Considerations about Global Data on Payback Times of PV-Installations:

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Three Payback Times

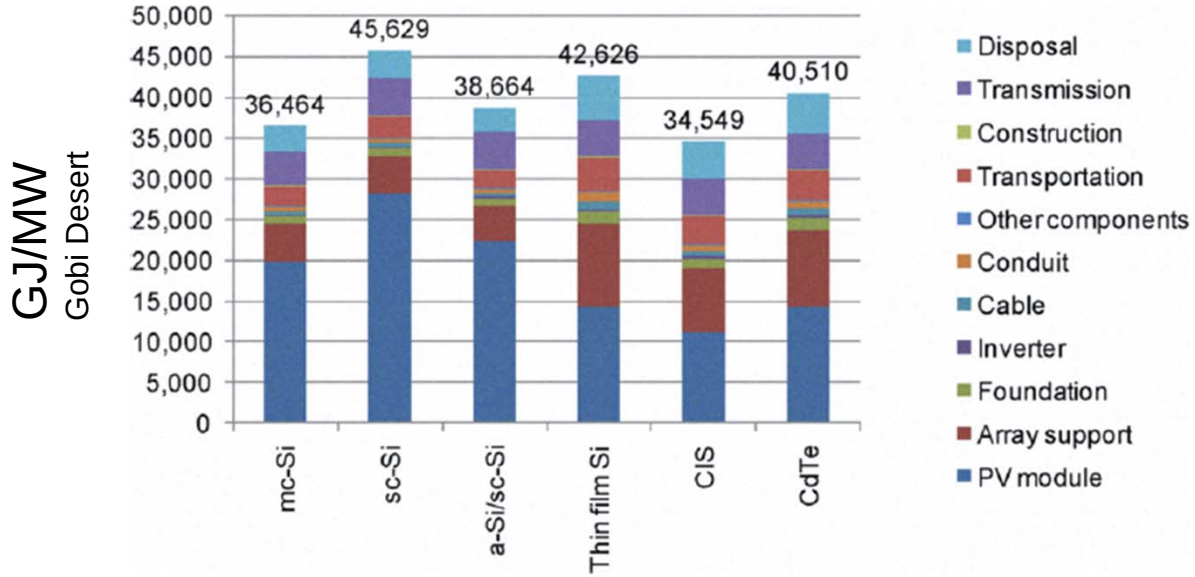
1. Energy to produce PV power plants
   - **E1PBT**: Energy PayBack Time
   - **E2PBT**: Energy «PayBack» Time
   - **DEPB**: Dynamic Energy PayBack

2. Financial payback
   - Feed-in Tarif Effect

3. Carbon
   - Carbon emission
   - Carbon «trading»

4. How to get payback for Switzerland

Energy to produce PV power plants: Masakazu Ito

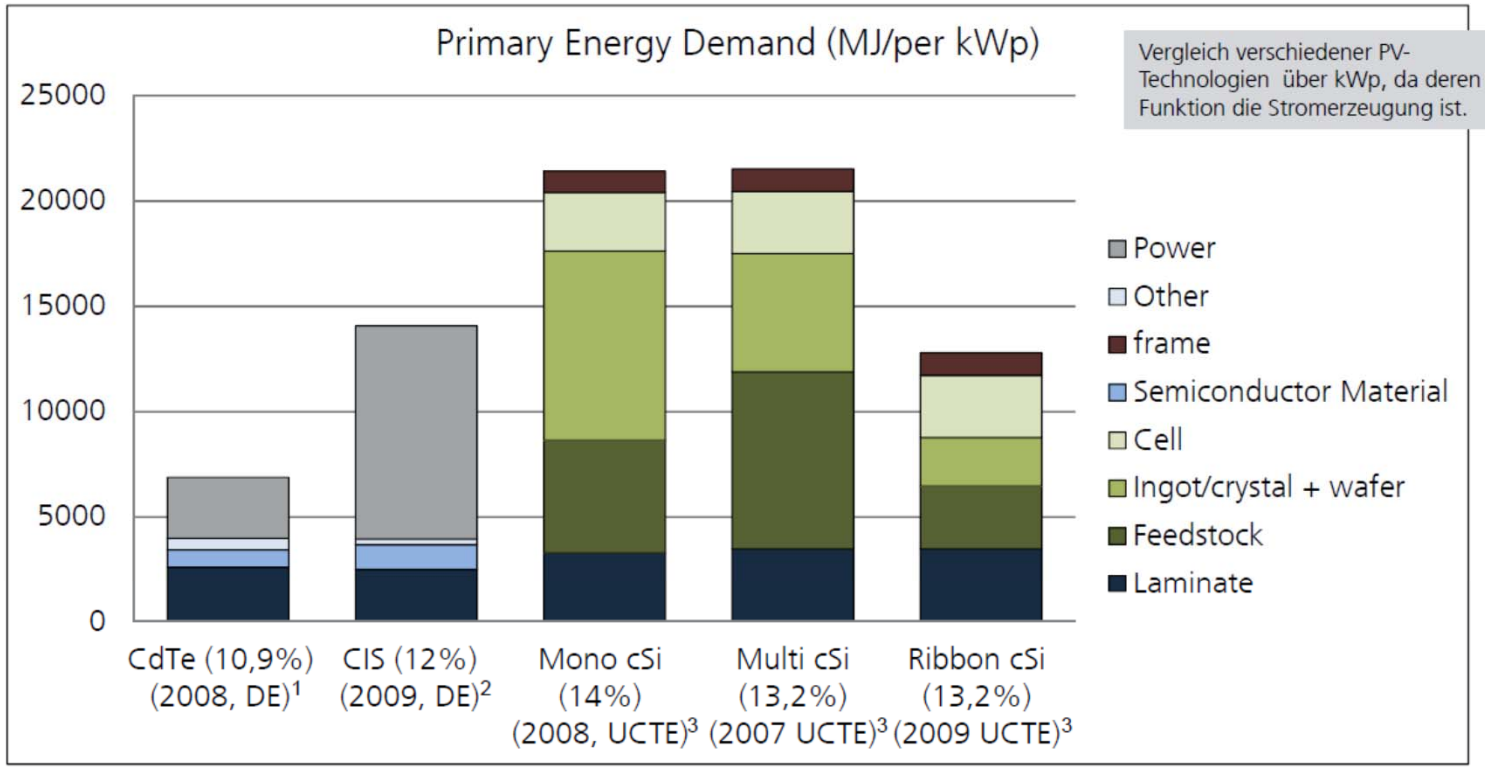


System	mc-Si	sc-Si	a-Si/sc-Si	Thin film	CIS	CdTe	Average	Eff	Ref
	13.9%	**14.3%**	**16.6%**	**8.6%**	**10.1%**	**9.0%**			
Power Plant	36	46	39	43	35	41	40	GJ/kWp	Ito, 2009
Power Plant	29	43		29	21		30	GJ/kWp	Ito, 2010
PV module	20	28	22	14	11	15		GJ/kWp	Ito, 2009

Ito, 2009:
1GW Gobi desert study (ref 1)
Ito, 2010:
Hokuto mega-solar plant (ref 2)

Energy to produce PV power plants: Michael Held

Primärenergiebedarf der Herstellung von PV-Modulen (pro kWp)



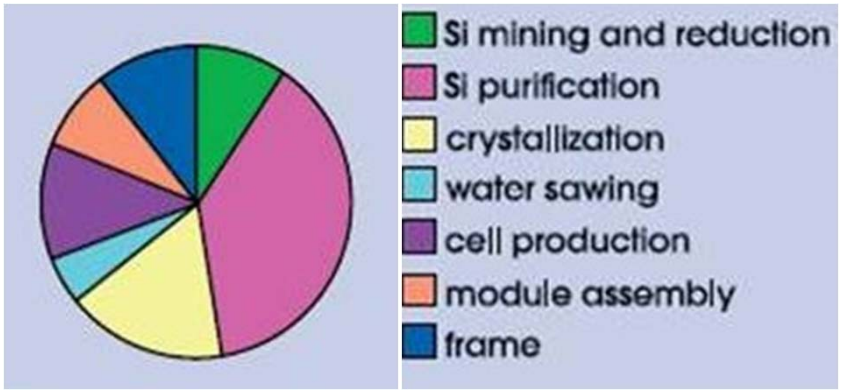
Vergleich verschiedener PV-Technologien über kWp, da deren Funktion die Stromerzeugung ist.

[1] Held (2009); [2]Lozanovski, Held (2010); [3]De-Wild (2009)

Held, 2010: (Ref 3)

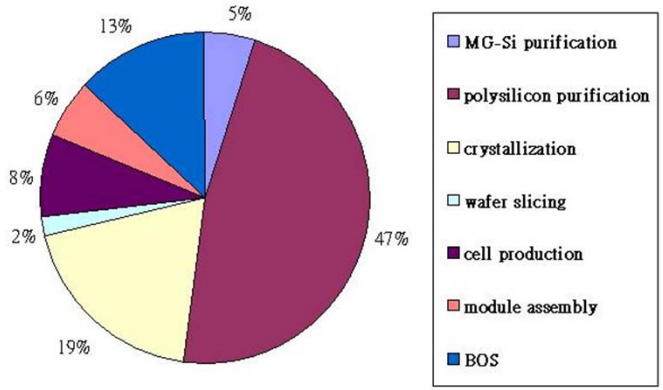
Energy to produce PV modules: Germany, Taiwan

Crystal Clear (Germany, ref 4)



- sc-Si PV module
  - 33GJ/kWp

PIDA (Taiwan) (ref 5)



- sc-Si module
  - 22GJ/kWp

E1PBT: Payback time

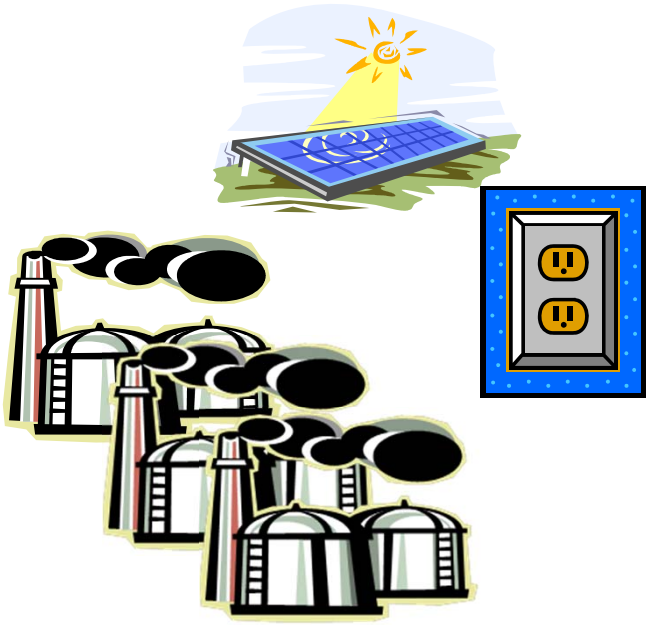
- E1PBT: 1J =1 Ws (all electrical world)
  - Harvest in southern Germany/Switzerland:
    - 1000kWh/(kWp*year)= 3.6GJ/(kWp*year))

E1PBT (years)	Bulk	Thin film		
	sc-Si	Si	CIS	CdTe
PV module	6 to 9 years	2 to 3 years	2 to 3 years	2 to 3 years
PV plant	8 to 12 years	8 to 12 years	6 to 9 years	6 to 12 years

    - E1PBT of thin film modules is offset by larger plant size (due to lower eff)

- Improvements
  - Harvest solar power in southern Europe: Factor 1.7
  - Reduce plant energy requirements
    - replace alu with plastic (inventux)
    - build on house roof tops
  - Improve efficiency of thin film technologies

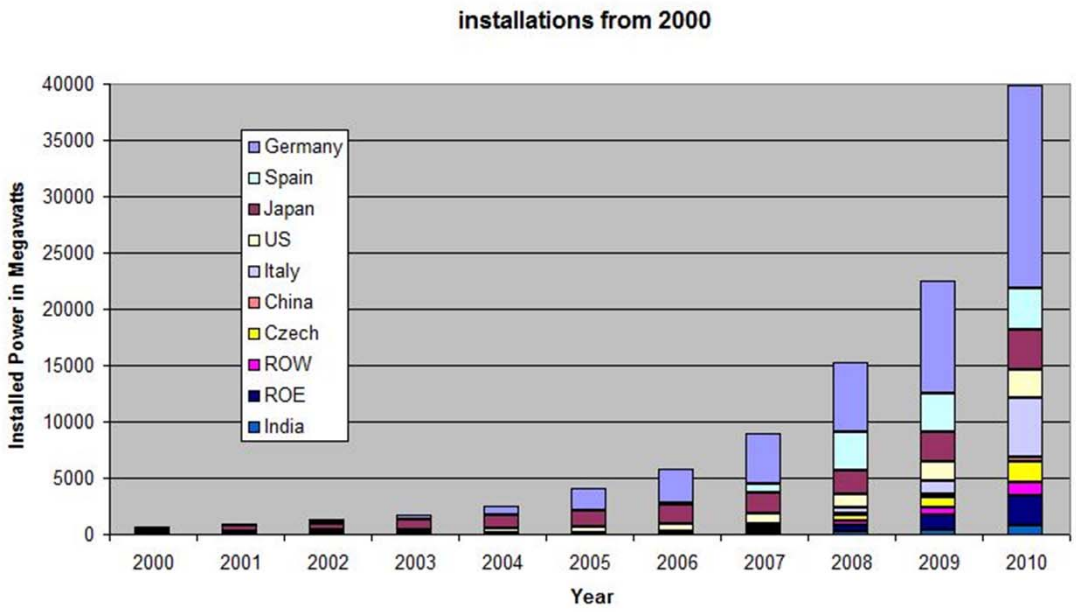
E2PBT: Energy «Pay Back» time



- E2PBT: 1J primary energy = 0.3Ws electrical energy
  - (UCTE: 0.3103, Japan: 0.3468, China:0.2998)
- E2PBT vs E1PBT
  - Calculated E2PBT is 3 times shorter than E1PBT
- E2PBT: Accepted point of view, but
  - works only as long as PV is a niche technology
  - does not work if whole world uses only PV energy
  - Sets wrong priorities in industry
    - «Energypaback used to be a problem. It is not an issue anymore»
- E2PBT (southern Germany), ref 5, 6 (Mariska deWild-Schloten)

E2PBT (years)	Bulk	Thin film		
	sc-Si	Si	CIS	CdTe
PV module	4.6 years	2.1 years		1.7 years
PV plant				

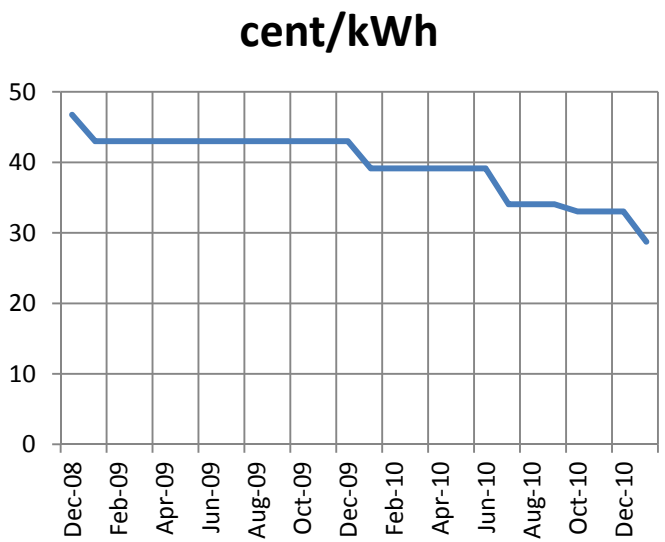
Dynamic EPB

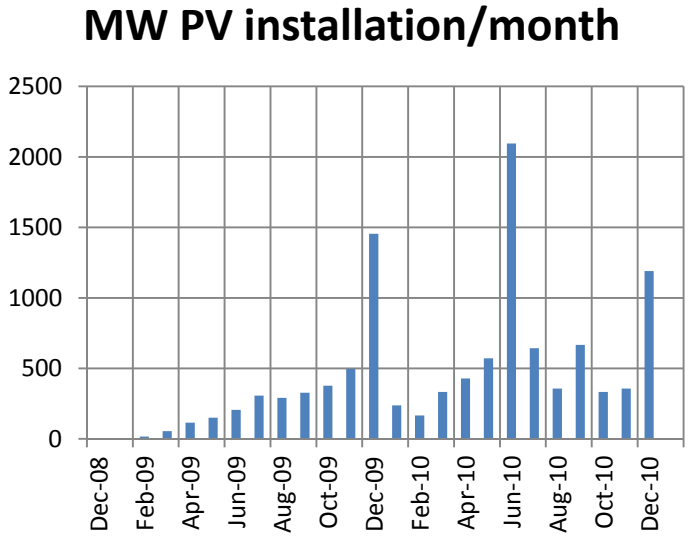


Pearsall, 2010:
EPIC PV report (ref 7)

- PV Installations: **Doubling every 1.5 years**
  - Faster than E1PBT or E2PBT:
  - PV energy production does not even cover own consumption
  - ➢ Is this a sign of a bubble? Or sustainable?

Financial: Germany

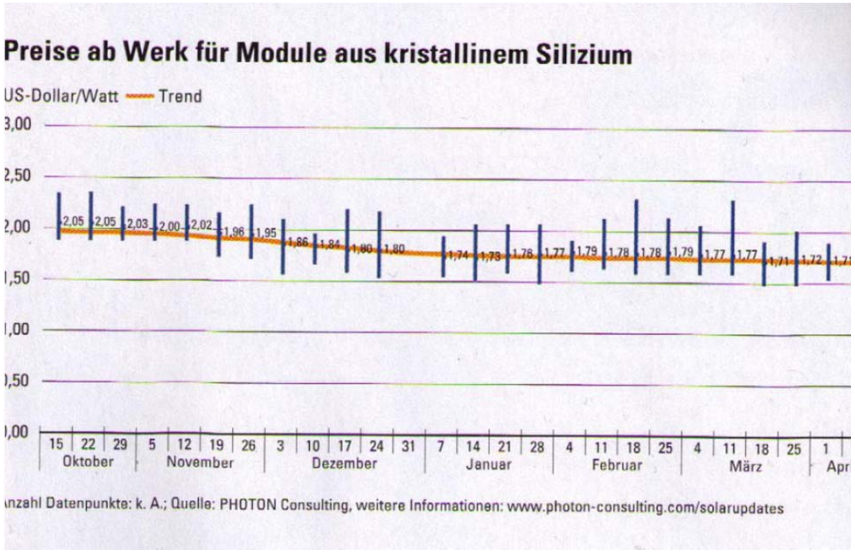


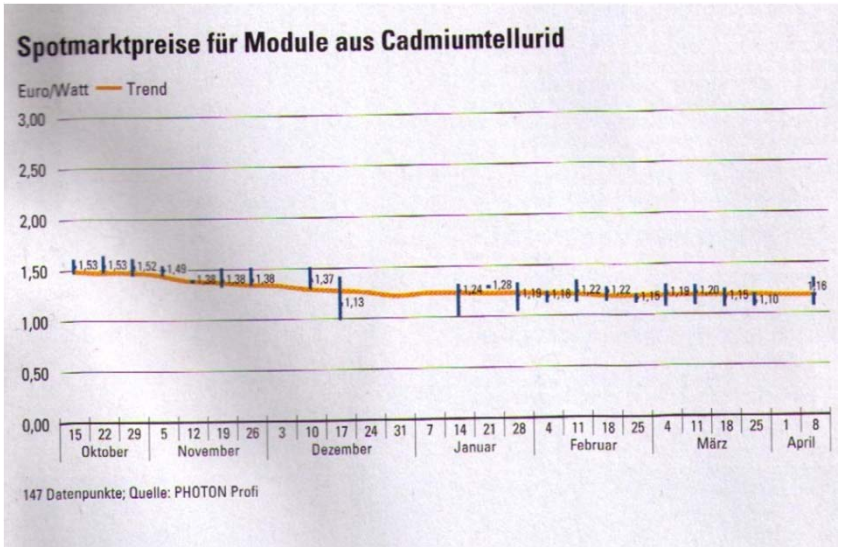


Pearsall, 2010:
EPIC PV report (ref 7)

- Financial Payback: Guaranteed by design
  - Complex system of tax break, feed-in tarif designed to give financial breakeven after 10 to 20 years
  - «Pedal» to control installation volumes
  - Decrease to reduce installation speed (fixed at installation date)
    - Acceleration of installations
    - PV manufactuerers could reduce prices dramatically and absorb price pressure

Financial: Great Progress!





Photon Profi, 2010: (ref 9)

- Tremendous progress in industry
  - **PV Modules below 1.7€/Wp (sc-Si) and 1.1€/Wp (CdTe)!**

Carbon Emission:

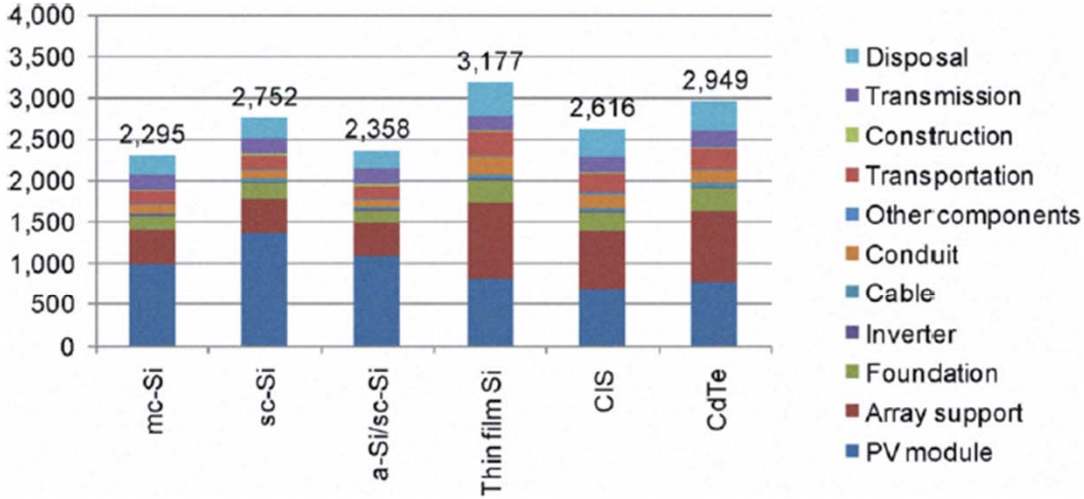
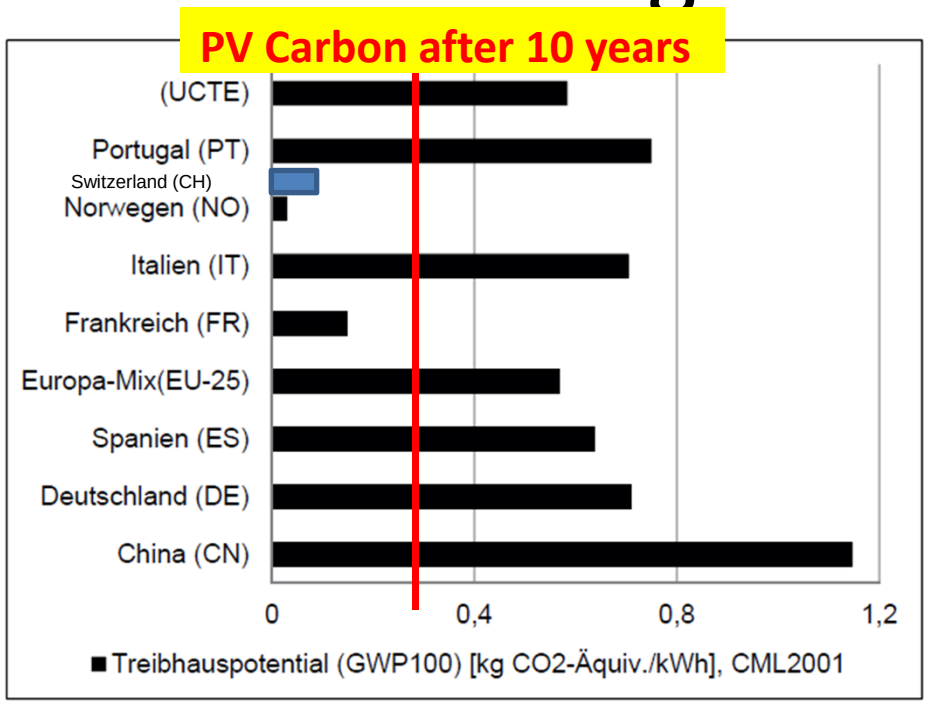


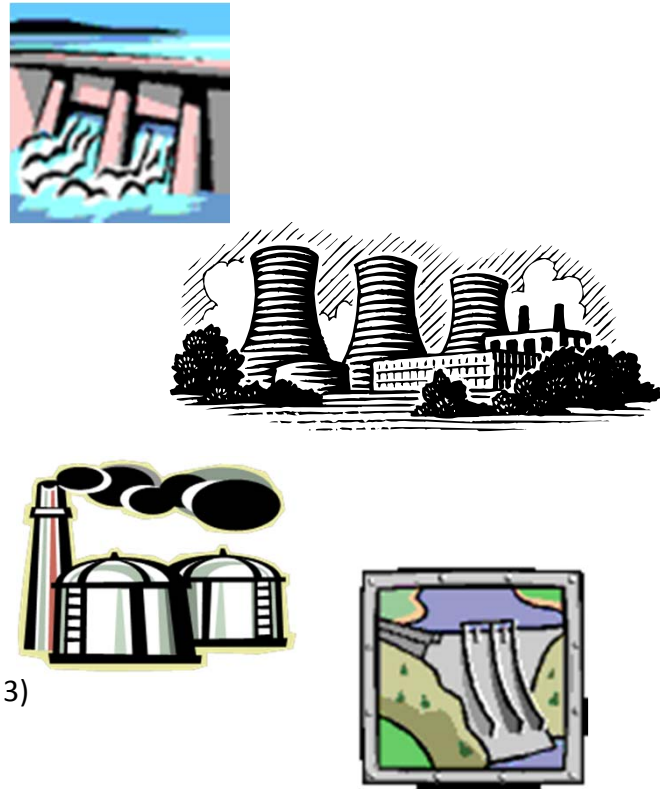
Fig. 5 CO2 emissions of six types of PV modules [t-CO2/MW]

Ito, 2009:
1GW Gobi desert study (ref 1)

- Carbon emission during 30 years (Manufactured in China)
  - 50gr-70gr CO2/kWh (operated in Gobi)
  - 80-120gr CO2/kWh (southern Germany)
  - Thin film PV module advantage is offset by bigger plant size

Carbon: Savings:



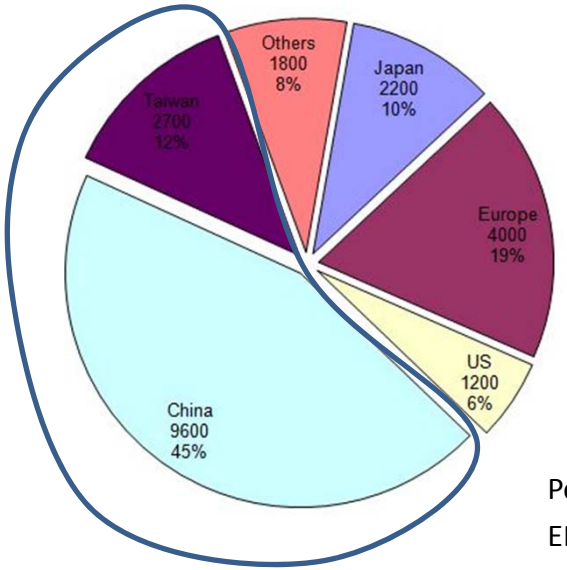


Held, 2010: (Ref 3)

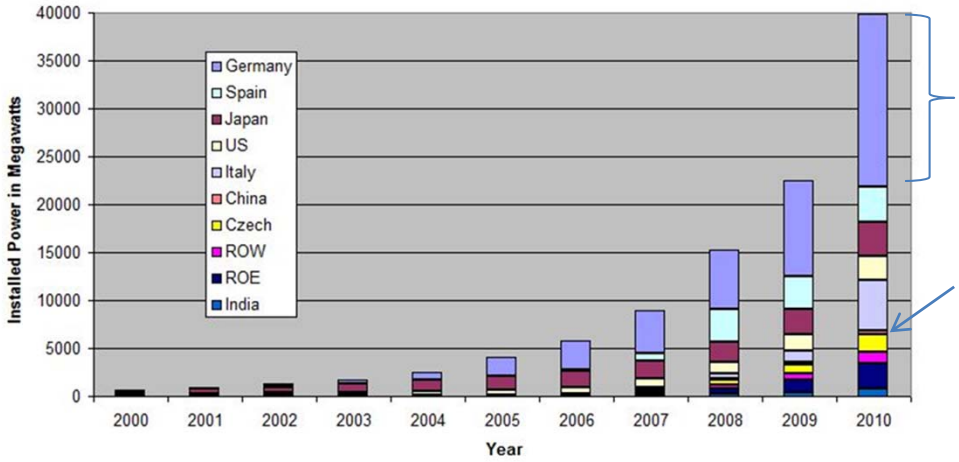
- Carbon payback of PV manufactured in China
  - 4 years in Germany
  - 30 years (?) in Switzerland !
- Carbon optimization
  - Manufacture PV in Norway (Switzerland) and operate it in China!

Present Carbon «trading»

PV Production in China: 57%



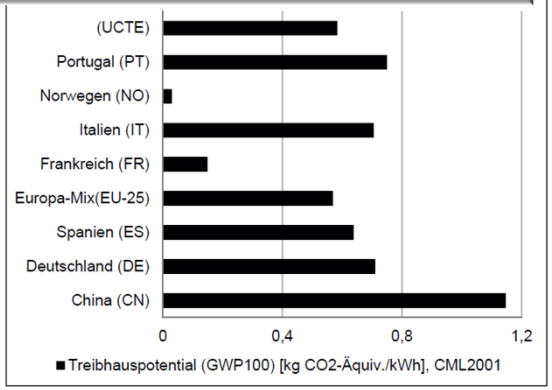
PV Installation in Germany: 45%



Pearsall, 2010:
EPIC PV report (ref 7)

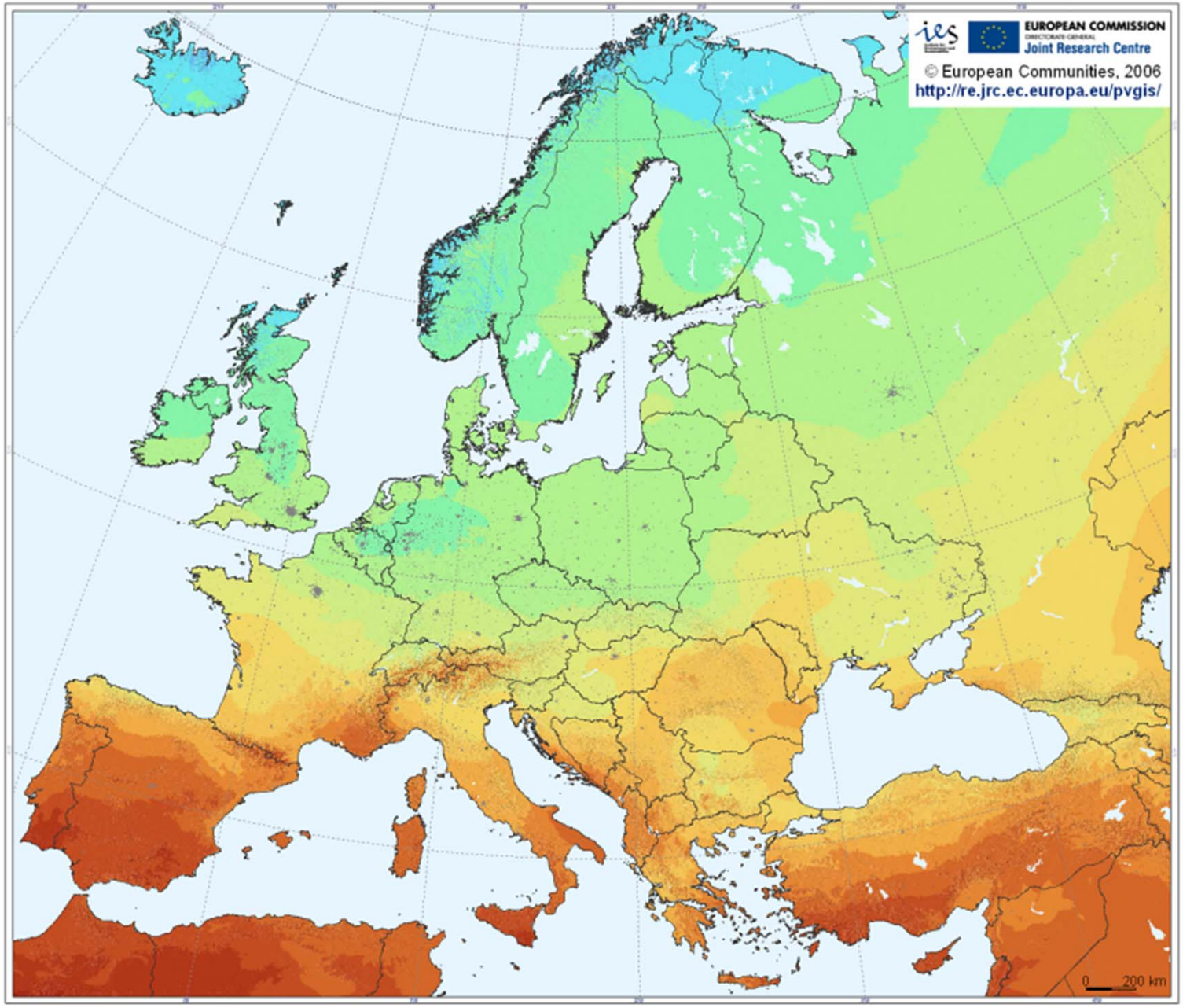
- Simplified Present Situation
  - High carbon PV manufacture in China
  - Harvest in Germany
- Optimized
  - Manufacture in Norway (Switzerland) (*10..20)
  - Harvest in Italy, Spain (*1.7)

Carbon in Electricity



Held, 2010: (Ref 3)

Photovoltaic Solar Electricity Potential in European Countries



Yearly sum of global irradiation incident on optimally-inclined south-oriented photovoltaic modules

Global irradiation [kWh/m²]
<600 800 1000 1200 1400 1600 1800 2000 2200>

Yearly sum of solar electricity generated by 1 kWp system with optimally-inclined modules and performance ratio 0.75

<450 600 750 900 1050 1200 1350 1500 1650>
Solar electricity [kWh/kWp]

PV Payback Times

- **Financial Payback:**
  - Great progress: The PV module price is at 1.2€/W to 1.7€/W due to feed-in tarif curve!
  - Finacial payback guaranteed!
  - Full systems run at 2 to 3€/W on your roof.
- **Energy Payback time:**
  - E2PBT: 2 to 5 years for PV modules, 5 to 10 years for PV plant (Germany),
    - ok: But is this the right figure of merit? Or optimistic by facor of 3?
  - E1PBT: Will force industry to high efficincy thin films and plastic enclosures
- **Carbon Payback:**
  - It does not make «carbon» sense to harvest in Switzerland with PV modules which were manufactured in China!
  - Much better (20 times) to harvest in China (or Italy or Spain) with PV modules which were manufactured in Switzerland (or Norway).
- **Research needed towards:**
  1. Thin film, high efficincy, plastic enclosure, aluminum-free PV modules
  2. Manufacturing technologies to be cost competitive in Switzerland, Norway, Island

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