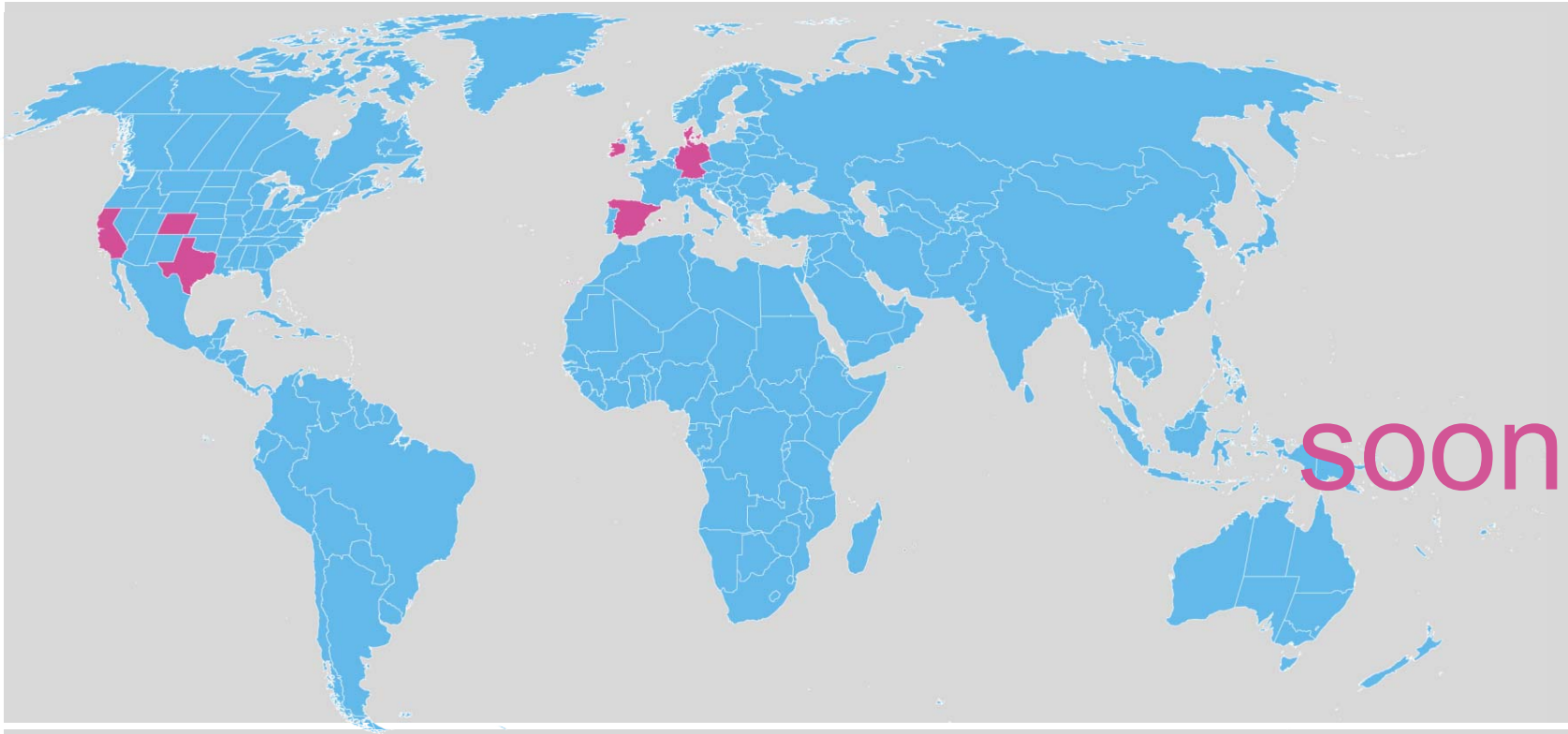
Renewables in 2030 – some insights from Germany's *energy transition*

Markus Steigenberger, Deputy Executive Director Agora Energiewende

BERLIN, 21 AUGUST 2015

Welcome to the Club, India!



The key question:
„How can you run a power system on the basis of variable Renewables?“

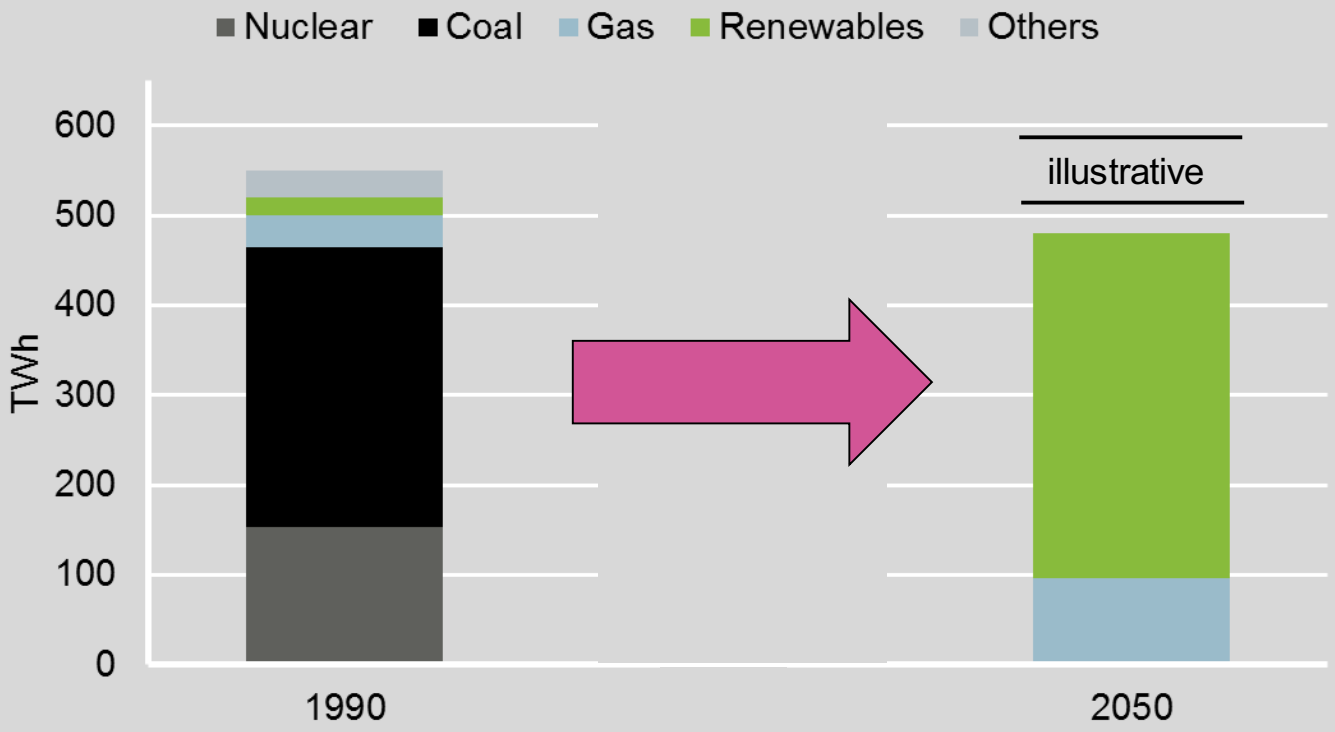
Who we are

- Independent and non-partisan Think Tank, currently 20 experts
- financed by philanthropic money (Mercator Foundation and European Climate Foundation)
- Mission: How to make the energy transition in Germany and Europe a success story?
- Approach: Combining research and dialogue in order to provide sound basis for decision makers

Development of the electricity sector in Germany – past and envisaged

The *energy transition* means changing the power system from fossil/nuclear to renewable

Gross power production in 1990 and 2050



AG Energiebilanzen (1990, 2014); illustration based on current targets (2050)

Greenhouse Gas Emissions
Reduction of 40% by 2020 and 80% to 95% by 2050 below 1990 levels

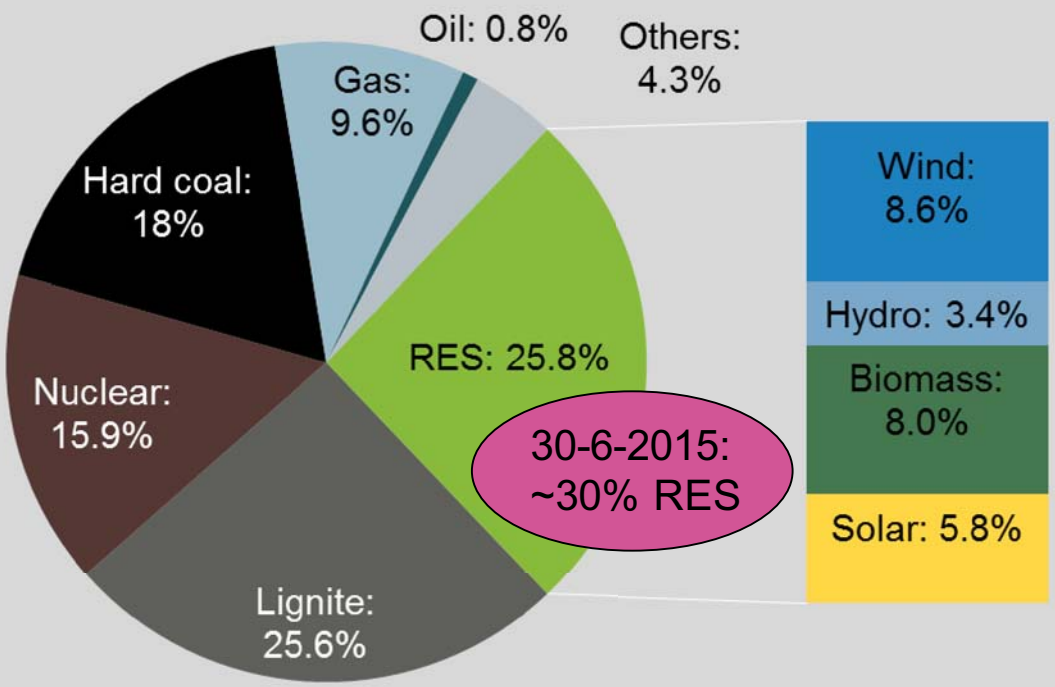
Nuclear
Stepwise shut down of all power plants until end of 2022

Renewables
Share in gross electricity consumption of 40-45% by 2025, 55-60% by 2035 and at least 80% by 2050

Efficiency
Reduction of electricity demand by 10% by 2020 and 25% by 2050 below 2008 levels

Renewables are growing quickly, but coal/lignite still provide almost half of the electricity

German Electricity Mix in 2014



The share of renewable electricity increased from ~5% in 2000 to ~26% in 2014. In first half of 2015, the share was ~30%.

Nuclear will be phased out until 2022. Coal and lignite still provide for 45% of electricity.

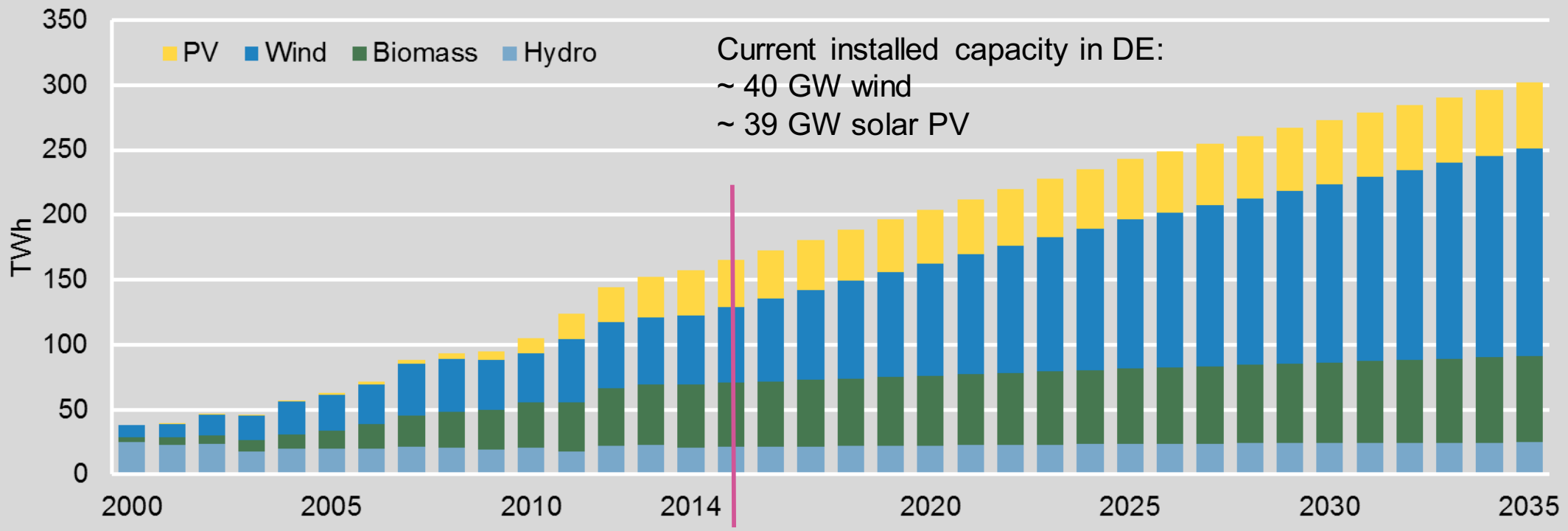
The Law stipulates shares of renewable electricity of 40-45% in 2025, 55-60% in 2035 and at least 80% in 2050

Variable renewables hold a share of 15-20% today and will provide by far the biggest share of electricity in the future

AG Energiebilanzen (2014)

Wind and solar will be the two dominating technologies of the future

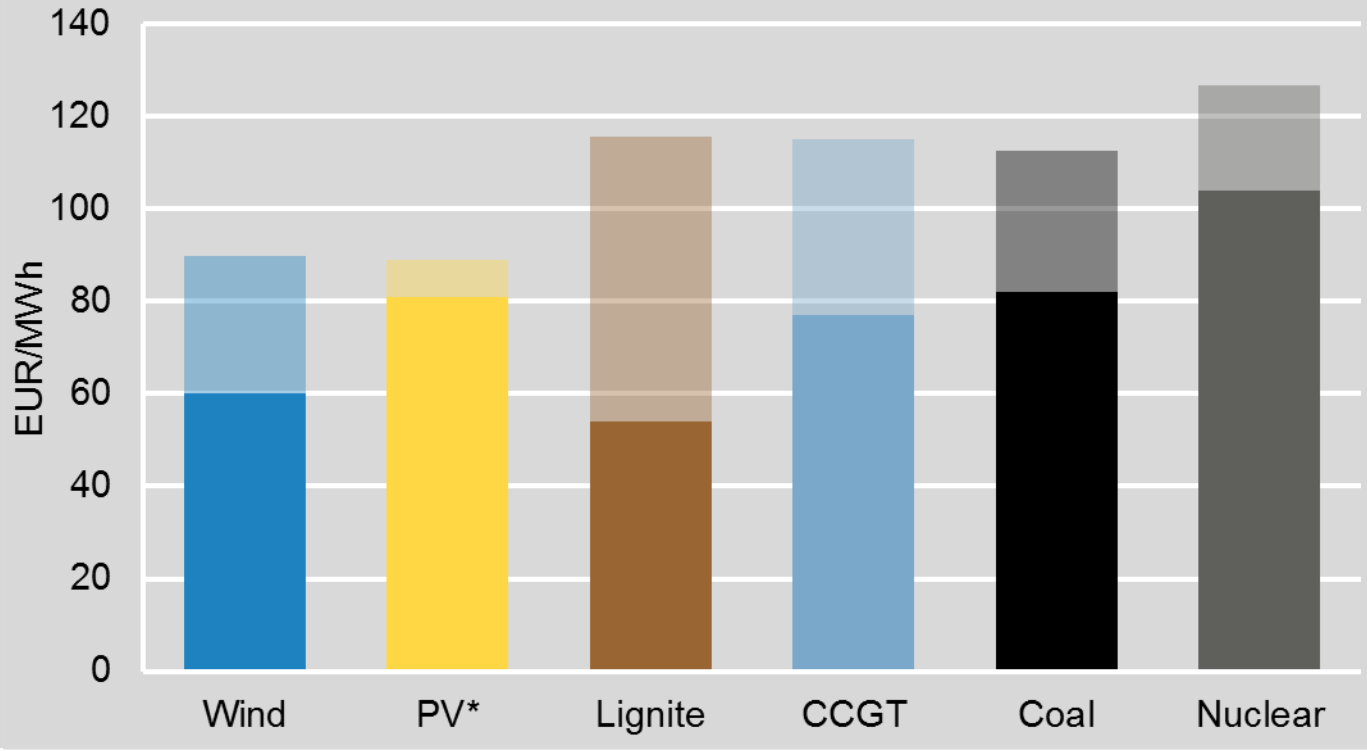
Gross electricity generation 1990 – 2035 of renewable energies



AG Energiebilanzen (2000 – 2014); BNetzA, own calculations (2015 – 2035)

Today, wind and solar are already cost competitive to all other newly built energy sources – and cheaper than Nuclear and CCS

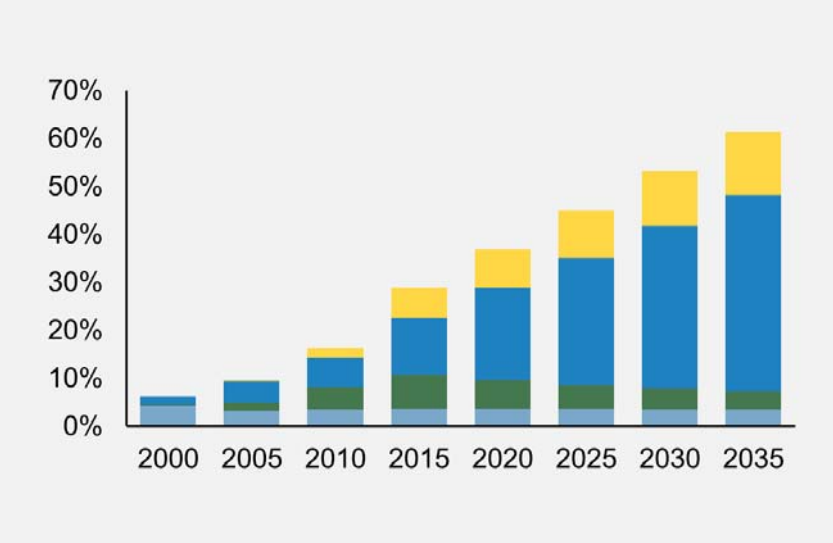
Range of levelized cost of electricity (LCOE) in 2015 in EUR/MWh



Agora Energiewende (2015)

The flexibility challenge

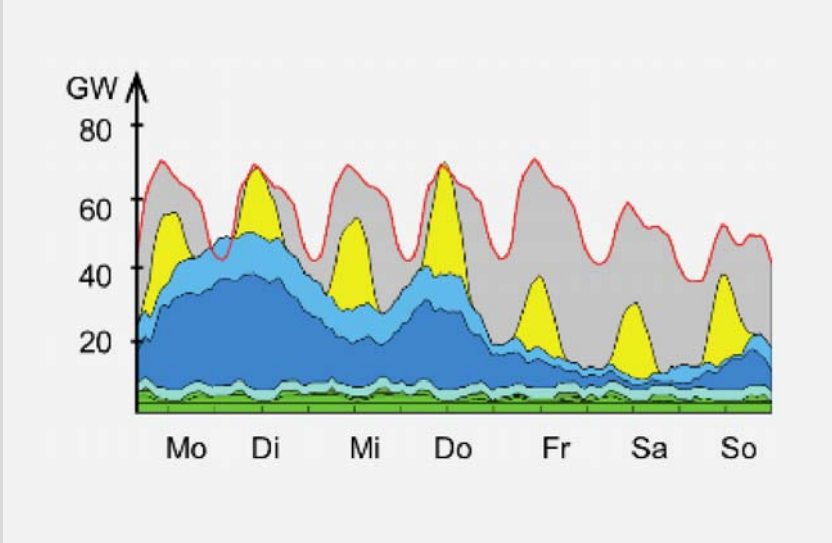
Variable Renewables (Wind and Solar PV) will fundamentally alter the way power systems work



weather-dependent

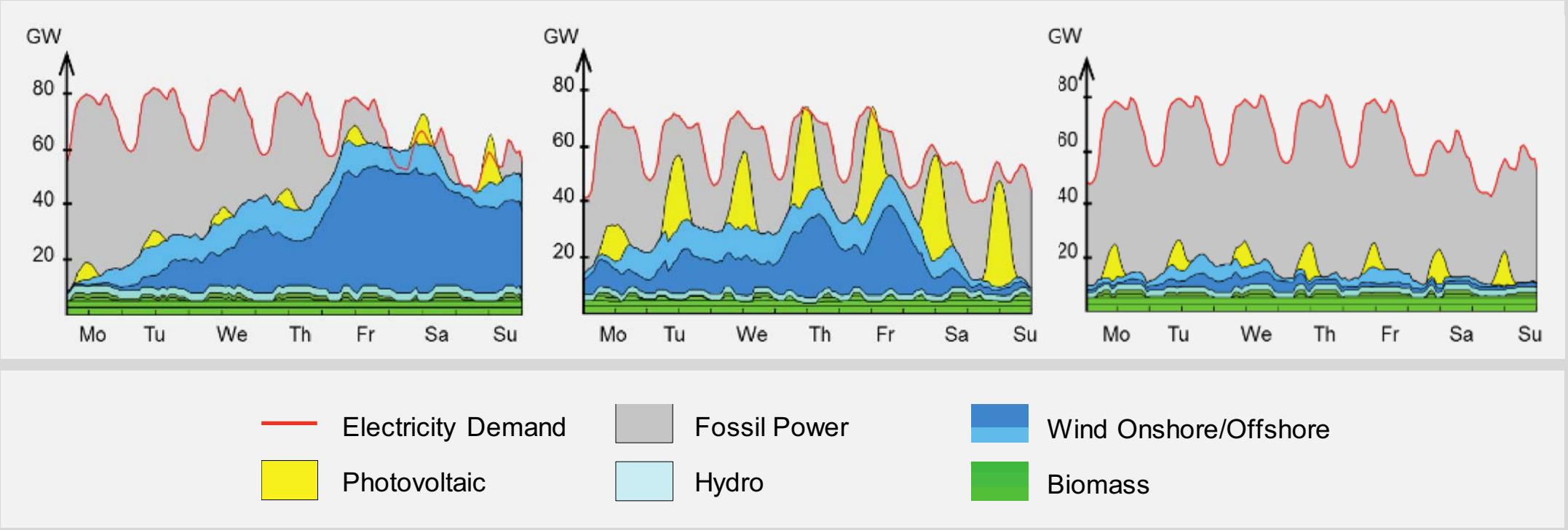
capital-intensive

zero marginal cost



Future power system needs to integrate variable electricity generation from wind and solar PV

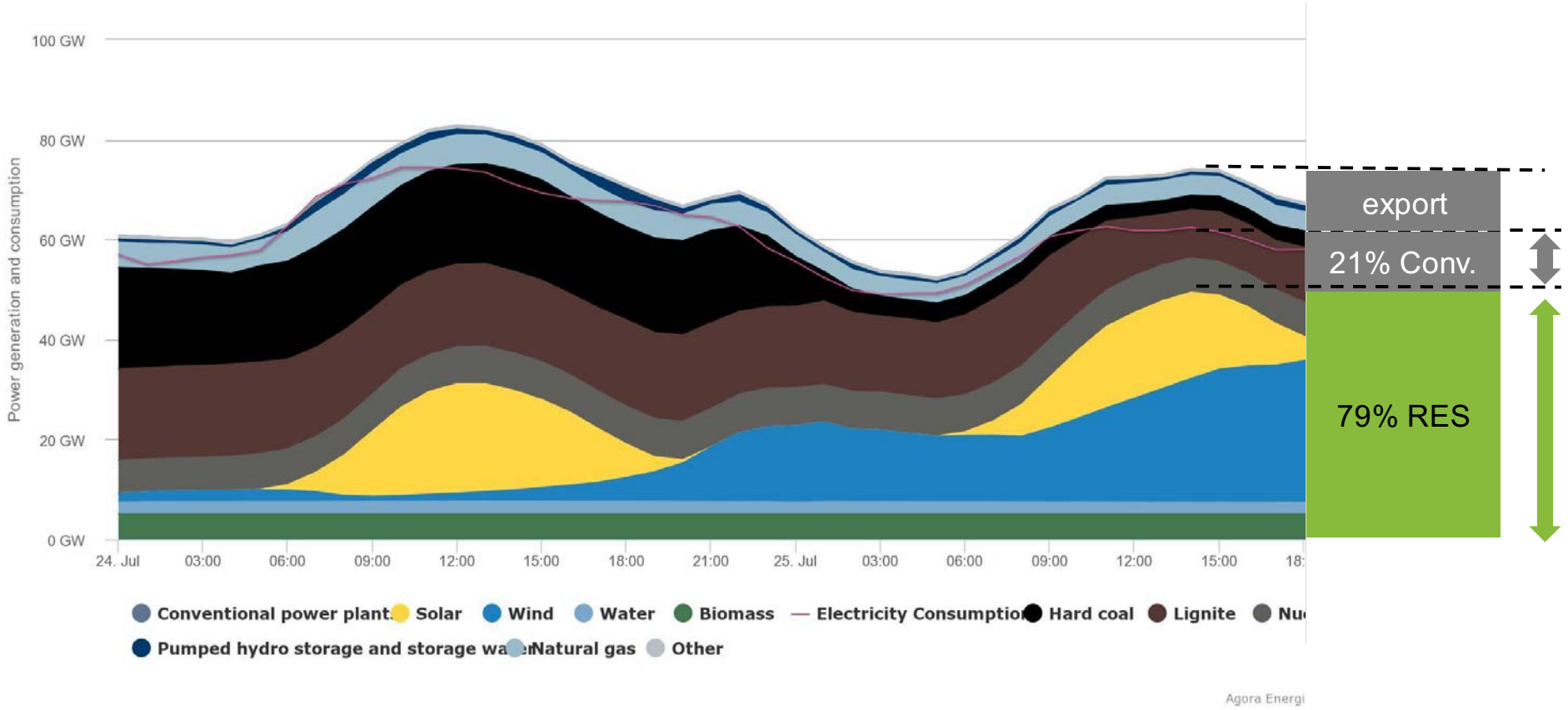
Electricity generation and demand in sample weeks of February, August and November 2023*



Agora Energiewende (2013)

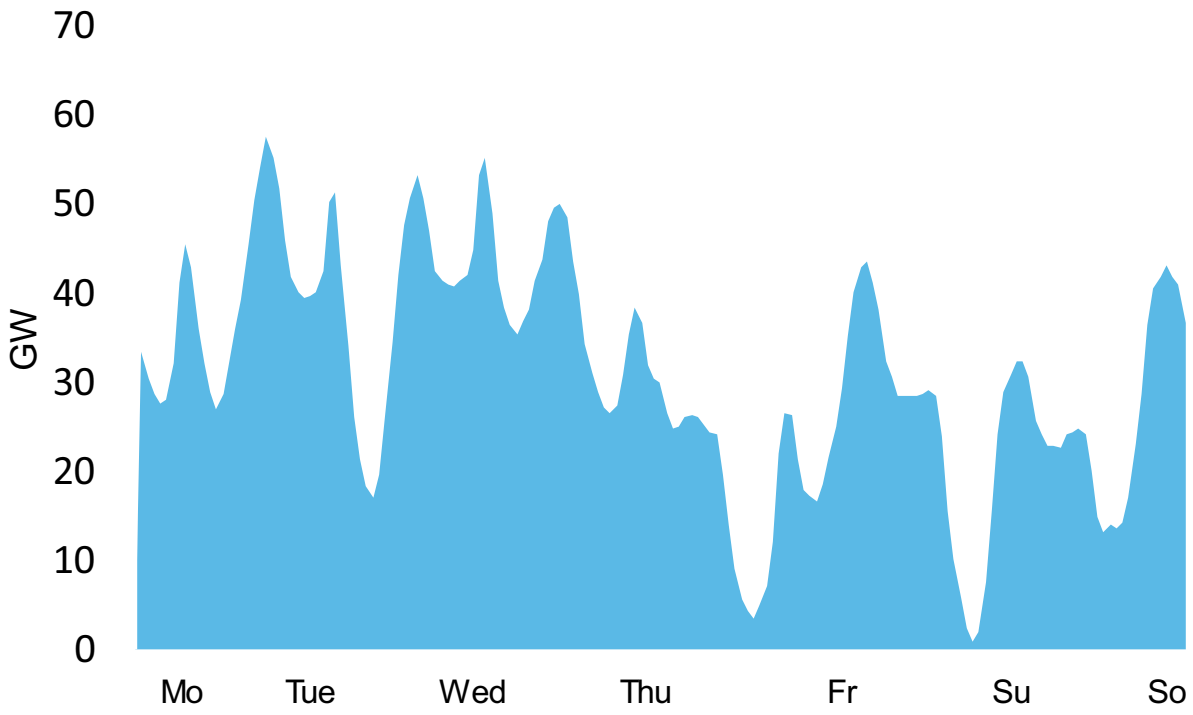
Flexibility is a matter of today already

Electricity Generation in Germany on 24/25 July 2015



Residual load will become the key variable

Residual load in a sample week in February 2023 in GW



Agora Energiewende/RAP (2013)

With growing shares of variable renewable energy, baseload capacities will less and less be needed

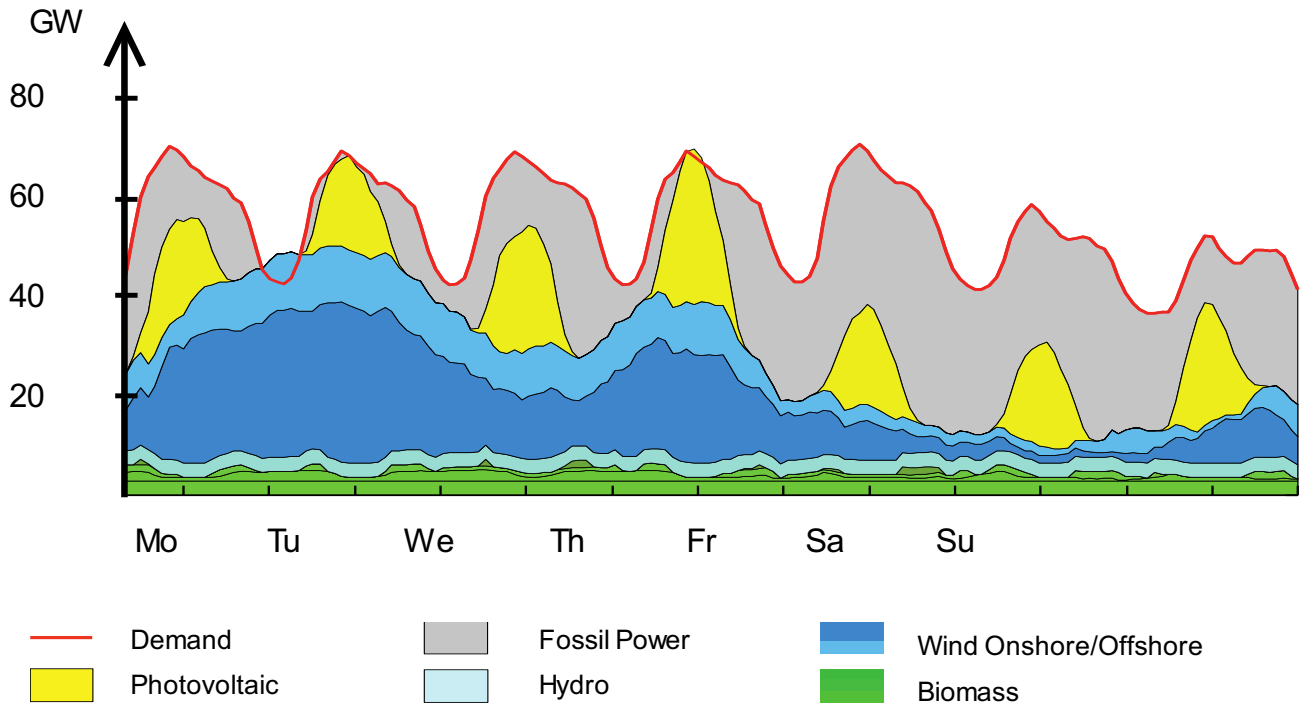
Instead, flexible resources (both on the supply and demand side) are required to cover the residual load

Residual load is defined as ‚load minus renewables“

How power system can react to the flexibility challenge

Flexibility options exist …

Envisaged electricity production in a week in May in 2023 in Germany



Agora Energiewende 2013

Flexibility options are not (yet) sufficiently incentivised

System-friendly RES deployment becomes more important with higher shares of vRES

Grid expansion is the cheapest option

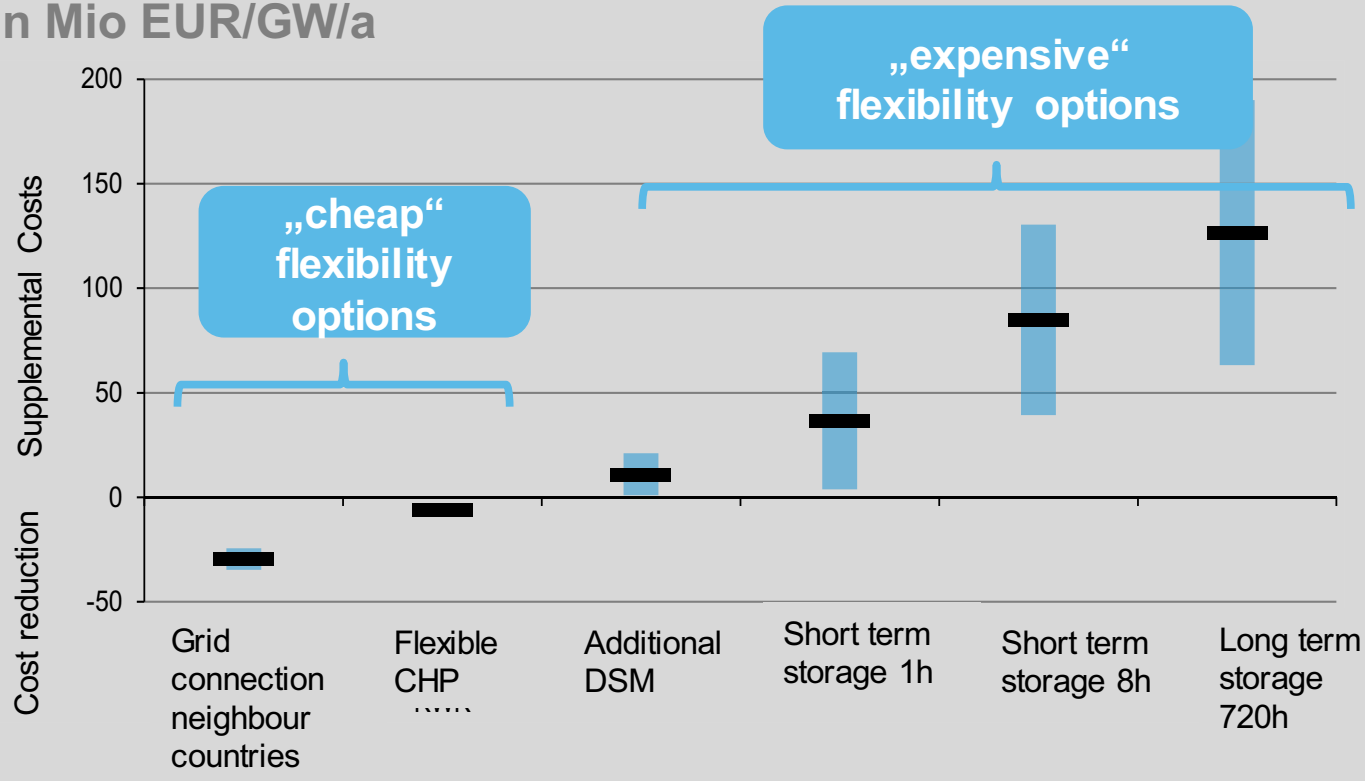
Other key flexibility options include:

- Flexible fossil power plants
- Biomass power plants
- demand side management
- storage

… but they come at different costs

Cost reduction vs. Cost increase for different flex options

in Mio EUR/GW/a



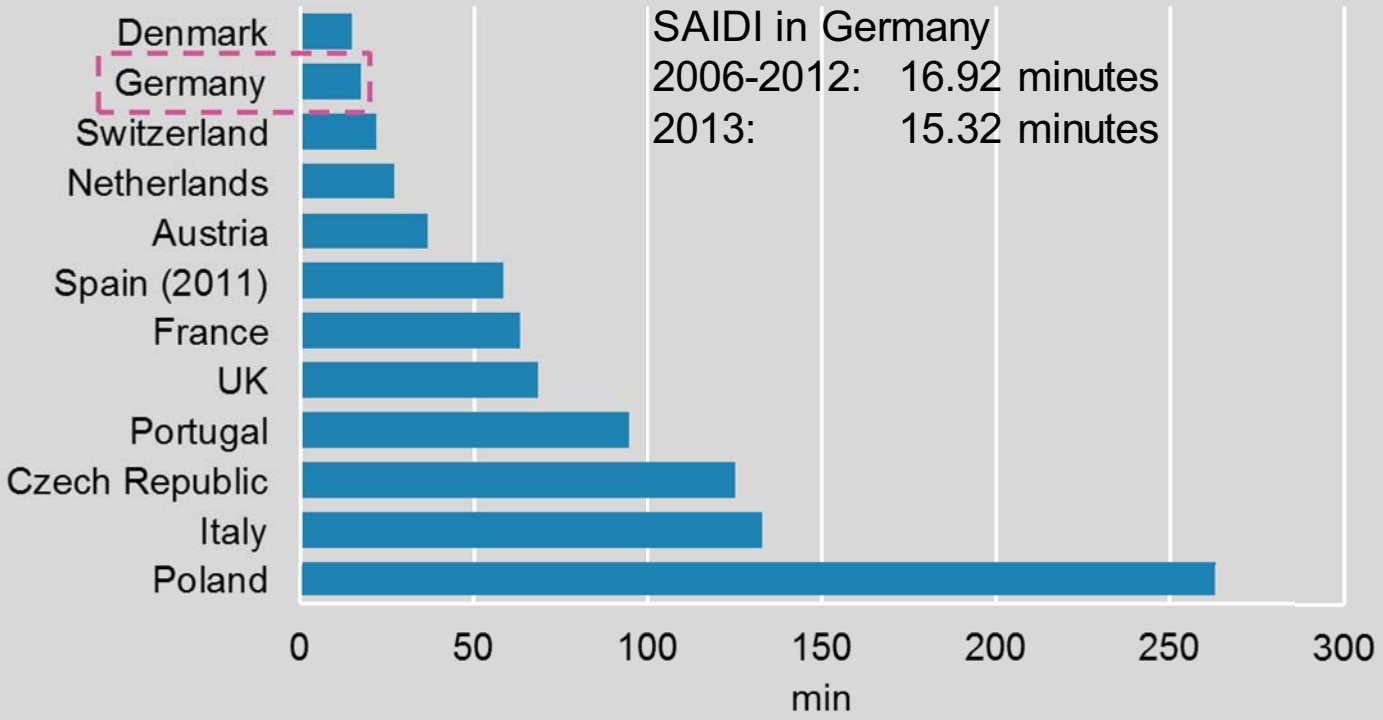
Different flexibility options serve different needs – from very short term up to long term (days and weeks)

Costs for (new) flexibility options vary significantly. Trading electricity over larger areas (=> grid expansion) prooves to be the cheapest option

New storage technologies need to be developed in the medium and long term. A lack of storage facilities is no reason to stop deployment of variable RES

At 25% RES, Germany remains world class in regard to system reliability and curtailment

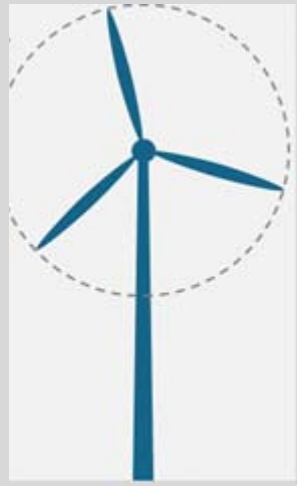
System Average Interruption Duration Index (SAIDI)* in 2012



CEER (2013)

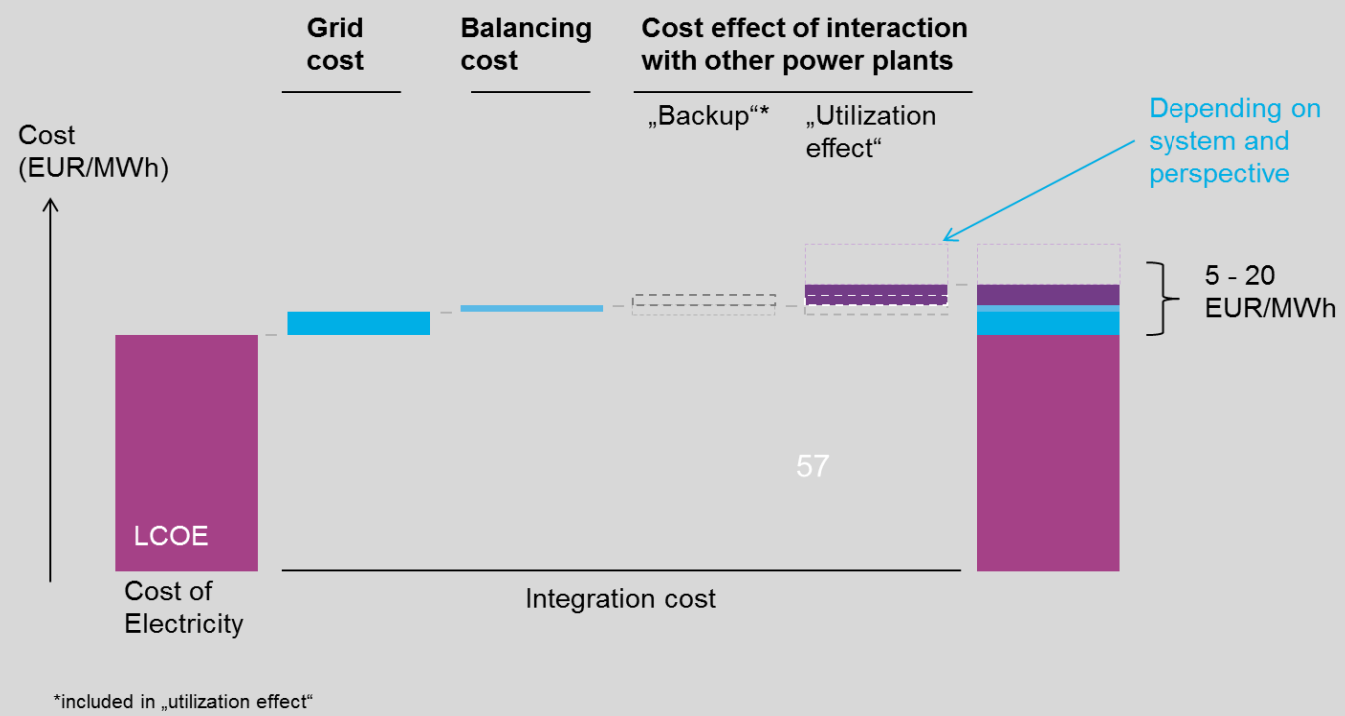
* including exceptional events

Curtailment Rate in 2013:
Wind: 0.4% (at ~35 GW)
Solar: 0.0% (at ~38 GW)



Additional integration costs depend on the system

Schematic depiction of integration costs



Agora Energiewende 2015 (forthcoming)

Variable RES trigger additional costs for grid expansion and balancing energy.

On top of this, wind and solar will have effects on other power plants („utilization effect“).

The magnitude of these integration costs depends on the system. The more flexible a system, the lower the integration costs.

In Germany, at a share of 50% RES, it is estimated that integration costs will be between 5-20 EUR/MWh.

To sum up

1. Triggered by cost reductions, variable RES (wind and solar) will shape future power systems.
2. Growing shares of variable RES will bring about a flexibility challenge to power systems.
3. Contrary to common believe, power systems with high shares of variable RES can be run cost effectively and reliable.
4. However, this requires a comprehensive perspective – the more flexible the entire power system, the more reliabe and the less costly the future power system will be. Hence, deploying high shares of wind and solar should go along with systemic changes in the residual system (generation, demand, transmission & distribution, storage).

More information and studies available at our website

www.agora-energiewende.org

Agora Energiewende
Rosenstraße 2
10178 Berlin

T +49 (0)30 284 49 01-00
F +49 (0)30 284 49 01-29
www.agora-energiewende.de

Thank you for your attention!

Questions or Comments? Feel free to contact me:
markus.steigenberger@agora-energiewende.de

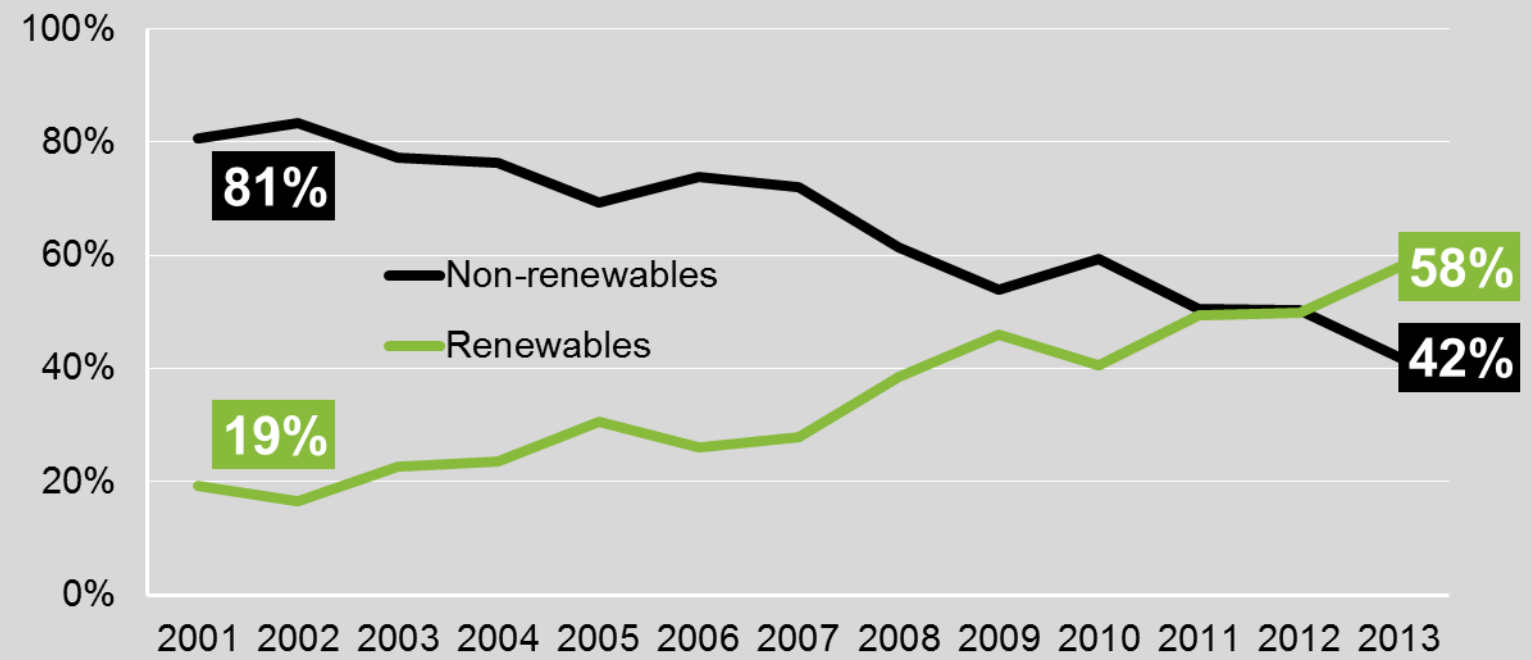
Agora Energiewende is a joint initiative
of the Mercator Foundation and
the European Climate Foundation.

Back Up

Markus Steigenberger | August 2015

Global investments in renewables have overtaken fossil investments

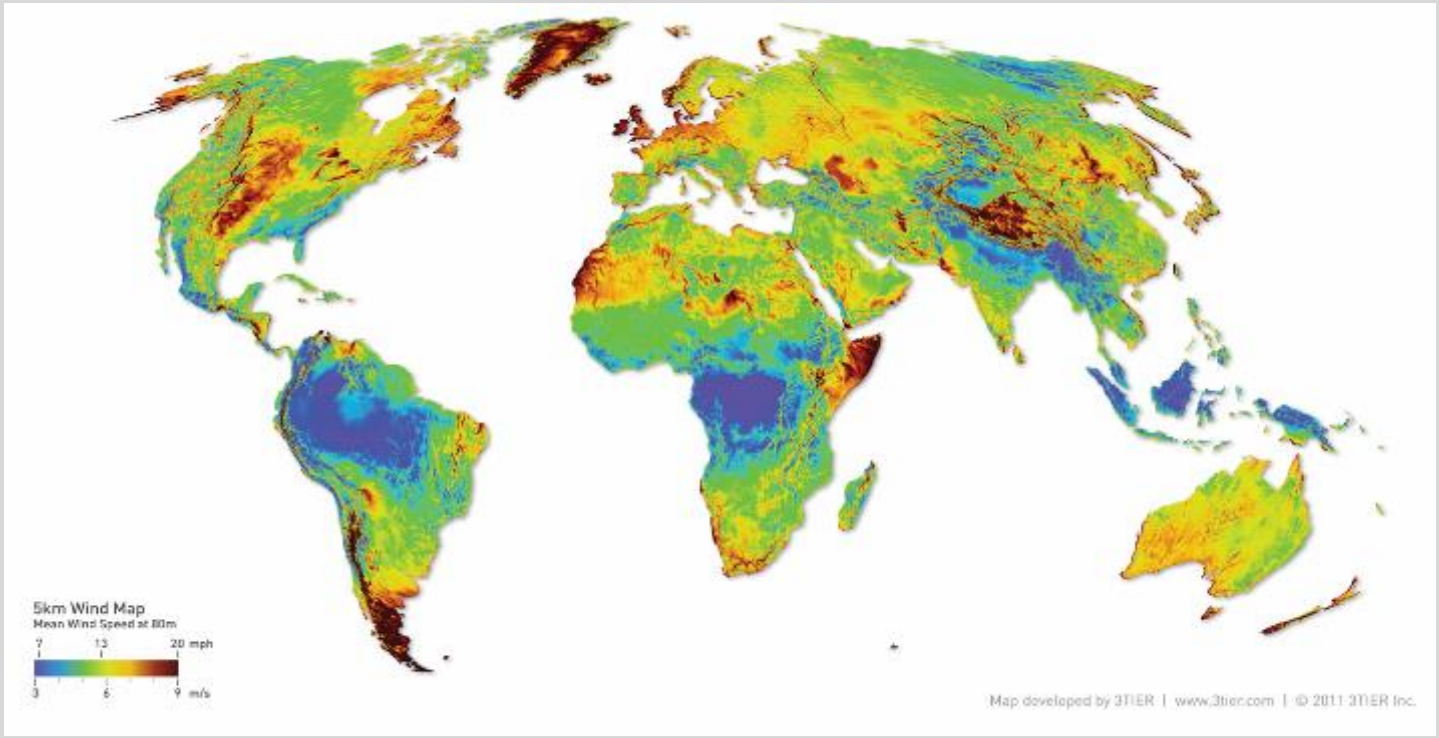
Share in global capacity investments 2001 - 2013



IRENA (2014)

There is wind available all over the world!

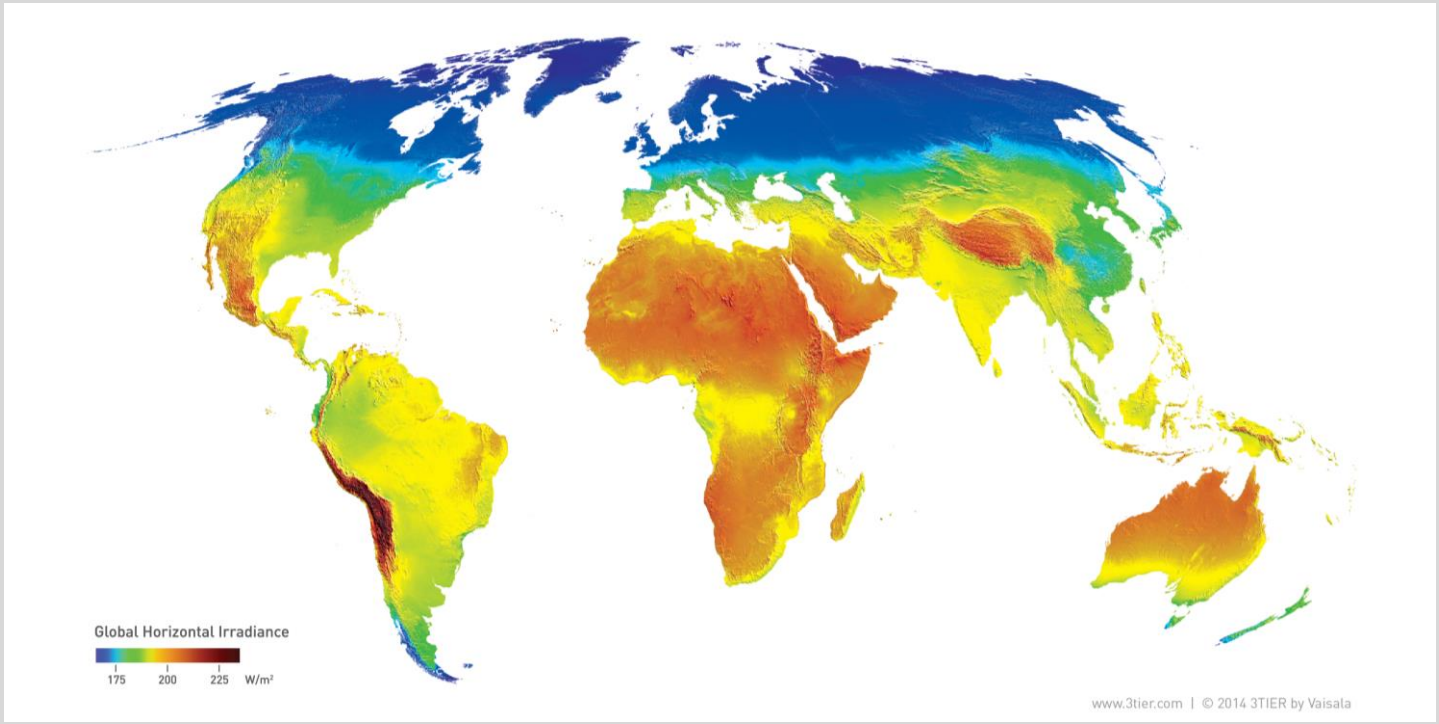
Average wind speed on 80m



3TIER (2011)

And almost everywhere there is more sun than in Germany!

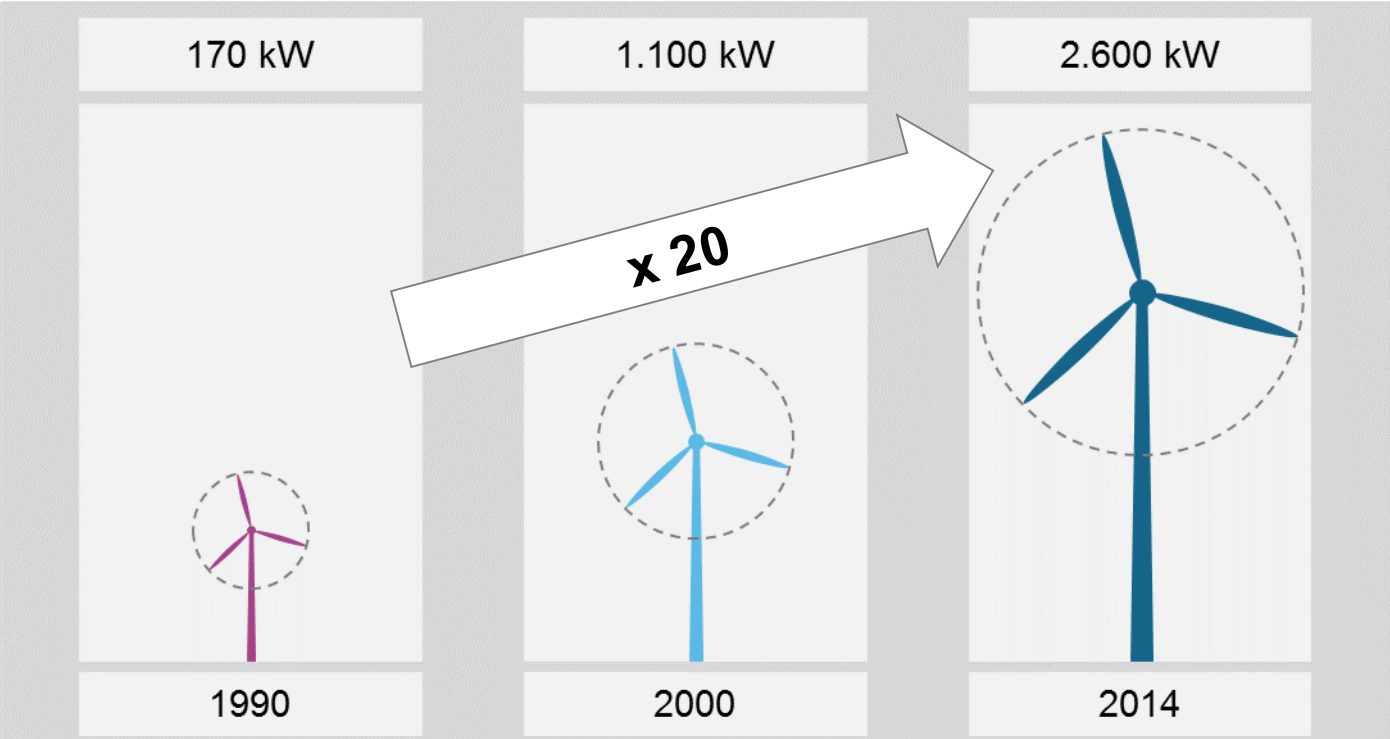
Annual solar radiation in W/m2



3TIER (2011)

Wind Energy has become a mature technology, with windmills of 2-3 MW being standard

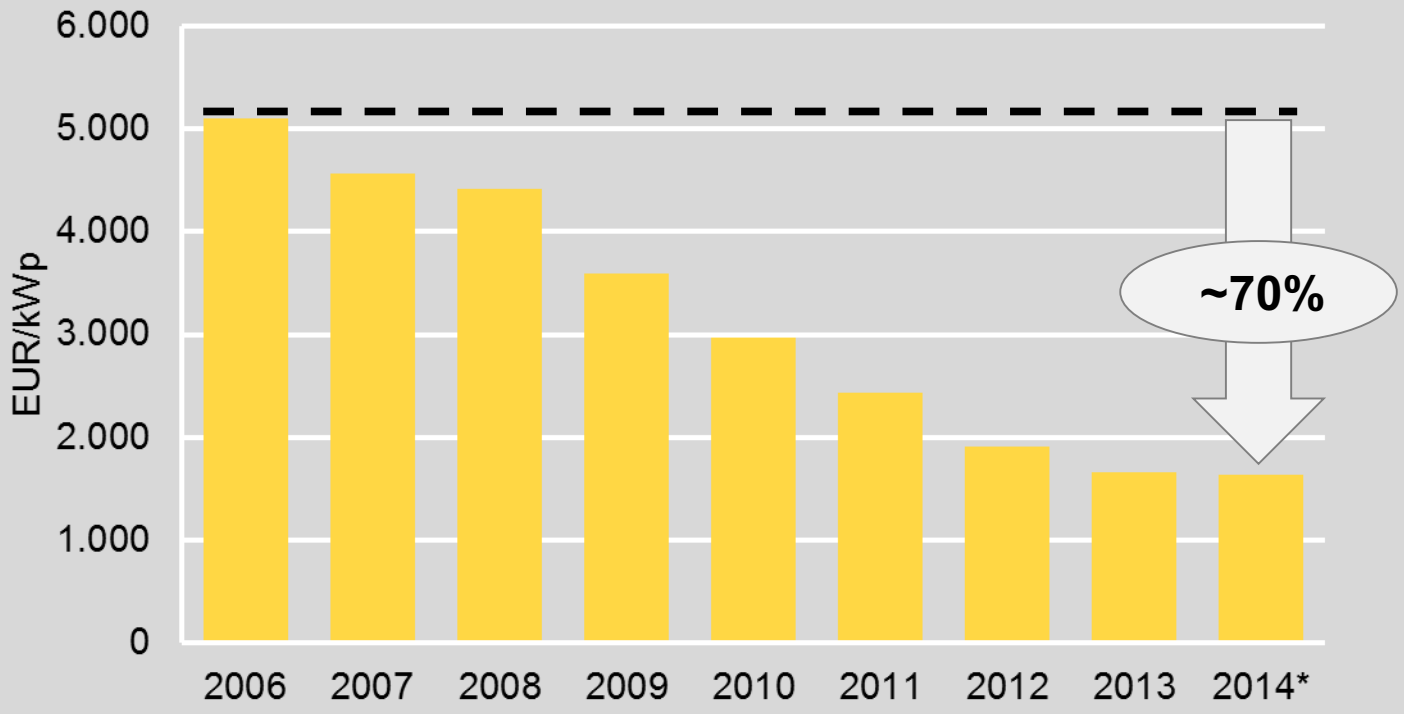
Size development of wind turbines (onshore)



Fraunhofer IWES

Cost breakthrough in solar PV reduced cost by ~70% since 2006

Average system price for new roof-mounted PV in EUR/kWp

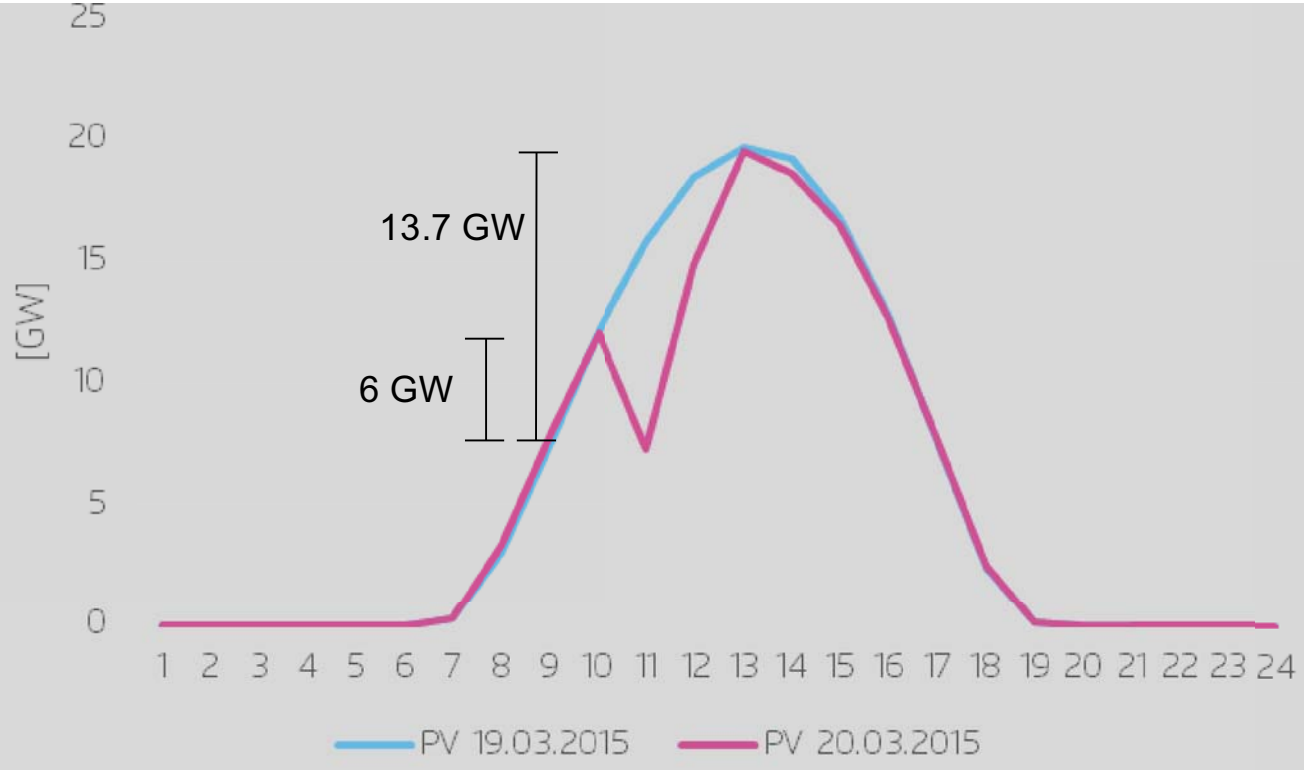


BSW Solar (2014), own calculations

* only Q1 2014

The challenge: extraordinary ramping rates

Electricity production of solar PV on 19/20 March 2015



Own; data: EEX

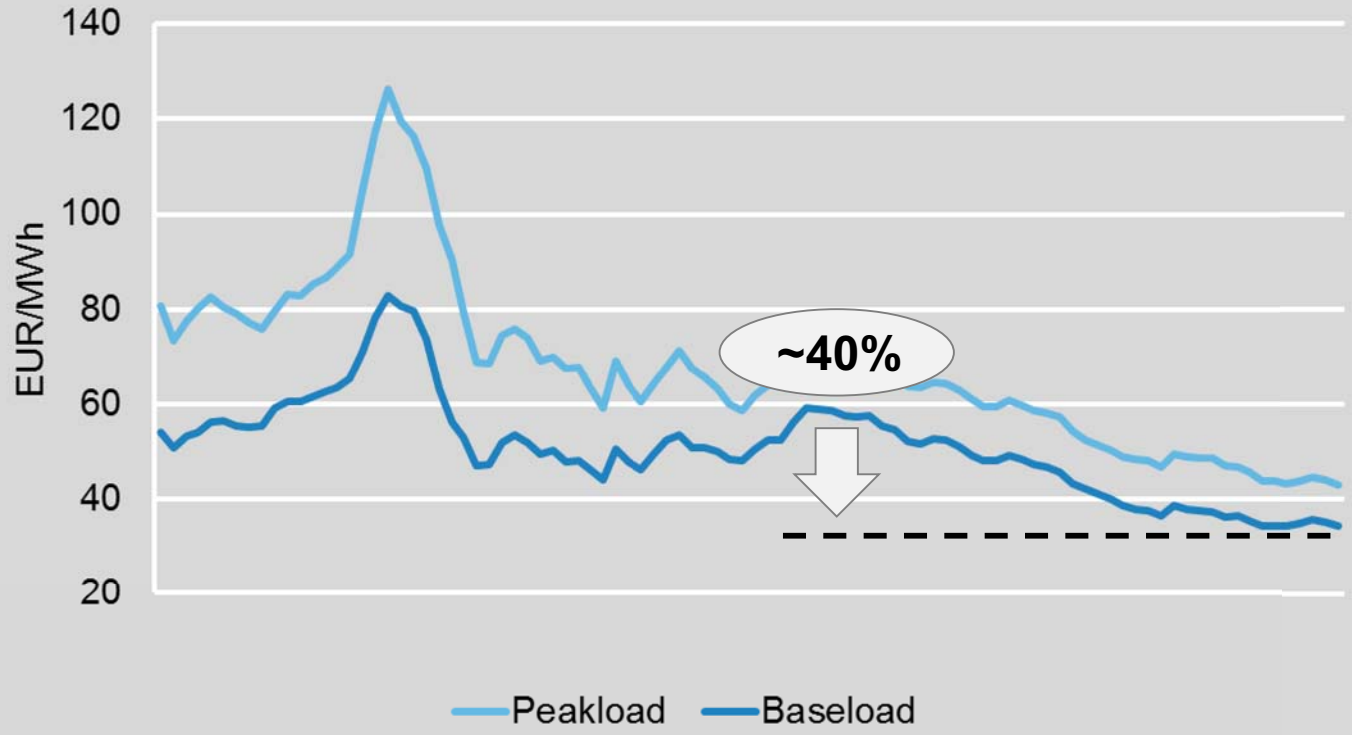
Due to the solar eclipse, electricity production from solar PV ramped down 6 GW within 65 minutes (between 10 a.m. and 11.30 a.m.), and ramped up again roughly 13.7 GW within 75 minutes (between 11.30 a.m. and 1 p.m.)

No shortages in the German power system occured.

These ramps are unusual today, but are expected frequently in 2030 in Germany, when roughly 50% of electricity will be produced by Renewables (according to current law).

Challenge 1: A new market design to finance renewable and fossil-fuel backup power plants is needed

Wholesale electricity prices in EUR/MWh (1-year future)



EEX (2014)

Low market prices: Due to low CO_2 and coal prices, wholesale prices are so low that no new power plant is able to refinance itself

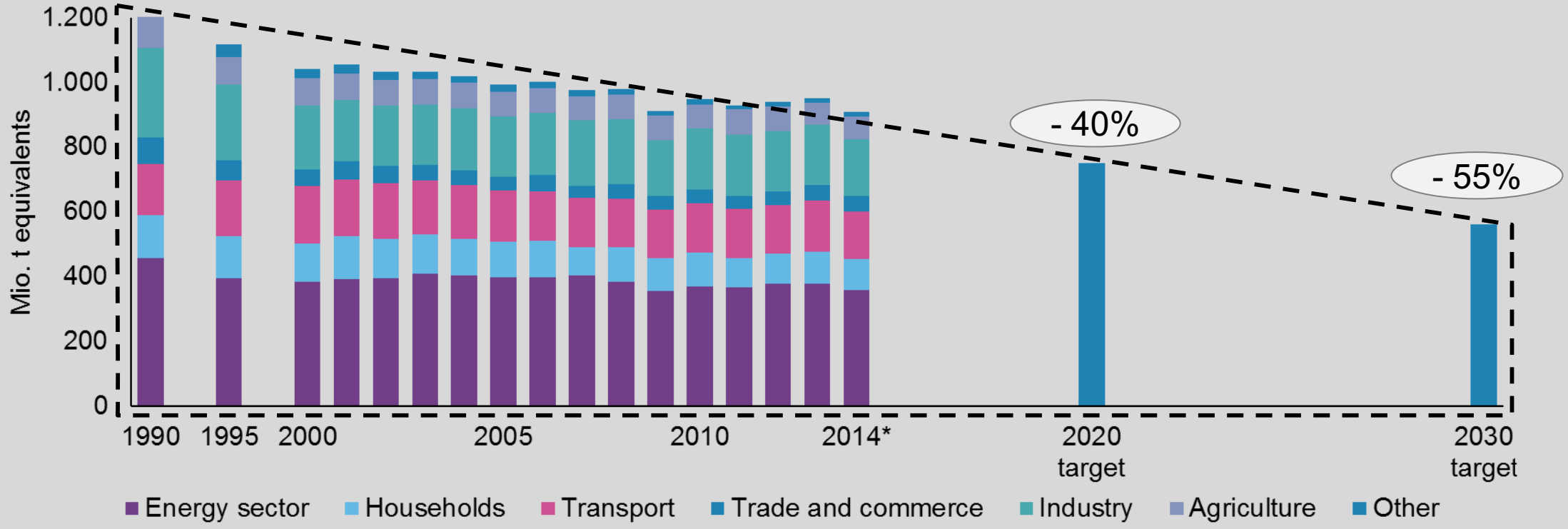
Wind and solar additionally face the merit order effect of destroying their own market price at times of high wind and sunshine

Solution for backup power plants: Remuneration either via very high pricing in times of scarcity or via a capacity market

Solution for renewables: Remuneration via auctions through a market premium (in the futre to be based on MW rather than Mwh)

Greenhouse gas emissions are currently at -26% compared to 1990 levels – with the power sector being the largest emitter

Greenhouse gas emissions by sector 1990 – 2014 and 2020/2030 targets

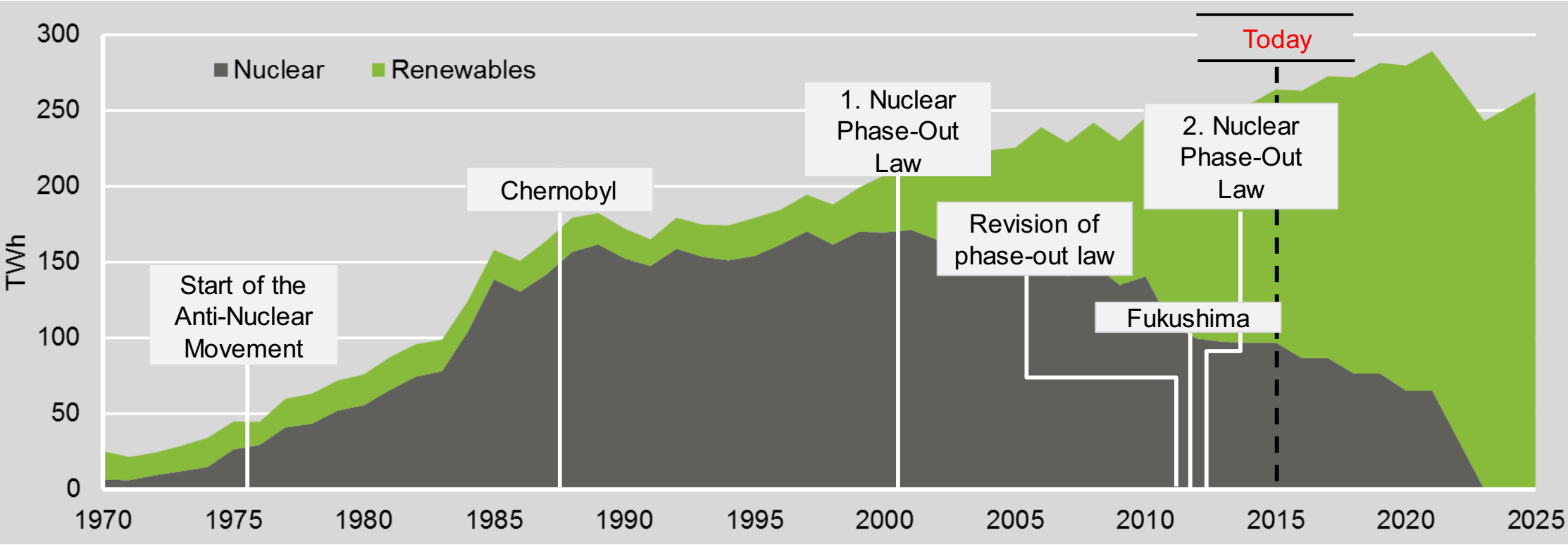


AG Energiebilanzen (2014), UBA (2014)

*preliminary data

The nuclear energy act foresees the shut down of all nuclear power plants by 2022 with renewables more than replacing their generation

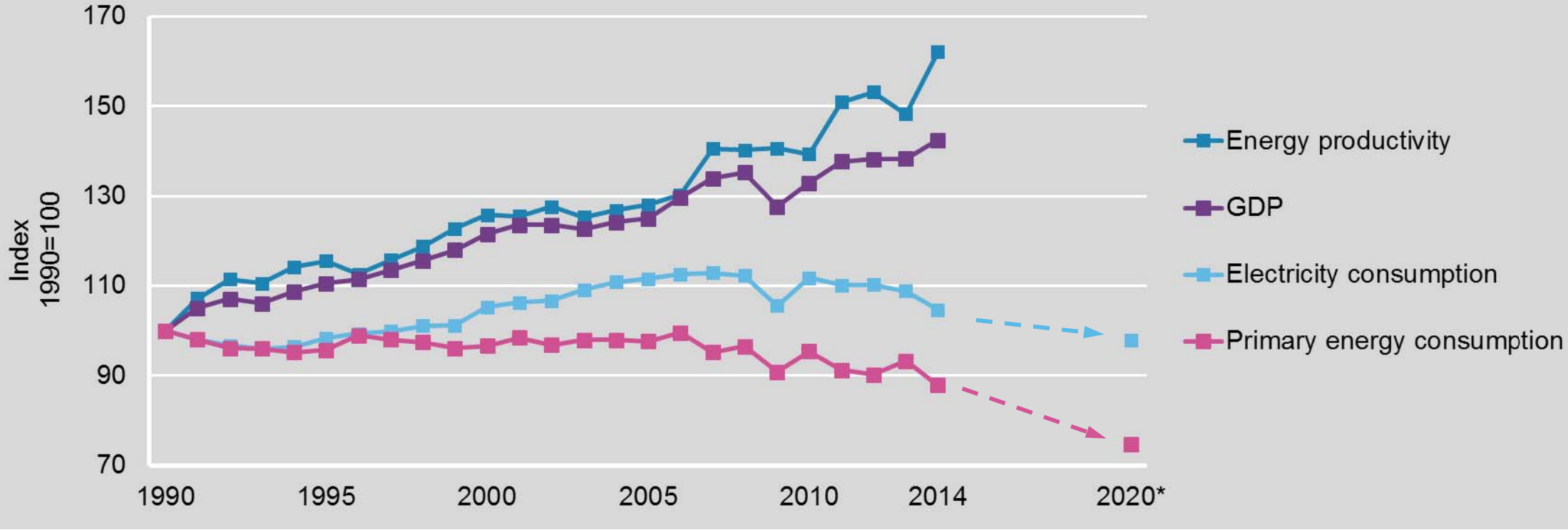
Gross electricity production by nuclear and renewable sources 1970 – 2025 in TWh



AG Energiebilanzen (1970 – 2014); BNetzA, own calculations (2015 – 2025). Data before 1990 comprises only West Germany

Germany decoupled economic growth from energy consumption – but there is still work to do to reach the 2020 efficiency targets

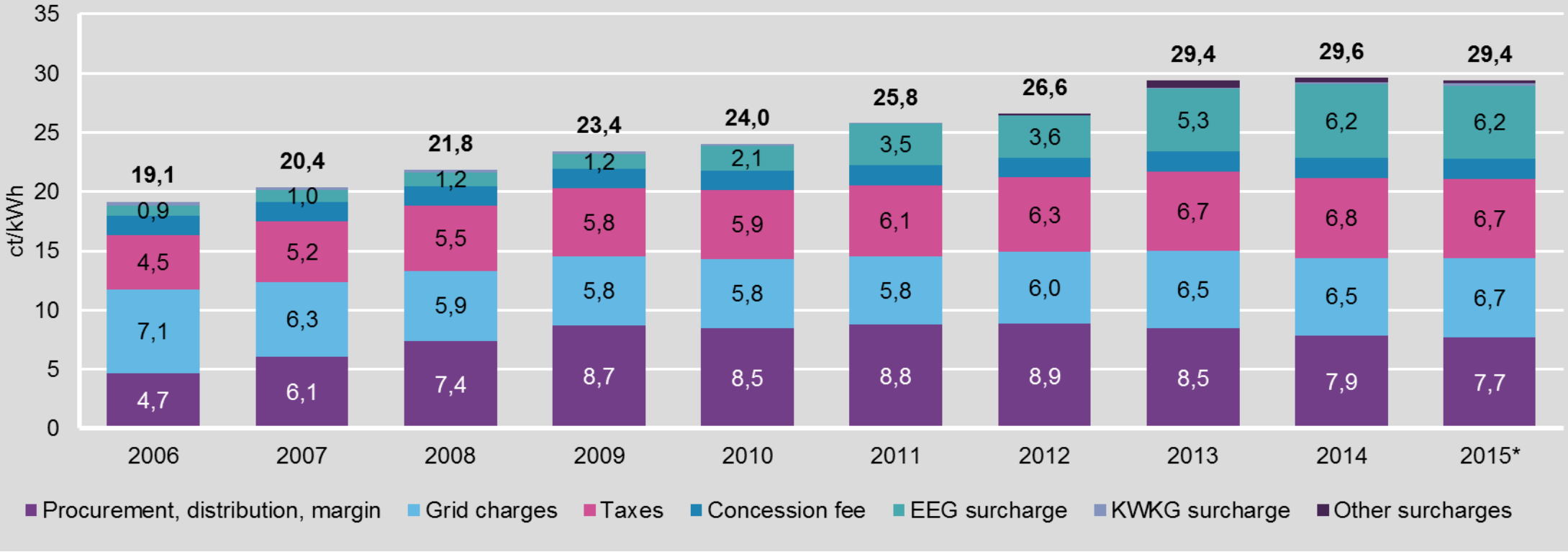
Energy productivity and consumption and economic growth 1990 – 2014 (Index, 1990=100)



AG Energiebilanzen (2014), BMWi (2014)

In 2014/2015, the rise in household electricity prices stopped…

Composition of household electricity prices 2006-2015

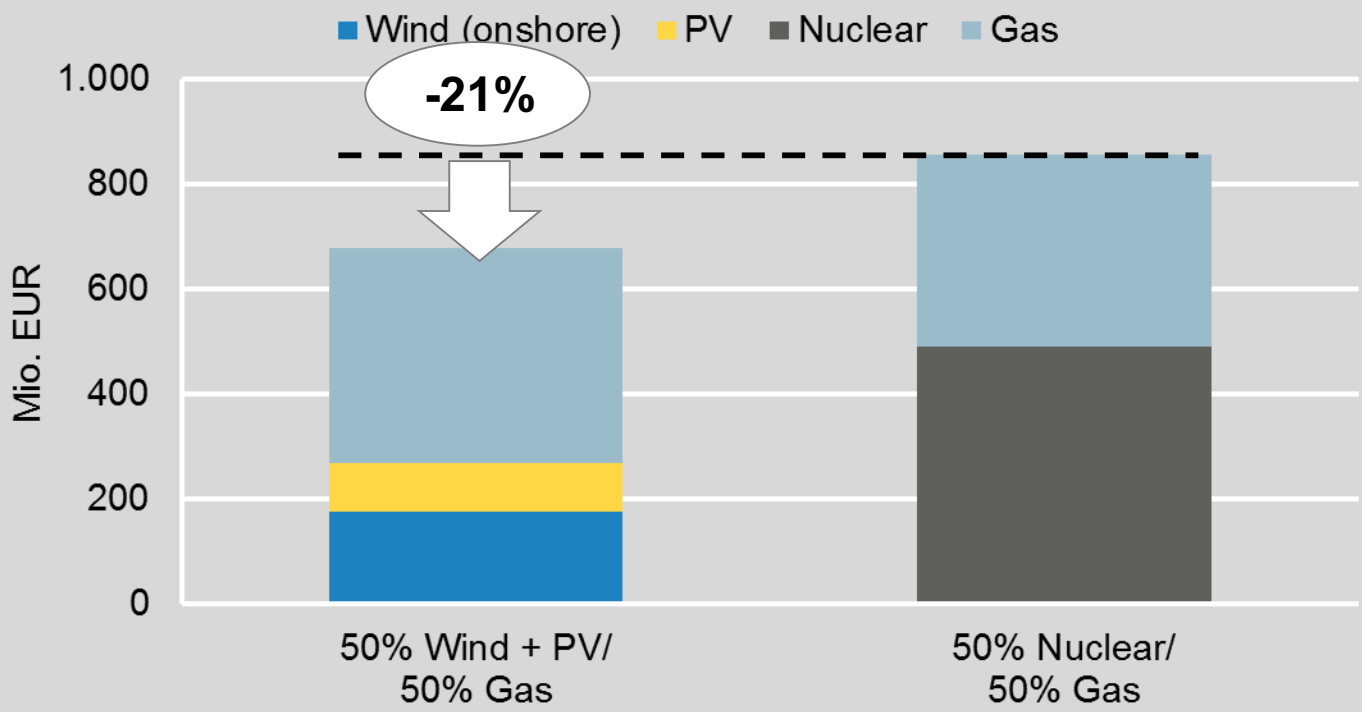


BDEW 2014, BNetzA 2014, own calculations;

*own prognosis for 2015

Integration cost of wind and solar do not change the picture

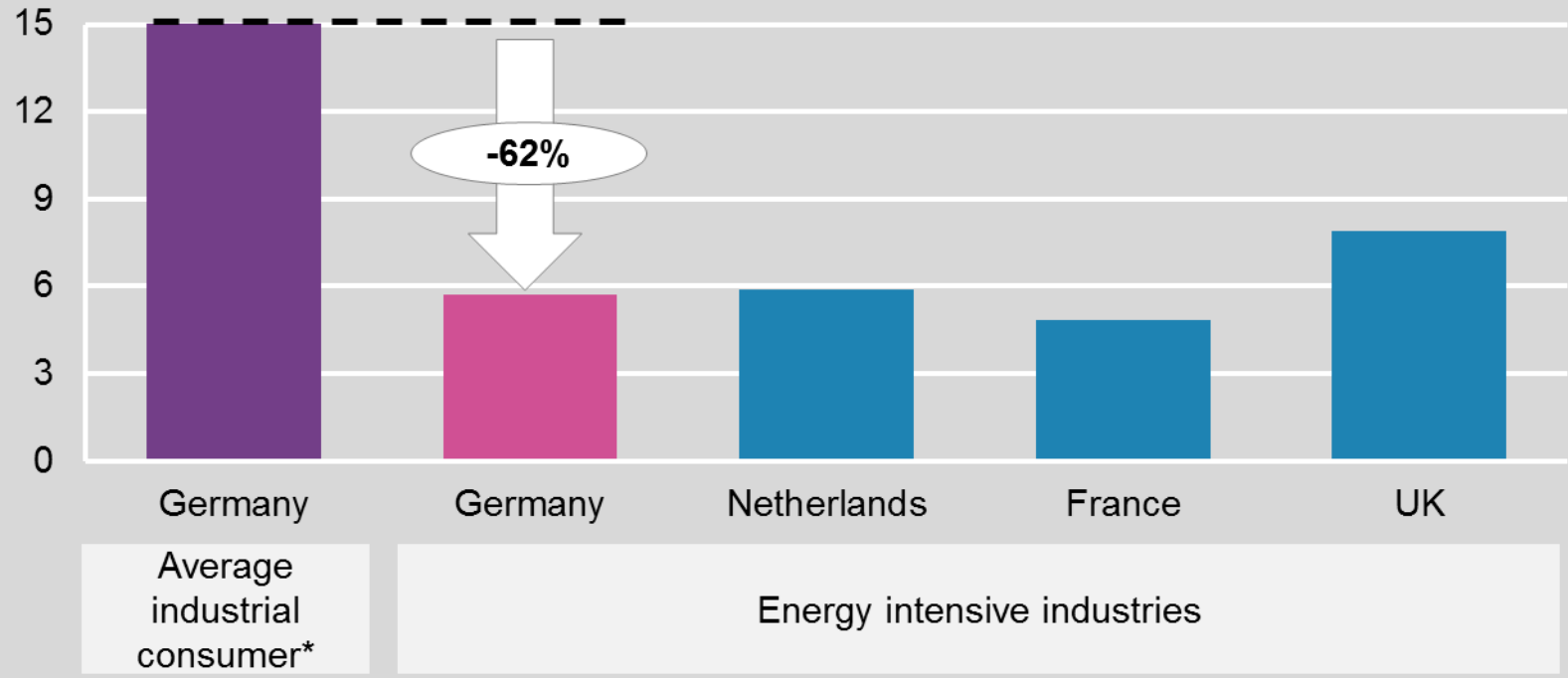
Annual generation costs of two different stylized new power systems, covering 1 GW demand



Agora Energiewende (2014)

…and energy intensive industries are largely exempt from taxes and levies to safeguard their competitiveness.

Average electricity prices for energy intensive industrial consumers in 2013 in ct/kWh

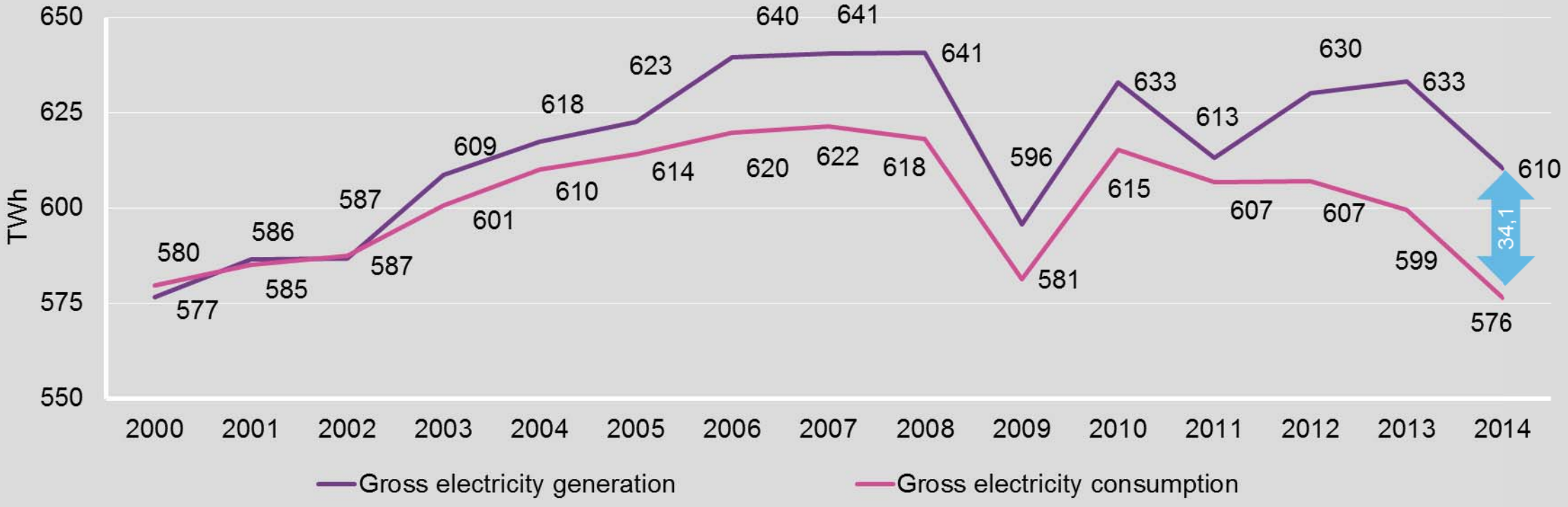


BMWi (2014)

*Assuming annual consumption of <20 MWh and partially exemptions from levies

Since 2001, Germany has produced more electricity than it uses – with an export record of >5% power production in 2014

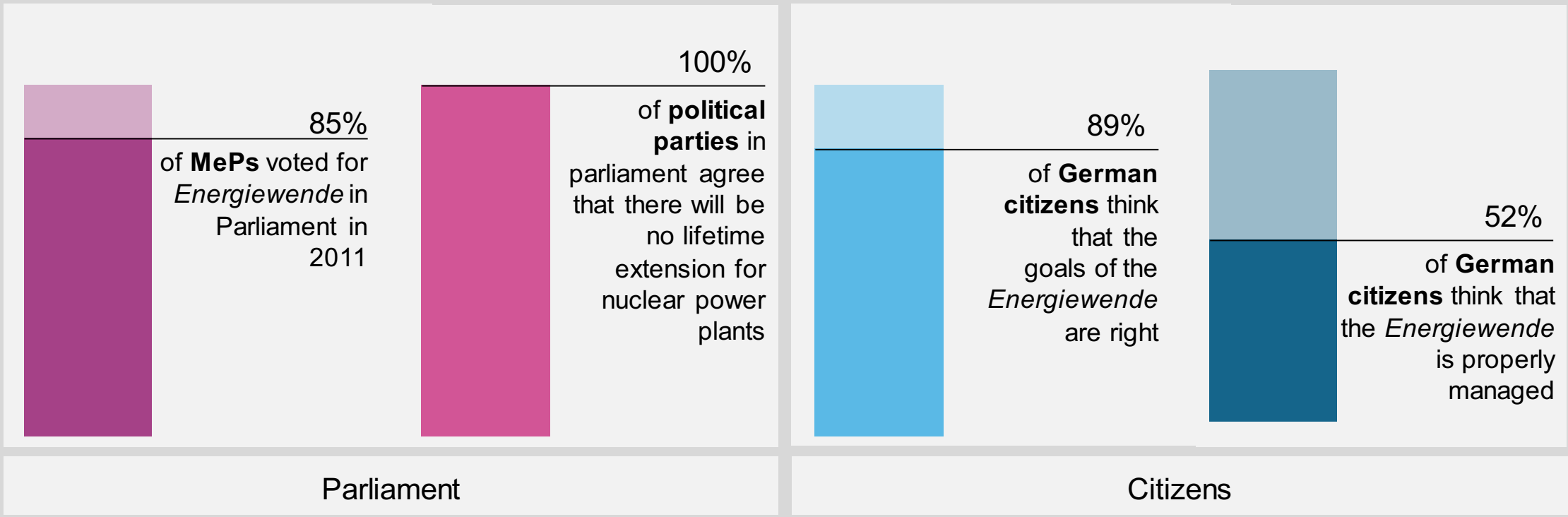
Gross electricity generation and consumption in TWh



AG Energiebilanzen (2014)

There is a broad political consensus on the goals of the *Energiewende* – and discussions are mainly targeting its implementation

Political decisions and public opinion on *Energiewende*

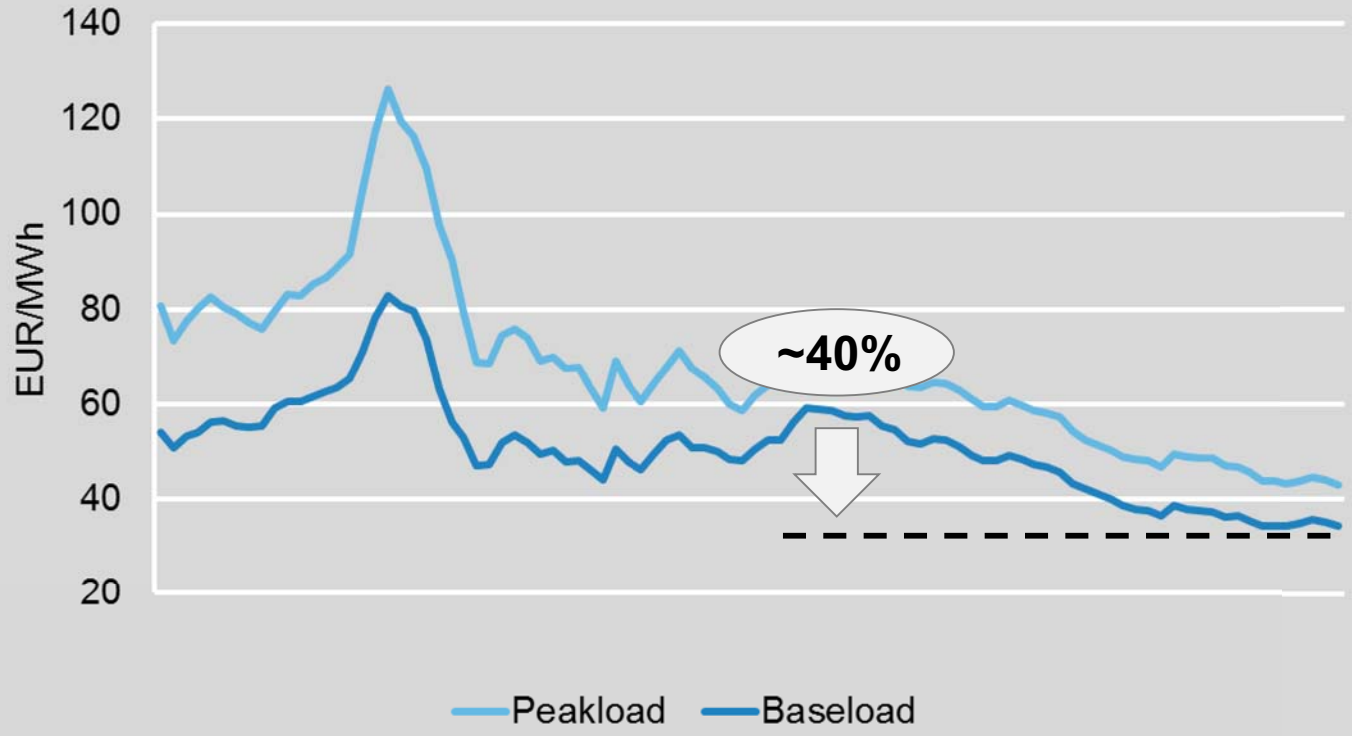


BDEW, Forsa

4. Challenges ahead

Challenge 1: A new market design to finance renewable and fossil-fuel backup power plants is needed

Wholesale electricity prices in EUR/MWh (1-year future)



EEX (2014)

Low market prices: Due to low CO_2 and coal prices, wholesale prices are so low that no new power plant is able to refinance itself

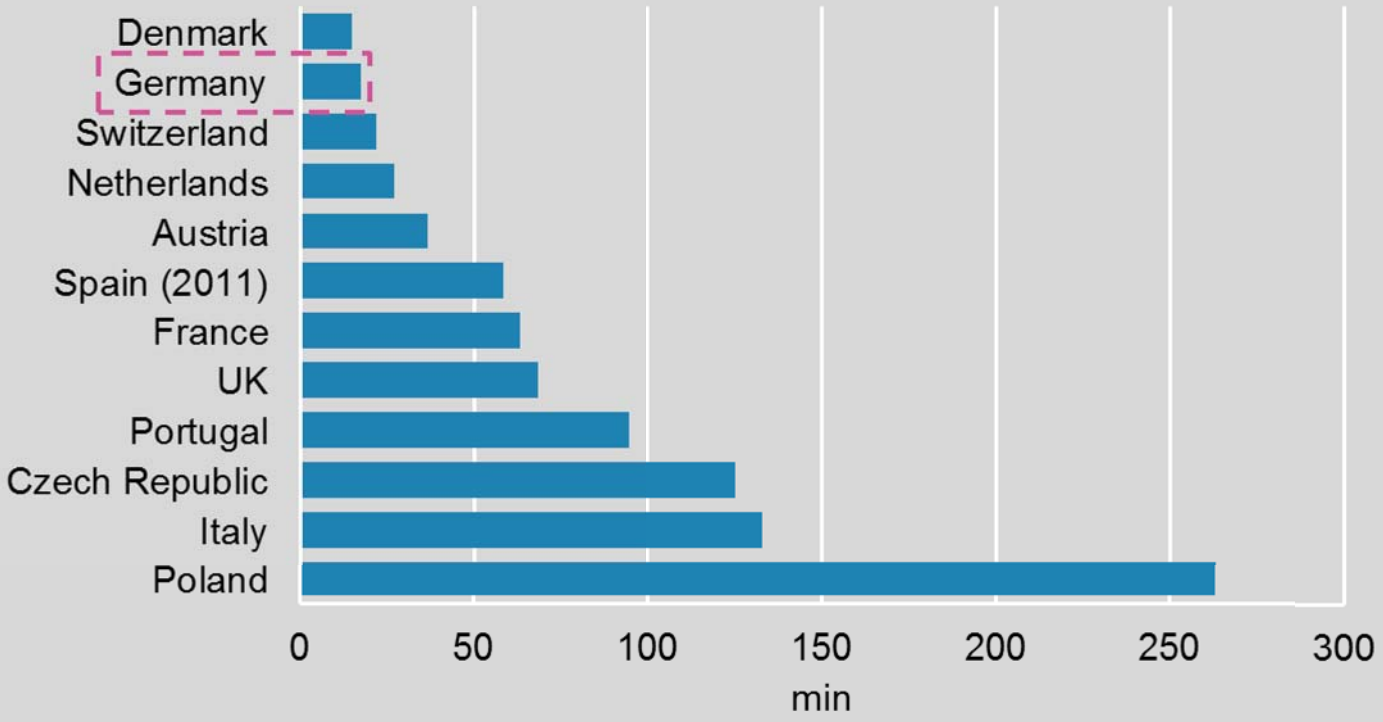
Wind and solar additionally face the merit order effect of destroying their own market price at times of high wind and sunshine

Solution for backup power plants: Remuneration either via very high pricing in times of scarcity or via a capacity market

Solution for renewables: Remuneration via auctions through a market premium (in the futre to be based on MW rather than Mwh)

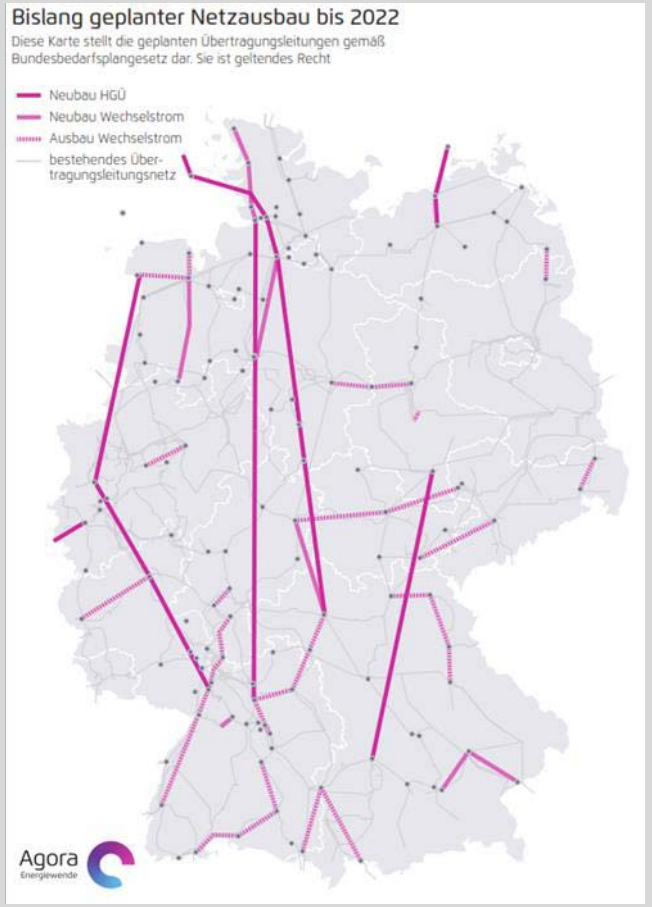
Challenge 2: We need to keep our high grid stability standards while at the same time building more grids from north to south

System Average Interruption Duration Index (SAIDI)* in 2012



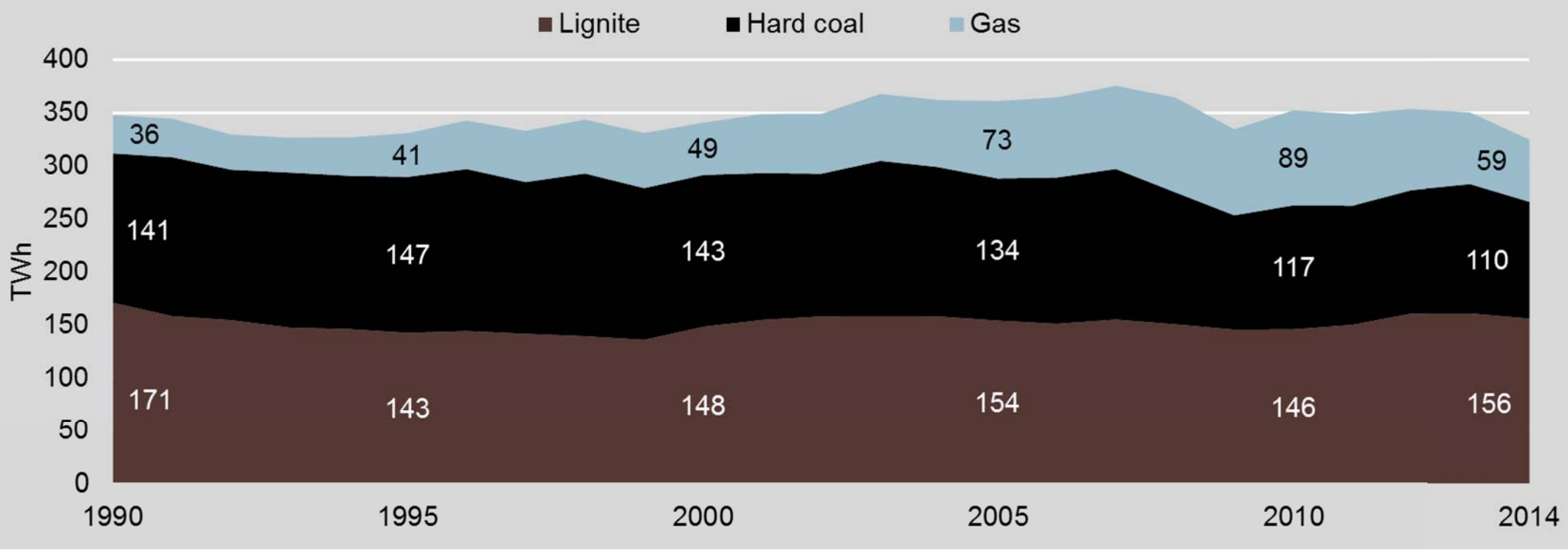
CEER (2013)

* including exceptional events



Challenge 3: Address CO_2 emissions from fossil-fuel power plants, especially coal

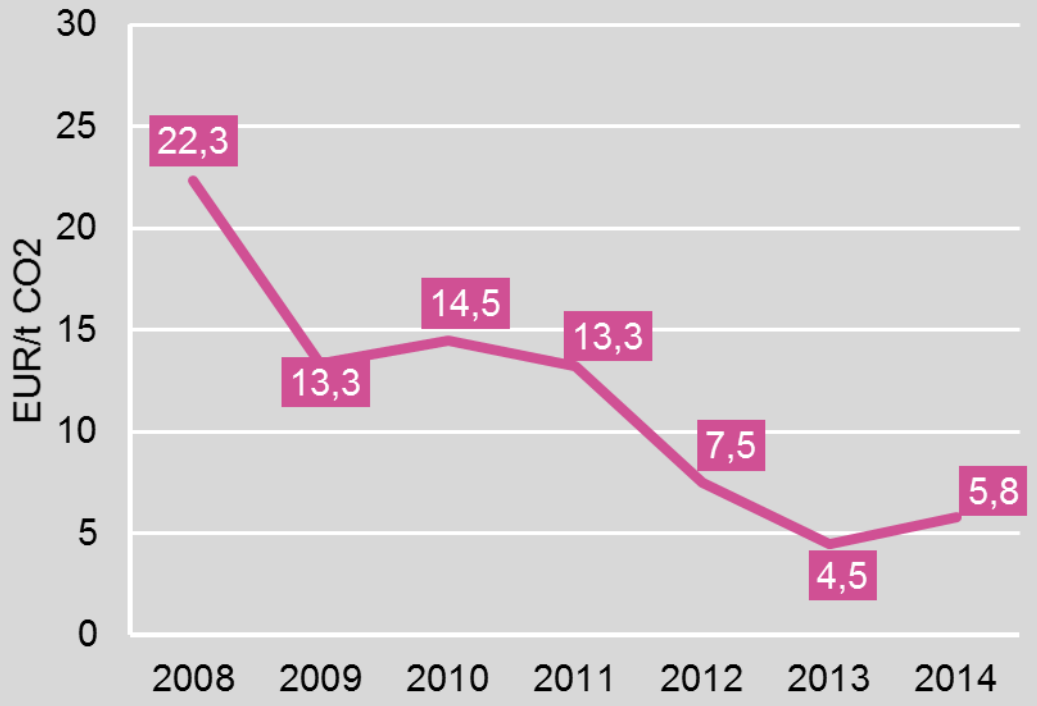
Gross Electricity Production from Lignite, Hard Coal and Gas Power Plants 1990-2014



AG Energiebilanzen (2014)

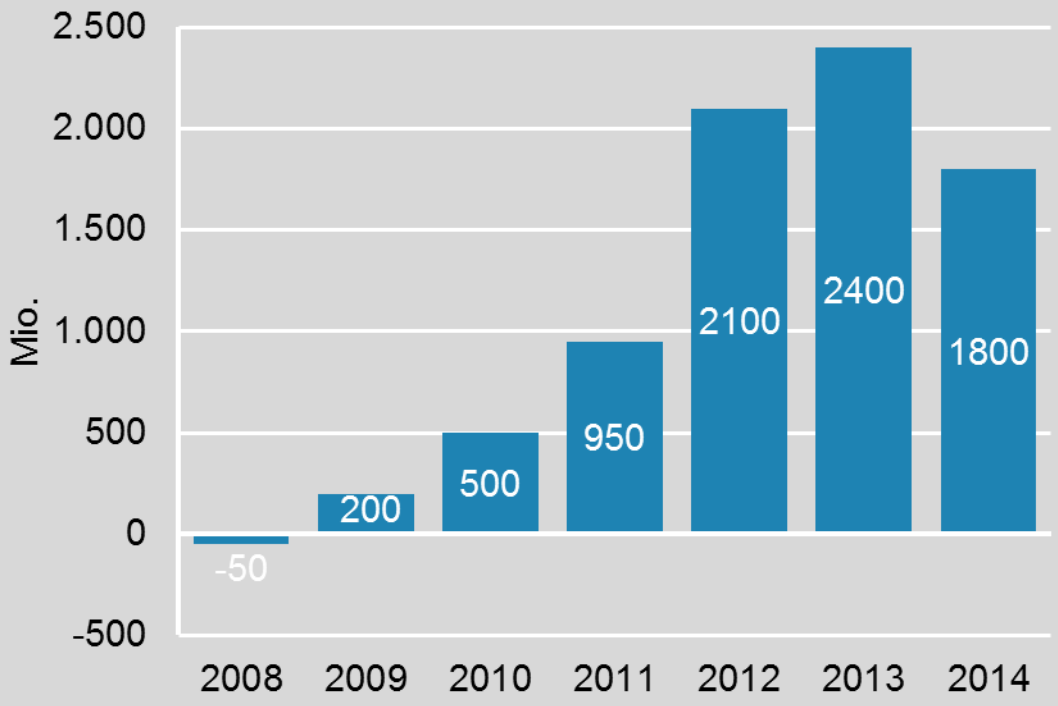
The key problem: The EU Emissions Trading system is facing huge overallocation, leading – even with the MSR – to persistent low CO_2 prices

Price development of CO_2-certificates in EUR/t CO_2



ICE, BMWi (2014)

Cumulated excess of CO_2-certificates in Mio.



EC, DIW (2014)

Thus, we need a coal & lignite consensus in Germany – with RWE, Vattenfall and the affected regions

Lignite mining and power production will have to end between 2040 and 2050 in order to meet climate targets

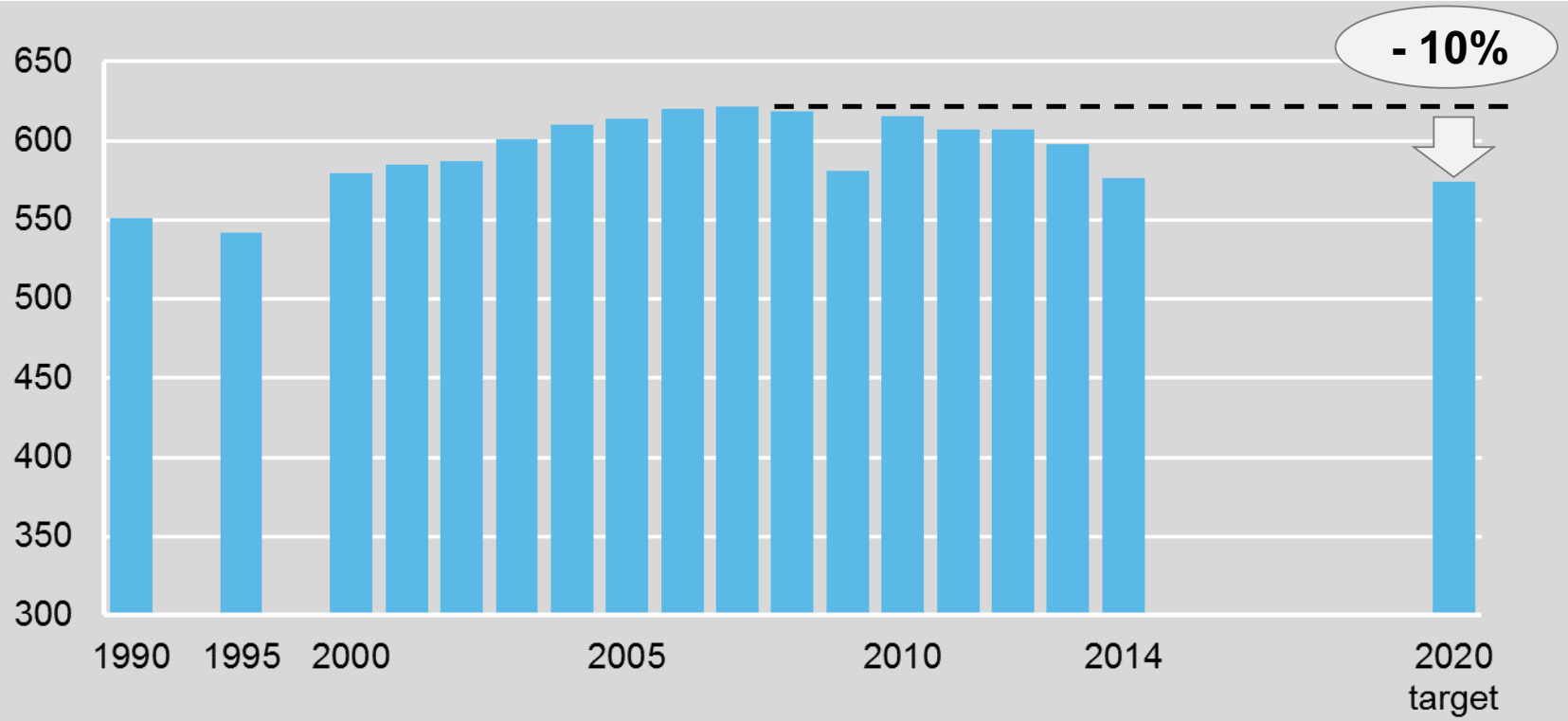
Hard Coal is a lot more CO2 intensive than Gas and will come under pressure once the EU Emissions Trading is fixed

Hence, Germany will have to develop **a plan for phasing out hard coal and lignite** in a socially balanced manner over the next three decades.

For **Vattenfall**‘s lignite assets in Eastern Germany this means not to „sell and run“, but to „stay and cooperate“.

Challenge 4: Implement a coherent efficiency strategy to consolidate declining trend in power demand

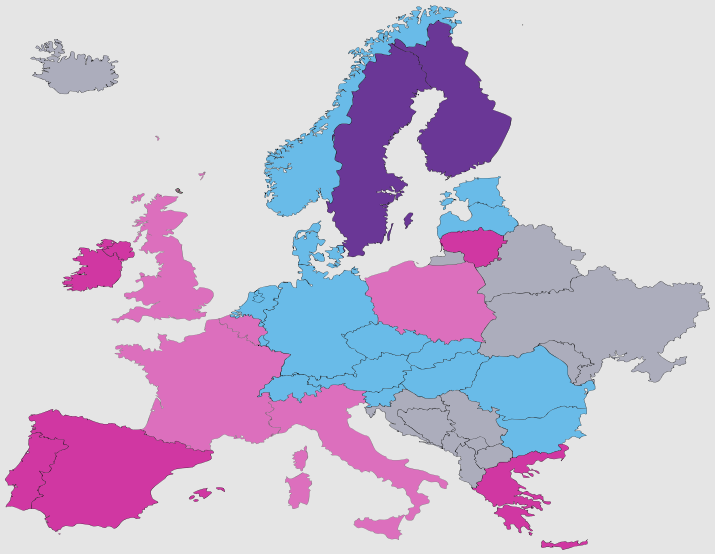
Gross electricity consumption in TWh



AG Energiebilanzen (2014)

Challenge 5: Promote further cooperation and integration with neighboring countries and Europe as a whole

Capacity mechanisms



No capacity market or discussions in an early stage

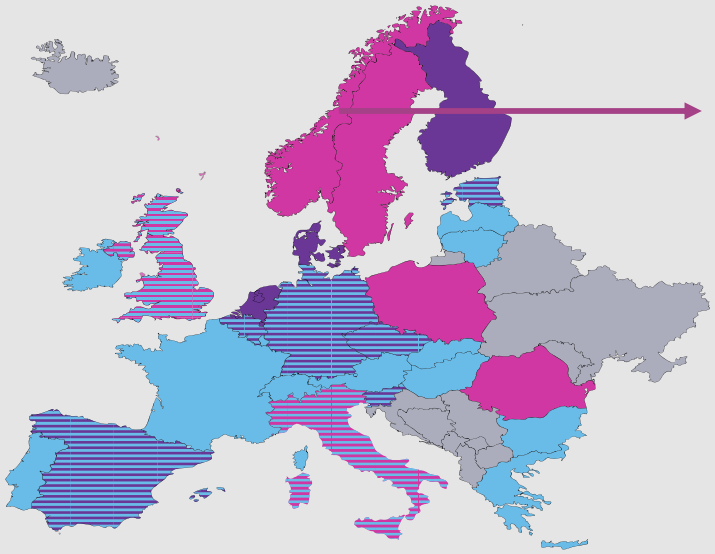
Capacity market in law-making process or intended

Full or partial capacity markets

Capacity reserve implemented

Eigene Darstellung nach Eurelectric (2012), Öko-Institut et al. (2012), Fraunhofer ISI et al. (2012)

Renewable Energy Support Schemes



Feed-in tariff

Quota

Feed-in premium

Combination Quota & Feed-in tariff

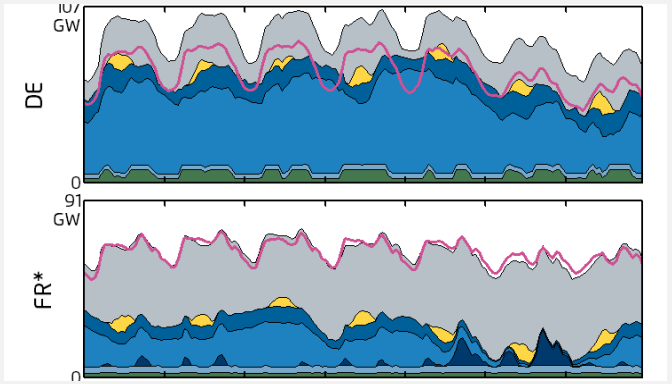
Combination Feed-in tariff and Feed-in premium

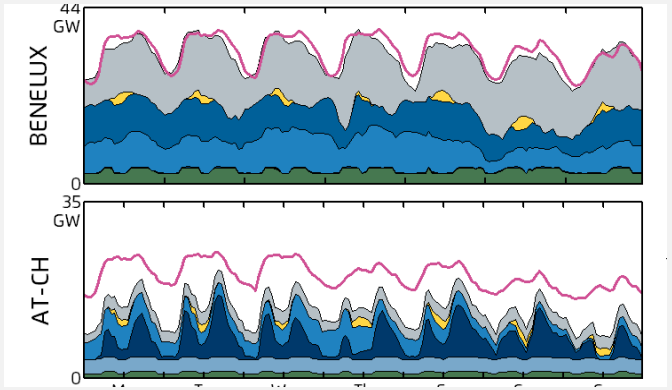
4. Is Germany a special case?

Markus Steigenberger | August 2015

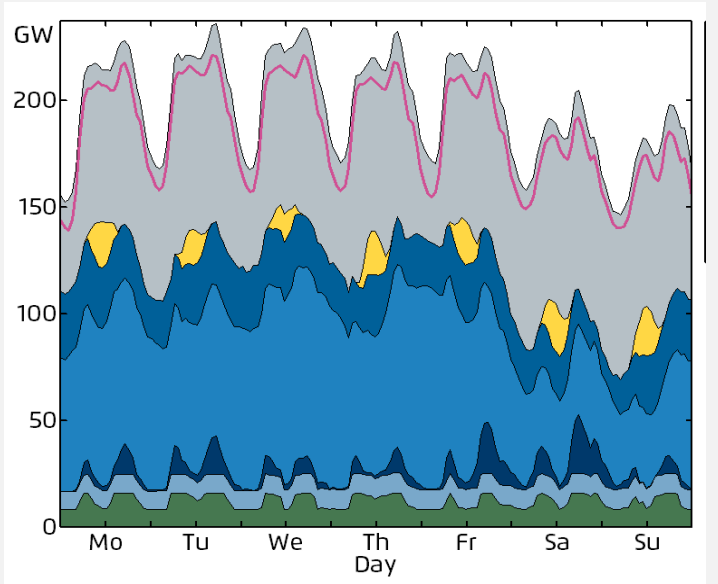
The EU 2030 targets mean 50% renewables in the EU electricity sector – implying high shares of wind and solar in many countries

Electricity generation in 2030* in a sample week in December in Central Western European





DE, FR, BENELUX, AT/CH



Central-Western Europe (CWE)

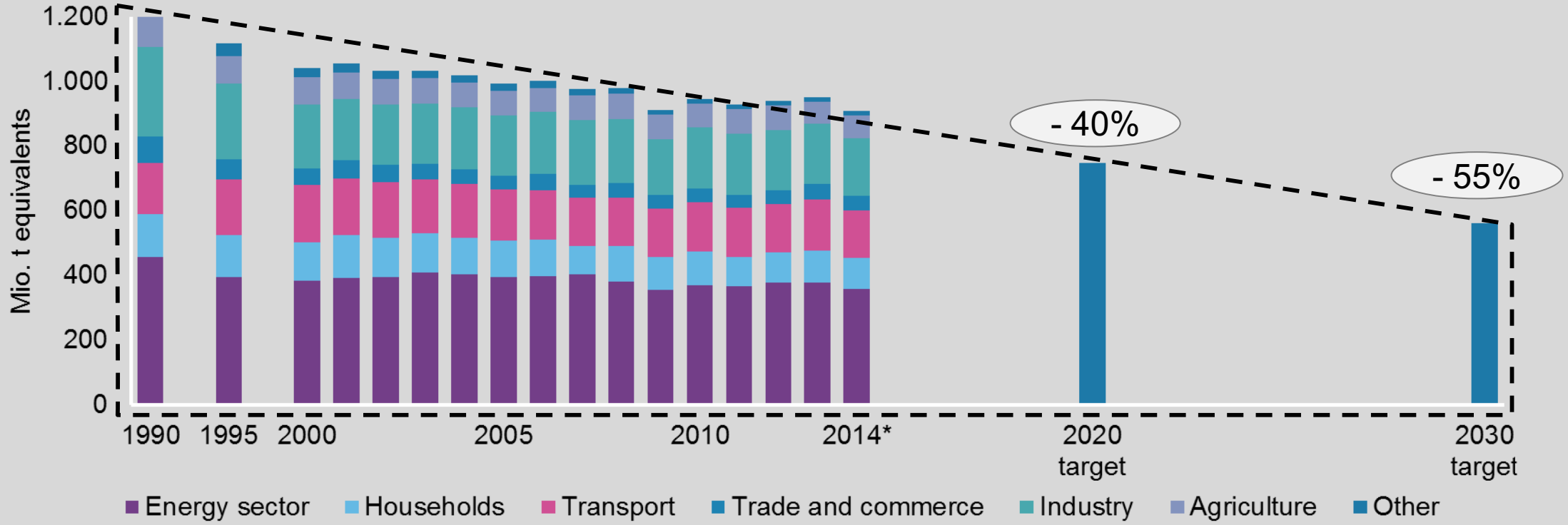
Agora Energiewende/IWES (2015), based on national energy strategies (2014)

A word on:
Greenhouse Gas Emissions

Markus Steigenberger | August 2015

Greenhouse gas emissions are currently at -26% compared to 1990 levels – with the power sector being the largest emitter

Greenhouse gas emissions by sector 1990 – 2014 and 2020/2030 targets

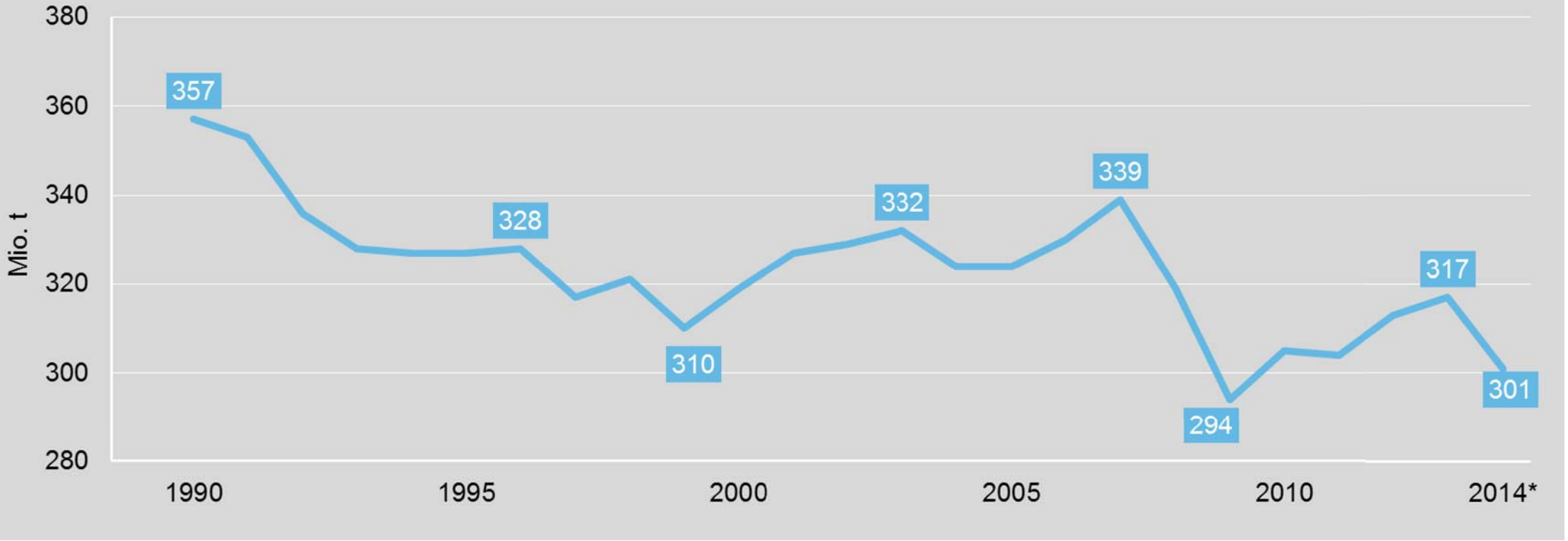


AG Energiebilanzen (2014), UBA (2014)

*Prognosis for 2014

After two years of rising emissions, in 2014 the CO_2 emissions in the power sector fell sharply due to less demand and more renewables

Greenhouse gas emissions of the power sector 1990 – 2014

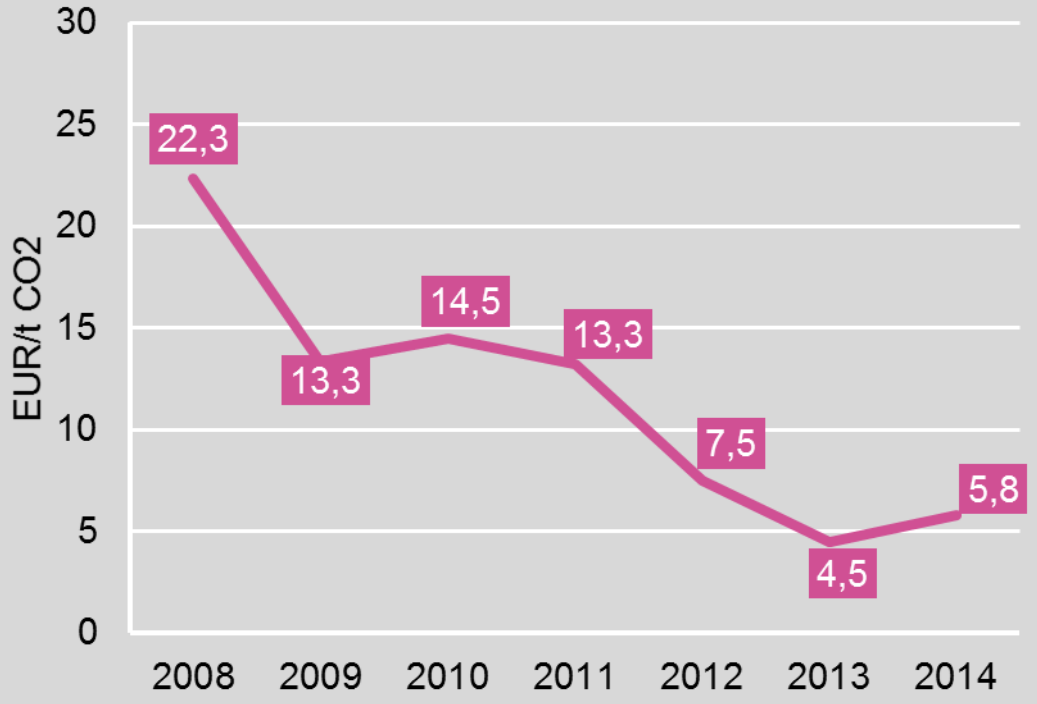


UBA (2014), own calculations

* prognosis

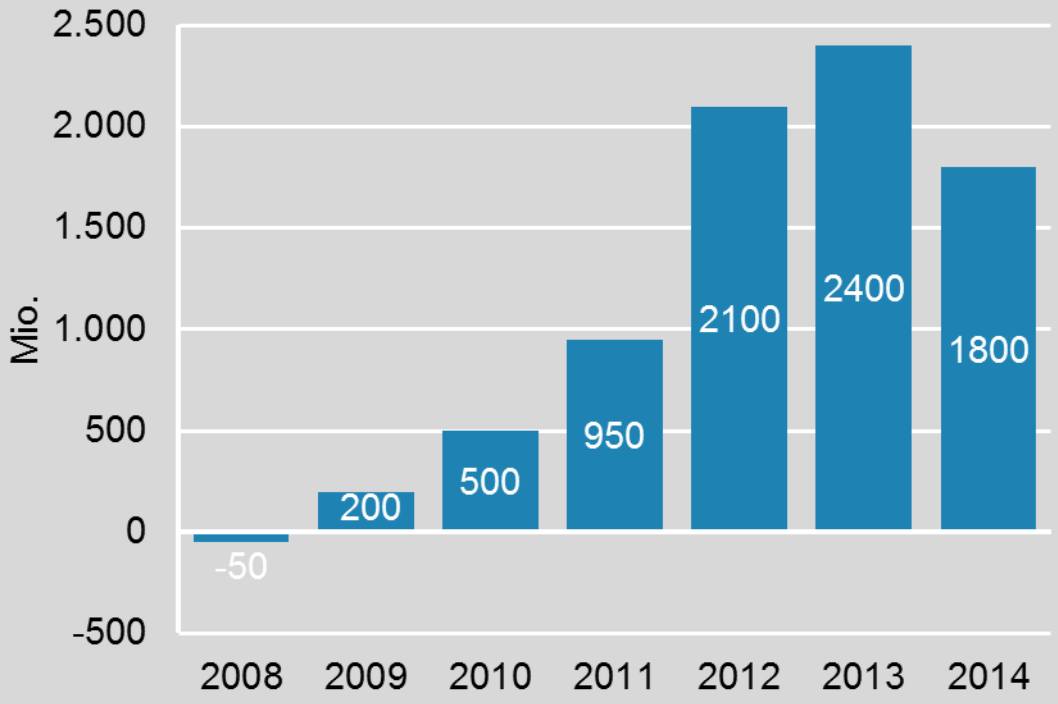
The key problem: The EU Emissions Trading system is facing huge overallocation, leading – unless fixed – to persistent low CO_2 prices

Price development of CO_2-certificates in EUR/t CO_2



ICE, BMWi (2014)

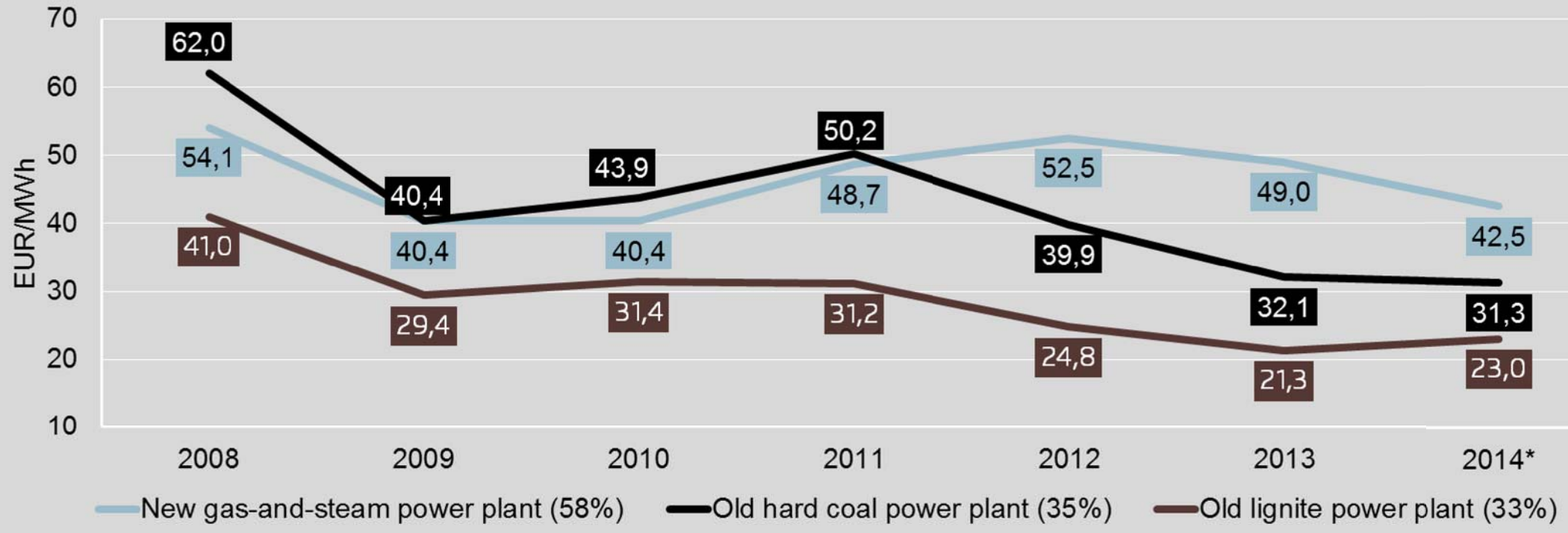
Cummulated overallocation of CO_2-certificates in Mio.



EC, DIW (2014)

Additionally, diverging fuel prices of coal and gas increased the price spread of coal and gas power plants

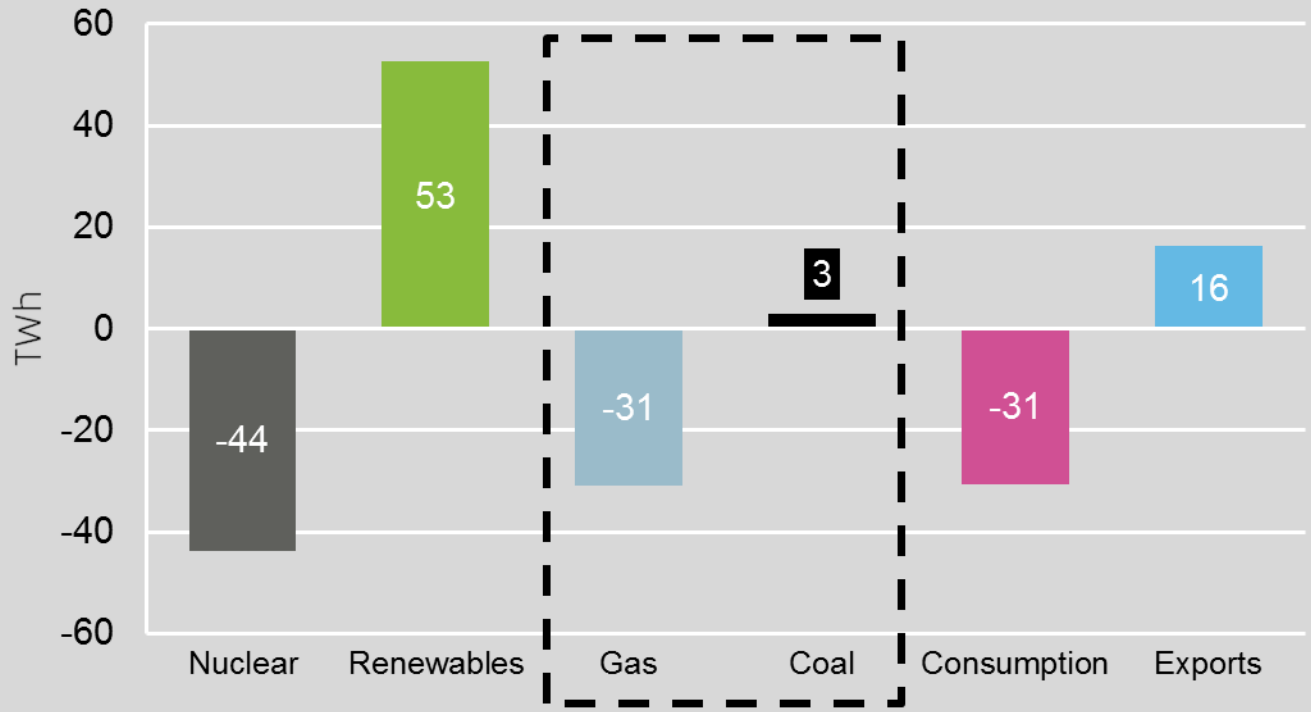
Marginal generation cost development of illustrative power plants in EUR/MWh



BAFA, BMWi, EEX, own calculations

As a consequence, coal use stays constant while gas in Germany and (via exports) in neighbouring countries is crowded out

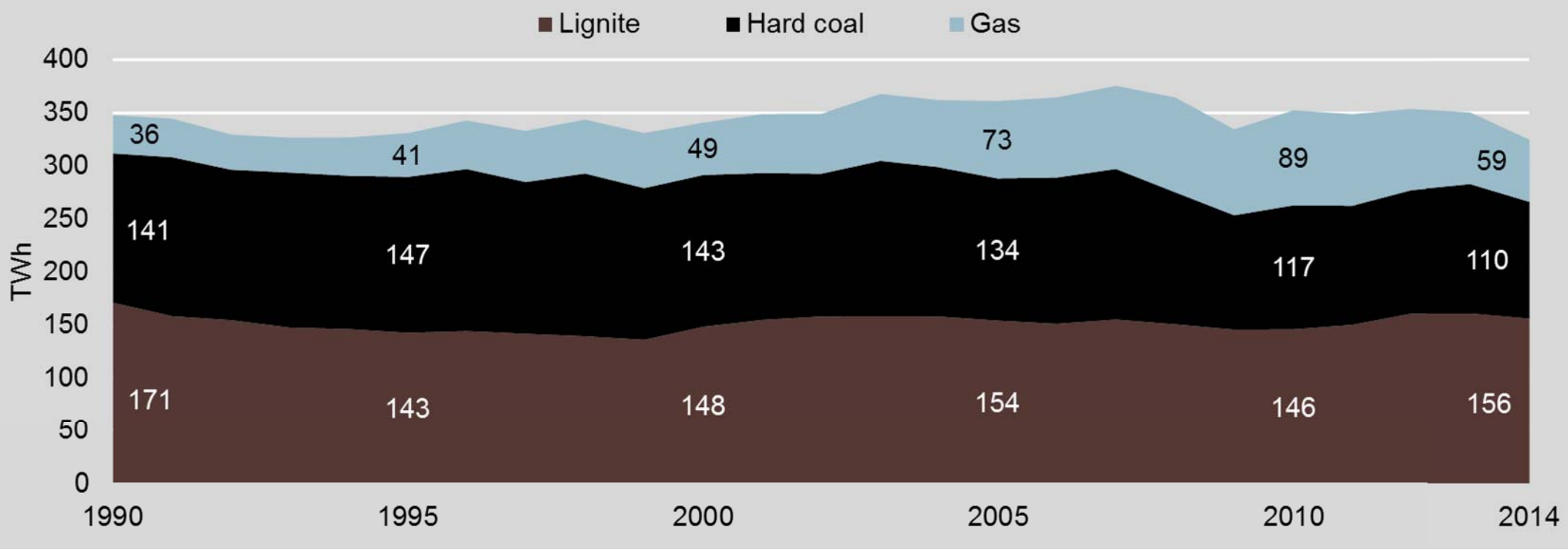
Change of electricity generation, consumption and export surplus 2010 -2014 in TWh



AG Energiebilanzen (2014)

Thus, Germany needs a coherent strategy towards fossil-fuel power plants, especially coal

Gross Electricity Production from Lignite, Hard Coal and Gas Power Plants 1990-2014



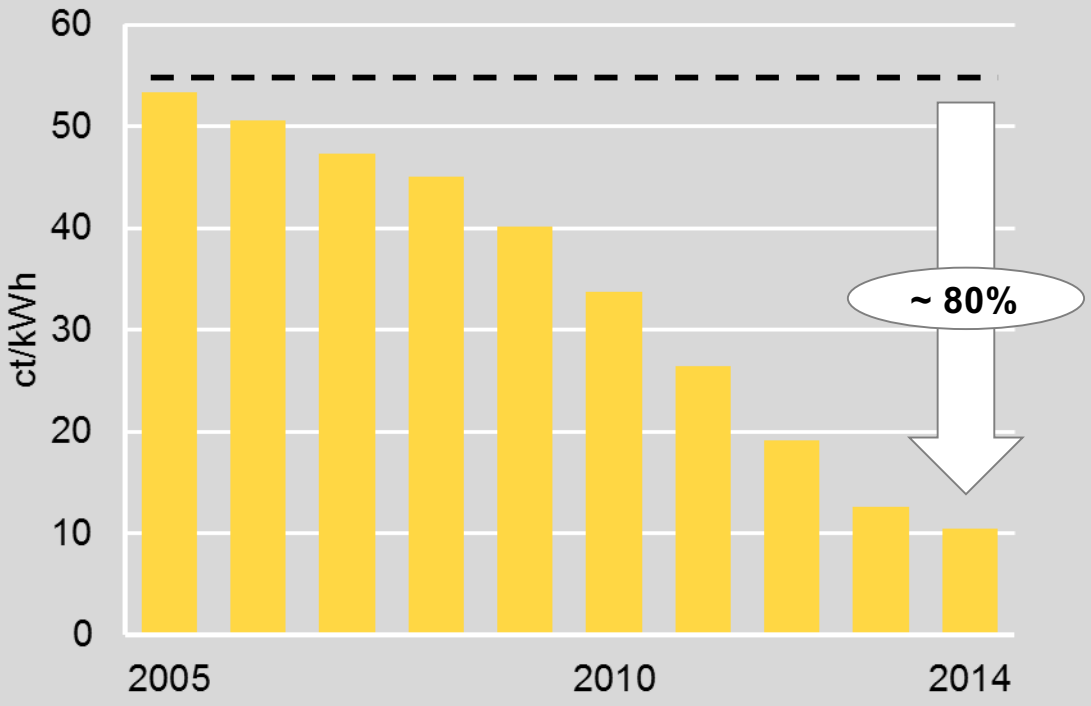
AG Energiebilanzen (2014)

A word on:
Household electricity prices

Markus Steigenberger | August 2015

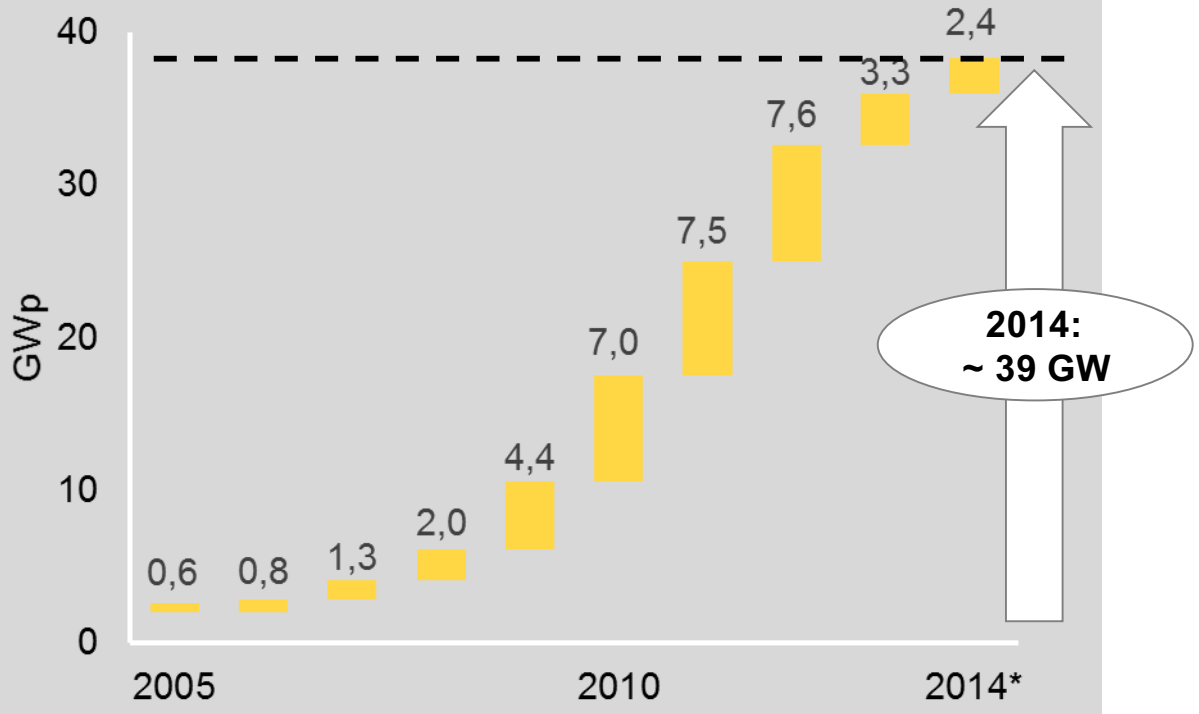
Germany took a lot of solar power plants into the system at times when they were still expensive

Average feed-in-tariff for solar PV panels 2005 - 2014



ZSW/BMWi (2014)

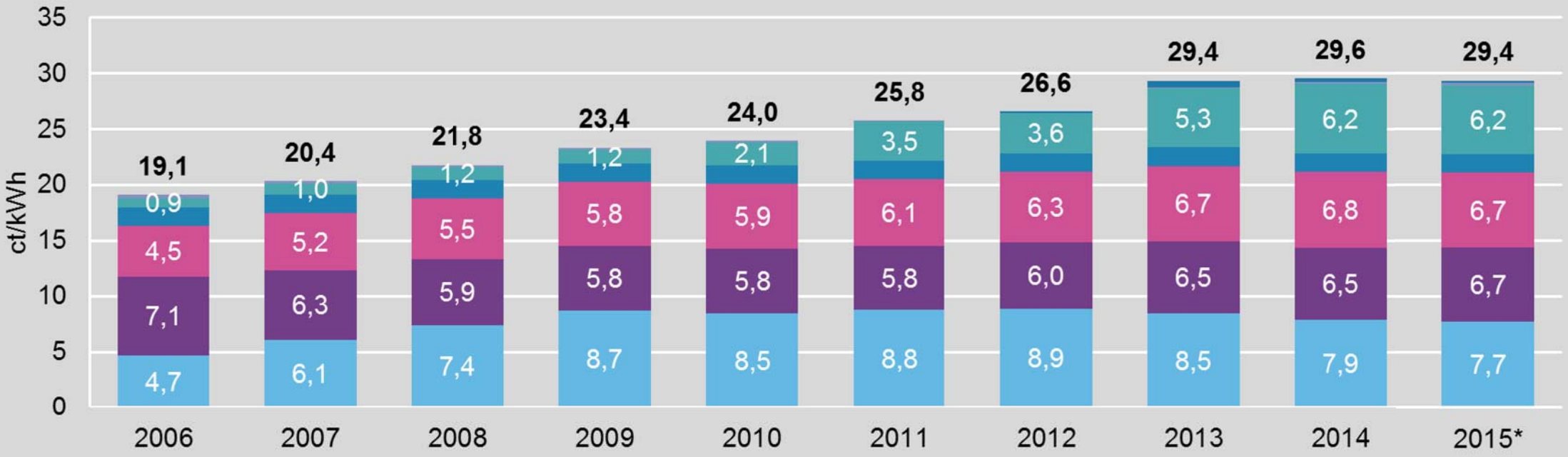
Annual installed solar capacities 2005 - 2014



BMWi (2014) *prognosis

This has driven household electricity prices in recent years. The price increase has come to an end in 2014…

Composition of household electricity prices 2006-2015 (3.500 kWh/a)

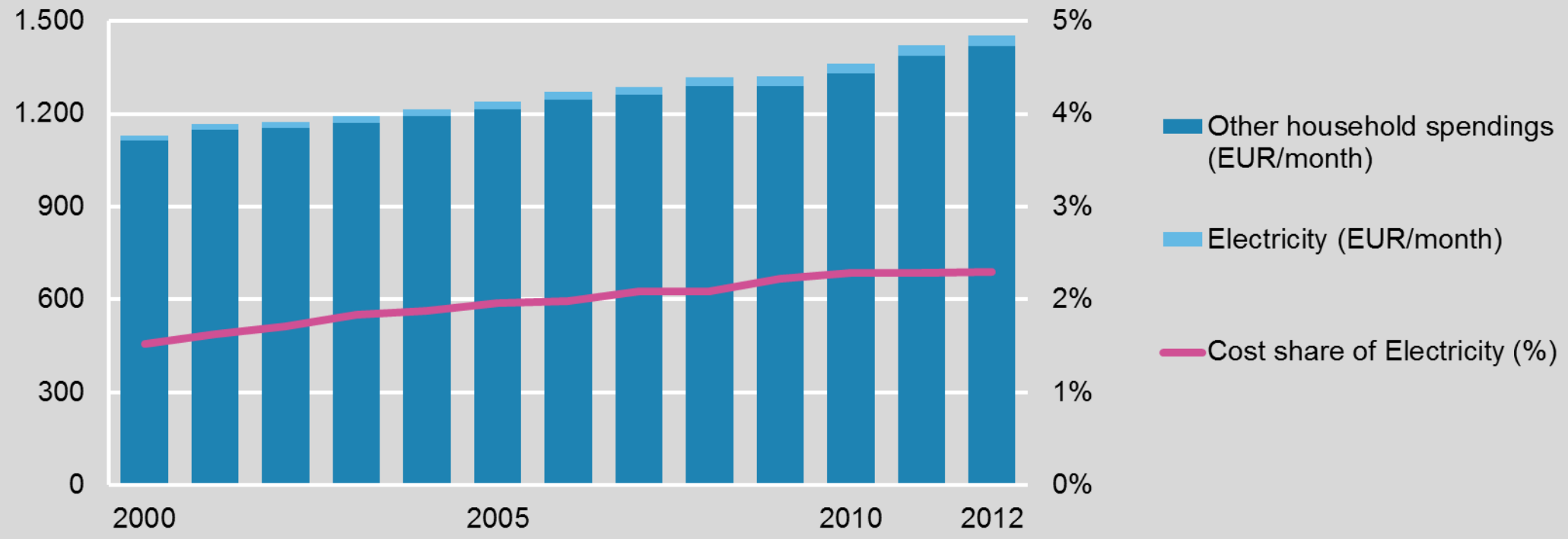


BDEW 2014, BNetzA 2014, own calculations;

*Prognosis for 2015

…with average household expenditures on electricity having varied between 1.6% and 2.4% in the past 20 years.

Share of electricity in average household spending



Destatis (2014)

Because of lower consumption, annual power bills of households in Germany are still in the same region as in other OECD countries.

Average household electricity bills in EUR/year

	Consumption (kWh)	Price (Ct/kWh)	Bill (EUR)
Denmark	4,000	30	1,200
US	11,800	9	1,060
Germany	3,500	30	1,050
Japan	5,600	18	1,010
Spain	4,400	23	1,010
Canada	10,800	8	850
UK	4,200	19	800
France	5,000	16	800
Italy	2,700	25	680

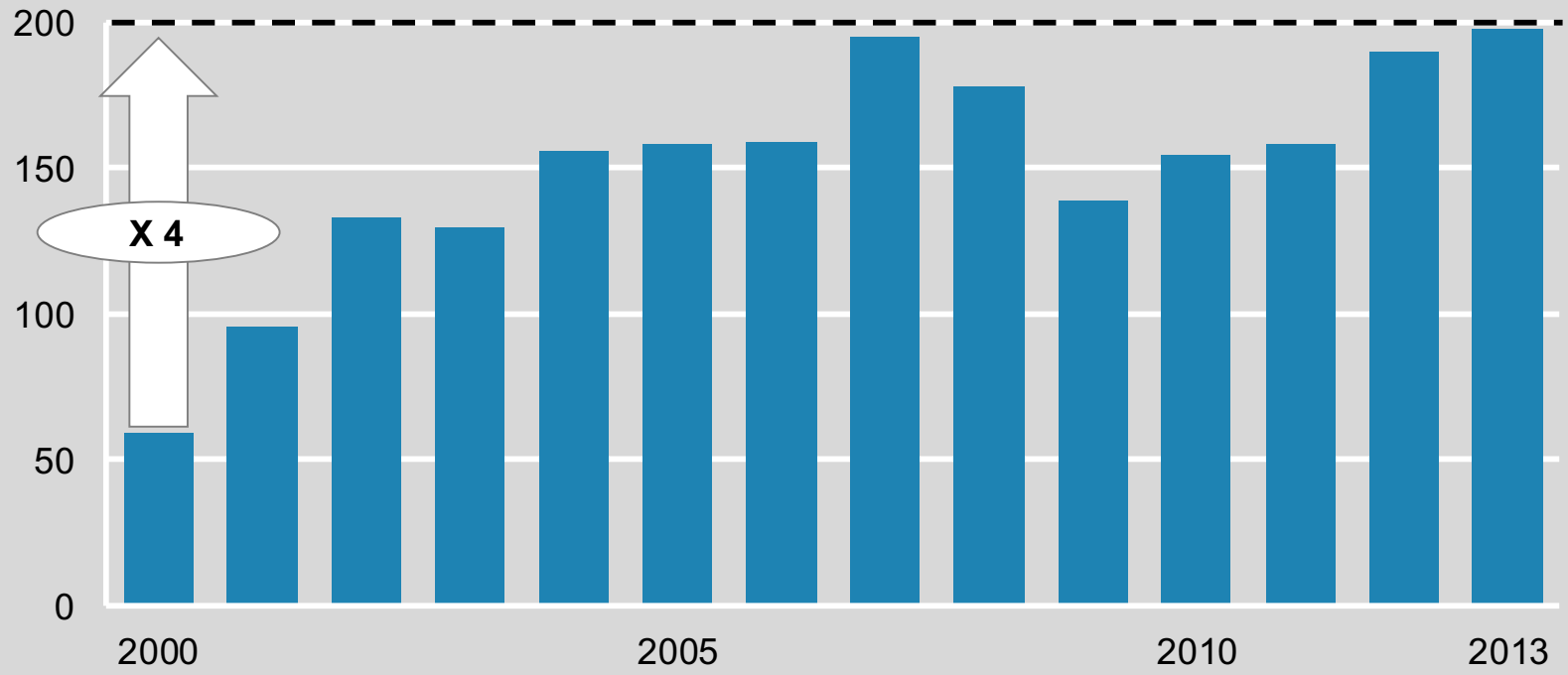
World Energy Council, EIA, Eurostat, Energy Intenlligence, New Energy, own calculations

A word on:
Industry electricity prices

Markus Steigenberger | August 2015

The *Energiewende* does not seem to harm Germany's economic competitiveness

Export surplus in Bln. EUR



Destatis

For industry as a whole, energy costs account in average for about 2% of total production value…

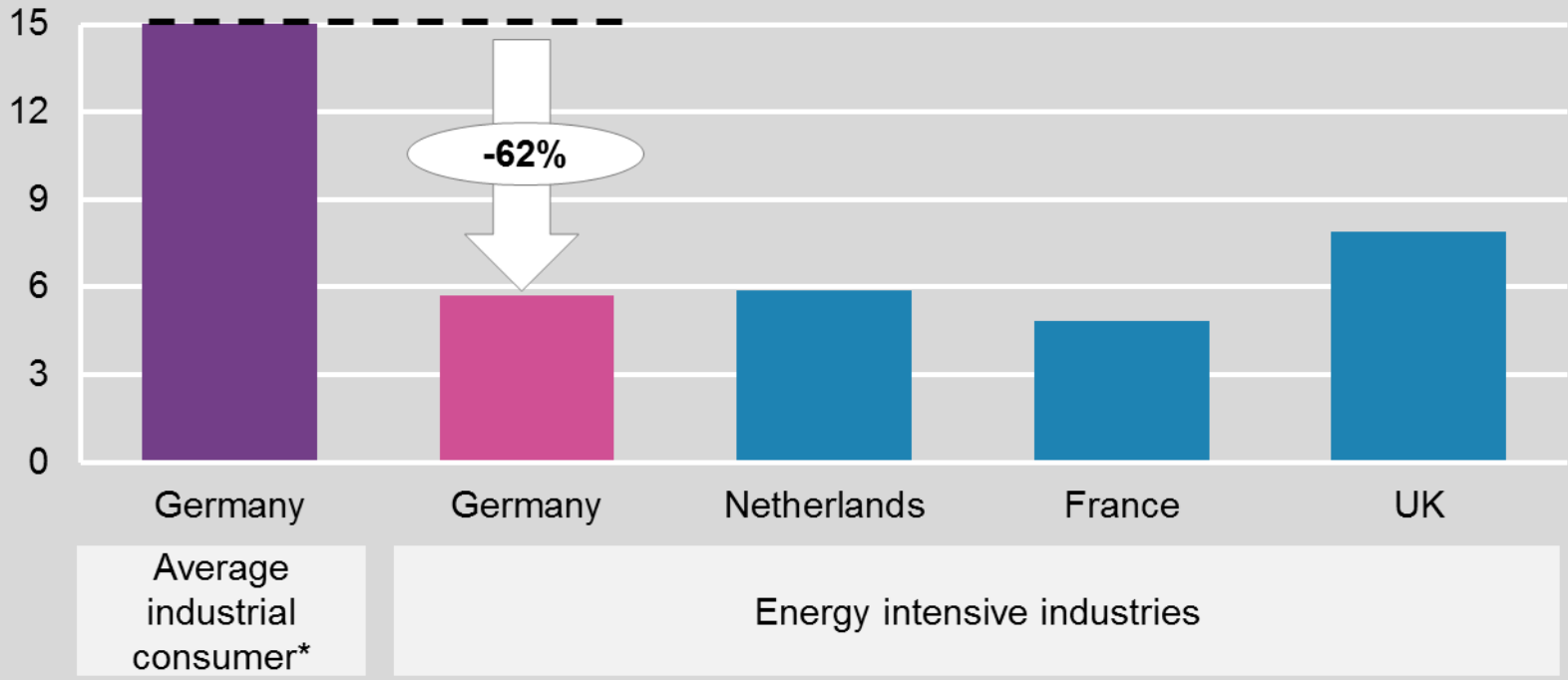
Gross production value* of the German manifacturing industry in Bln. EUR

Destatis

*incl. energy intensive sectors

…and energy intensive industries are largely exempt from taxes and levies to safeguard their competitiveness

Average electricity prices for energy intensive industrial consumers in 2013 in ct/kWh



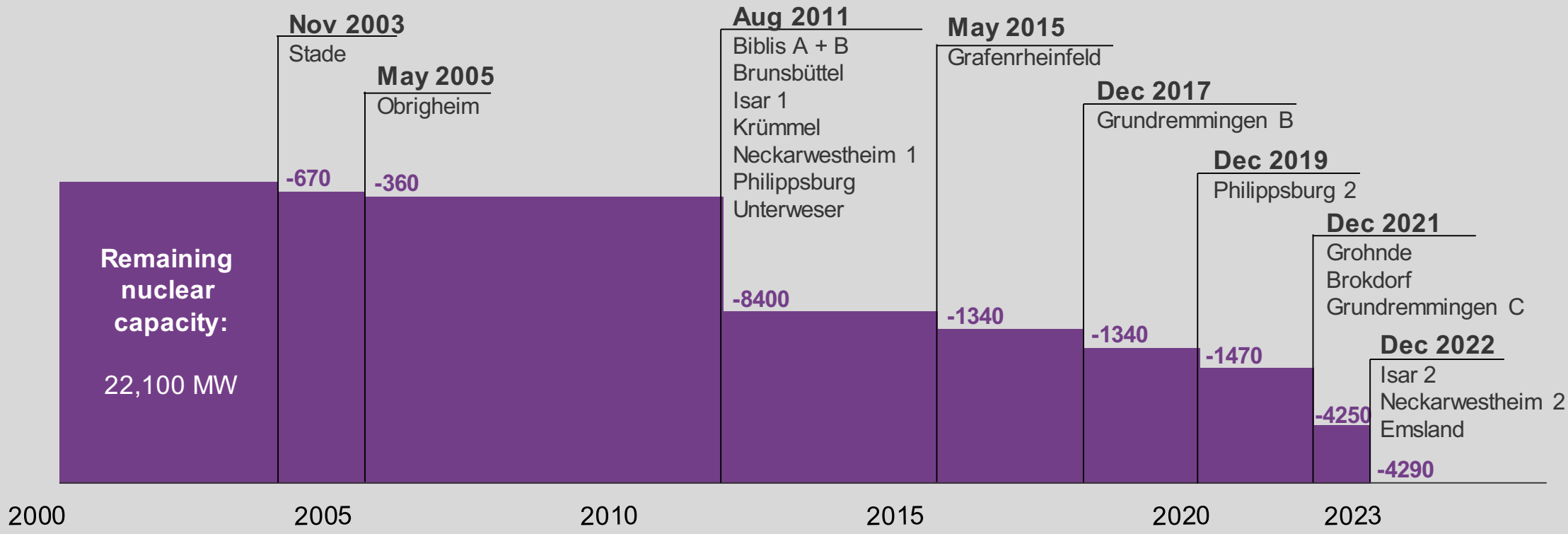
BMWi (2014)

*Assuming annual consumption of <20 MWh and partially exemptions from levies

Backup

Nuclear phase out is stretched over two decades

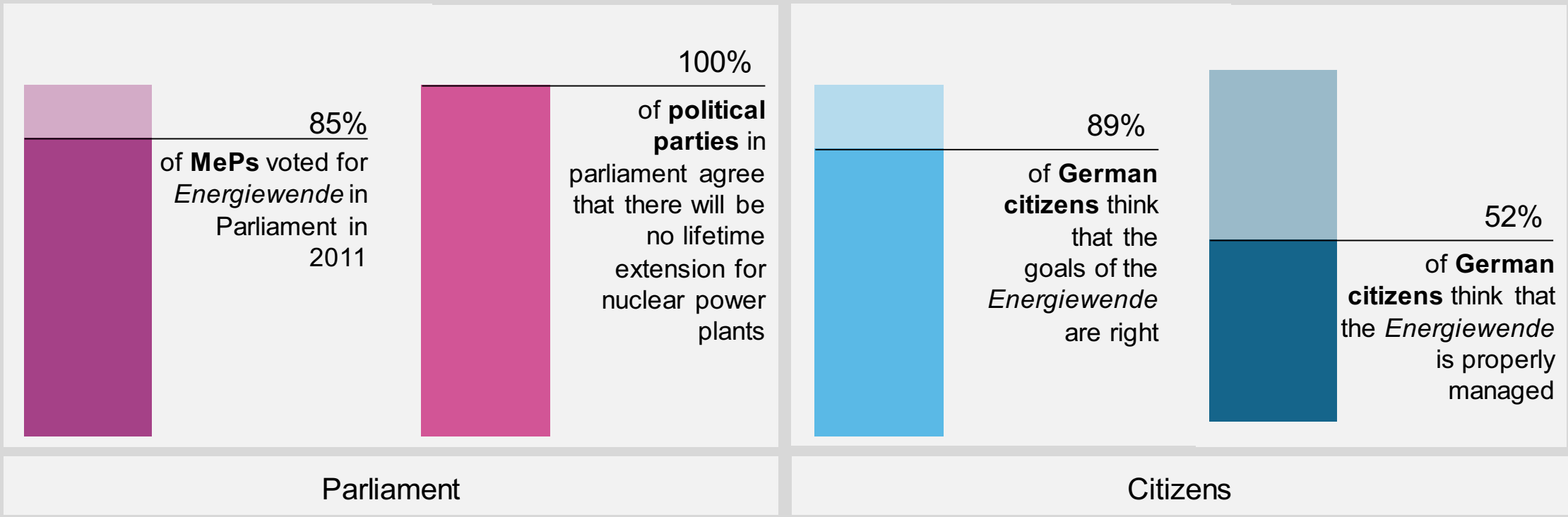
Planned phase-out of nuclear power plant units until 2022



BMWi, energytransition.org

There is a broad political consensus on the goals of the *Energiewende* – and discussions are mainly targeting its implementation

Political decisions and public opinion on *Energiewende*



BDEW, Forsa

Increasing shares of renewables led to sinking wholesale prices at the electricity exchange

Illustration of the Merit-Order-Effect

Agora Energiewende

LCOE – Cost assumptions

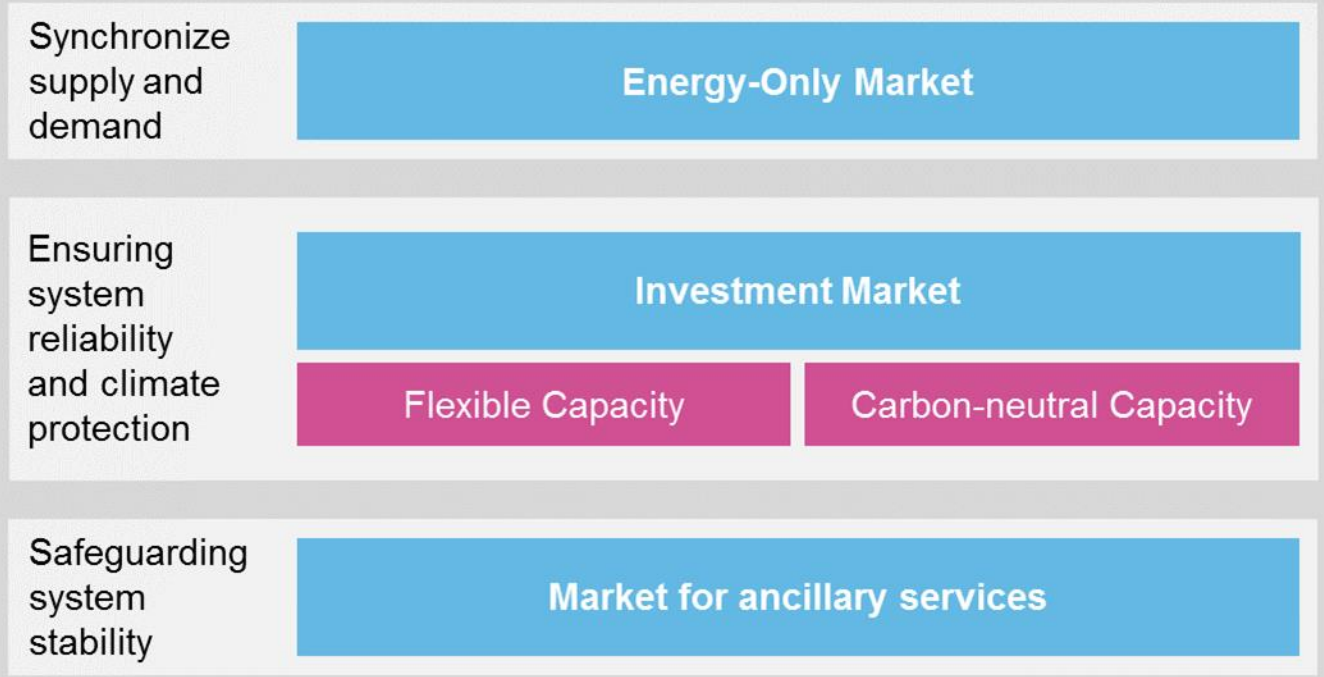
Range of levelized cost of electricity (LCOE) in 2015 in EUR/MWh - assumptions

	Invest (min./max.)	WACC (%)	Lifetime	Full load hours (min./max.)	CO2 certificats (min./max.)	Efficiency (min./max.)
	EUR/kW	%	a	h	EUR	%
Wind	1250/1500	7%	20	2000/2500		
PV	800/900	7%	30	1000		
Lignite	1850	12%	50	3000/6000	10/20	35%/45%
CCGT	900	12%	30	2000/4000	10/20	60%
Coal	1500/2250	12%	50	3000/6000	10/20	46%/50%
Nuclear	6000	12%	60	6000/7500		33%

Agora Energiewende

A new market design for the *Energiewende* is necessary

Illustrative structure of a future market design

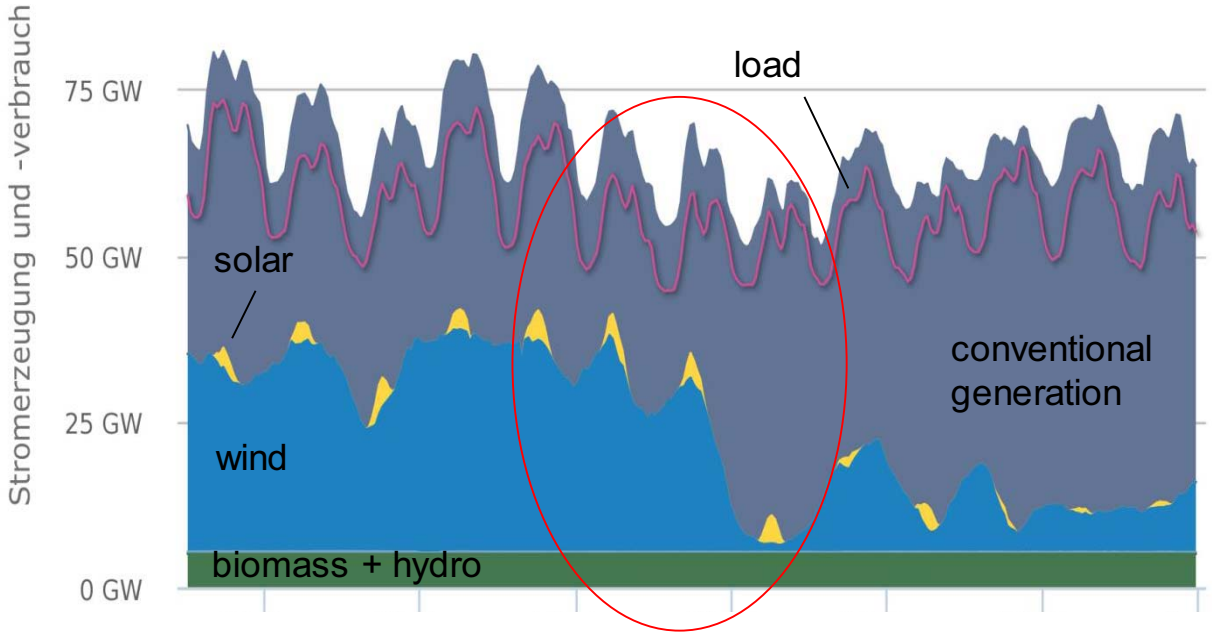


Agora Energiewende

Case Study 1
Flexibility of conventional generation at Christmas 2014

Electricity generation in Germany 20th to 31 December 2014

Electricity generation and demand



Agora Energiewende 2015

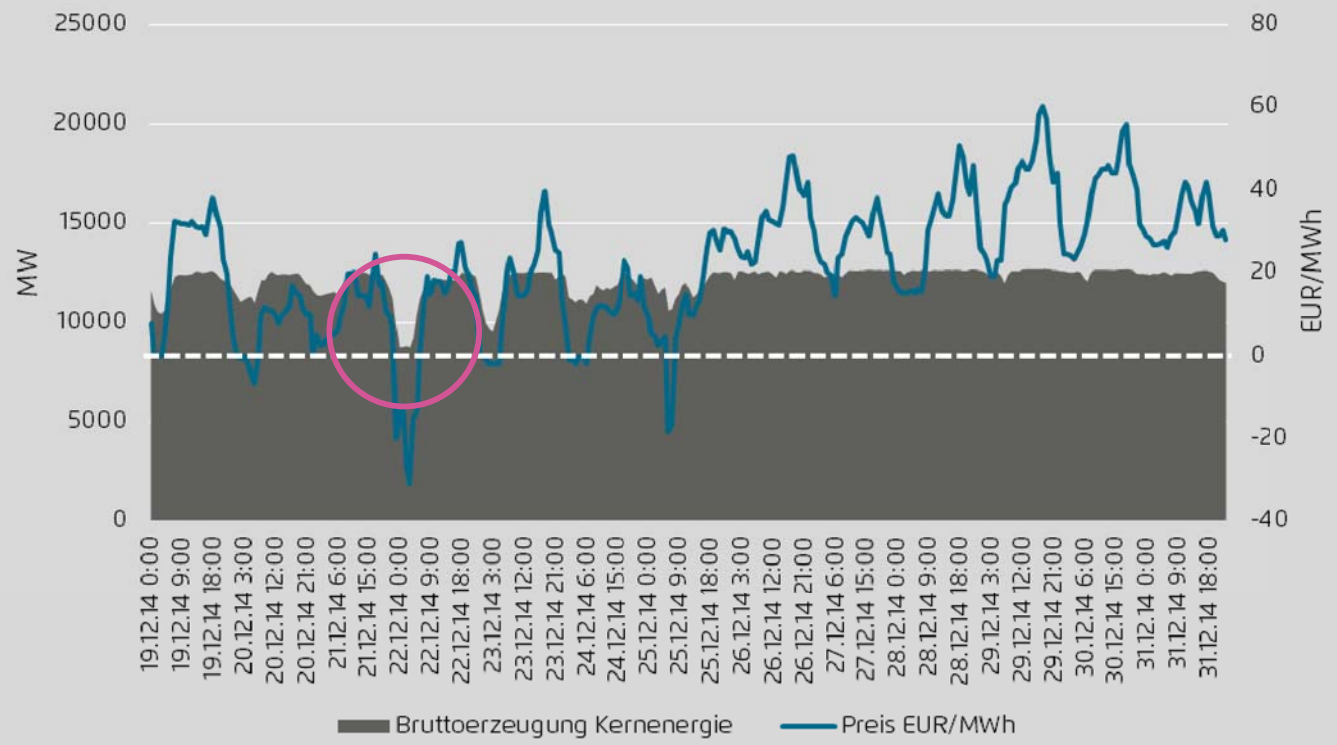
High generation from wind at 24th/25th December

Low demand at 24th/25th December due to Christmas festival (minimum of 44,5 GW)

Drastic drop of electricity generation from wind at night 25th/26th December

Reaction of conventional generation: nuclear

Electricity generation from nuclear plants and market prices 19th to 31 Dec. 2014



Agorameter 2015

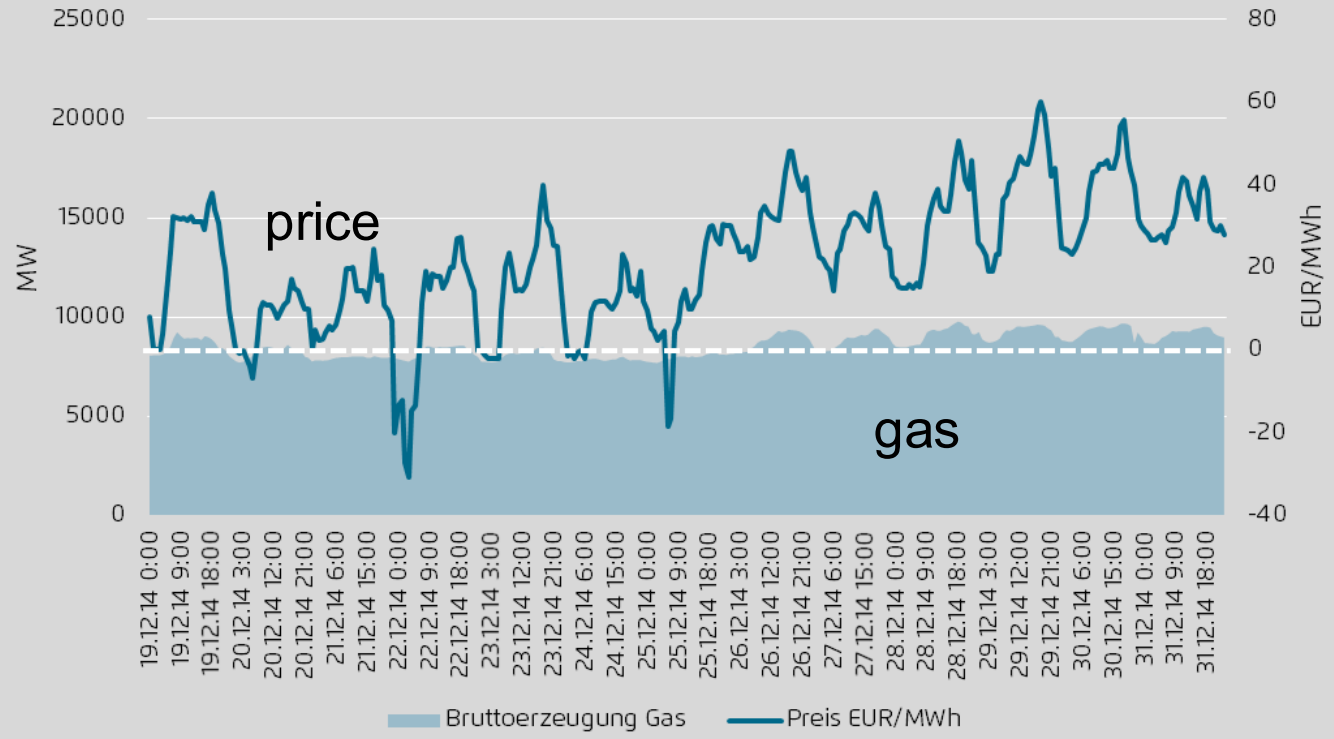
Nuclear plants – the conventional technology with lowest marginal costs – basically continues to run at full load

Only in times of very low/ negative market prices, nuclear plants slightly reduce their generation.

Market price dropped to zero seven times within six days; twice to -20 EUR/MWh and below.

Reaction of conventional generation: Gas

Electricity generation from gas plants and market prices 19th to 31 Dec. 2014



Agorameter 2015

Gas plants – as the conventional technology with the highest marginal costs – almost entirely leave the system.

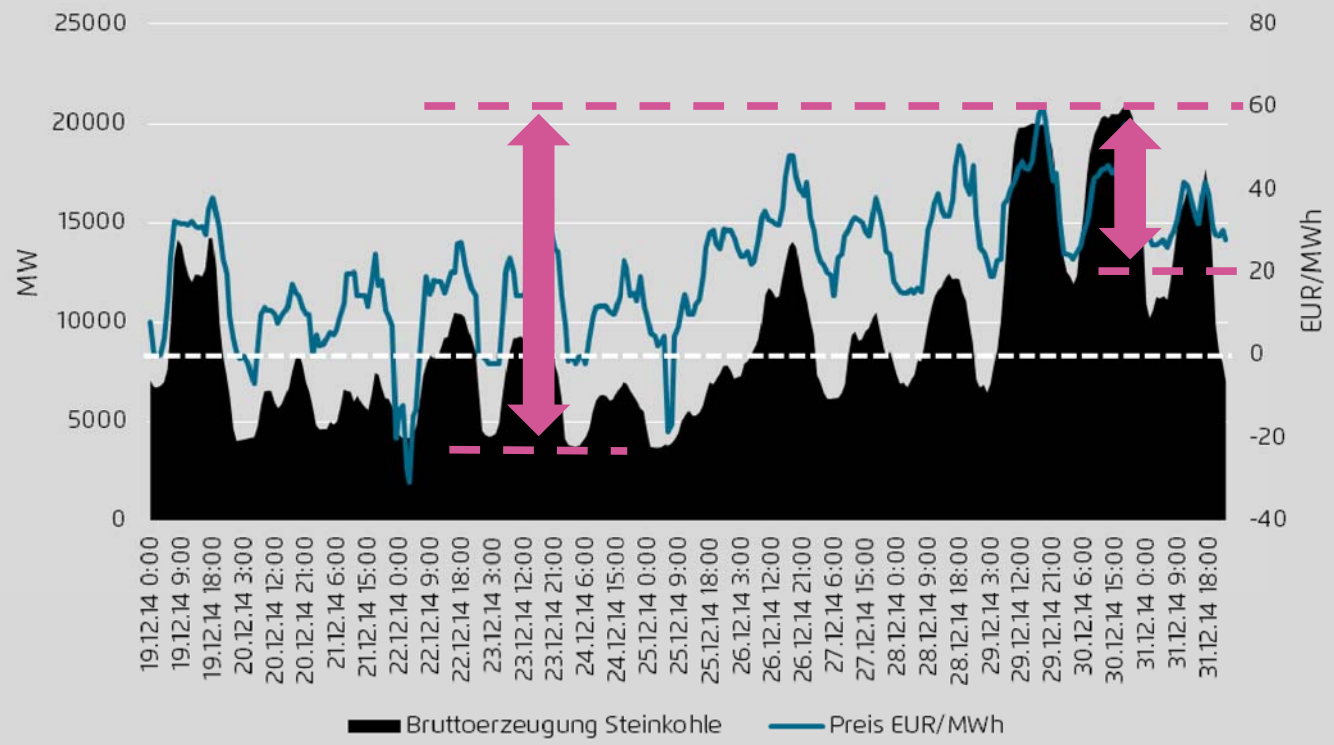
Sole exception: approx. 7,500 MW ‚must run' CCGTs (co-generation) - inflexible

Slightly increasing generation from gas plants only in times of higher prices and less RES (26th to 31st Dec.)

The market price dropped to zero seven times within six days – twice to -20 EUR/MWh and below.

Reaction of conventional generation: Hard Coal

Electricity generation from hard coal plants and market prices 19th to 31 Dec. 2014



Agorameter 2015

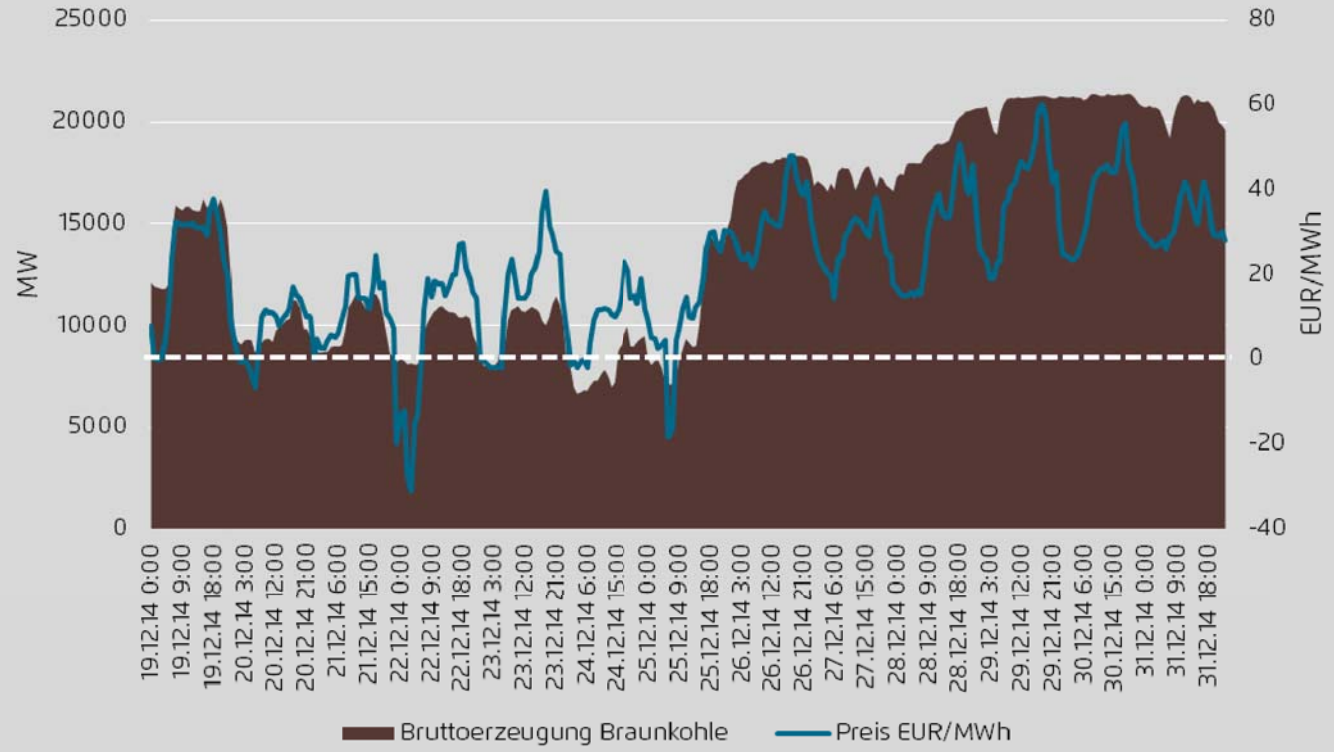
As no flexible gas plants are available, hard coal plants have to provide the flexibility to the system.

Hard coal plants proof to be able to ramp up and down 15 GW within a week, and 8 GW within a day.

Must-run capacity apparently relatively low (less than 5,000 MW)

Reaction of conventional generation: lignite

Electricity generation from lignite plants and market prices 19th to 31 Dec. 2014



Agorameter 2015

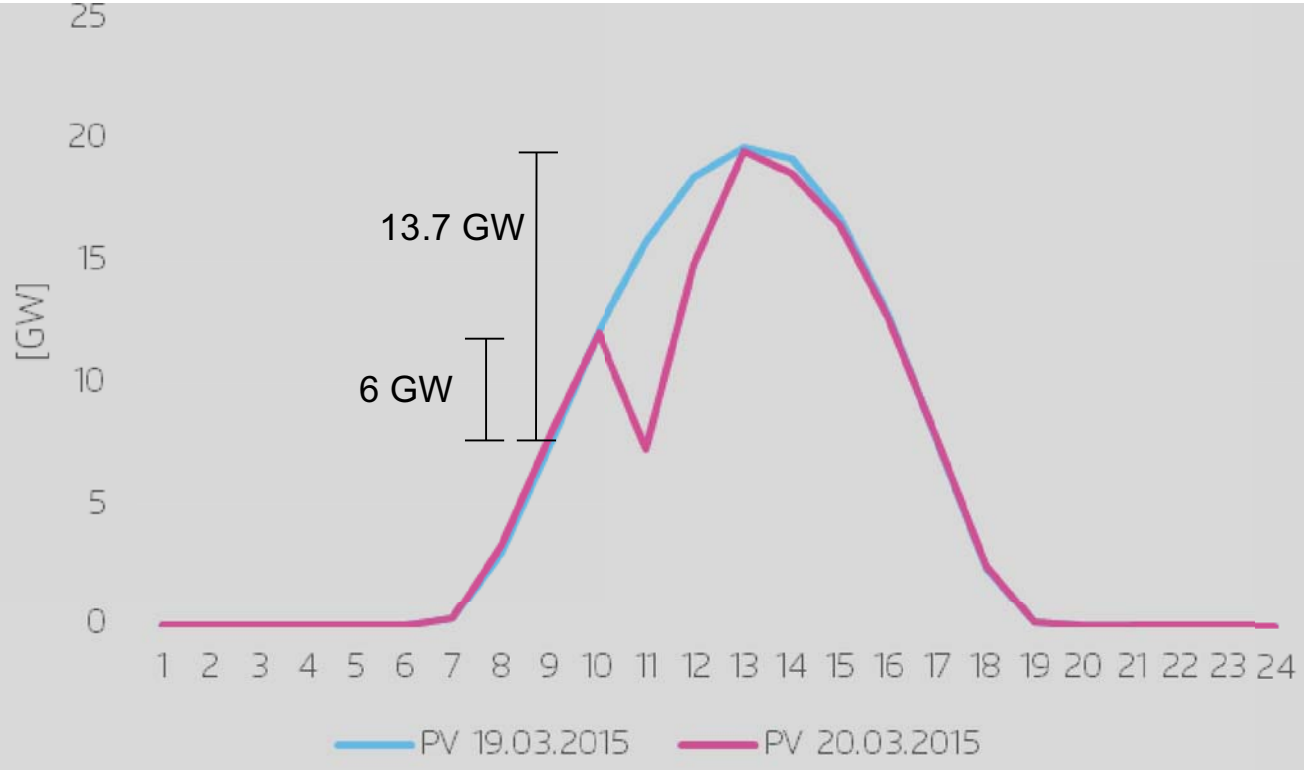
Very unusual: Lignite plants reacted relatively flexibel and reduced their generation to a minimum level of only 6.2 GW.

From 26th onwards, lignite production was back to normal (around 20 GW)

Case Study 2
Solar Eclipse – 20 March 2015

The challenge: extraordinary ramping rates

Electricity production of solar PV on 19/20 March 2015



Own; data: EEX

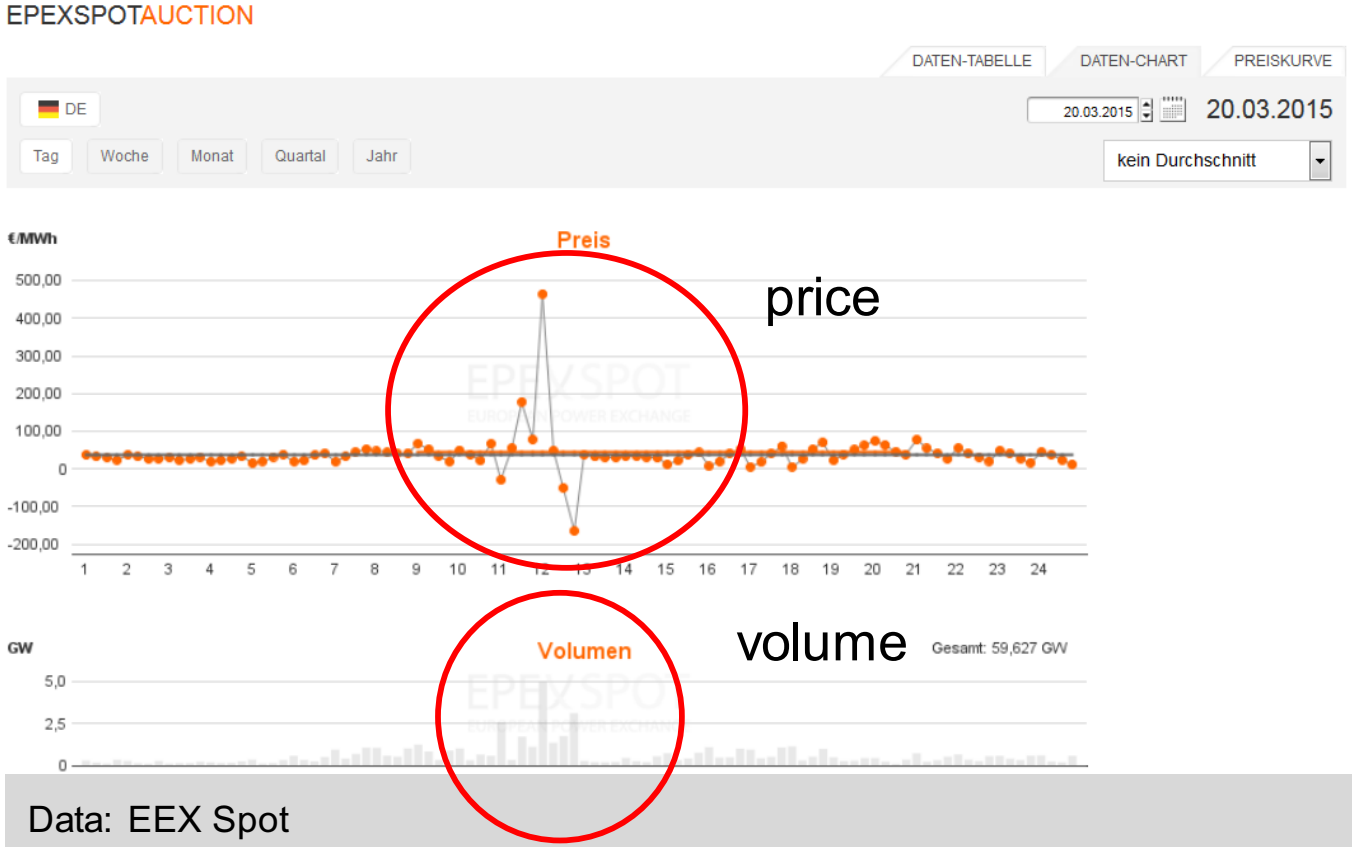
Due to the solar eclipse, electricity production from solar PV ramped down 6 GW within 65 minutes (between 10 a.m. and 11.30 a.m.), and ramped up again roughly 13.7 GW within 75 minutes (between 11.30 a.m. and 1 p.m.)

No shortages in the German power system occured.

These ramps are unusual today, but are expected frequently in 2030 in Germany, when roughly 50% of electricity will be produced by Renewables (according to current law).

Flexibility was traded in the intra-day market

Intra-Day Market in Germany on 20 March



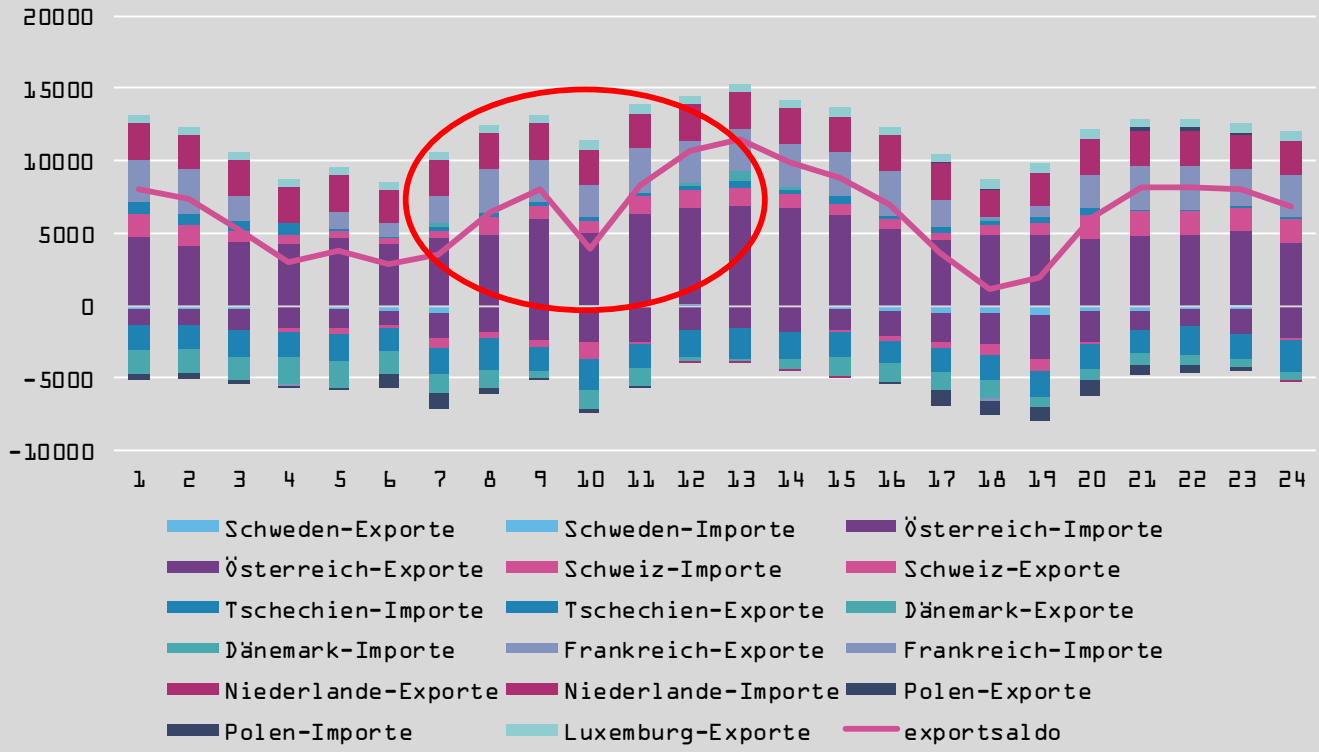
Data: EEX Spot

The day-ahead market saw slightly higher volumes and prices than usual.

The biggest effect was seen at the intra-day market where tranches of 15 minutes can be traded. Both volume and price showed significant variations – compared to normal levels.

System reaction: reduced exports

Electricity trade – Germany and neighbouring countries



Own; EEX data

Exports to neighbouring countries were reduced by approx. 4 GW.