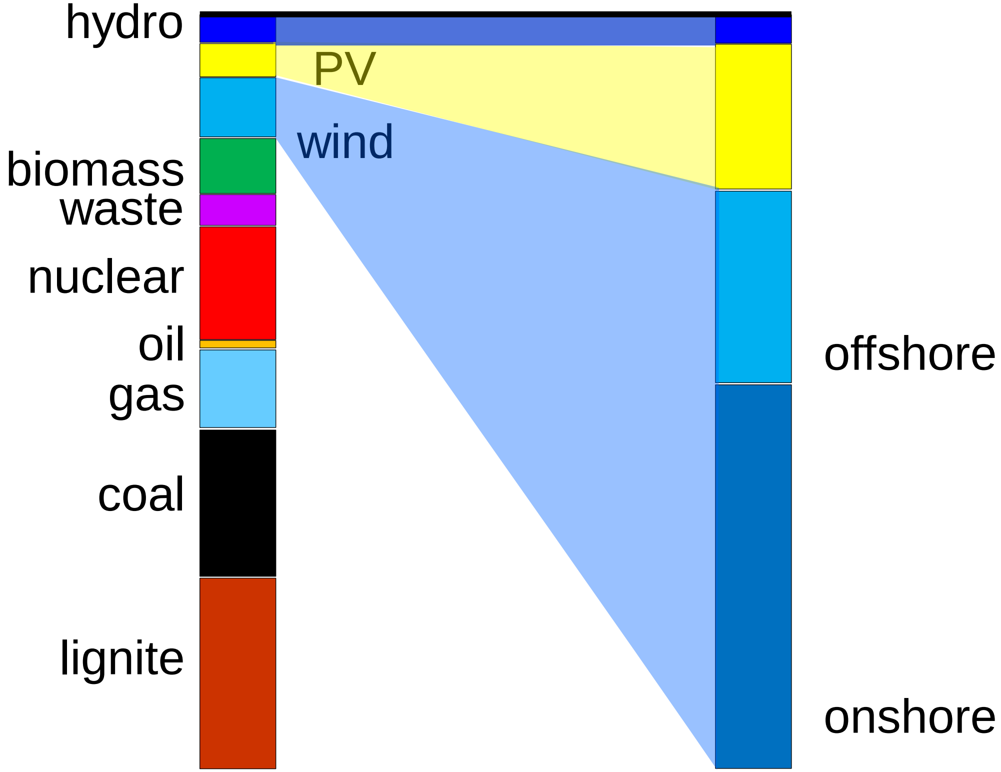
Surplus electricity and storage under conditions of intermittent supply

Friedrich Wagner
Max Planck Institut für Plasmaphysik, Greifswald, Germany

today: 520 TWh end energy



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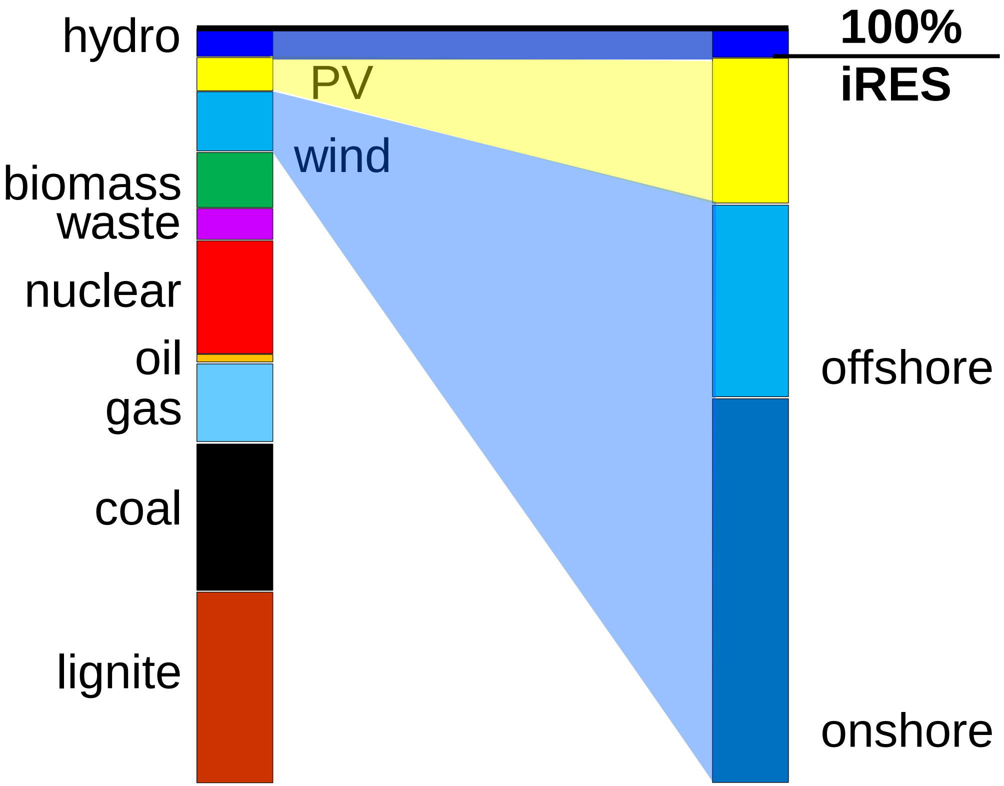

Extrapolation and assumptions

500 TWh =100%-case produced by iRES

hydro limited to 20 TWh

no nuclear power

no bio-gas (at present: 50TWh)

no export, import

wind and PV ratio: optimal mix

1. analysis step: **no losses**

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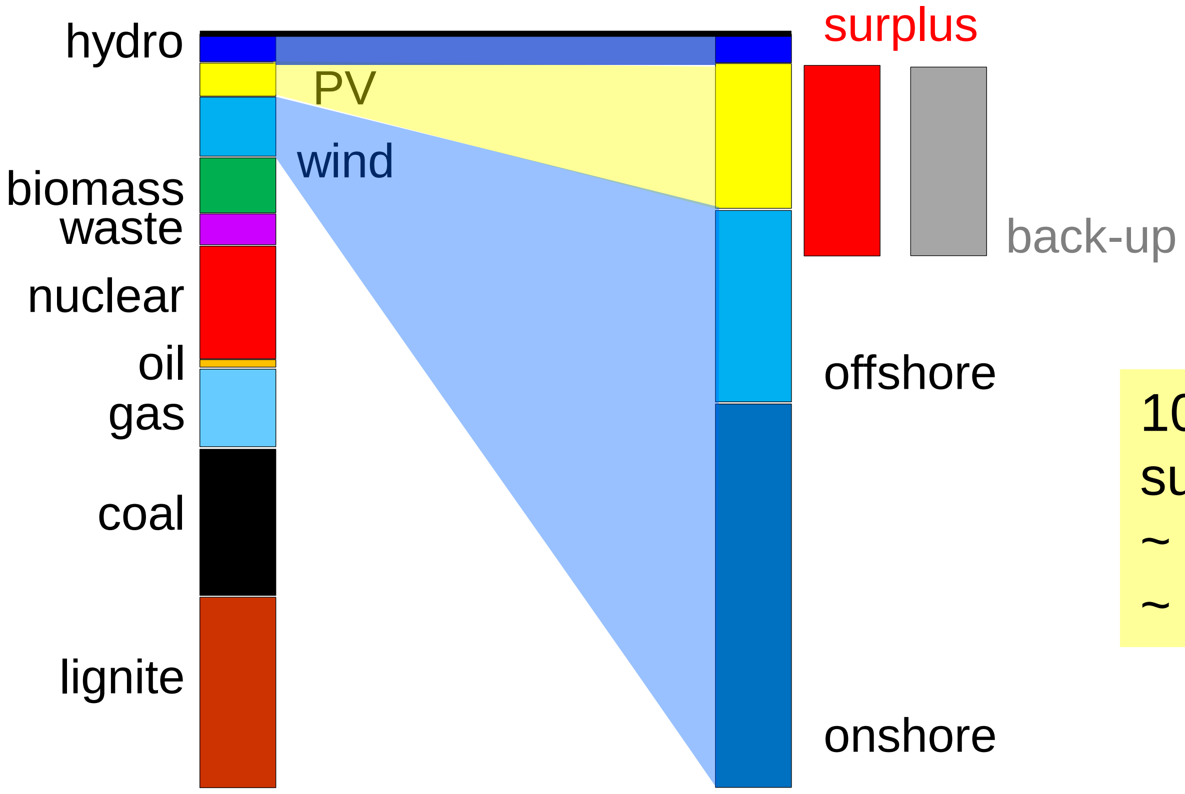
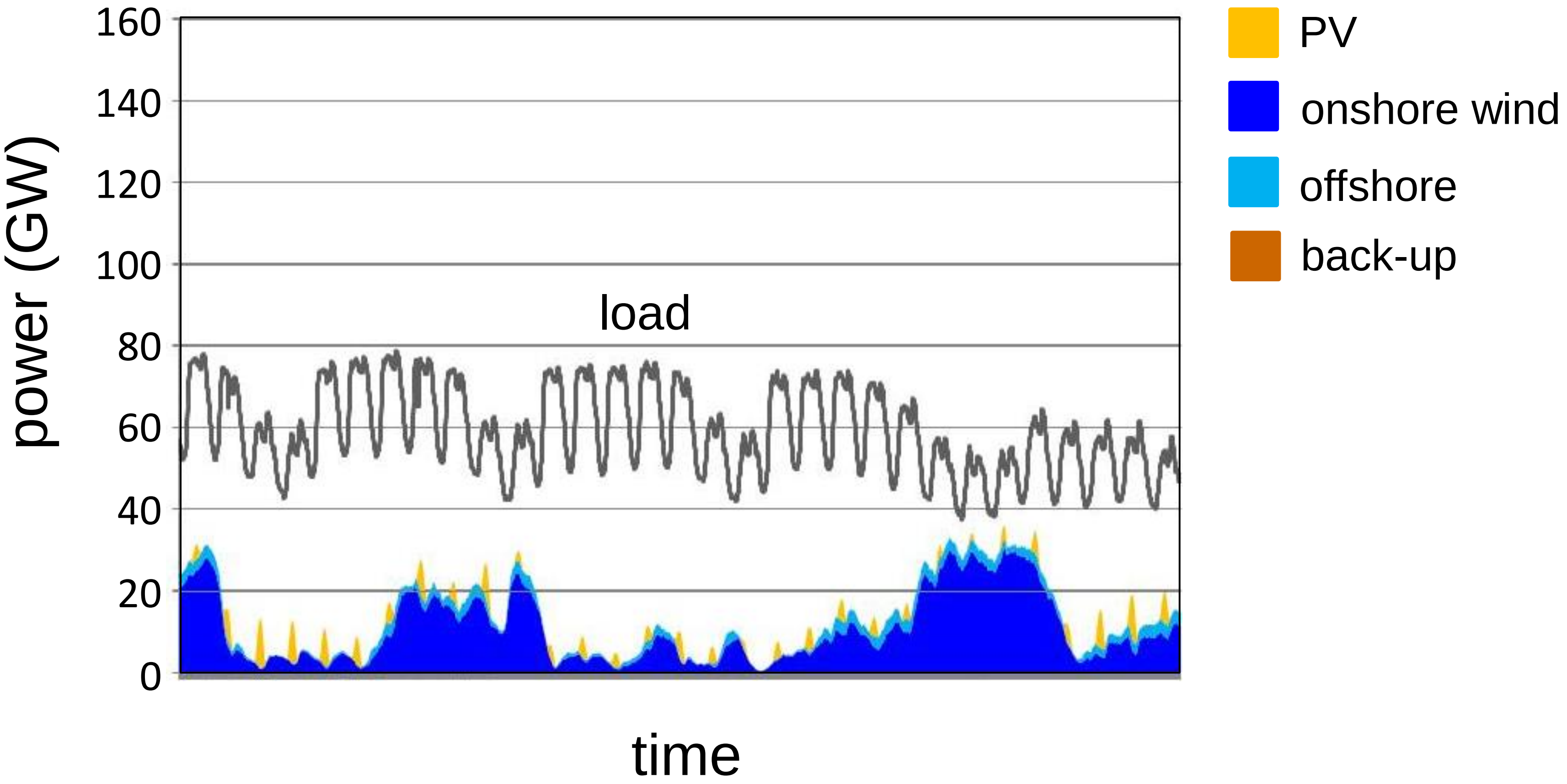


100% case:
surplus = back-up energy
~ 25% of total generation
~ 125 TWh

December 2016: back-up in action

Original data during a long-lasting high-pressure area with inversion layer



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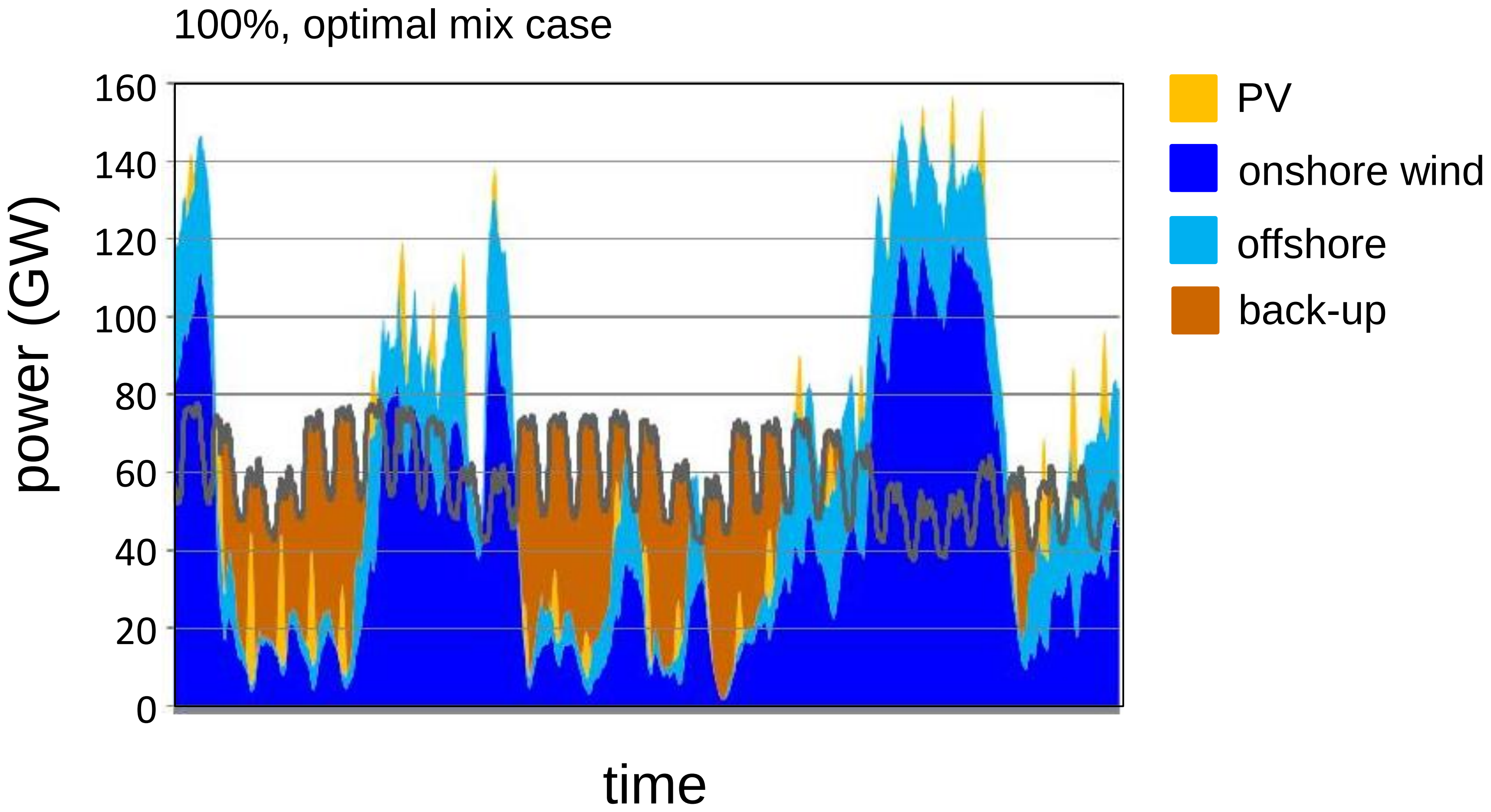
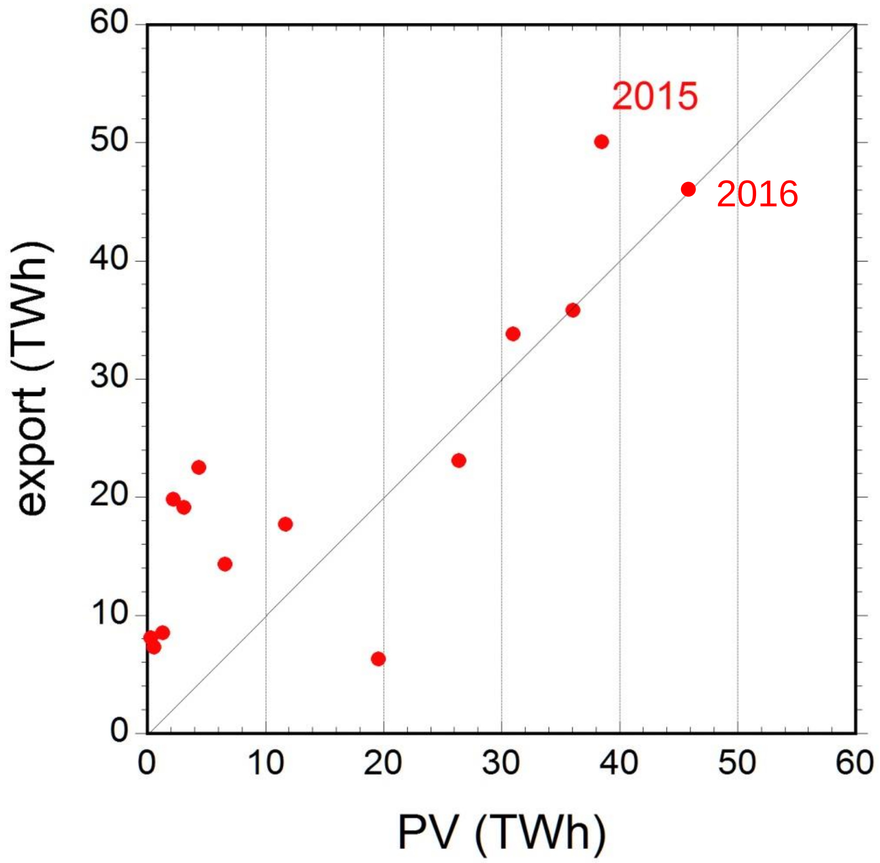


44 TWh needed ; 12.3 TWh from back-up

Surplus production today



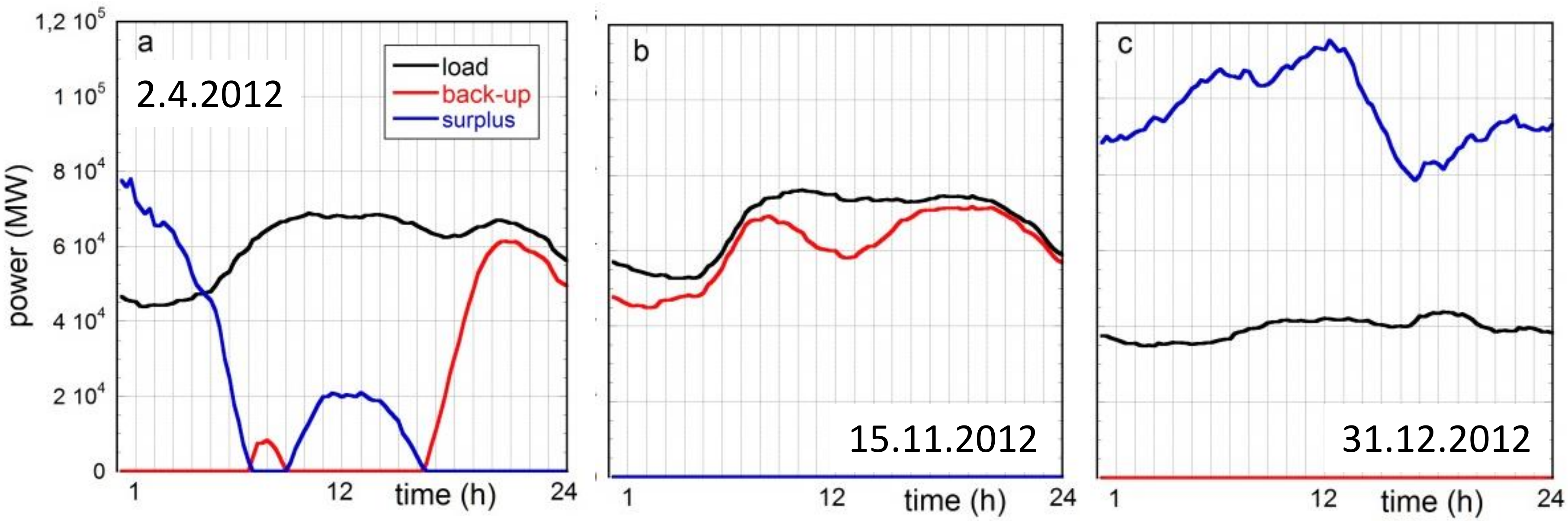
Today:

The electricity export strongly increases and agrees **nominally** with the PV energy generated

Scenarios for using surplus

100%, optimal mix case

day with highest transfer | highest back-up need | largest surplus



Quantitatively:

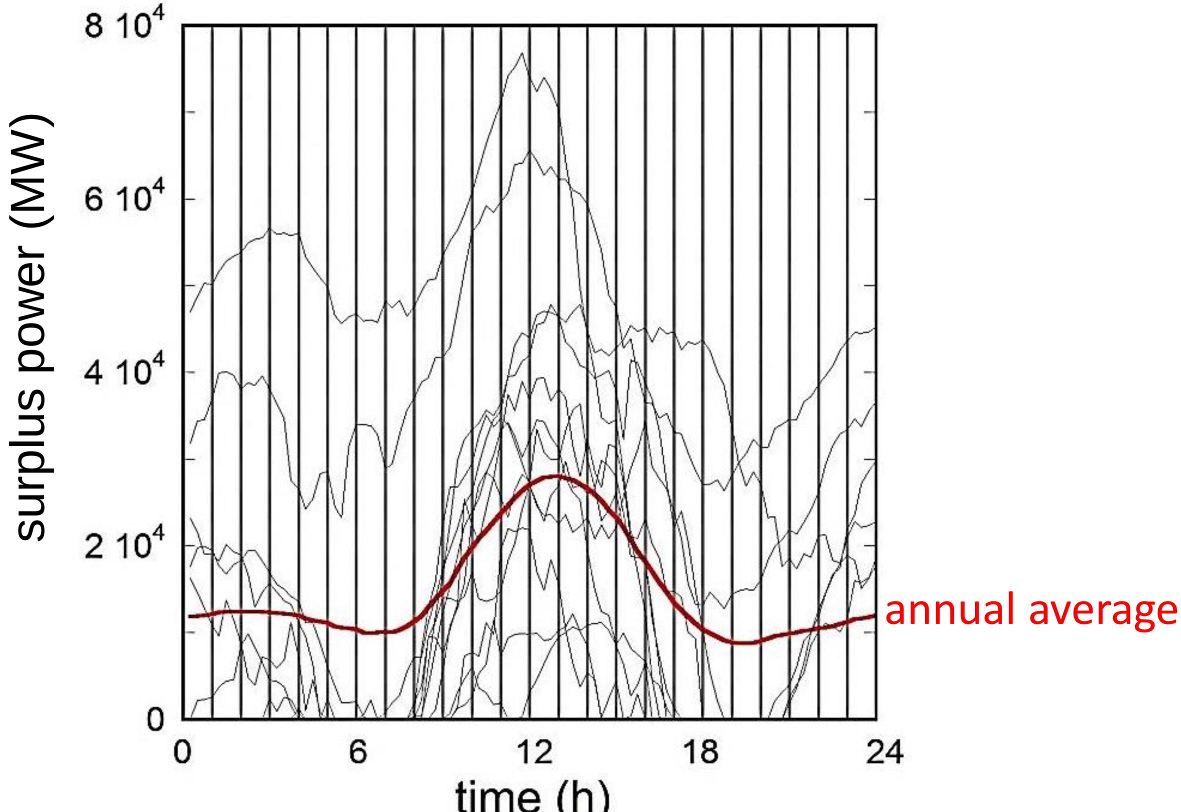
average daily need: 1.36 TWh

day with highest transfer	highest back-up need	largest surplus
0.47 TWh surplus	0 TWh surplus	2.33 TWh surplus
0.37 TWh back-up	1.47 TWh back-up	0 TWh back-up

Demand-side management

44 TWh could be transferred from surplus to demand periods
BUT: strong variation of surplus power
No surplus for 134 days

surplus power for the 100%, optimal mix case for 21 days in April 2012

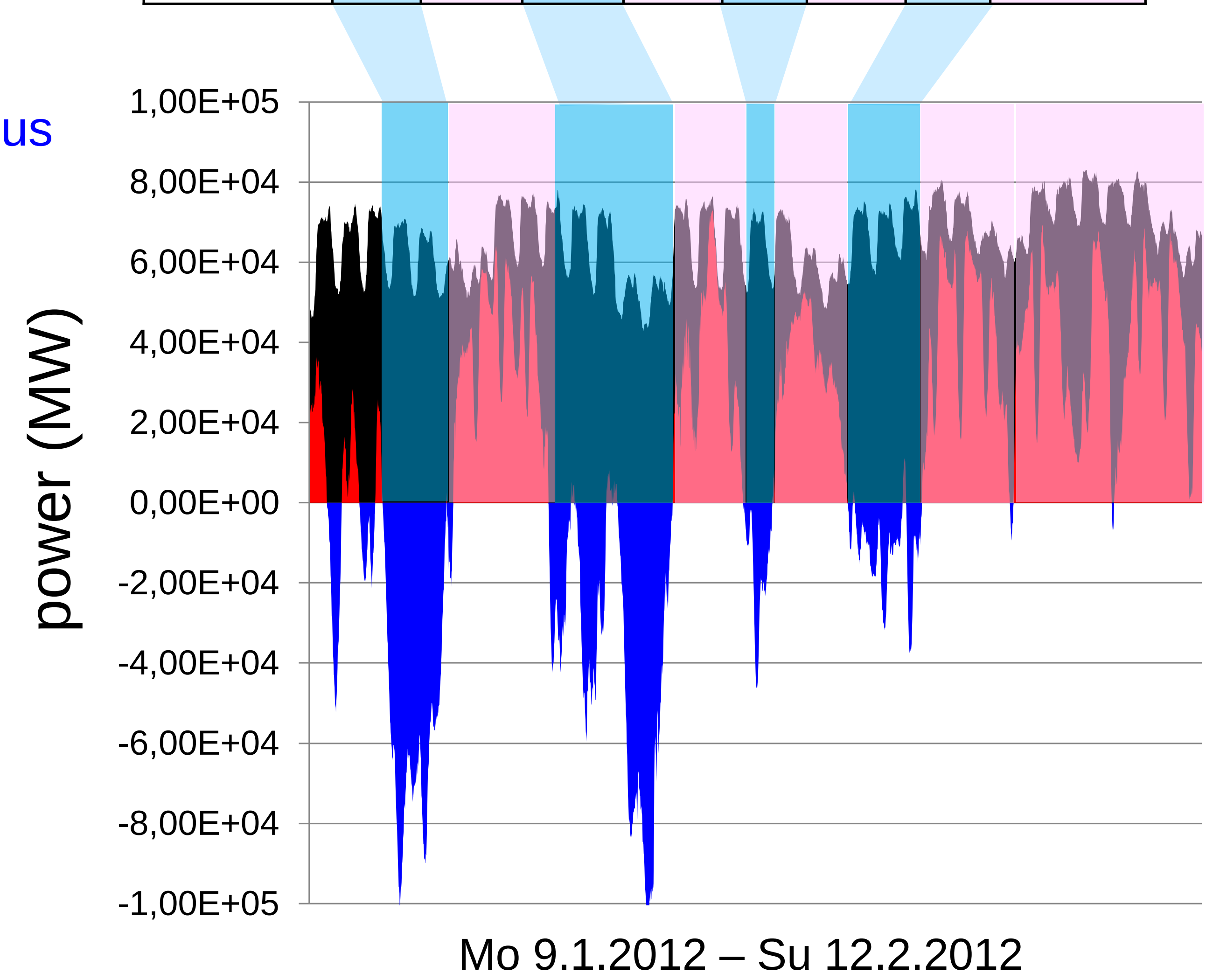


Seasonal storage

100%, optimal mix case

black: load
red: back-up
blue, negative: surplus

h	66	90	117	67	27	71	70	264
TWh	3.7	-3.5	4.5	-2.5	0.5	-2,4	0.8	-10.4



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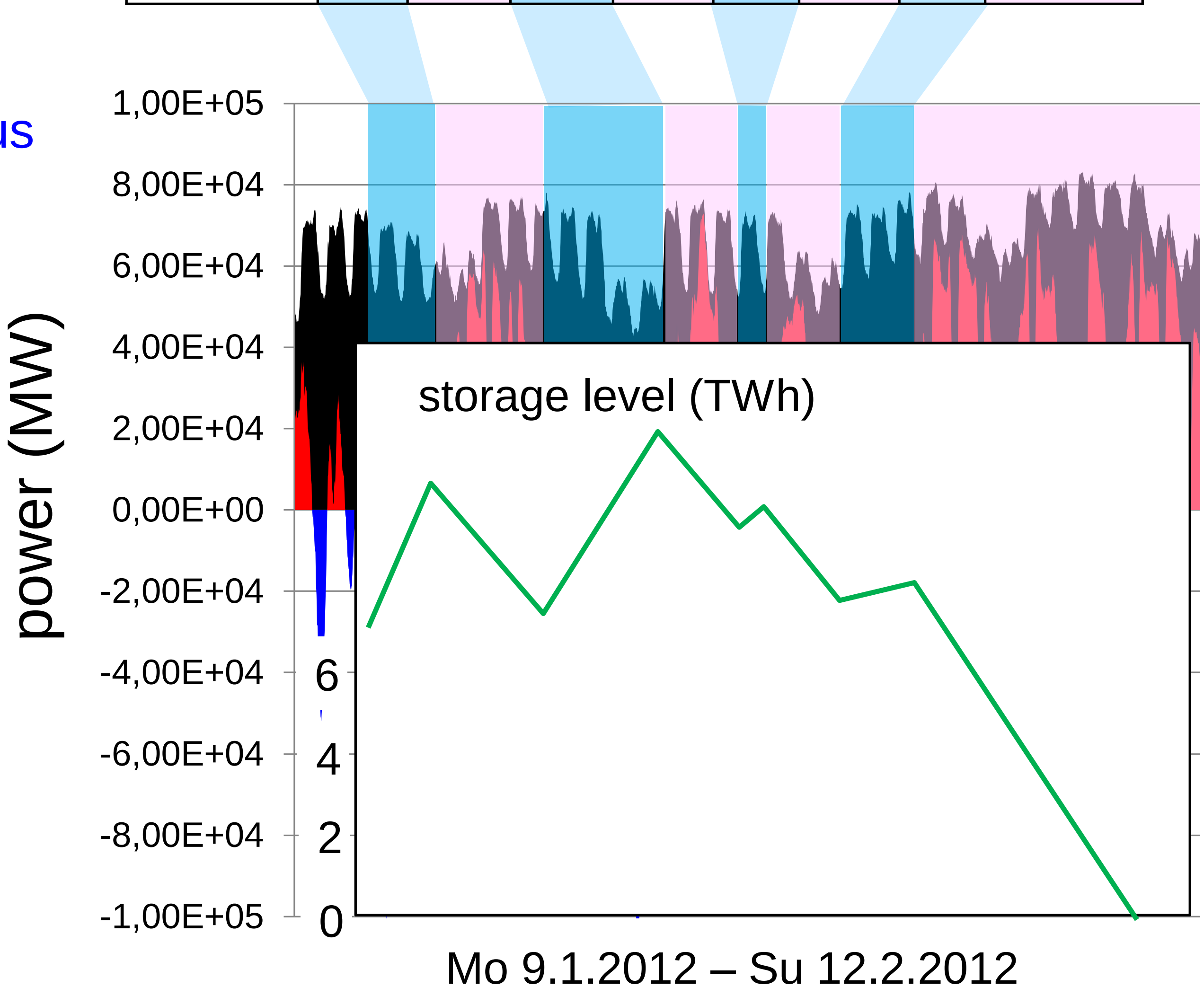
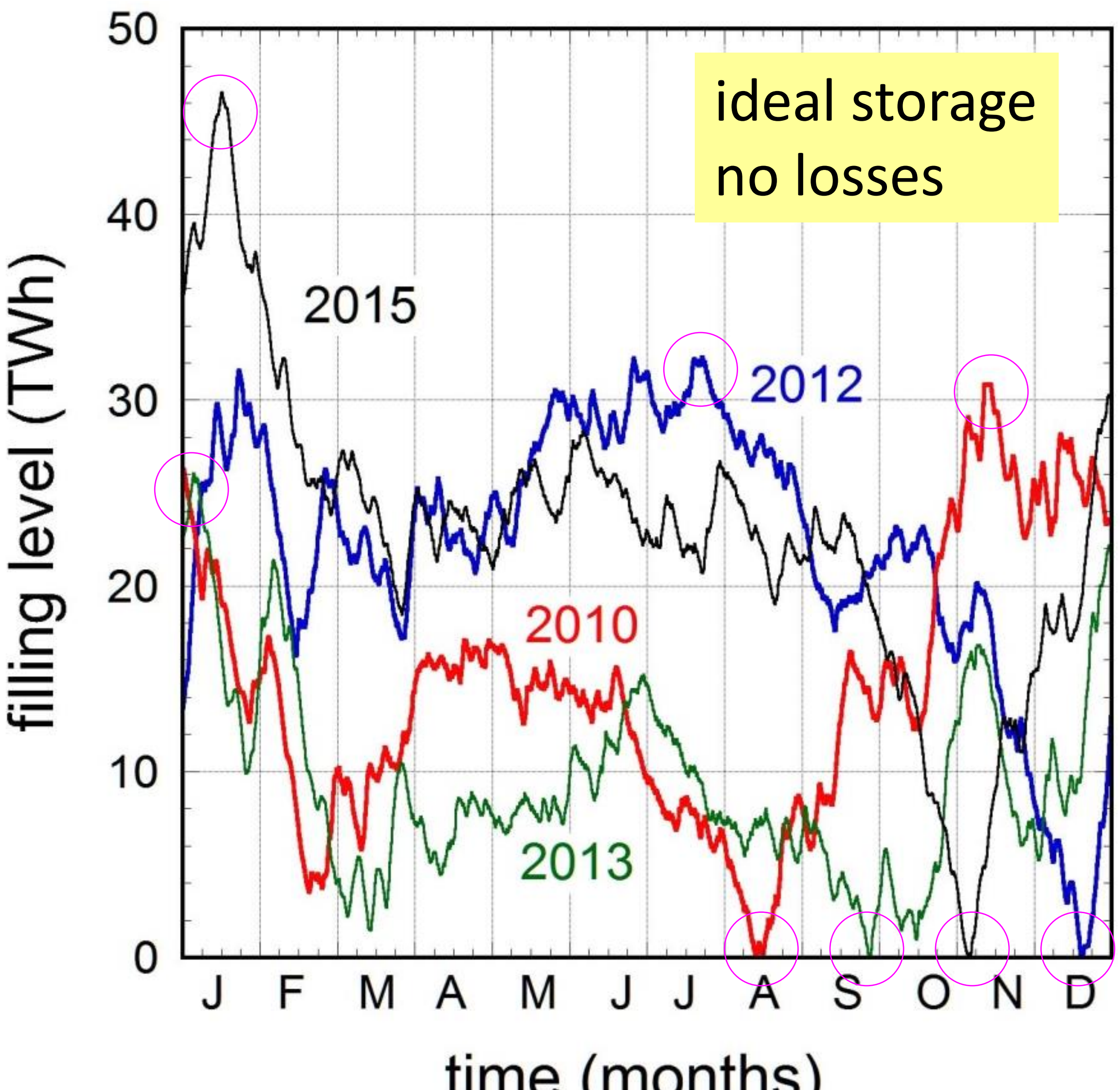


Variation from year to year



The effect of efficiencies

Assume: chemical storage and power-to-gas-to-power

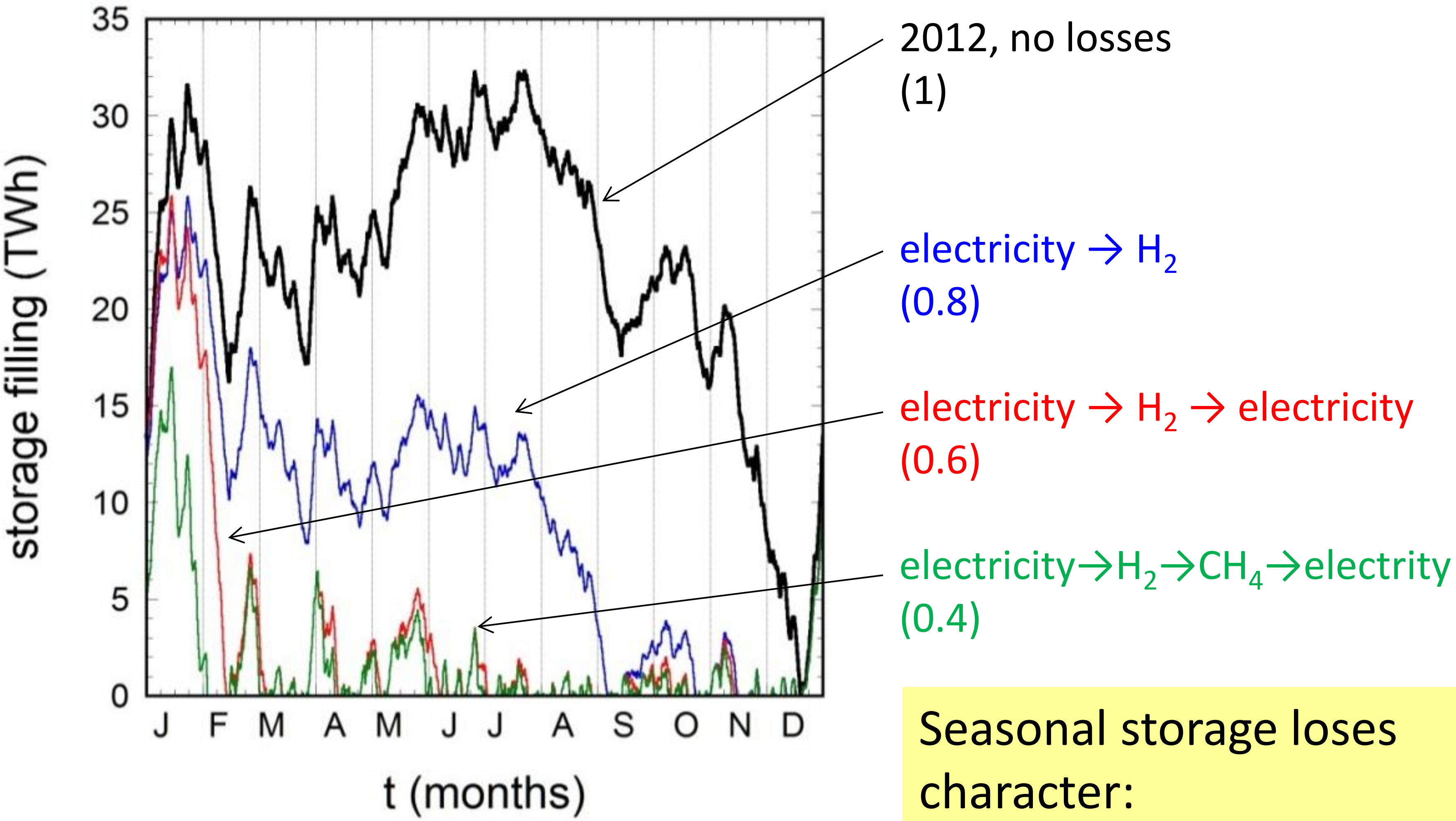
1. step: electrolysis with surplus: η ~ 0.65-0.7
2. step: electricity from H_2: η ~ 0.5 (fuel cell)

Alternatively
2. step: H_2 to CH_4: η ~ 0.65
3. step: CH_4 to electricity: η ~ 0.5

Total efficiencies: η ~ 0.2 – 0.35 → for 1 kWh output, 3 - 5 kWh input

From 131 TWh surplus, 25 - 45 TWh can be recovered

Transformation losses: power-to-gas



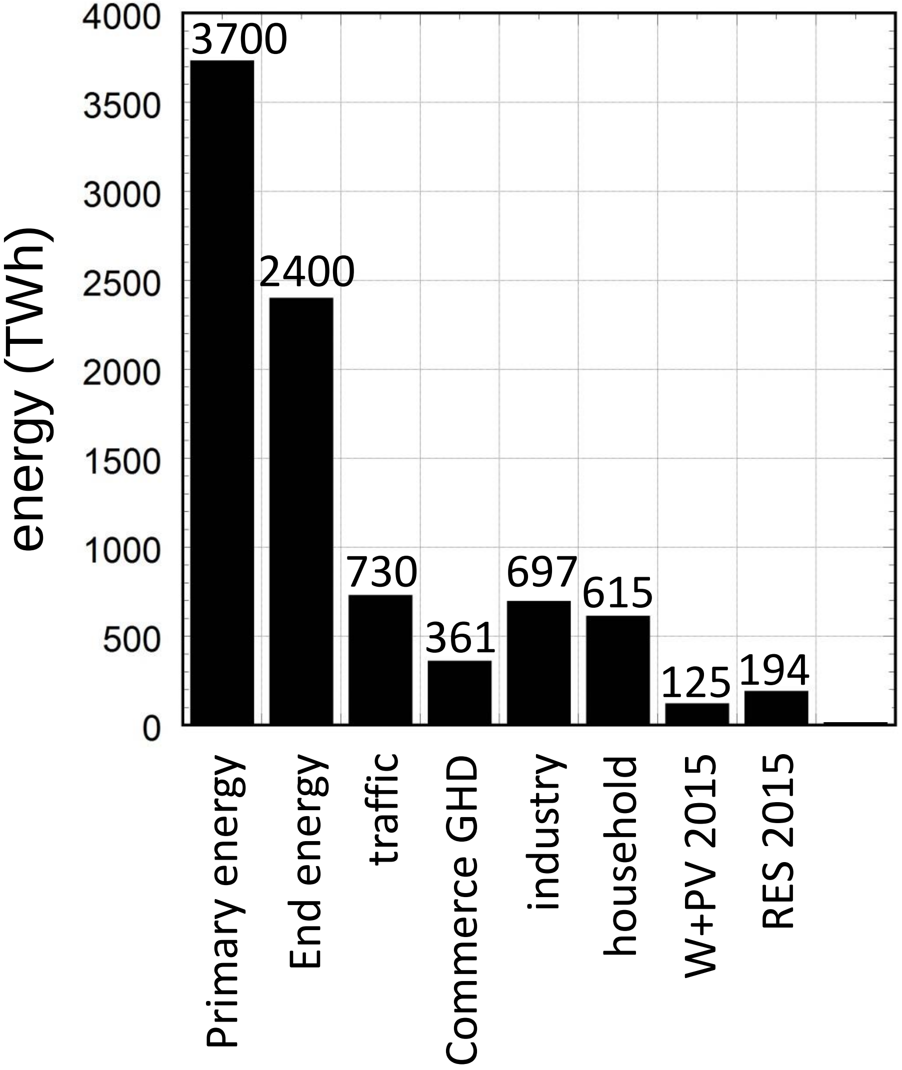
Seasonal storage loses character:
short operational periods after bursts of surplus

Conclusion #1

I doubt

- that a 100% electricity supply by iRES is possible
- that p-t-g with storage for closing the electricity loop is feasible

sector-coupling: electricity as primary energy



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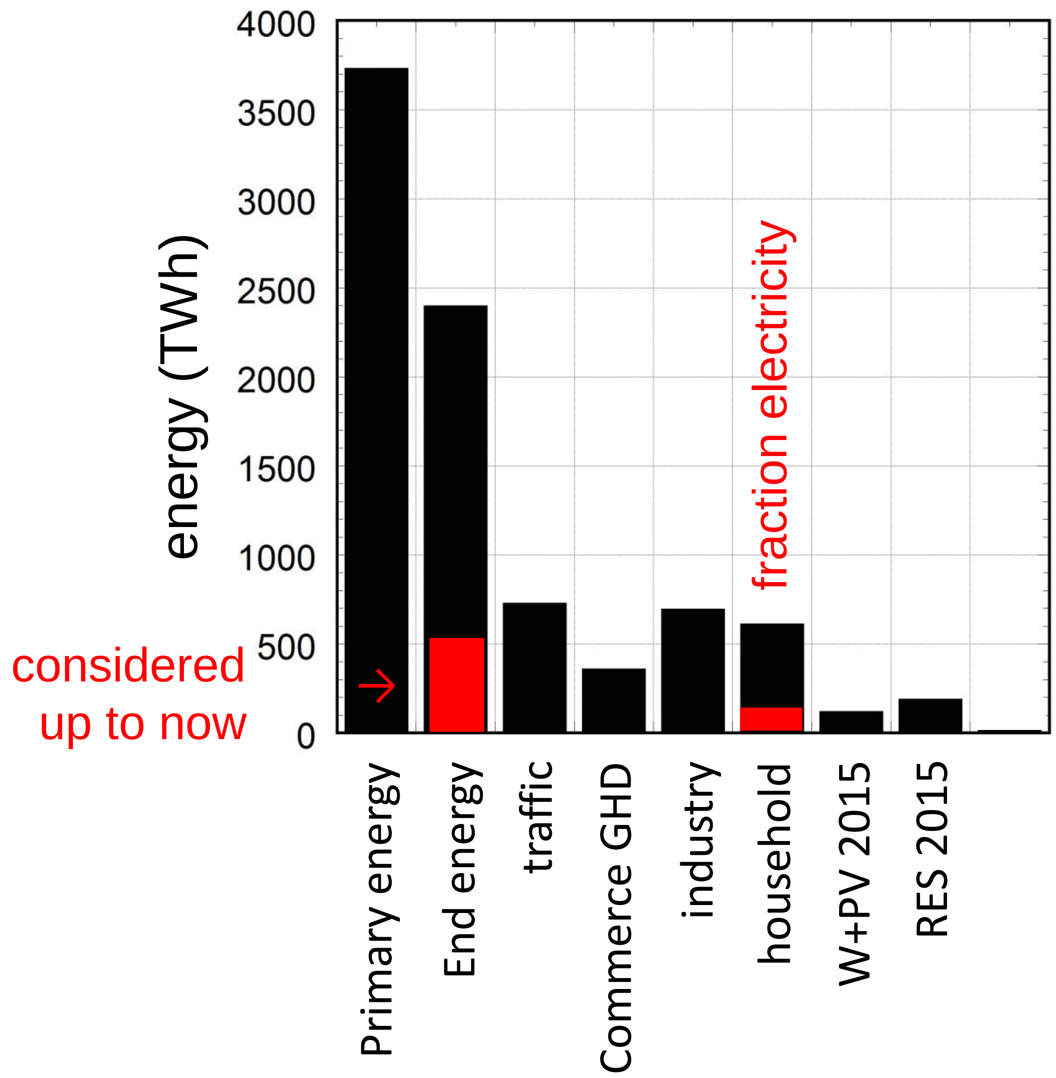
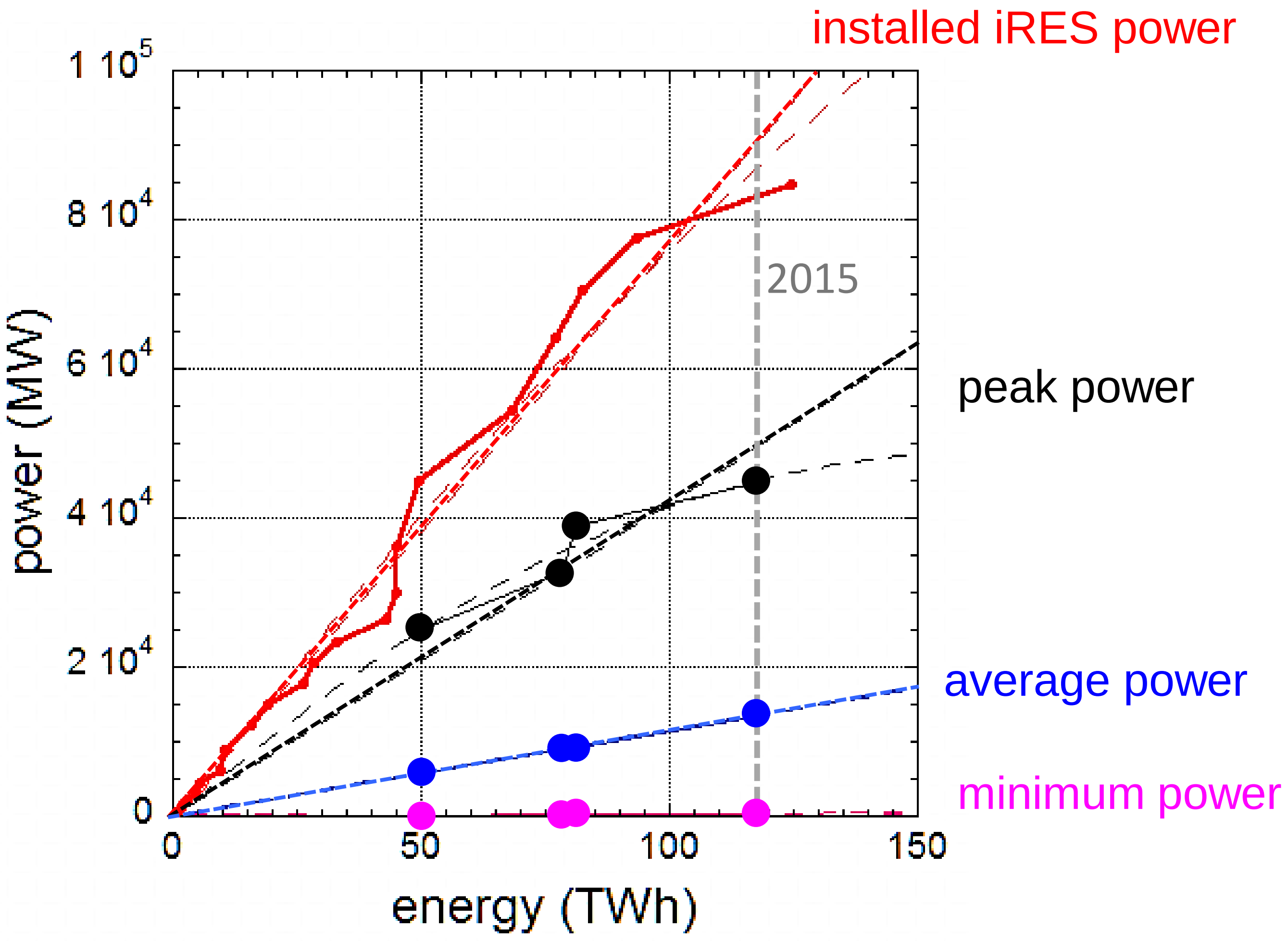
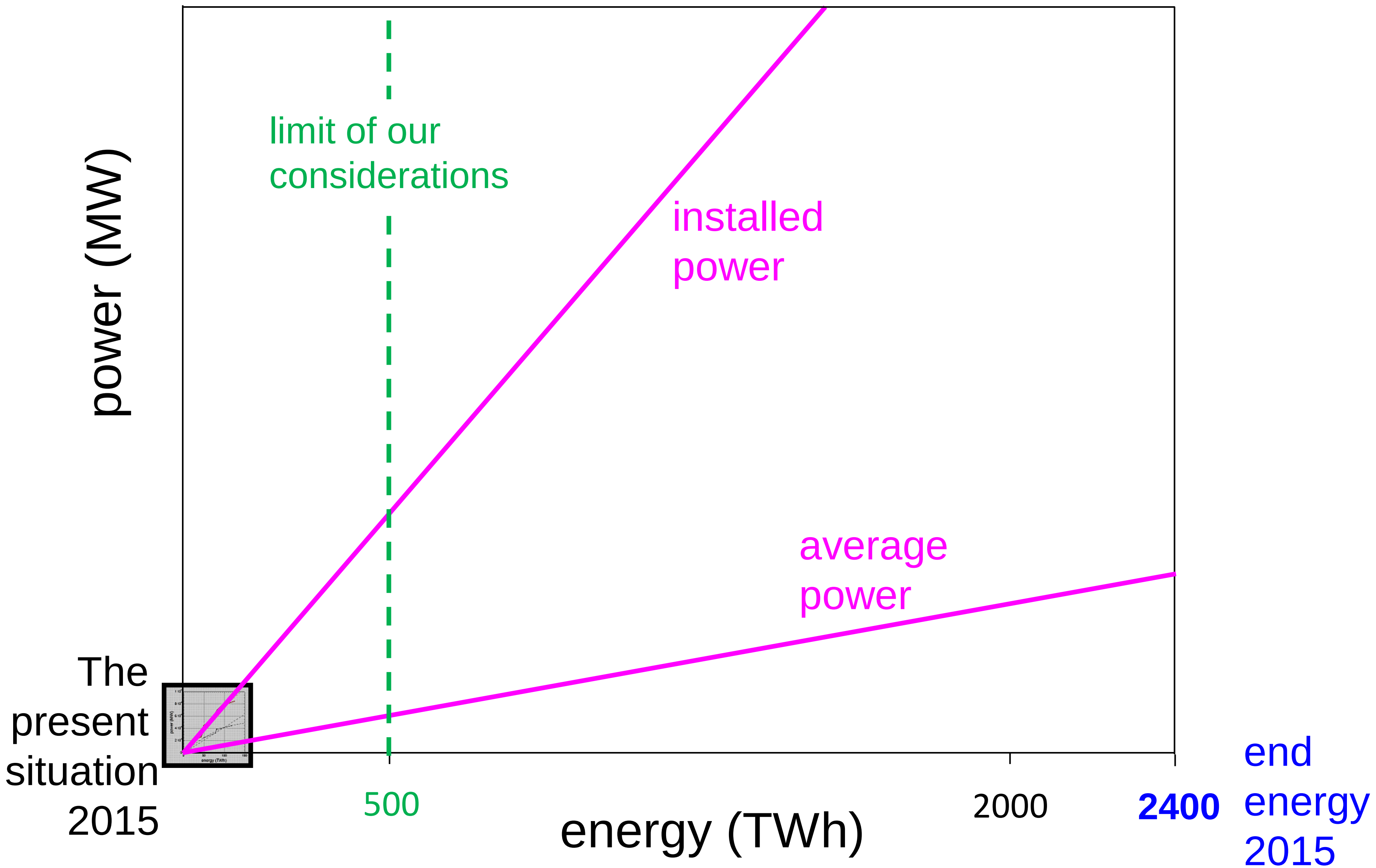


iRES situation end of 2015



The way to full decarbonisation



Analysis on the basis of a study by Prof. Quaschning

SEKTORKOPPLUNG DURCH DIE ENERGIEWENDE
Anforderungen an den Ausbau erneuerbarer Energien zum Erreichen der Pariser Klimaschutzziele unter Berücksichtigung der Sektorkopplung, 20.6.2016
Prof. Volker Quaschning, Hochschule für Technik und Wirtschaft Berlin
https://pvspeicher.htw-berlin.de/wp-content/uploads/2016/05/HTW-2016-Sektorkopplungsstudie.pdf

Consumption in the 4 energy sectors (TWh)

electricity	Heating warm water	Process heat	traffic	Storage, transfer losses
500	150	250	200	220

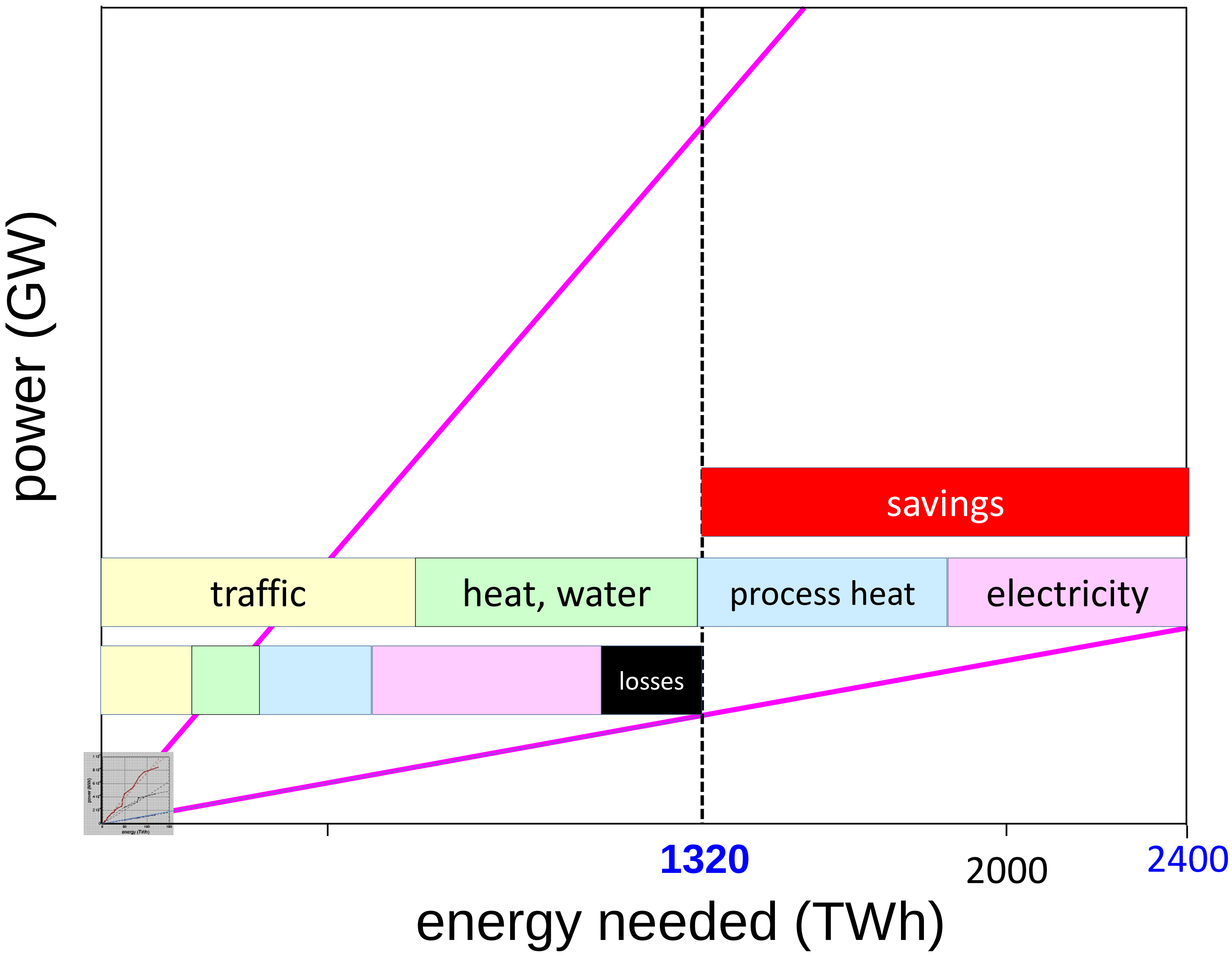
sum: 1320 TWh

Capacity and production

	Won	Woff	PV	bio-mass	hydro
installed power (GW)	199	76	415		
energy production (TWh)	498	343	394	58	27

sum: 1320 TWh

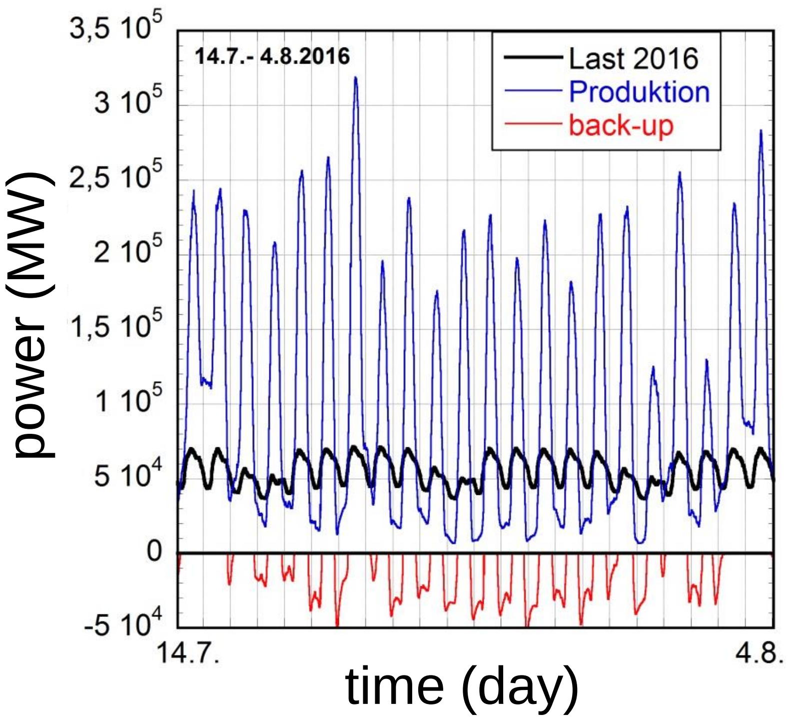
target values of the study



Problems

1. Problem: The installed power of 690 GW produces under the conditions of 2016 only 872 TWh.
   363 TWh are missing

2. Problem: back-up is necessary even with 690 GW installed power

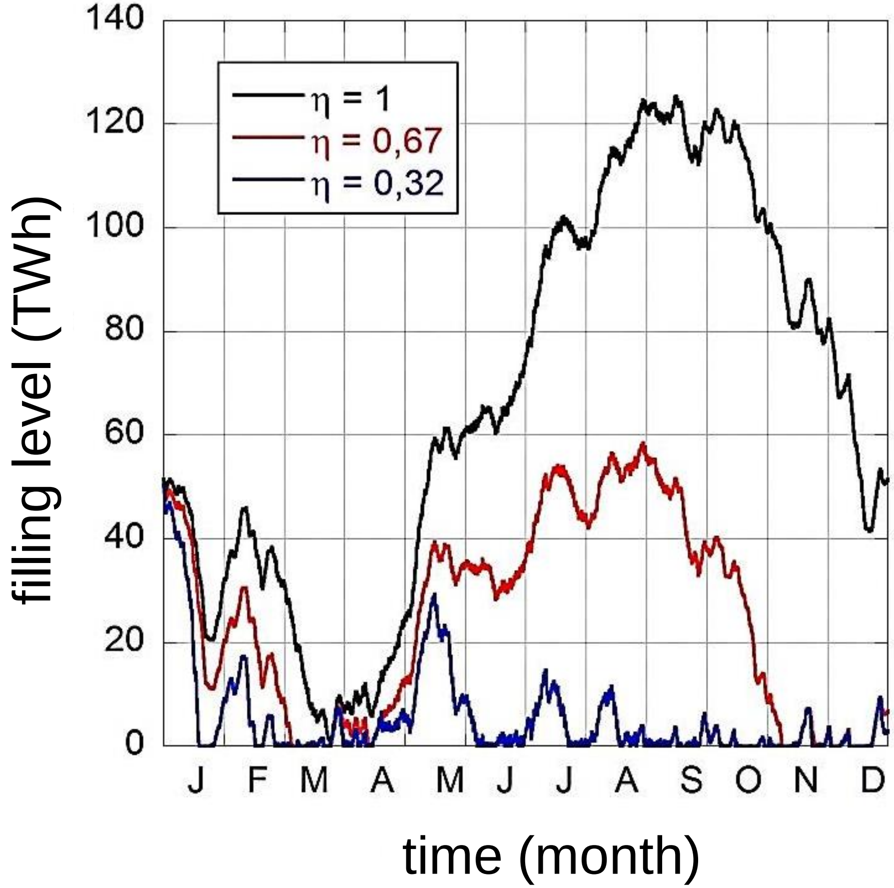


Over the year: surplus: 119 TWh; missing: 527 TWh

Formal solution

With 1035 GW installed power, surplus and back-up are the same: **379 TWh**

production and storage



Conclusion #2

In the future, the discussion on energy savings will complement, maybe replace the one on energy production.

I doubt that a complete decarbonisation with intermittent RES will be possible

If iRES alone will not do it:

What are the supplementary CO_2-free techniques?

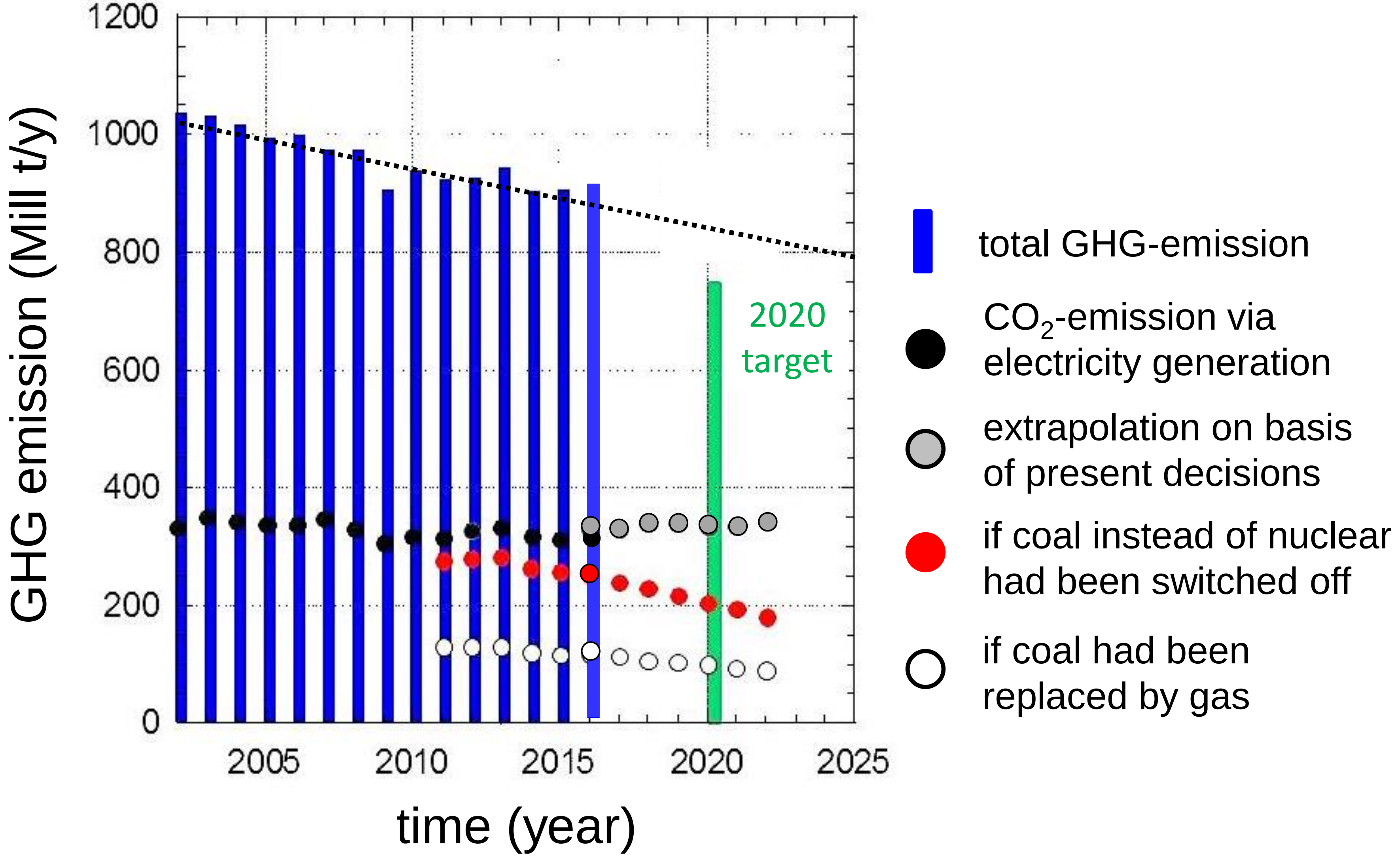
fission (generation-IV), fusion, CCS

In Germany the need of a 2nd CO_2-free system is not discussed

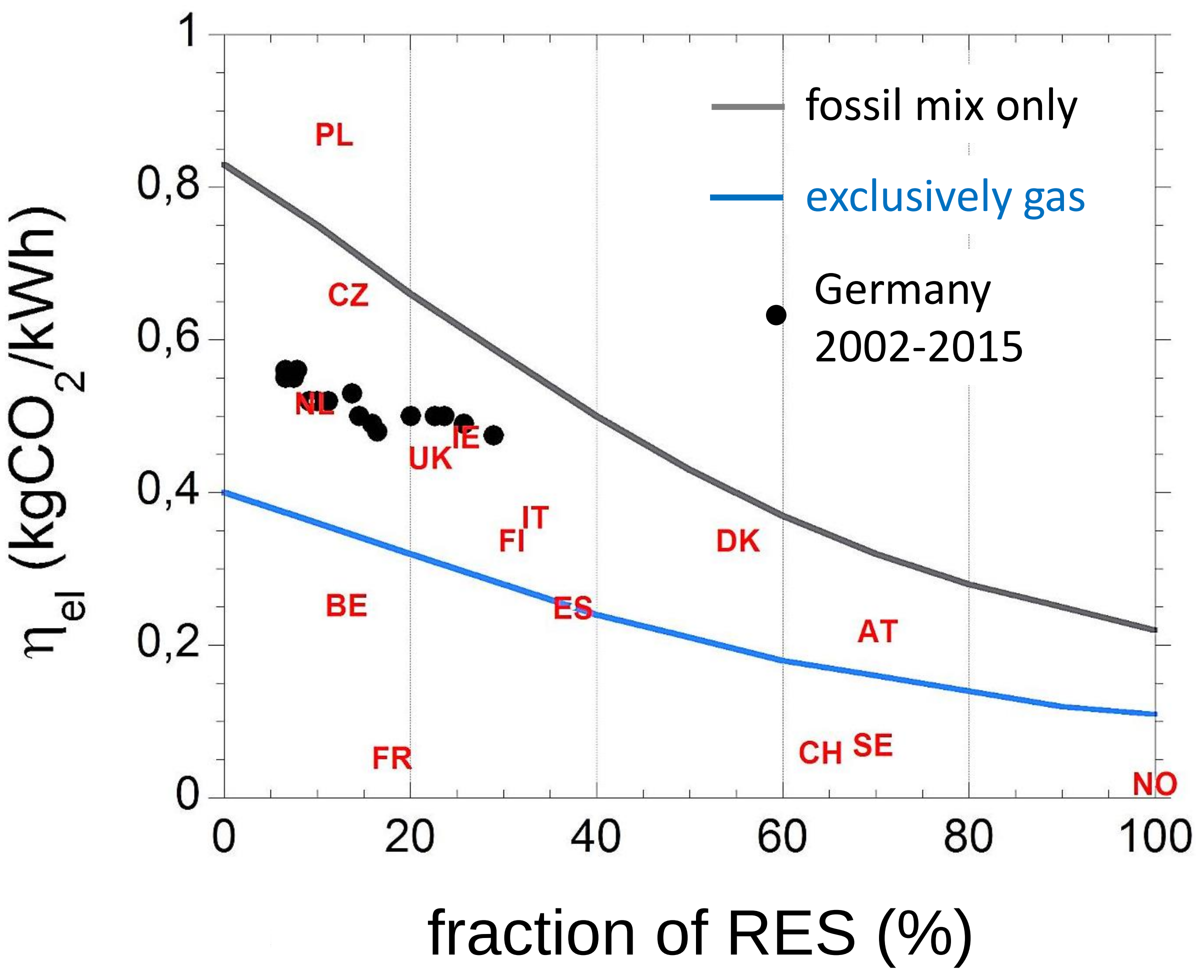
If a 2nd system is required, it can generate electricity in dispatchable form

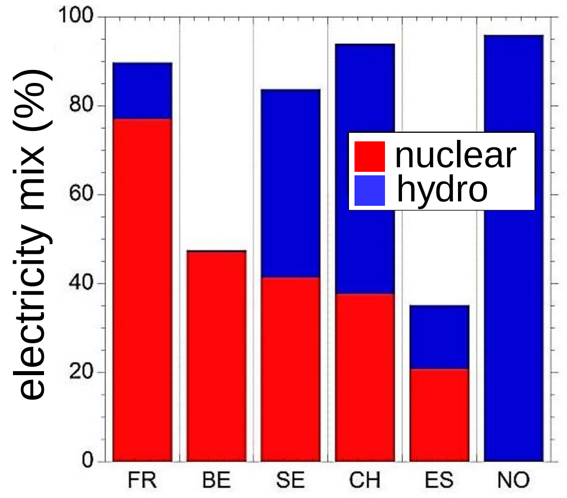
iRES could then produce H2 in separated grids

GHG and CO_2 emissions from Germany



Comparison of specific CO_2 emissions





Conclusion #3

Germany is worldwide the 6th largest GHG emission source

It is #1 in Europe, both in total and in per-capita release

Germany is on the way to miss its emission goals

They could have been met with a different energy strategy

With respect to CO2 emission from electricity generation:

Germany plans to reach an emission status
which others demonstrate since decades