Economic considerations

System size: This is often referred to as the ‘nameplate capacity’ of the system. Specifically, it is a measure of how much power the system could produce when running at full strength.

System cost: The cost to install the system – most often given on a per-watt basis. For example, if you get a quote for someone to build a 10kW (10,000 watts) nameplate system for €20,000, that is a cost of €2/W.

Watt-hours per watt-peak: The nameplate power is only half of the story: you then need to know how much energy you get out (power delivered over a period of time). So this number measures how many hours per year the system is operational – in other words, how many hours of sun does a system receive.

Productive years: Since the production happens over time, it’s critical to understand how many years the system will work. Most components are warranted for 20-25 years.

Degradation: Systems degrade over time – and this includes the PV modules themselves. Most assume that degradation is between 0.5% and 1% per year. Note that most modules are warranted to perform up to 90% of their rated power for 10 years, and 80% of their rated power for 25 years – numbers that aren't far off from 1% annual loss.

Maintenance: Someone has to clean the modules and repair the broken ones. This is often modeled as a percent of the initial cost (typically about 0.5%), recurring every year.

Inverter replacement: Unfortunately, most inverters need to be replaced. While reliability is improving, most people assume that the inverter will have to be replaced at about year 10.

Nameplate de-rating: PV system is usually rated in the PV field size, but it rarely produces that. There are a lot of steps in processing the power (efficiency losses in the inverter, wire, and other operation), and they eat up about 20% of the power between the module and the grid.

Levelised Cost of Energy LCOE(, also known as Levelized Energy Cost, abbreviated as LEC) is the price at which electricity must be generated from a specific source to break even over the lifetime of the project.

It is very useful in calculating the costs of generation from different sources.

LCOE is an economic assessment of the cost of the energy-generating system including all the costs over its lifetime:
-initial investment,
-cost of capital
-operations and maintenance
-cost of fuel,
-additional costs

LEOC can be defined in a single formula as

$$LEOC = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

where

I_t = investment expenditures in the year *t*

M_t = operations and maintenance expenditures in the year *t*

F_t = fuel expenditures in the year *t*

E_t = electricity generation in the year *t*

r = discount rate

n = life of the system (in years)

Capital costs (including waste disposal and decommisioning costs)

- **low** for fosil fuel power station
- **high** for wind turbines, solar PV;
- **very high** for, wave and tidall, solar thermal, and nuclear.

Fuel costs –

- **high** for fossil fuel and biomass sources,
- **low** for nuclear
- **zero** for many renewables.

Factors such as the costs of waste (and associated issues) and different insurance costs are usually not included

In the case of PV systems:

Cost of fuel is zero

Investments are done in relatively short time before the PV plant starts production

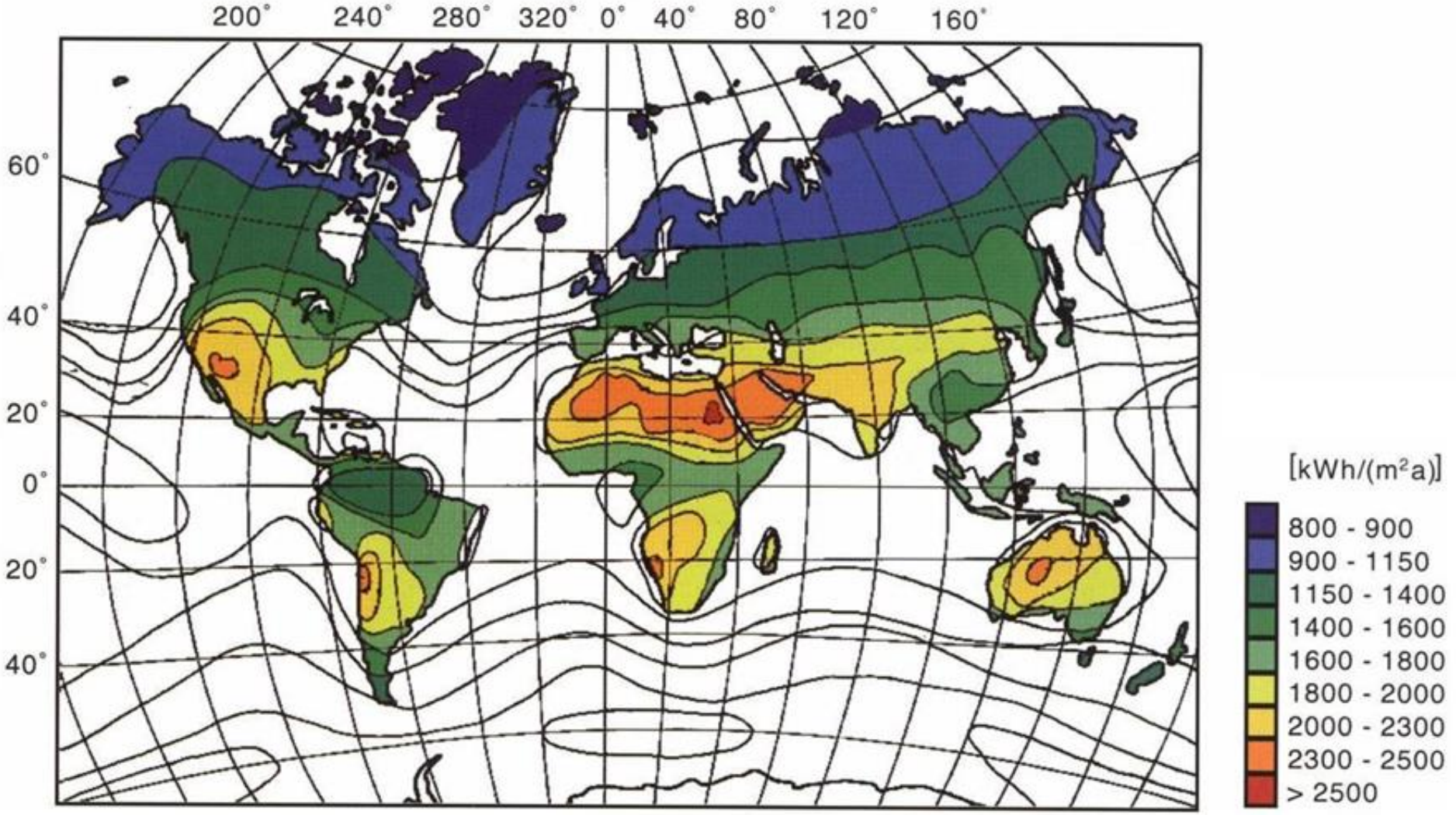
Energy production in the year *t* can be expected as

$$E_t = E_1(1-d)^t$$

Where

E_1 is starting energy production

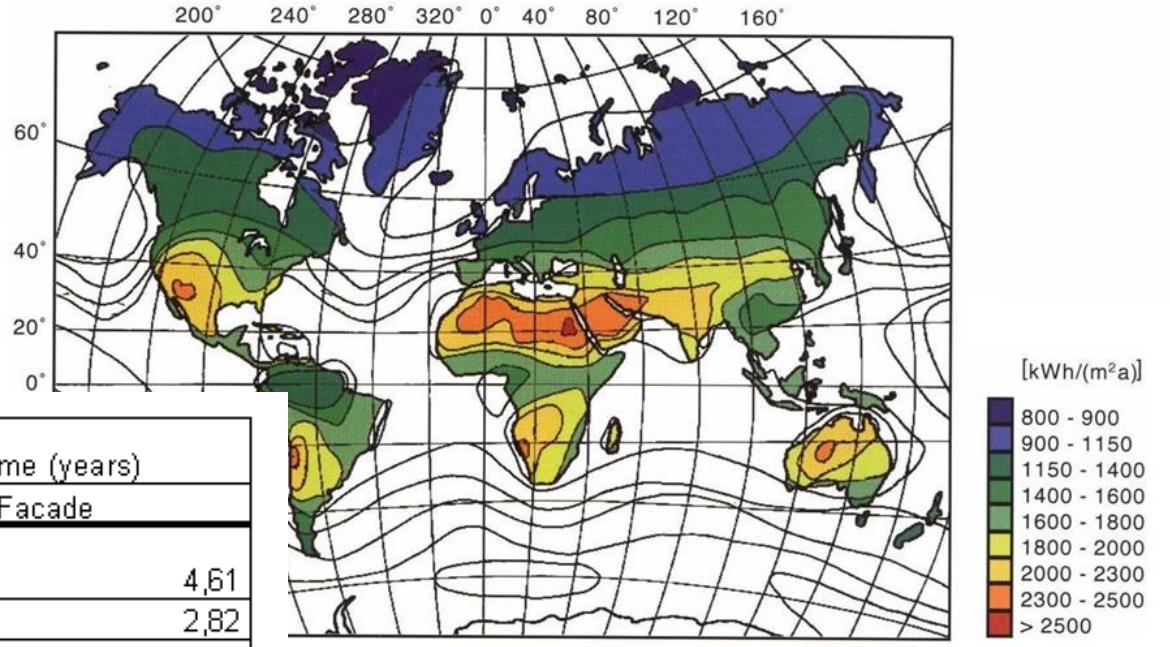
d is the degradation factor (it should include degradation of both PV modules and invertors and transformers)


200°
240°
280°
320°
0°
40°
80°
120°
160°
60°
40°
20°
0°
20°
40°
[kWh/(m²a)]
800 - 900
900 - 1150
1150 - 1400
1400 - 1600
1600 - 1800
1800 - 2000
2000 - 2300
2300 - 2500
> 2500

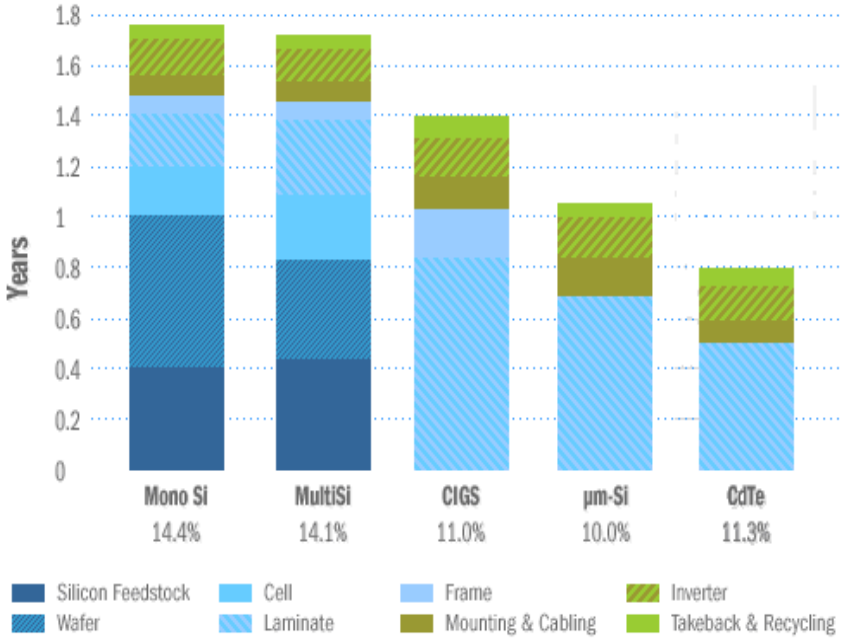
Energy pay back time

In 2004

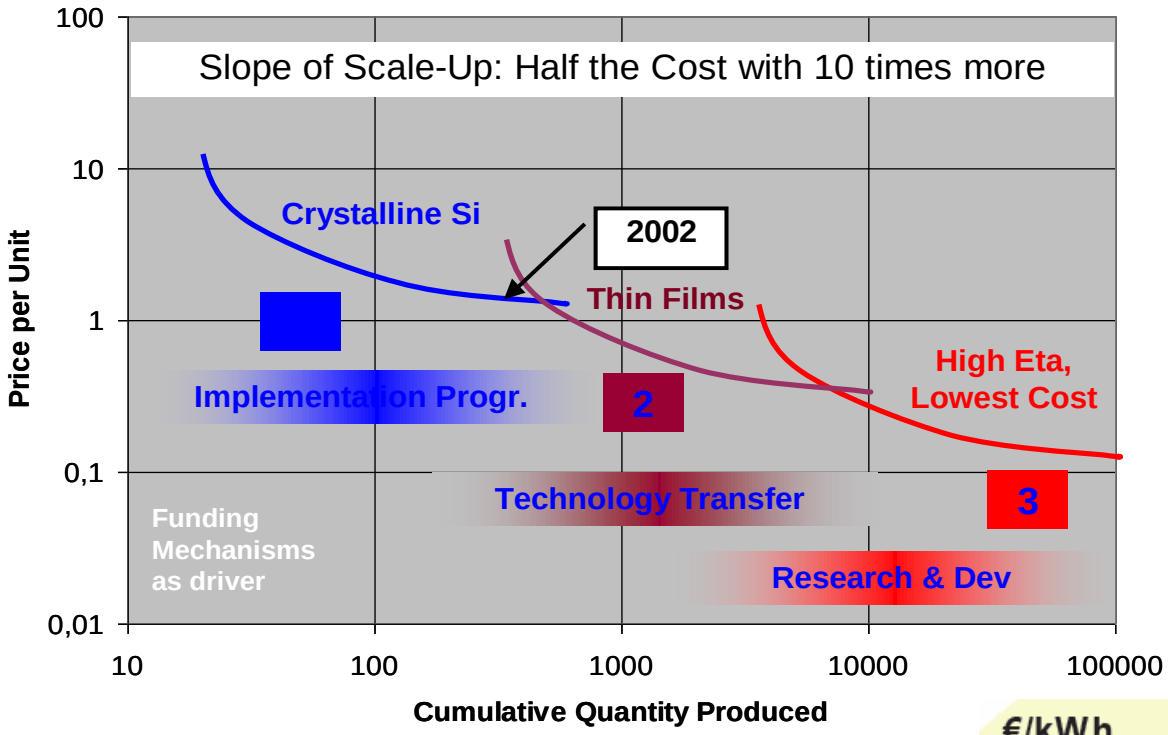
At present the Energy pay back time is about 60% of 2004 data

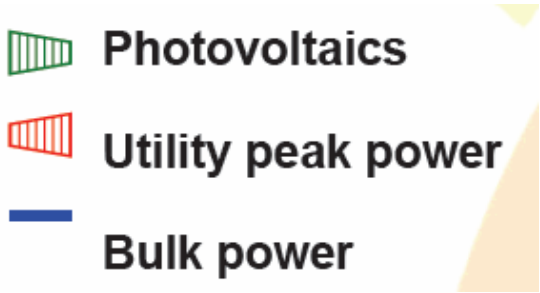


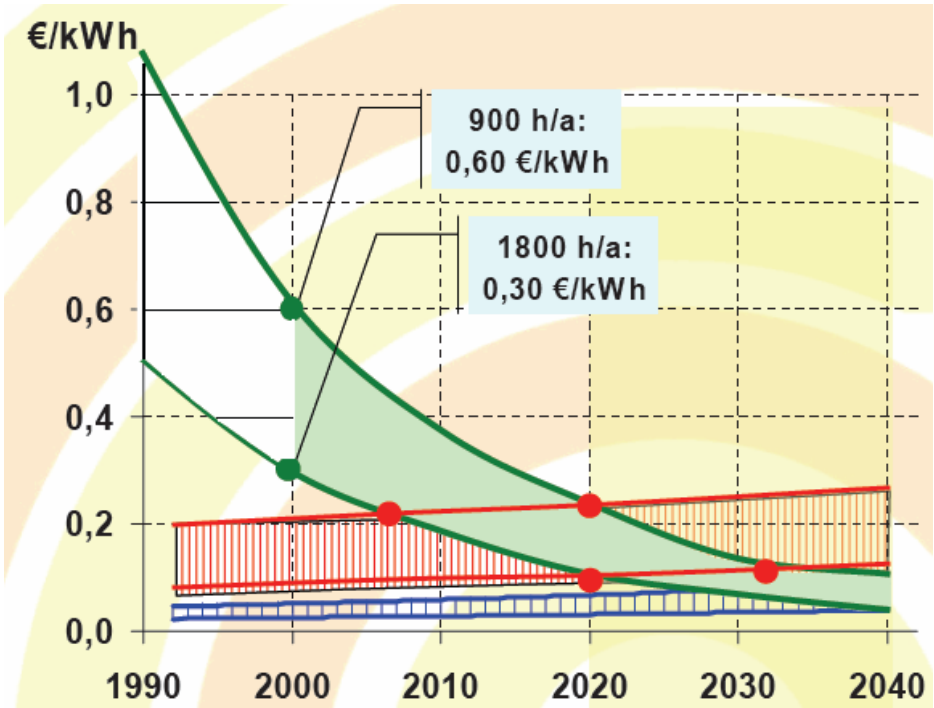
Country	City	Energy Pay-Back Time (years)	
		Roof-top	Facade
Czech Republic	Prague	3,09	4,61
Spain	Sevilla	1,73	2,82
	Barcelona	2,12	3,33
Australia	Perth	1,59	2,71
	Sydney	1,91	3,11
Turkey	Ankara	1,80	3,01
United Kingdom	London	3,21	4,64
United States	Los Angeles	1,67	2,77
	Washington	2,02	3,10
Austria	Vienna	2,79	4,22
Belgium	Brussels	3,21	4,68
Denmark	Copenhagen	2,97	4,12
France	Paris	2,90	4,25
	Marseille	1,92	2,88
Germany	Berlin	3,01	4,32
	Munich	2,63	3,83
Greece	Athens	1,98	3,26
Italy	Rome	1,92	2,93
	Milan	2,45	3,74
Japan	Tokyo	2,64	4,00

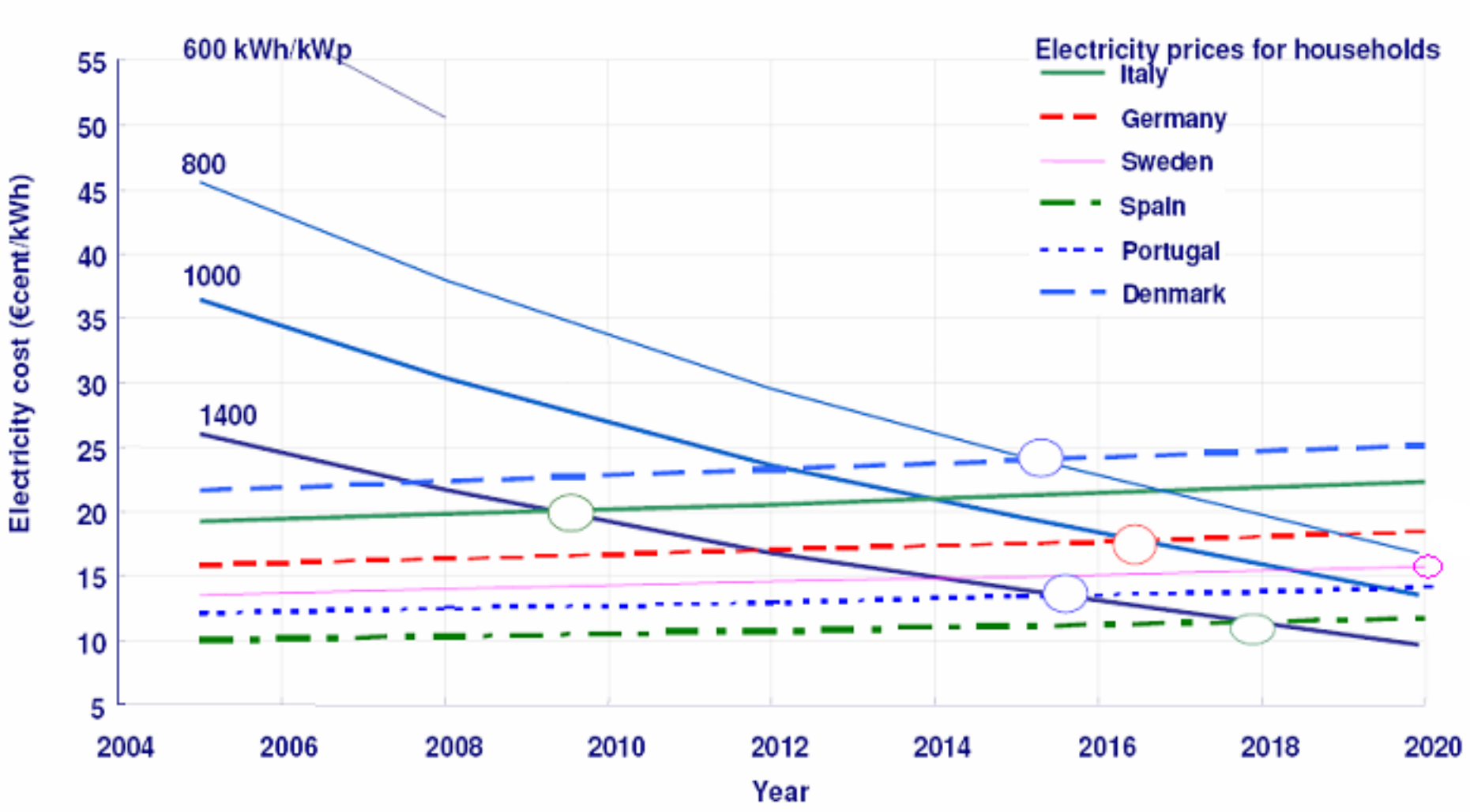


The photovoltaic roadmap

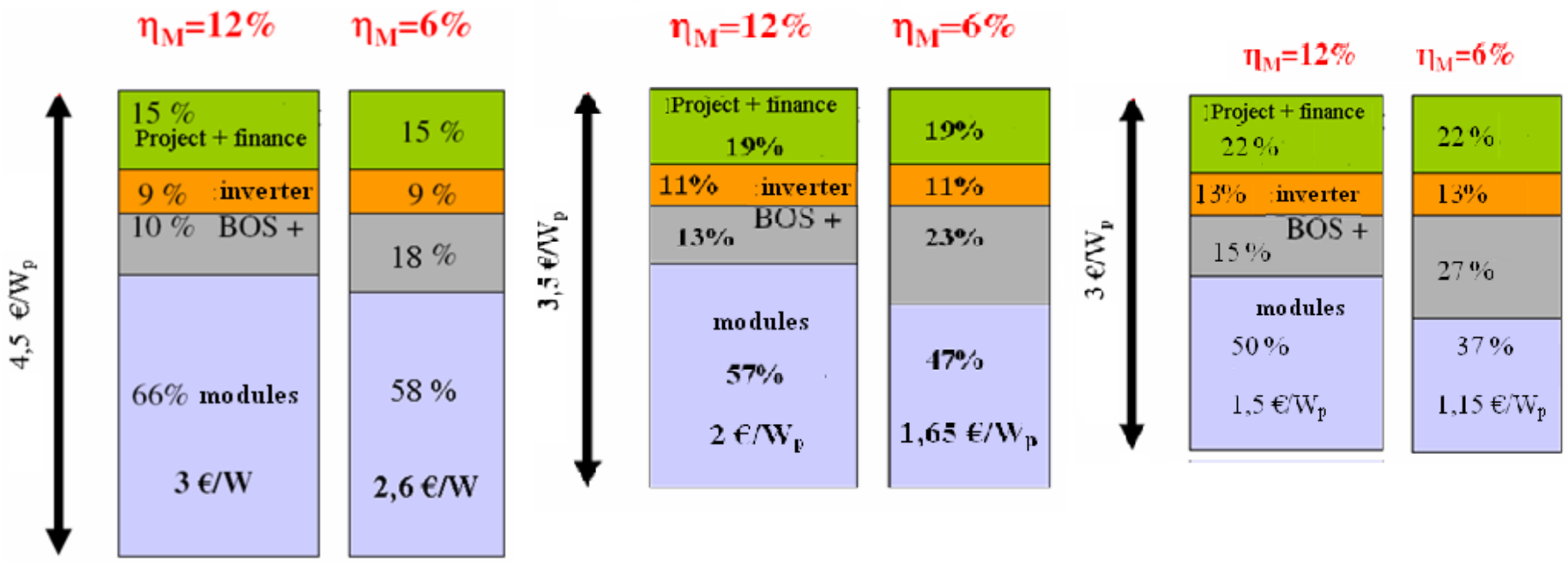


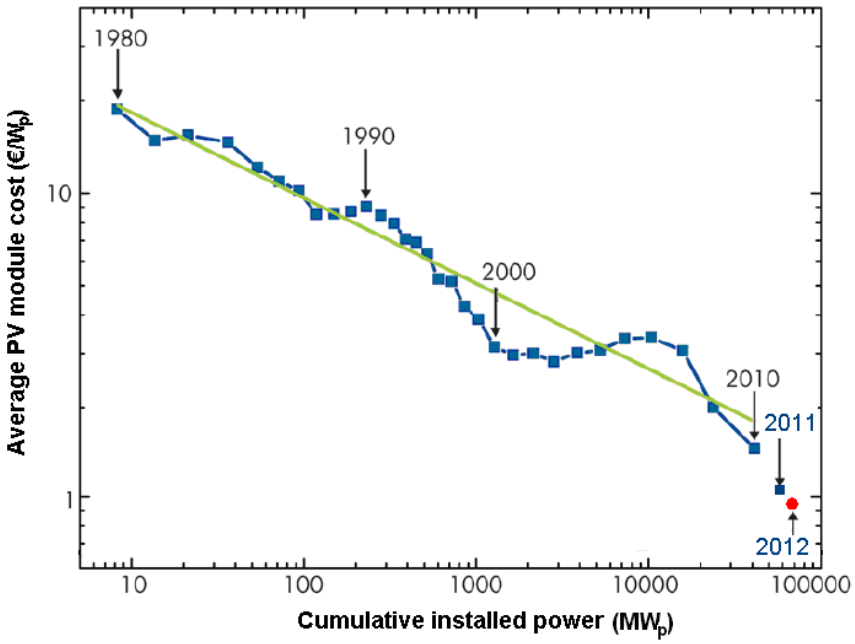


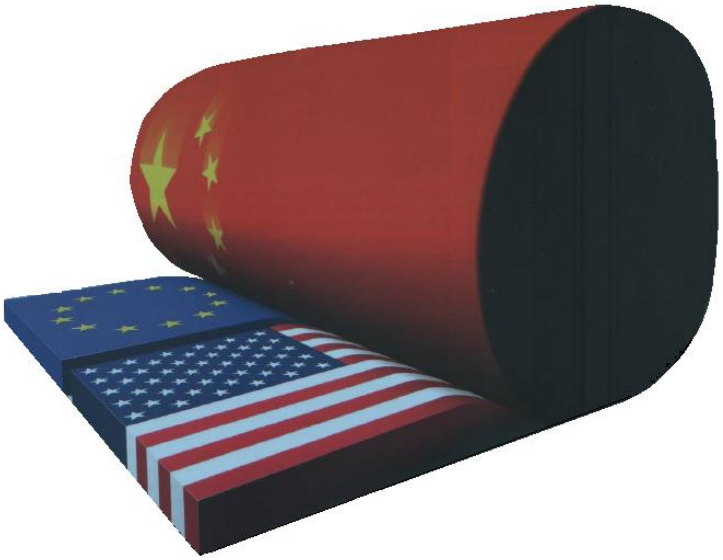


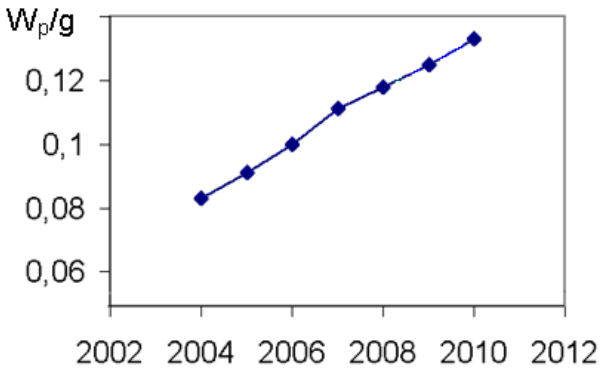

600 kWh/kWp
800
1000
1400
Electricity prices for households
Italy
Germany
Sweden
Spain
Portugal
Denmark
Electricity cost (€cent/kWh)
55
50
45
40
35
30
25
20
15
10
5
2004
2006
2008
2010
2012
2014
2016
2018
2020
Year

Cell and module efficiency						
Technology	Thin film				Crystalline Si	
	a:Si	CdTe	CIS	micromorf	mono	multi
STC efficiency	6-7 %	8-10 %	10-11%	8%	16-17%	14-15%
Module efficiency					13-15%	12-14%
Area for 1 kW_p	15 m²	11 m²	10 m²	12 m²	cca 7 m²	cca 8 m²

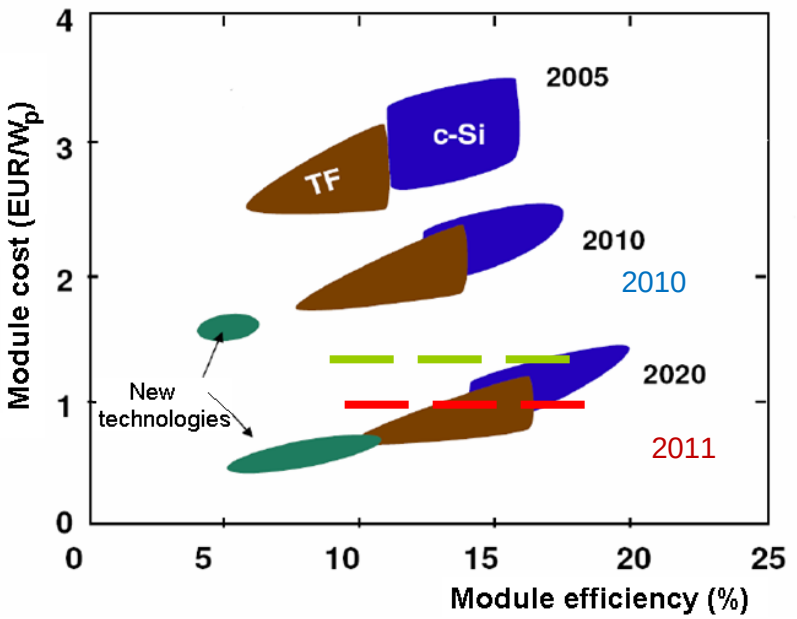


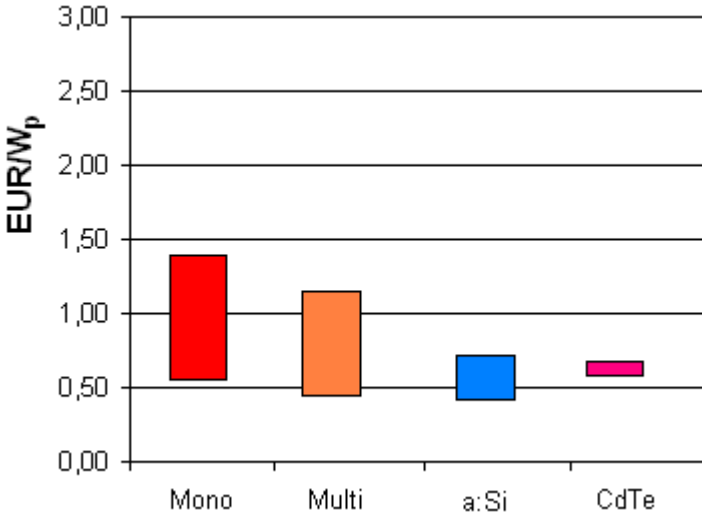

1980
1990
2000
2010
2011
2012
10
1
10
100
1000
10000
100000
Average PV module cost (€/Wp)
Cumulative installed power (MWp)

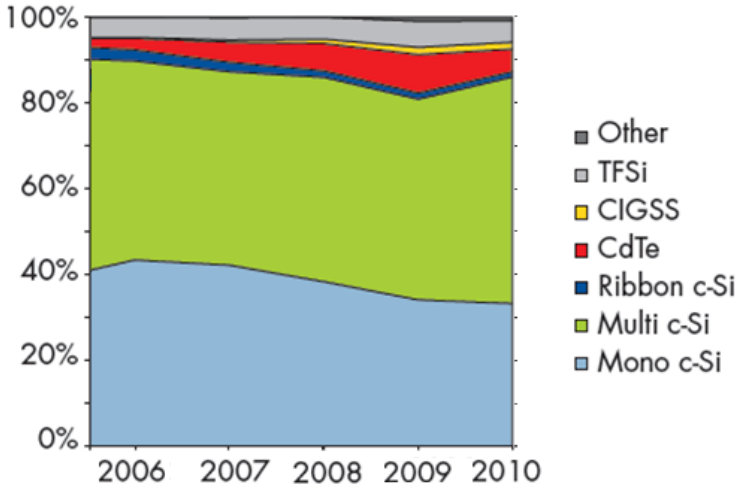



Wp/g
0,12
0,1
0,08
0,06
2002
2004
2006
2008
2010
2012


Zheng-Jing
Promotional!
1MW EUR 0.43 Per Watt
600KW EUR 0.45 Per Watt
150KW EUR 0.47 Per Watt
PWP-180W
Electrical Data
Limits
Temperature and Coefficients



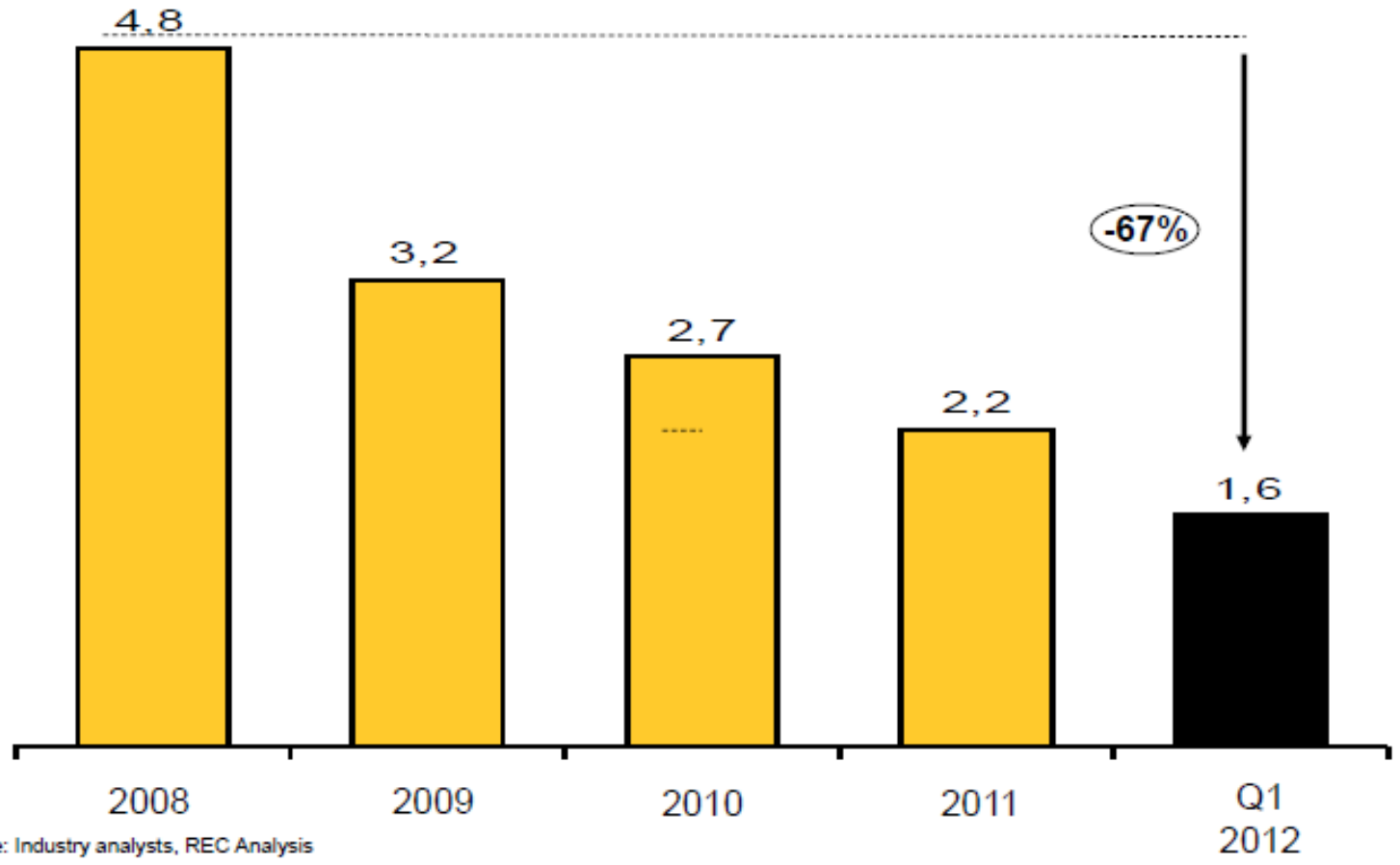




Thin-film modules are not cheaper than modules from crystalline silicon

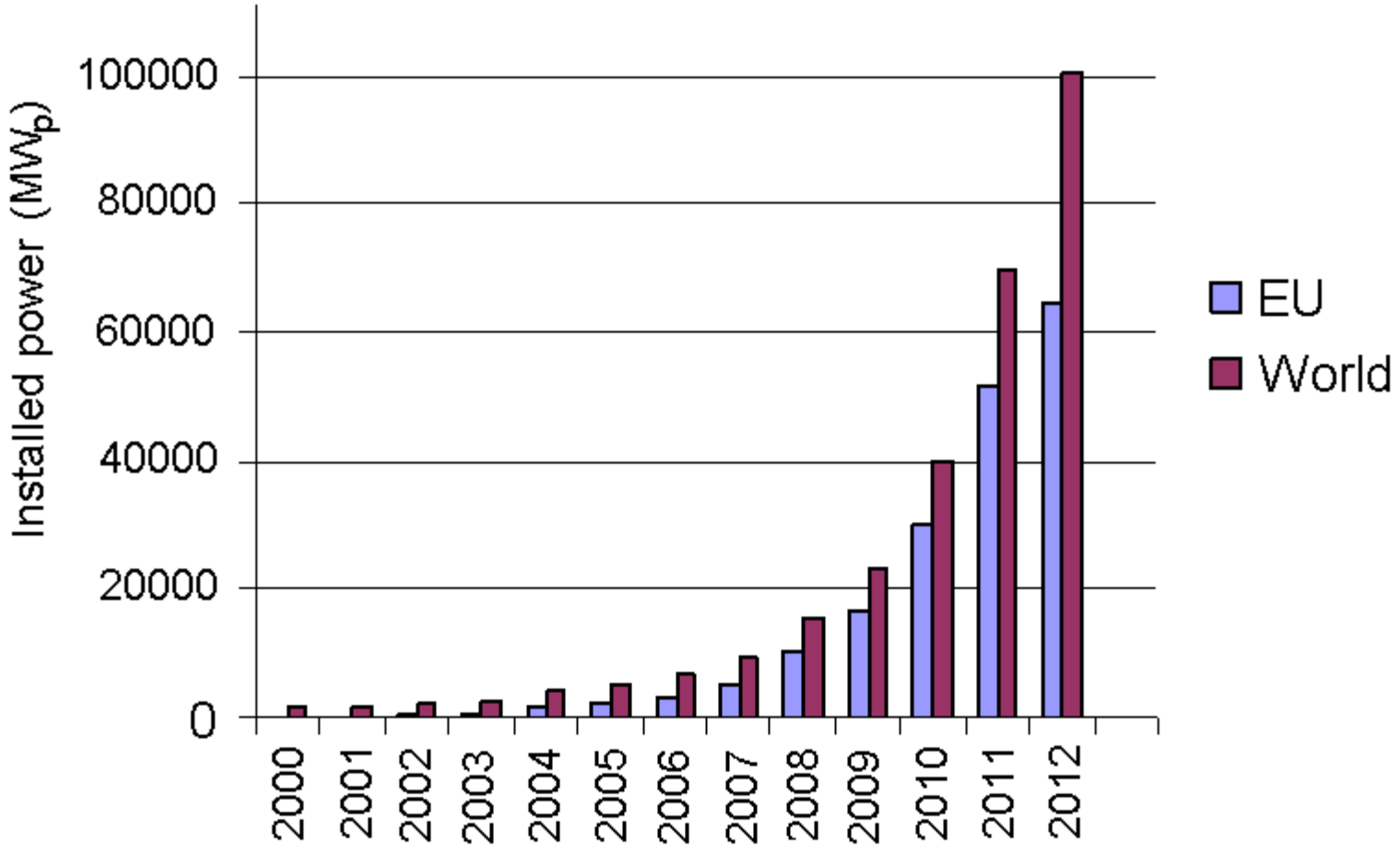
Solar system cost in Germany

Euro/Watt – residential systems

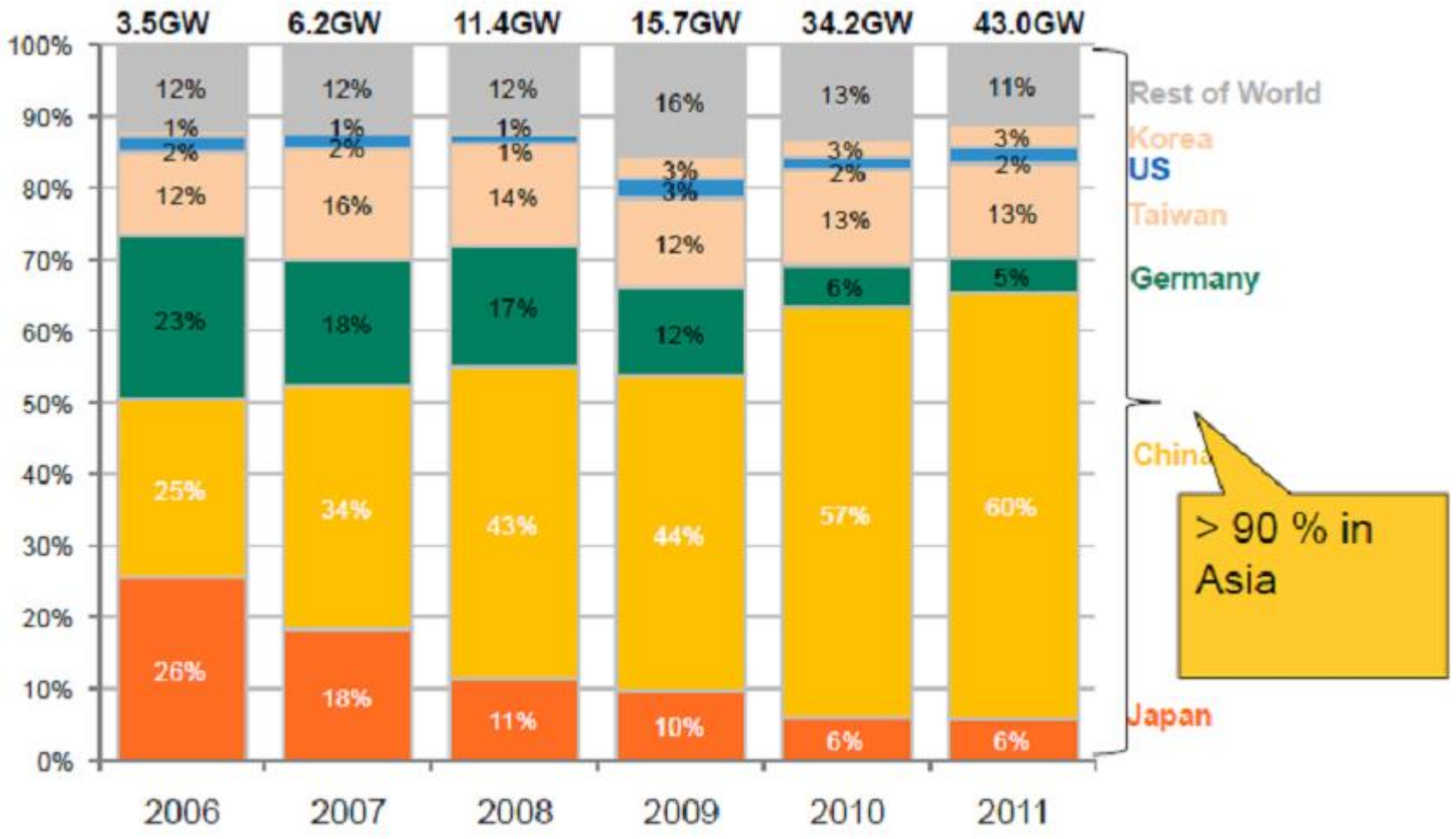


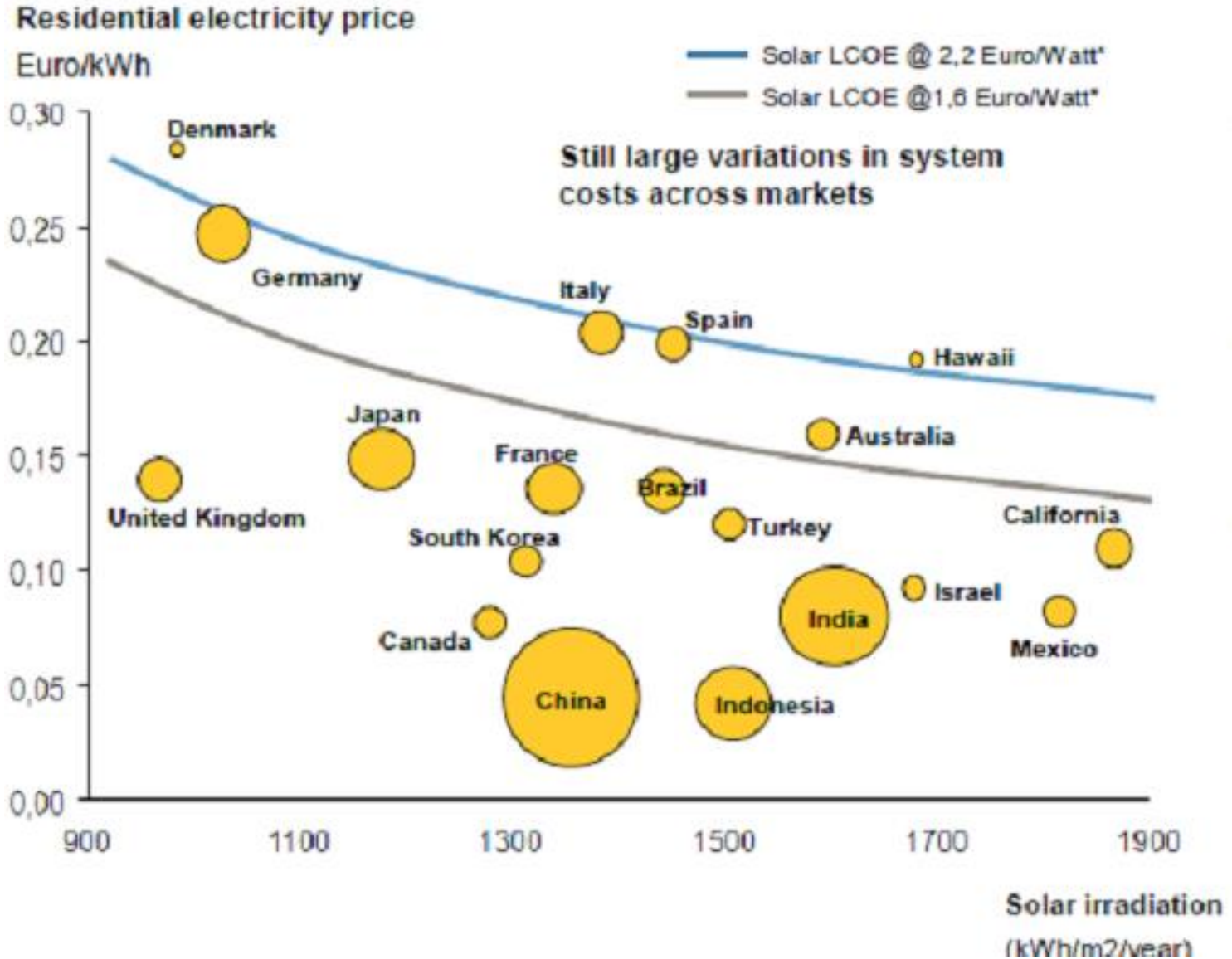
Source: Industry analysts, REC Analysis

Very fast development of Photovoltaics in the past decade

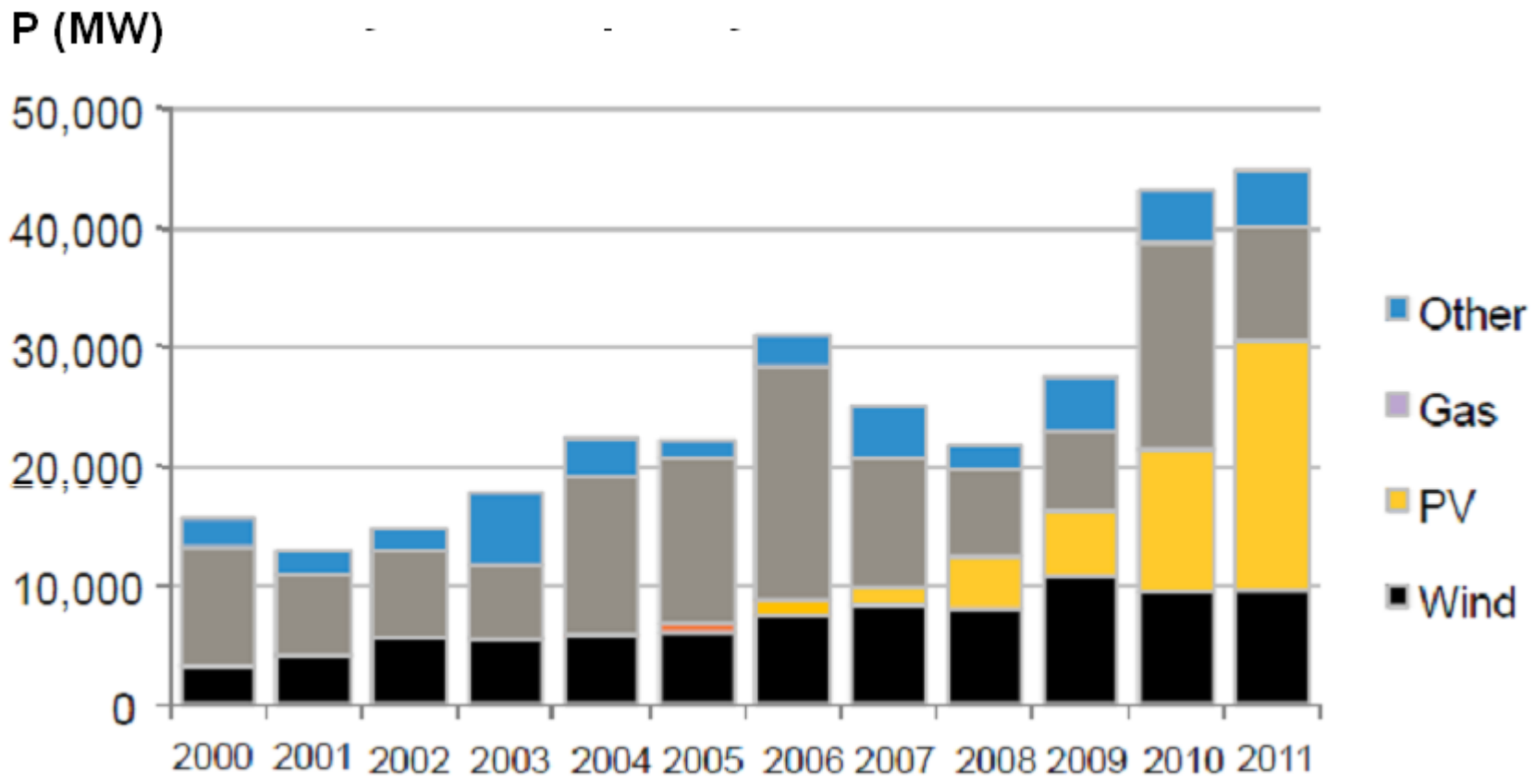


Production capacity

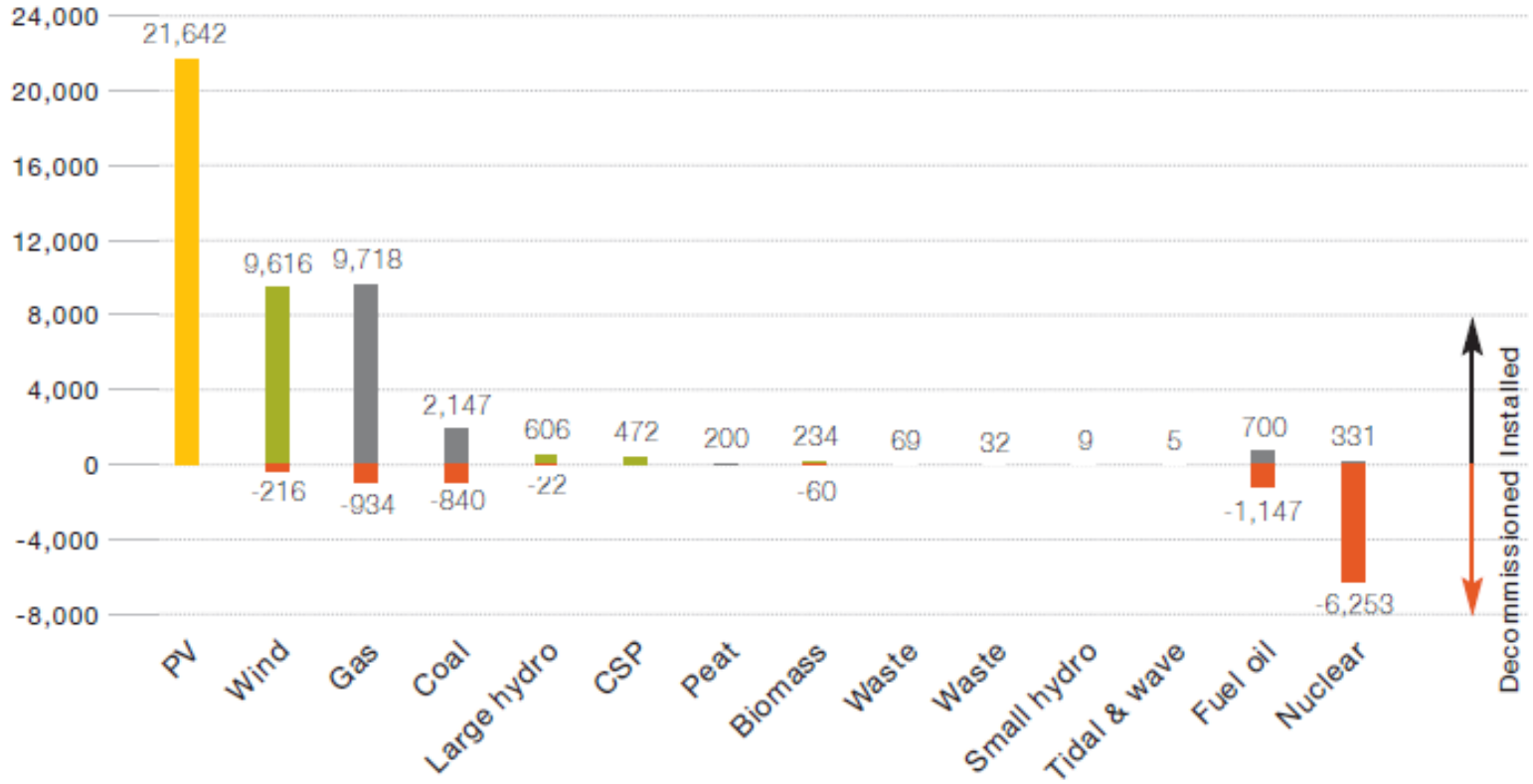



Residential electricity price
Euro/kWh
Solar LCOE @ 2,2 Euro/Watt*
Solar LCOE @1,6 Euro/Watt*
Still large variations in system costs across markets
0,30
0,25
0,20
0,15
0,10
0,05
0,00
900
1100
1300
1500
1700
1900
Solar irradiation
(kWh/m2/year)
Denmark
Germany
Italy
Spain
Hawaii
Japan
Australia
France
Brazil
United Kingdom
Turkey
California
South Korea
Israel
India
Canada
Mexico
China
Indonesia

Power generation capacities added in the EU 27



Power generation capacities added in the EU 27 in 2011 (MW)



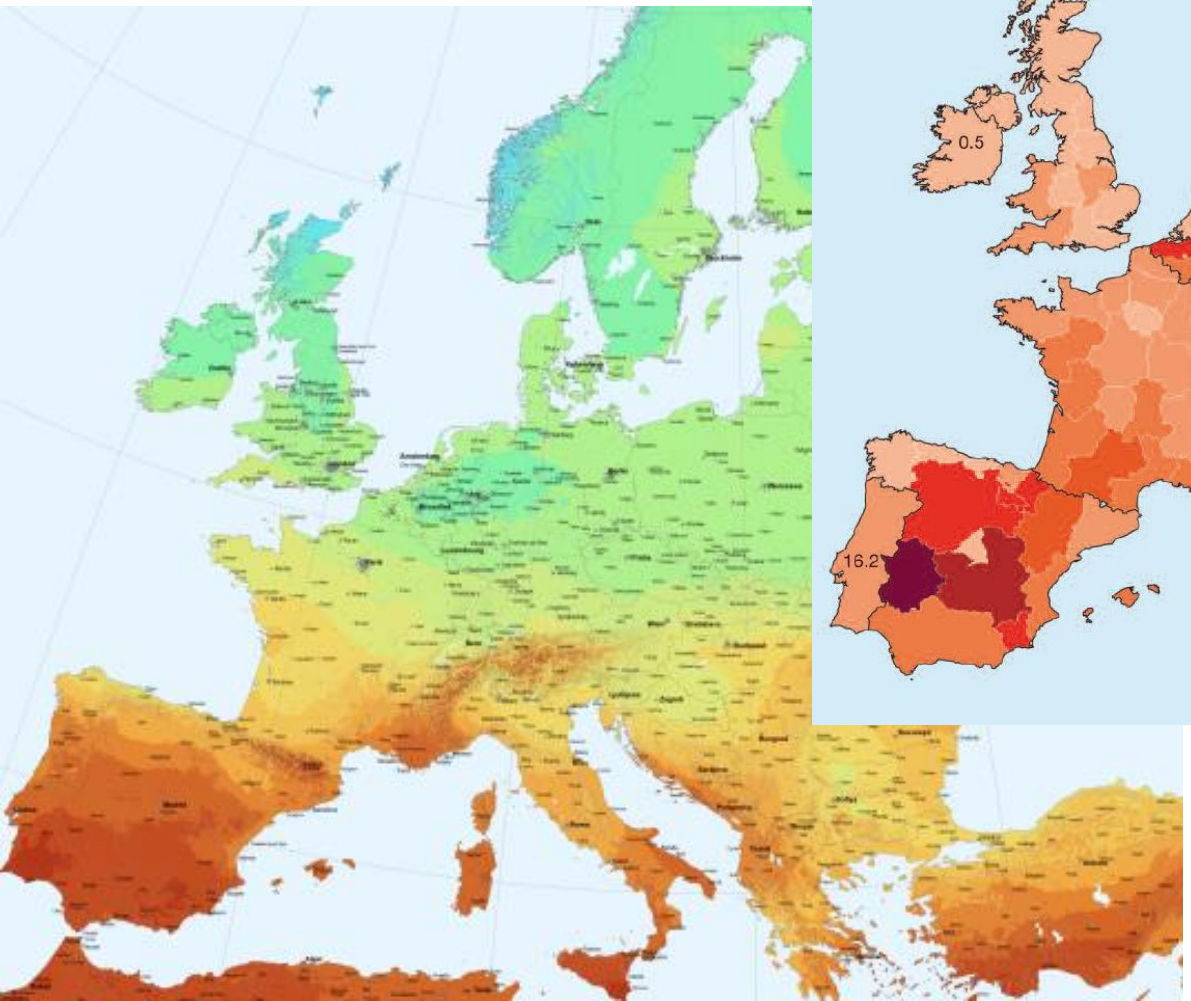
2004 - 1GW$_p$ installed in EU

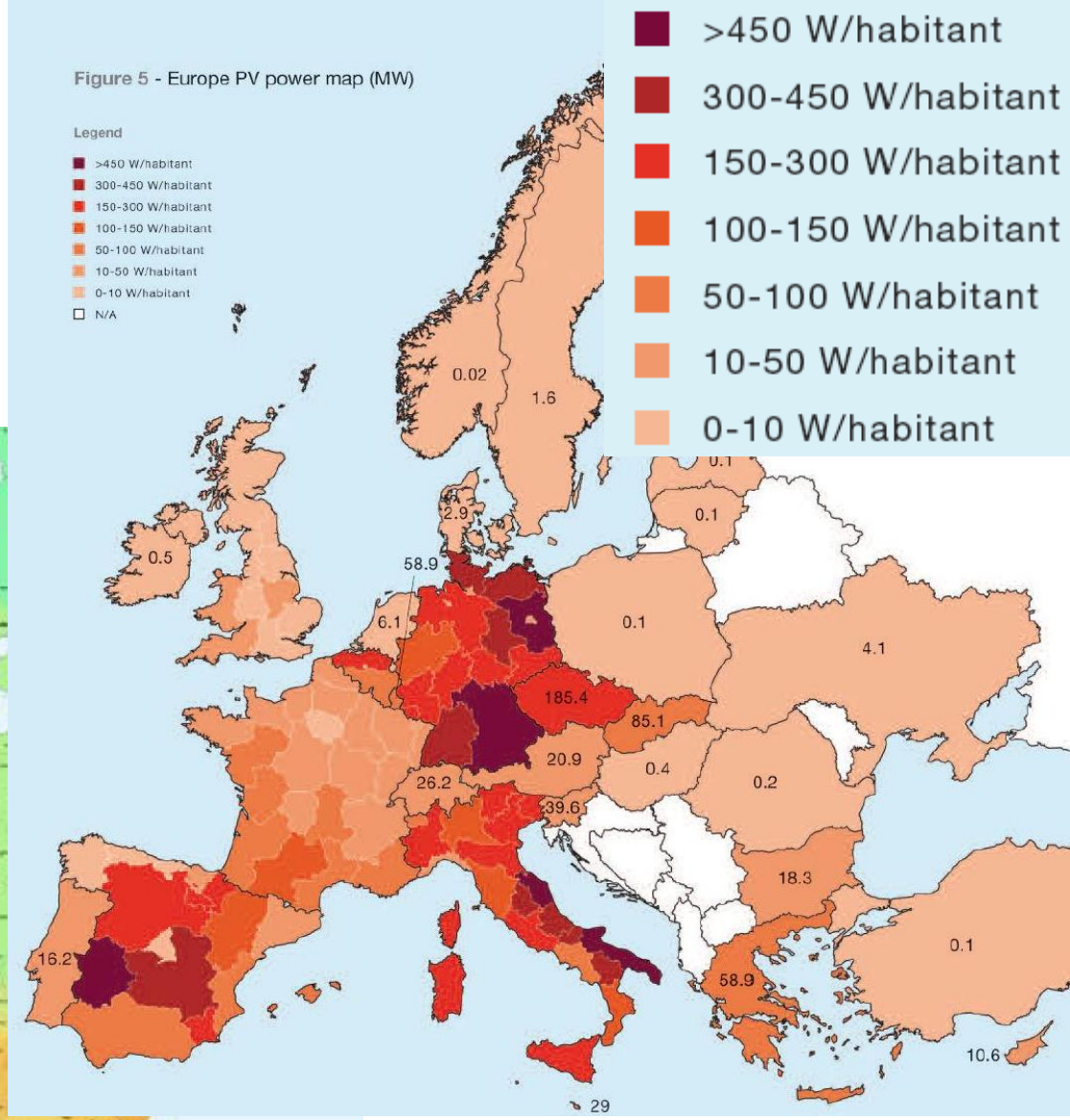
2006 - 3 GW$_p$ installed in EU

2010 - 29 GW$_p$ installed in EU

2011 - 50 GW$_p$ installed in EU

2012 – 63 GW$_p$ installed in EU

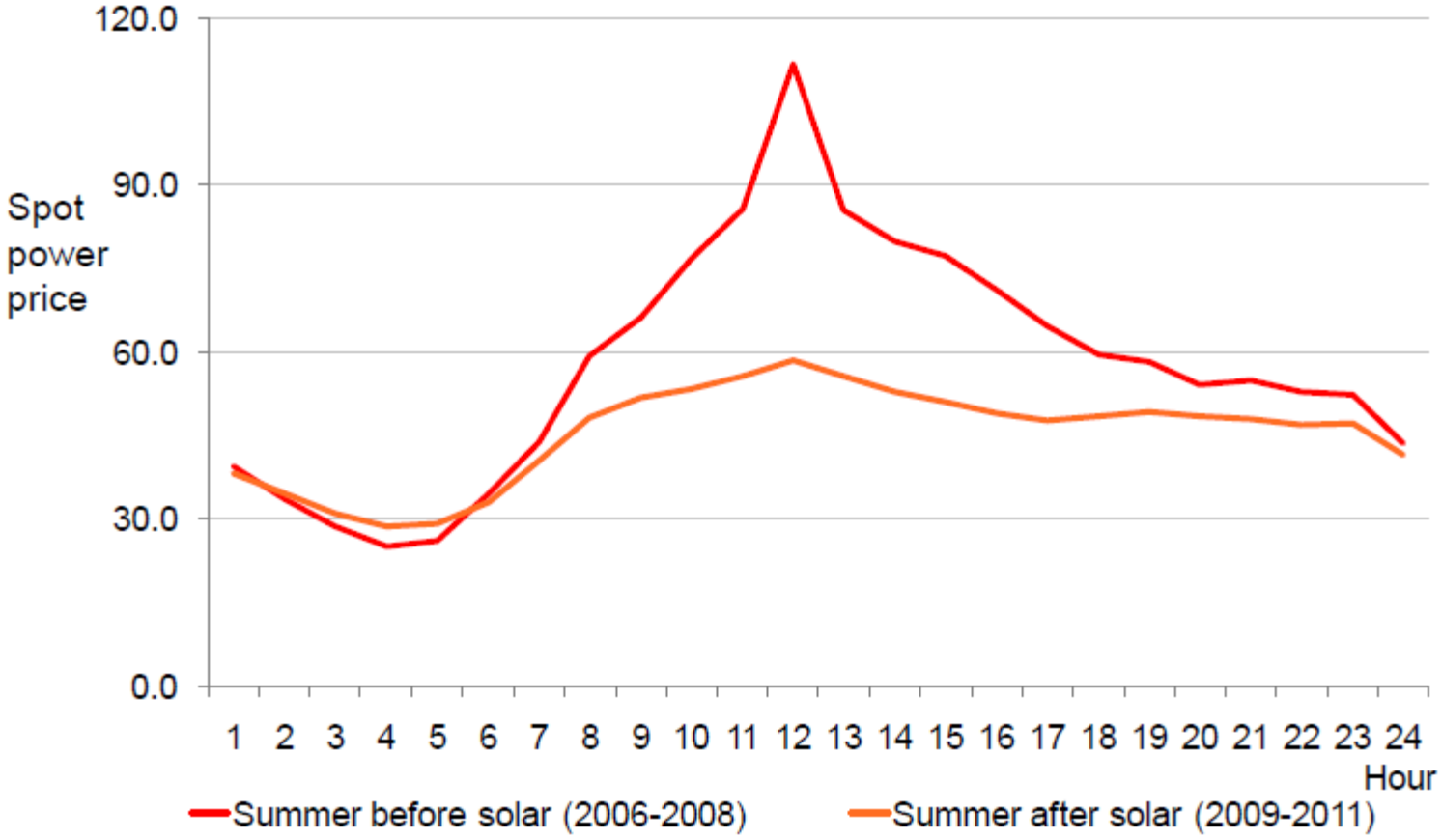




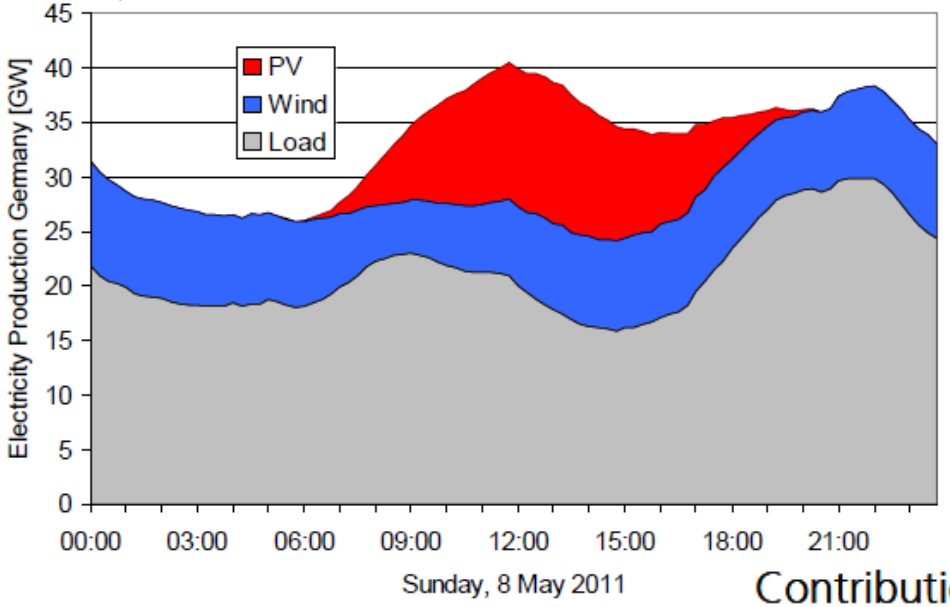
Hours of sun / year	1200	1500	1800
Typical LCOE 2012 * * Total installed cost 1.8 €	15	12	10
Typical LCOE 2016 ** ** Total installed cost 1.25 €	10.5	8.5	7

*, ** IRR=7%

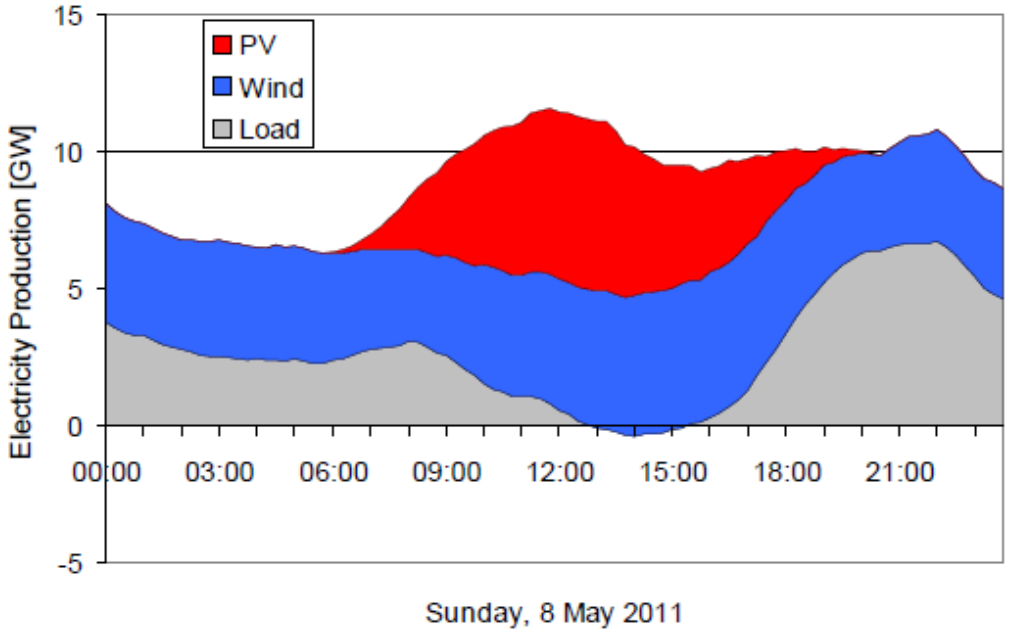
€ cts / Kwh	Germany	Italy	France	Spain
Generation costs	8	12	5	10
Grid utilization	6	5	4	4
Taxes	10	3	4	3
Public prices	24	20	13	17

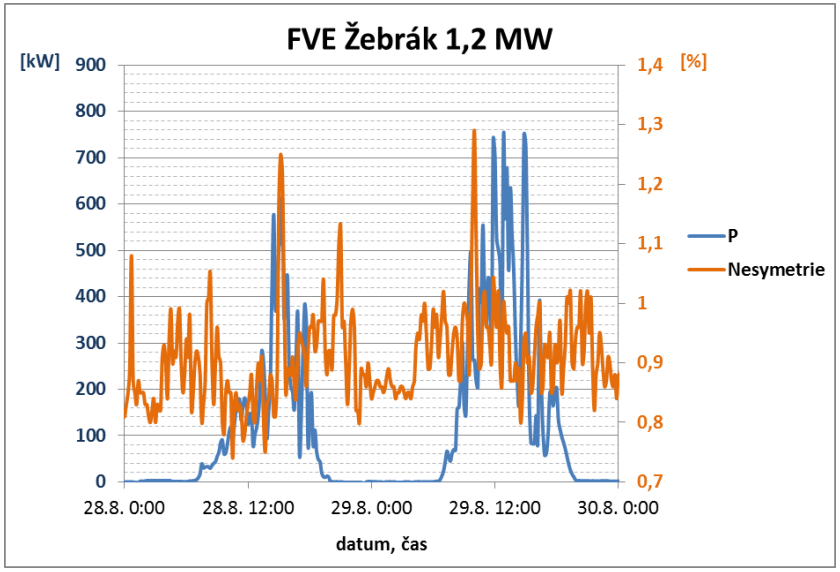

120.0
90.0
60.0
30.0
0.0
Spot power price
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour
Summer before solar (2006-2008)
Summer after solar (2009-2011)

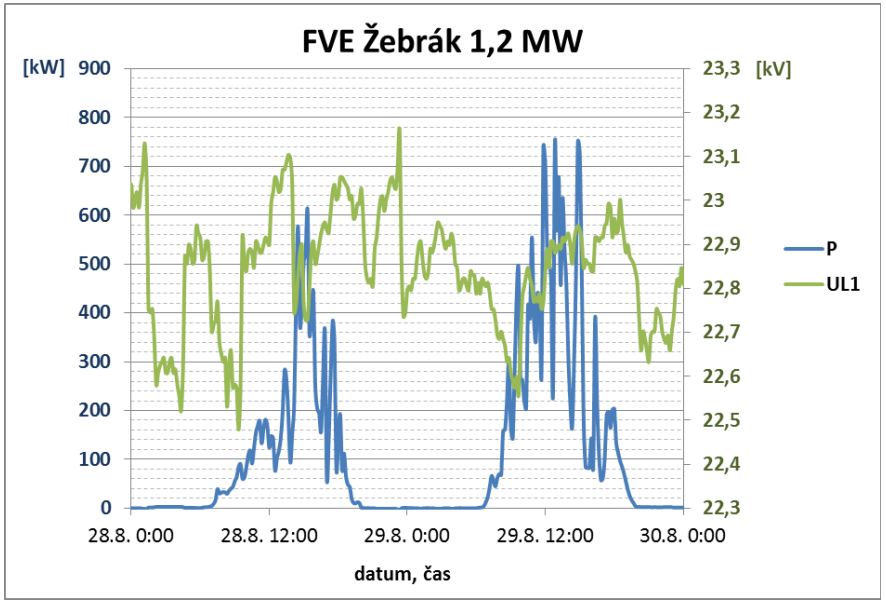
Contribution of PV on 8 May 2011 in Germany
(Estimation: 13 GW, >30%, PV+Wind: >50%)



Contribution of PV on 8 May 2011 in TenneT control area
(Estimation: 6 GW, > 50%, PV+Wind: > 100%)




FVE Žebrák 1,2 MW
[kW]
[%]
900
800
700
600
500
400
300
200
100
0
1,4
1,3
1,2
1,1
1
0,9
0,8
0,7
P
Nesymetrie
28.8. 0:00
28.8. 12:00
29.8. 0:00
29.8. 12:00
30.8. 0:00
datum, čas


FVE Žebrák 1,2 MW
[kW]
[kV]
900
800
700
600
500
400
300
200
100
0
23,3
23,2
23,1
23
22,9
22,8
22,7
22,6
22,5
22,4
22,3
P
UL1
28.8. 0:00
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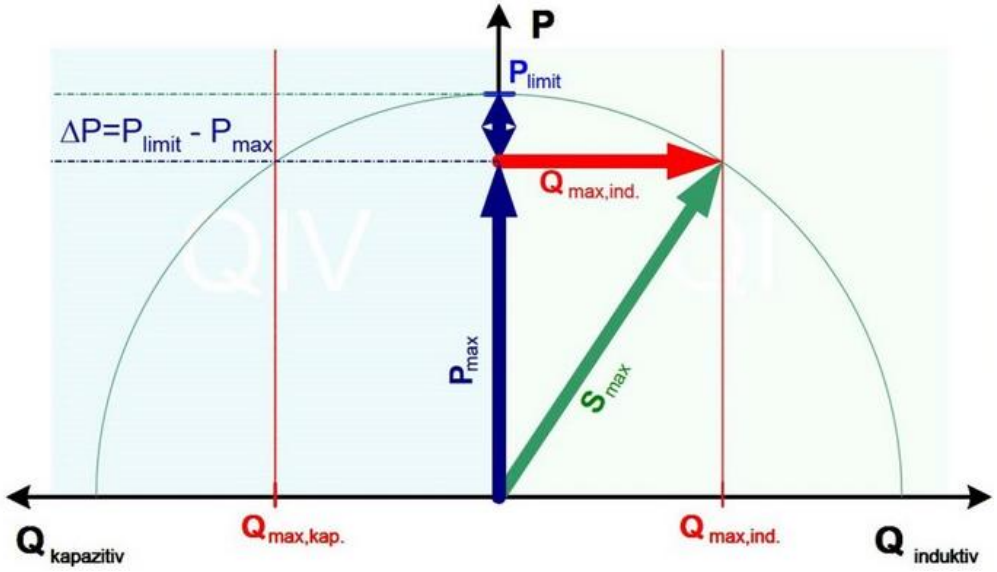
29.8. 12:00
30.8. 0:00
datum, čas


P
P limit
ΔP=P limit - P max
Q max,ind.
P max
S max
Q kapazitiv
Q max,kap.
Q max,ind.
Q induktiv

Smart grids

The 20-20-20 goal of the EU

12% of the electricity from PV in Europe by 2020