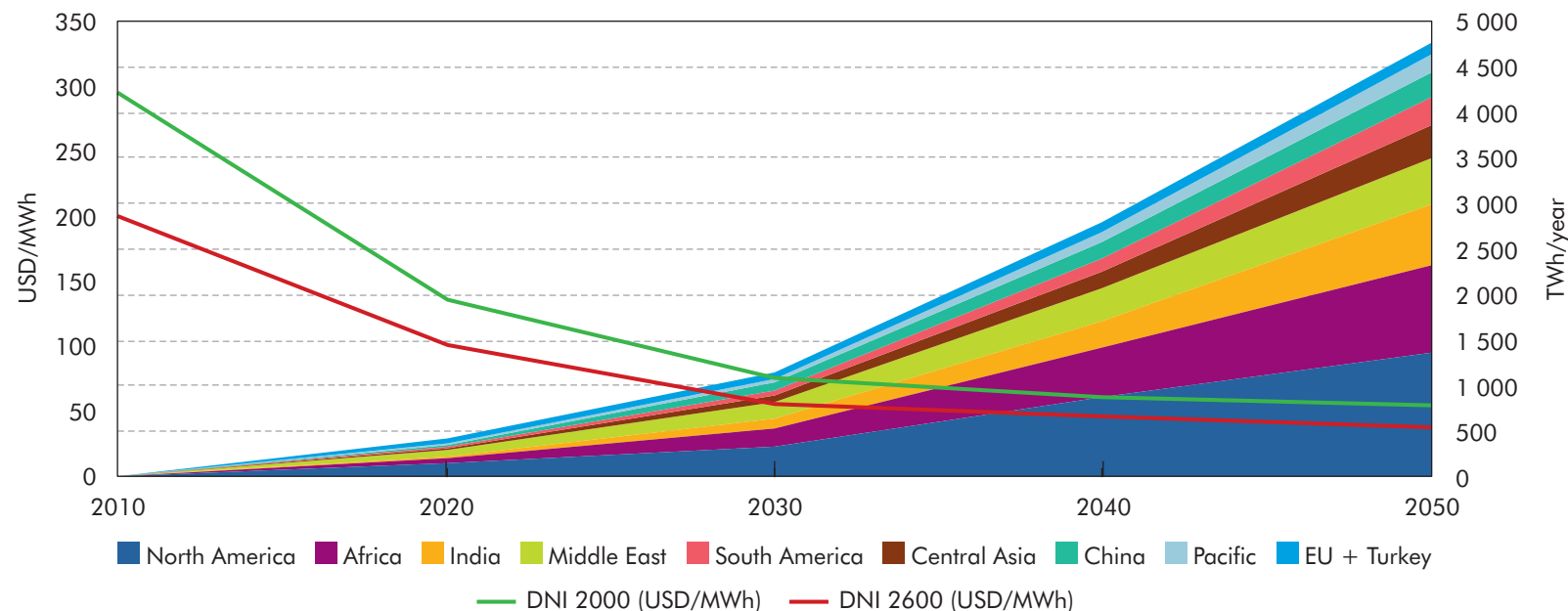


Decreasing cost and increasing production

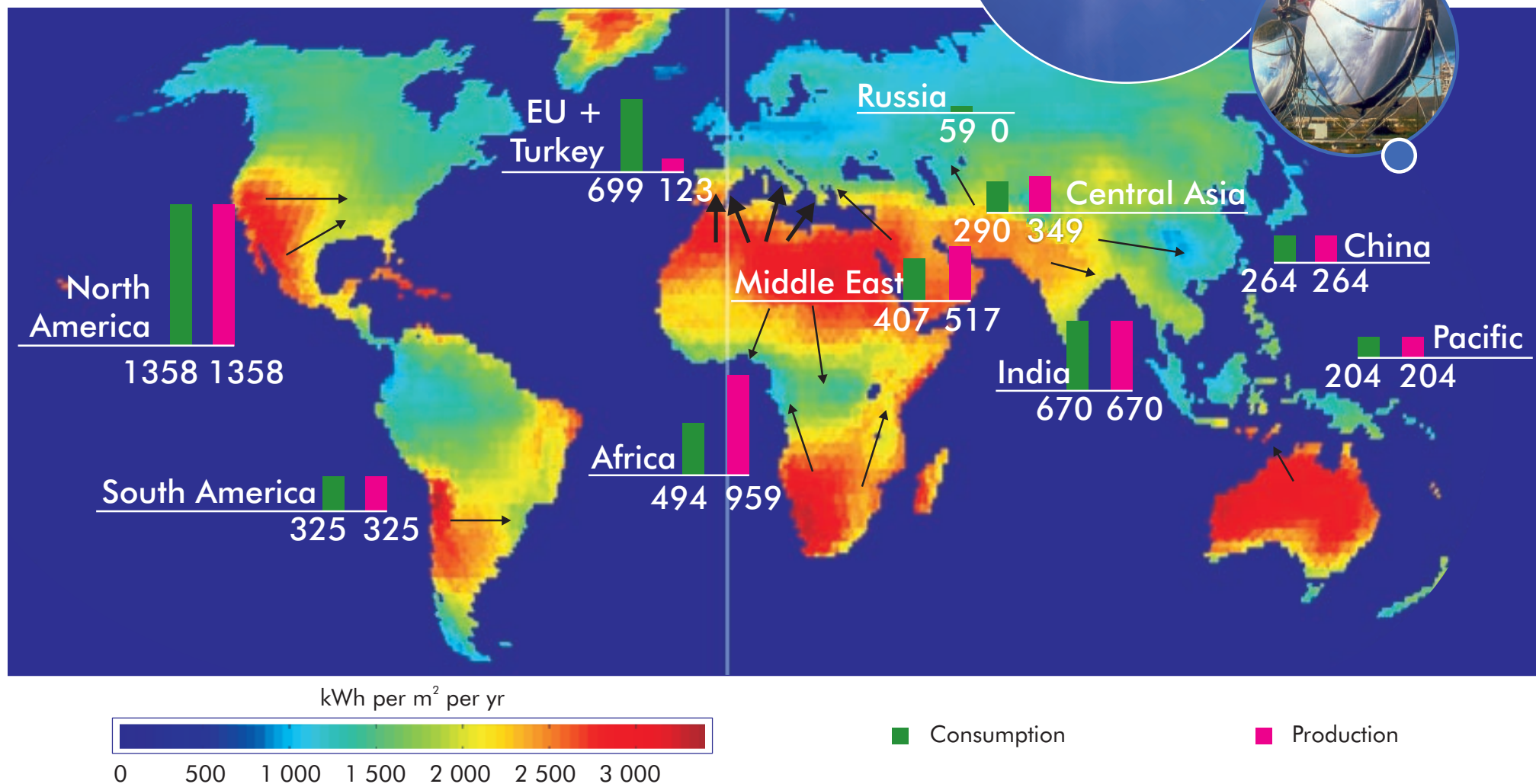


DNI = direct normal irradiance

Key findings

- ▶ By 2050, with appropriate support, CSP could provide 11.3% of global electricity, with 9.6% from solar power and 1.7% from backup fuels (fossil fuels or biomass).
- ▶ In the sunniest countries, CSP can be expected to become a competitive source of bulk power in peak and intermediate loads by 2020, and of base-load power by 2025 to 2030.
- ▶ The possibility of integrated thermal storage is an important feature of CSP plants, and virtually all of them have fuel-power backup capacity. Thus, CSP offers firm, flexible electrical production capacity to utilities and grid operators while also enabling effective management of a greater share of variable energy from other renewable sources (e.g. photovoltaic and wind power).
- ▶ This roadmap envisions North America as the largest producing and consuming region for CSP electricity, followed by Africa, India and the Middle East. Northern Africa has the potential to be a large exporter (mainly to Europe) as its high solar resource largely compensates for the additional cost of long transmission lines.
- ▶ CSP can also produce significant amounts of high-temperature heat for industrial processes, and in particular can help meet growing demand for water desalination in arid countries.
- ▶ Given the arid/semi-arid nature of environments that are well-suited for CSP, a key challenge is accessing the cooling water needed for CSP plants. Dry or hybrid dry/wet cooling can be used in areas with limited water resources.
- ▶ The main limitation to expansion of CSP plants is not the availability of areas suitable for power production, but the distance between these areas and many large consumption centres. This roadmap examines technologies that address this challenge through efficient, long-distance electricity transportation.
- ▶ CSP facilities could begin providing competitive solar-only or solar-enhanced gaseous or liquid fuels by 2030. By 2050, CSP could produce enough solar hydrogen to displace 3% of global natural gas consumption, and nearly 3% of the global consumption of liquid fuels.

Production and consumption of CSP electricity by 2050



Repartition of the direct normal irradiance (DNI) 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.

Key actions in the next ten years

Concerted action by all stakeholders is critical to realising the vision laid out in this roadmap.

Governments

- Ensure long-term funding for additional RDD&D in: all main CSP technologies; all component parts and all applications at all scales.
- Facilitate the development of ground and satellite measurement/modelling of global solar resources.
- Support CSP development through solar-specific incentives. These could include any combination of feed-in tariffs or premiums, binding renewable energy portfolio standards with solar targets, capacity payments and fiscal incentives.
- Where appropriate, require state-controlled utilities to bid for CSP capacities.
- Avoid establishing arbitrary limitations on plant size and hybridisation ratios (but develop procedures to reward only the electricity deriving from solar energy, not the portion produced by burning backup fuels).
- Streamline procedures for obtaining permits for CSP plants and access lines.

Industry

- Pursue cost reduction potential for all systems through:
 - New components
 - New transfer fluids
 - Higher working temperatures
 - Mass production
- Pursue cost reduction potential of heliostat fields with immediate control loop from receivers and power blocks to address transients
- Further develop heat storage, in particular three-step storage systems for direct steam generation solar plants, whether LFR, troughs, or towers
- Further develop central receiver concepts, notably superheated steam, molten salts and air receivers
- Work collaboratively with turbine manufacturers to develop new turbines

Utilities

- Provide certainty to investors with long-term power purchase agreements or bidding procedures
- Reward firm capacities of CSP plants
- Facilitate grid access for CSP developers
- Participate actively in project development

CSP Capacities, generation and consumption

| | Capacity (GW) | | | | | | | | | | World |
|------|---------------|-------------|---------------|--------------|-------|-------|---------|---------------|------------|--------|-------|
| | Africa | Middle East | North America | Central Asia | India | China | Pacific | South America | EU+ Turkey | Russia | |
| 2020 | 23 | 23 | 50 | 7 | 7 | 9 | 4 | 5 | 18 | 0 | 147 |
| 2030 | 62 | 50 | 94 | 20 | 33 | 26 | 10 | 19 | 23 | 0 | 337 |
| 2040 | 136 | 91 | 225 | 49 | 76 | 47 | 28 | 38 | 25 | 0 | 715 |
| 2050 | 219 | 118 | 310 | 80 | 152 | 60 | 47 | 74 | 28 | 0 | 1 089 |

| | Generation (TWh) | | | | | | | | | | World |
|------|------------------|-------------|---------------|--------------|-------|-------|---------|---------------|------------|--------|-------|
| | Africa | Middle East | North America | Central Asia | India | China | Pacific | South America | EU+ Turkey | Russia | |
| 2020 | 66 | 64 | 141 | 20 | 19 | 26 | 12 | 14 | 52 | 0 | 414 |
| 2030 | 211 | 170 | 319 | 67 | 113 | 88 | 34 | 66 | 79 | 0 | 1 147 |
| 2040 | 531 | 356 | 876 | 190 | 294 | 185 | 109 | 149 | 98 | 0 | 2 788 |
| 2050 | 959 | 517 | 1 358 | 349 | 670 | 264 | 204 | 325 | 123 | 0 | 4 770 |

| | Consumption from CSP (TWh) | | | | | | | | | | World |
|------|----------------------------|-------------|---------------|--------------|-------|-------|---------|---------------|------------|--------|-------|
| | Africa | Middle East | North America | Central Asia | India | China | Pacific | South America | EU+ Turkey | Russia | |
| 2020 | 34 | 49 | 141 | 16 | 19 | 26 | 12 | 14 | 98 | 4 | 413 |
| 2030 | 111 | 136 | 319 | 52 | 113 | 88 | 34 | 66 | 212 | 15 | 1 146 |
| 2040 | 293 | 293 | 876 | 155 | 294 | 185 | 109 | 148 | 400 | 35 | 2 788 |
| 2050 | 494 | 407 | 1 358 | 290 | 670 | 264 | 204 | 325 | 699 | 59 | 4 770 |

Analysis for this roadmap is consistent with the IEA *Energy Technology Perspectives 2010* BLUE Map Hi REN scenario, which describes how annual CO₂ emissions can be reduced by 50% from 2005 level, with renewable energy sources providing up to 75% of the global electricity production.

Concentrating solar power roadmap milestones

2010

2020

2030

2040

2050

GW capacity 148
Av. capacity factor 32%

GW capacity 337
Av. capacity factor 39%

GW capacity 715
Av. capacity factor 45%

GW capacity 1 089
Av. capacity factor 50%

Governments

Establish incentives for CSP electricity and heat; lift restrictions on plant size and hybridisation ratios

Adjust incentives to evolving market conditions

Eliminate incentives for power in many regions

Support mapping global solar resource from on-ground and satellite measures

Establish incentives for solar fuels

Facilitate grid access for CSP projects

Increase support to research, development and demonstration, establish incentives for innovation

Utilities and grid operators

Negotiate tariffs for exports/imports of CSP electricity

Build HVDC lines throughout China, India and the United States

Build HVDC lines between exporting and importing countries

Sign power purchase agreements with independent CSP producers

Take advantage of CSP flexibility to manage more variable renewable electricity

Participate in CSP project development

Reward storage and back-up capacities of CSP plants

Technology and RD&D

1st tower plants with DSG; 1st tower plants with molten salts

DSG in trough plants

All new plants dry-cooled; working temperature 540°C; larger storage capacities

Biogas and solar fuels substitute natural gas as back-up fuel in power plants

1st large-scale LFR

Three-step thermal storage for DSG

Desalination by co-generation in CSP plants

Hydrogen from solar towers /large dishes introduced in natural gas grids

1st plant with 100s dishes

Storage and back-up for large dishes

1st tower plants with air receivers and gas turbines

Production of solar-only hydrogen to manufacture liquid fuels

1st supercritical CSP plants

Solar production of other energy carriers (e.g. metals) for transportation sector

DSG: Direct Steam Generation.
LFR: Linear Fresnel Reflectors.
HVDC: High-voltage direct current.