Utrecht University

Koninklijk Nederlands
Meteorologisch Instituut
Ministerie van Infrastructuur en Waterstaat

TenneT

LAURENS STOOP & ROGIER WUIJTS

LINKING UNSERVED ENERGY TO WEATHER REGIMES

uu.nl/staff/LPStoop

l.p.stoop@uu.nl

L.P.STOOP@UU.NL

WHO AM I?

- PhD interested in critical events and their risks under climate change, focussing on energy systems right now.
- Working at the overlap in the fields of Data, Climate and Energy science, co-working with TSO's
- Personal focus on aligning methods between industry and academic research
  - Checks & balances / Cross pollination
- Today I'll share on going work on this interface

OUTLINE

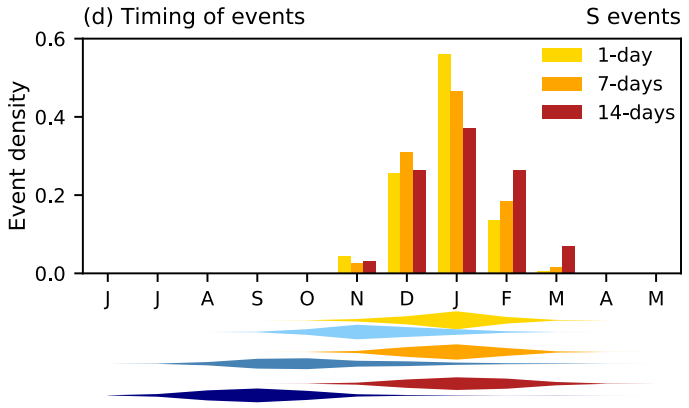
- The ACDC-ESM project
- Impacts in the energy system; different perspectives
  - Weather Regimes
  - Energy not served
- Linking unserved energy to weather regimes

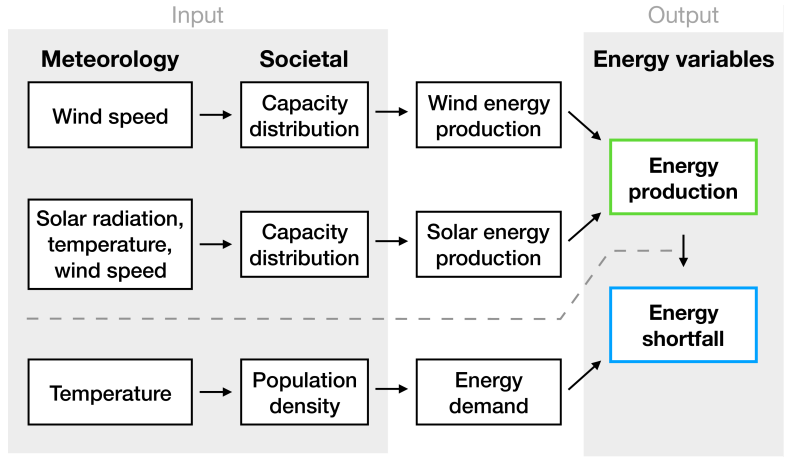
THE ACDC-ESM PROJECT

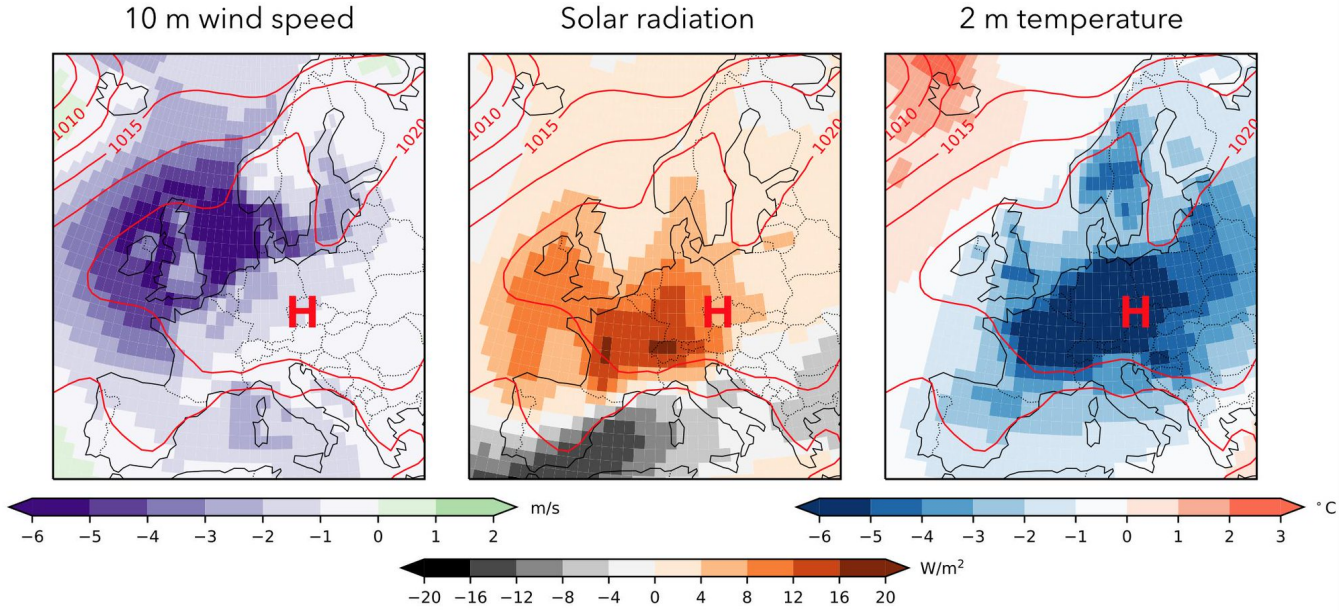
- Algorithmic Computing and Data mining for Climate integrated Energy System Models
  - Two PhD's: Algorithms (Rogier Wuijts) and Data mining (me)
  - Cooperation between Energy & Computing science (Utrecht University)
  - In collaboration with TenneT TSO B.V. and KNMI
- Building a framework using ICS knowledge to gain insights
- The influence of renewables, storage, and demand response on adequacy.

IMPACTS: METEOROLOGICAL PERSPECTIVE

- Weather leading to high energy shortfall
  - Finding extreme characteristics
  - Determine timing & risk



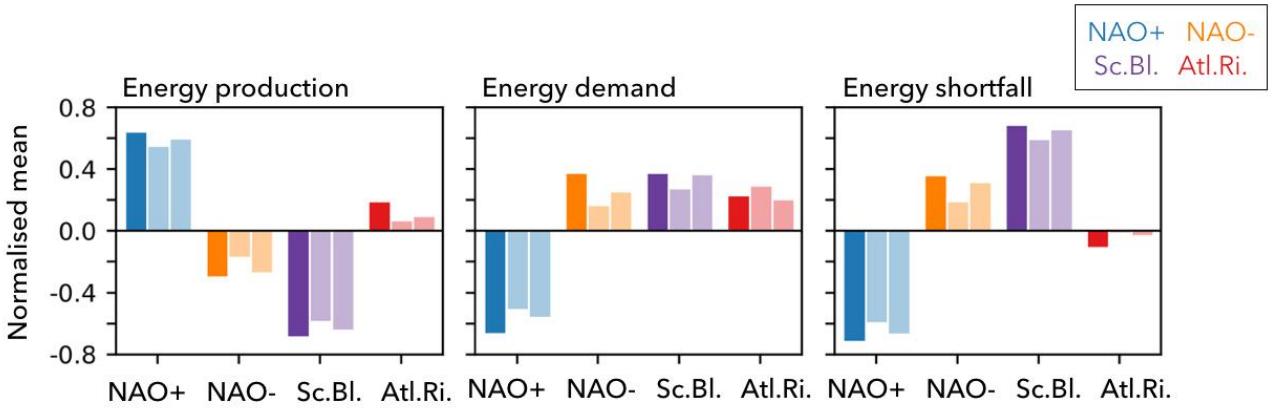


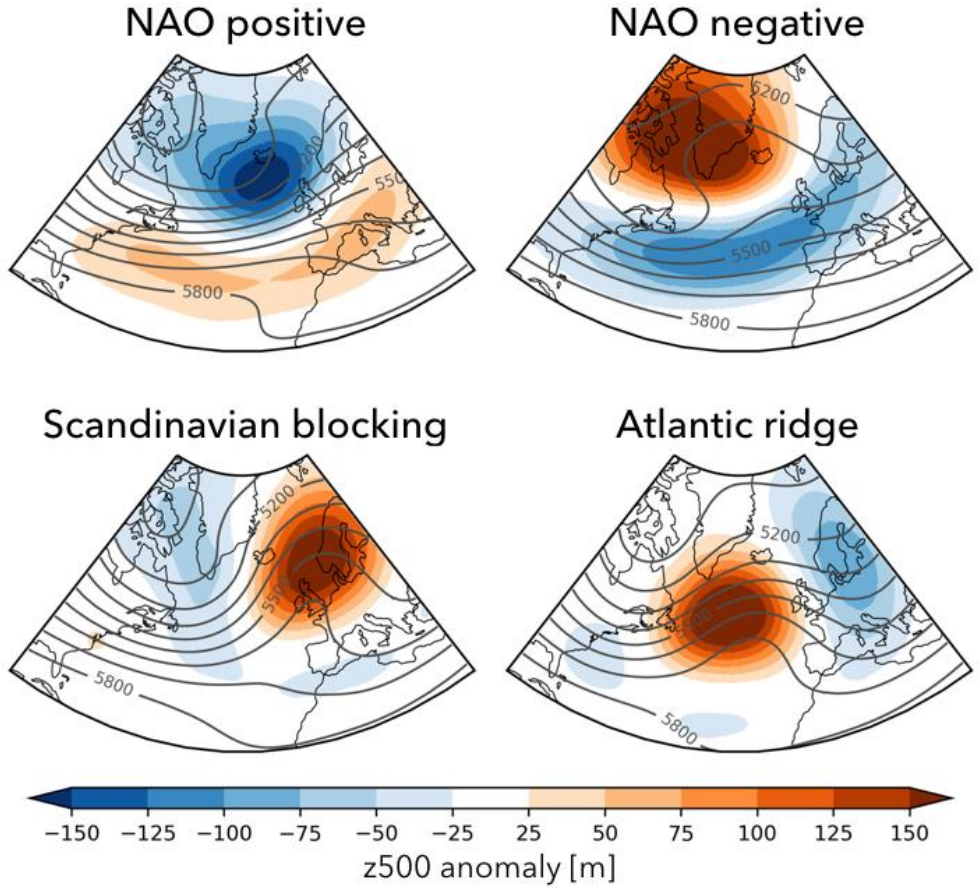


Meteorological conditions leading to extreme low variable renewable energy production and extreme high energy shortfall
van der Wiel, Stoop et al. (2019), Renewable and sustainable energy reviews, DOI: 10.1016/j.rser.2019.04.065

WINTERTIME EVENTS

- High risk events are in winter
  - Weather regimes as classification
  - Indicate large scale circulation patterns

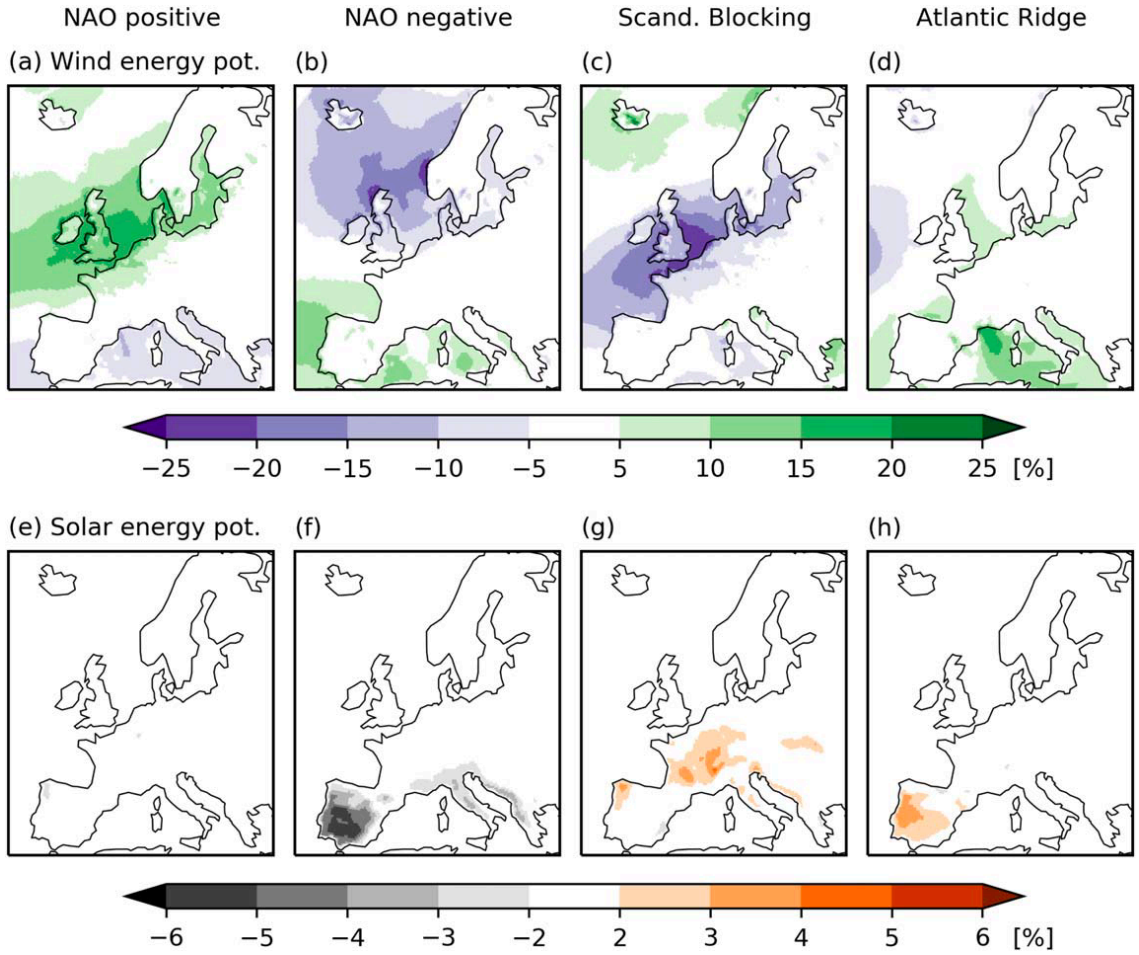




The influence of weather regimes on European renewable energy production and demand
van der Wiel et al. (2019), Environmental Research Letters, DOI: 10.1088/1748-9326/ab38d3

QUANTIFICATION THROUGH WEATHER REGIMES

- Based on classic k=4 regimes
- Blocked patterns are problematic
  - Lower RES & higher DEM
  - Increased residual load
- Seen in both ERA5 & HiWAVES3



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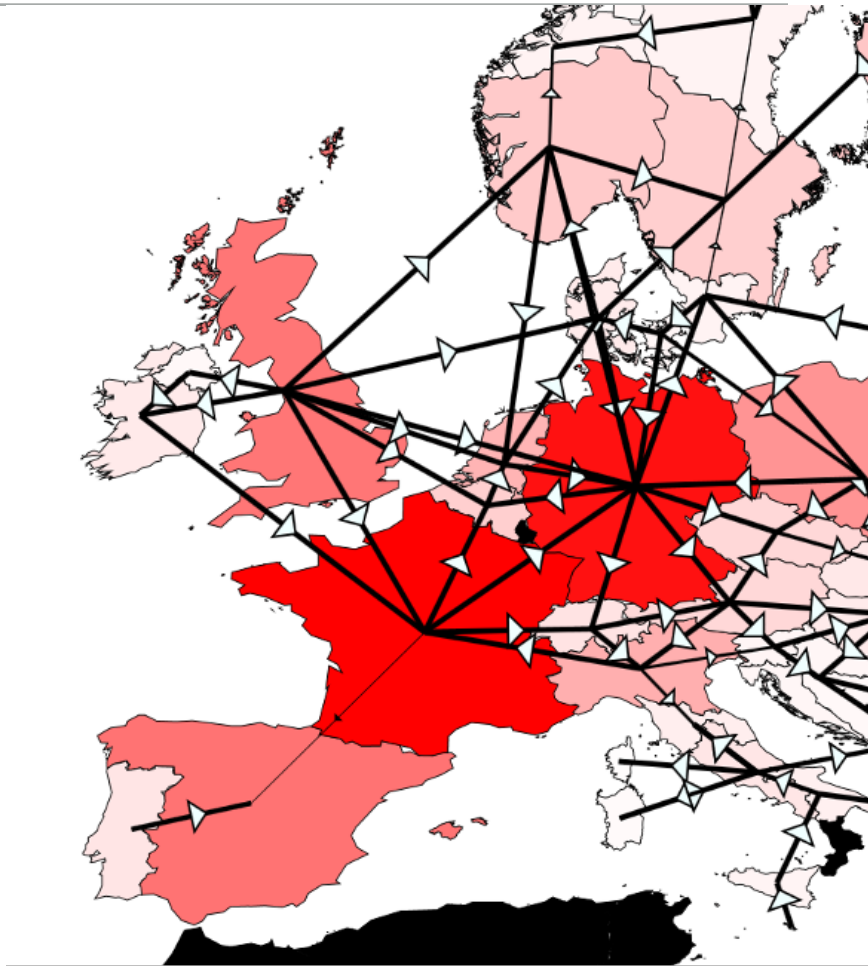
L.P.STOOP@UU.NL

IMPACTS: SYSTEM OPERATOR PERSPECTIVE

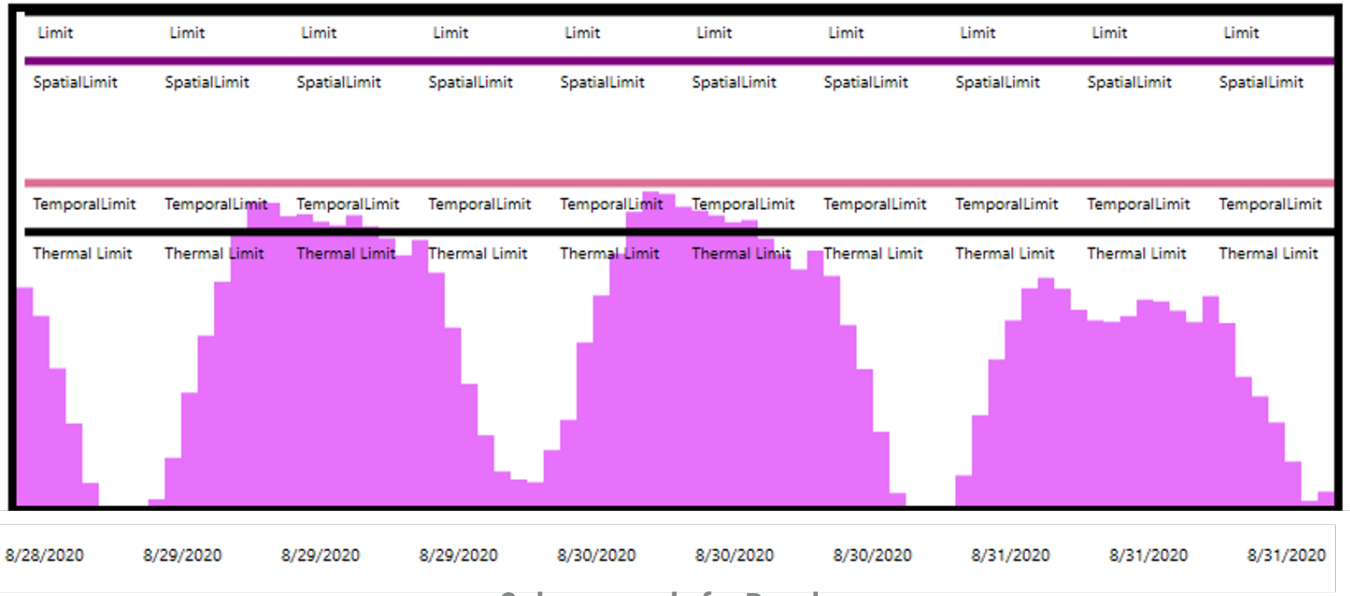
- Ten year network development plan (TYNDP'20)
  - Distributed Energy (DE)
  - National Trends (NT)
  - Global Ambitions (GA)
- Model needs to represent connected grid & market
  - Full market model with 55 zones
  - Explicit transmission
- System reliability/adequacy needs to be assessed



GA2040 example

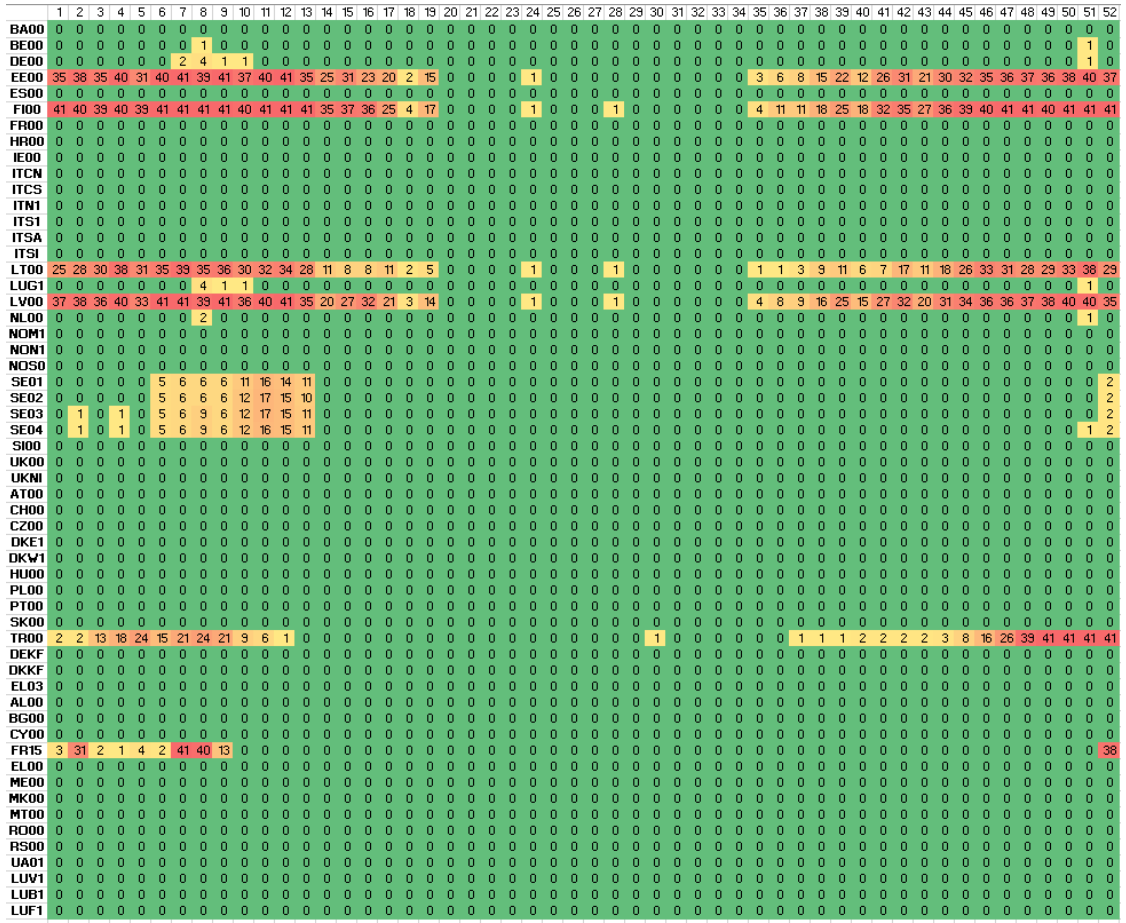
TIMING OF SYSTEM LIMITS

- Using an ESM allows to study system limits
  - Connection allows for transport
  - Storage allows for temporal shifting



3-day example for Benelux

DE 2040



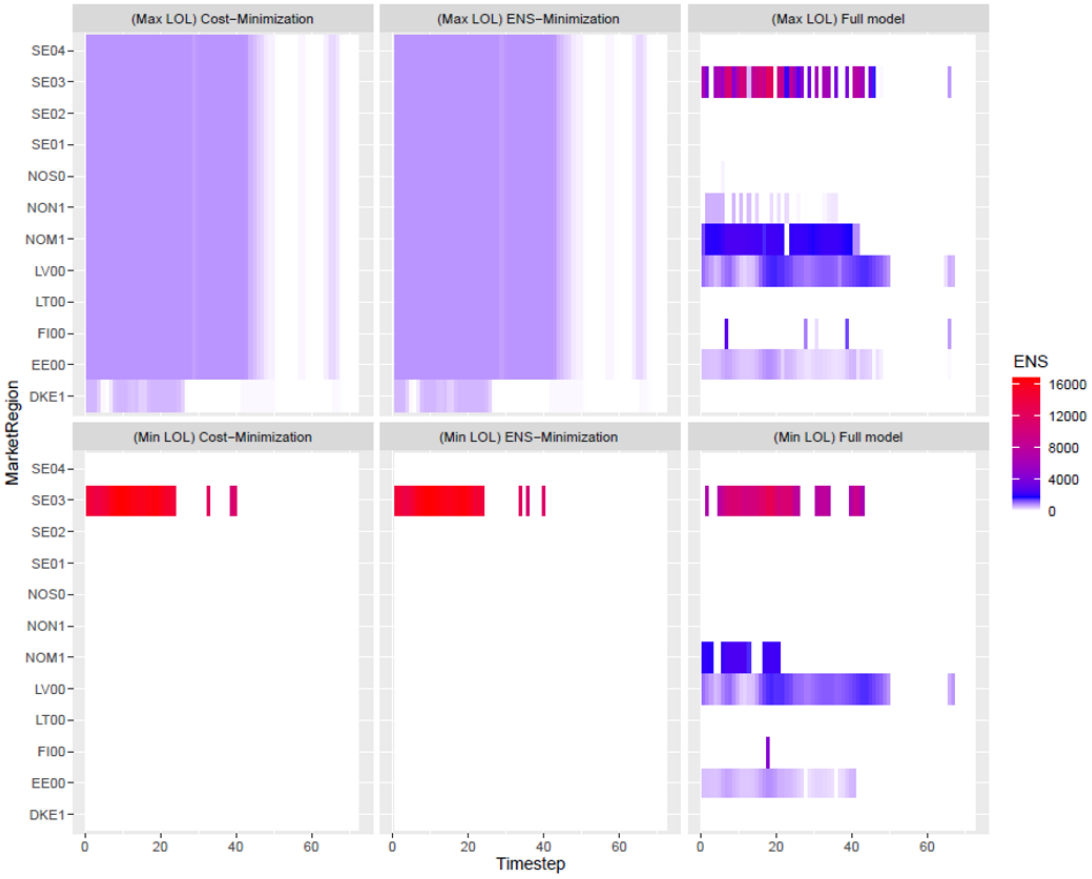
- Events are in extended winter!

QUANTIFICATION THROUGH UNSERVED ENERGY

- Quantification
  - ~~Loss of load expected (~~LoLe
  - Energy not served (ENS)
- Run ESM model give solution with a cost
  - Add cost as a constraint, min/max LoLe
- Same ENS, different LoLe

$$\min_x f(x)$$
$$\text{s.t.}$$
$$x \in X$$

$$\min_x \text{Loss of Load}$$
$$x \in X$$
$$x \leq f(x^*)$$



IMPACTS IN THE ENERGY SYSTEM: OVERLAP

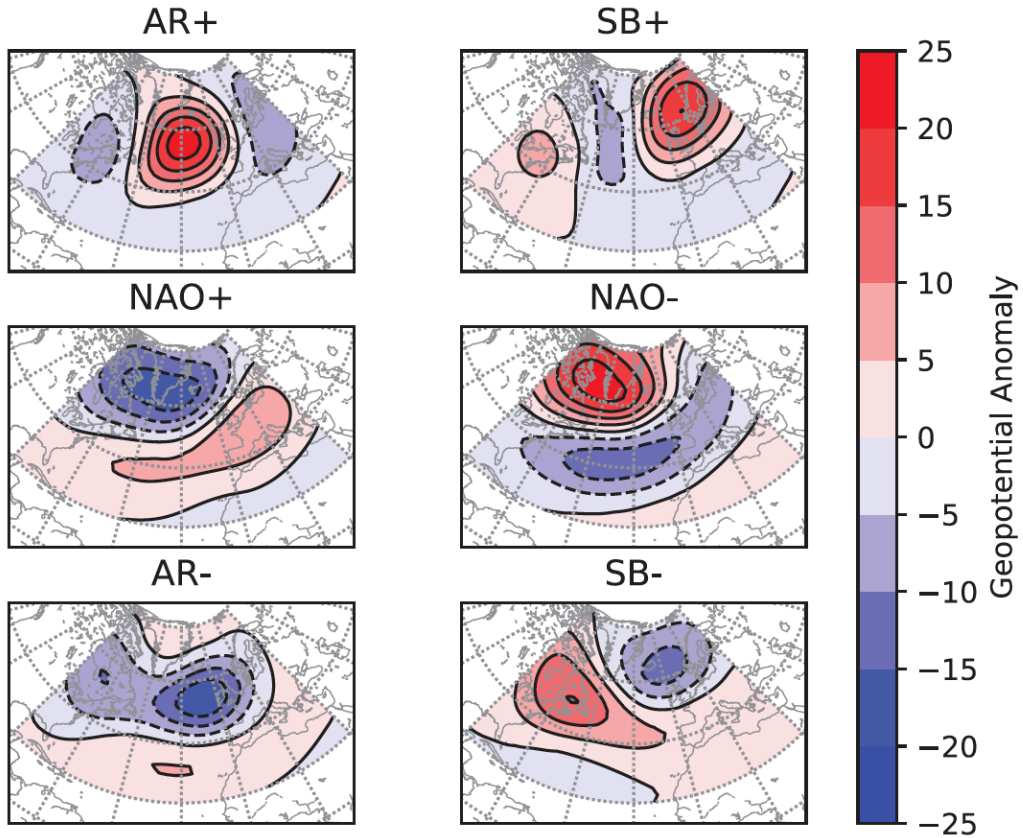
- High impact events are generally during extended winter period
  - Shortfall in climate impact model
  - Energy not served in ESM
- Wintertime quantification of Weather Regimes is good*
  - Enhanced predictability
  - Using 6 regimes based on Falkena'20

Revisiting the identification of wintertime atmospheric circulation regimes in the Euro-Atlantic sector
Falkena et al. (2020), Quarterly Journal of the Royal Meteorological Society, DOI: 10.1002/qj.3818

L.P.STOOP@UU.NL

USING WEATHER REGIMES (K=6)

- Well defined in winter time
- Falkena'20 found six is better
  - Atlantic Ridge (AR+, AR-)
  - Scandinavian Blocking (SB+, SB-)
  - North Atlantic Oscillation (NAO+, NAO-)



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LINKING UNSERVED ENERGY TO WEATHER REGIMES

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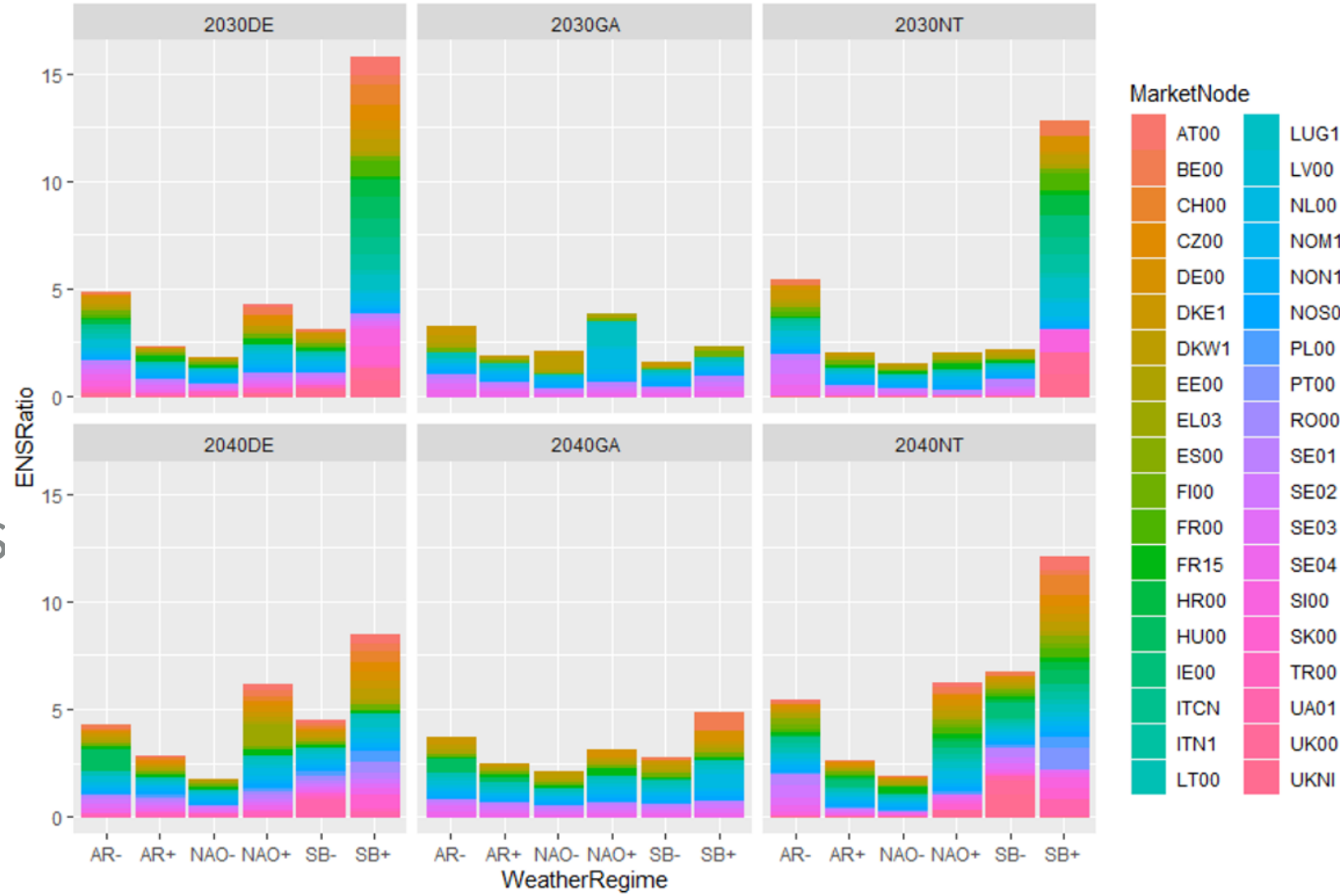
LINKING UNSERVED ENERGY TO WEATHER REGIMES

- Results depend on
  - TYNDP scenario
  - Country
- Some zones no ENS (20)
- Some zones persistent ENS
  - Nordics & TR

LINKING UNSERVED ENERGY TO WEATHER REGIMES

- Results depend on
  - TYNDP scenario
  - Country
- Some zones no ENS (20)
- Some zones persistent ENS
  - Nordics & TR
- Often under regime SB+



KEY POINTS

- Weather regimes can be used as an indicator for risk
  - Increase for SB+, reduced for NAO-
  - Well defined in extended winter, not in summer period
- Link between weather regimes & energy system dependent on
  - System scenario
  - Region under consideration
  - ESM model detail
- Changes in climate state not taken into account

QUICK QUESTION

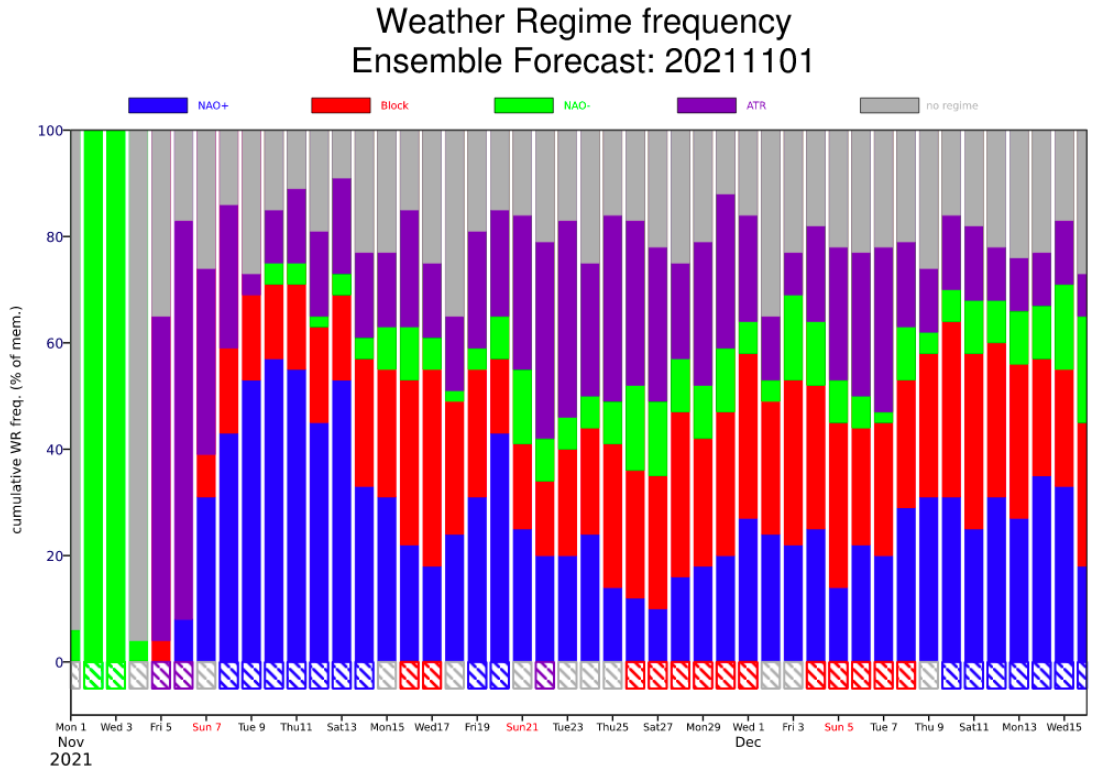
QUESTIONS

- TYNDP'20 scenario's
  - https://tyndp.entsoe.eu/scenarios/ -> look for TYNDP 2020
  -

	Thermal	DSR	Storage	RES	Demand Year
GA2030	576GW	38GW	125GW	794GW	4038TWh
GA2040	544GW	44GW	148GW	1089GW	4296TWh
DE2030	567GW	38GW	130GW	944GW	4214TWh
DE2040	535GW	44GW	221GW	1480GW	5075TWh
NT2030	587GW	26GW	121GW	818GW	3968TWh
NT2040	554GW	31GW	170GW	1093GW	4402TWh

QUESTIONS

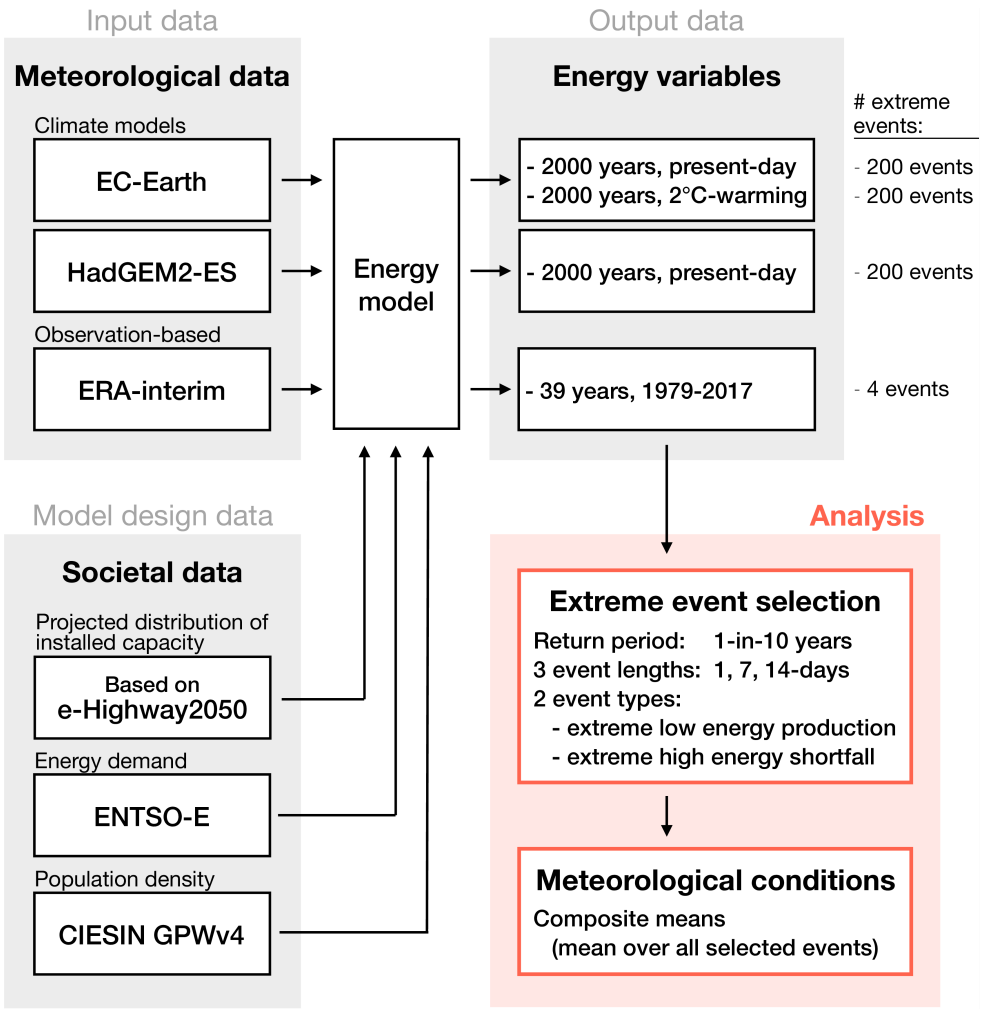
- Predictability of Weather Regimes
  - See: https://apps.ecmwf.int/webapps/opencharts/products/extended-regime-probabilities
  - To be answered!

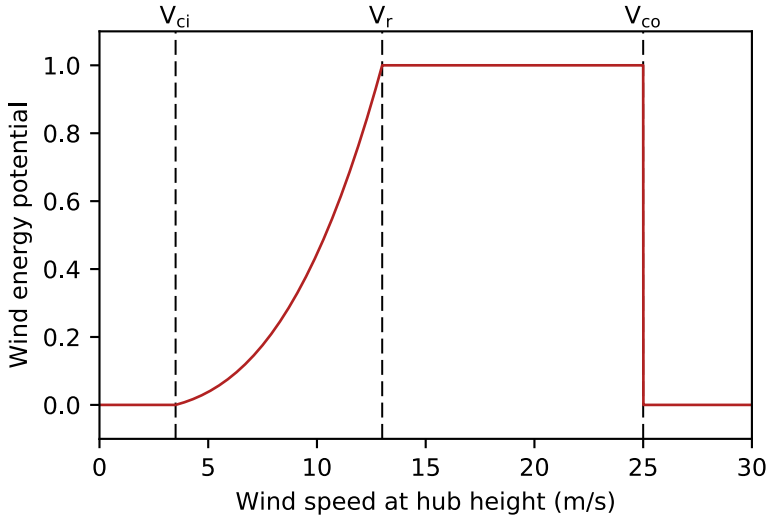


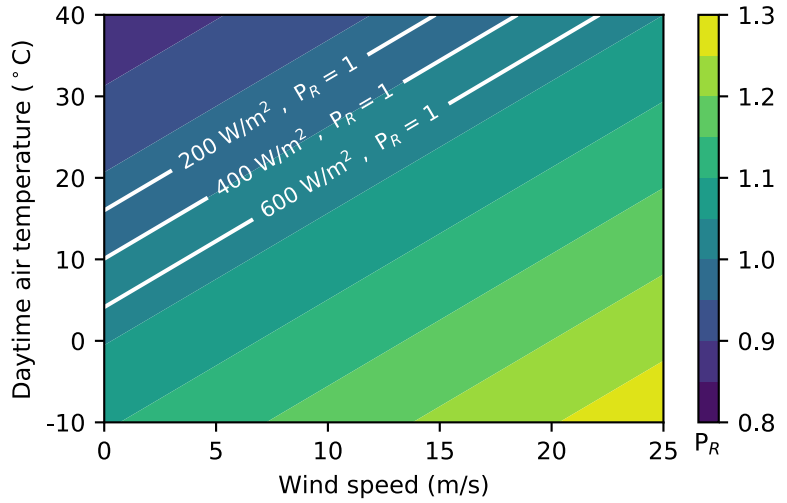
DATAFLOW

L.P.STOOP@UU.NL

CLIMATE BASED RISK







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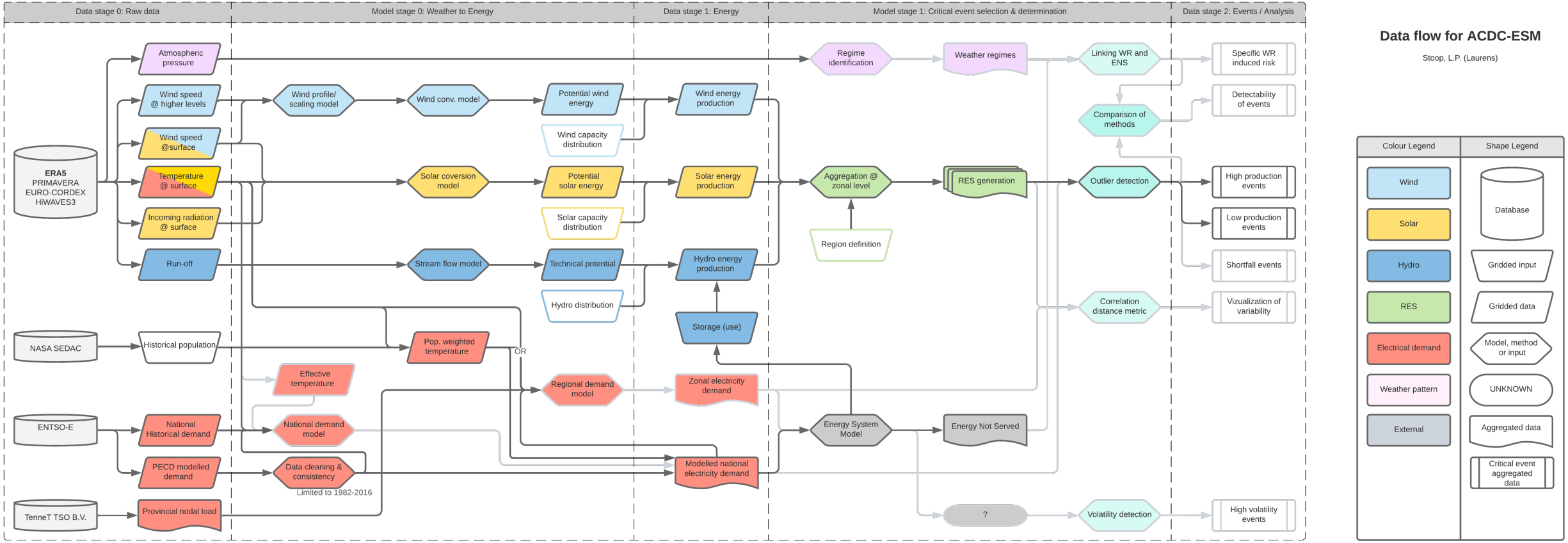
FUTURE PLANS FOR THE DATA FLOW



Data flow for ACDC-ESM

Stoop, L.P. (Laurens)

WEATHER REGIMES

DEFINING WEATHER REGIMES (K=6)

- The most recurrent patterns (500hPa height)
- Clustering of Empirical Orthogonal Functions
- Well defined in winter time
- Falkena'20 found six is better
  - Atlantic Ridge (AR+, AR-)
  - Scandinavian Blocking (SB+, SB-)
  - North Atlantic Oscillation (NAO+, NAO-)

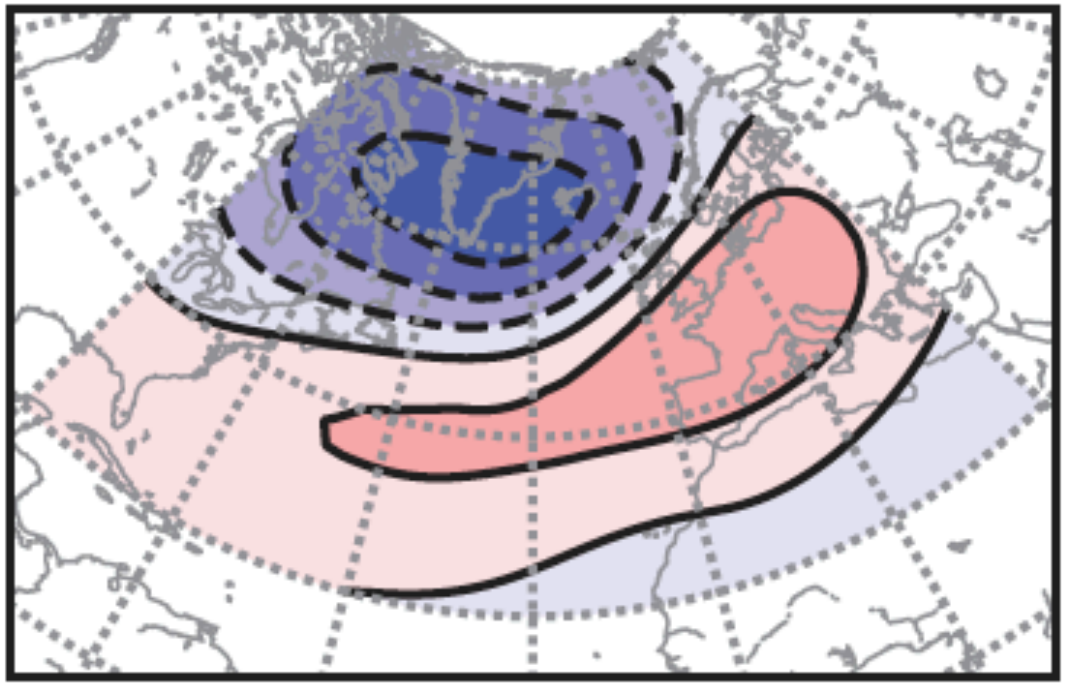
	$k = 6$					
	AR+	**SB+**	**NAO+**	**NAO−**	**AR−**	**SB−**
Occurrence (%)	15.6	19.6	16.9	15.5	16.3	16.1
Self-transition probability	0.712	0.748	0.751	0.847	0.787	0.730
e-folding time (days)	2.9	3.4	3.5	6.0	4.2	3.2
Average duration (days)	3.5	4.0	4.0	6.5	4.7	3.7

Revisiting the identification of wintertime atmospheric circulation regimes in the Euro-Atlantic sector
SKJ Falkena, J de Wiljes, A Weisheimer, TG Shepherd
QJRMS 2020, v.146, pp 2801-2814; https://doi.org/10.1002/qj.3818

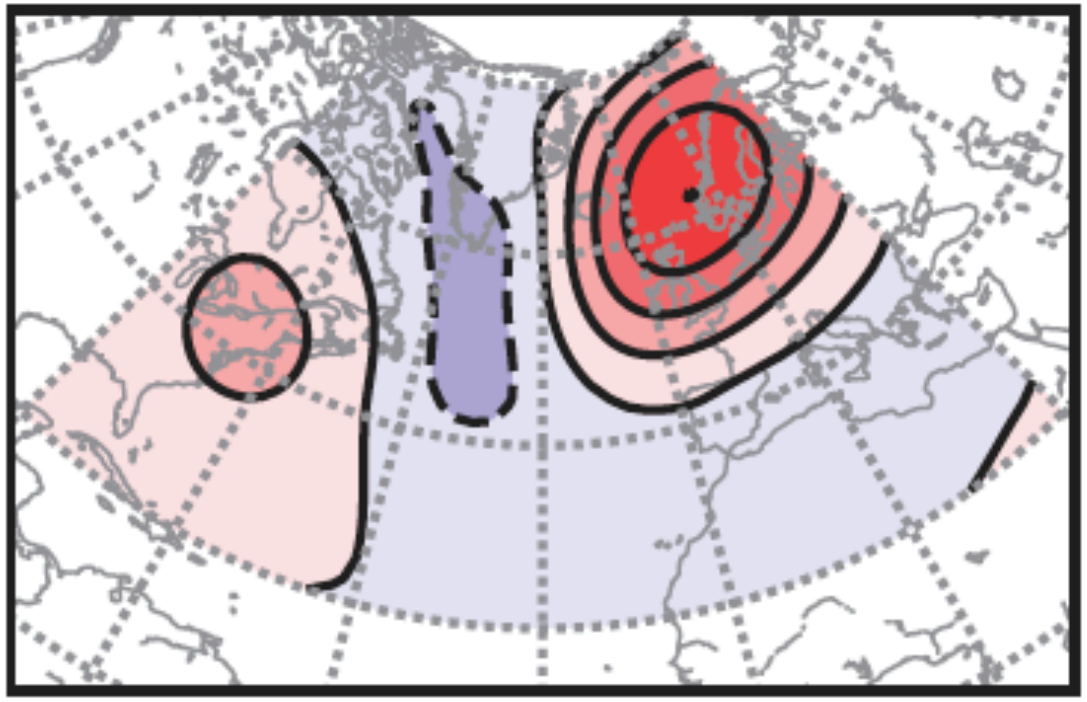
L.P.STOOP@UU.NL

FOUND CLUSTERS FOR K=6

NAO+

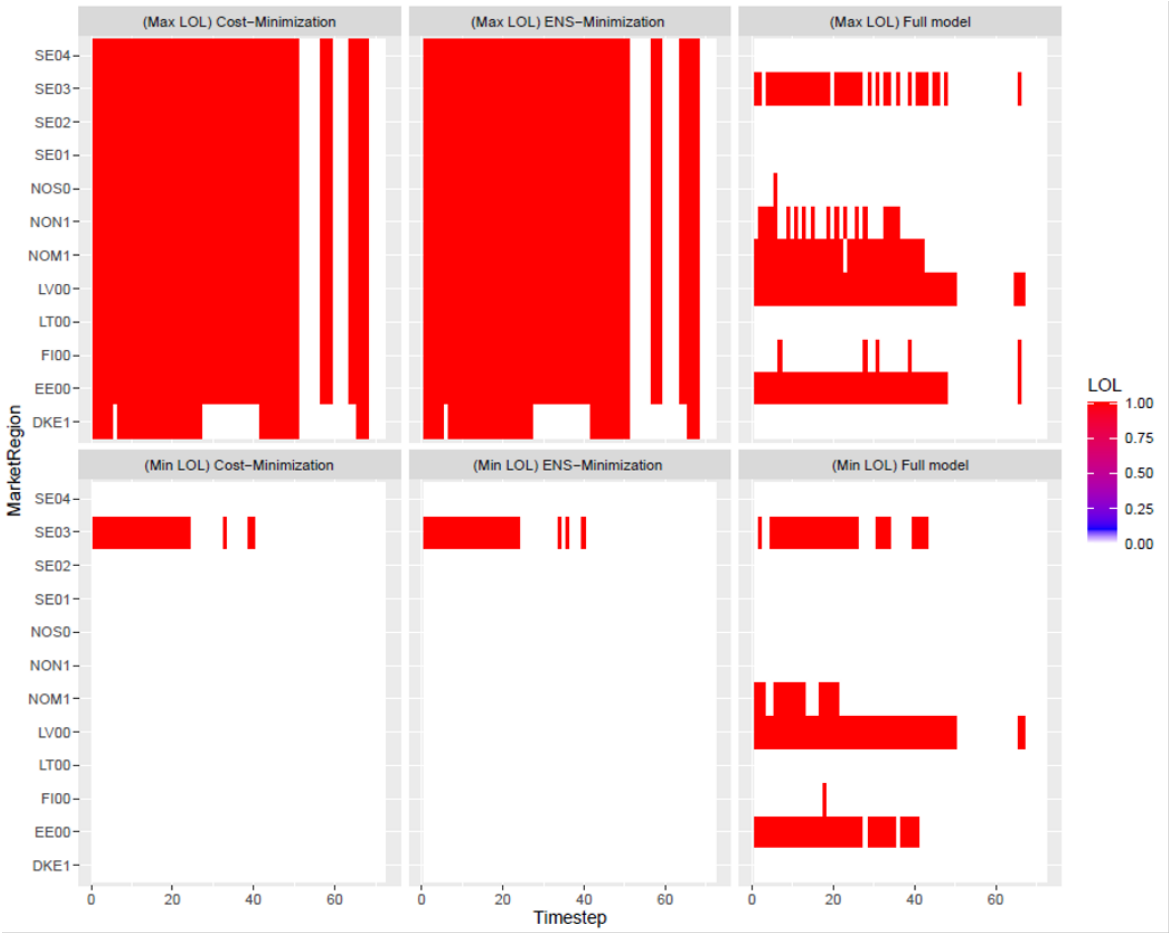


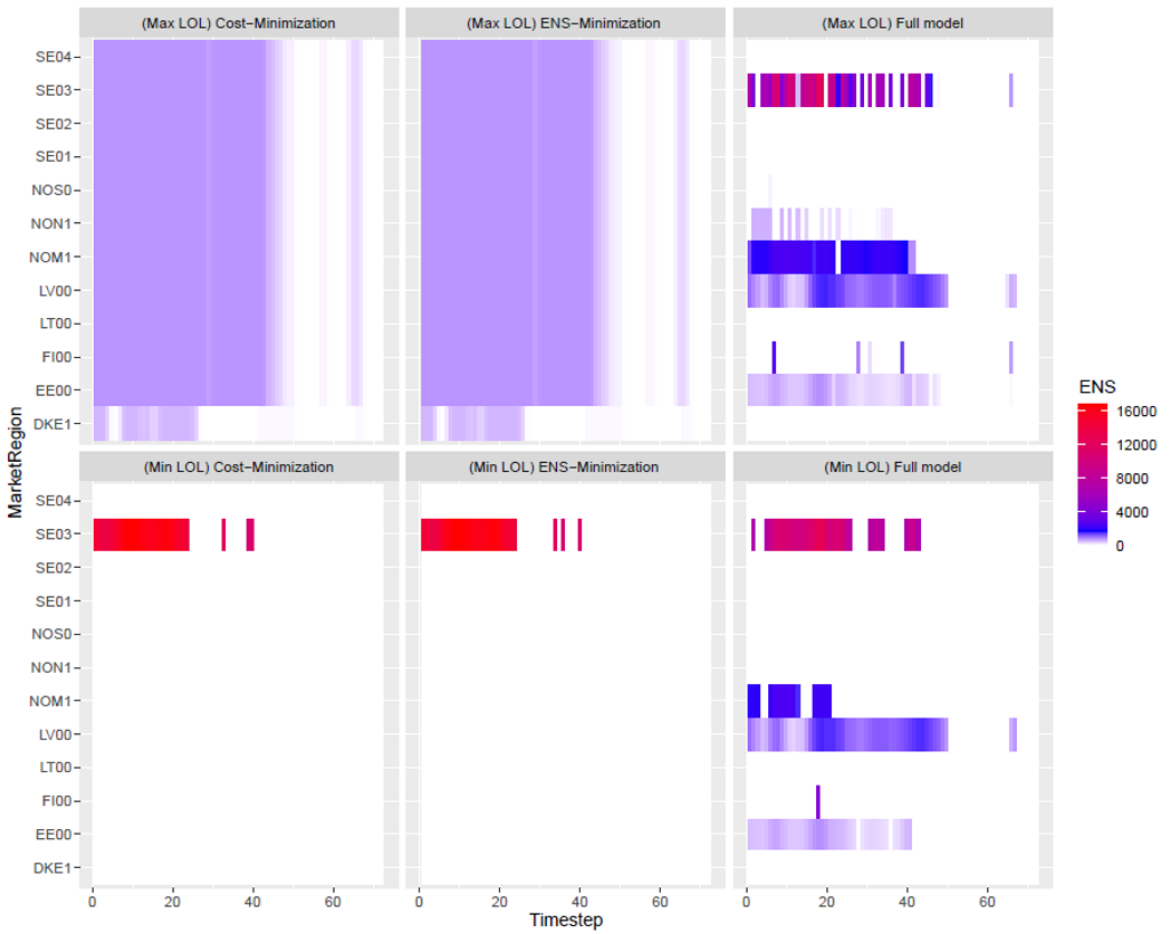
SB+



ENS VS LOLE

DIFFERENCE IN USING LOLE & ENS





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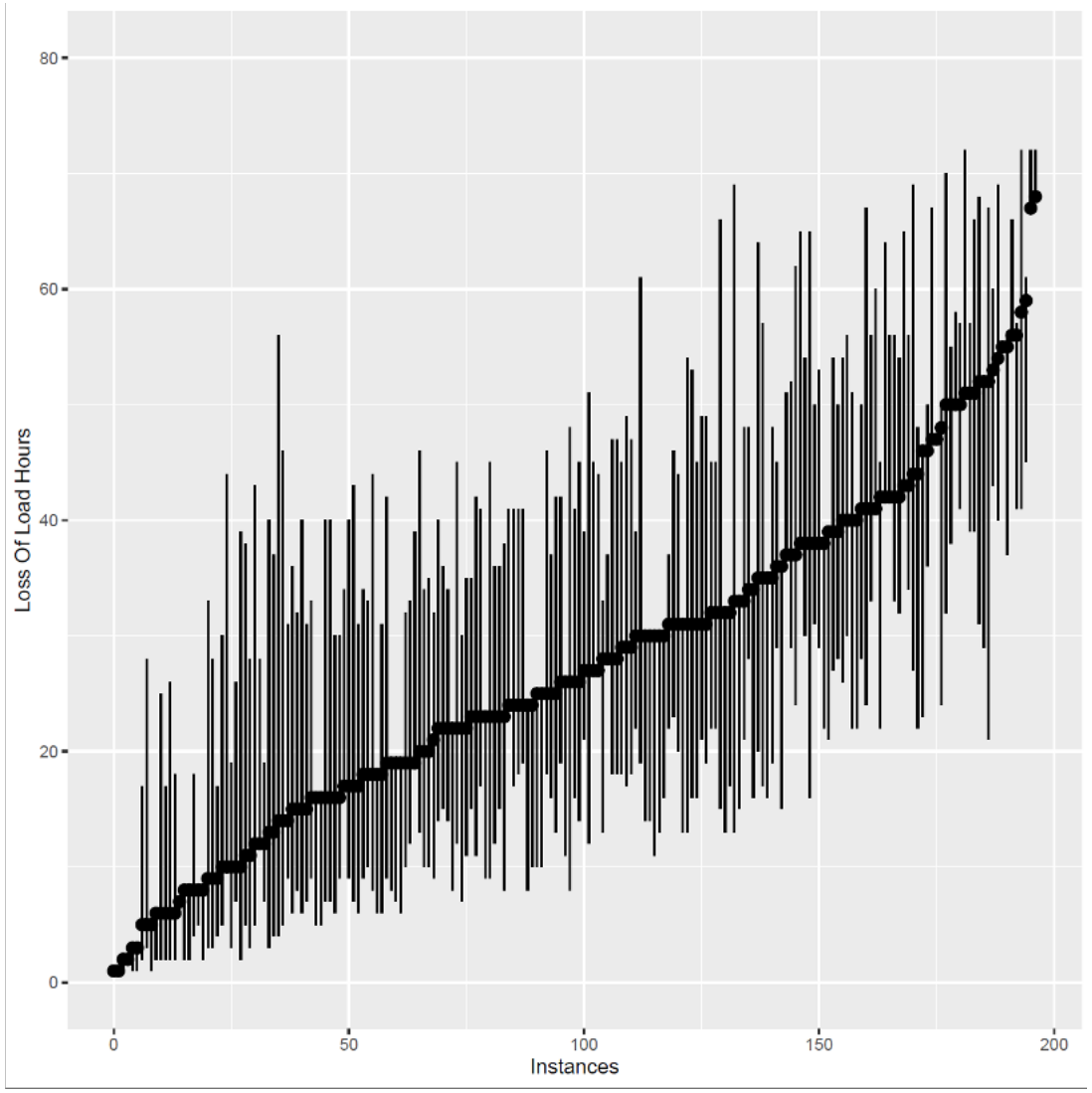
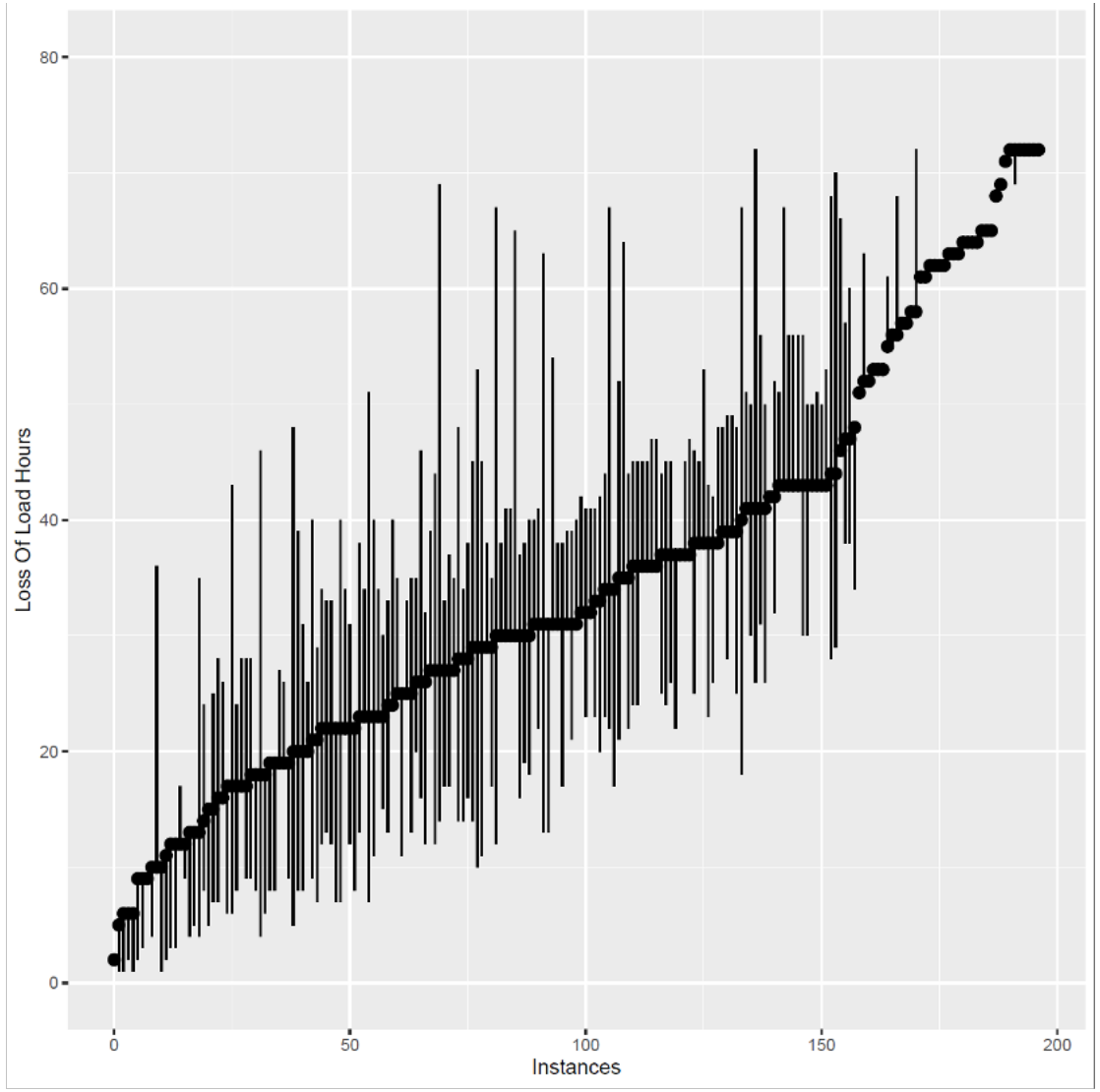
ESM MODEL FORMULATION, COST VS FULL+WHEELING CHARGE





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REDUCING THE LIMIT TO FIND MORE EVENTS

- Basic unserved energy events are sparse
- More events are found if system is stressed
  - Increasing demand
  - Reducing limits (transmission/storage)

DE
2040