International Energy Agency

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CST after COP-21

A global perspective

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Renewable Energy Division

International Energy Agency

ASTRI Workshop, Melbourne, 2 May 2016

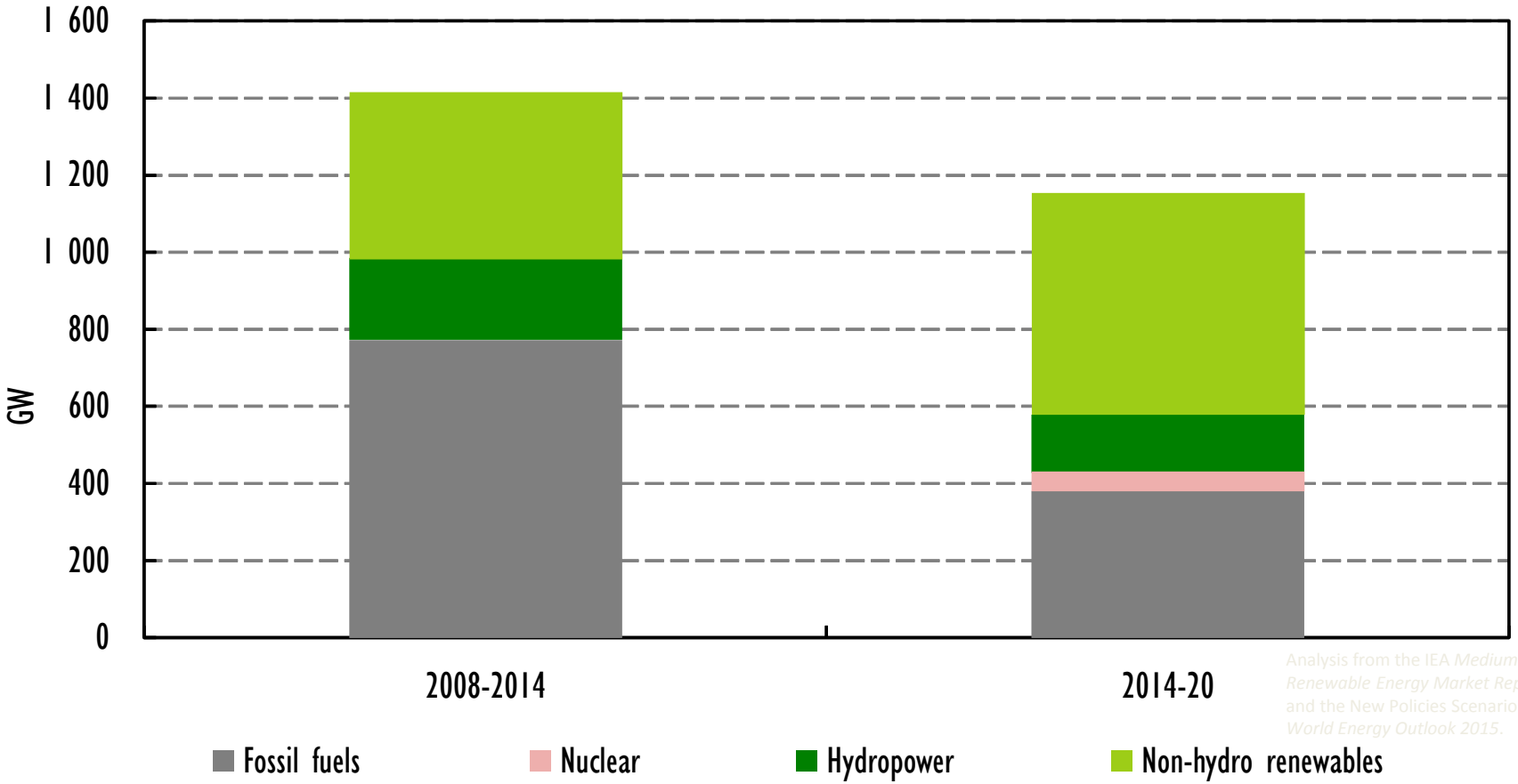
www.iea.org

COP21 a historic milestone

- **Universal agreement on:**
  - *"GHG emissions peak asap"*
  - *Stay "below 2°C" temperature increase, get close to 1.5*
  - *Reach "carbon-neutrality" in second half of this century*
- **Renewables around COP21**
  - *Renewables explicitly referred to in around 100 pledges*
  - *Record renewable capacity additions in 2014 and 2015*
  - *Lowest-ever announced wind and solar prices*
- **Downturn in prices for all fossil fuels**
  - *Oil & gas set to face a second year of falling upstream investment in 2016*
  - *Coal prices remain at rock-bottom as demand slows in China*

Renewables set to dominate additions in power systems

World net additions to power capacity

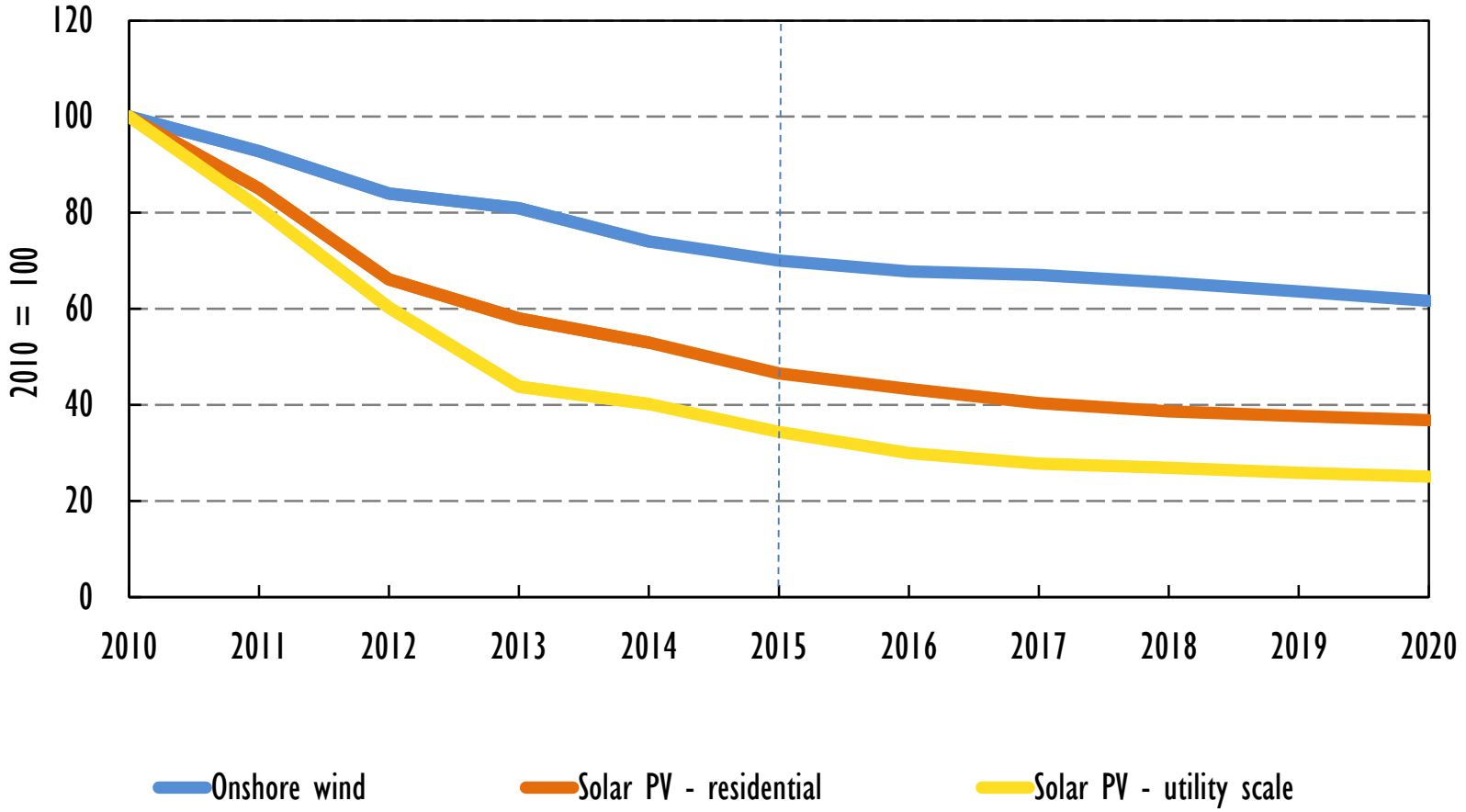


Analysis from the IEA *Medium-Term Renewable Energy Market Report 2015* and the New Policies Scenario of the *World Energy Outlook 2015*.

The share of renewables in net additions to power capacity continues to rise with non-hydro sources reaching nearly half of the total

Innovation and scale-up are driving costs down

Indexed generation costs



High levels of incentives are no longer necessary for solar PV and onshore wind, but their economic attractiveness still depends on regulatory framework and market design

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Wind and Solar PV prices declining sharply

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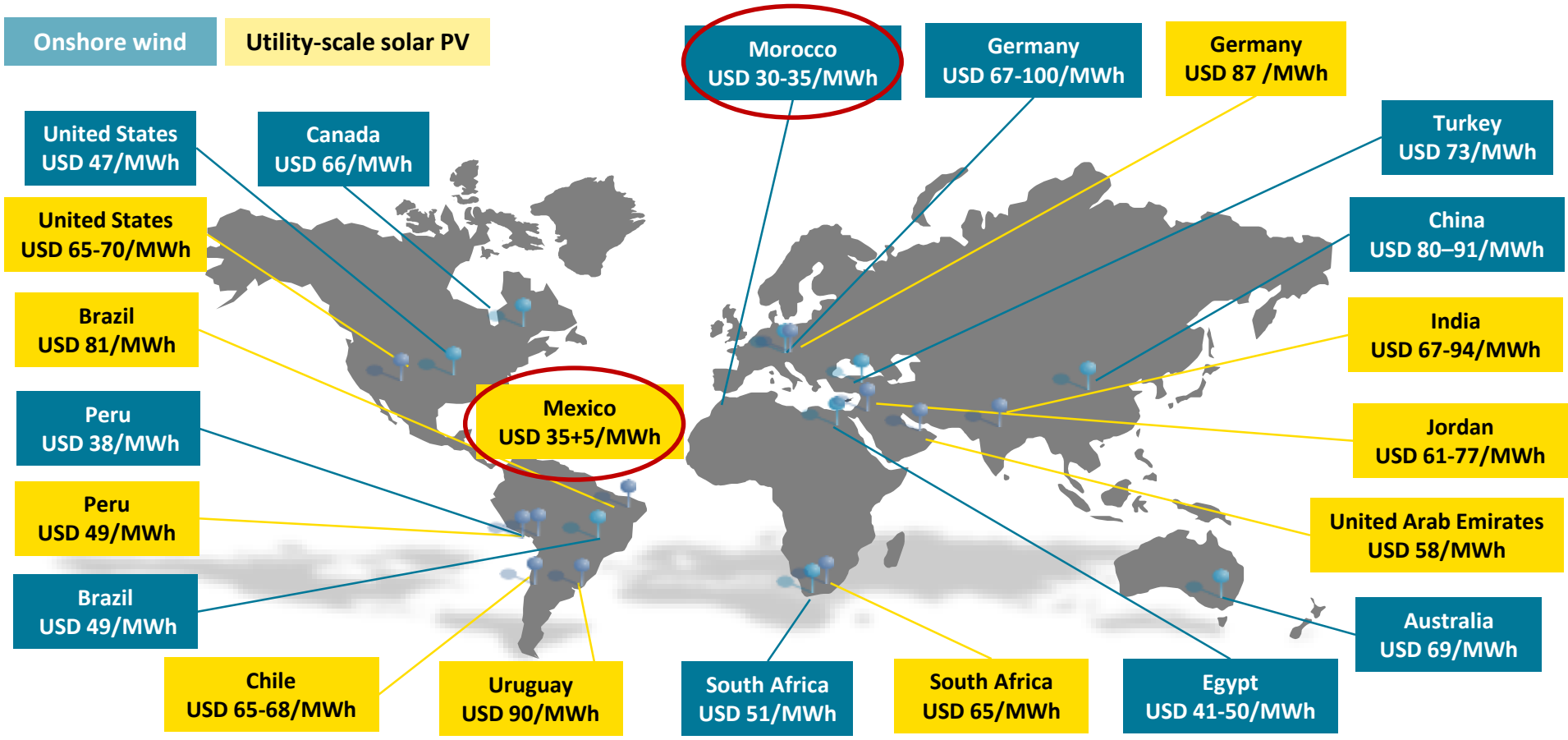
Recent announced long-term contract prices for new renewable power to be commissioned over 2016-2019



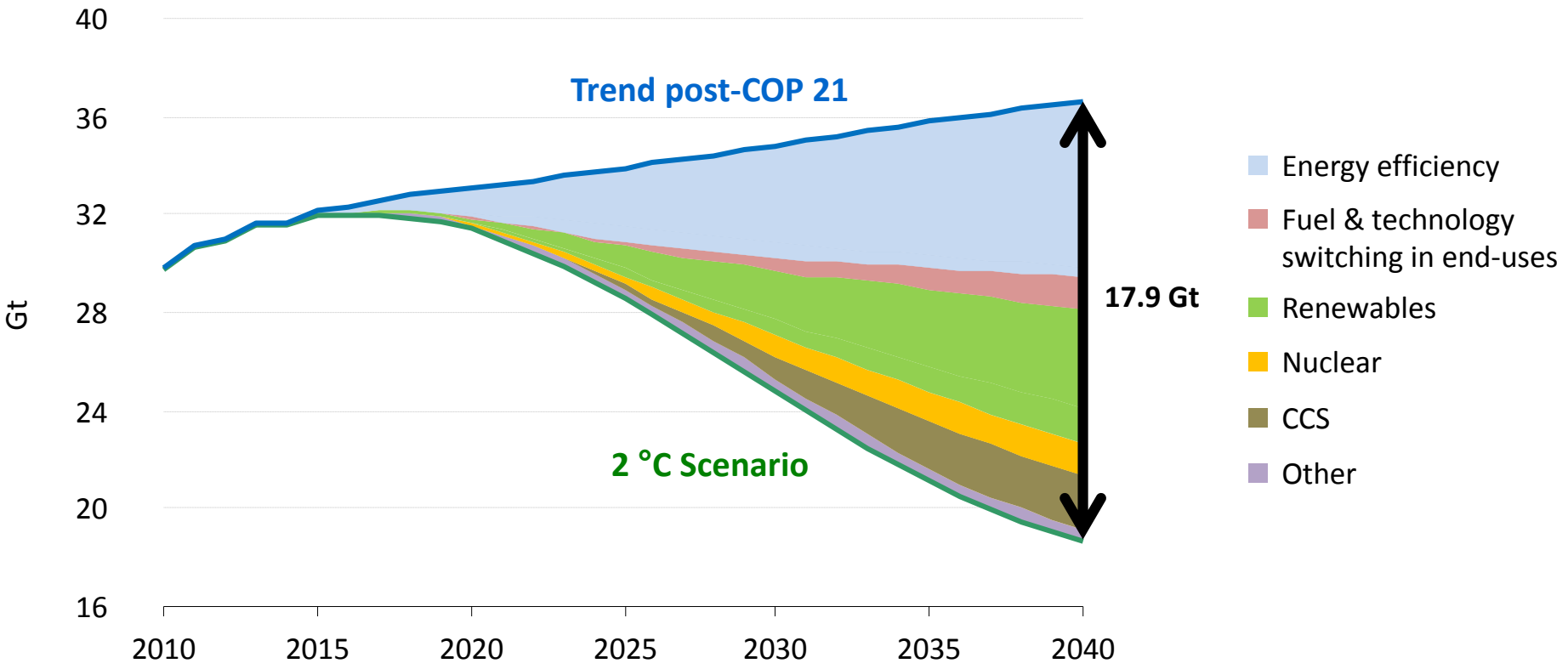
This map is without prejudice to the status or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area

Note: Values reported in nominal USD includes preferred bidders, PPAs or FITs. US values are calculated excluding tax credits. Delivery date and costs may be different than those reported at the time of the auction.

Best results occur where price competition, long-term contracts and good resource availability are combined

Greater efforts are still needed to reach a 2 °C pathway

WEO Special Report on Energy & Climate Change

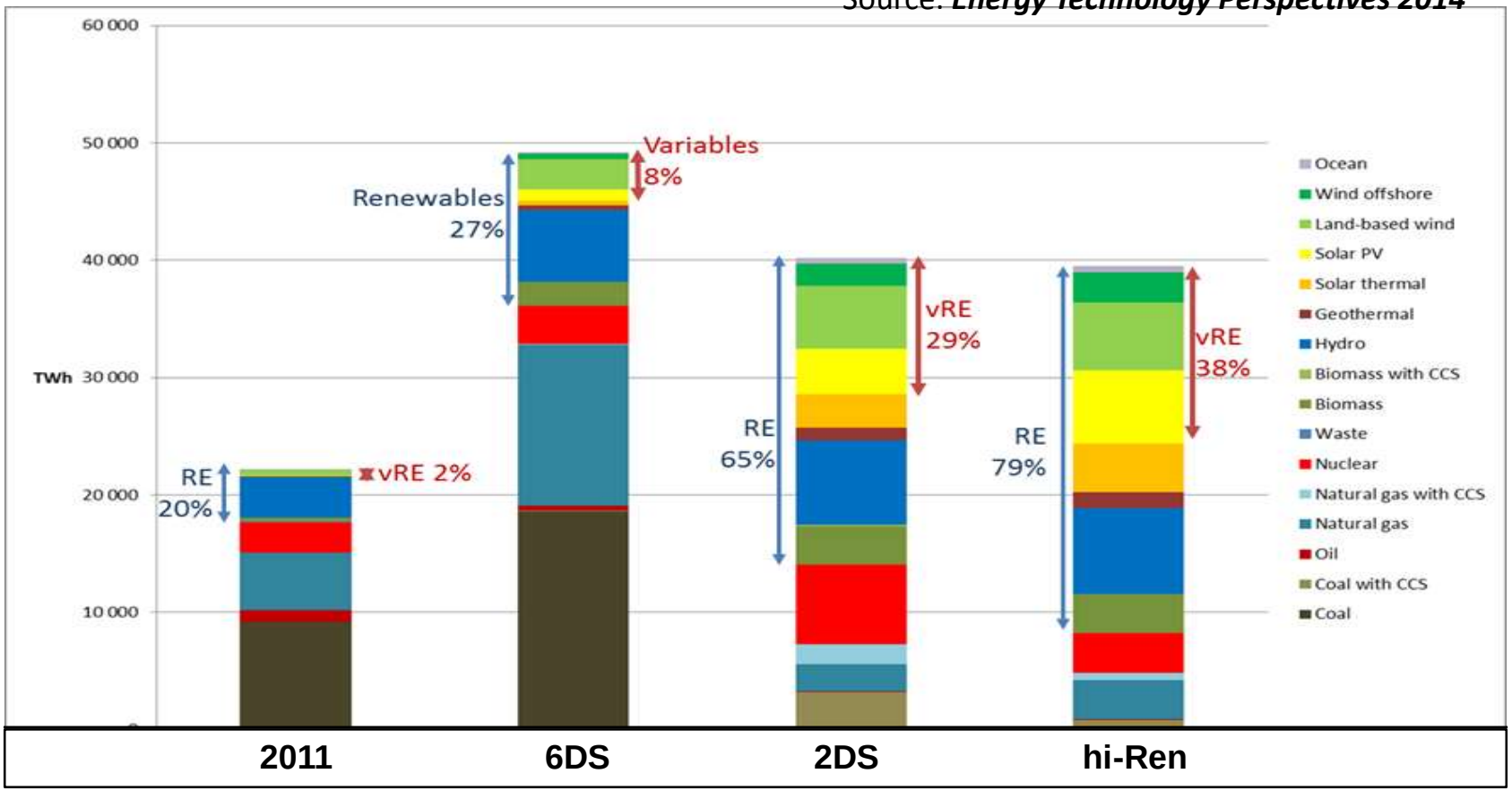


Source: World Energy Outlook 2015

In a 2° C Scenario, energy efficiency and renewables, notably solar and wind, deliver the bulk of GHG emission reductions

Global power mix needs a shift reversal

Source: ***Energy Technology Perspectives 2014***



- **Generation today:**
  - **Fossil fuels: 68%**
  - **Renewables: 20%**
- **Generation 2DS 2050:**
  - **Renewables: 65 - 79%**
  - **Fossil fuels: 20 - 12%**

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Where CST fits in the picture

1. Generate dispatchable electricity
2. Provide high-temperature industrial process heat
3. Manufacture energy vectors as « solar fuels »

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Solar Electricity

- PV takes all light
- PV almost everywhere
- Scalable from kW to GW
- Variable and mid-day
- Peak & mid-peak
- Smart grids

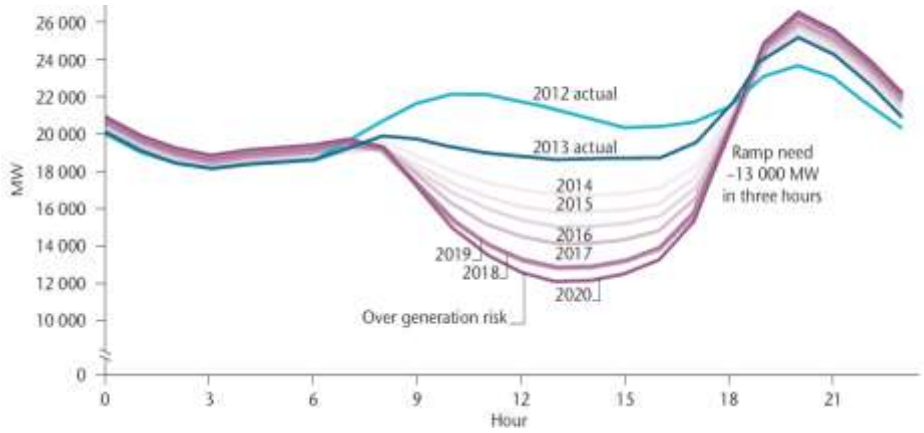
- STE takes direct light
- STE only in semi-arid countries
- Mostly for utilities
- Firm, dispatchable } backup
- Peak to base-load } storage
- HVDC lines for transport

Firm & flexible CSP capacities can help integrate more PV

Integrating large shares of PV is challenging

California:

- expected evolution of the net load of a typical spring day



Source: California ISO, 2014

- expected evolution of the value of PV and CST

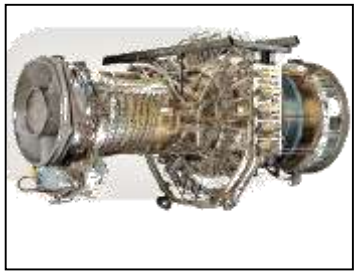
Value component	33% renewables		40% renewables	
	STE with storage value (USD/MWh)	PV Value (USD/MWh)	STE with storage value (USD/MWh)	PV Value (USD/MWh)
Operational	46.6	31.9	46.2	29.8
Capacity	47.9-60.8	15.2-26.3	49.8-63.1	2.4-17.6
Total	94.6-107	47.1-58.2	96.0-109	32.2-47.4

Source: Jorgenson, Denholm & Mehos, 2014

Flexibility of other power system components

Grids

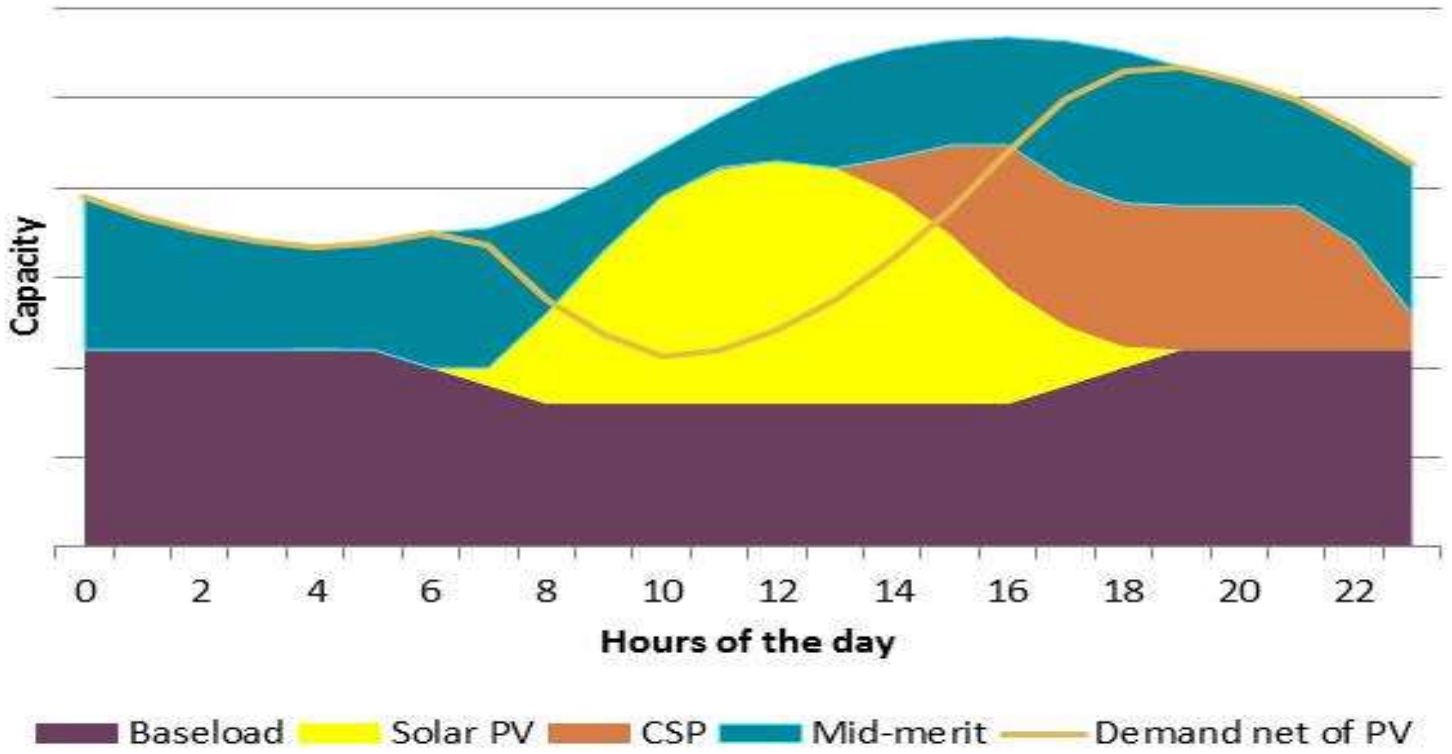
Generation



Storage

Demand Side

Complementary roles of PV and STE



Thanks to thermal storage, STE is generated on demand when the sun sets while demand often peaks and value of electricity increases

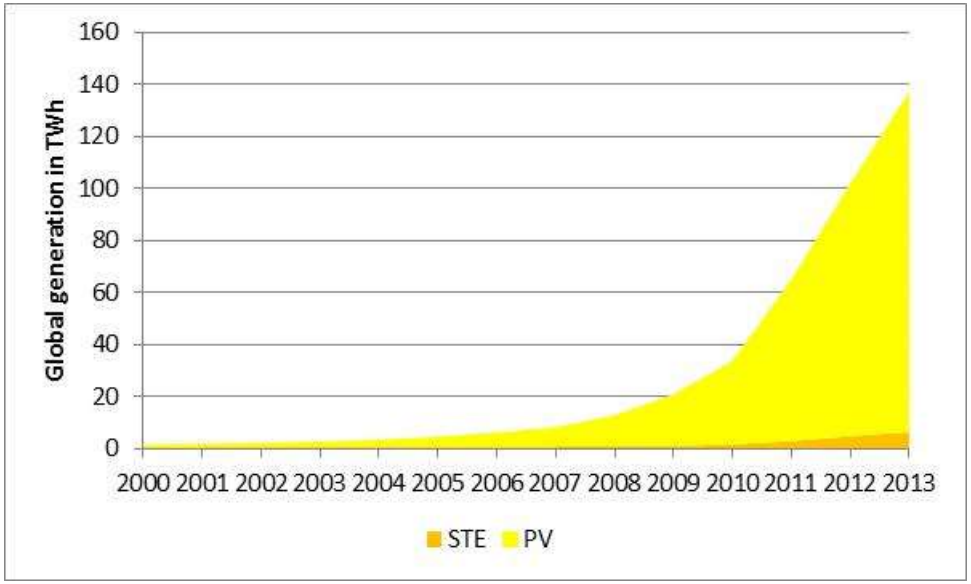
PV ahead, CST lags behind

PV:

- Massive cost reductions
- Also for distributed generation

STE:

- Flexible generation not yet fully valued
- Progress in the US
- Pipeline moved to Chile, China, Morocco, South Africa



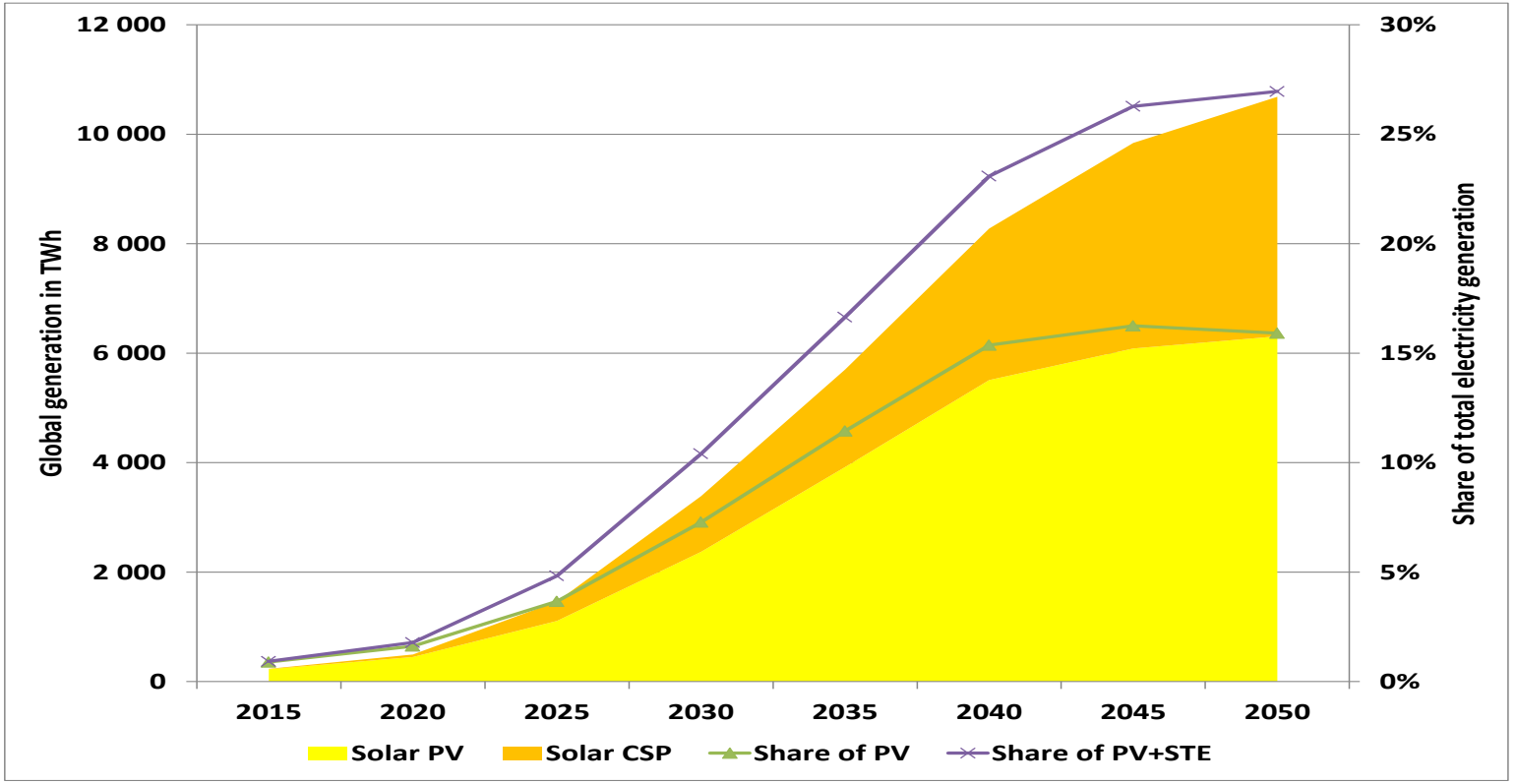
	Old Roadmap Milestones for 2020 (GW)	To be reached
PV	200	5 years ahead
STE	140	> 7 years later

Photovoltaic Energy

Solar Thermal Electricity

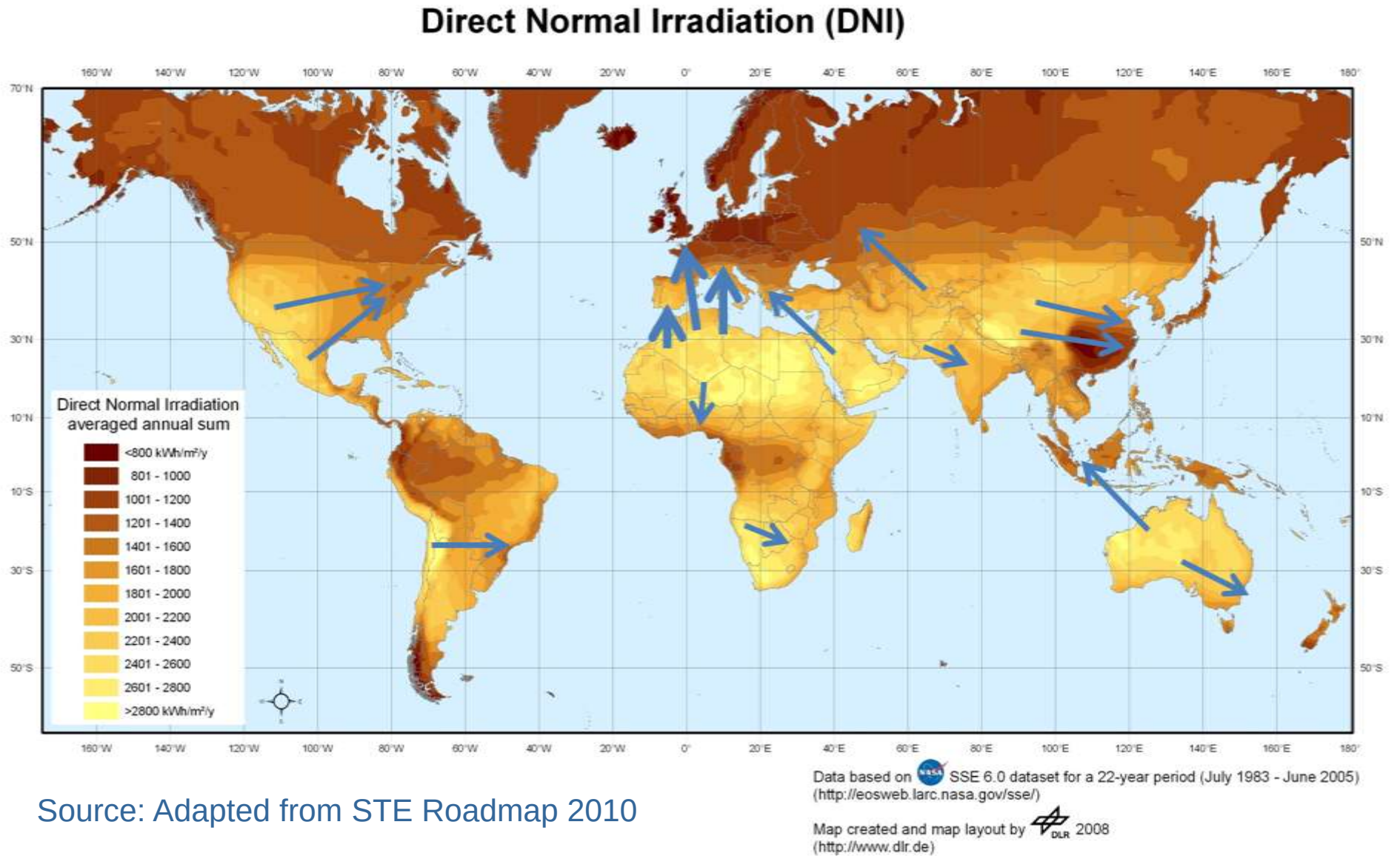
2014 Edition

New roadmap vision for solar electricity



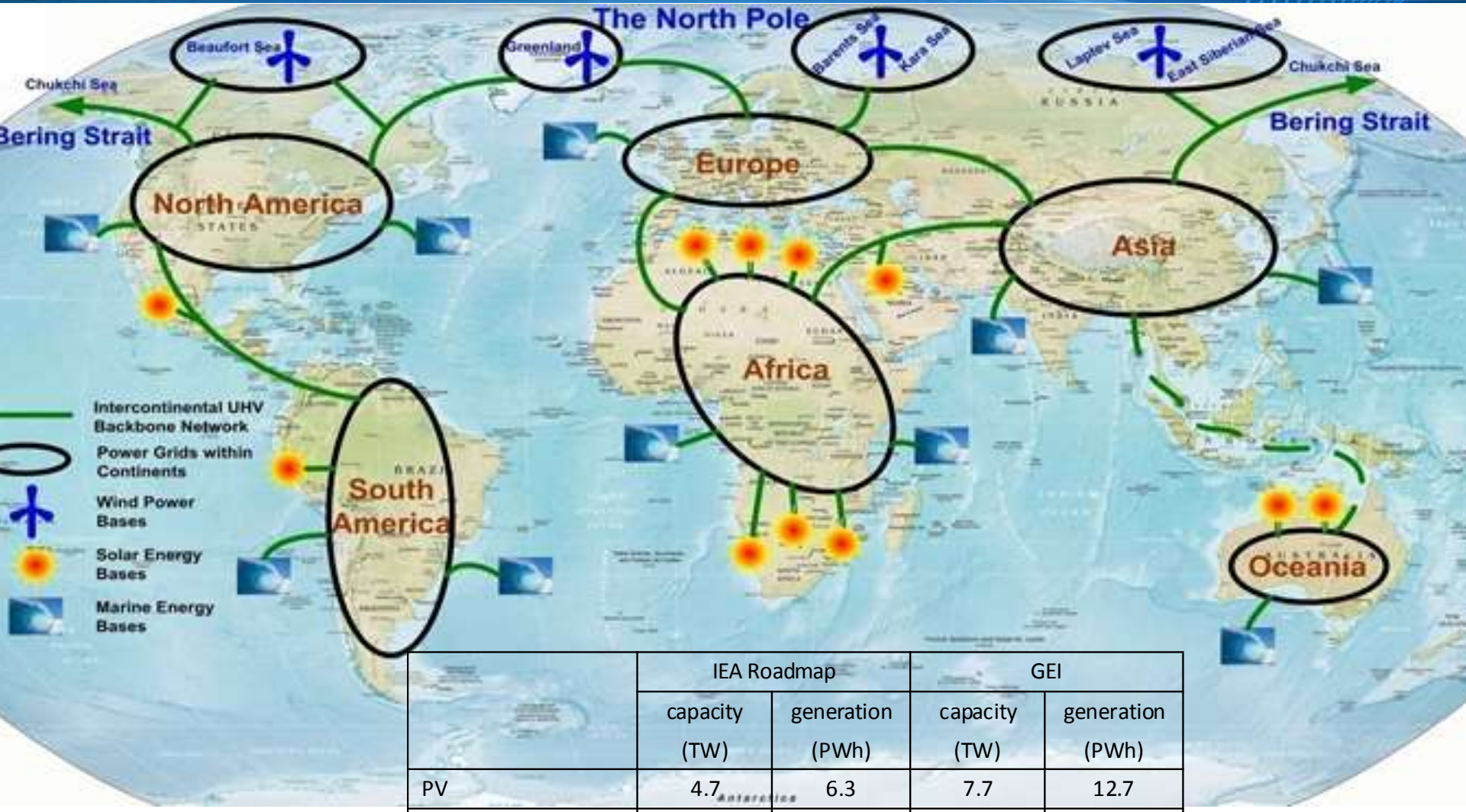
Together, PV and STE could become the largest source of electricity worldwide before 2050

Future possible interconnections



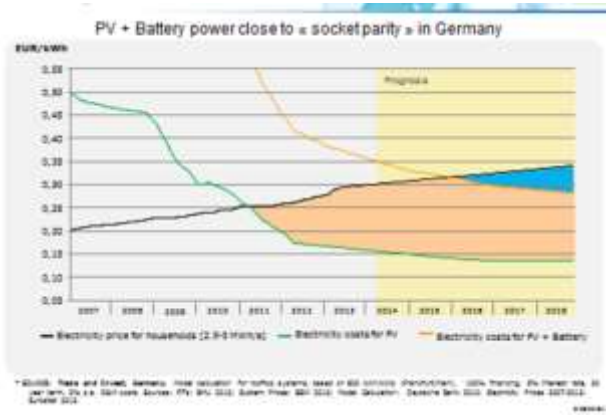
Source: Adapted from STE Roadmap 2010

Global Energy Interconnection



	IEA Roadmap		GEI	
	capacity (TW)	generation (PWh)	capacity (TW)	generation (PWh)
PV	4.7	6.3	7.7	12.7
Solar-thermal power	1.0	4.4	3.5	13.3
wind power	2.7	7.3	11.8	22.4

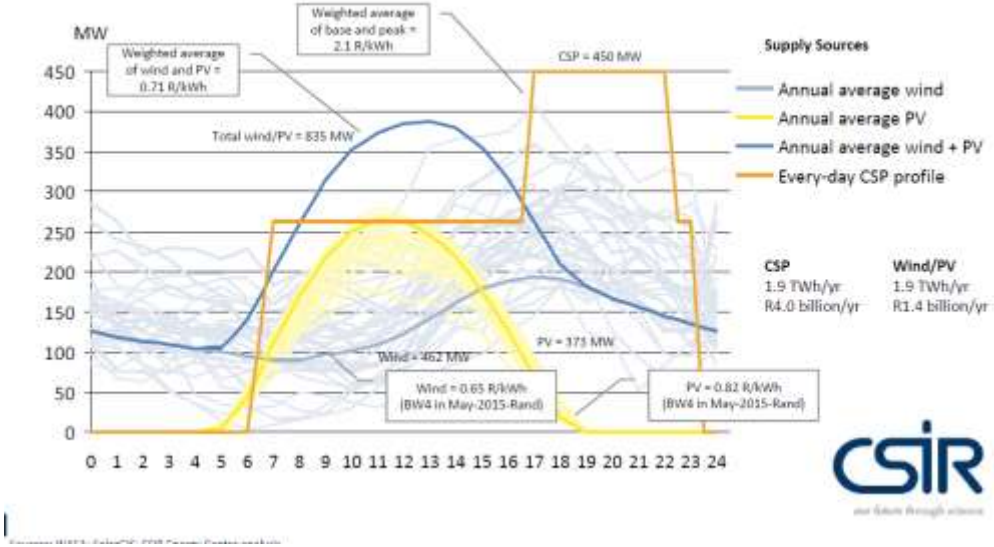
Power from CST compares with…



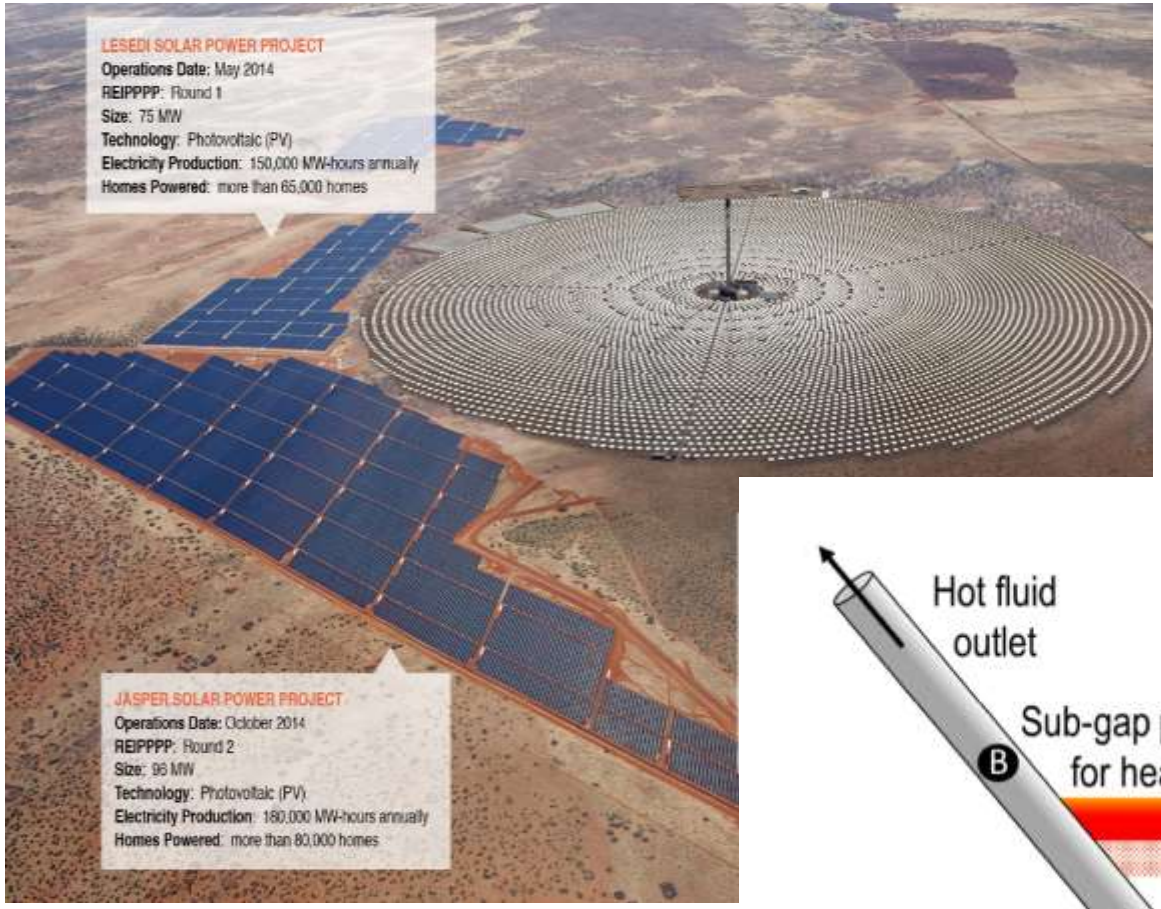
Distributed PV + battery
(e.g. Germany)

Utility-scale PV + pumped-hydro storage
(e.g. Chile)

PV + wind…
(e.g. South Africa)



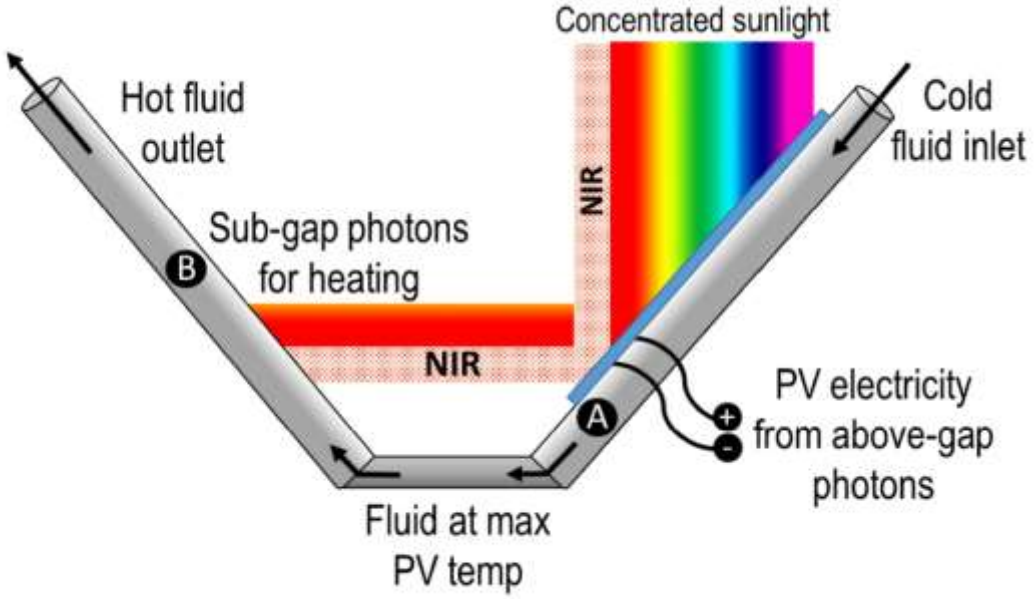
… or PV + CST!



Lesedi, Jasper and Redstone Power Projects. Source:

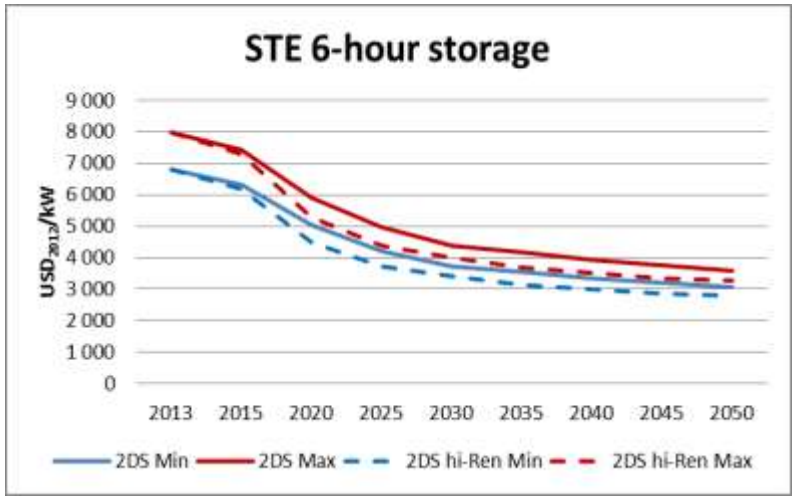
Today (almost)
(e.g. South Africa)

Tomorrow?
(e.g. ARPA-E's Focus programme, USA)

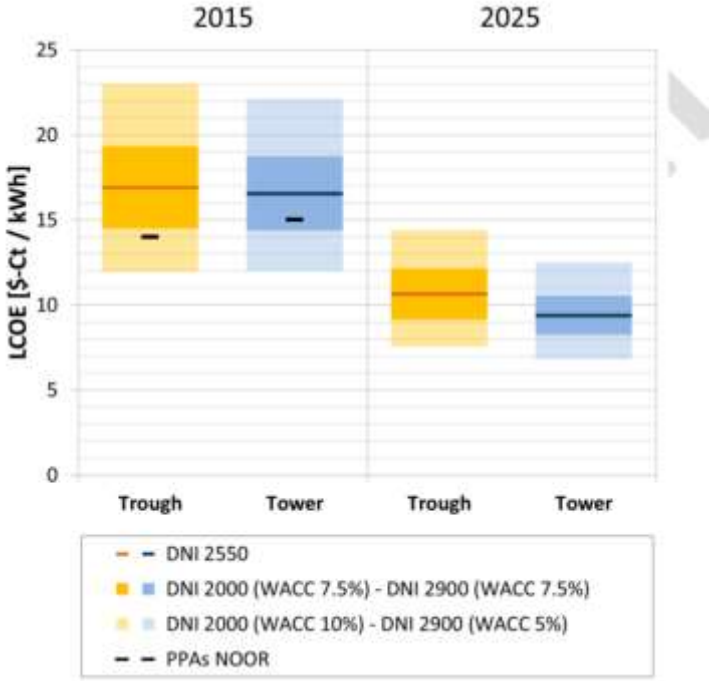


Costs matter…

CSP investment costs (IEA, 2014)



CSP LCOE (IRENA, forthcoming)



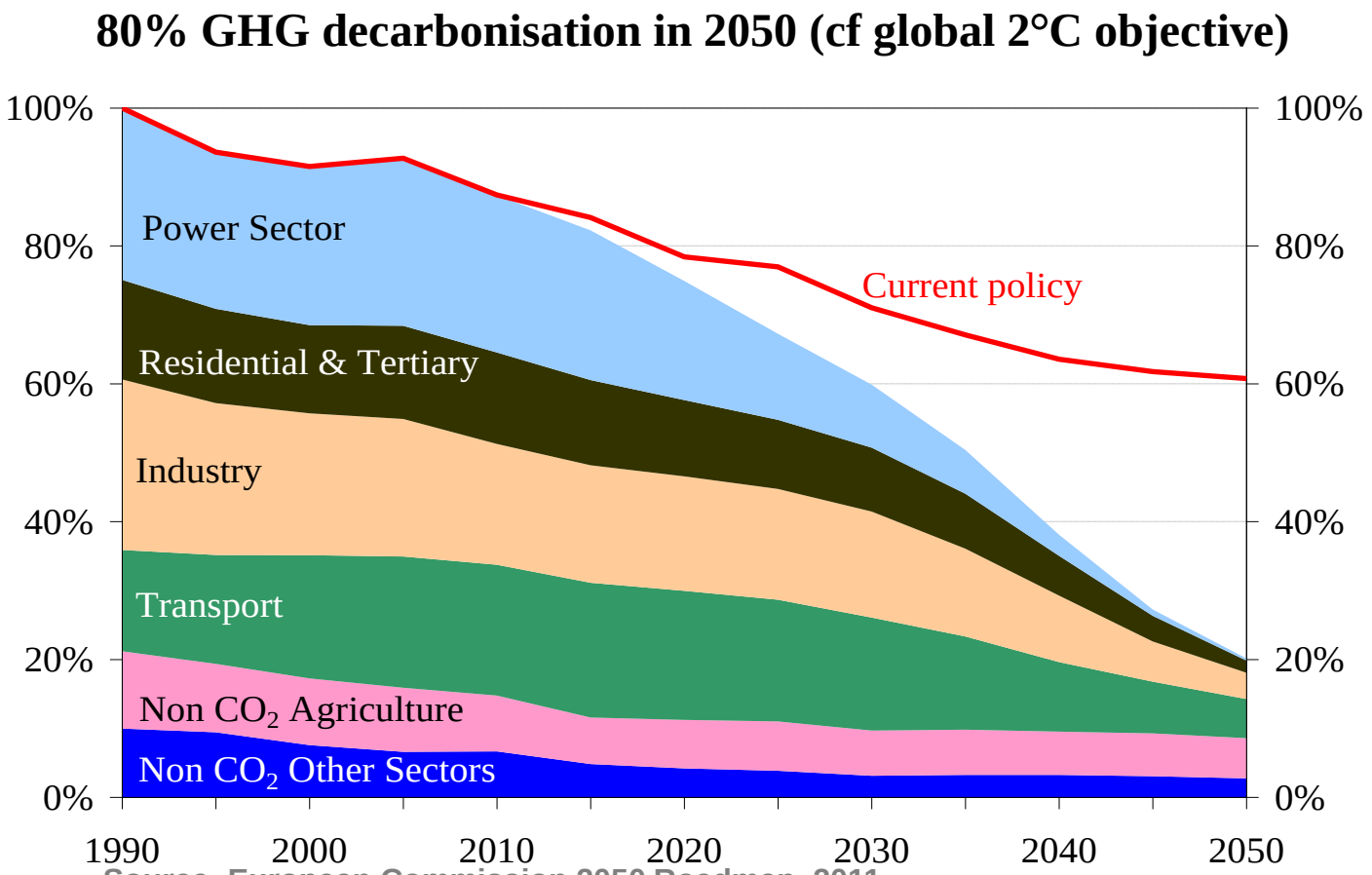
CSP LCOE (IEA, 2014)

USD/MWh		2015	2020	2025	2030	2035	2040	2045	2050
W/o storage	Min	158	126	105	93	88	83	80	76
	Max	263	209	175	156	147	139	133	127
W. 6-hour storage	Min	146	116	97	86	82	77	74	71
	Max	172	137	115	102	96	91	87	83

… value matters as much!

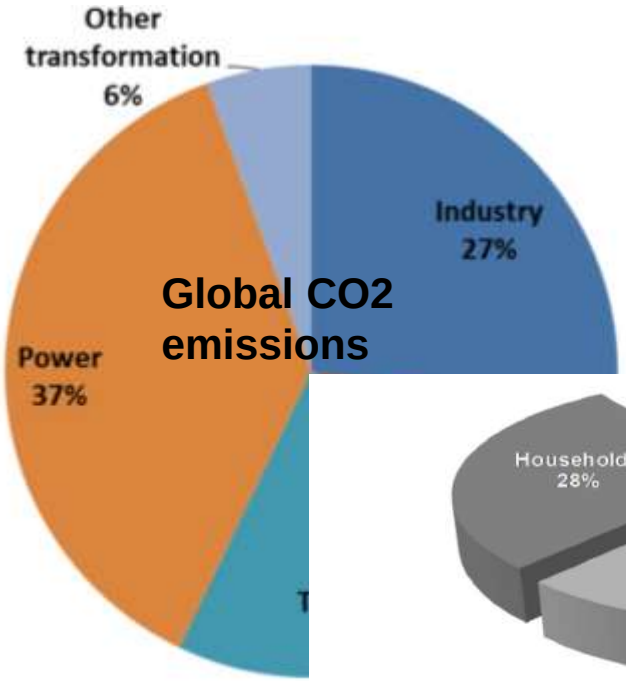
- Ten years ago, LCOE of CST power was half that of PV
- Now, the reverse holds true
- CST power will not beat PV on costs, but compares with PV + storage
- Time-of-delivery payments reflect the true value of storage
- CST Power was born in the 1980s in California thanks to time-of-delivery energy and capacity payments
- CST is being developed in South Africa thanks to a x2.7 multiplier of Base Price during 5 hours a day

2050 Low-Carbon Economy Roadmap

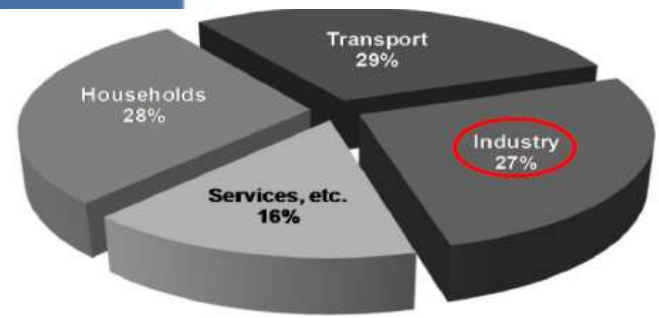


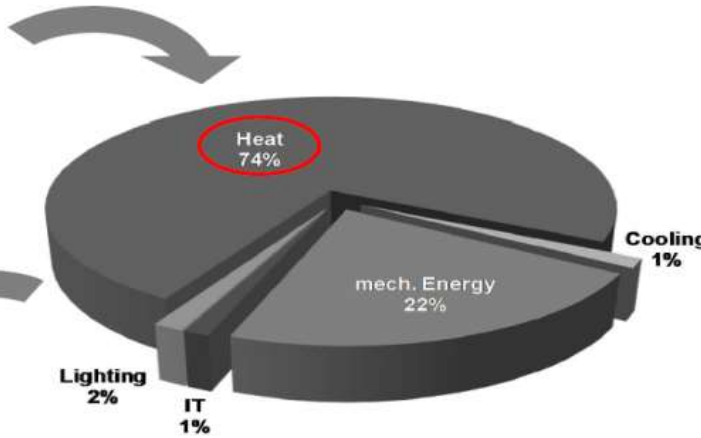
Source: European Commission 2050 Roadmap, 2011

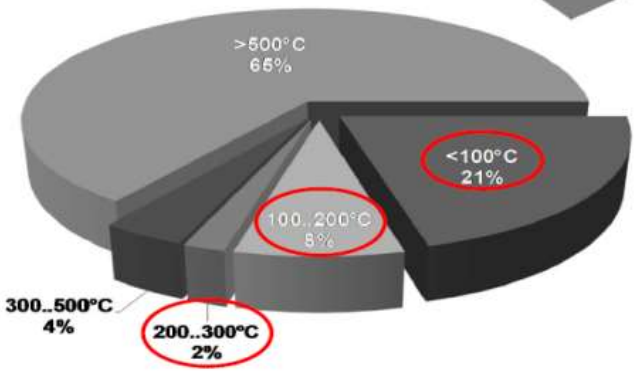
Industry next to power, mostly heat



Global CO2 emissions



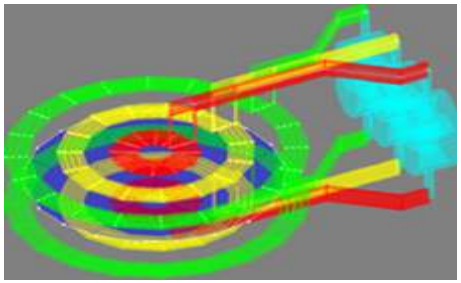




Germany (final energy consumption)

Electric heat technologies

- **Least efficient: resistances (Joule)**
  - Could play a transitory role in parallel with existing fossil fuel boilers
- **Industrial heat pumps**
  - Commercially available to 100°C output
  - Reaching 140°C output would double potential
- **Induction heating and smelting**
- **Microwaves (food, rubber, plastics)…**
- **Foucaut currents, electric ovens, electric arcs, plasma torches, etc…**

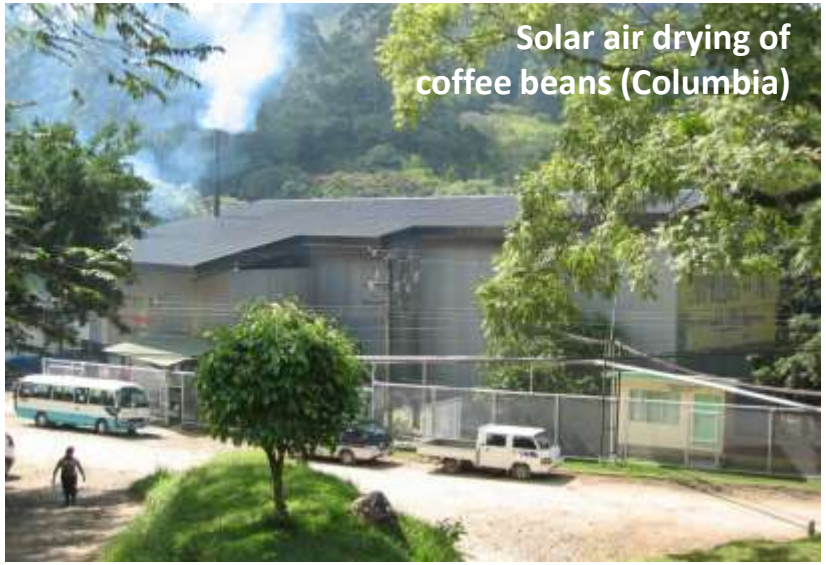


EDF CHANGER L'ÉNERGIE ENSEMBLE

Photo Credit : SAIREM

Solar heat for industries

Solar water heaters in a service area (Austria)
Source: AEE INTEC.



Solar air drying of coffee beans (Columbia)

Source: Deepak Gadhia
Cooking with Scheffler dishes (India)

Troughs for food industry

6 installations from „Inventive Power“ in Mexico:

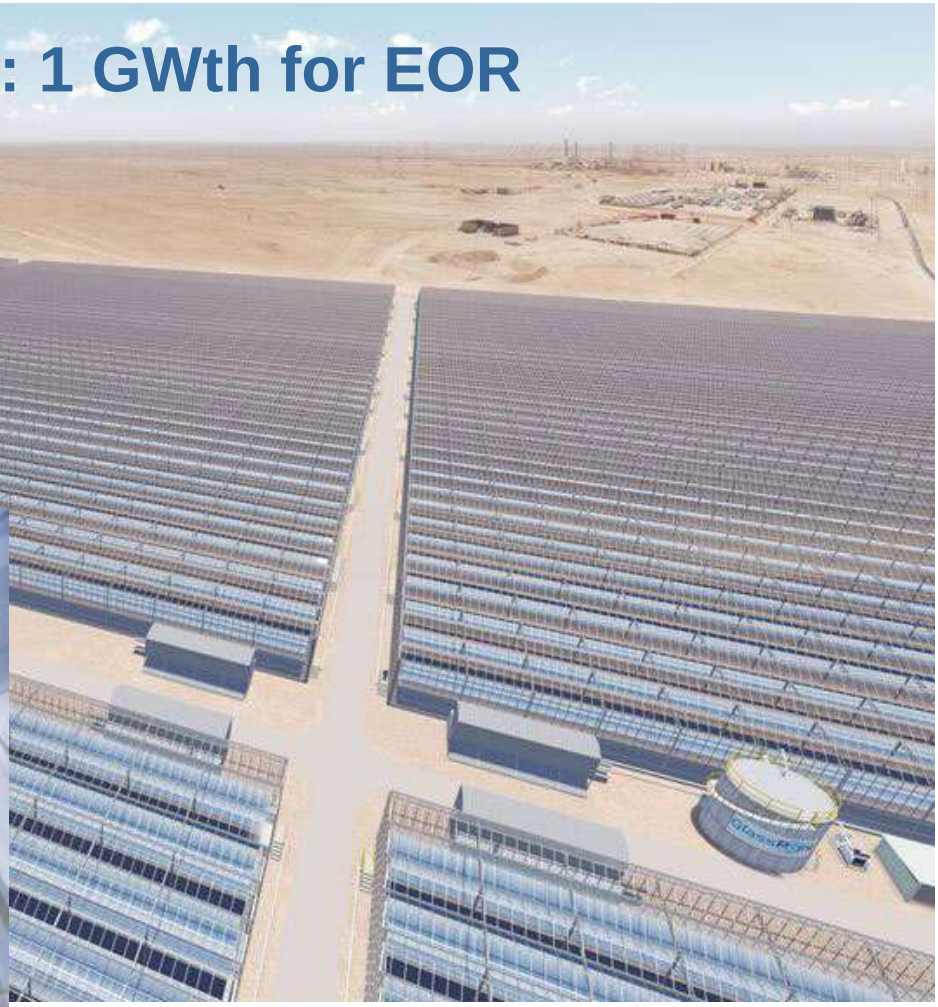
- Buenavista Greenhouse
- La Doñita Dairy
- Lácteos Covbars Dairy
- Nutrición Marina (Food Pellets)
- Matatlan Dairy
- El Indio Dairy

Solar ovens… in the Pyrenees

Source: Four Solaire Développement.

Oil men turn to solar to save gas

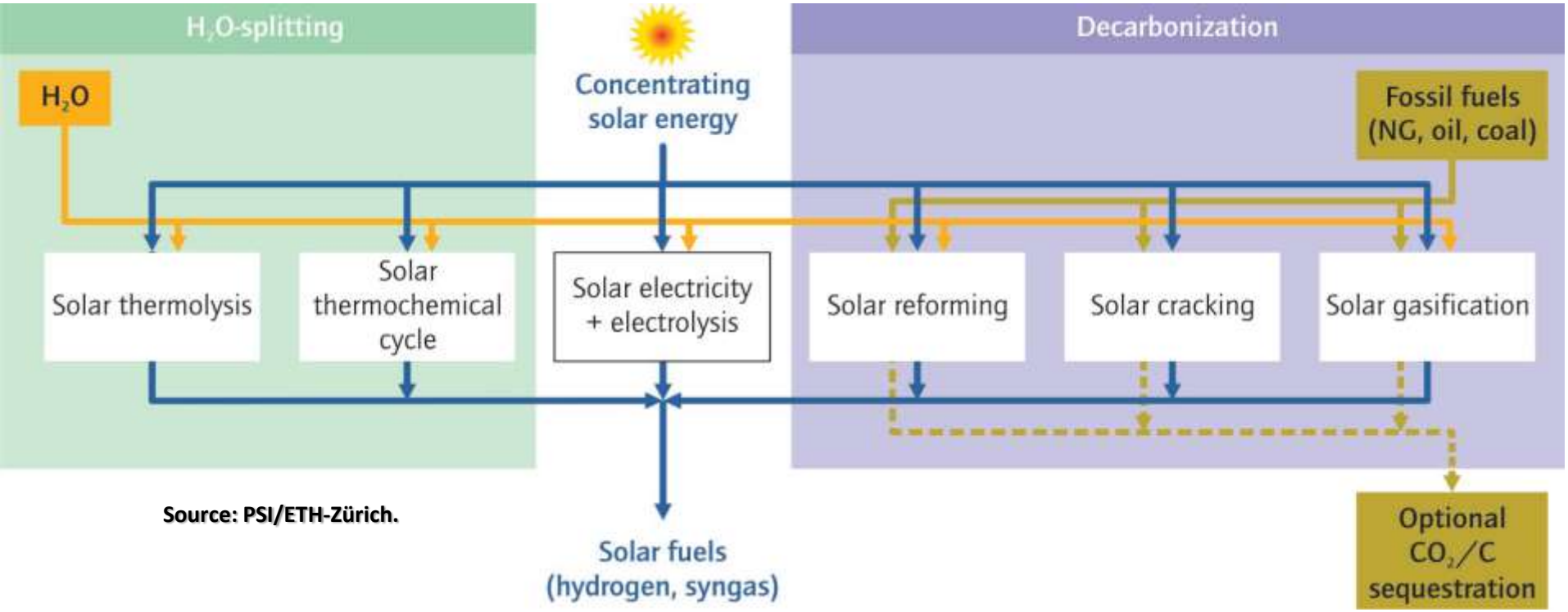
Mirrah, Oman, 2017: 1 GWth for EOR



***Glasspoint* technology**

Solar fuels

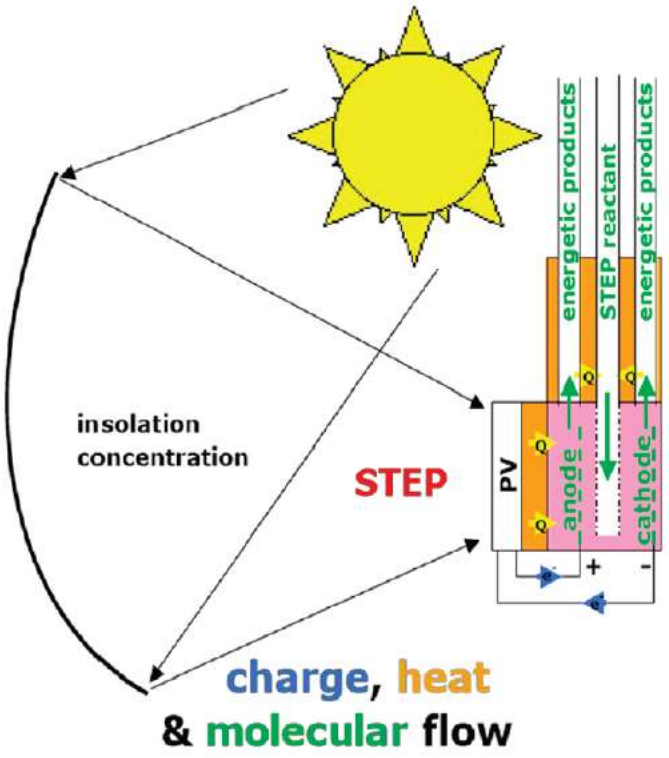
From hydrocarbon or water

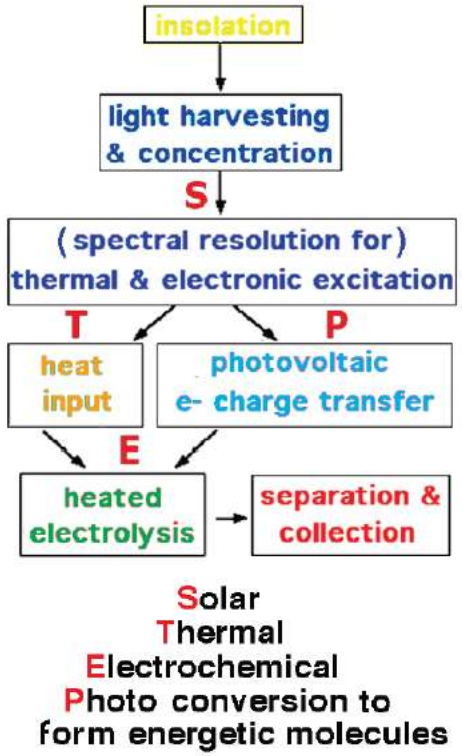


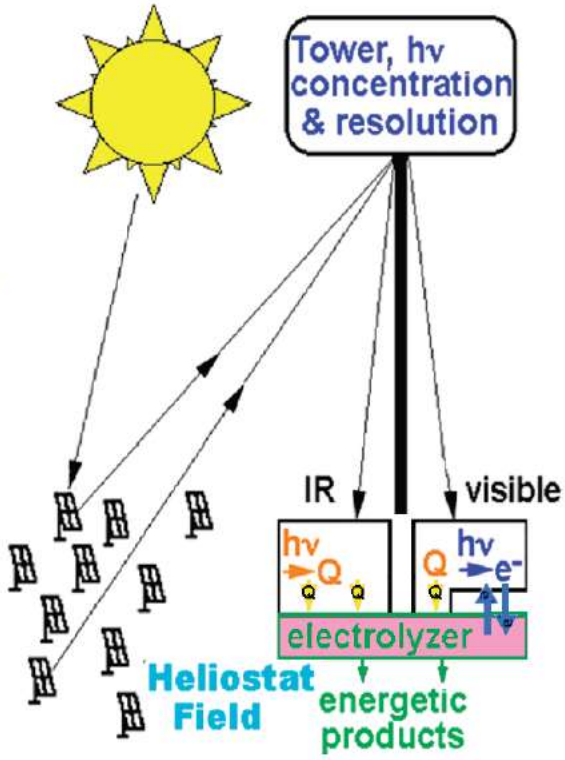
Source: PSI/ETH-Zürich.

- H_2 can first be blended with natural gas
- Can be converted into various energy carriers: methane, methanol, DME, ammonia…
- *Other options based on redox cycles, flow batteries…*

Others ways to combine PV and CST- for electrochemical processes

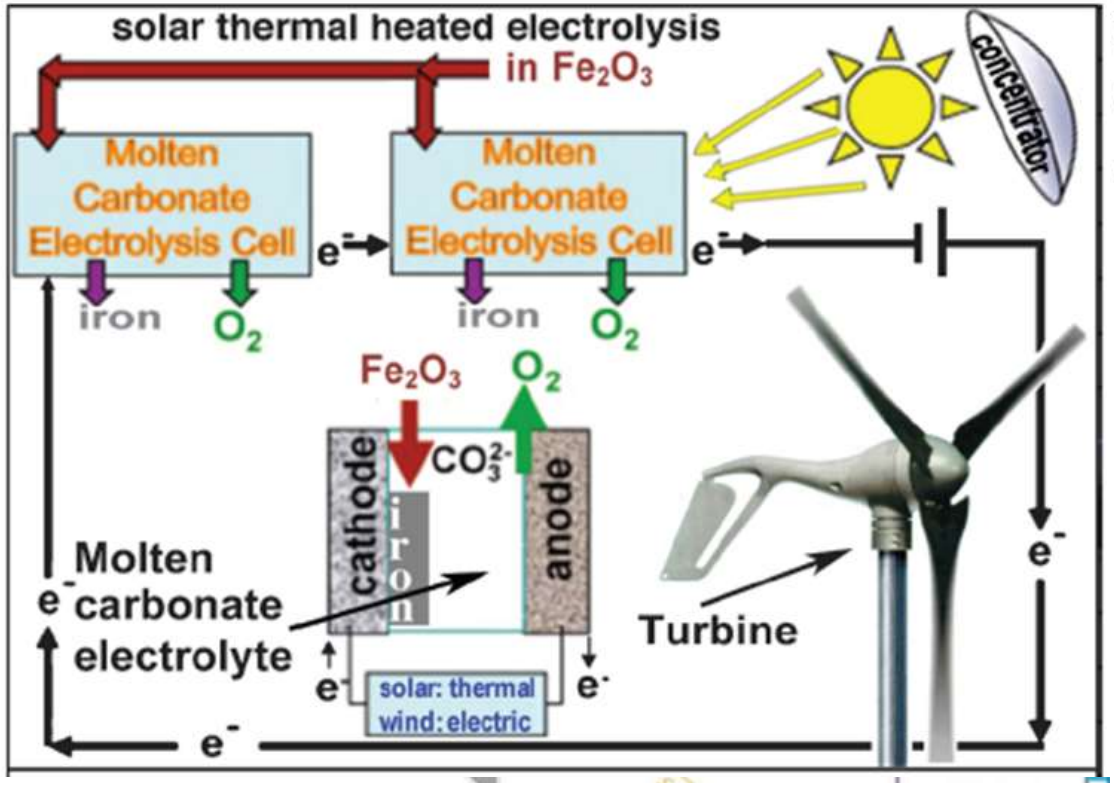




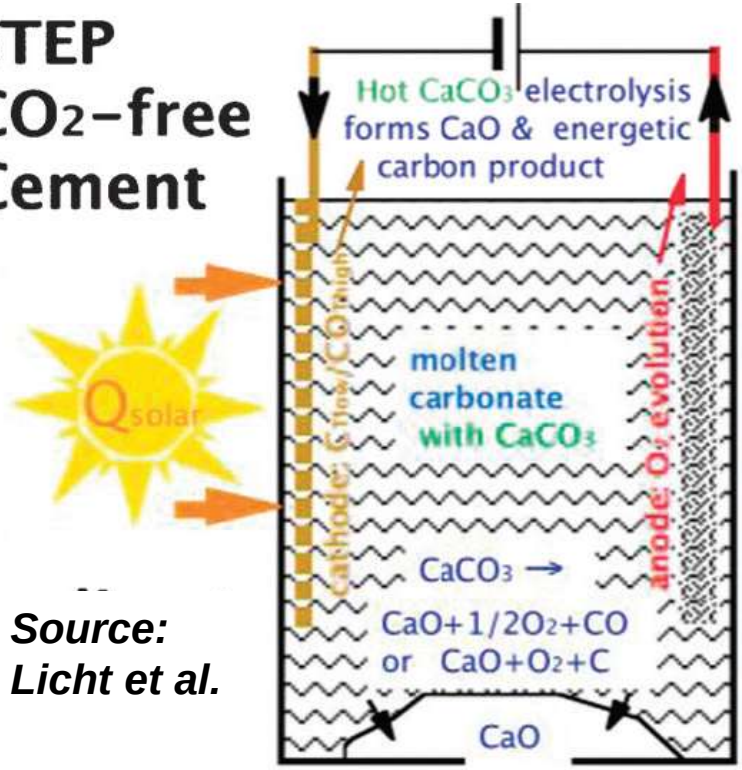


Electrolysis at high temperature requires significantly less power – combining CST heat and renewable power makes full sense

Various CST paths to carbon-free ammonia, steel, cement…



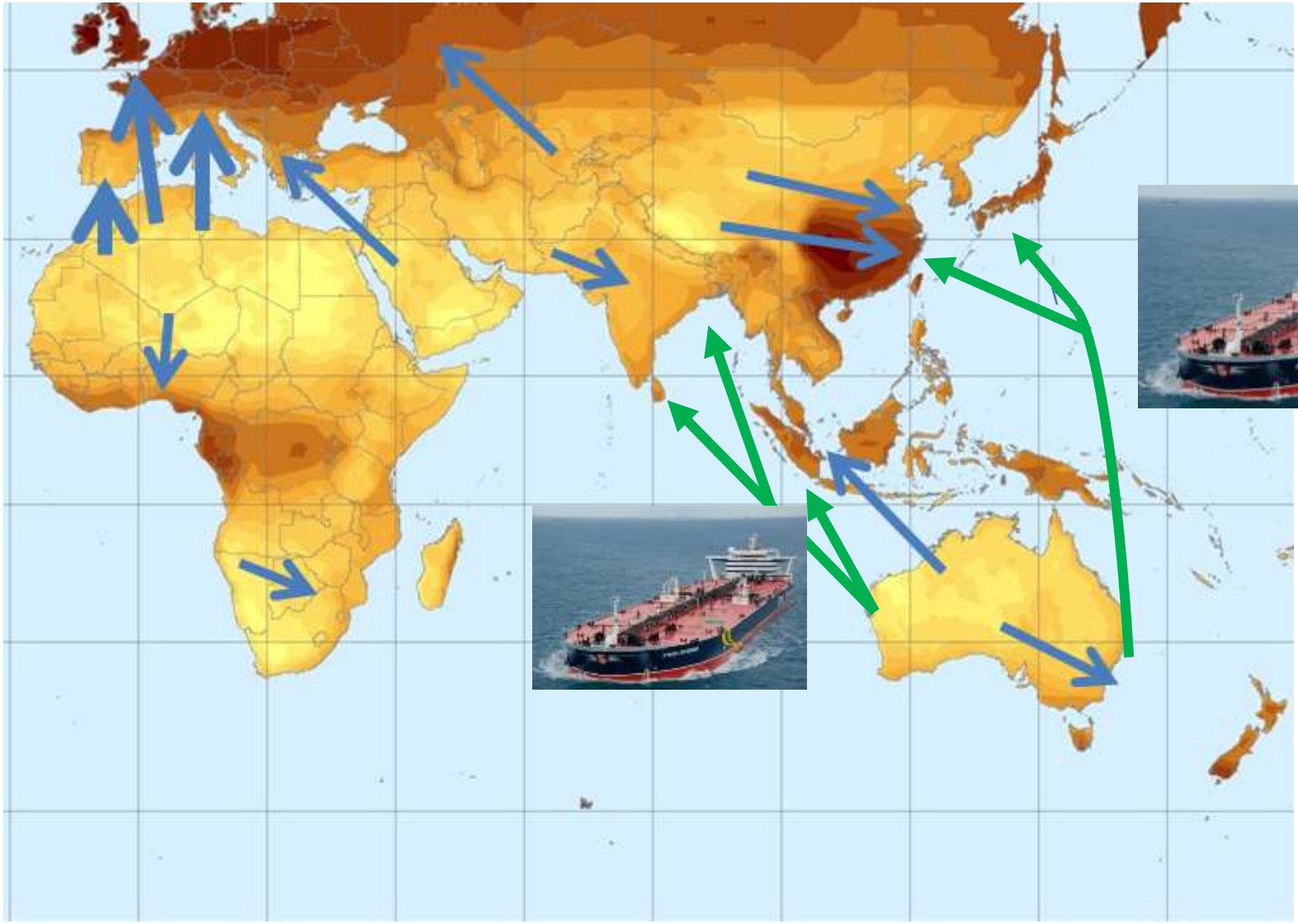
STEP CO_2-free Cement



Source: Licht et al.

- ***Including process CO2 emissions***
- ***Also to support CO2 capture from coal plants (ARENA), biomass plants or perhaps from air***

Interconnections reconsidered



In sum…

- CST is being challenged by PV but will have an important role to play in power systems thanks to built-in storage
- CST heat, alone or with RE power, can
  - substitute fossil fuel use in many industries, avoiding energy (and possibly process) CO2 emissions
  - manufacture CO2-free hydrogen and energy vectors
- CST will be needed to reach carbon-neutrality in second half of the century and stay below 2°C temperature change

And finally

- Australia needs CST
- The world needs CST
- CST needs Australia
- The world needs CST in Australia