

Solar PV Deployment in Europe



Open your mind. LUT.
Lappeenranta University of Technology

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Global: Power Market Development: 2007 - 2021



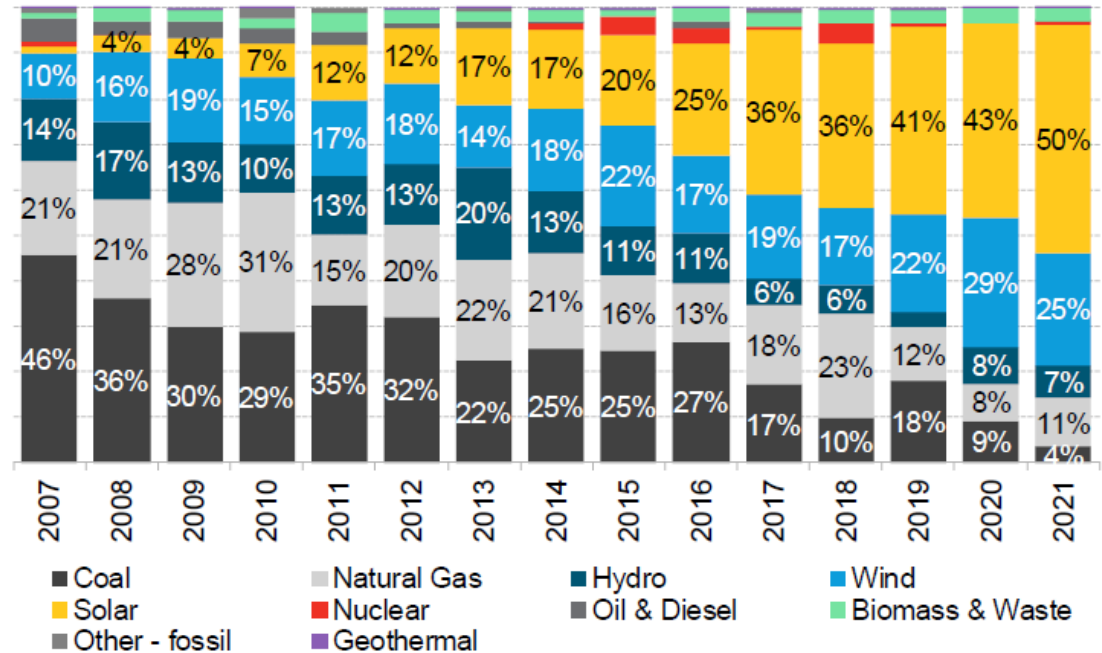
Empiric trends:

Electricity supply dominated by PV and wind power

Generation mix will adapt to the mix of new installations, year by year

Fossil-nuclear generation will be increasingly irrelevant

Share of global capacity additions by technology

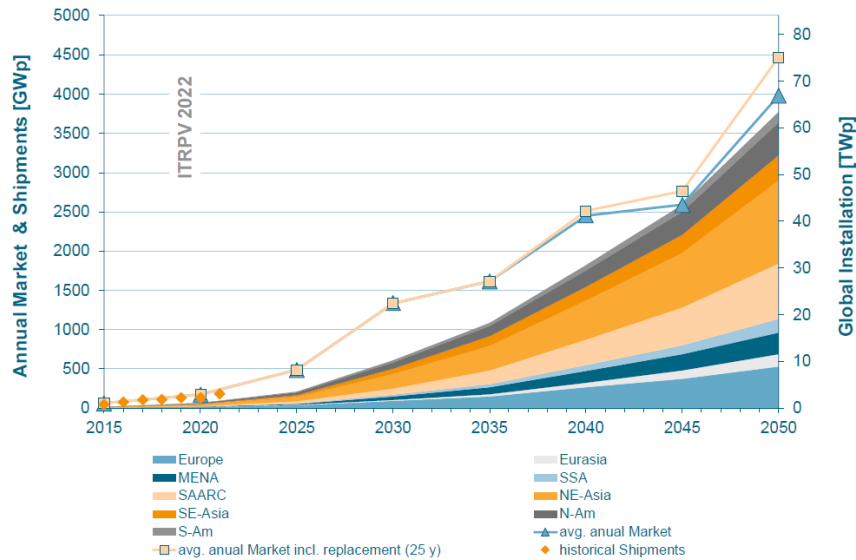


Source: BloombergNEF

Key insights:

- PV and wind power dominate new installations, with clear growth trends for PV
- Hydropower share declines, a consequence of overall capacity rise, and sustainability limits
- Bioenergy (incl. waste) remain on a constant low share
- New coal plants are close to fade out
- New gas plants decline, with very high gas prices pushing them towards peaking operation
- Nuclear is close to be negligible, the heated debate about nuclear lacks empirical facts

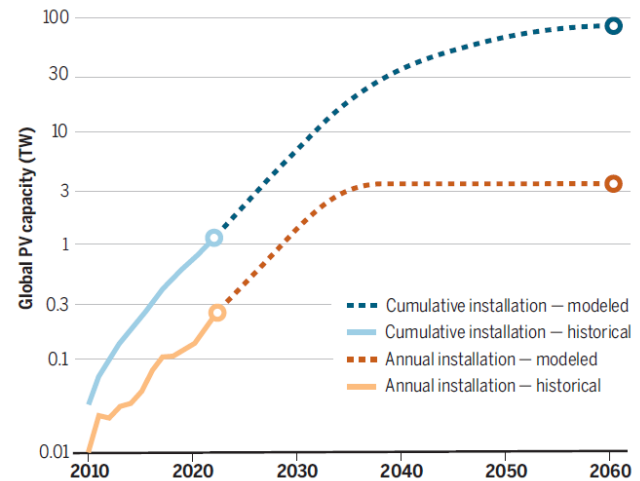
Global: 100% Renewable Energy System by 2050



source: [VDMA, 2022. ITRPV](#)
[Haegel et al., 2023. Science](#)

PV installations and growth toward 75 TW by 2050

Modeled cumulative capacity going forward is based on sustaining 25% production rate growth over the next 7 years and then reducing slowly to steady state. Replacement needs are included by simple subtraction of installations 25 years before the modeled date.

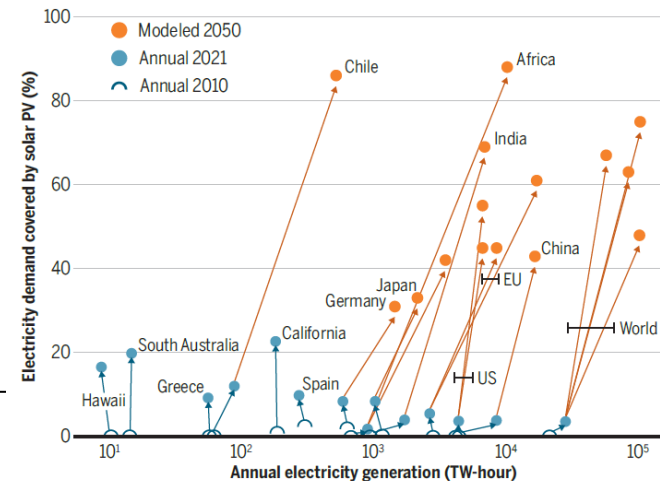


Key insights:

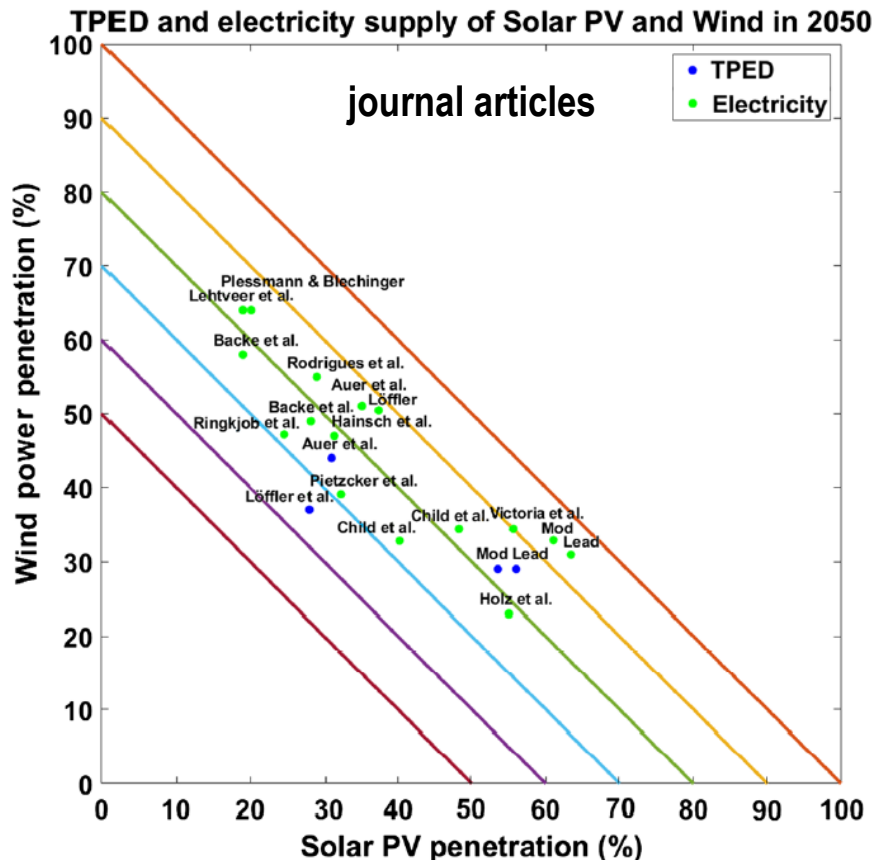
- Low-cost PV leads to a cost-neutral energy transition towards 2050
- This implies about **63 TW of PV by 2050** for the energy system & about **75 TW of PV** for the energy-industry system (chemicals, etc.)
- This leads to about **3 TW/a of PV** installations in 2040s
- This view is now common sense among PV experts
 - **ITRPV** uses this scenario as the most progressive scenario
 - **ISE & NREL & AIST** et al. use this scenario
 - **Pierre Verlinden** based the manufacturing ramping on it

Regional electricity demand supplied by solar PV

The data reflect annual percentages of historical regional demand (2010 and 2021) and modeled demand projections (2050). See supplementary materials for details.



Europe: Solar PV Share in 100% RE Studies



Key insights:

- 2 main groups:
 - high PV & wind: more PV
 - high PV & wind: more wind
- PV & wind electricity share >80% standard
- PV & wind TPED share in 65-85% range
- PV shares around 30-40% by 2050 standard for Europe
- Victoria et al. finds 56% PV share
- This research finds 61-63% PV share
- Reasons for PV shares >50%
 - low-cost of PV & batteries & electrolyzers
 - high levels of electrification
 - high levels of PtX: PV benefits strongly from H₂ buffering
- Difference between 50% and 60% PV share
 - PV differentiation: PV prosumers (RES, COM, IND), fixed and 1-axis plants
 - independent optimisation of PV options

- Major reports for public discourse document lack of up-to-date knowledge of consultants
 - McKinsey (20% PV share in 2050), DNV (15%), Navigant (14%); IEA WEO SDS (13%) NZE without regional data
 - lack of ambition: no 100% RE scenario known, much fossil CCS and nuclear, low levels of electrification
 - oversimplified models: low temporal and spatial resolution, no cost optimisation, low levels of PtX and sector coupling
 - cost assumptions used often violate market trends (too high renewables cost, too low CCS & nuclear costs)

Europe: Scientific studies in journals for PV



Authors	Year	Model	Temporal resolution	Sectors	Regions	electricity generation		generation share		TPED share		RE share	Target year
						PV [TWh]	Wind [TWh]	PV	Wind	PV	Wind		
Breyer et al. – Moderate	2022	LUT-ESTM	Hourly	all	20	10600	5630	61%	33%	54%	29%	99.5%	2050
Breyer et al. - Leadership	2022	LUT-ESTM	Hourly	all	20	12345	6400	63%	32%	56%	29%	100%	2040
Rodrigues et al.	2022	REMIND, PRIMES, TIMES	time slices	all	11	1550	2940	29%	55%	n/a	n/a	96%	2050
Backe et al.]	2022	EMPIRE	Hourly	P,H	35	2050	3550	28%	49%	n/a	n/a	97%	2050
Hainsch et al.	2022	OSeMOSYS - GENeSYS-MOD	time slices	all	-	n/a	n/a	n/a	n/a	n/a	n/a	95%	2050
Backe et al.	2022	EMPIRE	Hourly	P	35	765	2365	19%	58%	n/a	n/a	100%	2050
Holz et al.	2021	EMPIRE	Hourly	P,H,I	-	2140	890	55%	23%	n/a	n/a	96%	2050
Löffler]	2021	OSeMOSYS - GENeSYS-MOD	time slices	P	30	1730	860	37%	50%	n/a	n/a	100%	2050
Lehtveer et al.	2021	H2D	Annually	all	12	480	1600	19%	64%	n/a	n/a	98%	2050
Hainsch et al.	2021	OSeMOSYS - GENeSYS-MOD	time slices	P,H	17	2160	3360	30%	47%	n/a	n/a	96.0%	2050
Pietzcker et al.	2021	LIMES-EU	time slices	P	29	1870	2310	32%	39%	n/a	n/a	99.8%	2050
Victoria et al.	2020	PyPSA	Hourly	all	30	3360	2025	56%	34%	n/a	n/a	98%	2040
Ringkjøb et al.	2020	TIMES	time slices	all	28	970	1870	25%	47%	n/a	n/a	97%	2050
Auer et al.	2020	OSeMOSYS - GENeSYS-MOD	time slices	all	30	2800	3950	35%	50%	31%	44%	100%	2045
Child et al.	2019	LUT-ESTM	Hourly	P	20	2340	1900	41%	33%	n/a	n/a	99.8%	2035
Löffler et al.	2019	OSeMOSYS - GENeSYS-MOD	time slices	all	17	2330	3080	n/a	n/a	28%	37%	97%	2050
Child et al.	2018	LUT-ESTM	Hourly	P	20	2750	1960	48%	34%	n/a	n/a	99.8%	2035
Pleißmann and Blechinger	2017	elesplan-m	Hourly	P	18	1200	3800	20%	64%	n/a	n/a	98%	2040

- **PV shares around 30-40% by 2050** standard for Europe
- **3 studies are at PV share of >50%**
 - **Victoria et al. at 56% PV share**
 - **Breyer et al. (with SPE) at 61-63% PV share**
 - **Holz et al. at 55% PV share**

Europe: Reports of stakeholders for PV



Authors	Year	Model	Temporal resolution	Sectors	Regions	electricity generation		electricity generation share		TPED share		RE share ¹	Target year ²
						PV [TWh]	Wind [TWh]	PV	Wind	PV	Wind		
Breyer et al. – Moderate	2022	LUT-ESTM	Hourly	all	20	10600	5630	61%	33%	54%	29%	99.5%	2050
Breyer et al. - Leadership ¹	2022	LUT-ESTM	Hourly	all	20	12345	6400	63%	32%	56%	29%	100%	2040
ENTSO-E, TYNDP 2022	2021	n/a	n/a	all	n/a	1105	3803	18%	63%	12%	42%	98%	2050
Eurelectric Scenario 3	2018	McKinsey	n/a	all	8	1200	4000	20%	67%	n/a	n/a	82%	2045
WindEurope Paris Compatible	2018	DNV ETO	Annual	all	1	900	2223	15%	36%	n/a	n/a	78%	2050
EC 1.5 TECH	2018	PRIMES	Time slices	all	1	1232	4252	16%	53%	n/a	n/a	83%	2050
CAN Europe PAC	2021	unspecified	n/a	all ³	1	2500	3600	38%	55%	32%	46%	100%	2050
Navigant Optimised gas	2019	Navigant Energy System Model	Hourly	all	1	1000	4000	14%	56%	n/a	n/a	88%	2050
IEA WEO SDS ⁴	2020	IEA World Energy Model	Annual	all	1	747	2131	13%	38%	4%	13%	76%	2040
Greenpeace Adv E[R]	2015	Mesap/PlaNet (DLR-EM)	Annual	all	1	1080	2351	19%	41%	9%	21%	100%	2050

¹ RE share in electricity generation

² target year of displayed numbers

³ electric vehicles and power-to-heat are excluded

⁴ IEA WEO NZE no regional numbers disclosed due to lacking transparency

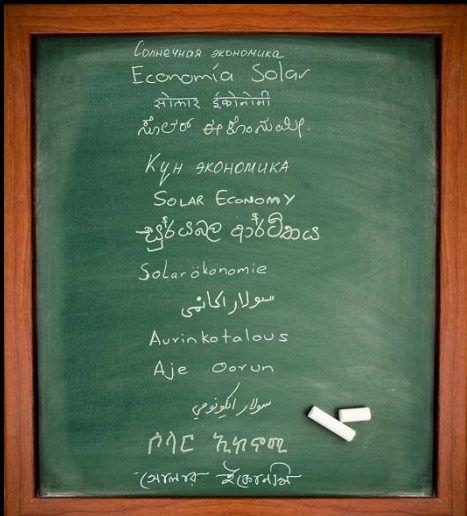
- **PV shares around 15-20% by 2050 for Europe**
- **Massive lack of knowledge at key stakeholders, in particular consultants lacking behind many years**
- **Lack of visions, lack of proper modelling tools, lack of sector coupling & electrification knowledge**
- **PV community have to push stakeholders on basis of scientific studies published in journals**

Key messages



- **PV is the least cost source of electricity, globally and in Europe**
- **PV and wind power are the central and dominant pillars of energy supply**
- **PV share (science) found at 30-40% as standard, with 50-60% in relevant studies**
- **PV share (stakeholders) found at 15-20%, due to multiple deficits**
- **PV community needs to push stakeholders for catching up with science**

Thank you for your attention and to the team!



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