DIW ECON

the consulting company of DIW Berlin

The Economic Potential of Thin Film Solar Photovoltaic Technologies in Germany

A DIW Econ study commissioned by

PVTHIN

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The Economic Potential of Thin Film Solar Photovoltaic Technologies in Germany

Overview

1. Introduction: PV and the “Energiewende”
2. Key technology parameters and characteristics of thin film PV
3. Thin film PV value chain in Germany
4. Policy scenarios and implications for PV deployment
5. The future economic potential of PV in Germany

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PV and the German "Energiewende"

Renewable energies are a core element of a transformed energy system with solar PV as one of the most relevant future energy sources

The switch from fossil and nuclear fuels to renewable energies is a core element of the "Energiewende". One essential goal is to increase the share of renewables in electricity generation to 65 percent by 2030.[1]

This transformation of the energy system will require multiple gigawatts of renewable energy capacity additions over the next decades.

Electricity generation from solar photovoltaic (PV) systems plays an important role for the "Energiewende", as solar PV is expected to be one of the least-cost and most relevant sources of energy by 2050.[2] [15]

Core elements of the "Energiewende"

Supply: A switch of generation technologies from fossil fuels to renewables	**Demand**: enhanced efficiency and more flexible consumption behaviour	**Transmission:** The development and deployment of smart grids and large-scale storage capacities

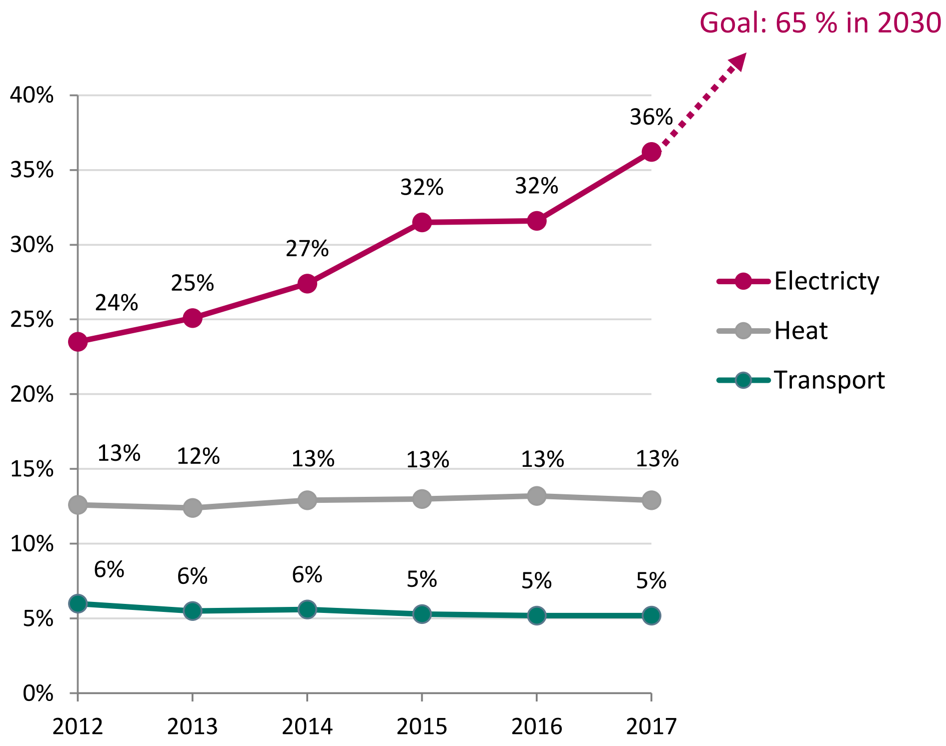
Goals of the "Energiewende"

Reduction of ecological and health strains associated with fossil fuel combustion and nuclear power	**Avoidance of risks** of nuclear power	Provision of **a long-term security of energy supply** at acceptable costs

PV and the German “Energiewende”

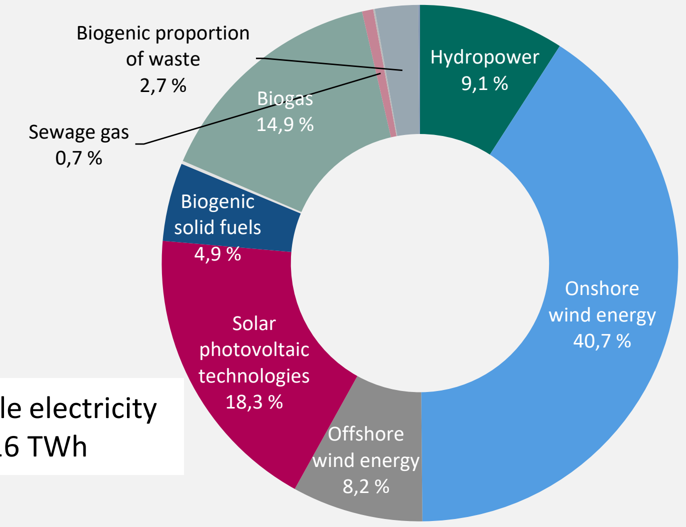
PV makes an important contribution to the growing share of renewables in electricity generation

Share of renewable energies in electricity, heat and transport (2012-2017)[3]



In 2017, electricity generation from solar (PV) technologies amounted to 39.4 TWh (18 percent of all renewable power generation and 7 percent of all power generation).

Greenhouse gas emissions avoided through PV amounted to 24.2 million tons CO2 eq. in 2017.[7]



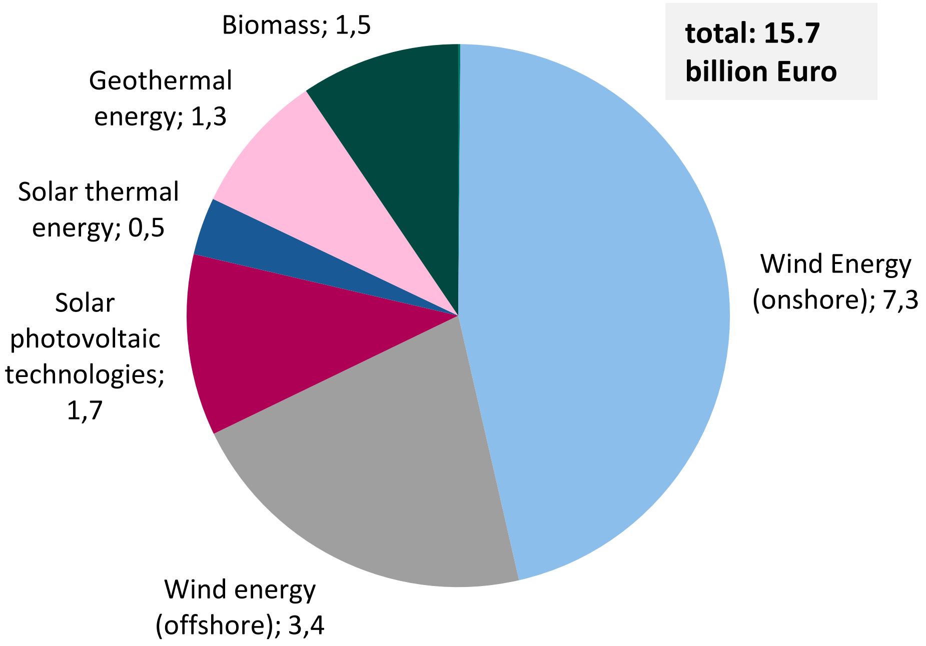
Total renewable electricity generation: 216 TWh

Renewables-based electricity generation in 2017 [3]

PV and the German “Energiewende”

The transformation of the energy system requires large-scale investments into renewable energies

2017 investment in renewables (billion Euro)[4]



1.7 GWp of new PV capacity were added in 2017.[5]

This addition required investments of 1.7 billion Euro.[4]

In 2017, cumulative PV capacity amounted to 42.3 GWp.[5] Thin film PV contributed an estimated 4.3 GWp (10 percent) to this.[6]

In 2018, added PV capacity increased compared with 2017. Until end of November 2018, 2.4 GWp of new PV capacity were installed.[5]

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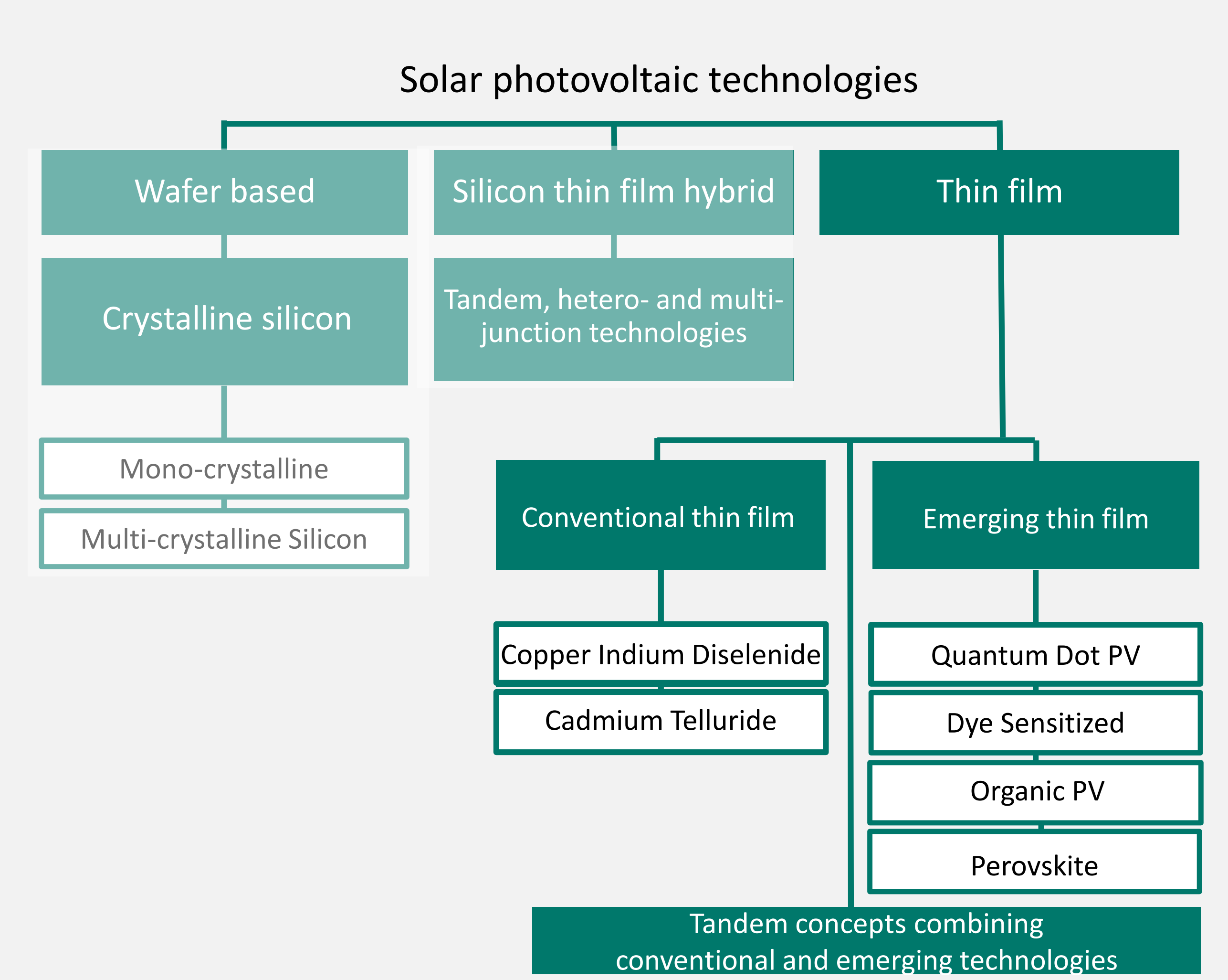
Thin Film PV technologies

What is thin film PV technology?

PV is the conversion of light into electricity using semiconducting materials.

Thin film solar cells are made by depositing one or more thin layers of photovoltaic material on a substrate, such as glass, plastic or metal.

PV encompasses many technologies which are evolving rapidly as the global PV industry is growing. Competition has spurred a steep learning and cost reduction curve, which is continuing as PV increasingly becomes the cheapest electricity generation technology globally. [2]



Thin Film PV technologies

Properties of thin film PV technologies: Overview

(1) Competitiveness

- Economies of scale and technological improvements led to a steep decrease in module prices.[8]
- Performance of thin film PV technologies is competitive with other PV and electricity generation technologies.[9]

(2) Environmental footprint

- Energy and material efficient manufacturing enables lowest resource use and emission profiles for thin film PV technologies.[10]
- Due to the low material input used, thin film panels have a small environmental footprint.

(3) Innovative potential

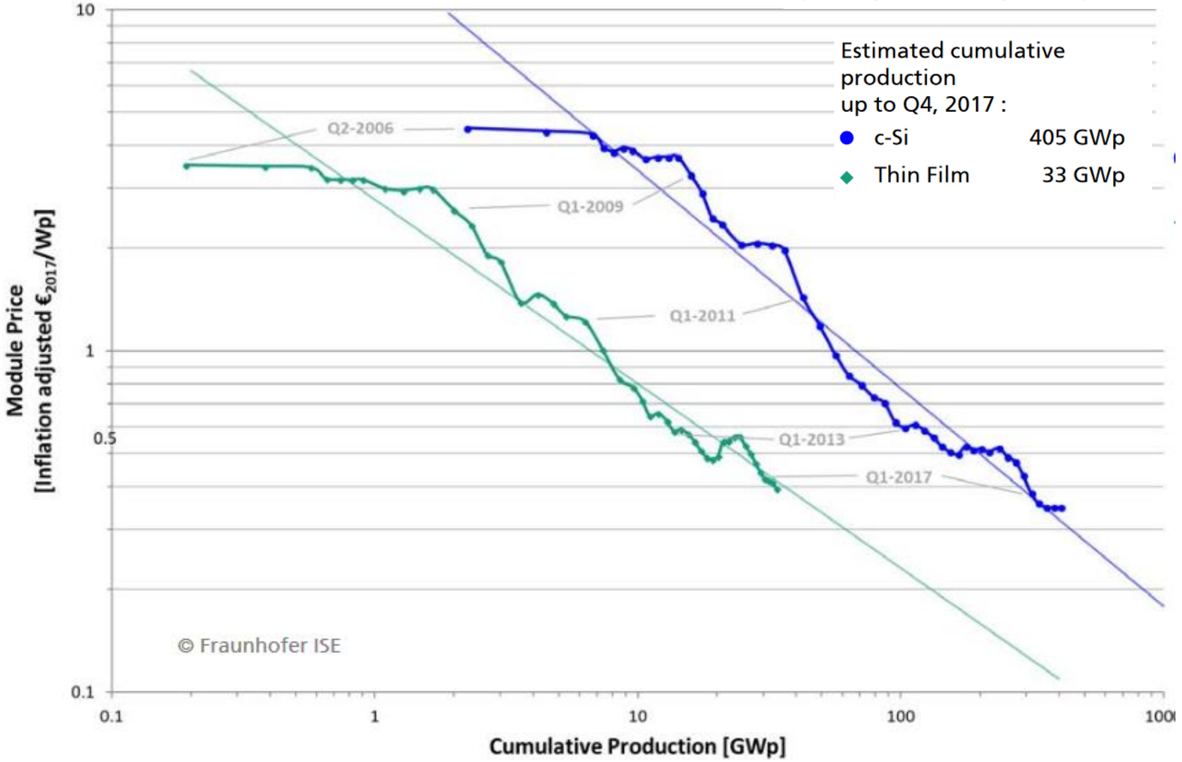
- Emerging thin film technologies have a great potential for further technological improvement and cost reduction.

Thin Film PV technologies

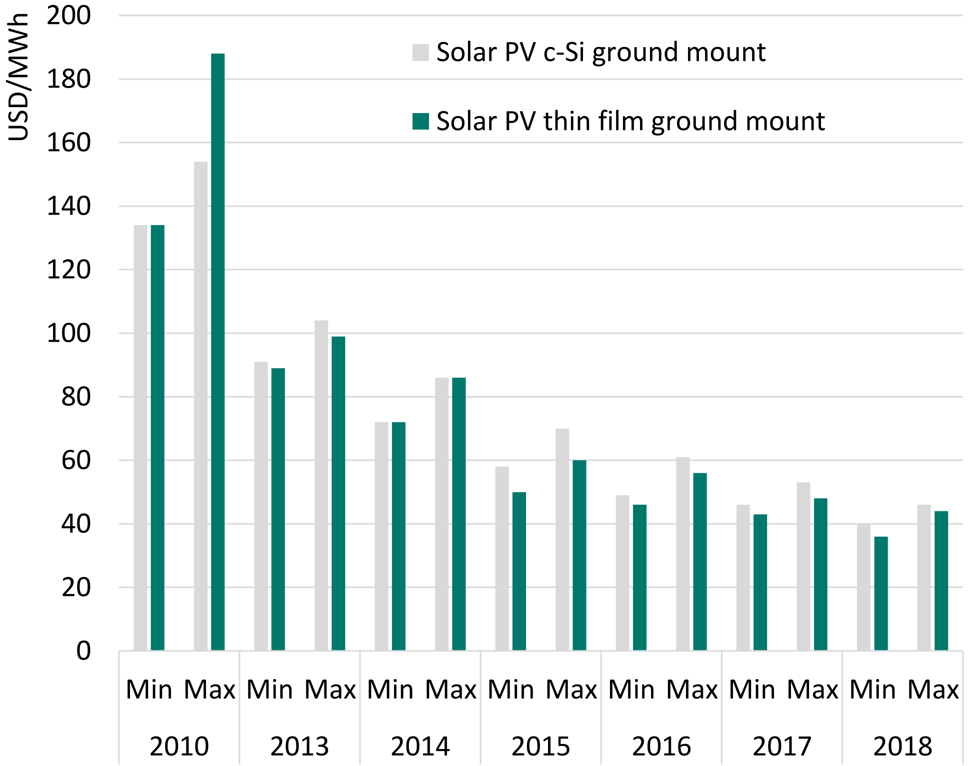
(1) Economies of scale and technological improvements led to a steep decrease in thin film module prices

Price Learning Curves and Learning Rates (LR)[8]

Thin Film Technology
(from Q2-2006 to Q4-2017) **LR 25**
Crystalline Technology
(from Q2-2006 to Q4-2017) **LR 29**



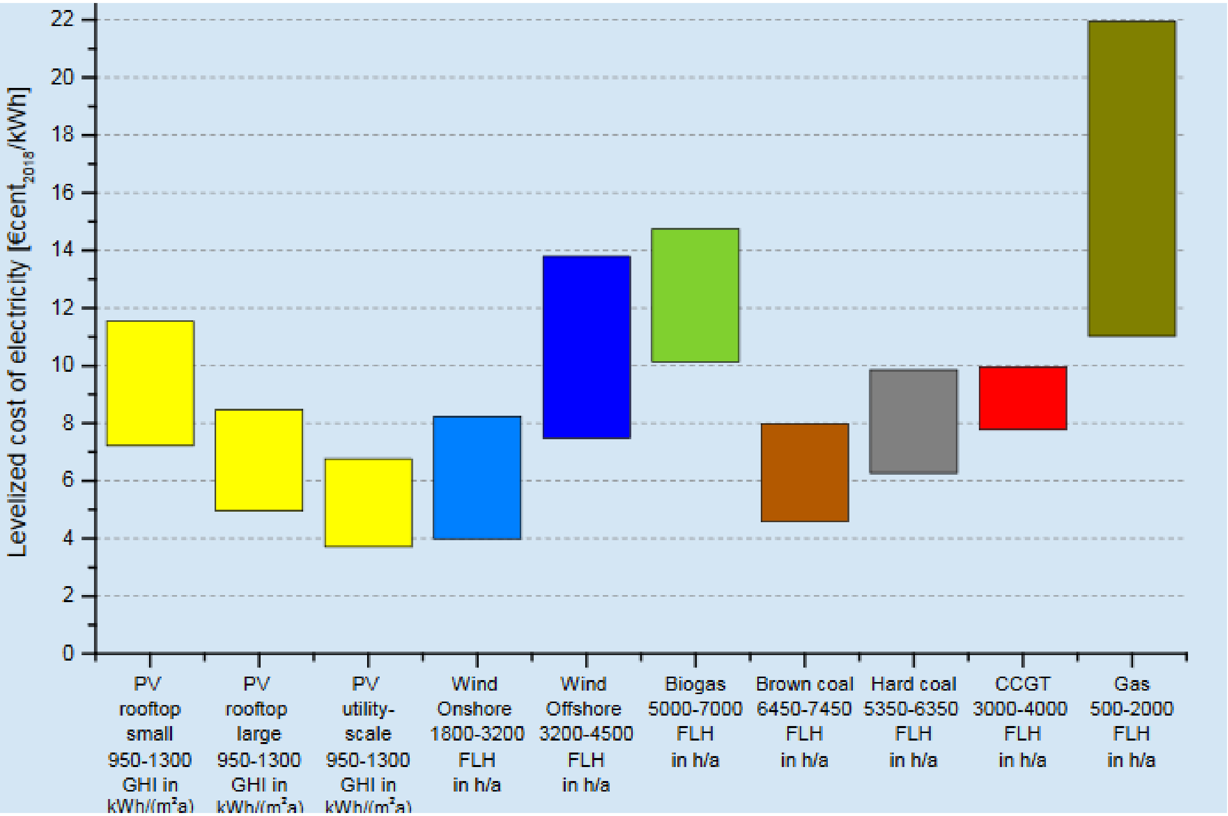
Lazard's Unsubsidized Levelized Cost of Energy Analysis 2010-2018[13]



Thin Film PV technologies

(1) Performance of PV technologies is competitive with other electricity generation technologies

Levelized cost of electricity of renewable energy technologies and (newly built) conventional power plants at locations in Germany in 2018[9]



Solar photovoltaic technologies and onshore wind energy have become the cheapest electricity generation technologies in Germany.

PV plants have reached levelized cost of electricity (LCOE) between 3.71 and 11.54 Euro/kWh (excl. VAT) in 2018.

Thin Film PV technologies

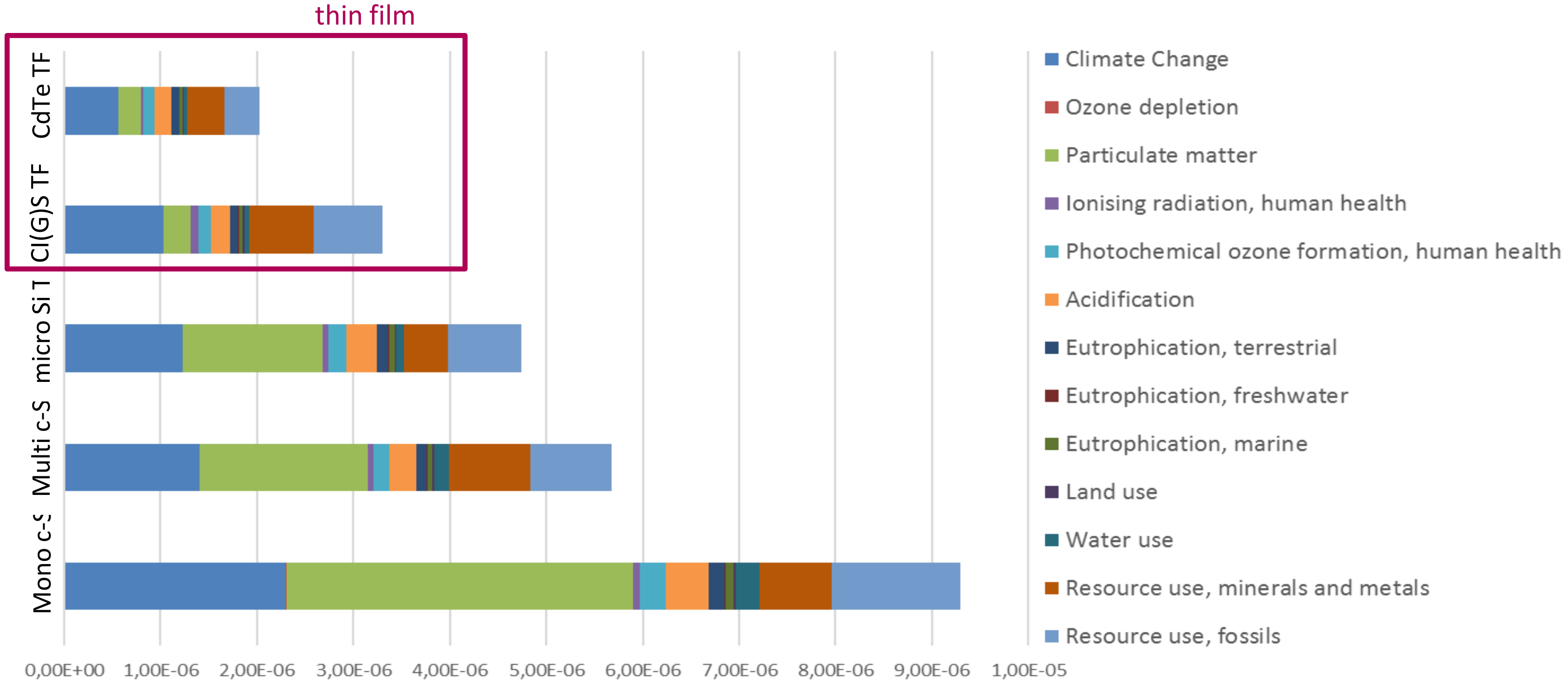
Properties of thin film PV technologies: Overview

(1) Competitiveness	(2) Environmental footprint	(3) Innovative potential
• Economies of scale and technological improvements led to a steep decrease in module prices.[8] • Performance of thin film PV technologies is competitive with other PV and electricity generation technologies.[9]	• Energy and material efficient manufacturing enables lowest resource use and emission profiles for thin film PV technologies.[10] • Due to the low material input used, thin film panels have a small environmental footprint.	• Emerging thin film technologies have a great potential for further technological improvement and cost reduction.

Thin Film PV technologies

(2) Due to the low material and energy input, thin film panels have a small environmental footprint

Product Environmental Footprint for a 3kWp slanted rooftop PV system, normalizing all impact categories and applying an equal weighting of those[10]

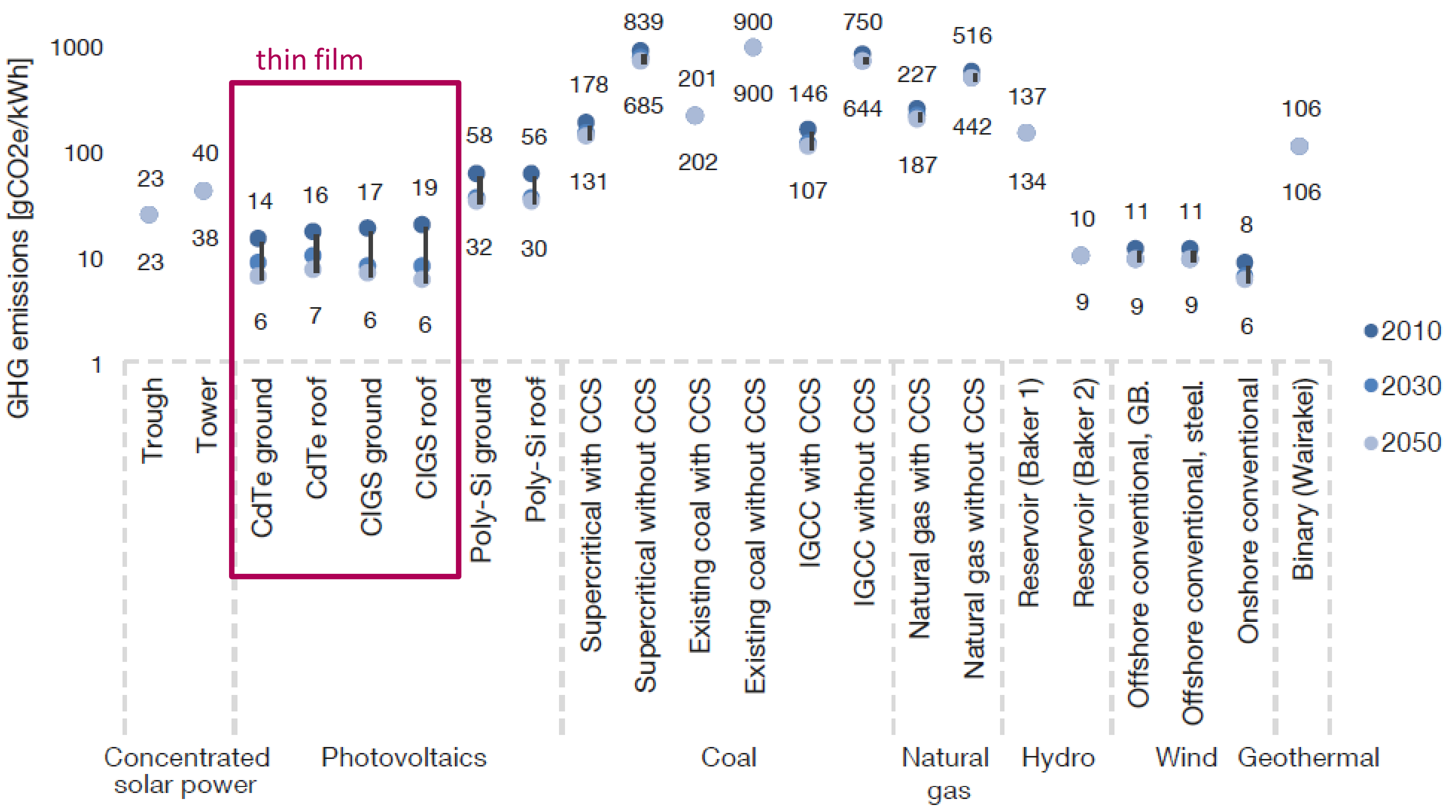


Due to lower resource and energy use in manufacturing of thin film PV panels and similar or better performance throughout the life cycle, the environmental footprint per kWh of generated electricity is very low.

Thin Film PV technologies

(2) Life cycle carbon emissions of thin film technologies are predicted to be among the lowest in 2050

Life cycle carbon emissions of thin film PV (2010-2050)[14]



Together with onshore wind energy, UNEP predicts thin film technologies to have the lowest life cycle carbon emissions by 2050.

The main sources of emissions in the life cycles of PV are in manufacturing and installation of equipment.

Thin Film PV technologies

Properties of thin film PV technologies: Overview

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Thin Film PV technologies

(3) Emerging thin film technologies have a great innovative potential

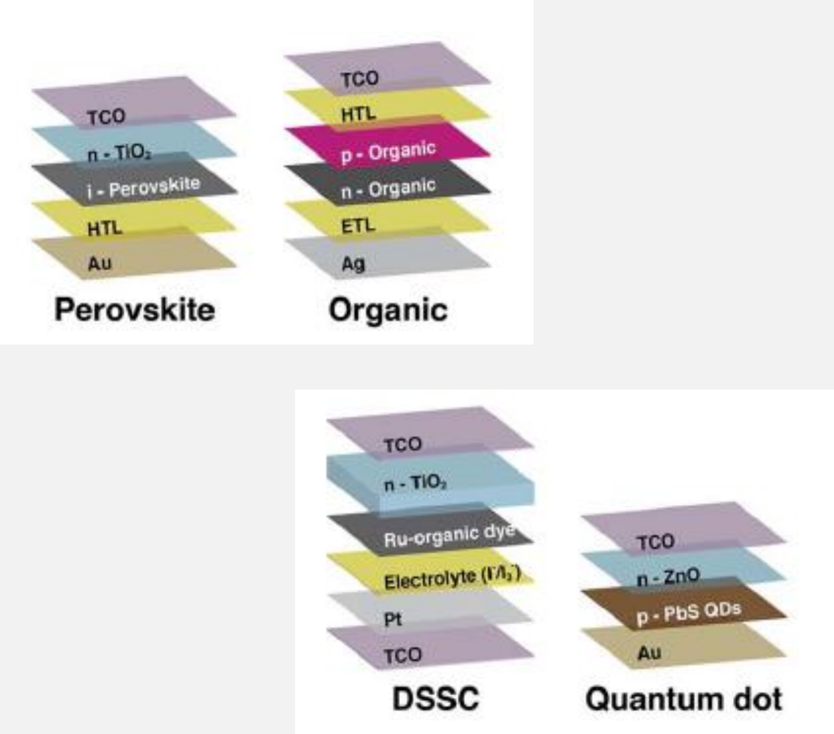
Significant progress in emerging thin film concepts have been made over the past years.

Perovskites have become one of the most promising emerging PV technologies showing remarkable progress in terms of low cost and high efficiency.

Another approach is the concept of tandem configurations, combining new technologies with existing commercial technologies, such as CdTe/Perovskite or CIGS/Perovskite approaches.

Within the framework of the BMBF funding "*Material research for the energy transition*", researchers in Germany have developed an internationally competitive expertise in the field of CIGS/perovskite tandem configurations.[12]

Emerging thin film technologies[11]



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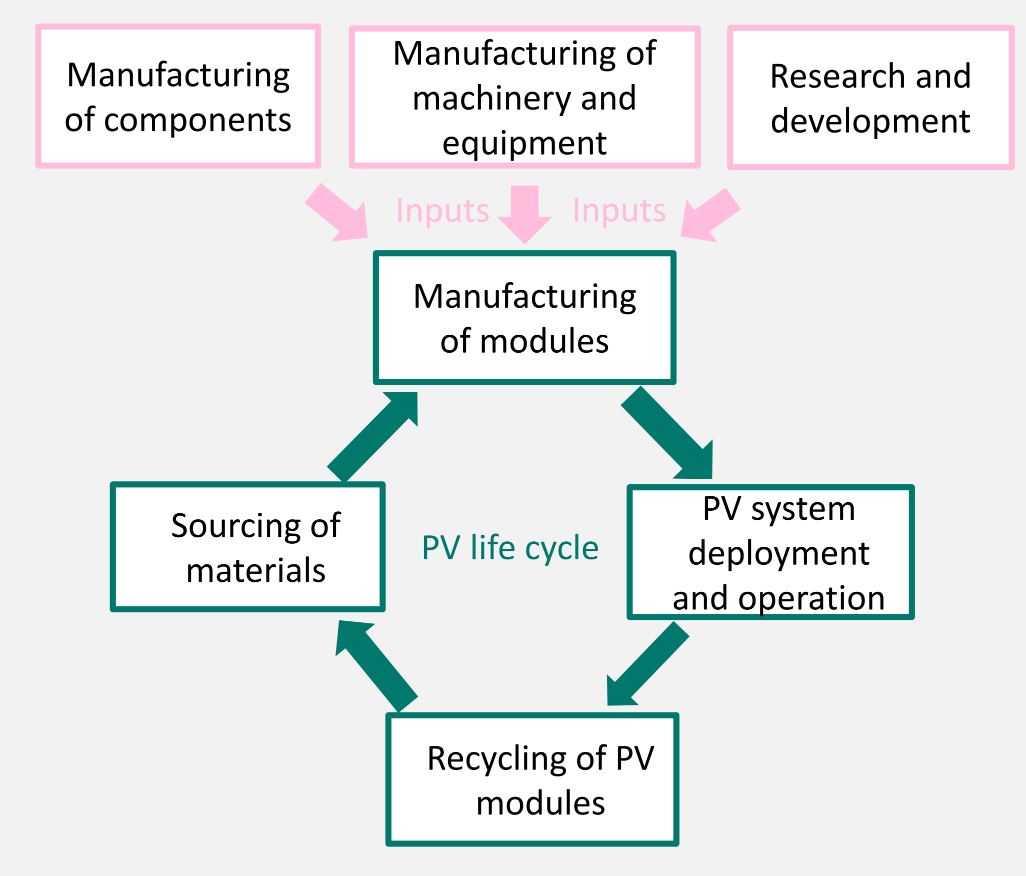
Thin film PV in Germany

The thin film PV value chain in Germany comprises activities over the entire PV life cycle

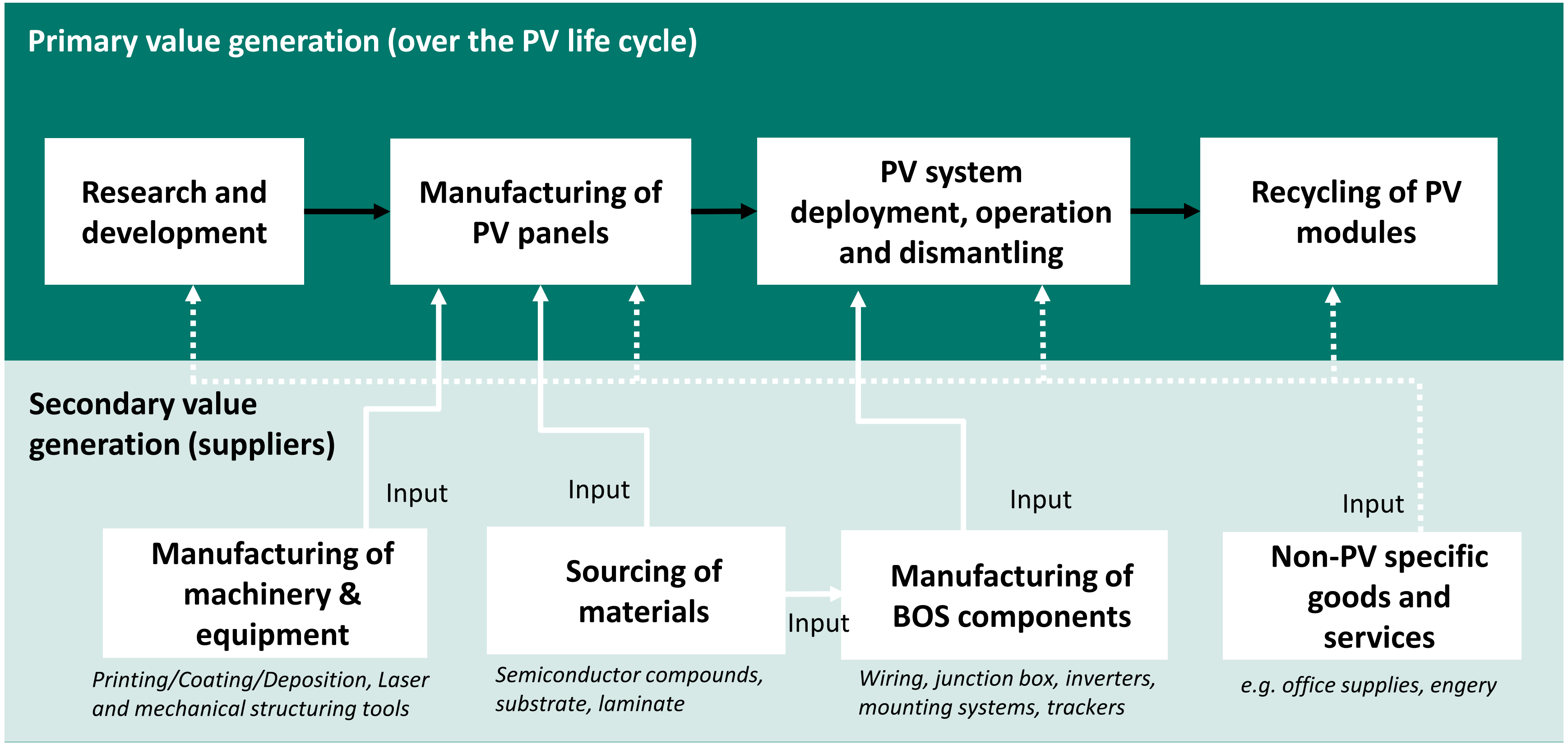


The PV life cycle encompasses raw material sourcing, manufacturing of modules, the deployment, operation and dismantling of PV systems as well as end-of-life disposal or recycling.

Other important segments of the value chain are manufacturing of components, manufacturing of machinery and equipment and research and development. These serve as inputs to the module manufacturing process.

Thin film PV in Germany

The thin film value chain comprises diverse segments with high value added

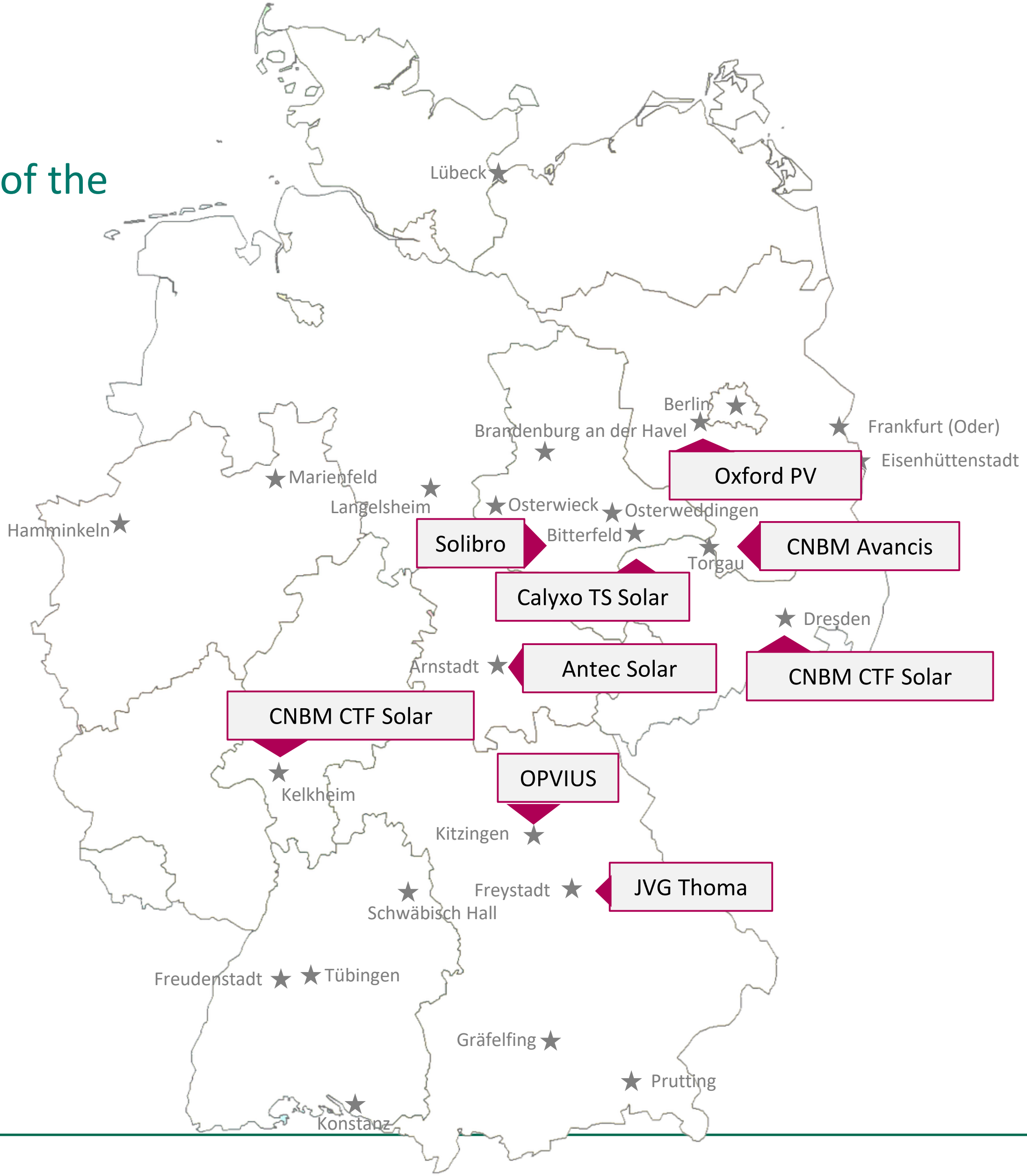


The balance of system (BOS) encompasses all components of a **photovoltaic system** other than the **photovoltaic panels**. This includes wiring, switches, a mounting system, one or more solar inverters, a battery bank and battery charger.

Thin film PV in Germany

Firms operating in Germany cover all segments of the thin film PV value chain

- **Manufacturing of thin film modules**
- Manufacturing of machinery and equiment
- Recycling of PV modules
- Manufacturing of components
- Research and Development



Thin film PV in Germany

Firms operating in Germany cover all segments of the thin film PV value chain

- Manufacturing of thin-film PV modules
- Manufacturing of machinery and equiment
- Recycling of PV modules
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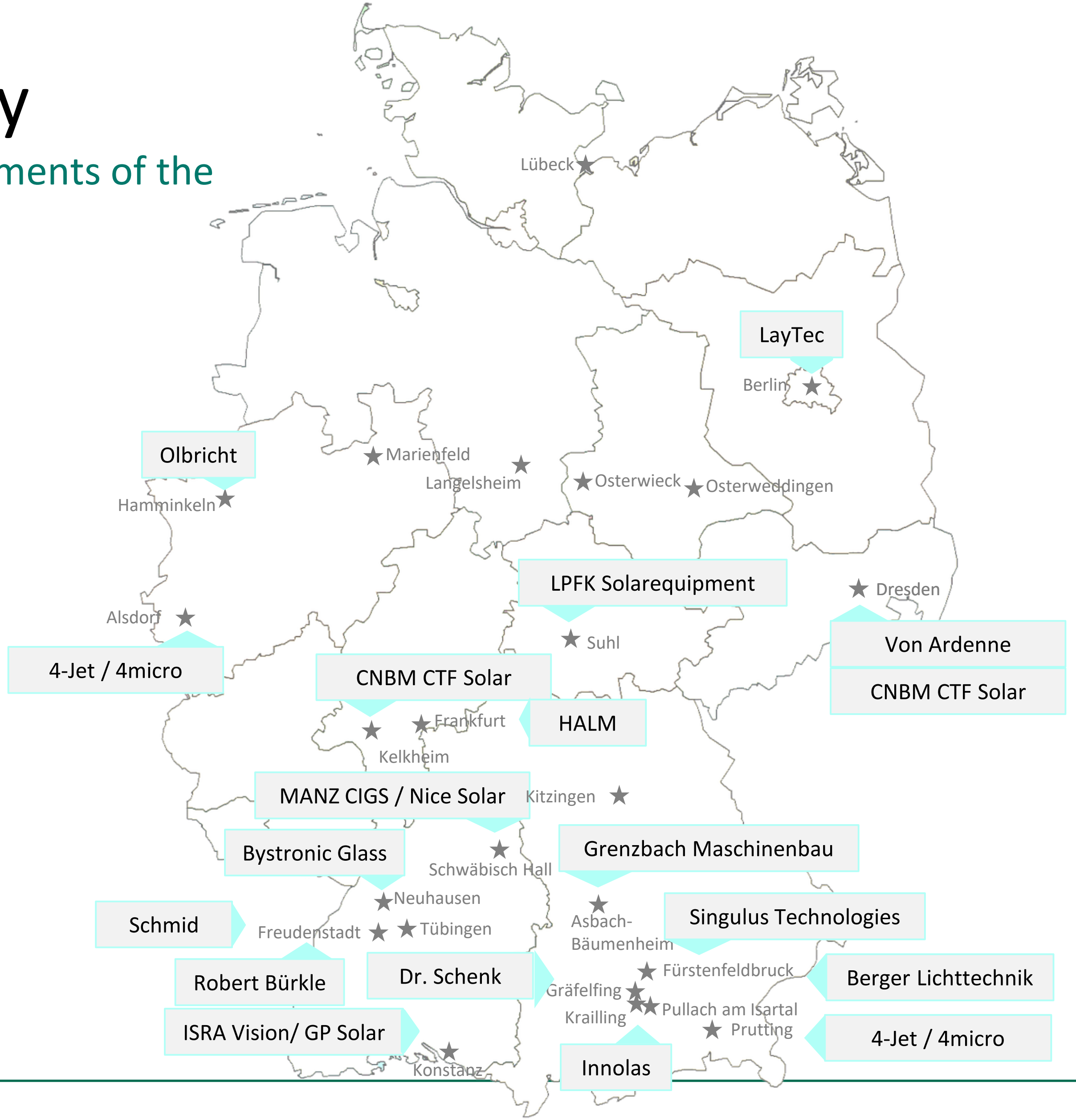
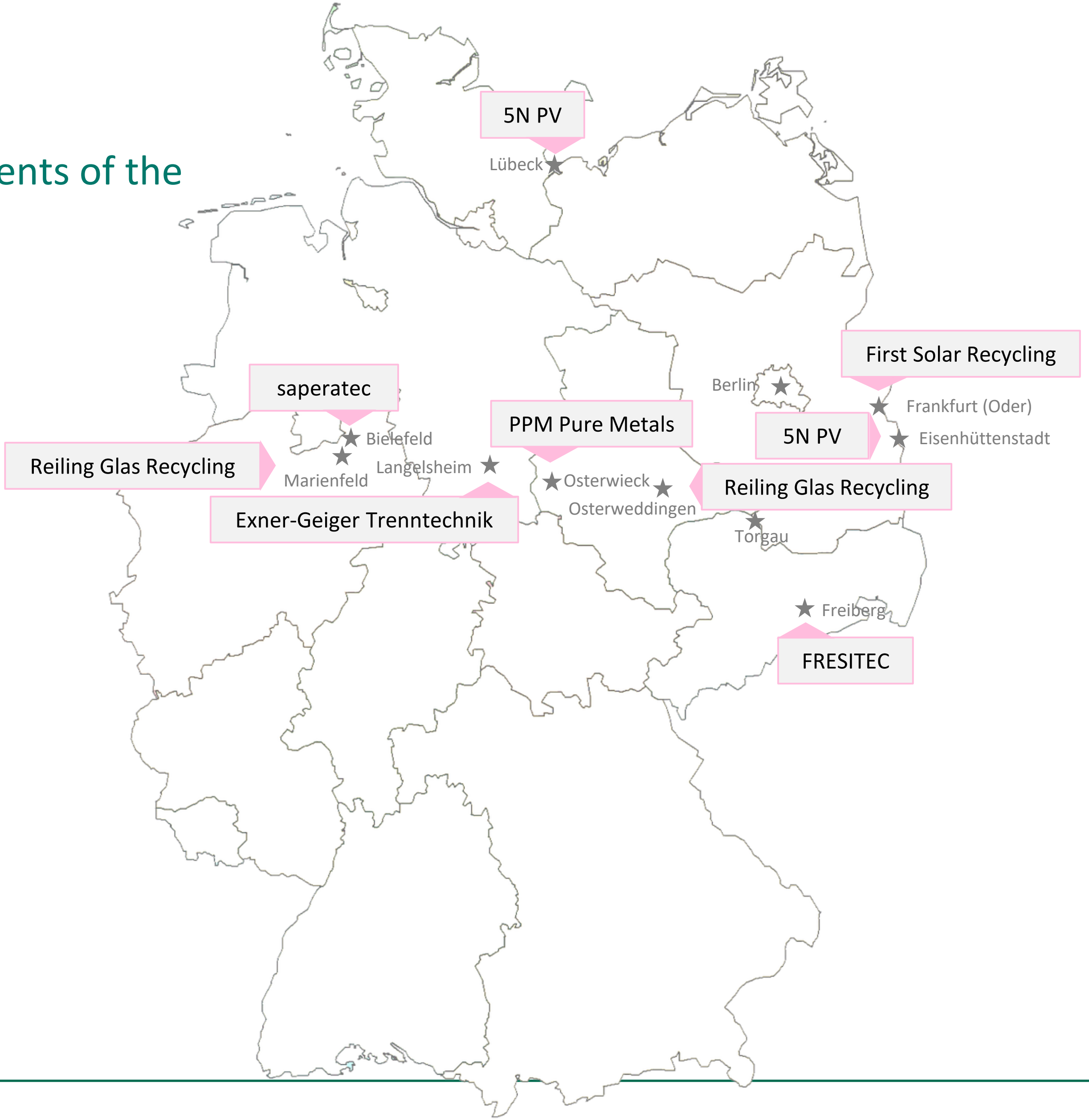


Thin film PV in Germany

Firms operating in Germany cover all segments of the thin film PV value chain

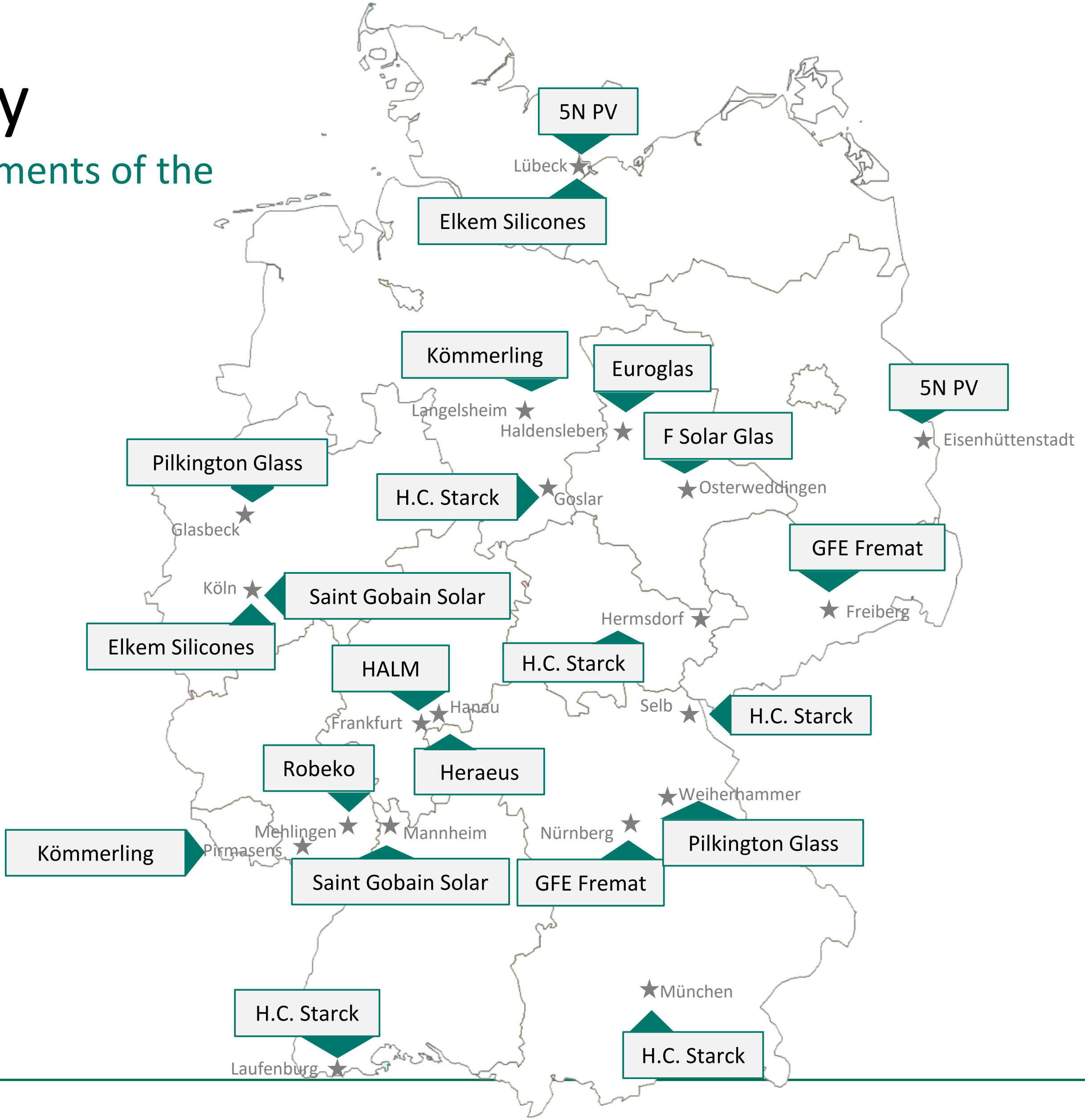
- Manufacturing of thin-film PV modules
- Manufacturing of machinery and equiment
- **Recycling of thin film modules**
- Manufacturing of components
- Research and Development



Thin film PV in Germany

Firms operating in Germany cover all segments of the thin film PV value chain

- Manufacturing of thin-film PV modules
- Manufacturing of machinery and equiment
- Recycling of PV modules
- **Manufacturing of thin film components**
- Research and Development



Thin film PV in Germany

Firms operating in Germany cover all segments of the thin film PV value chain[16]

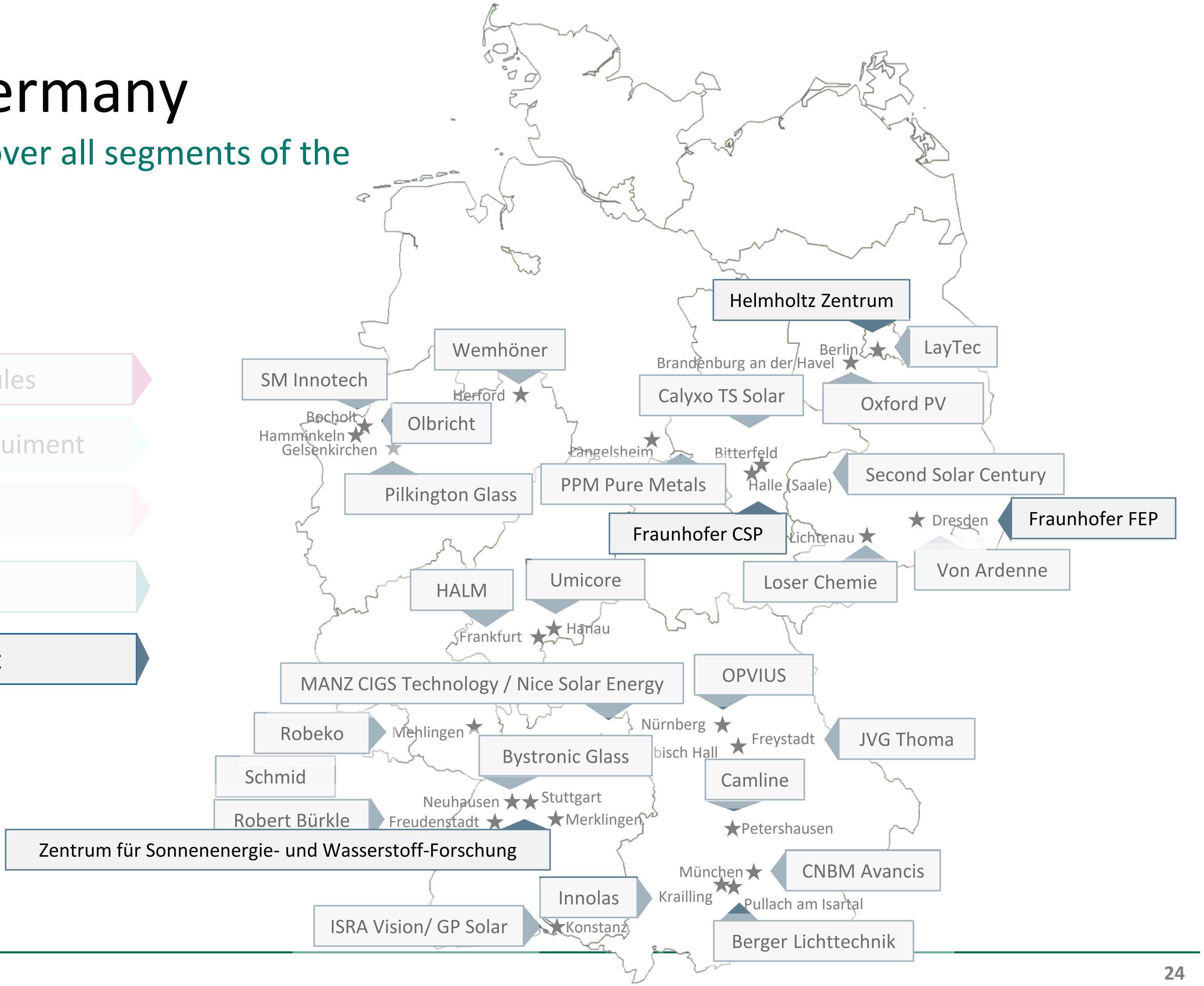
Manufacturing of thin-film PV modules

Manufacturing of machinery and equiment

Recycling of PV modules

Manufacturing of components

Thin film research and development



Dark blue indicates primarily public funded institutions, light blue indicates private firms active in R&D

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Policy scenarios and implications for PV

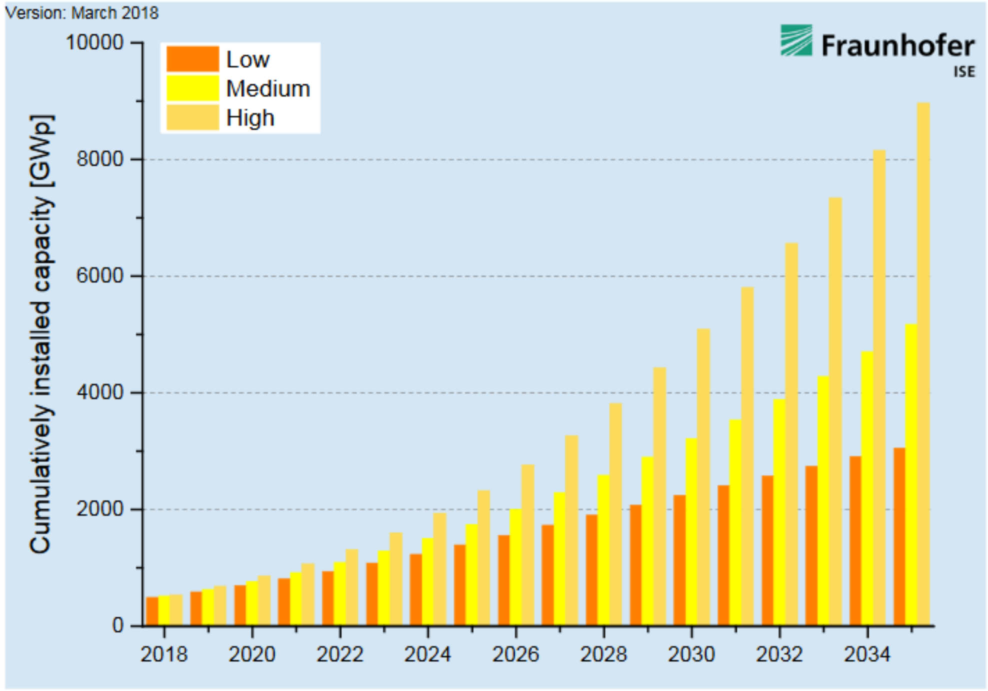
The global PV market will experience strong growth

In the end of 2017, installed PV capacity exceeded 400 GWp globally. The worldwide expansion in 2017 amounted to around 100 GWp, representing a market growth of over 30 percent.[9]

As more countries are installing PV on a significant scale, PV plants increasingly prevail in competition without subsidies.

The steep global market growth is expected to continue. Fraunhofer ISE estimates the global cumulatively installed capacity to rise to 5,200 GWp by 2035 (growth by a factor of 13 compared with 2017 in intermediate scenario).[9]

Global market development scenarios of cumulatively installed power (GWp) for PV, 2018-2035[9]



Policy scenarios and implications for PV

The future of PV in Germany: strong growth foreseeable

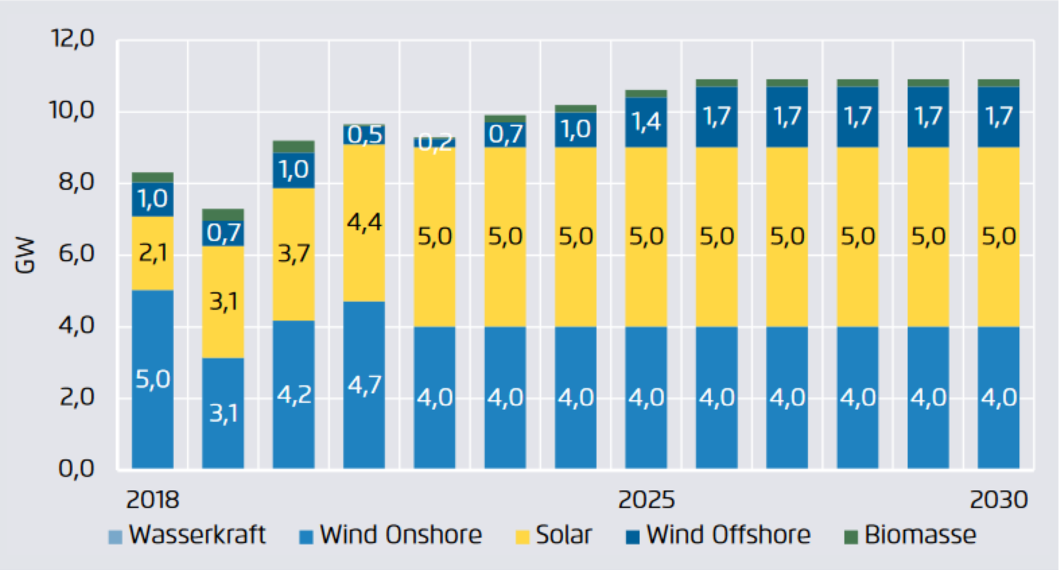
Also in Germany, large investments in PV are foreseeable.

Agora Energiewende finds:[15]

- in order to increase the share of renewable energies to 65 percent of gross electricity consumption by 2030 (as planed in the coalition agreement of March 2018)
- an annual PV expansion of 5 GW is necessary between 2020 and 2030.

This expansion path and assumed corresponding investments of EUR 1 billion/GWp imply an estimated annual economic potential of PV in Germany of EUR 5 billion in the upcoming years.

Annual expansion of electricity generation capacity for renewables in order to reach the 65 percent goal[15]



Note: Around EUR 1 billion was the investment volume associated with 1 GWp newly installed capacity in 2017, see Slide 6.

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Conclusions

Thin film PV is an ecologically **sustainable and competitive** technology for electricity generation. The **global PV market** will exhibit **high growth**, as PV is one of the major future energy generation technologies. In Germany, substantial investments in PV will be undertaken to reach the goals of the "*Energiewende*".

The German thin film PV industry is **highly innovative** and serves both the German and the global market. Firms operating in Germany **cover all segments of the PV value chain**. Moreover, the German industry can draw on a well-established knowledge base with top-level research and development institutions.

Jointly, these factors determine a high **economic potential** of PV in Germany. A **supportive, technology neutral policy framework** would foster the realisation of this potential with respect to **jobs and economic growth** in Germany.

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[14] United Nations Environment Programme UNEP (2016): Green Energy Choices: The benefits, risks and trade-offs of low-carbon technologies for electricity production. Report of the International Resource Panel.
[15] Agora Energiewende (2018): Stromnetze für 65 Prozent Erneuerbare bis 2030 Zwölf Maßnahmen für den synchronen Ausbau von Netzen und Erneuerbaren Energien, Juli 2018.
[16] The maps show companies by activities at their location in Germany at the end of 2018, data based on assessments of DWReco and PVThin.

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