Storage and Balancing Needs in Germany in the „German Lead Study“ Scenarios & Storage and Balancing Needs in Europe in a European 100% Wind and PV Scenario

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Fraunhofer Institute for Wind Energy and Energy Systems Technology (IWES): Institute Profile

Wind energy

Photovoltaics

Bio energy

Research spectrum:

- Wind energy from material development to grid optimization
- Energy system technology for all renewables

Foundation: 2009

Annual budget: approx. € 22 million

Staff: approx. 500

Electricity grids

Hydro power

Marine energies

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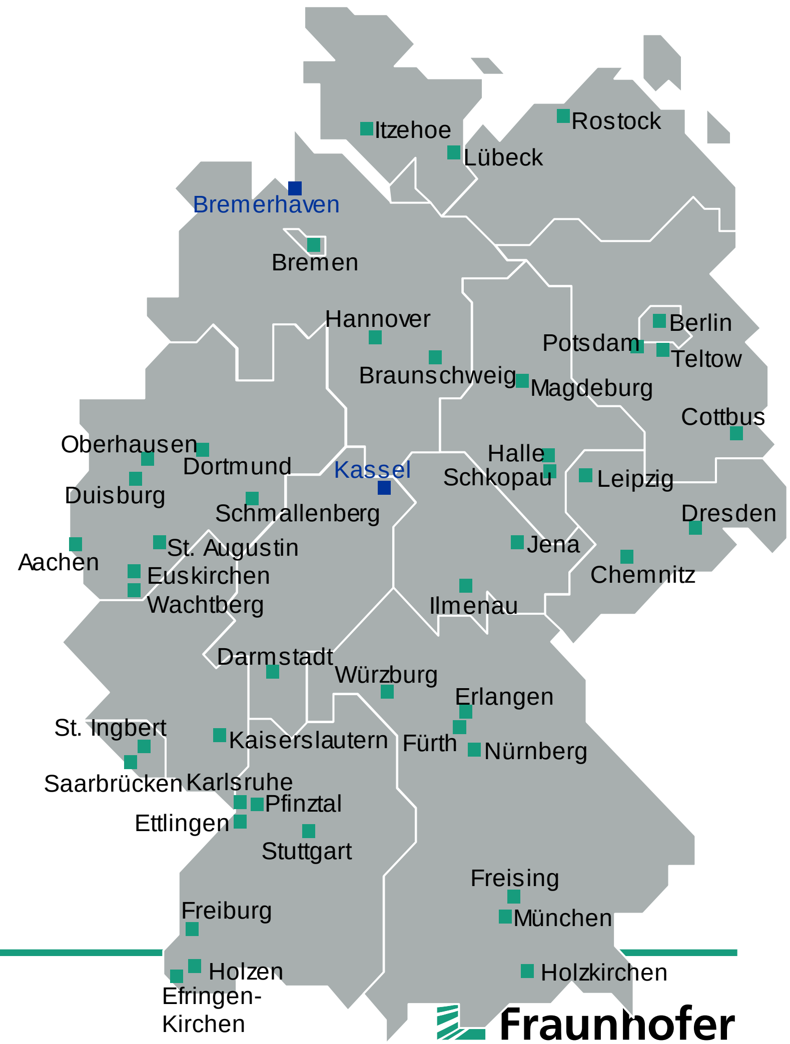
The Fraunhofer-Gesellschaft in Germany

60 Institutes at 40 locations

- Institutes
- Branches of Institutes, Research Institutions, Working Groups, Branch Labs and Application Centers

2011

Staff	20.000
R&D-budget	1.800 Million €



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Fraunhofer Institute for Wind Energy and Energy System Technology
Business fields I

- Wind energy technology and operation management
- Elasticity and dynamics of turbines and components
- Competence center rotor blade
- Development of rotors, drive trains and foundations

Fraunhofer Institute for Wind Energy and Energy System Technology
Business fields II

- Environmental analysis for wind and ocean energy
- Control and integration of decentralized converters
- Energy management and grid operation
- Energy supply structures and systems analysis

Contents

- Presentation of a hypothetical European 100% Wind and PV Electricity Scenario
- Evaluation of needed storage capacity and storage power

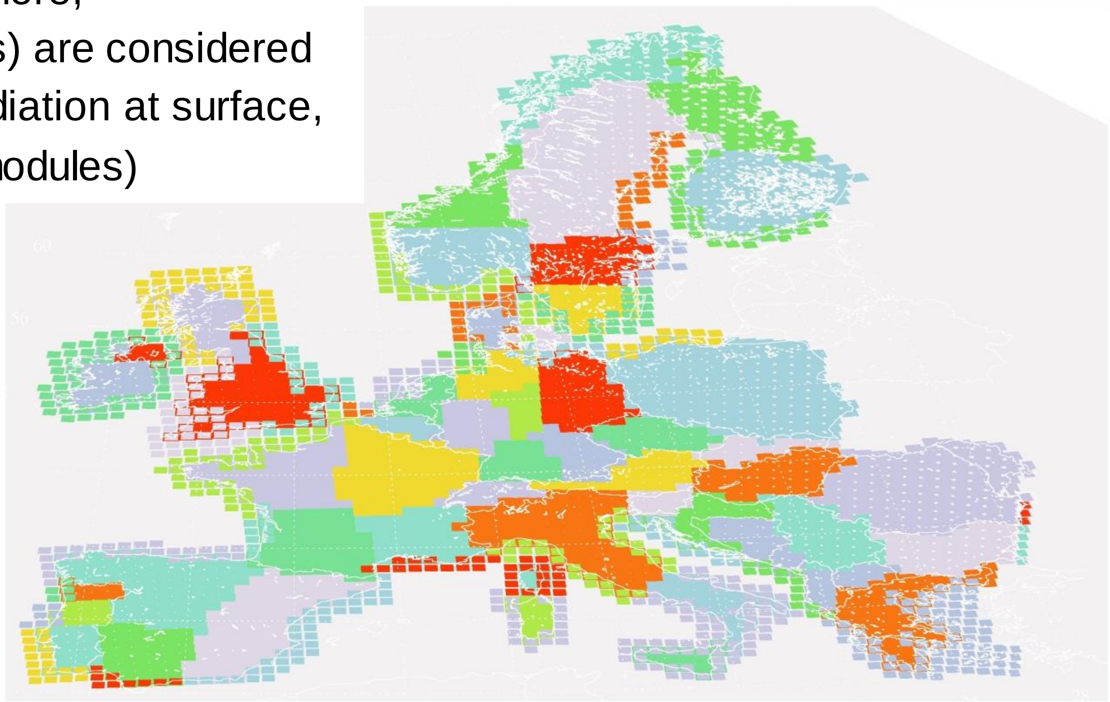
- Presentation of the German „Lead Study“ 2011
- Evaluation of electricity surpluses in Germany in the „Lead Study“ Scenarios for the years 2020, 2030 and 2050

Results from a 100% Wind and PV Scenario for Europe [1]

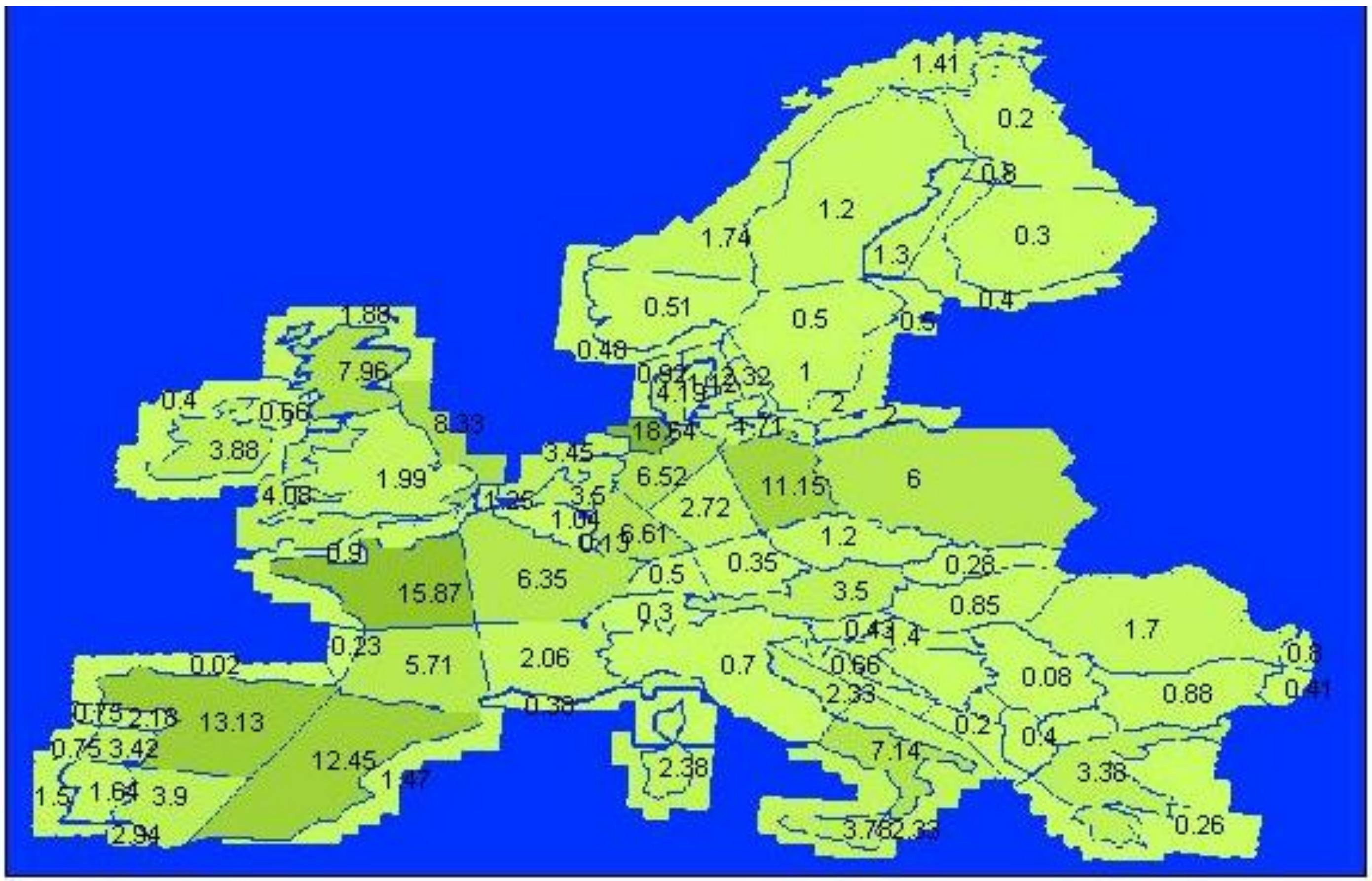
Model and input data

- Domain: UCTE + Nordel + UK/IR
- Study period: 2000-2007
- Data: 1hourly, 50km horizontal resolution
- <u>Wind Power:</u> Wind speed (~100m), standard power curves for on/offshore, losses (wake, availability, el. losses) are considered
- <u>PV:</u> cloud cover, net short wave radiation at surface, 2m Temp (ensemble of various PV modules)

- 83 regions (50 onshore, 33 offshore)



Distribution of wind power in 2020 (political targets)



sum of all installed Wind- power: 227 GW

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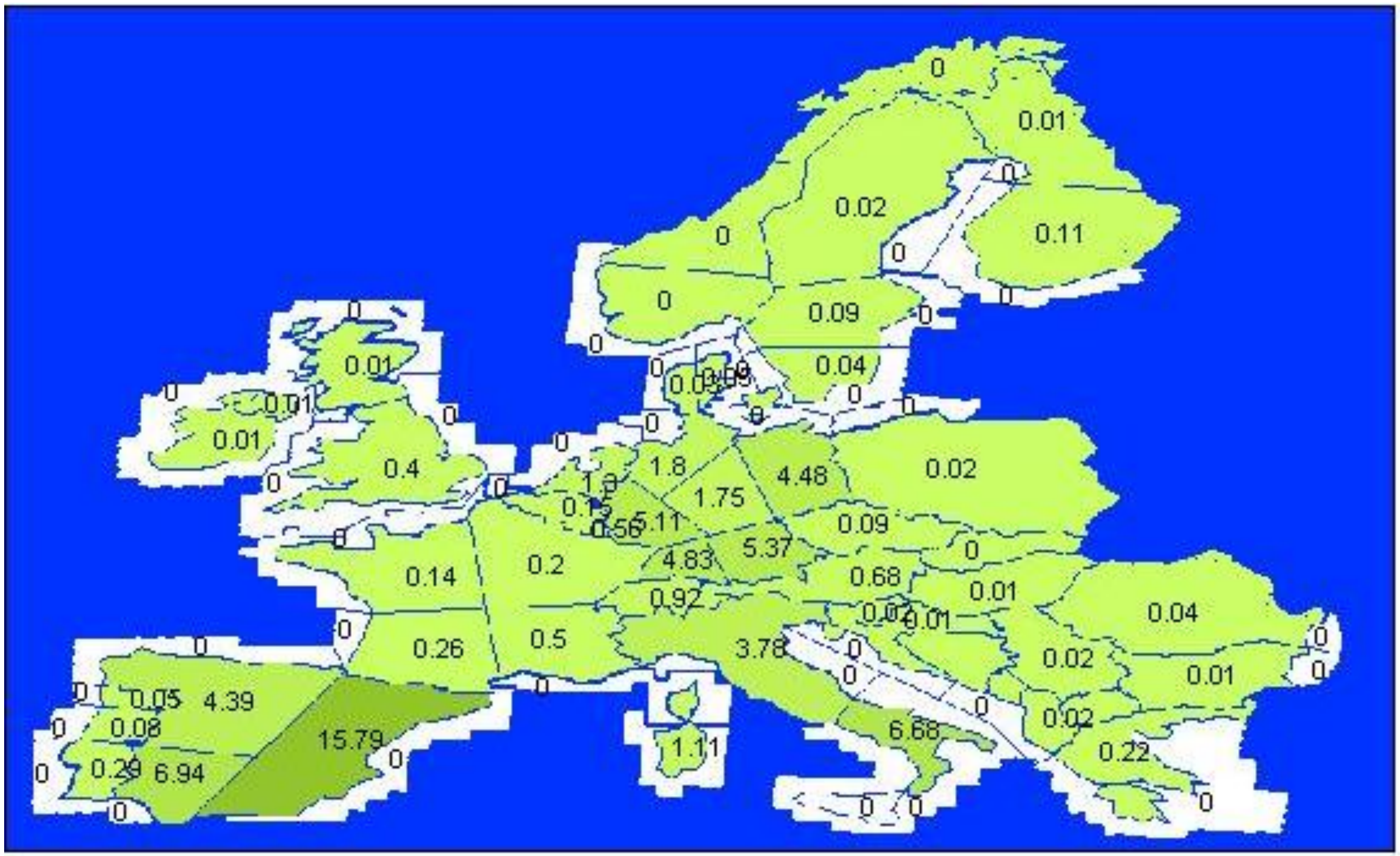
Distribution of PV in 2020 (political targets)



sum of all installed PV- power: 68 GW

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Scaling up of planned capacities for the 100% RES scenario

Average power demand in the domain: 357 GW

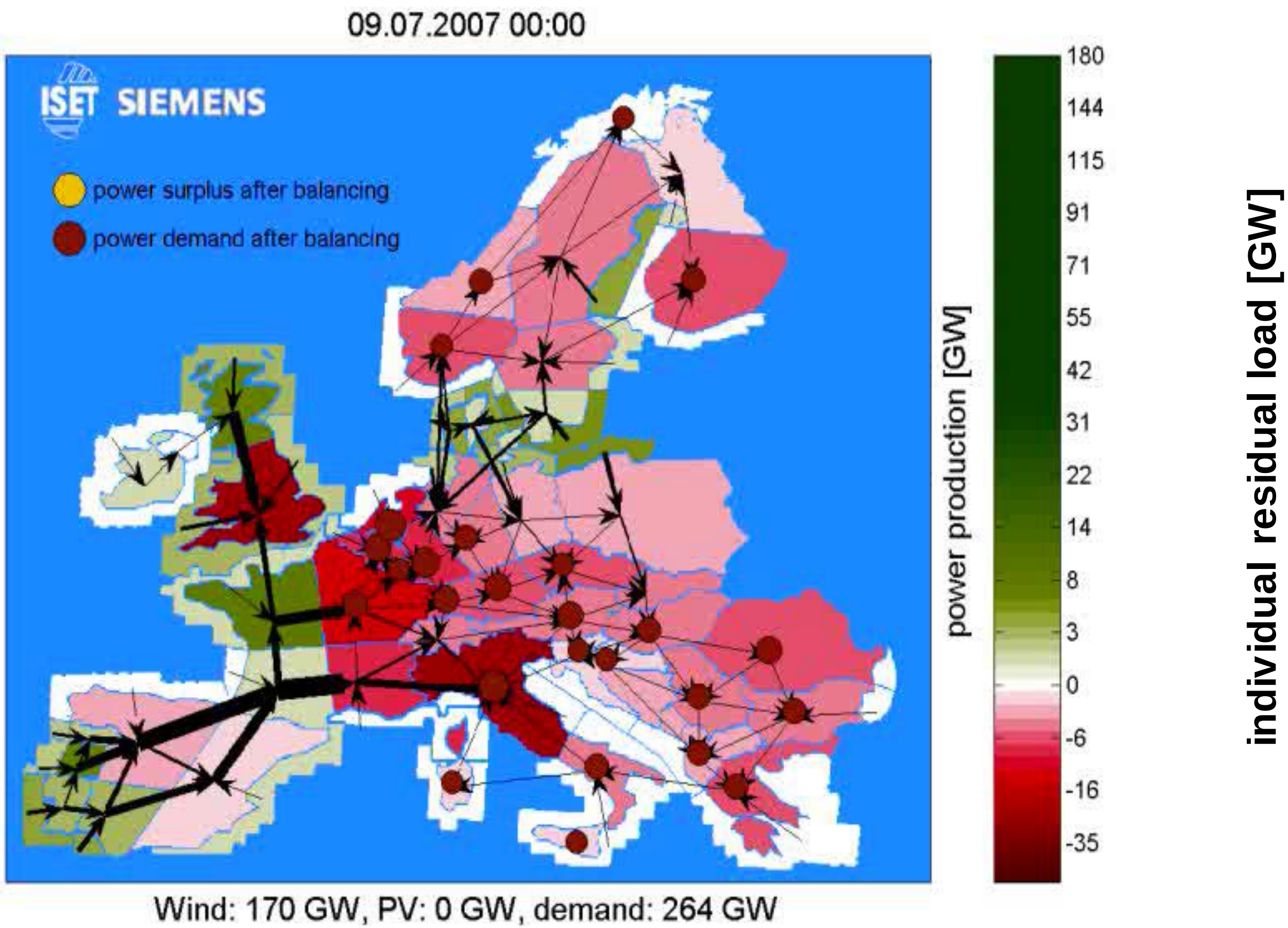
Assuming that demand remains the same as today about 23% of the consumption would be met by wind and PV power if political targets are realised

Therefore: scaling up of wind and PV targets by a factor of ~4

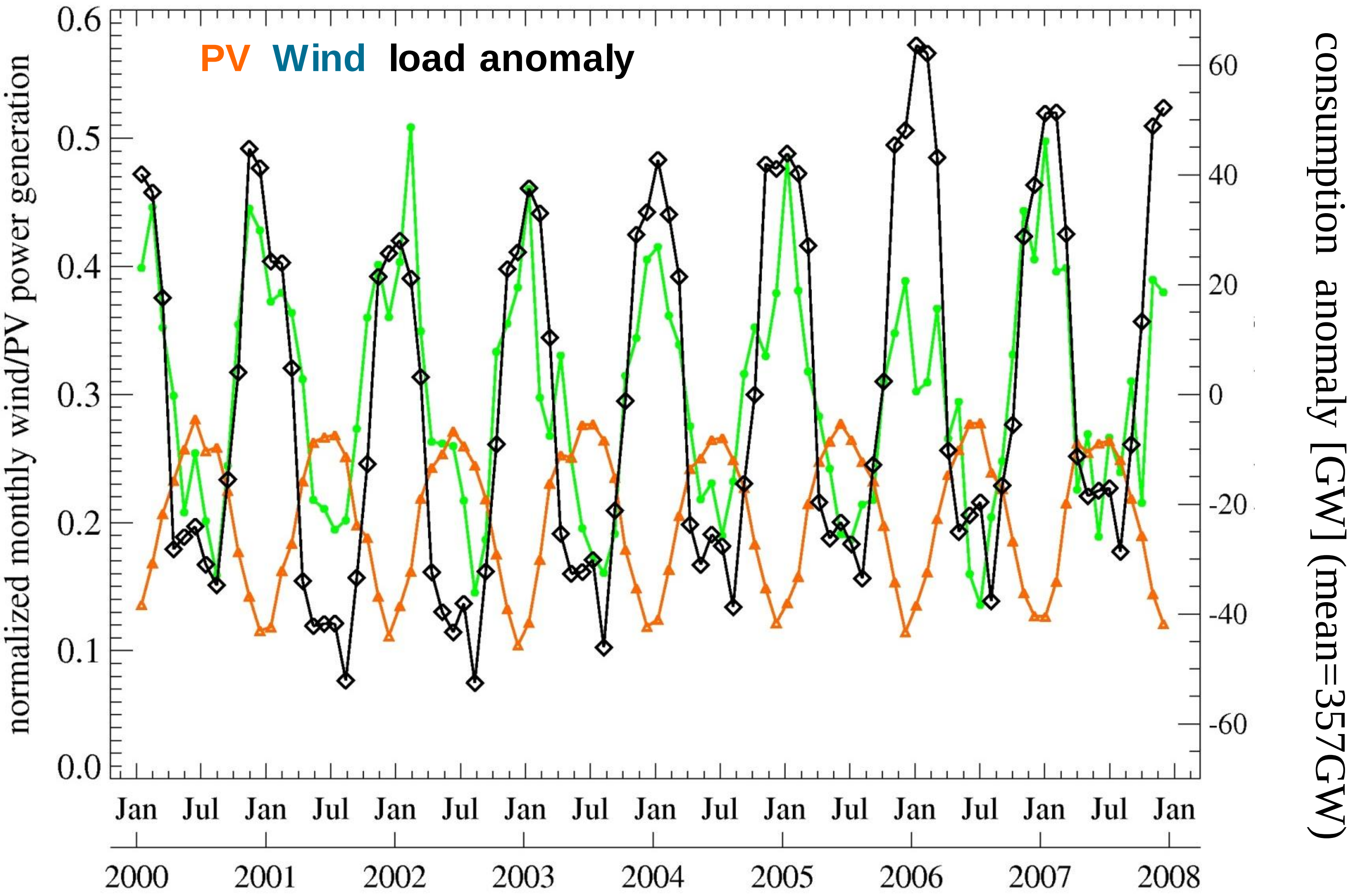
for a 100% scenario

i.e. : 908 GW wind & 272 GW PV

DC-Power flow calculation



Monthly PV, Wind generation and consumption anomalies



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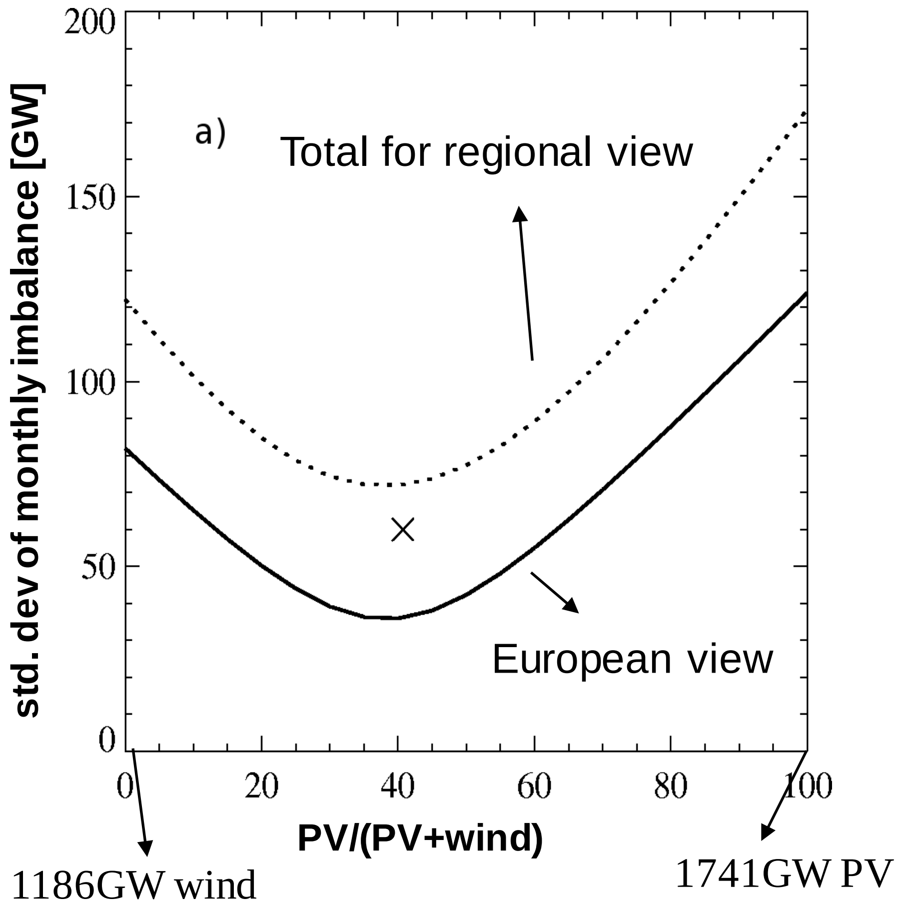
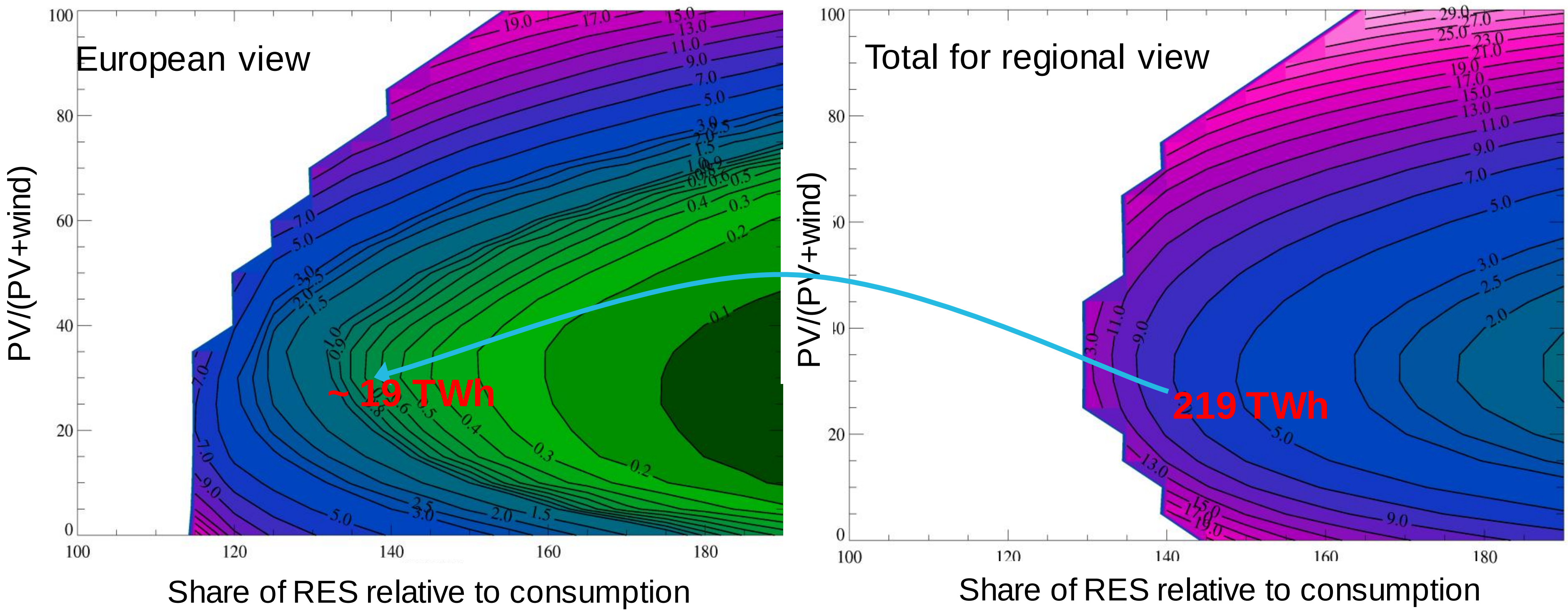
Finding the optimal ratio between PV and wind power via minimal fluctuations

- Fluctuation of monthly residual load (RES-consumption) in a 100% renewables scenario



Finding the optimal ratio between PV and wind power via required storage capacity

- Storage capacity (not considering storage losses) relative to annual consumption (=3127TWh) (in %)



- Example:140%RES, PV=30% → required storage capacity = 2.2 days of avg. consumption
- European balancing reduces storage capacity by factor of 11!

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Candidates for needed large scale storage technologies

Needed storage capacity in TWh for different technologies

Technology	Needed Capacity in TWh to store 2% of average European consumption
Hydrogen	100
Pump hydro	67
AA-CAES	80

Needed storage power: ~ 190 GW

Hydro storage plants in Nordel

Storage plants	Norway	Sweden	Finland	Sum
Capacity [TWh]	81,7	33,8	5,5	**121**
Power [GW]	29	16	3	**48**

Conclusions for the 100 % Wind and PV for Europe Scenario

- Transport can considerably reduce the need for storage (meteorological smoothing effects)
- Varying the ratio of installed PV to wind capacity can decrease the need for seasonal storage
- In a perfect European transport model the minimum needed storage capacity in pump hydro storage would be 25 TWh with a power of 190 GW

Results from the German Lead Study 2011 [2]

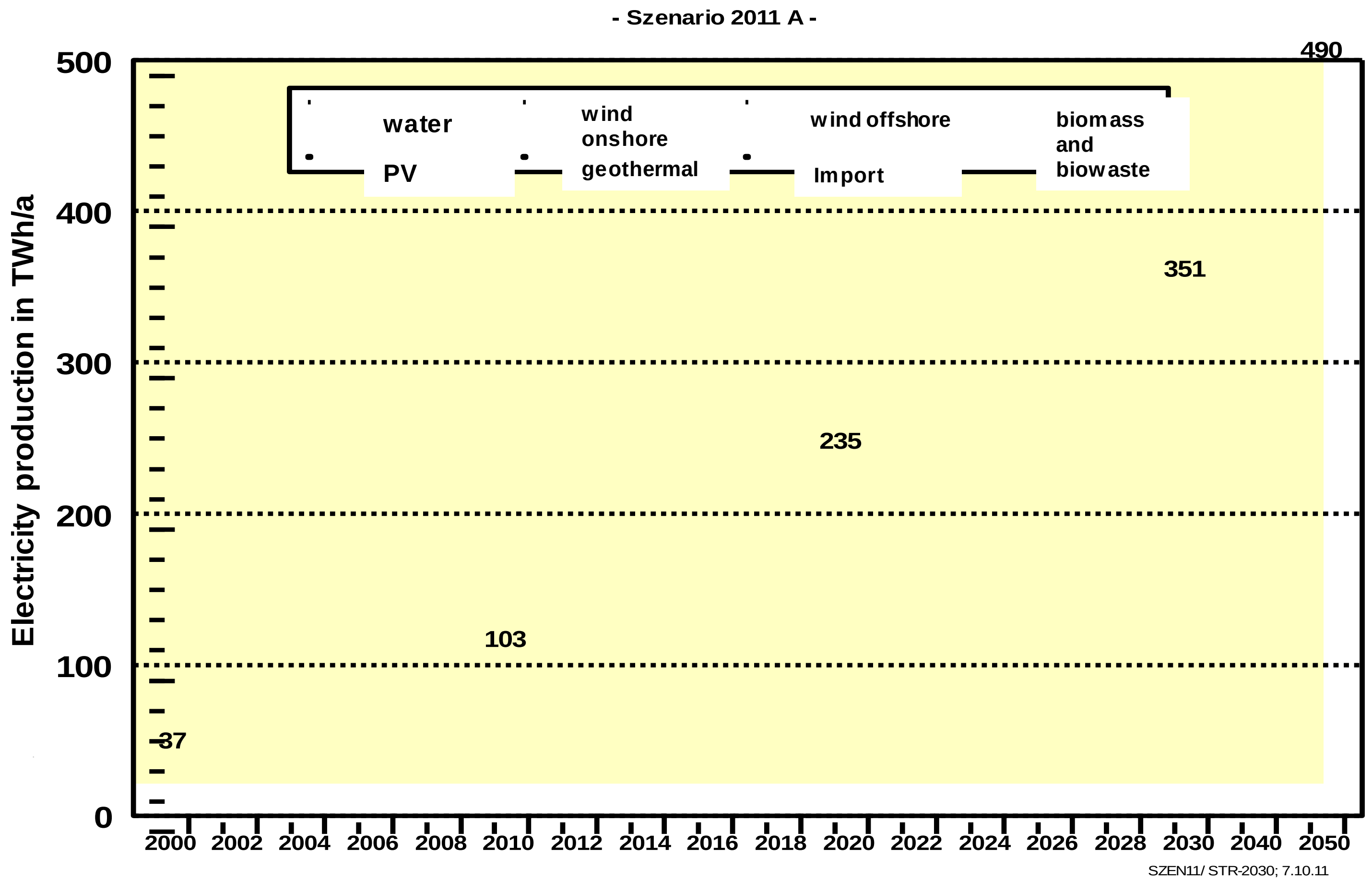
Germany‘s RE extension plans and the German Lead Study

	2020	2030	2050
Aim for RE share in gross electricity production according to the government‘s energy concept	35 %	50%	80%
RE share in gross electricity production the Lead Study Scenarios A and C	40,9% / 40,5 %	62,9 % / 63,2%	85% / 86,6%

RE Capacities installed in Germany in the Lead Study Scenario A and C

in GW	2020	2030	2050
Wind	49	70.2 **/** 67.23	79 **/** 82.8
PV	53.5	61	67.2
Water	4.7	4.9	5.2
Biomass	9 **/** 8.4	10	10.4
Geothermal	0.3	1	2.4 **/** 3
Import	0.4	3.6	7 **/** 10.5
Total	~ 117 GW	~ 150 GW	~ 175 GW

Electricity Production in Germany by Renewables according to the German Lead Study RE Extension Scenario A



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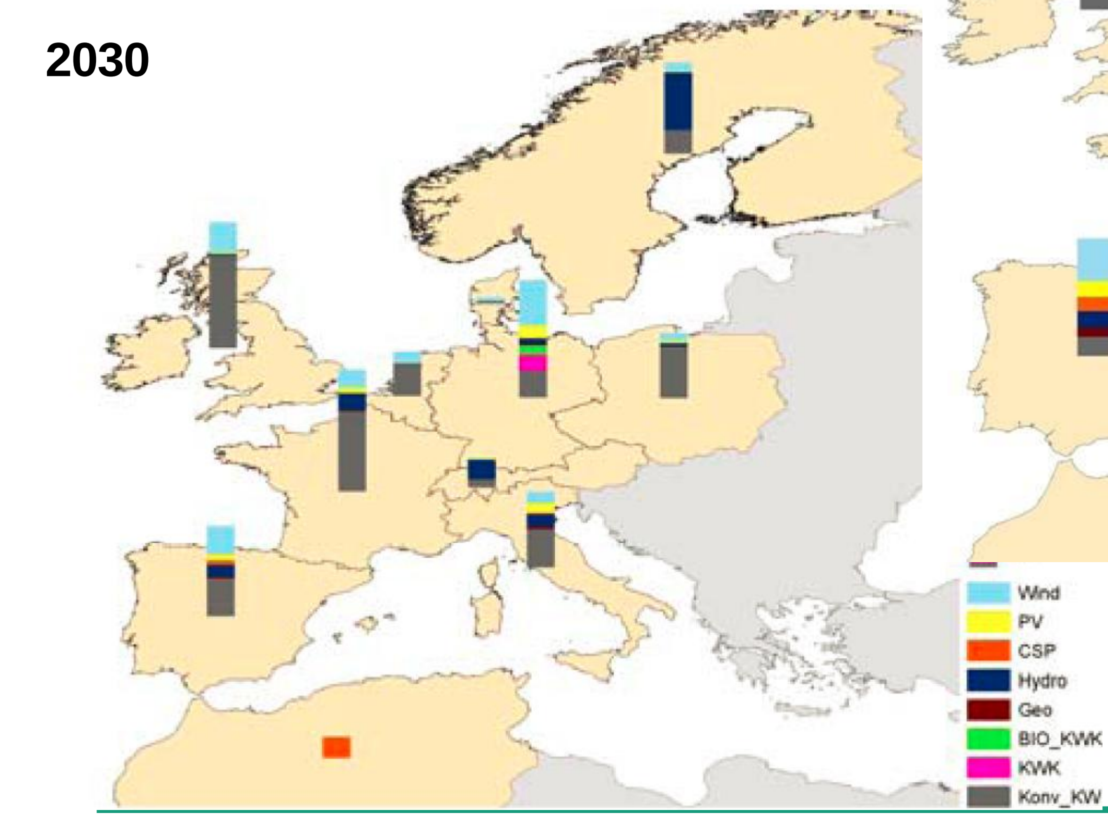
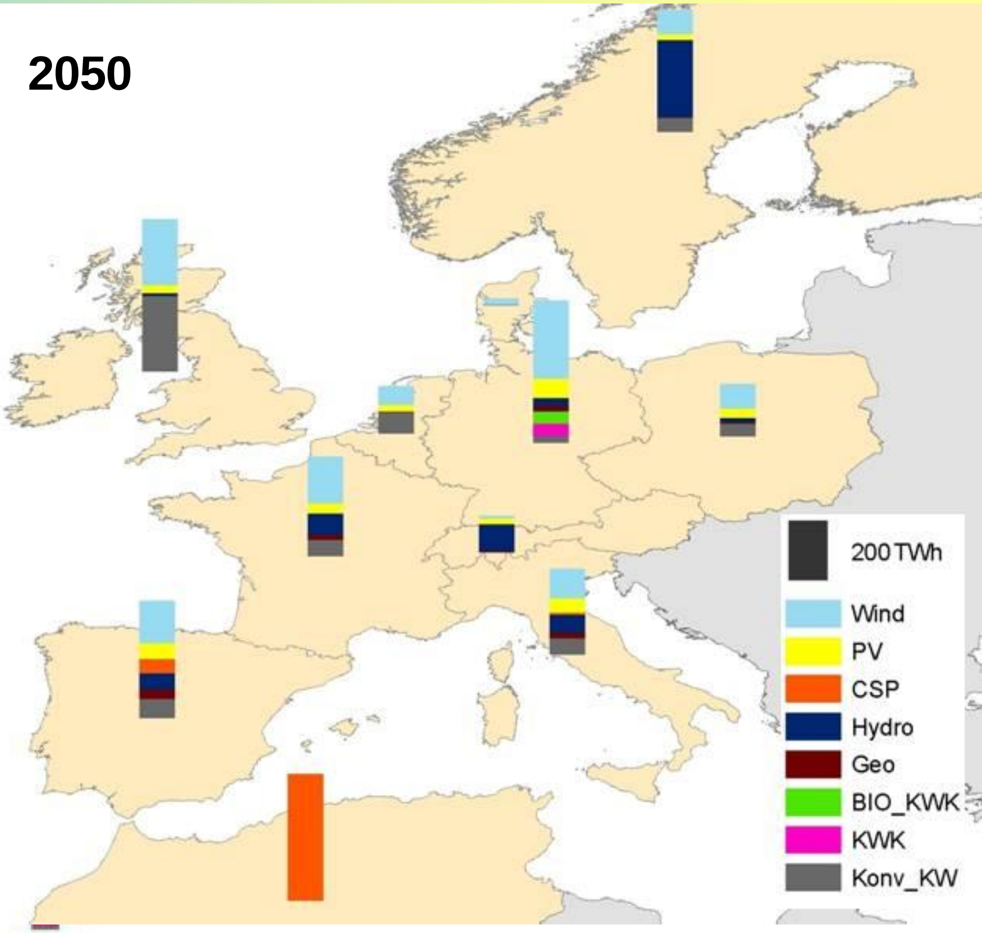
Scenario Electricity Production in Europe - Scenario 2011 A





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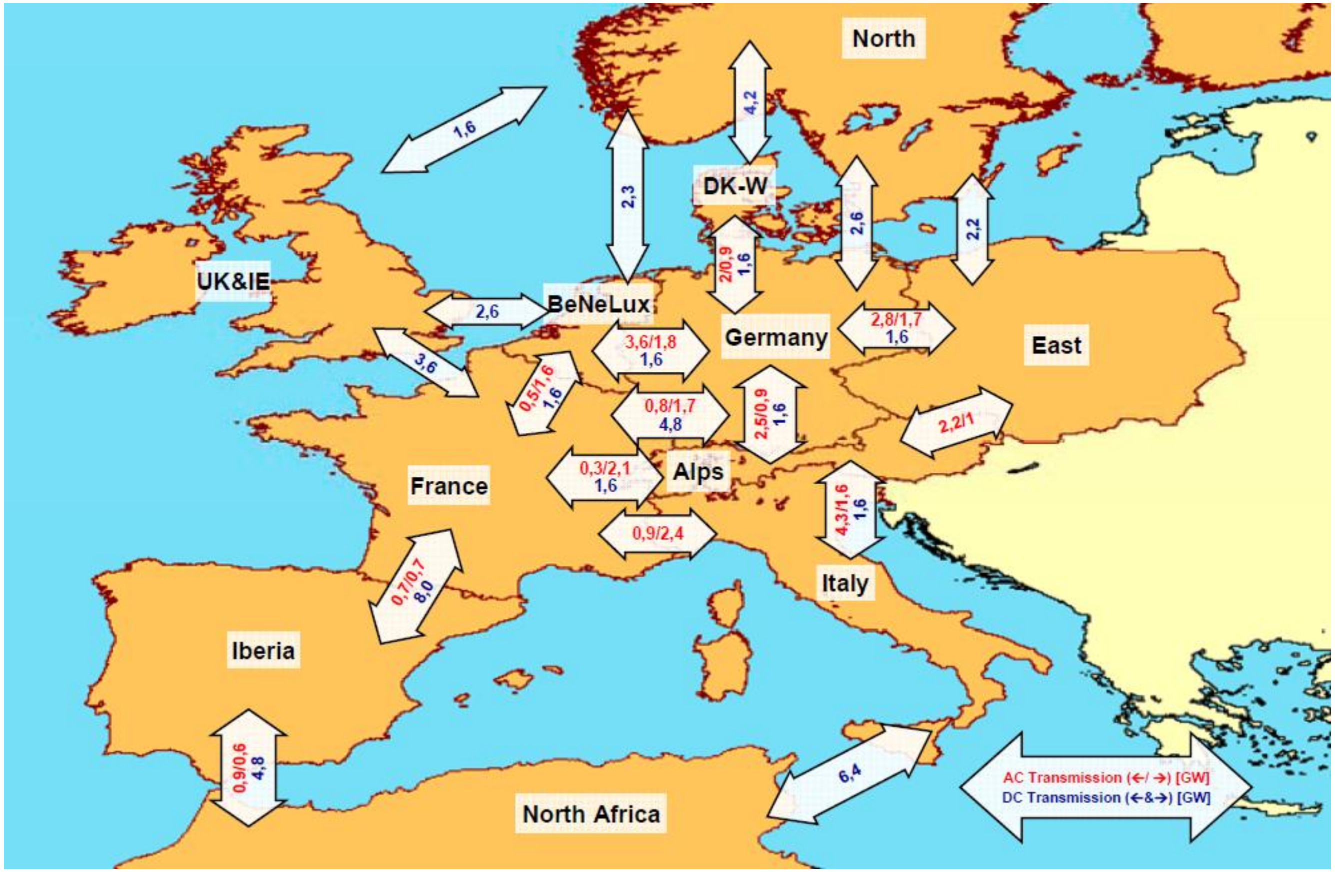
Grid Extension - Scenario 2011 A

2030 HVDC-transfer capacities Germany: 9 GW



Germany	Deutschland
North	Dänemark Nord, Finnland, Norwegen, Schweden
Dk-W	Dänemark West
BeNeLux	Belgien, Luxemburg, Niederlande
Iberia	Portugal, Spanien
Alps	Schweiz, Österreich, Liechtenstein
France	Frankreich
Italy	Italien
East	Polen, Tschechische Republik, Slowakei
UK&IE	Großbritannien, Irland
North Africa	Algerien, Marokko, Tunesien

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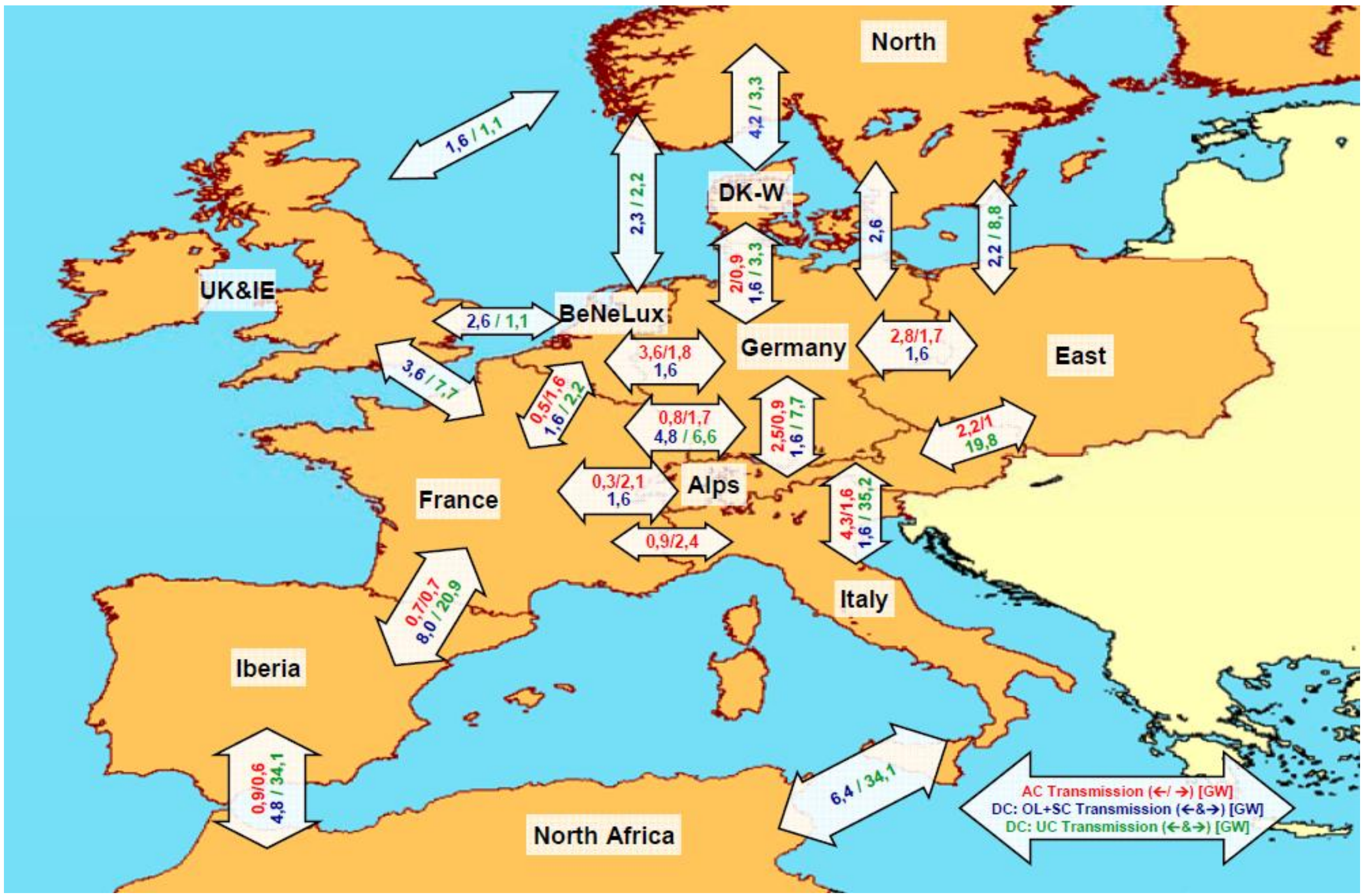
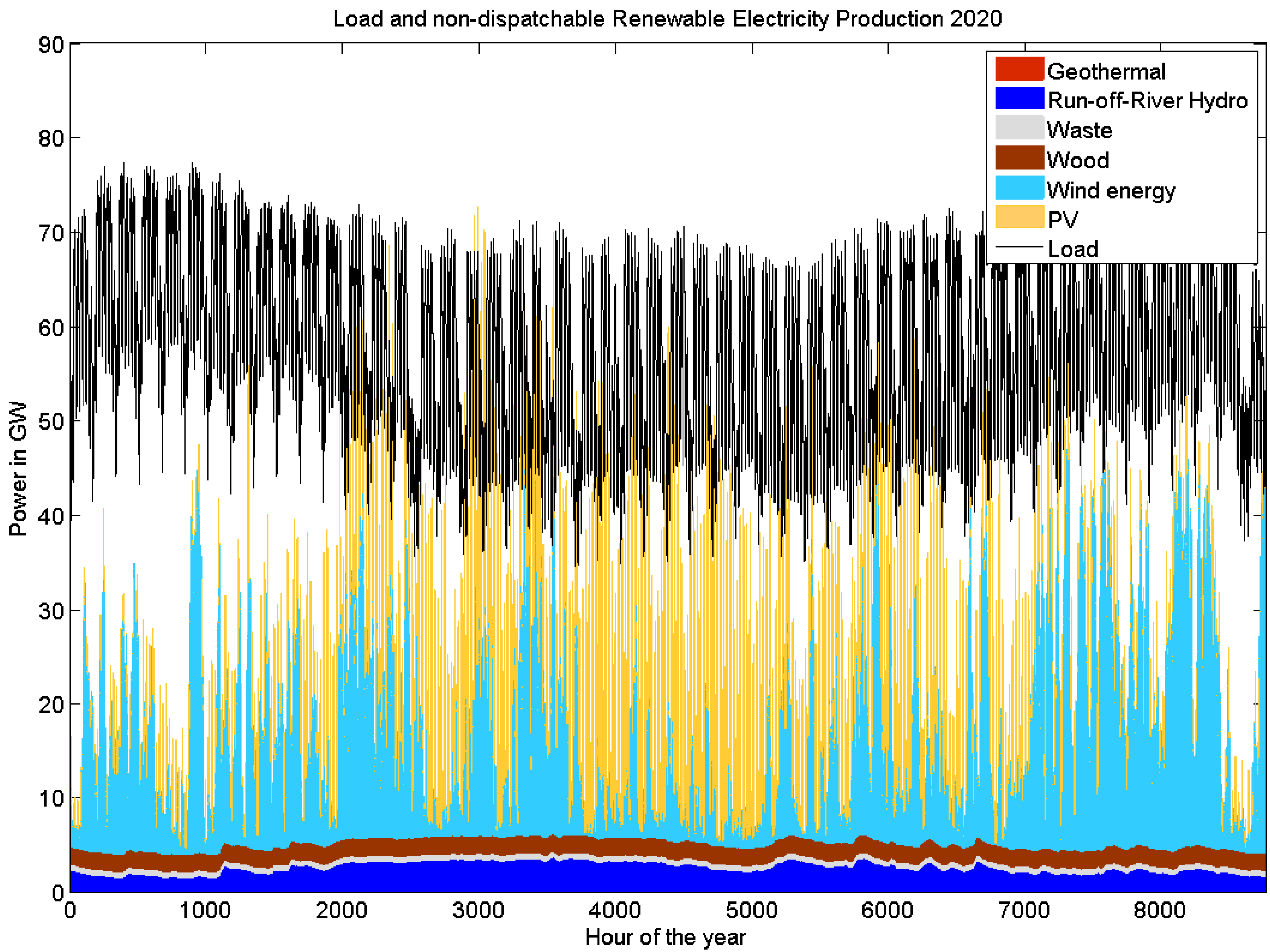
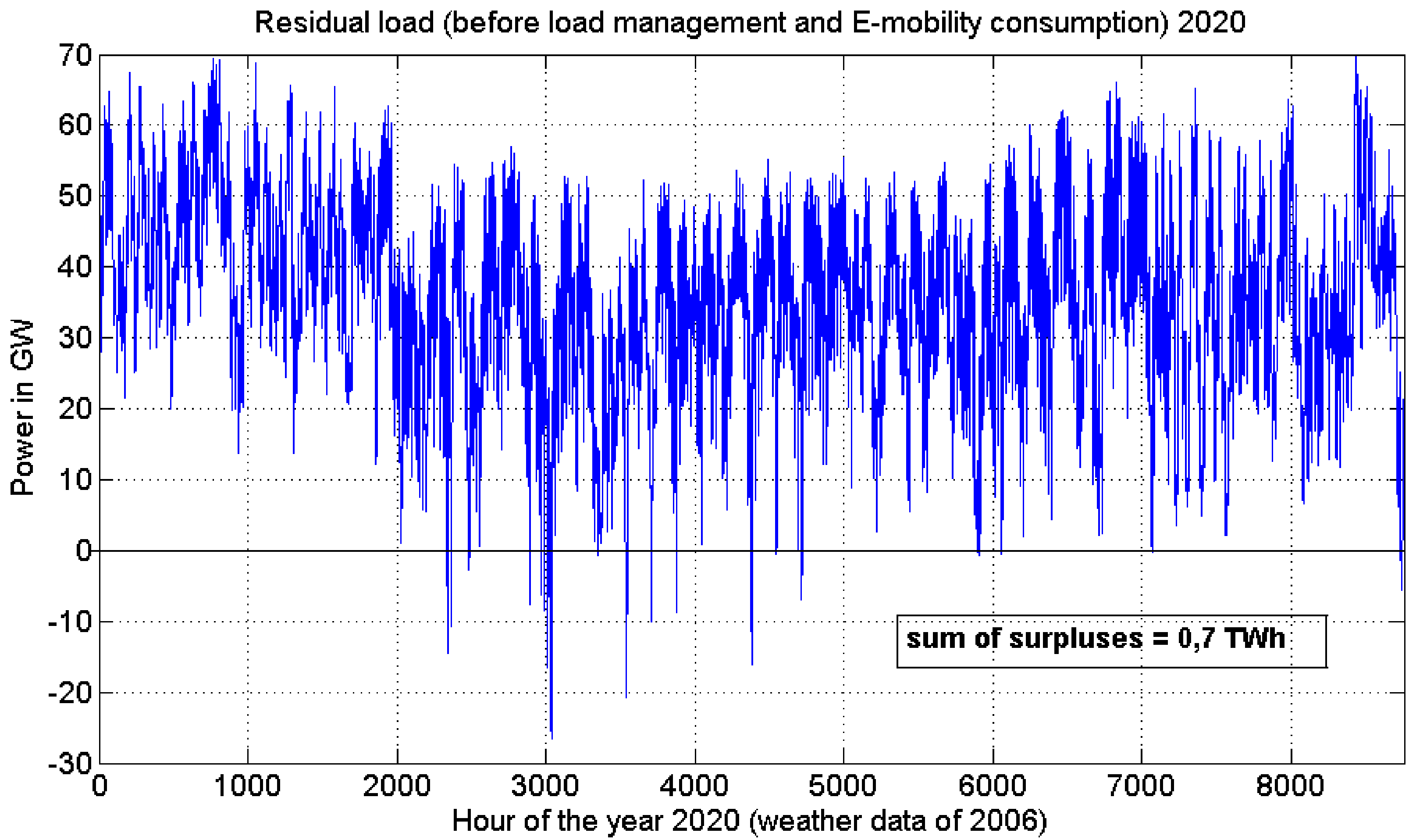
2050 HVDC-transfer capacities Germany: 29 GW




Load and non-dispatchable Renewable Electricity Production 2020
Power in GW
Hour of the year
0
10
20
30
40
50
60
70
80
90
1000
2000
3000
4000
5000
6000
7000
8000
Geothermal
Run-off-River Hydro
Waste
Wood
Wind energy
PV
Load



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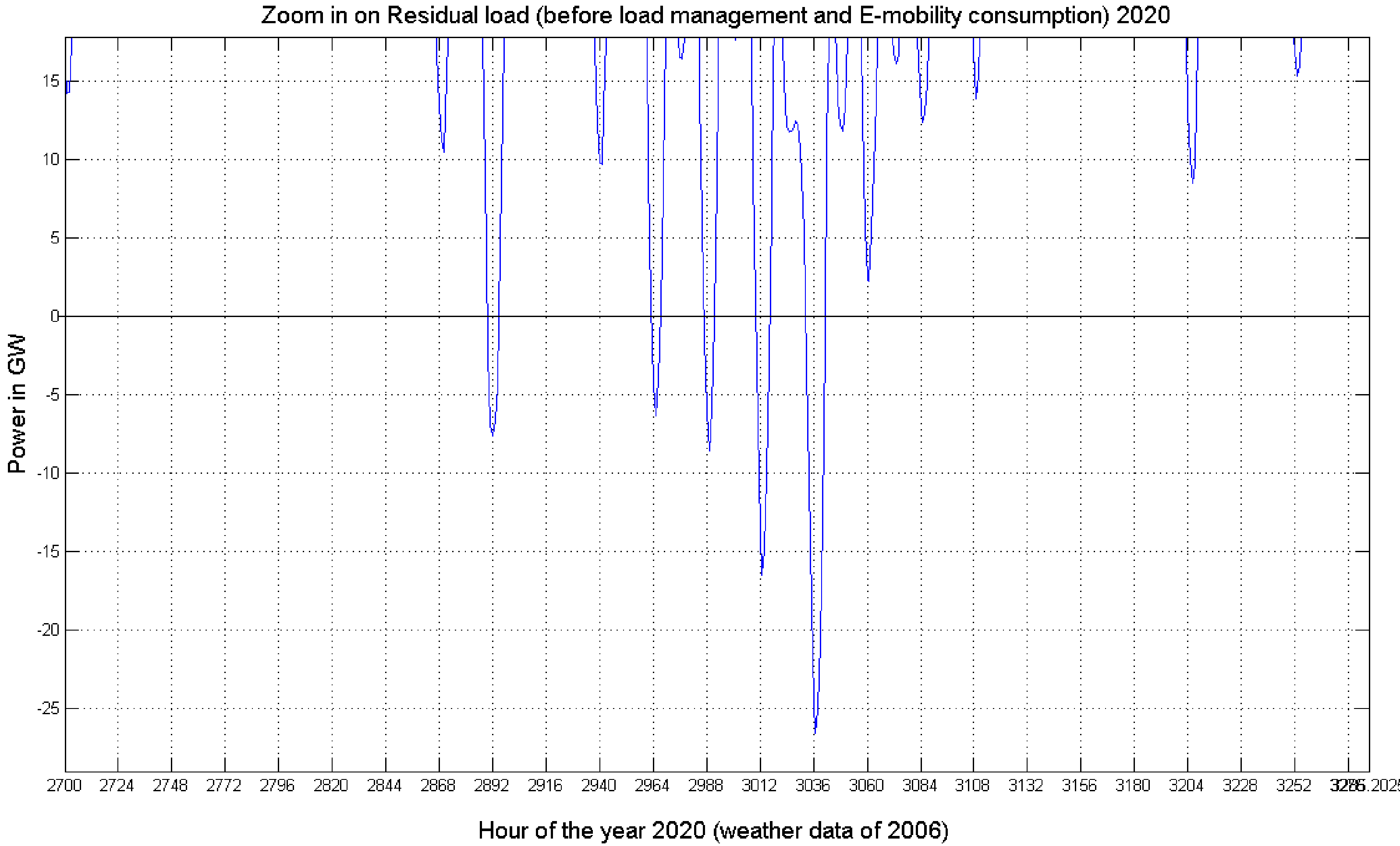
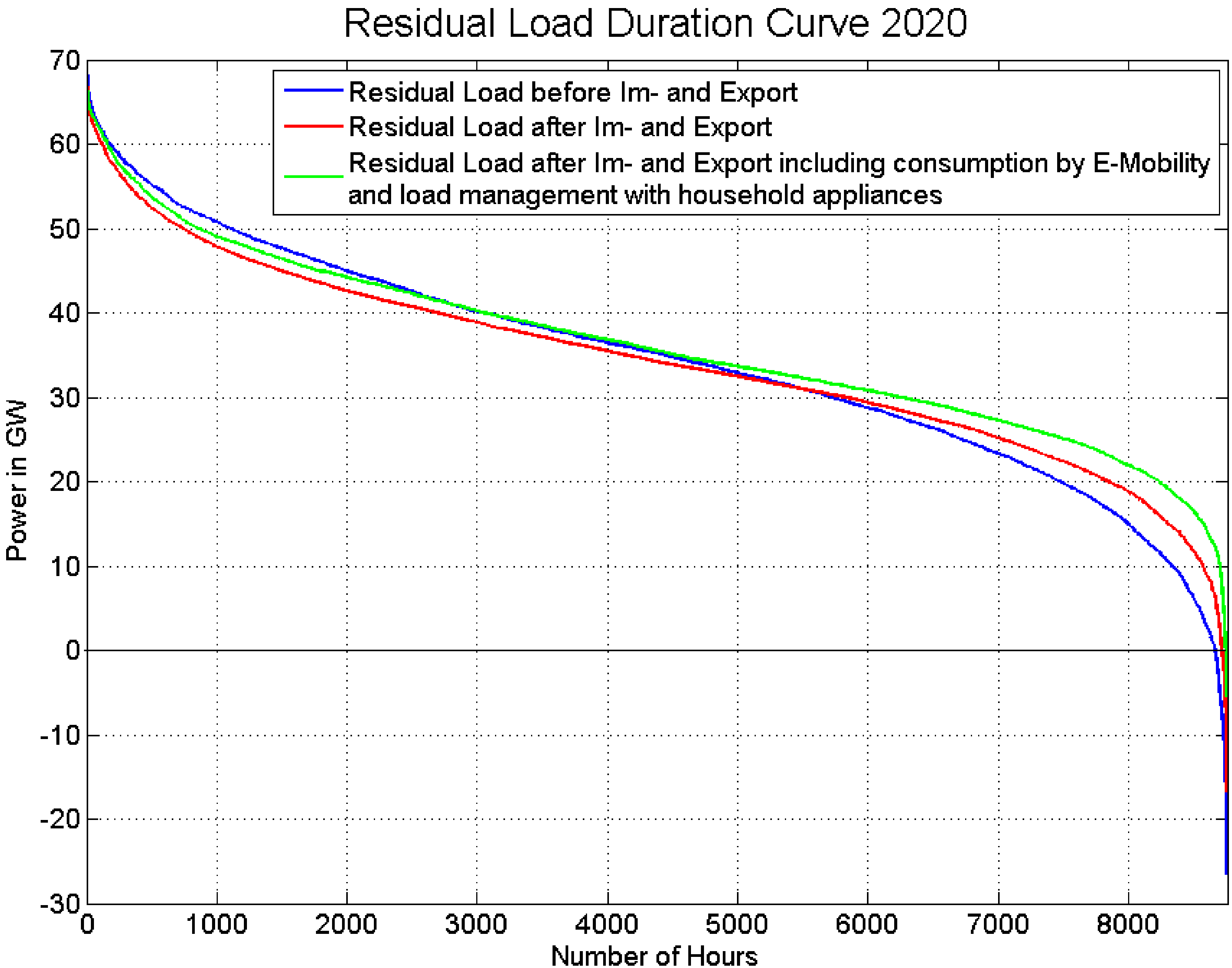
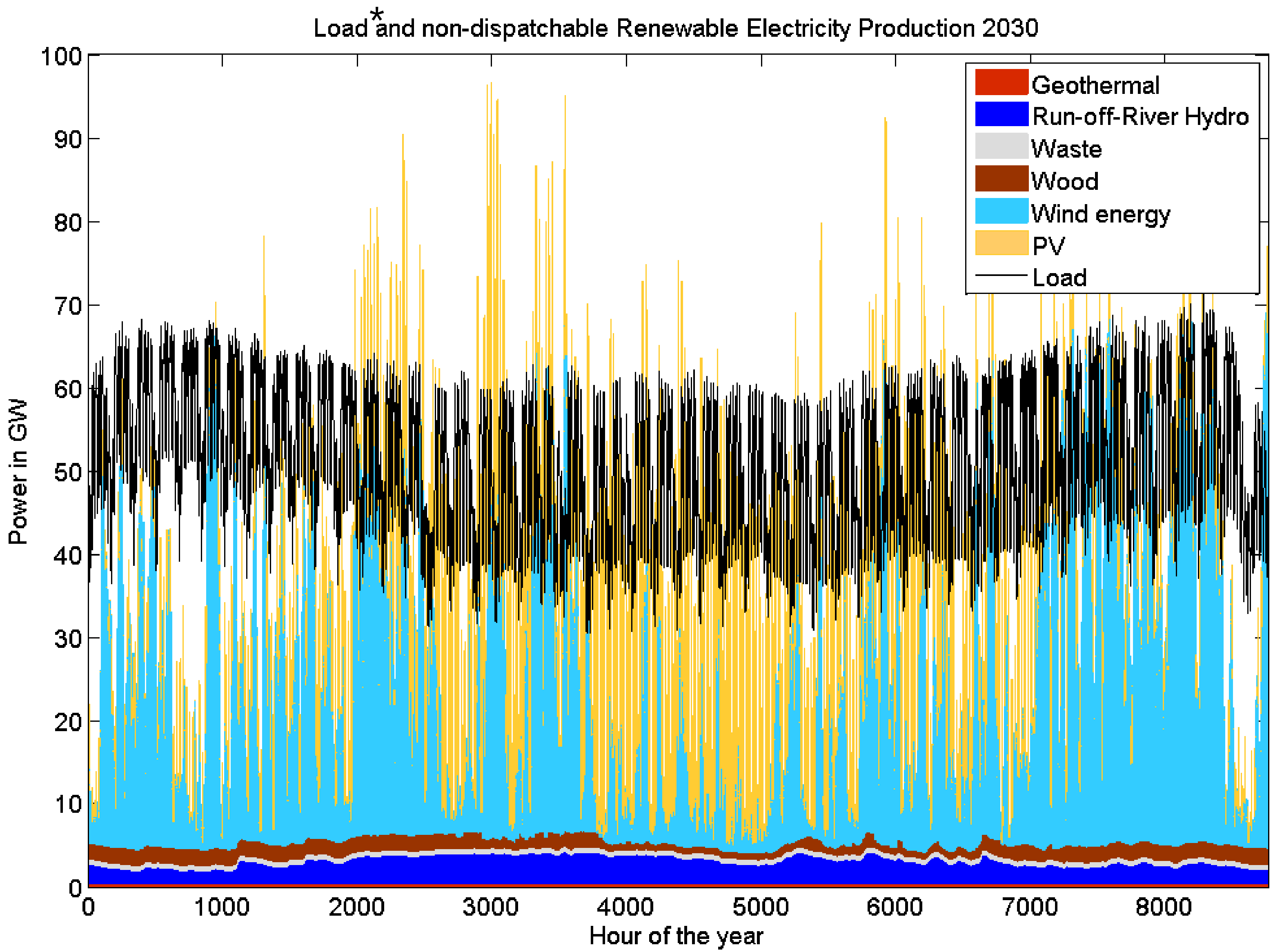

Zoom in on Residual load (before load management and E-mobility consumption) 2020
Power in GW
15
10
5
0
-5
-10
-15
-20
-25
2700
2724
2748
2772
2796
2820
2844
2868
2892
2916
2940
2964
2988
3012
3036
3060
3084
3108
3132
3156
3180
3204
3228
3252
3276
3285.2025
Hour of the year 2020 (weather data of 2006)


Residual Load Duration Curve 2020
Residual Load before Im- and Export
Residual Load after Im- and Export
Residual Load after Im- and Export including consumption by E-Mobility and load management with household appliances
Power in GW
70
60
50
40
30
20
10
0
-10
-20
-30
0
1000
2000
3000
4000
5000
6000
7000
8000
Number of Hours

IWES



*Load before consumption of electromobility (E-mobility consumption= 9,3 TWh/a) and load management appliances

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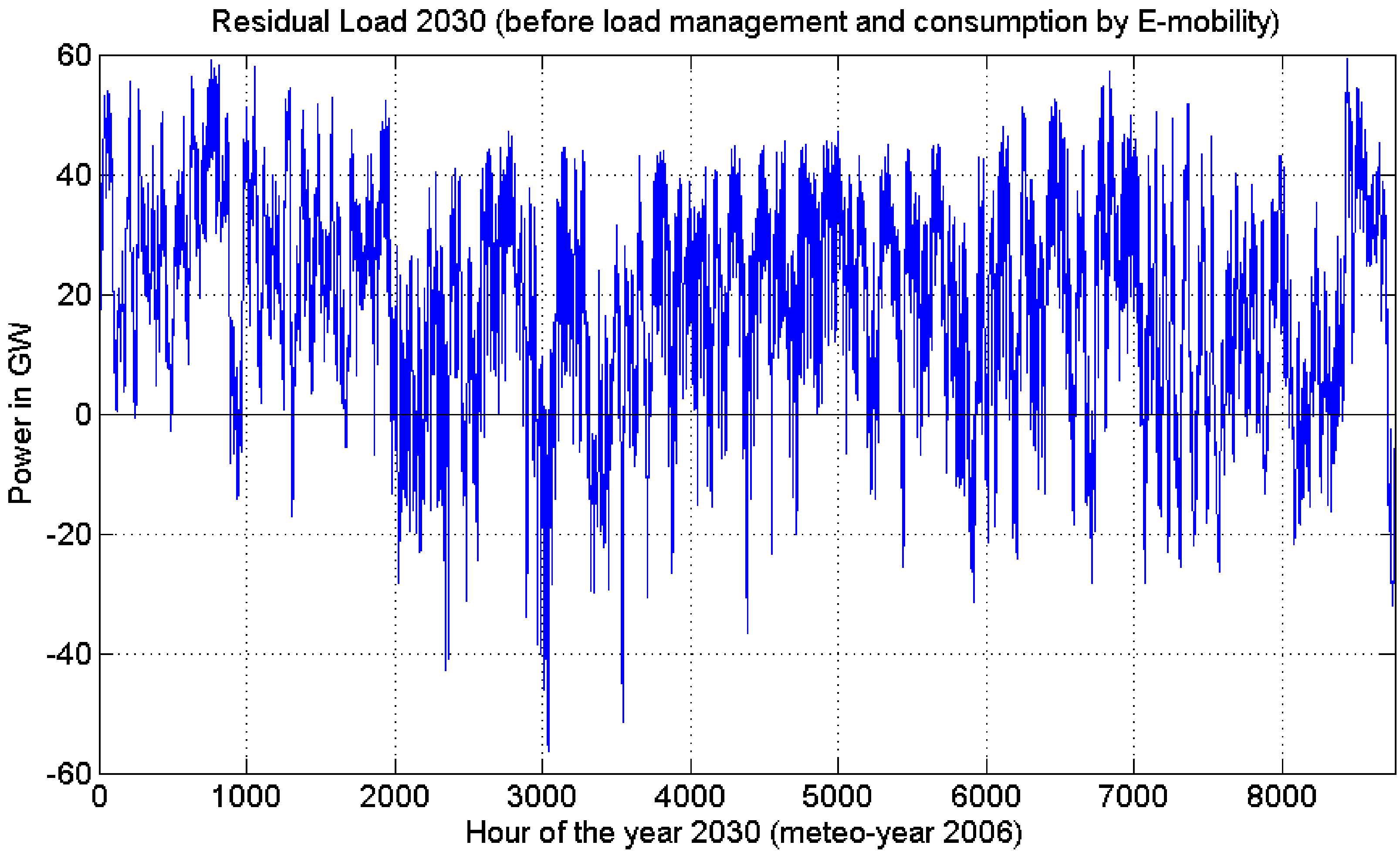

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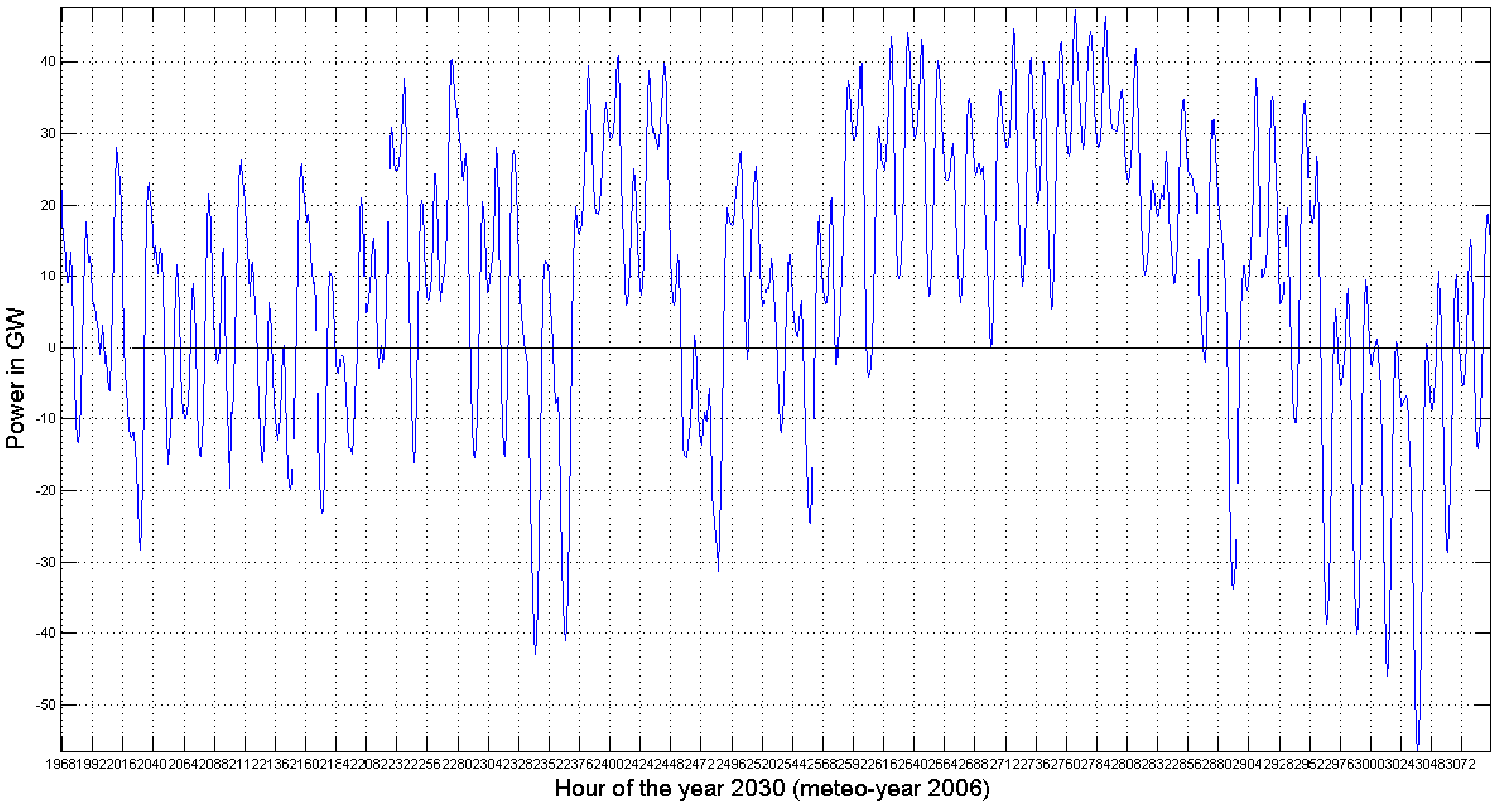
Zoom in on Residual Load 2030 (before load management and consumption by E-mobility)



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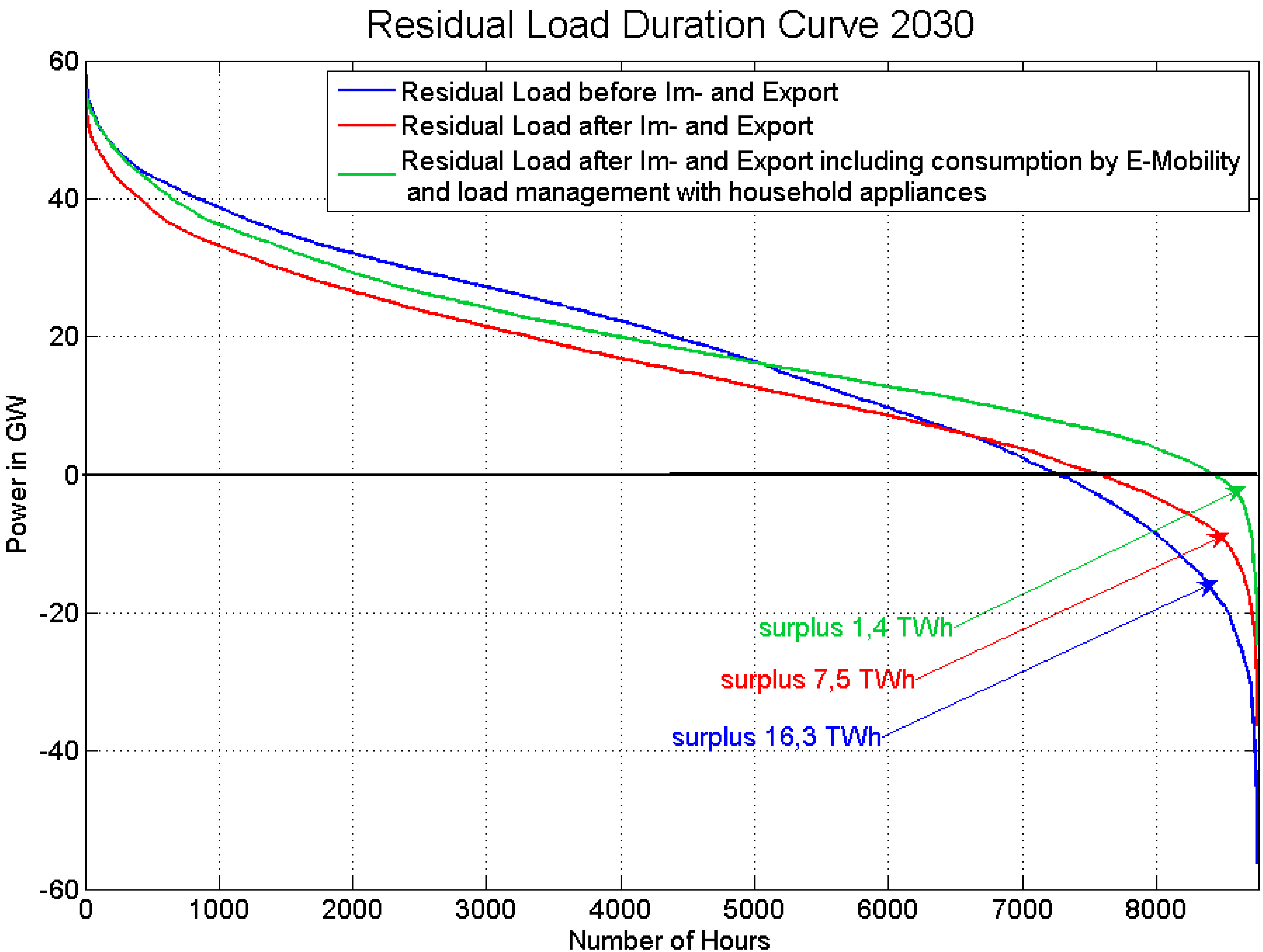
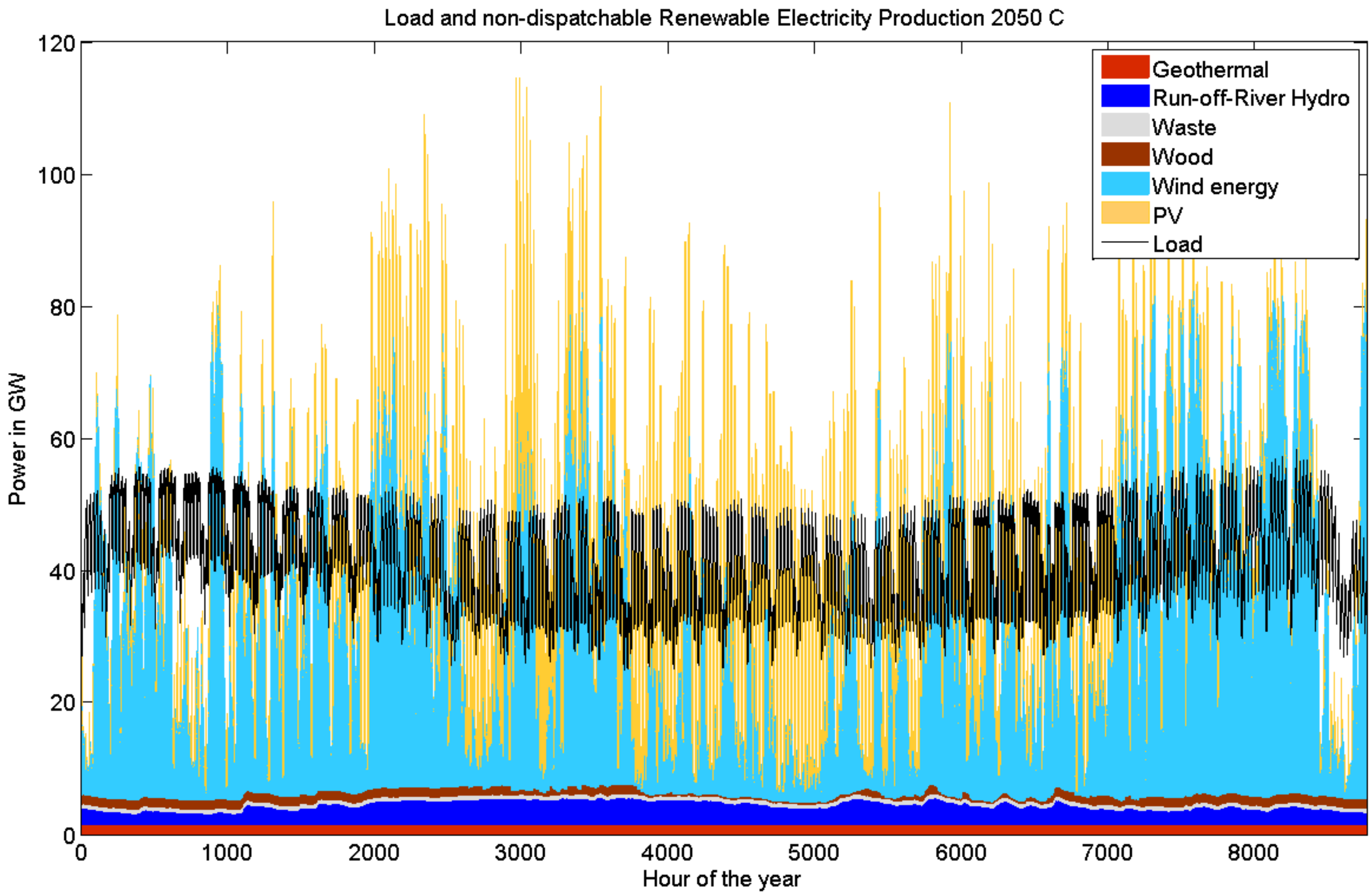
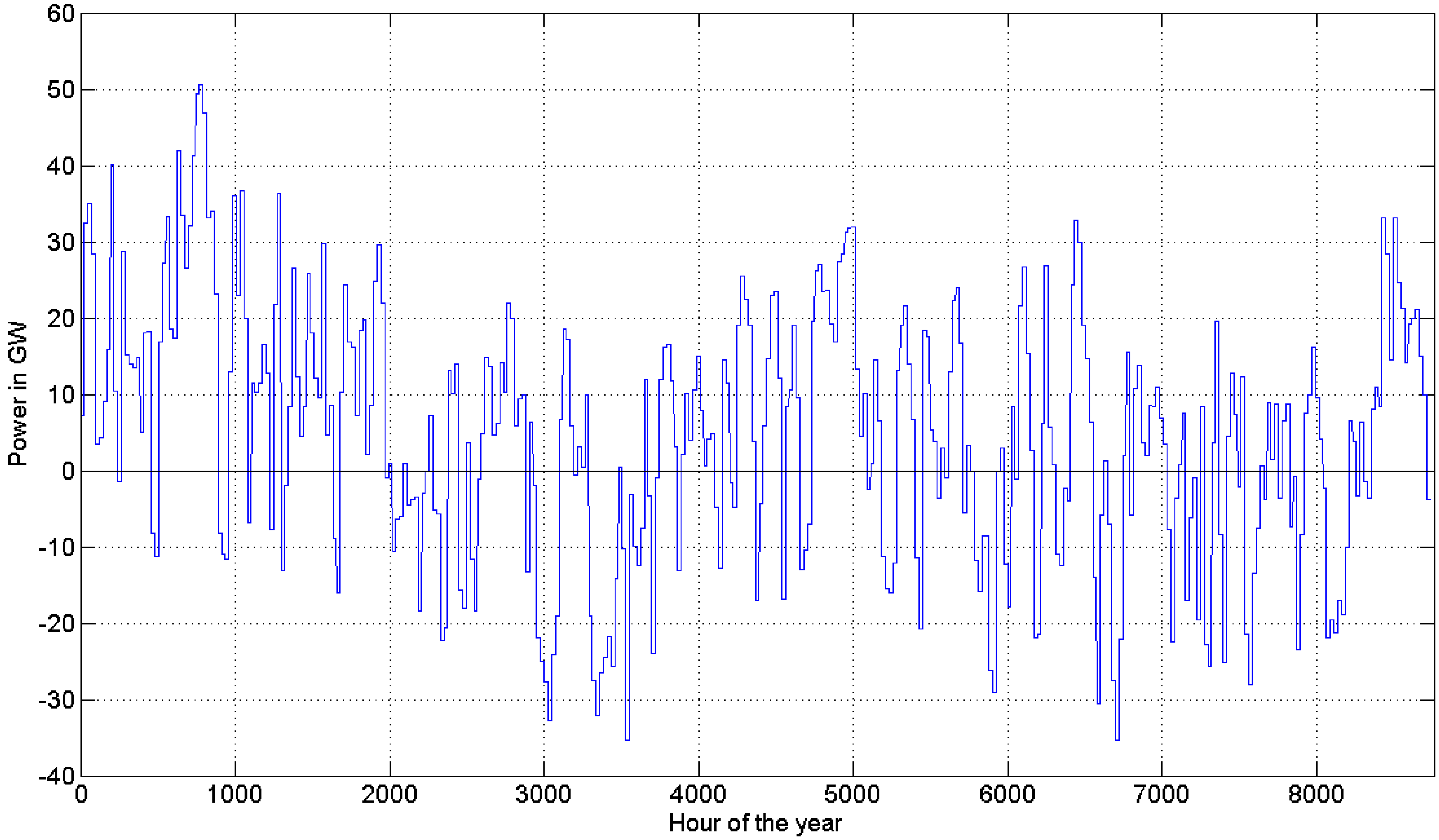


Residual Load Duration Curve 2030
Residual Load before Im- and Export
Residual Load after Im- and Export
Residual Load after Im- and Export including consumption by E-Mobility and load management with household appliances
surplus 1,4 TWh
surplus 7,5 TWh
surplus 16,3 TWh
Power in GW
Number of Hours
60
40
20
0
-20
-40
-60
0
1000
2000
3000
4000
5000
6000
7000
8000


Load and non-dispatchable Renewable Electricity Production 2050 C
Power in GW
Hour of the year
0
20
40
60
80
100
120
0
1000
2000
3000
4000
5000
6000
7000
8000
Geothermal
Run-off-River Hydro
Waste
Wood
Wind energy
PV
Load

24 – hour average of the residual load in Scenario 2050 C including load



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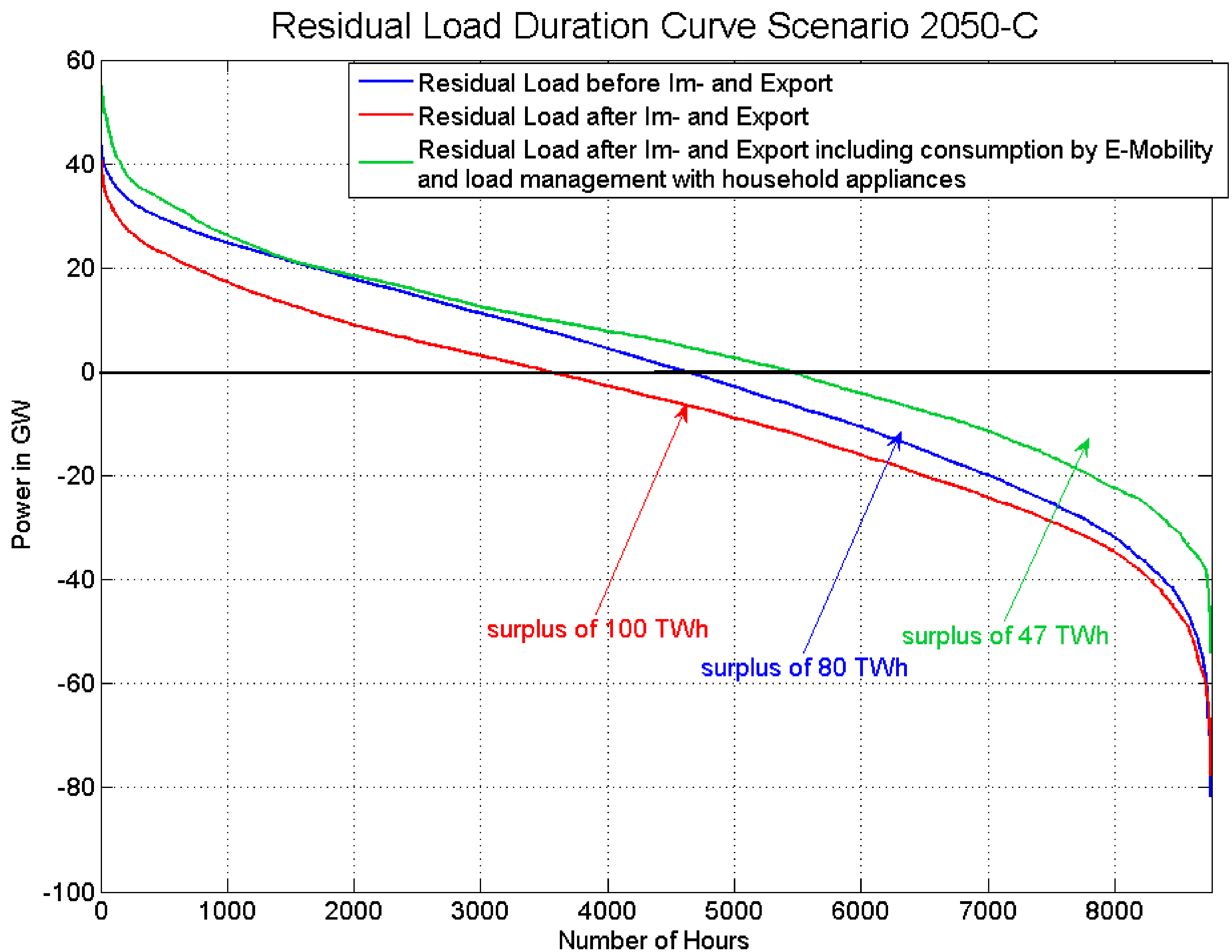

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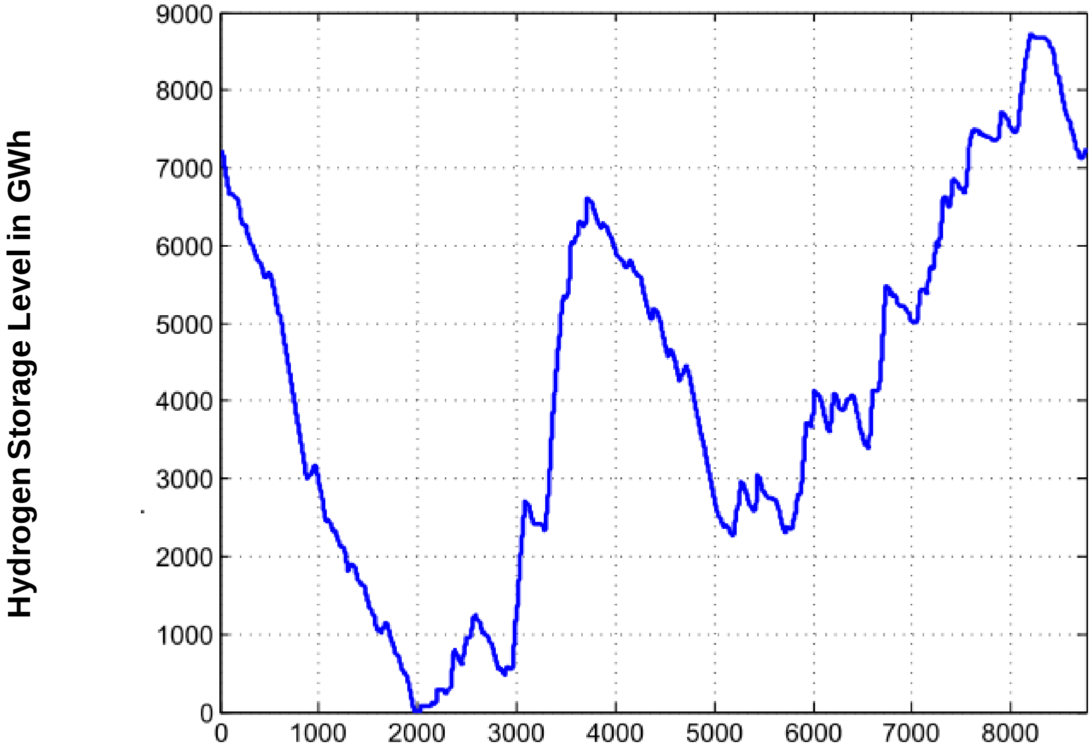
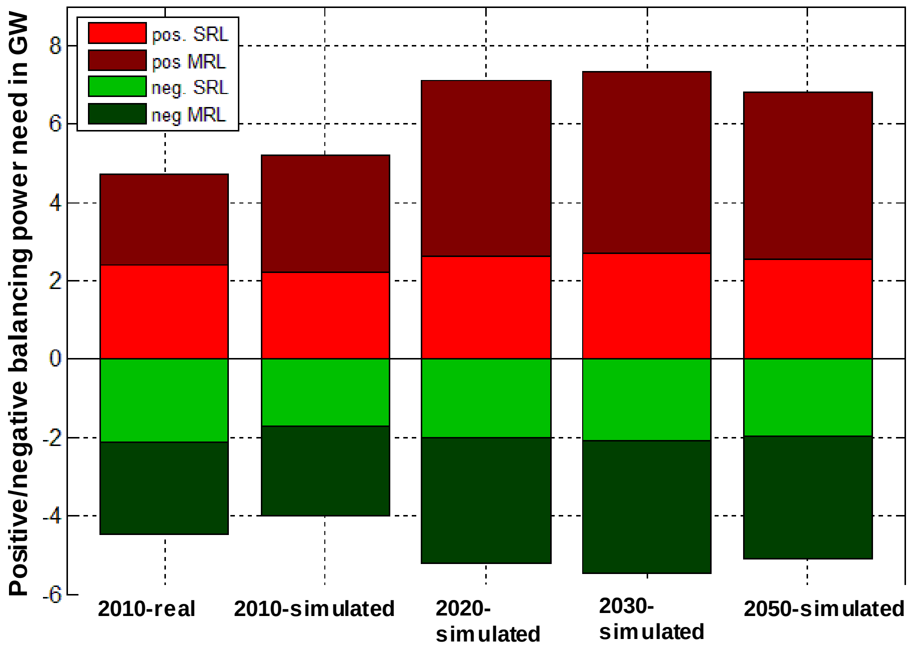
Needed hydrogen storage capacity in Scenario 2050 C



Estimation of needed Capacity for Secondary and Tertiary Balancing Power in Germany Scenario 2020- 2050 A



Balacing power decreases if the forecast error can be decreased enough. Assumed forecast error as nRMSE (see table on the left)

nRMSE	2010	2020	2030	2040	2050
Wind onshore – 1 hour	4,0 %	3,2 %	3,0 %	2,8 %	2,6 %
Wind offshore 1 hour	12.0 %	7.0 %	4.5 %	4.0 %	3.5 %
PV 1 hour	6,0 %	4,0 %	3,8 %	3,4 %	3,1 %

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Conclusions for the Lead Study Scenarios

- Electricity surpluses in Germany (defined as demand<RE-production) are likely smaller than 1 TWh in 2020
- Between 2020 and 2030 surplusses increase
- Load management can considerably diminish electricity surplusses in 2030 and 2050
- In 2050 the balancing possibilities by load management are by far not enough, large (seasonal) storage capacties are needed, that might be provided by Norwegian Hydro Power more efficiently than by hydrogen