

Photovoltaic solar energy: key to a sustainable energy future

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Acknowledgements:

Slovak Renewable Energy Agency

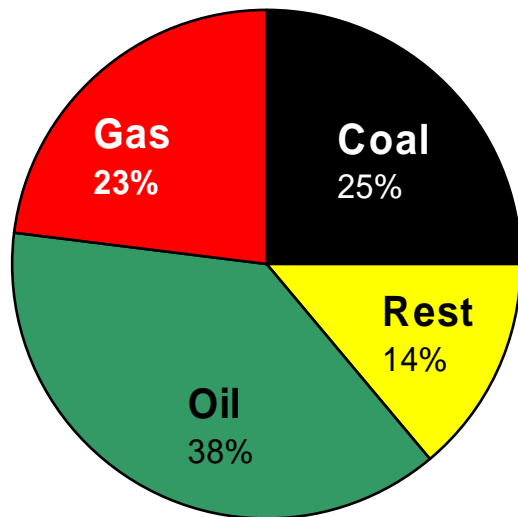


Slovak RE Agency
Slovak Renewable Energy Agency

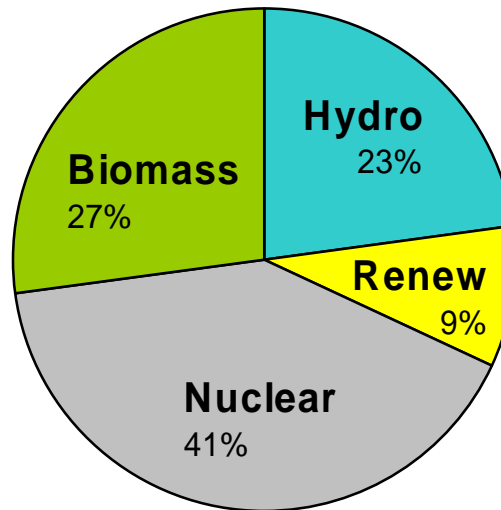


World energy consumption in 2004

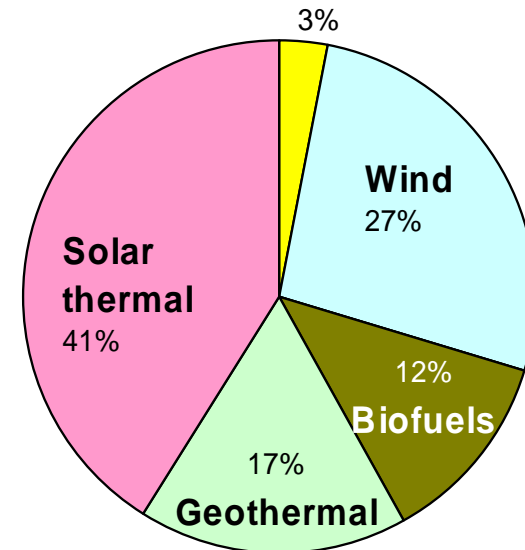
Total: 473 EJ



Rest: 66 EJ



Solar PV



420 EJ = 10 000 Mtoe

1 PJ = 278 GWh

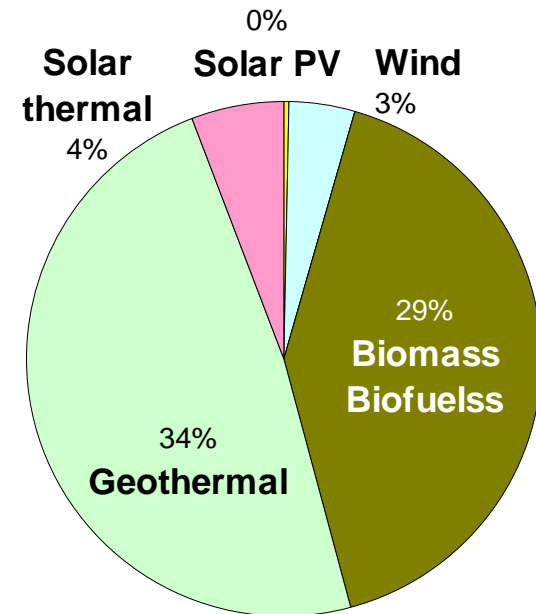
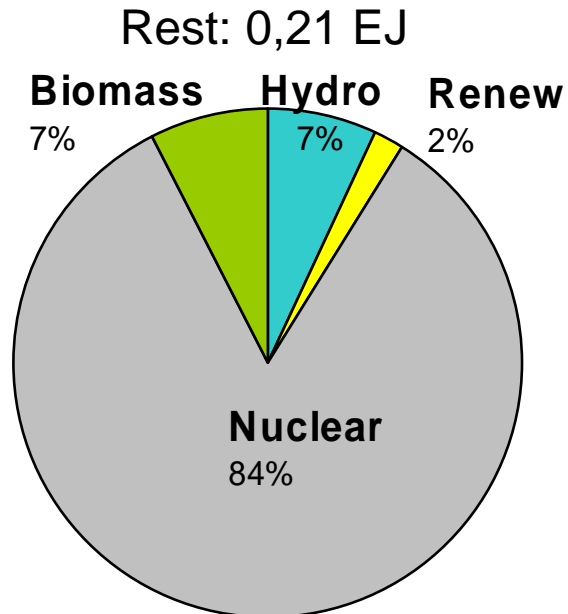
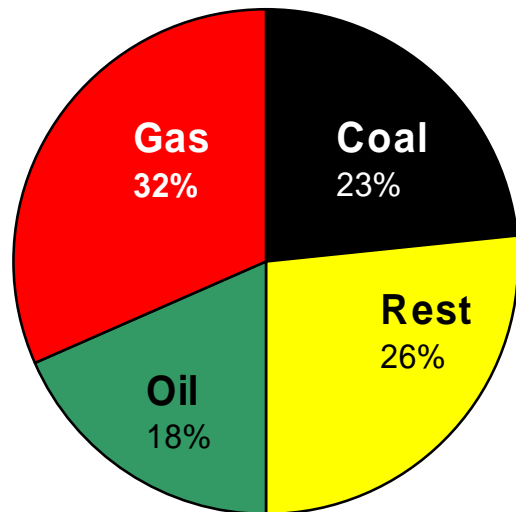
1 PJ ~ 32 MW installed power

Renewables: 6 EJ

Source: BP, Statistical review of world energy, June 2006

Slovakia energy consumption in 2004

Total: 0,81 EJ

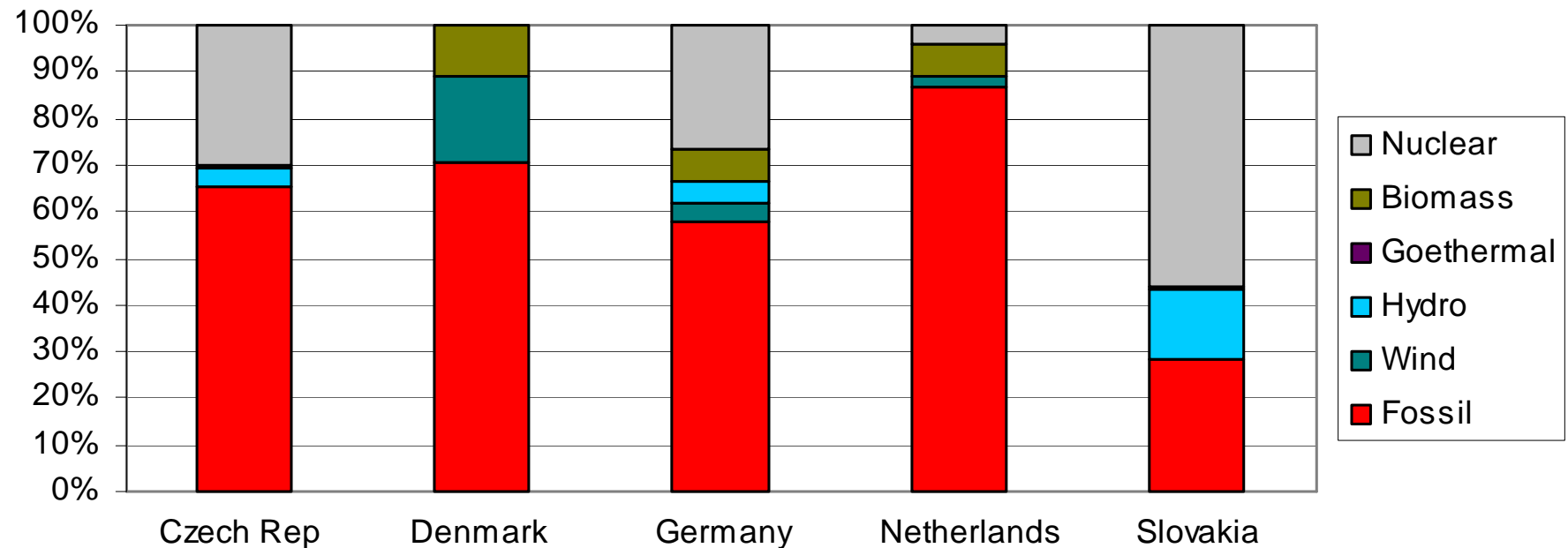


Renewables: 1 PJ

Source: Eurostat, Energy, September 2007

Electricity generation 2005

Selected EU countries:



Source: Eurostat, Energy, September 2007

The use and implementation of **renewable energy sources** is low!

World fossil-fuel energy consumption

Two major global problems:

1. Shortage of energy
2. Climate change

Solutions:

1. Efficient use of energy
2. Renewable energy source

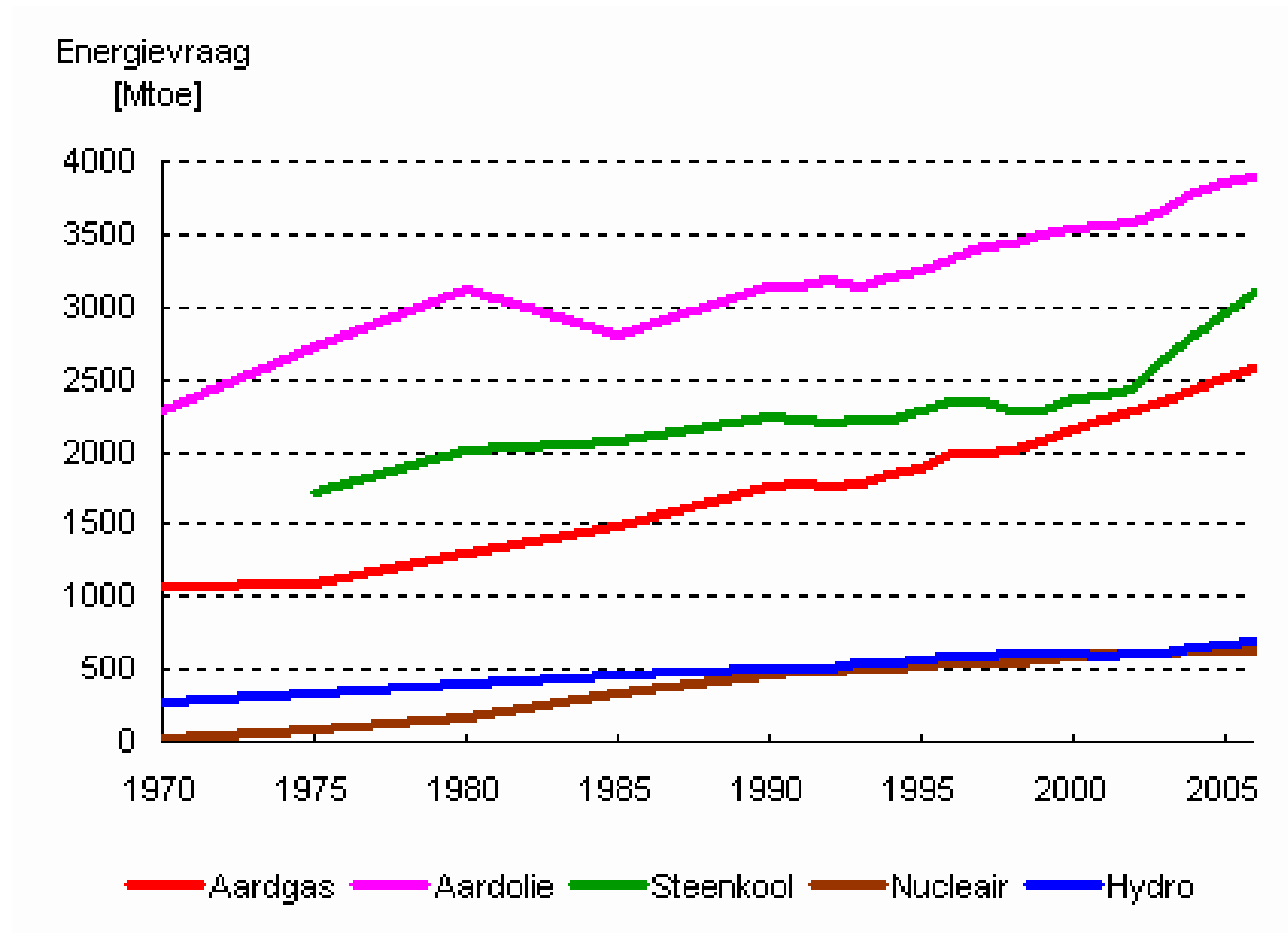
Brent Crude Oil \$/barrel 2007 (source BBC)



Mexico, Tabasco floods, November 2007 (source BBC)

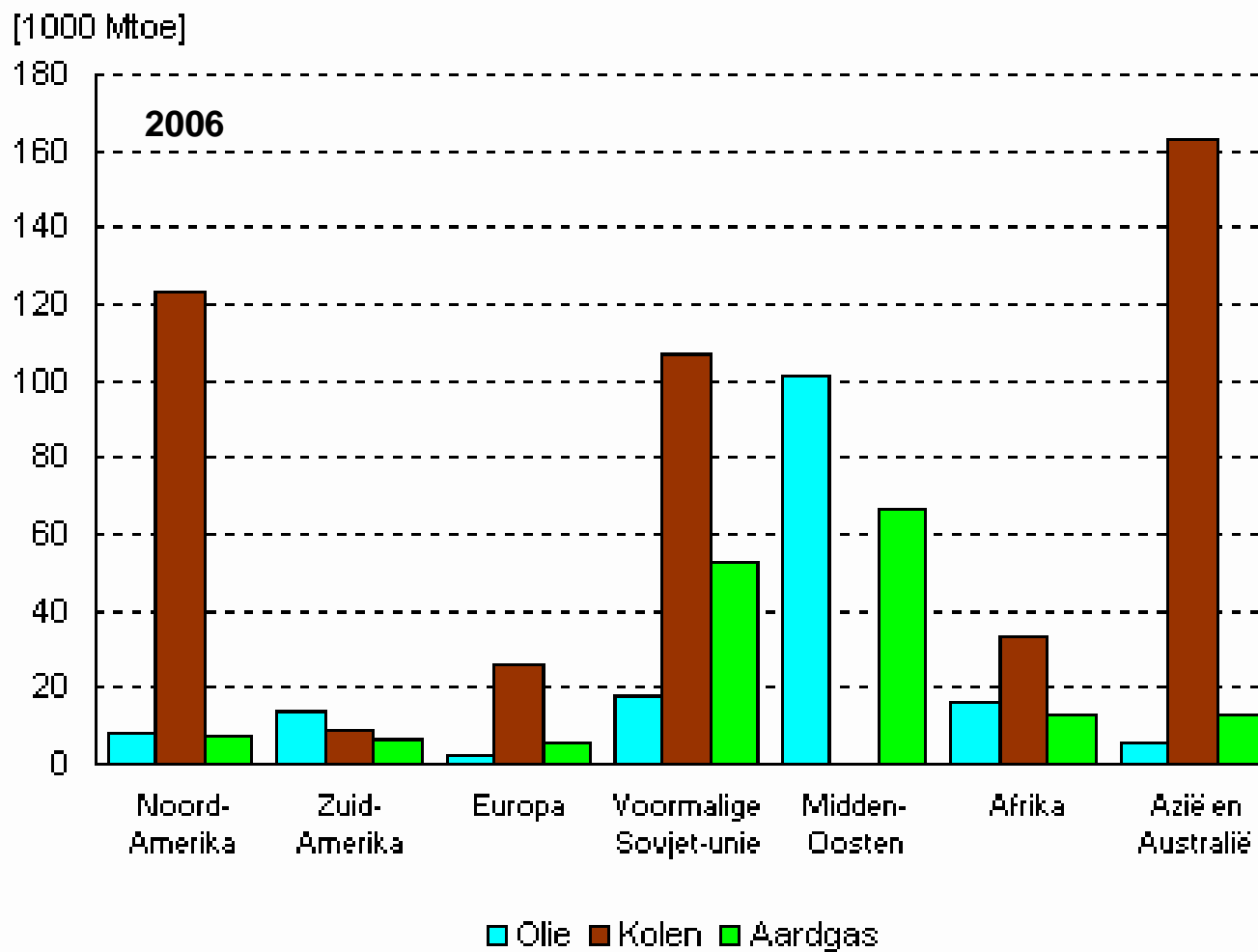


World-wide demand for primary energy



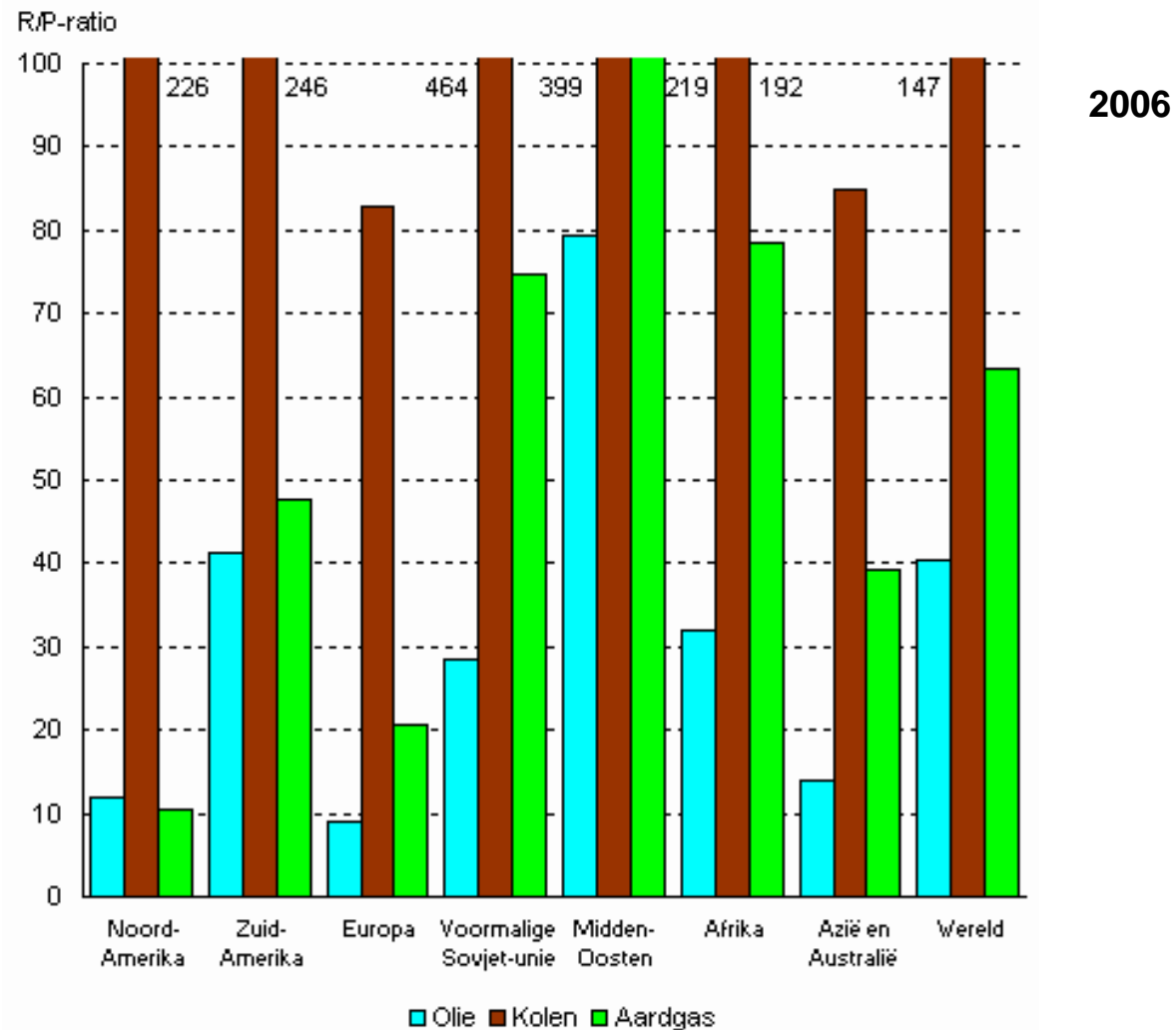
- Use of oil, natural gas, and coal has increased with 18,5% since 2000
- In 2005 the total demand for fossil fuels amounted to 9 555 Mtoe
- Including nuclear power and hydropower the energy use in 2005 was 10 878 Mtoe

World fossil fuel resources



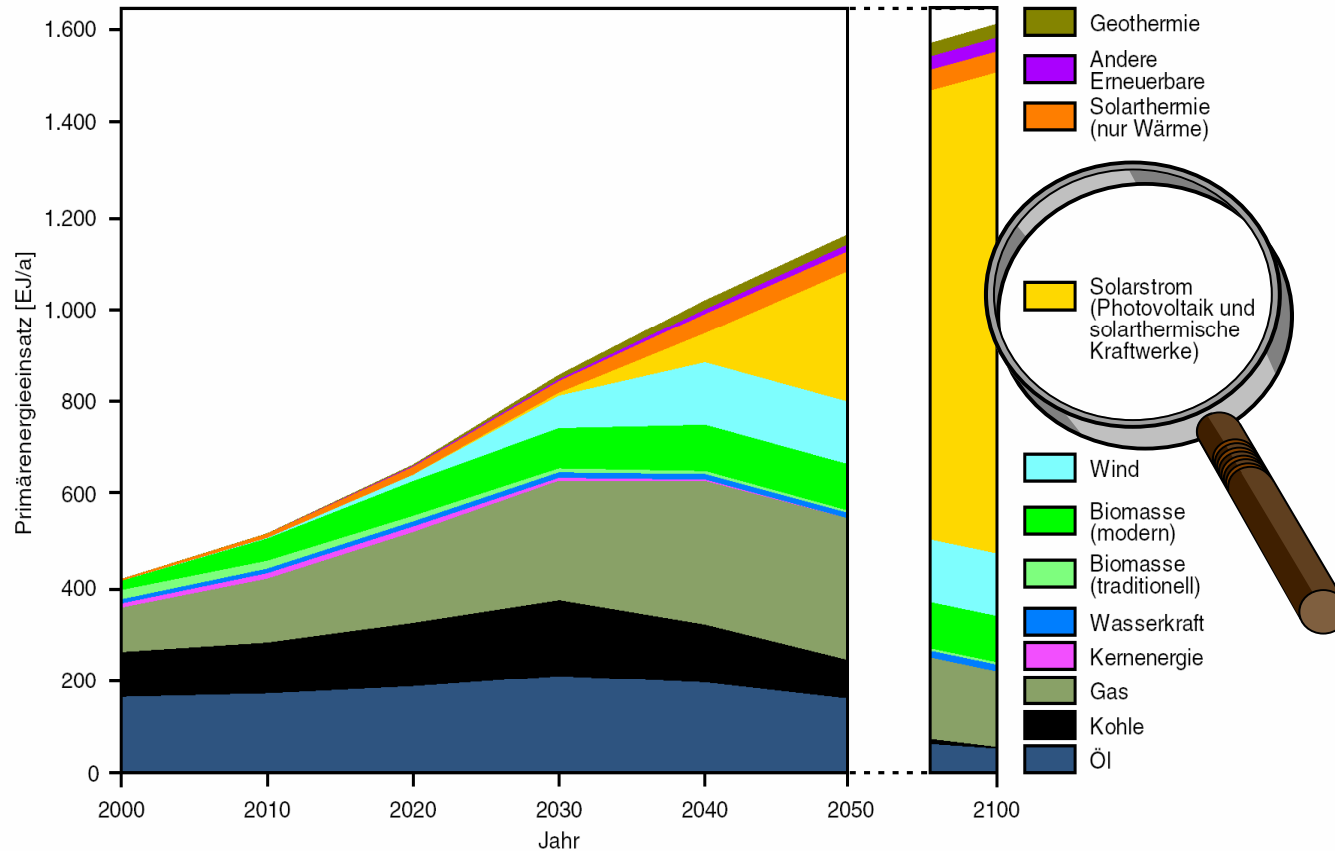
Oil supplies: 164.800 Mtoe, Coal supplies: 462.800 Mtoe, Gas supplies: 163.300 Mtoe
 Total: 790.900 Mtoe 33,8 ZJ (10^{21} Joule).

Resources/production for coal, gas, oil



- R/P-ratio differs per region, worldwide **oil ca. 40, coal 147, gas 63**
- Production of fossil fuels strongly increases (especially coal)
- R/P ratio for coal has decreased from 214 in 2000 to 147 in 2006

The energy transitions



Advisory Council
to the German
government on
global climate
change WBGU
(2003)

Abbildung 4.4-3

Energieeinsatz nach Energieträgern für den exemplarischen Transformationspfad. Dieser Pfad demonstriert, dass der nachhaltige Umbau der globalen Energiesysteme technologisch möglich ist. Ein anderer Technologiemitmix bei den erneuerbaren Energien könnte dies ebenfalls leisten.

Quelle: WBGU

Energy sources

2050: 1000 EJ (32 TW installed power)

2007: ~ 500 EJ (16 TW installed power)

In 43 years additional 16 TW power has to be installed

16 000 GW/15695 days = ~ 1 GW/day

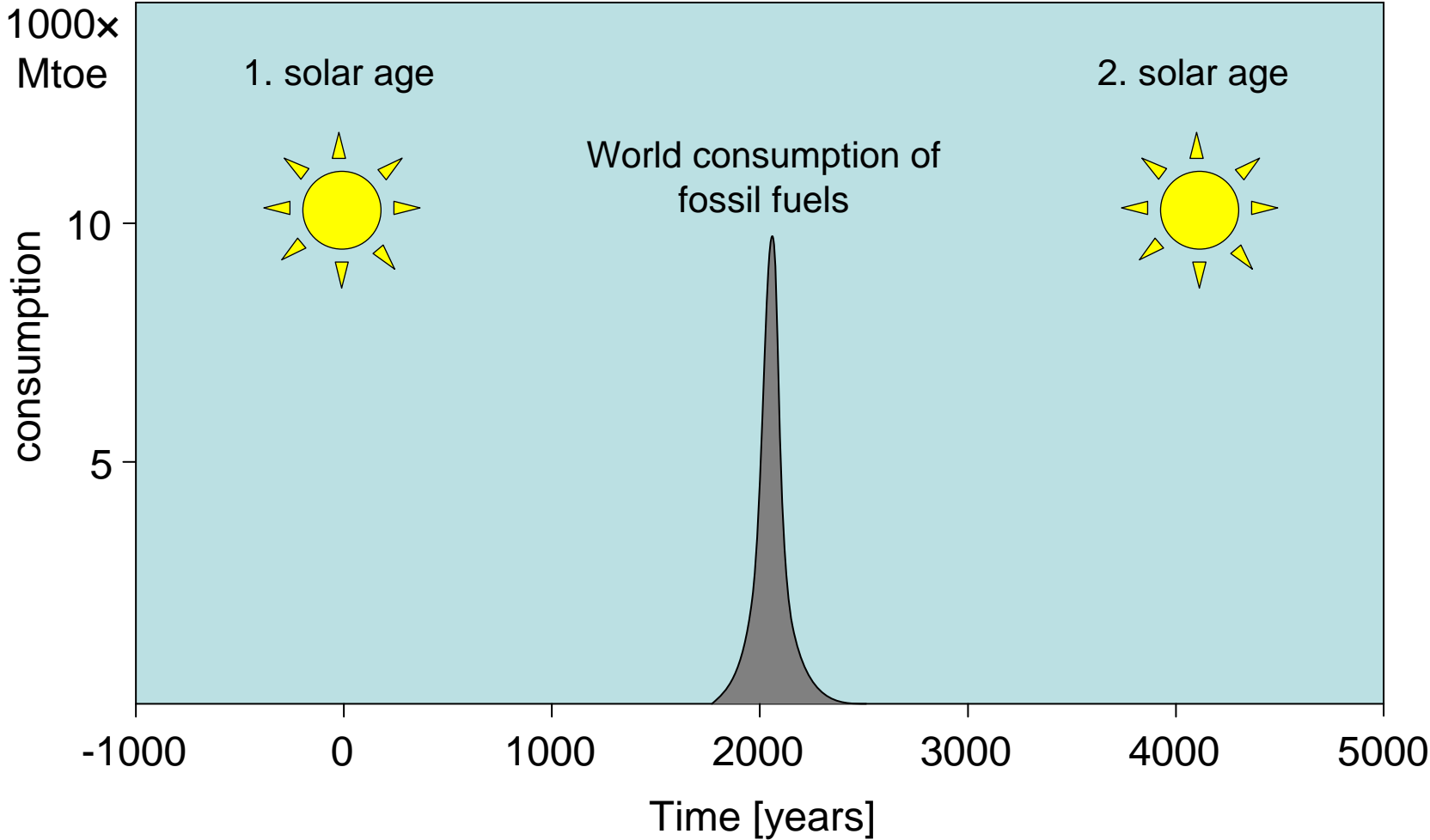


Nuclear Power Plant Bohunice

Installed capacity: 2×440 MW

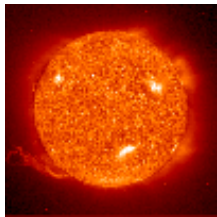
From now on **everyday for coming **43 years** one nuclear power plant of 1 GW capacity has to be build to fulfil the future energy requirements**

World fossil-fuel energy consumption



Solar energy

Solar energy is a generic term for a number of different techniques which convert the solar energy into useful energy



Direct (energy directly converted into a useful energy):

- Solar electricity (photovoltaics)
- Solar heat (thermal collectors)

In-direct (energy converted into a useful energy in steps):

- Wind
- Biomass (not sensitive for changes in energy supply)
- Hydro (not sensitive for changes in energy supply)

Photovoltaics

Photovoltaics (PV) literally means "light-electricity"

- direct conversion of light into electricity based on the photovoltaic effect
- advanced semiconductor device: **solar cells**
(do not confuse with **solar collectors**)
- the main energy source for the "post-fossil-era"

Solar Cells

- convert light directly into electricity

Advantages:

- Modular
- Minimal maintenance
- You make business with it



Solar resource



Image: Solarwatt



Image: Voltwerk

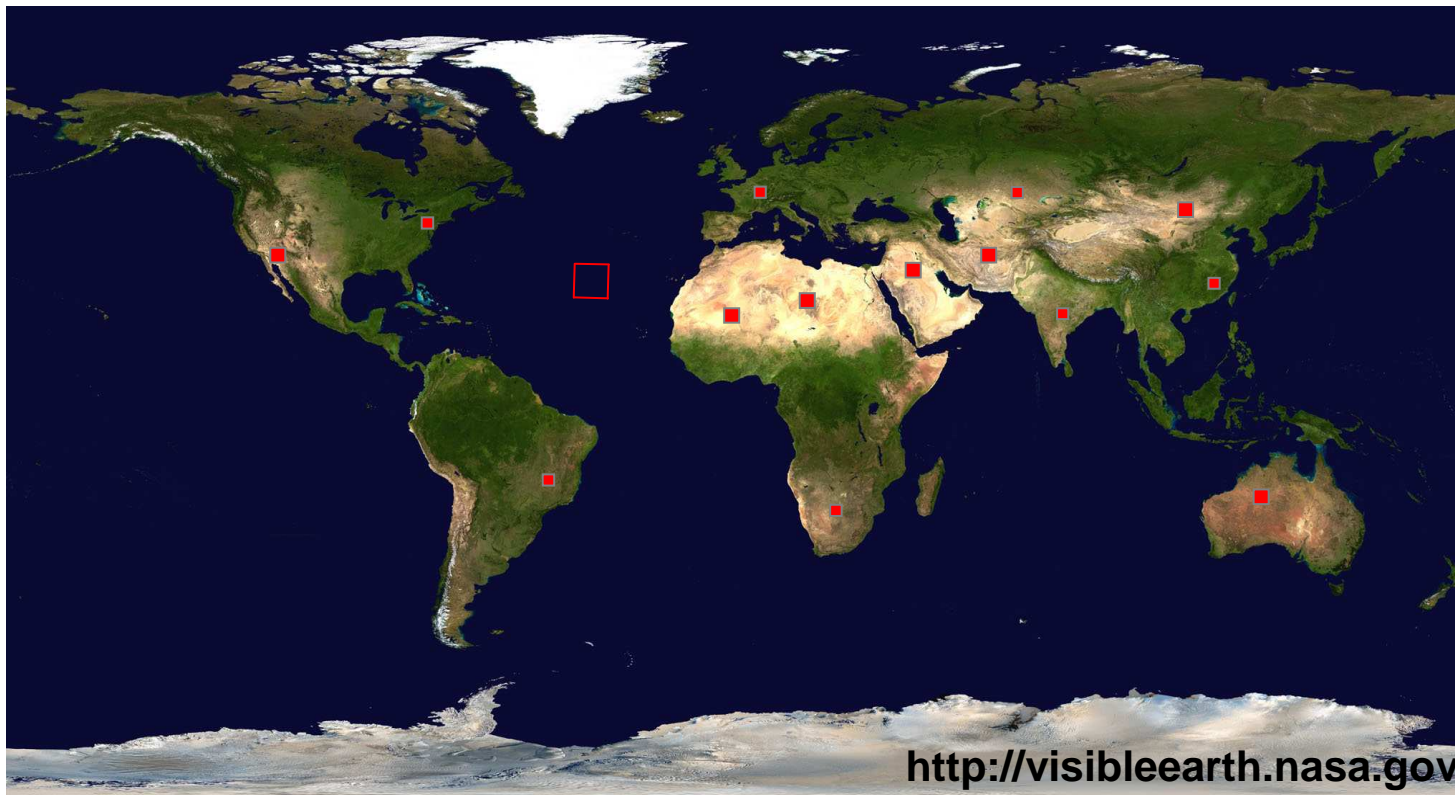


Image: Solarwatt

Solar resource

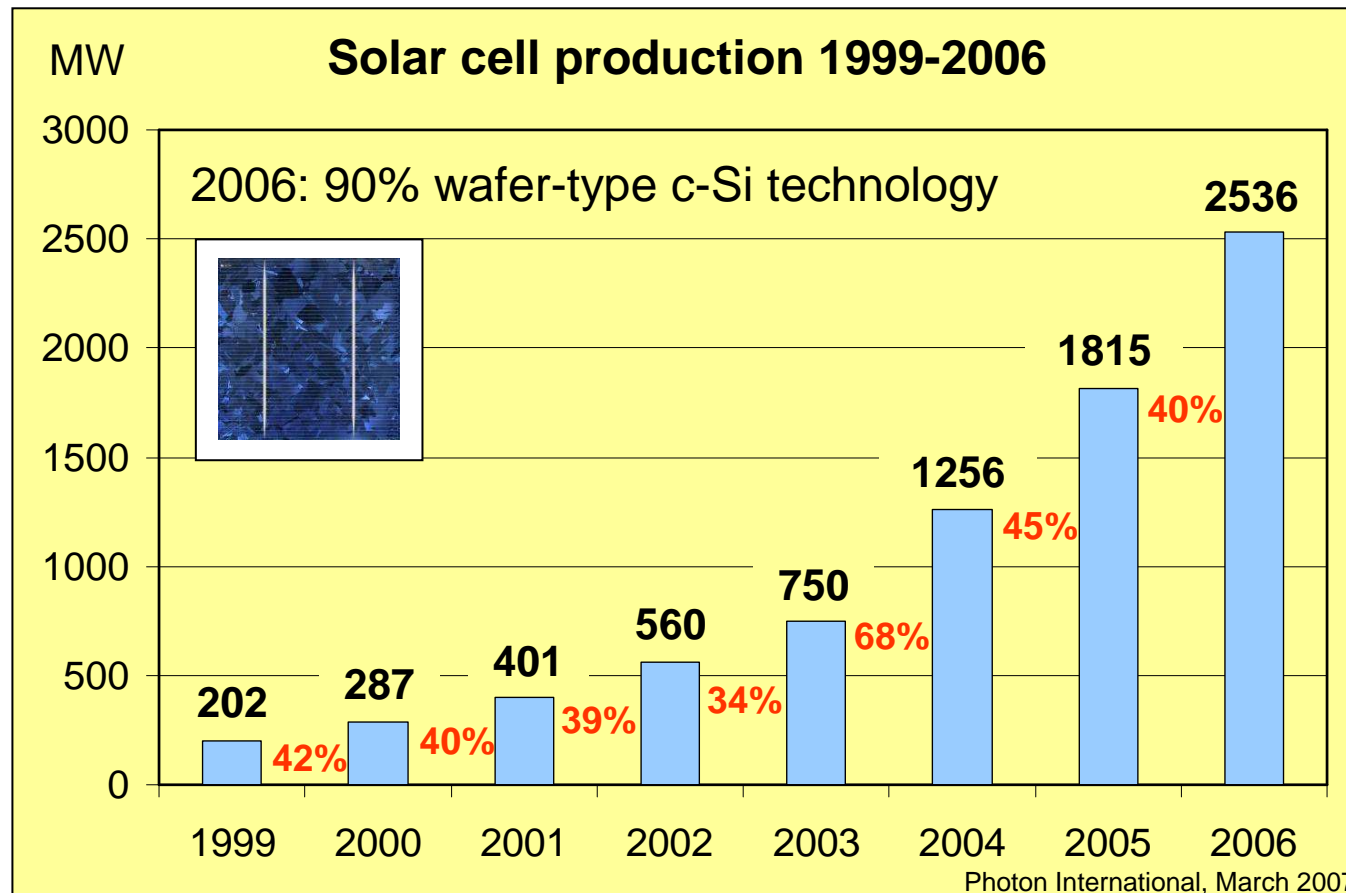
At 10% overall efficiency (generation & storage):

1200x1200 km² to supply 2050 energy needs (~1000 EJ)



World of photovoltaics

PV industry: the fastest growing industry in the world



Market

Jobs

Predictions

Estimation

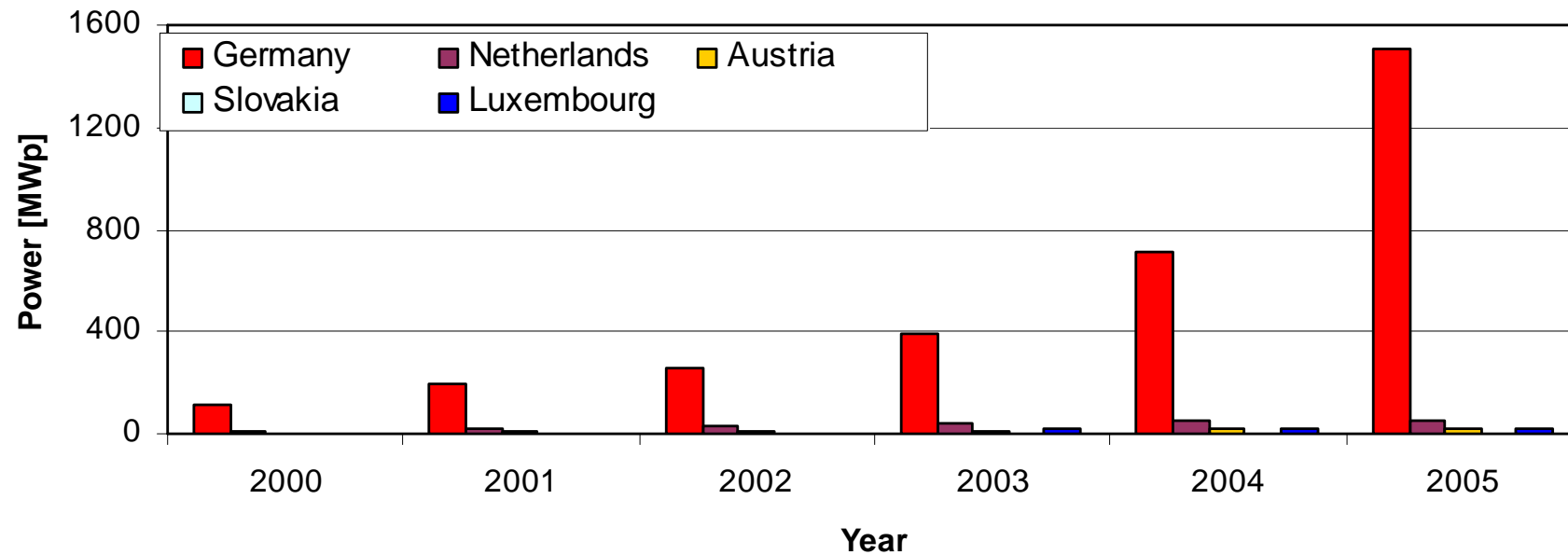
market:

2005

~ 9 000x10⁶ €

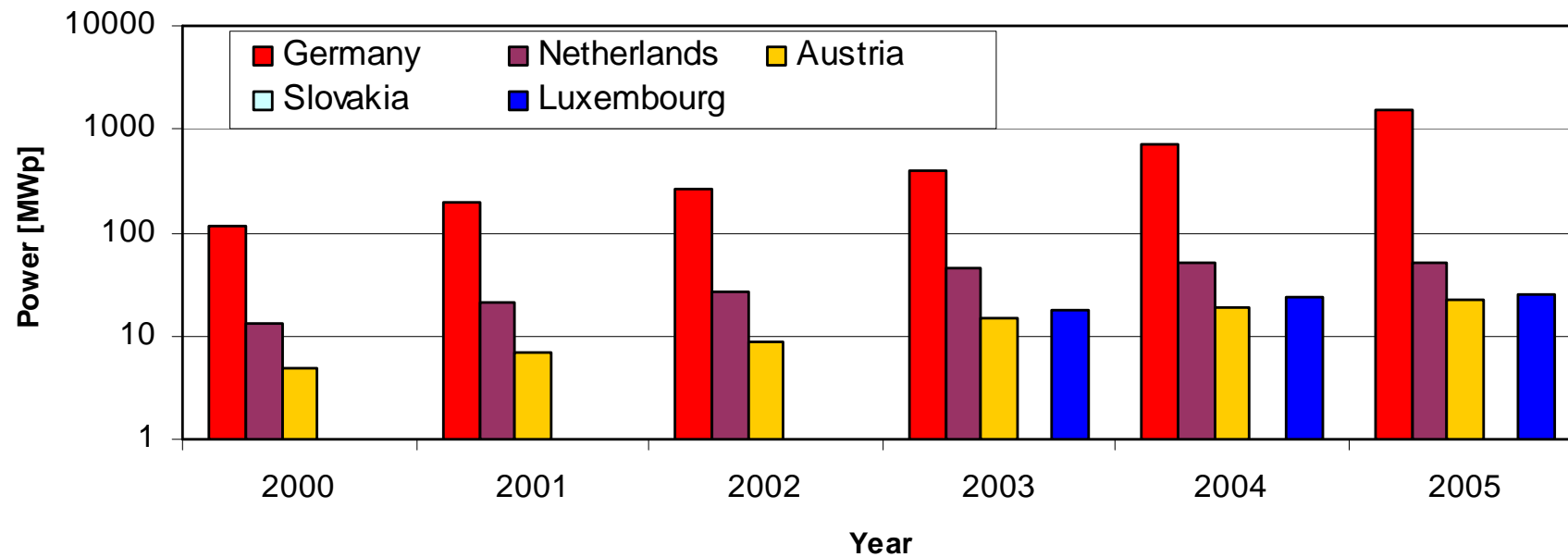
~ 70 000 jobs

PV installed power



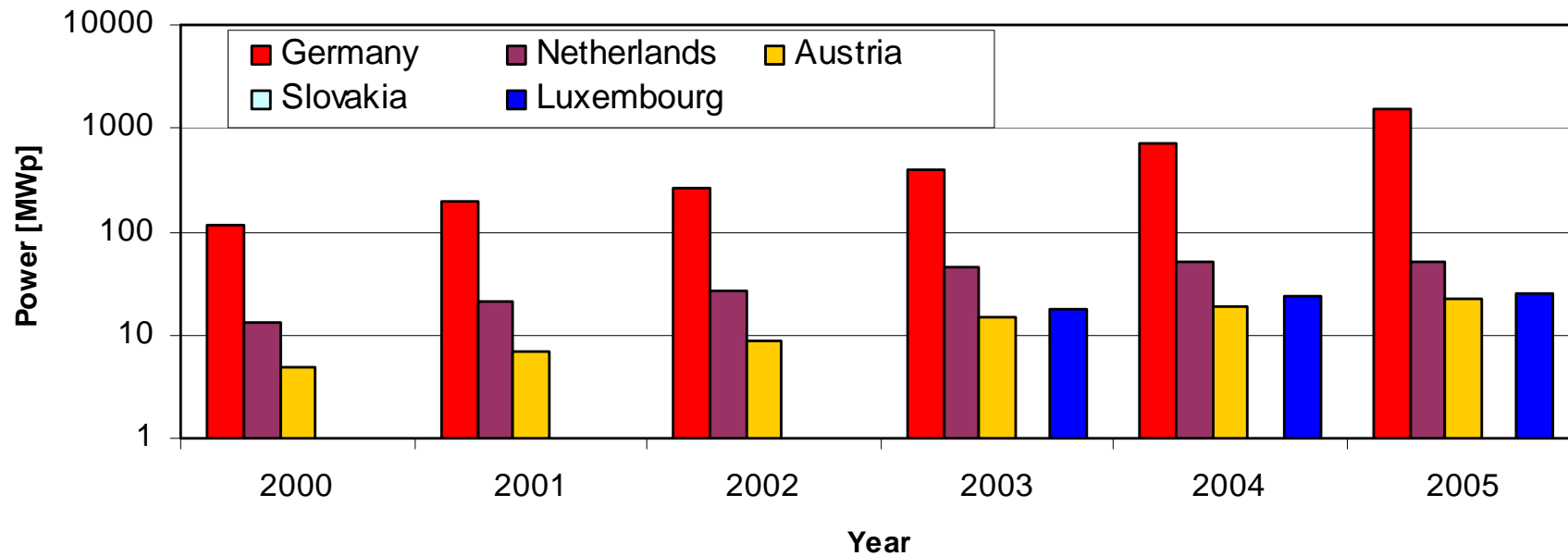
PV installed power

Logarithmic scale!



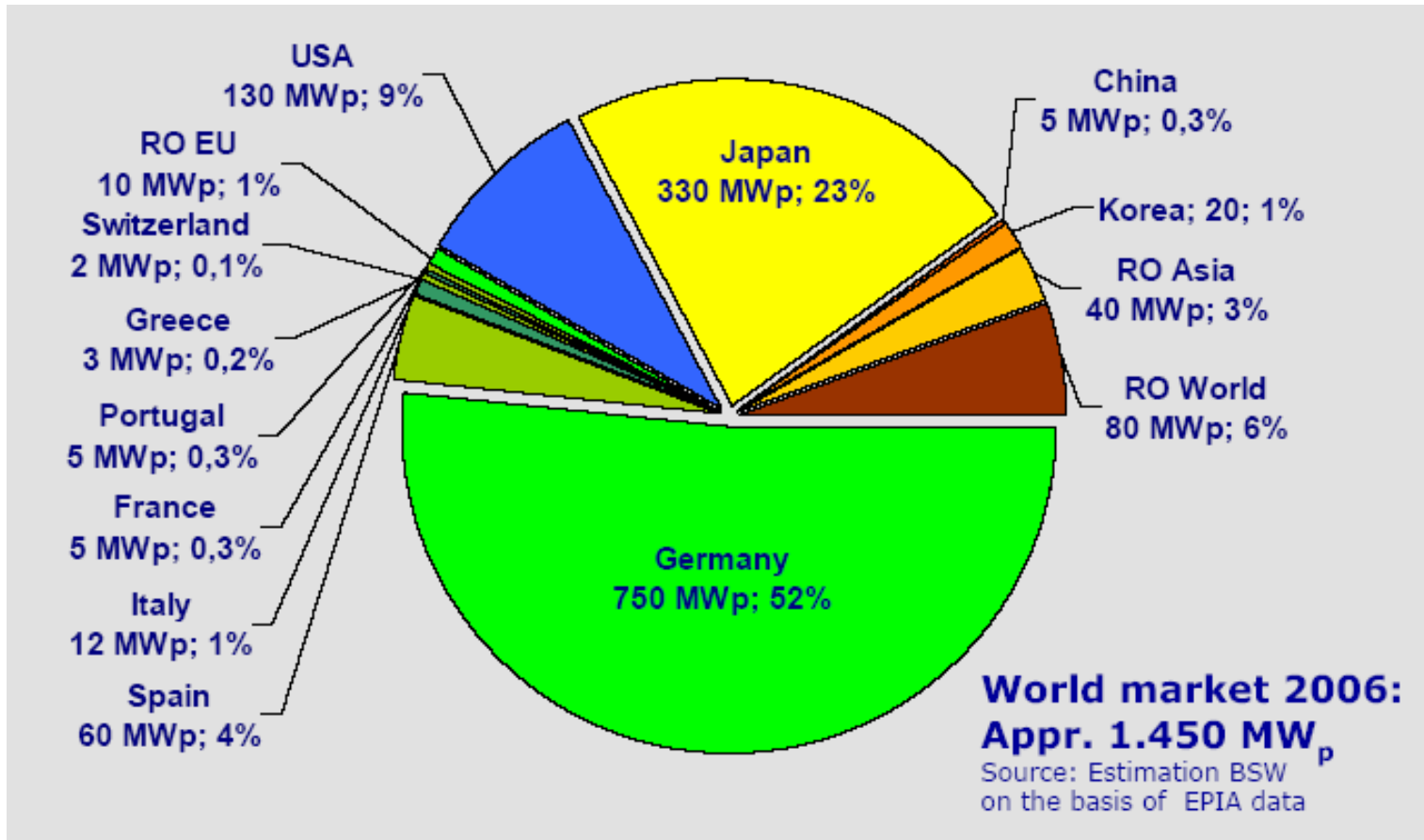
PV installed power

Logarithmic scale!



	grid-connected	off-grid
Slovakia	0 MW	0,004 + 0,060? MW
Czech Rep.	0.15 MW	0,62 MW

PV market 2006



Germany is the biggest PV-market since 2004

Loy Energy Consulting, 9/2007

Development of German PV market

PV Market Data 2006

Newly installed power: 750 MWp

Total installed power: 2,540 MWp

No. of newly installed systems: 90,000

No. of total systems installed: 300,000

Turnover 2006: 3.8bn € (5b US\$)

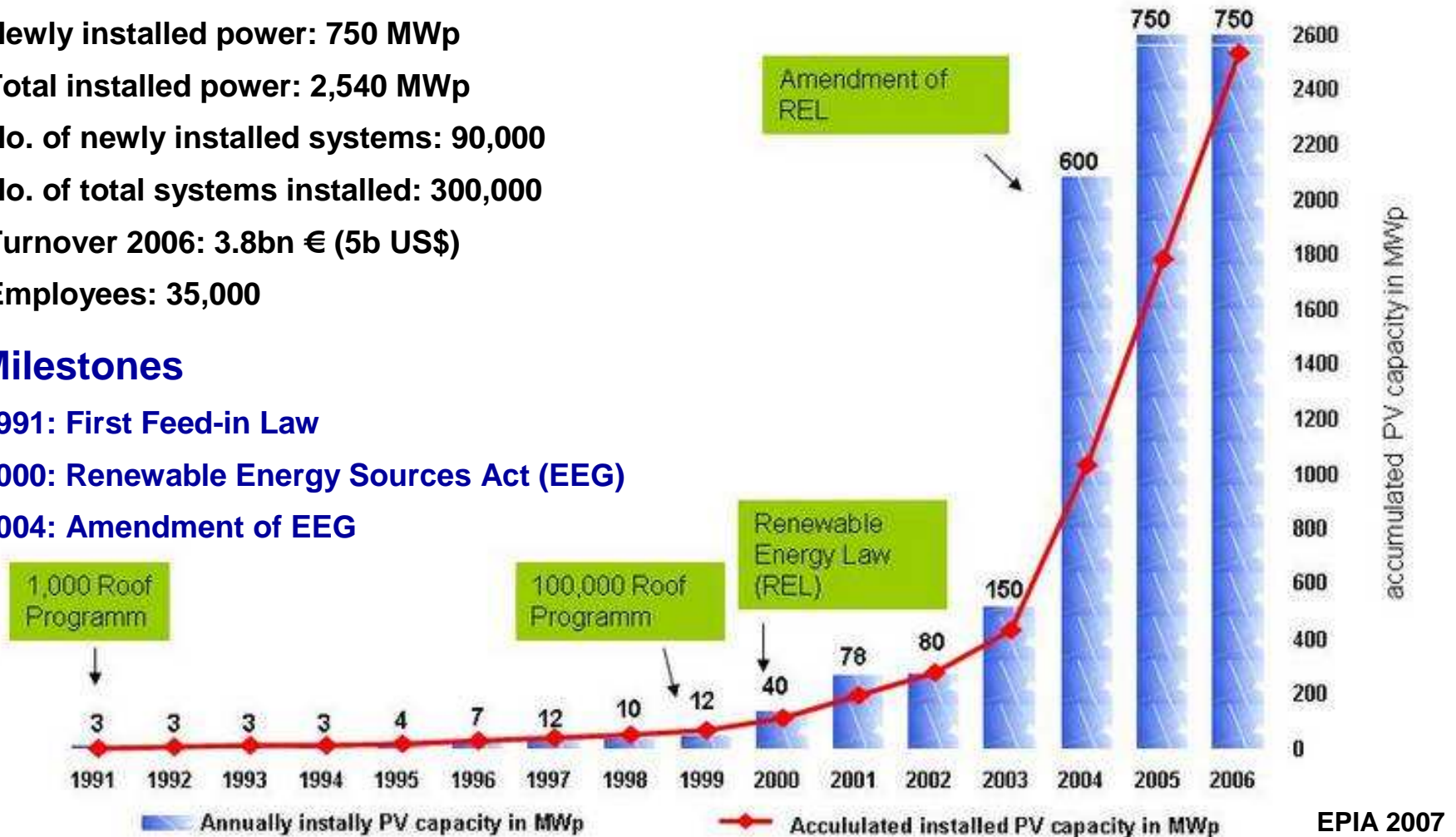
Employees: 35,000

Milestones

1991: First Feed-in Law

2000: Renewable Energy Sources Act (EEG)

2004: Amendment of EEG



PV installed power

Stratégia vyššieho využitia OZE pre SR

Tabuľka č. 8: Výroba elektriny v roku 2015

Zdroj / Rok	2004 [GWh]	2010 [GWh]	2015 [GWh]
Malé vodné elektrárne	250	350	400
Biomasa	33	410	650
Veterné elektrárne	6	300	900
Bioplyn	2	180	300
Geotermálna energia	0	0	40
Fotovoltaické články	0	0	10
Spolu	291	1 240	2 300

Zdroj: MH SR

German PV industry

Raw silicon	Wafer	Solar cells	Solar modules	Special modules	Inverters / Bat. chargers
Wacker Chemie	ASI Intertech	Deutsche Cell	GSS	ASS	Aixcon
PV Silicon	Deutsche Solar	Ersol	Heckert-B.X.T.	Schüco	Dorf Müller
	PV Silicon	Schott Solar	Schott Solar	Sunovations	Kaco
Silicon ingots	Schott Solar	Sunways	Scheuten	Sunware	Siemens
PV Silicon		Q-Cells	SMD	Webasto	SMA
			Solar-Fabrik	Solarc	Solar Konzept
			Solar Factory	Solarnova	Solar-Fabrik
			Solara	Glaswerke	Sunways
			Solarwatt	Arnold	Steca
			Solon	Thin film Modules	Würth Solergy
			Sunset		
				Antec	
				Sulfurcell	
				Würth	
				Schott Solar	

Loy Energy Consulting, 9/2007

Summary

Accelerated price increase and depletion of fossil fuels

OIL: Should not be a major energy source for future due to its reserves

COAL: Largest source of CO₂ emission, primary contributor to global warming

More radioactive waste than nuclear-power plants

Extensively used in rapid growing economies

(China 2 coal-fired power plants built every week) (cheap and abundant)

GAS: Environmentally most suitable for electricity generation

NUCLEAR ENERGY: biggest problem is the storage of radioactive waste

Accelerate implementation of renewable energy sources (RES)

- Increase the diversity in energy mix
- Do not discriminate any of RES
- Pass the energy law, design effective feed-in tariff

**„Solar architecture
is not about fashion,
it is about survival“
Sir Norman Foster**



Thank you very much for your attention

Loy Energy Consulting, 9/2007

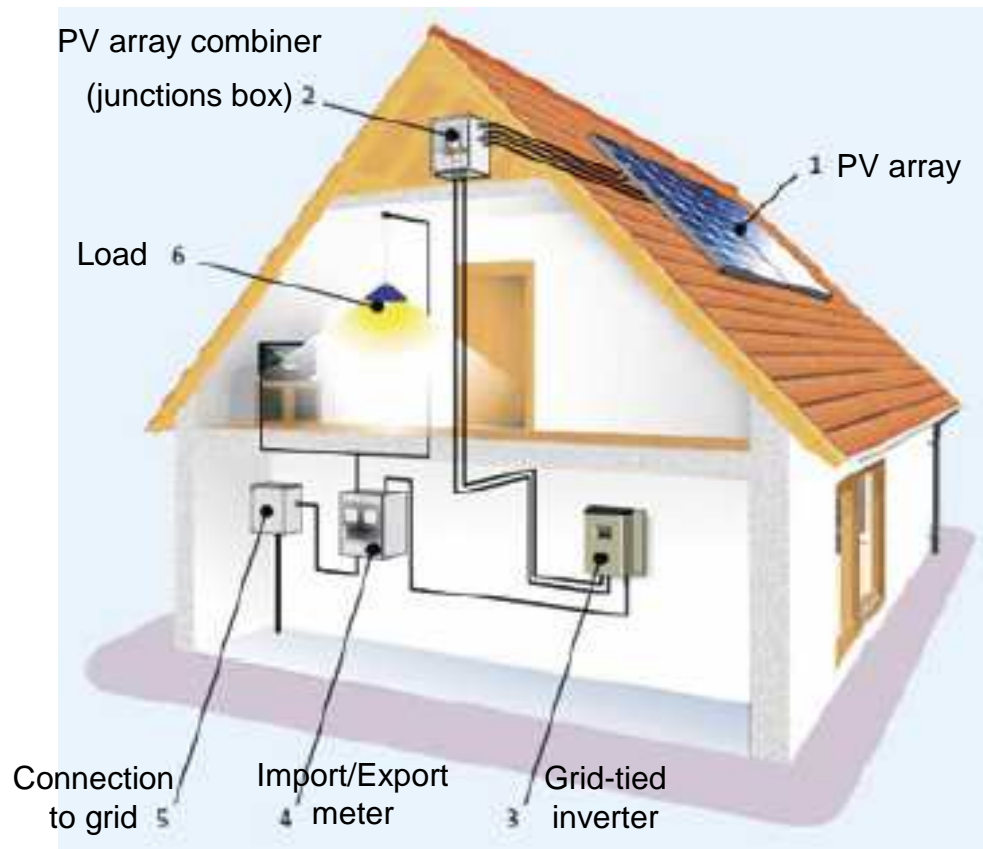


Slovak RE Agency
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TU Delft
Delft University of Technology

Grid-connected PV system in Germany

Every kWh of solar electricity produced is fed into the grid, sold to the utility and re-paid with a fixed price



Typical data of a small PV system (per kWp)

Investment costs: 4,800 €
(6,400 US\$)

Annual production of solar electricity: 900 kWh/a

Feed-in tariff: 0.492 €/kWh
(0.65 US\$/kWh) payed over 20 years

Feed-in payment: 443 €/a
(590 US\$/a)

Interest rates: 4.7%/a eff

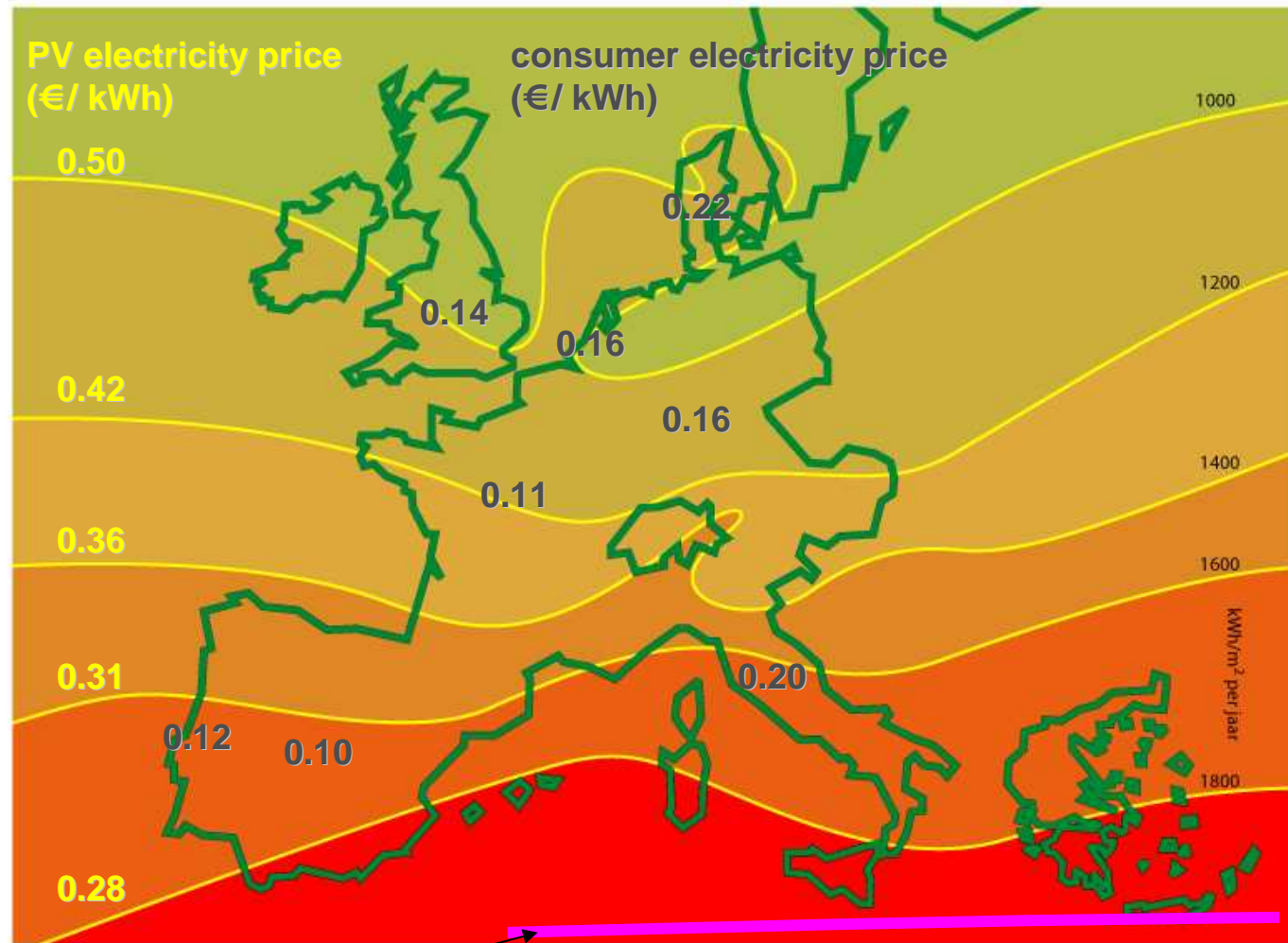
1 US\$ = 0.75 €

PV electricity price

2005

PV electricity prices*)
compared with
typical **consumer**
electricity prices

*) depreciation 25 yrs,
real interest rate 4%,
O&M cost 1%/yr,
PR 0.75 (example)

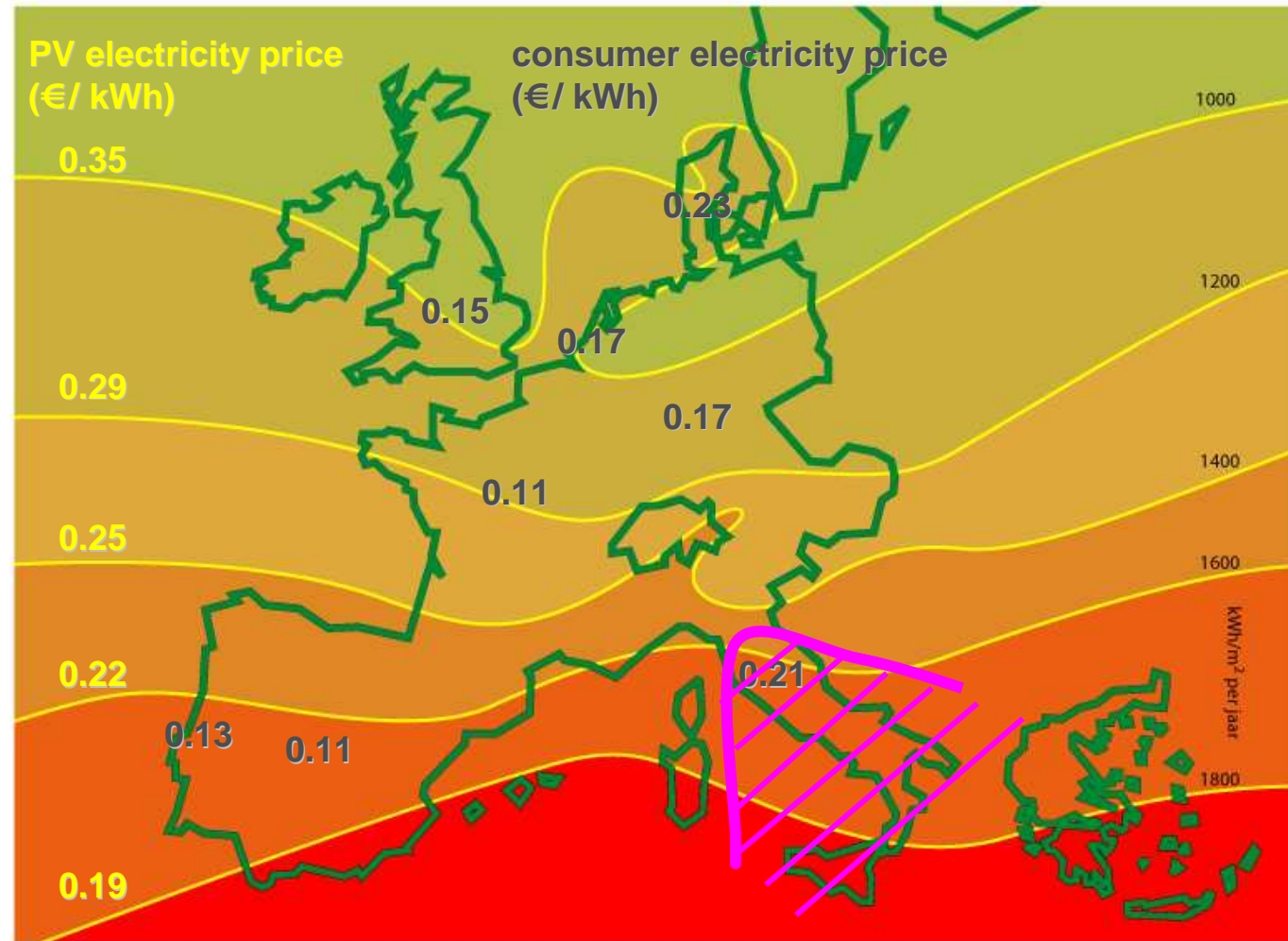


“grid parity”

PV electricity price

2010

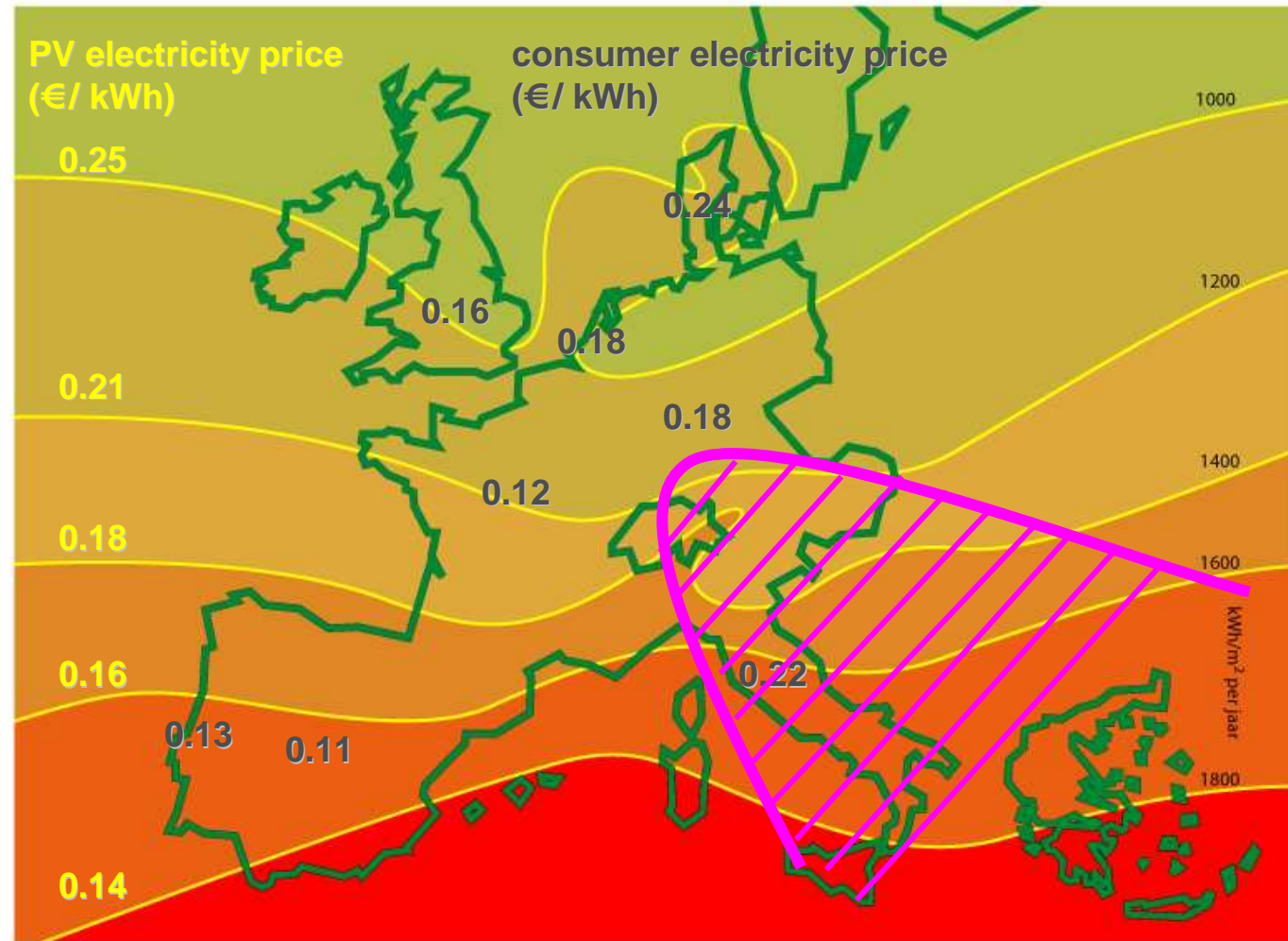
PV electricity prices compared with expected consumer electricity prices (+ 1%/yr)



PV electricity price

2015

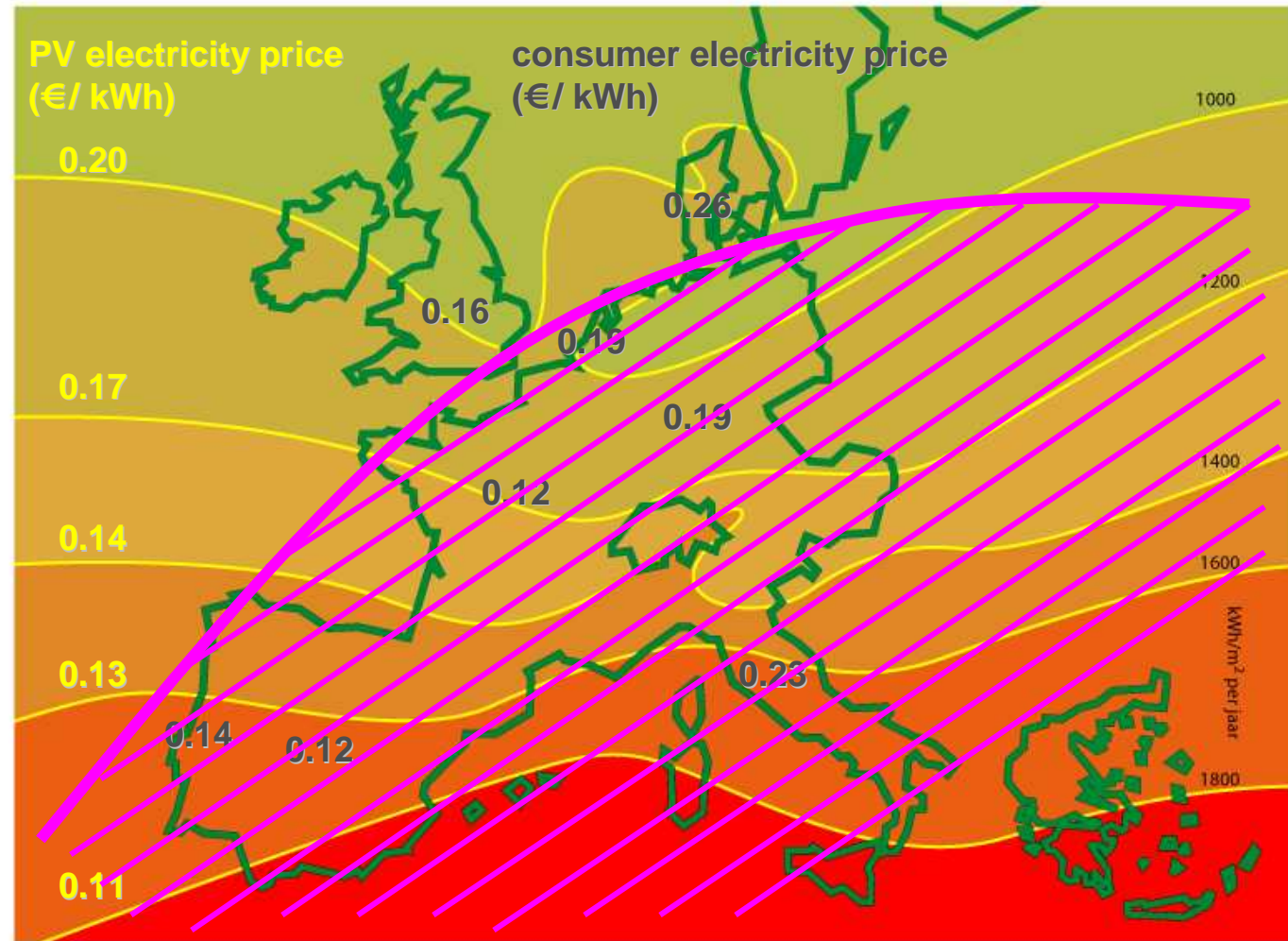
PV electricity prices compared with expected consumer electricity prices (+ 1%/yr)



PV electricity price

2020

PV electricity prices compared with expected consumer electricity prices (+ 1%/yr)



PV electricity price

2030

PV electricity prices
compared with
expected **consumer**
electricity prices
(+ 1%/yr)

