



***A critical view on the European plans for a future
electricity supply***

***Illustrated by recent results of the German
Energiewende***

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***Belgian Nuclear Society
Brussels, 25 January 2018***

INTRODUCTION

Unit for energy used in this presentation

Some examples of our daily energy consumption

We consume a lot of energy without realizing

- Unit of energy consumption in this talk: **kWh**

Some examples

- 20 minutes of a water cooker – **1kWh**
- food (to keep our bodies going) – **3kWh/day**
- hot bath – **5kWh**
- 1 liter of gasoline – **10kWh**
- energy to fabricate 1 aluminum can of soft drink (15g) – **0.6kWh**

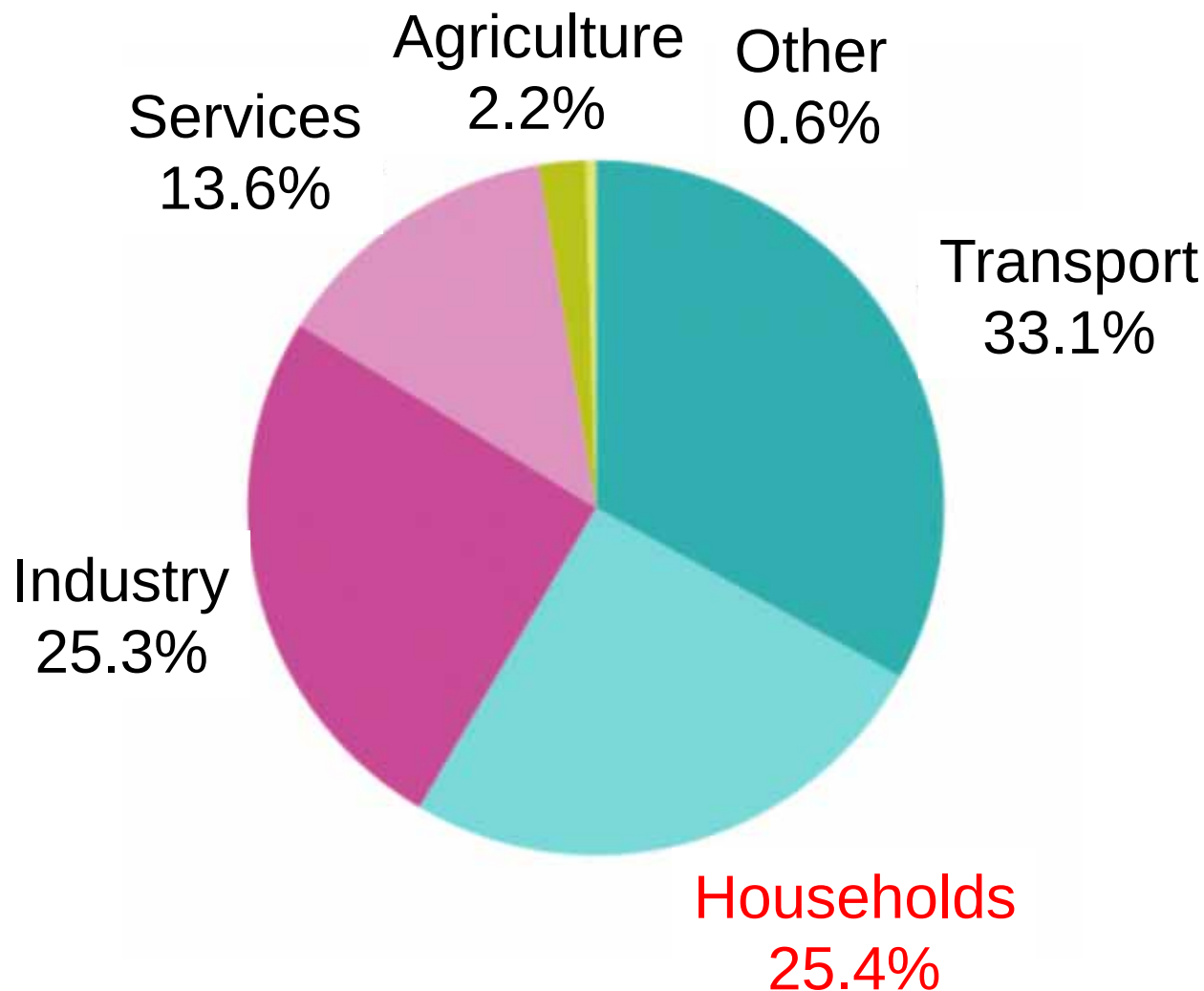
Average EU citizen: 100kWh/day

Every EU citizen has 33 slaves at work ($100/3 = 33$)...

Source: “Key World Energy Statistics”, IEA, Paris

Household energy use is only a fraction of EU total primary energy consumption

Data averaged over all EU countries



...and thus individual actions can only have a limited impact

Source: "Eurostat" (2016) "nrg_100a"

Electricity: Only one third of the CO₂ problem

Three main sectors*



~ 1/3 of primary energy for
transport



~ 1/3 of primary energy for
Heating and air-conditioning

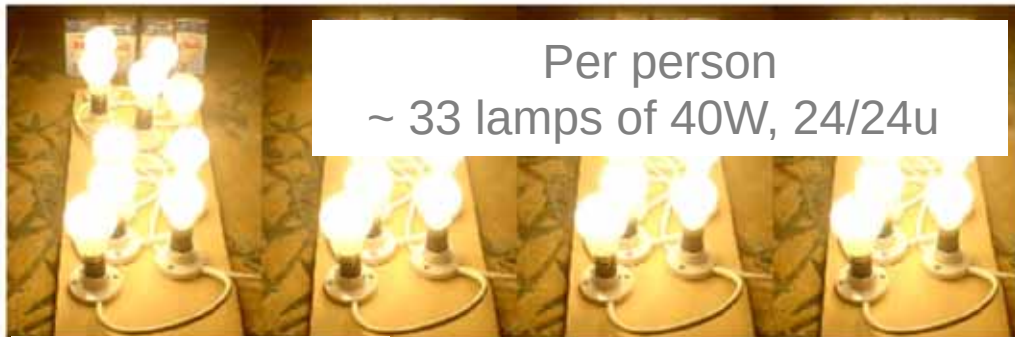


~ 1/3 of primary energy for
Electricity

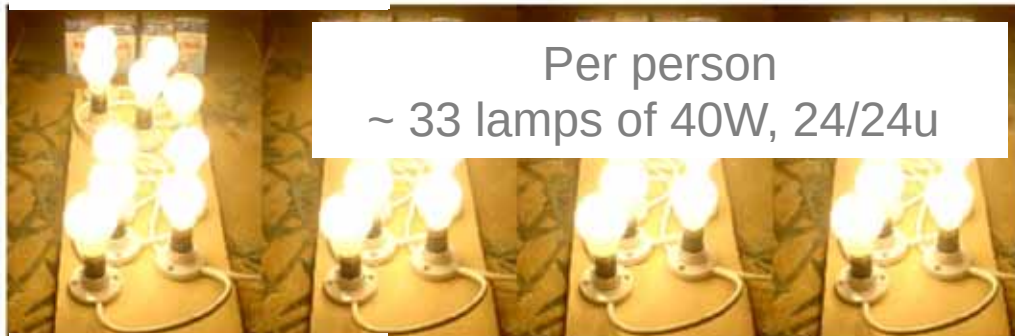
*numbers are approximate, and somewhat
different for each EU country

We consume a lot of energy without realizing

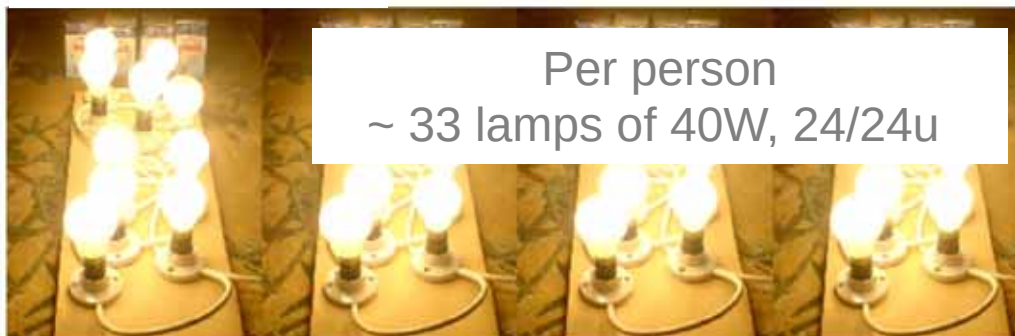
Europe



Average primary energy
consumption



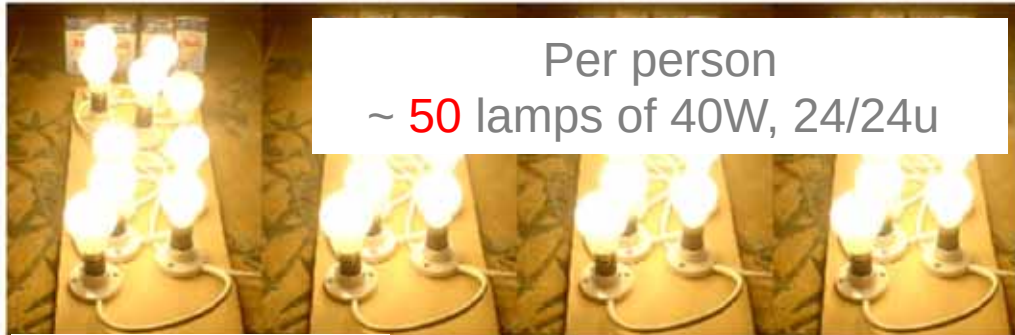
Europe: 100kWh
per person
per day



Or ~100 lamps
of 40W, 24/24h

We consume a lot of energy without realizing

Belgium



Per person
~ 50 lamps of 40W, 24/24u



Per person
~ 50 lamps of 40W, 24/24u



Per person
~ 50 lamps of 40W, 24/24u

Average primary energy
consumption

Belgium: 150kWh
per person
per day

Or ~150 lamps
of 40W, 24/24h

Primary Energy Use in Belgium and EU

EU-27:
100kWh
Per capita per day

x 1.5 (!) =

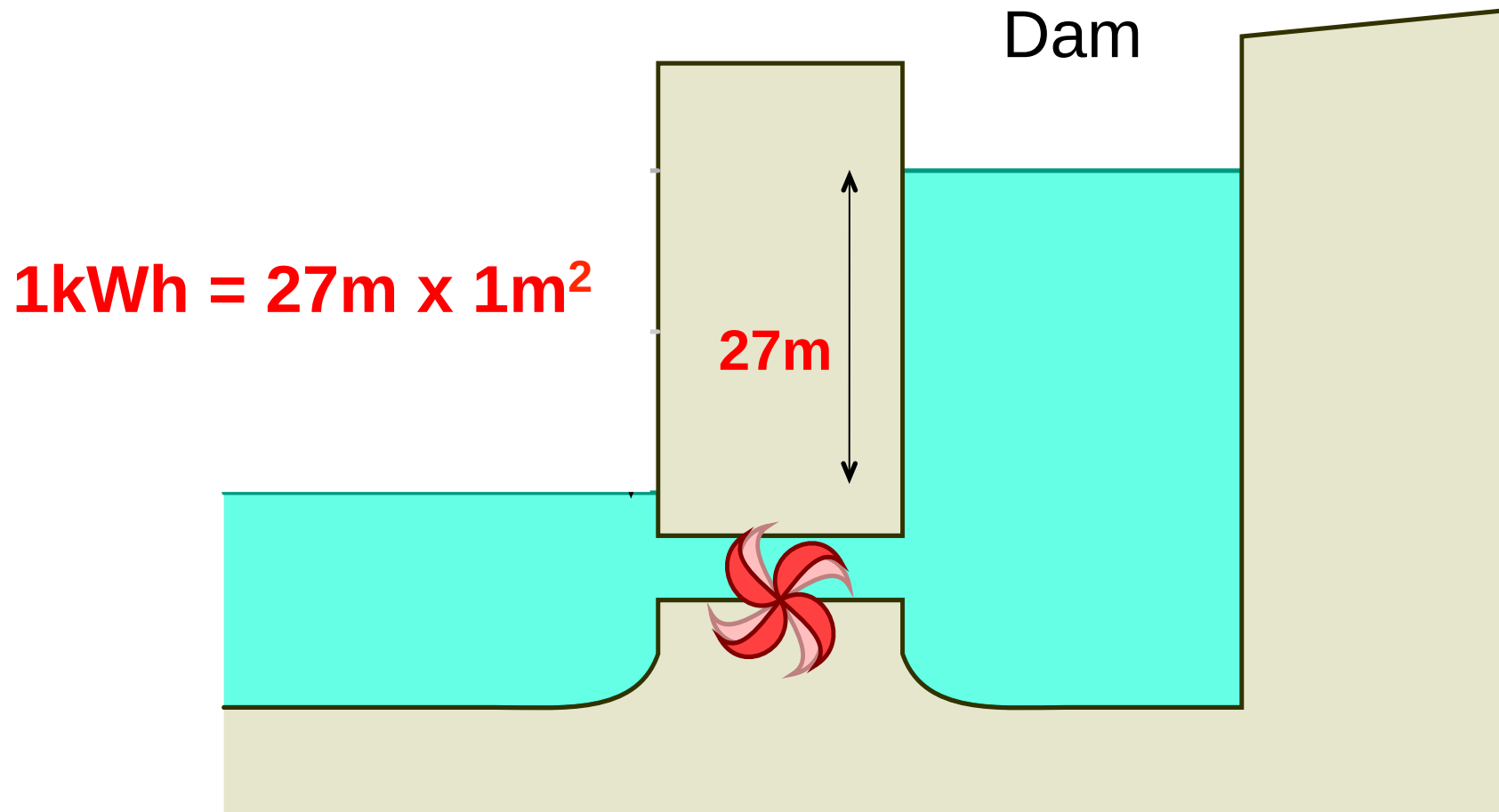
Belgium:
150kWh
Per capita per day

Europe		
Industry	25.9%	26.1kWh
Transport	33.2%	33.5kWh
Households	24.8%	25.0kWh
Services	13.3%	13.4kWh
Agriculture/ Fishing	2.3%	2.3kWh
Other	0.4%	0.5kWh

Belgium		
Industry	34.4%	52.2kWh
Transport	29.5%	44.7kWh
Households	21.7%	33.0kWh
Services	12.5%	19.0kWh
Agriculture/ Fishing	1.9%	2.9kWh
Other	1.1%	0.2kWh

Energy is extremely important for the Belgian economy

1 kWh in water...



Average B consumption 150kWh/person/day = 150m³ x 27m
150kWh/person/day = 150m³ x 27m ~ 2700m³
~1/2 sports hall in water.... (40 x 25 x 8m)

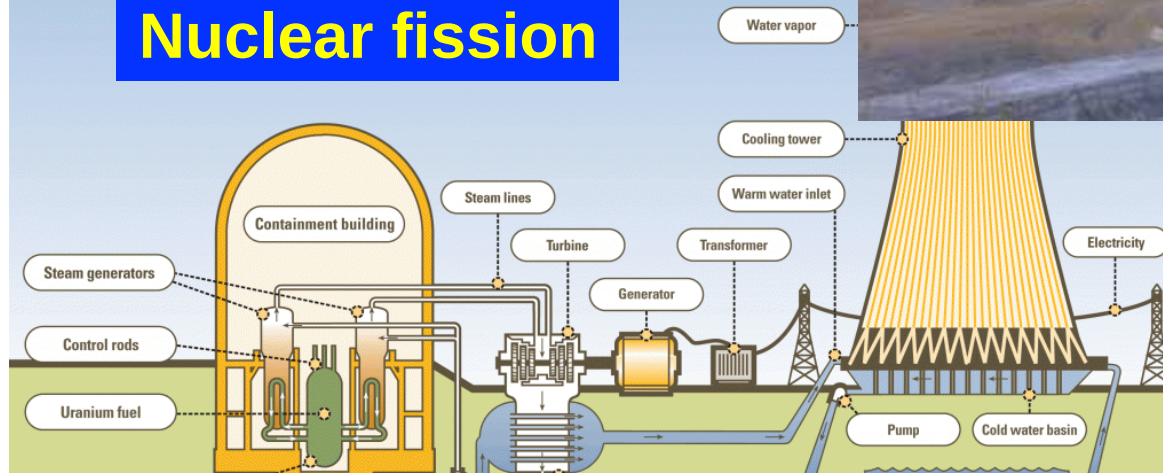
The energy problem

Only three options to produce electricity

**Renewable energy:
Photovoltaic,
windturbines, biofuels...**

Fossil fuels

Nuclear fission



Only 3 different methods for producing energy

1. **Renewables: sun, wind, hydro, biomass, ...**
 - Very large installations (very low intensity energy source)
 - Very large diurnal and seasonal fluctuations
 - Less CO₂
2. **Burning Fossil Fuels : Coal, Oil, Gas**
 - Enormous emission of CO₂
 - Major Climate change
 - Heavy dependence on suppliers (e.g. Middle East)
 - Easy
3. **Nuclear fission:**
 - Public acceptance (West) and safety
 - Waste management
 - Very little CO₂

Only 3 different methods for producing energy

If we are against fossil fuels...

1. **Renewables: sun, wind, hydro, biomass, ...**
 - Very large installations (very low intensity energy source)
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 - Less CO₂
2. ~~**Burning Fossil Fuels : Coal, Oil, Gas**~~
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Only 3 different methods for producing energy

and also against nuclear energy...

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Only 3 different methods for producing energy

Then all electricity will have to be renewable...

1. Renewables: sun, wind, hydro, biomass, ...

- Very large installations (very low intensity energy source)
- Very large diurnal and seasonal fluctuations
- Less CO₂

2. ~~Burning Fossil Fuels : Coal, Oil, Gas~~

- Enormous emission of CO₂
- Major Climate change
- Heavy dependence on suppliers (e.g. Middle East)
- ~~Easy~~

3. ~~Nuclear fission:~~

- Public acceptance (West) and safety
- Waste management
- Very little CO₂



Only 3 different methods for producing energy

And then there is a dark and windstill period...

1. ~~Renewables: sun, wind, hydro, biomass, ...~~
 - Very large installations (very low intensity energy source)
 - Very large diurnal and seasonal fluctuations
 - Less CO₂
2. ~~Burning Fossil Fuels : Coal, Oil, Gas~~
 - Enormous emission of CO₂
 - Major Climate change
 - Heavy dependence on suppliers (e.g. Middle East)
 - Easy
3. ~~Nuclear fission:~~
 - Public acceptance (West) and safety
 - Waste management
 - Very little CO₂

?

What with the electricity supply in that case ?

We consume a lot of energy without realizing

Olympic cyclist versus toaster...

HOW MUCH ENERGY DOES IT TAKE
TO TOAST A SLICE OF BREAD?



The world energy problem

Primary energy consumption per capita per day (2014)

Country	Energy use kWh/person/day
USA	222
Europe	100
Japan	110
China	71
India	21
World average	60

World consumption of primary energy in 2014

$$\begin{aligned} &7.2 \text{ billion people} \times 60 \text{ kWh} \times 365 \text{ days} \\ &= \mathbf{18 \text{ TWyr}} \end{aligned}$$

Source: "Key World Energy Statistics", IEA, Paris

The world energy problem

Estimated Primary Energy Consumption in 50 years

Assumptions:

- 9 (low) or 12.5 (high) billion people in 2065
- Average world energy consumption : 60 – 75 kWh/p/day
(Only 1/4-1/3 of the current consumption in USA or ~ ½ average OECD consumption)

thus in 50 years, possibly:

$$(9 \text{ to } 12.5) \text{ billion people} \times (60 \text{ to } 75) \text{ kWh/person/day} \times 365 \text{ days} \\ = 22.5 - 40 \text{ TW/yr}$$

About 1.3 – 2.2 x current energy consumption!

The world energy problem

Huge increase to be expected

$4500\text{GWyr} / 50 \text{ year} = 90\text{GWyr} / \text{year}$

$22000\text{GWyr} / 50 \text{ year} = 440\text{GWyr} / \text{year}$

**Need on average in the world
for the next 50 years, every week
between 2 - 8 systems equivalent to
1 GW to satisfy this expected increase**

Hopefully, this is an overestimation...

1. It should be low CO₂ systems: nuclear and renewable ?
2. If not, then (partly?) fossil... But with carbon capture and storage?
3. Possible ? Yes with fossil alone: China > 160 GW/year...

None of the 3 energy options can be excluded !!!

Colossal task for the coming 50 years

- 1. Increase the existing capacity, as estimated
AND**
- 2. Replace the existing capacity (~85% fossil)
with low-carbon systems**

**Enormous world-wide programme
Need up to 40000GW in clean systems
for the next 50 years**

This underlines again:

It is unrealistic to exclude any of the 3 energy options!

THE PROBLEM

The European plans for the future of our electricity supply

Example : Germany's Energiewende

Note: these plans **only deal with** the decarbonisation of the
electricity supply.

Thus **NOT with transport and heating/air-conditioning** of buildings

Europe's Plans for future electricity production

EU Energy Roadmap 2050

- By 2030 : a reduction in power sector CO₂ emissions of 40-50%
- By 2050 : a reduction in power sector CO₂ emissions of 93-99% compared to CO₂ levels of 1990

Source : " A Roadmap for moving to a competitive low carbon economy in 2050",
COM(2014)015 final, EC Brussels

Europe's Plans for future electricity production

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This implies a vast transformation of the power sector, which in the EU currently uses 50% of fossil fuel

Is this possible with only renewable energy ?

Europe's Plans for future electricity production

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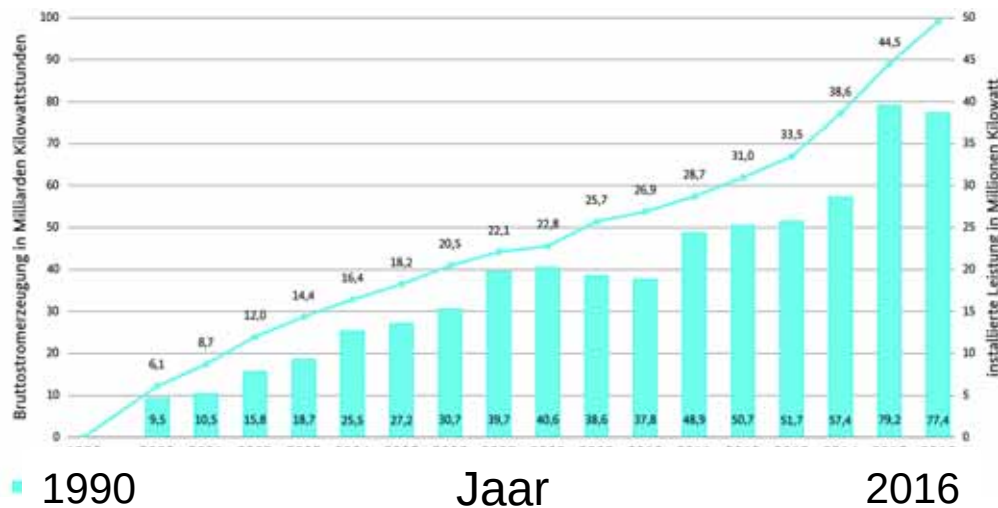
Is this possible with only renewable energy ?

Lack of realism from decision makers...

- Need to consider results obtained so far, e.g. in Germany, and accept the consequences
- Then, adapt plans with respect for science, economy and the well-being of all EU citizens.

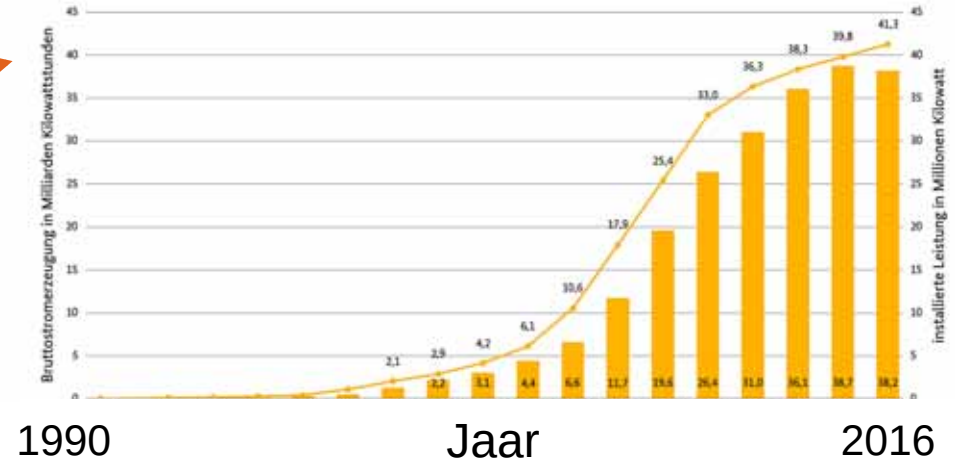
Recent results from the German Energiewende

The German Energiewende: success ...



50GW
Installed power
In windturbines (2016)

41.2GW
Installed power
In photovoltaic panels (2016)



The sum (91.2 GW) represents more than the maximum grid load (83 GW)

But... recent comments... ??

Frankfurter Allgemeine Zeitung – 8 May 2015

SEITE 18 · FREITAG, 8. MAI 2015 · NR. 106

Die Ordnung der Wirtschaft

FRANKFURTER ALLGEMEINE ZEITUNG

Björn Lomborg Deutschlands gescheiterte Klimapolitik

Die Energiewende hat sich als unglaublich kostspielig und unwirksam erwiesen. Dennoch werden in Paris viele auf eine ähnliche Politik wie die deutsche dringen. Dabei gibt es eine viel wirksamere Antwort auf den Klimawandel.

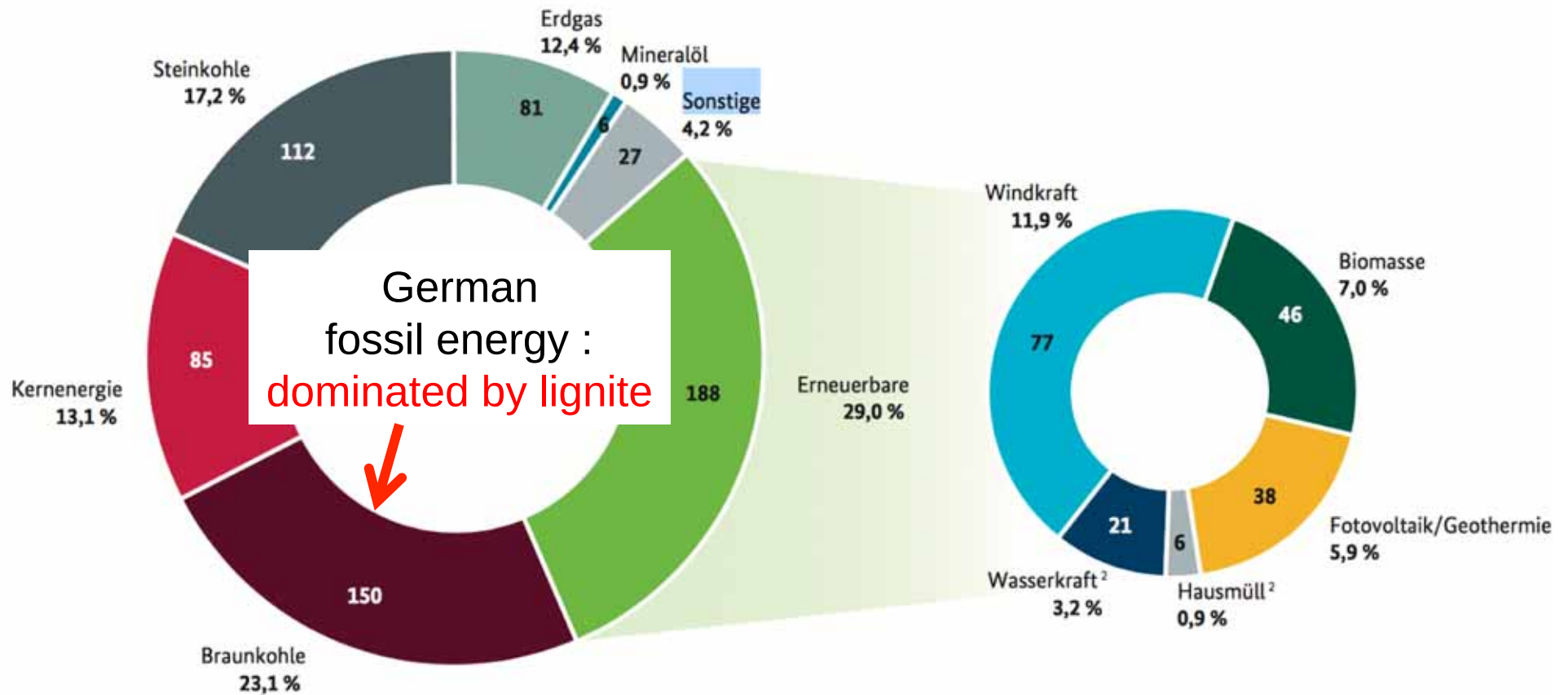
**“Germany’s failed
Climate Policy”**

- (i) extremely expensive**
- (ii) nearly no reduction in CO₂**
- (iii) small contribution to
the yearly electricity needs**

?????

Structure of the German gross electricity production

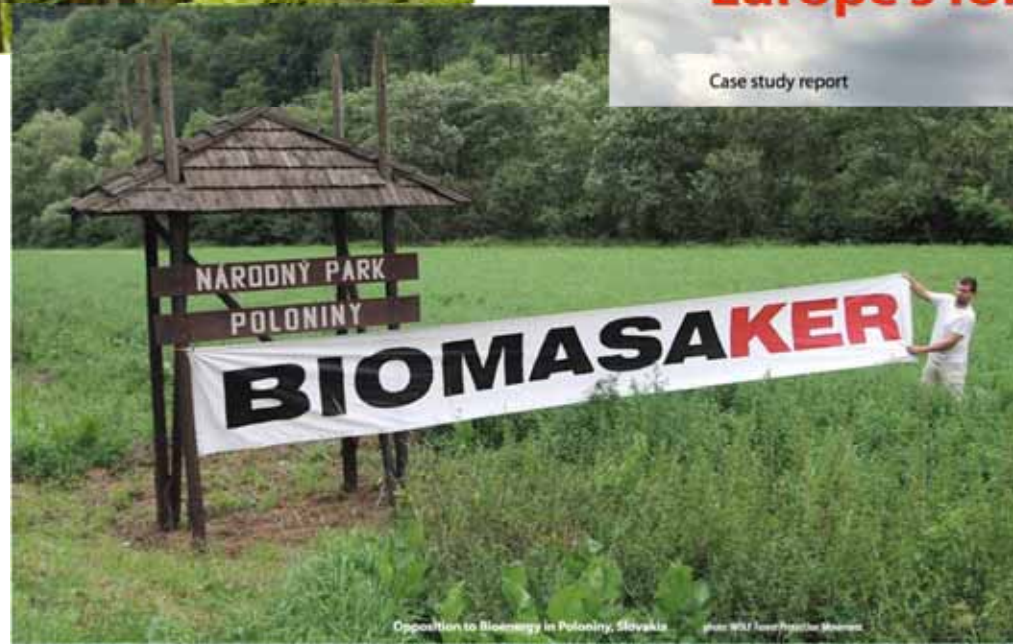
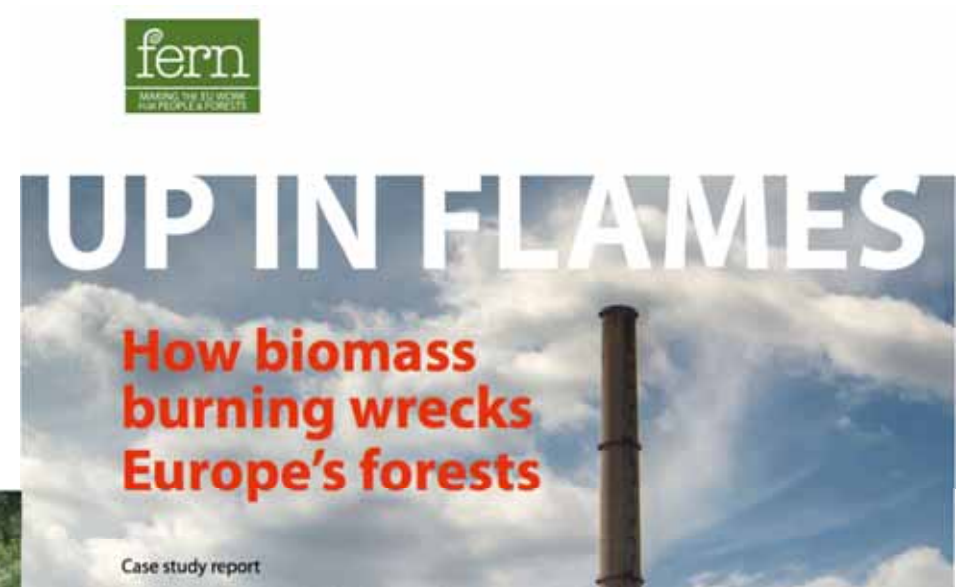
Total German gross electricity production (2016): 648.4 TWh



Solar PV + Wind: intermittent – 17.8%; potential for increase
Waste, Hydro, 'Biomass': dispatchable – 11.7%; ~saturated

Source : "BMWi Energiedaten-Gesamt (okt 2017)"

'Biomass' further expansion wished / possible ?



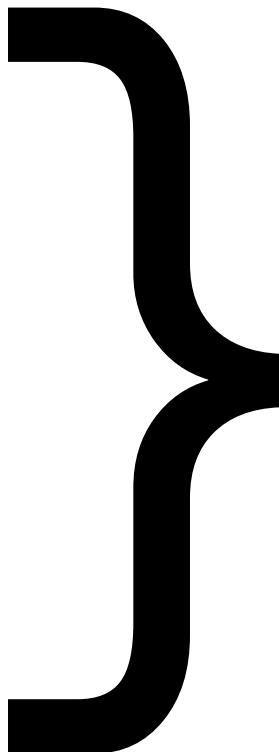
Source : "NRDC –USA and FERN – The Netherlands (2015)"

Solar PV + Wind: Small contribution to the German electricity production ... ?

Wind (2016)	
Installed power	50 GW
Energy produced	77.4 TWh
Contribution	11.9 %

Solar PV (2016)	
Installed power	41.2 GW
Energy produced	38.2 TWh
Contribution	5.9 %

17.8%



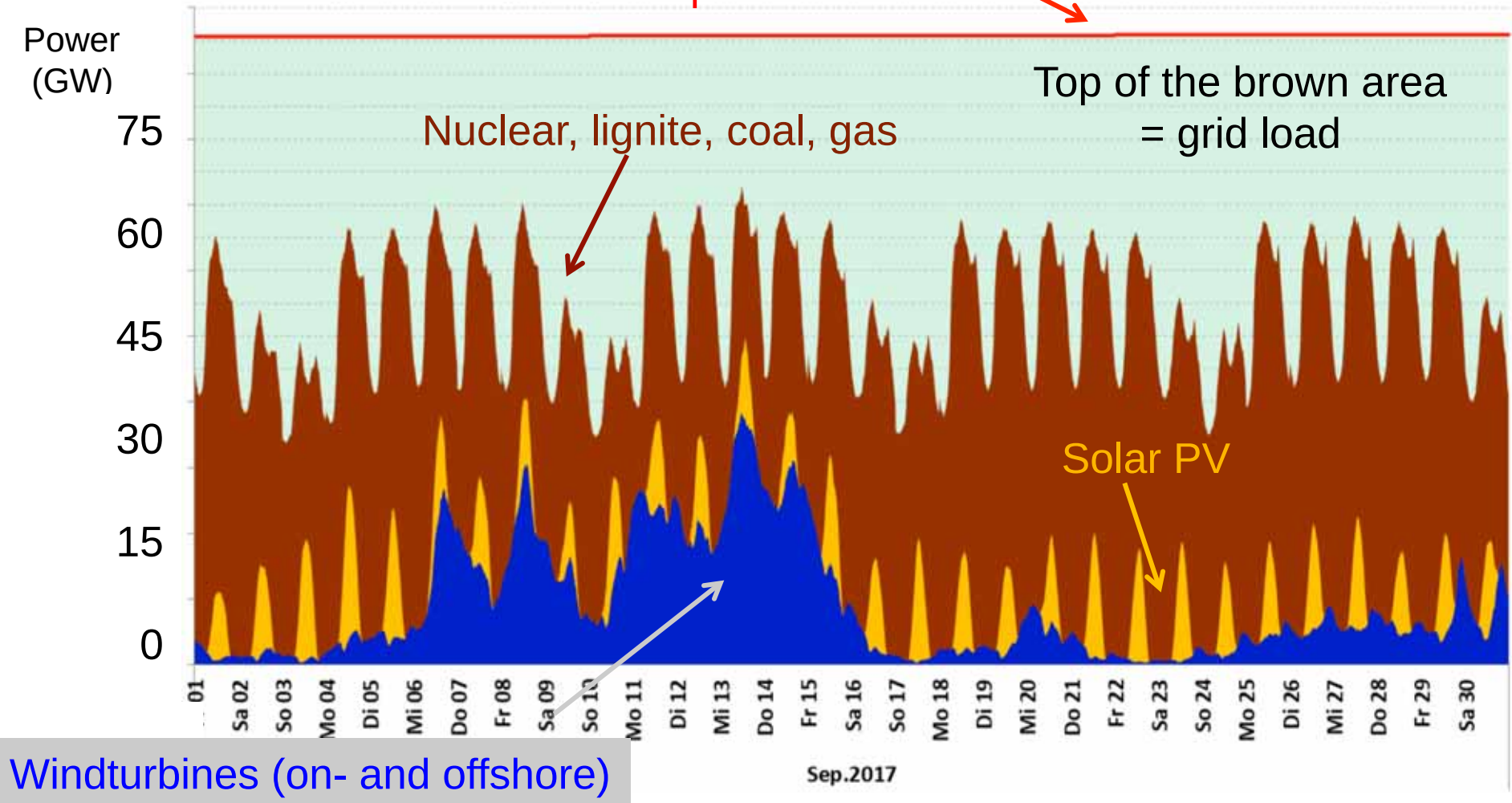
**Solar PV + Wind: < 20% of the
yearly German gross electricity production (~650 TWh)**

Source : "BMWI Energiedaten-Gesamt (okt 2017)"

Reason ? The large intermittency of solar PV + Wind!

Example: September 2017

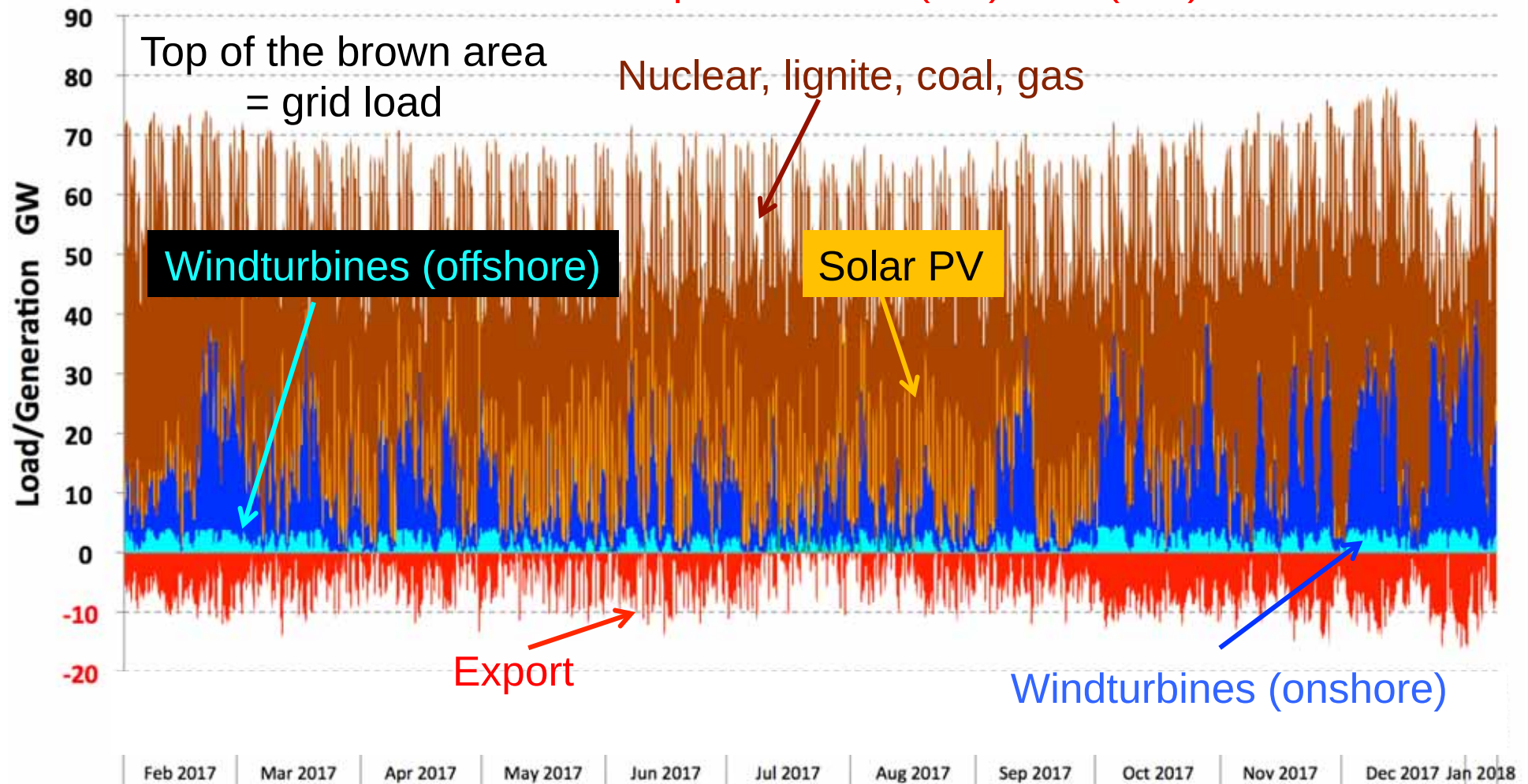
Installed solar and wind power : ~95 GW



Reason ? The large intermittency of solar PV + Wind!

Year 2017

Installed solar and wind power of 91 (feb) – 98 (dec) GW



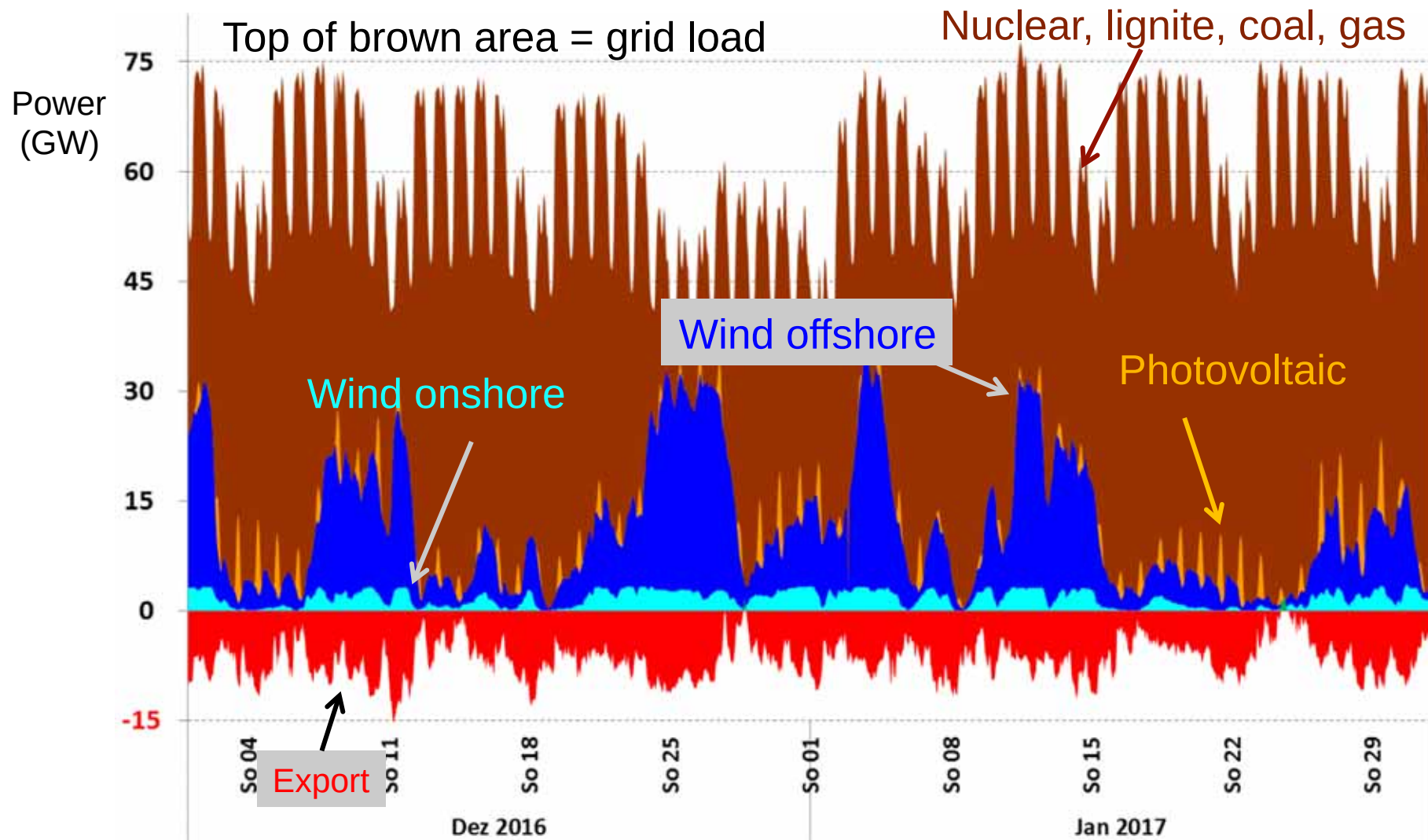
Total installed power (91GW): **NEVER** reached in 2017...

Total grid load : **NEVER** satisfied in 2017...

Large (and increasing) export of electrical energy

~10% of total electricity production is exported to neighbours

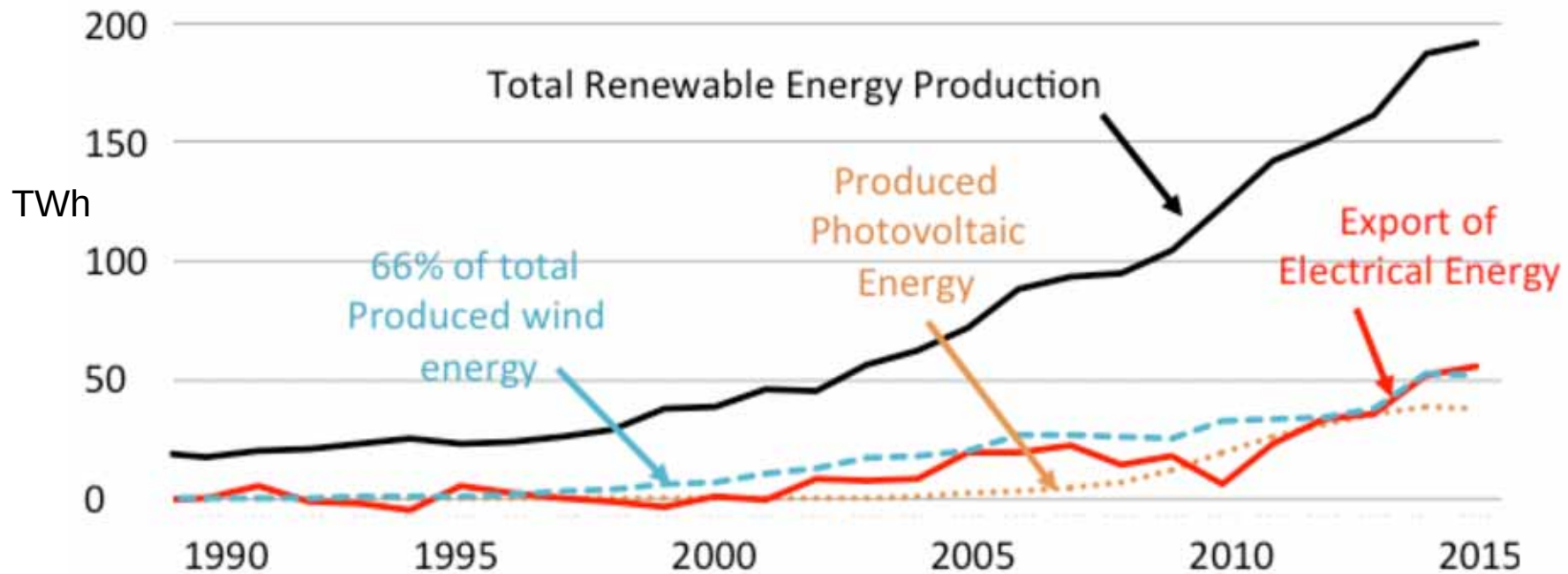
Dec 2016 – Jan 2017



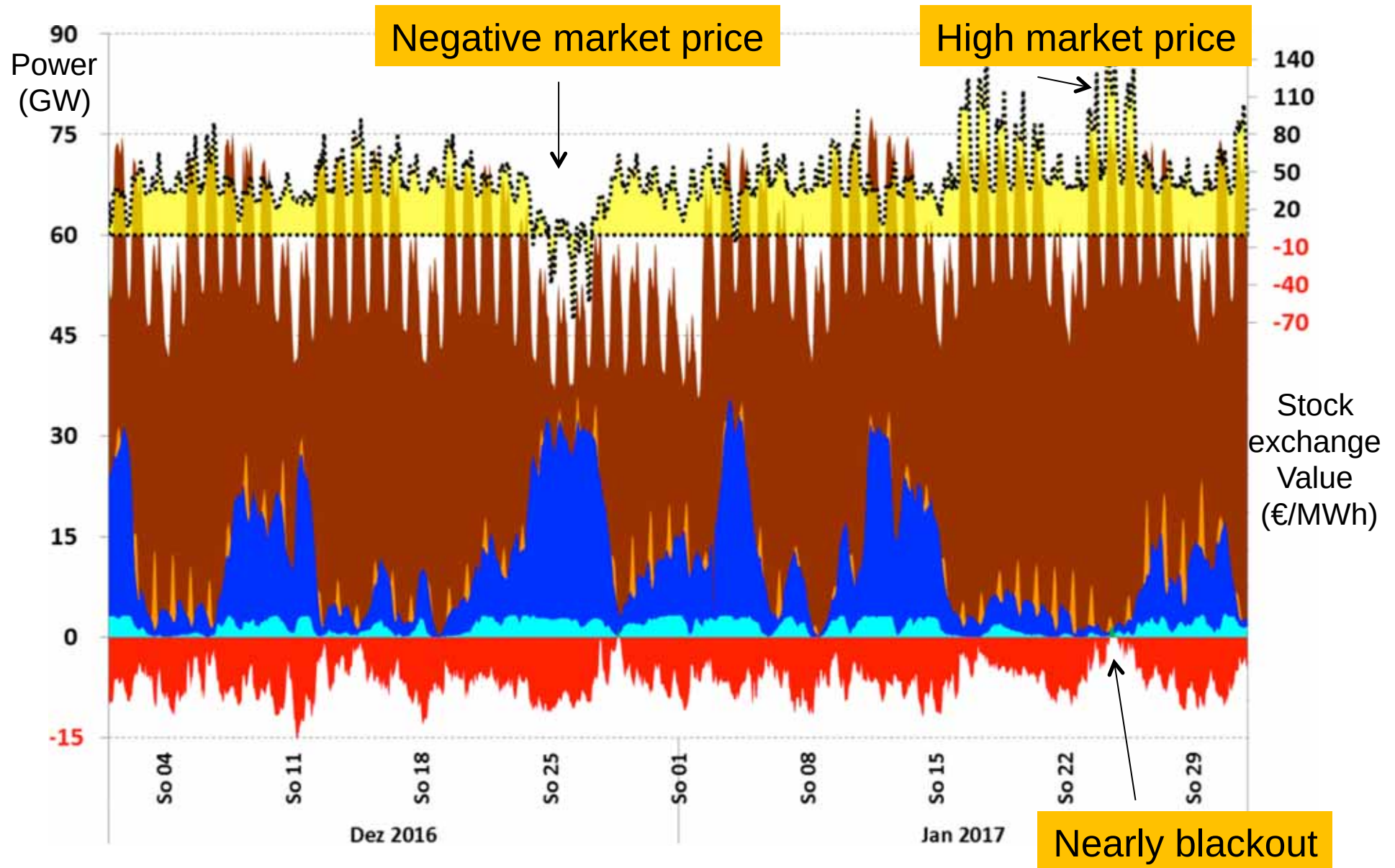
Source : ENTSOE-e

Solar PV electricity 'serves only the export' in Germany...

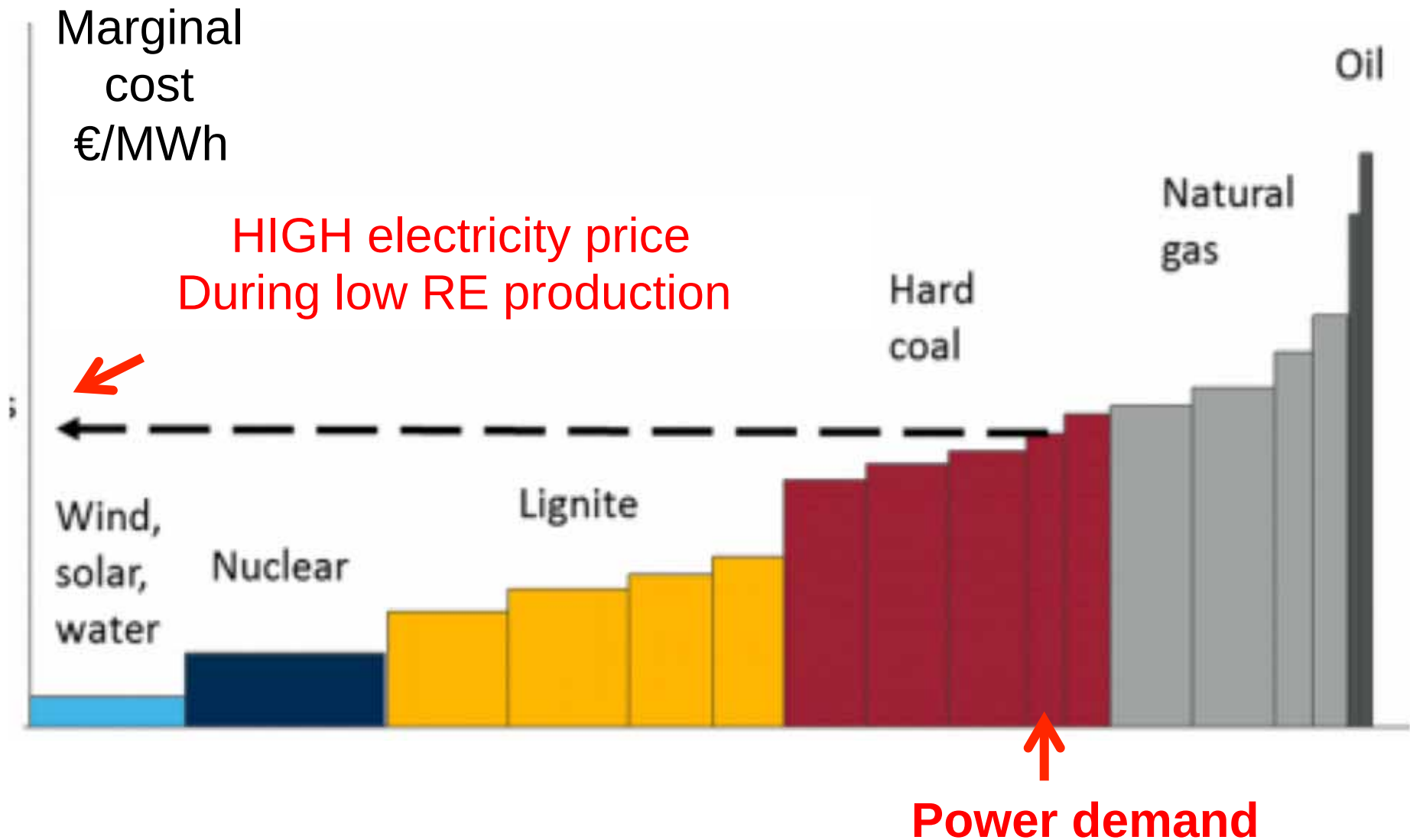
Or, equivalently 2/3 of the produced wind energy...



Sometimes strongly negative market price

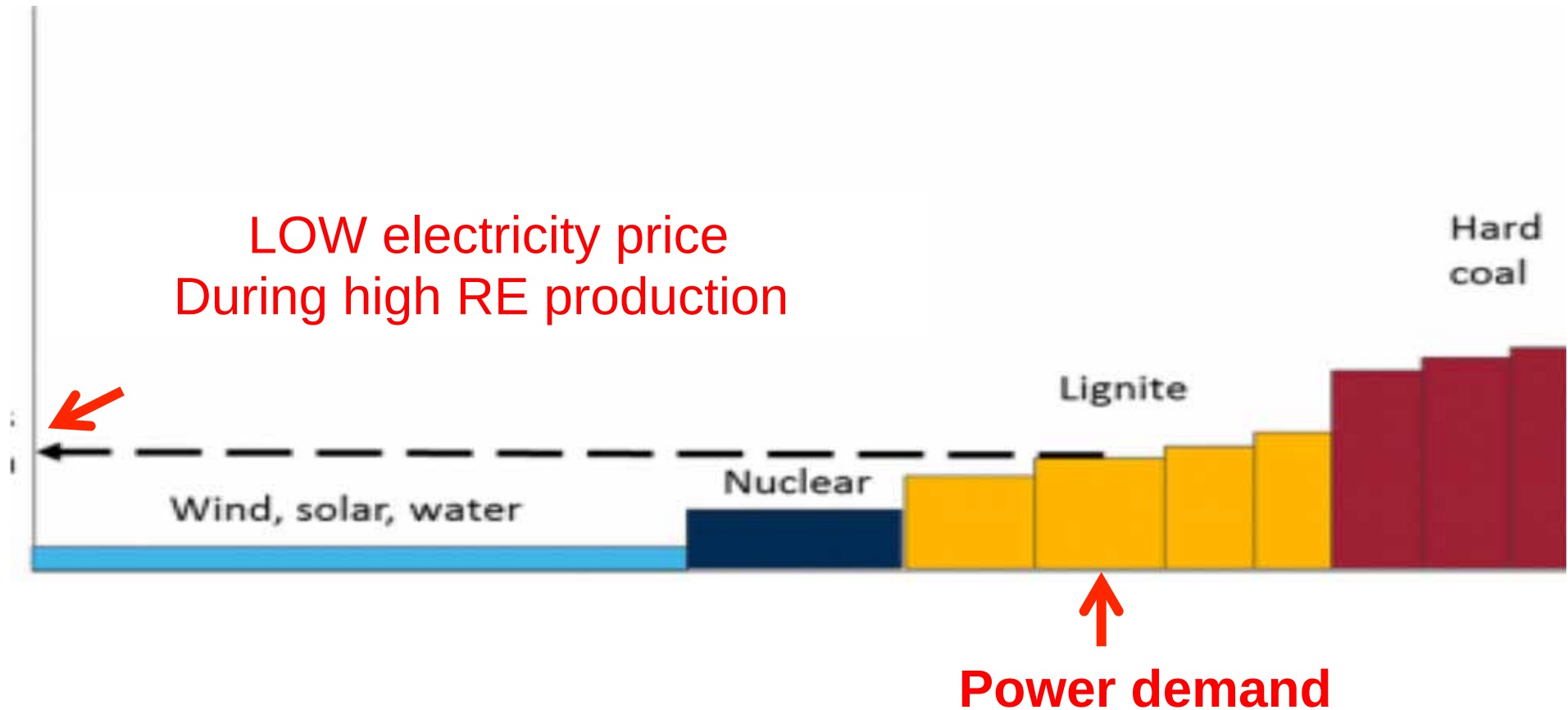


Stock exchange value for electrical energy: merit order



Stock exchange value for electrical energy: merit order

Marginal
costs
€/MWh

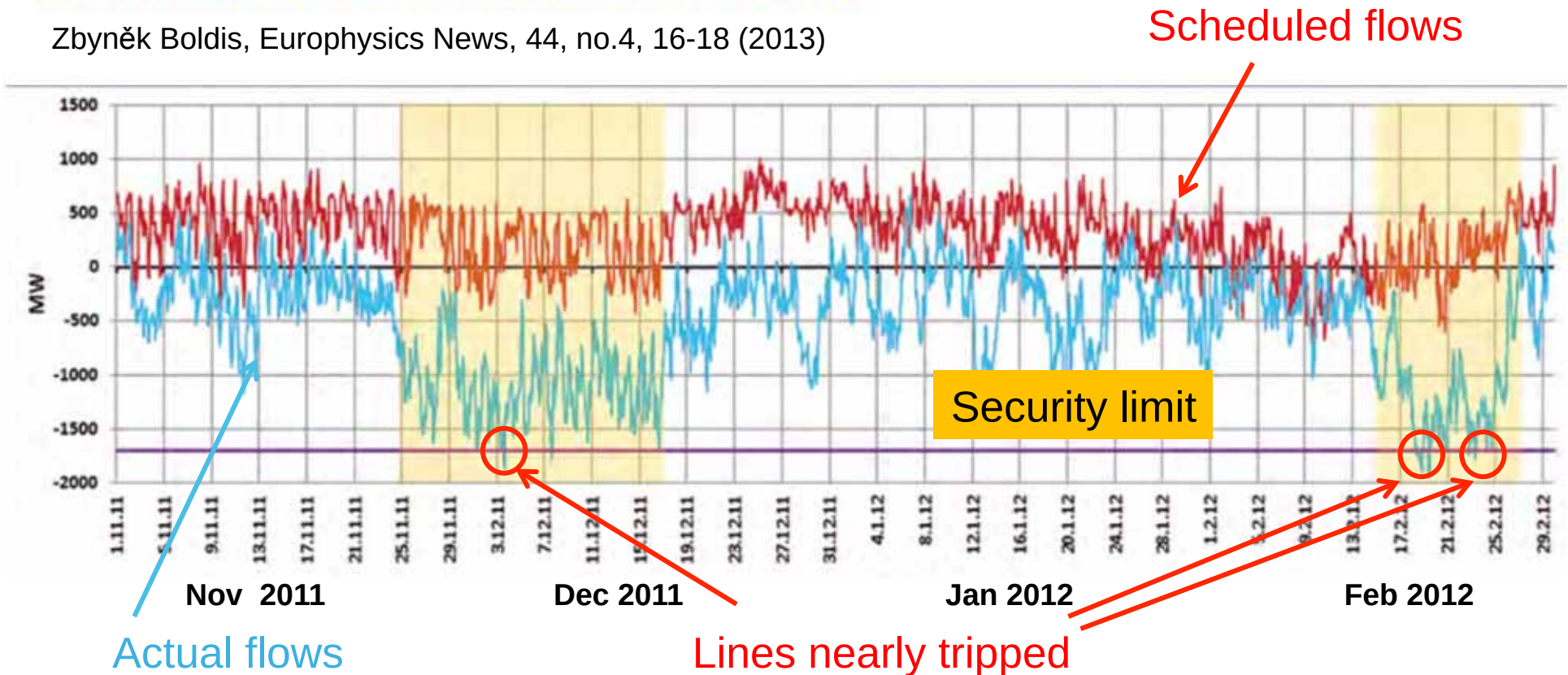


Large German export presents blackout risks for Europe

Several dangerous situations in Czech grid (example nov/dec 2012)

CZECH ELECTRICITY GRID CHALLENGED BY GERMAN WIND

Zbyněk Boldis, Europhysics News, 44, no.4, 16-18 (2013)



CZ-DE phase shift transformers installed to limit German influx

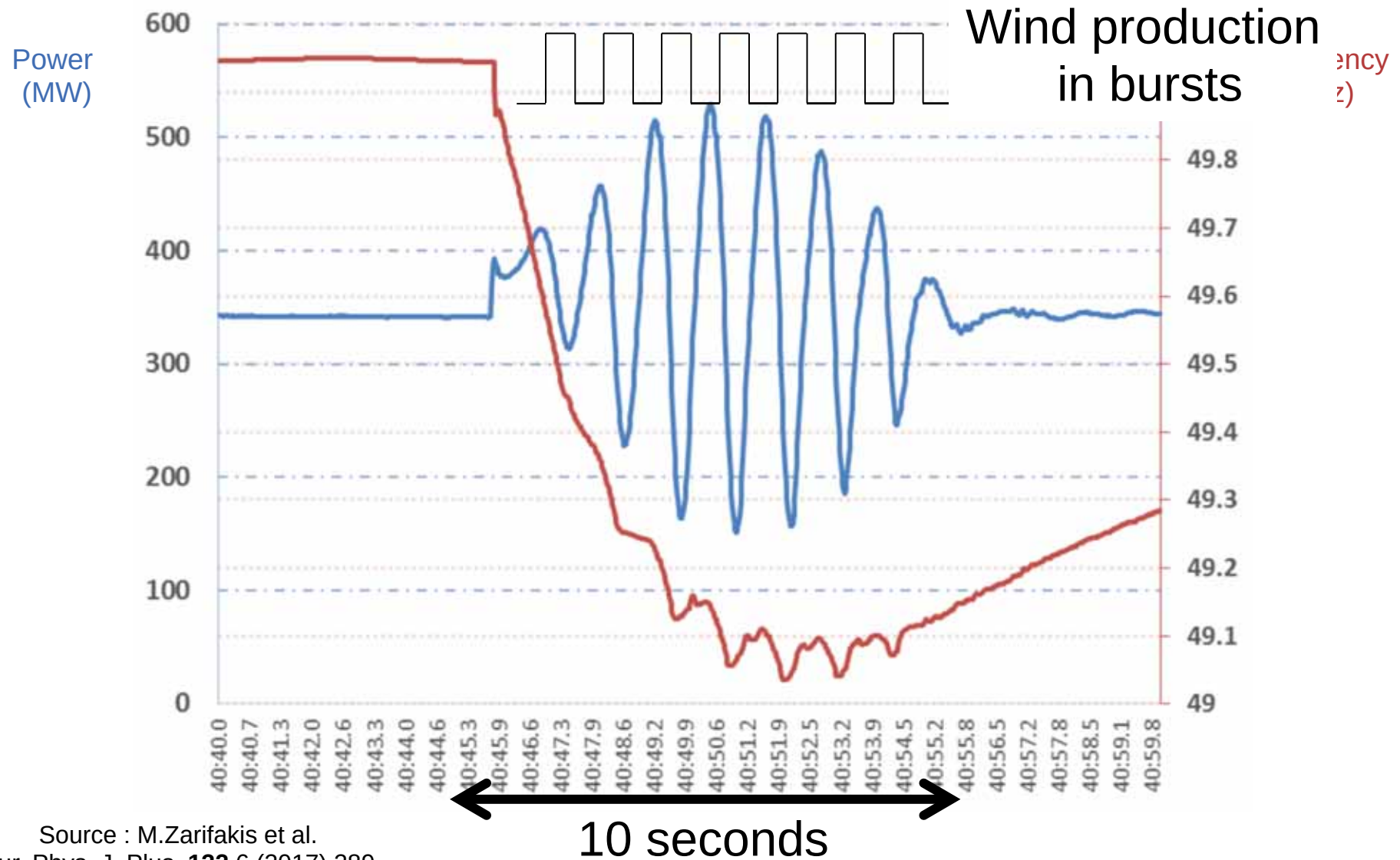
Increasing risk of net instabilities (example from Ireland)

Huge oscillations in power and frequency in 10s intervals (wind bursts)



Increasing risk of net instabilities (example from Ireland)

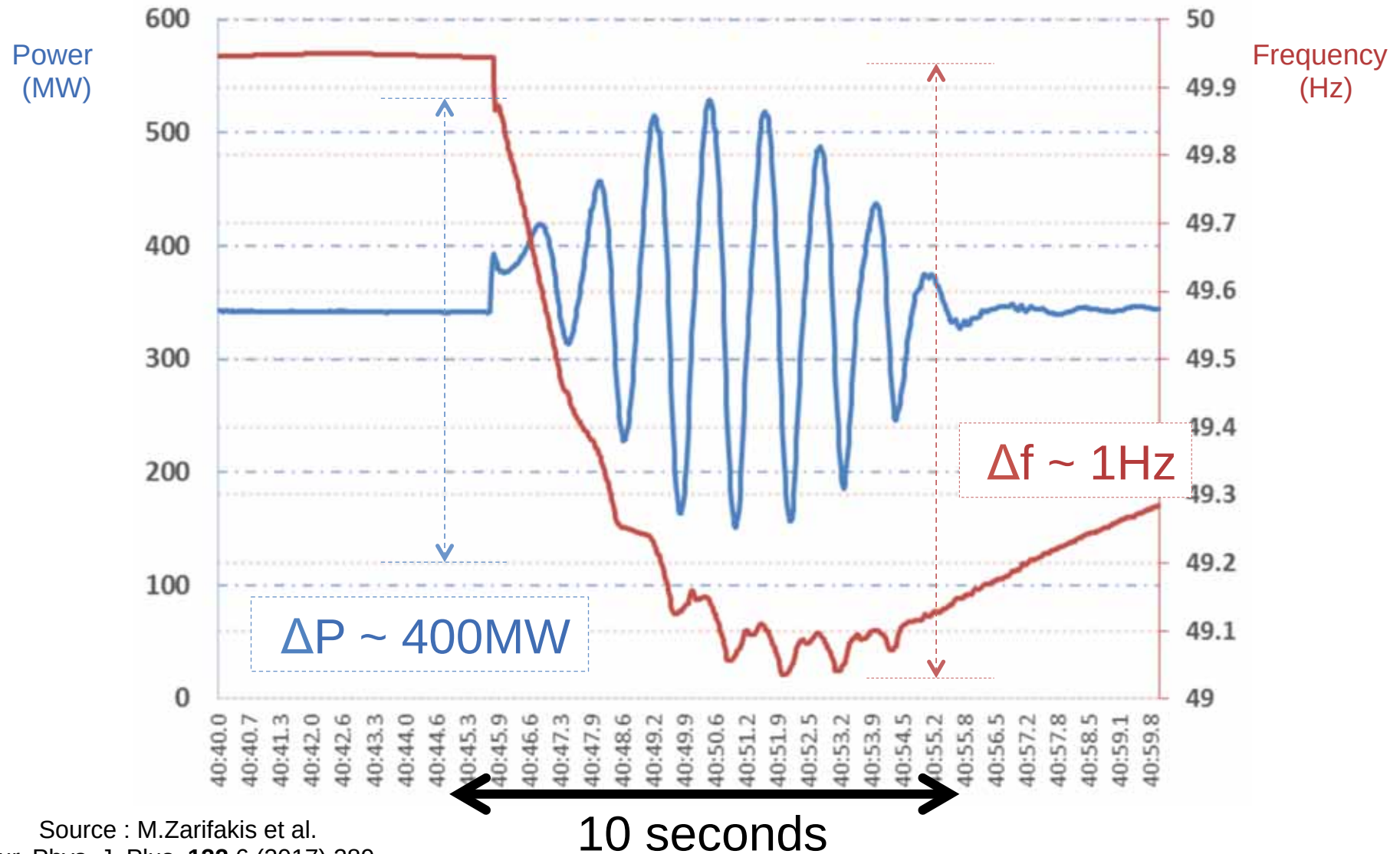
Huge oscillations in power and frequency in 10s intervals (wind bursts)



Source : M.Zarifakis et al.
Eur. Phys. J. Plus, **132** 6 (2017) 289

Increasing risk of net instabilities (example from Ireland)

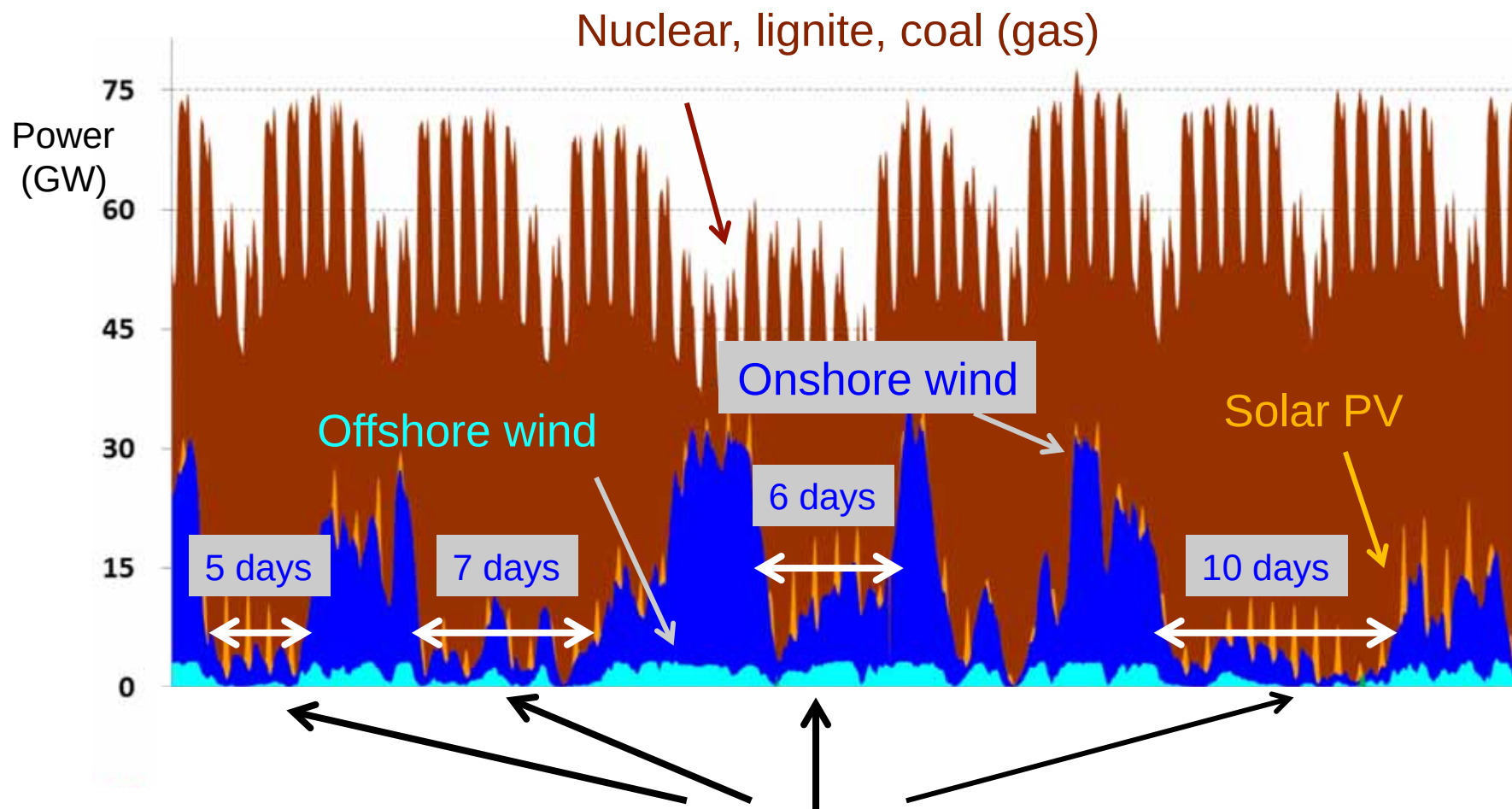
Huge oscillations in power and frequency in 10s intervals (wind bursts)



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Missing electrical energy is complemented by fossil energy (large fraction lignite) and nuclear

Example: Dec 2015 – Jan 2016

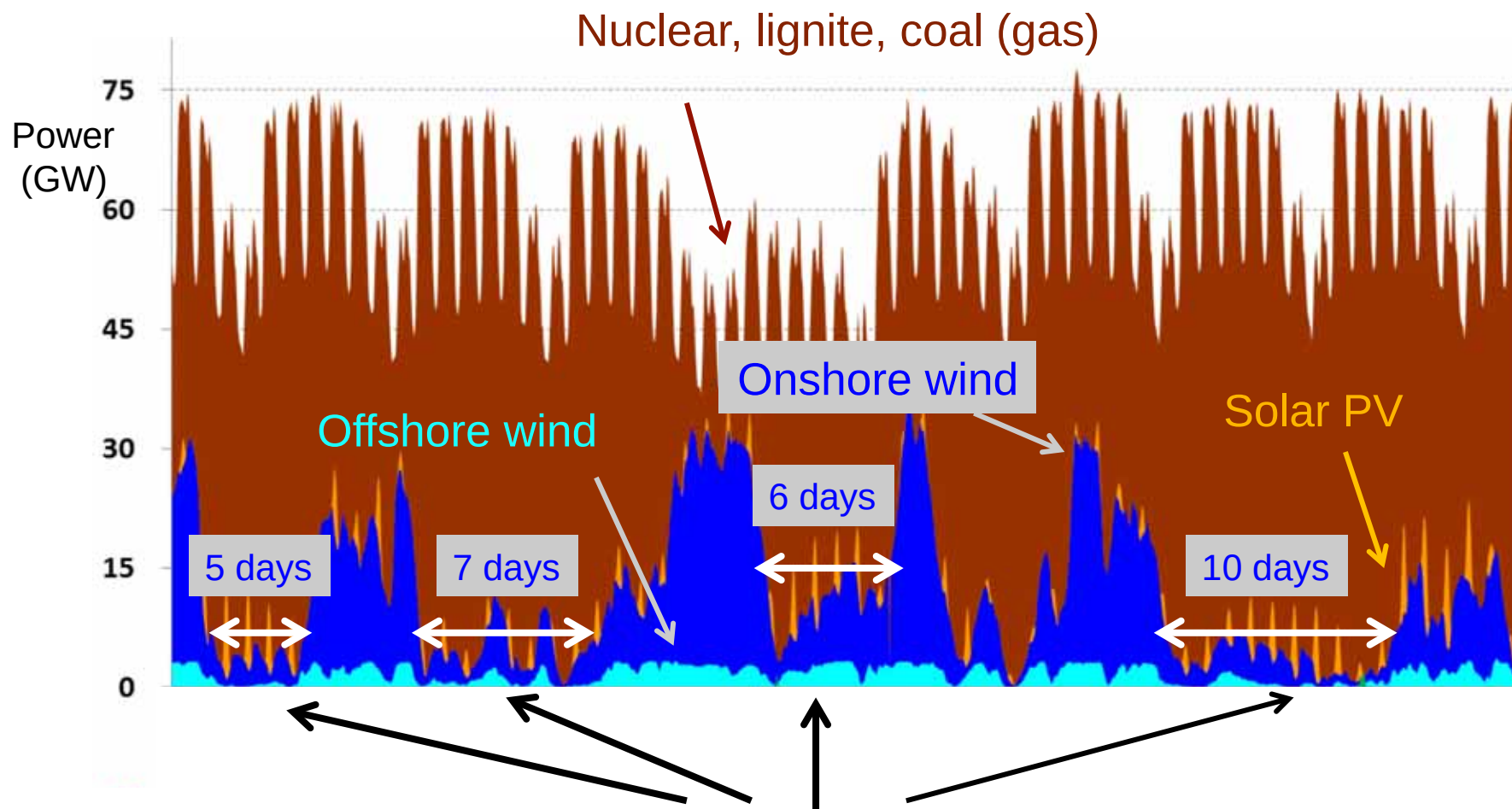


Missing energy:

$28\text{days} \times 55\text{GW} \times 24\text{h} =$

Missing electrical energy is complemented by fossil energy (large fraction lignite) and nuclear

Example: Dec 2015 – Jan 2016



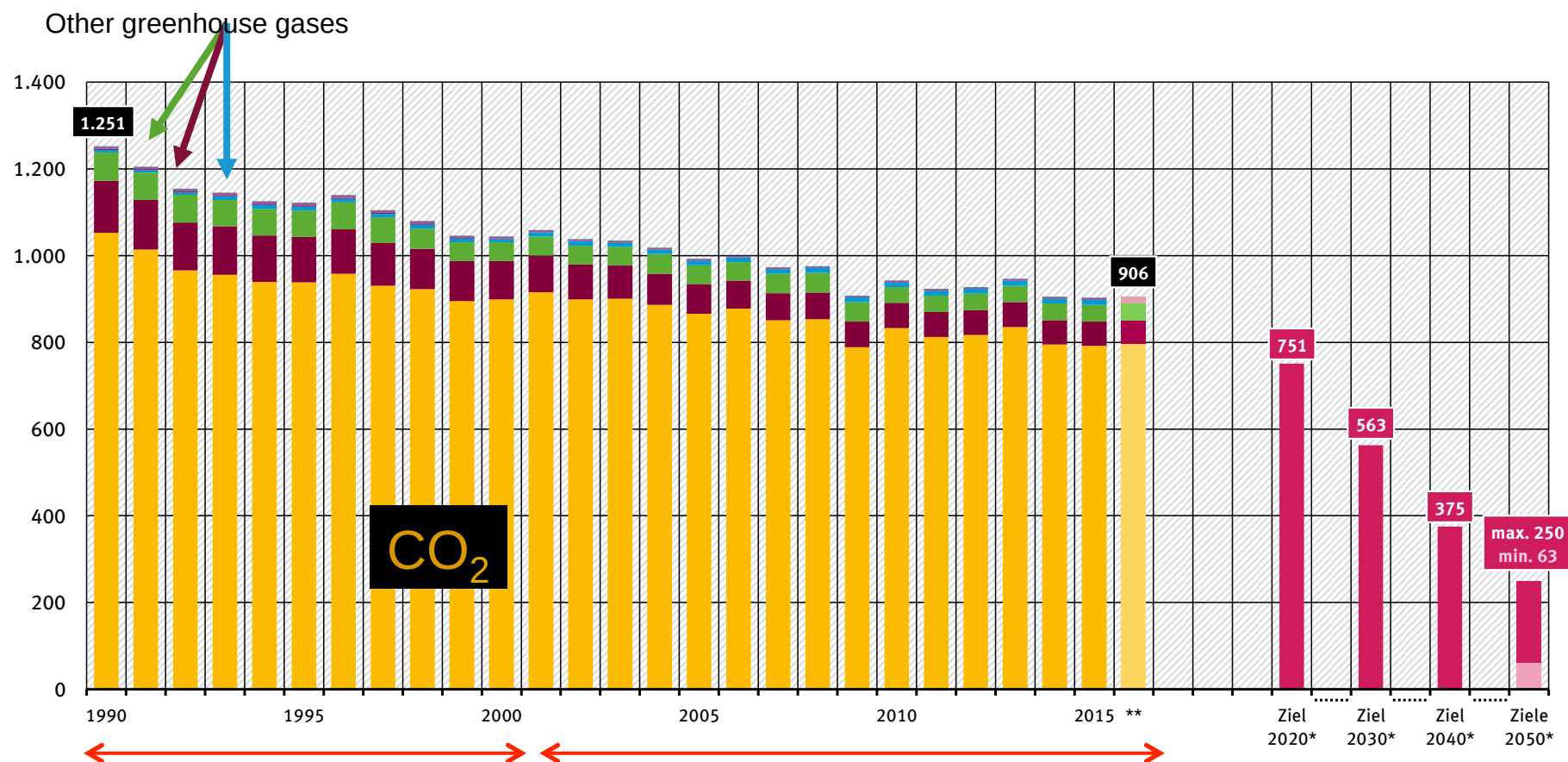
Missing energy:
 $28\text{days} \times 55\text{GW} \times 24\text{h} = 37\text{TWh} \sim \text{yearly German solar PV output}$

Source : ENTSOE-e

Rather poor result from enormous renewable investments

Evolution Total GHG emissions in Germany since 1990

(in Million tonnes CO₂ equivalents)



20% ↓ End DDR

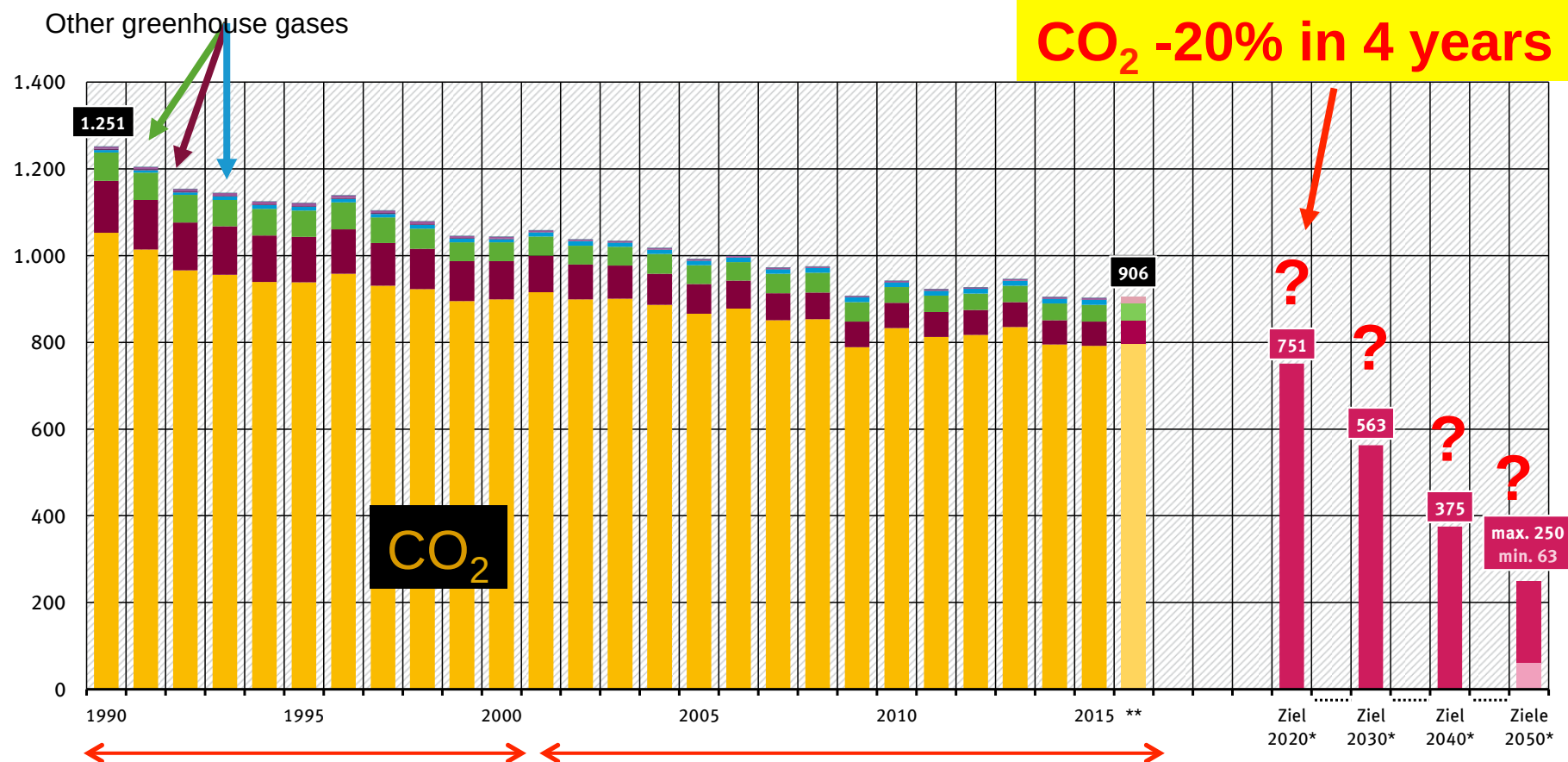
(source : Umweltbundesamt 2017)

Energiewende up to 2016
a few % ↓ over ~10 years
~ 250 000 000 000 Euro

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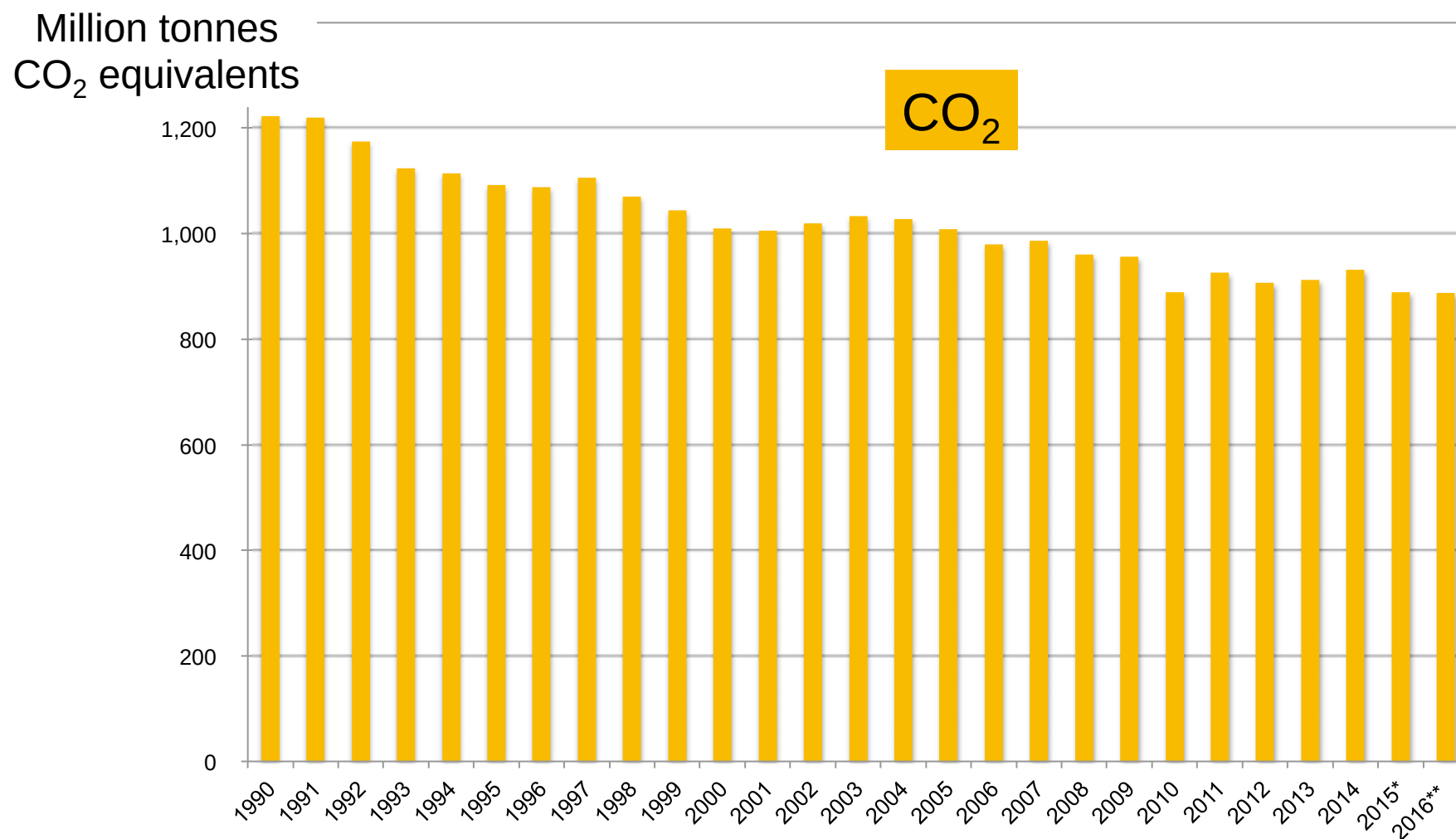
20% ↓ End DDR

(source : Umweltbundesamt 2017)

**Energiewende up to 2016
a few % ↓ over ~10 years
~ 250 000 000 000 Euro**

**Up to 2030:
+ 500 000 000 000 €?
Effect on CO₂
emissions ?**

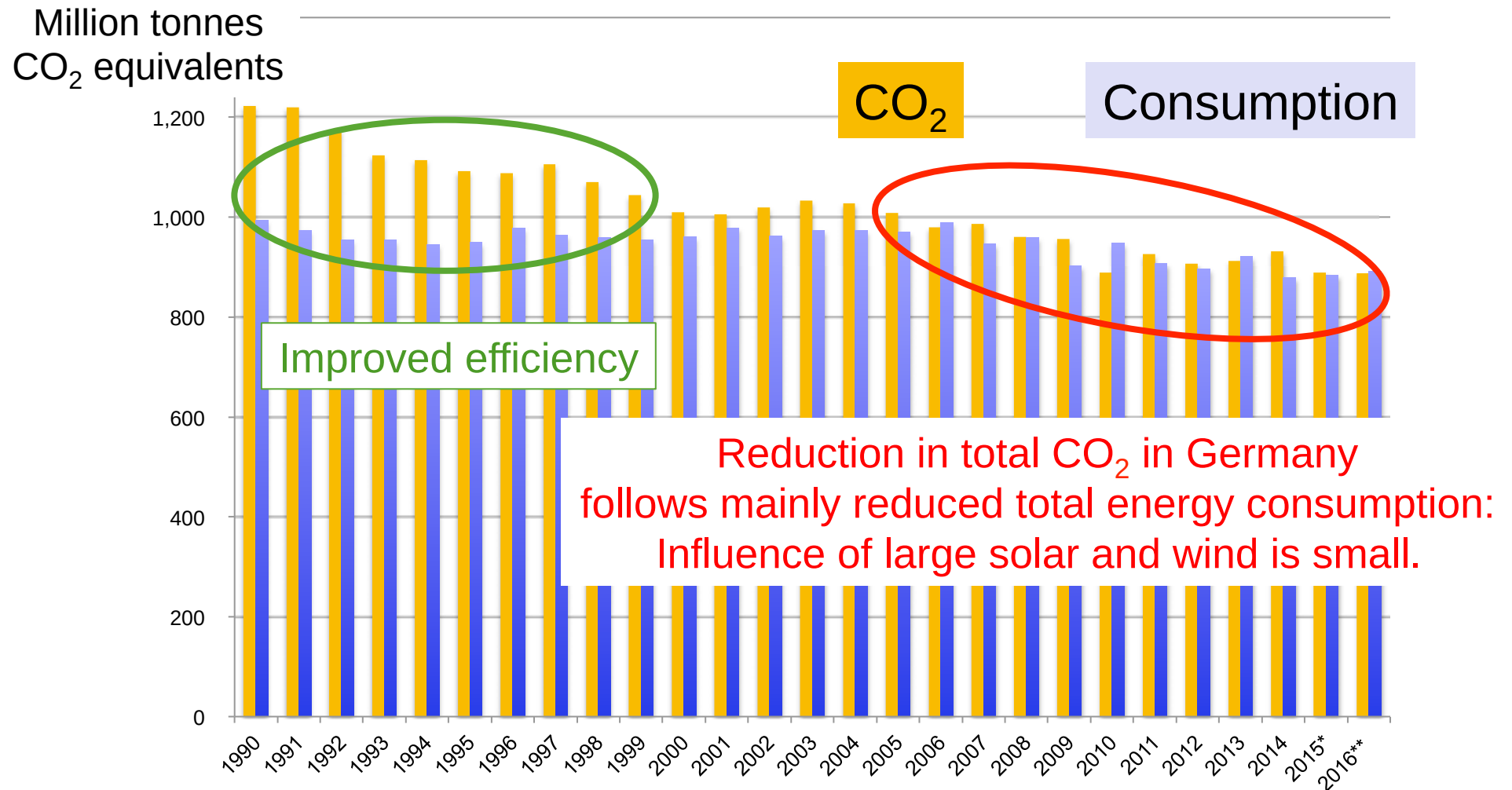
Germany: Reduction in CO₂ emissions...



Source: "<https://www.bmwi.de/Redaktion/DE/Artikel/Energie/energiedaten-gesamtausgabe.html>"

Germany: Reduction in CO₂ emissions... follows the reduction in consumption...

Effect on CO₂ of 91GW installed wind+solar PV system is minimal (~ 4%)



Source: "<https://www.bmwi.de/Redaktion/DE/Artikel/Energie/energiedaten-gesamtausgabe.html>"

German CO₂ savings in the global context

Savings in CO₂ (from wind+solar PV) Germany (2016): 90 million tonnes

World emissions of CO₂ (2016) : ~ 32 billion tonnes

Ratio : $90 / 32000 = 1 / 355$

~ 1 day of yearly world CO₂ emissions ...

The integrated cost (~10 years) is ~250 billion Euro

‘Example’ for the rest of the world ... ?

Source : “BMWI Energiedaten-Gesamt (okt 2017)”

Germany admits defeat in climate plans... !

09.01.2018 | 11:55 Uhr

UNION UND SPD KIPPEN KLIMAZIEL

„Eine völlig absurde Entscheidung“

von Silke Kersting

Die Sondierer von Union und SPD haben das deutsche Klimaziel für 2020 gekippt und nehmen stattdessen 2030 in den Fokus. Angedacht ist ein Klimaschutzgesetz. Umweltverbände und Opposition reagieren mit harscher Kritik.

Berlin. Noch nach den Bundestagswahlen im September hielt Angela Merkel (CDU) am Klimaziel 2020 fest. Sie wolle sich, betonte die Kanzlerin im Oktober auf dem Kongress der Gewerkschaft IG BCE, „nicht vom Ziel verabschieden“. Vielmehr werde das Klimaziel in den kommenden



gCO₂/kWh in various EU countries (2016)

Country	Gram CO ₂ / kWh	
GERMANY	503	Dominant fossil Energy
England	496	
Netherlands	432	
Belgium	253	Nuclear and fossil
France	92	
Sweden	43	Nuclear and hydro
Norway	4	

Source: European Environmental Agency
<http://www.eea.europa.eu/data-and-maps/figures/co2-electricity-g-per-kwh>

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Country	Gram CO ₂ / kWh
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Germany:
½ kg CO₂
per kWh !

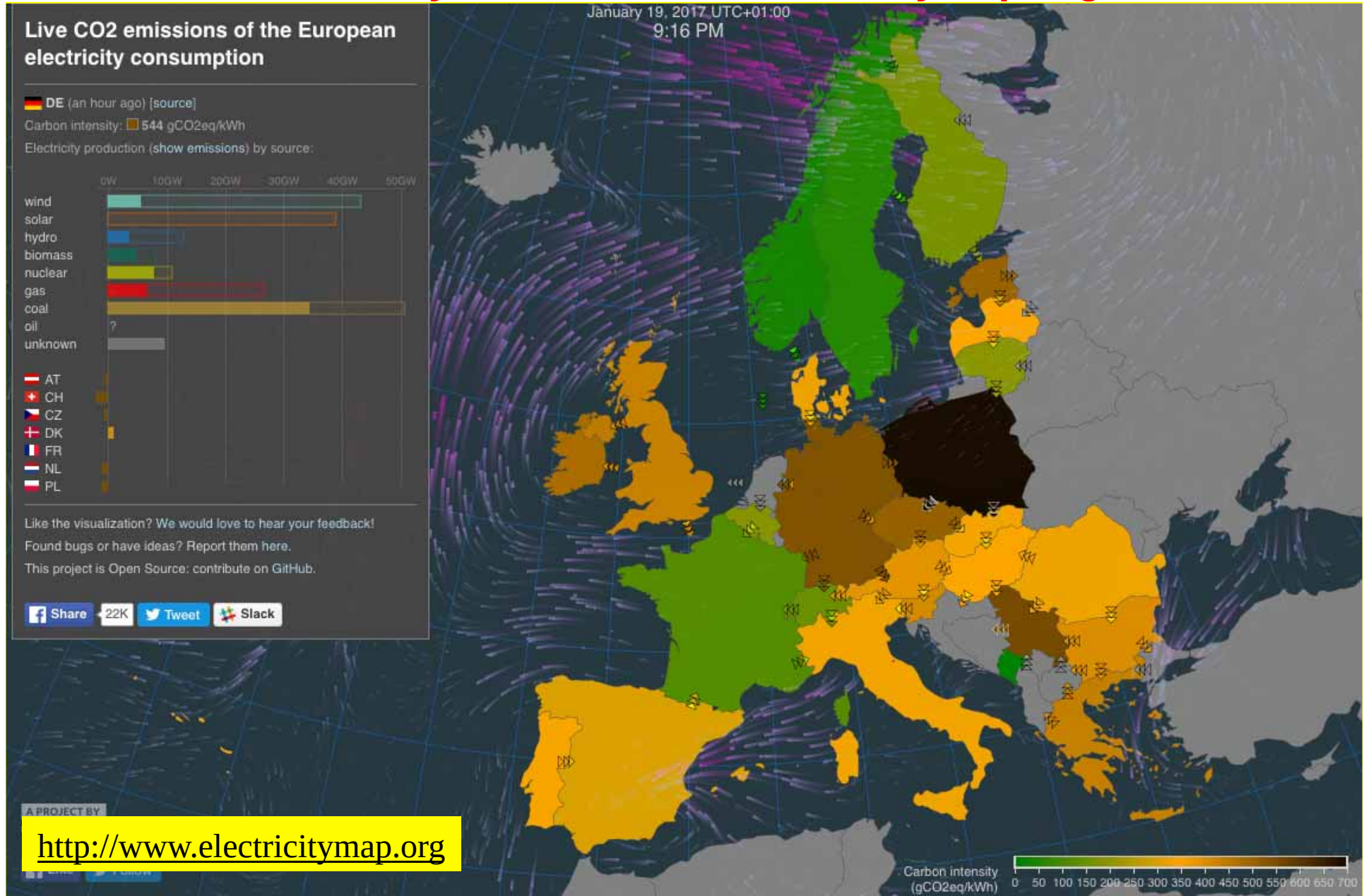
**Dominant fossil
Energy**

Nuclear and fossil

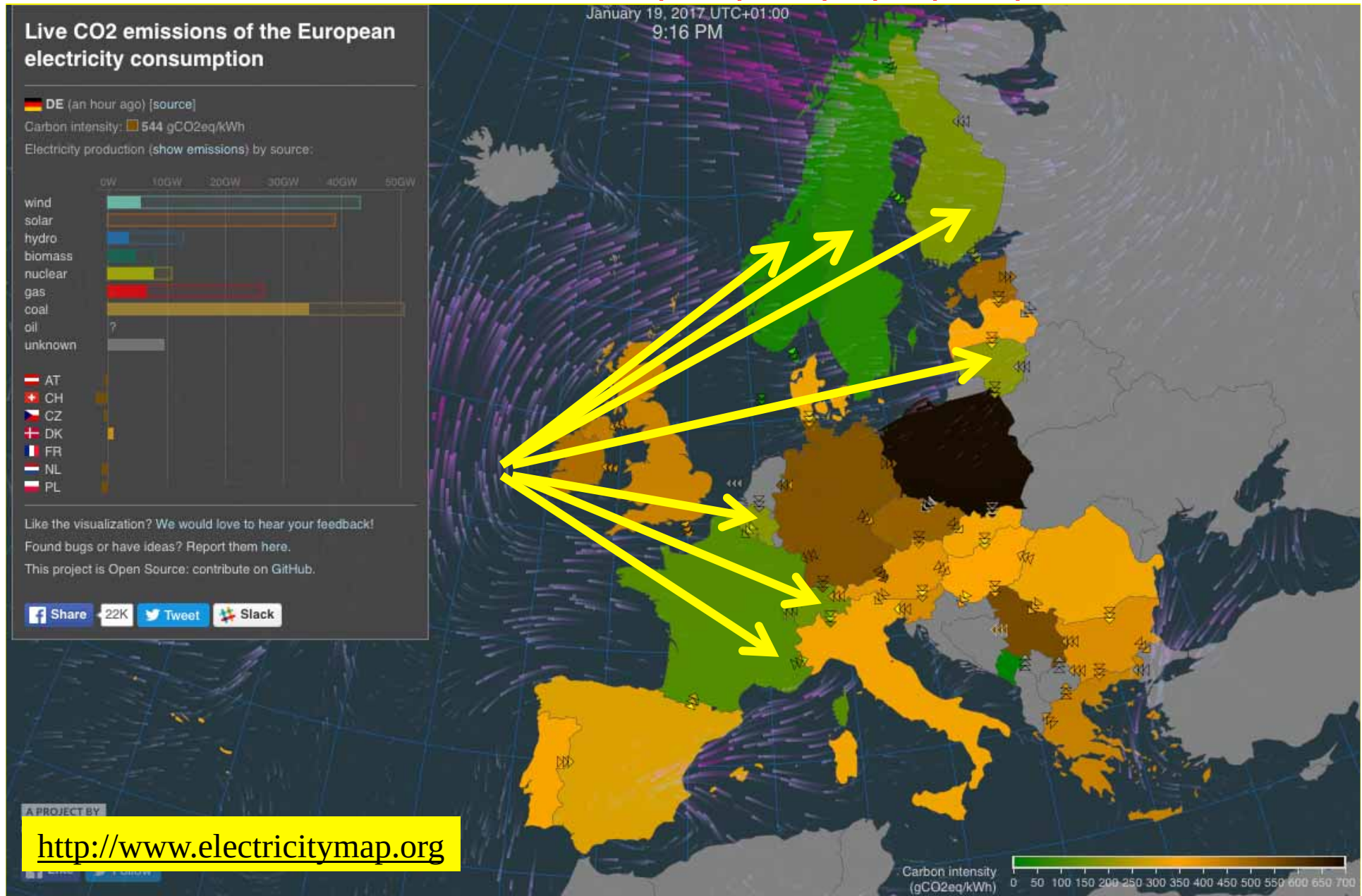
Nuclear and hydro

Source: European Environmental Agency
<http://www.eea.europa.eu/data-and-maps/figures/co2-electricity-g-per-kwh>

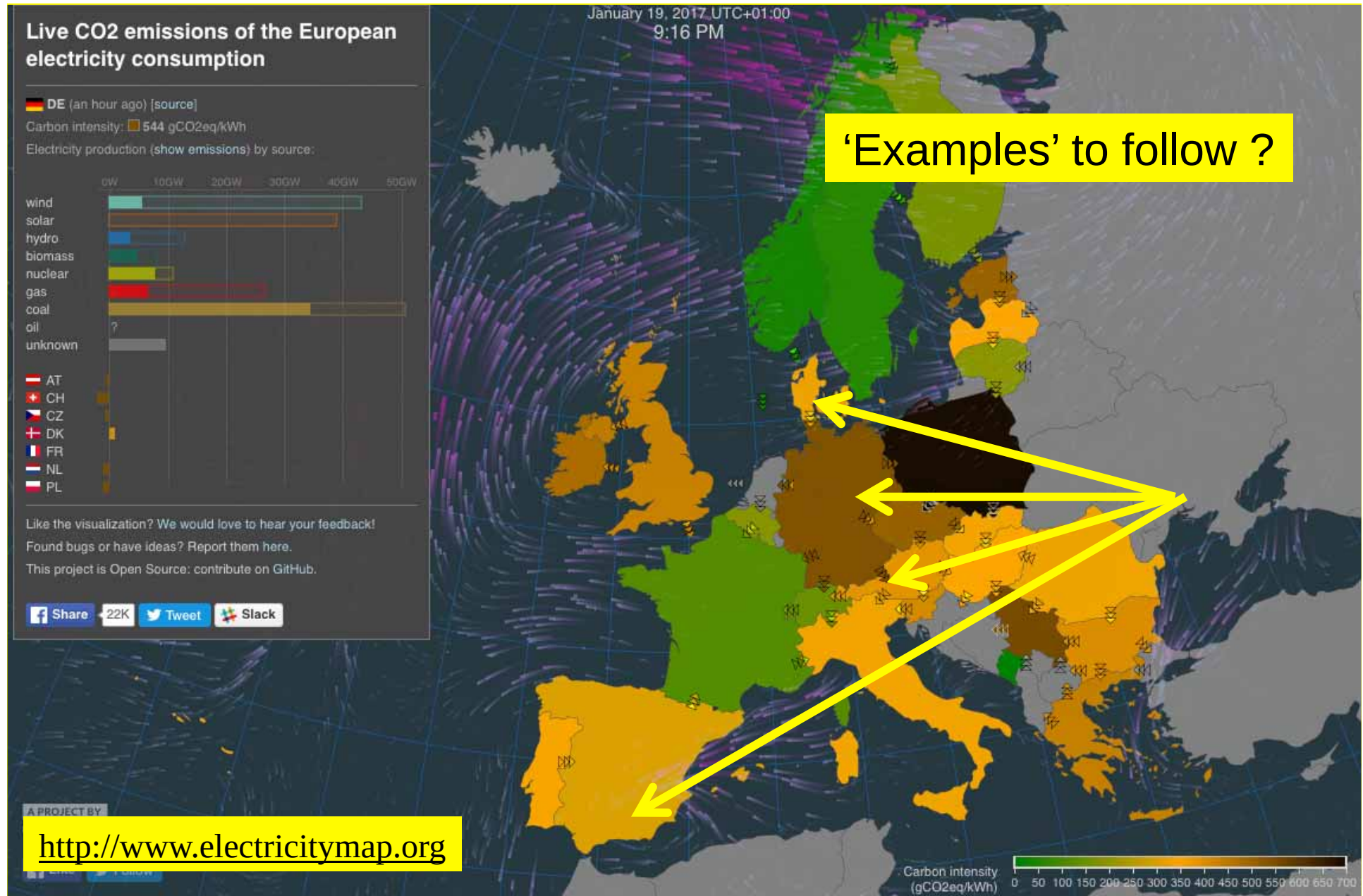
Convince yourself ! www.electricitymap.org !



Green countries: B, FR, NO, S, FI, CH, LT



The 'Green Champions' are not so green...



Braunkohle statt beten.... Lignite still very important...



Von 1888 bis 1891 wurde die Kirche St. Lambertus gebaut, 2013 mit einem Gottesdienst entwidmet.

(Foto: REUTERS)

Dienstag, 09. Januar 2018

Braunkohle statt beten

Immerather Dom wird abgerissen

Villages swallowed by expanding lignite mines... (Jan 2018)

Renewable energy is rather 'diluted'

Example : hydropower



~50m

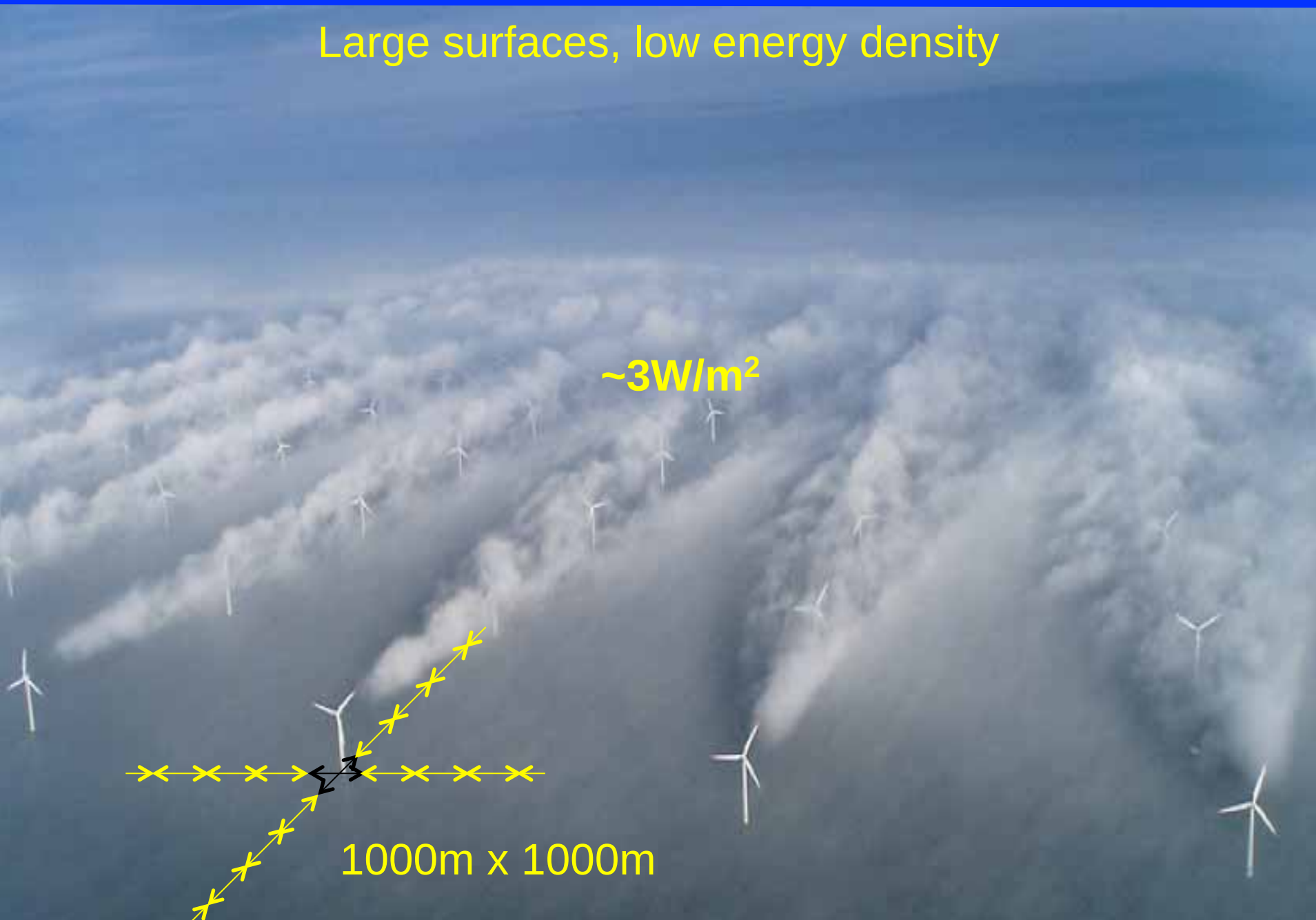
Energy to boil 1 liter H_2O ($0 \rightarrow 100^\circ\text{C}$) =
Energy of ~1 ton of water falling over 50m (e.g. from the Niagara)

Offshore wind

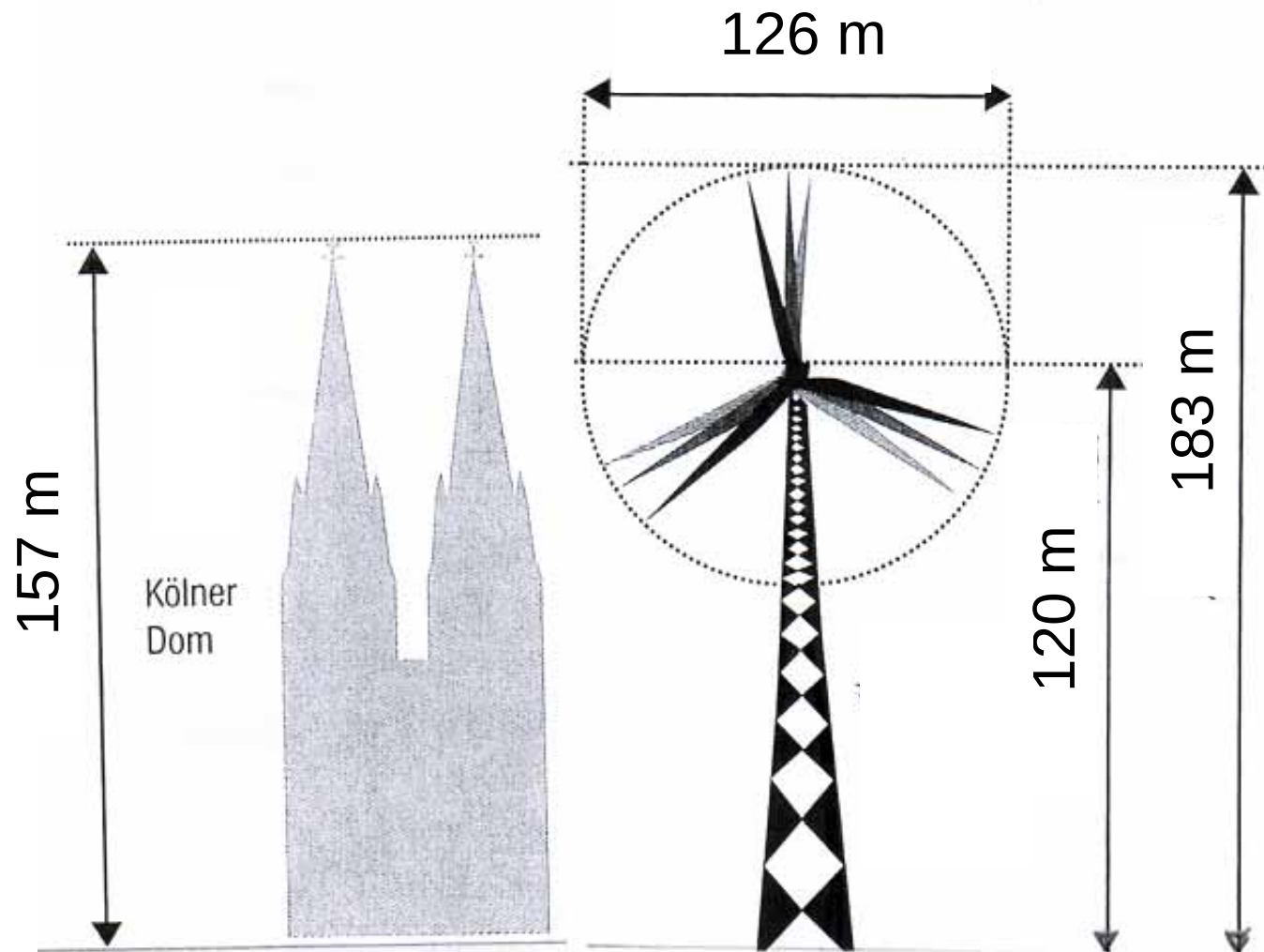
Large surfaces, low energy density

$\sim 3\text{W/m}^2$

1000m x 1000m

An aerial photograph of an offshore wind farm. Numerous white wind turbines are visible, arranged in a grid-like pattern. The sea is a deep blue. In the lower-left quadrant, a 1000m x 1000m area is outlined by yellow arrows pointing in four directions from a central point. The text '~3W/m²' is written in yellow in the center of the image, and '1000m x 1000m' is written in yellow at the bottom of the outlined area.

Windturbines of 5MW_{peak} → Huge



(Note: windturbine of 5MW → 15-20% load factor, i.e. average of 1MW over the year)

Replacing a 2GW_{el} lignite plant by onshore wind



**Weissweiler lignite plant: 2 200 MW_{el}
(= Doel 3 + Doel 4)**

Replacing a 2GW,el lignite plant by onshore wind



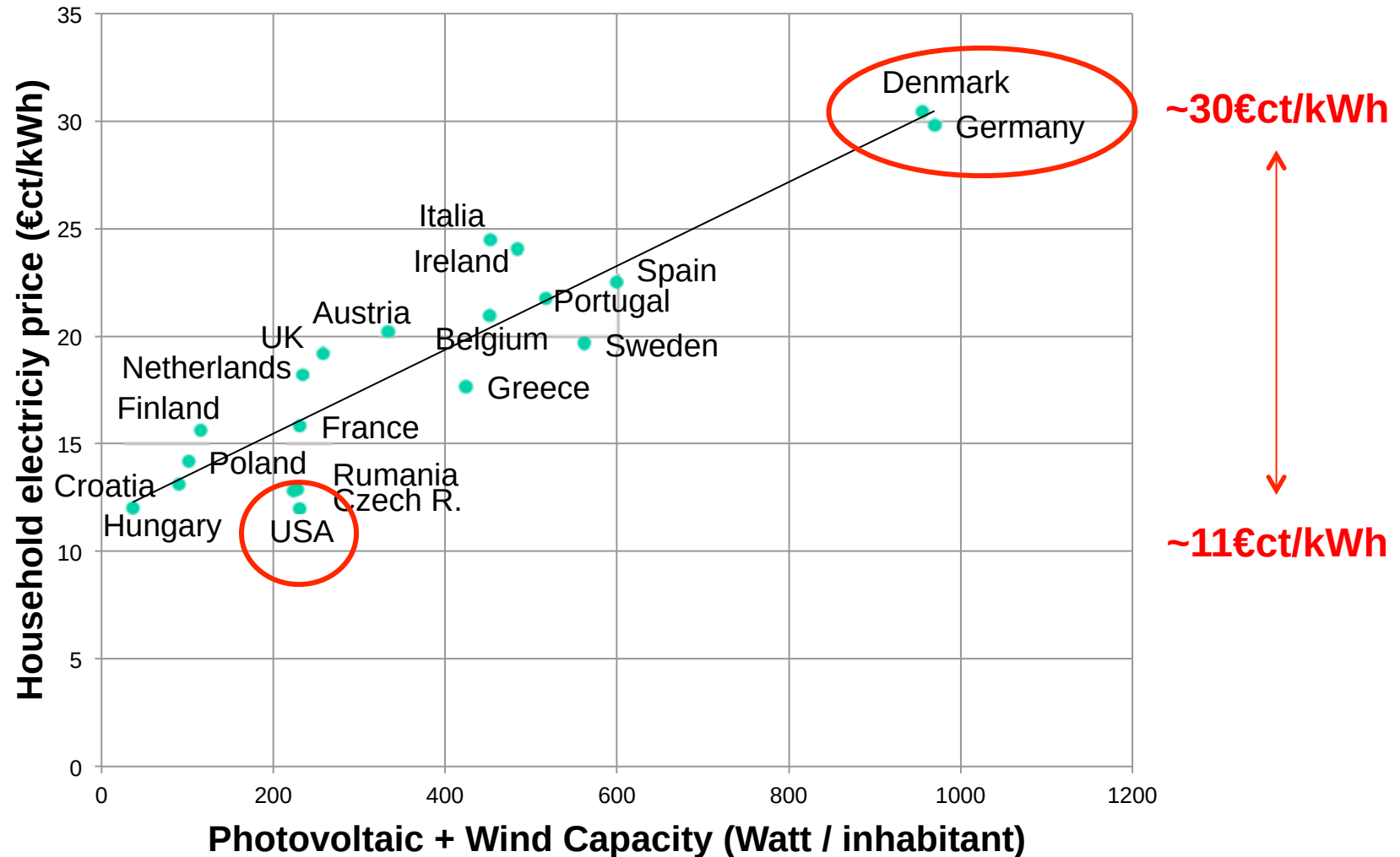
2000 windturbines onshore @ 5 MW

Surface
 $2000 \times 1 \text{ km}^2$
 $= 2000 \text{ km}^2$
~1 Belgian Province

**Weissweiler lignite plant: 2 200 MW,el
(= Doel 3 + Doel 4)**

Electricity cost in various EU countries (2015)

German (and Danish) household electricity highest in EU



Source : Eurostat (2016)

The european energy policy does not convince...

SPAIN

The Spanish PV experience was either very successful or a fiasco ...
The cost in euros and energy has been enormous and clearly has contributed to the current Spanish economic crisis

(Piedro A.Prieto and Charles A.S.Hall, "Spains Photovoltaic Revolution", Springer Verlag 2013)

DENMARK

Over the last eight years West Denmark has exported (couldn't use) 57% of the wind power and East Denmark 45%.

The wind power that is exported from Denmark saves neither fossil fuel consumption nor CO₂ emissions in Denmark, where it is all paid for [because of export to Norway and Sweden, which have nearly 100% from nuclear + hydro]

(Danish Centre for Political Studies, "Wind Energy, The Case of Denmark", Copenhagen 2009)

GERMANY

Australia's Prime Minister: The horrifying example of Germany

(Der Spiegel, 17.2.2014)

A shame, given the enormous EU investments...
But comments reflect reality

Europe in the world context

‘Europe alone will NOT make the world clean again...!’

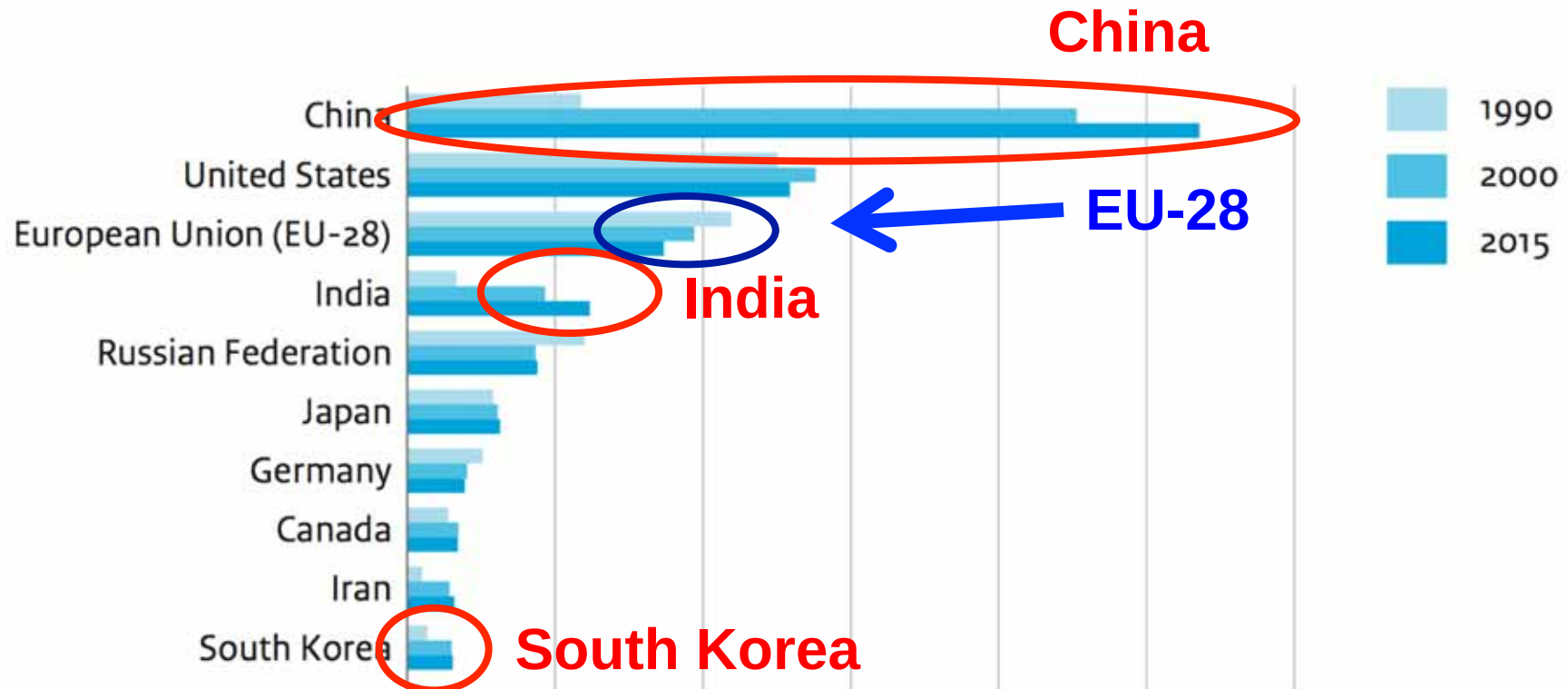
Country	CO ₂ emissions (in million tonnes)	Contribution (2015)
United States	5 620	17.7%
EU-27	3 895	8.2%
China	8 320	26.2%
India	1695	5.3%
Germany	730	2.3%
France	360	1.2%
Belgium	128	0.4%
World	31 780	100%

Europe should show an excellent example

EU CO₂ saving efforts negligible...

Figure 2.11

CO₂ emissions per country from fossil-fuel use and cement production



Europe should show an excellent example

Total decarbonisation in Europe or the world – Utopia ?

Energy source	Contribution [%]
Oil	35.4
Coal	28.7
Gas	22.7
Hydro	6.8
Nuclear fission	4.4
All renewables	2.0
Total	100



World:

Fossil
energy
~ **85%**
(=CO₂)

Europe:

Fossil
energy
~ **71%**
(=CO₂)

Source : "Energy International Annual, DOE, Washington DC, 2016

How to replace the dominant position of fossil energy ?

On what timescale ?

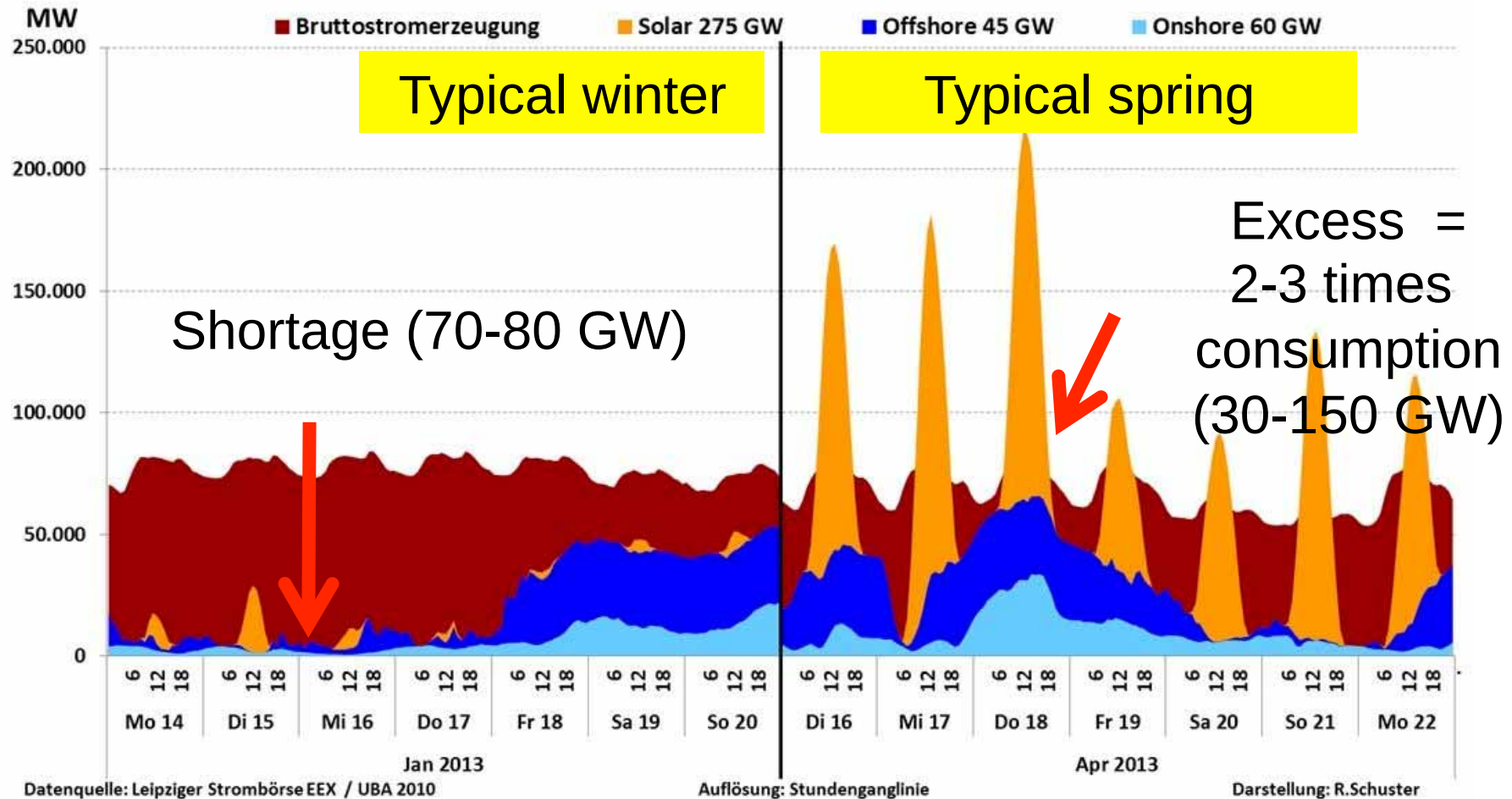
With what kind of system(s) ?

Discussion

1. Further increase solar + wind in Germany ?

Study by Umweltbundesamt - Scenario 2050

Current solar+wind system x 5-6



No matter how large the (solar+PV) system, large missing power gaps will remain during dark and windstill periods !

Discussion

Three parallel systems are needed
(at full grid load capacity)

1. Photovoltaic / Wind
2. Backup system
3. Storage (in as far as feasible)

Cost is ~3-4 times that of a conventional system

Storage for electrical energy: what size ?

Germany

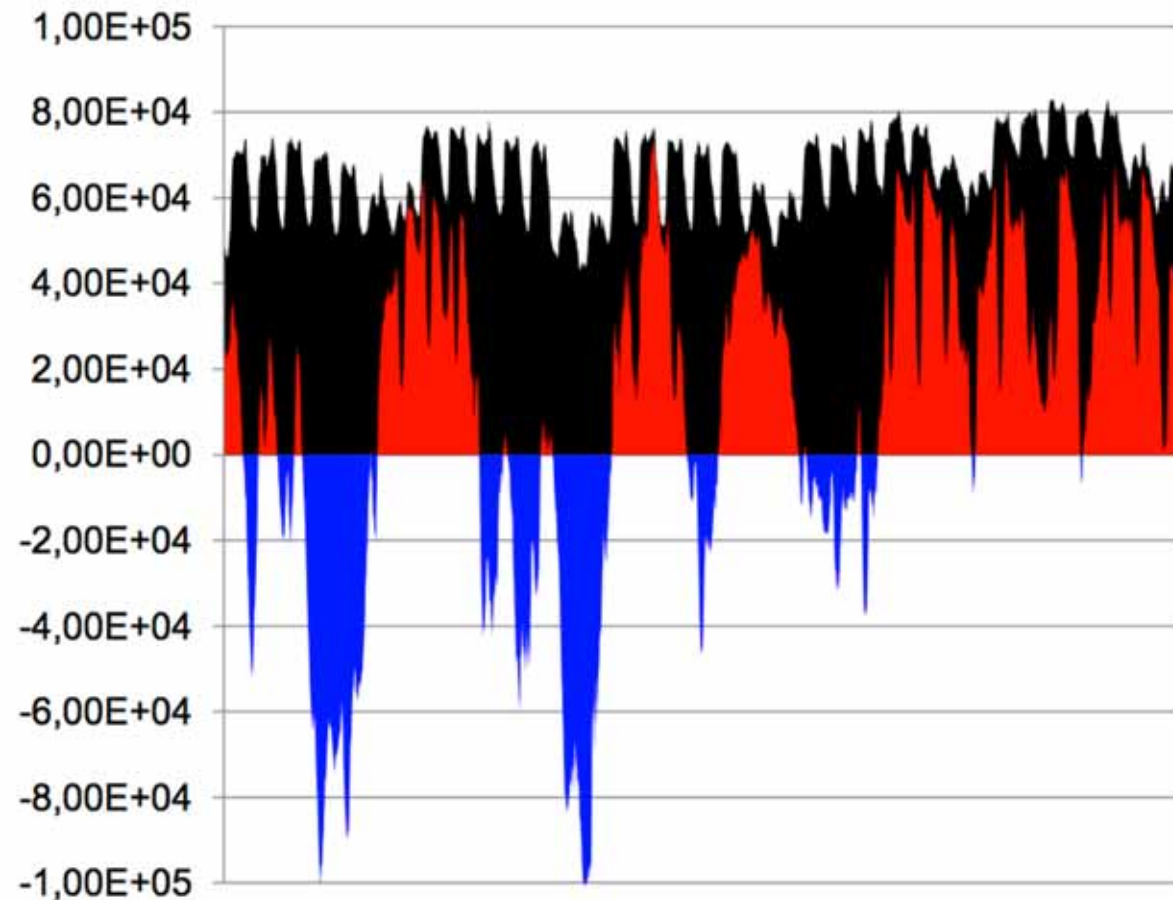
Assuming 100% of renewable energy

Jan / Feb 2012

Power demand

Backup

Excess wind+solar

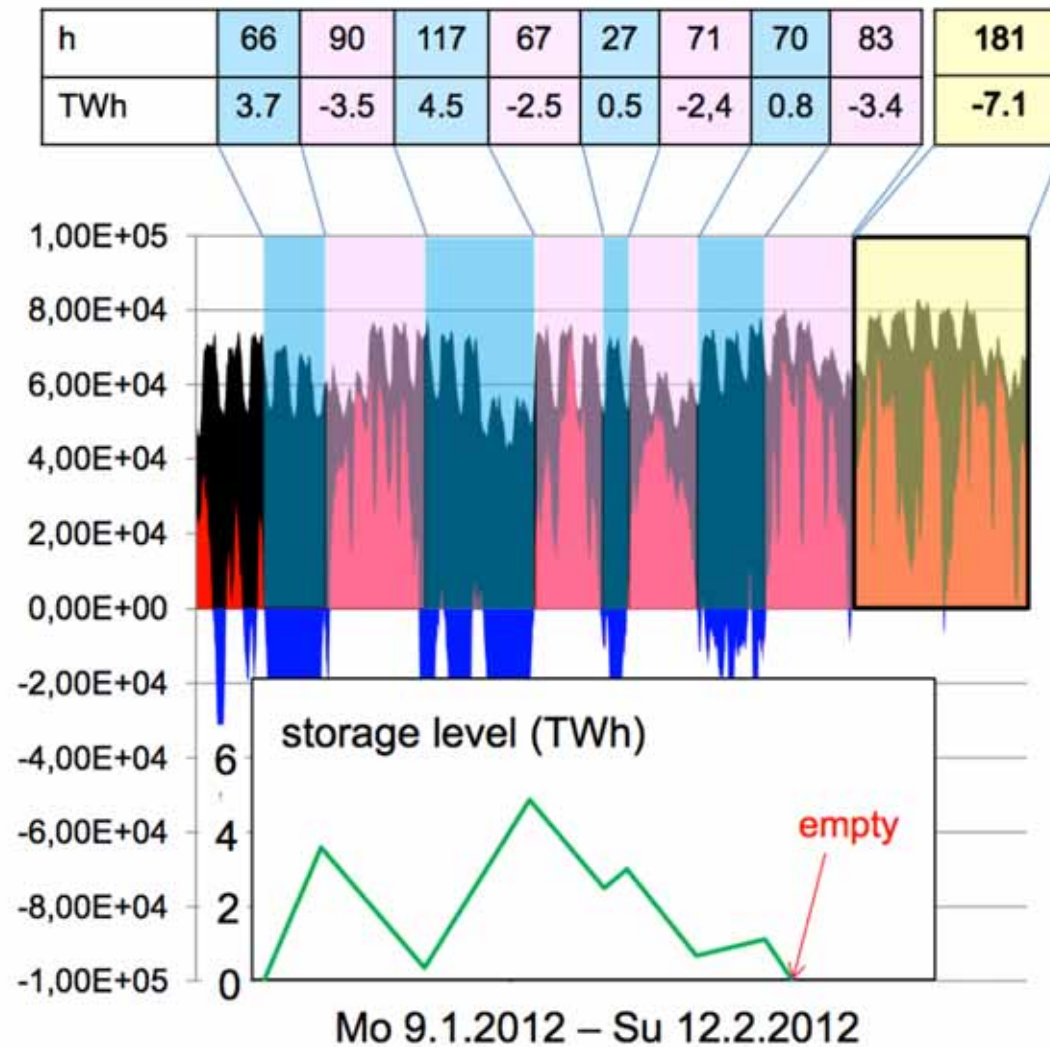


Mo 9.1.2012 – Su 12.2.2012

Source: F.Wagner, "Surplus from and storage of electricity generated by intermittent sources"
Eur.Phys.Journal Plus, **131**, 445 (2016)

Storage for electrical energy: what size ?

Need to be at least several 10s of TWh or runs out quickly

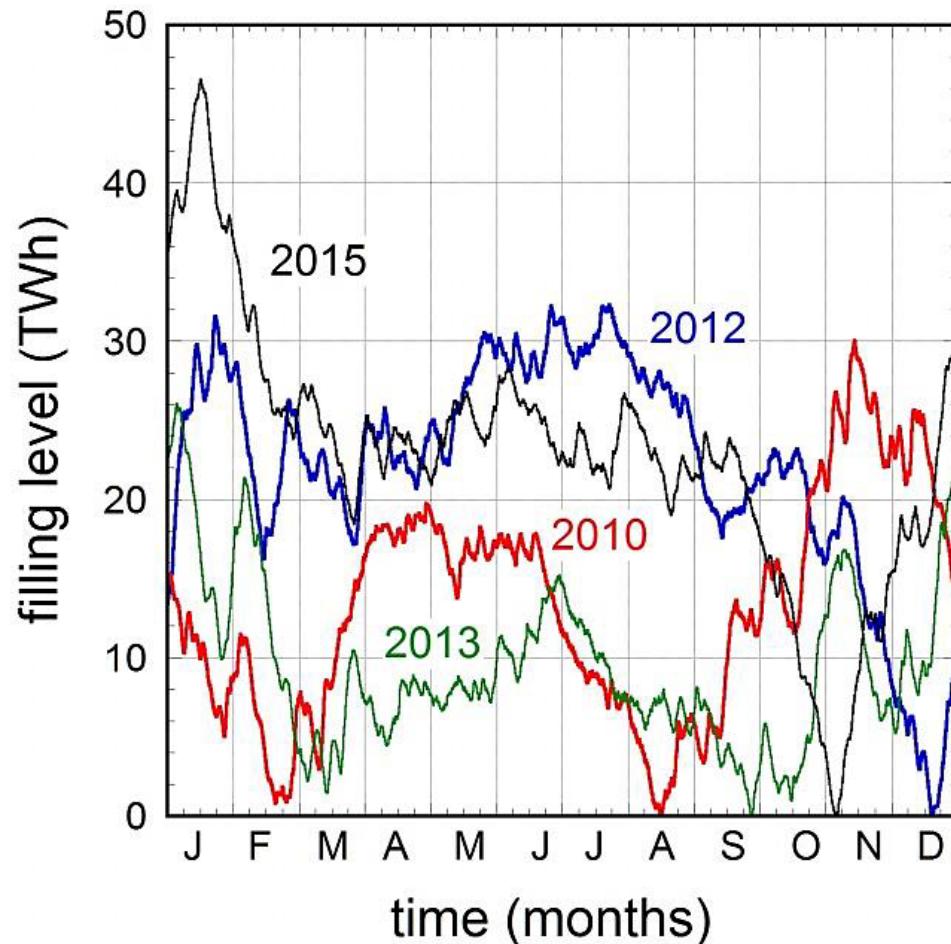


Source: F.Wagner, "Surplus from and storage of electricity generated by intermittent sources"
Eur.Phys.Journal Plus, **131**, 445 (2016)

Seasonal storage: ideal case without losses

73

Storage capacity needs to be well dimensioned
Large yearly variations (50%)



Estimated (minimal) seasonal storage capacity varies by 50%:

26 TWh (2013) $\leftrightarrow$ 46 TWh (2015)

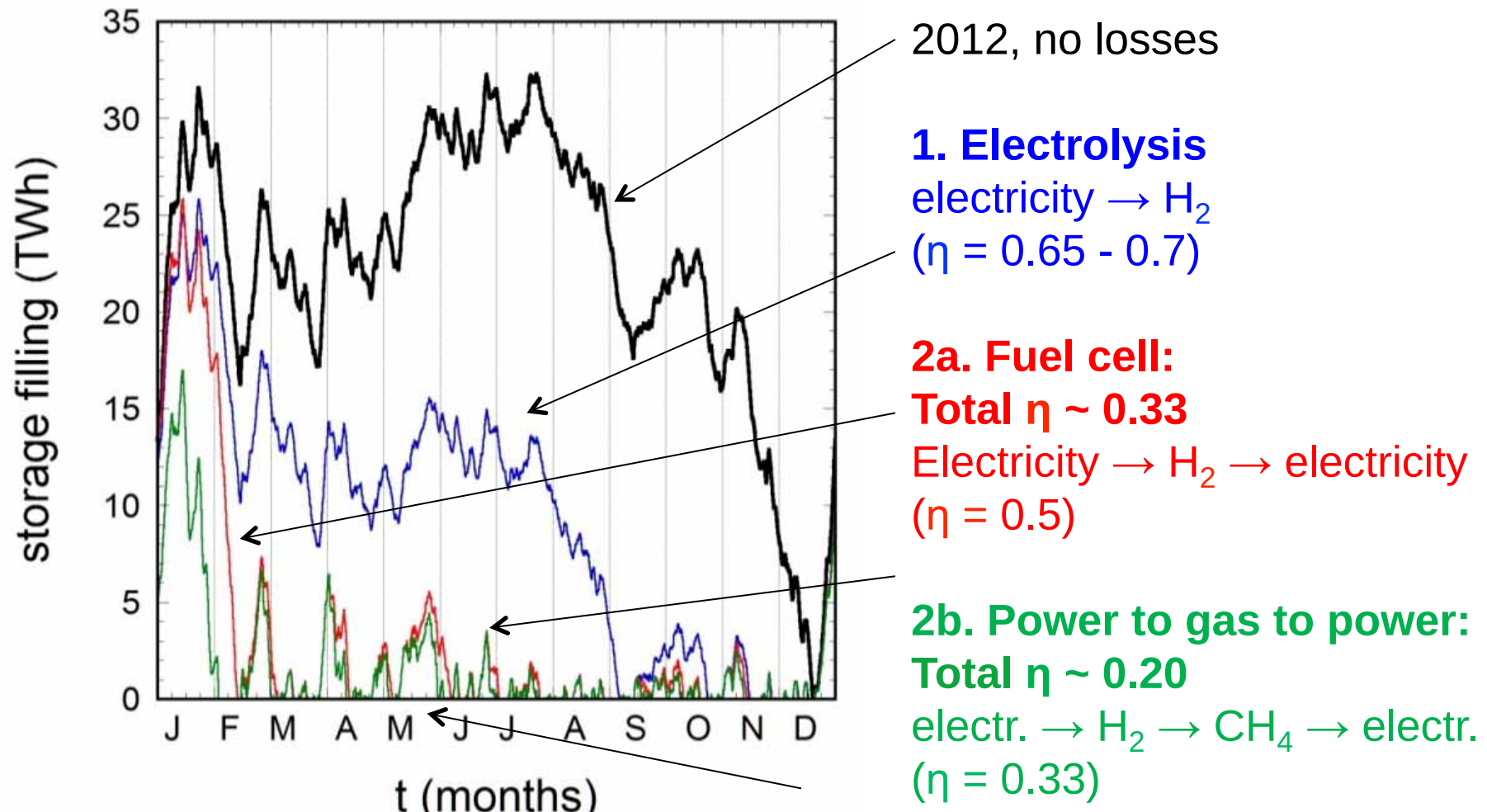
But runs out near end of year ...

Source: F.Wagner, "Surplus from and storage of electricity generated by intermittent sources"
Eur.Phys.Journal Plus, **131**, 445 (2016)

Seasonal storage: real case including losses

74

Conversion losses strongly reduce storage capacity



Including losses: seasonal storage transforms into „burst“ operation
Quality of thermal generation or worse
~1 kWh output from ~3 kWh input

2. Li batteries to store excess electricity?

Suppose to provide missing electrical energy (45.6TWh)
only for Germany and only for Jan 2019

Elon Musk Li-battery in Australia



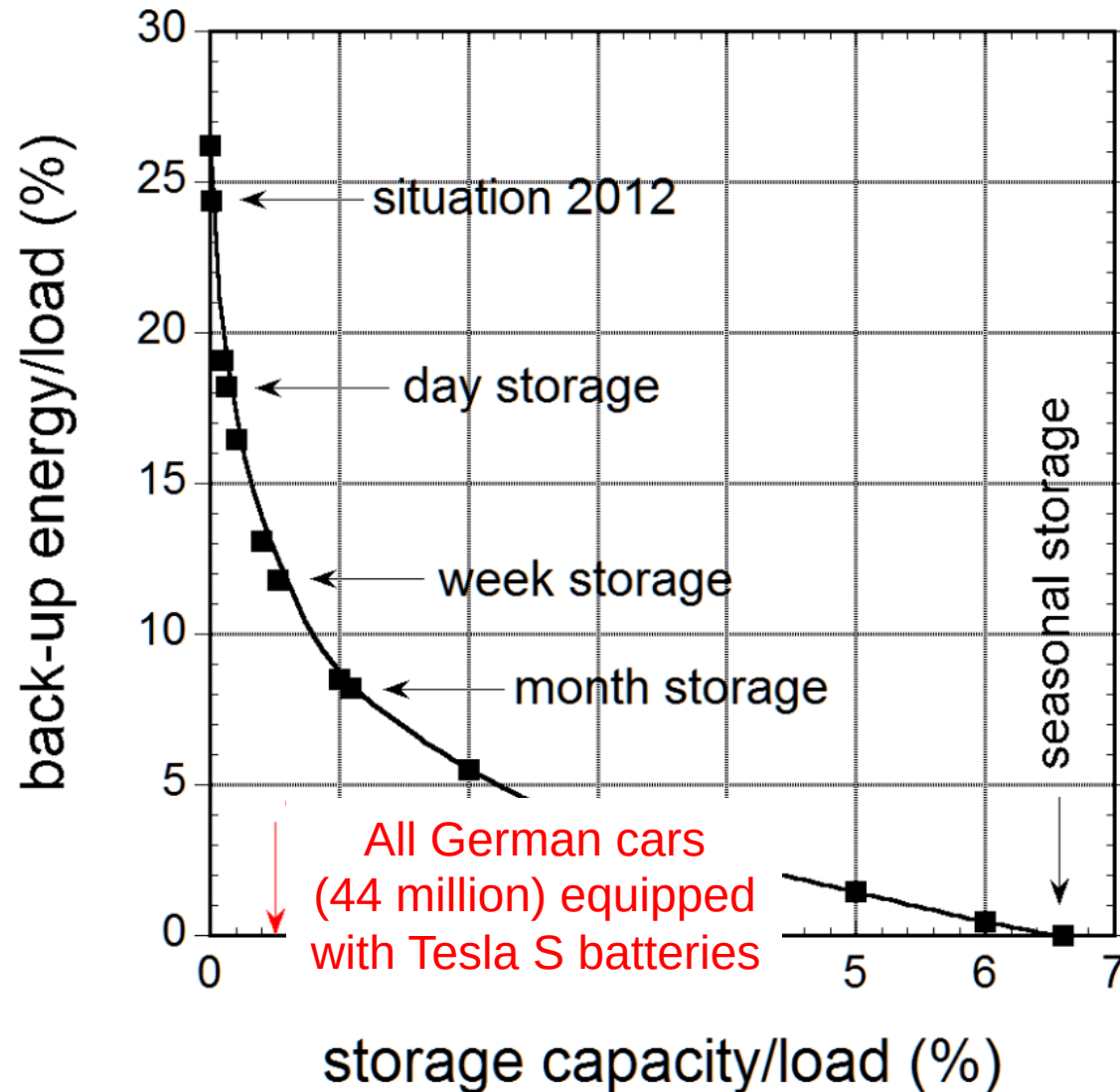
~353 000 such batteries (~ size of one football field).

Lifetime ~ 10 year ? Fire hazard? Cost ! Amount of Li ?

Can be optimized, but gives a good impression of investment

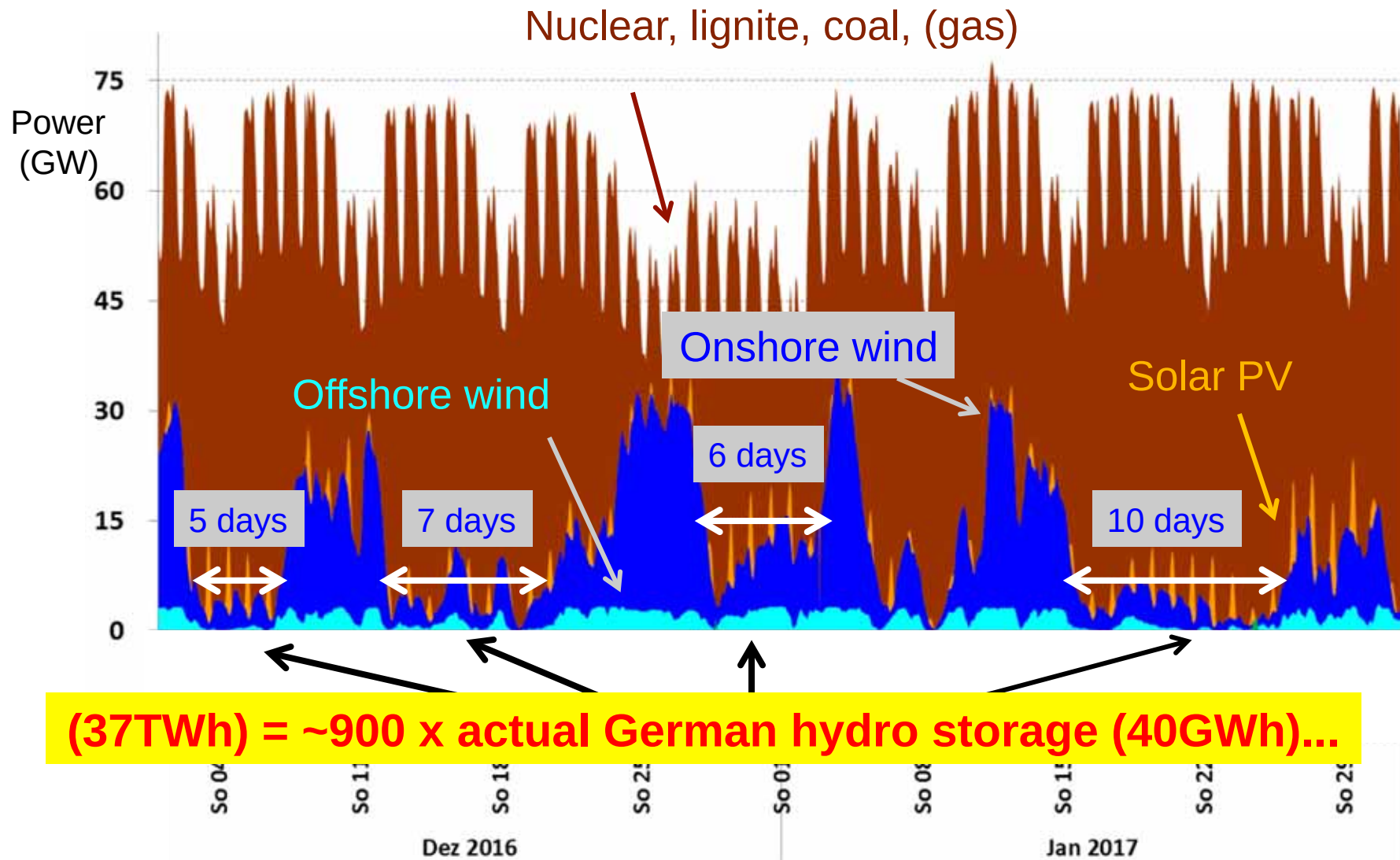
All cars in the plug ?

No conversion losses considered



Source: F.Wagner, "Surplus from and storage of electricity generated by intermittent sources"
Eur.Phys.Journal Plus, **131**, 445 (2016)

3. Hydro storage ? (Pumped storage, dams, lakes...)?



(37TWh) = ~900 x actual German hydro storage (40GWh)...

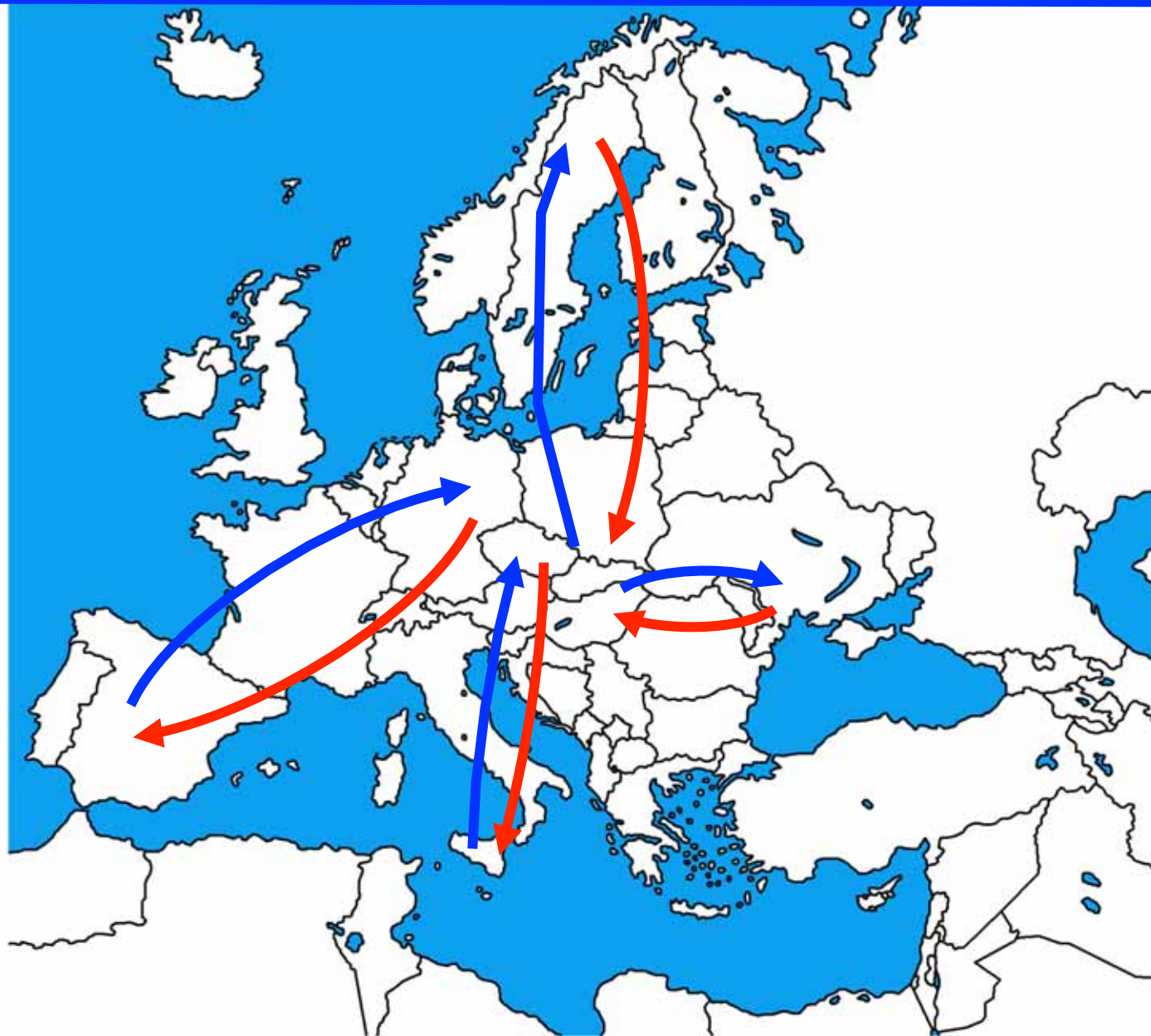
Discussion

Storage of large volumes of electrical energy is not simple

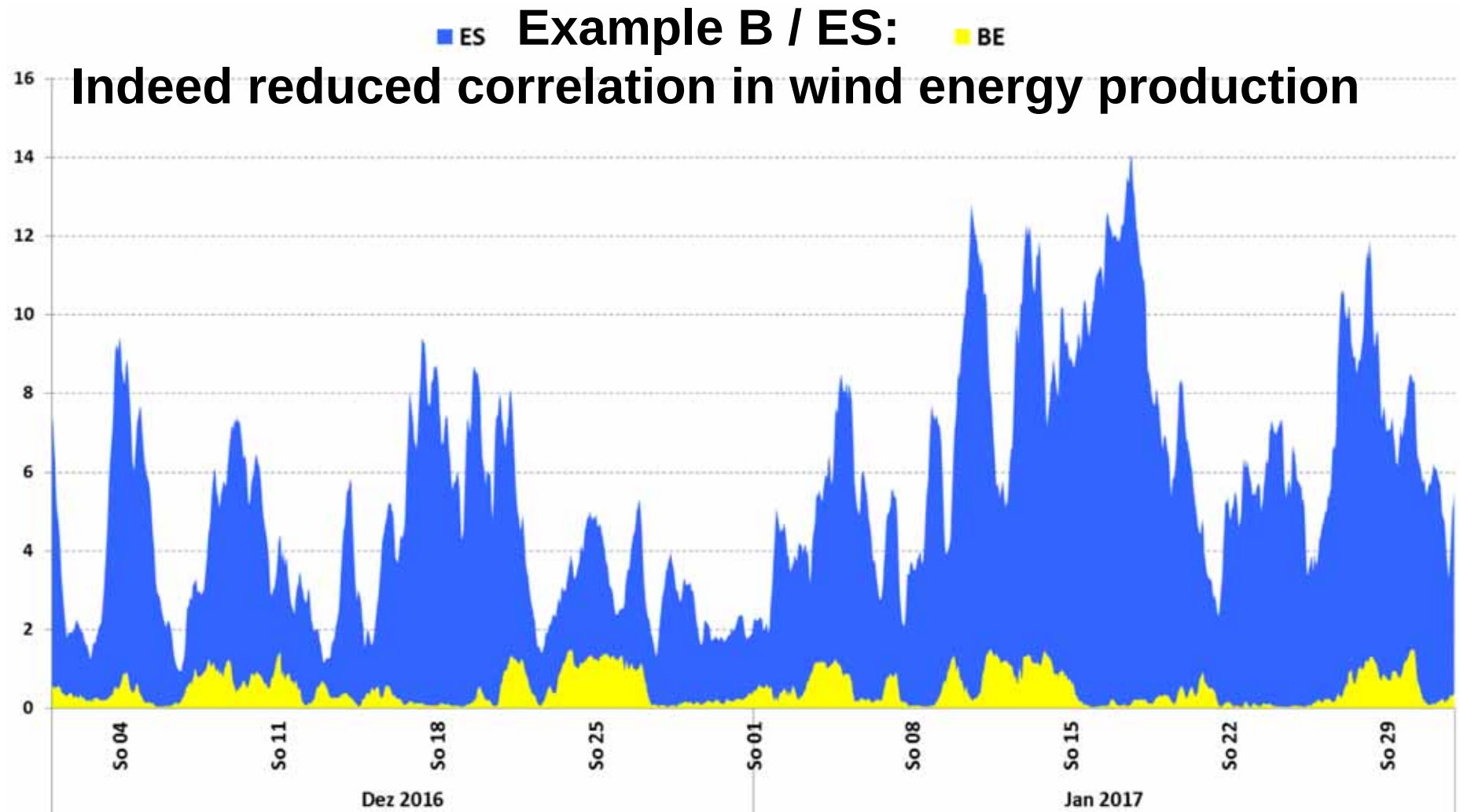
How to avoid large fluctuations (and thus reduce storage needs)?

- 1. Averaging over Europe?**
- 2. Export / Import excess energy?**
 - Many countries have simultaneous excesses or shortages of solar+wind as anticyclones/ depressions cover most of the time many EU countries simultaneously**
- 3. Switch off solar PV or windturbines ?**
 - strongly reduced efficiency...**
- 4. 'Smart' systems?**
 - Irregular use ... → reduced practicability ?**

4. Exchange of renewable (wind) power everywhere in EU? (over 1000's of km and capacities of 100's of GW)

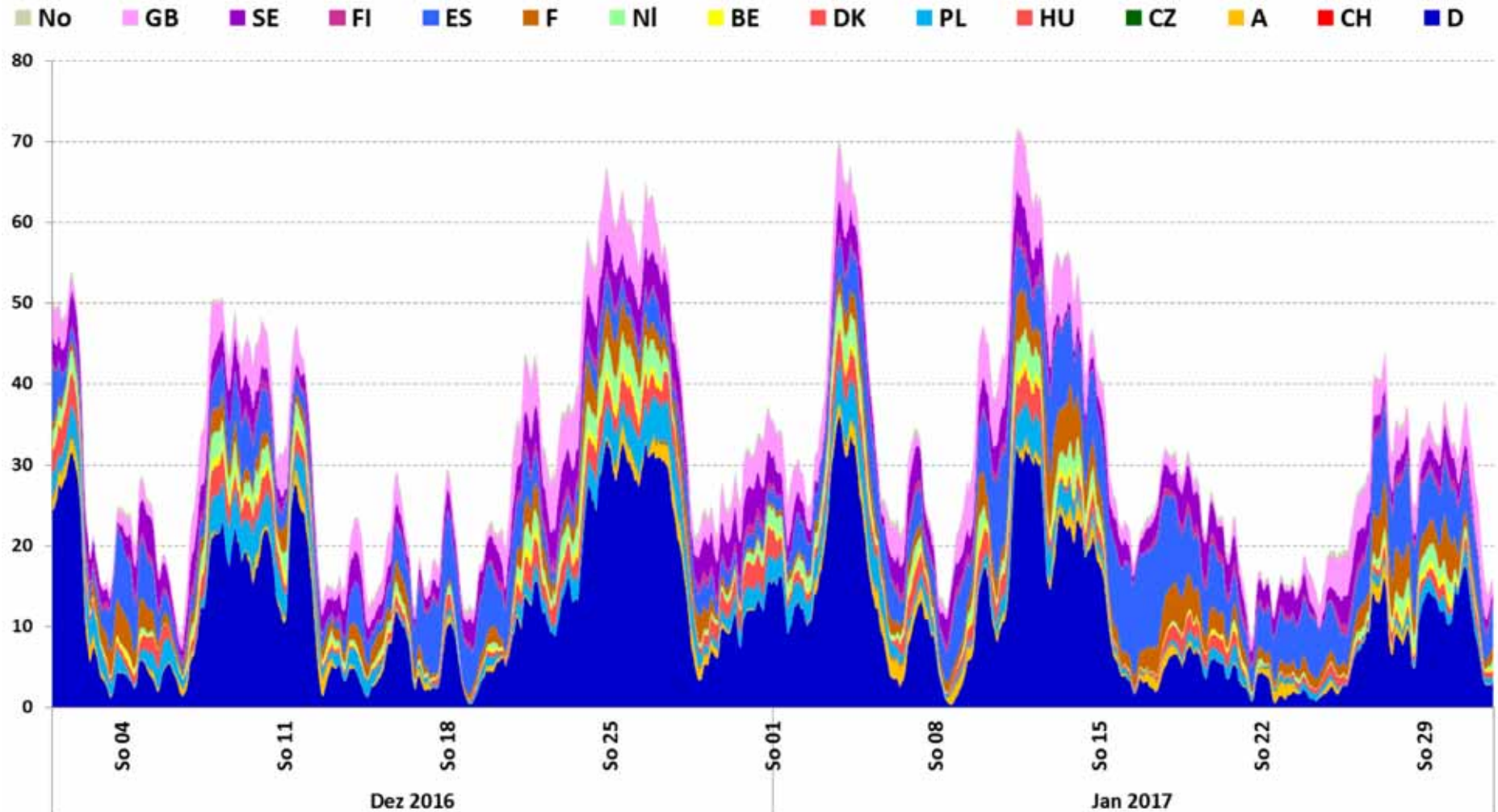


4. Averaging of power production using windturbines everywhere in EU?



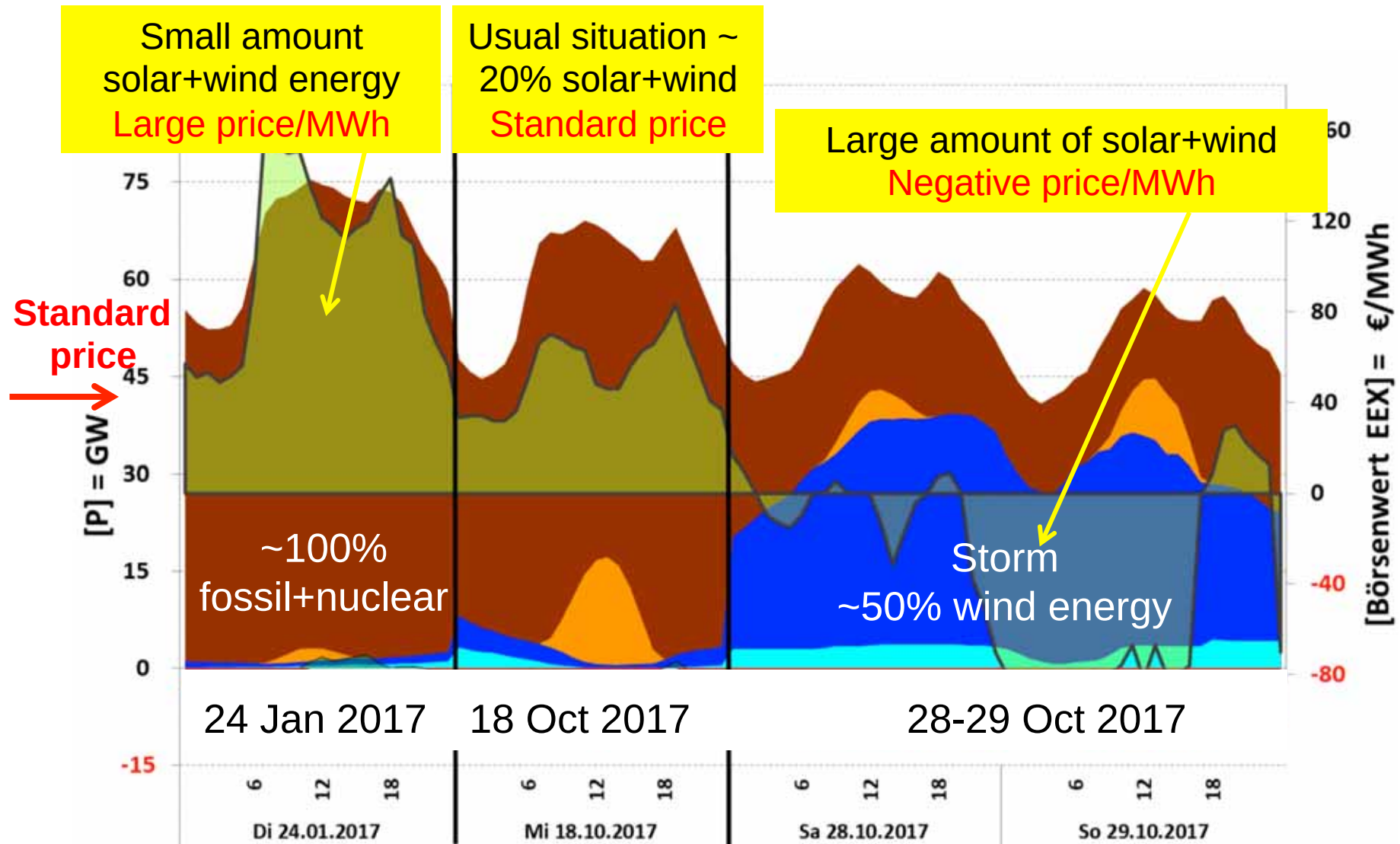
4. Averaging of power production using windturbines everywhere in EU?

Wind energy – summed over all EU countries
(Dec 2016 – Jan 2017)



No real averaging... not the miracle solution neither...

Export/Import costs in Germany



The difference with market price in those 2 october days integrates to **63 million Euros...**

Discussion

Storage of large quantities of electrical energy is not simple

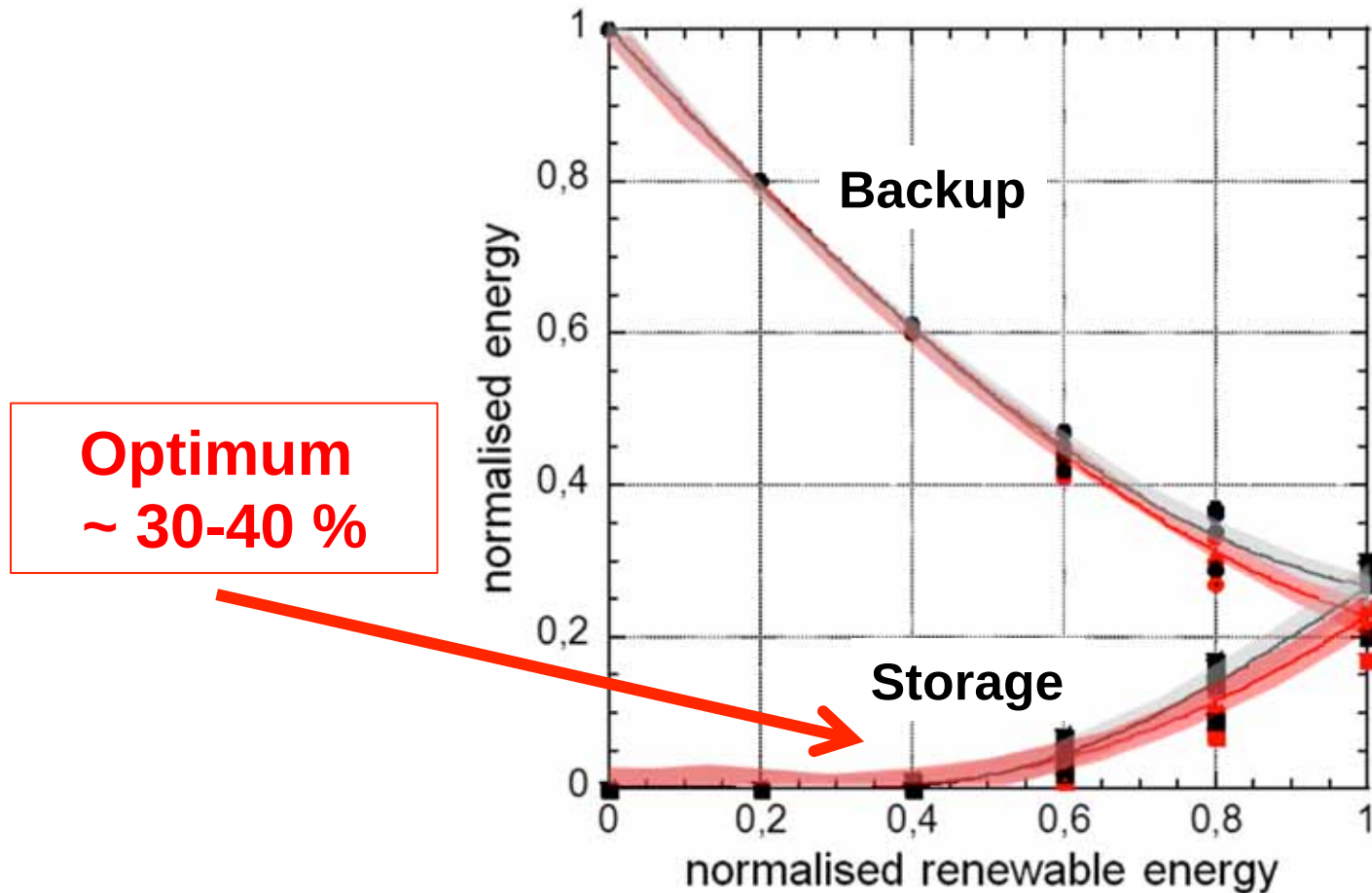
1. Reducing by 100% CO₂ emissions in the electricity sector with 100% renewable energy (dominated by intermittent solar+wind), needs unrealistically large storage capacities.
2. Such a system needs to be complemented by
now: nuclear, fossil + Carbon Capture and Storage (CCS) , ... ?
future : fusion, thorium reactors generation IV or V, geothermal..?

Acceptance of CCS ?



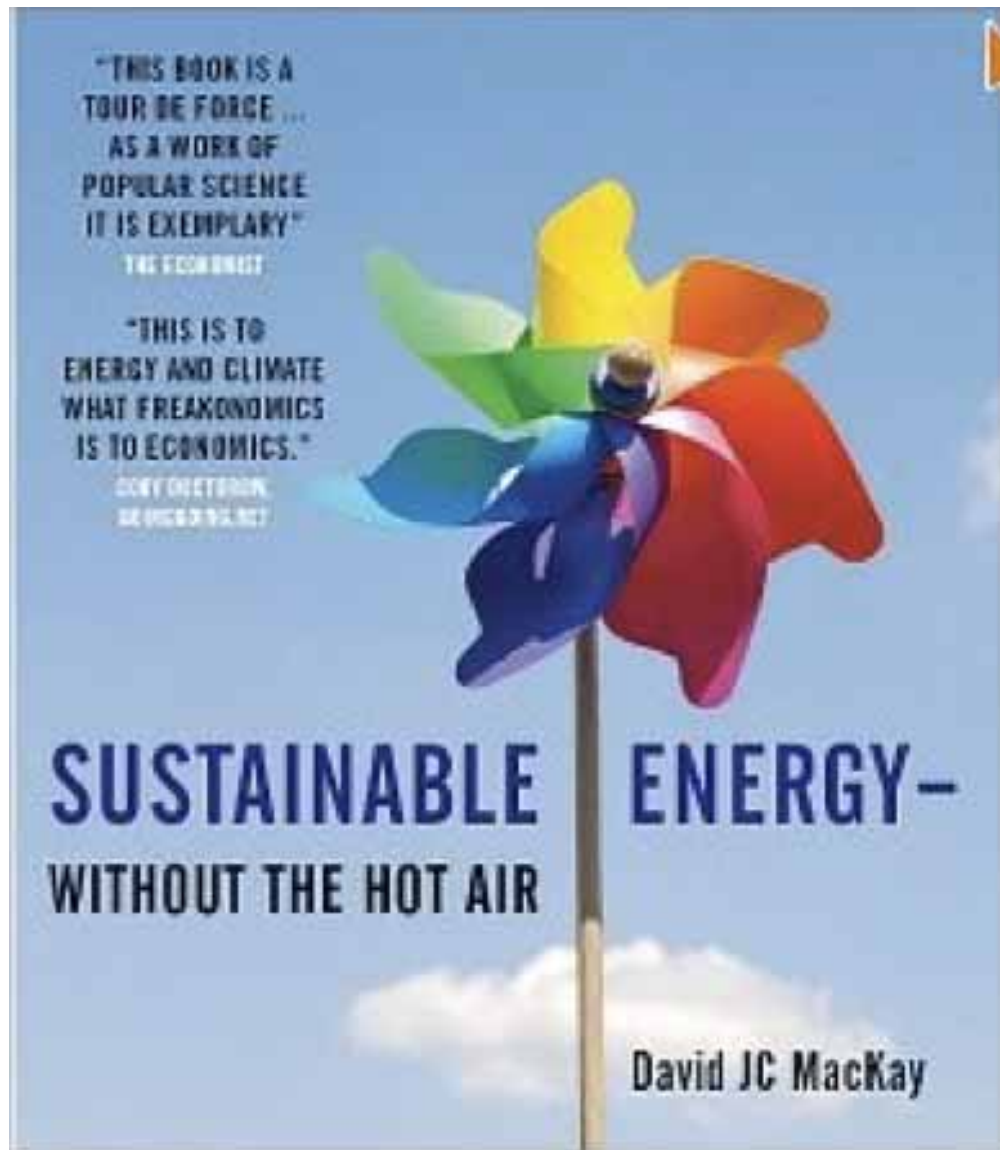
5. Limit solar PV + wind to 30-40%

Size of backup and storage as a function of solar+wind produced energy



Source: F.Wagner, "Surplus from and storage of electricity generated by intermittent sources"
Eur.Phys.Journal Plus, **131**, 445 (2016)

A must for everyone interested in energy systems



David JC MacKay

Professor, Department of Physics,
University of Cambridge

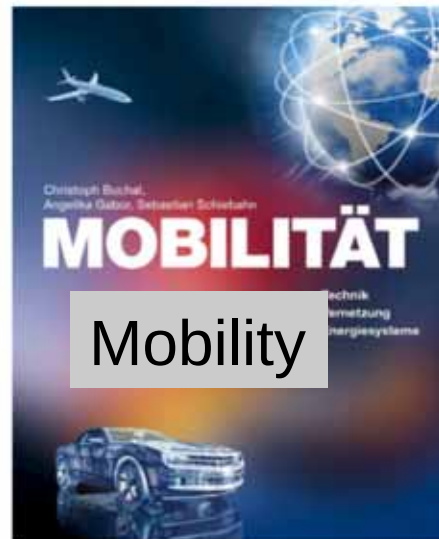
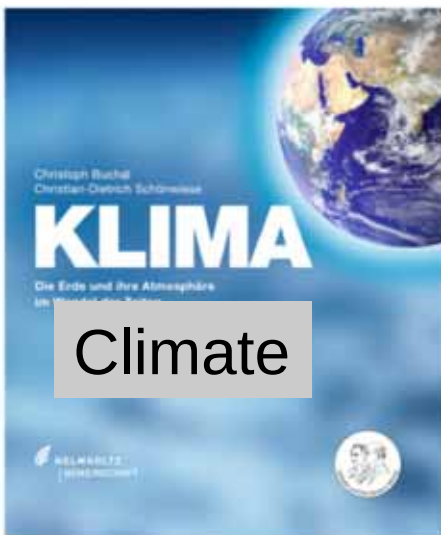
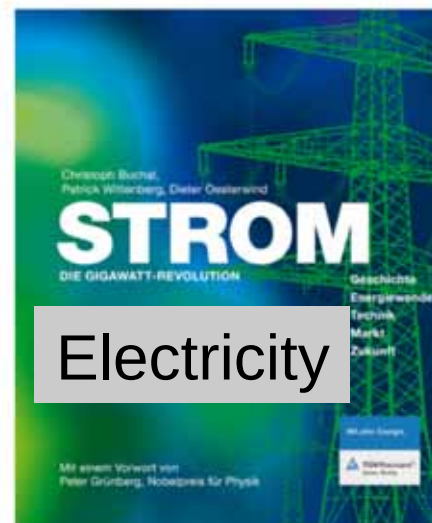
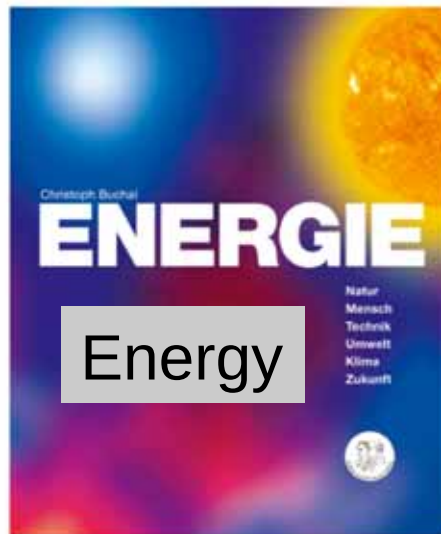
Former Chief Scientific Adviser at the
UK Department of Energy and Climate
Change

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Very well documented study books (only in German for now)

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Physics,
University of Köln
and Forschungszentrum Juelich

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Very harsh but to the point criticisms by Prof. H.Sinn

Ludwig-Maximilian University in München

Talk on-line: “Wie viel Zappelstrom verträgt das Netz?”

See:

<http://mediathek.cesifo-group.de/iptv/player/macros/cesifo/mediathek>

and **associated paper:**

European Economic Review 99 (2017) 130–150



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Hans-Werner Sinn

CESifo and Ludwig-Maximilian University of Munich, Germany



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Friedrich Wagner

Eur. Phys. J. Plus, 131 12 (2016) 445

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F. Wagner and F. Wertz

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Towards 50% wind electricity in Denmark: Dilemmas and challenges

Paul-Frederik Bach

Eur. Phys. J. Plus, 131 5 (2016) 161

Published online: 24 May 2016

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[Abstract](#) | [PDF \(2.74 MB\)](#)



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Strategies for the integration of intermittent renewable energy sources in the electrical system

Francesco Romanelli

Eur. Phys. J. Plus, 131 3 (2016) 53

Published online: 02 March 2016

DOI: 10.1140/epjp/i2016-16053-3

[Abstract](#) | [PDF \(1.79 MB\)](#)

CONCLUSIONS

1. Do not hastily put 'something' together – it fires back
2. Reasonable aims – 30-40% of (solar PV+ wind) electrical energy

At the longer term:

- Always take into account all 3 energy options (i.e. also the nuclear option)
- Massive investments in R&D of new techniques needed (generation IV, thorium, fusion, batteries, CCS, geothermal energy,...)
- Minimise world population increase (education, improve standards of living,...)

**REALIZING THE ENERGY TRANSITION IS NOT FOR
TOMORROW...**

CONCLUSIONS

1. If the aim stays to produce 100% CO₂ free electricity
2. AND the storage problem cannot be satisfactorily solved

- Then nuclear energy is unavoidable
- Fossil and/or CCS ? But there are also risks...
(and... it supposes burning finite fossil fuel reserves...)
- Otherwise: strong dependence of society on weather
 - ➔ difficulty to organise work (weekend ?, holidays ?)
 - ➔ back to the Neanderthal era... ?

Not simple to wind back 200 last years in energy developments – keeping the same comfort !

