Überlegungen zu einer EU-weiten Versorgung mit intermittierenden Strom-quellen

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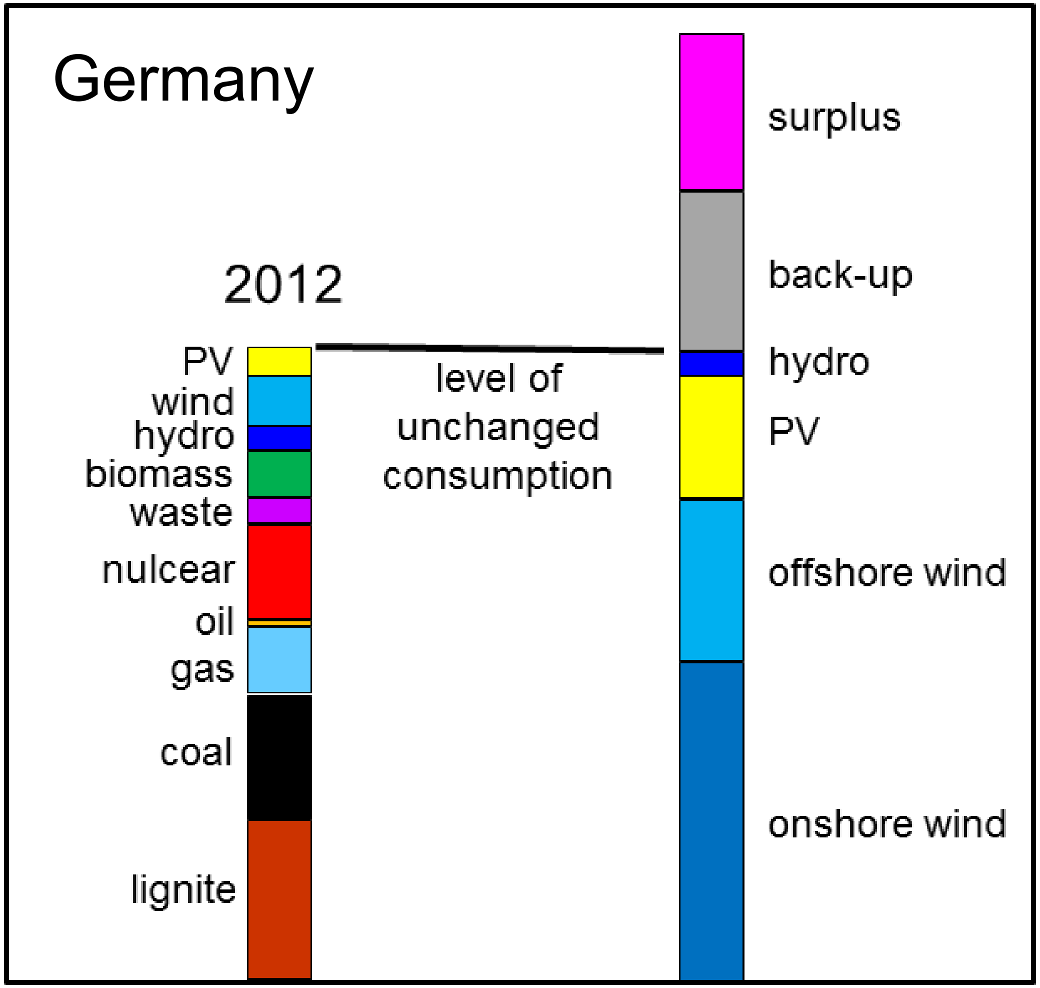


Method and assumptions

Method:

Take load-, wind-, PV-… data from 2012 and scale the intermittent RES to higher capacities (e.g. to the **100% case**)

Assumptions:

- no savings in electricity consumption
- hydro remains the same, subtracted from load → **reduced load**
- no nuclear power
- no import-export
- no biogas
- no losses

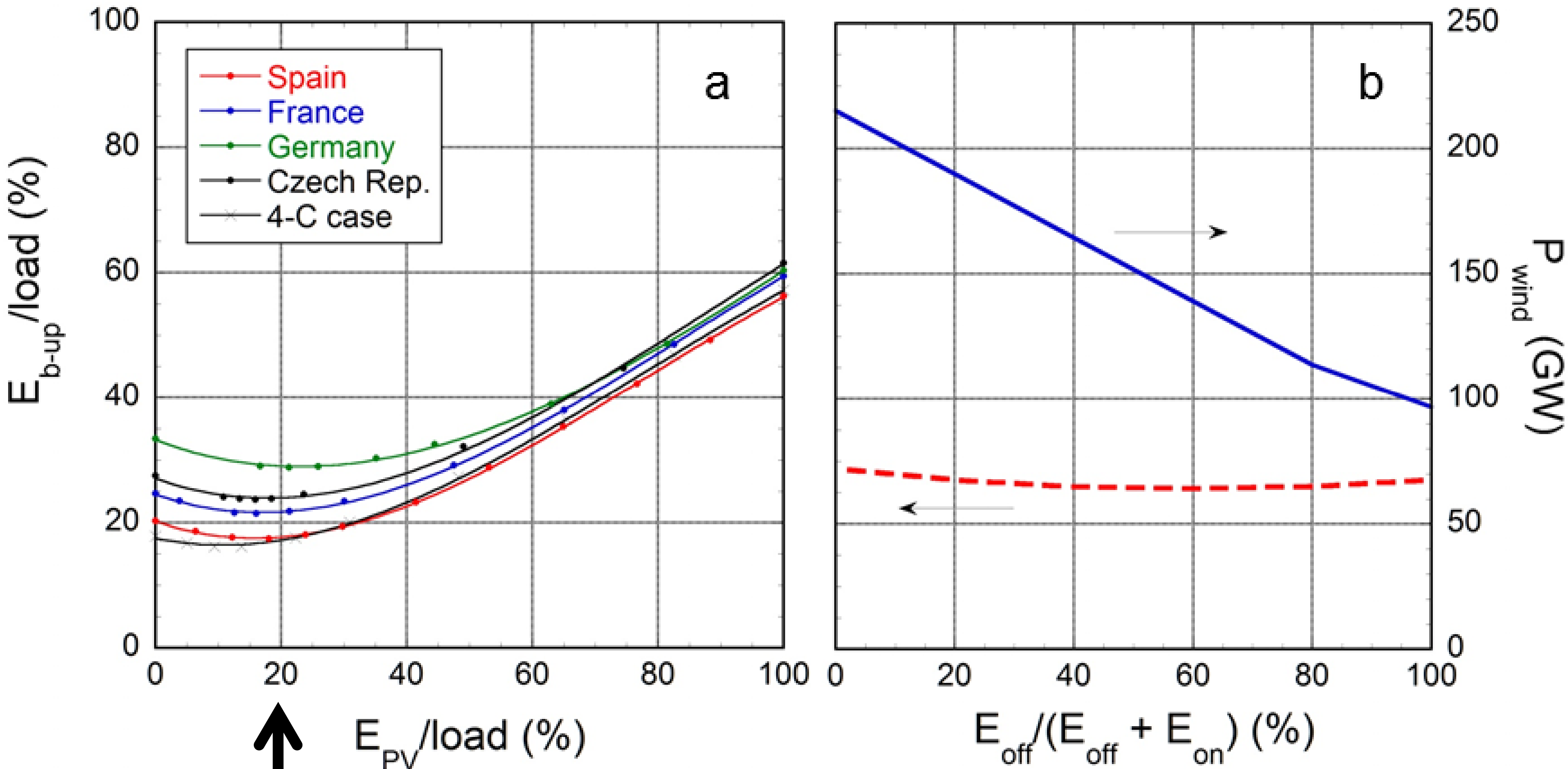
Topics:

How much power has to be installed?
The remaining need for back-up power?
The extent of surplus energy?
Dimension of storage?
The dynamics of the back-up system?
The conditions for DSM (demand-side management)?

The amount of CO2 reduction?
Conditions of a 100% supply by RES?
What could be a reasonable share by intermittent RES?
The benefits of an EU-wide use of RES
Costs of RES?

Mix between wind and PV, onshore and offshore wind

load = annual consumption



optimal mix

Major Results

How much power has to be installed?
Enough to serve Europe in good days

P_{won} =176GW ; P_{woff} =33GW; P_{PV} =97GW

The remaining need for back-up power?
88%; 2 parallel systems

$P_{back-up}$ = 73 GW
$W_{back-up}$ = 26% of red. load

The extent of surplus energy?
Formally enough to serve Poland

Dimension of storage?
For the 100% case: 660 x present capacity

The dynamics of the back-up system?
From 0 up to the load; strong gradients

The conditions for DSM (demand-side management)?
Cheap electricity prices during the day

The amount of CO_2 reduction?
Not to the level of France, Sweden...

Conditions of a 100% supply by RES?
Use of biogas (e.g. 40 TWh) and savings (down to 30%)

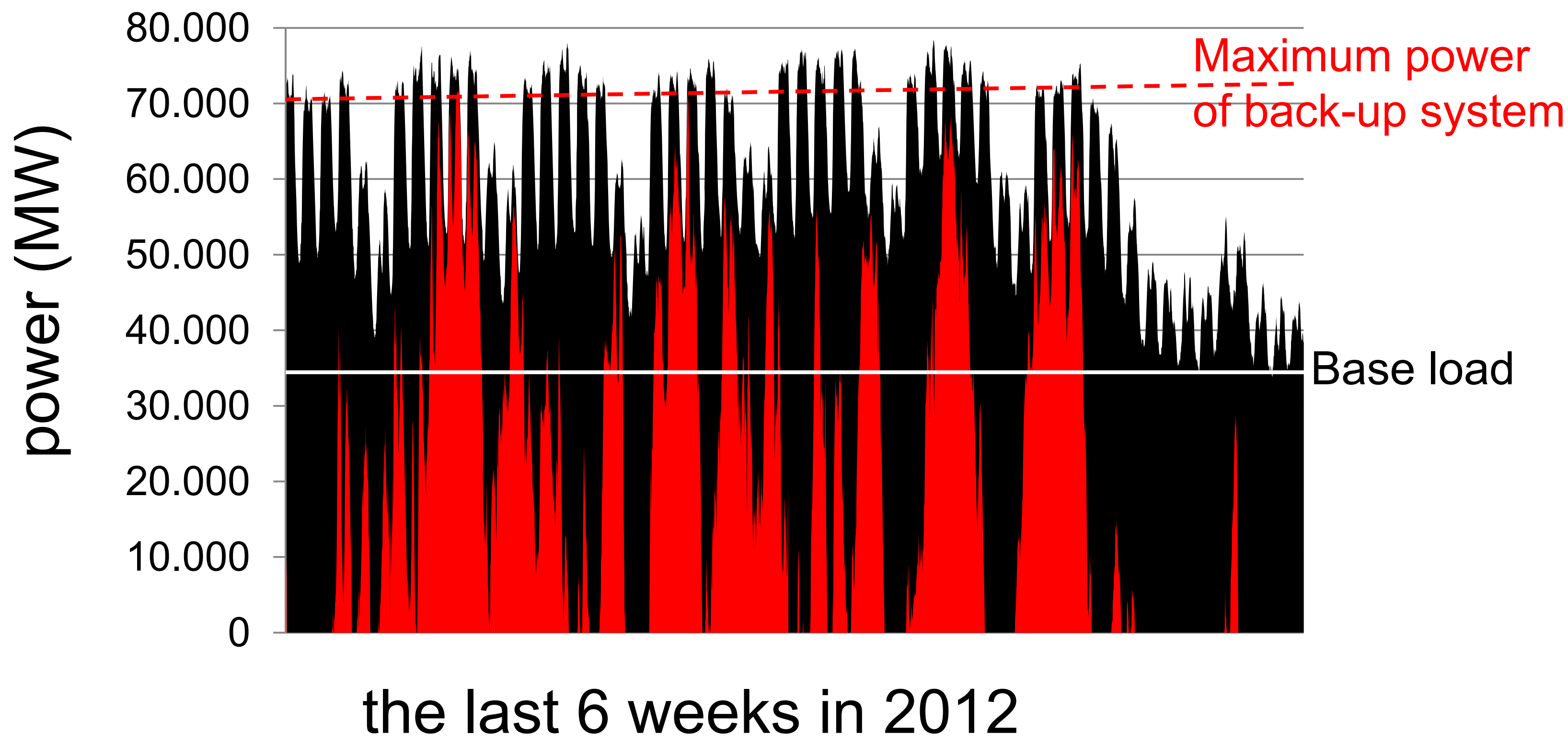
What could be a reasonable share by intermittent RES?
40%

The benefits of an EU-wide use of RES?
Effects in the order of 20-30%

Costs to implement RES?
high

Results in more detail: Back-up system

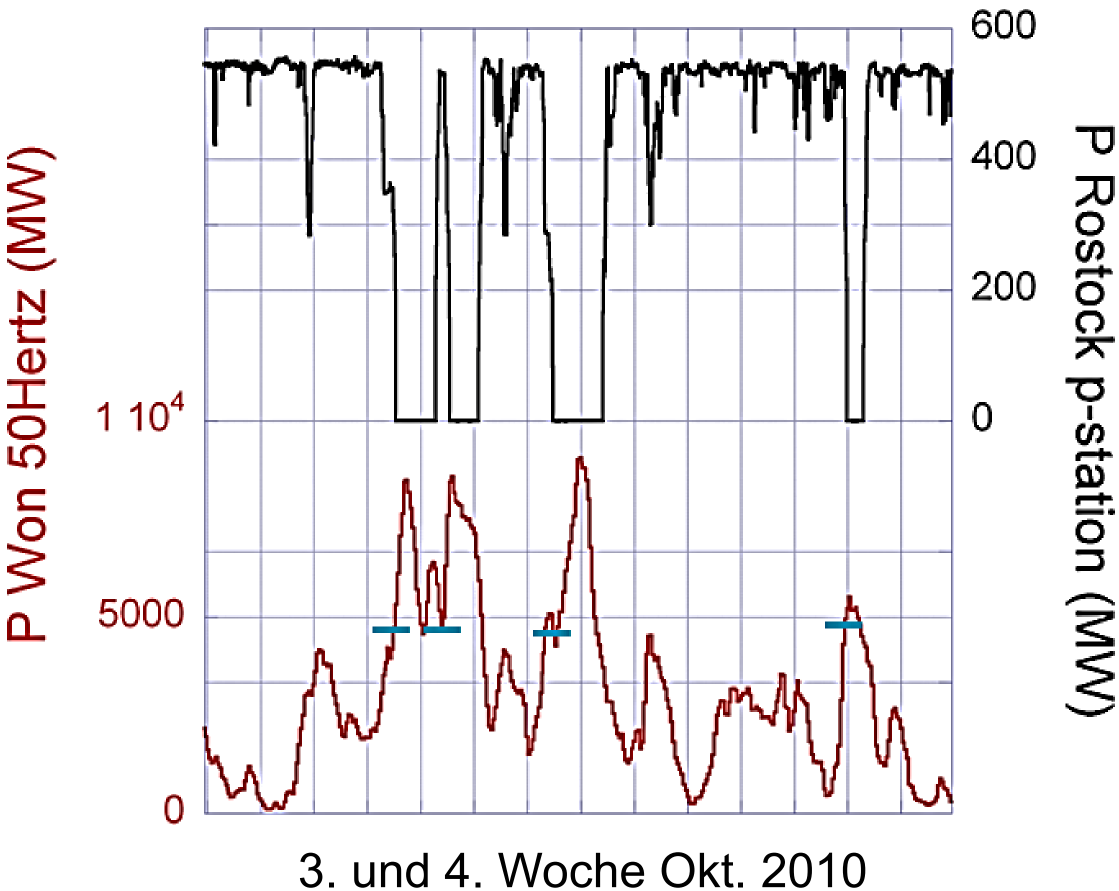
100%, optimal mix case



The power of the back-up system remains high
It has to meet the full dynamic range from 0 to nearly peak load
→ the power gradients increase strongly

Dynamics of the back-up system

Operation of the coal power station in Rostock
Anti-correlation of wind (50Hertz region) and thermal power

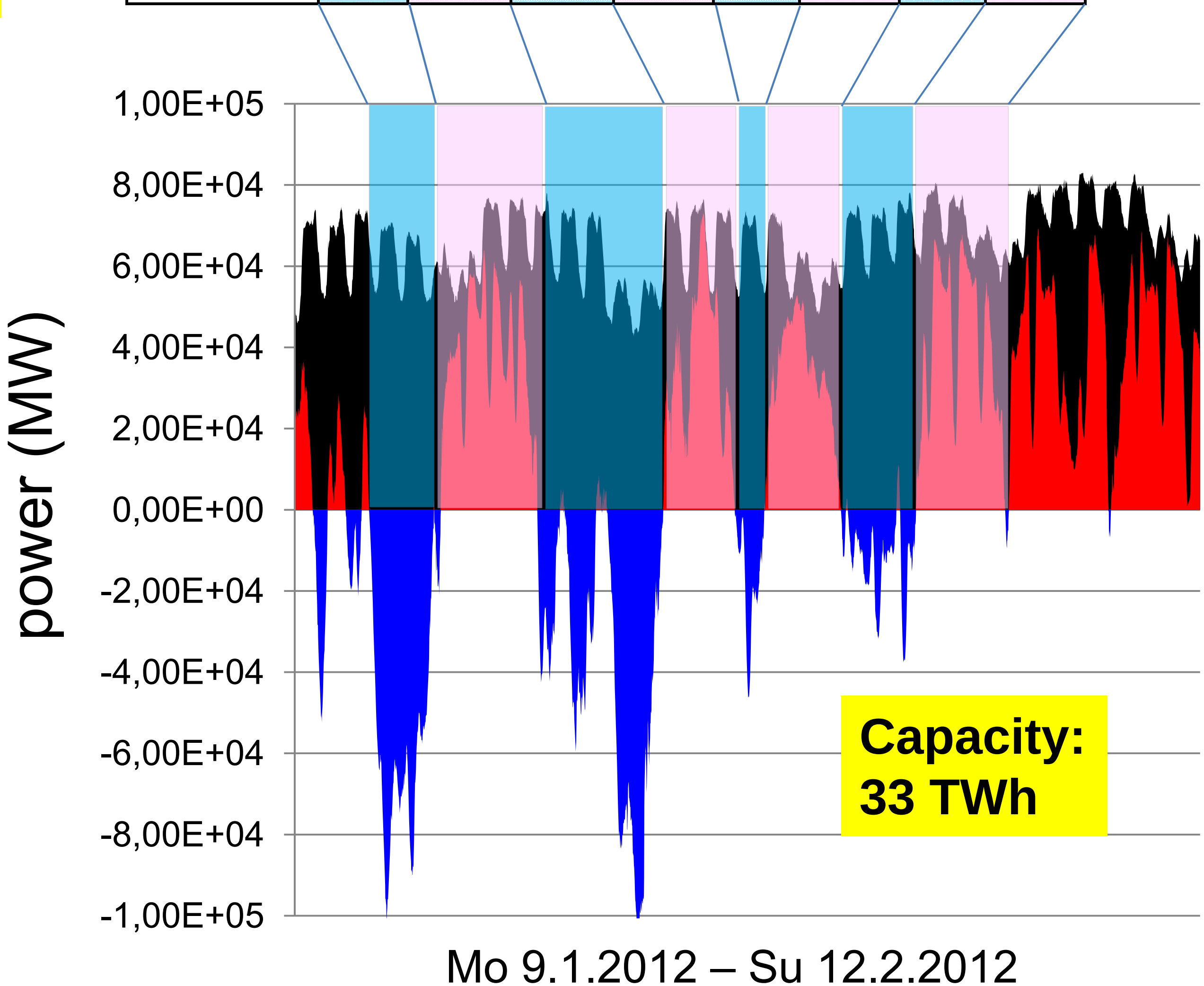


← Wind level for the power station to switch off

Storage

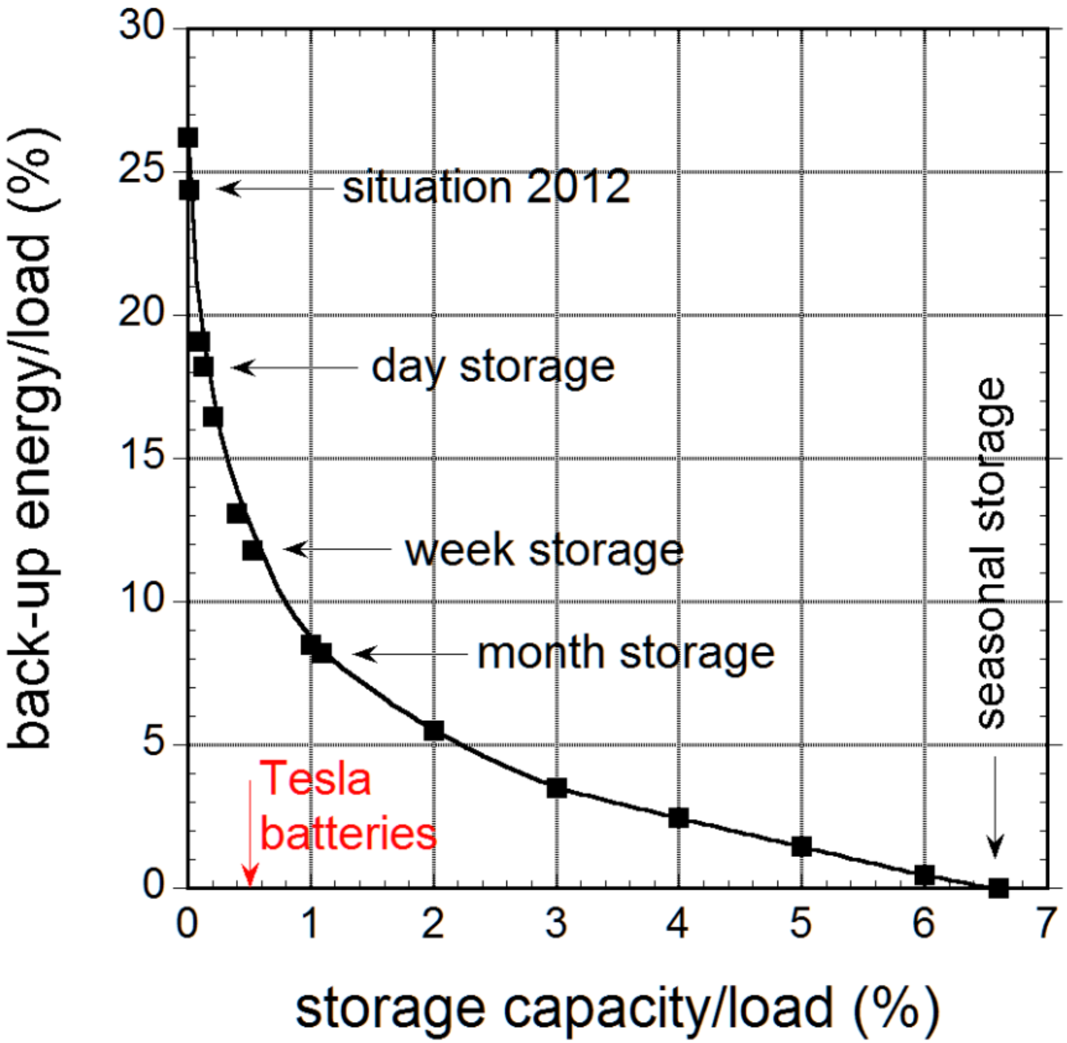
100%
optimal mix case

h	66	90	117	67	27	71	70	83
TWh	3.7	-3.5	4.5	-2.5	0.5	-2.4	0.8	-3.4



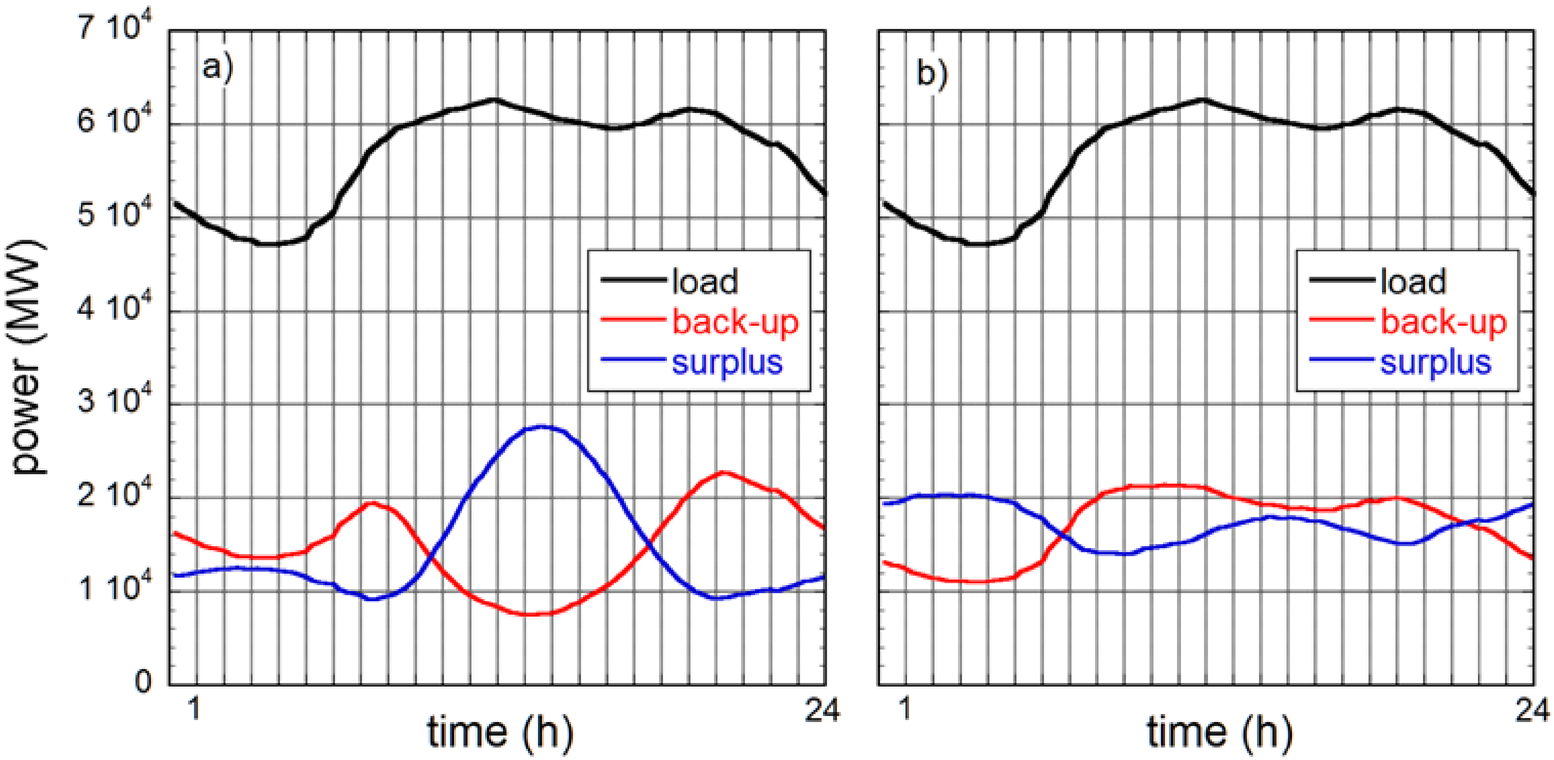
Storage

Need of back-up depending on storage capacity

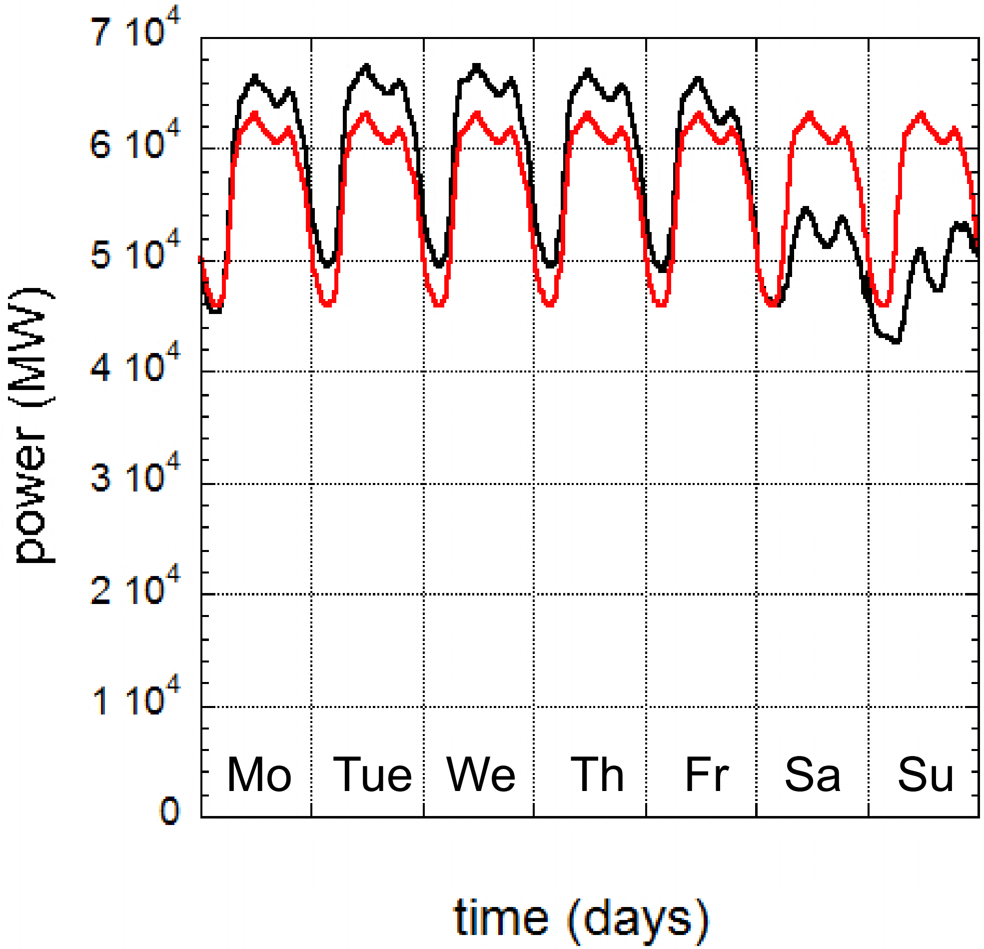


Demand-side-management

100%, optimal mix case



Demand-side-management: use of weekends



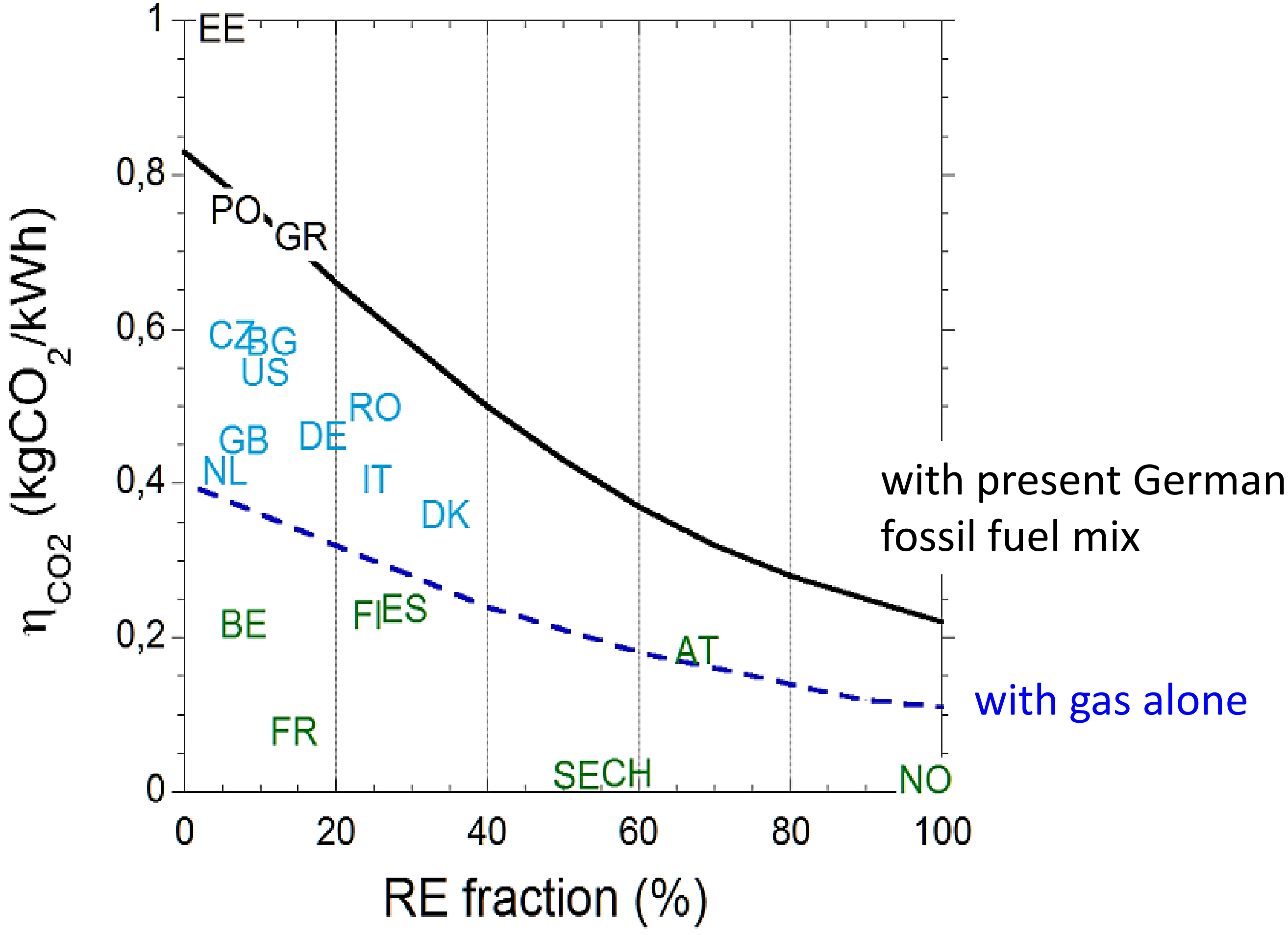
Full integration of weekends:

Additional use of RES: 7.9 TWh

Peak-load: 83 → 63 GW

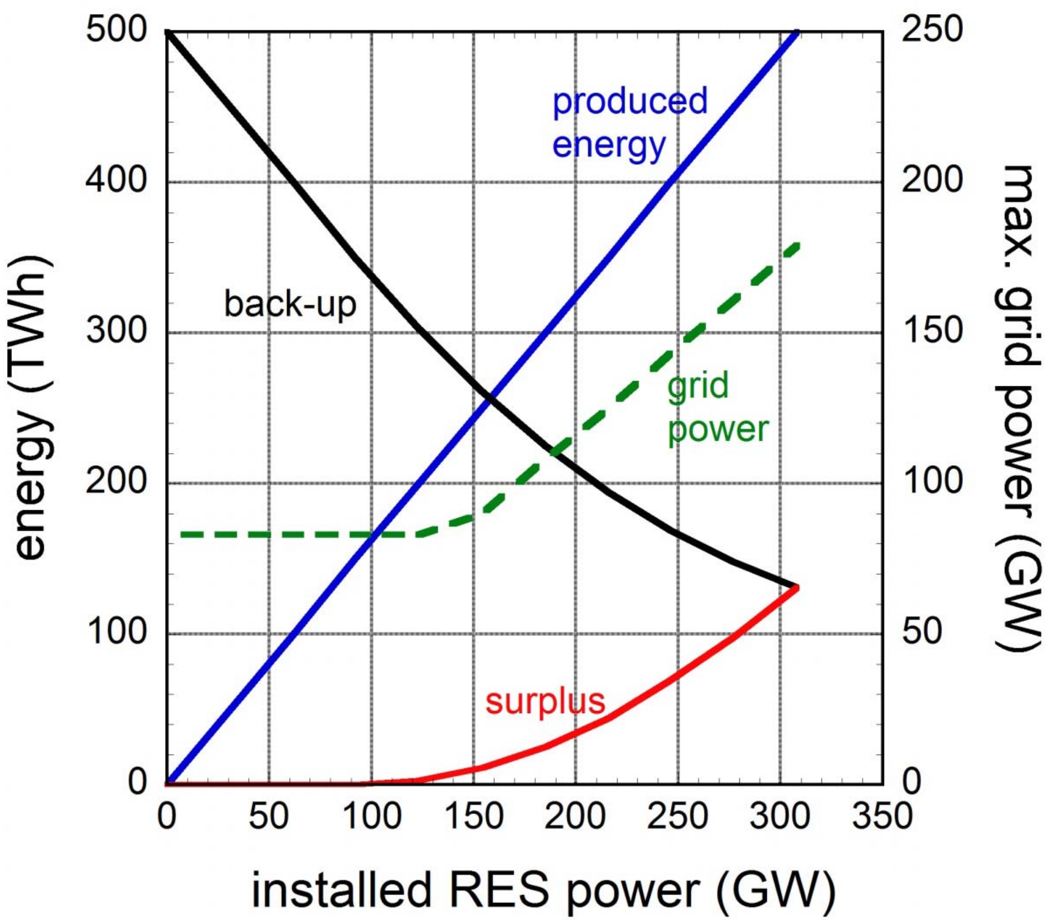
Reduction of back-up system:
131 → 123 TWh

Specific CO2 emission



Countries with hydro + nuclear are already where others would like to be in 2050

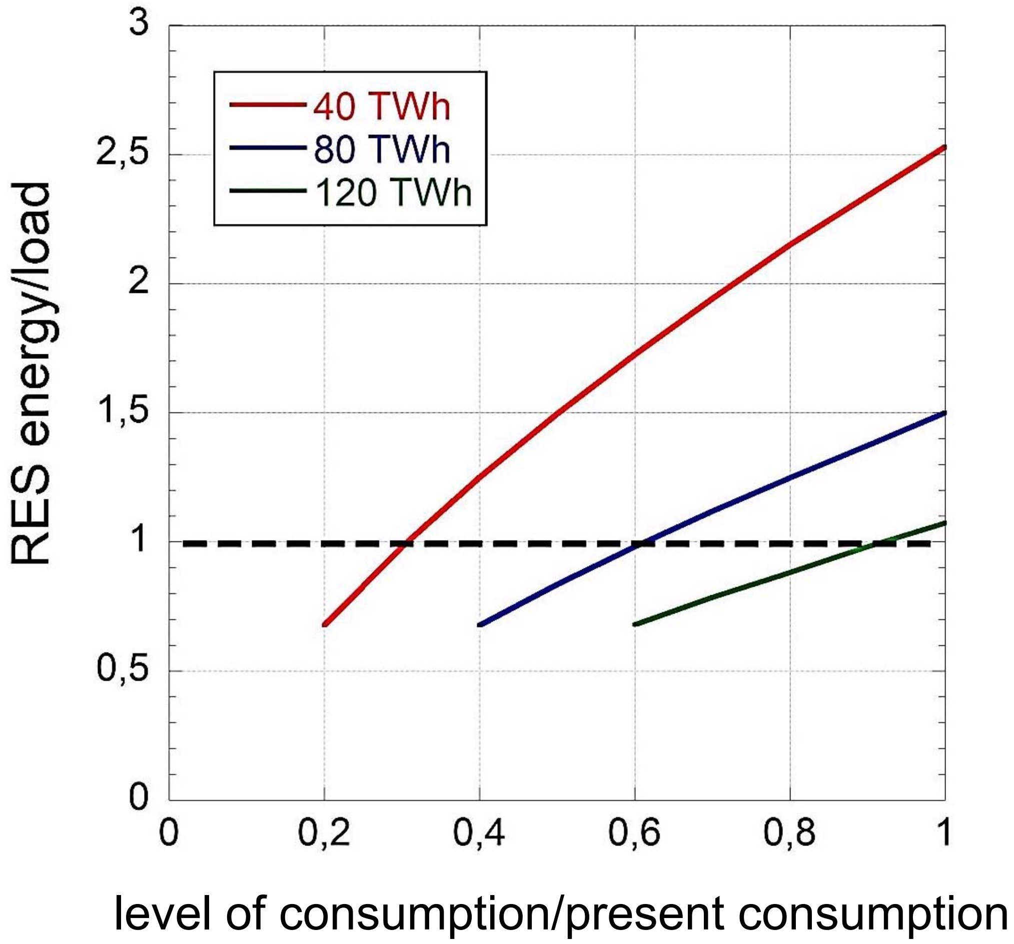
Possible contribution by intermittent sources



possible limit

Conditions of a 100% supply by RES

Main knobs: savings/efficiency + use of biomass
Minor knobs: decrease of population, import (dispatchable power), geo-th-power



German lesson

Large-scale Wind and PV electricity possible if the necessary space is allocated

Large power to be installed – comparable to the load of Europe → **high costs**

PV can effectively be replaced by wind

Back-up system required in all scenarios: **little saving in thermal power**

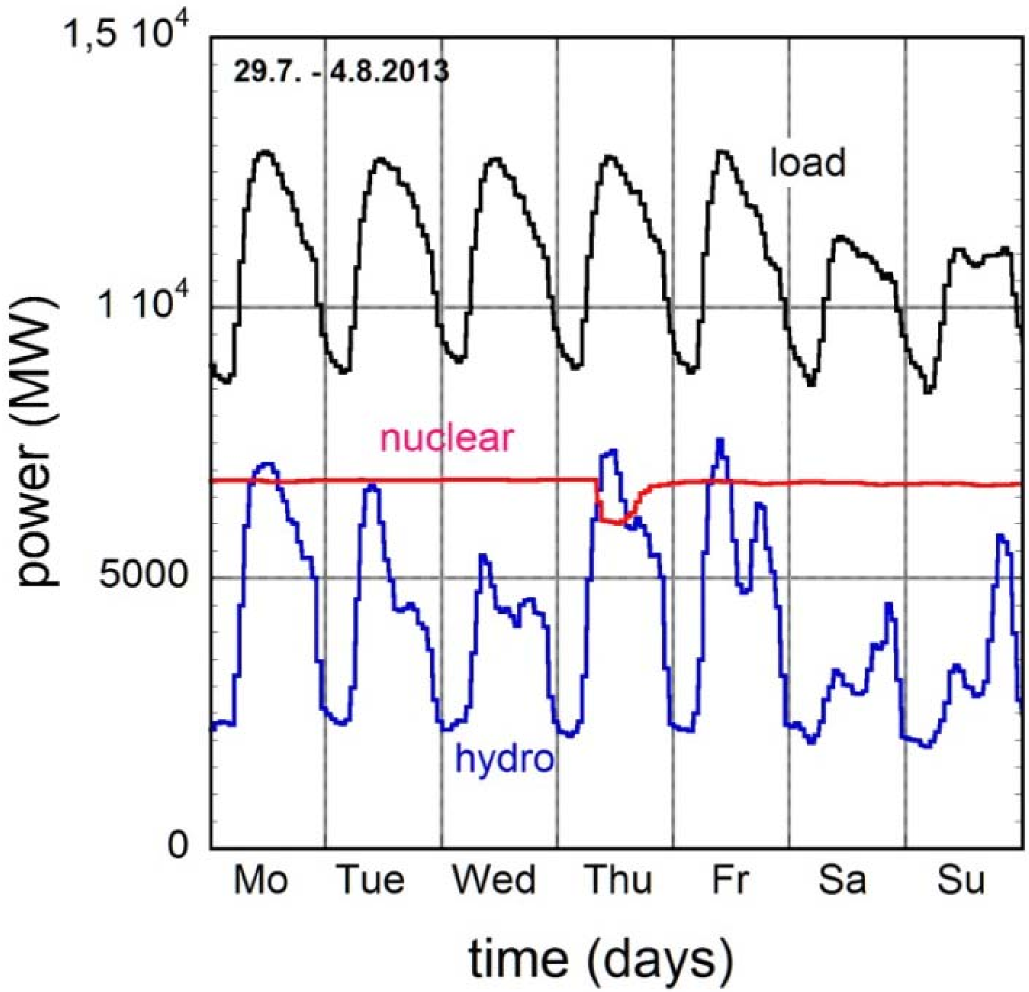
Storage technology not available; its future operation not economic

CO_2 reduction by RES: **not to the level already achieved by others in EU**

DSM: **misguided public expectation**

Can Sweden replace nuclear by wind power?

present situation



Hydro power follows the load

Operation of hydro-power plants

Electricity production is only one hydro-system requirement

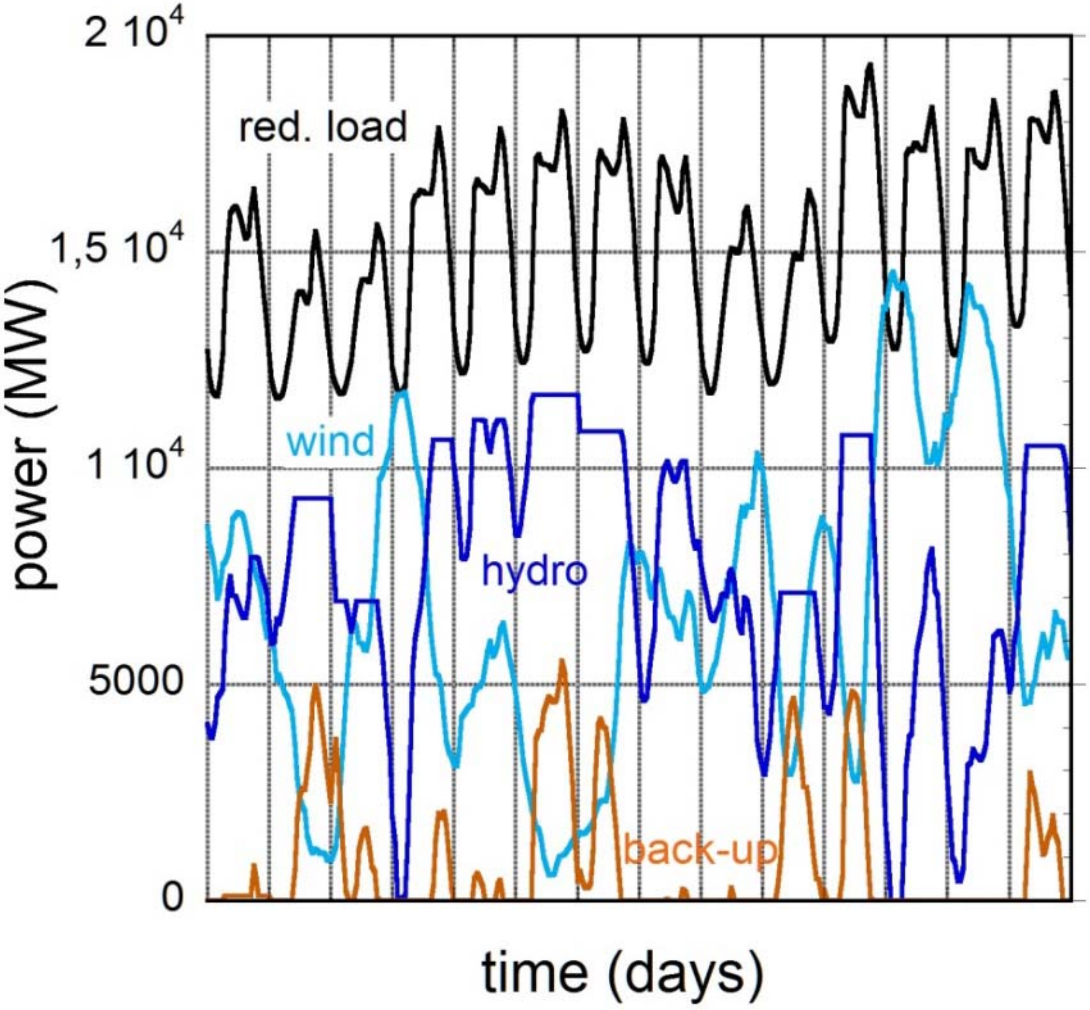
water supply
flood prevention + avoidance of low water levels
fishing
recreation and environment

Hydrosystem with serveral power stations along river

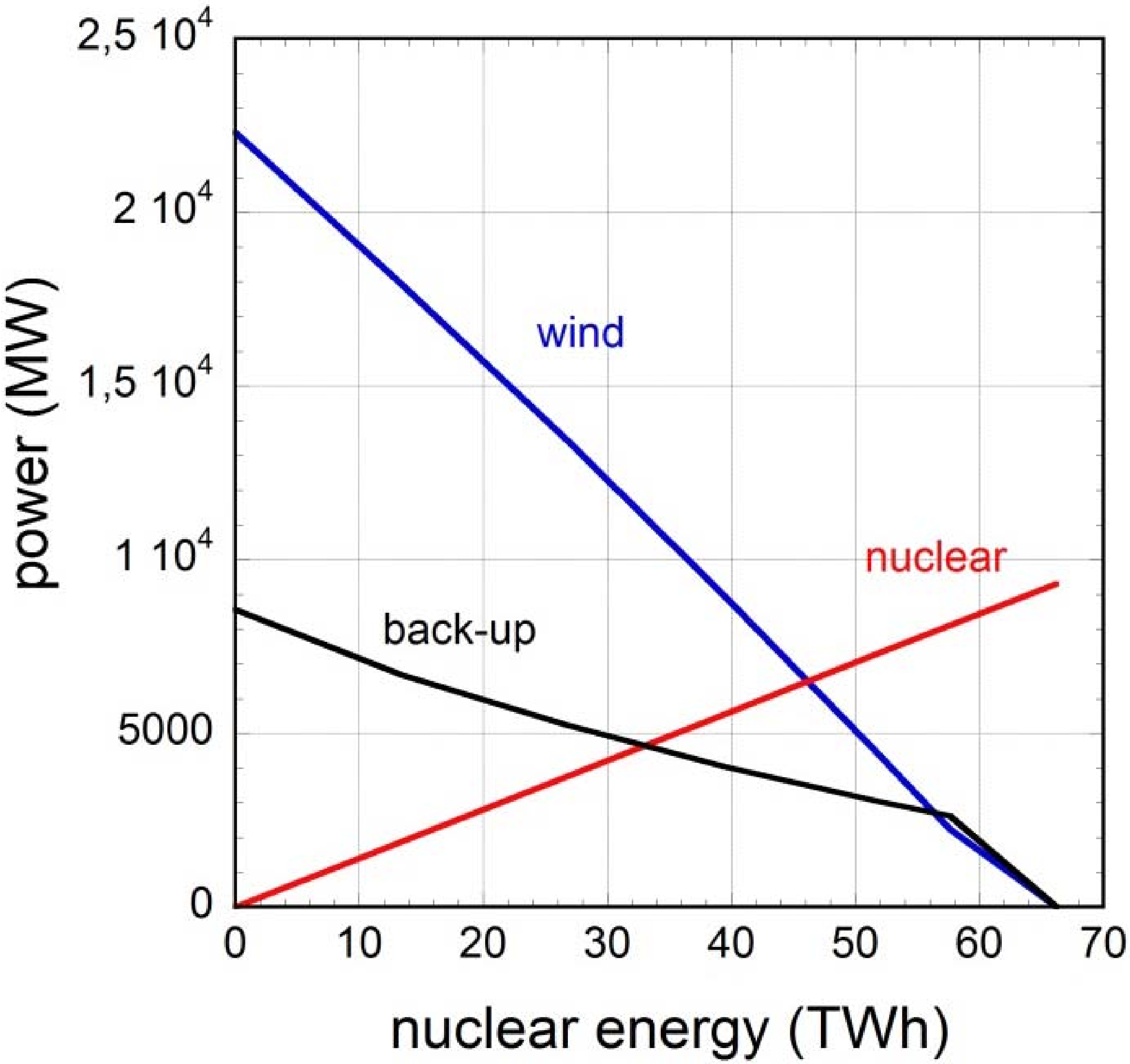
→ coherent action to avoid spills

Limits in P_{hy} and gradP_{hy} which vary during season

The case without nuclear power



The alternatives



Hydro electricity constant: 62 TWh

The consequences

A gas back-up system is necessary

→ the specific CO2 emission increases by 50%

The back-up power cannot be replaced by PV

Storage is not meaningful because surplus power is small

Excessive surplus production leads to the replacement of hydro by wind power

The installation of pumped storage is not motivated by national needs

Benefit from an EU-wide RES field

Construction of an EU-wide RES field

Germany, wind+PV
Denmark, wind
Belgium, wind
France, wind+PV
UK, wind
Ireland, wind
Spain, wind+PV
Czech Rep., wind+PV

Sweden, wind+PV

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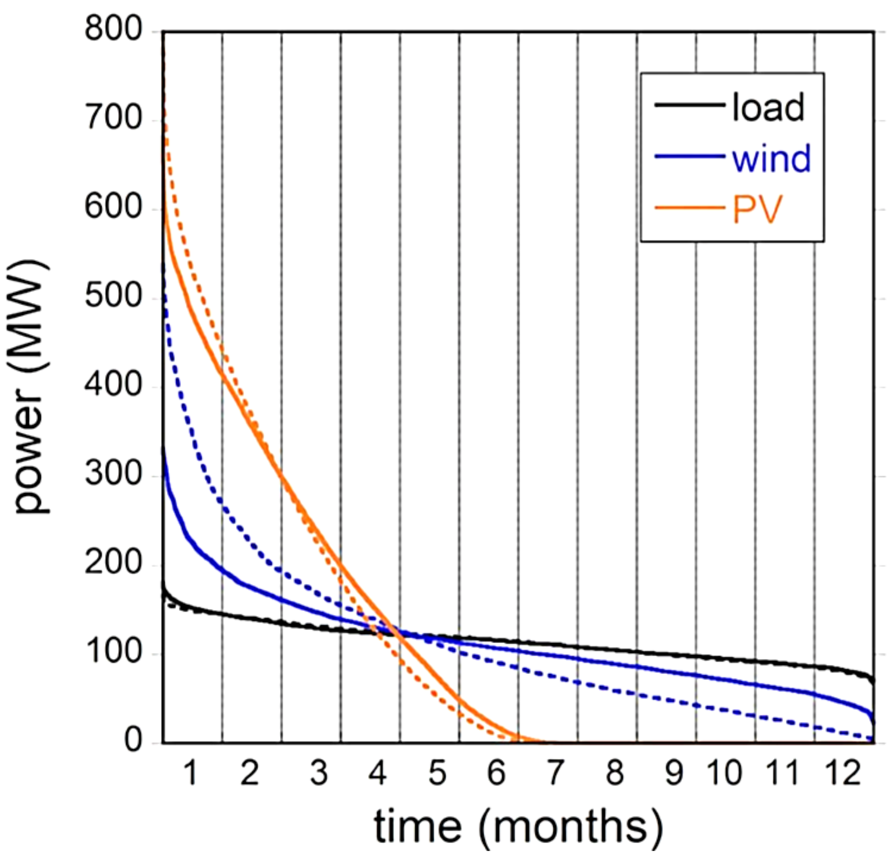
Annual duration curves for German RES field (**dashed**) and EU-wide RES field



Only wind has averaging effect

The benefit of working with an EU-wide RES field

the back-up energy is reduced by 24%,

the maximal back-up power by 9%,

the maximal surplus power by 15%,

the maximal grid power by 7%,

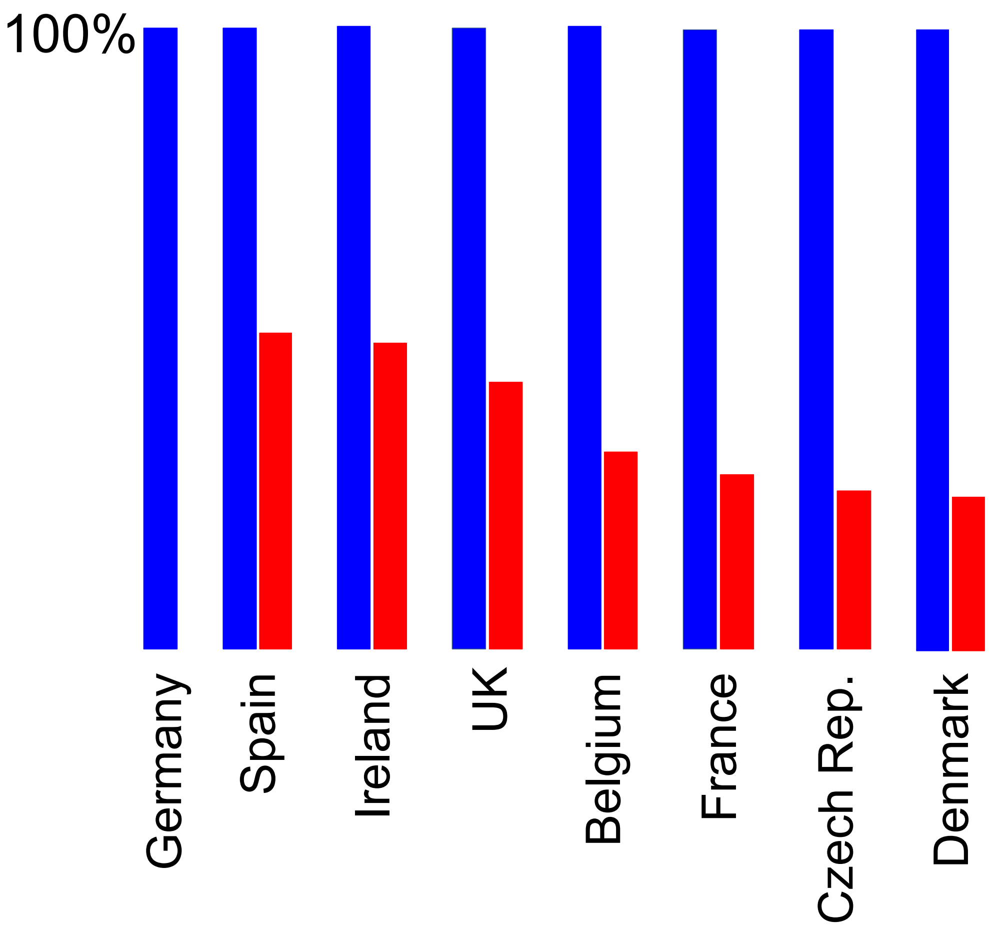
the typical grid fluctuation level by 35%

the maximal storage capacity by 28%

Distribution of wind field expressed as regression coefficient

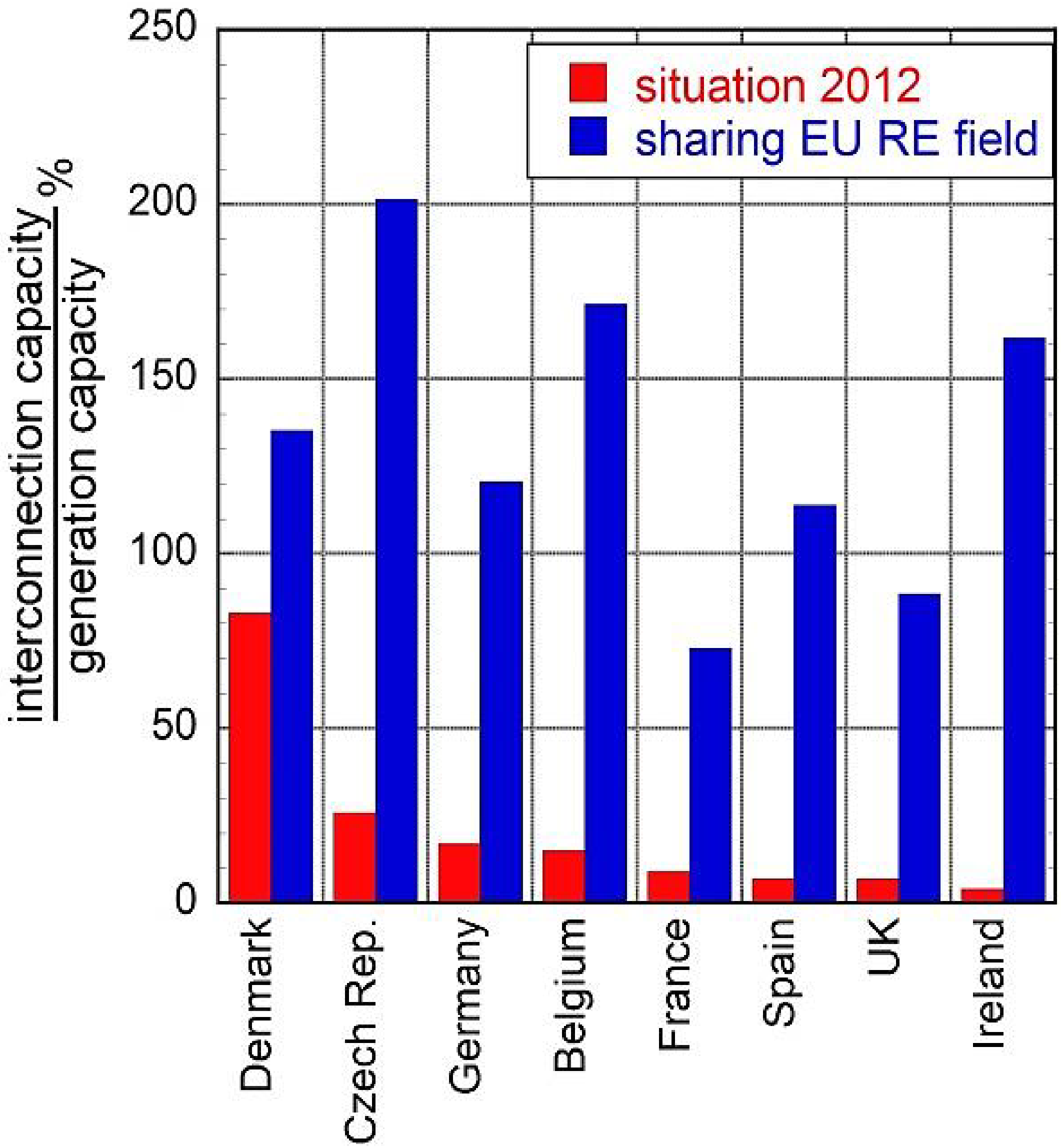
Useful surplus (from German point of view)

normalised surplus
and
„useful“ surplus



In case of surplus – simultaneously also by the neighbours

Interconnector capacity



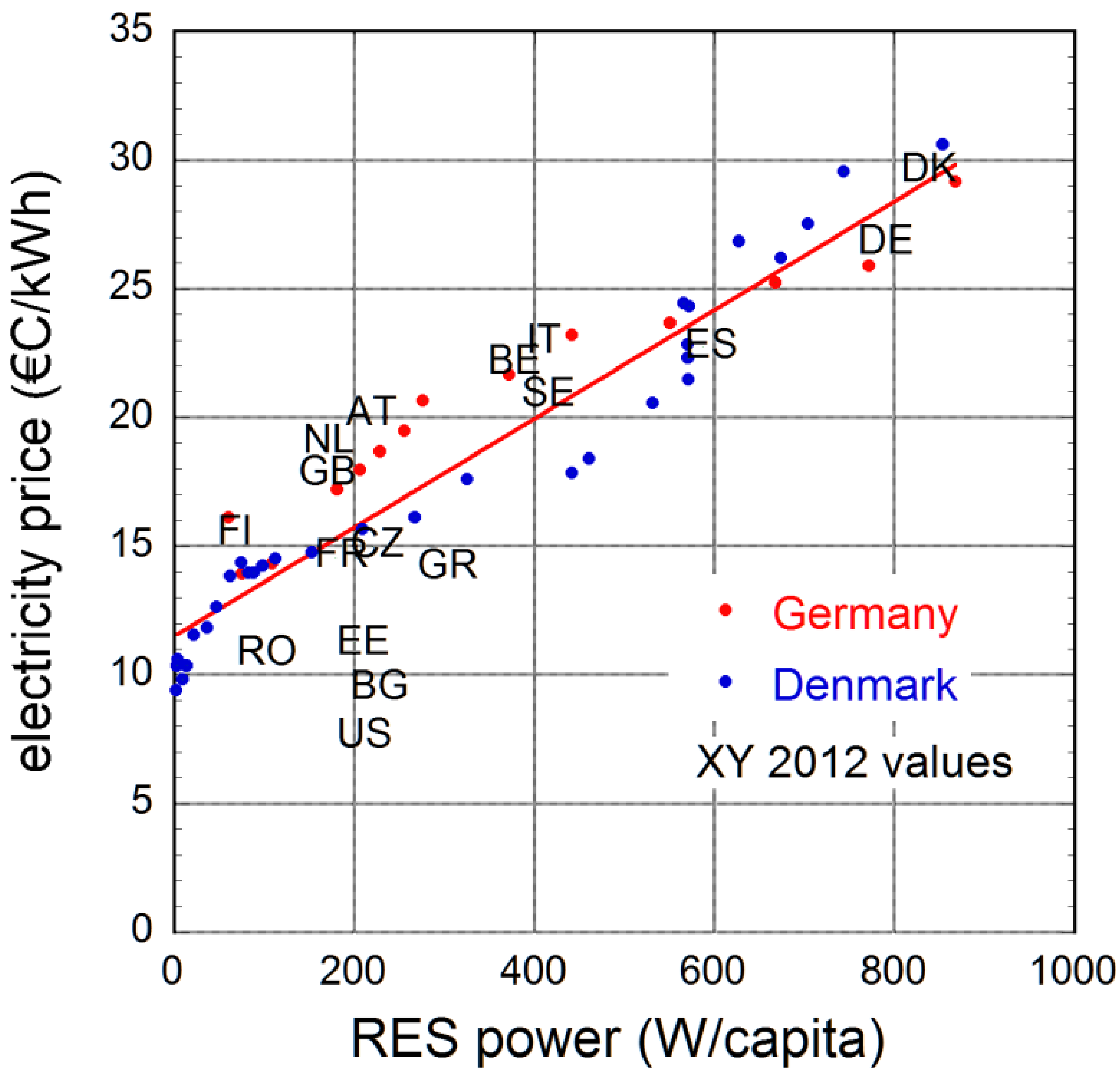
EU power installations

	demand	hydro-electr.	P(Won)	P(Woff)	P(PV)	surplus
Country	TWh	TWh	GW	GW	GW	TWh
Austria	70	37,7	16	0	5	7,2
Belgium	82	2	37	8	0	18,0
Bulgaria	32	3,2	15	0	5	6,5
Croatia	17	5,2	6	0	2	2,7
Cyprus	4	0	2	0	1	0,9
Czech Rep.	68	2	39	0	13	17,2
Denmark	34	0	10	3	0	9,0
Estonia	8	0	3	1	0	2,1
Finland	84	12,6	30	6	0	18,9
France	485	65	100	29	89	94,5
Germany	530	20	173	33	106	114,8
Greece	50	4	19	0	7	10,3
Hungary	39	0,2	22	0	8	8,7
Ireland	26	1	6	2	0	5,6
Italy	316	43,2	119	0	39	61,4
Latvia	7	3,1	1	0	0	1,1
Lithuania	11	0,4	4	1	0	2,7
Luxembourg	6	0,1	3	0	0	1,4
Netherlands	111	0,1	33	9	0	29,3
Norway	128	123,6	1	0	0	1,1
Poland	145	2,4	60	12	0	37,9
Portugal	49	6,8	14	3	6	9,5
Romania	52	15,3	17	0	6	8,3
Slovakia	27	4,4	12	0	4	5,9
Slovenia	13	4	4	0	2	2,0
Spain	260	35	46	15	34	50,6
Sweden	140	64,5	26	6	0	19,9
Switzerland	65	35,3	15	0	5	6,7
UK	320	5	57	20	66	70,9
sum	3179	496	819	128	325	625

EU power installations

	demand	hydro-electr.	P(Won)	P(Woff)	P(PV)	surplus
	TWh	TWh	GW	GW	GW	TWh
sum	3179	496	819	128	325	625

Development costs



Source: F. Wagner Finadvice

EU-wide consequences

Large RES power necessary for all countries

National RES use demand typically north-south grids

Cross-border exchange requires east-west grids

Exchange over large distances beneficial

Large interconnector capacities needed

Not all countries benefit from an EU-wide RES field