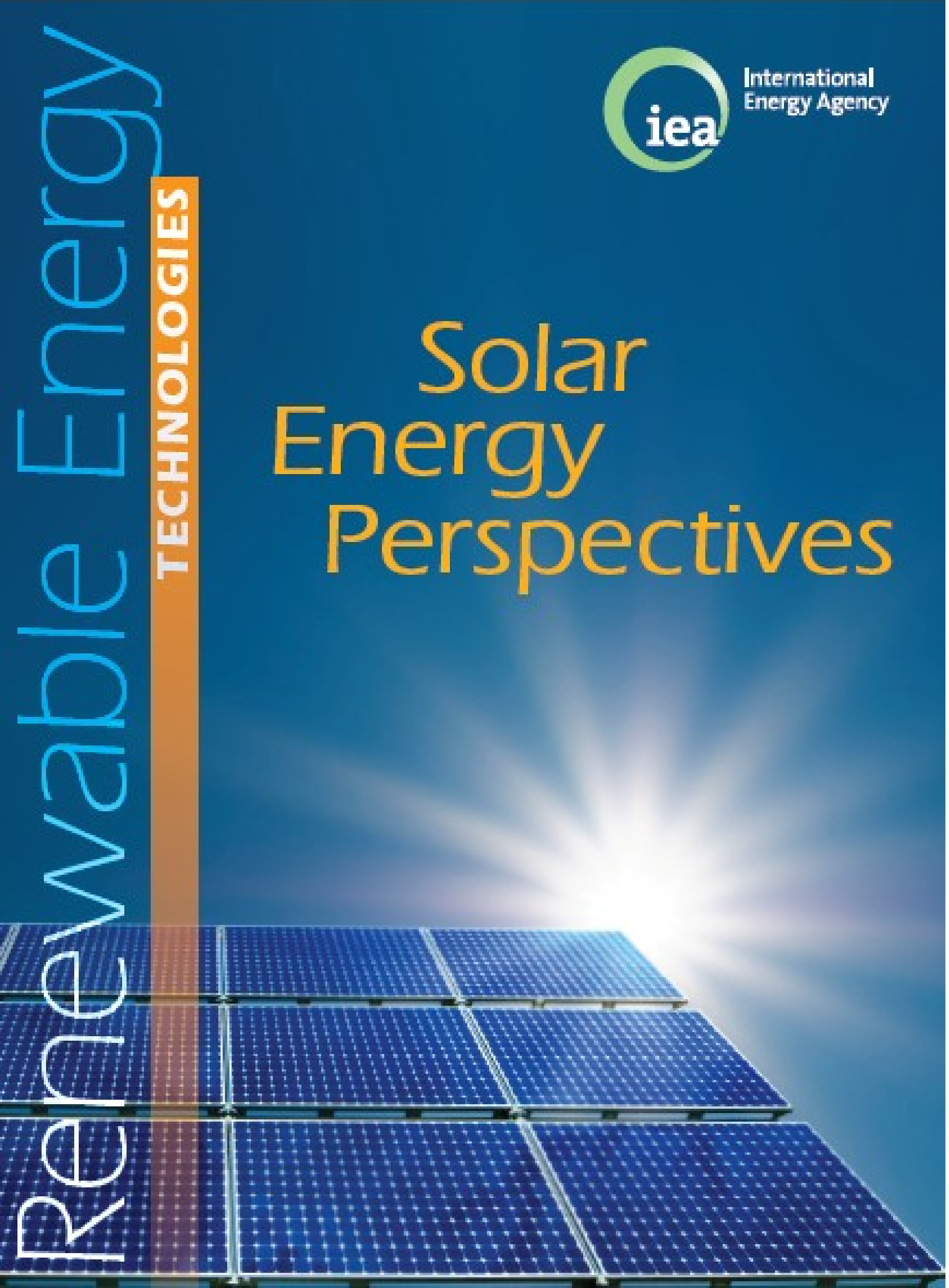
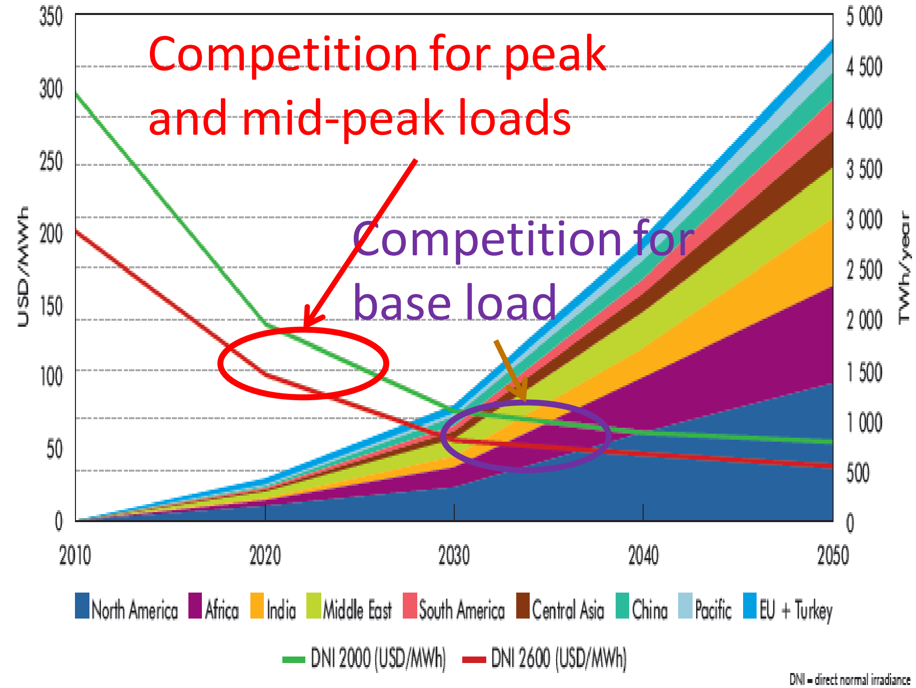


- **A new IEA publication launched 1st December**
- **First RE in-depth technology study**
- **Support from the French and US governments**
- **cedric.philibert@iea.org**

Formation des Experts Marocains, Oujda, 20 mars 2012

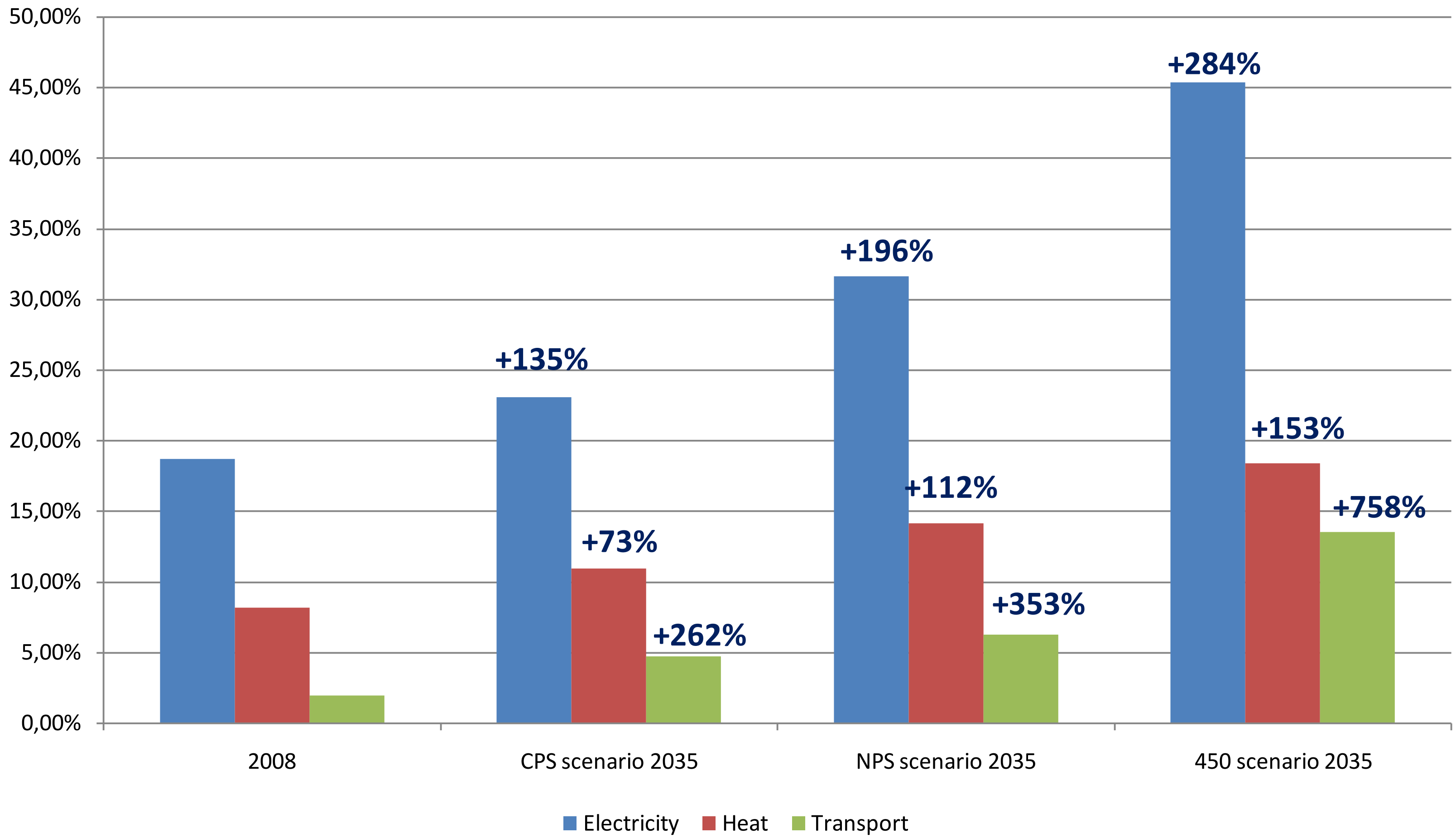
Building on…



- **Solar electricity and other roadmaps**
- ***World Energy Outlook***
- ***Energy Technology Perspectives***
- **Also starring…**
  - **Solar heating and cooling**
    - **Forthcoming IEA Roadmap**
  - **Solar Fuels**
    - **From PV and CSP, H_2 and liquids**

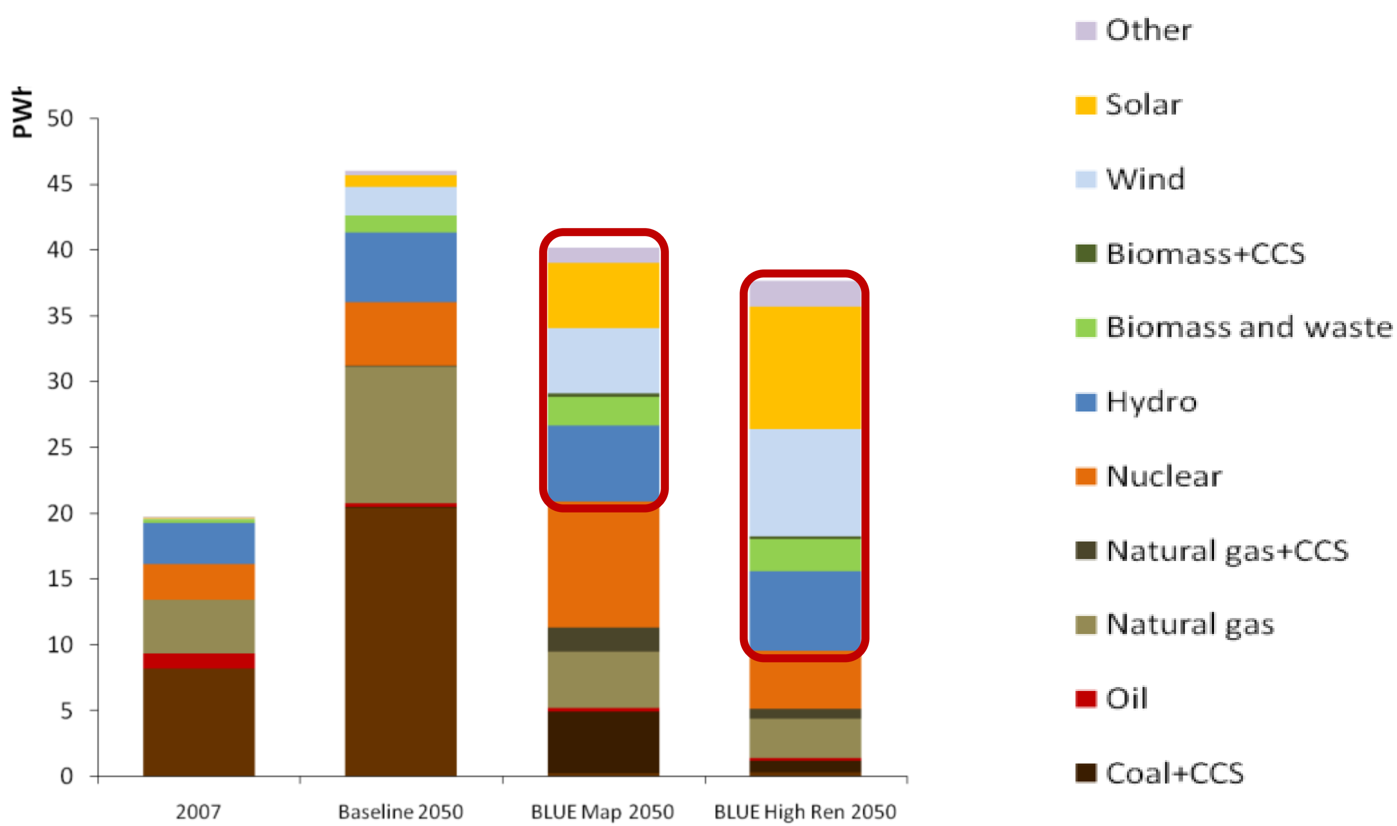
Growing shares of renewables

World Energy Outlook 2010



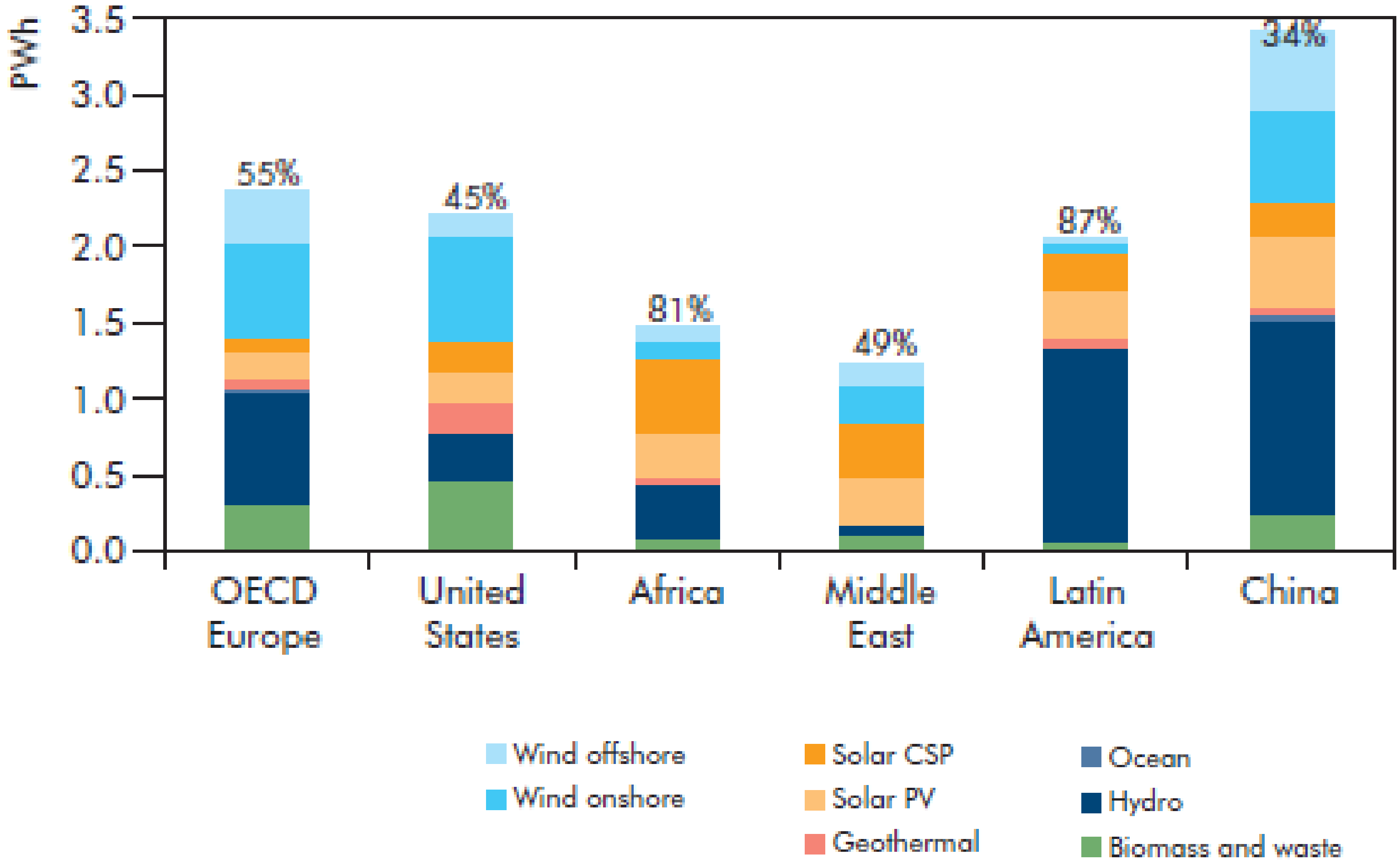
All scenarios point out a large growth of renewables

The primary role of renewables in the BLUE scenarios



Renewables provide from almost half to three quarters of the global electricity mix in 2050

RE generation in 2050 for key countries/regions



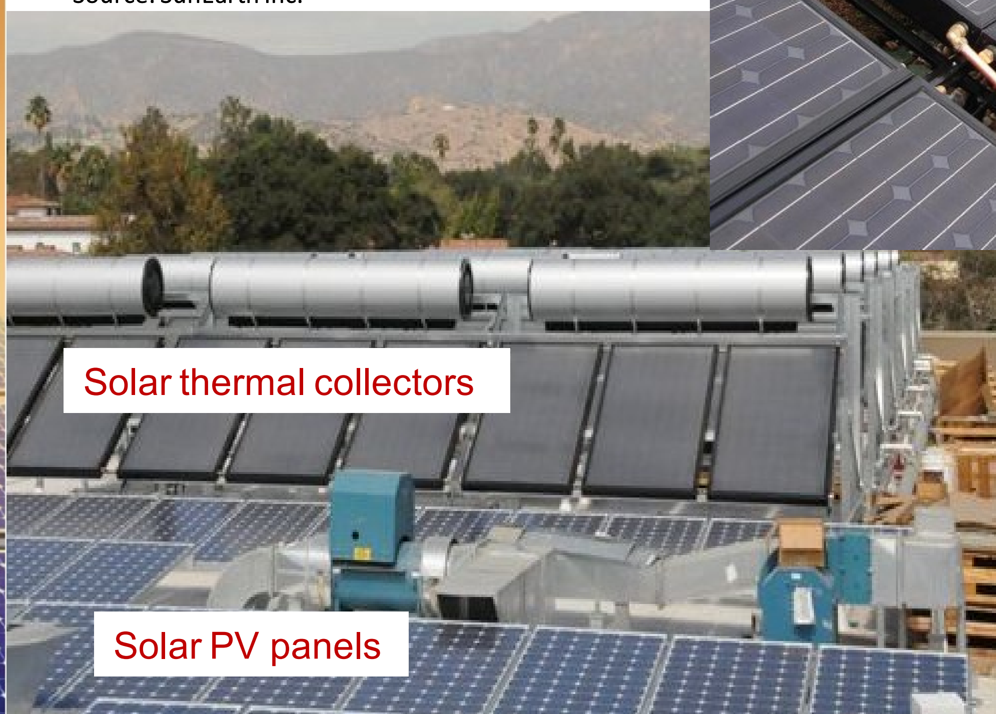
The mix varies according to resources

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

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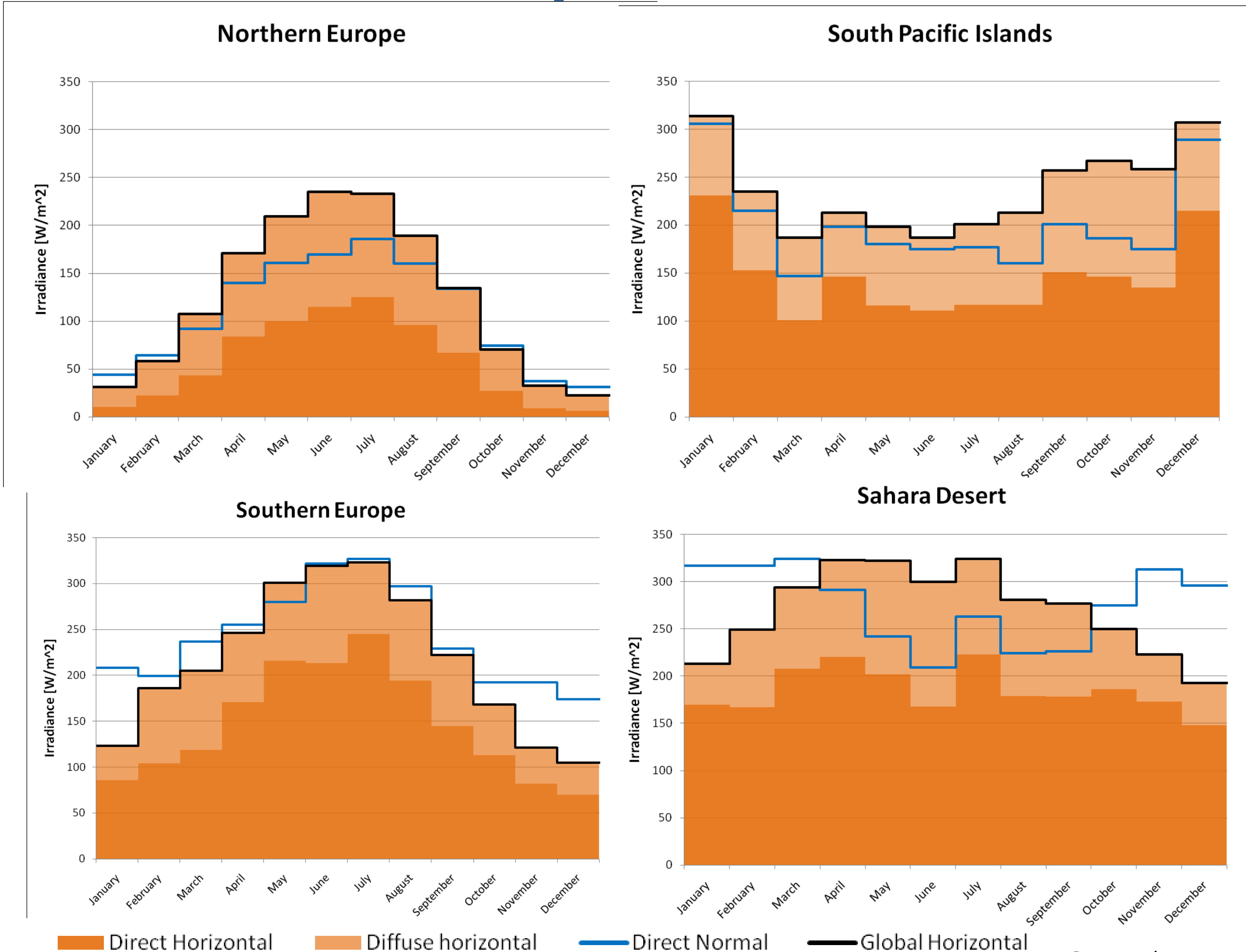
DNI often compares with GHI…

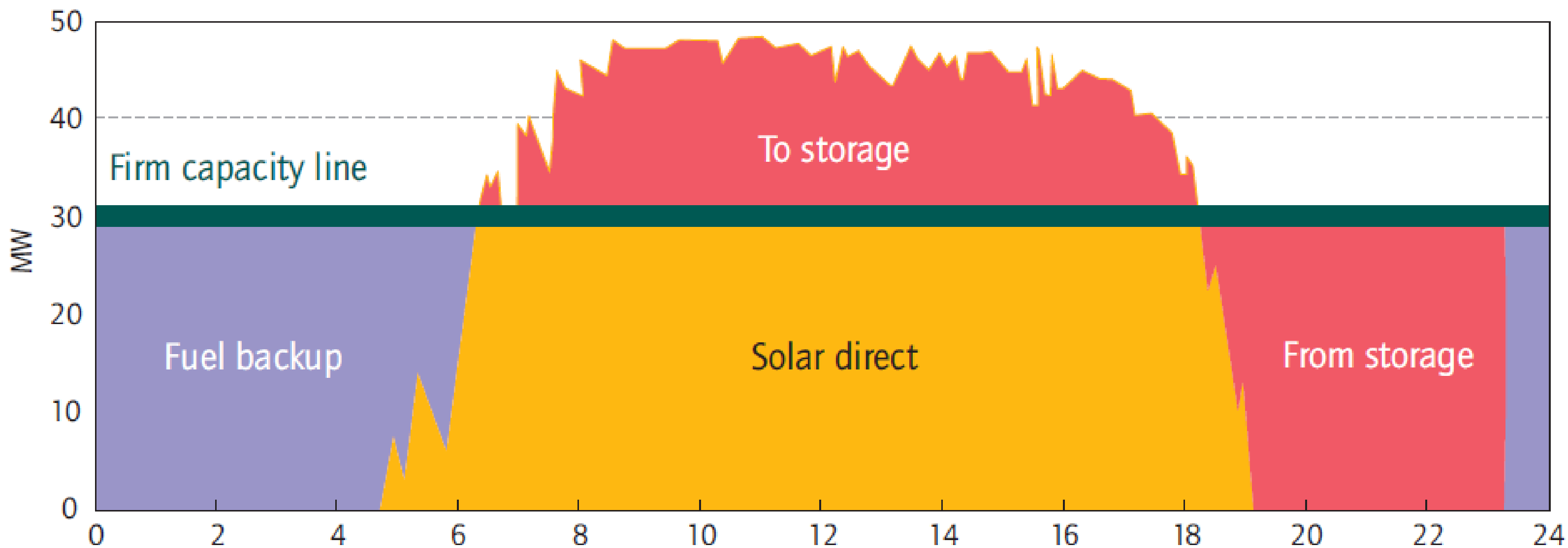


Source: Chhatbar & Meyer 2011

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



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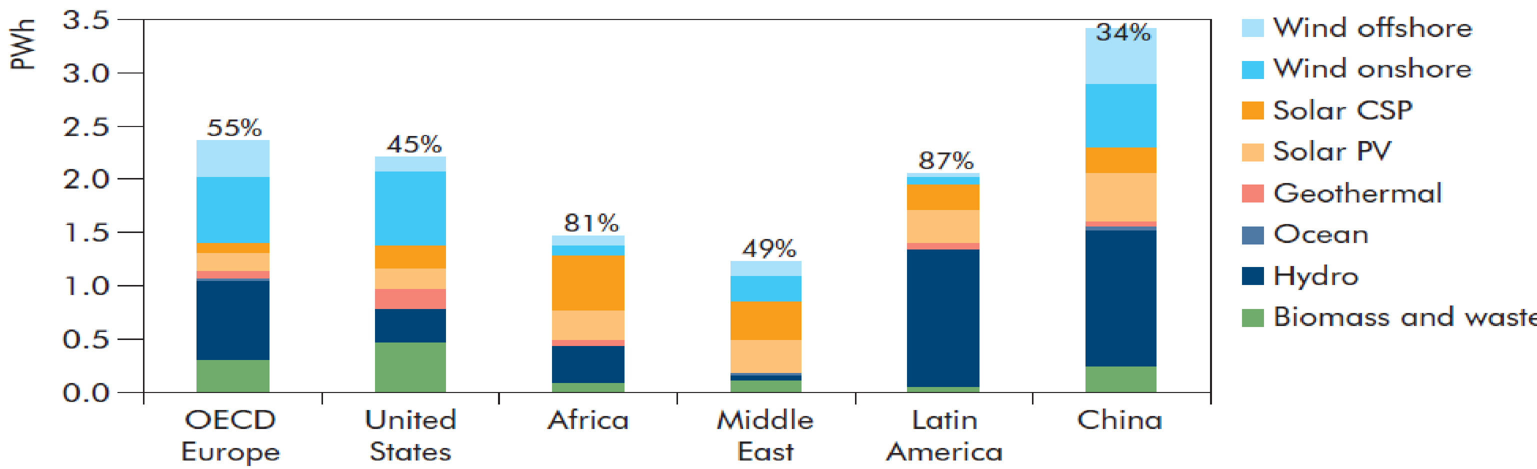
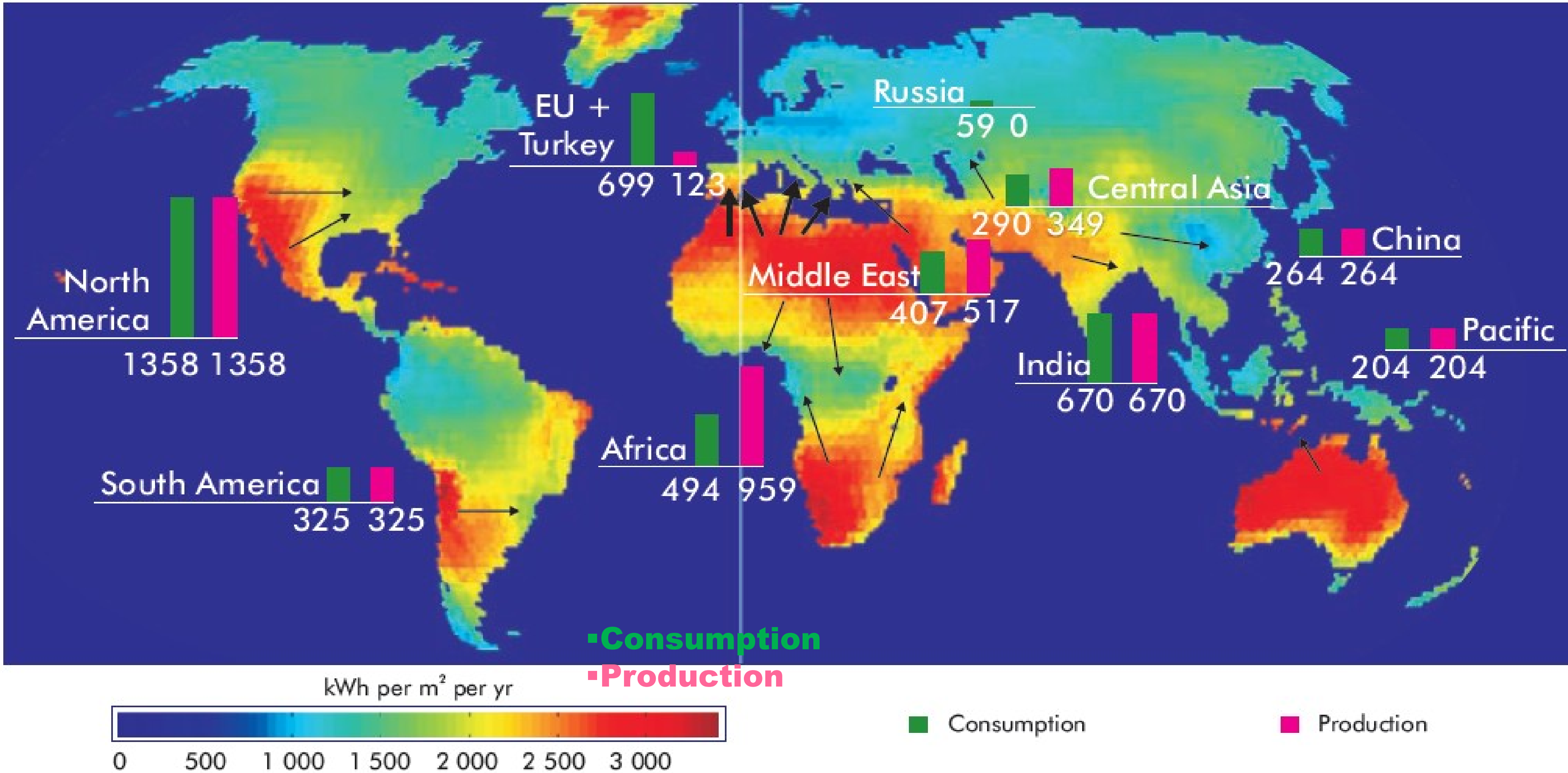
Electricity generation from renewable in 2050, BLUE Map scenario



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

Firm & flexible CSP capacities can help integrate more PV

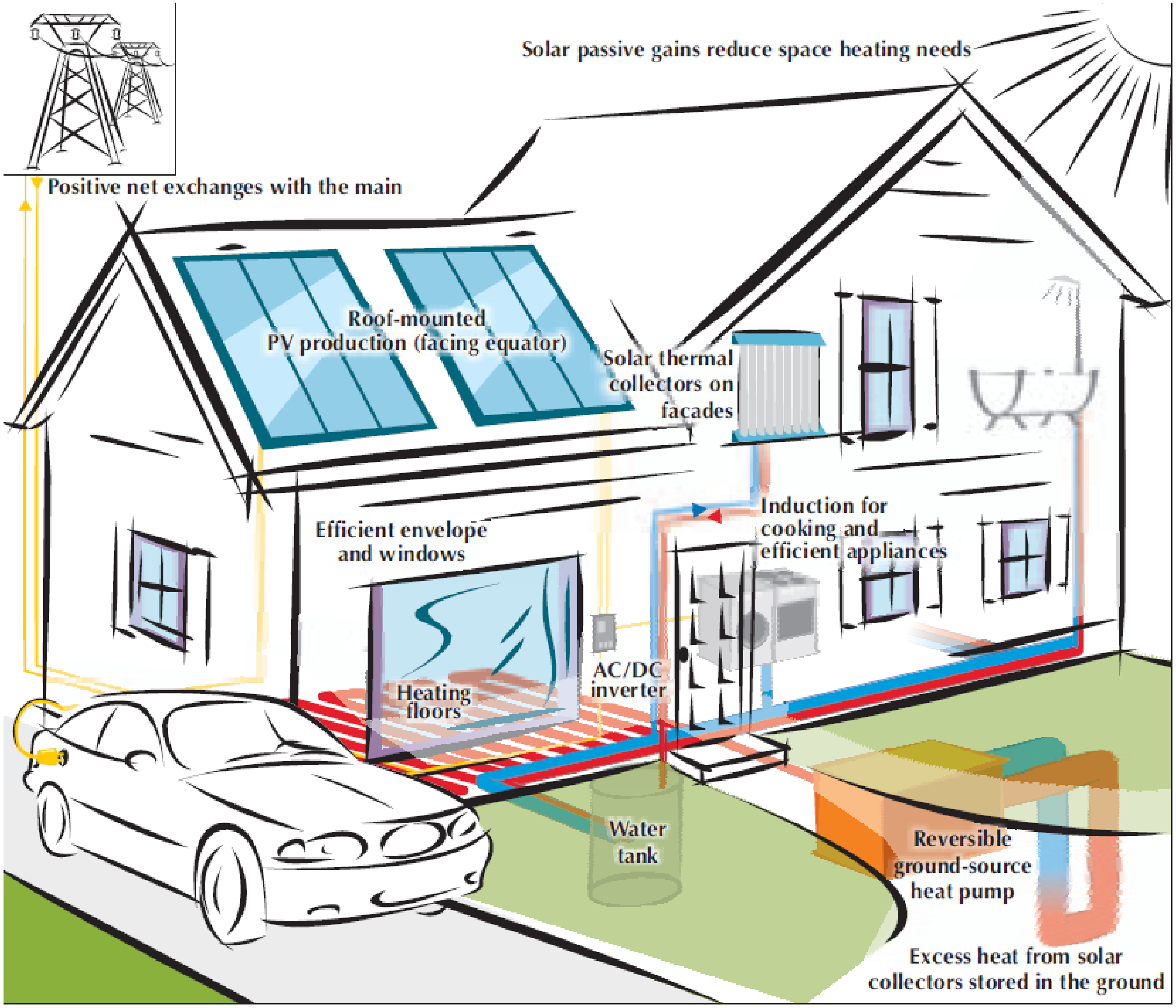
The CSP Roadmap: 2050



Repartition of the solar resource for CSP plants in kWh/m²/y, and of the production and consumption of CSP electricity (in TWh) by world region in 2050 as foreseen in this roadmap. Arrows represent transfers of CSP electricity from sunniest regions or countries to large electricity demand centres.

Sources: Breyer & Knies, 2009 based on DNI data from DLR-ISIS and IEA Analysis.

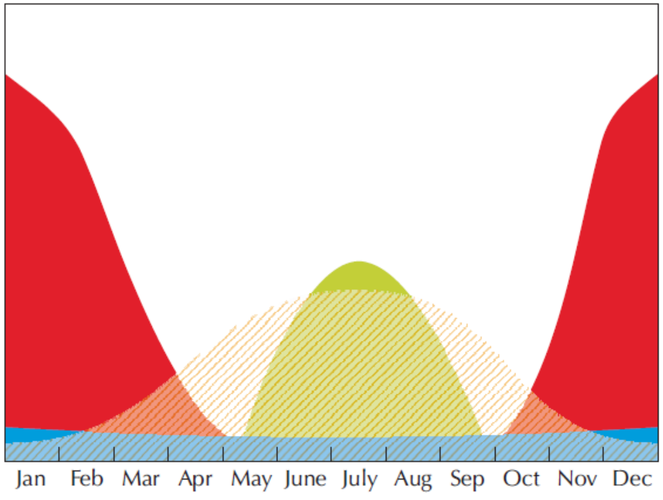
Markets: Buildings



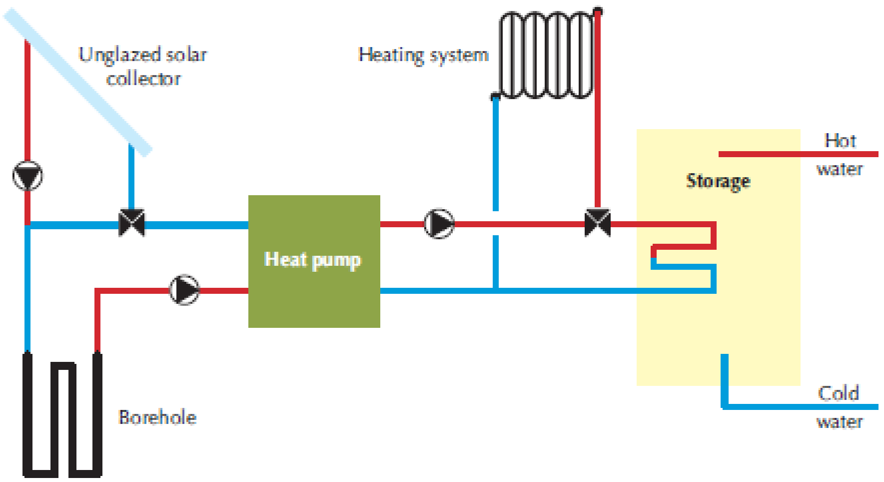
An integrated approach increases efficiency and reduces total costs

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

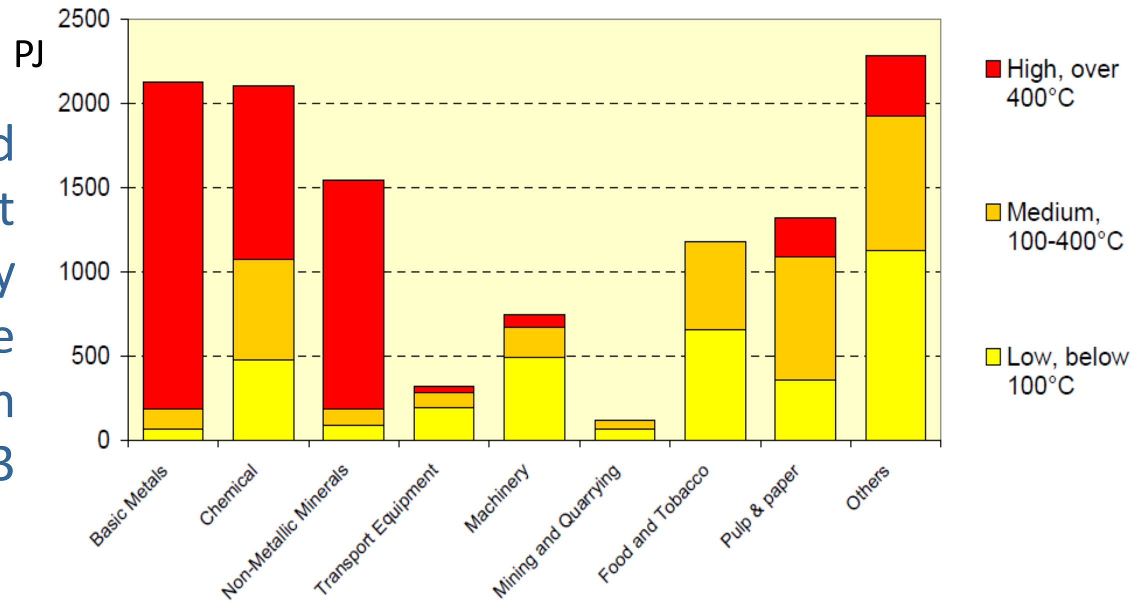


Source: Henning & Miara/Fraunhofer ISES

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

Markets: industry

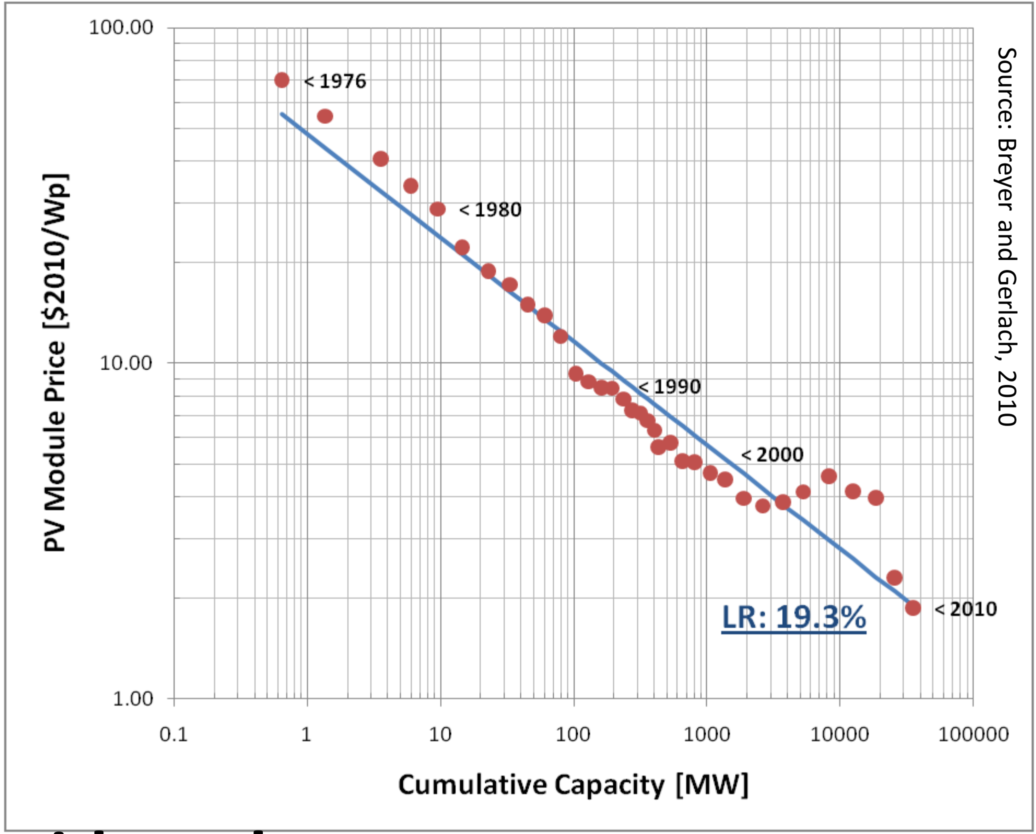
Estimated industrial heat demand by temperature range in Europe, 2003



Source: Werner, 2005-2006

- **Large heat needs at various temperature levels in industry and services; low-temp. solar heat available everywhere, demand all year round**
- **High-temp. solar heat under hot and dry climates**
- **But solar electricity and biomass key to reduce the use of fossil fuels in industry**

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…

Solar Energy Perspectives

RENEWABLES ENERGY TECHNOLOGIES

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*

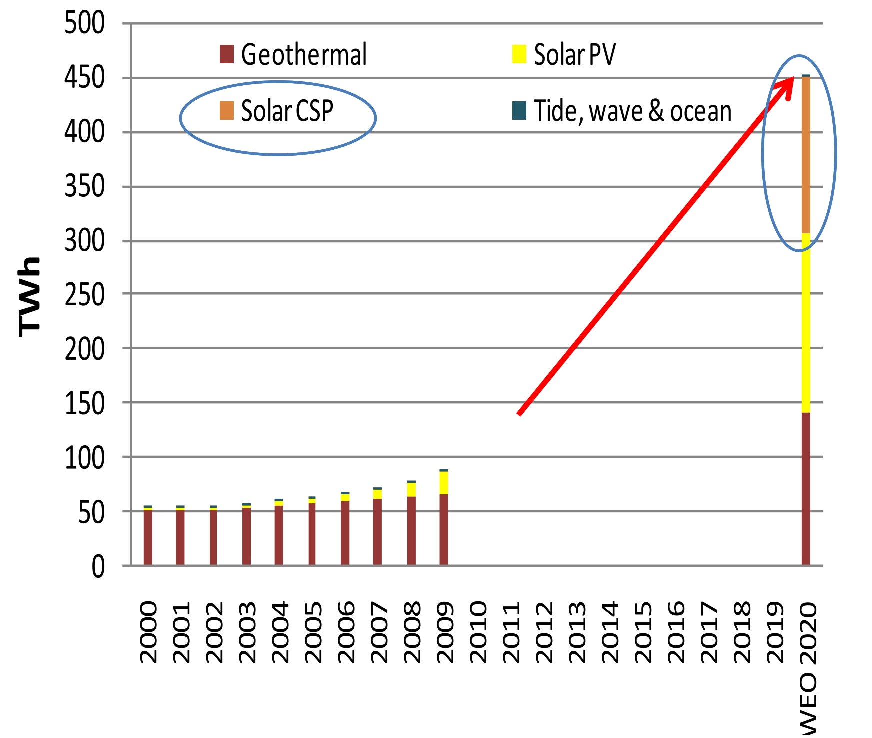
Cost targets for the utility sector

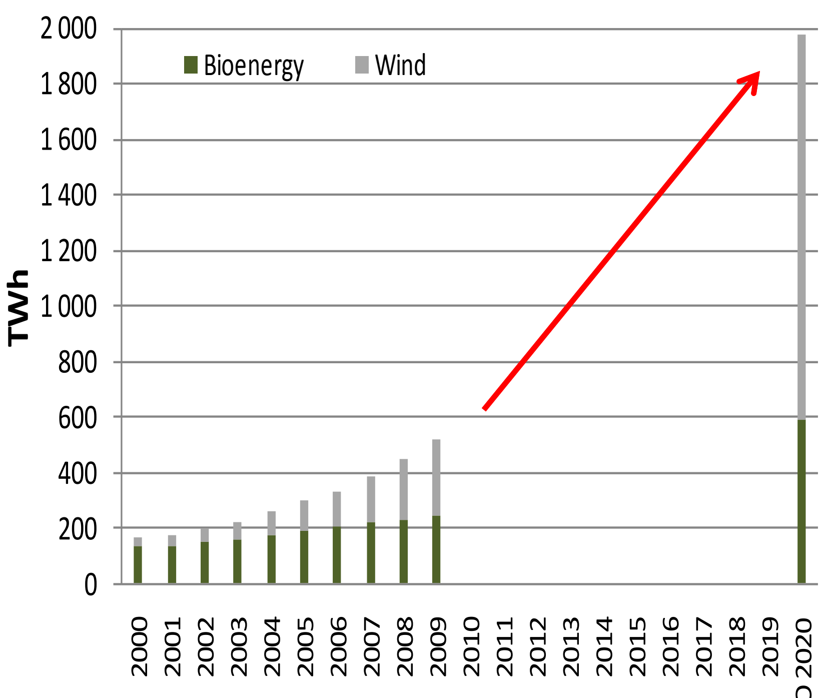
		2010	2020	2030	2050
Typical turnkey system price (2010 USD/kW)		3120	1390	1100	*850*
Typical electricity generation costs (2010 USD/MWH)*	2000 kWh/kW	187	81	62	*48*
	1500 kWh/kW	249	108	83	*64*
	1000 kWh/kW	374	162	125	*96*

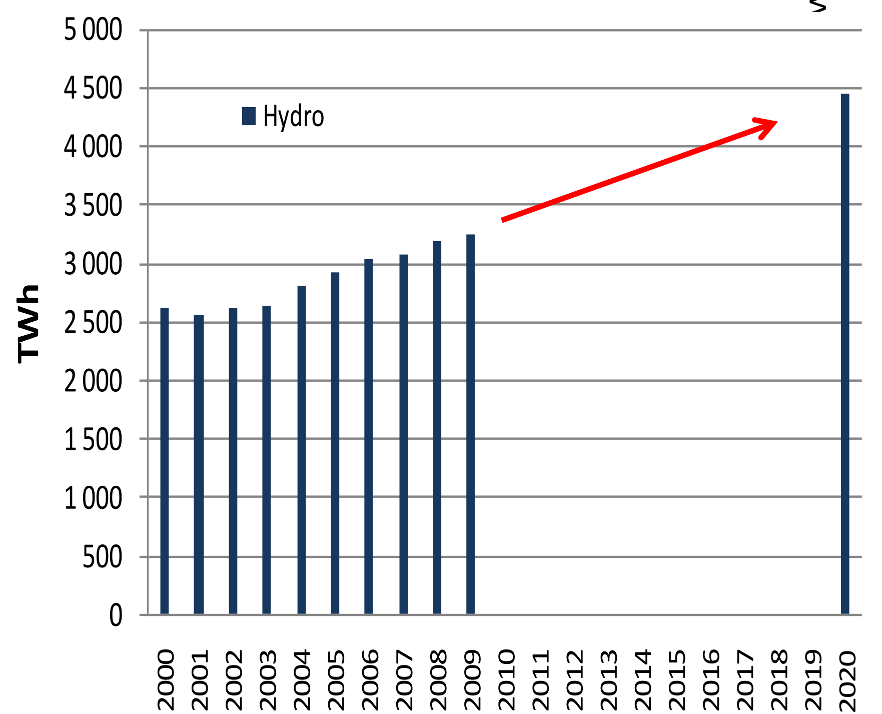
Notes: Based on the following assumptions: interest rate 10%, technical lifetime 25 years (2008), 30 years (2020), 35 years (2030) and 40 years (2050). Numbers in italics are considered more speculative.
Sources: IEA 2010*d*, Bloomberg New Energy Finance, and IEA data and analysis.

Deployment: Are we on track?

Well… not for CSP!



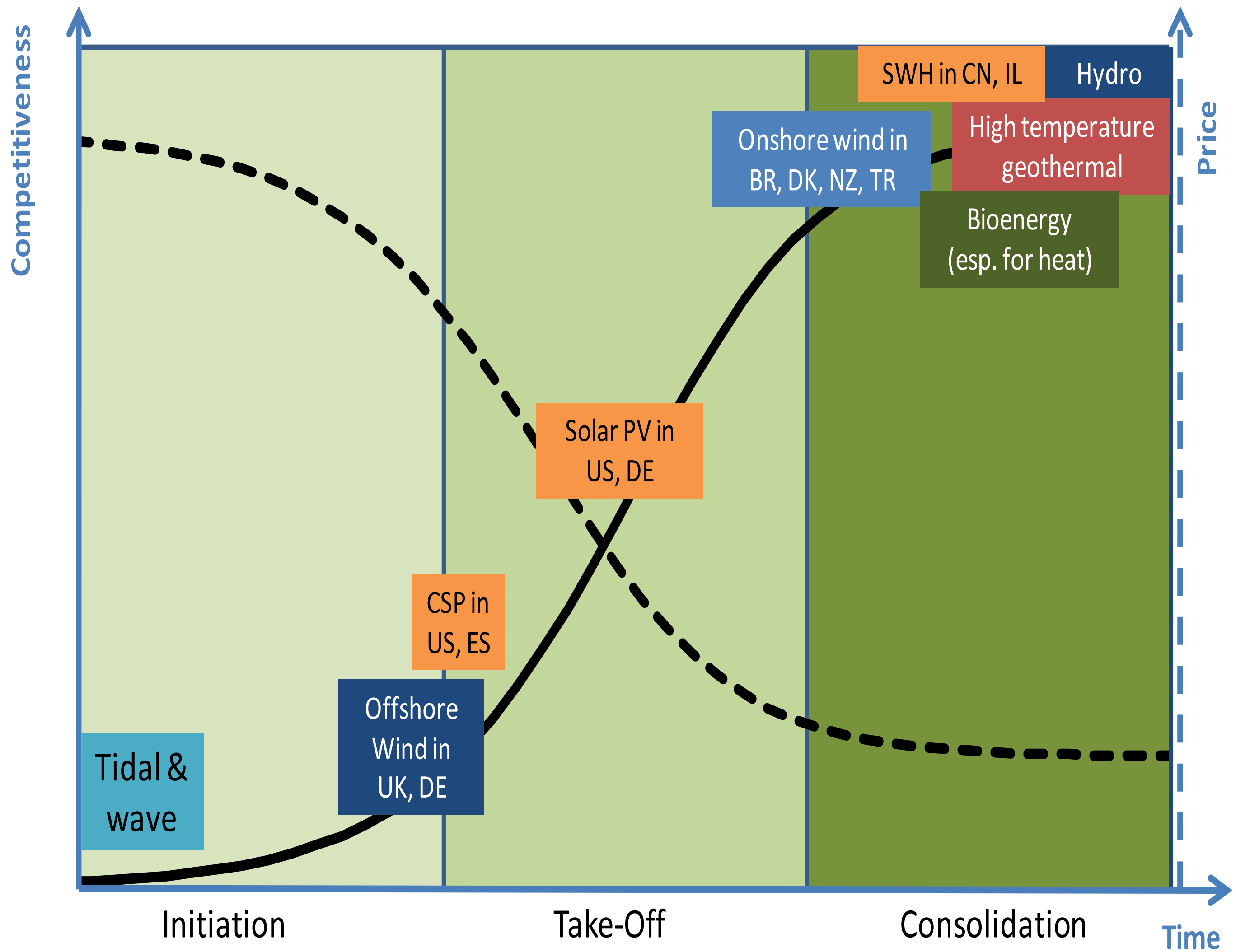




RENEWABLES ENERGY MARKETS & POLICIES

Deploying Renewables 2011

RE technologies: competitiveness



•Prices for many technologies have been declining *(dotted line, right hand scale)*.

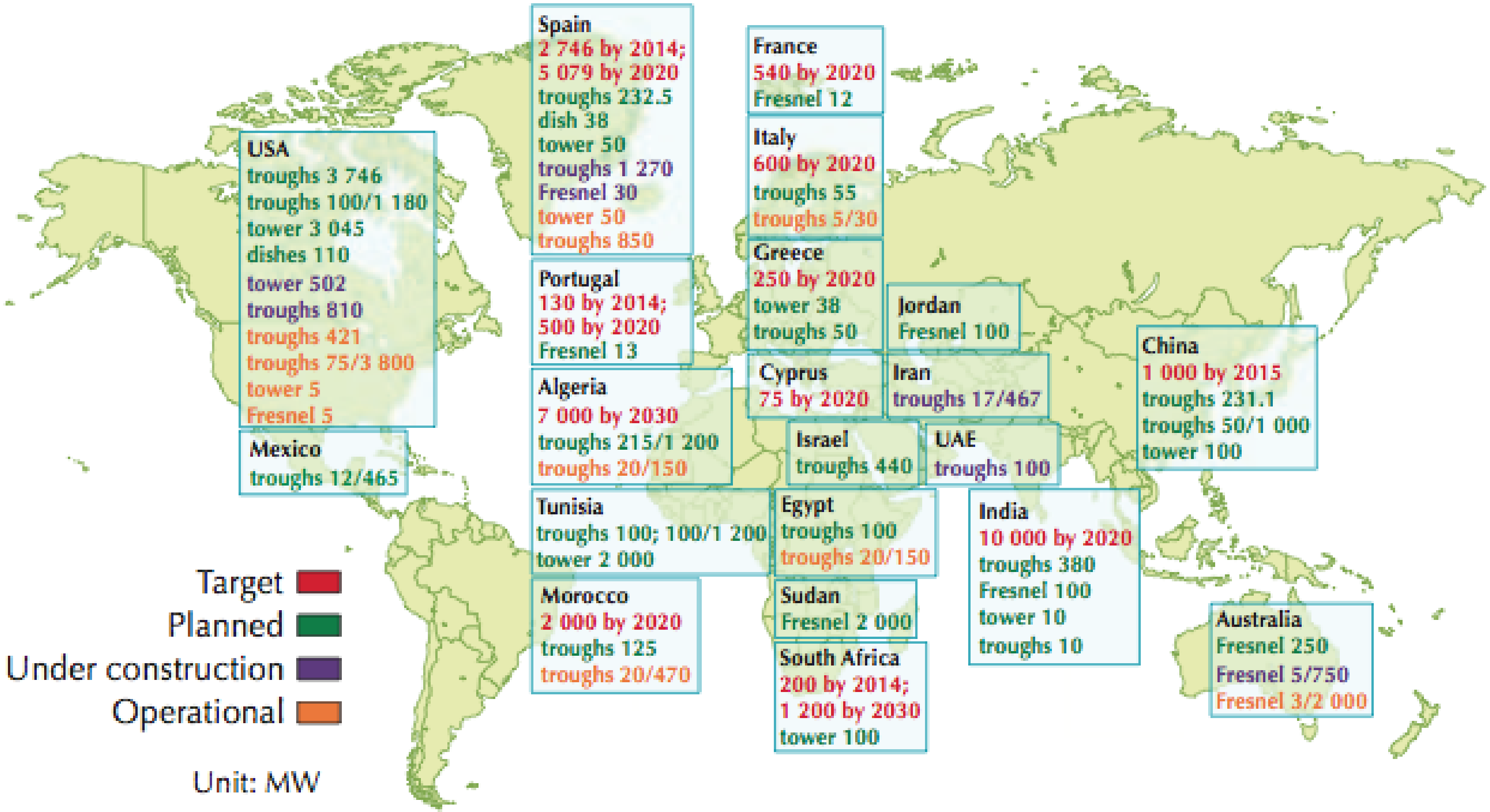
•Growing set of circumstances in which RET are competitive *(straight line, left hand scale)*

Technologies: solar thermal electricity

Source: Torresol Energy

- Key value of STE/CSP is in thermal storage to better match demand
  - effective and cheaper than electrical storage
- Concentration requires good direct irradiance
- Many different designs and options

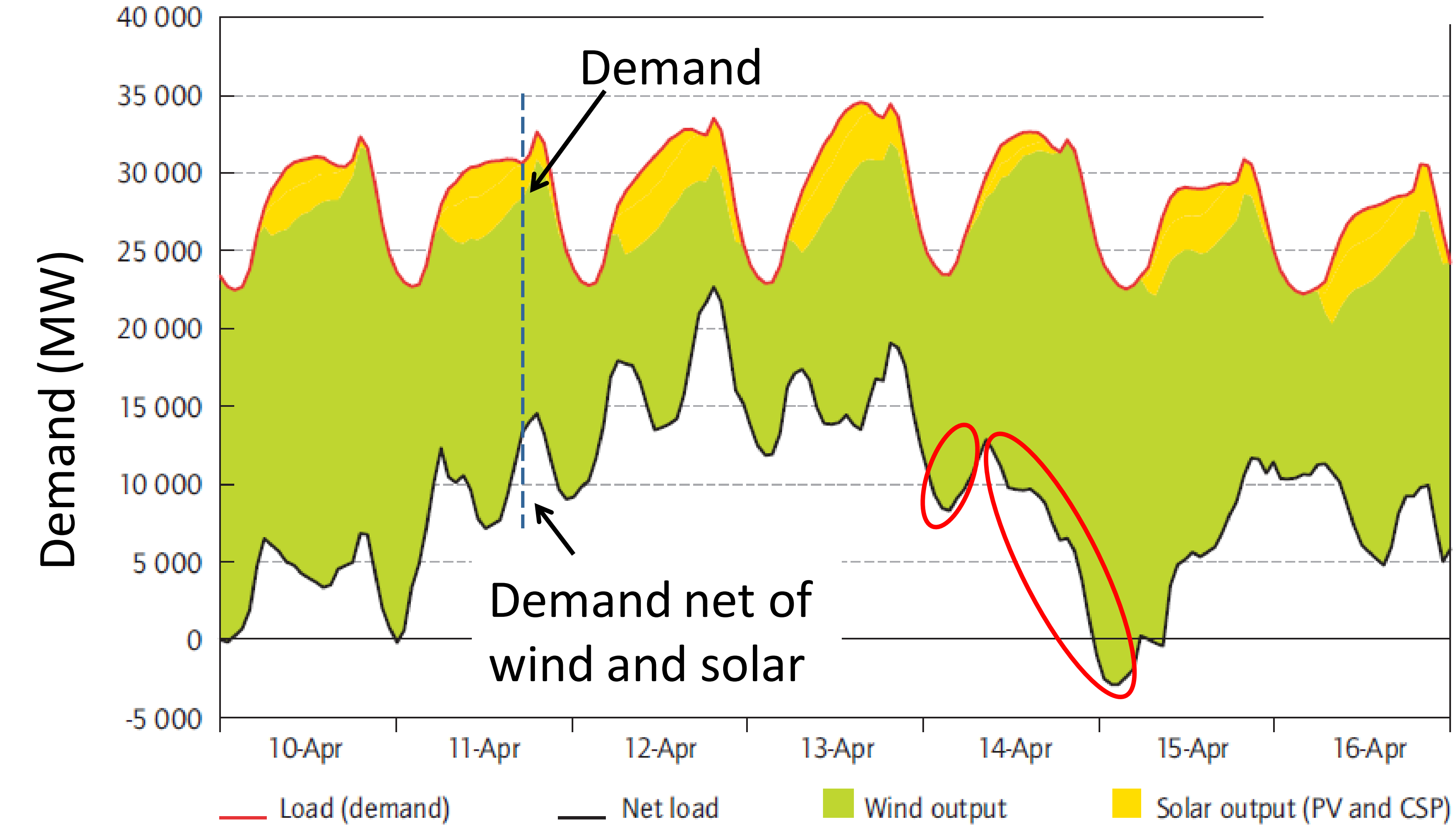
On-going CSP targets and plants



Note: xx/yy: for Integrated Solar Combined Cycle or fuel saver systems, xx indicates the solar capacity, yy indicates the overall capacity.

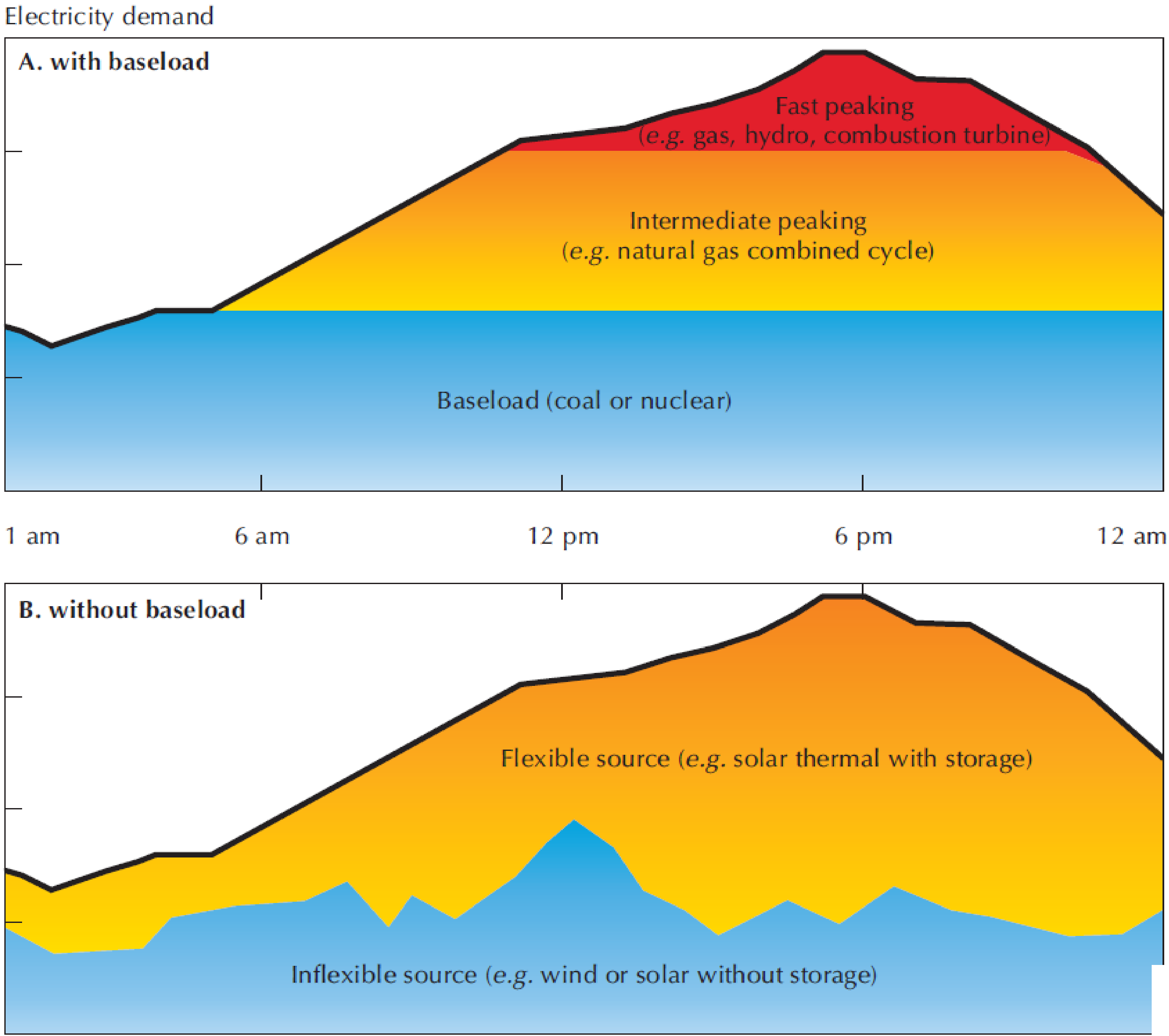
Emerging challenges: grid integration

Variability is not new, but it does get bigger



Source: *Western Wind and Solar Integration Study*, GE Energy for NREL (2010)

Load-matching rather than base-load



Source: Mills and Cheng, 2011

Solar Energy Perspectives

RENEWABLES ENERGY TECHNOLOGIES

Time of use payments are key

SCE

Monthly Period	On-Peak	Mid-Peak	Off-Peak	Super-Off- Peak
Winter		1.00000	0.83000	0.61000
Summer	3.13000	1.35000	0.75000	

PG&E

Monthly Period	Super Peak	Shoulder	Night
Jun-Sept	2.204900	1.122370	0.689880
Oct -Dec, Jan&Feb	1.057830	0.934770	0.763840
Mar-May	1.145880	0.846340	0.642350

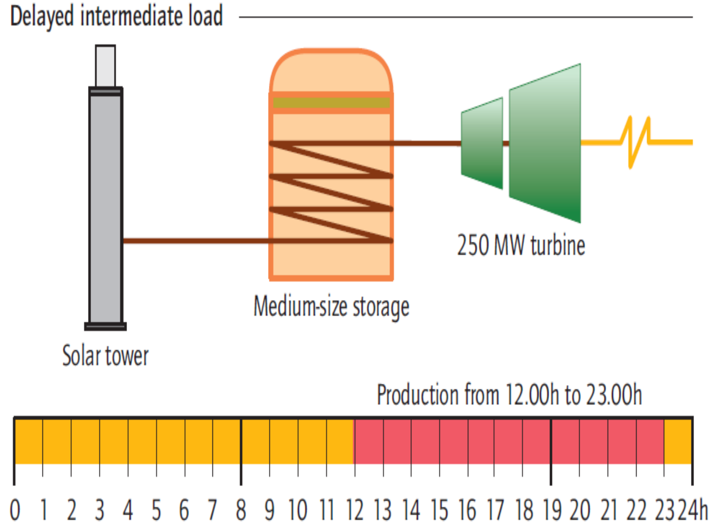
SDG&E

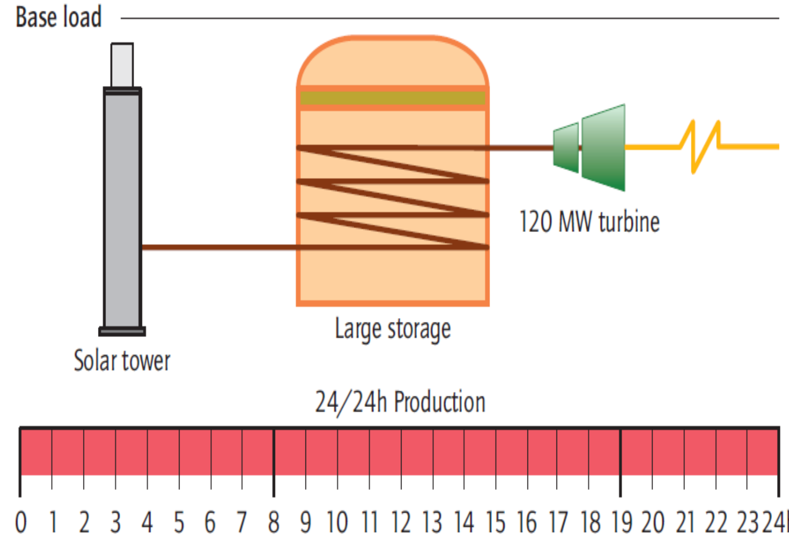
Monthly Period	On-Peak	Semi-Peak	*Off-Peak*
Nov-June	1.1916	1.0790	0.7928
July-Oct	1.6411	1.0400	0.8833

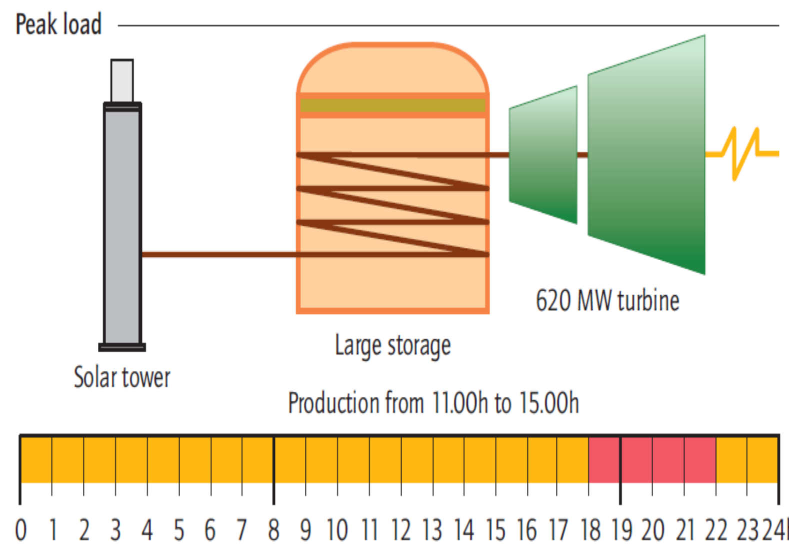
RENEWABLES ENERGY TECHNOLOGIES

Solar Energy Perspectives

Possible roles of storage



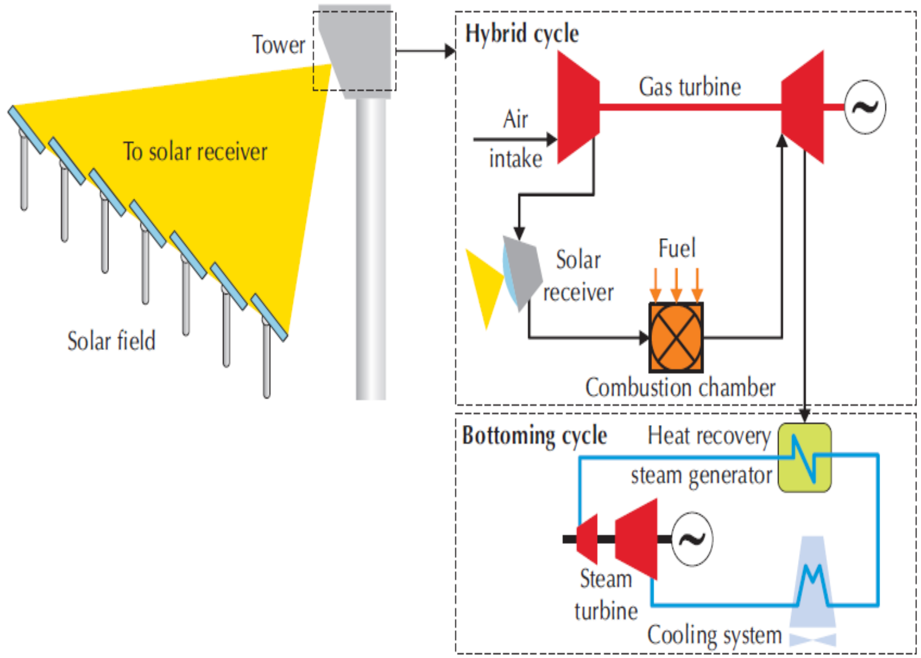




- **Thermal storage can be used to shift production, to extend it to base load or to concentrate it to super peak load**

Back-up/hybridisation

Source: PEGASE/CNRS.

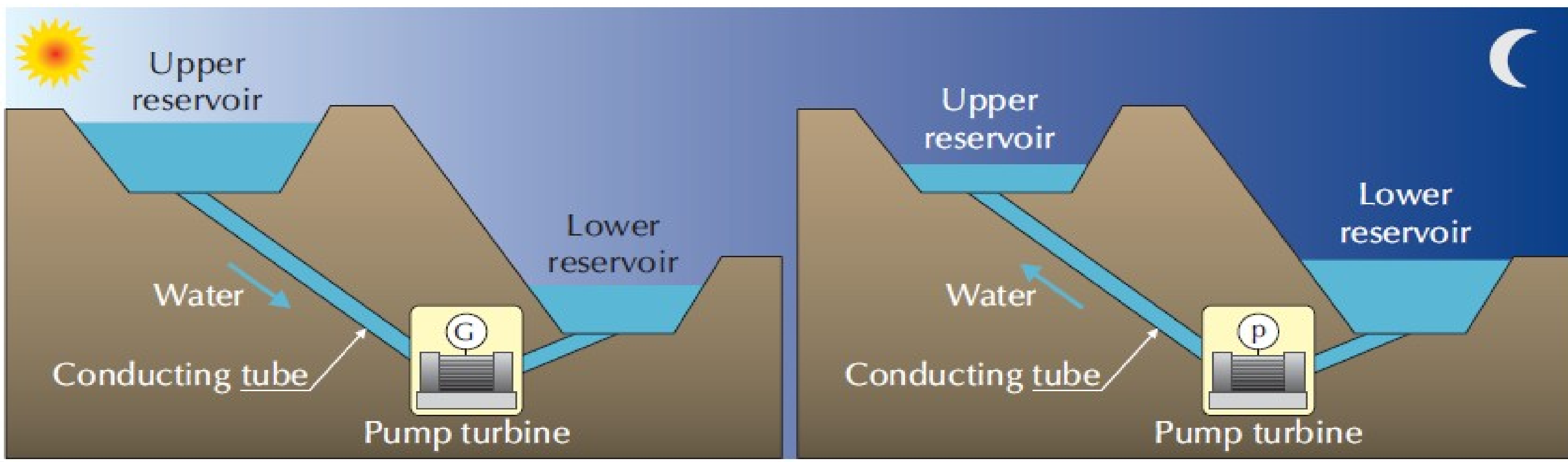


- Firming capacities
- Increase the solar share in the mix
- Walk the learning curve
- Currently in use:
  - Back-up or routine fuel use in PT plants; efficient?
  - Fresnel pre-heating feedwater in coal plants
  - Steam augmentation in bottoming cycles (ISCC)
- Options to be developped
  - Main steam augmentation in efficient coal plants
  - Hybrid solar-gas with combined cycle

Storage for large-scale variable RE

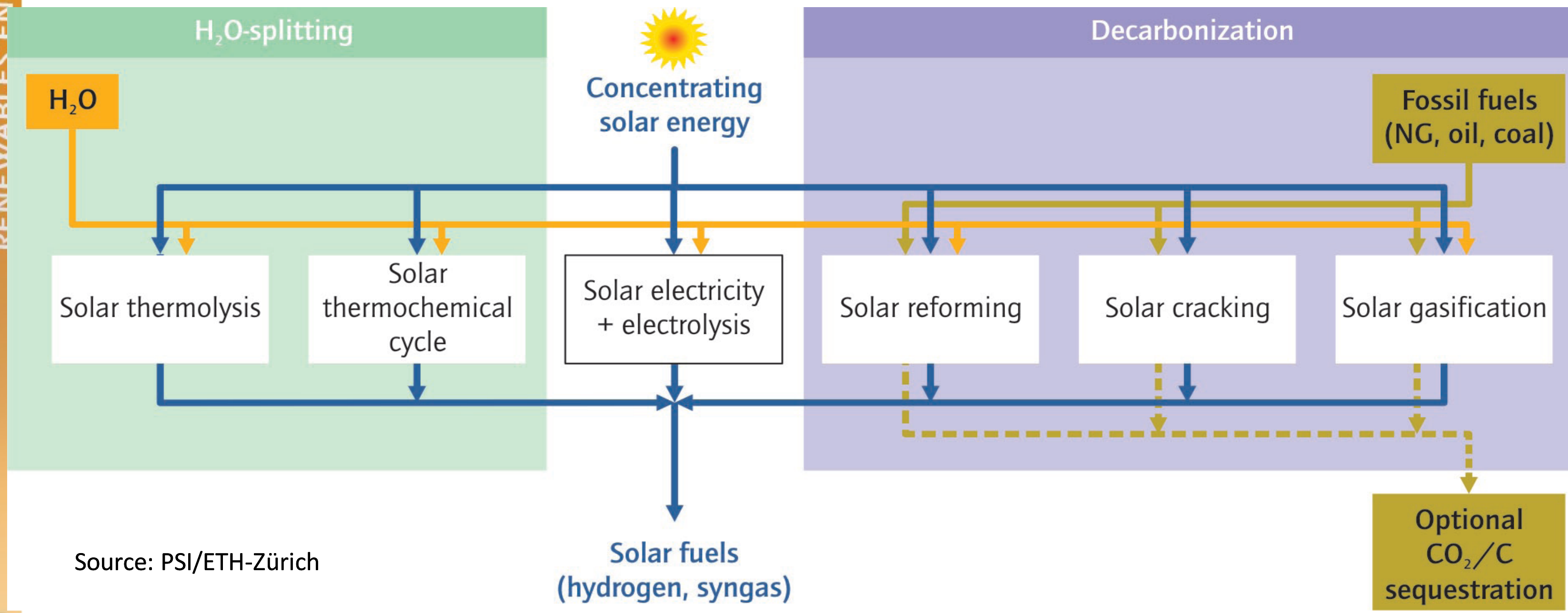
- Small or large, batteries are expensive
- G2V to avoid curtailment. V2G to shave peaks?
- Pumped-hydro plants the reference solution
  - 140 GW in service, much more necessary
  - Daily/weekly storage does not require large areas
  - Can be built on the coast or offshore using seawater
  - Less efficient than thermal storage but affordable

Source: Inage, 2009.



Technologies: solar fuels

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

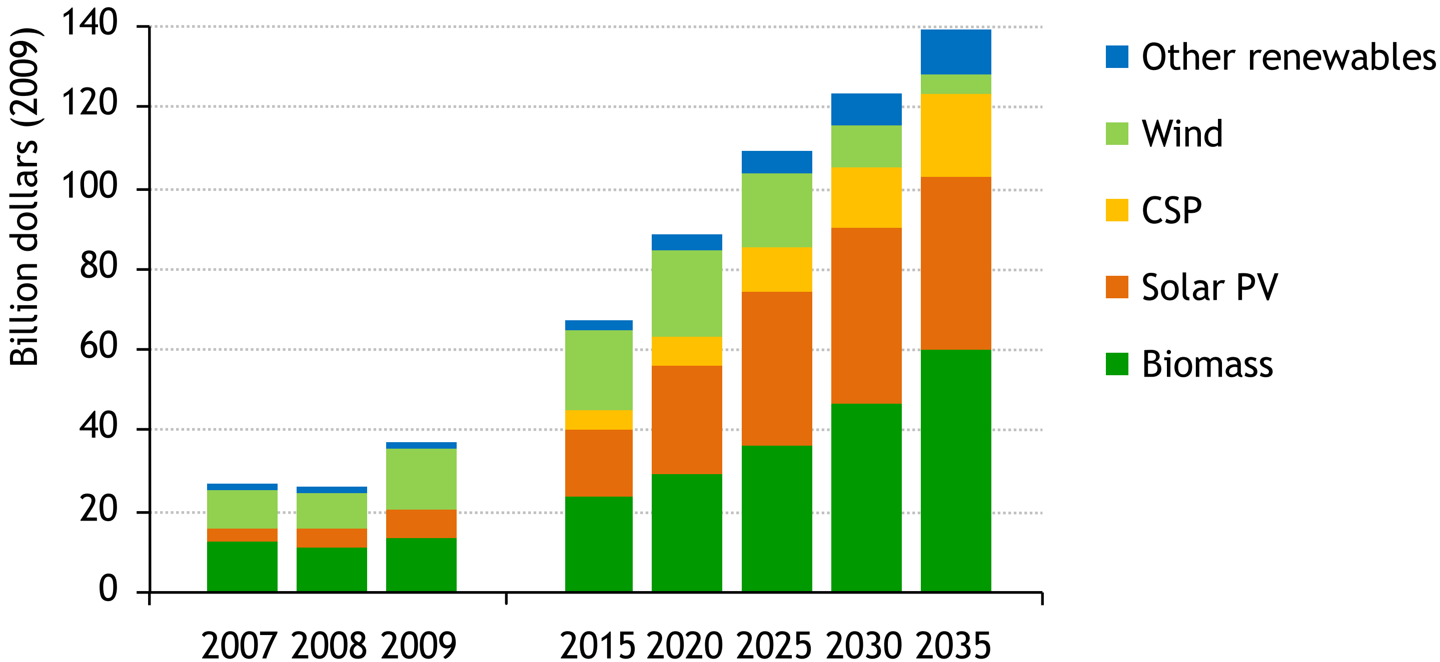


Source: PSI/ETH-Zürich

- **H_2 easier to use blended with natural gas, could be stored then used in balancing plants**
- **Can be converted into various energy carriers**

Renewables need government support to deliver…

Global government support for renewables-based electricity generation in the New Policies Scenario



Global government support for renewables reached $37 billion in 2009 and grows to $140 billion in 2035; support costs per unit of electricity fall over time as technologies mature

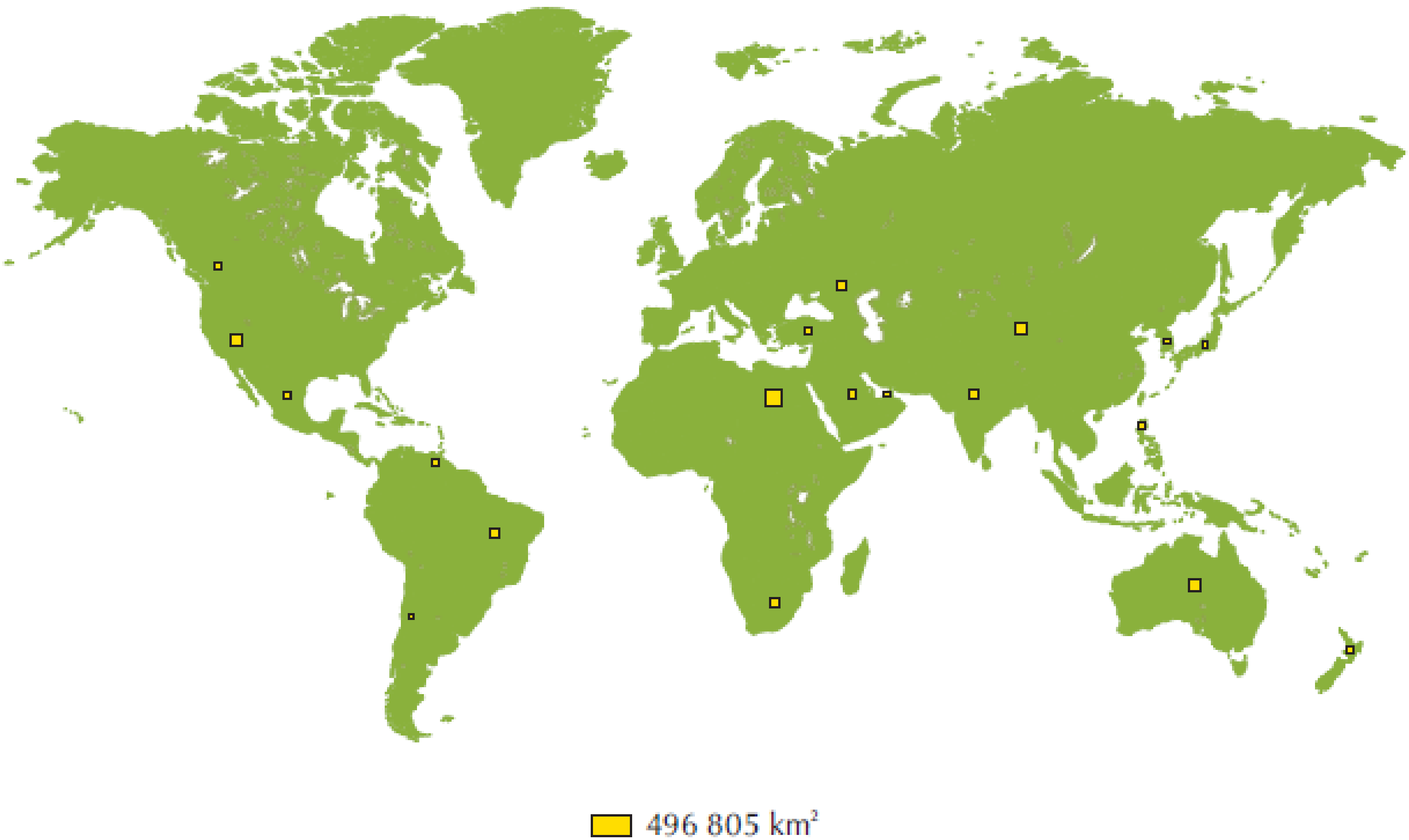
The way forward: testing the limits

- **A possible vision, under severe climate constraints, if other low-carbon energy options are not available...**
- **Where are the technical limits to solar energy?**
  - **Many electricity technologies converging towards USD100/MWh (incl. CO_2) around 2030 [Roadmaps, ETP]**
  - **→ Cost no longer main limit, but footprint, variability and convenience issues**
  - **Not necessarily least cost, but affordable options:**
    - **Sunny and dry climates, where CSP dominates**
    - **Sunny and wet climates, with PV backed by hydro**
    - **Temperate climates, with wind power and PV backed by pumped-hydro and solar-H_2/NG balancing plants**
  - **Assuming efficiency improvements as in ETP but further electrification of buildings, industry and transport:**
  - **→ Under best conditions, solar energy (mostly electricity) could become a key contributor to the global energy mix**
  - **→ Some fossil fuels still needed in transport, industry, electricity**

Solar Energy Perspectives

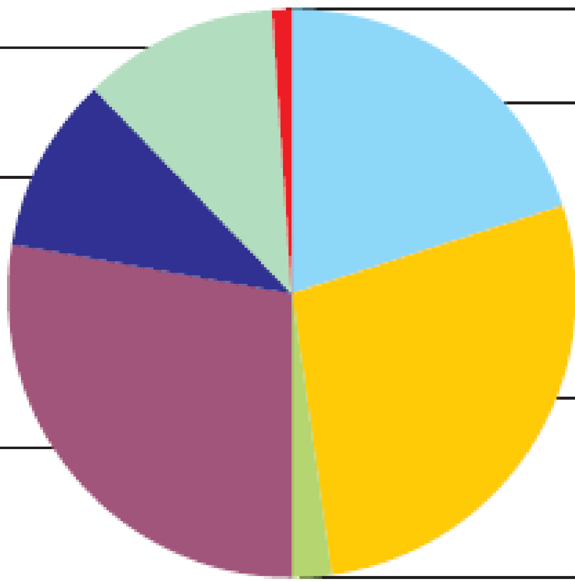
RENEWABLES ENERGY TECHNOLOGIES

500 000 km2 of hypothetical on-ground solar power plants



Source: landartgenerator.

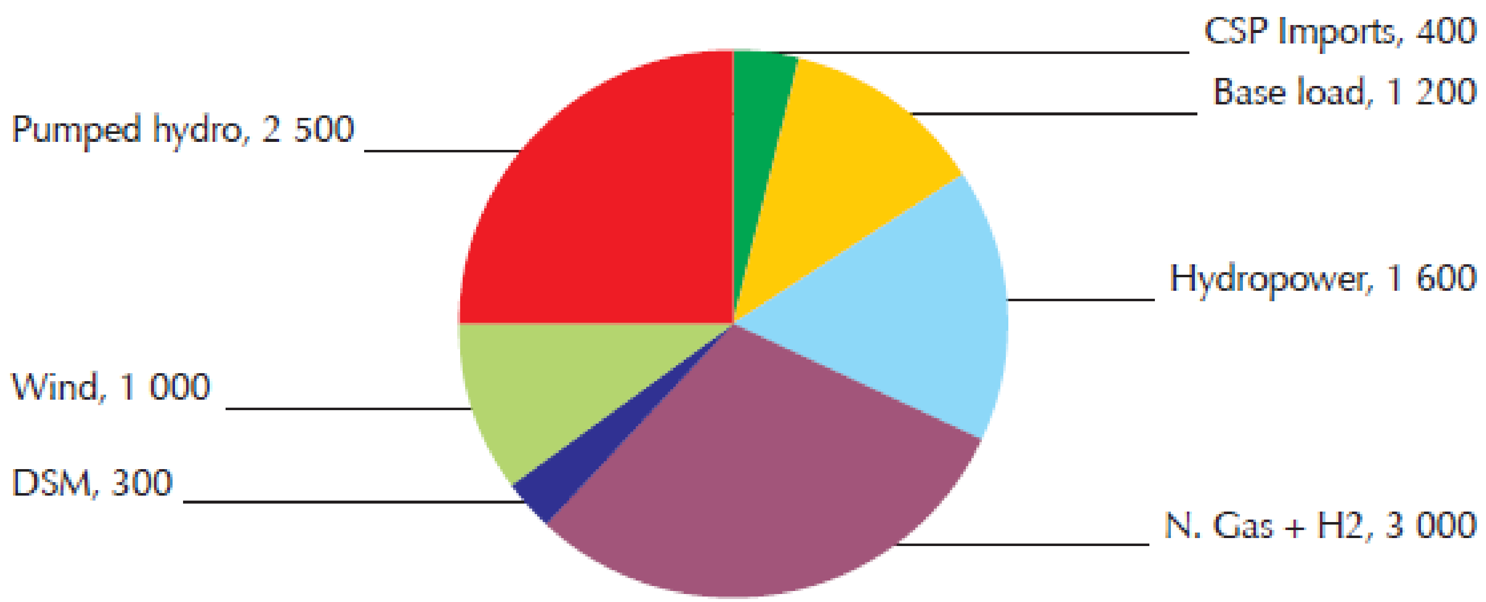
Testing the limits: 2060



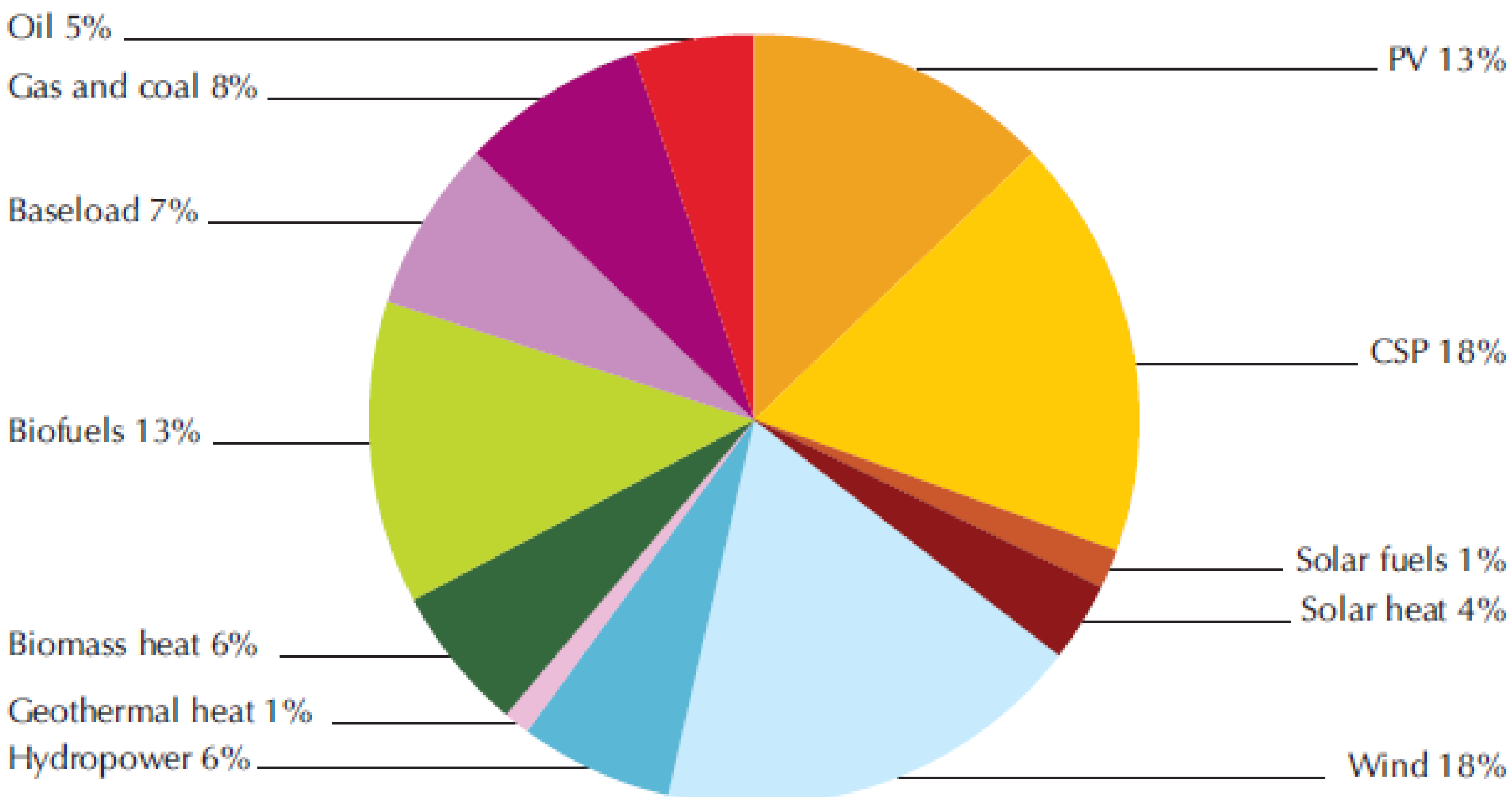
Technology	Capacity (GW)	Electricity generation (TWh/y)
PV	12 000	18 000
CSP	*6 000	25 000
Solar fuels	**3 000	2 000
Wind power	10 000	25 000
Hydro power and marine	1 600	9 000
Base load (Geothermal, nuclear, solid biomass w. CCS)	1 200	10 000
Natural gas	**3 000	1 000
Total		90 000

* Thermal storage would give CSP plants an average capacity factor of almost 50%. **Shared capacities.

Capacities requires for peak deamnd after sunset with low winds in non-CSP areas



Testing the limits:
Total final energy by sources, 2060



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

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
  - 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"