ECN

Energy research Centre of the Netherlands

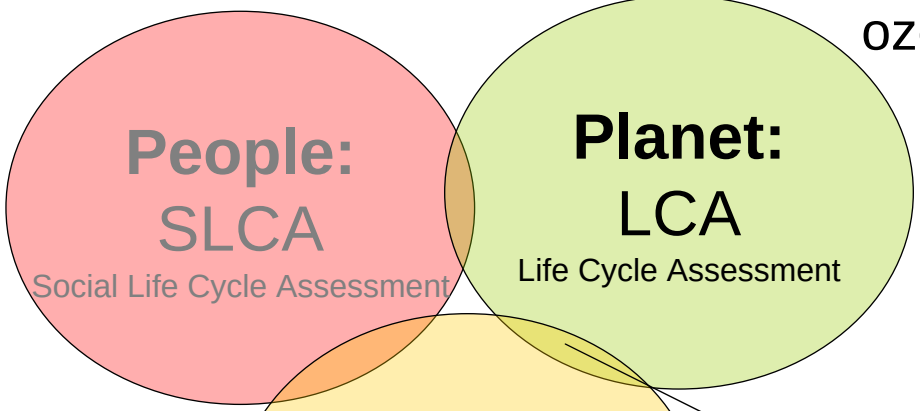
Energierücklaufzeiten für PV-Module und Systeme
Energy payback times of PV modules and systems

Mariska de Wild-Scholten

Outline

- Sustainability
- Life Cycle Assessment
- Energy payback time
- Energy yield ratio
- Conclusions

Sustainability: the 3 pillars



environment:
photochemical oxidation
ozone layer depletion
global warming
toxicity
acidification
eutrophication

depletion of resources
external costs

Levelized Cost of Electricity

EPIA Sustainability Working Group & IEA PVPS task 12

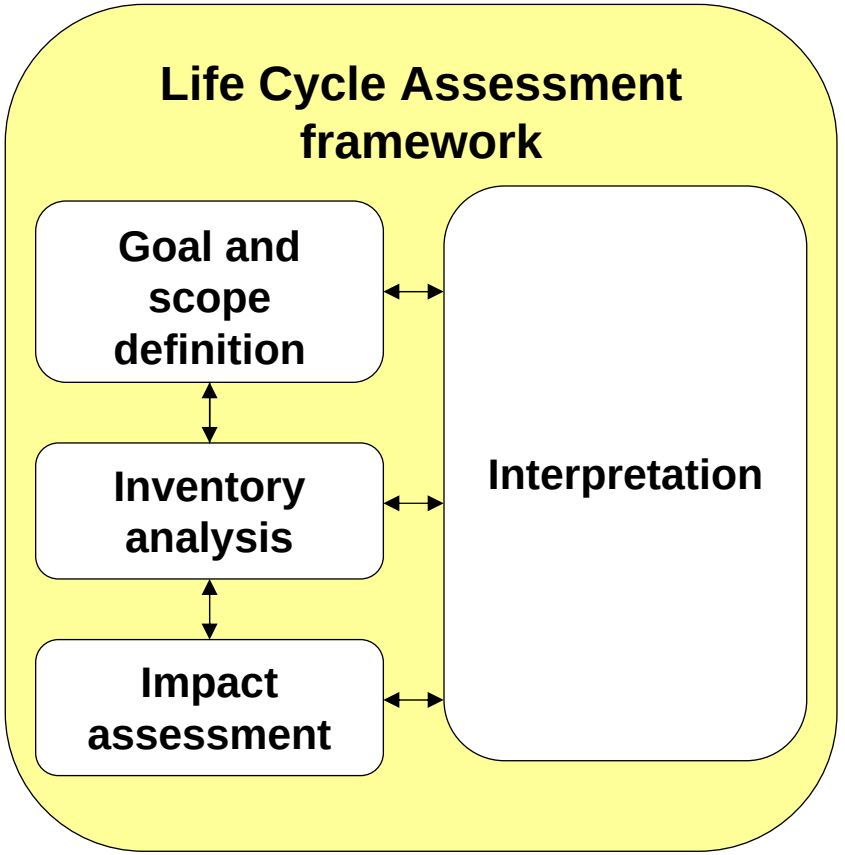
Life Cycle Assessment (LCA)

ISO14040 series

Determination of the environmental impact of a product from cradle to grave

Simapro software

Ecoinvent database



Photovoltaics cannot pay back it's energy investment?

Energy payback time (EPBT)

- definition: time in which the energy input during the PV system life-cycle is compensated by electricity generated by the PV system
- $EPBT = E_{input} / (E_{output}/year)$

- ☹ Lifetime of PV system not included!

Energy payback time: calculation example CdTe PV module

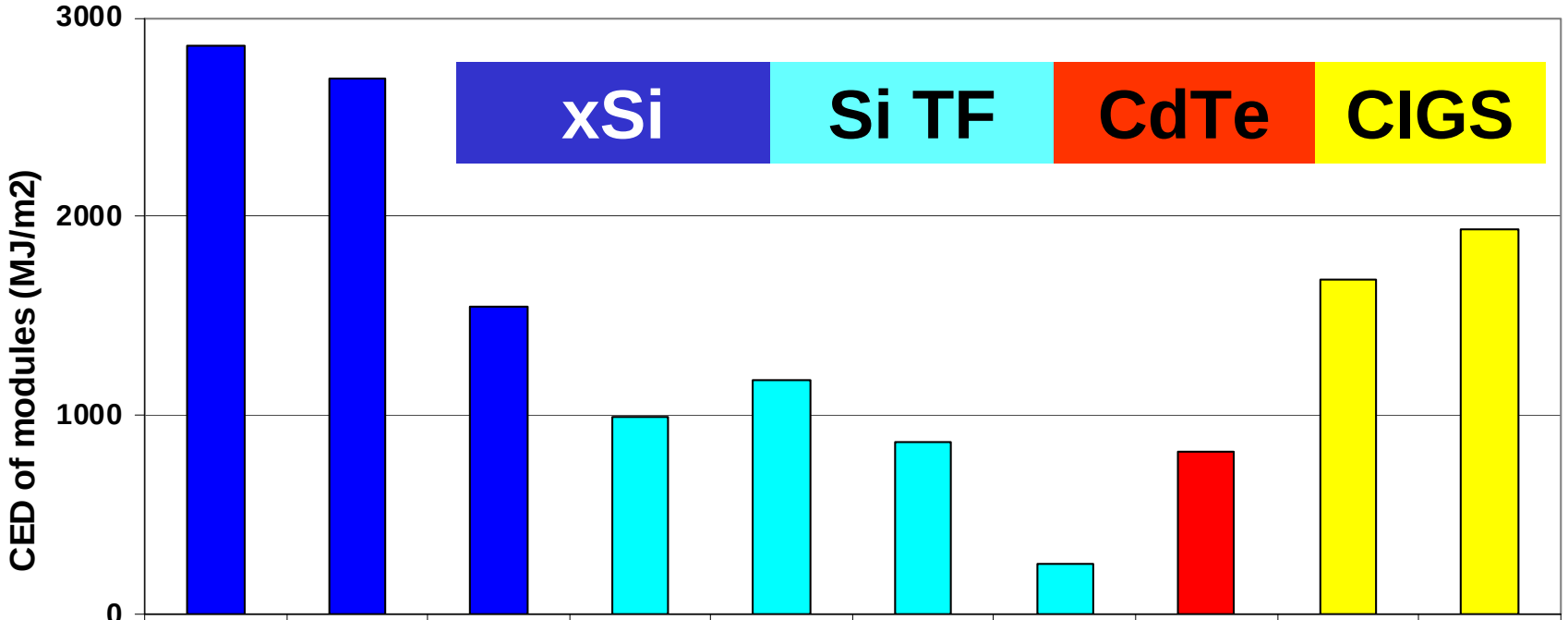
E_{input} = Cumulative Energy Demand (CED) from LCA	**12236** MJ_{prim}/kWp
Irradiation	1700 kWh/m^2.year
Performance ratio (IEC 61724)	0.75
Generated electricity	**1275** kWh/kWp.year
Efficiency electricity supply	**11.4** MJ_{prim}/kWh
Avoided energy	**1275 x 11.4 = 14535** MJ_{prim}/kWp.year
Energy payback time	**12236 / 14535 = 0.84 years**

Data & assumptions

- **UCTE (European) electricity mix**
- **Slanted roof-top installation for flat plate, 2-axis tracker for CPV; performance ratio 0.75**

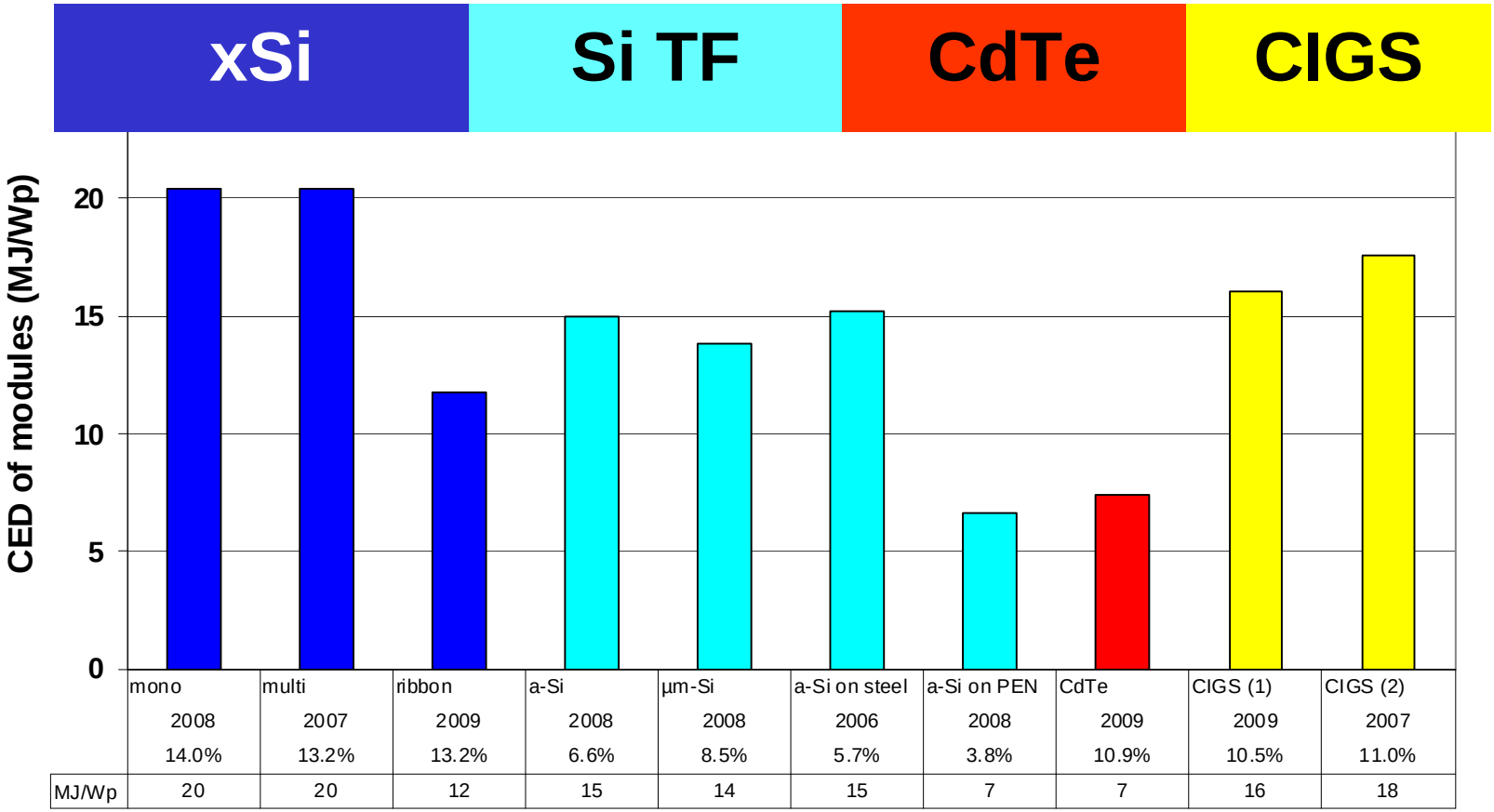
- **x-Si:** CrystalClear project
  - **Si feedstock = REC Siemens, multi wafers = REC, ribbon "wafers" = Evergreen Solar, frameless modules**
- **Si TF: Performance project**
  - **a-Si: German producer, µm-Si: best data equipment manufacturers,**
  - ***excluding* SF_6/NF_3 consumption/emissions**
  - **fiX mounting of frameless module**
  - **a-Si on steel: United Solar**
  - **a-Si on PEN: Flexcell (Flexcellence project)**
- **CdTe: Performance project**
  - **First Solar data 2004 ecoinvent 2.0 + updated energy/glass consumption/Cd emission**
  - **mounting of frameless modules: Schletter roof-top, assumed same as xSi**
  - **module recycling: no data for filtercake treatment**
- **CIGS: Performance project**
  - **German producer + ecoinvent 2.0 data for water & some metals**
  - **mounting of frameless modules: Schletter roof-top, assumed same as xSi**
  - **module recycling: assumed the same as CdTe**
- **CPV: Apollon project**
  - **ENE, NaREC, CPower, SolarTech International AG**

Cumulative Energy Demand
MJ_{prim} / m^2 of module



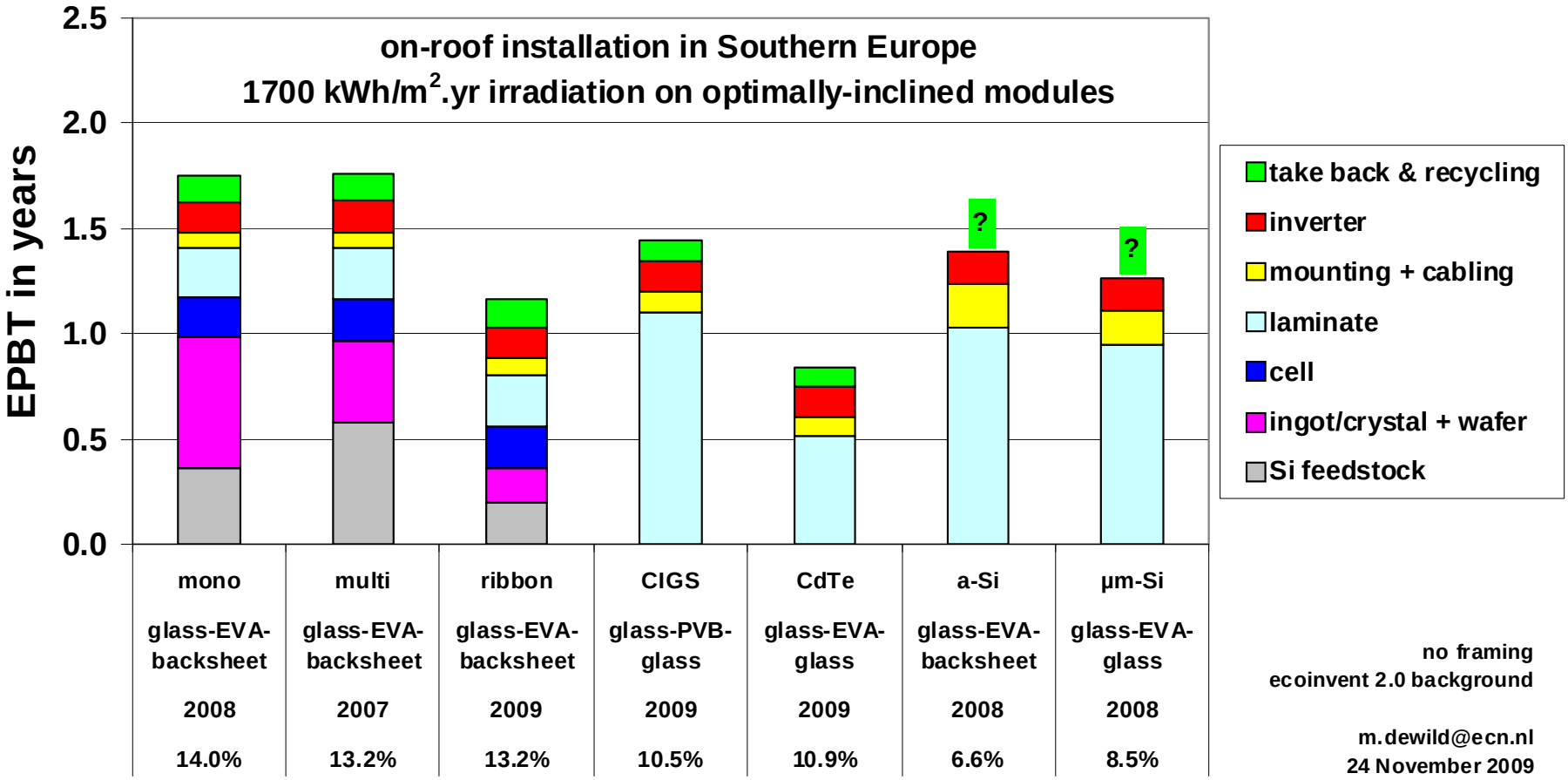
	mono	multi	ribbon	a-Si	µm-Si	a-Si on steel	a-Si on PEN	CdTe	CIGS (1)	CIGS (2)
	2008	2007	2009	2008	2008	2006	2008	2009	2009	2007
	14.0%	13.2%	13.2%	6.6%	8.5%	5.7%	3.8%	10.9%	10.5%	11.0%
MJ/m2	2860	2699	1548	989	1173	866	252	811	1684	1936

Cumulative Energy Demand
MJ_{prim} / Wp of modules



	mono	multi	ribbon	a-Si	µm-Si	a-Si on steel	a-Si on PEN	CdTe	CIGS (1)	CIGS (2)
	2008	2007	2009	2008	2008	2006	2008	2009	2009	2007
	14.0%	13.2%	13.2%	6.6%	8.5%	5.7%	3.8%	10.9%	10.5%	11.0%
MJ/Wp	20	20	12	15	14	15	7	7	16	18

Energy payback time



no framing
ecoinvent 2.0 background

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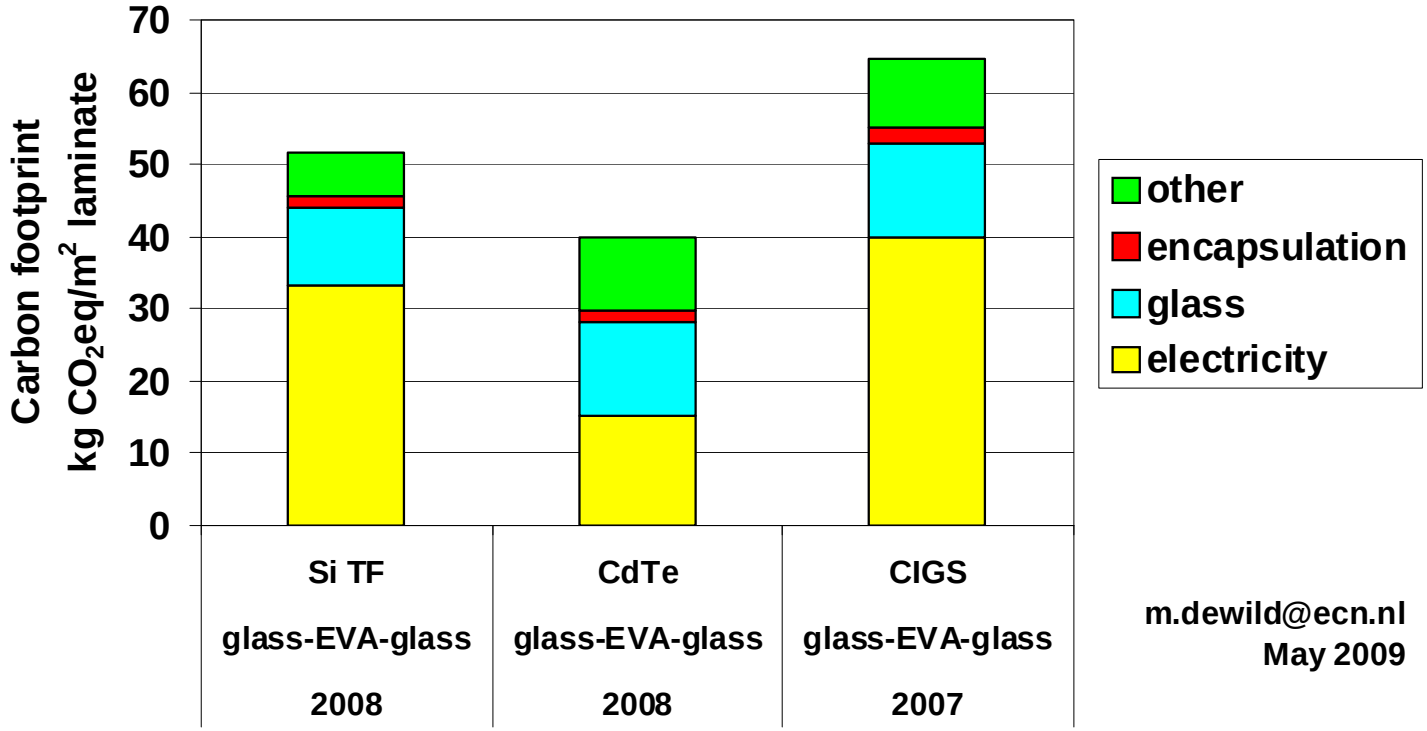
24 November 2009

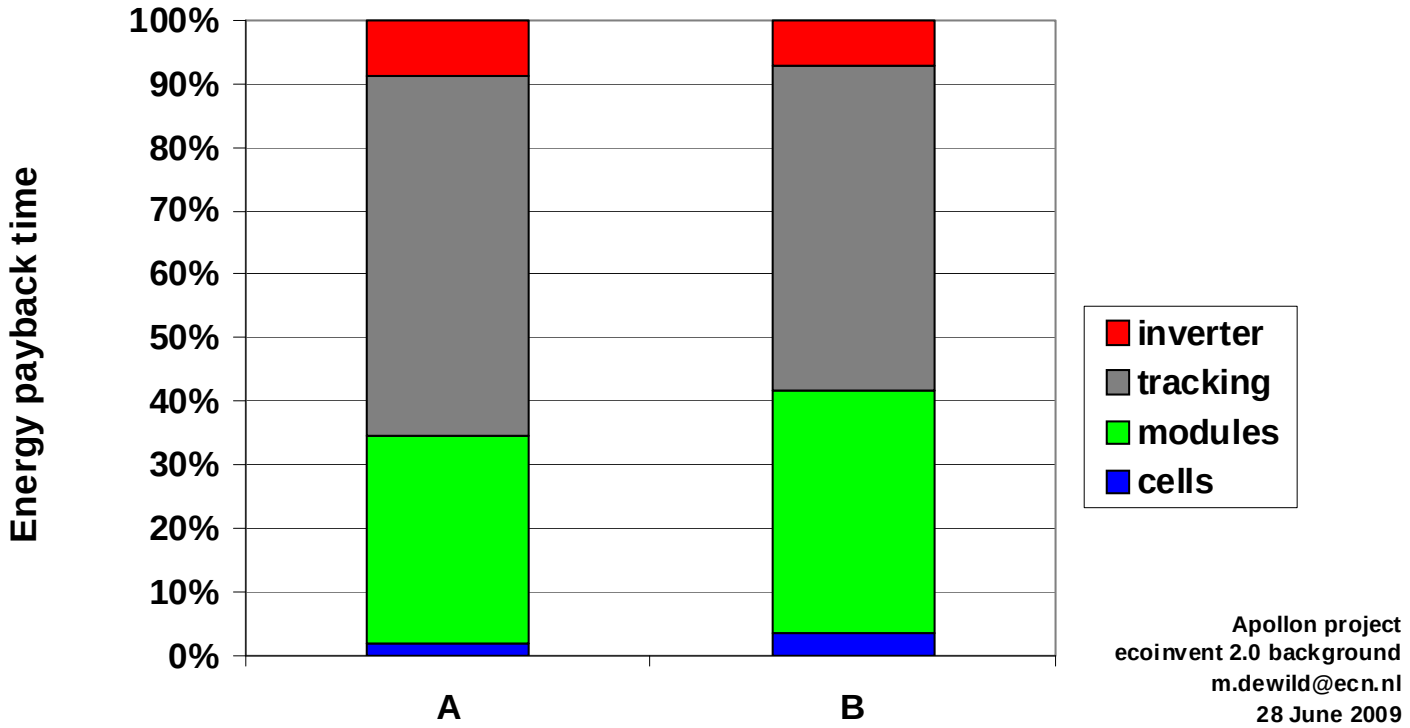
Carbon footprint (!) breakdown

- largest contribution from electricity & glass
- similar picture for EPBT



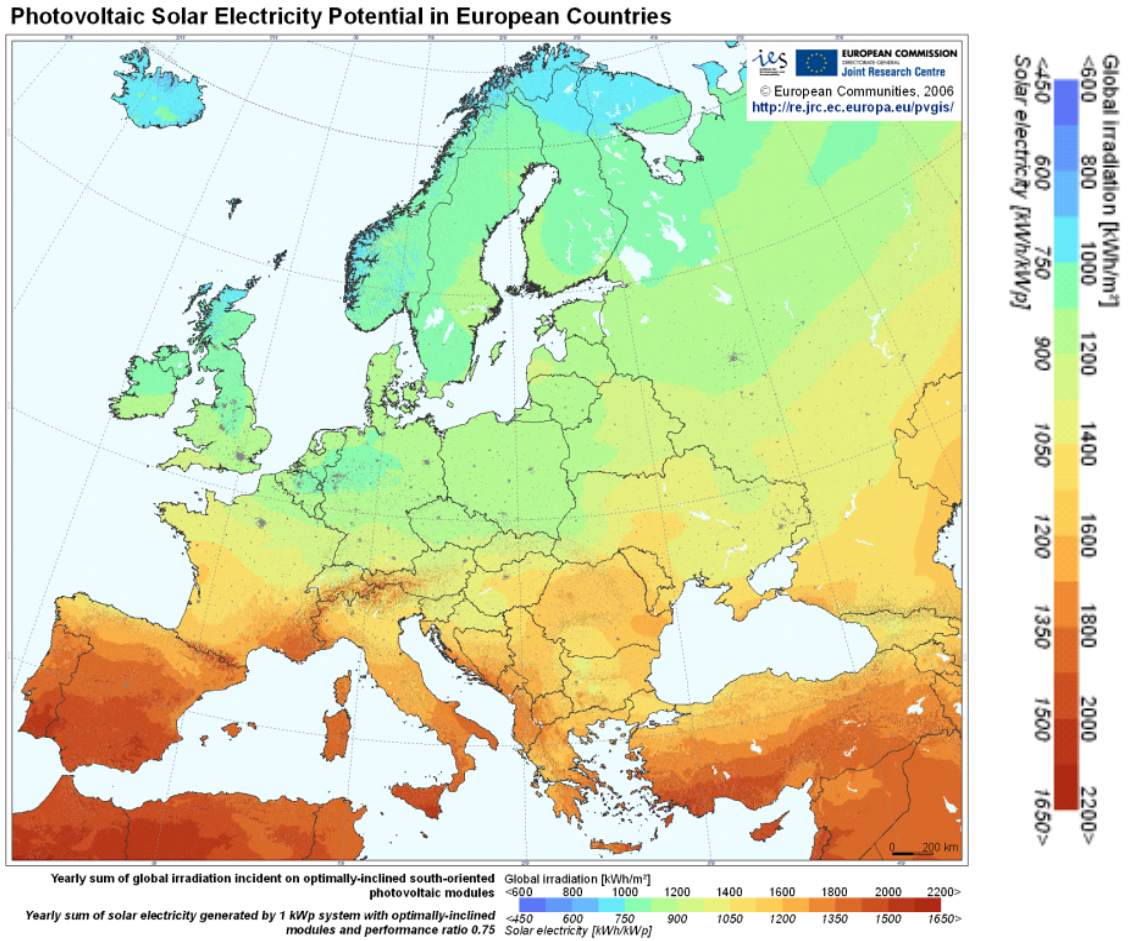
Energy payback time of Concentrator PV systems

- largest contribution from tracking system



What is THE energy payback time of PV?

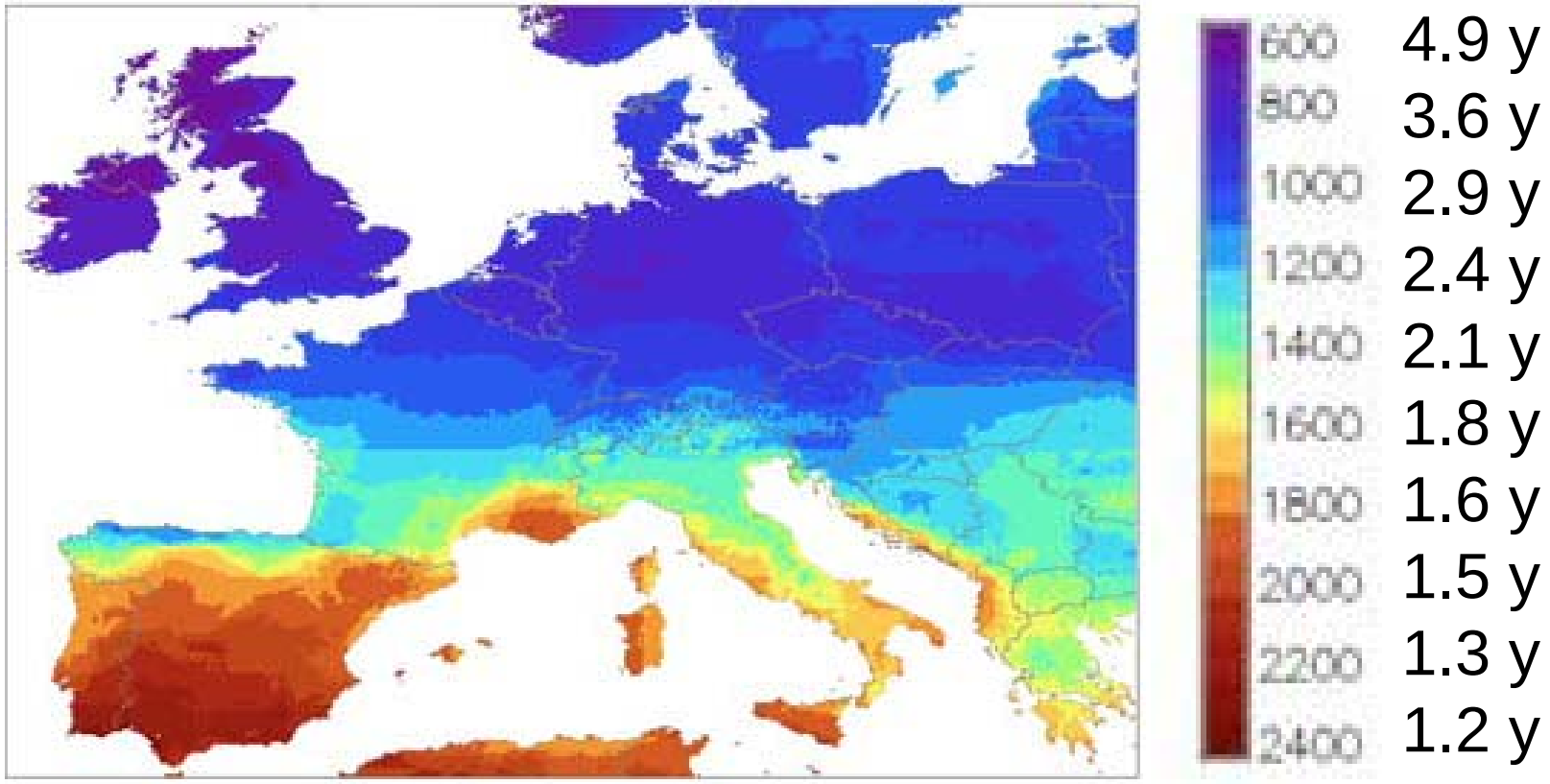
“The” energy payback time: CdTe PV system



2.4 years
1.8 years
1.4 years
1.2 years
1.0 years
0.9 years
0.8 years
0.7 years

“The” energy payback time for CPV system

Direct Normal Irradiation (DNI): kWh/m^2.year & EPBT



Source of DNI map: suri@geomodel.eu

preliminary results Apollon project

Energy yield ratio (EYR)

- definition: how many times the energy invested is returned or paid back by the system in its entire life
- $EYR = E_{output\ in\ lifetime} / E_{input}$
- EYR < 1 : ☹
- EYR > 1 : ☺

Energy Yield Ratio of PV systems

- to be calculated when reliable data about system lifetime and module degradation become available [Performance project]

Conclusions

- Energy payback time

  ~ 1 year for PV systems in S-Europe
  < lifetime of PV system
- Major contributions

  - for flat plate PV from module production (electricity + glass),

  - for CPV from tracking system
- Energy Yield Ratio is a better metric for comparisons because based on lifetime energy output

Acknowledgements & further info

- EU projects: Flexcellence, CrystalClear, Performance, Apollon

- B.S. Richards, M.E. Watt (2007) Permanently dispelling a myth of photovoltaics via the adoption of a new net energy indicator

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- papers: http://www.ecn.nl/publicaties/default.aspx?au=44649

Thank you!