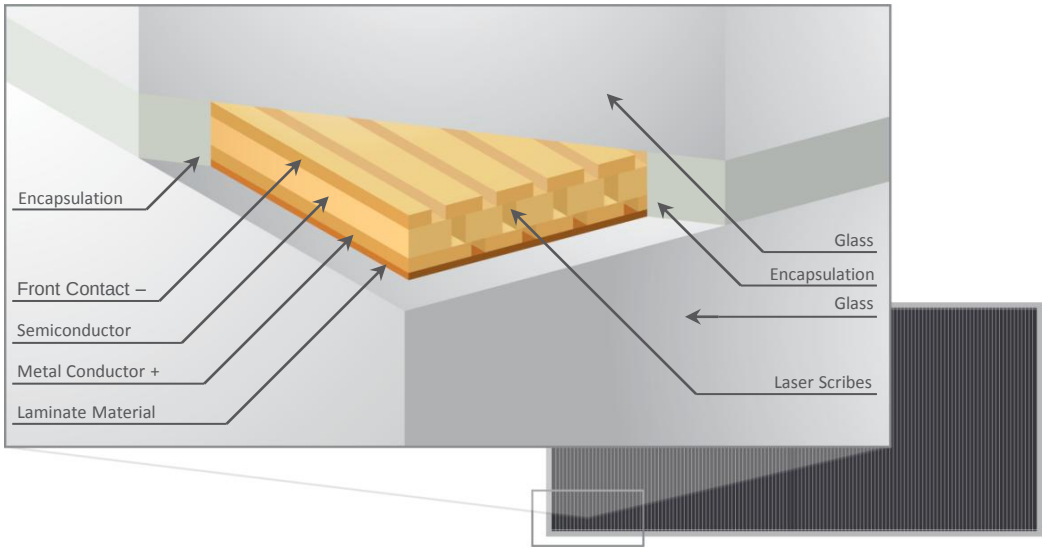
Product Design

Semiconductor is:

- Bonded under high temp to a sheet of glass AND
- Encapsulated between two sheets of glass with an industrial laminate

Chemical Properties of CdTe:

- A stable compound with melting point of $1041^{0}C$
- Insoluble in water[1]
- Will not chemically decompose unless it comes into direct contact with an oxidizing acid



[1] Lange's Handbook of Chemistry', Eleventh Edition.

CdTe PV Safety Confirmed by Peer Review Studies

Review	Conclusions
• **European Commission's Joint Research Centre (JRC), moderated by German Federal Ministry of Environment (BMU)**	• "…CdTe used in PV is in an environmentally stable form that doesn't leak into the environment during normal use or foreseeable accidents …." • "…CdTe modules do not represent an environmental risk under normal operating conditions. The potential environmental impacts in the case of fire and landfill deposition are extremely low…."
• **Authority of French Ministry of Ecology Energy, Sustainable Development (MEEDAT)**	• "…During standard operation of CdTe PV systems, there are no cadmium emissions – to air, to water, or to soil. In the exceptional case of accidental fires or broken panels, scientific studies show that cadmium emissions remain negligible. Accordingly, large-scale deployment of CdTe PV can be considered safe to human health and the environment."
• **Brookhaven National Laboratory**	• "Large-scale implementation of CdTe PV modules do not present any risks to health and the environment…"
• **Progress in Photovoltaics: Research and Applications** • **Bavarian Environmental Protection Agency**	• "The probability of sustained fires and subsequent emissions in adequately designed and maintained utility systems appears to be zero." • "..serious danger for the neighborhood and general public can be excluded if there is a fire involving CdTe PV modules."

Please see appendices for study details

Recycling solutions have been in operation since 2005

First Solar's Module Collection and Recycling Program

- Anyone in possession of First Solar modules can request take back… at any time, at no charge
- All modules labeled with contact information
- First Solar provides packaging, transportation and recycling services
- Approximately 90% (by mass) recovered
- First Solar pre-funds, through a trust structure, the estimated future collection and recycling costs for 100% of modules sold

Unconditional. Convenient. Free.