

Developments in the German PV Sector

Technology advances and cluster building

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eclareon GmbH

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Solar Boom in the USA

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eclareon GmbH Management Consultants

TASK	International consulting firm with a focus on the renewable energy and energy efficiency sectors
SERVICES	Market and Industry Analysis, Industry Consulting, Mergers & Acquisitions, Policy Consulting
HISTORY	Founded in 2000.
CLIENTS	Manufacturers of systems & components Wholesalers & suppliers Planners & installers Public bodies
OFFICES	Berlin, Madrid & Milan; 20 people

PRESENTATION OVERVIEW

Market Overview

Technology Overview

Research Initiatives

Economic Development

PRESENTATION OVERVIEW

Market Overview

- Market segmentation
- Installation diagram

Technology Overview

Research Initiatives

Economic Development



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MARKET

TECHNOLOGY

RESEARCH

ECONOMIC DEVELOPMENT

MARKET SEGMENTATION

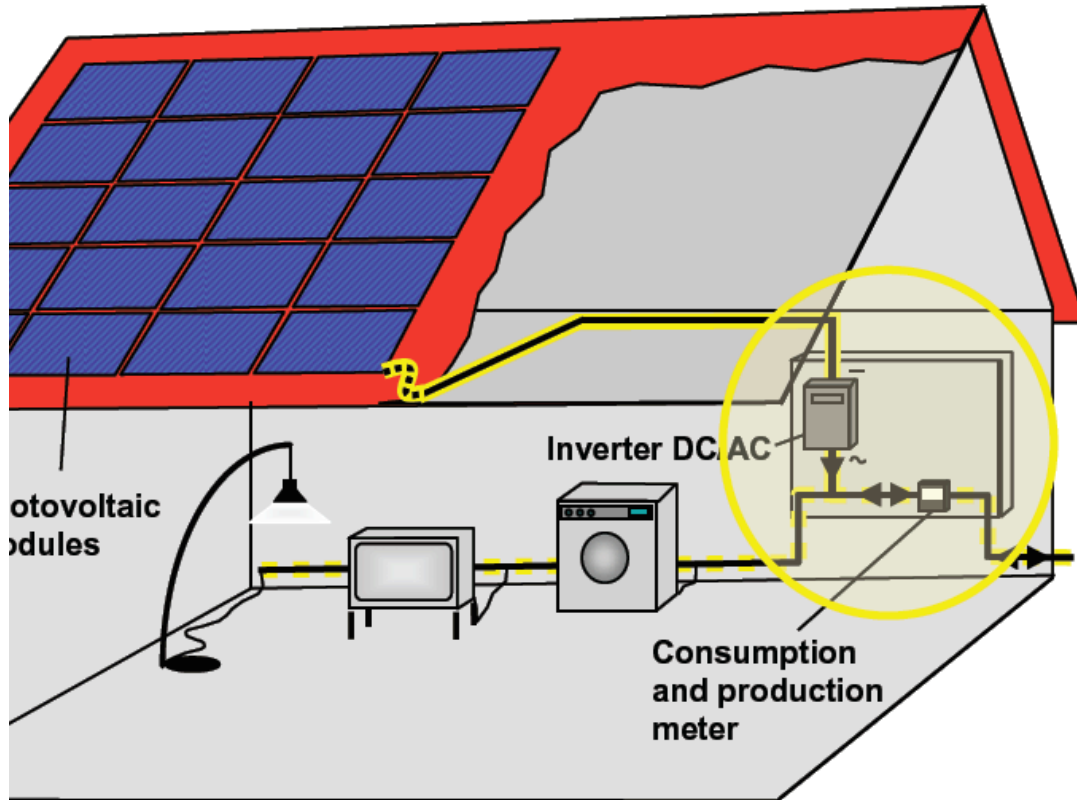
The majority of the installed capacity in Germany is in roof top systems 100 kWp and smaller



Source: BSW (2008)

INSTALLATION OVERVIEW

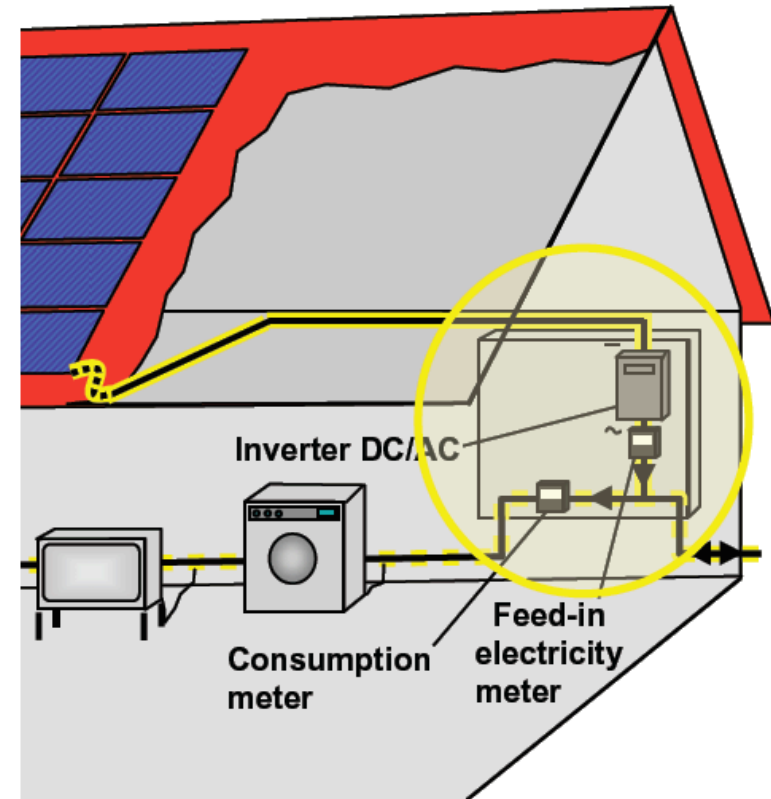
Energy offsets



USA: Net-metering

Solar electricity is used for own consumption first, only excess electricity is fed into the grid

Energy production



Germany: Feed-in tariff

Solar electricity is exclusively fed into the grid



PRESENTATION OVERVIEW

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- Current technologies and market share
- Price reductions and efficiency increases



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ECONOMIC DEVELOPMENT

The PV industry is extremely dynamic and innovative. Hundreds of new product concepts may be clustered in 5 major groups.

Overview of alternative technologies groups competing with standard c-Si PV

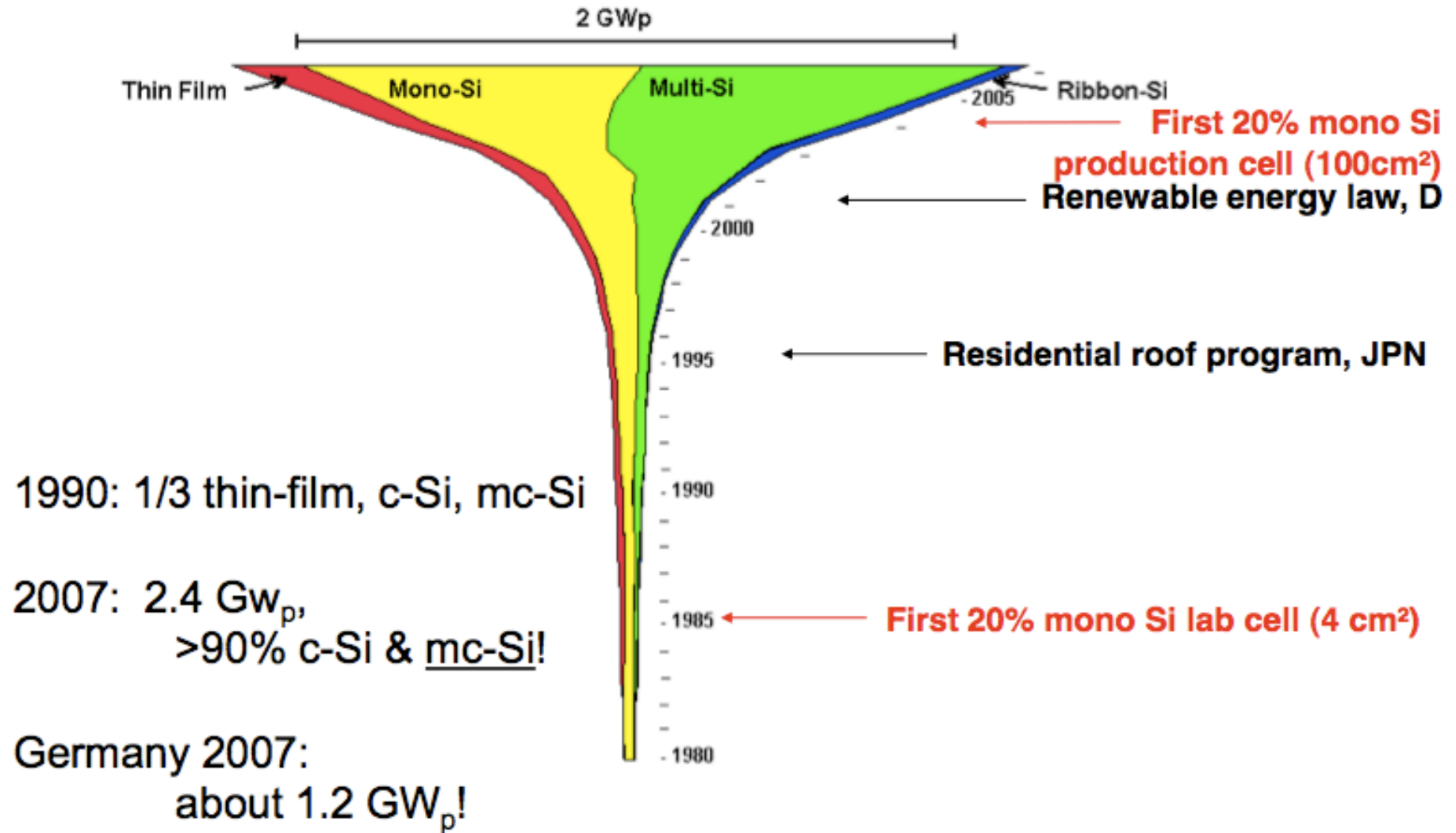
	1st generation	2nd generation	2nd generation	3rd generation	3rd generation
	Standard c-Si technologies	Non Standard c-Si technologies	Thin film technologies	Concentration technologies	Emerging PV cell technologies
Major types	Mono c-Si Poly c-Si Ribbon c-Si	Various individual concepts (HIT, Saturn, PERL, Point contact, etc.)	Amorphous Si (a-Si) Hybrid Si (micro / micromorph Si) CIS / CISG CdTe	II junction (tandem) cells III-V junction cells	Dye cells Organic cells
Cell efficiency	Average / standard	High	Low	Very high	Very low
Production cost	Average / standard	High	Low	Very high	High
Development stage	Mature	Early > mature	Very early > mature	Very early	Embryonic
Number of players	Many	Few, increasing	Increasing	Few	Very few

Thin-film technologies are distinguished by semiconductor material and production process characteristics.

	CdTe	CIS (CIGS)	Hybrid Si	a-Si
Semi-conductor material (thin-film layer)	<ul style="list-style-type: none"> • Cadmium-Tellurid 	<ul style="list-style-type: none"> • Copper-Indium-Selenide (Gallium) 	<ul style="list-style-type: none"> • Amorphous Si + Micro Si (2+ layers) • Micromorphous Si 	<ul style="list-style-type: none"> • Amorphous Si
Substrate material	<ul style="list-style-type: none"> • Glass 	<ul style="list-style-type: none"> • Glass • Flexible materials (e.g. stainless steel, plastics) 	<ul style="list-style-type: none"> • Glass 	<ul style="list-style-type: none"> • Glass • Flexible materials (e.g. stainless steel, plastics)
Efficiency (future potential)	<ul style="list-style-type: none"> • 7-9 % (< 14%) 	<ul style="list-style-type: none"> • 9-11% (< 16%) 	<ul style="list-style-type: none"> • 13-15% (> 20%) 	<ul style="list-style-type: none"> • 5-7% (< 10%)

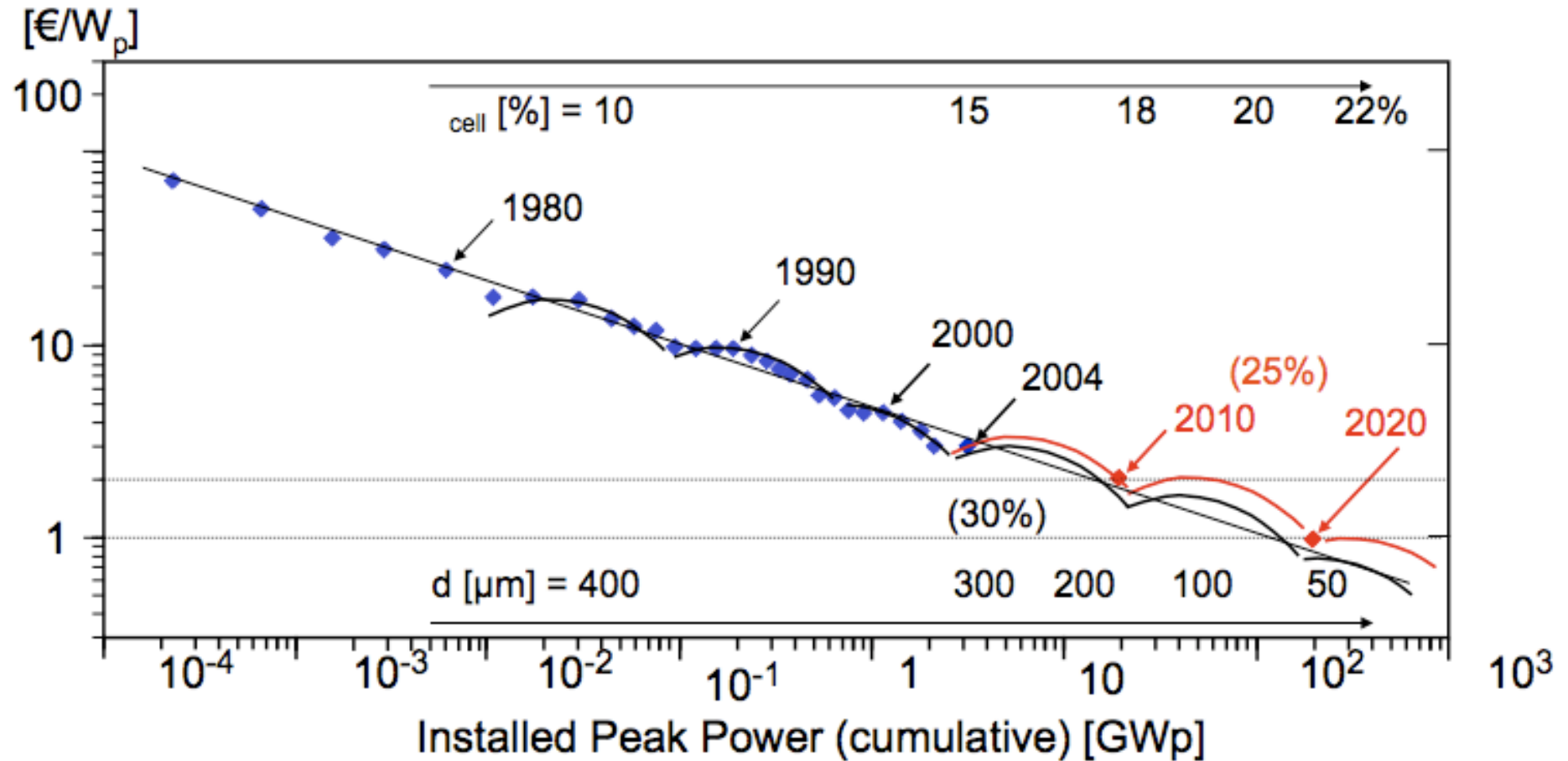


Crystalline silicon technologies hold dominant market share



Source: G. Willeke 2008, Eicke Weber

Economies of scale drive down Wp prices – innovation in engineering and production techniques



Source: G. Willeke 2008, Eicke Weber



The great challenge for cell producers is to reduce unitary production costs. Apart from economies of scale this can be achieved by constant process innovation.

Key activities conducted by cell manufacturers to achieve unitary cost reductions

Target	Key measures	What is required?	Is size an advantage?
Economies of scale	<ul style="list-style-type: none"> • Increase production volumes (gigawatt factories) 	High CAPEX	Yes
Increase cell efficiency	<ul style="list-style-type: none"> • Various techniques 	High R&D expenditures	No
Decrease cell thickness	<ul style="list-style-type: none"> • Process thinner wafers 	Preferential agreements with wafer suppliers	No
Increase throughput	<ul style="list-style-type: none"> • Higher automation / less manual handling steps • More HR to clean the machines 	Strong production / supply chain management know-how	No
Increase yield	<ul style="list-style-type: none"> • Reduce breakage rates 	Quality management New line concepts (belt to belt)	No

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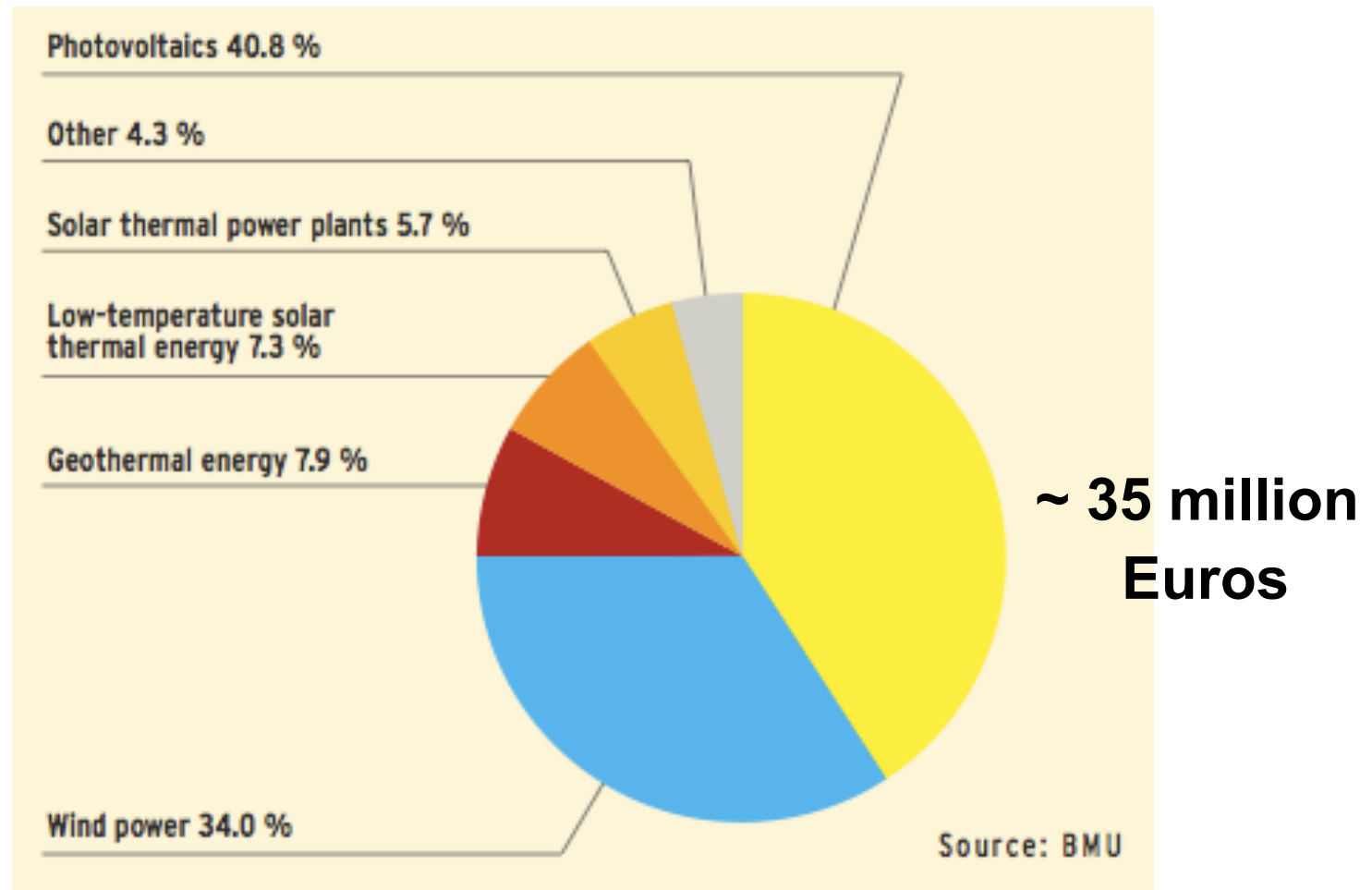
Research Initiatives

Economic Development

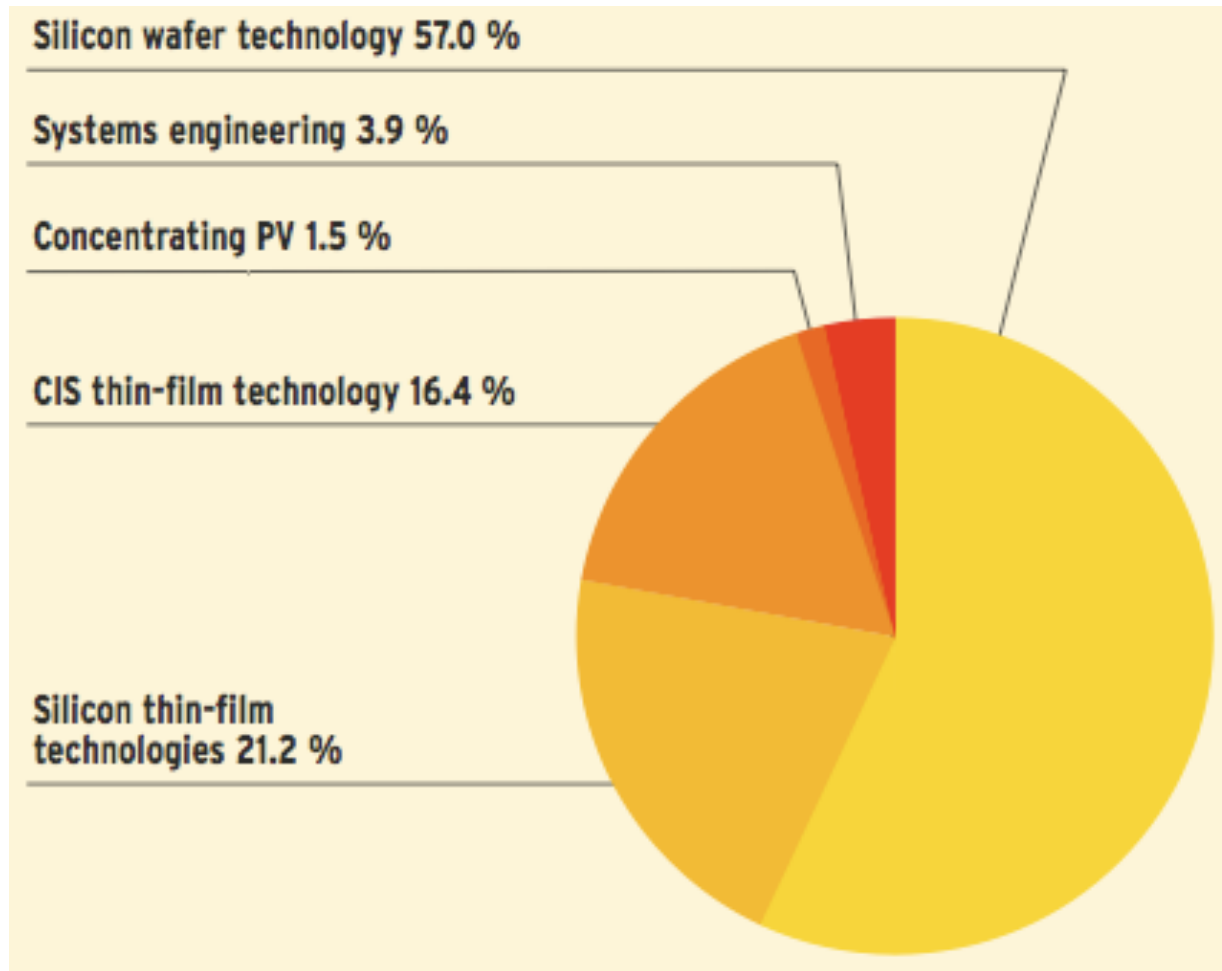
- Federal programs
- Research institutes and education



Federal Ministry for the Environment – 88 million Euros in renewable energy in 2007



Federal Ministry for the Environment – 88 million Euros in renewable energy in 2007 (~35 million in PV)



World class education, research and innovation

- **Where it all started: Fraunhofer Institute for Solar Energy Systems (ISE) and University of Freiburg**
 - **>580 employees and ~35 million Euro budget**
- **SolarValley: The world's largest solar PV cluster**
 - **4 technical universities**
 - **7 research centers including Fraunhofer Center for Sillicium PV, Max-Planck Institute for Microstructure Physics and the Leibniz Institute for Crsytal Growth.**
- **Thin film research center, Berlin-Brandenburg**



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Research Initiatives

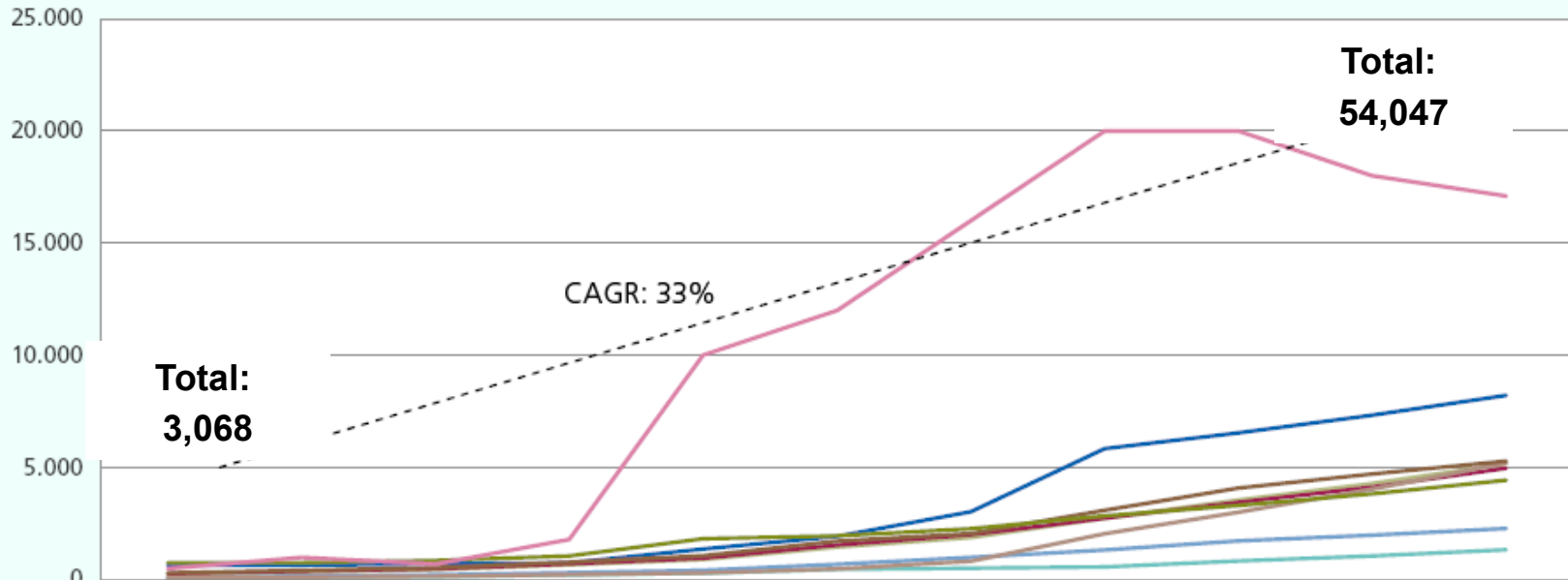
Economic Development

- **Jobs**
- **Financial support**
- **Cluster building**



Jobs in the German photovoltaic sector

Quelle: EuPD Research 2008



	2000	2001	2002	2003	2004	2005	2006	2007e	2008e	2009e	2010e
Supplier	666	666	713	761	1.379	1.937	3.036	5.847	6.551	7.339	8.222
Silicon	84	119	151	217	295	475	531	576	844	1.064	1.348
Wafer/Ingots	122	173	219	316	428	690	996	1.332	1.732	1.992	2.286
Cells	260	368	465	671	909	1.465	1.877	2.742	3.549	4.283	5.168
C-modules	275	389	492	710	962	1.550	2.022	2.740	3.443	4.132	4.966
Thin film modules	88	124	157	226	307	495	828	2.057	3.014	4.036	5.210
BOS	306	433	548	790	1.071	1.727	2.067	3.105	4.086	4.722	5.299
Wholesaler	769	769	865	1.057	1.825	1.960	2.278	2.861	3.314	3.840	4.448
Craftsmen	500	1.000	700	1.800	10.000	12.000	16.000	20.000	20.000	18.000	17.100
Total	3.068	4.041	4.310	6.548	17.176	22.298	29.633	41.260	46.533	49.408	54.047

Source: Standortgutachten EuPD Research/ifo 2008



‘Solar Valley’ emerges as leading PV cluster, focusing on crystalline research and production innovations

- Winner of German Federal Ministry of Education and Research’s ‘Top Cluster’ competition – up to 200 million Euros in funding
- Solar Valley’s goal is economic competitiveness of PV:
 - Grid parity in Germany by 2015 by reducing total system price through increased production efficiency, economies of scale and technology advances



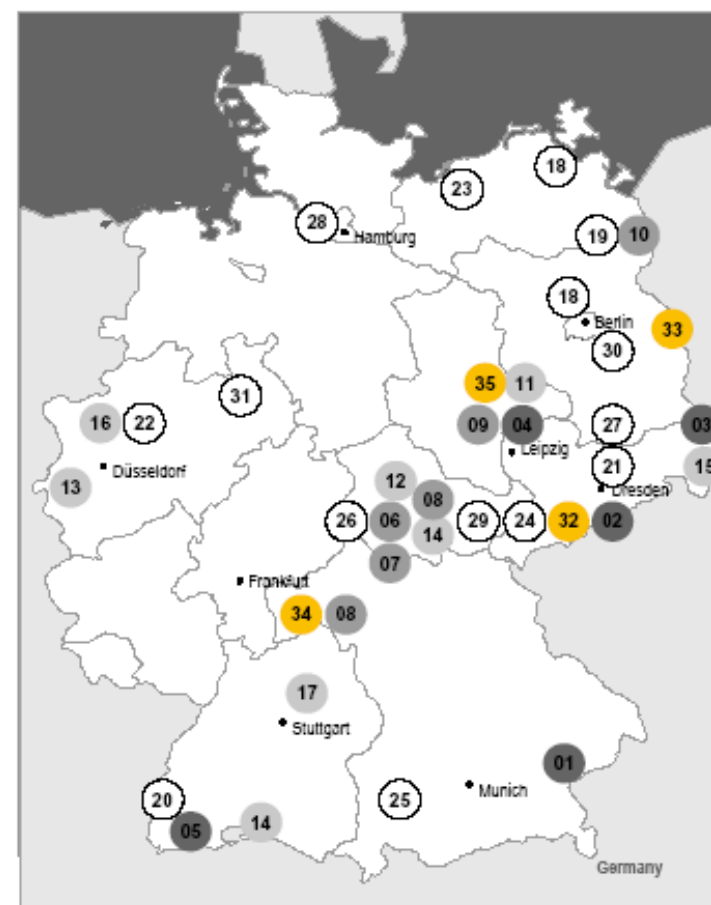
Economic growth through technology development and cooperation

- Economic rebound: 27 international **corporations**, 7 renowned **research centers**, 4 **universities**, 3 federal states with roughly 8,500 jobs in the sector today.
- Projection of 15,000 skilled jobs by 2011 and over 60,000 jobs by 2020
- Currently produces 80% of PV modules in Germany, 20% of world wide production with (German PV sector has annual turnover of roughly \$7.4 Billion USD)



Germany hosts the world's largest PV cluster (1) Companies in wafer-based technologies

Value Chain	No.	Company	Location	Capacity 2008 [MWp]	Current Empl.	
Silicon	1	Wacker Chemie	Burghausen	10,000t	960	
	2	Scheuten Solar World Solizium	Freiberg ¹	1000t	n/a	
	3	Sunways	Spreewitz ¹	1000t	n/a	
	4	PV Silicon	Bitterfeld-Wolfen ¹	900t	20	
	5	Joint Solar Silicon	Rheinfelden ¹	850t	10	
Wafers	6	PV Silicon ²	Erfurt	290	160	
	7	ASi Industries ³	Amstadt	180	480	
	8	Wacker Schott Solar	Alzenau, Jena ¹	120	300	
	9	Q-Cells	Thalheim ¹	80	10	
	10	Mola Solaire	Pasewalk ¹	n/a	n/a	
Cells	11	Q-Cells	Thalheim	760	1900	
	12	Ersol Solar Energy	Erfurt, Arnstadt	220	300	
	13	Solland Solar Cells	Aachen	170	300	
	14	Sunways	Konstanz, Amstadt	120	290	
	15	Arise Technologies	Bischofswerda	35	10	
	16	Scheuten Solar Cells	Gelsenkirchen	35	80	
	17	Solarwatt	Heilbronn	15	60	
	Modules	18	Solon	Berlin, Greifswald	260	400
		19	Aleo Solar	Prenzlau	170	425
		20	Solar-Fabrik	Freiburg	130	290
21		Solarwatt	Dresden	120	430	
22		Scheuten Solar Technology	Gelsenkirchen	90	140	
23		Centrosolar / Solara	Wismar	80	160	
24		Heckert Solar	Chemnitz	60	120	
25		Webasto Solar	Landsberg/Lech	35	20	
26		Asola	Erfurt	30	100	
27		Algatec	Elsterwerda	15	65	
28		Solamova	Wedel	10	30	
29		GSS	Löbichau	10	30	
30		PVflex Solar	Fürstenwalde	5	30	
31		Schüco Solar	Bielefeld	5	450	
Fully Integrated	32	Solarworld ⁵	Freiberg	450/300/250	1200	
(Wafers/Cells/Modules)	33	Conergy ²	Frankfurt (Oder) ¹	250/250/250	370	
	34	Schott Solar ⁶	Alzenau	160/275/200	450	
	35	EverQ	Thalheim	100/100/100	1000	



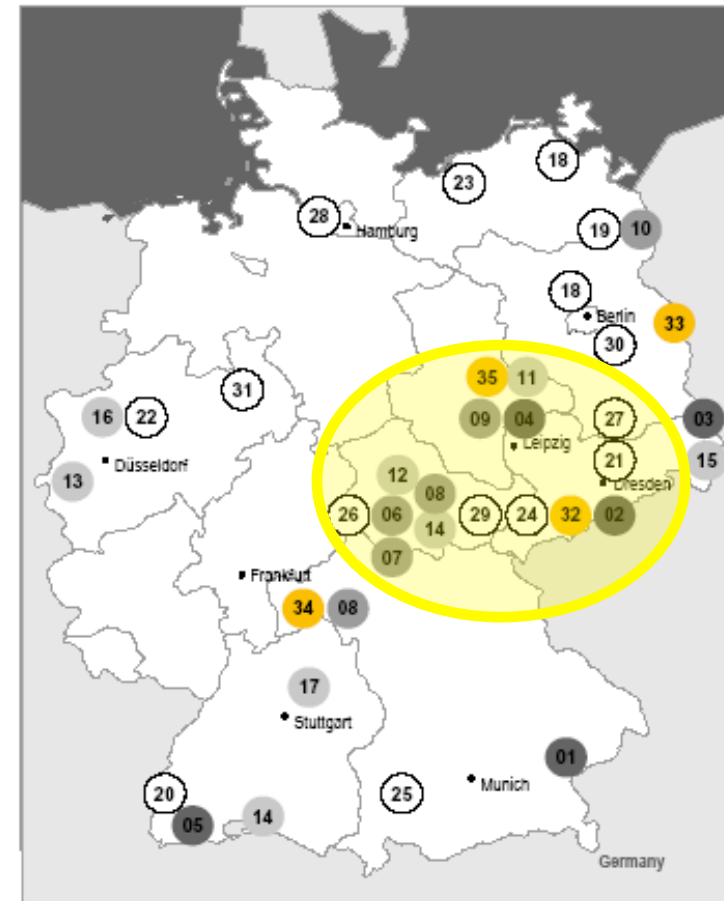
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- 6) Wafer production by Wacker Schott Solar No. 8

Source: Invest in Germany Research, Information provided by the respective company, July 2008

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Germany hosts the world's largest PV cluster (1) Companies in wafer-based technologies

- PV silicon wafer based manufacturing in 'solar valley':
- 3 of the largest silicon plants
- The 4 largest wafer plants
- The 2 largest cell plants
- 5 module assembly plants
- The largest fully integrated plant



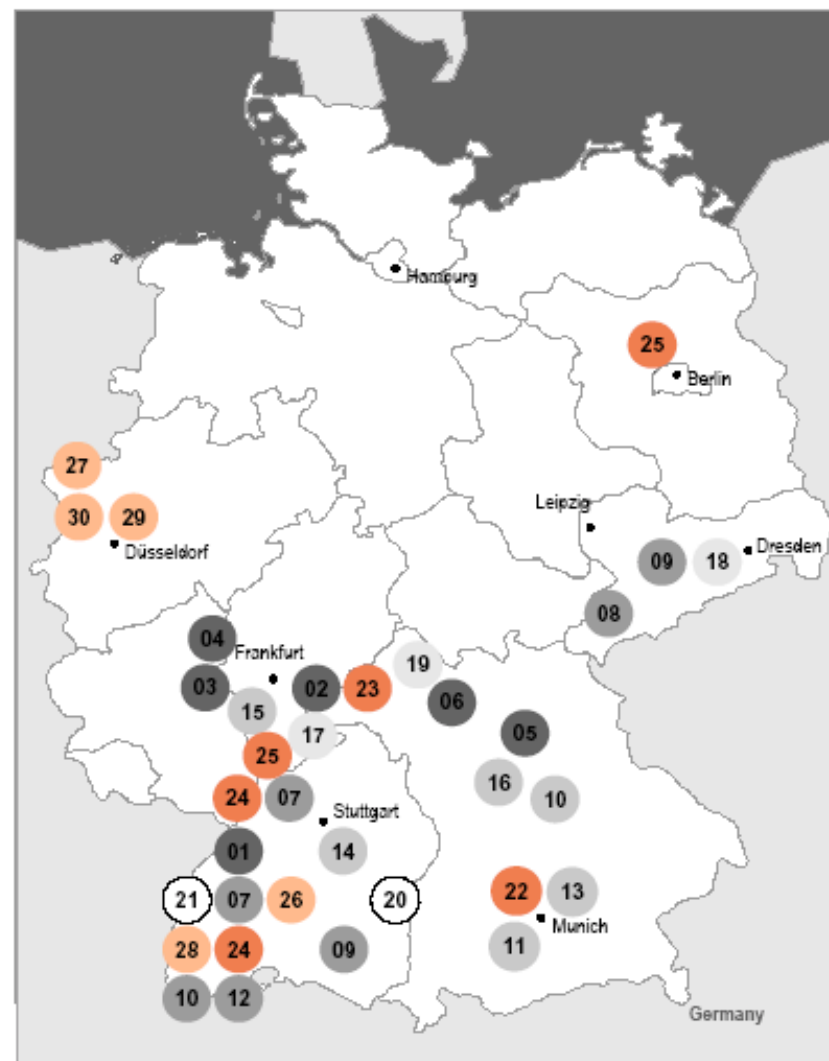
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Proximity to leading PV equipment companies accelerates production ramp-up (1)

Equipment	No.	Company	Location	Empl.
Ingots/Wafers - Equipment	1	Gebrüder Schmid	Freudenstadt	380
	2	ALD Vacuum Technologies	Hanau	360
	3	Herbert Arnold	Weilburg	130
	4	CGS / PVA Tepla	Asslar	50
	5	G&N	Erlangen	40
	6	Logomatic	Mainaschaff	20
Cells - Turnkey Lines	7	Gebrüder Schmid	Freudenstadt, Schwetzingen	430
	8	Roth & Rau	Hohenstein-Ernstthal	300
	9	Centrotherm Photovoltaics	Blaubeuren, Dresden	200
Cells - Wet Chemistry	10	Rena	Gütenbach, Berg	450
	11	Stangl Semiconductor	Eichenau, Puchheim	100
	12	Lotus Systems	Gutmadingen	70
	13	Ramgraber	Hofolding b. Braunthal	40
	14	HMS Höllmüller	Herrenberg	40
	15	M-O-T	Speyer	20
	16	Decker	Berching	30
Cells - Anti-reflective Coating	17	Applied Materials	Alzenau	500
	18	Von Ardenne Anlagentechnik	Dresden	400
	19	Singulus	Kahl	300
Cells - Screenprinters	20	Manz Automation	Reutlingen	400
	21	Thieme	Teningen	350
Modules - Turnkey Lines	22	Kuka Systems	Augsburg	1200
	22	Reis Robotics	Oberruberg	720
	23	Gebrüder Schmid	Freudenstadt, Niedereeschach	530
	24	Teamtechnik	Freiburg am Neckar, Berlin	350
Modules - Tabbers, Stringers, Laminators	25	Robert Bürkle	Freudenstadt	350
	26	Meier Vakuumtechnik	Bocholt	170
	27	Somont	Umkirch	100
	28	Robust	Remscheid	50
	29	SunWare	Duisburg	20
	30	Solarwatt	Dresden	20



Source: Invest in Germany Research, Information provided by the respective company, March 2008

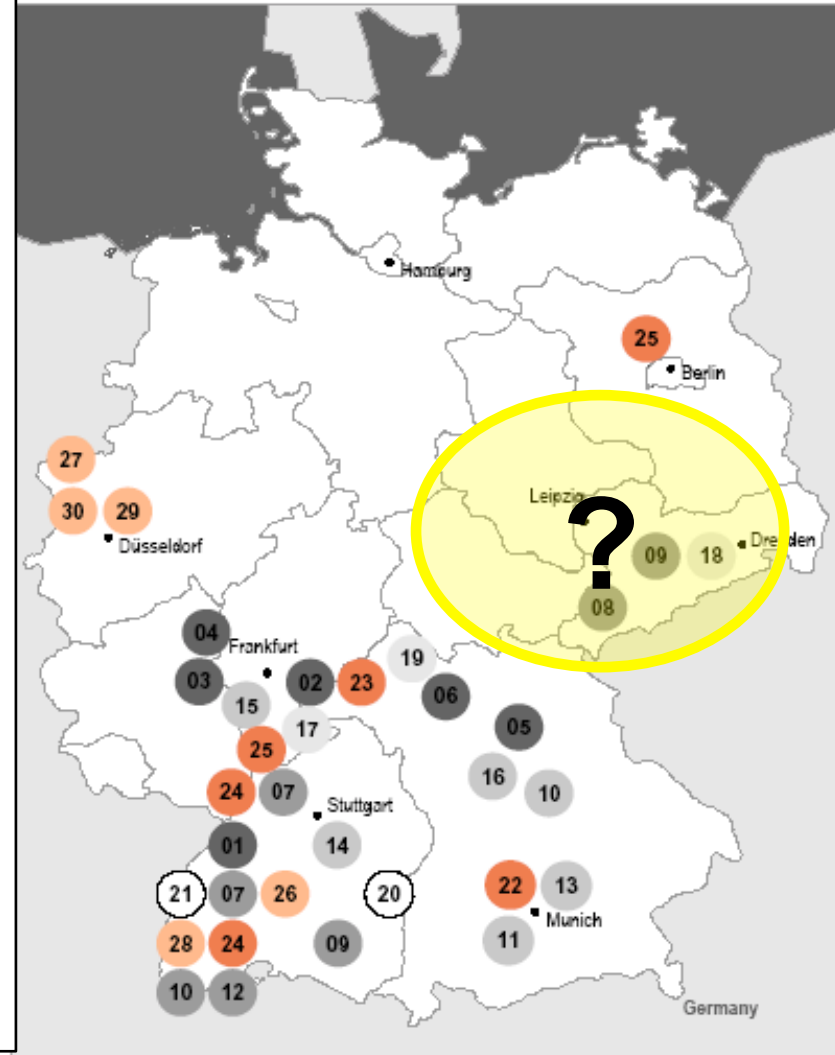
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COOPERATION

Proximity to leading PV equipment companies accelerates production ramp-up

- Production equipment and technical processing is based in Baden-Wurttemberg and Bayern...



Source: Invest in Germany Research, Information provided by the respective company, March 2008

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MARKET

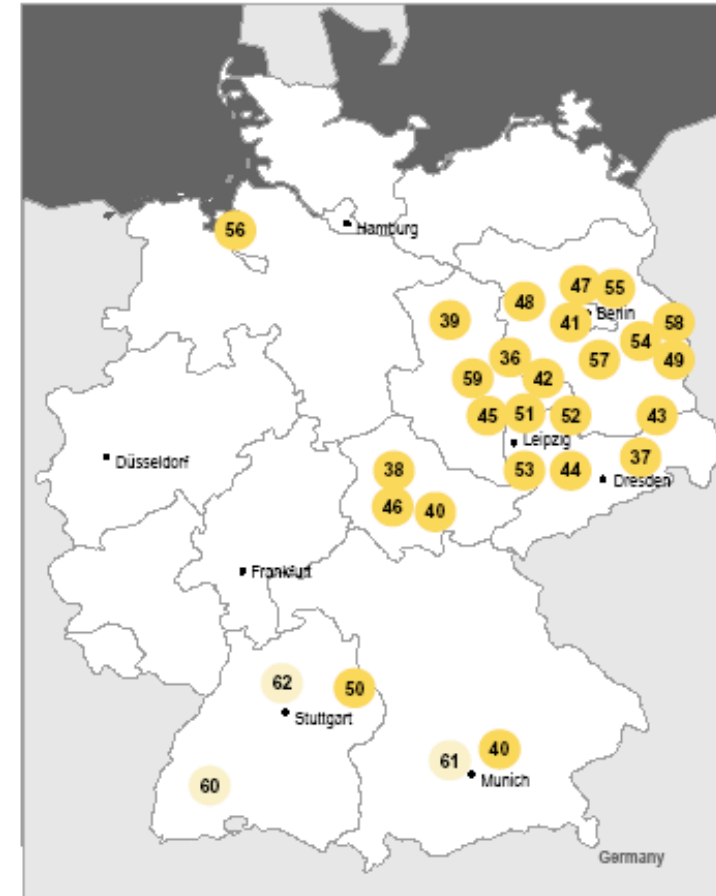
TECHNOLOGY

RESEARCH

ECONOMIC DEVELOPMENT

Germany hosts the world's largest PV cluster (2) Companies in thin-film technologies

Value Chain	No.	Company	Location	Capacity 2008 [MWp]	Current Empl.
Thin Film					
Poly-Si	36	CSG Solar	Thalheim	20	150
a-Si	37	Sunfilm	Großröhrsdorf ¹	60	50
a-Si/ μ c-Si	38	Ersol Thin Film	Erfurt	40	180
	39	Malibu	Osterweddingen ¹	40	150
	40	Schott Solar Thin Film	Jena, Putzbrunn ¹	30	160
	41	Inventux	Berlin ¹	30	n/a
	42	Sontor ⁴	Thalheim	25	60
	43	EPV	Senftenberg ¹	25	n/a
	44	Signet Solar	Mochau	20	70
	45	Intico Solar	Halle ¹	n/a	n/a
	46	Masdar PV	Amstadt ¹	n/a	n/a
	CIS	47	Global Solar Energy	Berlin ¹	35
CIGS	48	Johanna Solar Technology	Brandenburg	30	100
CIGS _{Se}	49	Odersun	Frankfurt (Oder), Fürstenwalde ¹	30	90
	50	Würth Solar	Schwäbisch Hall	30	220
	51	Solibro ⁴	Thalheim ¹	25	150
	52	Avancis	Torgau ¹	20	60
	53	Solarion	Leipzig	10	35
	54	PVflex Solar	Fürstenwalde	Pilot	130
	55	Sulfurcell	Berlin	Pilot	120
	56	CIS-Solartechnik	Bremerhaven	Pilot	20
	57	Nanosolar	Luckenwalde ¹	n/a	n/a
	CdTe	58	First Solar	Frankfurt (Oder)	175
	59	Calyxo ⁴	Thalheim	25	40



Companies in concentrator technologies

Value Chain	No.	Company	Location	Capacity 2008 [MWp]	Current Empl.
CPV	60	Concentrix Solar	Freiburg	25	70
	61	SolarTec	Munich	10	50
	62	Archimedes Solar	Stuttgart	n/a	n/a

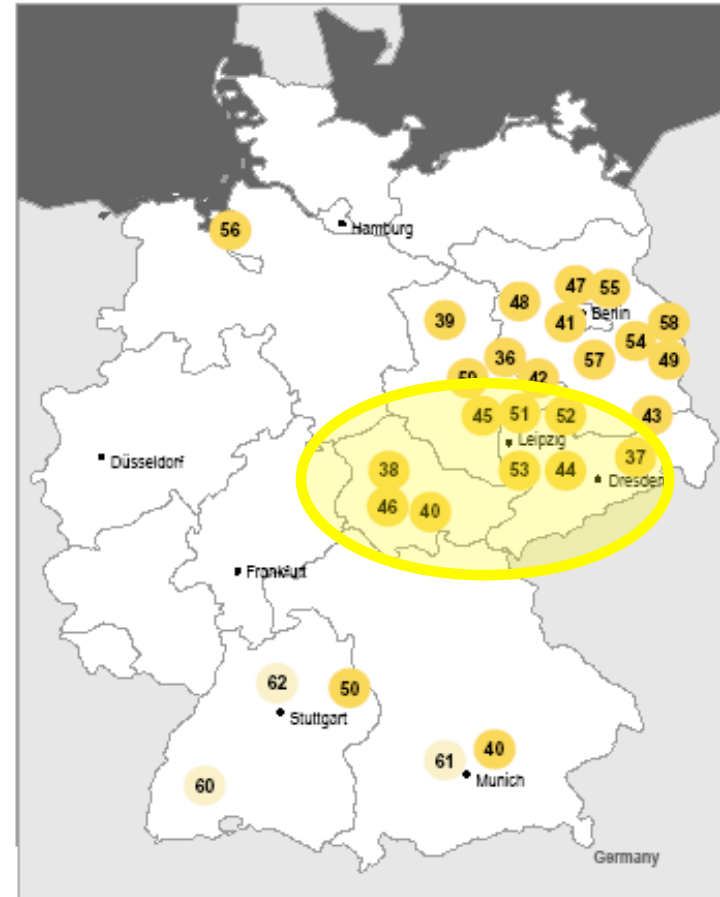
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Source: Invest in Germany Research, Information provided by the respective company, July 2008

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Germany hosts the world's largest PV cluster (2) Companies in thin-film technologies

•Thin film technology manufacturing facilities are spread through 'SolarValley' and Berlin-Brandenburg

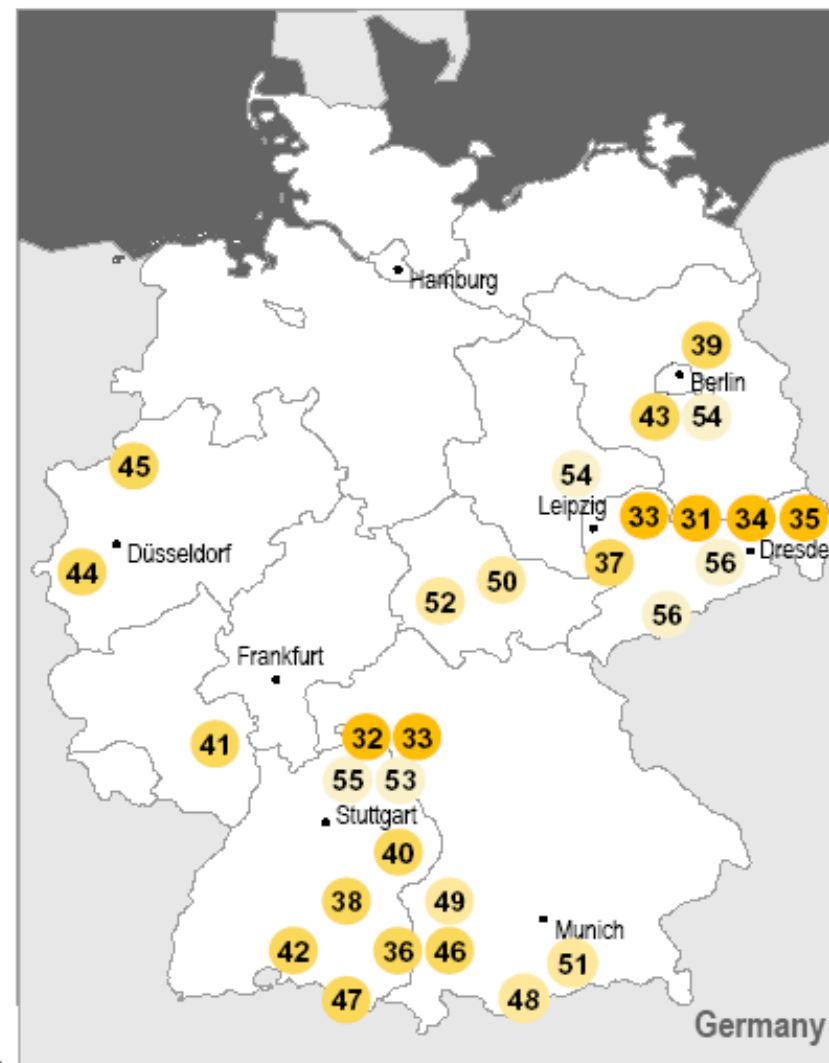


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Proximity to leading PV equipment companies accelerates production ramp-up (2)

Equipment	No.	Company	Location	Empl.
Thin Film - Vacuum Deposition	31	Applied Materials	Alzenau	500
	32	Von Ardenne Anlagentechnik	Dresden	400
	33	Leibold Optics	Alzenau, Dresden	320
	34	FHR Anlagenbau	Ottendorf-Okrilla	90
Automation	36	ASYS Automatisierungssysteme	Domstadt	300
	37	USK Karl Utz Sondermaschinen	Limbach-Oberfrohna	260
	38	Manz Automation	Reutlingen	250
	39	Jonas & Redmann Photovoltaics	Berlin	240
	40	Schiller Automation	Sonnenbühl-Genkingen	200
	41	Minitec Maschinenbau	Waldmohr	140
	42	ACI-ecotec	St. Georgen	70
	43	Feintool Automation	Berlin	60
	44	Maschinenbau Gerold	Nettetal	50
	45	Olbricht	Hamminkeln-Brünen	30
	46	Amb bernhard brain	Gersthofen	20
47	Mondragon Assembly	Stockach	20	
Laser Processing	48	Carl Baasel	Stamberg	350
	49	Manz Automation	Reutlingen	300
	50	Jenoptik Automatisierungstechnik	Jena	170
	51	InnoLas	Krailling	80
	52	LPKF SolarQuipment	Suhl-Friedberg	40
Fab Engineering and Planning	53	M+W Zander FE	Stuttgart	400
	54	IB Vogt	Berlin, Thalheim	160
	55	Caverion	Stuttgart	160
	56	AIC	Chemnitz, Dresden	80



Source: Invest in Germany Research, Information provided by the respective company, March 2008

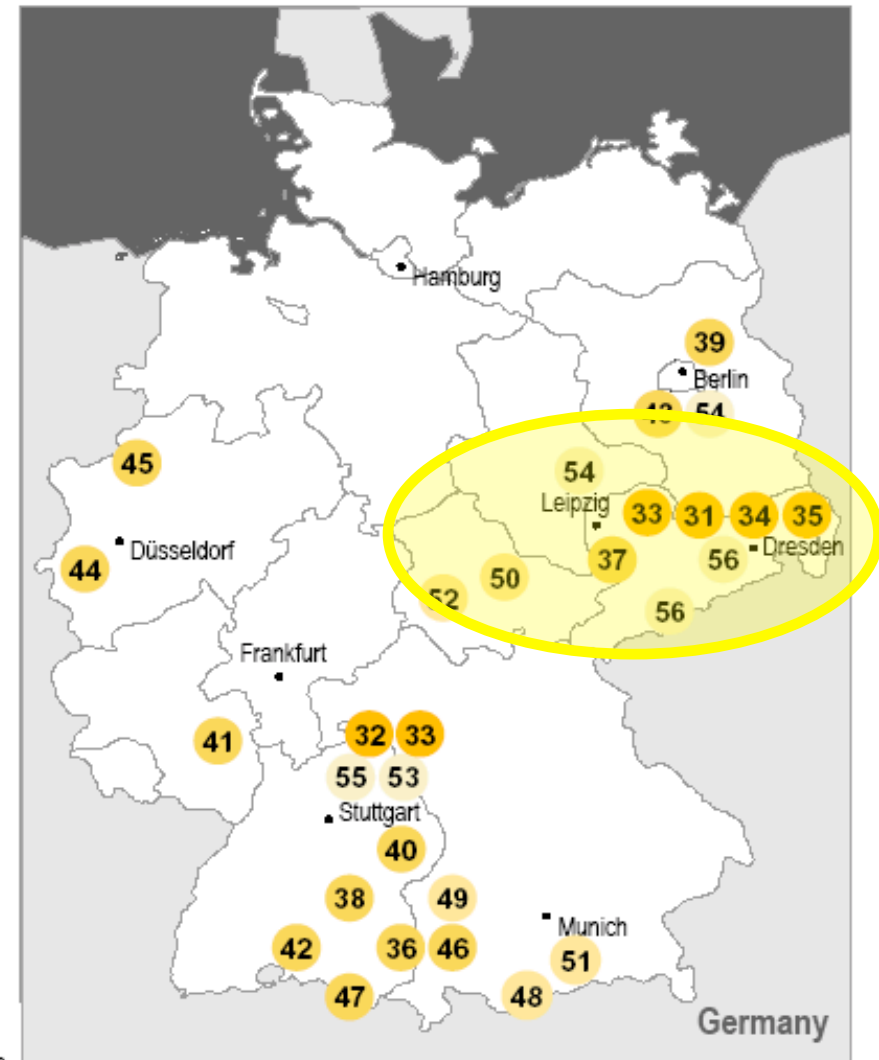
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Proximity to leading PV equipment companies accelerates production ramp-up

- ‘SolarValley’ is home to a number of production equipment manufacturers serving the thin film sector:
- Vacuum deposition
- Laser processing
- Fabrication facility engineering and planning



Source: Invest in Germany Research, Information provided by the respective company, March 2008

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MARKET

TECHNOLOGY

RESEARCH

ECONOMIC DEVELOPMENT

CONCLUSIONS

- Installation **type** drives **technology** specification
- **Crystalline Silicon** is predominant technology in market
- **Thin film** competency is increasing and prices are dropping – will play an important role, but receives more media attention than market penetration
- The key driver is **installed watt peak costs** – economies of scale, process innovation, new technologies, **and** installation cost reductions
- Solar is an ‘emerging industry’ and **research** is vital
- “It’s the economy, stupid”: Solar energy promotes **industry growth** and **job creation**
- Build a **local** market, create **local** jobs

Developments in the German PV Sector

Technology advances and cluster building

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