DTU Library

Needs for Flexibility in Energy Systems Caused by the Increasing Share of Variable Renewable Energy Generation in 2020, 2030 and 2050 Scenarios

Koivisto, Matti Juhani; Sørensen, Poul Ejnar; Maule, Petr; Nuño Martinez, Edgar; Traber, Thure

Publication date:
2017

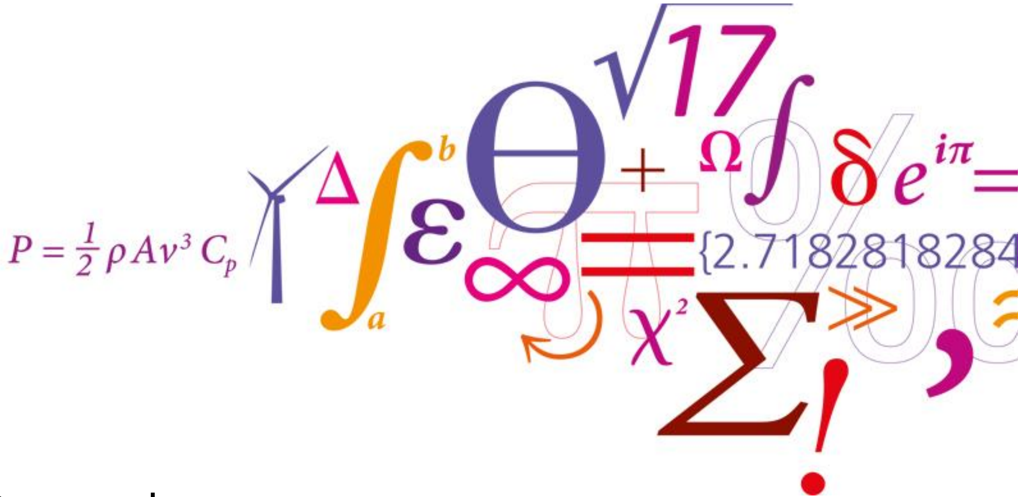
Document Version
Publisher's PDF, also known as Version of record

Needs for Flexibility in Energy Systems Caused by the Increasing Share of Variable Renewable Energy Generation in 2020, 2030 and 2050 Scenarios

M. Koivisto[a], P. Sørensen[a],
P. Maule[a], E. Nuño[a],
T. Traber[b]

[a]DTU Wind Energy
[b]DTU Management Engineering

June 29th 2017, Kongens Lyngby, Denmark



Contents

Flex4RES project

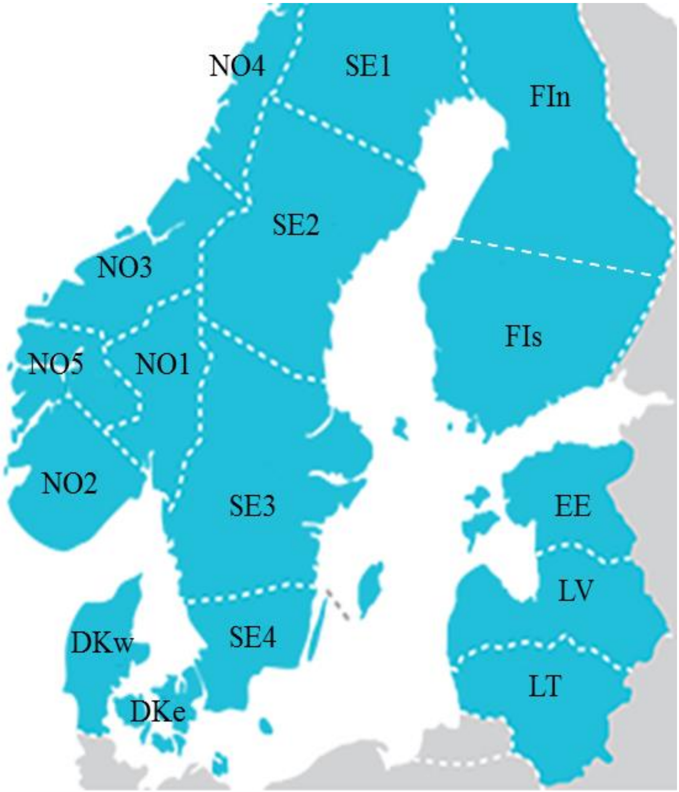
- Flex4RES is a project lead by DTU Management Engineering, with funding from Nordic Energy Research:
  - http://www.nordicenergy.org/flagship/flex4res/

- The project investigates how an intensified interaction between coupled energy markets, supported by coherent regulatory frameworks, can facilitate the integration of high shares of variable renewable energy (VRE), ensuring stable, sustainable and cost-efficient Nordic energy systems

- For assessing the need for flexibility in future scenarios with higher shares of VRE generation, DTU Wind Energy provides simulated hourly VRE generation time series for the project
  - Both wind (onshore & offshore) and solar PV are simulated
  - Nordic and Baltic countries
    - Also relevant surrounding countries for market studies

The analysed scenarios

Scenario	Offshore wind (GW)	Onshore wind (GW)	Solar (GW)	Total (GW)
2014	1.46 (12%)	9.78 (82%)	0.65 (5.4%)	11.9
2020	3.56 (17%)	15.9 (78%)	0.99 (4.9%)	20.4
2030	3.87 (11%)	30.6 (84%)	1.76 (4.9%)	36.3
2050	3.87 (6.4%)	54.3 (91%)	1.75 (2.9%)	60.0



The installed VRE generation capacities are from the baseline scenario from the Nordic Energy Technology Perspectives (NETP) 2016 report:

http://www.nordicenergy.org/project/nordic-energy-technology-perspectives/

Wind and solar PV simulations

- CorWind, a simulation tool developed at DTU Wind Energy, was used to simulate hourly wind generation time series for the analysed regions
  - Solar photovoltaic (PV) generation time series were also simulated

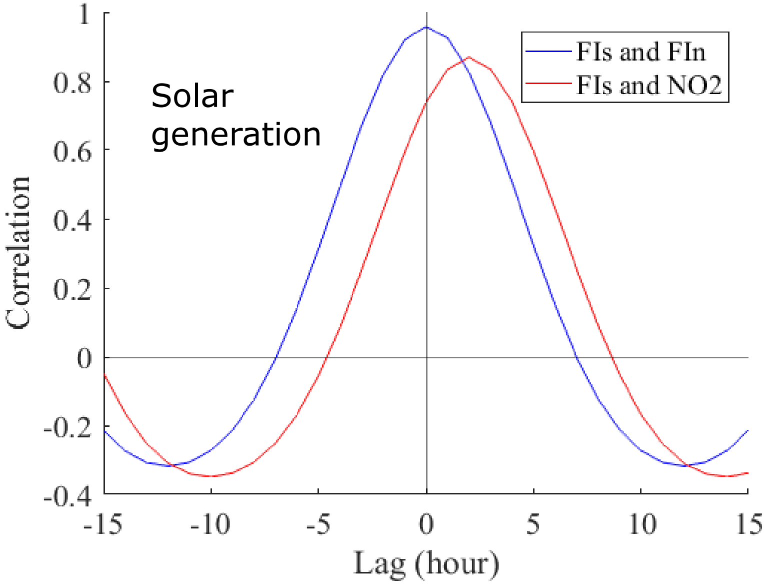
- Simulations were carried out for 34 meteorological years (1982-2015)

- A Weather Research and Forecasting (WRF) model was used to generate the underlying meteorological time series data
  - Mesoscale reanalysis
  - Local downscaling is done so that historical capacity factors are met
  - Some references about WRF and its applications:
    - M. Marinelli et al., "Wind and photovoltaic large-scale regional models for hourly production evaluatio.n," *IEEE Trans. Sustain. Energy*, vol. 6, no. 3, pp. 916–923, July 2015.
    - W. Wang et al., WRF-ARW Version 3 Modeling System User's Guide. Boulder, CO, USA: Mesoscale & Microscale Meteorology Division, National Center for Atmospheric Research, 2009.
    - A. N. Hahmann et al., "A reanalysis system for the generation of mesoscale climatographies," *J. Appl. Meteorol. Climatol.*, vol. 49, no. 5, pp. 954–972, May 2010.

Spatial correlations of VRE generation

	Offshore wind	Onshore wind	Solar
Offshore wind	0.40 (0.13... 0.81)	0.38 (0.04... 0.91)	-0.13 (-0.22... -0.05)
Onshore wind		0.33 (0.02... 0.84)	-0.12 (-0.28... -0.03)
Solar			0.89 (0.74... 0.98)

Average spatial correlations for different VRE generation types between the analysed regions (values in the brackets are the min and max correlations between all possible region pairs)



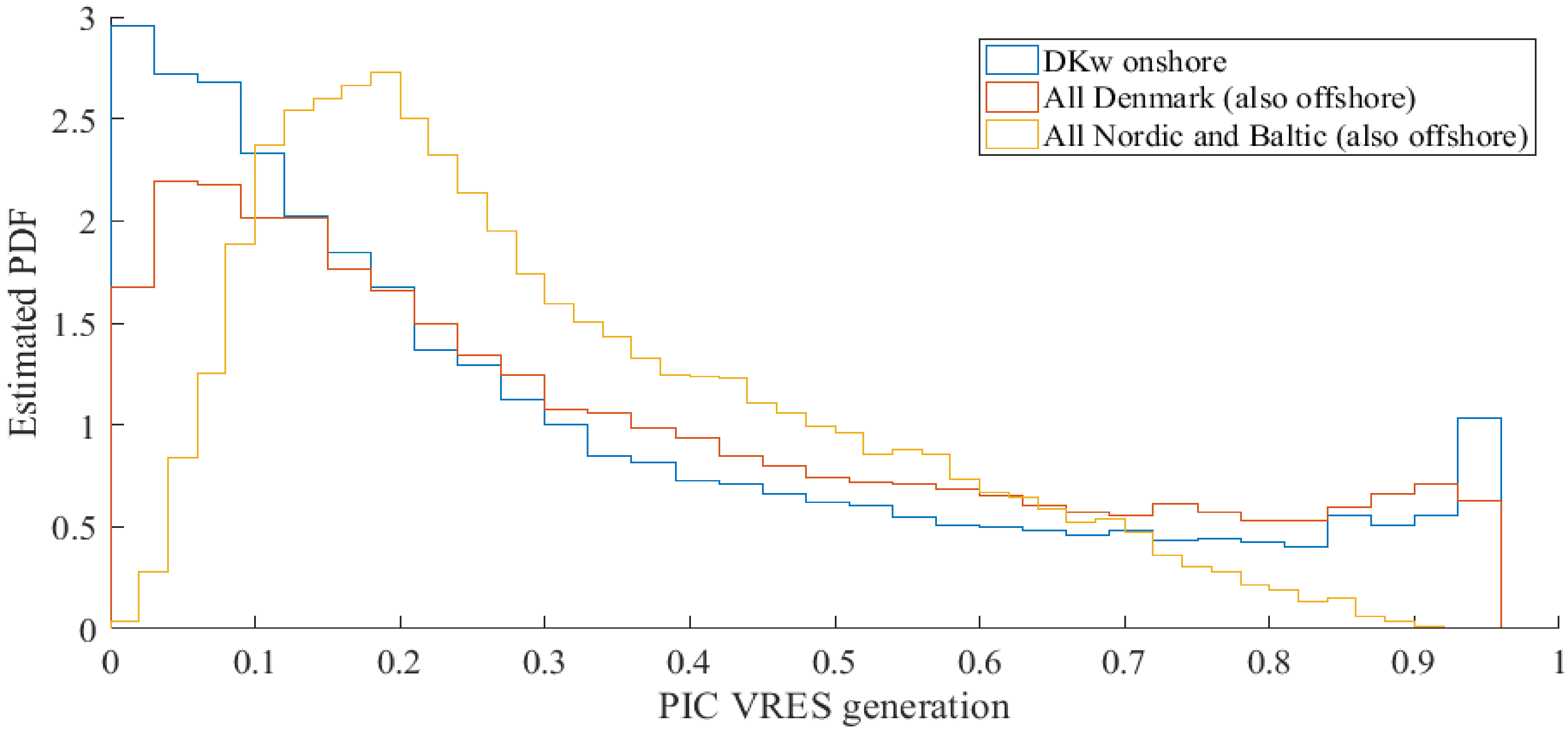
Cross-correlation function between two different solar region pairs

Standard deviation of a sum: $\mathrm{Std}(\sum_{i=1}^{k} x_i) = \sqrt{\sum_{i=1}^{k} \sigma_i^2 + 2\sum_{1 \le i < j \le k} \mathrm{Cov}(x_i, x_j)}$

Negative correlation between solar and wind seems to hold also for the stochastic part (cloud movements etc.):

J. Ekström, M. Koivisto, I. Mellin, J. Millar, M. Lehtonen, "A Statistical Model for Hourly Large-Scale Wind and Photovoltaic Generation in New Locations", *IEEE Trans. Sustain. Energy*, early view article

Wind generation variability decreases as the geographical area increases



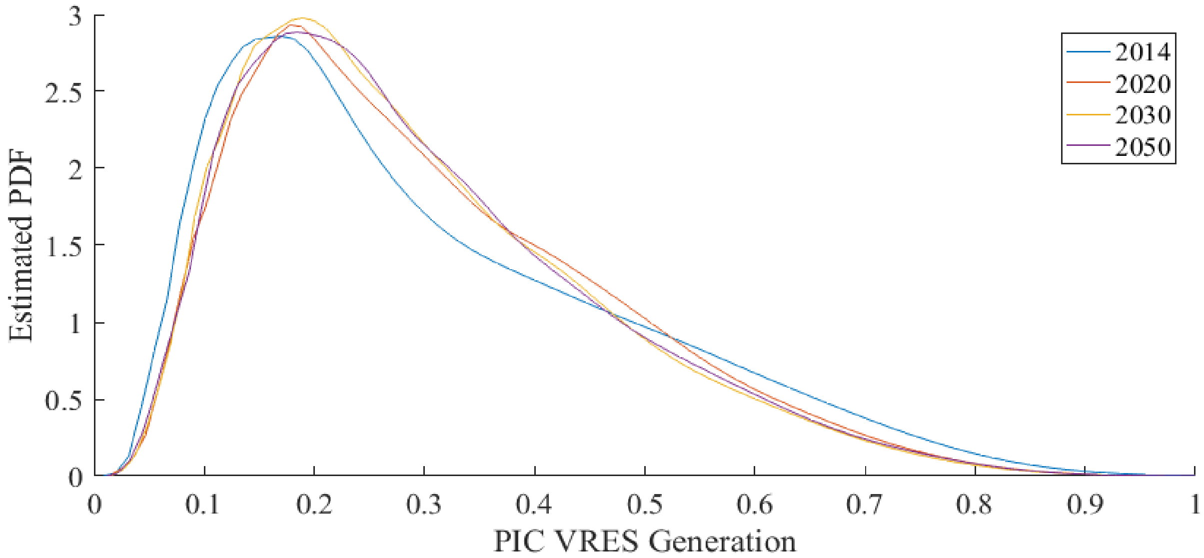
PIC = Proportion of Installed Capacity

Relative shares of installed onshore wind capacity in the different regions

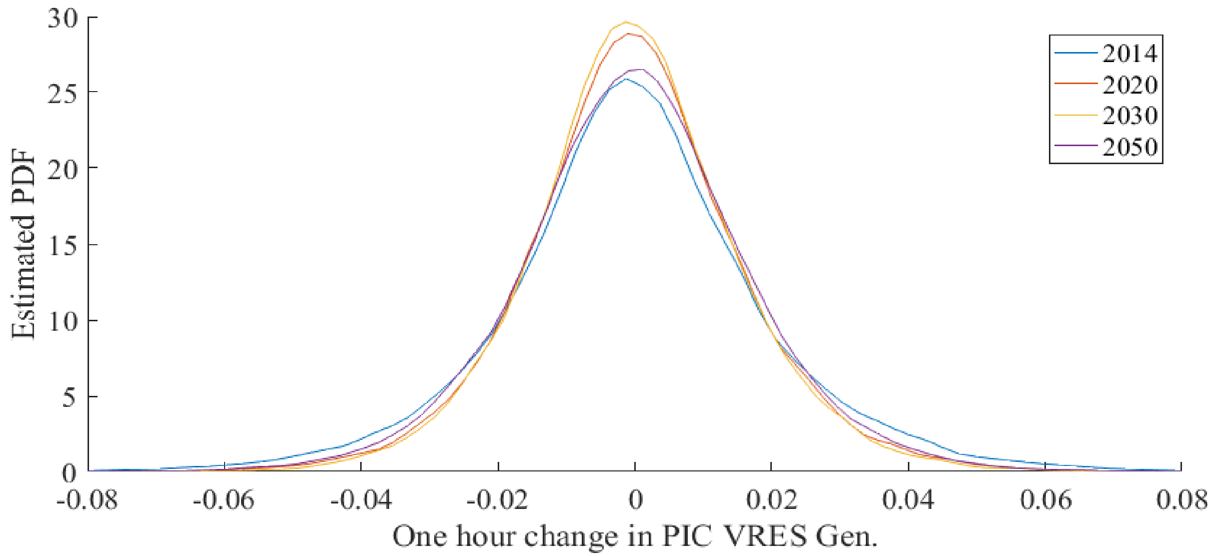
Scenario	DK	SE south (SE3 and 4)	NO south (NO1, 2 and 5)	SE north (SE1 and 2)	NO north (NO3 and 4)	Baltic countries	FI
2014	36%	29%	3%	15%	6%	7%	4%
2020	26%	18%	3%	15%	20%	9%	10%
2030	17%	18%	5%	19%	18%	17%	5%
2050	15%	22%	3%	20%	19%	18%	3%

- From 2014 to 2020, the geographical distribution moves away from Denmark and southern Sweden (with currently high installed capacities), towards a more dispersed geographical distribution for 2020.
- From 2020 to 2030, the share in Denmark decreases. The share in Finland also decreases, but the share in the Baltic countries increases significantly. The end result is only a slightly increased geographical spread for 2030.
- The shares in 2050 are quite similar to 2030; however, the share in southern Sweden increases a little.

Variability of the aggregate VRE generation

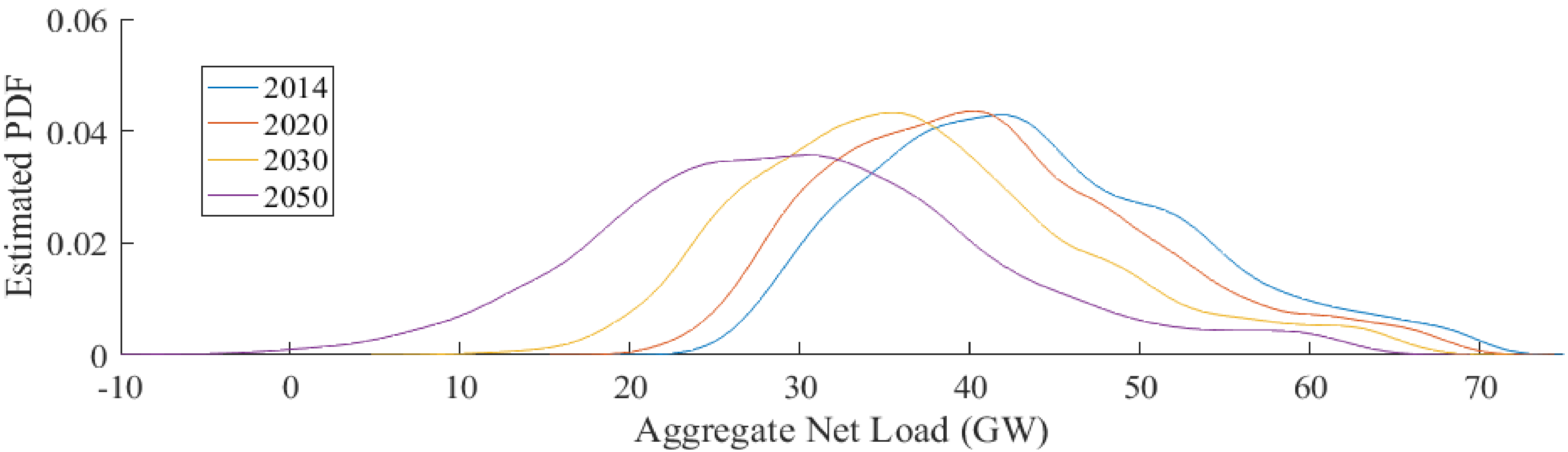


Scenario	Mean	Std
2014	0.305	0.179
2020	0.305	0.161
2030	0.296	0.156
2050	0.299	0.158



Scenario	Std
2014	0.0197
2020	0.0161
2030	0.0154
2050	0.0169

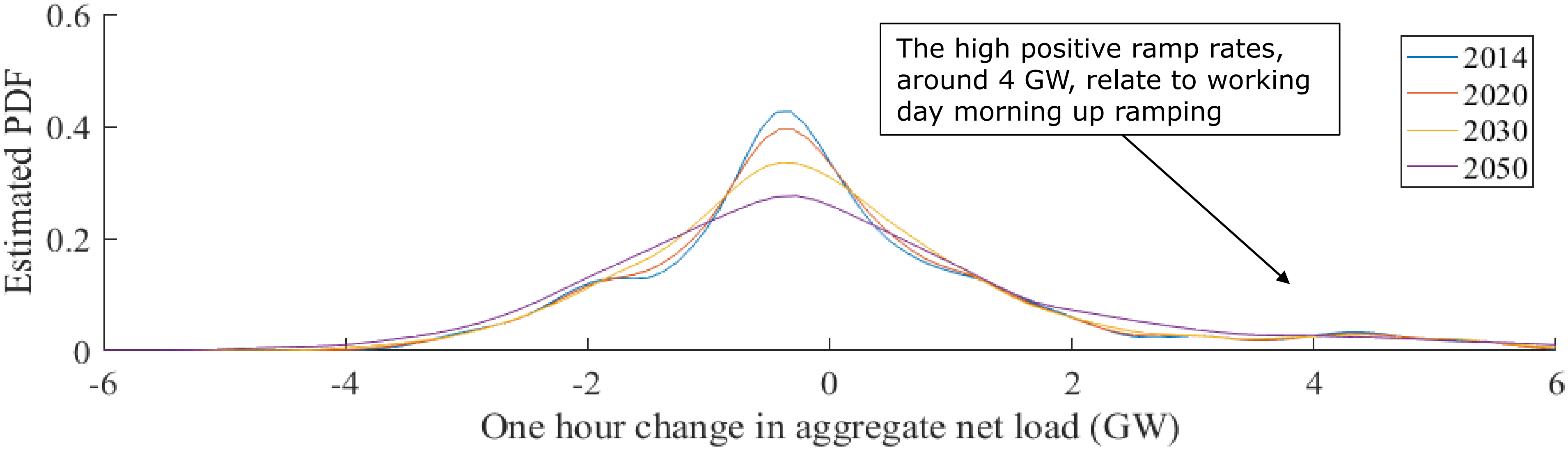
Variability of aggregate net load (based on 2012 data)



Scenario	Mean (GW)	Std (GW)	5th percentile (GW)	95th percentile (GW)
Only consumption	47.3	9.5	33.1	64.8
2014	43.8	9.4	30.2	61.9
2020	41.2	9.4	28.0	59.8
2030	36.9	9.9	23.0	56.2
2050	30.0	11.5	12.1	50.9

Net load = electricity consumption - VRE generation, consumption data from Entso-E

Ramp rates of aggregate net load (based on 2012 data)



Scenario	Std (GW)	5th percentile (GW)	95th percentile (GW)
Only consumption	1.63	-2.28	3.62
2014	1.63	-2.29	3.62
2020	1.63	-2.29	3.57
2030	1.66	-2.34	3.58
2050	1.86	-2.62	3.75

Consumption data from Entso-E

Conclusions

- Hourly aggregate net load
  - Std increases notably in 2050 (22% higher than in 2014)
  - At the same time, the mean decreases
  - Thus, there will be less energy to be generated by the other generation types, such as hydro power, while the need for flexibility increases (also, e.g., demand-side response can be utilized)

- Hourly ramp rates in the aggregate net load
  - Ramp rate Std increases moderately in 2050 (14% higher than in 2014)
  - While ramping in consumption happens usually at well-known times, the hourly changes in VRE generation are less predictable

- Peak net load
  - The probability of very high net load decreases (when VRE share increases)
  - However, aggregate VRE generation can be zero, so the highest possible net load is determined by peak consumption
  - This may raise questions considering the incentives to hold enough other generation capacity to meet the rare peak net load

Discussion and future work

- For now, the simulations are based on current capacity factors (i.e., full load hours) for all scenario years
  - Capacity factor changes in the future are being modelled, and the changes will be incorporated into the simulations

- CorWind can do also forecasting simulations for wind generation
  - Can be used to assess uncertainty in wind generation (in addition to variability, which was discussed in this presentation)
  - Similar capabilities are being developed also for solar PV generation:
    - E. Nuño, M. Koivisto, Nicolaos Cutululis, Poul Sørensen, "Simulation of regional day-ahead PV power forecast scenarios", *IEEE PES PowerTech*, Manchester, UK, June 2017.

- Similar simulations as presented here will also be used in the NSON-DK project
  - Focus in the North Sea area (thus much higher offshore share)
  - http://www.nson-dk-project.dk/