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Contract N° :
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Duration: 05/2011 – 04/2014

Methodology estimating the energy storage needs

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Overview

1. Development of renewable energies
2. Calculation of residual load
3. Calculation of total energy storage needs
4. Seperation of long and short term energy storage needs

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Development scenarios for RE

Target country	40 % RE	80 % RE	Import/Export	Heating sector
Austria	Already more than 40 % RE ➔2020 scenarios A,B,C	2050 scenarios GREEN, BAU	Yes, combined system Germany - Austria	No
Denmark	Scenarios 2020 A,B,C Different wind development	One scenario	Yes, import/export via AC to Germany	Yes, for 80 % RE
Germany	3 scenarios A,B,C Different RE development	3 scenarios A,B,C Different RE development	No	No
Greece	2 Scenarios A,B Strong PV, strong Wind	3 scenarios A,B,C Different RE development	No	No
Ireland	Scenarios 2020 A,B,C Different wind development	One scenario	Yes, import/export via HVDC to GB	No
Spain	2 Scenarios A,B Strong PV, strong Wind	2 Scenarios A,B Strong PV, strong Wind	No	No

Development of renewable energies → Calculation of residual load → Calculation of total energy storage needs → Separation of long and short term energy storage needs

Time series

- Defining a reference scenario ➔ 2011
- Feed-in curves of PV, Wind and hydropower for reference scenario from national TSOs
- Load curves of reference scenario from national TSOs and ENTSO-E
- Normalization of feed-in and load curves
- Scaling the feed-in and load curves accordingly to the expected installed RE to reach the desired share of renewable energies
- All data in hourly values

Development of renewable energies
Calculation of residual load
Calculation of total energy storage needs
Separation of long and short term energy storage needs

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Calculation of residual load

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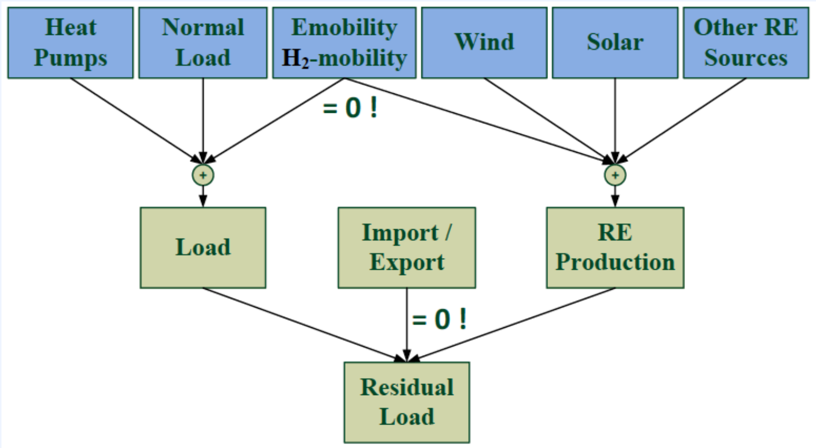
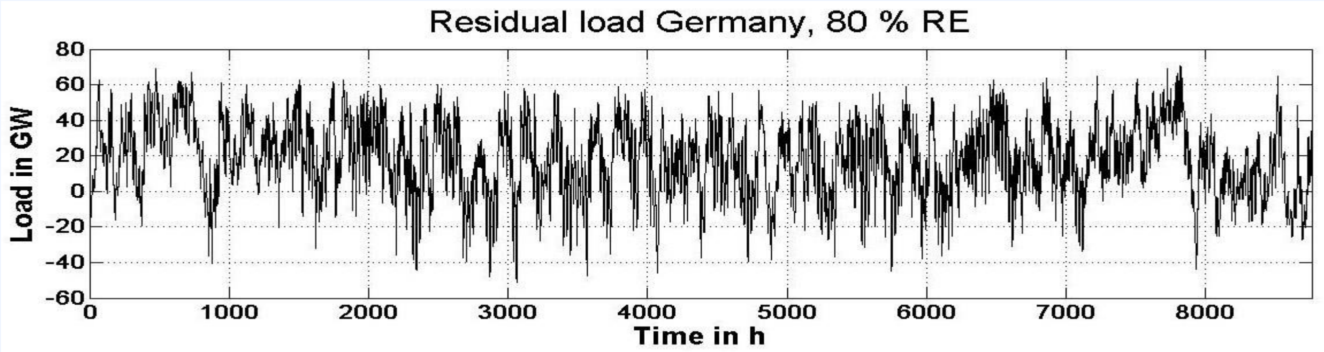
„Residual load = load demand that has to be covered by controllable power plants or import/export of energy“





Development of renewable energies → **Calculation of residual load** → Calculation of total energy storage needs → Separation of long and short term energy storage needs

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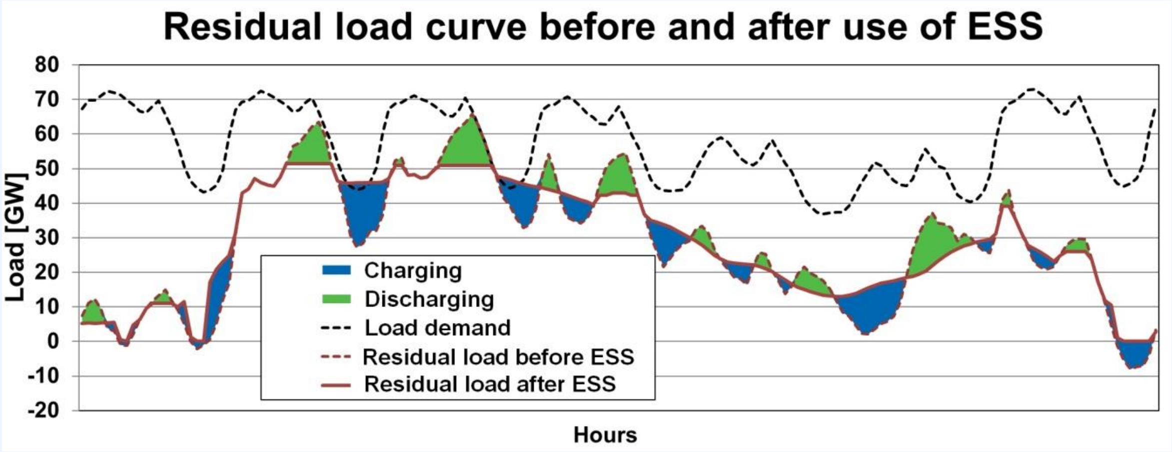
Operating strategy for ESS



Source: EEG

- Energy storage system (ESS) follows a peak shaving – valley filling operation strategy
- Intelligent operation strategy to integrate the most renewable energies possible
- Integration of up to 6 different technologies
- No focus on electricity spot market prices

Development of renewable energies → Calculation of residual load → **Calculation of total energy storage needs** → Separation of long and short term energy storage needs

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Determination of storage needs

- Using the described algorithm with two technologies
- First the existing and planed energy storage facilities
  - For Germany: PHES facilities with 8 GW installed pump and turbine power and a capacity of 60 GWh
- Second an energy storage system with unlimited power and capacity (ESS 2)
- The unlimited nature of ESS 2 ensures that all renewable energies can be integrated
- The actual used power and capacity of ESS 2 is an indicator for the total energy storage needs

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General assumptions

- No bottlenecks in transmission grids
- No import/export
- DSM/DSR as well as electric vehicles are regarded as possible additional energy storage system
- Increasing flexibility of conventional power plant mix

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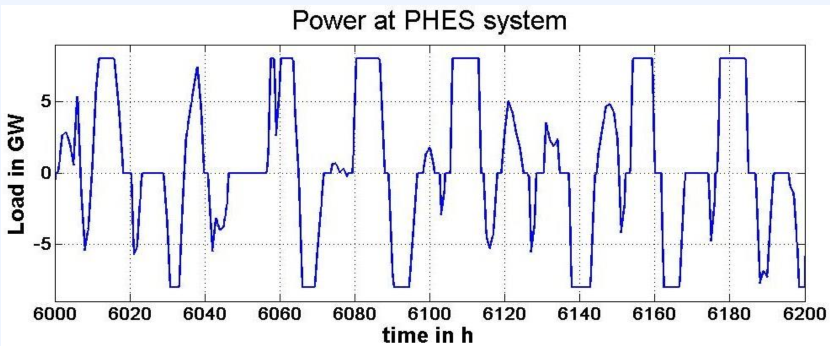
System stability

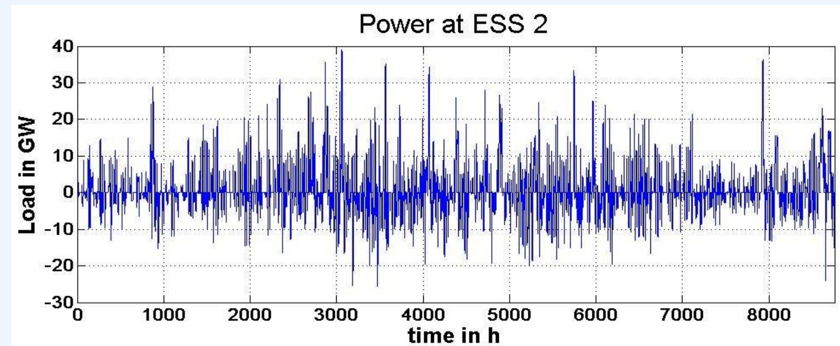
- System Non Synchronous Penetration limit (SNSP)
  - Maximum share of generation units with generator speeds asynchron to grid frequency
- Technical Minimum (TM)
  - Must run units of conventional power plants

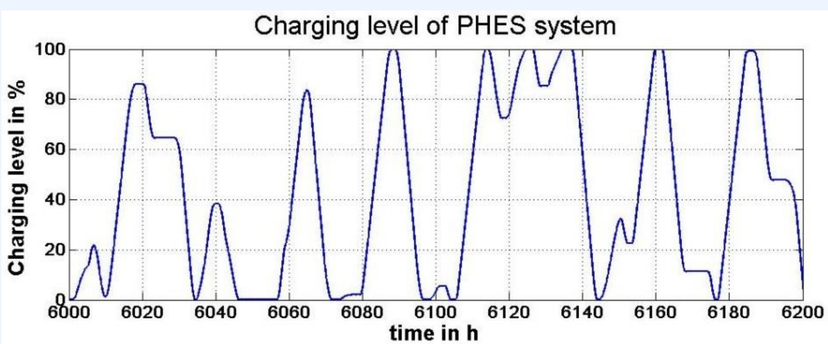
Target country	40% RE	80 % RE
Austria	-	-
Denmark	-	-
Germany	TM: 0 GW – 10 GW	-
Greece	TM: 3.7 GW	TM: 0.4 GW – 2 GW
Ireland	SNSP: 75 %	-
Spain	TM: 18 GW	TM: 0 GW - 10 GW

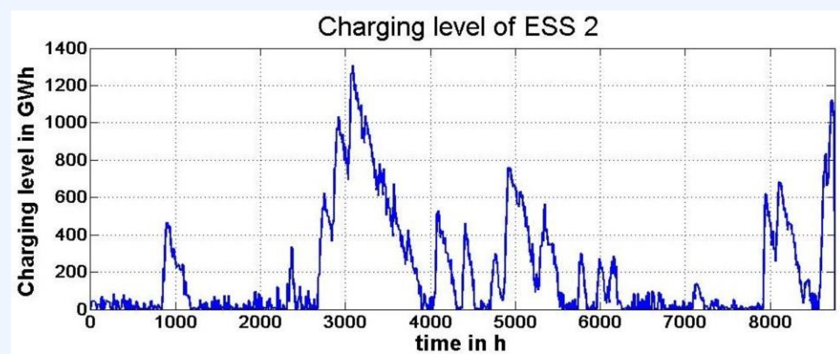
Simulation results

Germany, sceario 80 %, equal development wind and PV









Development of renewable energies → Calculation of residual load → **Calculation of total energy storage needs** → Separation of long and short term energy storage needs

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Simulation results (no SNSP/TM)

Scenarios 2020	Needed power [GW]		Needed capcity [GWh]	Capacity factor		
	Charging	Discharging		Charging	Discharging	Total
AT-A	0	0	0	11.63%	9.58%	21.21%
AT-B	0	0	0	9.00%	7.30%	16.30%
AT-C	0	0	0	7.00%	5.67%	12.68%
DE-A	0	0	0	29.51 %	24.01 %	53.52 %
DE-B	0	0	0	27.15 %	22.04 %	49.19 %
DE-C	0	0	0	30.38 %	25.12 %	55.50 %
DK-A	2.33	2.36	55.22	10.6 %	8.43 %	19.03 %
DK-B	2.26	2.27	46.71	10.6 %	8.51 %	19.11 %
DK-C	2.19	2.18	38.68	10.6 %	8.63 %	19.23 %
IR-A	1.83	1.79	59.12	11.17 %	8.89 %	20.06 %
IR-B	1.73	1.60	14.32	10.59 %	9.23 %	19.23 %
IR-C	1.86	1.76	70	10.76 %	8.91 %	19.67 %

Development of renewable energies → Calculation of residual load → **Calculation of total energy storage needs** → Separation of long and short term energy storage needs

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Simulation results

Scenario	Needed Power [GW]		Needed Capacity	Capacity Factor		
	Charging	Discharging	[GWh]	Charging	Discharging	Total
Austria	0 - 2,98	0	0	9.65% - 10,38%	8,34% - 10.37%	18,72% - 20.03%
Germany	31,85 - 55,16	25,17 - 29,04	950 - 1.534	4,97% - 5,43%	4,48% - 8,07%	9,45% - 13.43%
Denmark	4,85	3,25	660,75	10,8 %	11,3 %	22,1 %
Ireland	6.8	4.3	2.700	12,4 %	9,9 %	22,3 %
Spain	35.31 – 44.32	18.13 - 19.56	2.143 – 4.367	4,89% - 6,39%	7,52% - 13,05%	12,41% - 19,44%
Greece	7.50 - 10.56	2,17 - 2.79	172 – 1.400	3,58% - 4,71%	9,94% -13,45%	8,29% - 18,61 %

Development of renewable energies → Calculation of residual load → **Calculation of total energy storage needs** → Separation of long and short term energy storage needs

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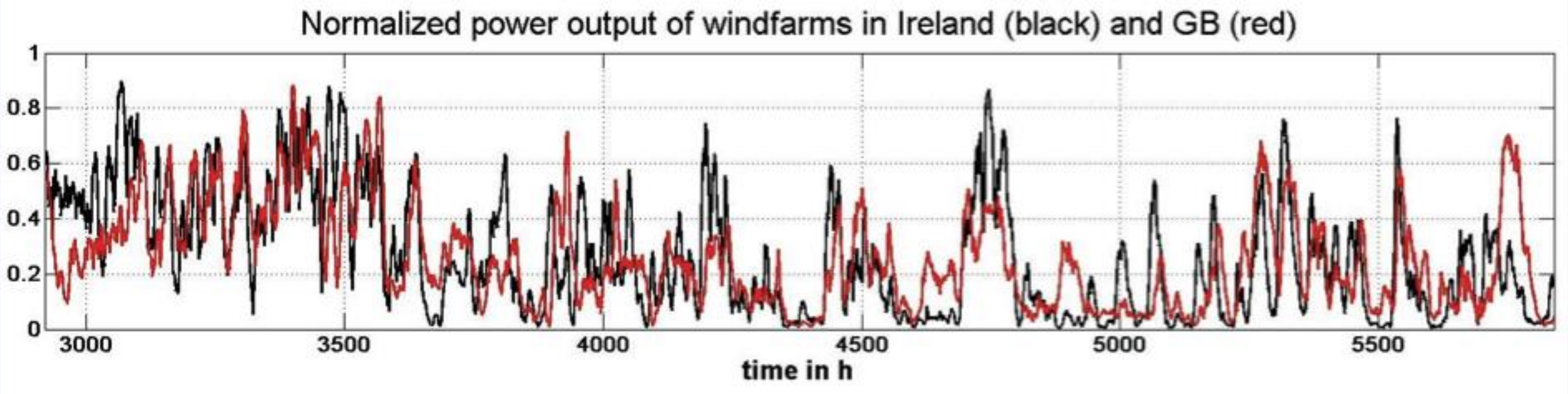
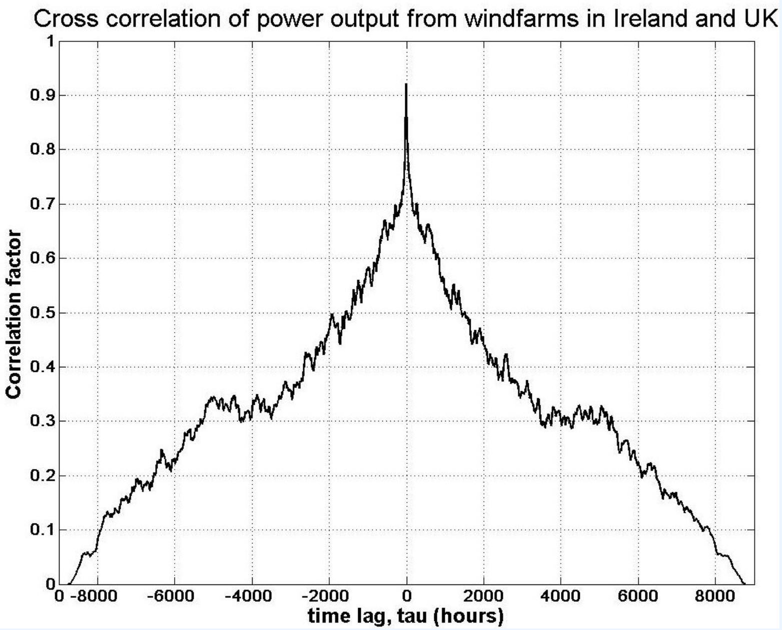
Simulation results (Ireland)





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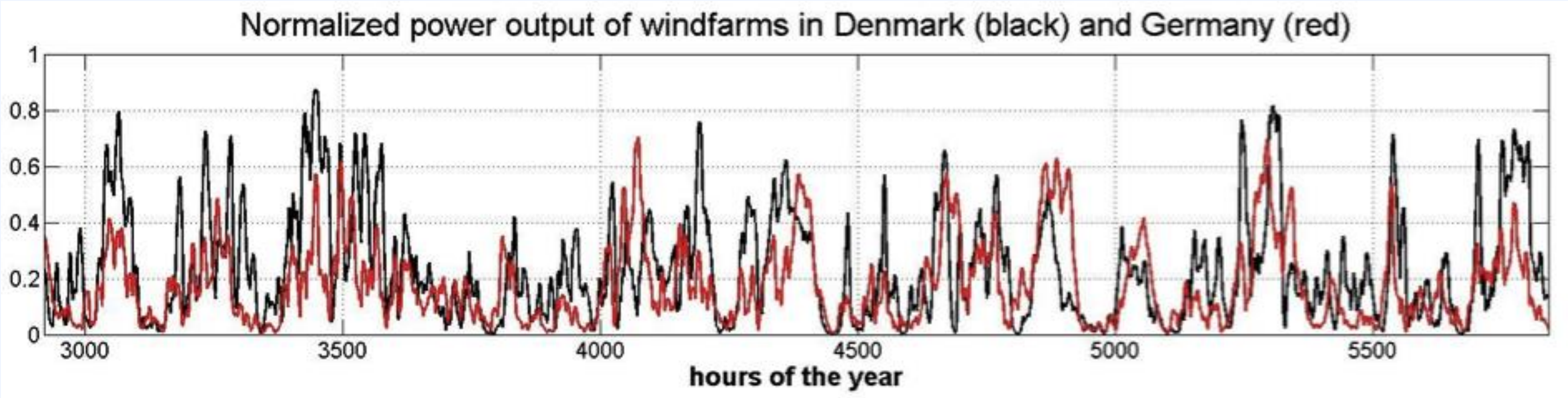
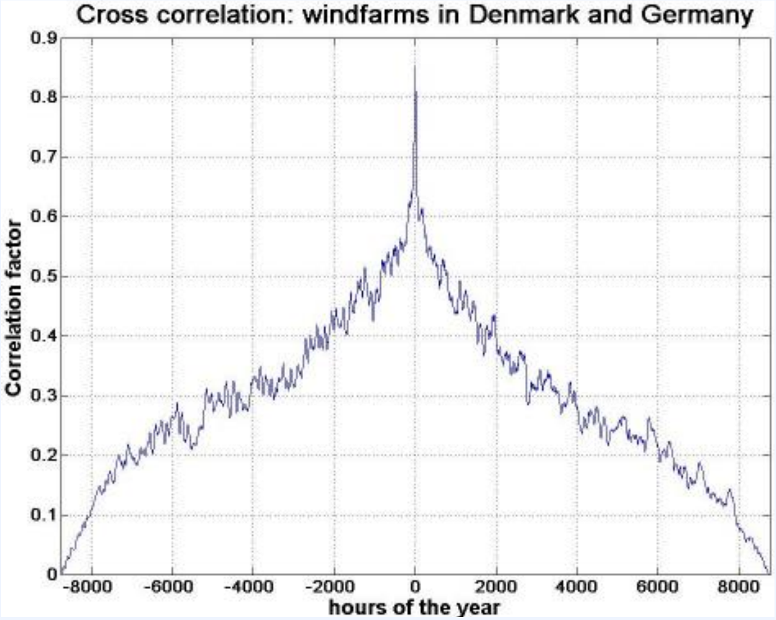
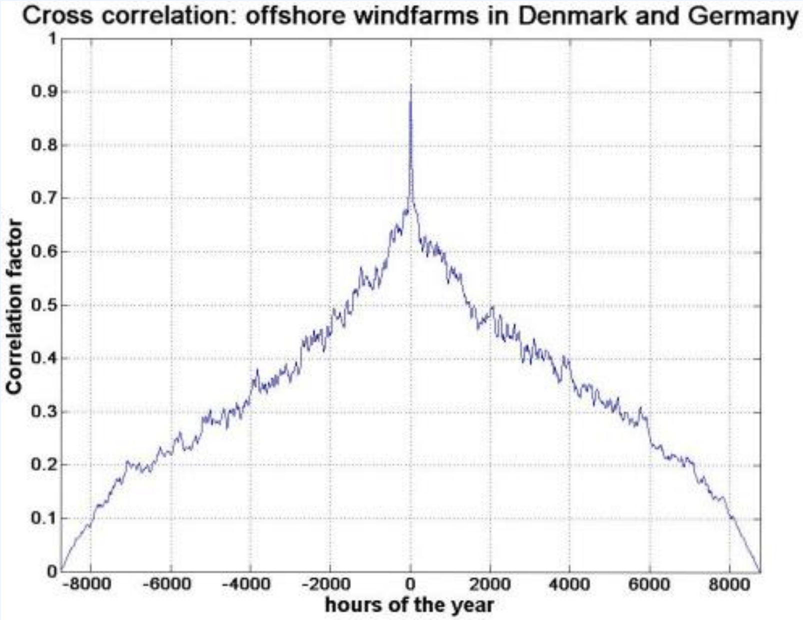
Simulation results (Denmark)







Simulation results (Denmark)

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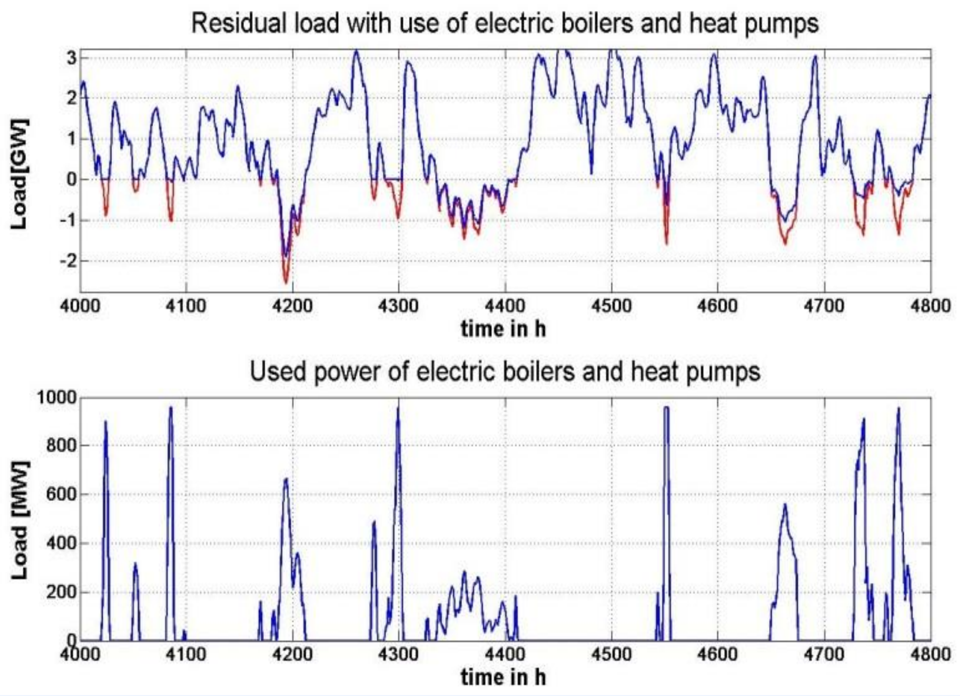
Western Denmark		2012	2020	2035
Heat pumps (DH)	MW_{el}	0	44	82
Heat pumps (indiv.)	MW_{el}	40	222	631
Elec. Boilers (DH)	MW_{el}	207	244	244
Total	MW_{el}	247	510	957

- During positive residual load the heat demand is covered by the CHP, bio fueled and centralized power plants. The heat storage is used accordingly to the operation planning of the particular power plant. The planning of the operation should be in a way that the storage capacity is fully available when a surplus of renewable energy is expected



- During periods with surplus of renewable energy the heat storage capacity is fully available

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Further improvement of the algorithm

Seperation of short and long term storage needs

For the separation of the total energy storage needs into short and long term storage needs, some technical limitation can be set:

- Benchmark for separation
- Power and capacity limitations
- Setting minimum capacity factor
- Cycle efficiencies

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Seperation of short and long term storage needs

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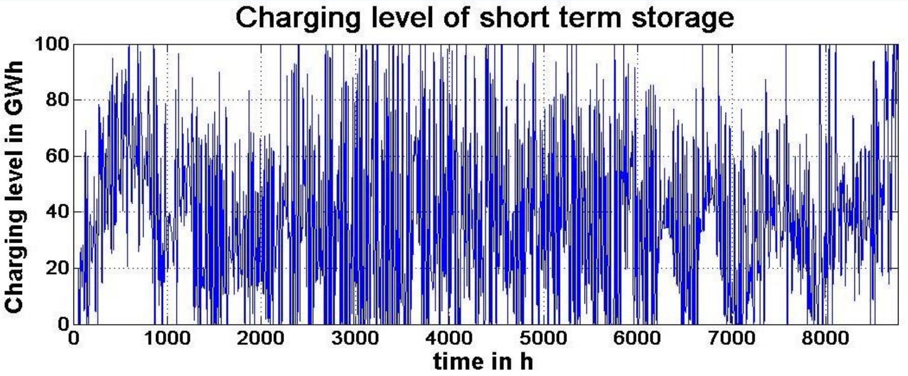
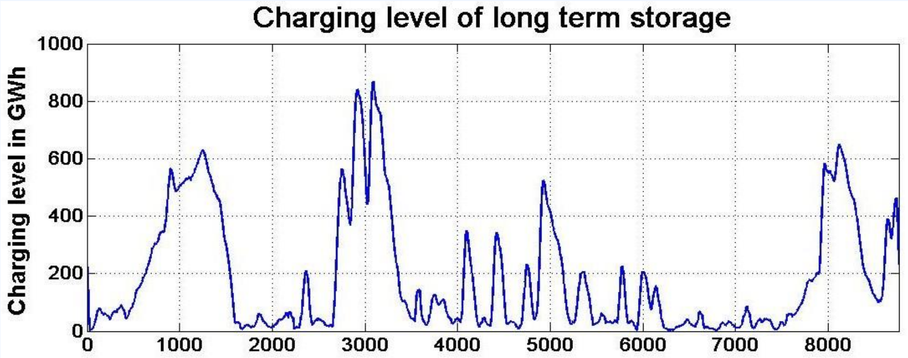
Input parameters:

- Scenario A
- Benchmark set to T=48h
- Short term ES (SES) limited to 12 GW and 100 GWh
- Cycle efficiency of SES set to 85 %
- Cycle efficiency of LES set to 40 %

Results:

- High CF of SES: 36.5 %
- High needed power for LES (10 GW for charging, 7.5 GW for discharging)
- Low CF of LES: 17.22 %
- Rejected energy from RE: 6.3 TWh
- Increasing the CF of LES, the rejected energy will increase as well





Development of renewable energies → Calculation of residual load → Calculation of total energy storage needs → **Seperation of long and short term energy storage nees**

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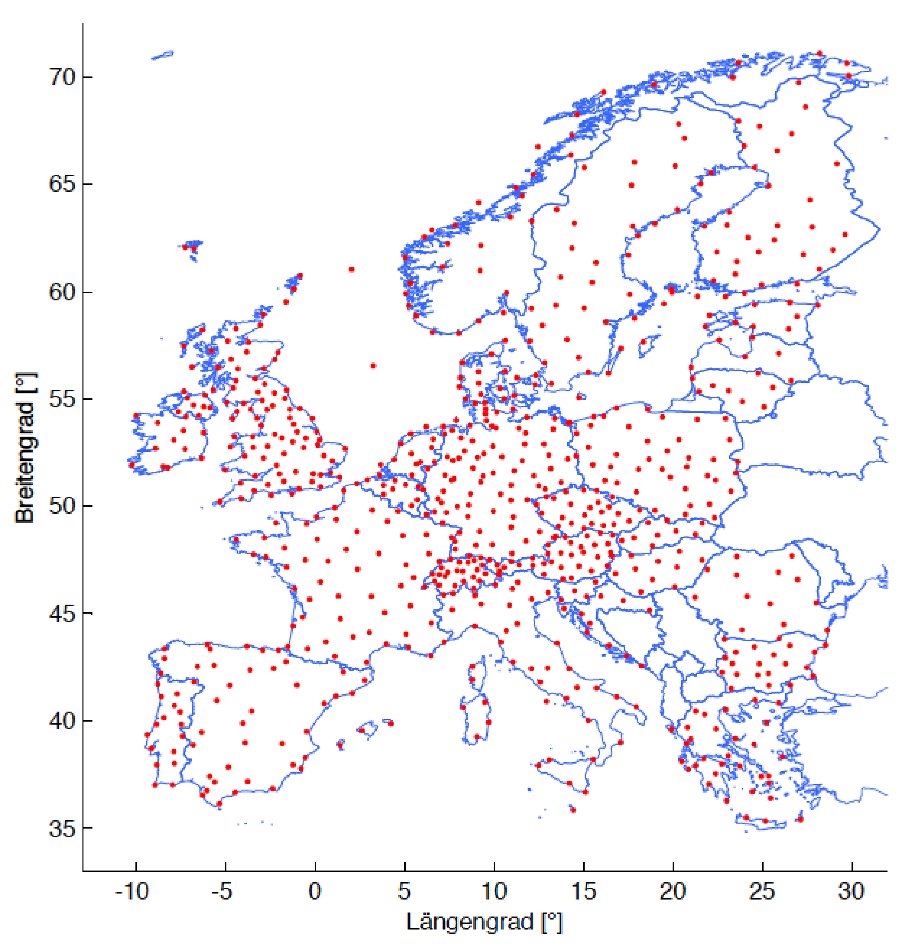
RE input data

- Feed-in data from renewable energies can now be obtained by
  - Weather data from national weather services, the internet platform S@tel-light and the meteorological data base Meteonorm®
  - Developed Wind and PV/CSP models
  - Geographical allocation of existing units

  Models were validated with actual feed-in data of different countries

- Load demand is calculated with synthetic load profiles and real load demand data provided by national TSOs and ENTSO-E



Including the power plant mix

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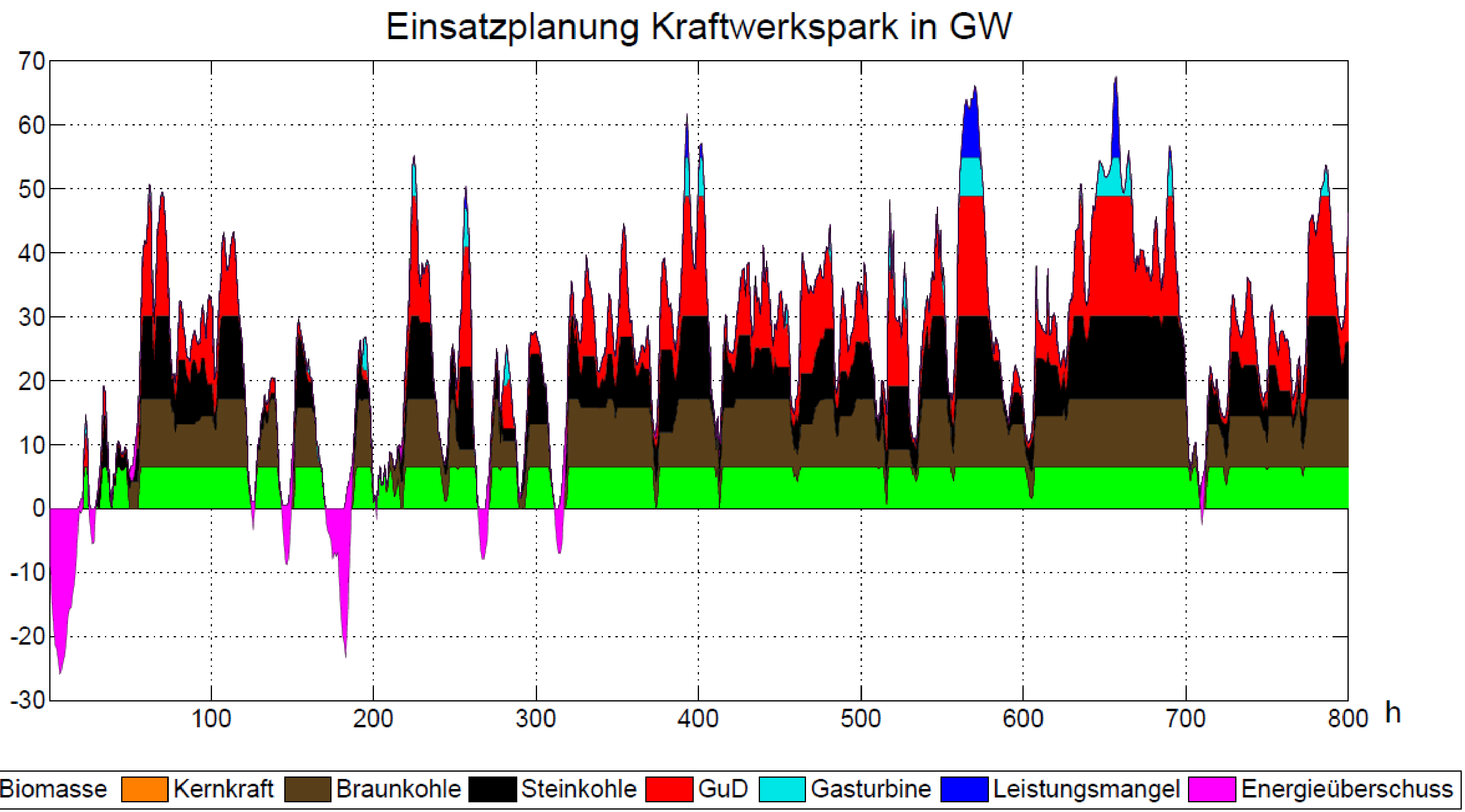

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Defining different operation strategies

- Using ESS only for RES-E integration
- Minimum CO_2 emissions
- Minimum electricity genertation costs
- Minimum new installed power plant capacity

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Thank you for you attention

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