Renewable Energy TECHNOLOGIES

Cédric Philibert, Renewable Energy Division
World Solar Congress, Kassel, 1 Sept. 2011

International Energy Agency

# Solar Energy Perspectives

# Building on…

Solar Energy Perspectives

RENEWABLES ENERGY TECHNOLOGIES


Technology Roadmap

Solar photovoltaic energy

International Energy Agency


Technology Roadmap

Concentrating Solar Power

International Energy Agency

Source: Sundrop Fuels, Inc.

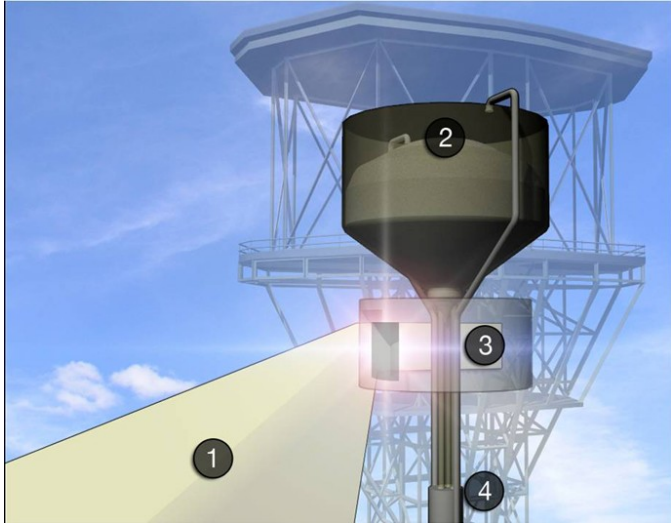
Solar Energy Perspectives

RENEWABLES ENERGY TECHNOLOGIES

# … also starring…

## Solar heating and cooling

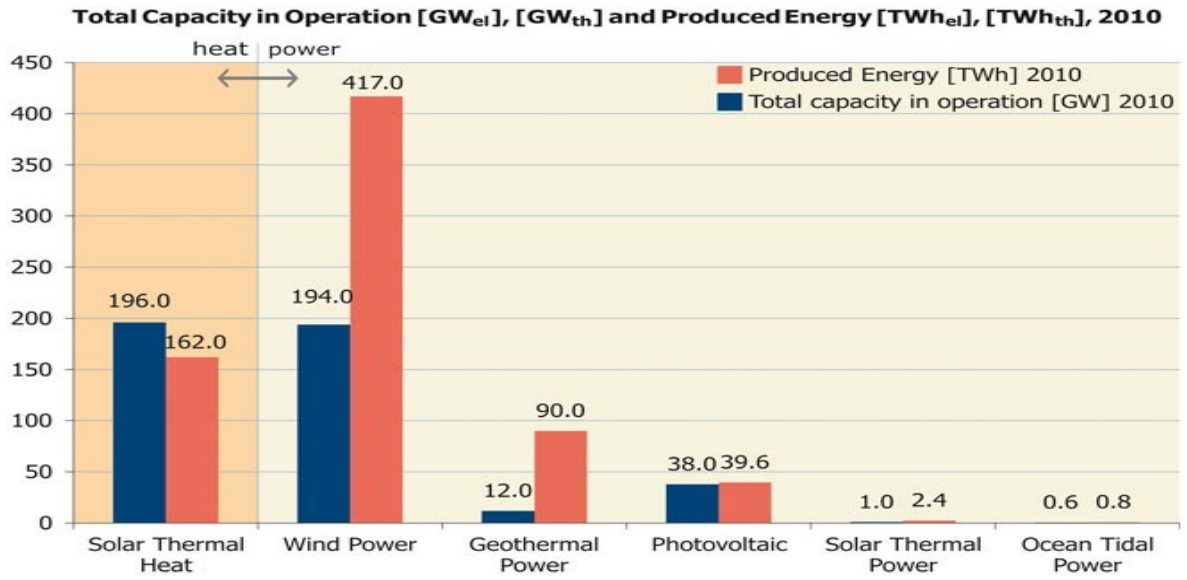
- Forthcoming IEA roadmap: workshops Paris, 28-29 April, Kassel, 28 August



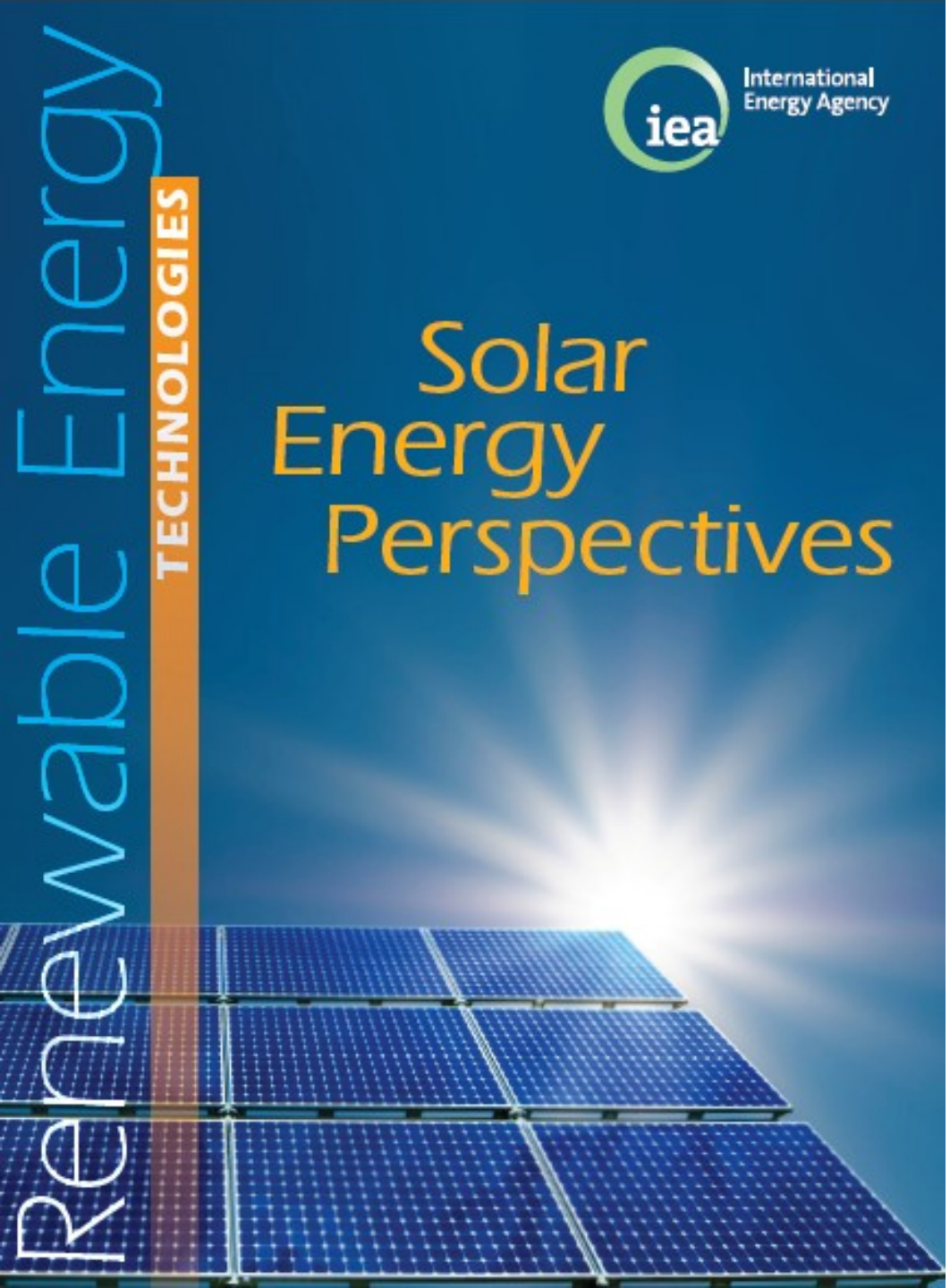

Source: Sundrop Fuels Inc.

## 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

# In search of synergies

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

Source: Solimpeks Solar Energy

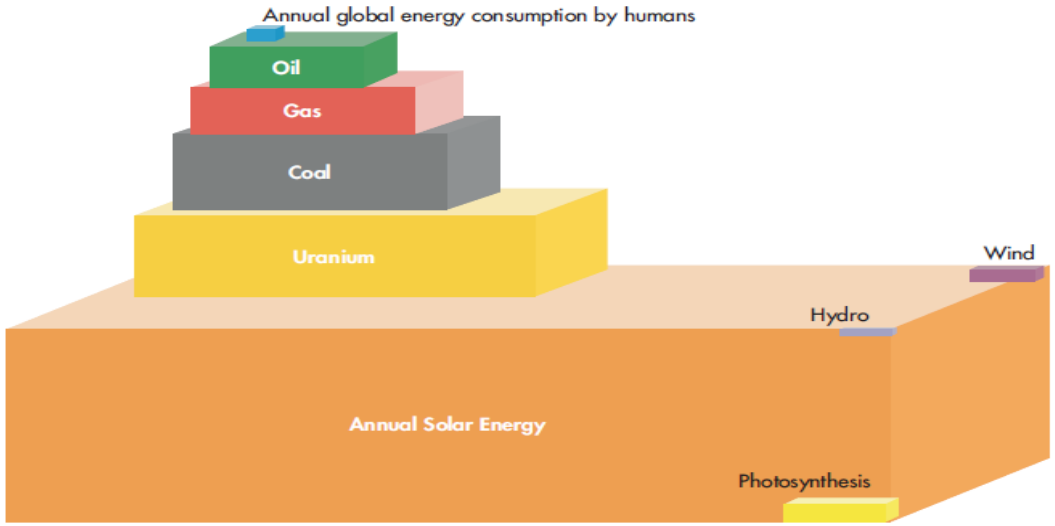
Source: SolarThermal Magazine

- Driven by analyses of the demand for various uses

RENEWABLES ENERGY TECHNOLOGIES

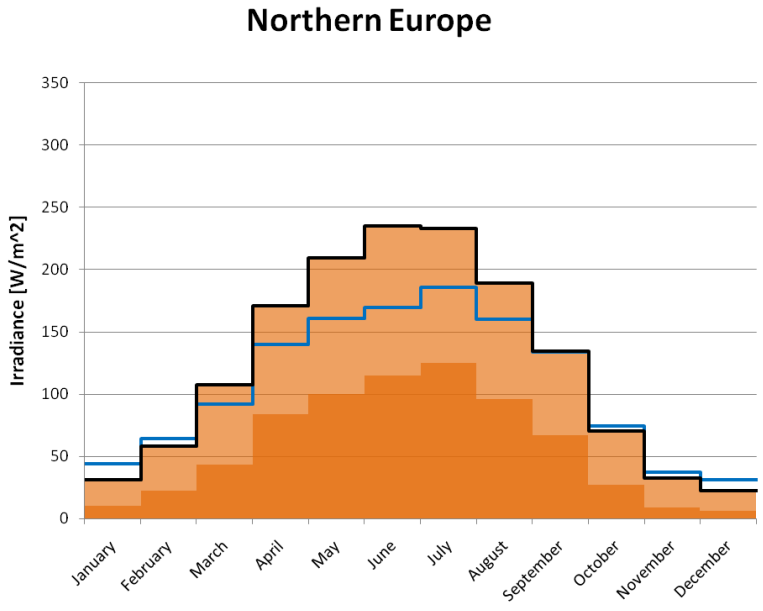
Solar Energy Perspectives

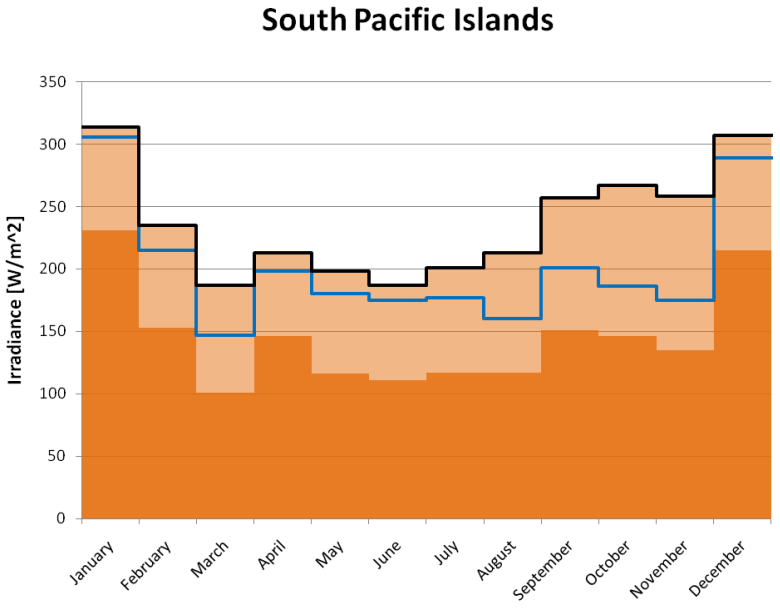
# Content

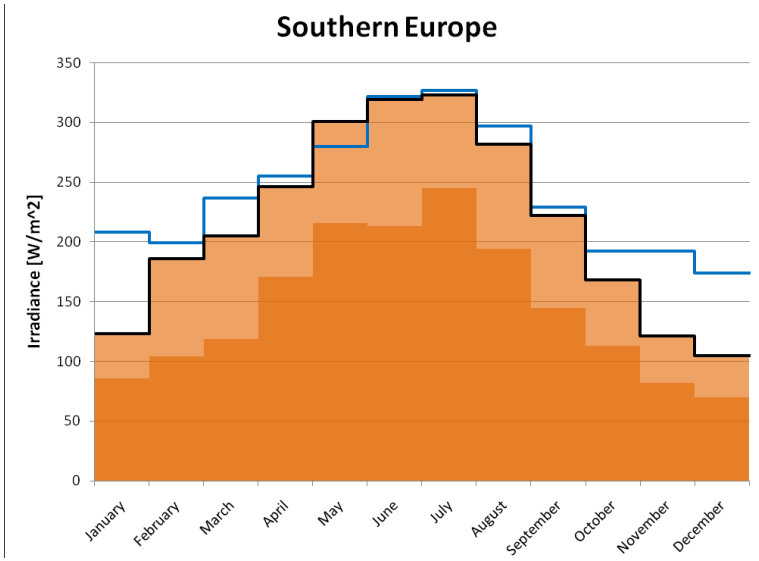


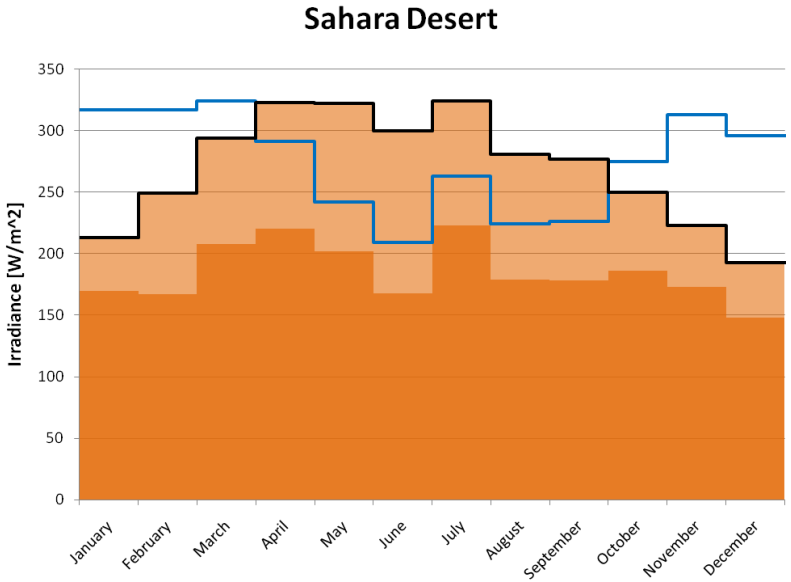

- Rationale
- Markets & outlook
  - The solar resource
  - Electricity
  - Buildings
  - Industry
  - Transport
- Technologies
  - Photovoltaics
  - Heat
  - Solar thermal power
  - Solar fuels
- The way forward
  - Policies
  - Testing the limits

# Solar resource




Direct Horizontal | Diffuse horizontal | Direct Normal | Global Horizontal

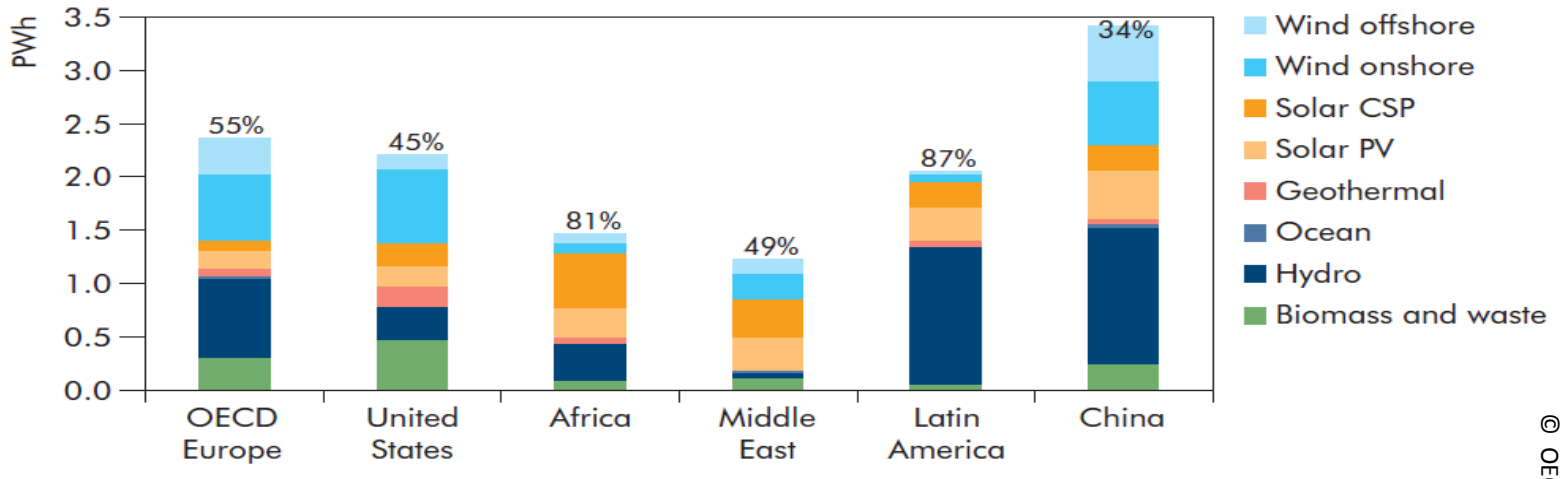
Source: Chhatbar & Meyer 2011

# 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
- Peak to **base-load** } storage
- 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

Solar Energy Perspectives

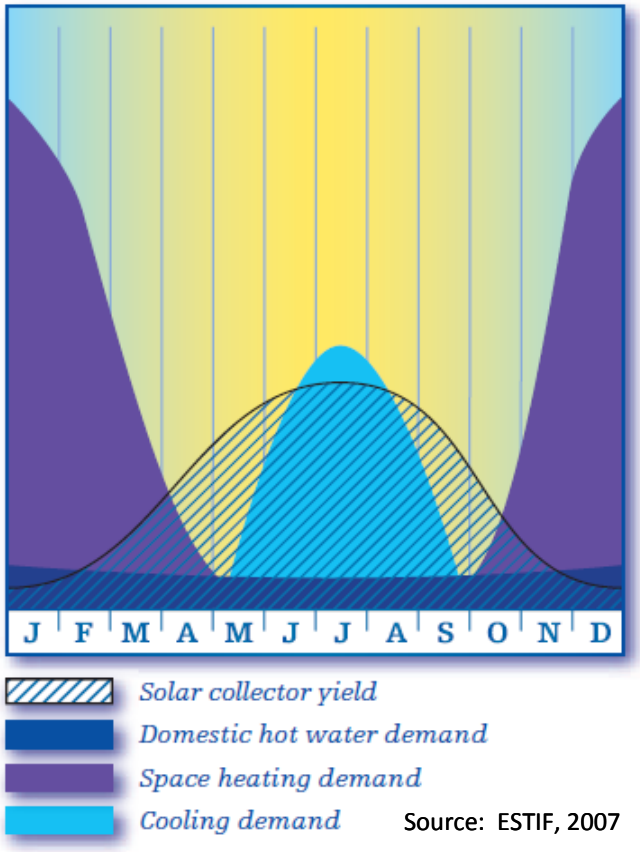
RENEWABLES ENERGY TECHNOLOGIES

| | | |
|---|---|---|
| Efficient enveloppe and windows | Induction for cooking and efficient appliances | Reduced electricity needs |
| Solar passive gains further reduce space heating needs | Reversible ground-source heat pump | Roof-mounted PV production |
| Solar thermal collectors on façades | Ambient (solar) energy + stored energy from the collectors | Positive net exchanges with the main |
| Domestic hot water + hot water for washing machines: solar share 30-70% | Excess heat from solar collectors stored in the ground | |

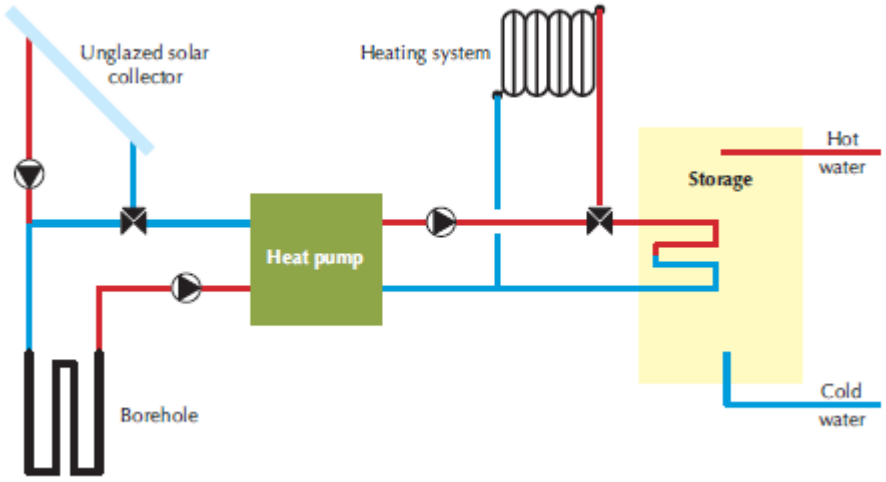
A system approach
-Increases efficiency
-Reduces total costs

# Focus: Space heating and cooling

- **Storage is key**
  - **Compact thermo-chemical?**
  - **Large-scale heat storage cheaper (district heating)**




Source: ESTIF, 2007

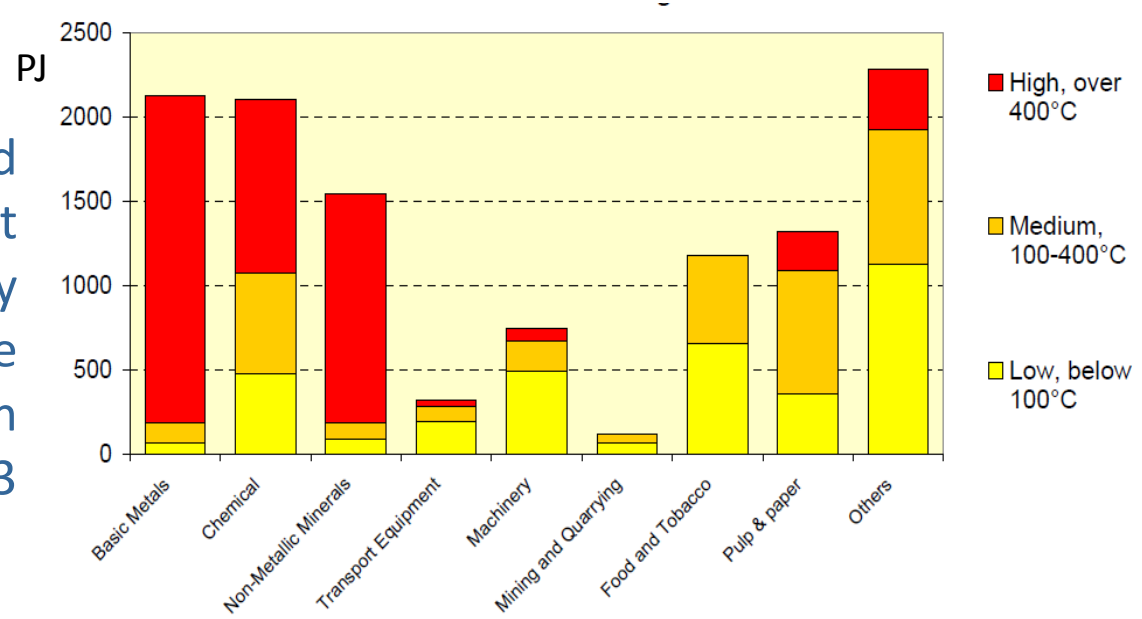



Source: Henning & Miara/Fraunhofer ISES

- **Ground-source heat pumps = effective low-temp storage**
- **Solar electricity + reversible heat pumps the best option?**

# Markets: Industry

Estimated industrial heat demand by temperature range in Europe, 2003




Source: EcoHeatCool 2005-2006

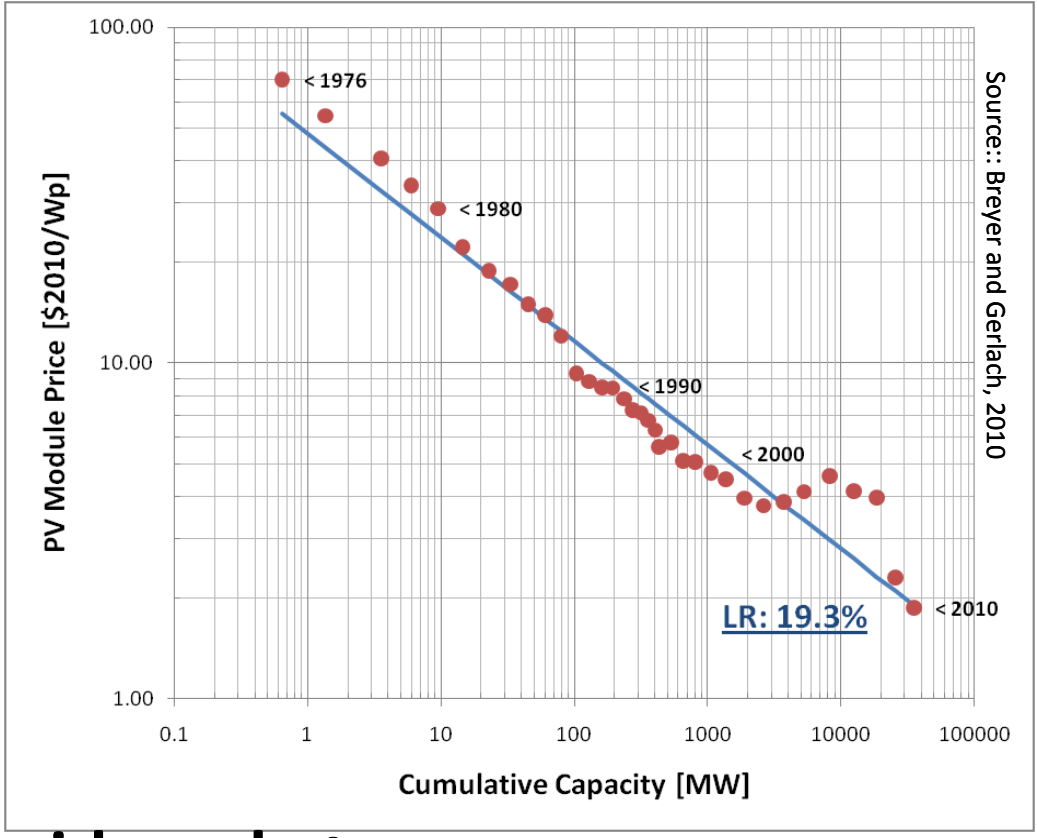
- **Large heat needs at various temperature levels**
- **Low-temperature solar heat available everywhere, demand throughout the year**
- **High-temp. solar heat under hot and dry climates**
- **Solar electricity and biomass also needed to reduce the use of fossil fuels**

# 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…)

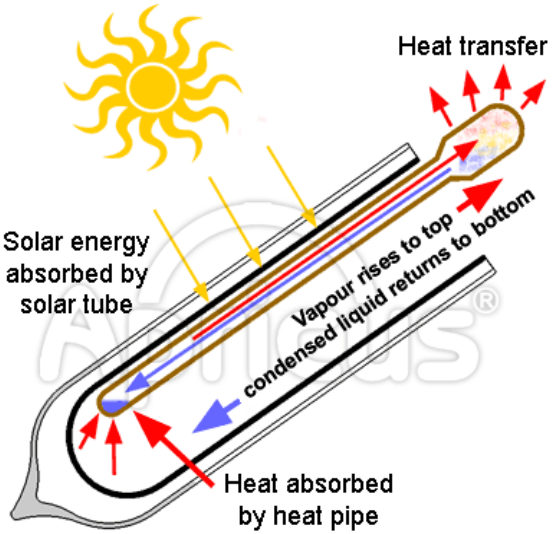
# Technologies: photovoltaics



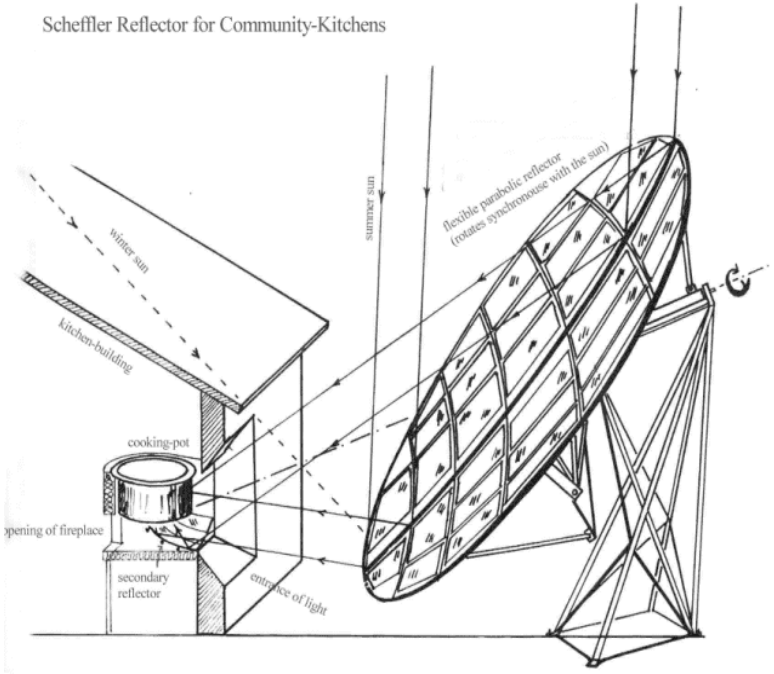

- Fast growth & cost decline
- Important role off grid
- Competitive on-grid markets appear: sunny islands and countries with high retail electricity prices, and/or using oil to generate electricity
- Incentive-driven growth concentrated in too few (EU) countries, will spread to China, Japan, USA…

# Technologies: solar heat

- A great variety of technologies, concentrating or not (flat-plate, evacuated tubes)



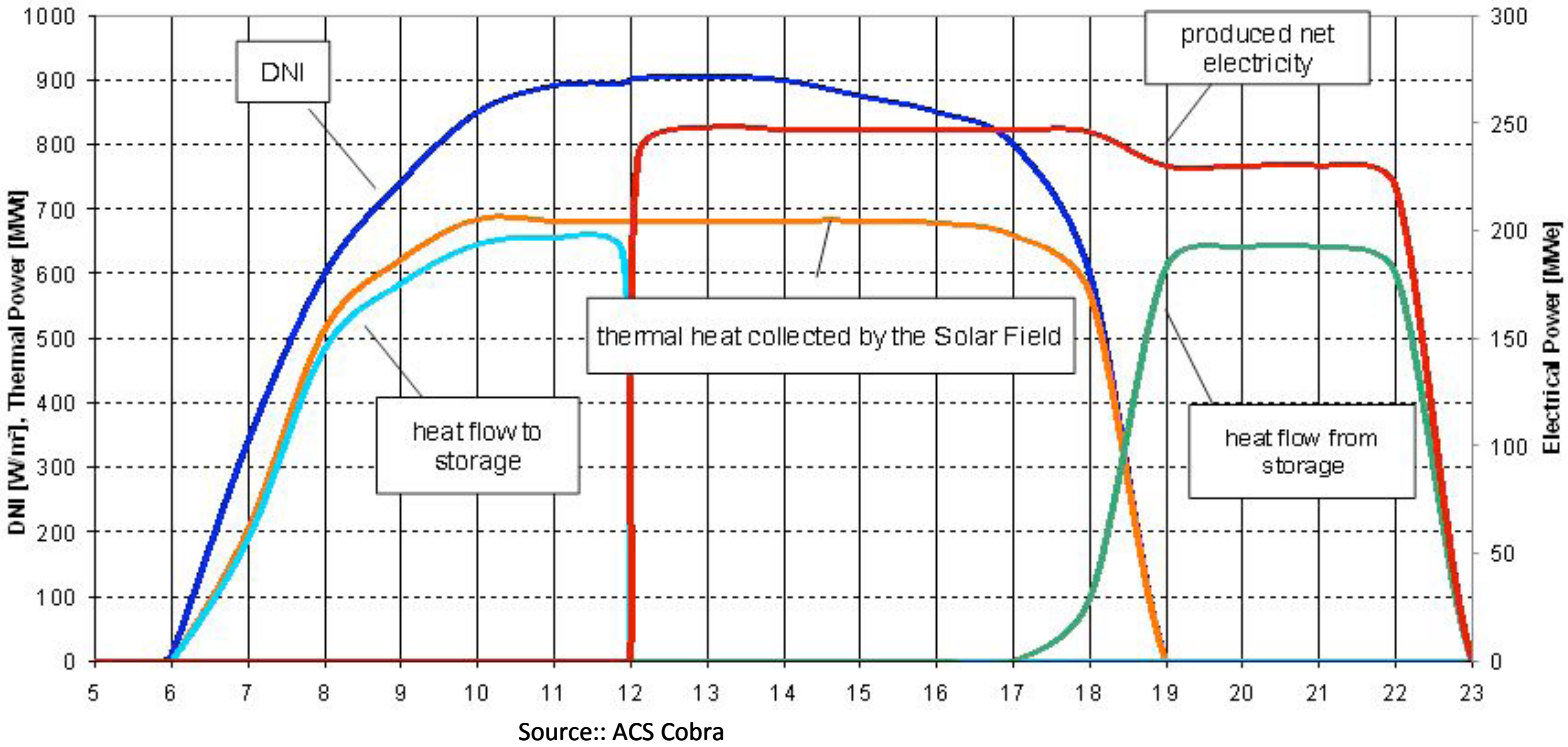

Source:: Apricus Solar




Source:: Wolfgang Scheffler

- For direct heat use (hot water, industry, cooking more than space heating), or for electricity generation or fuels (other carriers)

# Technologies: solar thermal electricity

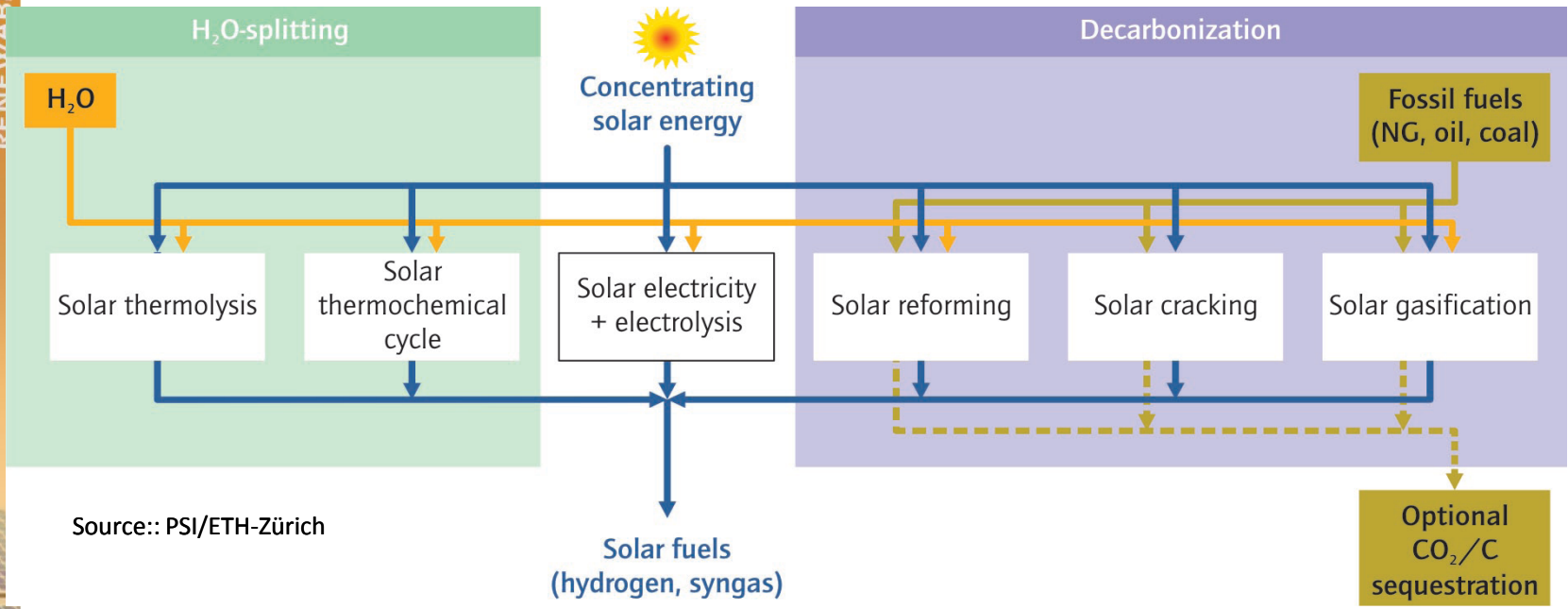



Source:: ACS Cobra

- **Key value of STE/CSP is in thermal storage, effective and cheap, to better match the needs**
- **Concentration requires good direct irradiance**
- **Many different designs and options**

# Technologies: solar fuels

- From hydrocarbon (incl. biomass) or water
- Cheaper with high-temp. heat than electricity?




Source:: PSI/ETH-Zürich

- $H_2$ easier to use blended with natural gas
- Can be converted into various energy carriers

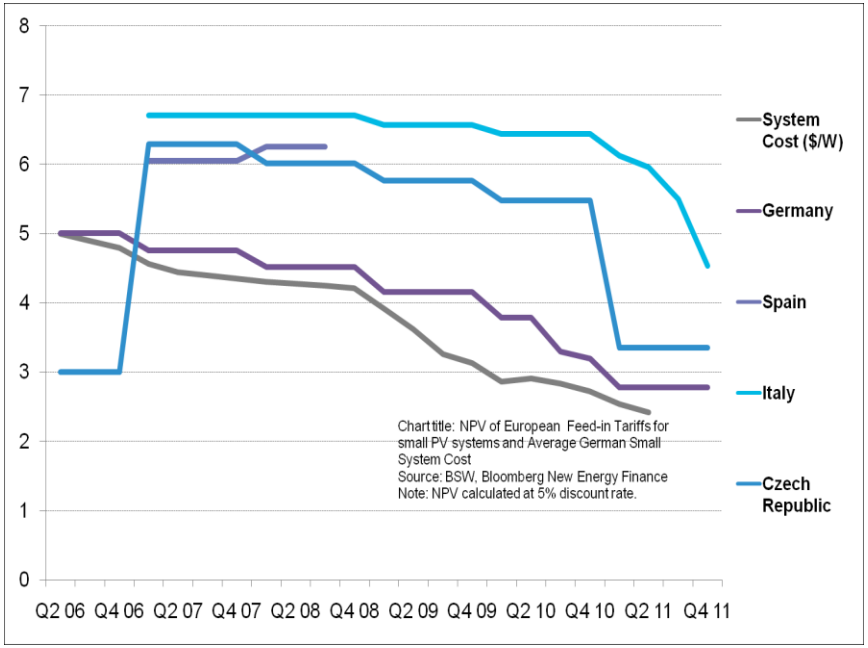
# The way forward: policies

| 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



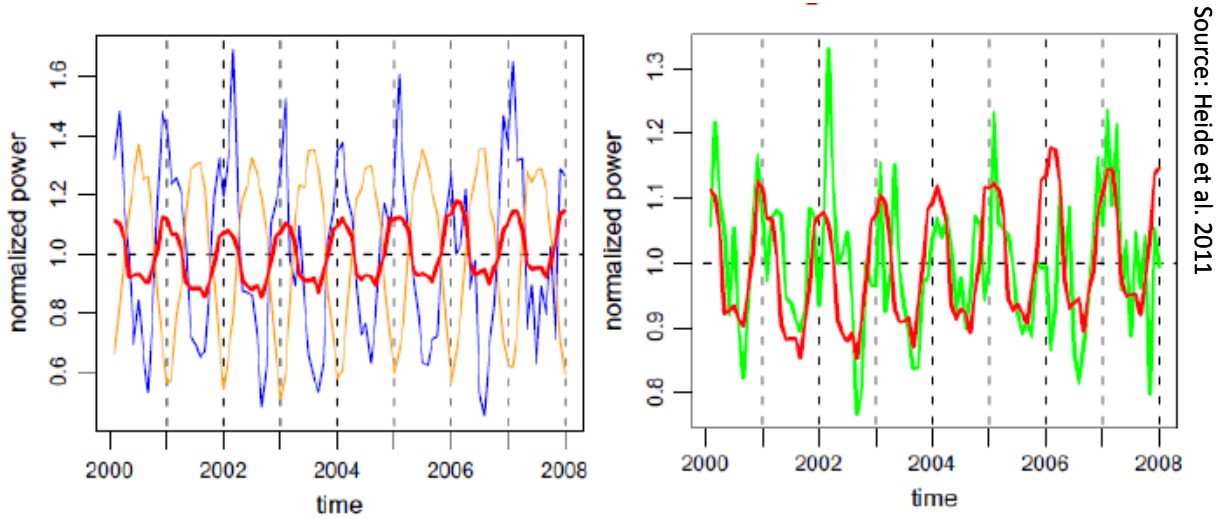

Source: BNEF. 2011

# 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**




Source: Heide et al. 2011

- **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"