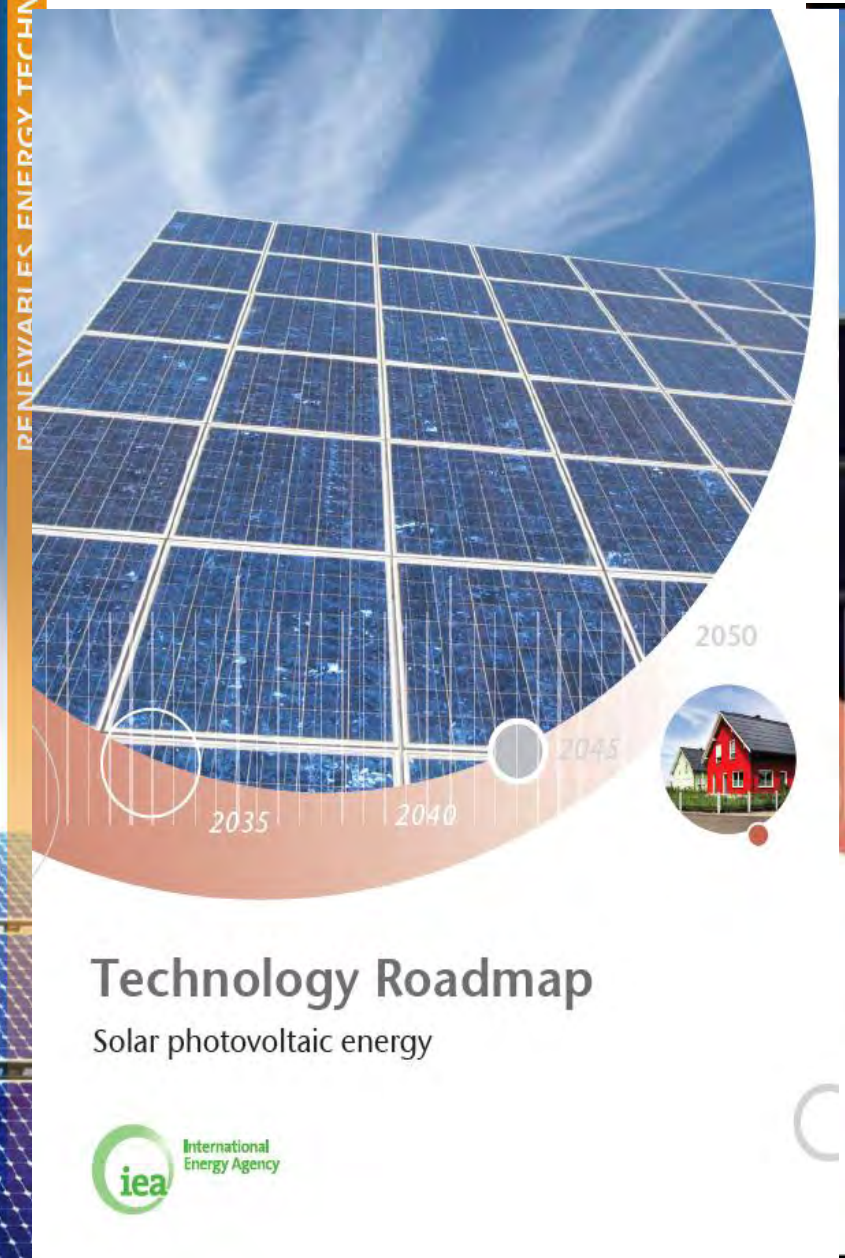
Renewable Energy TECHNOLOGIES

Cédric Philibert, Renewable Energy Division
Austrian PV Conference, Vienna, 20 Oct. 2011

International Energy Agency

Solar Energy Perspectives

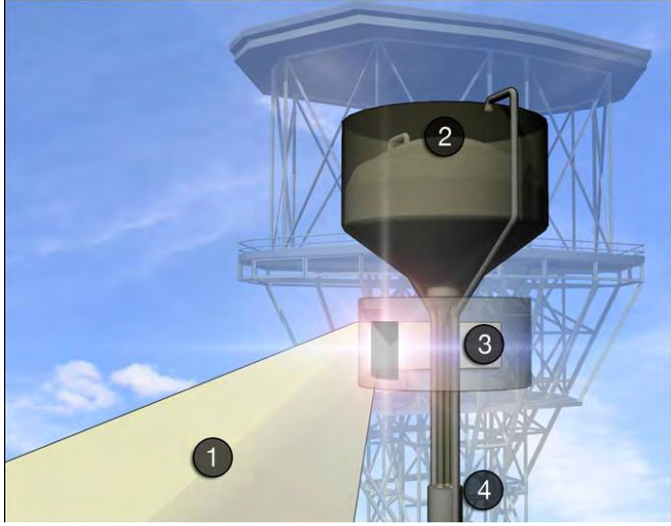
Building on…



… also starring…

Solar heating and cooling

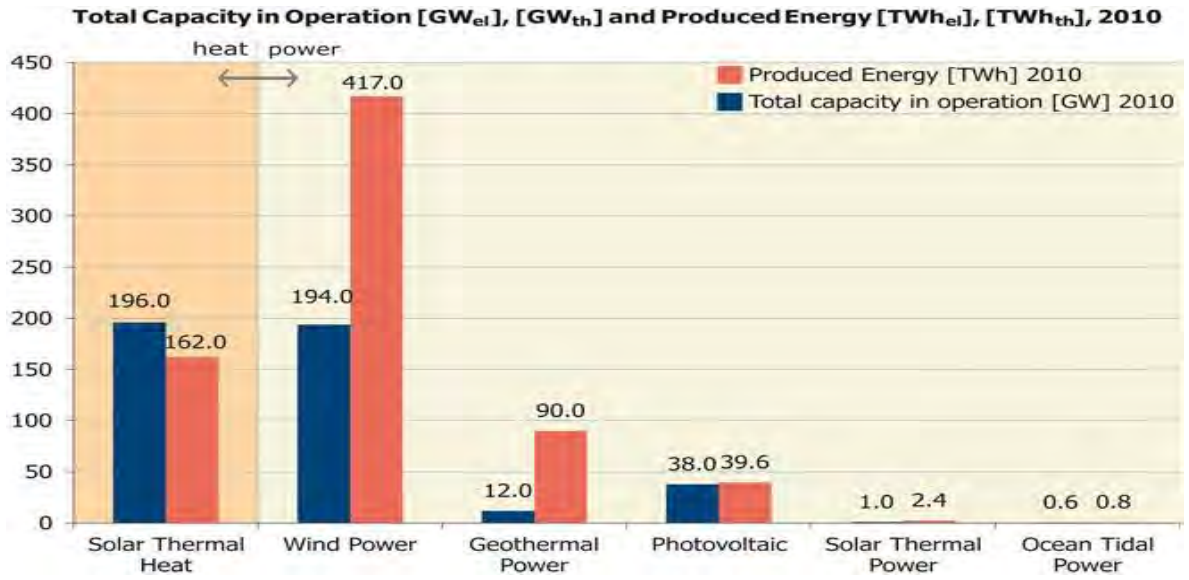
- Forthcoming IEA roadmap:
  - 4 workshops:
  - Paris (April), Kassel (Aug.)
  - Beijing & Sidney (Nov.)



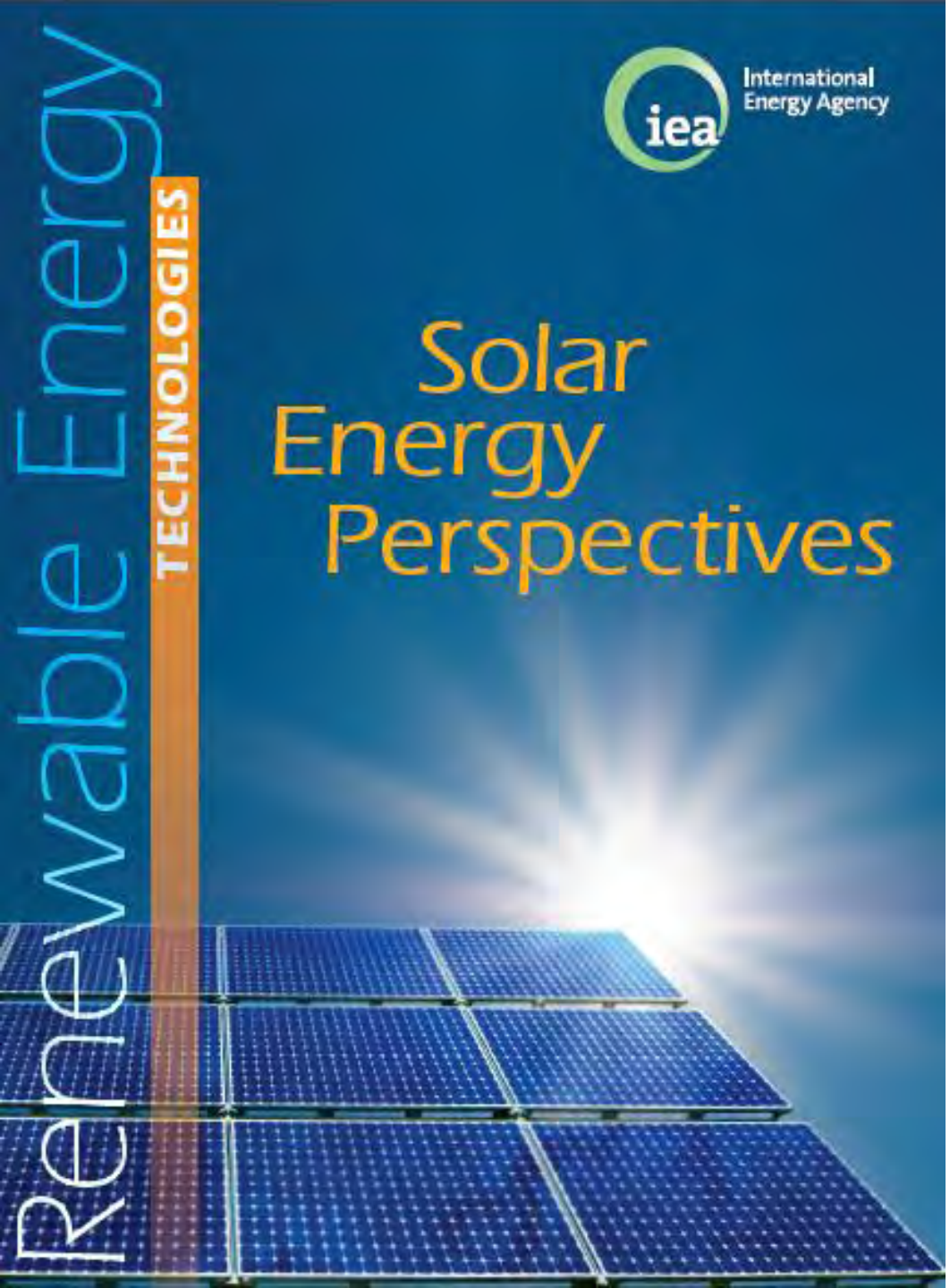
Source: Sundrop Fuels Inc.

Solar fuels

- From PV & CSP
- H_2 and liquids



Source: Weiss and Mauthner, 2011



Introducing:

- A new IEA publication to be launched in Fall
- First RE in-depth technology study
- Support from the French and US governments

Solar Energy Perspectives

In search of synergies

- Between various solar technologies
- With other RE/EE technologies

Source: Solimpeks Solar Energy

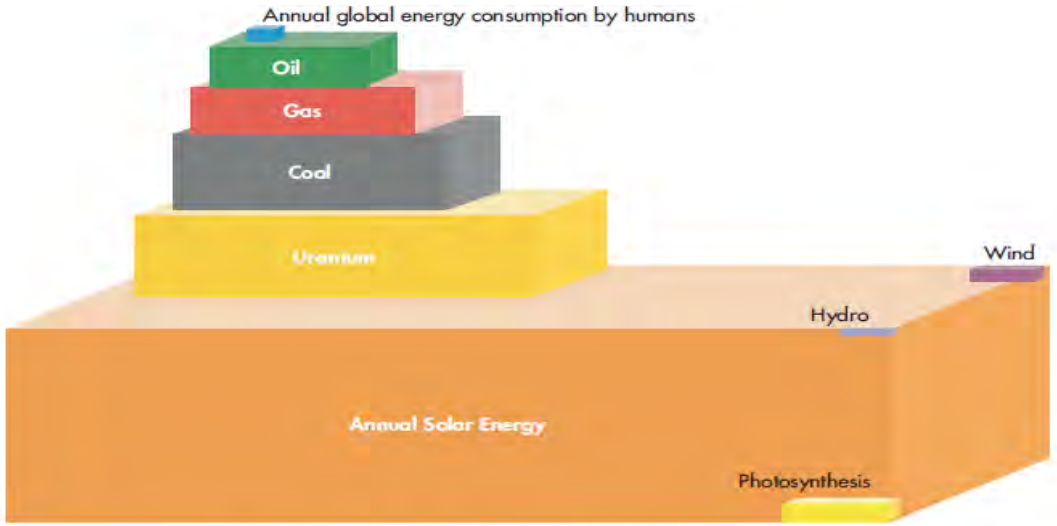
Source: SunEarth Inc

- Driven by analyses of the demand for various uses

RENEWABLES ENERGY TECHNOLOGIES

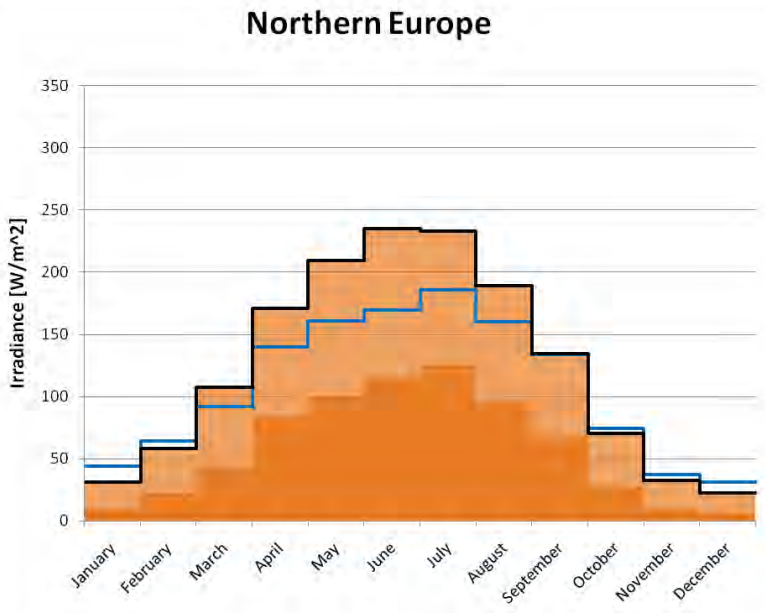
Solar Energy Perspectives

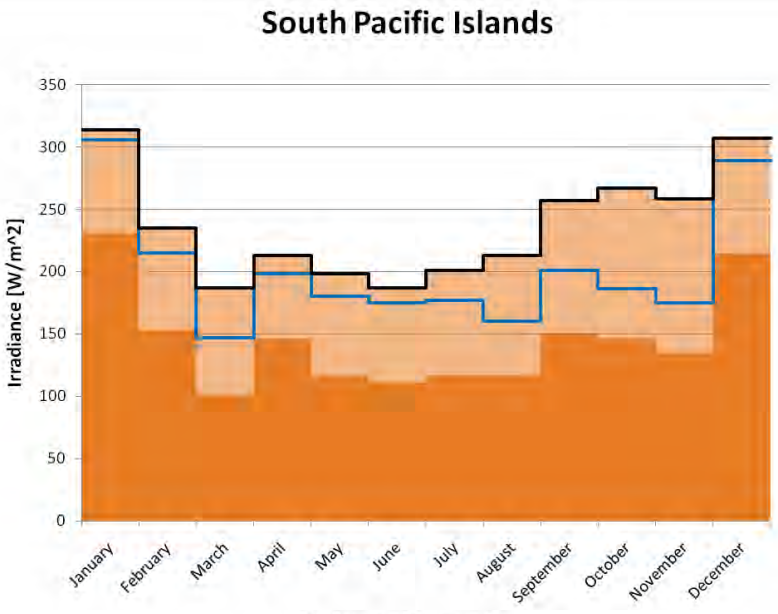
Content

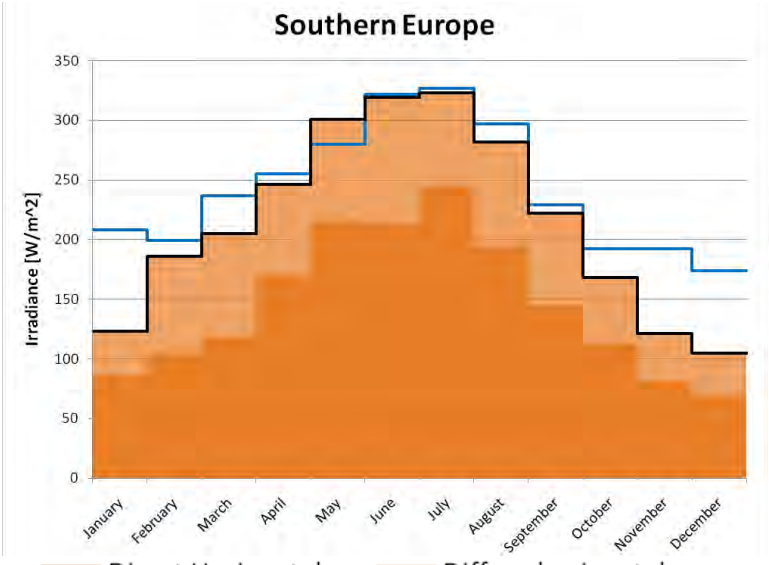


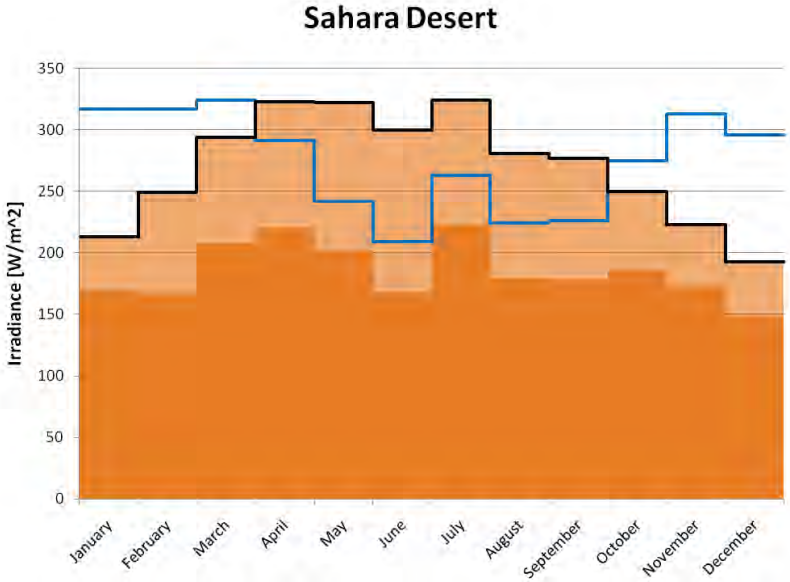
- Rationale
- Markets & outlook
  - The solar resource
  - Electricity
  - Buildings
  - Industry
  - Transport
- Technologies
  - Photovoltaics
  - Heat
  - Solar thermal power
  - Solar fuels
- The way forward
  - Policies
  - Testing the limits

Solar resource









Direct Horizontal | Diffuse horizontal | Direct Normal | Global Horizontal

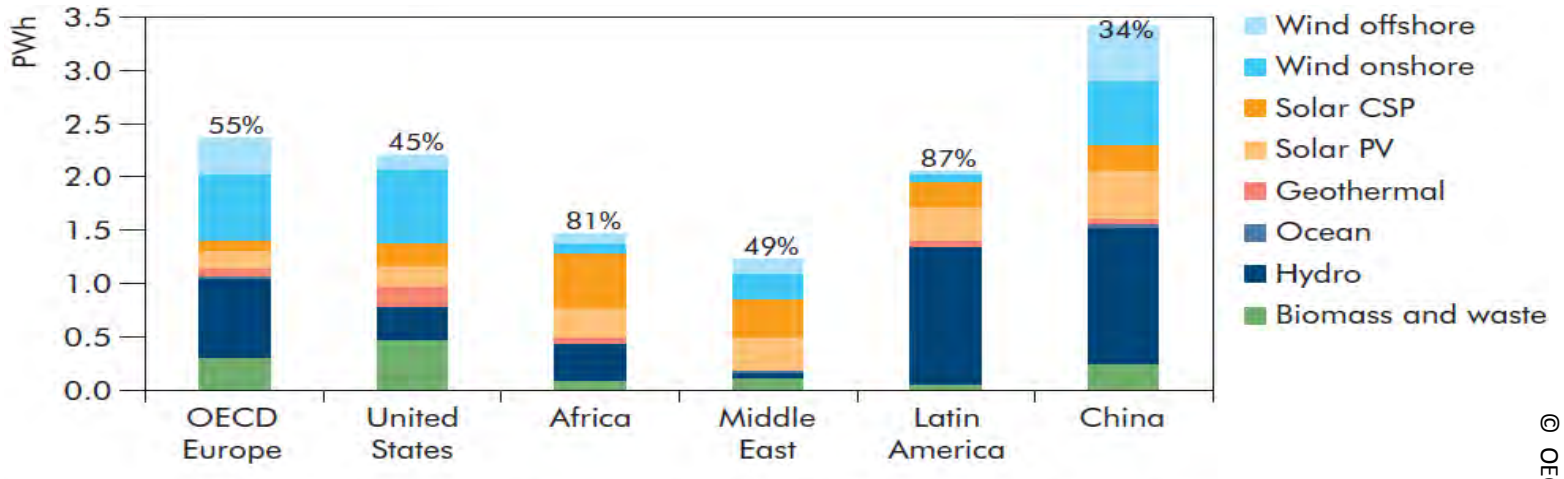
Source: Chhatbar & Meyer 2011

Markets: Electricity

- PV takes **all** light
- PV almost **everywhere**
- Mostly at **end-users'**
- **Variable**
- Peak & mid-peak
- Grid parity **by 2020**
- **Smart grids**

- CSP takes **direct** light
- CSP **semi-arid** countries
- Mostly for **utilities**
- **Firm**, dispatchable } backup / storage
- Peak to **base-load**
- Competitive peak power **by 2020**
- **HVDC lines** for transport

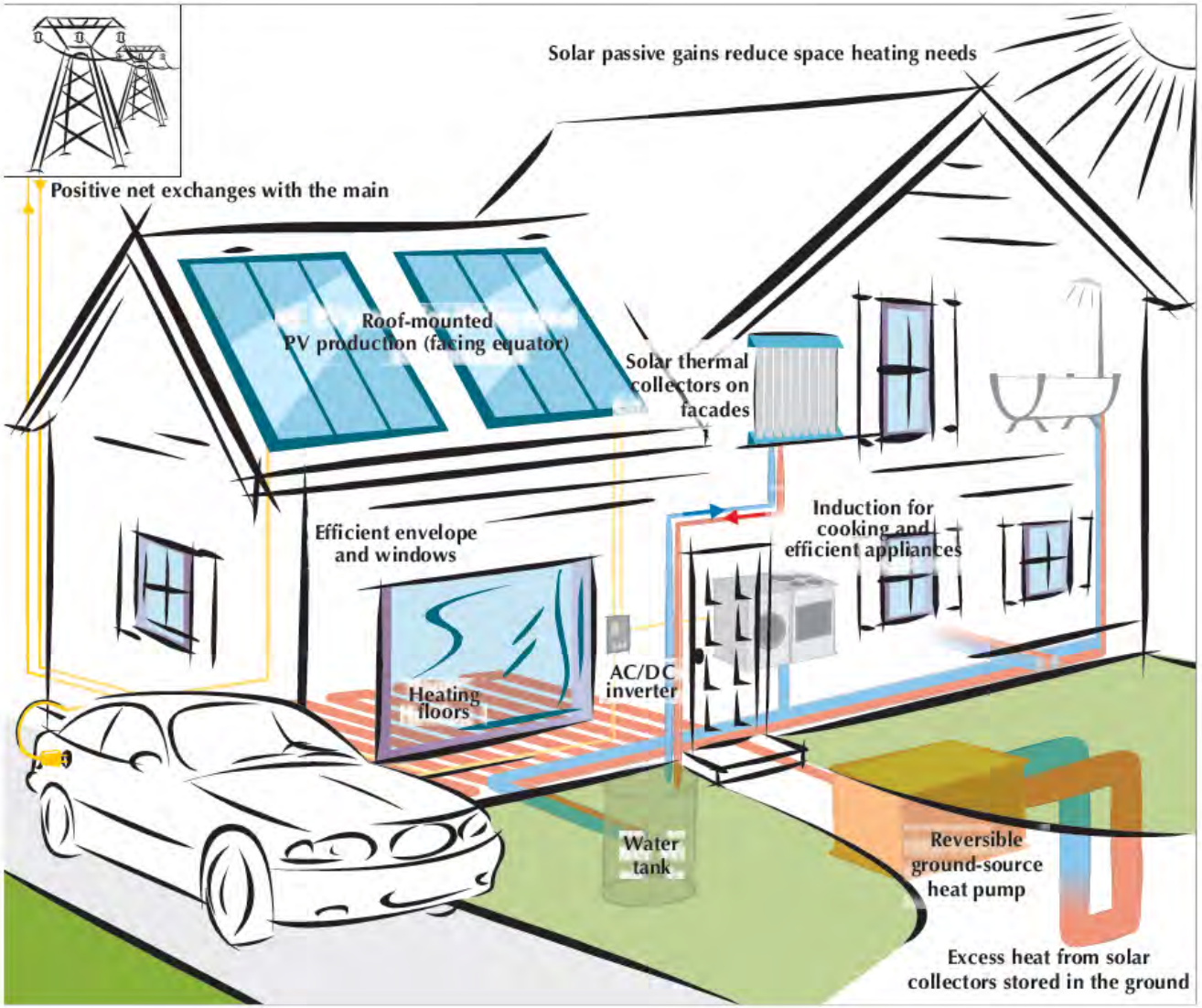
Electricity generation from renewable in 2050, BLUE Map scenario



Note: Percentages above columns show the share of renewables in total electricity generation.

Firm & flexible CSP capacities can help integrate more PV

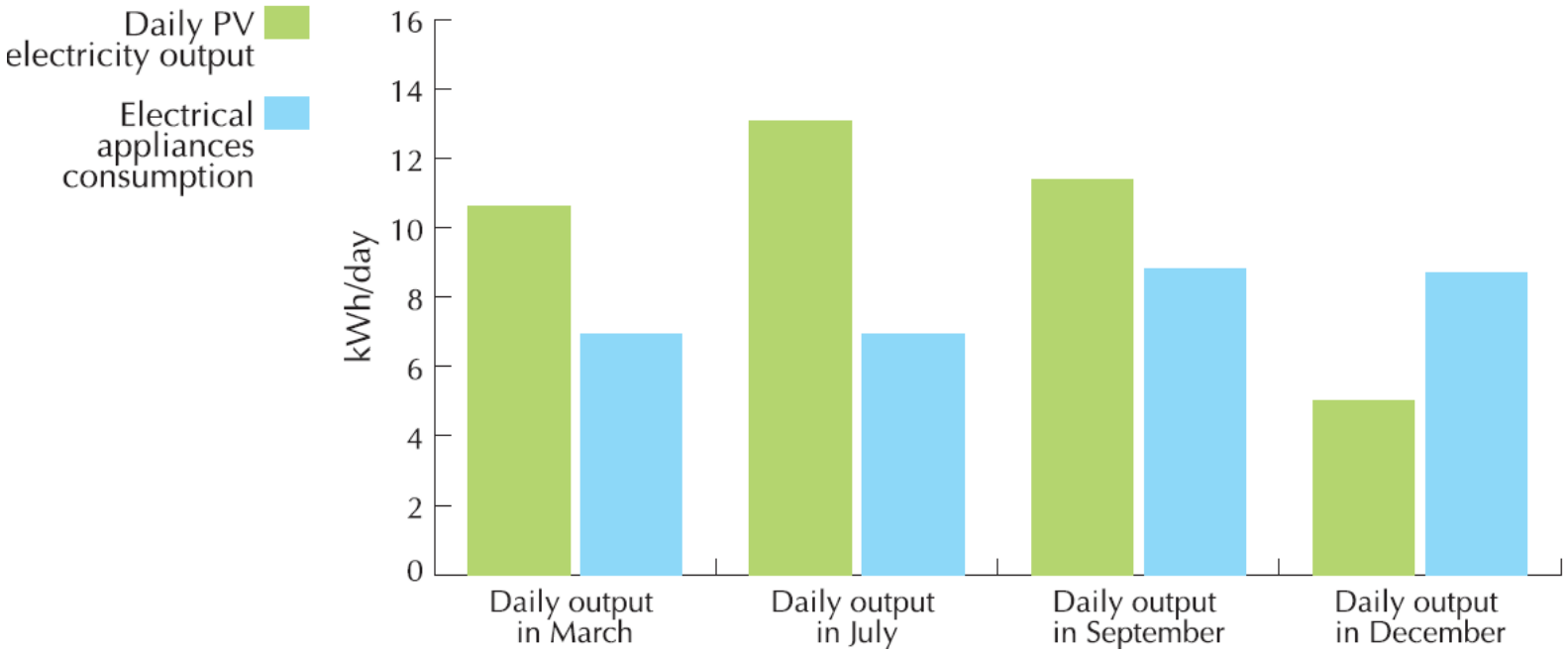
Markets: Buildings



A system approach increases efficiency and reduces total costs

Exchanges with the grid

Daily production of a 20 m^2-PV roof and appliance electricity consumption of small family in sunny region*

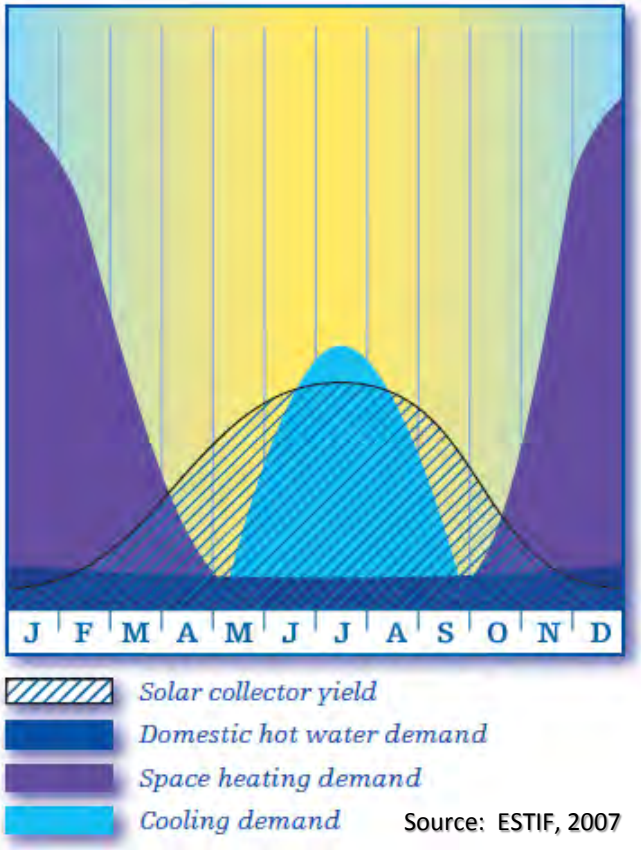


*not including heating and/or air-conditionning

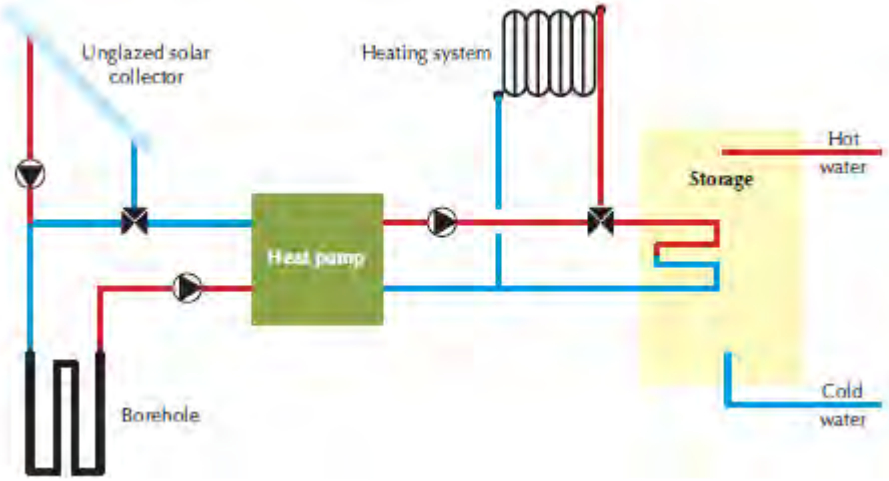
Source: Sunrise project/EPIA.

Focus: Space heating and cooling

- **Storage is key**
  - **Compact thermo-chemical?**
  - **Large-scale heat storage**
  - **Ground-source heat pumps = effective low-temp storage**



Source: ESTIF, 2007

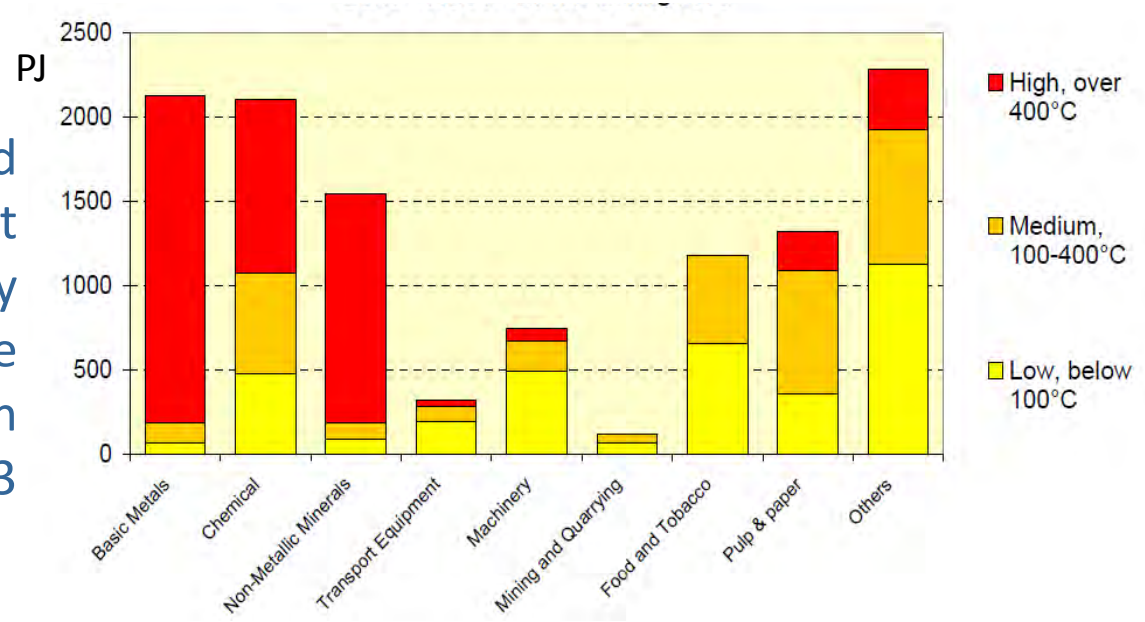


Source: Henning & Miara/Fraunhofer ISES

- **(Wind and) Solar electricity + heat pumps the best option for heating?**
- **Thermally-driven or (solar) electricity-driven cooling?**

Markets: Industry

Estimated industrial heat demand by temperature range in Europe, 2003



Source: EcoHeatCool 2005-2006

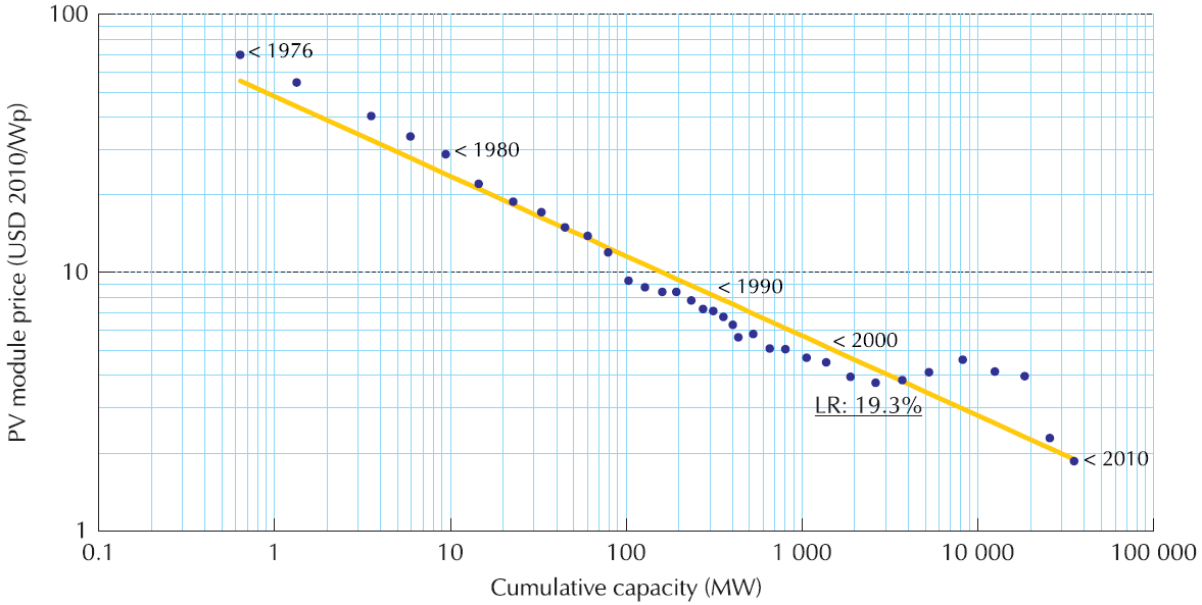
- **Large heat needs at various temperature levels**
- **Low-temperature solar heat available everywhere, demand throughout the year**
- **High-temp. solar heat under hot and dry climates**
- **Solar electricity and biomass also needed to reduce the use of fossil fuels**

Markets: Transports

Source: Kia Motors

- Solar electricity and biofuels best options to substitute fossil fuels
- Electric and plug-in hybrid vehicles, modal shift
- On-road electrification of trucks on highways
- Small direct solar contributions except for high-value niche markets (rooftops, satellites, unmanned planes…)

Technologies: photovoltaics



Source:: Breyer and Gerlach, 2010

- **Fast growth & cost decline**
- **Important role off grid**
- **Competitive on-grid markets appear: sunny islands and countries with high retail electricity prices, and/or using oil to generate electricity**
- **Incentive-driven growth concentrated in too few (EU) countries, will spread to China, Japan, USA…**

Cost reductions will continue

Cost targets for the residential sector

		2010	2020	2030	2050
Typical turnkey system price (2010 USD/kW)		3800	1960	1405	1040
Typical electricity generation costs (2010 USD/MWH)*	2000 kWh/kW	228	116	79	56
	1500 kWh/kW	304	155	106	75
	1000 kWh/kW	456	232	159	112

Cost targets for the commercial sector

		2010	2020	2030	2050
Typical turnkey system price (2010 USD/kW)		3400	1850	1325	*980*
Typical electricity generation costs (2010 USD/MWH)*	2000 kWh/kW	204	107	75	*54*
	1500 kWh/kW	272	143	100	*72*
	1000 kWh/kW	408	214	150	*108*

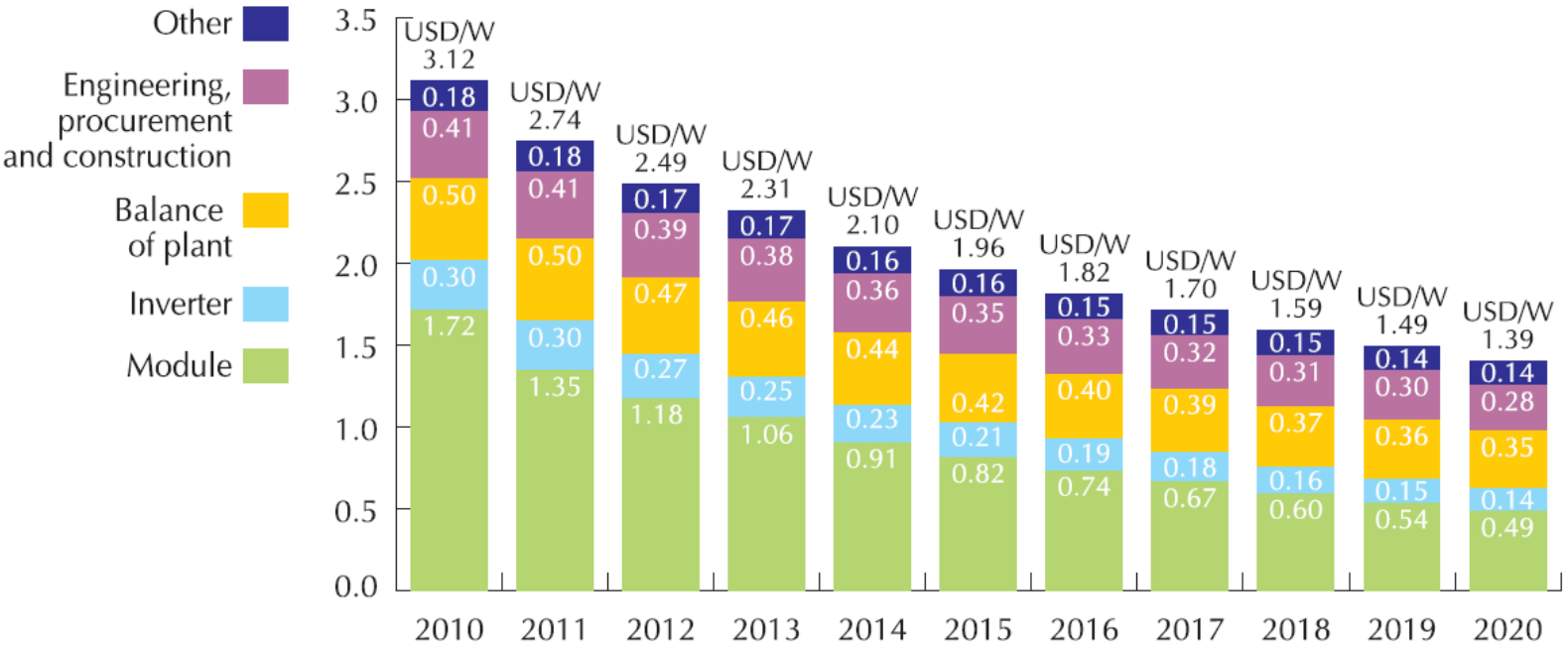
Cost targets for the utility sector

		2010	2020	2030	2050
Typical turnkey system price (2010 USD/kW)		3120	1390	1100	*850*
Typical electricity generation costs (2010 USD/MWH)*	2000 kWh/kW	187	81	62	*48*
	1500 kWh/kW	249	108	83	*64*
	1000 kWh/kW	374	162	125	*96*

Notes: Based on the following assumptions: interest rate 10%, technical lifetime 25 years (2008), 30 years (2020), 35 years (2030) and 40 years (2050). Numbers in italics are considered more speculative.
Sources: IEA 2010*d*, Bloomberg New Energy Finance, and IEA data and analysis.

Modules from 2/3 to 1/3 of system costs?

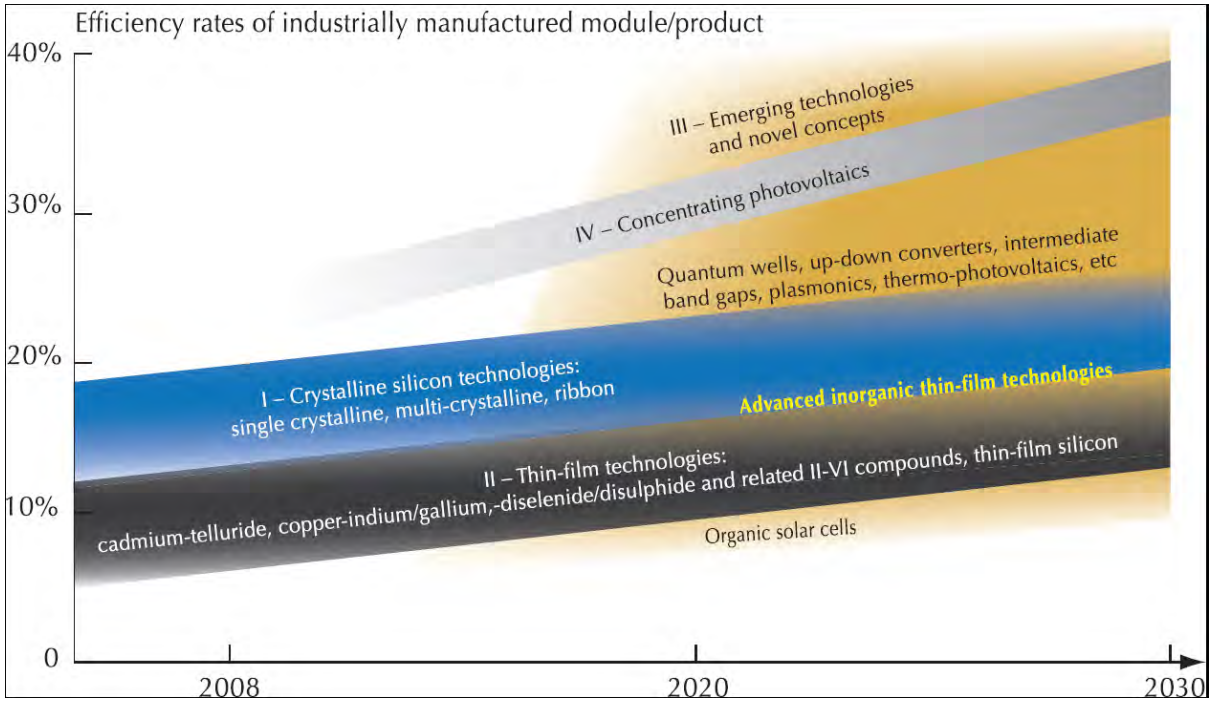
Utility-scale PV system price forecast



Note: Module price derives from experience curve + margin; system price in markets with cost-based, rather than value-based pricing (such as Germany).
Source: Bloomberg New Energy Finance.

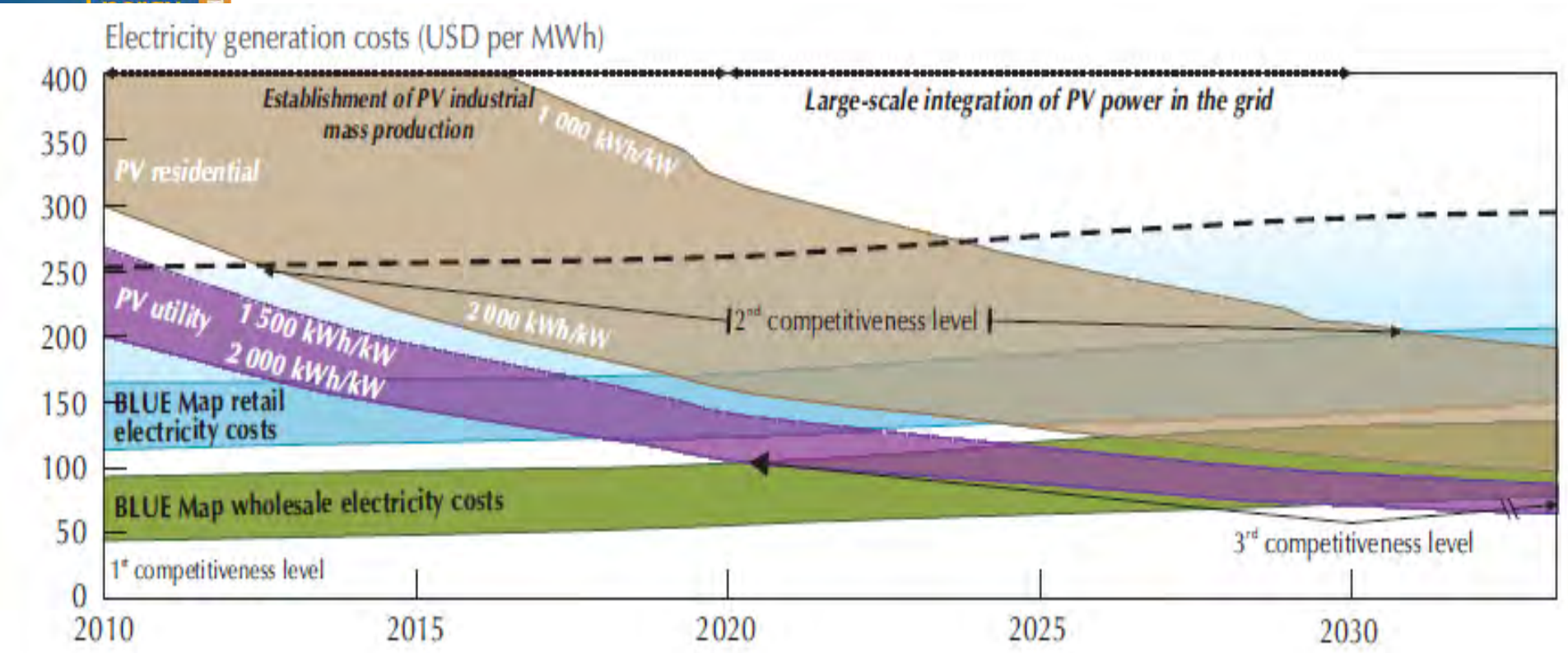
A wider diversity of technologies

PV technology status and prospects



Source: IEA PVPS.

Competitiveness levels



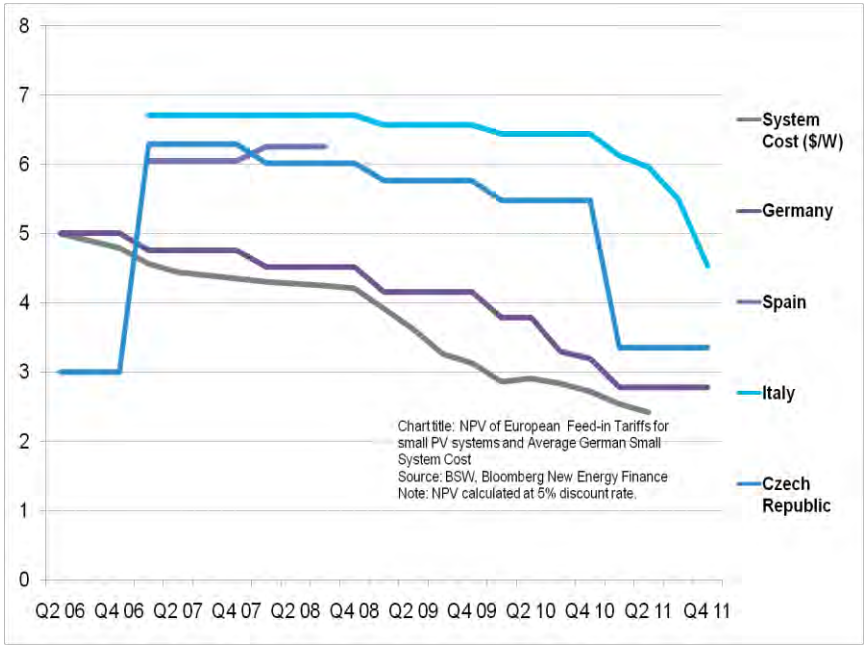
The way forward: policies

Integrated approach	Current gaps
Support to R&D	Solar Fuels
Support to innovation	Process heat
Addressing split incentives	Solar obligations for DHW (but Israel and Spain)
Pushing toward integrated solutions	Buildings regulations (but in the EU)
Addressing financing needs (e.g. off-grid solar electricity)	Linking MDA, climate change money and micro-finance
Support to early deployment	Not all sunny countries support deployment

Costs of policies

Costs of support policies will build up in the coming years, despite specific cost reductions

- This is the price to pay to bring solar technologies to competitiveness with fossil fuels
- Not easy to be effective while avoiding excessive remuneration
- True costs of support must be distinguished from the much larger amounts of investment involved
- Electricity spot prices will be reduced as shares of RE increase
- Electricity markets based on marginal pricing may not be able to finance required renewable and balancing capacities



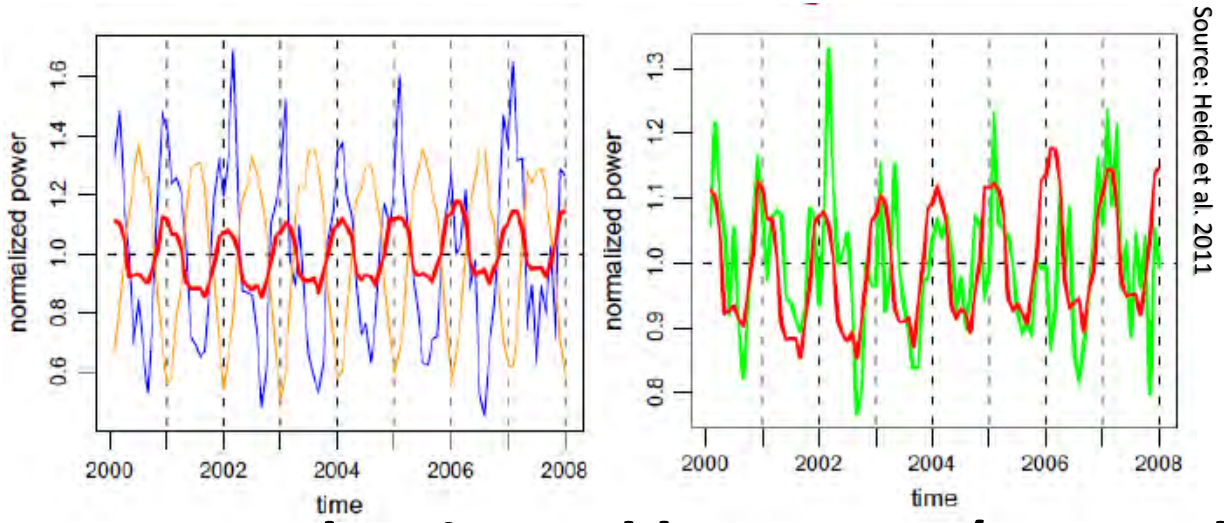
Source: BNEF. 2011

The way forward: testing the limits

- Under severe climate constraints…
- What if other low-carbon energy options are not easily available?
- Where are the technical limits to solar energy?
  - Assuming efficiency improvements and further electrification of buildings, industry and transport
  - Not always least cost, but affordable options
  - Footprint, variability and convenience issues
- Three broad categories of situations:
  - Sunny and dry climates, where CSP dominates
  - Sunny and wet climates, with PV backed by hydro
  - Temperate climates, with wind power and PV

Testing limits: key role of electricity

- **Electricity share keeps growing as efficient end-use technologies continue to penetrate markets**



- **Solar energy dominated by power (STE and PV)**
  - **Space heating needs reduced and satisfied with ambient heat through heat pumps**
  - **Many options converging towards USD 100/MWh**
  - **Solar PV (and wind) electricity storage where STE is not feasible: pumped-hydro plants**

A global approach is needed

- The bulk of the forthcoming growth of energy demand is in sunny countries
  - 7 out of 9 billion people, growing economies
- Solar provides access to modern energy services
  - Potentially changing the lives of 1.4 billion people
- Solar energy has the potential to become a key contributor to final energy demand after 2060
  - Under the assumptions of a massive penetration of electricity, efficiency improvements and willingness to decarbonise the energy sector
- Efforts/benefits need to be shared globally
  - "Spend wisely, share widely"

RENEWABLES ENERGY TECHNOLOGIES

Solar Energy Perspectives

Thank you!

Source: Daniel Dietmann, Saint-Gobain Solar