Variability of the wind and PV power production in UK and Germany in 2050 – assessment of need for balancing

(preliminary results)

PhD study 2014-2017

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Outline of presentation

- Wind and solar resource model
- Scenarios for installed capacities of wind and PV power production in 2050
- Analysis of variability of wind and PV production in UK and Germany in 2050
- Assessment of need for balancing
- Further work

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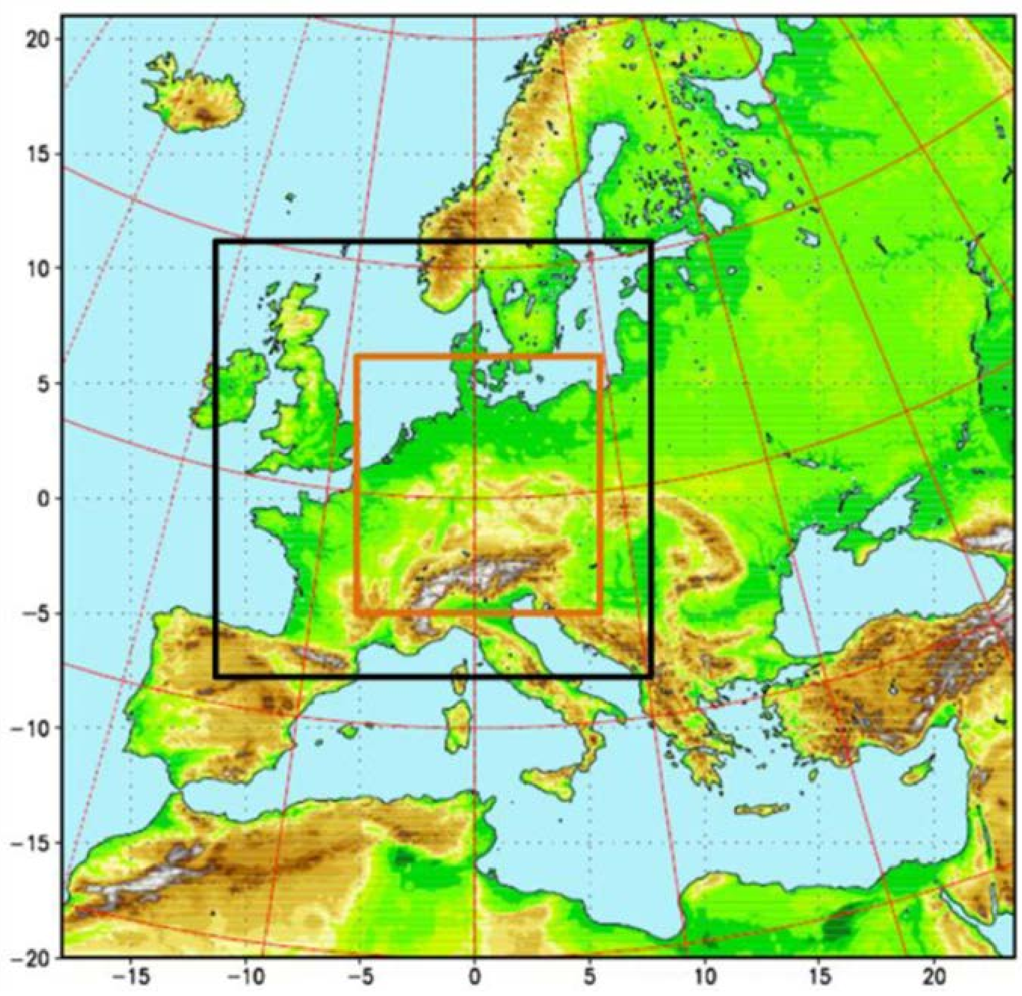
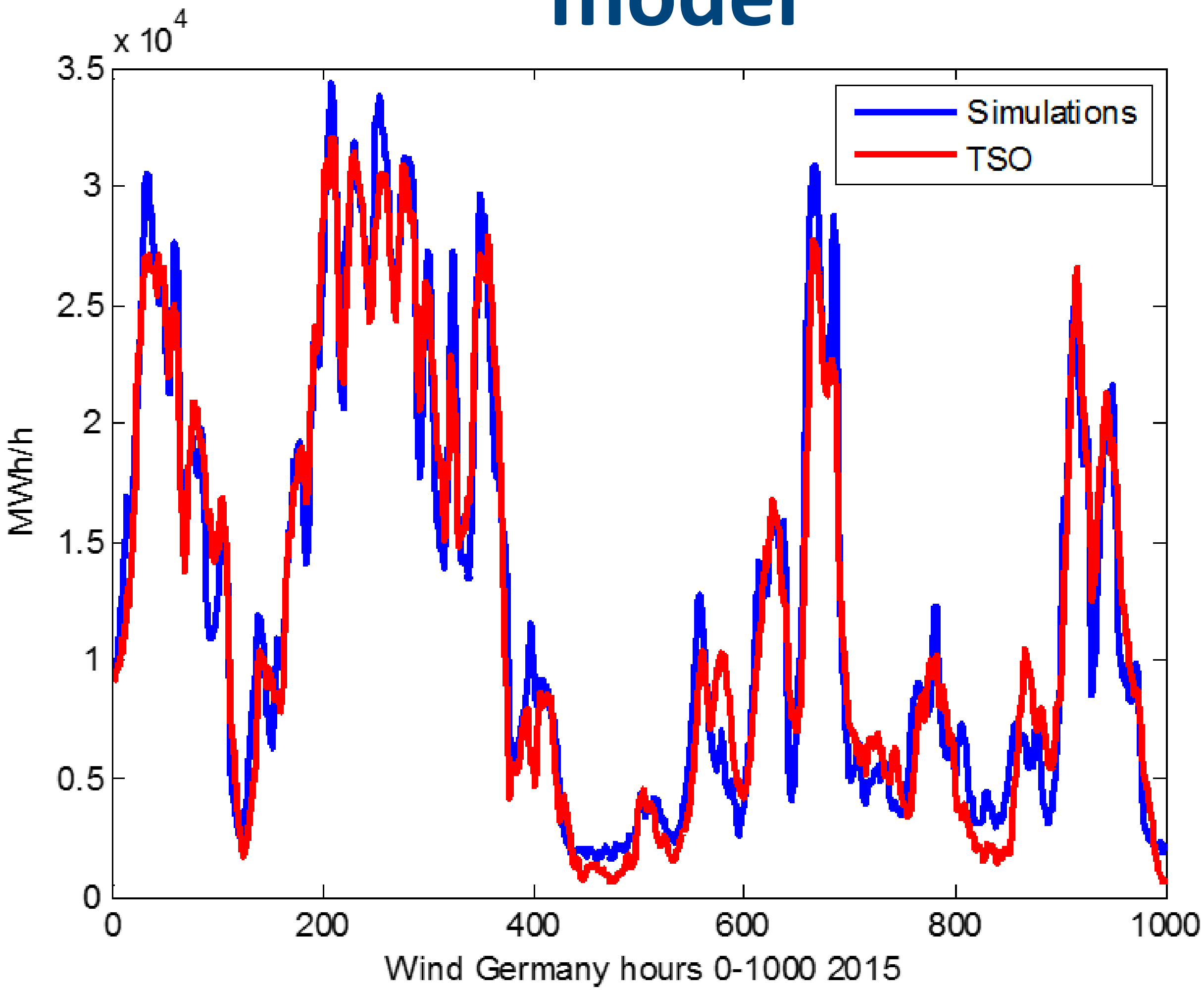
Wind and solar resource model

- Numerical weather prediction model: COSMO EU (DWD)
- Include both wind (2006-2015), solar radiation (2011-2015) and temperature
- Hourly resolution
- Spatial resolution: 7x7 km Europe and Northern Africa
- Further development of Aigner's PhD work

The COSMO EU model



Validation of the wind power production model



COSMO based simulations

VALIDATION OF WIND POWER PRODUCTION FOR 2015

	Total production [TWh/year]	MAE relative TSO [MWh/h]	MAE /installed capacity [%]	RMSE relative TSO	RMSE/ installed capacity [%]
DK TSO	14.1				
Simulations	14.4	278	5.5	358	7.1
GE TSO	83.6				
Simulations	83.2	2198	4.9	2789	6.2
Spain TSO	48.4				
Simulations	48.2	1364	5.9	1755	7.6

MAE – Mean Absolute Error
RMSE – Root Mean Square Error

COSMO based simulations
VALIDATION OF THE PV POWER PRODUCTION FOR 2014

	Total production [TWh/year]	MAE relative TSO [MWh/h]	MAE /installed capacity [%]	RMSE relative TSO	RMSE/ installed capacity [%]
DK TSO	0.6				
Simulations	0.6	23.7	3.9	46.2	7.6
GE TSO	32.6				
Simulations	29.2	883	2.4	1659	4.5
Spain TSO	8				
Simulations	6.6	244	5.5	415	9.3

MAE – Mean Absolute Error
RMSE – Root Mean Square Error

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Developing a wind and solar power data model for Europe with high spatial-temporal resolution

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***Abstract*— This paper describes a wind and solar power production model for Europe based on the numerical weather prediction model COSMO-EU. The COSMO-EU model has hourly time resolution and a spatial resolution of 7 km x 7 km for Europe. The model is validated against power production information from the system operators in Denmark, Germany and Spain. Mean Average Error (hourly error averaged for a year) relative to the installed capacity is in the range 4.9% -6.0% for wind power production and 2.4%-5.5% for PV power production. Root Mean Square Error is in the range 6.2%-7.6% and 4.5%-9.3% for wind and PV power production respectively. The results are compared with similar modelling based on wind and radiation from the NCEP reanalysis model. This model has six hourly time resolution for wind resources and daily resolution for radiation data. Modelling of wind power production in Denmark, German and Spain has a mean average error in the range 5.6%-8.5% and solar PV production 4.9%-6.4% for the NCEP reanalysis model.**

***Index Terms*—Wind power generation, solar power generation, power system simulation, power system planning.**

I. Introduction

The future power system in Europe will probably include large shares of variable wind and solar resources. Increasing shares of wind and solar power production will probably result in fewer and shorter periods where it is profitable to operate the fossil fuel based plants. Furthermore, the power production has to be more or less without greenhouse gas with hourly resolution and a spatial resolution of 7 km x 7 km.

Furthermore, the present installed capacities of wind turbines and solar PVs are modelled in great detail in order to be able to study the variable characteristics of the present system. By upscaling the power production capacities, the future variability can be studied for different configurations of production plants. The results from the developed model are verified by comparison with real production data from Transmission System Operators in Denmark, Germany and Spain.

To our knowledge, there are few papers about wind and solar power production models for Europe. One paper describes a bottom-up approach for modelling hourly electricity output based on meteorological data and technical specifications for different reference plants [1]. Since hourly time series for wind and solar power production were not available when the paper was written, a simplified approach was used for validation.

Wind and solar data models are to some degree described in largescale studies of the future European power system. However, according to [2] there are few largescale studies of the future European power system available. The paper describes a study of a future European system with 50% wind and solar and analyses the system for different combination of these resources. The study uses NASA reanalysis data

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Scenarios of renewable and thermal power generation

- e-Highway 2050 aimed to define the future transmission system structures that are capable of reaching the ambitious European targets.
- Scenarios
  - **X-5, Large scale RES.** Deployment of large-scale RES technologies and centralized storage solutions.
  - **X-7, 100% RES electricity.** Both large-scale and small scale RES technologies, links to North Africa. Both large-scale and small scale storage technologies
  - **X-10, High GDP growth and market based energy policies.** CCS is assumed mature.
  - **X-13, Large fossil fuel deployment with CCS and nuclear electricity.** No flexibility is needed since variable generation from PV and wind is low.
  - **X-16, Small and local.** Decentralised generation and storage and smart grid solutions mainly at distribution level.

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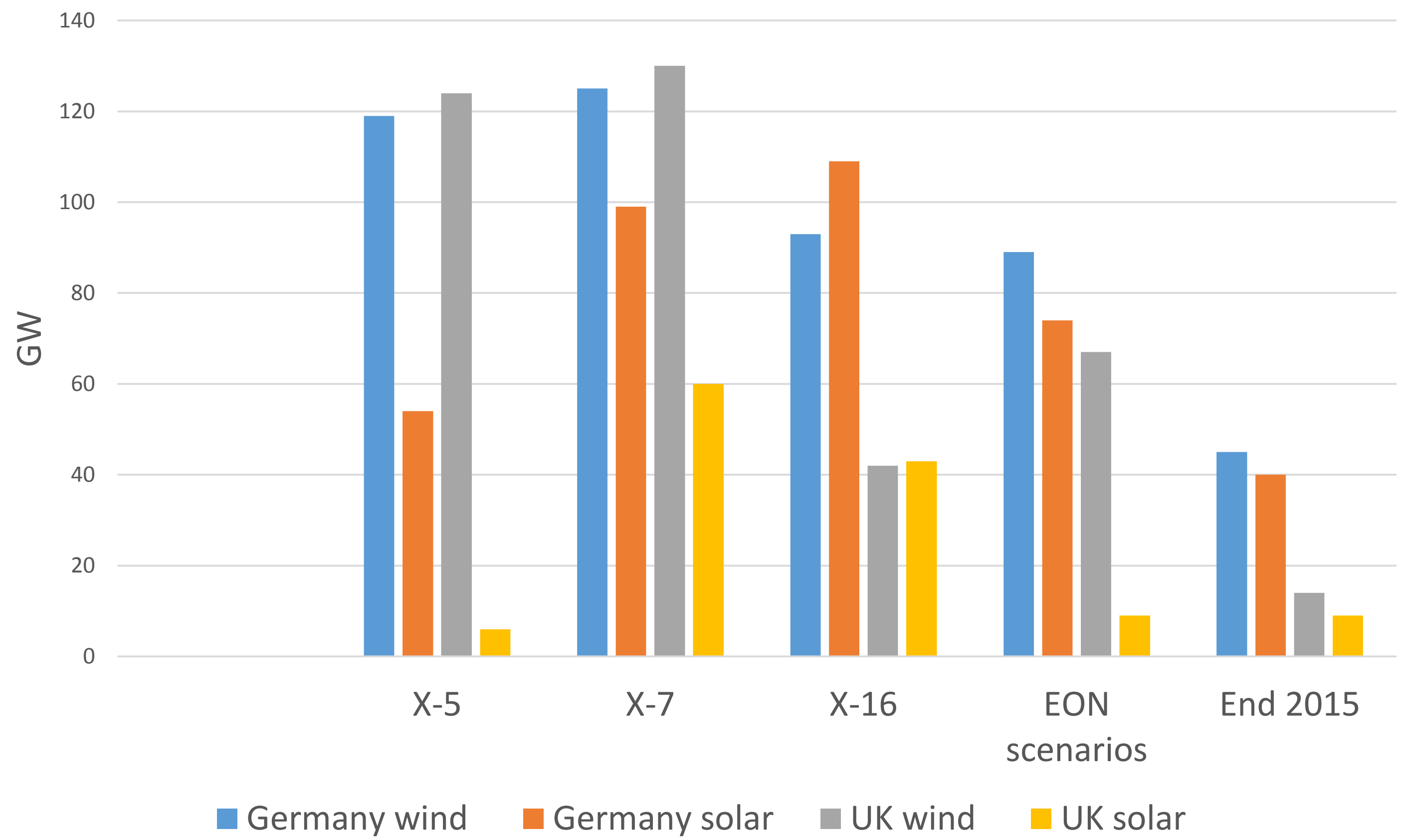
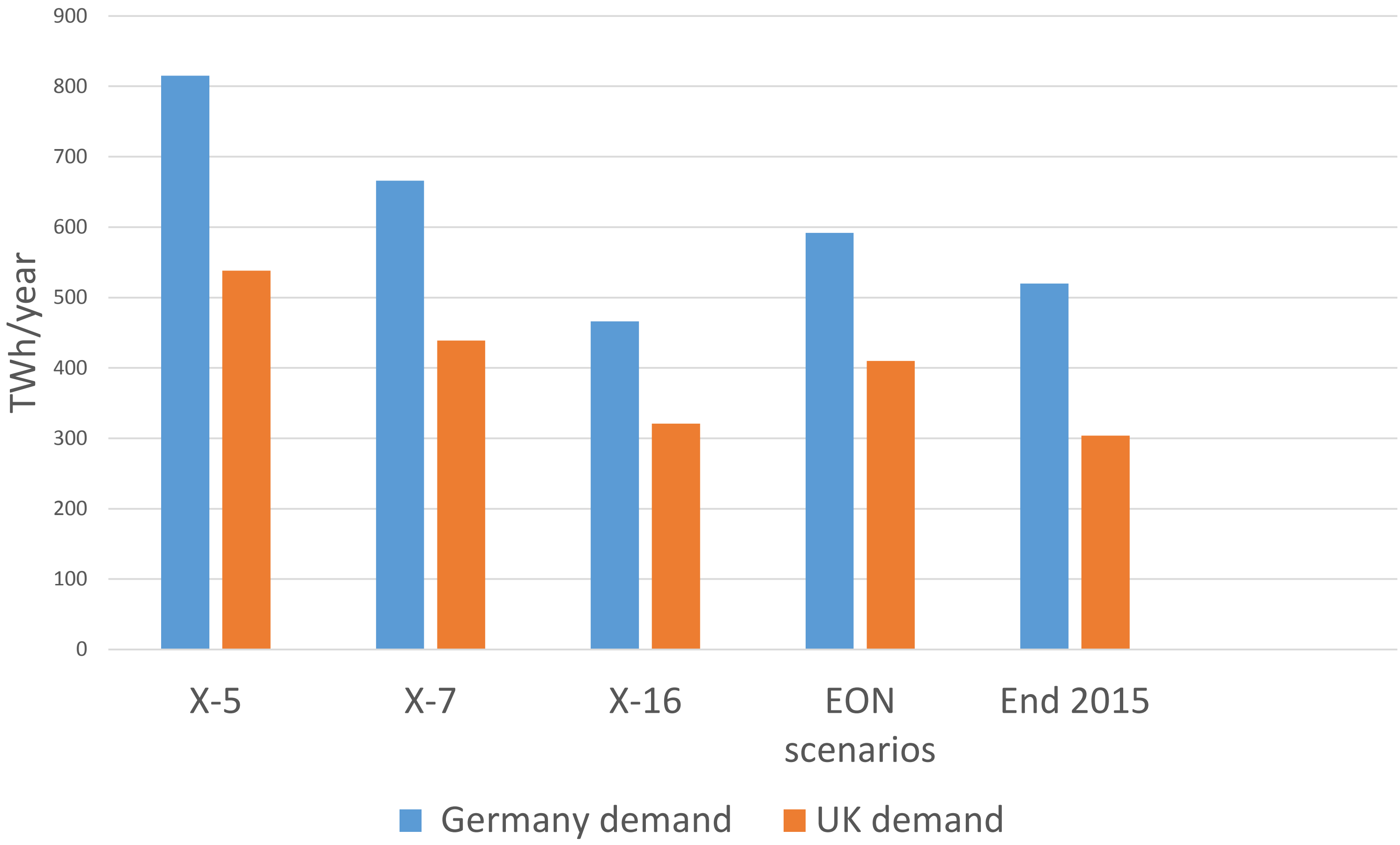
Assumed wind and solar capacities 2050 Germany and UK e-Highway scenarios



Assumed demand 2050 Germany and UK, e-Highway scenarios



Assumed capacities EU 2050 e-Highway scenarios

EU-25 (minus Cyprus and Malta)			
	Wind *)	Solar	Demand
	GW	GW	GWh
X-5	787	242	4873
X-7	846	655	4002
X-16	381	554	2957
	*) Including grid in the North Sea		

EU Road Map 2050				
		Wind	Solar	Demand
Scenario		GW	GW	GWh
Reference		382	171	4 130
Energy Efficiency		548	330	3 203
High Res		984	603	3 377

Cluster model used

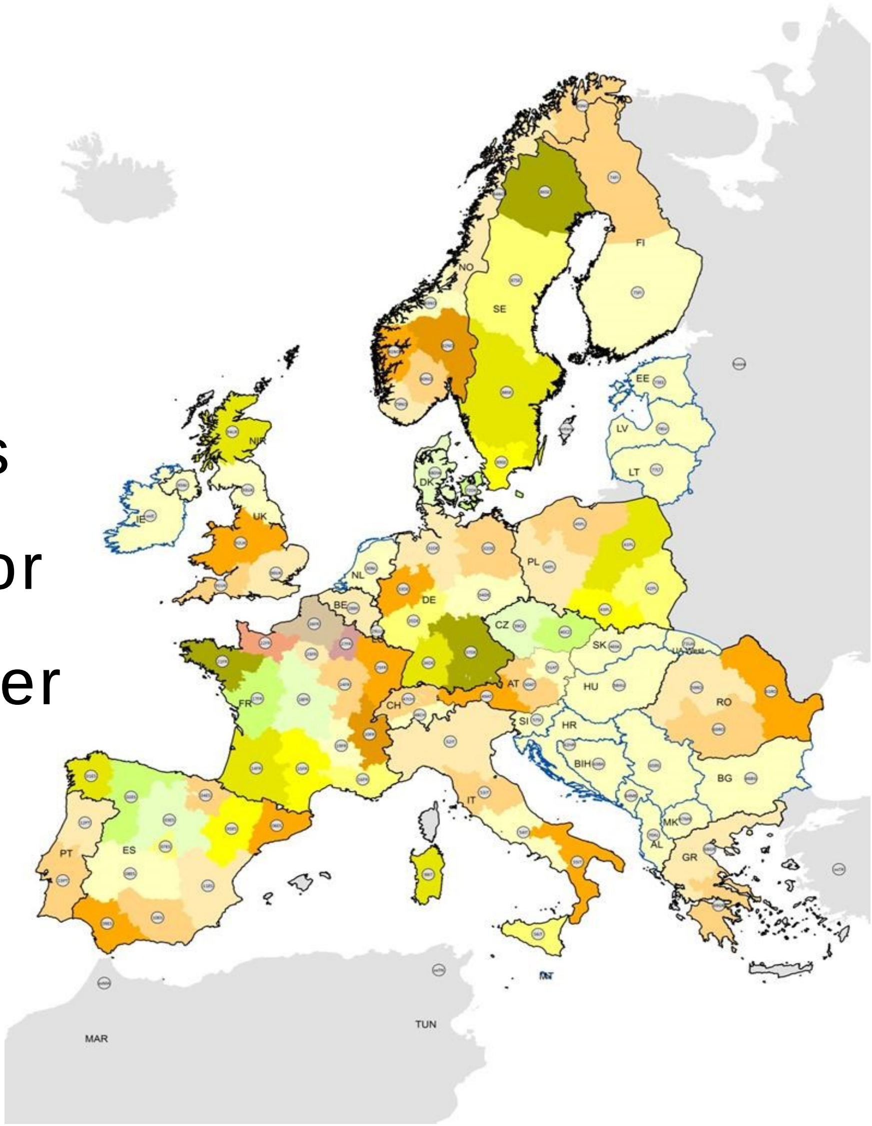
in eHighway.

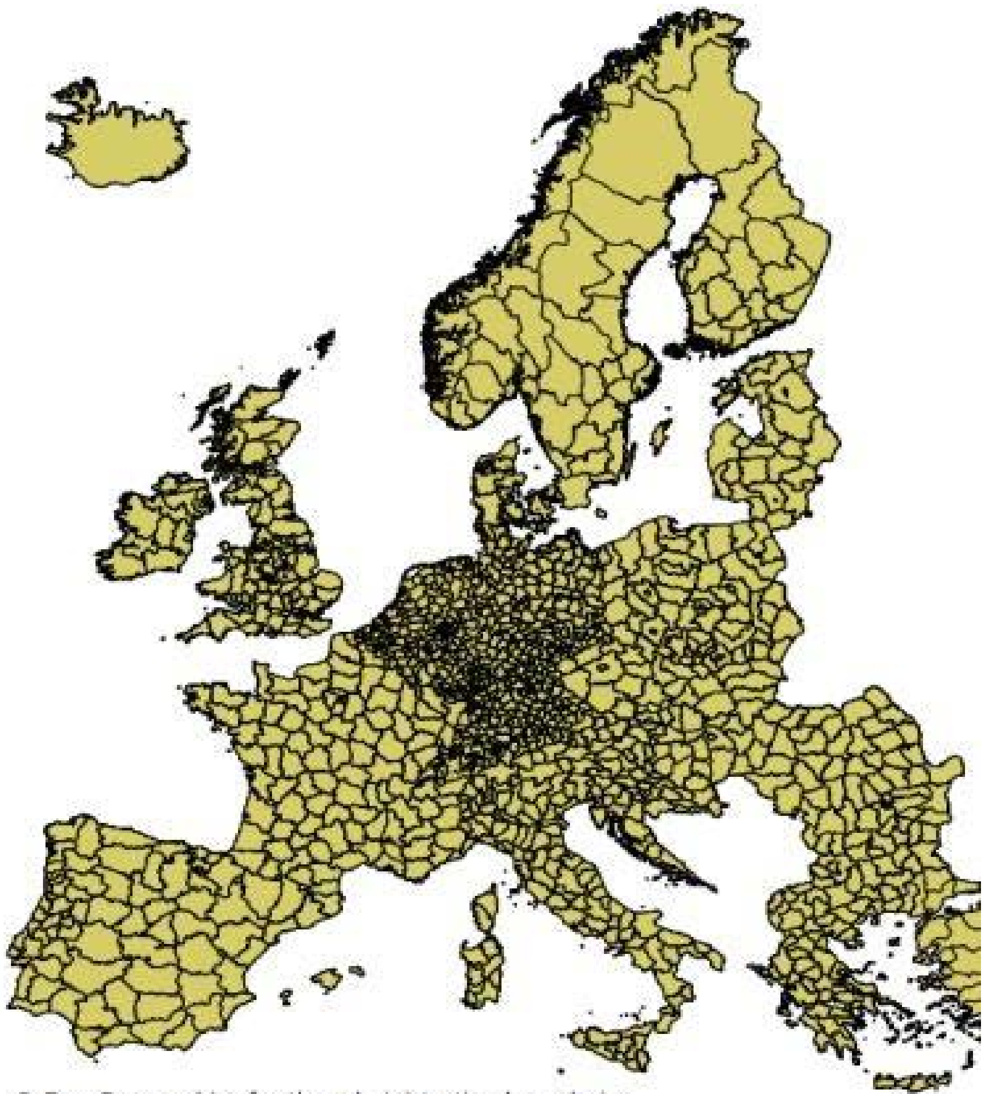
More than 100 clusters

in Europe. Estimates for

renewable capacities per

cluster.





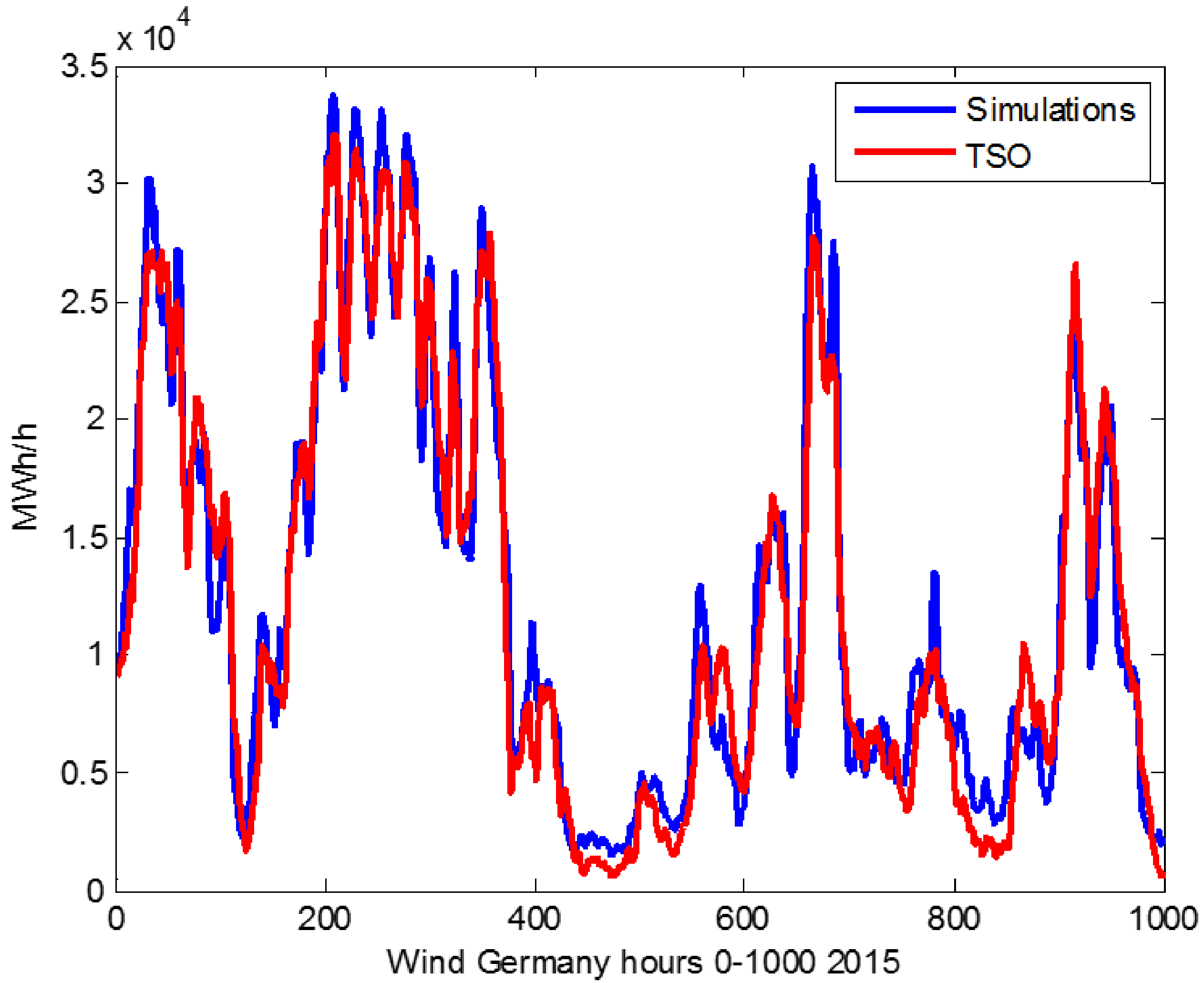
© EuroGeographics for the administrative boundaries

Each cluster consists of several nuts. More than 1300 nuts in Europe.

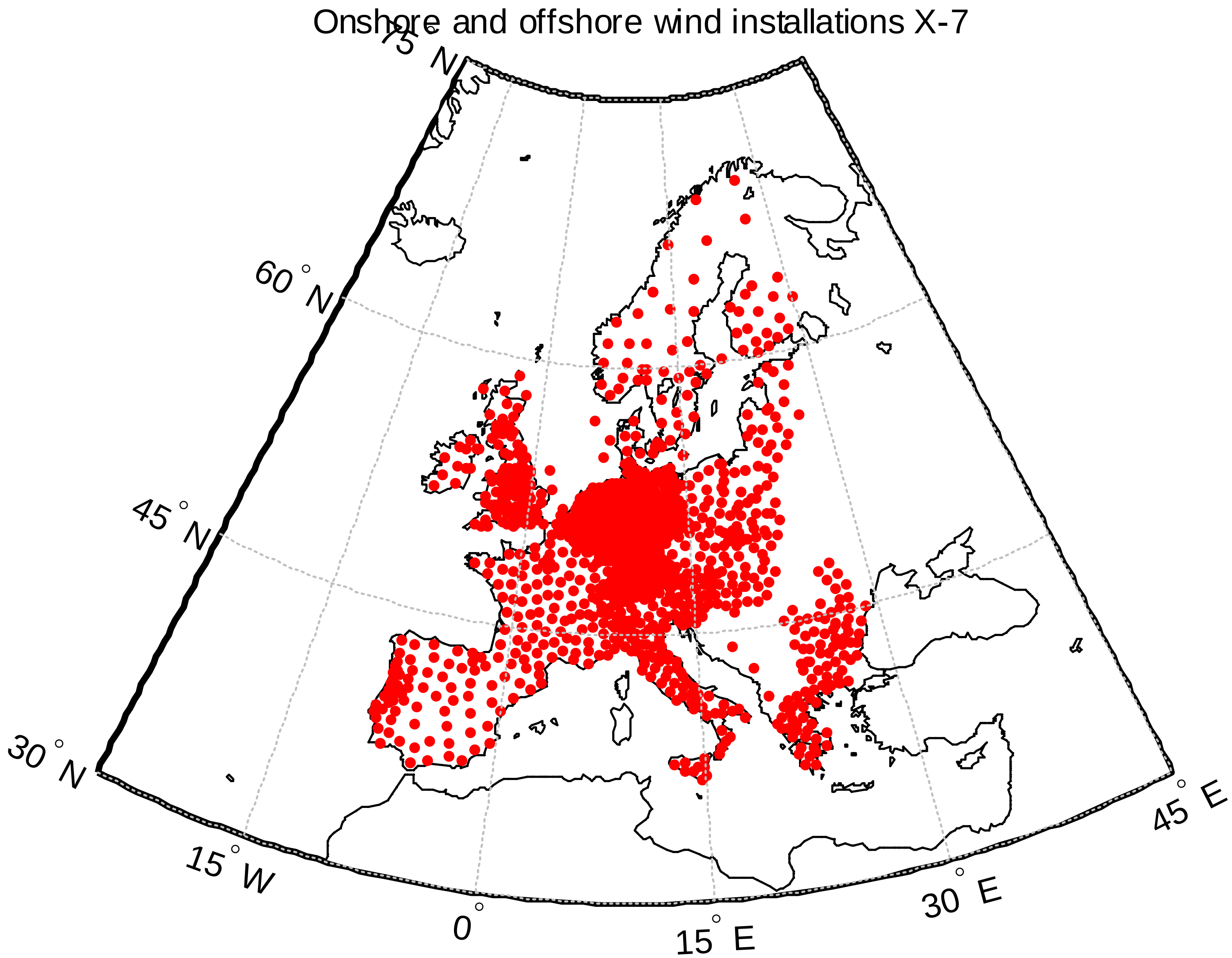
A nut is a unique in EU, with a latitude and a longitude.

The nuts are used for distribution of the capacities per cluster

Validation of the cluster/nuts distribution



Distribution of wind power production in the X-7 scenarios



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Variability characteristics of wind and solar resources – a review with focus on the Northern Europe

- Variability cannot be considered as a distinct resource property with a single measurable parameter, but is a multi-faceted concept best described by a range of distinct characters.

Distribution long term

Distribution short term

Step changes/ramping

Auto Correlation

Spatial correlation

Cross correlation

Predictable patterns

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energies

MDPI

Review

Variability characteristics of European wind and solar power resources - a review

Ingeborg Graabak [1], and Magnus Korpås [2]

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Academic Editor: name

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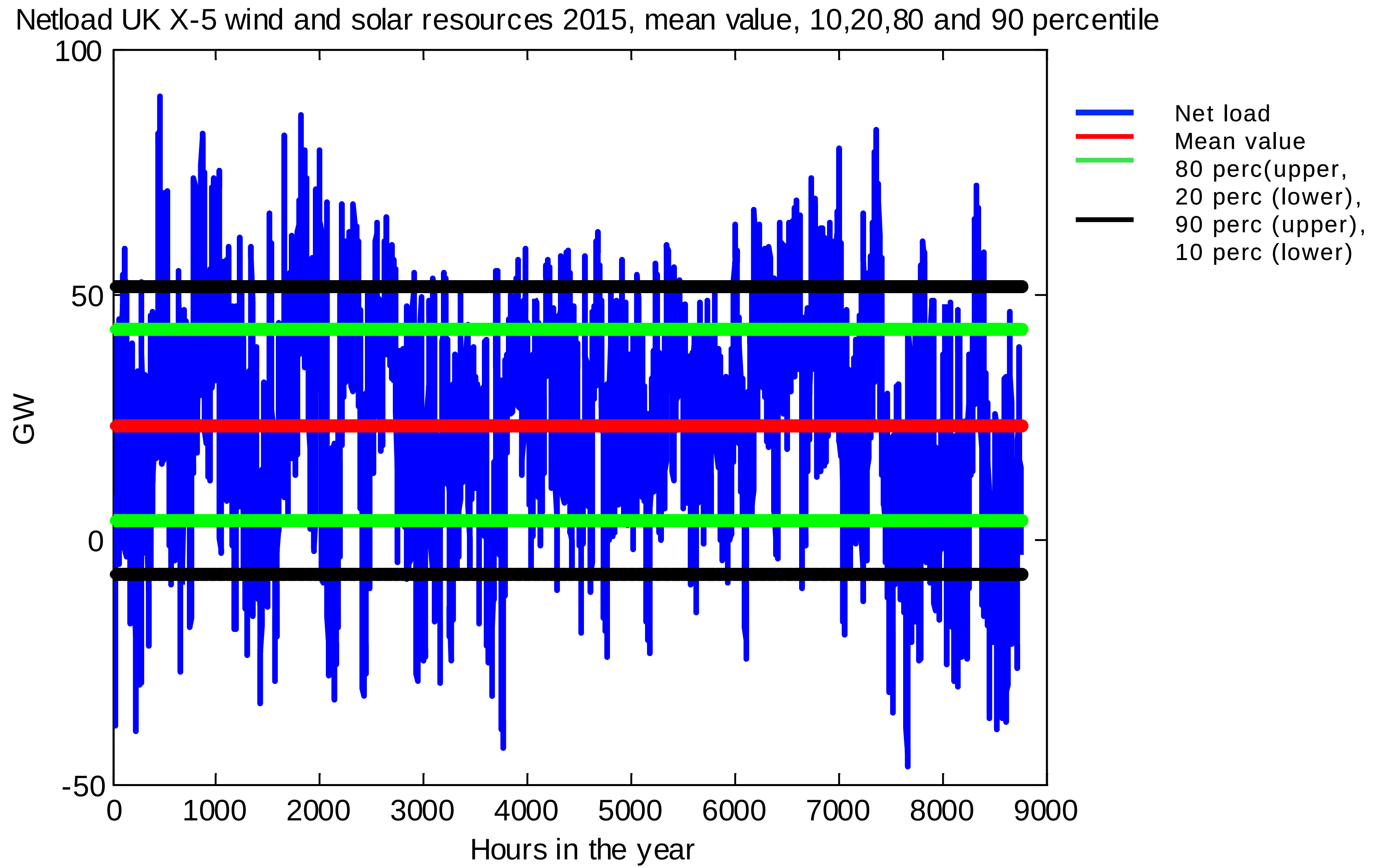
Abstract: This paper reviews the most recent and relevant research into the variability characteristics of wind and solar power resources with a particular focus on Europe. The background for this study is that wind and solar resources will probably constitute major components of the future European power system. Such resources are variable, and planning for the future power system requires an in-depth understanding of the variability. Resource variability is a multi-faceted concept best described using a range of distinct characteristics, and this review is structured on the basis of seven of these; Distribution Long-Term (hours to years), Distribution Short-Term (less than one hour), Step Changes, Autocorrelation, Spatial Correlation, Cross Correlation and Predictable Patterns. The review presents simulations and empirical results related to resource variability for each of these characteristics. Results to date reveal a patchwork of fragmented studies, some addressing only one or a few of the characteristics, others just one of the resources, and others still focusing on a small geographical area. This study recommends the development of a scheme for greater systematic assessment of variability. Such a scheme will contribute to the understanding of the impacts of variability and will make it possible to compare alternative power production portfolios.

Keywords:

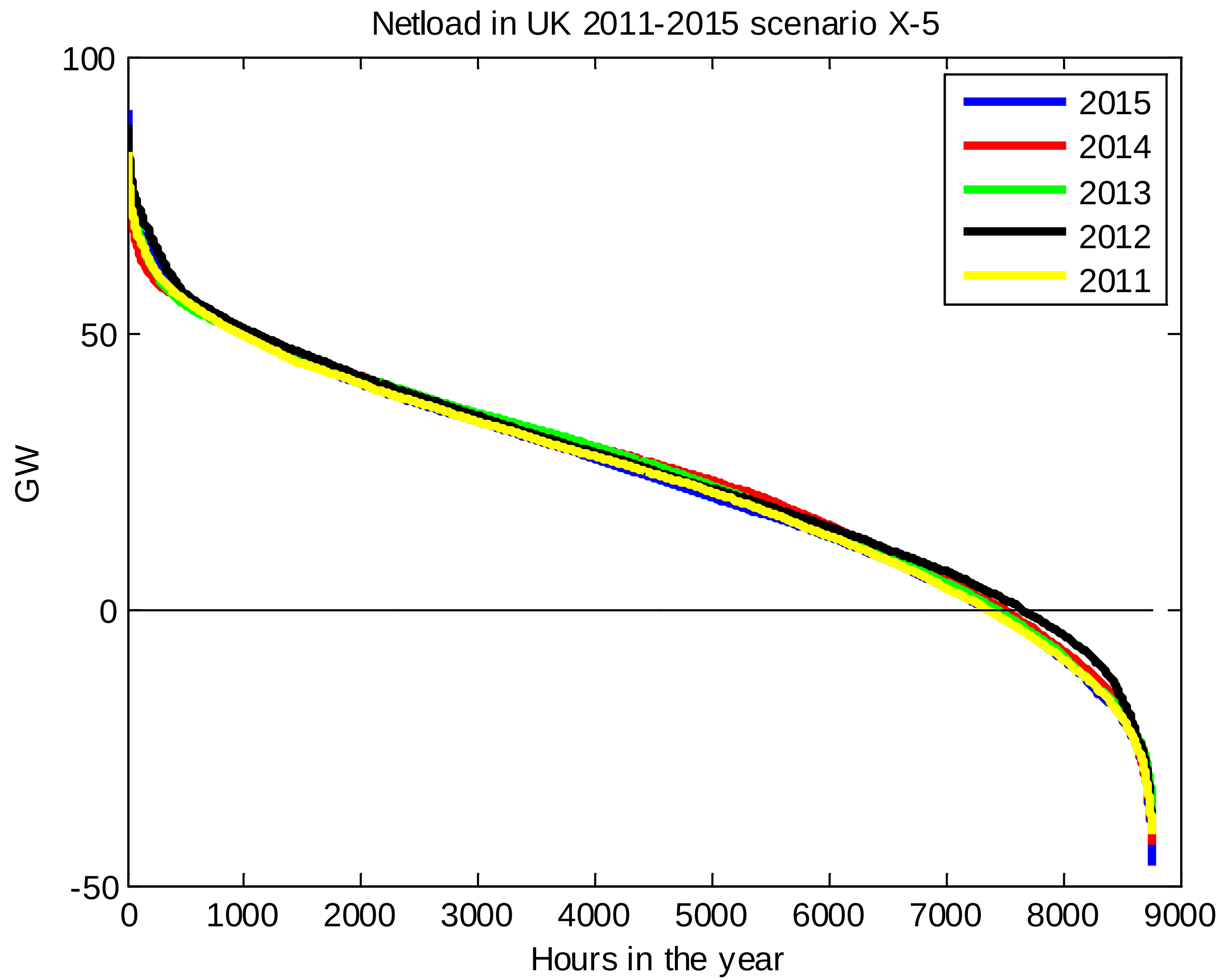
1; Variable renewable energy 2; Wind power production 3; Solar power production 4; The future power production in Europe

UK X-5 net load,

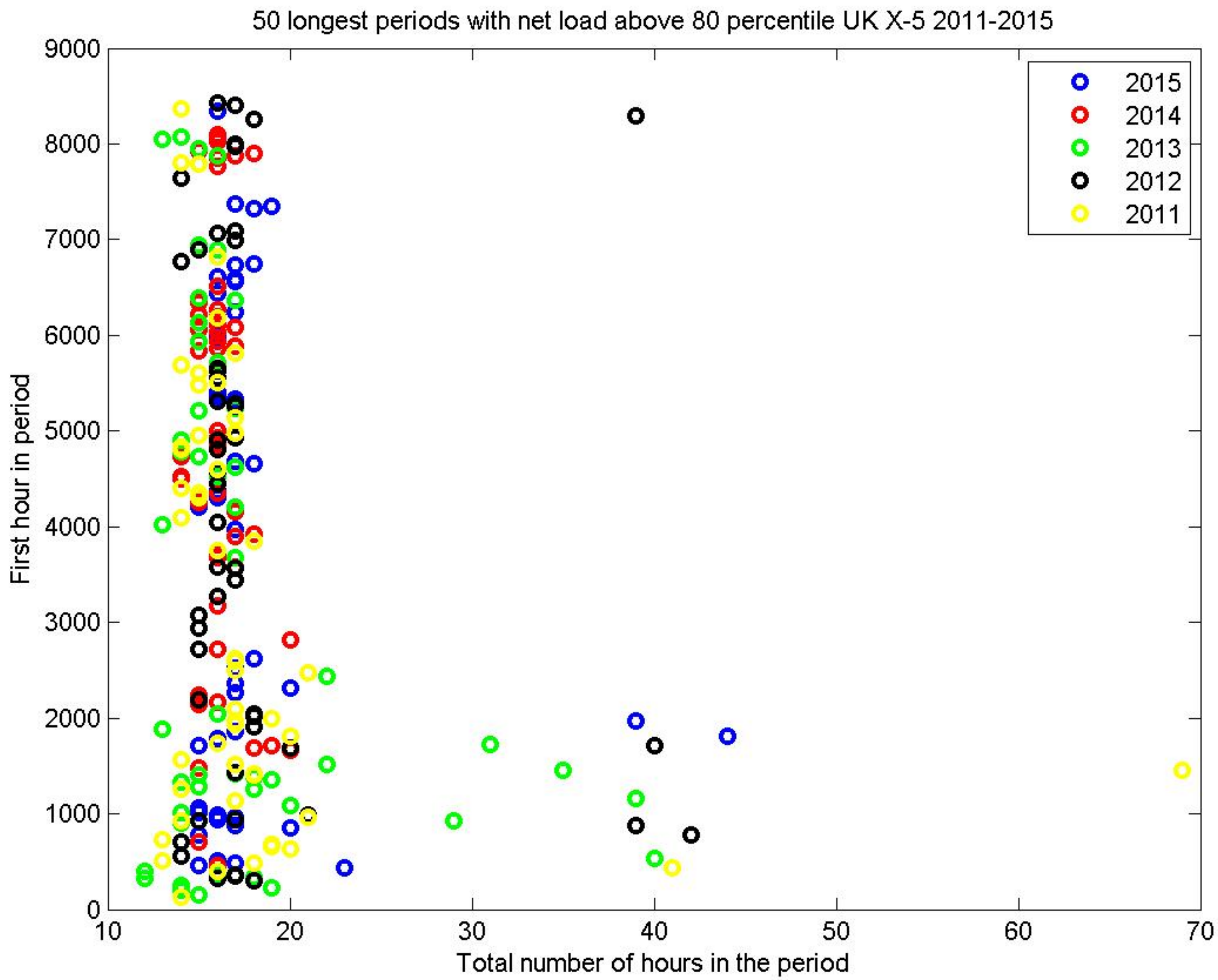
wind and solar resources 2015



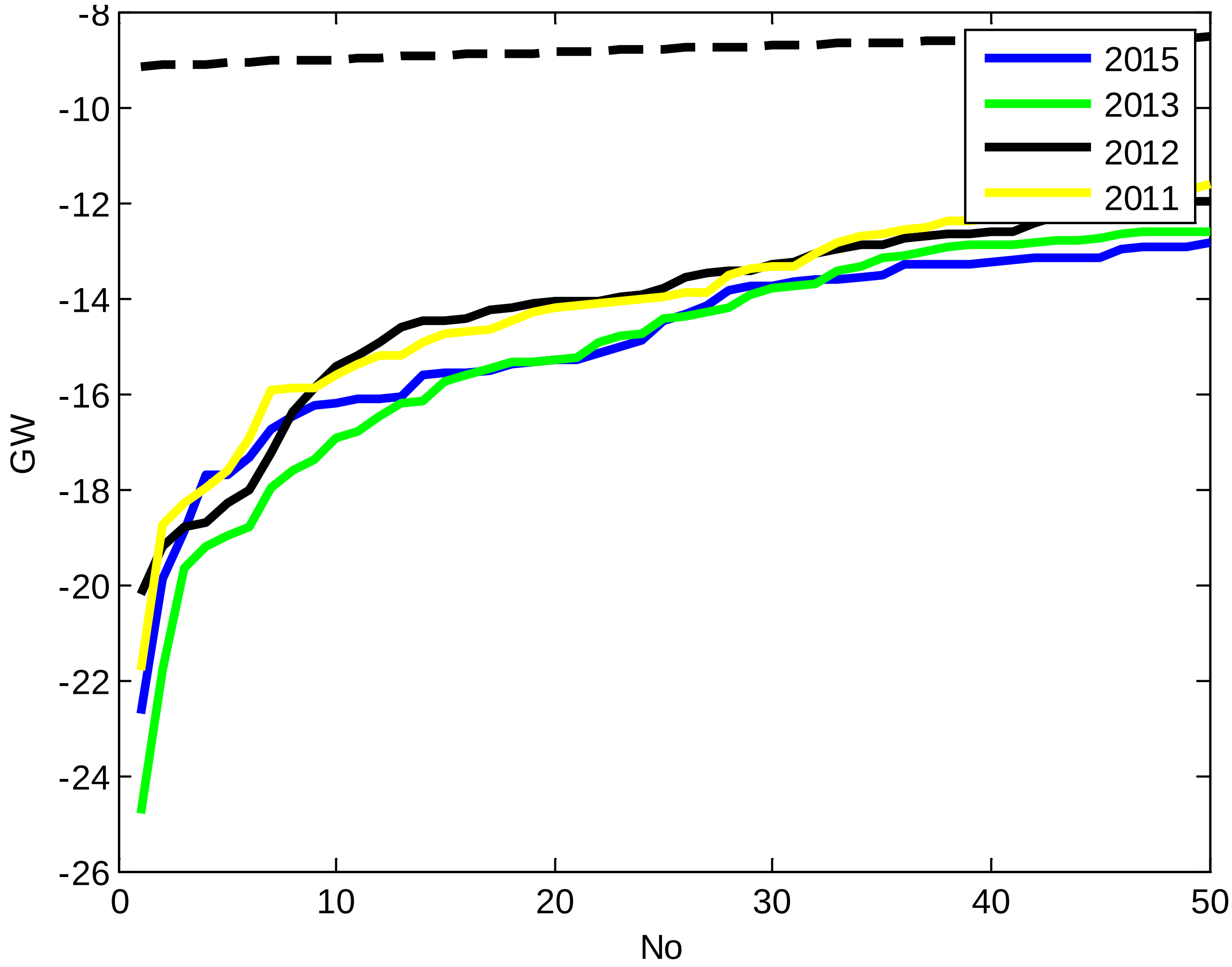
Sorted net load UK 2011-2015



50 longest periods with net load above 80 percentile UK X-5



The 50 largest 1-hour ramps in net load UK X-5



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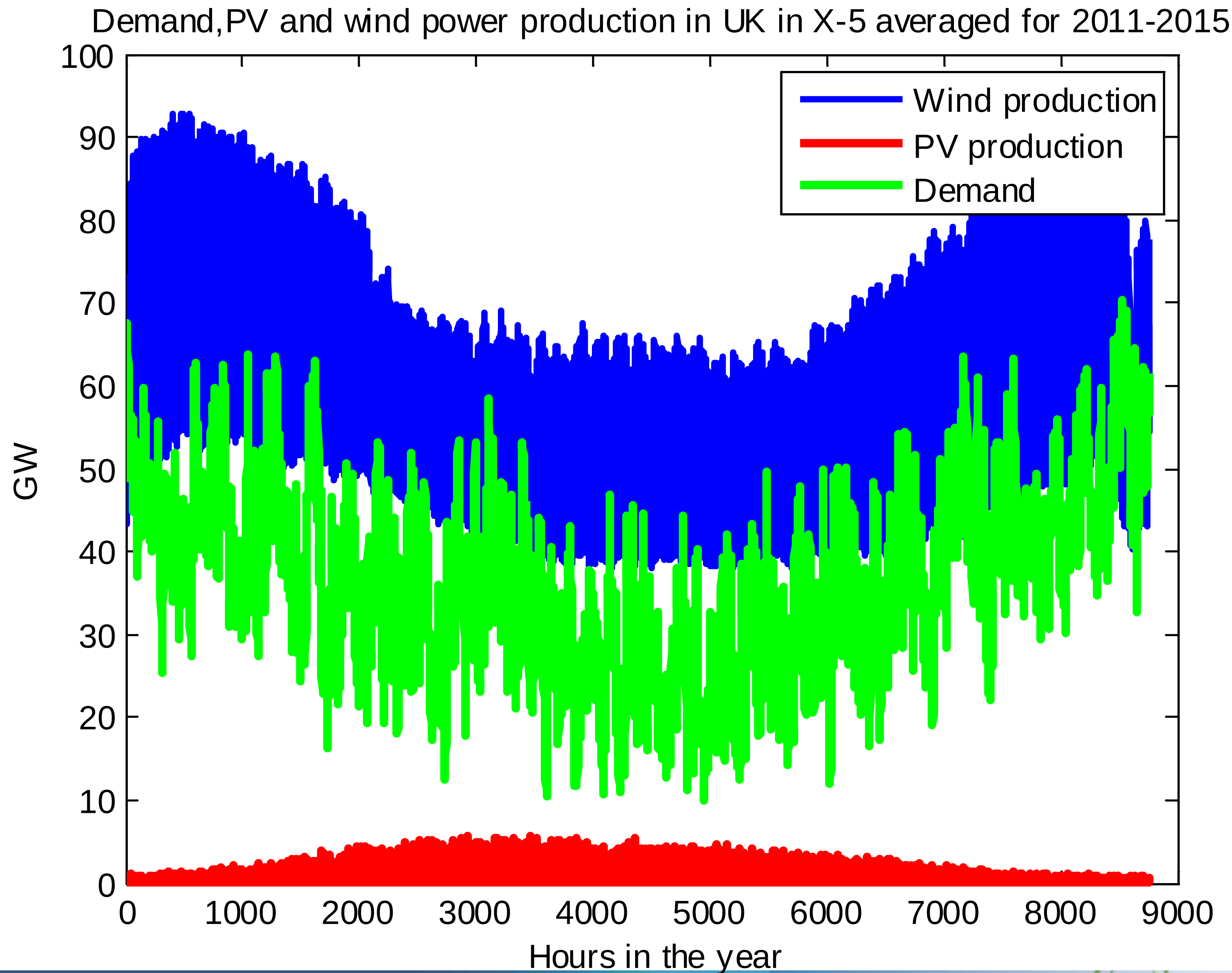
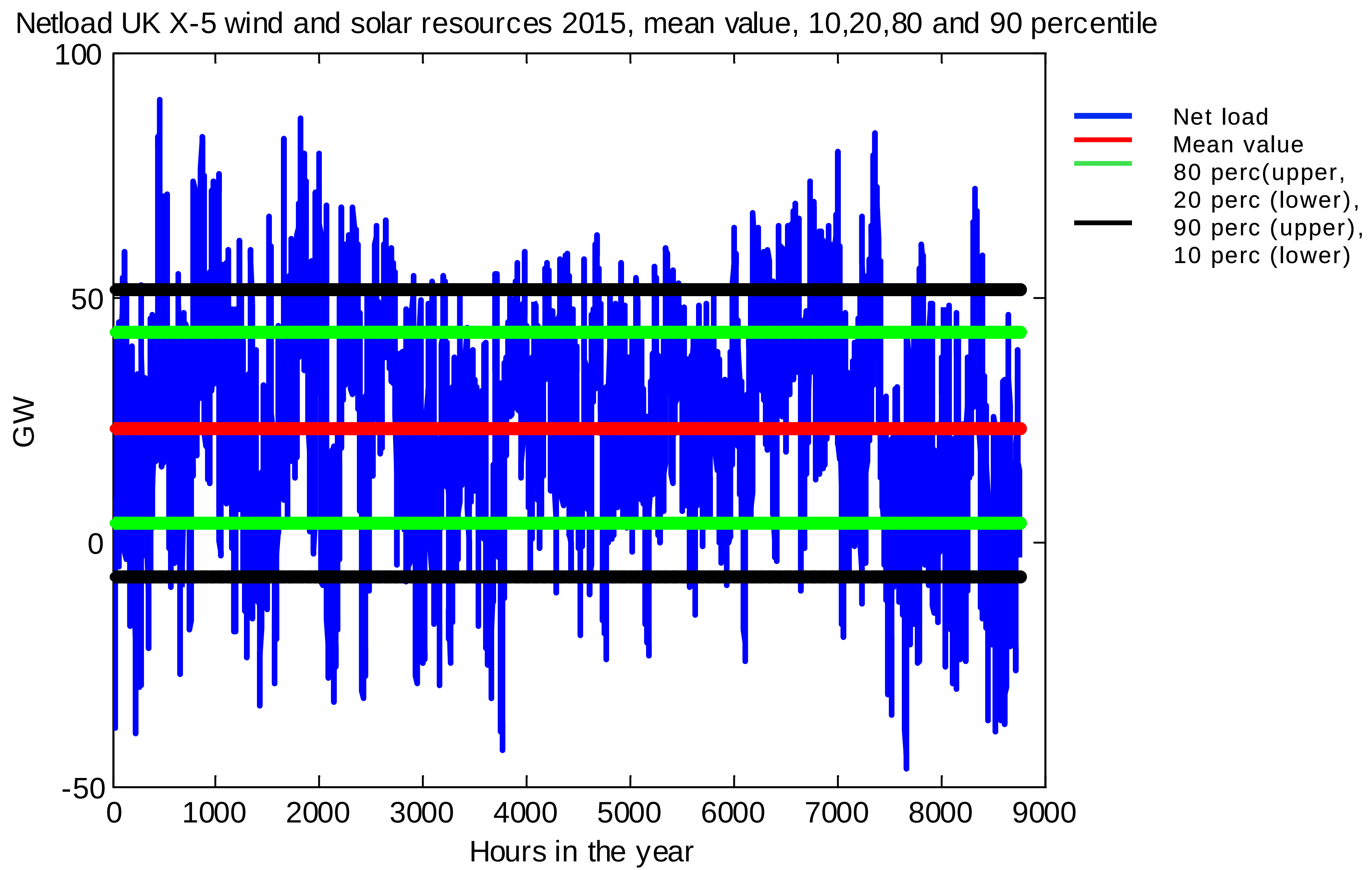
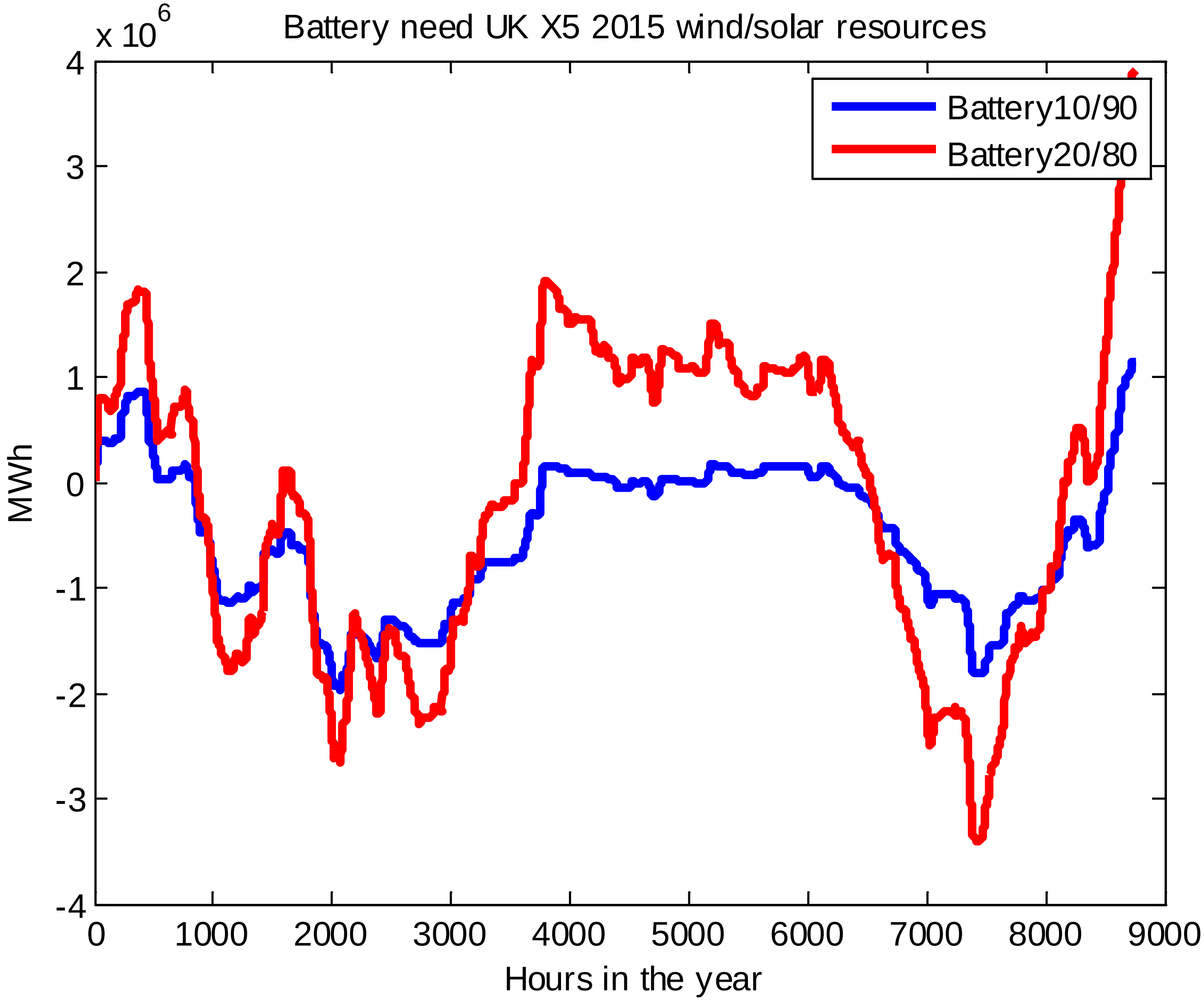
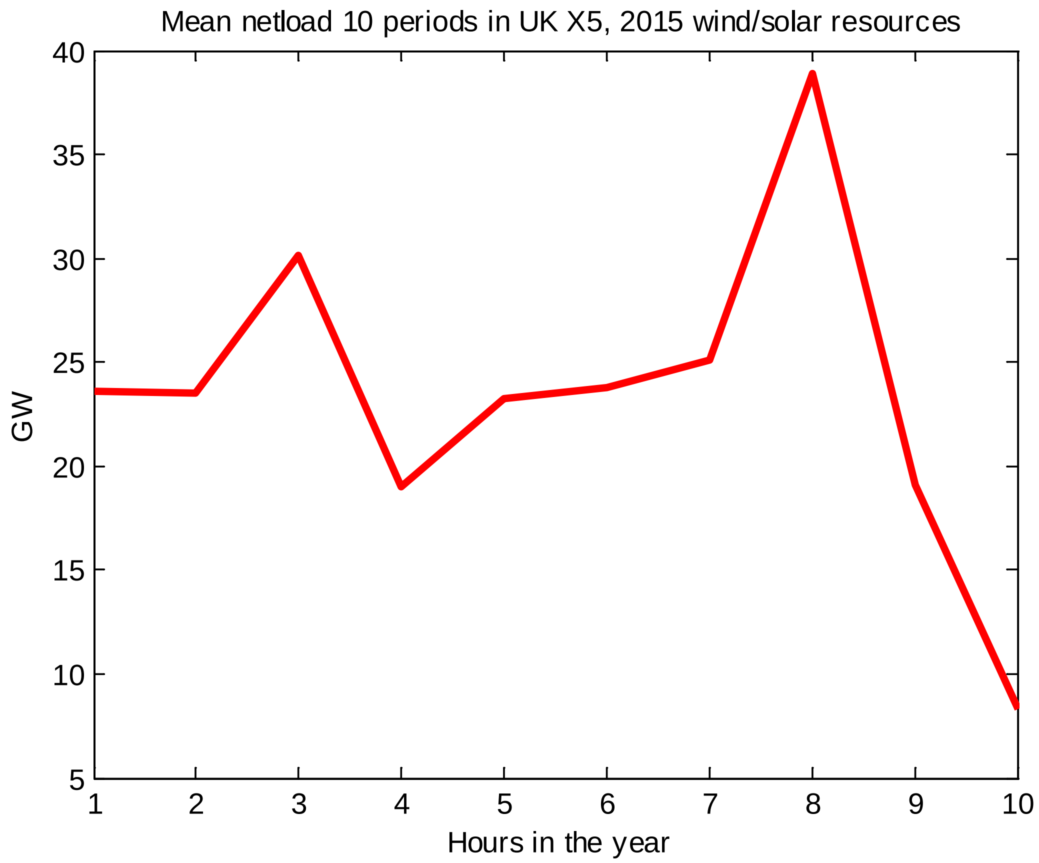

Demand,PV and wind power production in UK in X-5 averaged for 2011-2015
Wind production
PV production
Demand
GW
Hours in the year
0
10
20
30
40
50
60
70
80
90
100
0
1000
2000
3000
4000
5000
6000
7000
8000
9000

UK X-5, wind and solar resources 2015

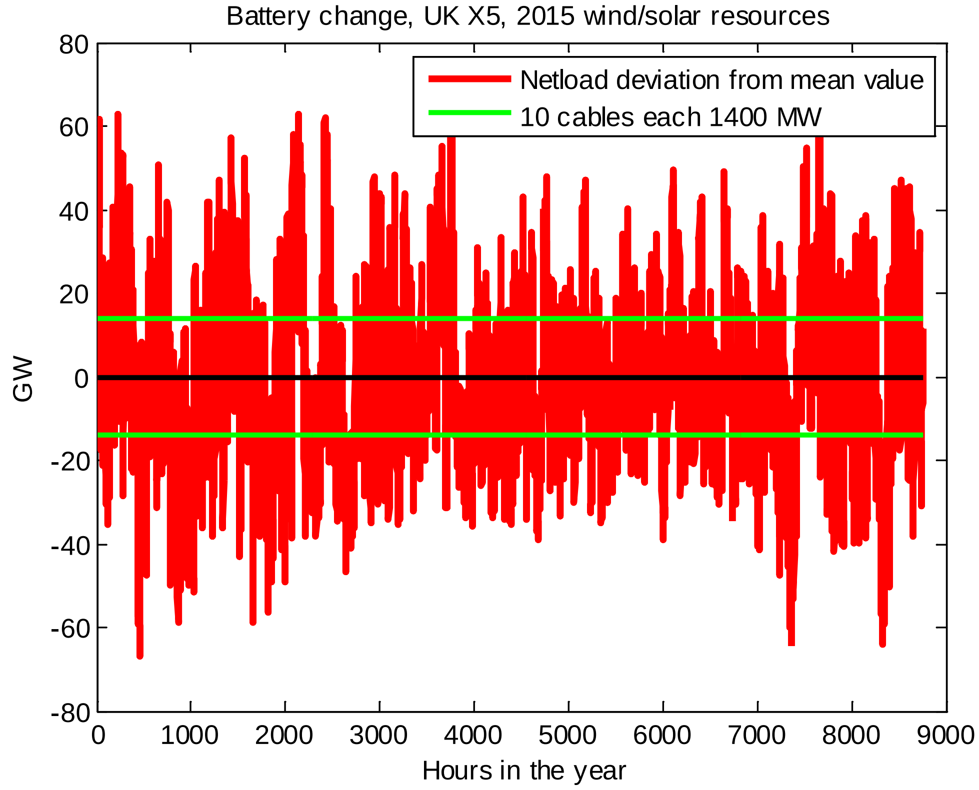


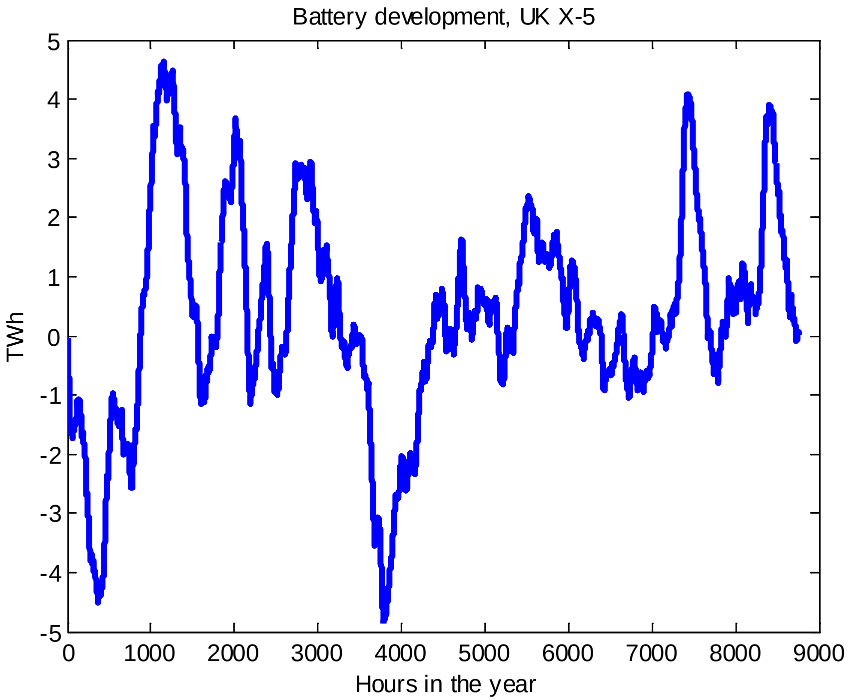

Battery need UK X5 2015 wind/solar resources
x 10^6
4
3
2
1
0
-1
-2
-3
-4
MWh
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
Hours in the year
Battery10/90
Battery20/80

Need for battery based on deviation from mean value of net load in 10 periods of the year (I:II)

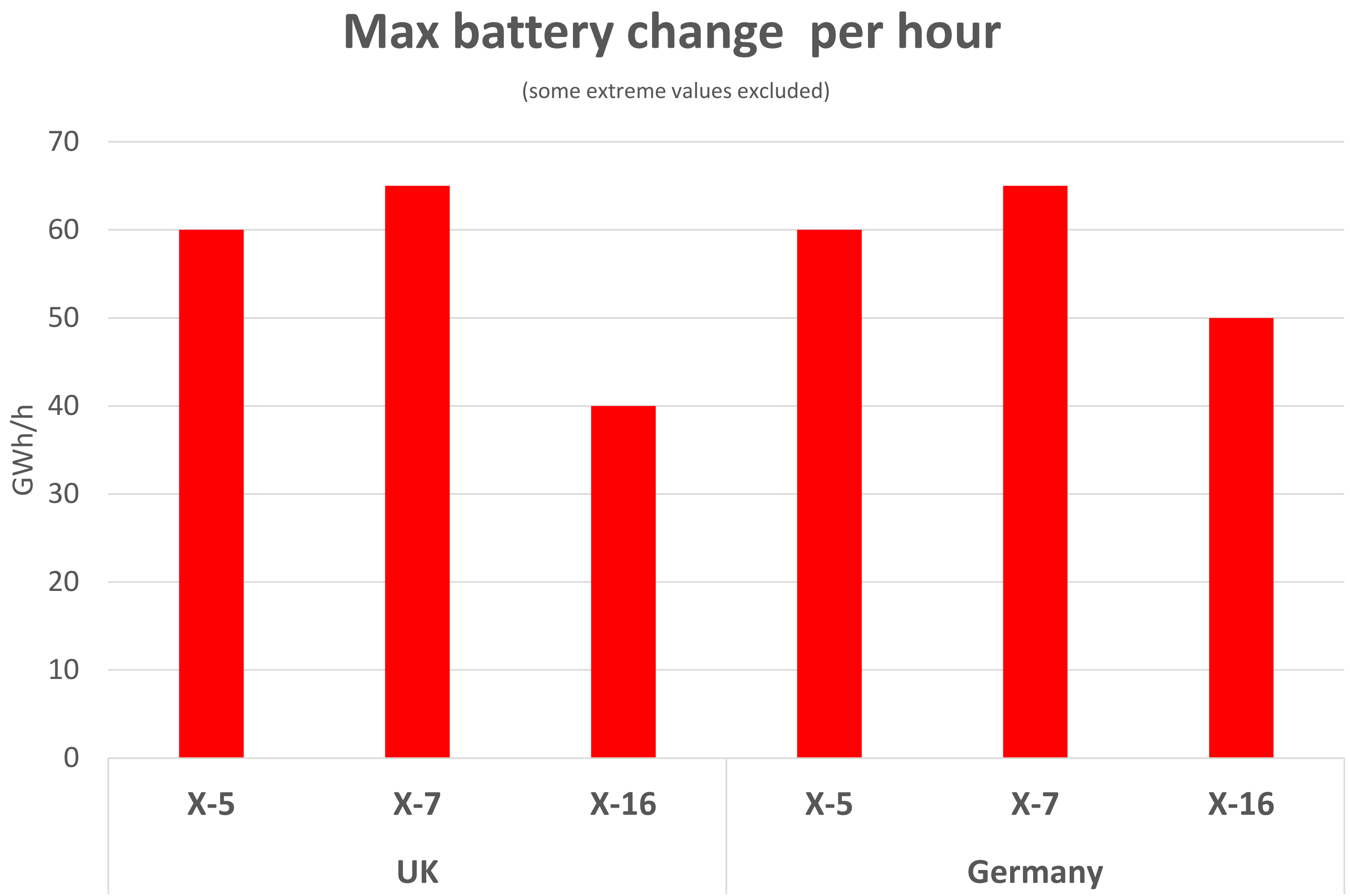


Need for battery based on deviation from mean value of net load in 10 periods of the year (II:II)

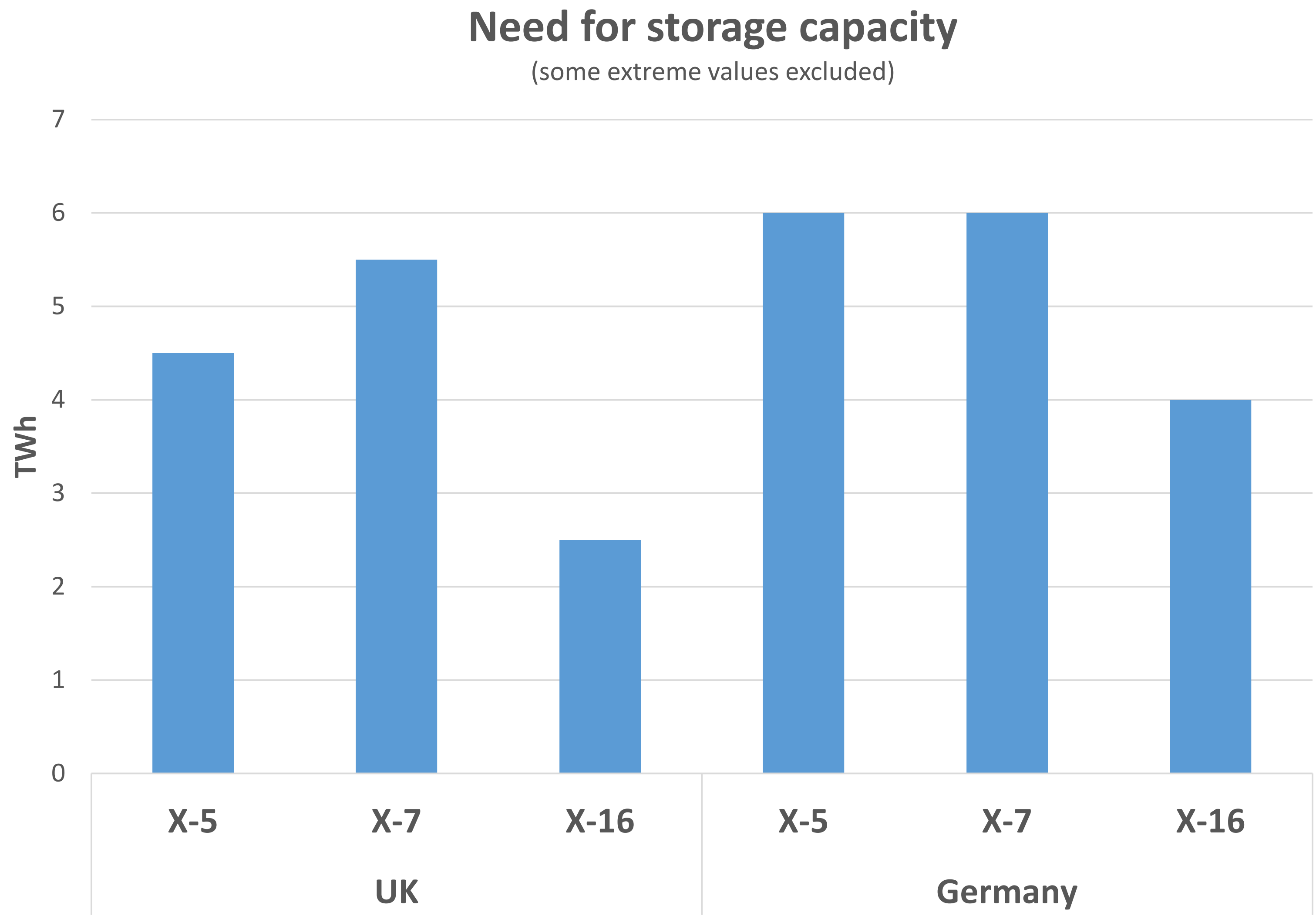




The need for battery based on deviation from mean value of net load in 10 periods of 2015



The need for battery based on deviation from mean value of net load in 10 periods of 2015



Further work

- Some further development of the analysis presented today
- A fourth scenario, possibly with 100% wind and PV power production in Europe over a year
- Assess how demand response, smaller batteries and cross-border grids can smooth out production
- Study the interaction between the Norwegian hydro power system and UK and Germany + neighbouring countries (power market models)