Insights from Germany’s Energiewende

State of affairs, trends and challenges

Last Update:

14.10.2015

Agora Energiewende – Who we are

Think Tank with 20 Experts

Independent and non-partisan

Project duration 2012-2017

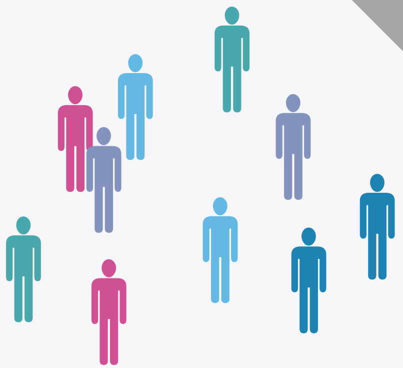
Financed with 14 Mio. Euro by Mercator Foundation & ECF

Mission: How do we make the energy transition in Germany a success story?

Methods: Analyzing, assessing, understanding, discussing, putting forward proposals, Council of Agora

Agora Energiewende – How we work

Stakeholder



Impulse

Regular exchange and changing advisory committees in different projects

Team of Agora

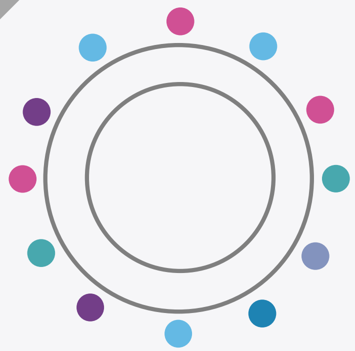
Director

- Team Germany
- Team Europe
- Central Services

Studies,
public events etc.

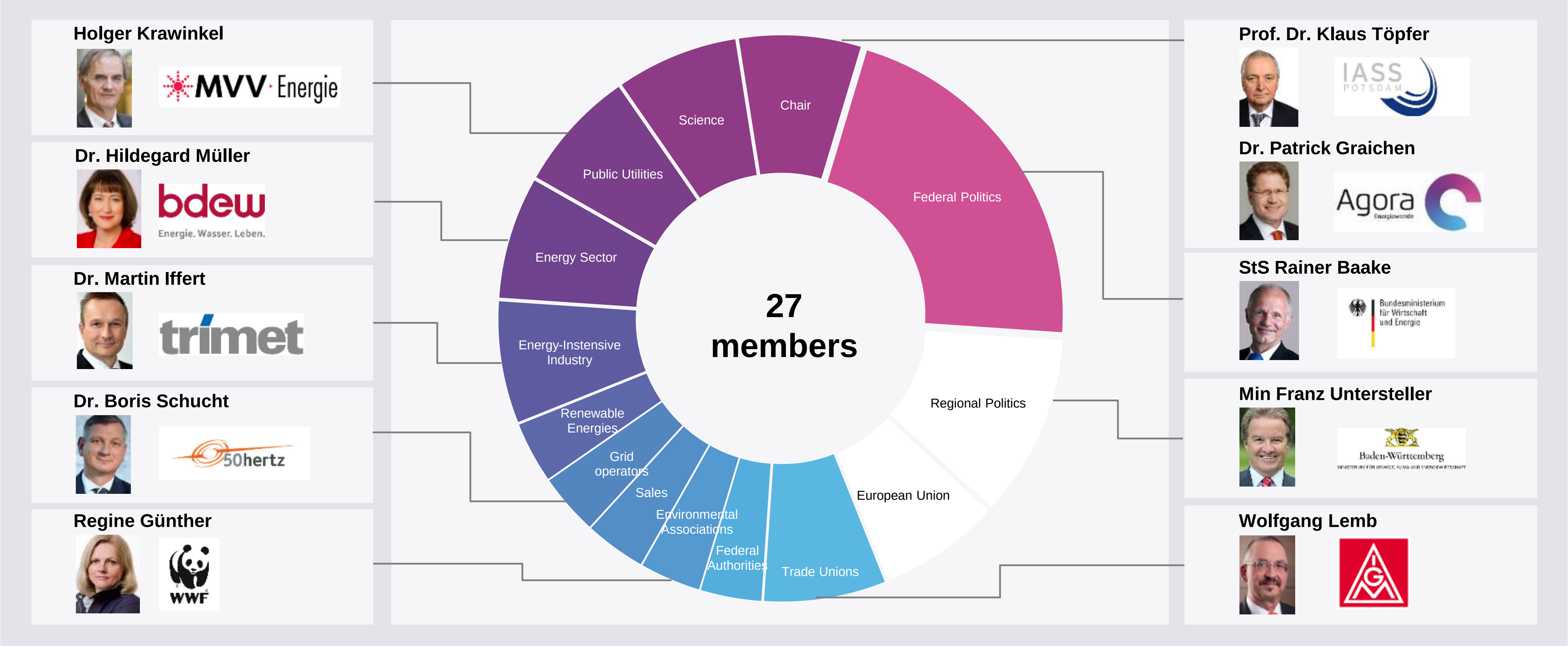
Impulse

Council of Agora



Internal discussion and exchange of the 28 permanent members

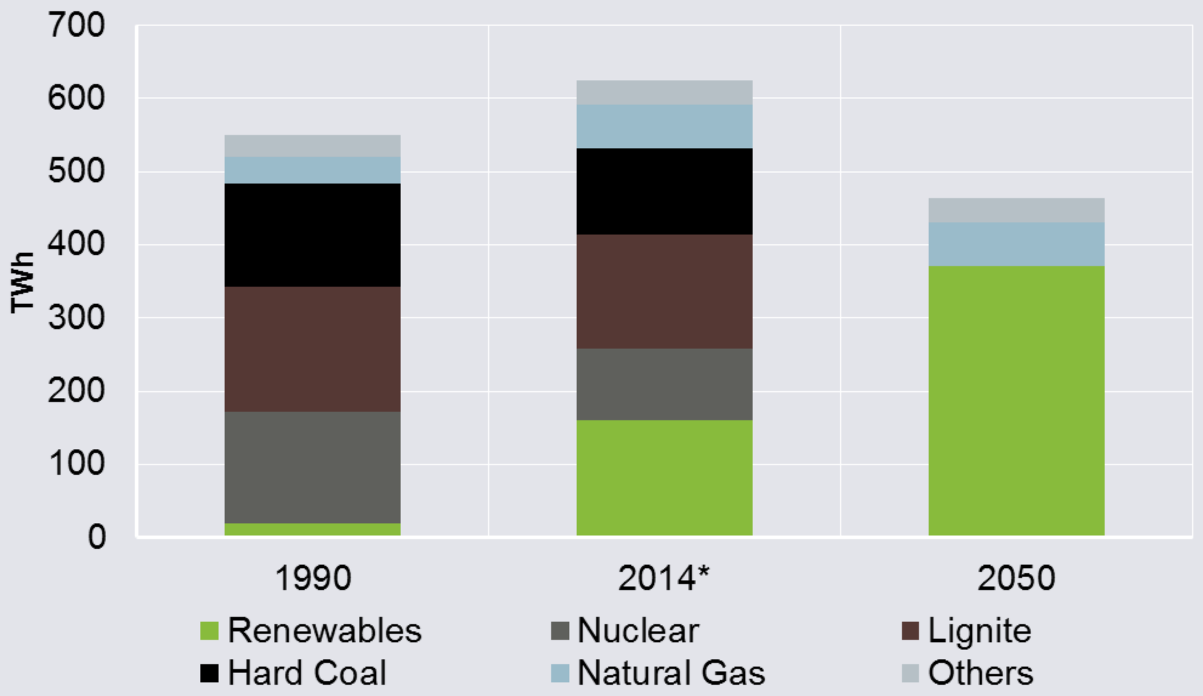
Agora Energiewende – Council of Agora



The Energiewende in the power sector in a nutshell

The Energiewende means fundamentally changing the power system

Gross electricity generation 1990, 2014 and 2050



AGEB (2015a), BReg (2010), EEG (2014), own calculations * preliminary

Phase out of Nuclear Power
Gradual shut down of all nuclear power plants until 2022

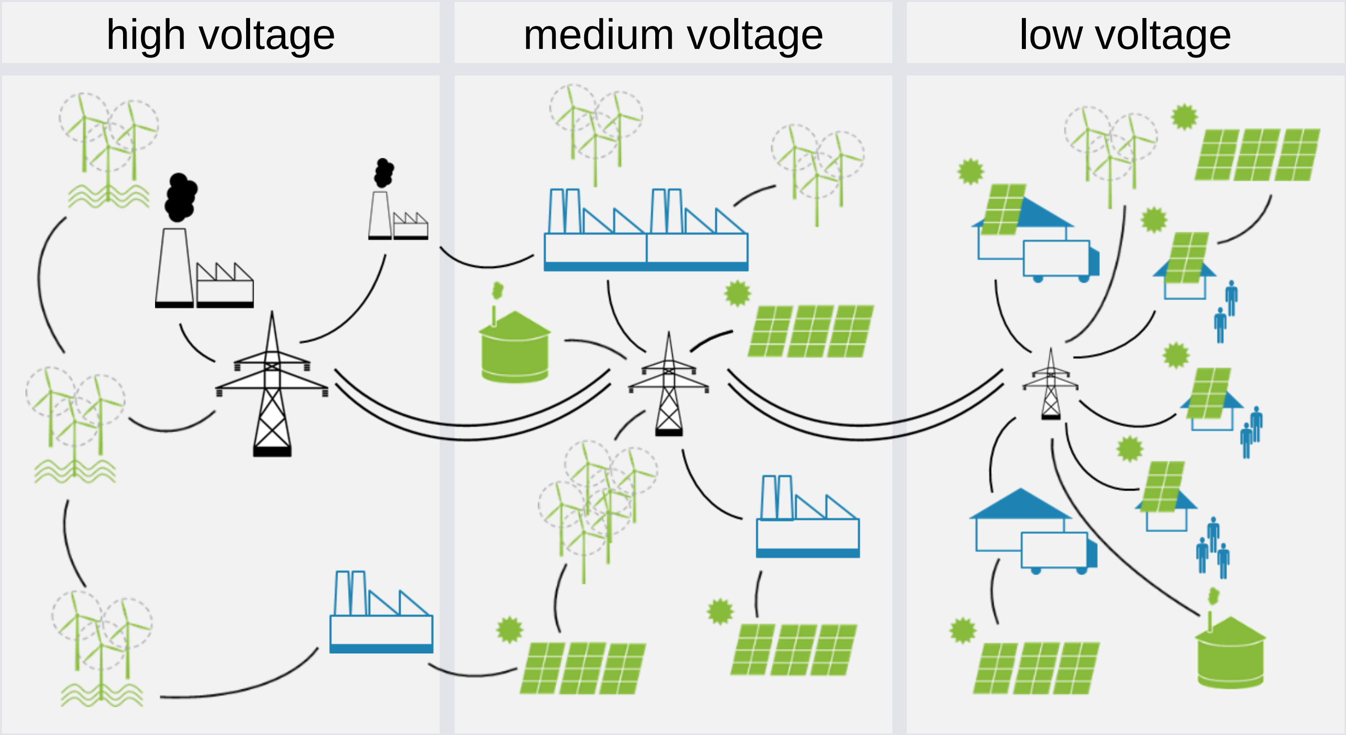
Reduction of Greenhouse Gas Emissions
Reduction targets below 1990 levels:
- 40% by 2020; - 55% by 2030; - 70% by 2040;
- 80% to - 95% by 2050

Development of renewable energies
Share in power consumption to increase to:
40 - 45% in 2025; 55 - 60% in 2035; ≥ 80% in 2050

Increase in efficiency
Reduction of power consumption compared to 2008 levels: - 10% in 2020; - 25% in 2050

The Energiewende implies a new energy world – characterized by flexibility, decentralized structures and a wide variety of actors

Illustrative visualisation of the old and the new electricity system



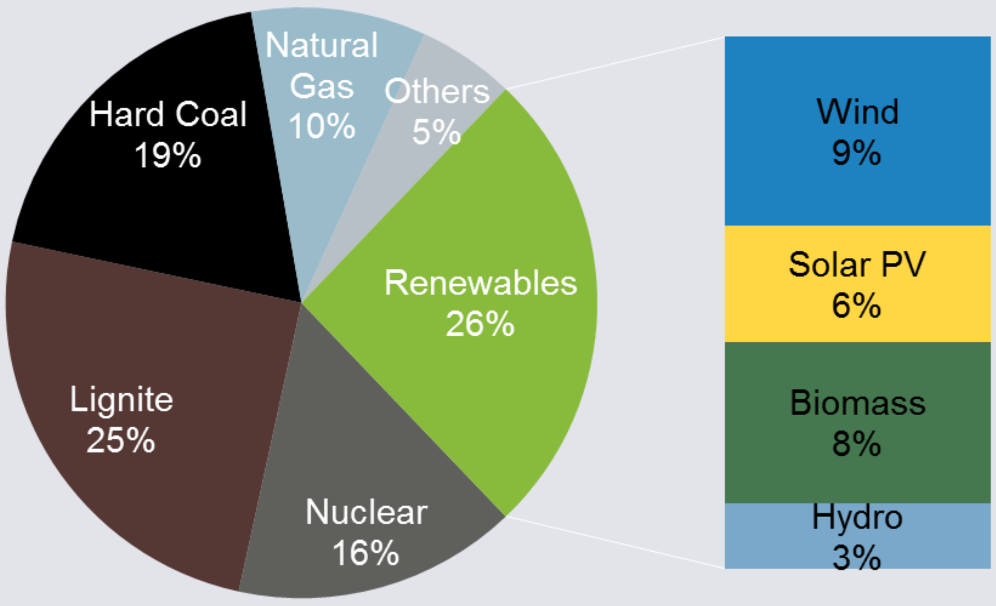
Own illustration

The Energiewende in the power sector

State of affairs 2015

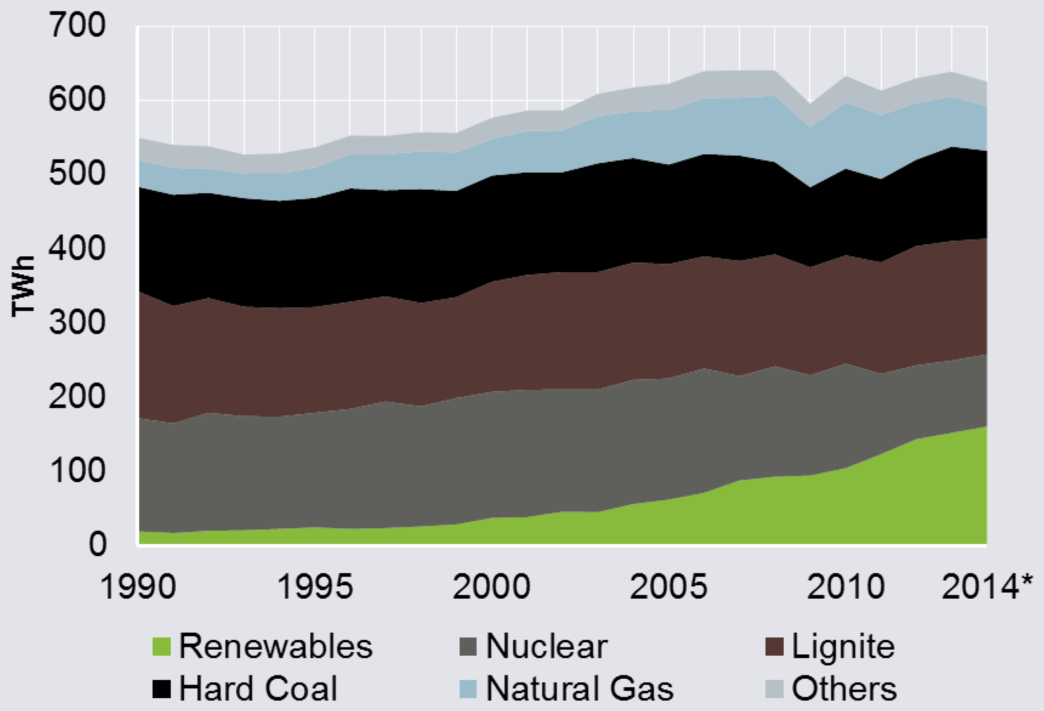
Renewables are the most important source in the electricity system – followed by lignite and hard coal

Share in gross electricity generation by fuel 2014



AGEB (2015a) * preliminary

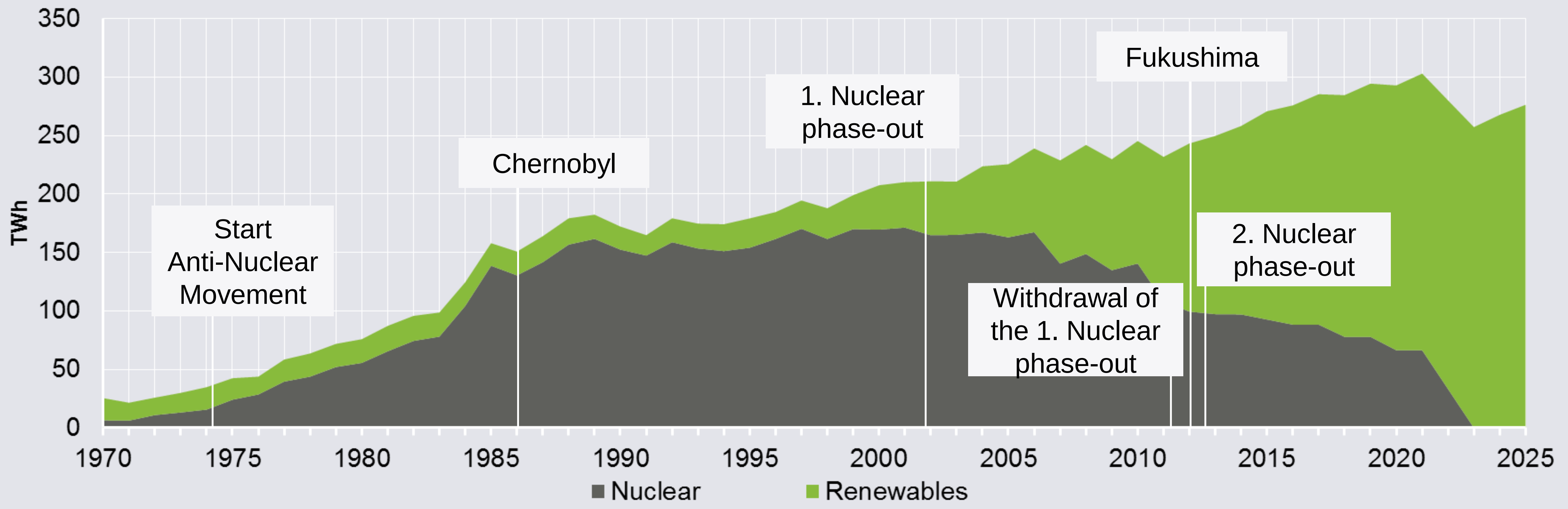
Gross electricity generation by fuel 1990 - 2014



AGEB (2015a) * preliminary

The nuclear energy act rules the nuclear phase out until 2022 – with renewables overcompensating the loss in nuclear power

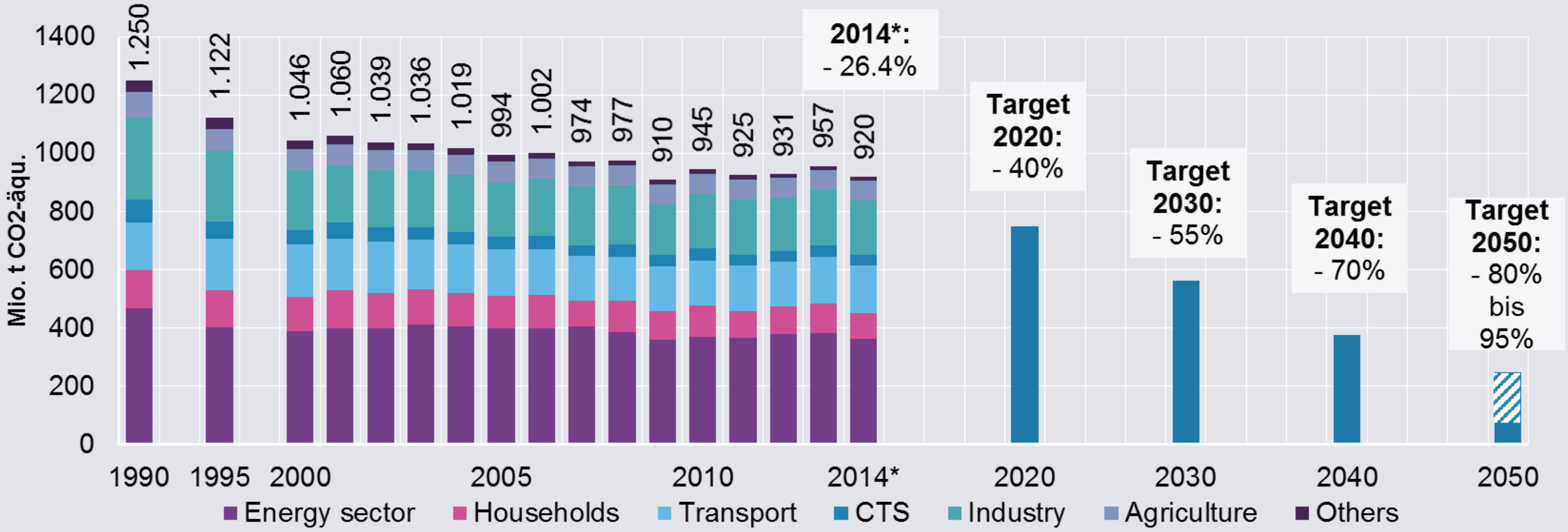
Gross electricity generation of nuclear and renewables 1970 - 2025



AGEB (2015a), AGEE (2015), BNetzA (2014), Statistisches Jahrbuch der DDR (1973 - 1988), own calculations

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

Greenhouse gas emissions by sector 1990 - 2014 and climate targets 2020 - 2050

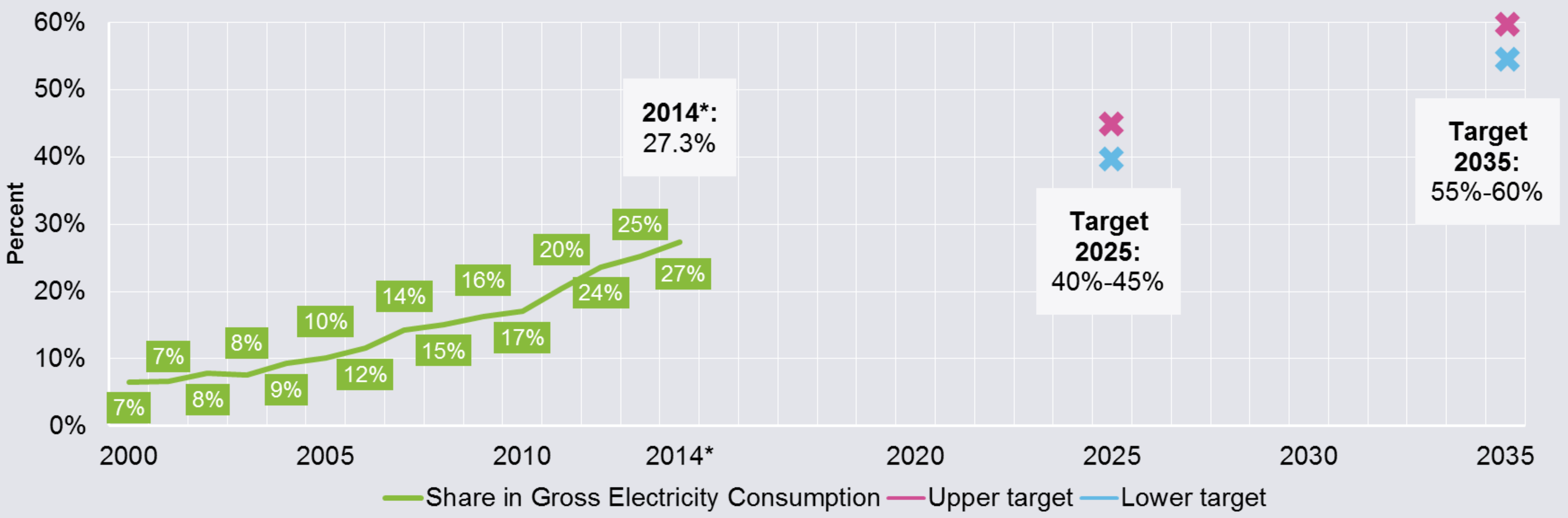


AGEB (2015a), UBA (2015), own calculations

* preliminary

The Renewable Energy Act aims at increasing the share of renewables to 40 - 45% by 2025 and 55 - 60% by 2035

Share of renewable energies in gross electricity consumption 2000 - 2014 and targets 2025 - 2035

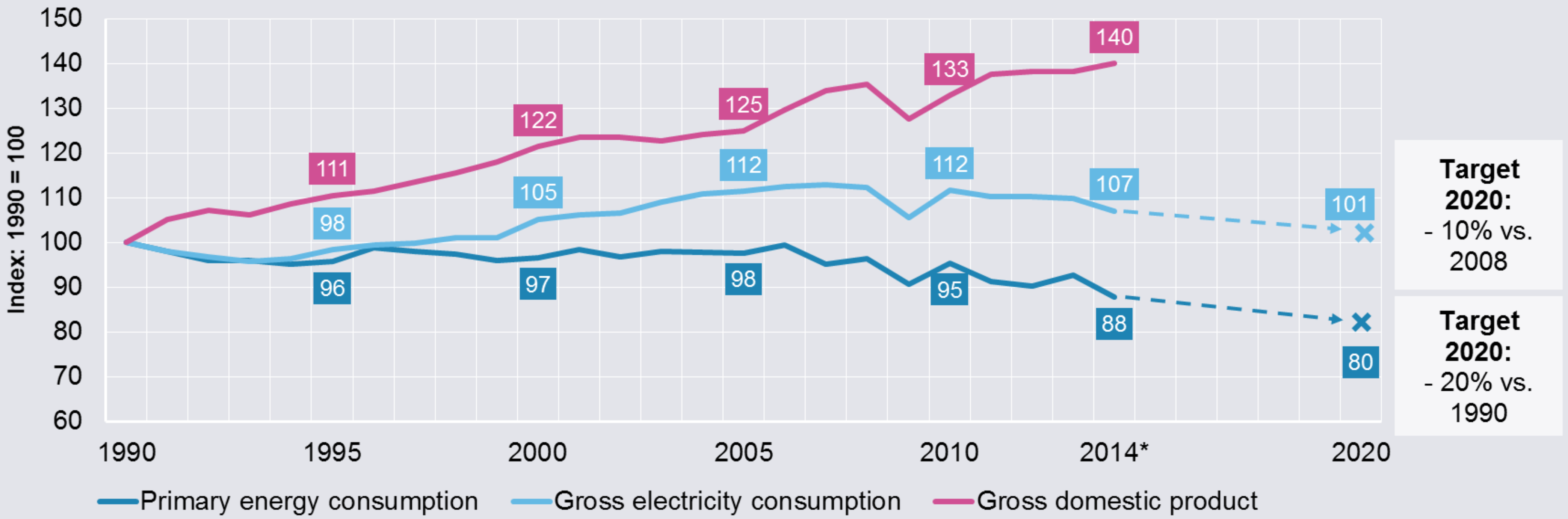


AGEB (2015a), EEG (2014)

* preliminary

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

Primary energy consumption, gross electricity consumption and GDP 1990 - 2014 and efficiency target 2020

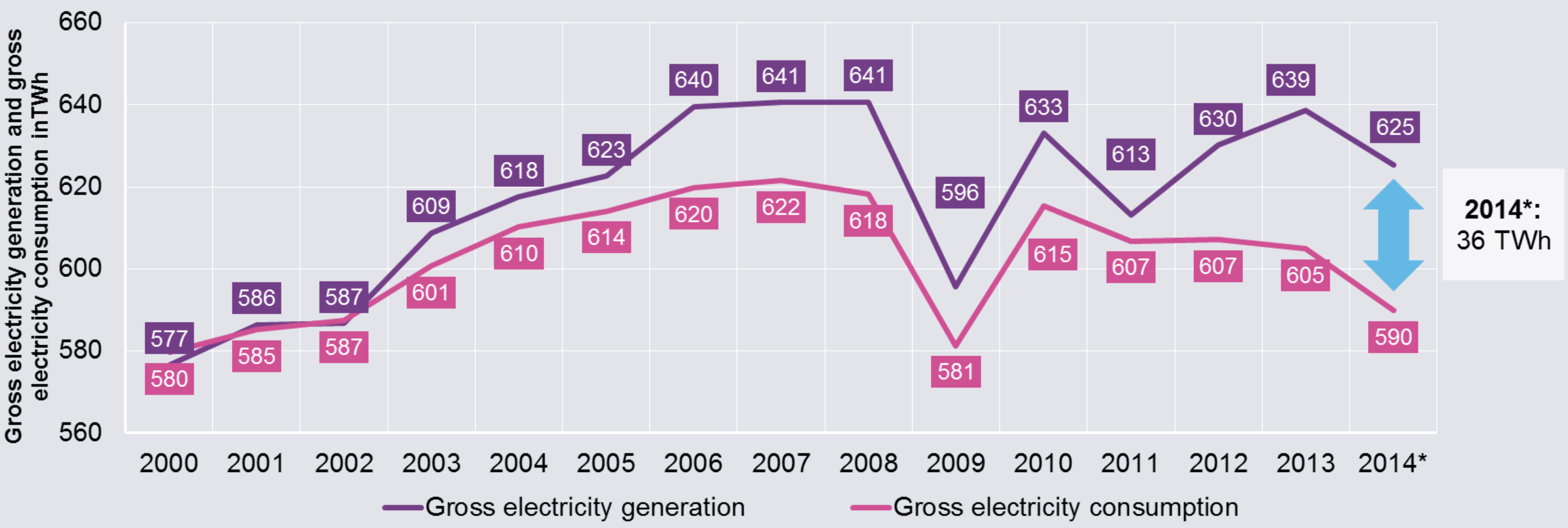


BMWi (2015) following AGEB (2015a), AGEB (2015b), Destatis (2015c); BReg (2010)

* preliminary

Since 2001, Germany has produced more electricity than it consumes – 2014 marked a new record with 6% of power production being exported to neighbouring countries

Gross electricity generation and gross electricity consumption 2000 - 2014

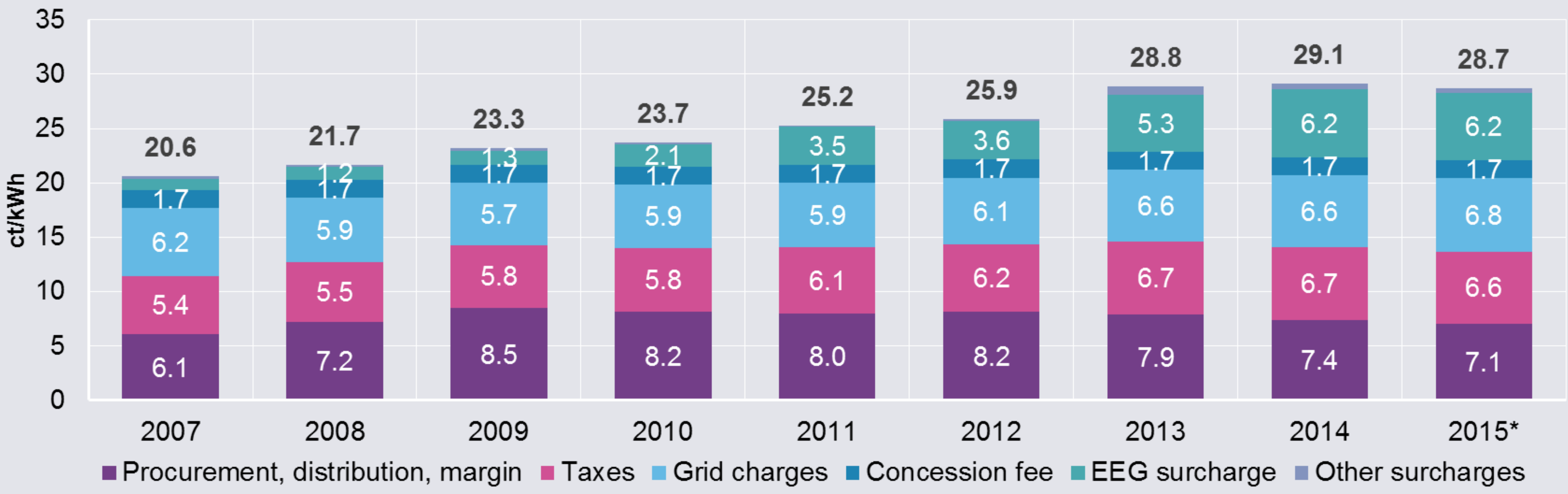


AGEB (2015a)

* preliminary

After significant increases in previous years, household electricity prices are relatively stable since 2013

Average household electricity prices in a 3-person household 2007 - 2015

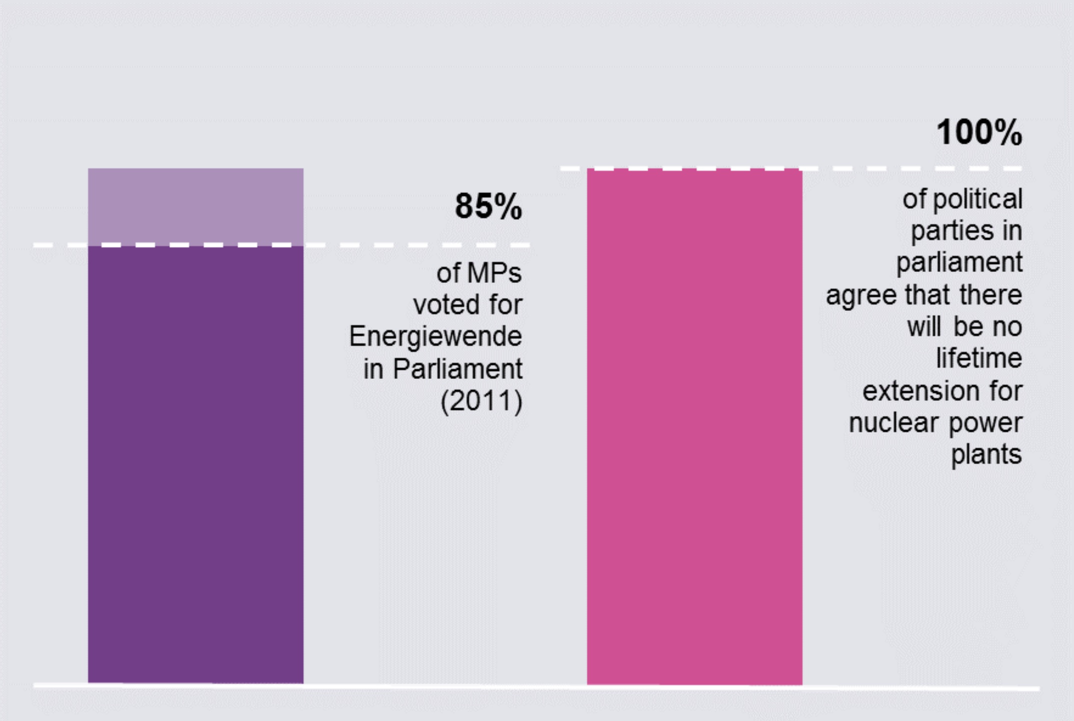


BDEW (2015b)

* preliminary

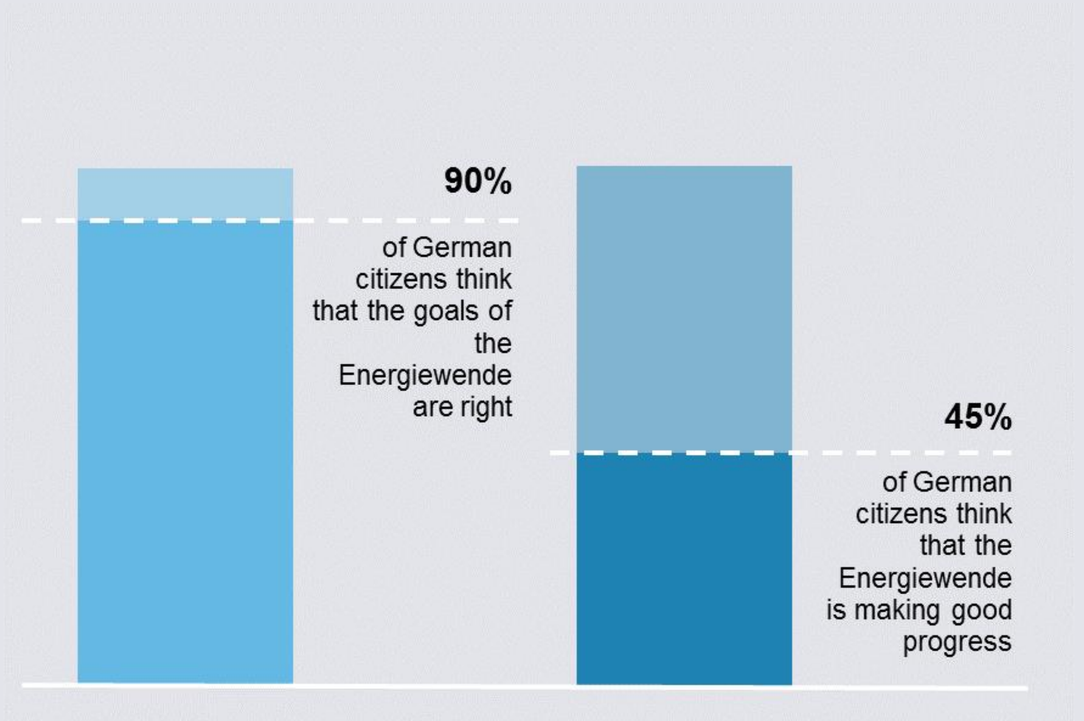
The Energiewende is based on a broad consensus - public discussions is basically focussing on the concrete implementation

Voting results in the Bundestag on Energiewende



Deutscher Bundestag (2011)

Public opinion on Energiewende 2015



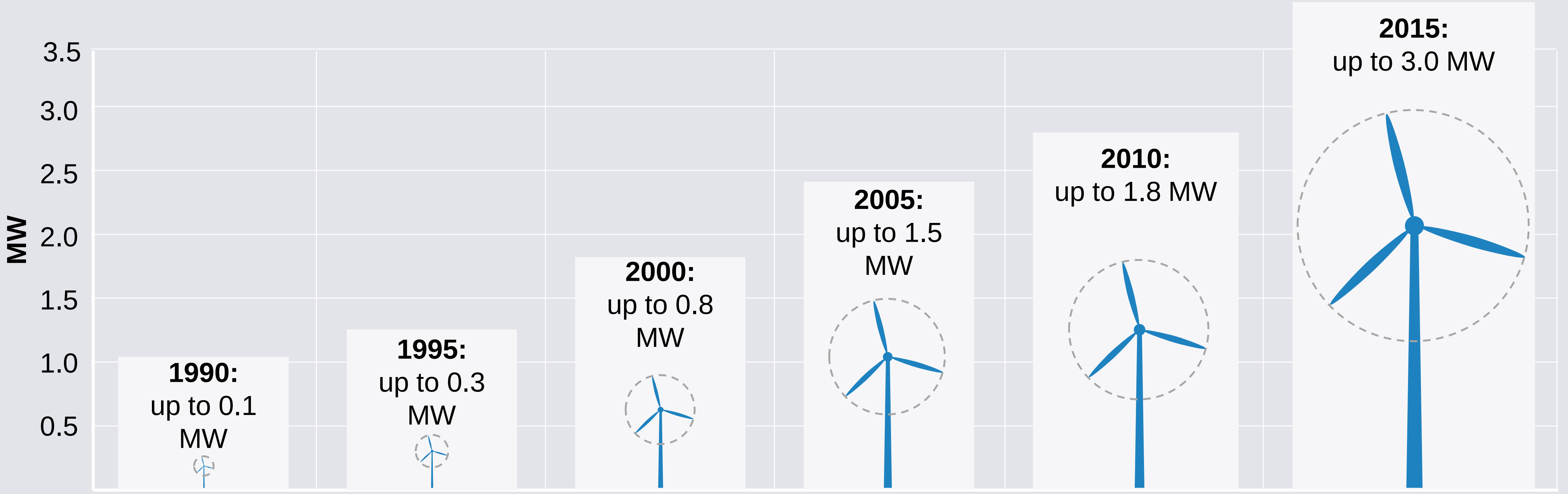
BDEW (2015a)

Agora Energiewende

The Key Insight: It’s all about Wind and Solar!

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

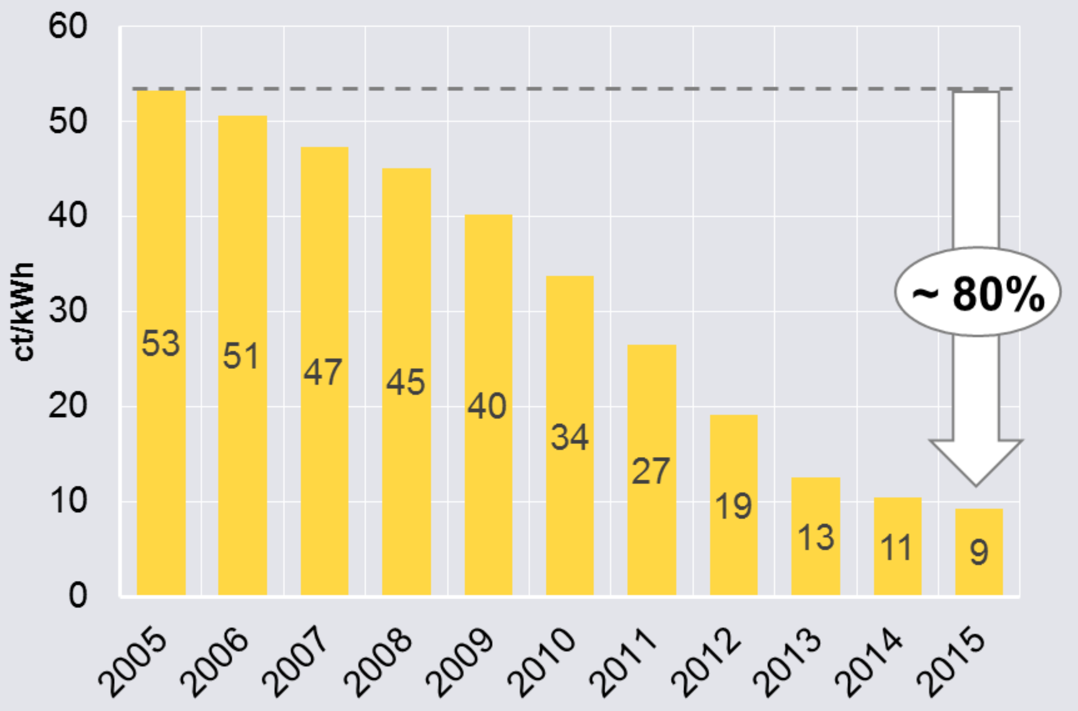
Size development of wind turbines 1990 - 2015



IEA (2013)

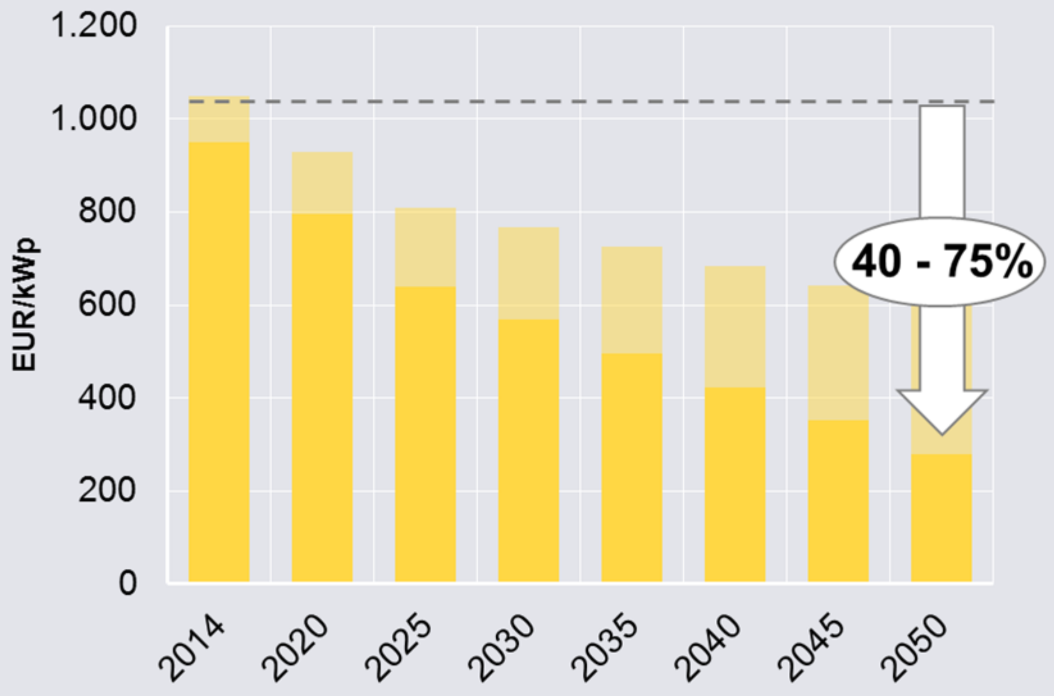
Due to falling module prices, feed-in tariffs for Solar PV dropped massively in the last 10 years - and the end of the cost digression is not yet reached

Average PV feed-in tariff for new installations 2005 - 2015



ZSW et. al (2014), own calculations

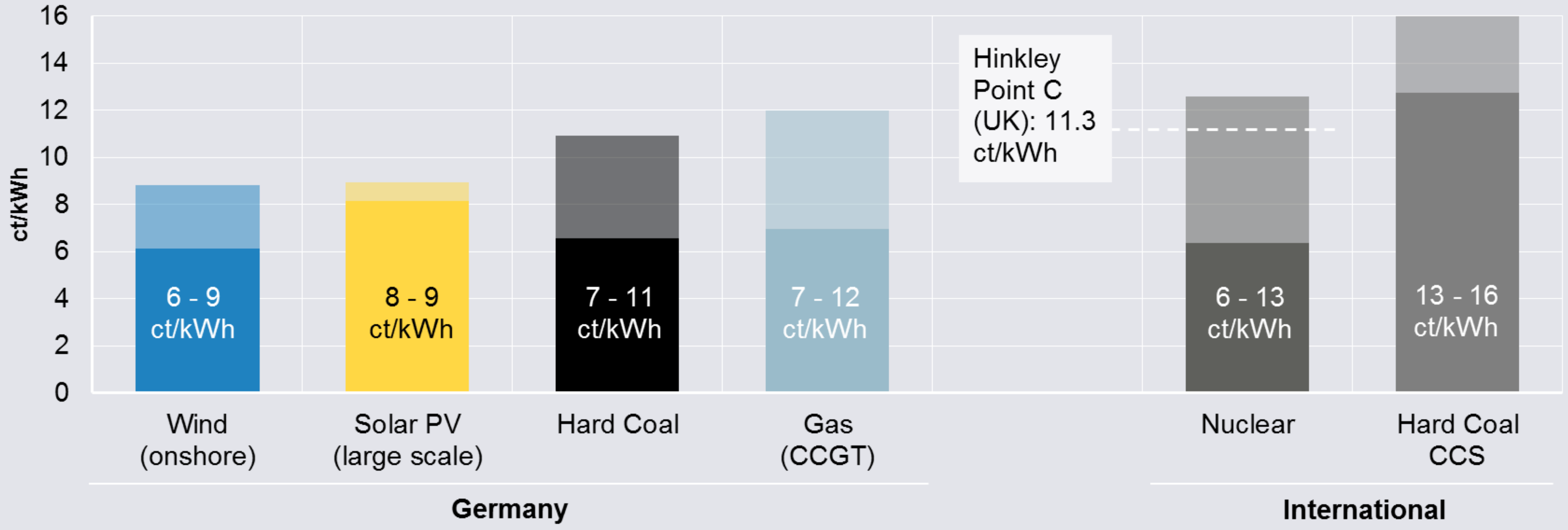
Expected cost digression for large-scale PV systems 2014 - 2050



Fraunhofer ISE (2015)

Today, wind and solar are already cost competitive to all other newly built power plants

Range* of levelized cost of electricity (LCOE) 2015

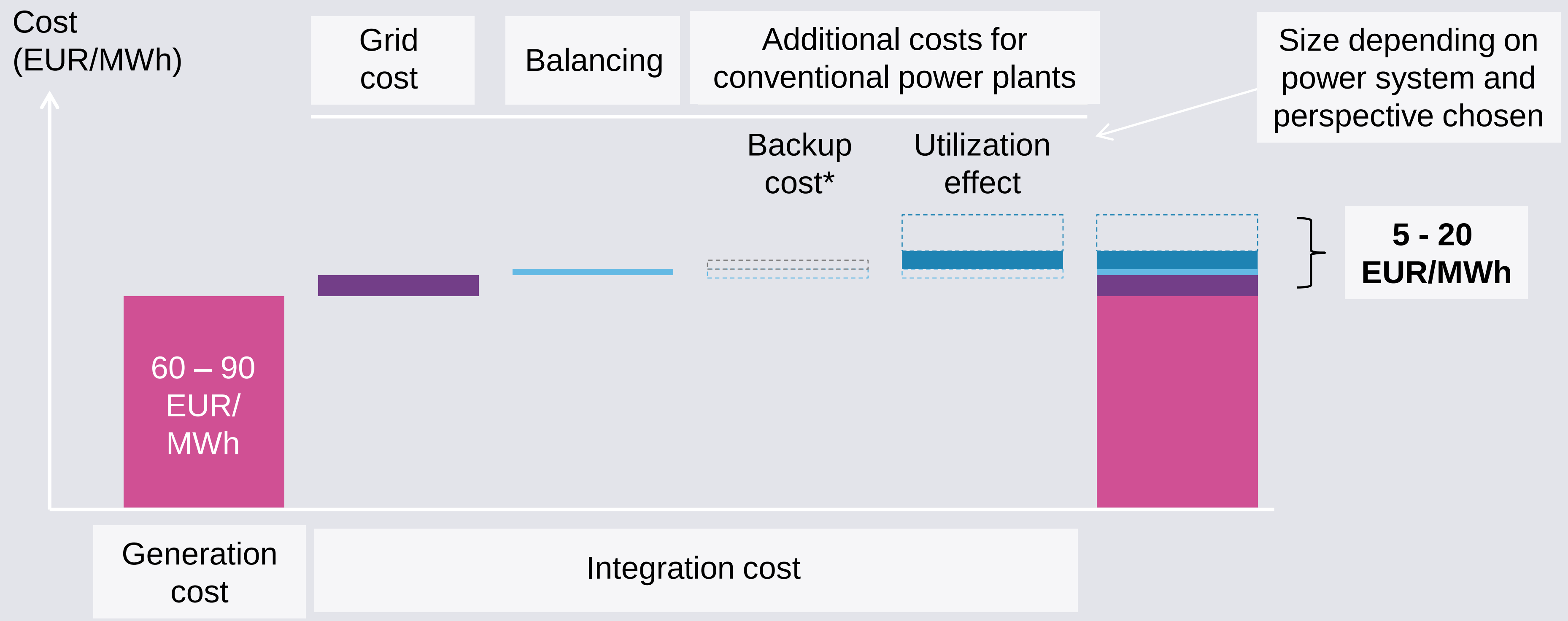


Agora Energiewende (2015e)

* based on varying utilization, CO_2-price and investment cost

The integration cost of wind and solar (5 to 20 EUR/MWh) do not change the picture

Components of integration costs

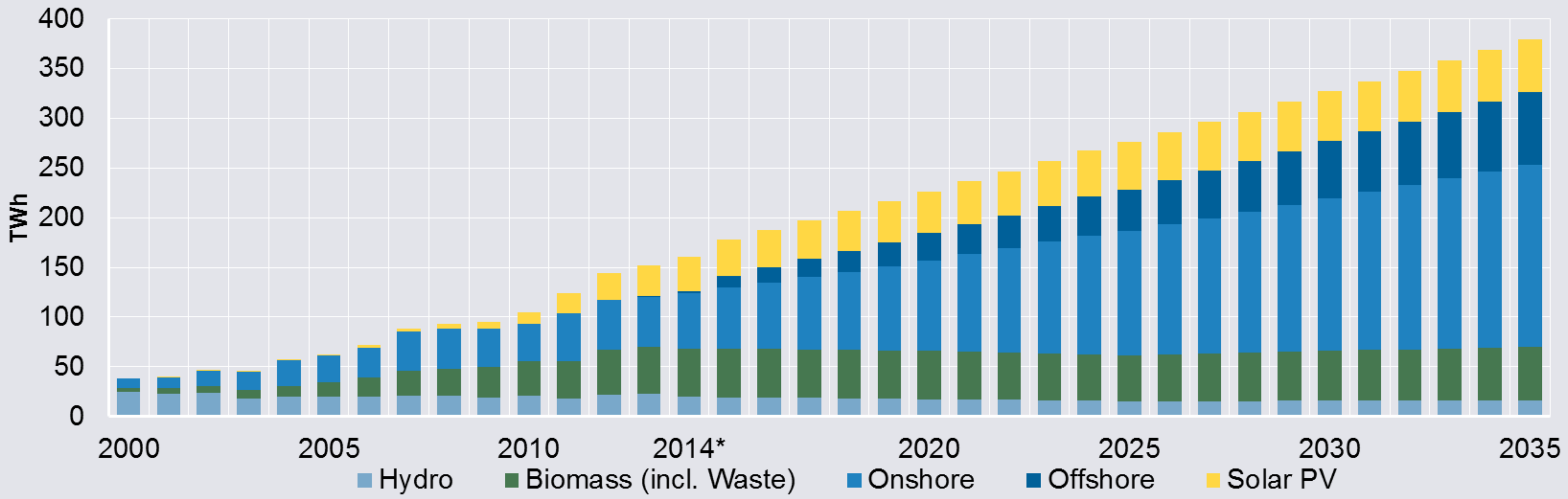


Agora Energiewende (2015a)

* part of utilization effect

The key insight for the Energiewende:
It’s all about wind and solar!

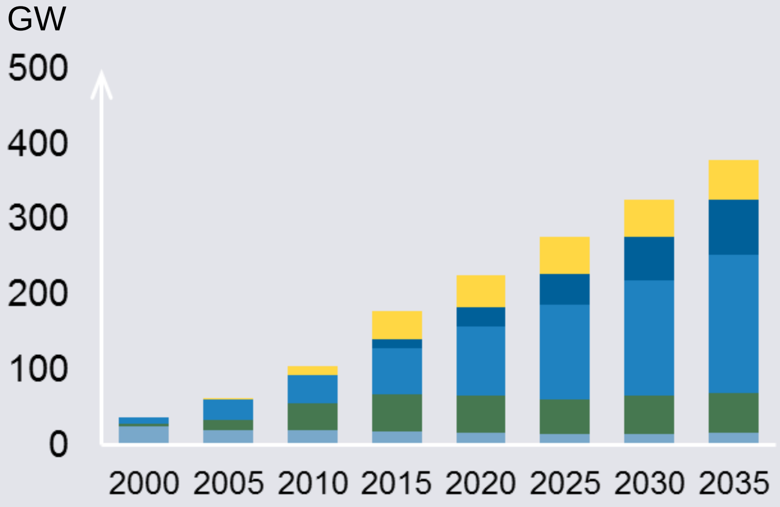
Gross electricity generation of renewable energies 2000 - 2035



2000 - 2014: AGEB (2015a); 2015 - 2035: own calculation on basis of BNetzA (2014)/BNetzA (2015b) * preliminary

With wind and solar, the new power system will be based on two technologies that completely change the picture

Gross electricity generation of renewable energies 2000 - 2035

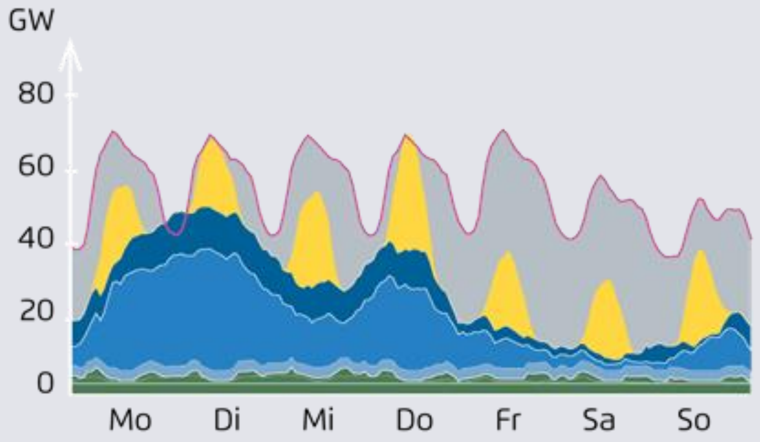


AGEB (2015a), BNetzA (2014), BNetzA (2015b), own calculations

Specific characteristics of Wind and Solar PV

1. Intermittent
2. High capital costs
3. Very low variable cost

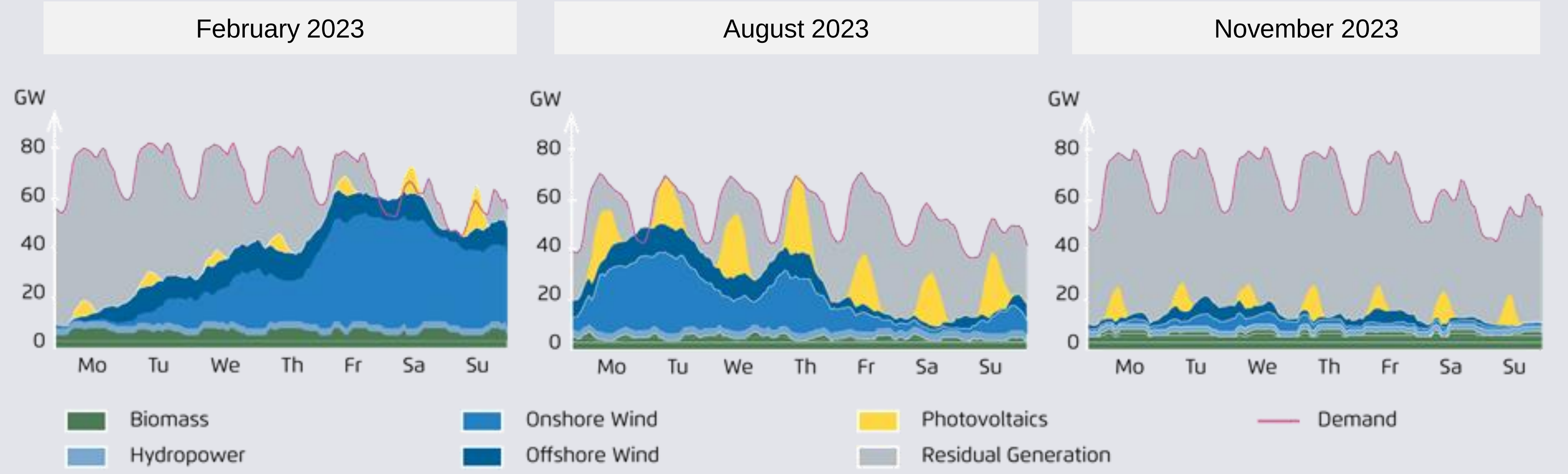
Electricity generation and consumption in a sample week 2023



Fraunhofer IWES (2013)

The power system and power markets will need to cope with a highly fluctuating power production from wind and solar

Electricity generation* and consumption* in three sample weeks, 2023

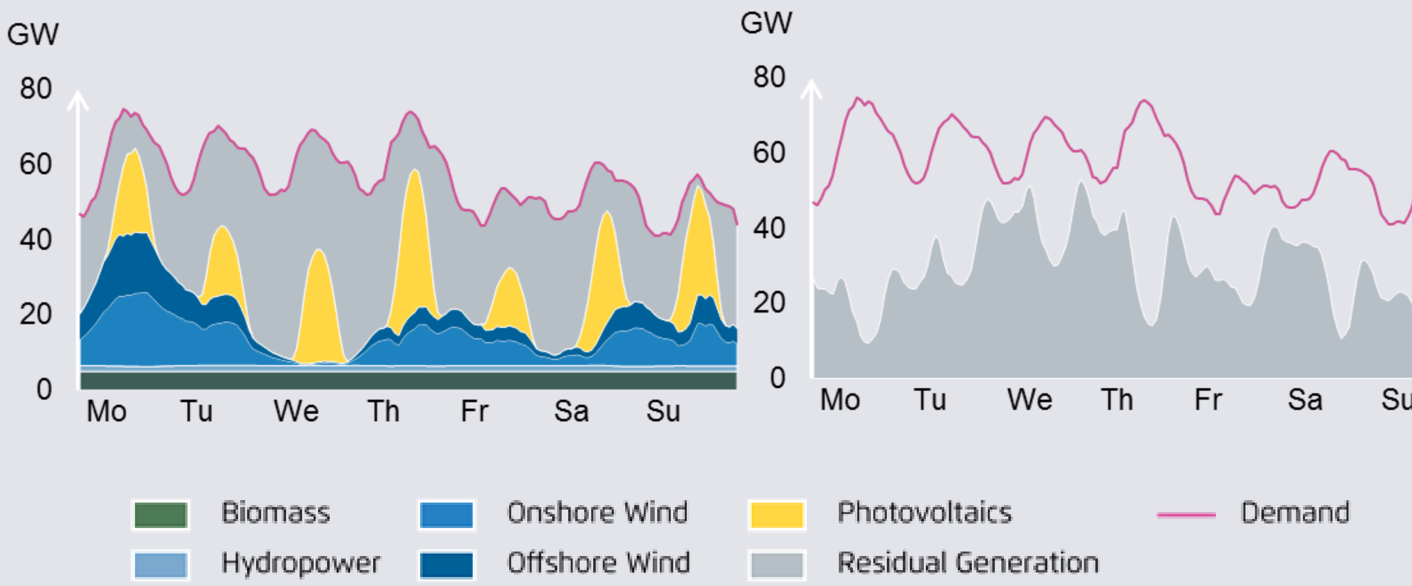


Fraunhofer IWES (2013)

* Modelling based on 2011 weather and load data

Flexibility is the paradigm of the new power system – baseload capacities are not needed any more

Electricity generation and consumption in a sample week with 50% RES share



Key flexibility options

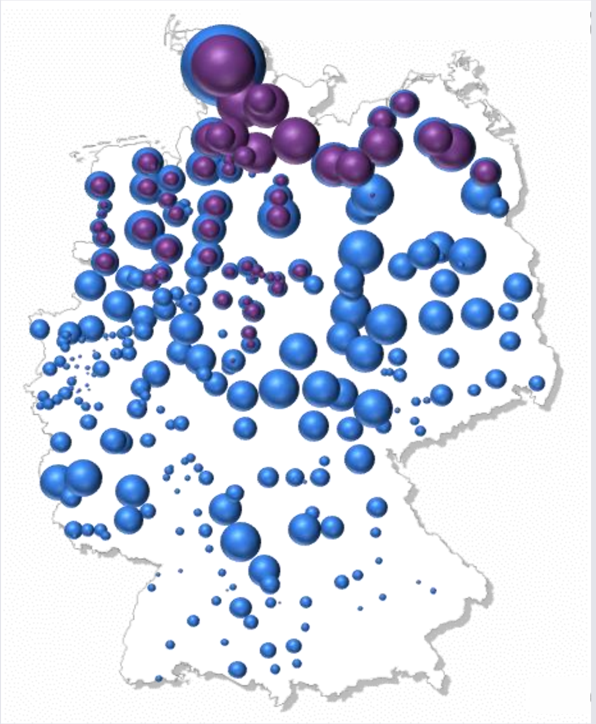
- Flexible fossil and bioenergy power plants (incl. CHP)
- Grids and transmission capacities for exports/imports
- Demand Side Management
- Storage technologies (Batteries, Power-to-Gas)
- Integration of the power, heat and transport sectors (power-to-heat, electric cars)

Own calculations on basis of Agora Energiewende (2015b)

Key challenges ahead towards a world with 50% renewable energies

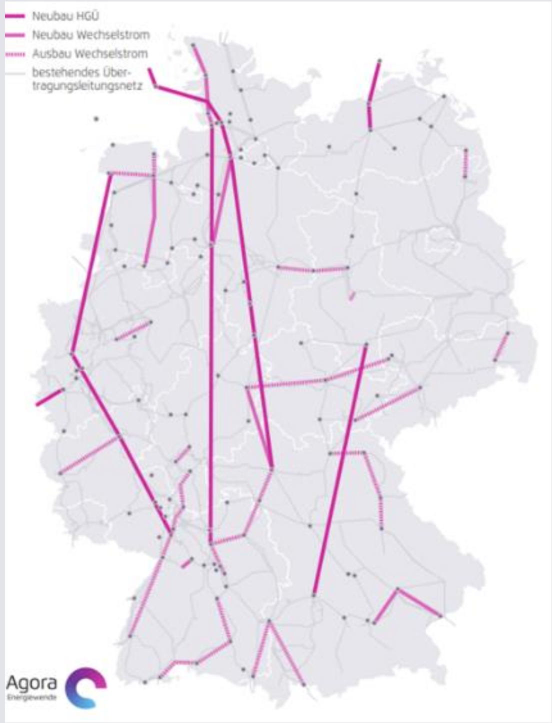
Challenge 1: Grids
Build more grids to transport wind energy to the south of Germany – in 2016 a new grid power plan is expected

Installed wind capacity (103 GW, Scenario „Best Sites“) 2033



Fraunhofer IWES (2013)

Planned transmission grid extensions until 2022



Bundesbedarfsplangesetz (2013)

Wind power will be installed mainly near the coast in the north of Germany, but key consumptions centres are located in the south

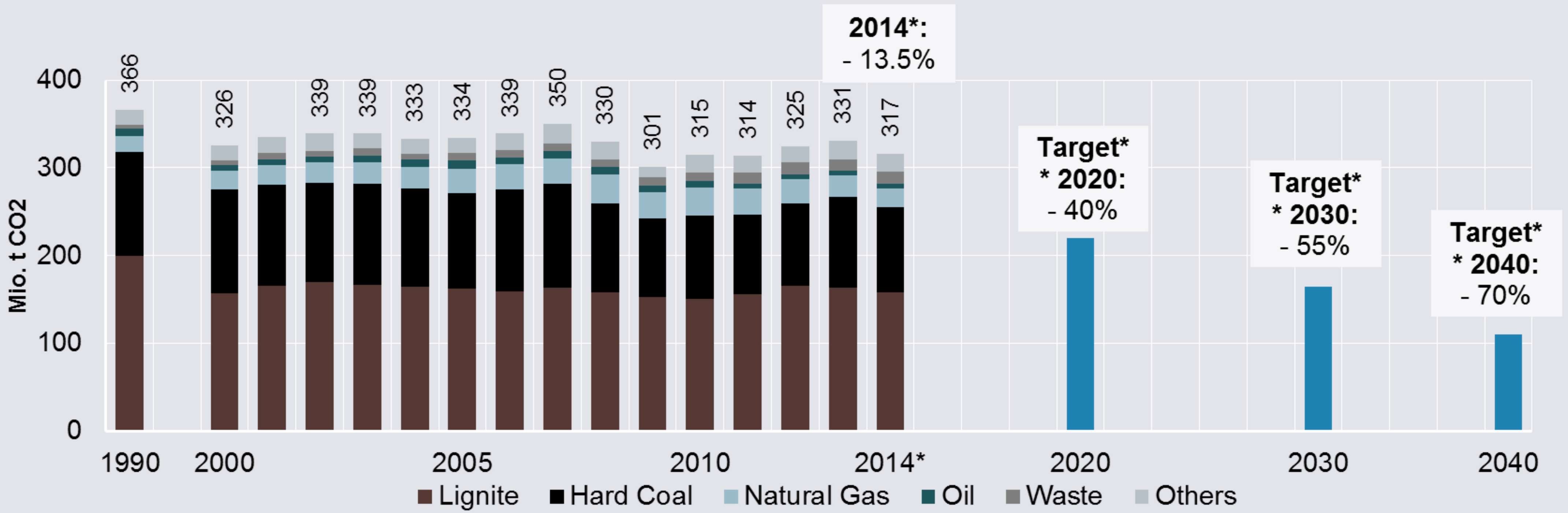
Additional power lines are necessary to transport wind electricity from north to south

In 2016, the government will propose a new transmission power plan which will enable to use underground cable whenever necessary

Measures to reduce consternation and compensation for concerned parties need to be considered from the very beginning

Challenge 2: Climate Targets
Gradual reduction of coal use is needed – in 2017, a “coal reserve” is planned, for 2030/2040 we need a “coal consensus”

CO_2 emissions from electricity generation 1990 - 2014 and climate targets** 2020 - 2040

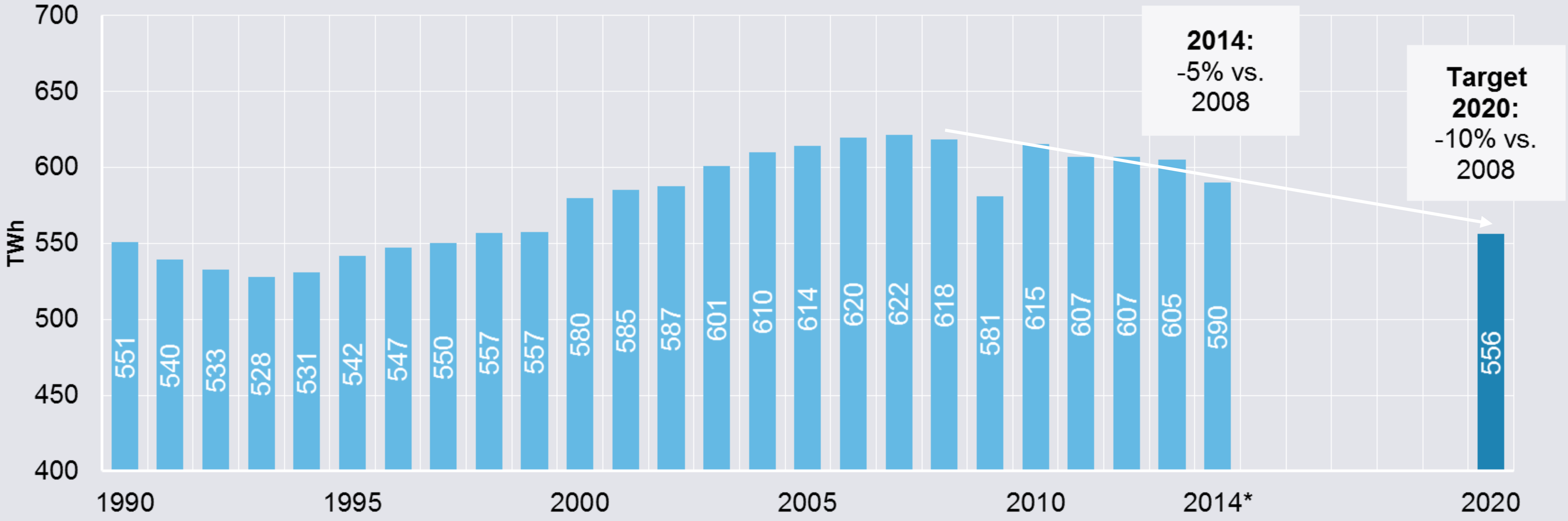


UBA (2015), own calculations

*preliminary, **application of a sectoral 40%-target

Challenge 3: Energy efficiency
Consequently implement the 2014 Energy Efficiency Action Plan in order to reach 2020 target

Gross electricity consumption 1990 - 2014

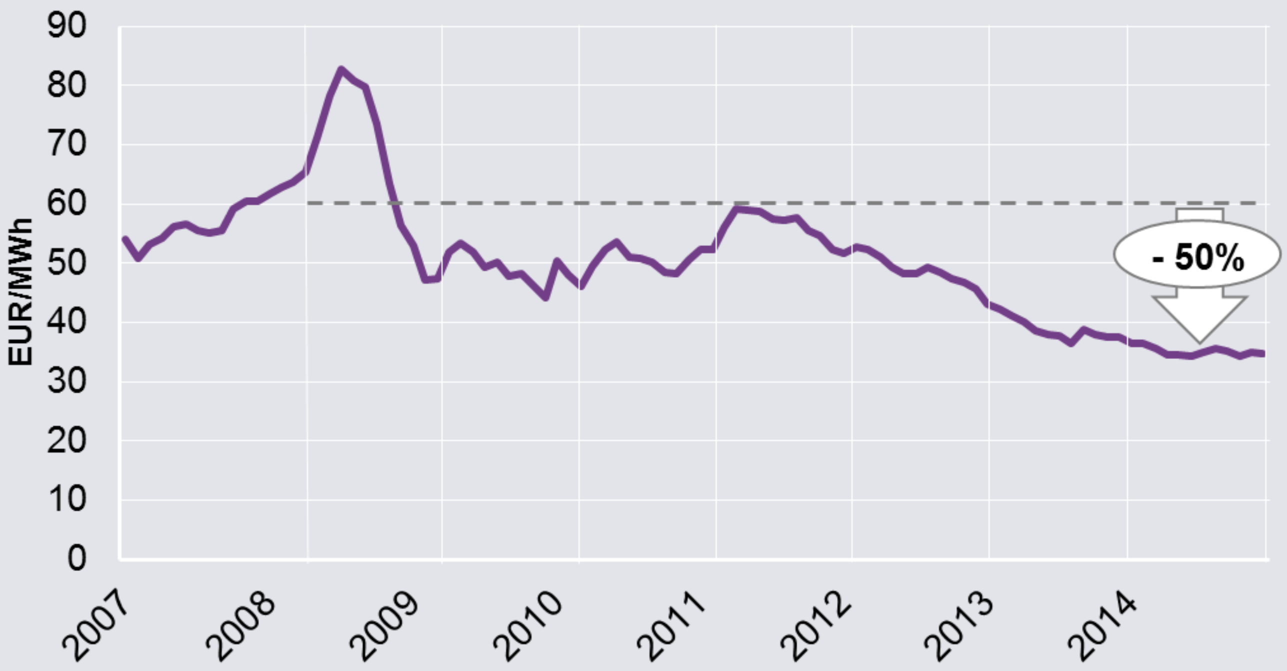


AGEB (2015a)

* preliminary

Challenge 4: Power Market Design
At the current wholesale power prices, no new power plant can be financed – be it fossil or renewable

Wholesale electricity prices* 2007 - 2014



EEX (2015) * rolling annual futures

Reasons for the decline in power prices

- **CO_2 price dropped:** CO_2 prices in the EU Emissions Trading system dropped since 2008 by around 70% due to high amount of excess certificates
- **Falling resource prices:** Coal prices decreased by a third since 2008
- **Merit-Order-effect:** Increasing power production of renewables is pushing expensive power plants out of the market
- **Decreasing demand:** Power demand is continuously falling since 2007 (-5% by 2014)
- **Excess capacities:** Large quantities of lignite and coal power plants are pushing gas power plants out of the market

Challenge 4: Power Market Design
The government is planning to propose in 2016 both a new power market law and a new renewable energy law

Schematic diagram of the governments‘ envisaged power market design

Coordinate supply and demand	**Power Market 2.0** (complemented by flexible markets for balancing energy)	
Guarantee security of supply and build up of renewables	**Resource Adequacy** Capacity reserve (partly consisting of old lignite power plants)	**Renewables** Auctions for large wind- and solar power plants, feed-in tariffs for small scale RES
Reaching climate targets	**EU Emissions Trading**	

Own illustration

Power Market 2.0
Power market is to become highly flexible, so as to continuously let fossil power plants, renewables, demand and storage interact with each other

Resource Adequacy
Peak prices in times of scarcity are to refinance fossil backup power plants; for emergency situations, a capacity reserve is installed

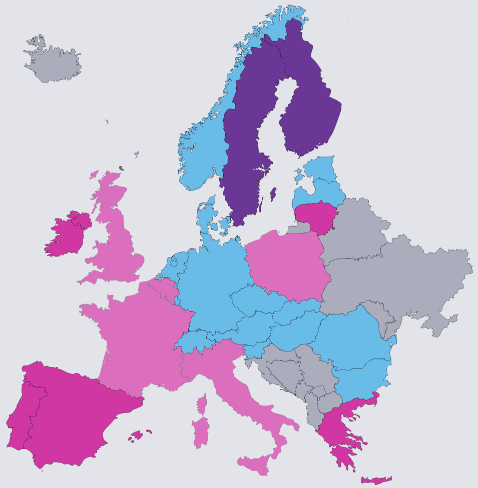
Renewables
Renewables receive 20year-market premium, support level for large wind and solar power farms is to be determined by auctions as of 2017

EU Emissions Trading
CO_2 price is to be restored through ambitious EU ETS reform including enhanced market stability reserve and higher emission reduction factor

Challenge 5: European Cooperation
Further enhance the cooperation between neighbouring countries and deepen European power market integration

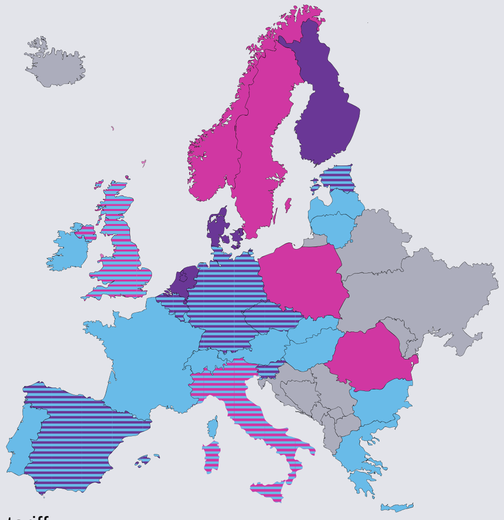
Capacity mechanisms and RES support schemes 2013

Capacity mechanisms



- No capacity mechanism or discussion on an early stage
- Planned capacity mechanism
- Implemented capacity mechanism
- Implemented capacity reserve

RES support schemes



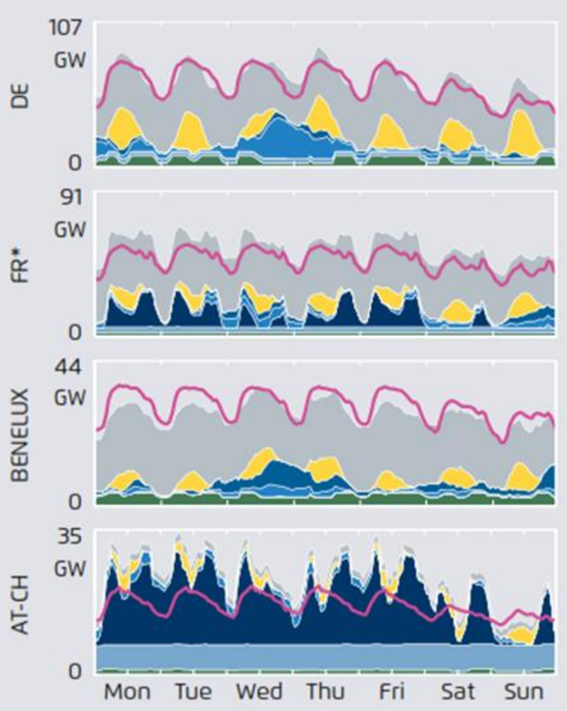
- Feed-in tariff
- Quota
- Feed-in premium
- Combination of quota and feed-in tariff
- Combination of feed-in premium and feed-in tariff

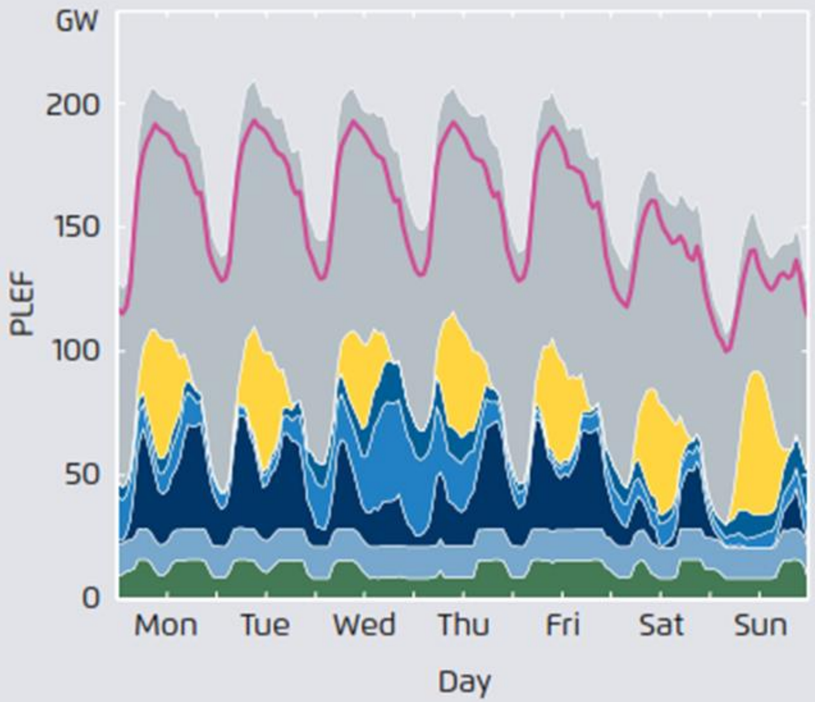
Own illustration

Is Germany a special case?

Europe: The EU 2030 targets imply a 50% renewables share in the European power sector – with high shares of wind and solar in many EU member states

Electricity generation and consumption in Central-Western Europe* in a sample week in 2030



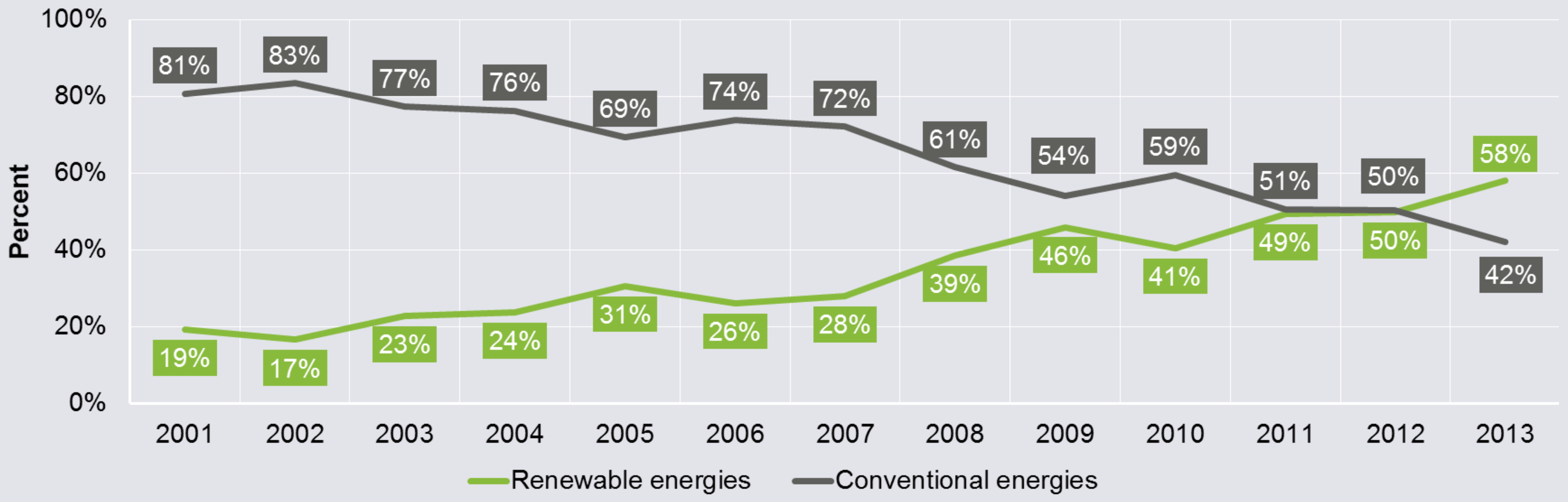


Fraunhofer IWES (2015)

* Germany, France, Benelux, Austria, Switzerland

World: Global capacity additions in renewables have overtaken those of conventional sources (coal, gas, nuclear)

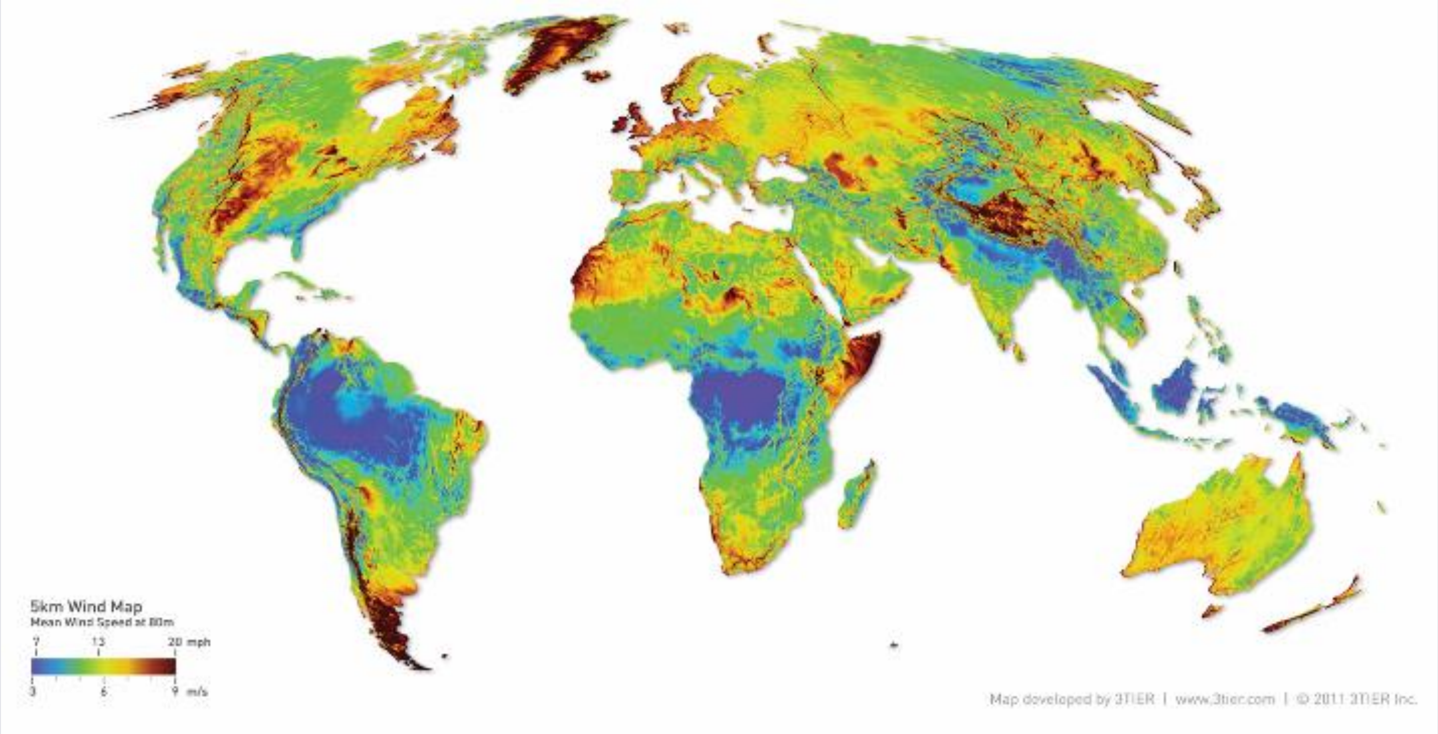
Share in global capacity additions 2001- 2013



IRENA (2014)

There is wind available all over the world…

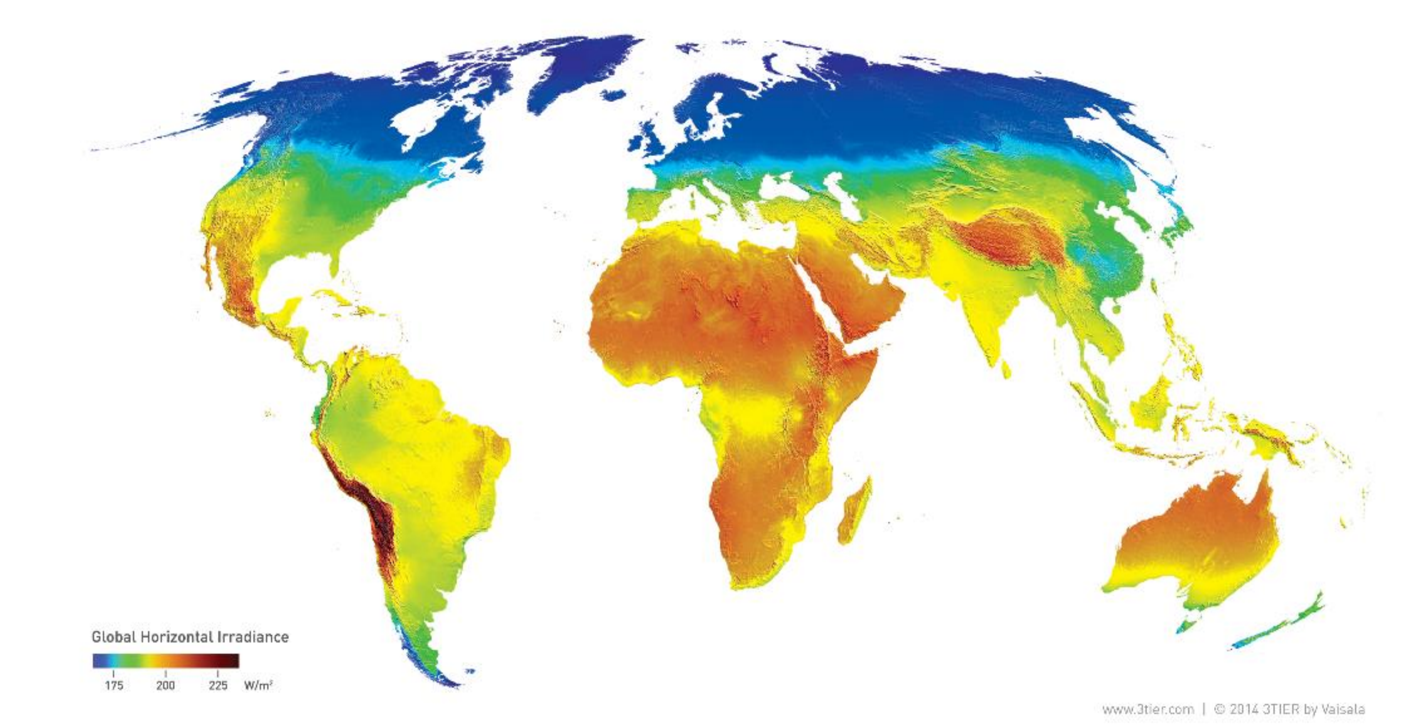
Average wind speed at 80m



3TIER (2011)

…and almost everywhere there is more sun than in Germany!

Global horizontal irradiance



3TIER (2011)

More information and studies available at our website
www.agora-energiewende.org

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

Bibliography „Insights from Germany´s Energiewende“ (1)

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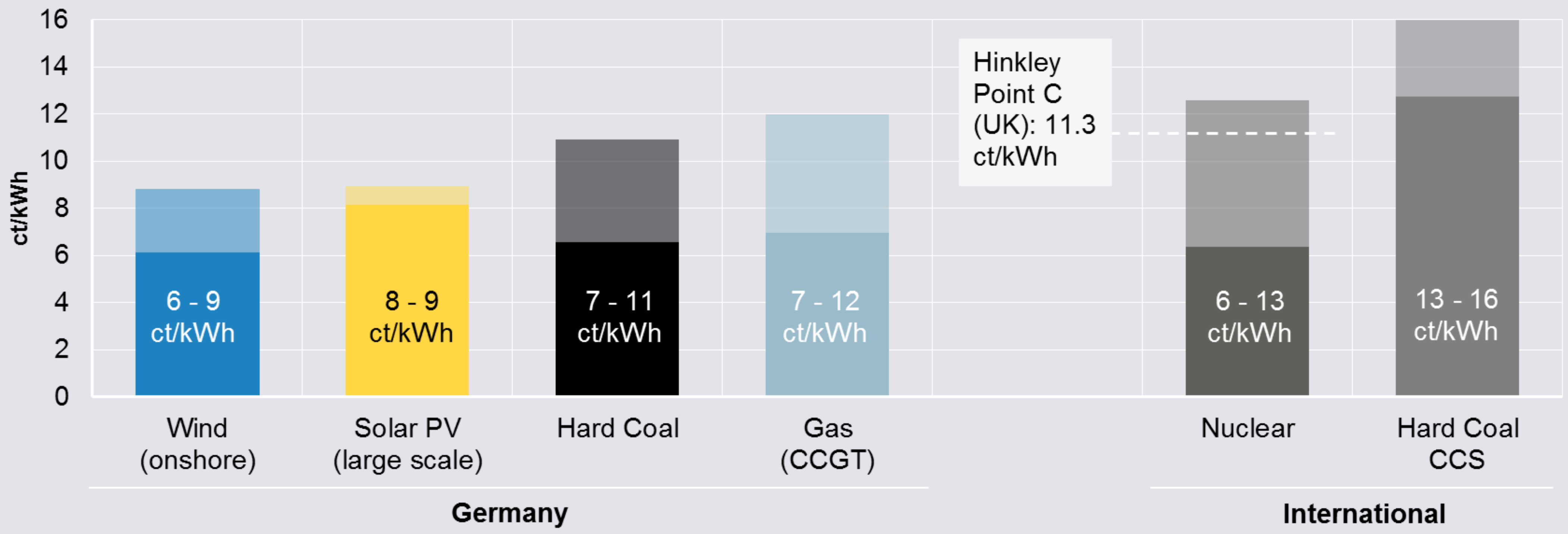
Calculation of LCOE

Today, wind and solar are already cost competitive to all other newly built power plants

Range* of levelized cost of electricity (LCOE) 2015

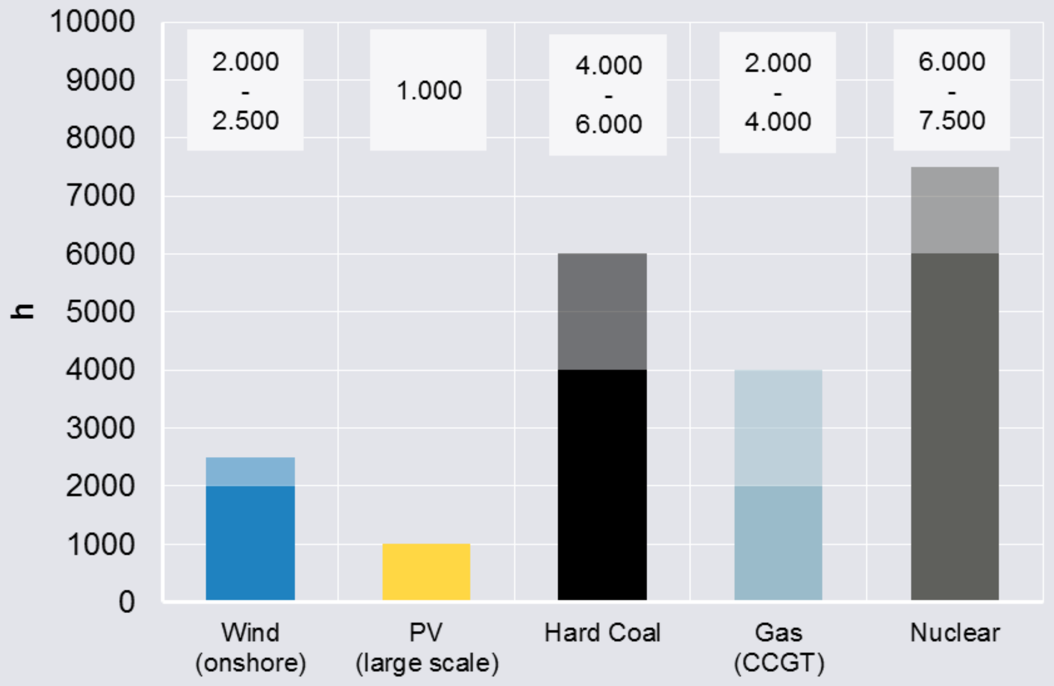


Agora Energiewende (2015e)

* based on varying utilization, CO_2-price and investment cost

Assumptions (1)

Range of full load hours



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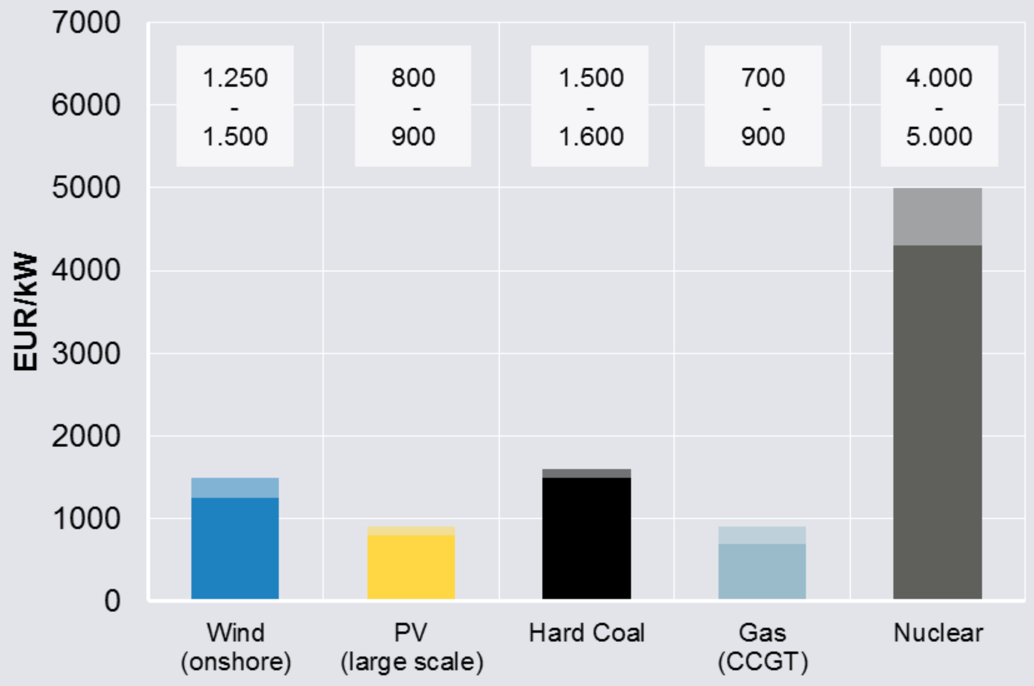
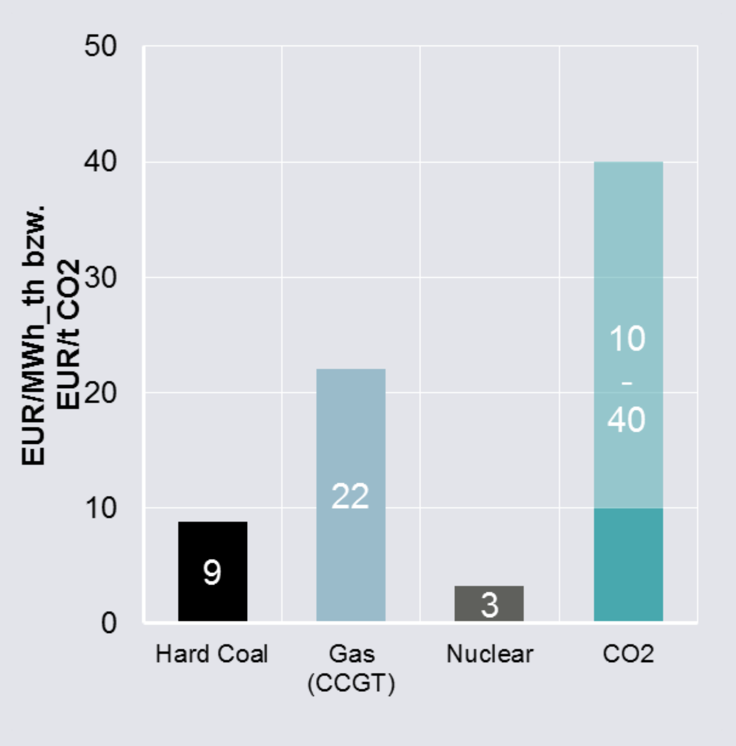
Range of investment cost



Agora Energiewende (2015e)

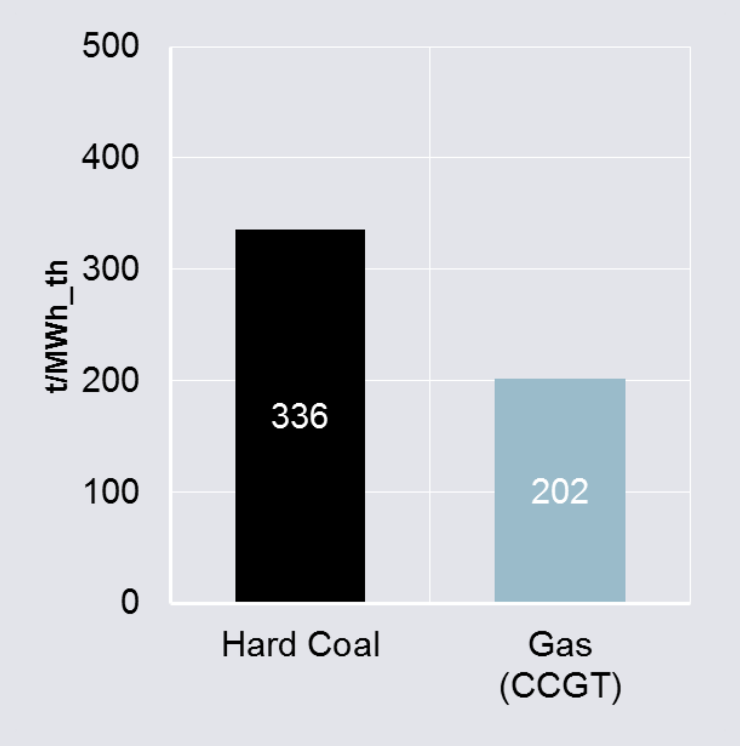
Assumptions (2)

Range of fuel- and CO_2-cost



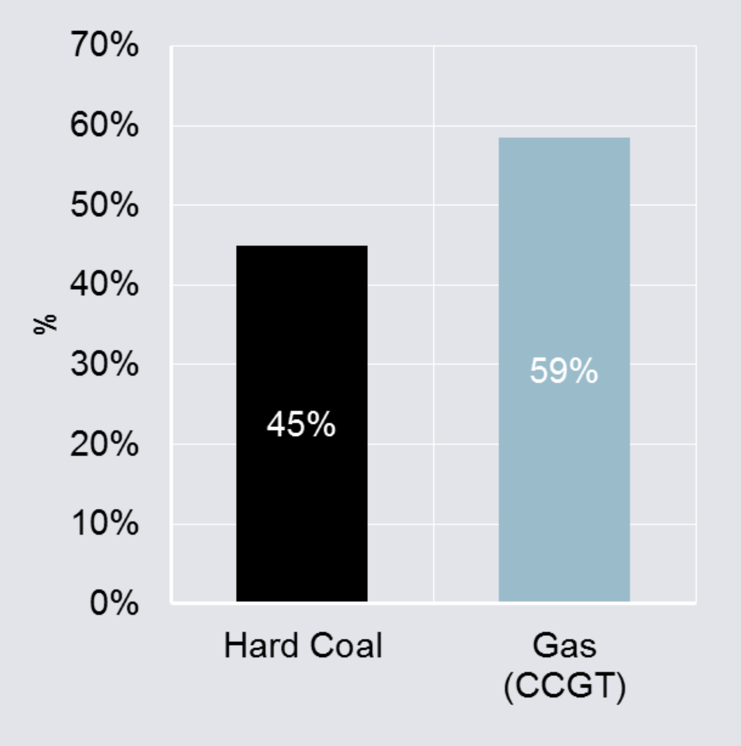
Agora Energiewende (2015e)

Emission factors



Agora Energiewende (2015e)

Efficiency of fossil power plants



Agora Energiewende (2015e)

Assumptions (3)

- **WACC:** Wind and PV 7%, Hard Coal und Gas 12%, Nuclear 7% – 12%
- **Technical lifetime:** Wind 20 years, PV 30 years, Hard Coal 40 years, Gas 25 years, Nuclear 40 years
- **Fixed operation cost:** Wind 35 EUR/kW/a, PV 17 EUR/kW/a, Hard Coal 34 EUR/kW/a, Gas 19 EUR/kW/a, Nuclear 90 EUR/kW/a
- **Variable operation cost:** Wind 0 EUR/kW/a, PV 0 EUR/kW/a, Hard Coal 3 EUR/kW/a, Gas 2 EUR/kW/a, Nuclear 1 EUR/kW/a

Source: Agora Energiewende (2015e)

Levelized cost of electricity (LCOE) are calculated on the basis of total generation cost and total electricity generation over the technical lifetime of a plant

Applied formulas for calculating LCOE

Berechnung der Stromgestehungskosten je Technologie

$$p_{Tech} = \sum \frac{Gesamte\ Kosten}{Gesamte\ \ Stromerzeugung}$$

$$p_{Tech} = \left(\frac{\sum_{BZ}(I_t + BB_t + Z_t)}{\sum_{BZ} E_t} \right)_{Tech}$$

$p_{Tech} =$ Stromerzeugungskosten je Technologie

$\sum_{BZ}() =$ Summe aller Werte über den Benutzungszeitraum

$I_t =$ Kapitalausgaben im Jahr t

$BB_t =$ Betriebs – und Brennstoffkosten im Jahr t

$Z_t =$ CO2 – Zertifikatekosten im Jahr t

$E_t =$ Stromerzeugung im Jahr t

Kapitalkosten im Jahr t

$$I_t = I_{gesamt} \times \frac{i \times (1+i)^{BZ}}{(1+i)^{BZ} - 1}$$

$I_{gesamt} =$ Gesamte Investitionskosten für das Kraftwerk für die gesamte Benutzungsdauer, diskontiert auf $t = 0$, [in $\frac{EUR}{kW}$]

$i =$ Kalkulatorischer Zinsatz für die gesamte Investition (Summe aus Eigenkapital und Fremdkapital) [in %]

$BZ =$ Benutzungszeitraum [in Jahren]

IER Stuttgart (2008)

Levelized cost of electricity (LCOE) are calculated on the basis of total generation cost and total electricity generation over the technical lifetime of a plant

Applied formulas for calculating operation-, fuel- and CO_2-cost

Betriebs – und Brennstoffkosten im Jahr t

$$BB_t = M_{fix,t} + M_{var,t} + B_t$$

$M_{fix,t}$ = Fixe Betriebskosten im Jahr t (z.B. Personal, zeitabhängige Wartung), [in EUR/kW/Jahr]

$M_{var,t}$ = Variable Betriebskosten im Jahr t (z.B. nutzungsabhängige Wartung)

$$M_{var,t} = E_t \times m_{var}$$

m_{var} = Variable Betriebskosten pro erzeugter Stommenge [in EUR/MWh_{elekt}]

B_t = Brennstoffkosten im Jahr t

$$B_t = \frac{E_t}{W} \times b$$

W = Wirkungsgrad der Umwandlung der Energie vom Brennstoff in Strom [in %]

b = Kosten je Einheit des eingesetzten Brennstoffs [in EUR/MWh_{therm}]

CO2 – Zertifikatekosten im Jahr t

$$Z_t = \frac{E_t}{W} \times EF_{Brennstoff} \times z$$

$EF_{Brennstoff}$ = Emissionsfaktor des eingesetzten Brennstoffs [in tCO_2/MWh_{therm}]

z = Kosten für CO_2 – Emmissionszertifikate [in EUR/tCO_2]

Stromerzeugung im Jahr t

$$E_t = P \times FLH$$

P = Maximale Kraftwerksleistung [in MW]

FLH = Vollaststunden pro Jahr [in h]

IER Stuttgart (2008)

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