Definition and assessment of weather stress events for energy
17th September 2021 13:00 - 17:00 (BST)

There is a large amount of literature emerging on extreme events relevant to the operation of energy systems around the world. The definition of these extreme events is varied, encompassing a spectrum of definitions from extreme weather events (such as heatwaves, large storms, wildfires, or droughts) or an extreme energy system response (such as forced curtailment of generators, infrastructure damage, or system adequacy issues). This breakout group will build on discussions from the NextGen2020 meeting, focussed around how the definition of 'extreme events' differs between the climate and energy communities. We will discuss how improved collaboration between the fields can benefit our understanding of extreme events, including:
• What is an extreme event from the perspective of energy and of climate science, and how do these perspectives differ?
• What tools and metrics exist for identifying extreme events? To what extent do they need to be adapted for energy-climate applications and what challenges are there in doing so?
• What is known about the weather/climate drivers of extreme energy events?
• Can we identify gaps in existing extreme events analysis for future work?

This is a very interdisciplinary group! Jargon-busters from climate and energy are on hand to help with anything that doesn't make sense! Ask in the chat, or in the google doc.

Breakout groups timetable

1300: Intro to discussion session topics for whole conference (brief motivation and 'how to' mechanics)

1315: Enter breakout rooms session 1

13:15-13:20 Intro from Hannah on what's happening and short ice-breaker

13:20-13:35: Emanuele Bevacqua: 'A compound event perspective on extreme weather events'

'An introduction to extreme weather events: a compound events perspective'

13:40-13:50 Matt Deakin: 'An introduction to extreme energy events'

13:55 - 14:45 Discussion focussed on first 2 questions:

- *What is an extreme event from the perspective of energy and of climate science, and how do these perspectives differ?*
    - Weak storms that are not necessarily interesting meteorologically are of great impact from power systems.
    - Temporal scales of importance may differ
- *What is known about the weather/climate drivers of extreme energy events?*
    - Does the met community use quantitative thresholds differently than energy community?
    - Is the energy community relying more on historical events.

Tasks:

Can we build flowcharts/links from extreme weather events to extreme energy events? Do we know of existing examples in the literature that already does this?

1445: Break (possibly with poster sessions continued from day 1?)
1500: Enter breakout rooms session 2

1500-15:10 Isabel Rushby and Megan Pearce ‘Adverse Weather Scenarios for Future Electricity Systems: An example dataset’

15:15- 15:50 Discussion focussed on last two questions:

- *What tools and metrics exist for identifying extreme events? To what extent do they need to be adapted for energy-climate applications and what challenges are there in doing so?*
- *Can we identify gaps in existing extreme events analysis for future work?*

15:50:16:00 wrap up from Hannah

Tasks:
Can we identify literature examples for identifying extremes? (Emanuele and Matt’s presentations can be used as examples if this is difficult!)
What kind of datasets do we need? (Reflecting on Megan and Isabel’s presentation)
In an ideal scenario, what would we like to rigorously perform extreme event analysis compared to what we have?
Have we talked about climate change yet? If not, lets include this!

1600: Report to plenary (Katharina to report this back to the main plenary).
1630: Plenary discussion
1700: Close/social+drinks
1800: End

Energy-Climate Jargon busting

We are all here to learn, so please write down any confusing phrases below and one of our experts will give you a quick explainer (check back after the session if we don't get to them al

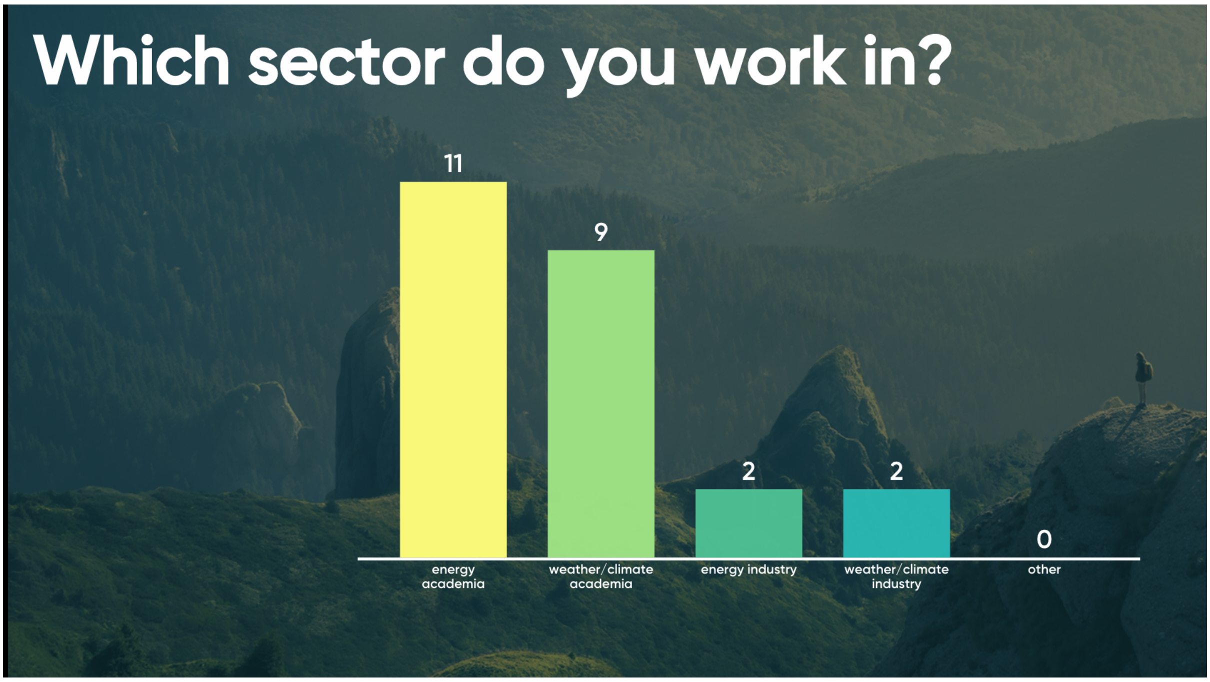
Climate

What did someone say?	What does that mean?
RCP	Representative Concentration Pathway: A **Representative Concentration Pathway** (**RCP**) is a greenhouse gas concentration (not emissions) trajectory adopted by the Intergovermental Pannel for Climate Change. More info: https://en.wikipedia.org/wiki/Representative_Concentration_Pathway
CMIP5	Coupled Model Intercomparison Project phase 5, following the IPCC AR4 process aims at creating a greater understanding of climate models and climate change processes
"Stippling" [?]	

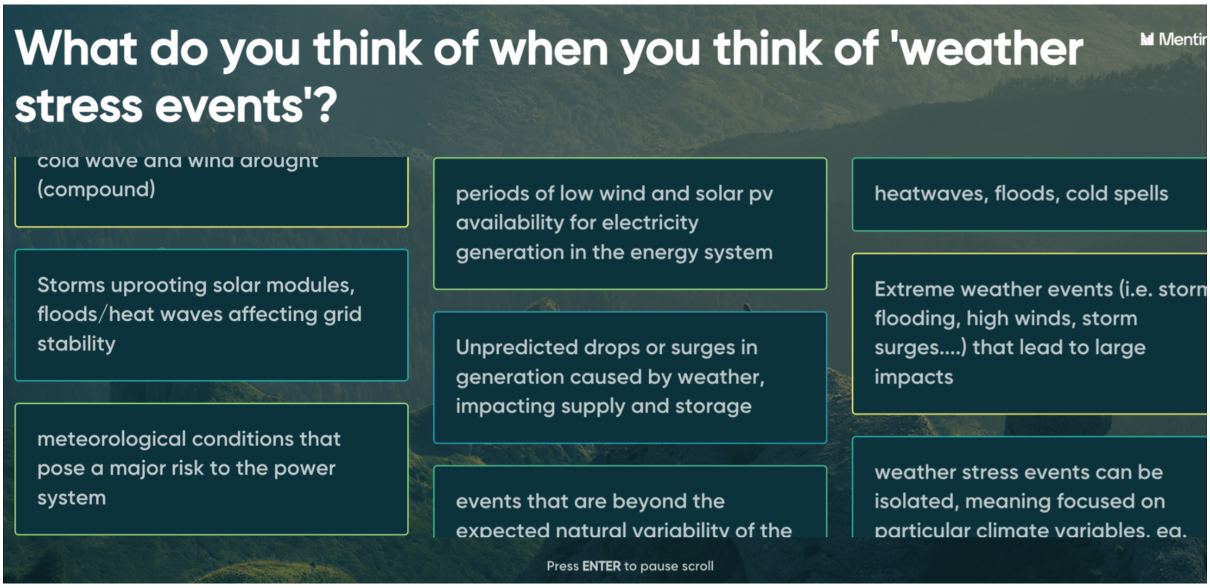
Energy

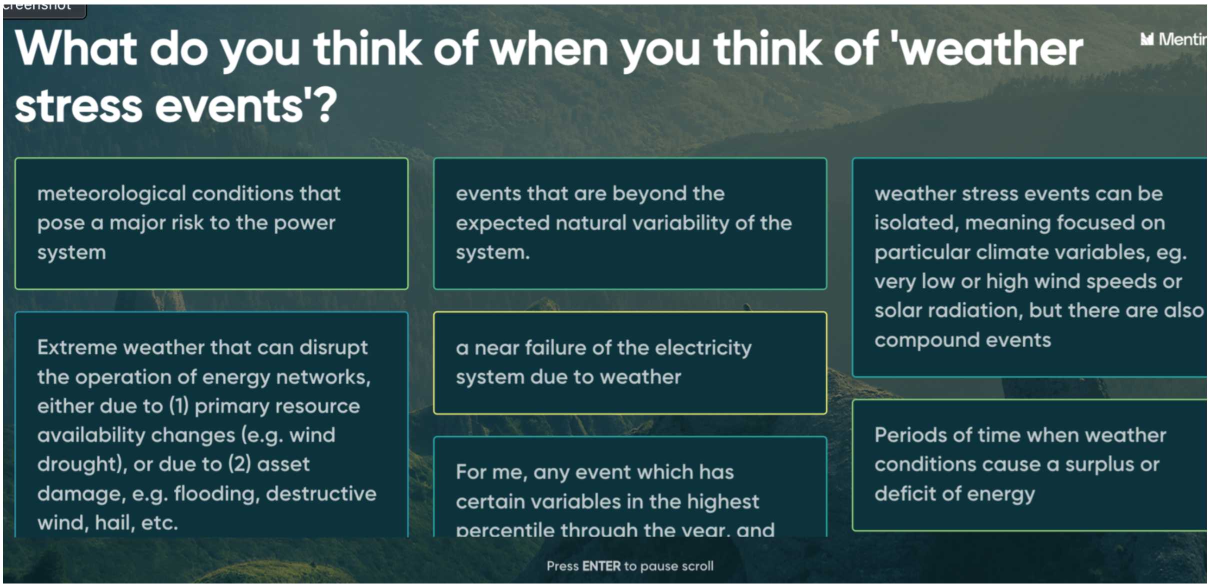
What did someone say?	What does that mean?
LOLP	Loss of Load probability
LOLE	Loss of Load Expectation, generally expressed as a number of hours per year where energy can't be delivered to consumers
ENS	Energy Not Served : the amount of energy that is not delivered in case of loss of load
System adequacy	The ability of a power system to cope with its load in all the steady states it may operate under standard conditions. Other names: 'resource adequacy', 'generation adequacy'. The word adequacy is, as in, adequate but not sufficient (for avoiding loss of load); conversely, inadequate implies guaranteed loss of load.
HILP	High Impact Low Probability
Reliability	Measured in terms of adequacy and security,

	typical indicators include LOLP, LOLE, ENS (as above) and others.
Resilience	Encompassing reliability in a loose sense, but focusing on HILP events mainly, and including phases such as restoration / recovery after an event. See https://www.cigre.org/article/GB/news/the_latest_news/defining-power-system-resilience
Ramping event	A shift from high or low. Could be present in demand, wind power generation or solar pV. All cause problems for grid balancing.



Discussion 1:


What do you think of when you think of 'weather stress events'?
cold wave and wind drought (compound)
Storms uprooting solar modules, floods/heat waves affecting grid stability
meteorological conditions that pose a major risk to the power system
periods of low wind and solar pv availability for electricity generation in the energy system
Unpredicted drops or surges in generation caused by weather, impacting supply and storage
events that are beyond the expected natural variability of the
heatwaves, floods, cold spells
Extreme weather events (i.e. storm flooding, high winds, storm surges....) that lead to large impacts
weather stress events can be isolated, meaning focused on particular climate variables, eg.
Press ENTER to pause scroll


What do you think of when you think of 'weather stress events'?
meteorological conditions that pose a major risk to the power system
Extreme weather that can disrupt the operation of energy networks, either due to (1) primary resource availability changes (e.g. wind drought), or due to (2) asset damage, e.g. flooding, destructive wind, hail, etc.
events that are beyond the expected natural variability of the system.
a near failure of the electricity system due to weather
For me, any event which has certain variables in the highest percentile through the year, and
weather stress events can be isolated, meaning focused on particular climate variables, eg. very low or high wind speeds or solar radiation, but there are also compound events
Periods of time when weather conditions cause a surplus or deficit of energy
Press ENTER to pause scroll


What do you think of when you think of 'weather stress events'?
Inability of power generation to meet electricity demand
damages to society in different ways
In power grids, I think of adverse weather conditions stressing network infrastructure and possibly affecting operation.
weather stress events can be isolated, meaning focused on particular climate variables, eg. very low or high wind speeds or solar radiation, but there are also compound events
Periods of time when weather conditions cause a surplus or deficit of energy
Press ENTER to pause scroll

- *What is an extreme event from the perspective of energy and of climate science, and how do these perspectives differ?*
- *What is known about the weather/climate drivers of extreme energy events?*

What is an extreme event?

- *'We can have an extreme in anything!'*
- *Cold waves and wind droughts are particularly relevant when studying future energy systems at the EU level. Particularly in France, but also in a lot of other European countries.*
- *RTE have a report coming about this - 20th October (synthesis report, ca 150 pages) then a more comprehensive version (most likely > 1000 pages) early 2022. They use climate simulations, 3 sets of 200 climate years: one representative of the 2000s, and 2 representative of the 2050s with respectively RCP4.5 and RCP8.5*
- *In Germany having a 'sun drought' is also important*
- *Kalte Dunkelflaute*
- *In the UK location of the weather system is also important due to the location of the offshore wind farms.*
- *Low wind, cloudy, low temperature. - the 'perfect storm'*
- *'Portfolio effects' - spatial extremes in high/low wind /solar*
- *As our energy system evolves risk shifts from cold wave in winter → cold wave and wind drought.*
- *Climate think 'super extreme!' energy events can be relatively 'bland'. E.g. a wind drought.*
- *Definitions of uncertainty are different: e.g. choice of climate model vs. uncertainty in capacity expansion of wind. Investment,*
- *Increasing probability of record shattering climate extremes: https://www.nature.com/articles/s41558-021-01092-9*
- *The consequences of the extreme should be linked to the threshold used to define the extreme. (e.g. density of population/infrastructure linked to the potential impacts of exceeding an event).*
- *There are a lot of large ensembles of climate model simulations available that could be used to identify and then prepare for most extreme, low probabilities energy-related events… collaboration*
- *Compound events: https://www.essoar.org/doi/abs/10.1002/essoar.10507810.1 Here, we suggest using a bottom-up approach, such to identify and analyse weather conditions that are actually relevant for extreme impacts*
- *Using the EURO-CORDEX ensemble to analyse projected future changes in frequency and duration of low wind energy events in Ireland: https://onlinelibrary.wiley.com/doi/full/10.1002/we.2673*
- *Would 1-year climate data based on climate model, with a good estimation of its probability of occurence, and which specifically identify hypothetical years that would be stressful to energy sector, be useful/actionable for the energy sector ?*
    - *Response: This would probably help. Maybe even better having deterministic time series that represent different weather years: moderate and different extreme situations*

- *Response 2: For me it would be useful to have many possible future weather years, a combination of not extreme events for meteorology could cause an extreme event in the power sector*
- *Response 2: In terms of more systematic ways of modelling, apart from the classic brute force, a stochastic approach (e.g. Monte Carlo) would probably work best, by mapping out scenarios across all dimensions (weather, load, generation capacity, transmission capacity, etc). We use it widely in power system modelling and I've seen work in the past about even reducing the MC sets to increase computational efficiency, although I am not sure how the whole stochastic approach would work with climate data, as there are plenty of factors to map out. We can discuss after the break.*
- *Response 3: Would the fact that different weather variables are physically related (and autocorrelated) to each other cause difficulties when using a Monte Carlo approach?*
  - *of course, that's a very good point. That's why in power system analysis we always use a model of the system, even a simplified power flow analysis, within the MC loop. I don't know what would be the equivalent in climate modelling.*
- *Response 2: thanks for your input. We are running a power system expansion +dispatch model. We sometimes use the worst weather year (i.e. the one that leads to the highest total system costs), optimise over many years individually or over many years at once.*
  - *Response 3: For me what is interesting is if your year which leads to the highest system costs is the one with the 'seasonally average coldest/stillest winter' or if it is just a few short days of horrendously low wind and extreme cold that leads to the really high costs (as I assume you have to be able to meet demand with something very expensive). Sometimes when I look at 'extreme energy years' they are not the obvious worst ones for climatic indices (like the North Atlantic Oscillation) so for me it's interesting to understand the timescale of the extreme that causes the system failure.*
  - *When using a few years only, how to cope with events like these?*

- *When thinking about infrastructure damage we need 3 second gusts*

Supply can get away with hourly → daily.

Distinction between:

(1) *Energy availability / capacity levels, which would define supply/demand balance. This has more sensitivity, as "non-extreme" events can have a big impact.*
(2) *Asset damage risk, which may affect reliability and resilience. This probably requires a more rare event, as it is associated with HILP events, like floods or extreme wind gusts.*

Complementary events:

Meteorological event	**Energy Event**	**Energy-met Link between them - ‘Meteorological drivers.’**
		Events that are beyond the expected natural variability of the system
	Social and economic costs of different kinds of extreme events	
Very extreme and rare events are seen as important	*Not so extreme and less rare events like wind droughts play an important role in the energy system*	
Sometimes extreme weather events ARE extreme in energy, but this is not always the case. It is more subtle!		
Extremes on larger time scales like days	*Short term extremes within hours can cause problems*	
	If you have high density infrastructure you should design for a low frequency event, if its lower density design for lower frequency event	

Extra discussion 1 notes:

Local energy communities with local storage could help shift the problem of energy shortage from the supply to the demand side

Discussion 2:

- *What tools and metrics exist for identifying extreme events? To what extent do they need to be adapted for energy-climate applications and what challenges are there in doing so?*
- *Can we identify gaps in existing extreme events analysis for future work?*

- *There are different metrics for measuring extremes and they measure different kinds of extremes - if one metric is to be optimised this might impact other metrics negatively, there might be some kind of tradeoff*

- *Met office dataset: https://catalogue.ceda.ac.uk/uuid/7beeed0bc7fa41feb10be22ee9d10f00*

- *Statistical extreme value analysis (EVA): return periods and durations*

- *I challenge anyone to find an extreme weather event that doesn't impact either the operation or the infrastructure of the powr system!*
- *There are however a whole new set of seemingly mundane weather things (e.g. lots of cloudy and still days) that meteoorlogists don't naturally look at but which have critical importance for power system operation.*
- *Lost of meteorological literature on the Energy-met events - because they're the focus of a lot of climate science! But less on the blue ones. Wind droughts are the new growing research area!*

Attempts at categorisation:

Energy specific
Climate specific
Energy-met events

	Infrastructure risk	*Infrastructure and operational risk*	*Power system operation risk*
Seasonal timescale	***Fires on transmission lines,***		***System Adequacy, Loss of Load Probabilty,*** ***Wind drought, Drought Compound: Drought and Hot***
Weekly timescale	***Flood***	***heatwave***	***Wind drought, cold wave Compound: cold+still***
multi-day timescale	***Flash Flood***	***Wild Fires, Tropical Cyclones, Extra-tropical Cyclones, Dust-storm, Blizzard,***	***Energy Shortfall***
sub-daily	***Tornado, Hail-storm, Ice-storm,***		***Surplus renewable supply, Energy shortfall Peak demand, Ramping events,***

Big events table:

Type of extreme event	**Definition** **Notes on methods and comments for adaptation/improvement**	**Reference (if available)**
Wind drought	*In some regions like Brazil low wind resources may be overcome by complementary energy sources such as hydropower* Frequency and duration of low-wind-power events in Germany *We used the EURO-CORDEX ensemble to analyse projected future changes in frequency and duration of low wind energy events in Ireland:*	 *https://doi.org/10.1088/1748-9326/ab91e9* *https://onlinelibrary.wiley.com/doi/full/10.1002/we.2673*
Cold wave		
Wind drought and cold wave (compound)		
heatwave	*For exmaple, daily temperature or X-day average daily temperature (e.g., over 7 days) above fixed thresholds. Threshodld can be quantiles or based on impacts, e.g., related to human heat. (Also night temperature is considered). Importantly, also heat stress indices are used in a similar manner.*	
flood	*High river discharge. For flash flood, high values of precipitation, or -- as a flood indicator -- 5-days accumulated precipitation.* *Compound coastal flooding: concurrent precipitation and sea level extremes.*	*IPCC reports (rainfall)* *Can provide more refs if needed later.*

Surplus (renewable) energy supply	*Using capacity expansion models this really depends on the optimal investment and dispatch decisions determined by energy models*	
Not enough energy supply	*Extreme shortfall events*	https://iopscience.iop.org/article/10.1088/1748-9326/ab38d3/pdf
Infrastructure damage on power system		
Fire on transmission lines		*IFA1 is on fire right now!*
Unprecedented natural variability of the system		
Failure of the electricity system due to weather		
Kalte Dunkelflaute		
Excess solar		
Changes in extreme event due to climate change examples?		
Optimal renewable deployment		
Peak demand (winter or summer)		
Drought and Hot-dry (compound)	*Compound hot-dry: Concurrent summertime hot and dry conditions (based on season characterised by high average temperature and low average precipitation).*	*https://www.science.org/doi/10.1126/sciadv.1700263*
Fires/smoke obscuring solar, damaging network		
Ramping events		
High to low wind, solar demand within the day		
System adequacy		
Loss of load probability		

Dust storms covering PV pannel		
Tropical cyclones		
Flooding of substations and other equipment		
Asset damage by wind gusts		
Extreme rain drought causing lack of water for hydro or power station cooling		

Extra discussion 2 notes:

https://nic.org.uk/app/uploads/ Includes literature review on characterising adverse weather for the UK power sector. The original literature review for this project: https://nic.org.uk/app/uploads/MetOffice_NIC_LiteratureReview_2019.pdf

- *Do concurrent wind ramps and PV ramps happen a lot? I've never thought about this!*
- *Do you think that a climate person could know what a power extreme event is (without running a power system model)?*
    - *If it's a storm that could destroy infrastructure then that is different to what we consider as extreme in power system modelling*
    - *i think a Climate Person would have to ask an Energy system Person for what extreme means for a specific power system from the Energy system perspective extreme Events depend on how the power system is built. If you know the configuration of the power system, eg. high Shares of wind or solar you can try to define what could be threatening to the system*
    - *in view of climate change and higher unpredictability, how can we mitigate extreme events such as Texas energy crisis?*
    - *there it not one Explanation of an extreme Event, but multiple possibilities of what could be extreme for a power system. depending on what Kind of extreme like Energy droughts, Peak loads, compound Events (Keyword "kalte Dunkelflaute") different Climate variables are important. considering all different types of extreme Events is certainly a challenging Task!*
    - *I would say knowing would be impossible due to non-linearities and different event definitions, and would definitely *not* line up with meteorological extremes https://doi.org/10.1088/1748-9326/ab7668I would say knowing would be impossible due to non-linearities and different event definitions, and would definitely *not* line up with meteorological extremes https://doi.org/10.1088/1748-9326/ab7668*
        - *that's what I expected. We had no discussion in group 2 about infrastructure resilience and there's generally as little discussion*

between power system modellers and infrastructure specialists as there is between those two and climate modellers...

- *S problem with an extreme events framework for me is some of these extremes are just unexpected! For example the current fire on the French inter-connector - As a met person I wouldn't think to model this! But i'm guessing this falls in the infrastructure risk category and lots of energy people think about it.*
- *Storylines! With wind power generation etc.*
-

Wishlist from energy modellers:

- *Need hourly data! But some climate data only comes daily (e.g. UKCP).*
- *Give us ready to use data (don't want to do the bias correction and processing)*
- *Not only wind and solar but also good hydro data*
- *100m Wind data would be very useful*
- *Guideline/workshop: how to convert weather data to standardized availability factors (here often called capacity factor) on a scale [0-1]*
- *Guideline/workshop: how to (dis)aggregate the spatial resolution → many models use data on (sub-)country level*

Wishlist from climate modellers:

- *Good energy data to help me define these times of 'stress' ENTSOe is not always reliable or particularly easy to understand*
- *Stop using a 'typical meteorological year!' and ask questions about if there are meteorological reasons for particular adverse weather events occurring.*
- *Need the climate models outputting high temporal and spatial data to use in impacts. We need hourly! And gusts!*
- *While the two communities bridge very well, can the energy modellers let us know what simple combination of weather events (temperature, wind, solar radiation? -- spatial and temporal aggregation) should we focus on to account for extreme events in the energy sector? That could help to develop some first-order analyses.*
- *Is there a (relatively) simple model which the energy modellers would recommend climate modellers to study, to better understand the issues they are interested in?*