Solar energy: A sustainable source for a 24 h electricity supply

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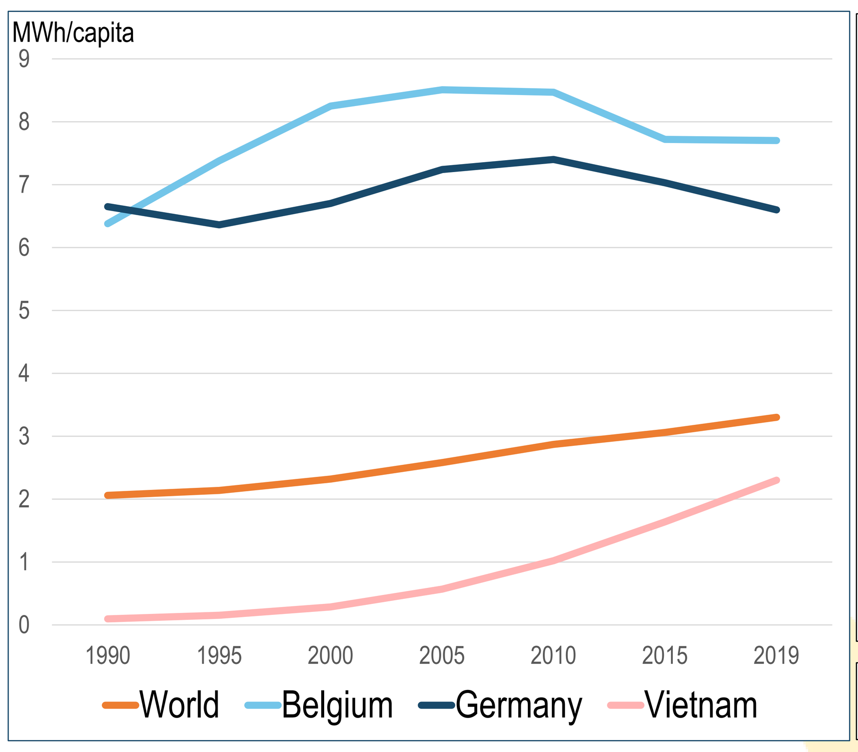
International WritingLab

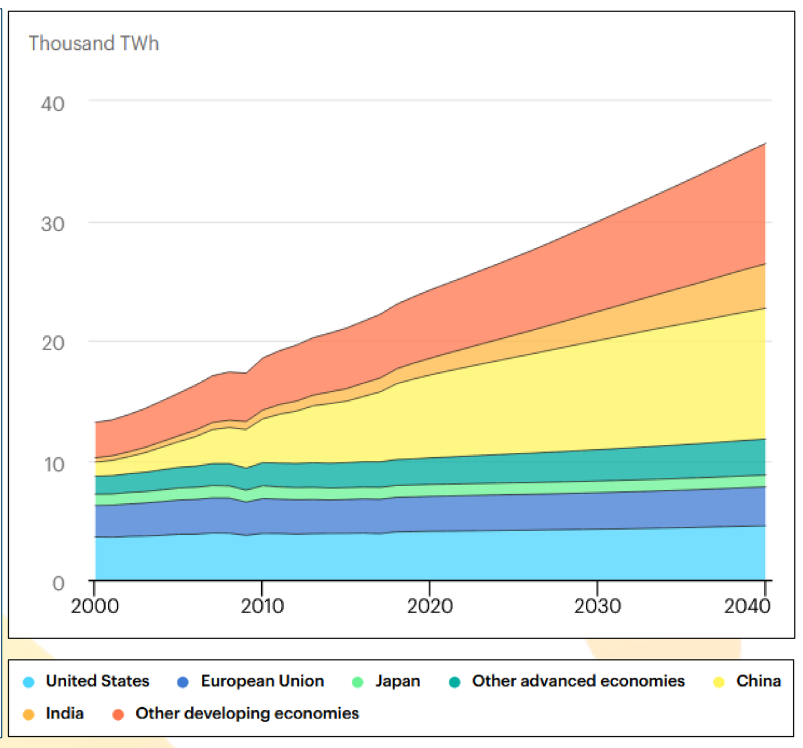
ENLIGHT

Motivation: Increasing demand of electricity

Electricity consumption in MWh per capita, 1990-2019 [12]

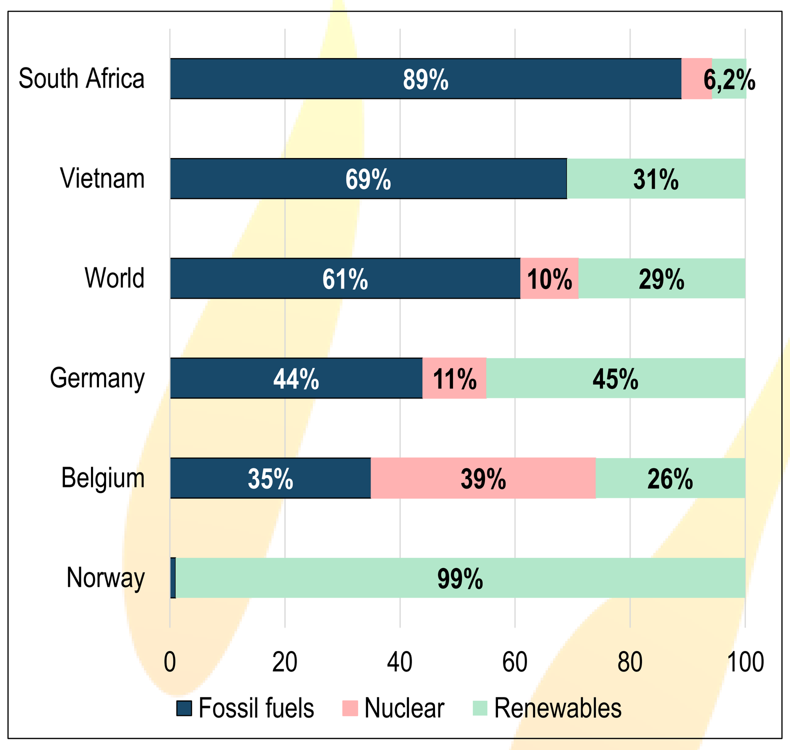


Global electricity demand by region in the Stated Policies Scenario, 2000-2040 [13]

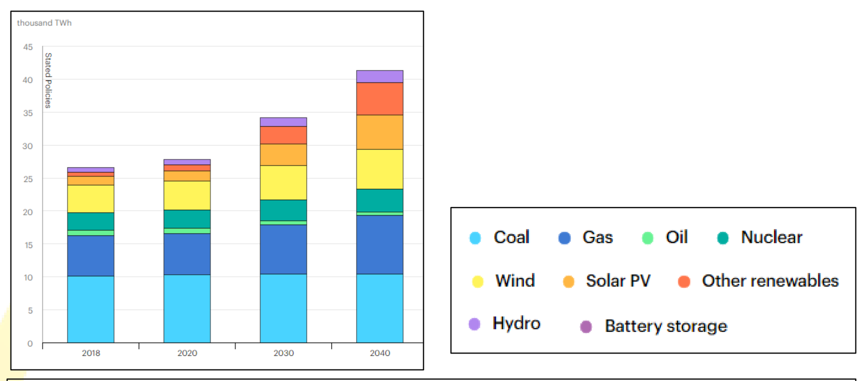


Solar light as a competitive and sustainable energy source

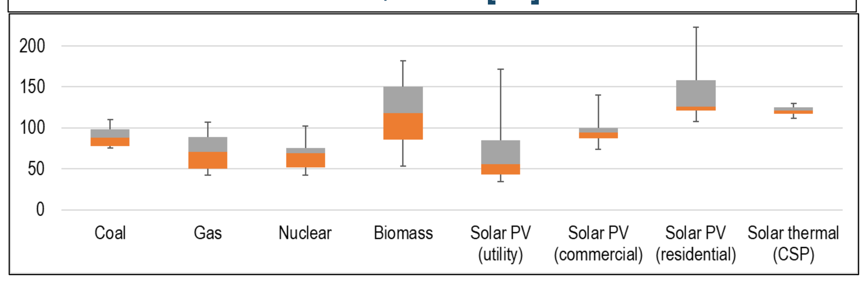
Electricity consumption from fossil fuels, nuclear and renewables, 2020 [14]



Electricity generation by fuel, Stated Policies Scenario, 2018-2040 [13]



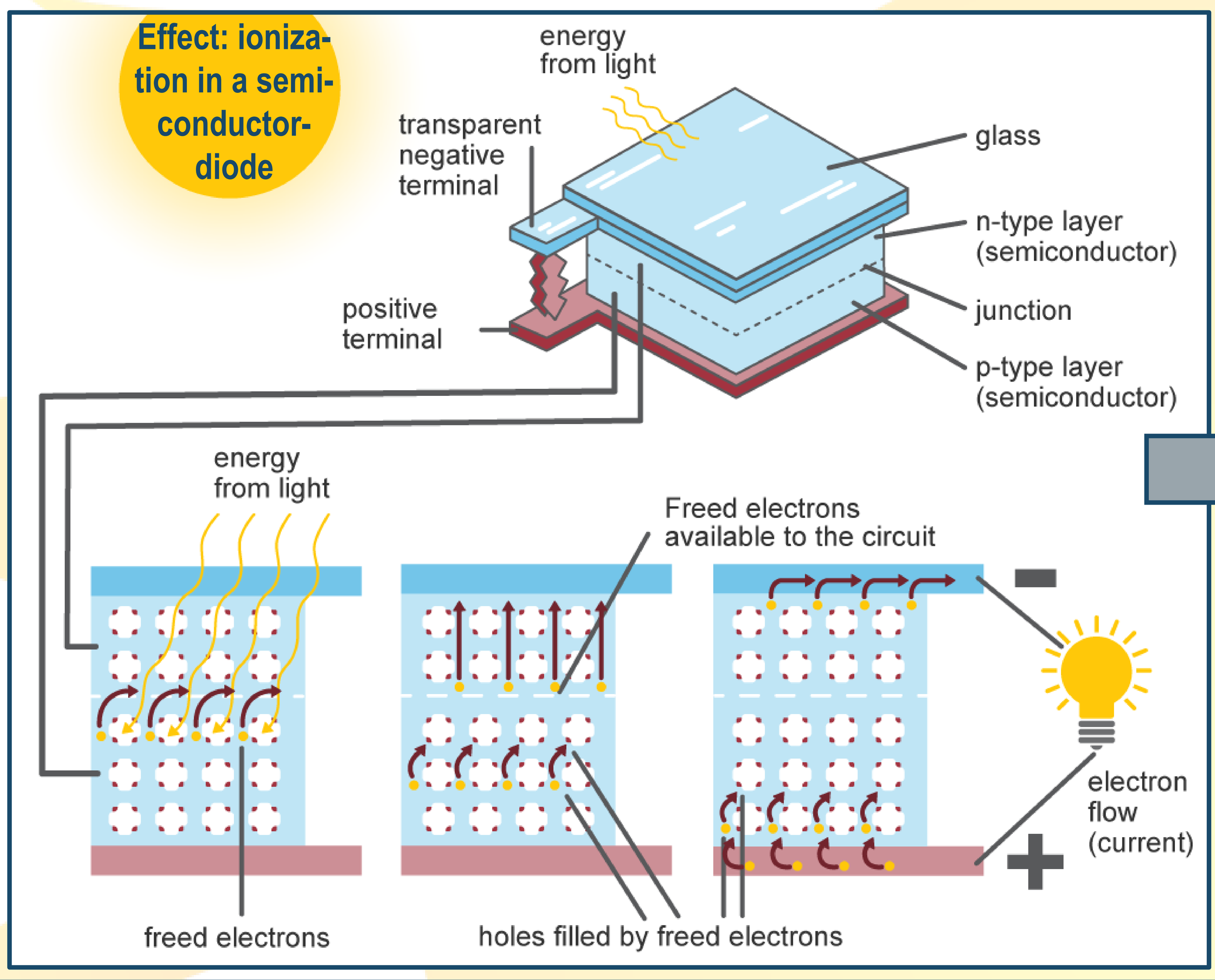
LCOE (= levelized cost of electricity) by technology in US-$/MWh [15]



Integration of two solar energy technologies to provide a 24h electricity supply

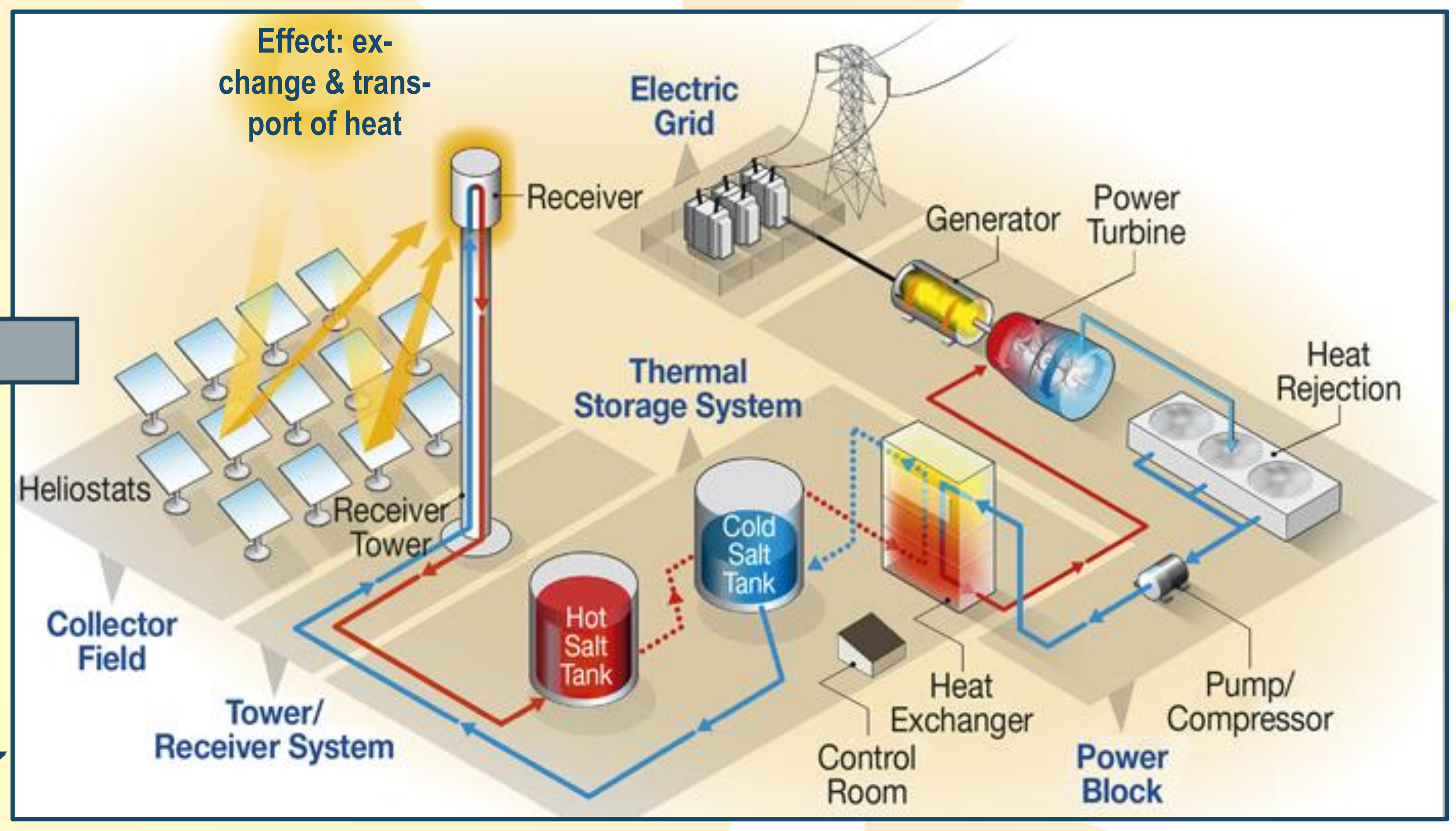
Photovoltaics (PV) for daytime supply [10, 2]

A Energy from solar light looses electrons within a semiconductor material. Freed electrons and holes occur.
B The electric field produced by n- and p-doped semiconductor layers attract electons and holes.
C An outflow of the charges secures a stable current flow.
D After transformation in alternating current, the electricity can be utilized for immediate purposes.



Concentrated solar thermal power (CSP) for nighttime supply [11]

A Daytime: Mirrors concentrate solar light on a receiver heating up a transfer fluid. The heated fluid is storaged.
B Nighttime: In a heat exchanger, the heat evaporates water. The steam drives a turbine generating electricity.



Increasing efficiency and supply security by combining specific advantages of PV and CSP [1, 2, 8]

PV	Integration of PV & CSP	CSP
Low LCOE (see above)	Optimized cost-benefit ratio	High LCOE (see above)
Produces power at day [2]	Produces power over the whole day	Produces power on demand [2]
Difficult storage of power with batteries (duration of 1min to 10 h, cycling <10,000, efficiency 60-98%) [9]	Storage (mainly) in the easier to handle form (heat instead of power)	Easier storage of heat with molten salt (duration of many hours, cycling of 30 years, 80-90% efficiency) [9]
Provides electricity only	Provides electricity & heat	Provides electricity & heat
Easy scalable (for single households or bigger power plants) [3]	Integration in one power plant or two systems (PV local & CSP centralized)	Only as power plants realizable, but scalable (storage & field size) [1, 3]
Provides DC current (transformation necessary leading to poor quality issues, e. g. harmonics) [2]	Transformation still necessary as systems are independent	Provides AC current (no transformation necessary) [2]
No direct sunlight necessary for harvesting energy	To a certain extent independent from direct sunlight	Direct sunlight necessary for harvesting energy

Integration of PV and CSP near Postmasburg, South Africa [5, 6]

On the left: **PV** (Lesedi Solar Project): 75 MW (~65,000 households), in operation since 05/2014;
On the right: **CSP** (REDSTONE) under construction by the Arabian Company for Water and Power Development (ACWA POWER) with costs of 789 Mn US-$: 100 MW (>200,000 households, commercial operation from Q4 2023)

Further CSP projects [7]: Andasol in Guadix, Spain (150 MW), Noor in Ouarzazate, Morocco (510 MW), or Ivanpah Solar Power Facility in San Bernardino, California (392 MW) [*compare: coal-fired power stations in Germany: 100-4400 MW*]

Discussion of challenges and possible solutions

Challenges

- Variability of insolation [2]
- Disposal or recycling of worn-out panels [2]
- Toxic materials (e.g. plumb in PV modules) and possible damages [2]
- Land-consumption for solar power equipment (difficult to share land with other purposes) [2, 3]
- Demand for better power storage options for PV modules [9]

Solutions

- Use tracking systems to orientate the systems (PV modules, mirrors, …) to the sun (increasing efficiency) [1]
- Install solar power plants in different locations to minimize local cloud cover's impact on generation variability [2]
- Store excess energy for later use (CSP) [2]
- Shift customers' demand (Energy consumption when the insolation is high) --> precise forecasting Tools necessary [2]
- Build waste factories to recycle or dismantle toxic materials and worn-out panels in remote areas
- Make more use of deserts and wasted lands [2, 3]
- More investments on research & technological developments [3]

Maintenance and water consumption (clean mirrors & PV modules and cool down the steam)

Conclusion and outlook

Conclusion

2 main technologies to generate electricity from sunshine: PV and CSP [3]

PV technology: less expensive, unique in its extreme scalability (domestic & industrial power systems and power plants) [3]

CSP: "improve power system flexibility and stability, increase the solar share and integrate more variable renewable energy" [3, no page]

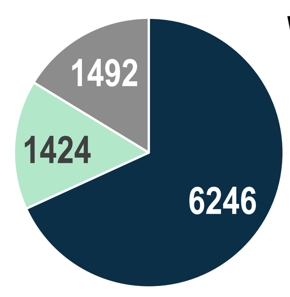
Solar technologies using radiative energy of sunshine to: "provide electricity, heat and cold; produce and export hydrogen-rich chemicals and fuels" [3, no page]

Outlook

Uses of solar energy beyond electricity supply: **domestic hot water**, space heating, district heating, process heat [3])

23 countries with 106 CSP projects including operational: 65; currently non-operational: 9; under construction: 14; under development: 18 [7]

Worldwide CSP power in MW in September 2021 [7]



Governments should have more investments on developing solar power systems and build more plants to ensure the successive deployment [3]

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