JADE UNIVERSITY OF APPLIED SCIENCES
Wilhelmshaven Oldenburg Elsfleth

WFEO webinar

PV Module Recycling
- a necessity for future PV development

First steps towards a PV circular economy?

Friday, 4th July 2025, 14:00 – 15:30 h CEST

Carsten Ahrens, ZDI
Jadehochschule Oldenburg
WFEO, Chair Solar Group

SCHEDULE, PARTICIPANTS

DURATION	1,5 hours (90 minutes)	
HOST WFEO	Marie-Line Vaiani, Chair SC Energy	(5 min.)
PANELLISTS	from 4 regions of the world	
Germany	Carsten Ahrens, Chair Solar Group	(25+ min.)
	Florian Haase (Jan-Philipp Mai), Solar Materials	
Australia	Adrian Piani, Solar Group	(15+ min.)
	James Petesic, PV Industries	
South Africa	Ismail Jeffries	(15+ min.)
	Steffen Schröder, Reclite Company	
USA	Yogi Goswami	(10+ min.)

Discussion (20- min.)

INTRODUCTION / BACKGROUND / QUESTIONS

Development of PV

- PV installations and yearly additions
- PV as largest power capacity
- PV as cheapest electricity

Future amount of PV waste / end of life modules

- Material content of PV modules
- Recycled materials

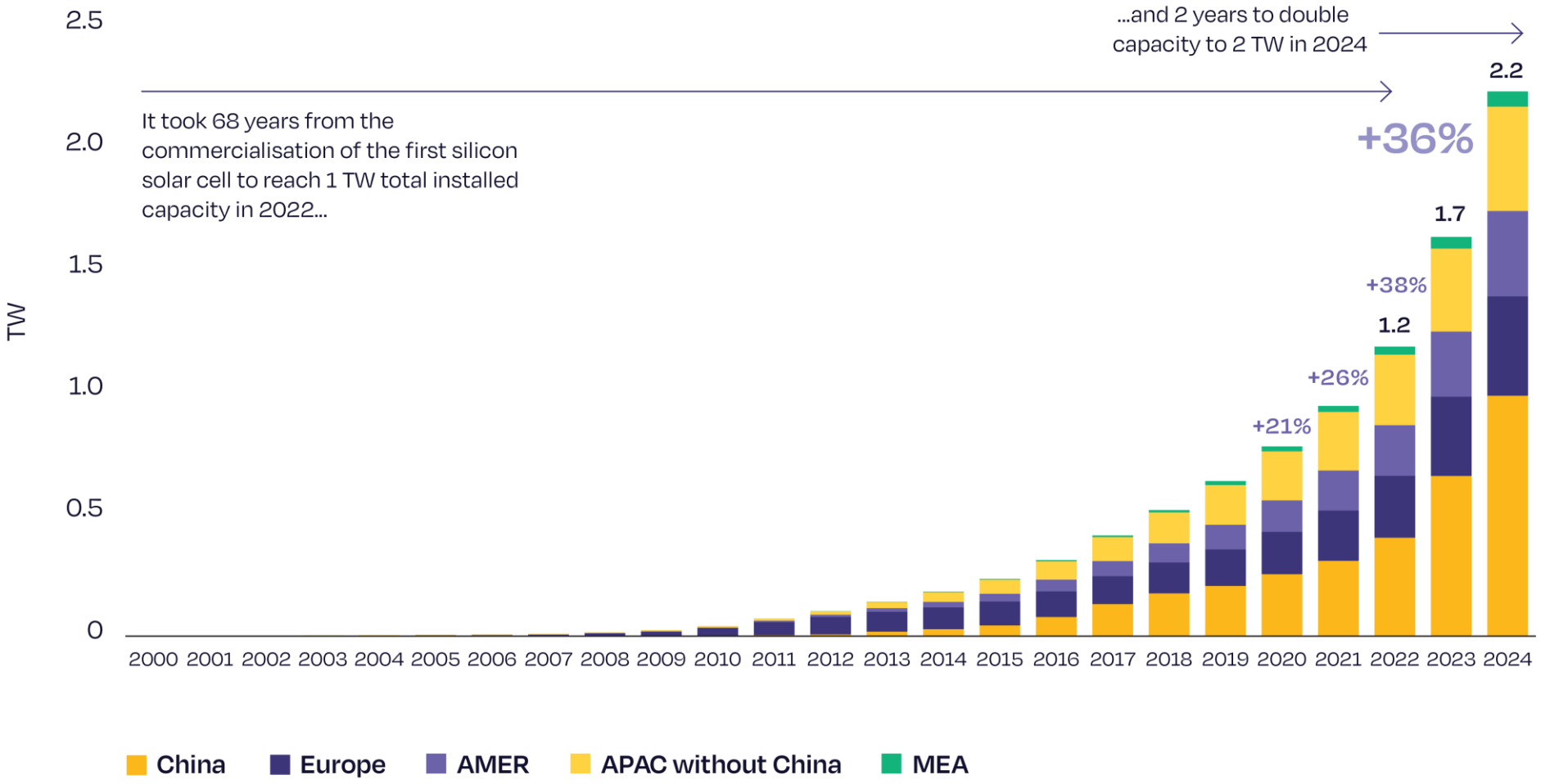
Circular Economy in the EU

National obligations

Recycling activities (amount, purity of recycled materials)

Need for industrial recycling

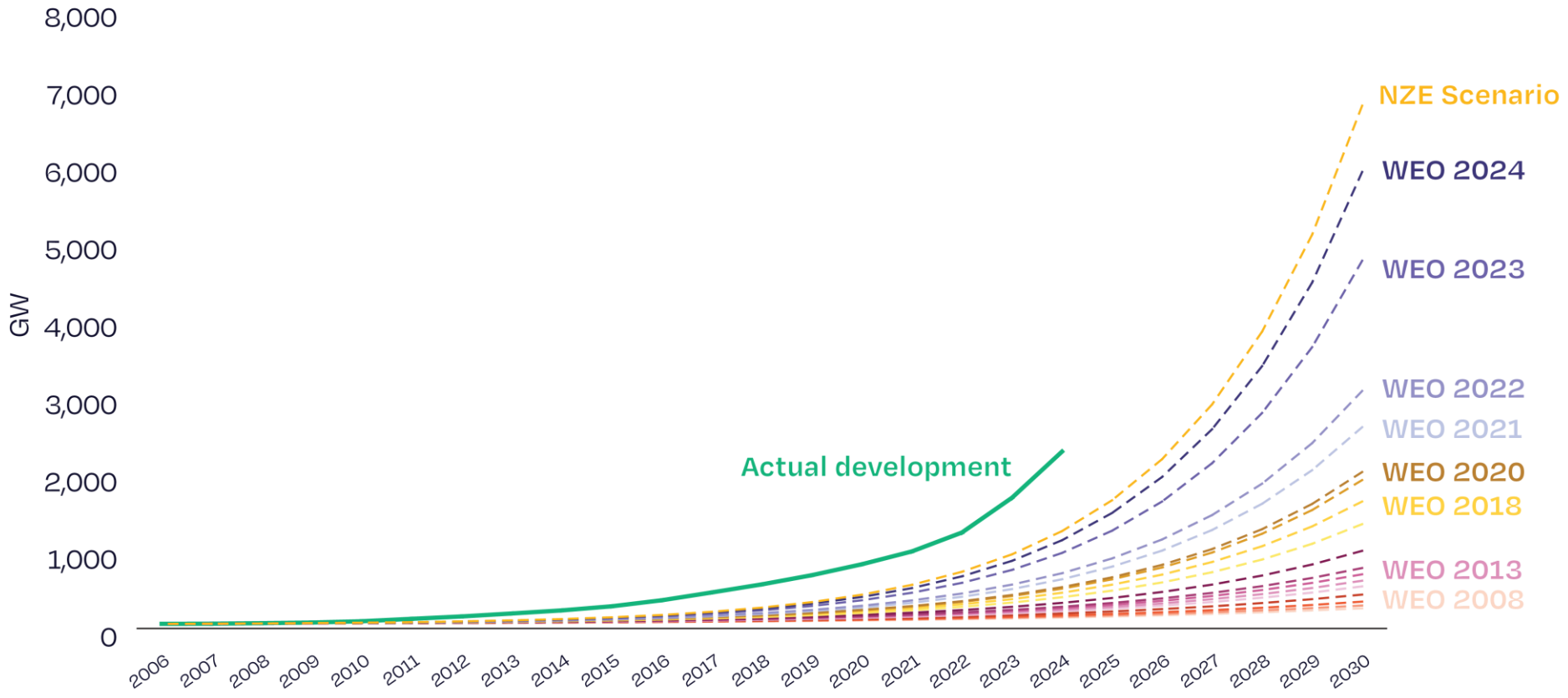
CUMULATIVE PV POWER CAPACITY WORLDWIDE



CUMULATIVE PV POWER DEVELOPMENT

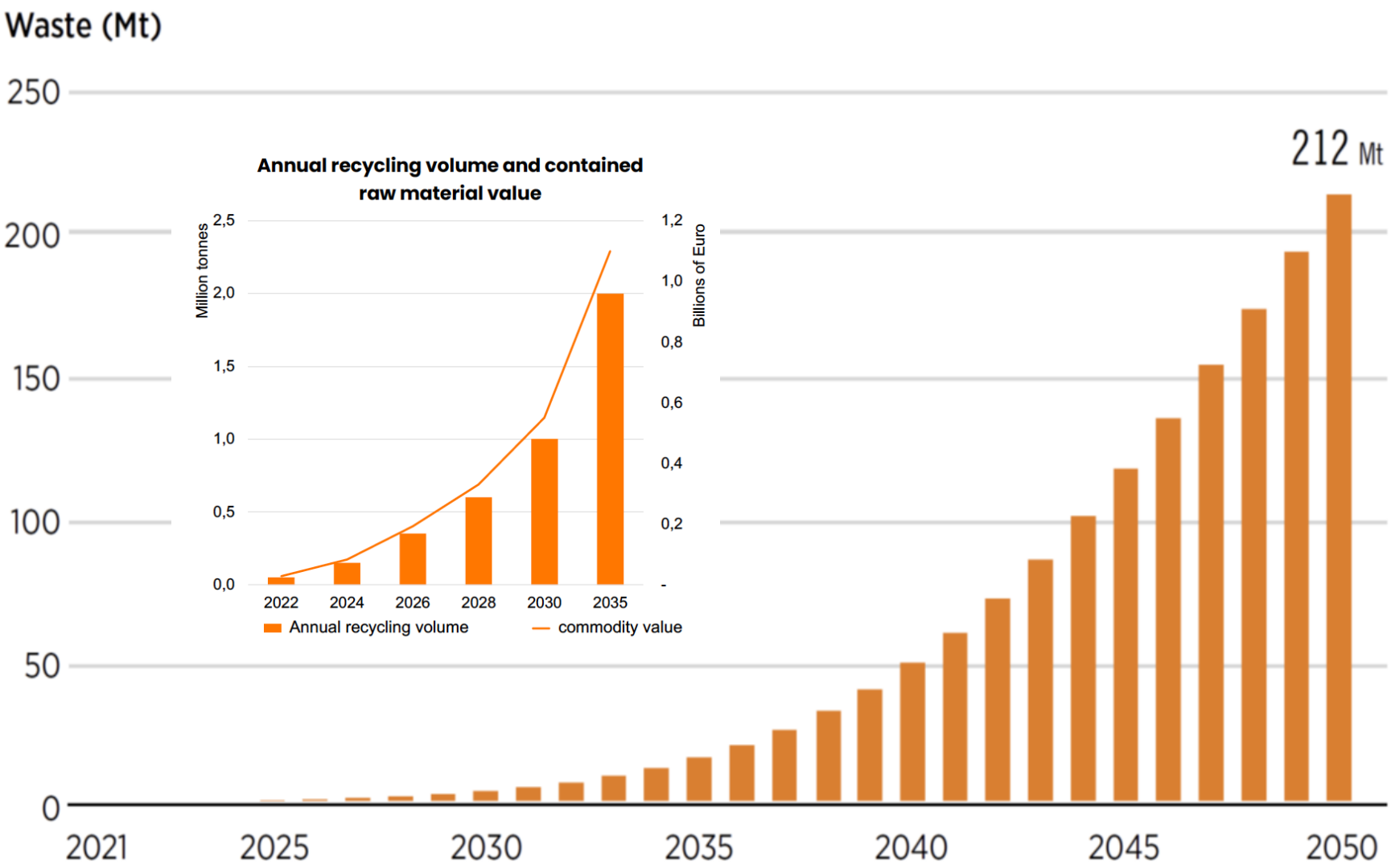
Historical solar PV development growth curve indicates continued systematic underestimation of future installations

IEA world energy forecasts versus actual historical development of solar PV

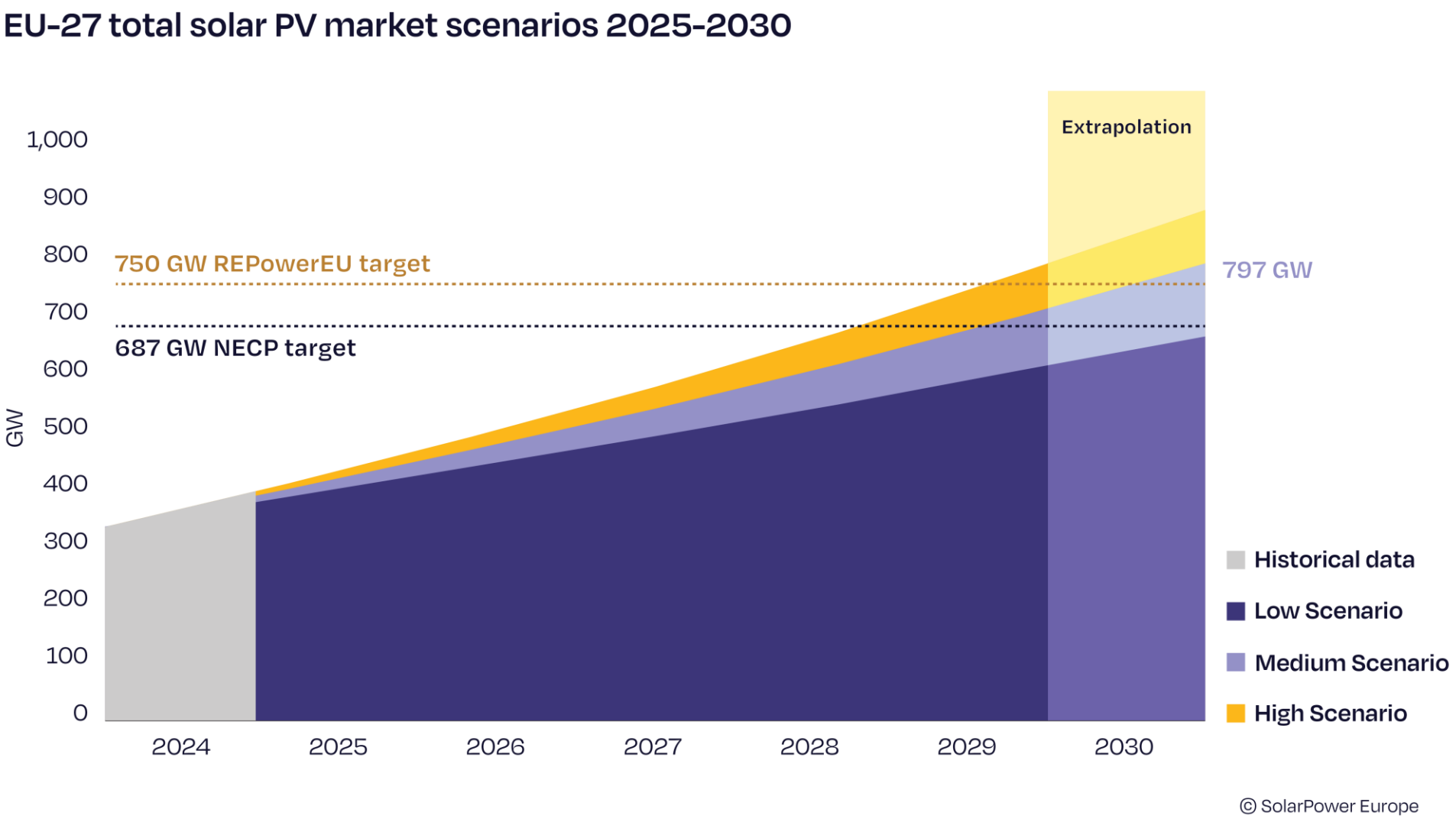


Source: IEA (2025)

DEVELOPMENT OF PV-WASTE

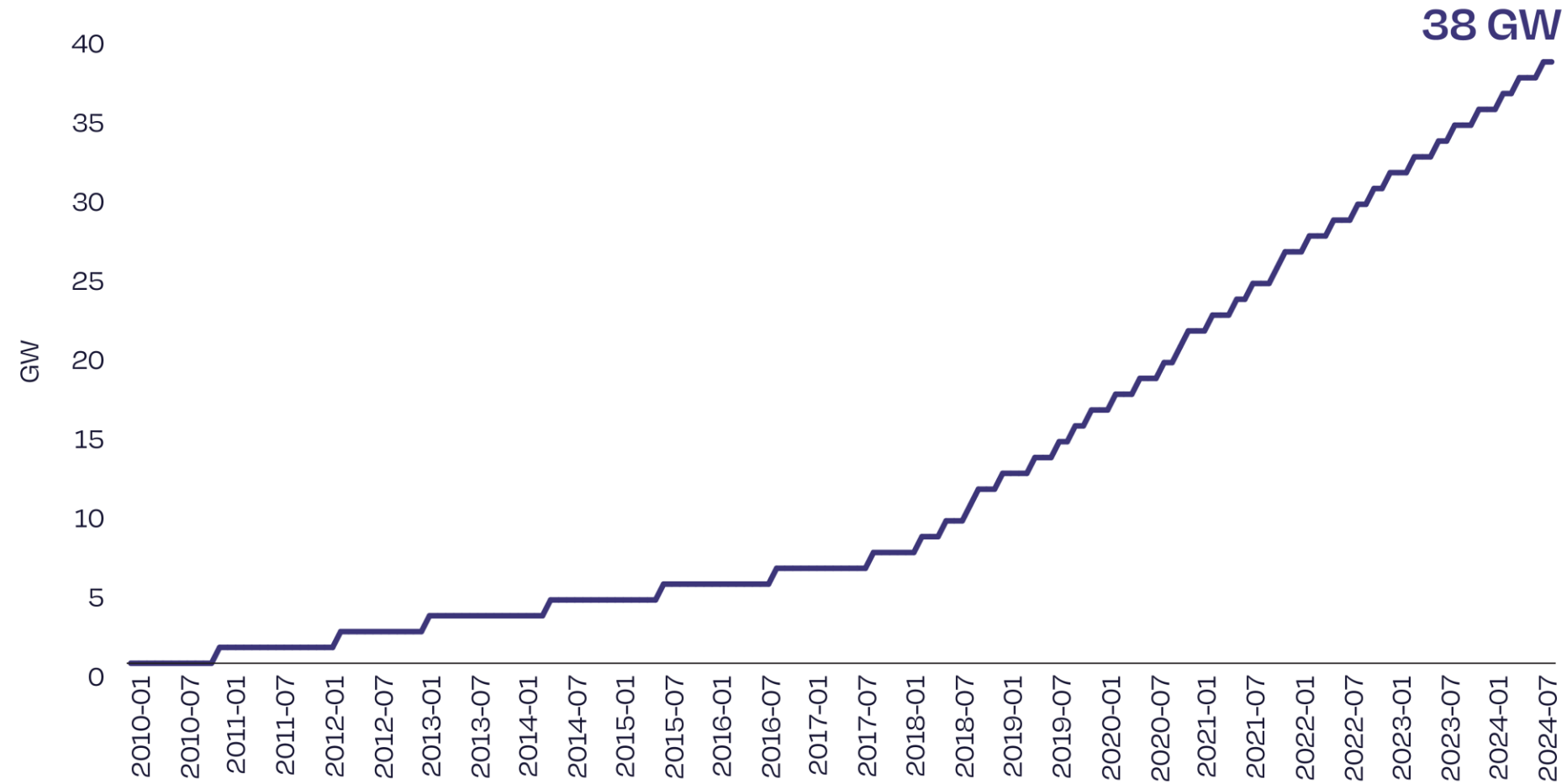


EU-27 PV DEVELOPMENT



AUSTRALIA PV CAPACITY DEVELOPMENT

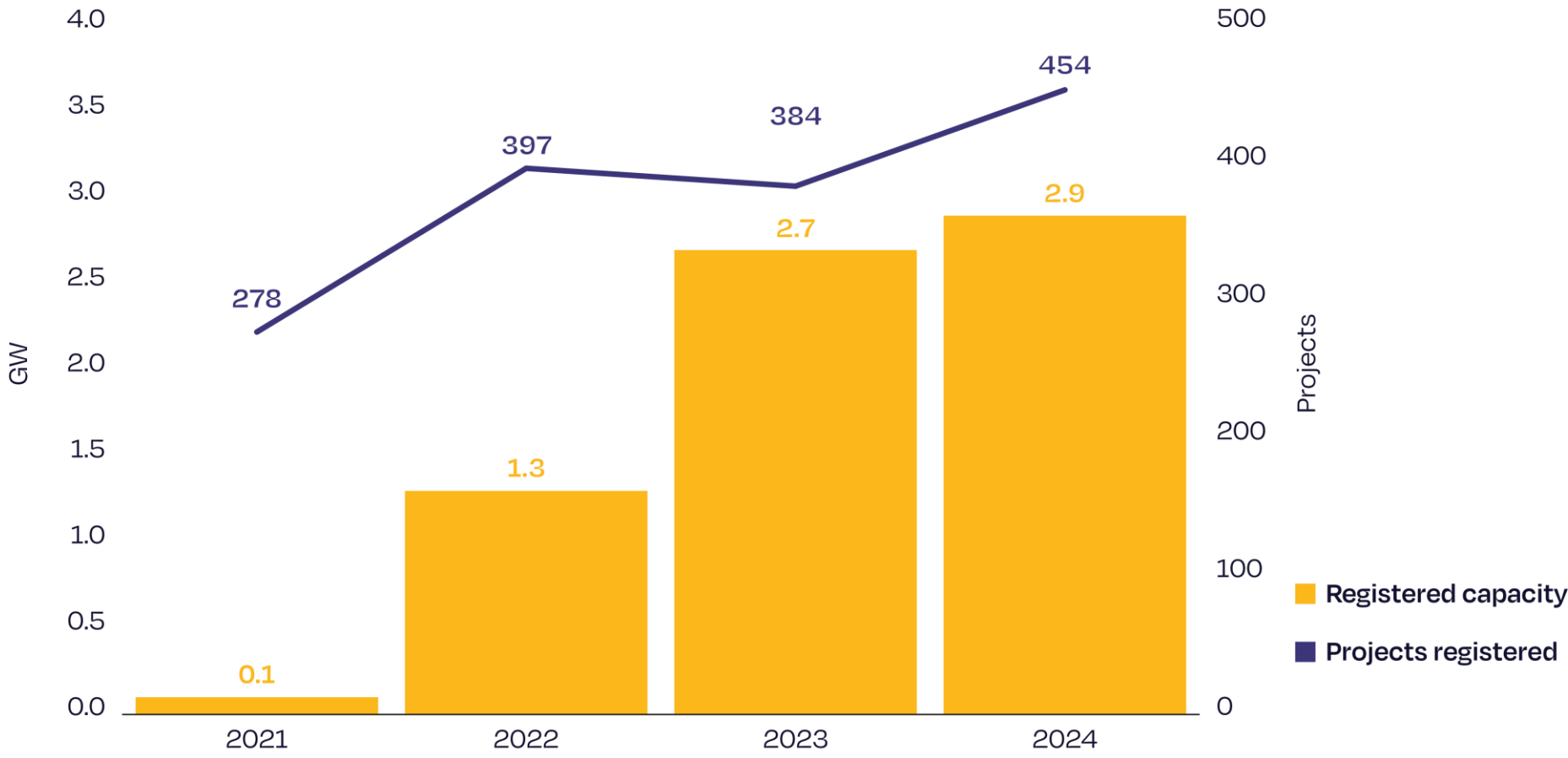
Australia cumulative solar PV installed capacity 2010-2024



Source: Australian PV Institute, 2025

SOUTH AFRICA PV DEVELOPMENT

South Africa annual solar PV registered capacity and projects 2021-2024

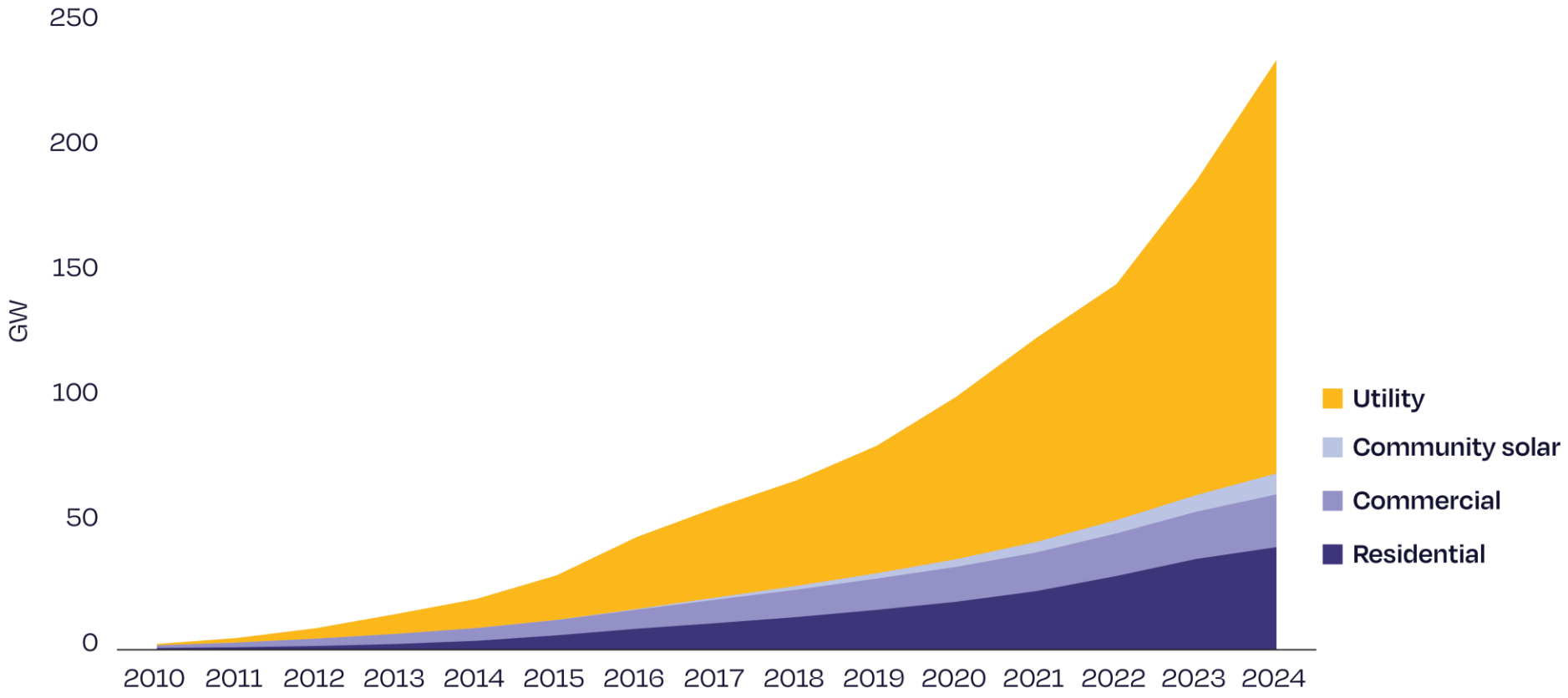


Source: NERSA

Note: Pre-construction registration with the national energy regulator (NERSA). Forward looking, indicative of the potential capacity to come online within the short to medium term

US PV DEVELOPMENT

US cumulative solar PV installations 2010-2024

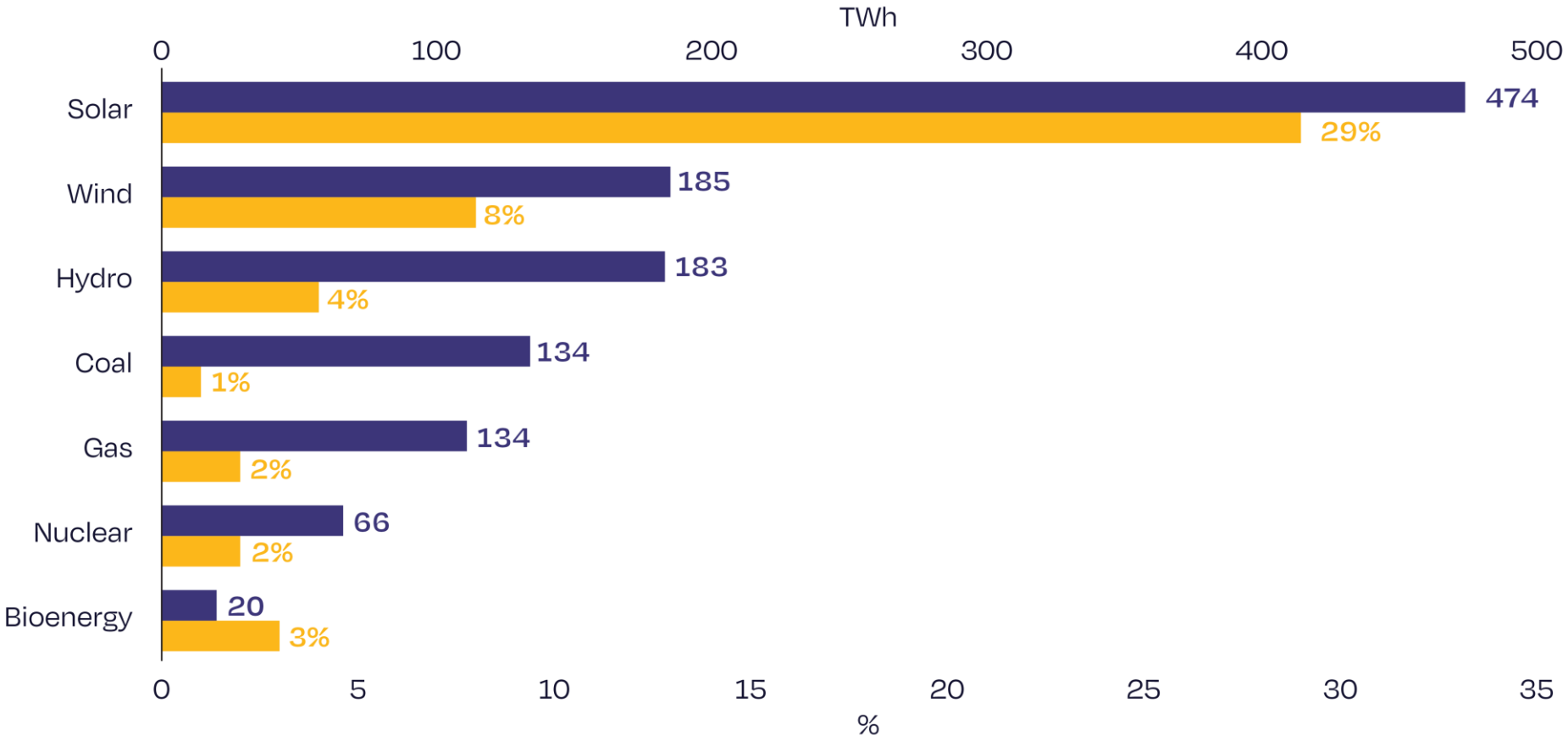


Source: SEIA/Wood Mackenzie Solar Market Insight Report 2024 Year in Review

ANNUAL CAPACITY ADDITIONS (PV, wind)

Solar electricity generation growth outpaces all other technologies with 474 TWh added last year, a 29% annual increase

Absolute and relative growth of electricity generation by technology 2023-2024

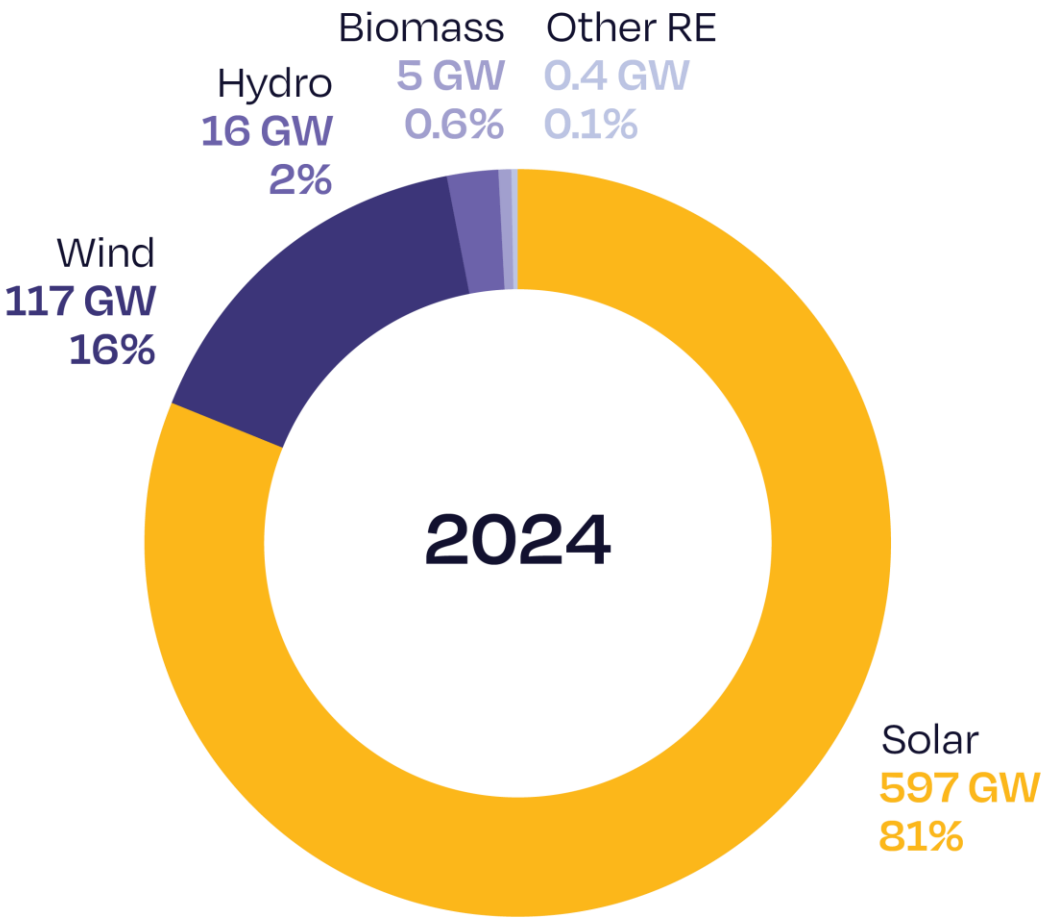


Source: Ember (2025)

POWER CAPACITY ADDITIONS BY TECHNOLOGY

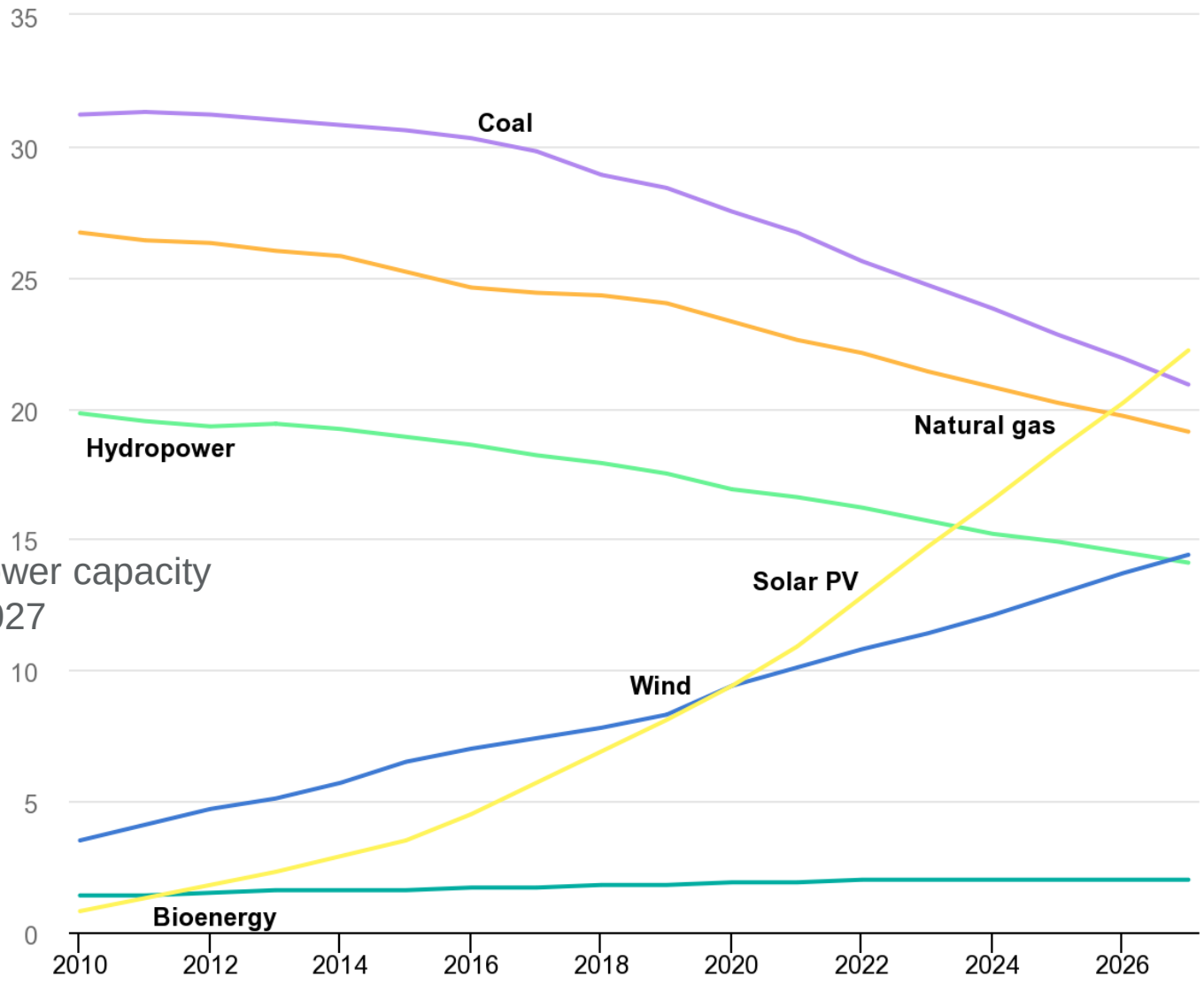
Solar makes more than 80% of all new renewable capacity additions in 2024

Net renewable power generation capacity installed in 2024



CUMULATIVE POWER CAPACITY BY TECHNOLOGY

Share of cumulative power capacity by technology, 2010-2027
lea.org



NESSESSITY FOR RECYCLING

Just in Germany today about 60,000 tons of used PV modules reach their end of life and many will be disposed, very likely by landfill method.

In 2030 a quantity of 1.000,000 tons is expected.

Just in Germany! Worldwide it is a multiple of this number!

These numbers have to be reinstalled, and, in addition a

multifold has to be added

to reach the net-zero goals. But the still existing

shortage of rare elements

becomes a real problematic bottleneck, which could stop further increase of PV-electricity share in the renewable power supply.

So there is the need not only to recycle, but to install a

CIRCULAR PV-ECONOMY.

Germany could become the first country

to do it ON AN INDUSTRIAL BASIS.

ACHIEVEMENT OF SDG 12

Sustainable growth and development require

MINIMIZING THE NATURAL RESOURCES

and toxic materials used, and the waste and pollutants generated,

throughout the entire production and consumption process.

Achieving this contributes to

SUSTAINABLE DEVELOPMENT GOAL 12,

which focuses on

“DOING MORE AND BETTER WITH LESS”,

By 2030, substantially reduce waste generation through prevention, reduction,

RECYCLING AND REUSE

Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle

CIRCULAR ECONOMY IN THE EU

The EU installed an ambitious first circular action plan, with 54 delivered actions. The EU's transition to a circular economy is now guided by the new circular economy action plan. On March 2019 the EU commission adopted a comprehensive report on the implementation, which includes PV development.

RECYCLING IN GERMANY

Fraunhofer Center for Silicon Photovoltaics (CSP) with

Reiling GmbH & Co. KG Group

started to recycled on an industrial scale

Right: PERC solar cells made of 100 % recycled silicon with an efficiency of 19.7 percent.

Another rexycling company on an industrial scale is

Solar Materials

(see next speaker Florian Haase) as start-up with facilities in Germany and very soon also in Italy

OUTLOOK

In all countries there are numbers of barriers to/against recycling.

For example: In a survey of U.S. Policies and Initiatives, the NREL identified several barriers to PV panel recycling opportunities in the US, as there are

- data gaps;
- inadequate recycling technology;
- infrastructure;
- regulatory uncertainties;
- education and awareness of people.

Germany has worked a lot on this field, having

- **Fraunhofer ISE and CSP research center and**
- **Reiling Group as collecting and recycling company**
- **Solar Materials as recycling start-up**

Result and hope: Germany may become the first country for

INDUSTRIAL RECYCLING OF PV-MODULES

MATERIALS IN CRYSTALLINE SI MODULES

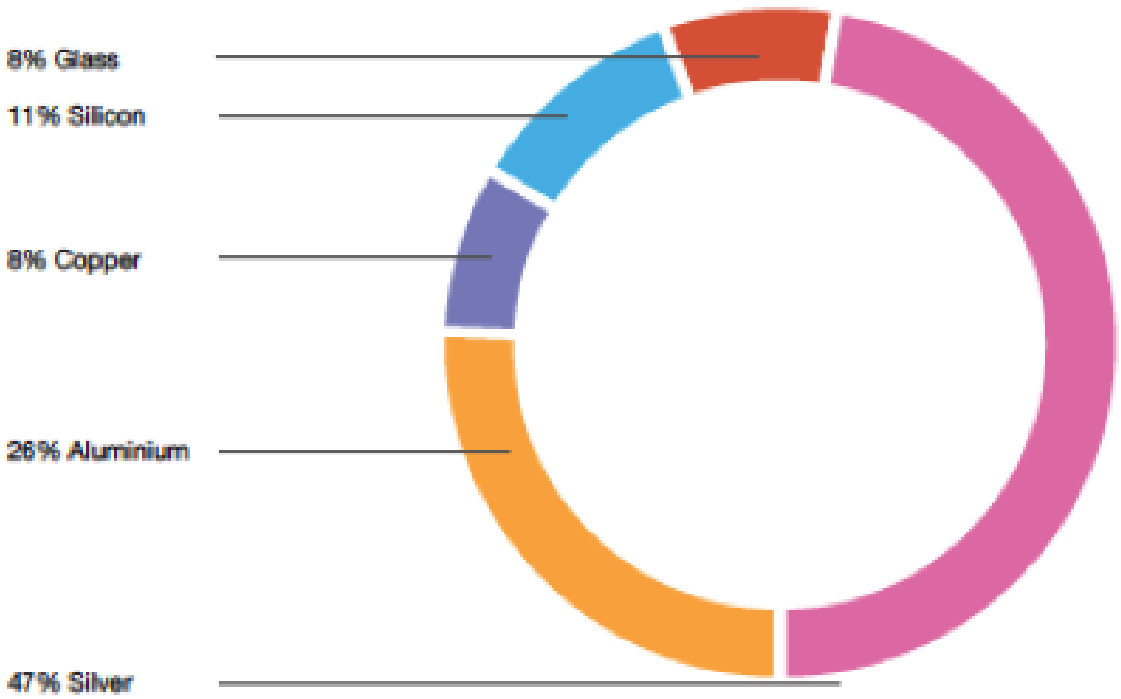
Content by mass

Average proportion per ton of module scrap:

Silver	< 0.1%	0.5 - 1 kg
Copper	< 1%	5 - 10 kg
Tin	< 01%	0.5 - 1 kg
Silicon	5%	25 - 50 kg
Alu	8%	100 - 150 kg
Glass	76%	700 - 750 kg
Plastics, other reminders		
	ca. 10%	

Silver is present in small volumes in the cells, but represents the highest value material in typical SI-panels with a share of nearly 50% of the panel value. It is followed by copper and aluminium,the last of which has a share of 26 %

Relative value of materials



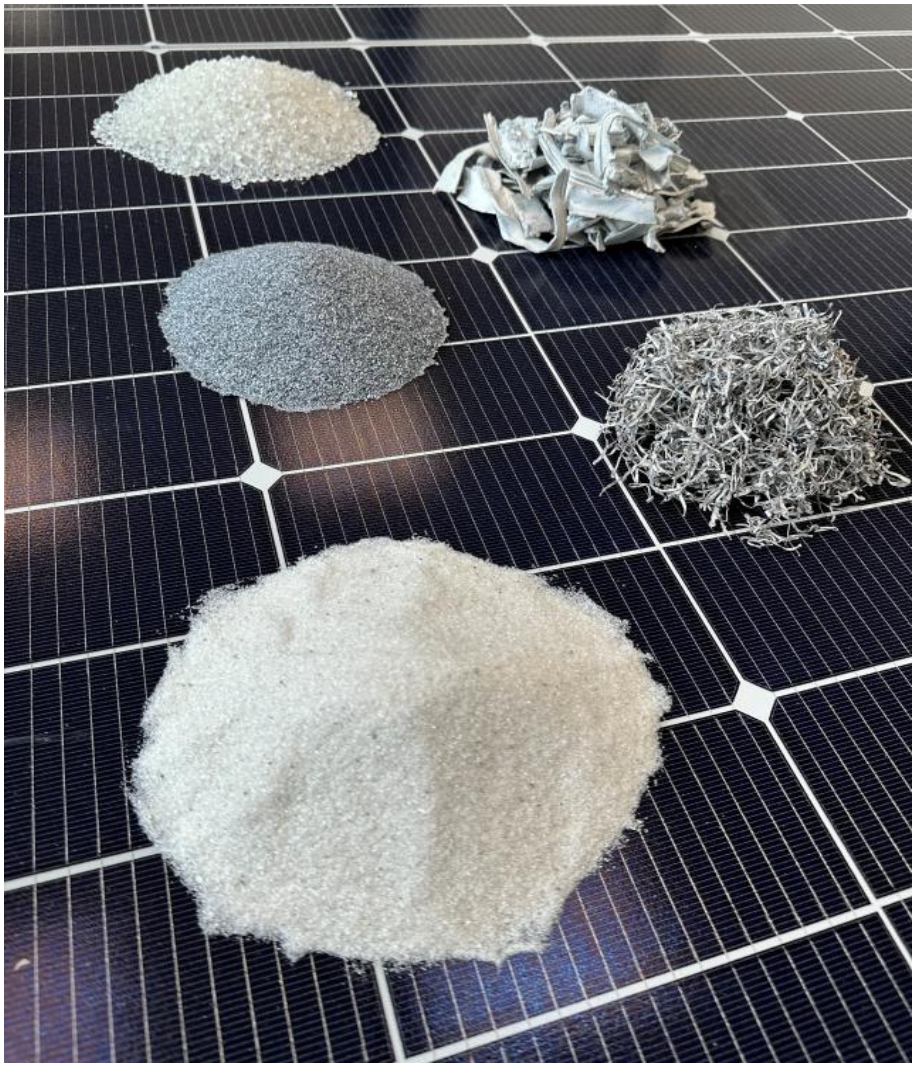
RECYCLED MATERIALS FROM PV MODULES

- Highest quality recyclates to customers
- Main component of PV modules is glass and will be recovered completely.
- Other materials, such as aluminium, will also be optimally recycled and returned to high-quality applications.
- Continuous development of the recycling processes and cutting-edge sorting techniques allow to produce secondary raw materials of high quallity.

The end products are

- glass (fine and course grain);
- silicon;
- aluminium;
- conductors (tinned copper);
- cables and foil.

see picture on right



www.reiling.de/recycling

PV ELECTRICITY IN A CIRCULAR ECONOMY

- this is a need for the energy future

Carsten Ahrens
WFEO, Chair Solar Group
carsten.ahrens@jade-hs.de