Techno-Economic Modelling and Assessment of Forward Resilience Measures

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Alex Martínez Ceseña – A bit about myself

- Academic Fellow – Multi-energy Systems

Research:

- Techno-economics, resilience and business cases
- Multi-energy and whole energy systems
- Integrated network planning
- Investment under uncertainty

Teaching:

Power System Analysis

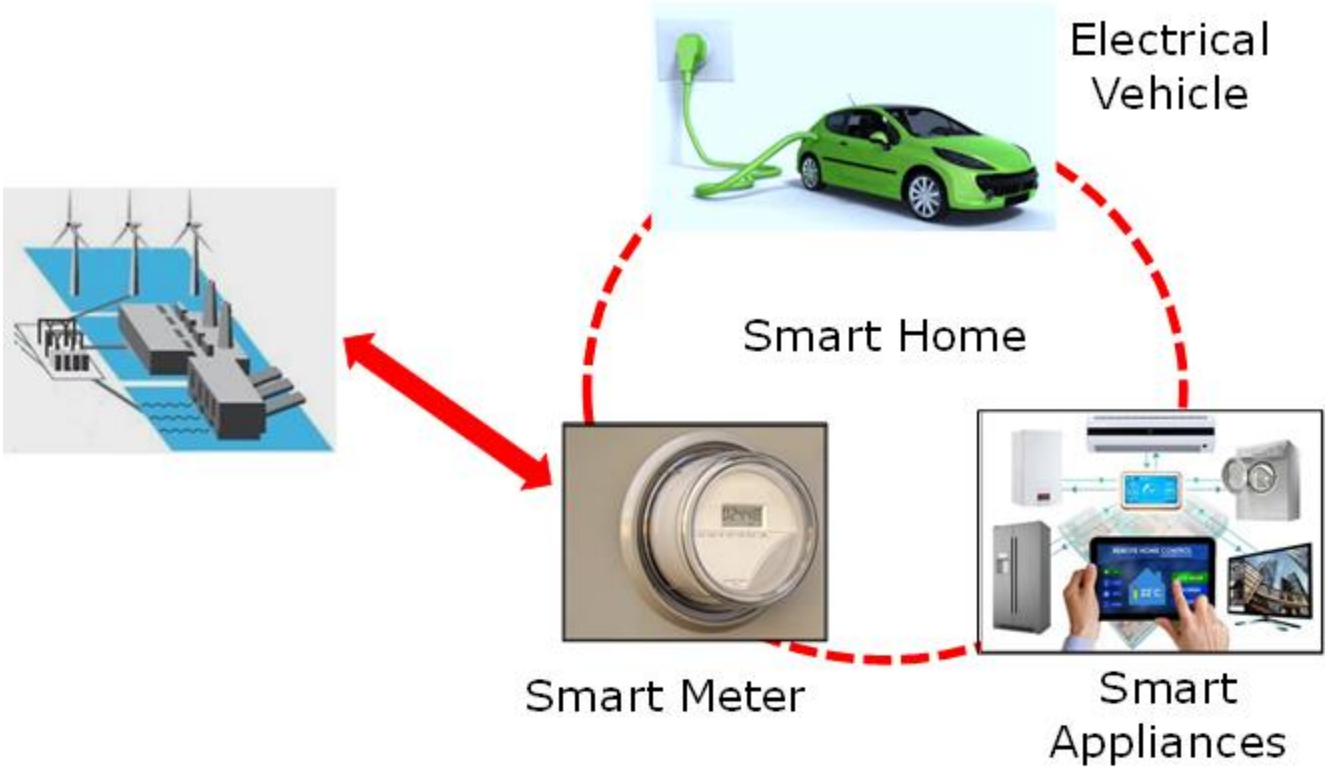
Power System Operation and Economics

Increasing Uncertainty Levels

Increasing integration of distributed energy sources

Renewables:

- Low carbon
- Cheap
- <u>**Inflexible**</u>



Smart buildings:

- Flexible
- Controllable
- <u>**Small and complex**</u>

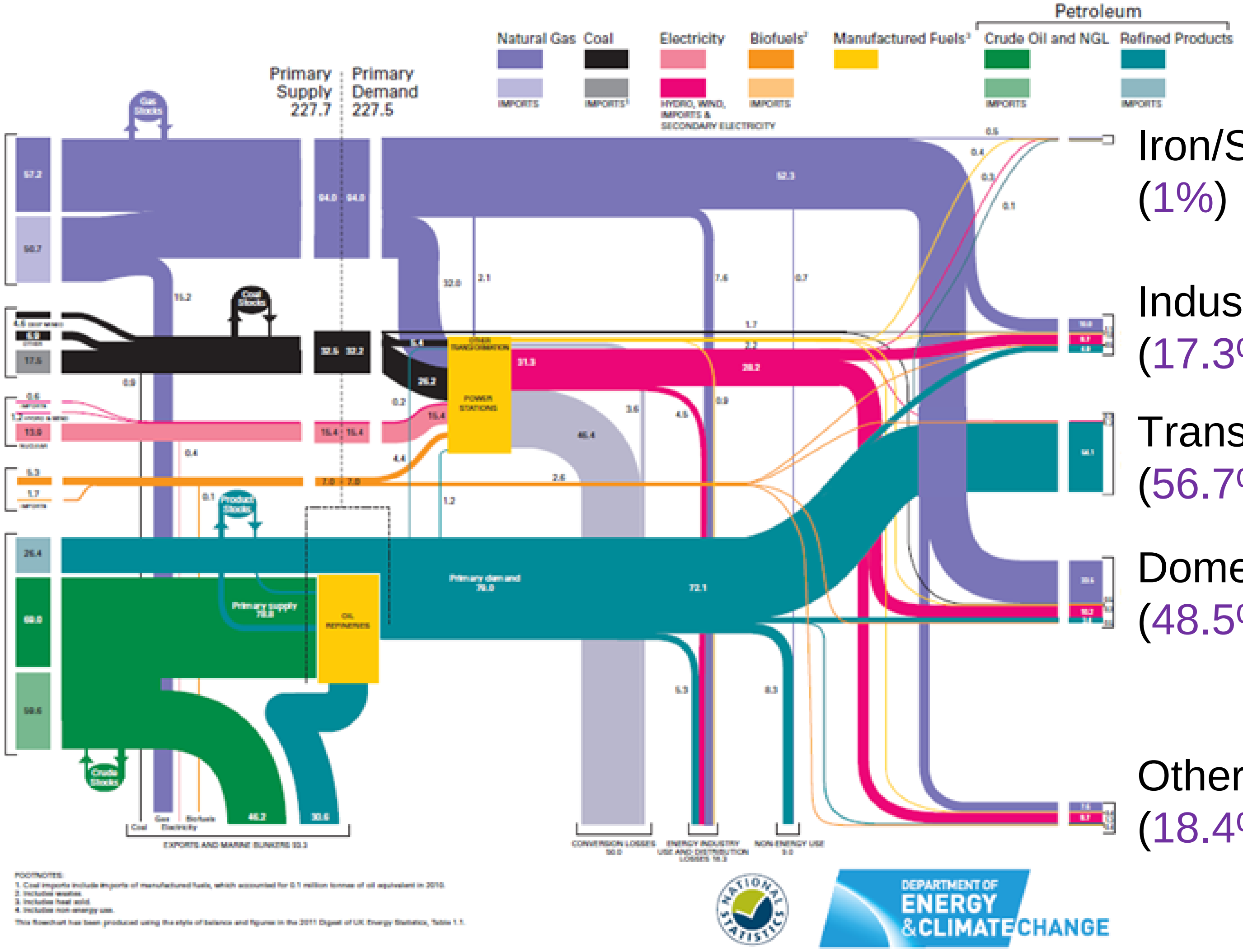
Increasingly integrated systems

Gas
(34.3%)

Coal (9.2%)

Electricity (5%)
Biofuels (2.2%)

Petroleum
(49.3%)



Iron/Steel
(1%)

Industry
(17.3%)

Transport
(56.7%)

Domestic
(48.5%)

Other
(18.4%)

It's not only about electricity...

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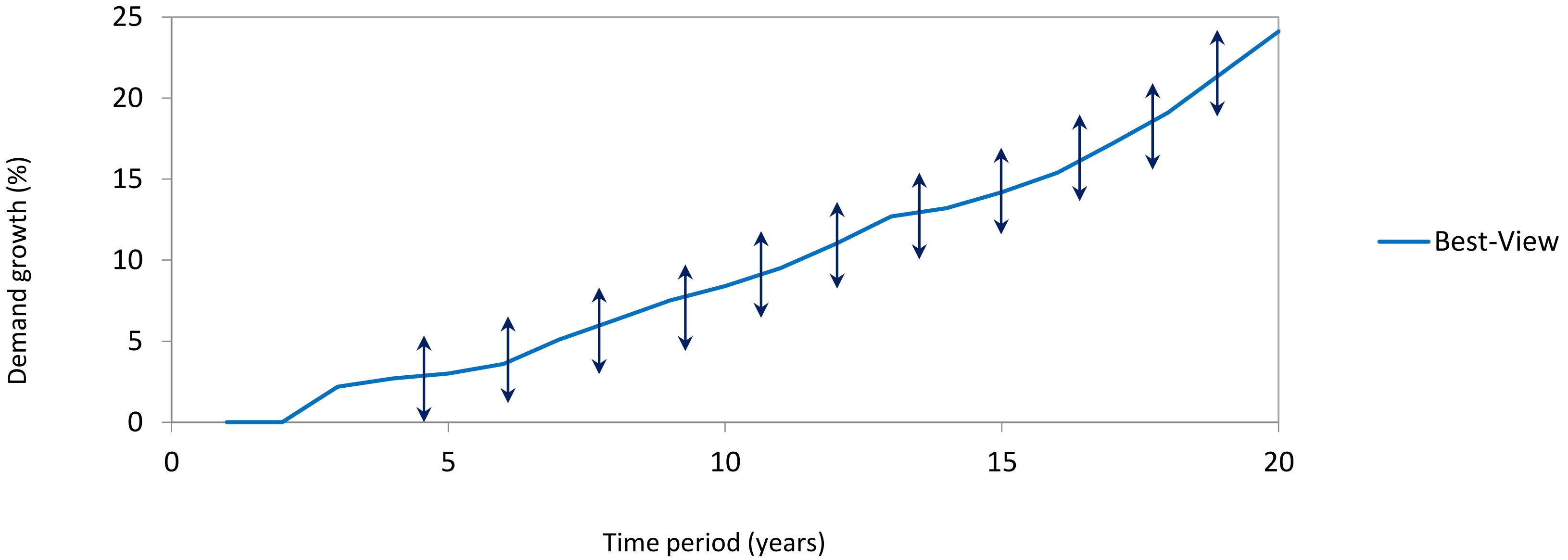
Increased threat of extreme weather events

Levels of uncertainty – Deterministic?

How do we see the future?

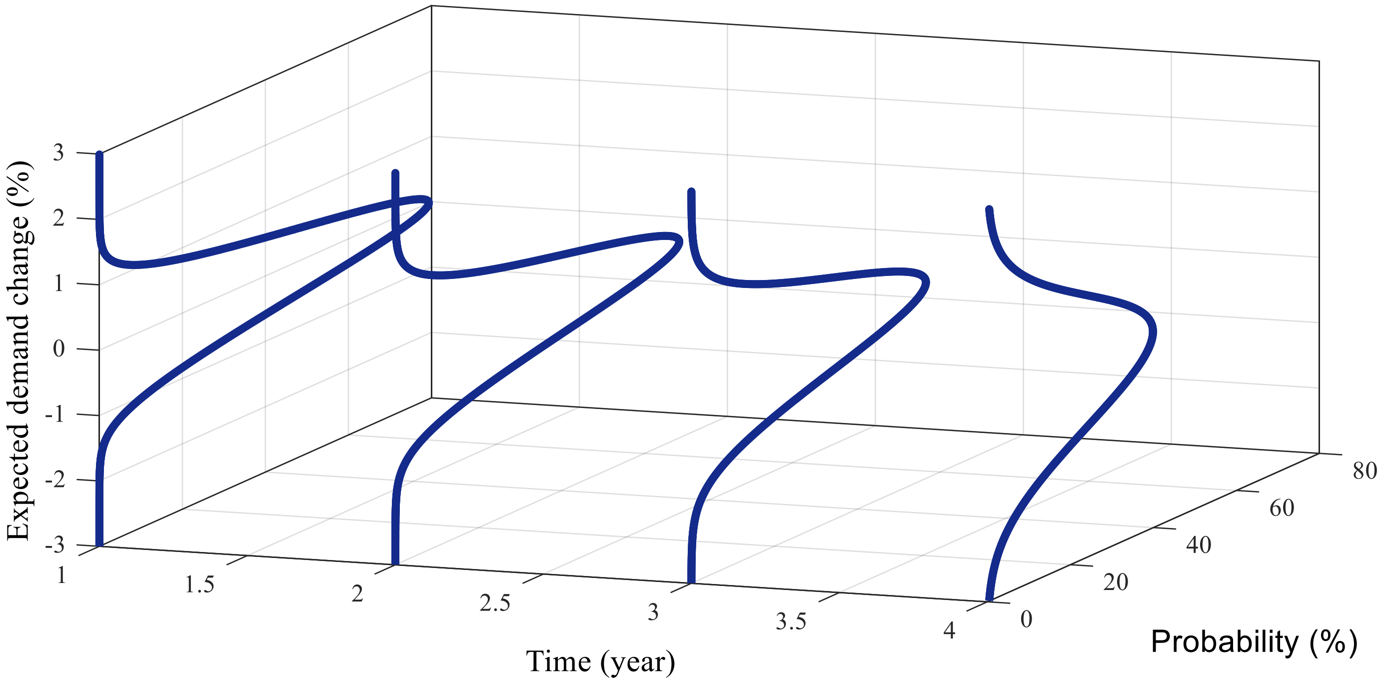
- Deterministic: There is a best-view future, and potential variations can be explored with sensitivity studies



Levels of uncertainty – Probabilistic?

How do we see the future?

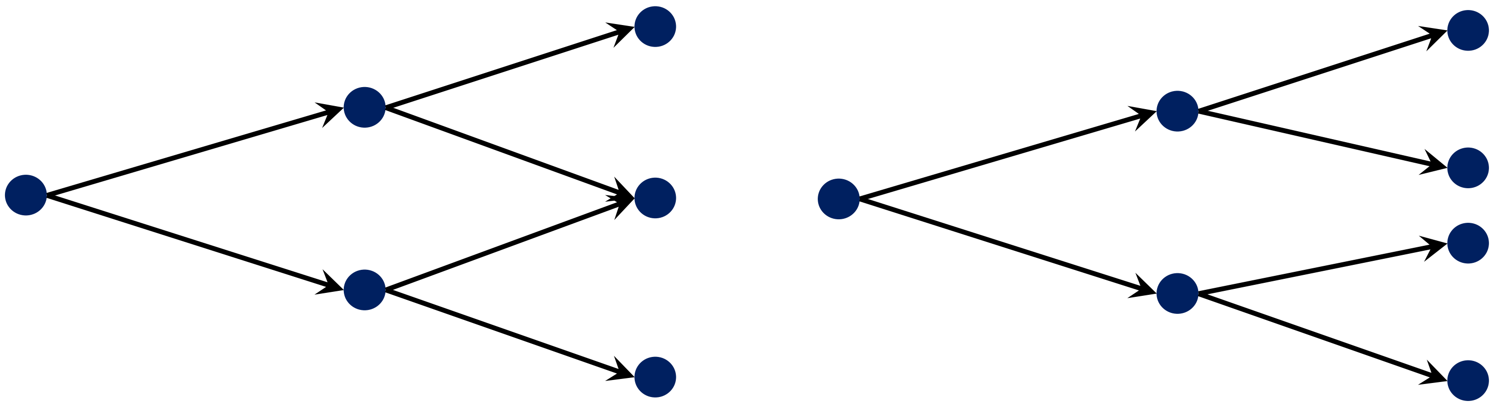
- Probabilistic: There are multiple potential futures, which can be modelled with probabilistic functions



Levels of uncertainty – Deep Uncertainty?

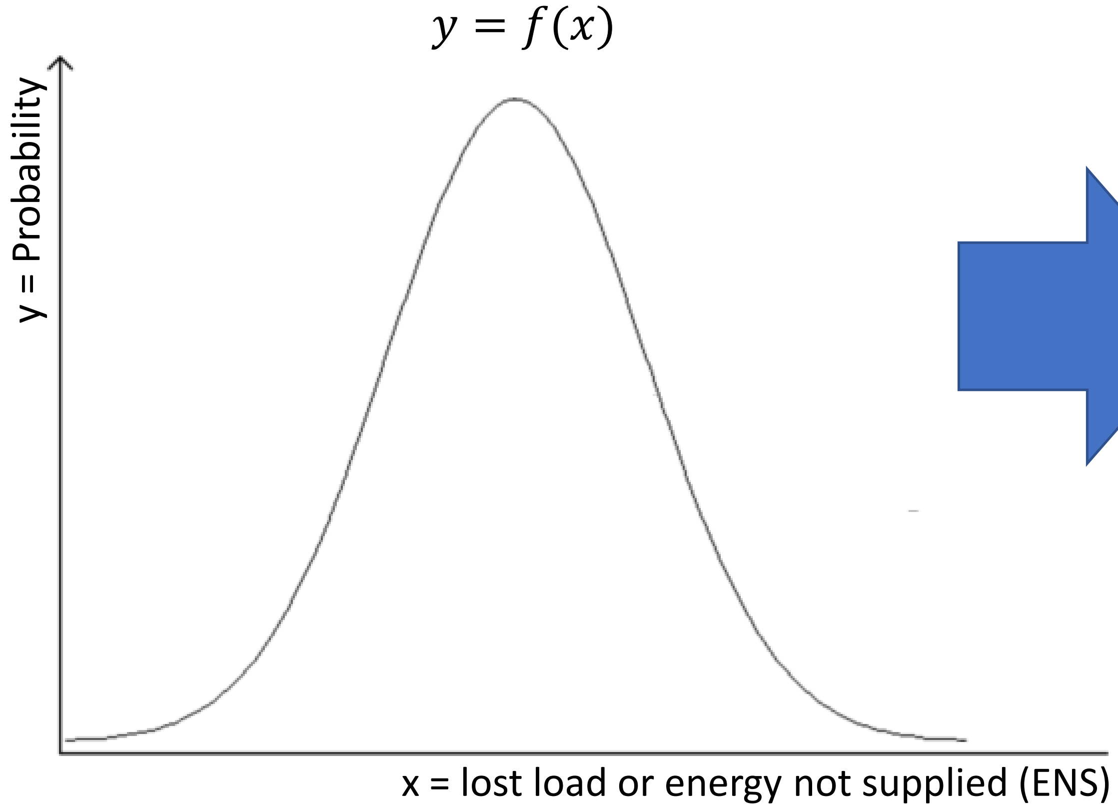
How do we see the future?

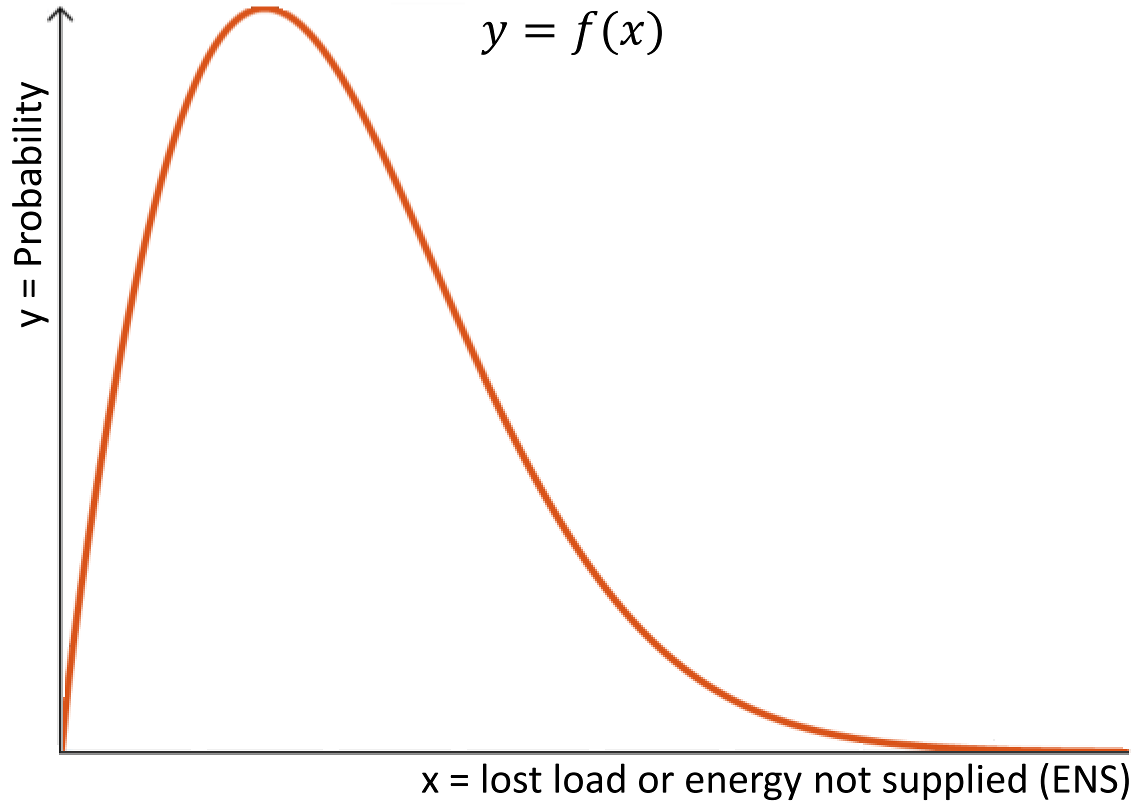
- Uncertain scenarios: There are multiple potential futures, it is not always possible to rank them or assign probabilities of occurrence



- Unknown: There is no consensus about how the future may look like

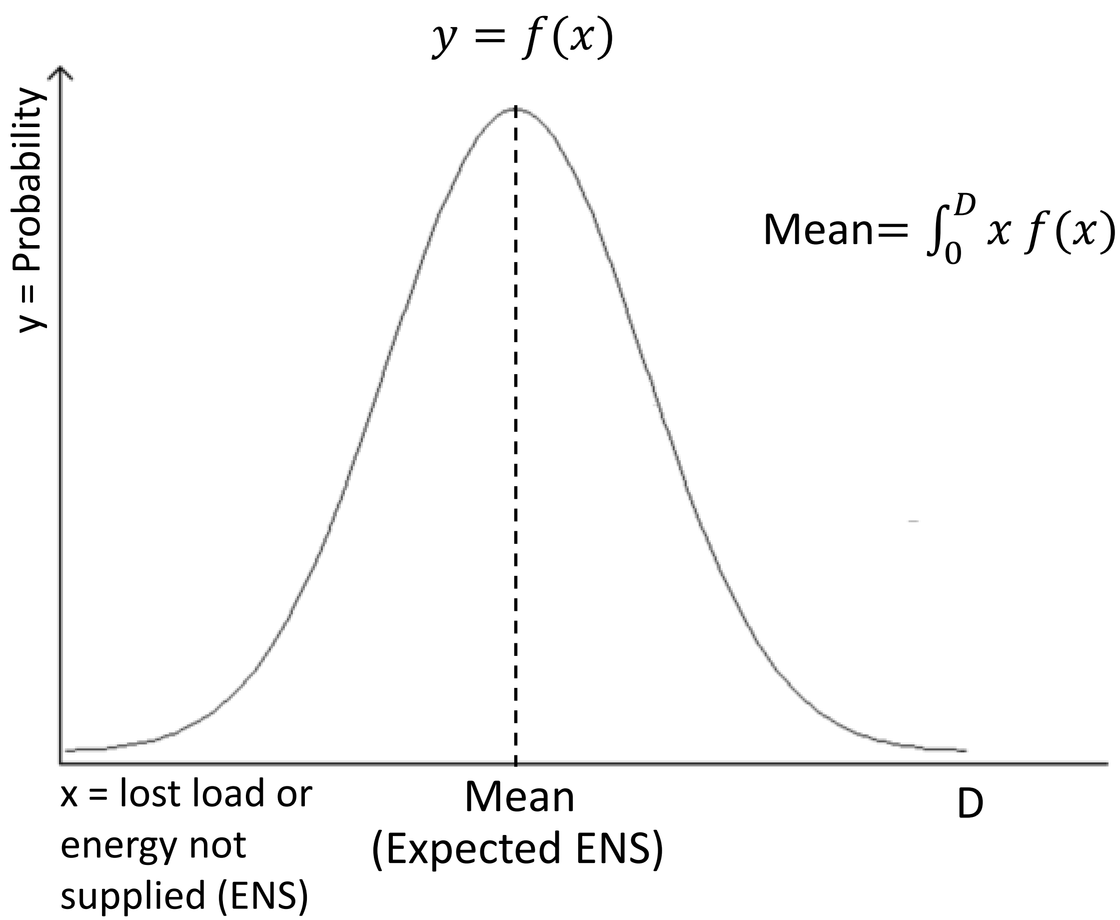
Levels of uncertainty – What does it mean?



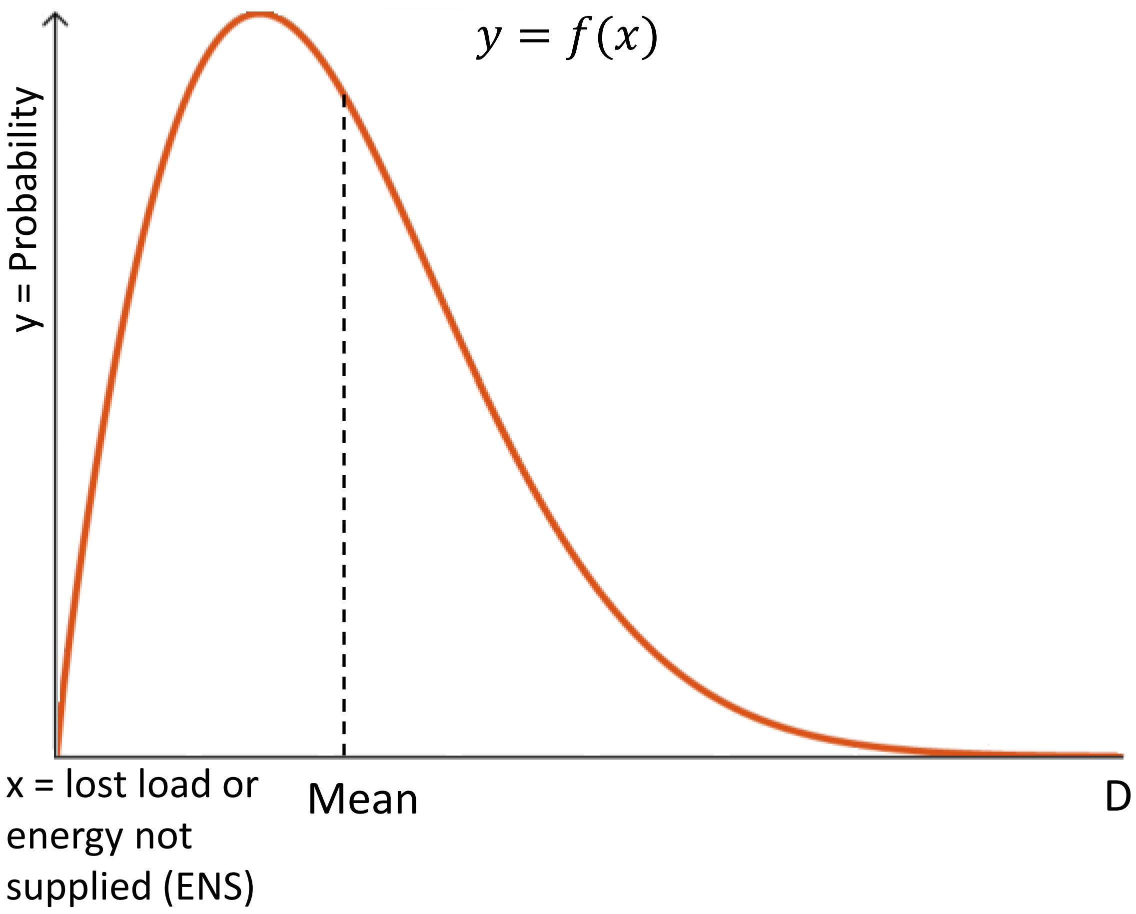


Assessing System Resilience

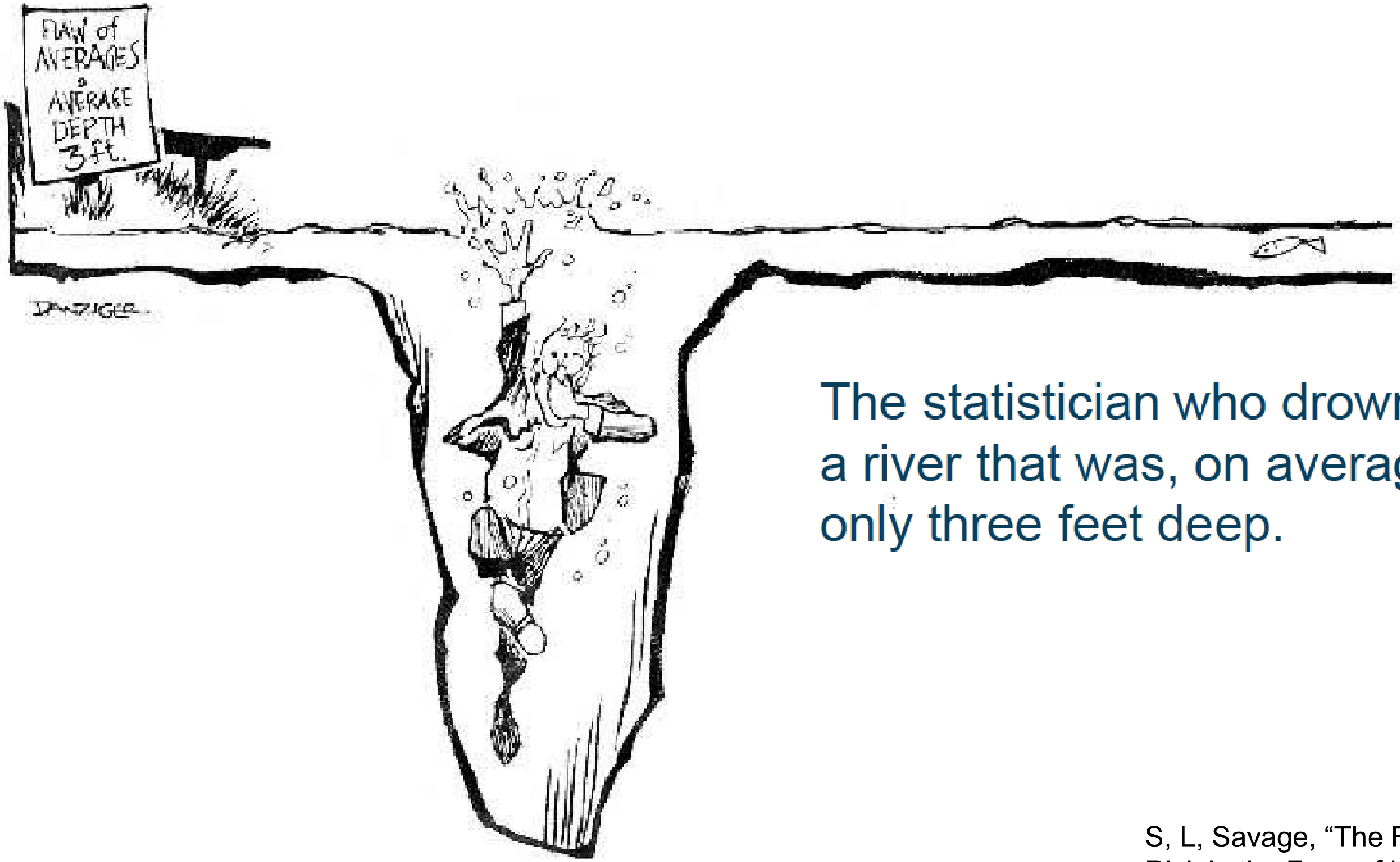
Expected values



Mean= $\int_0^D x\, f(x)\, dx$



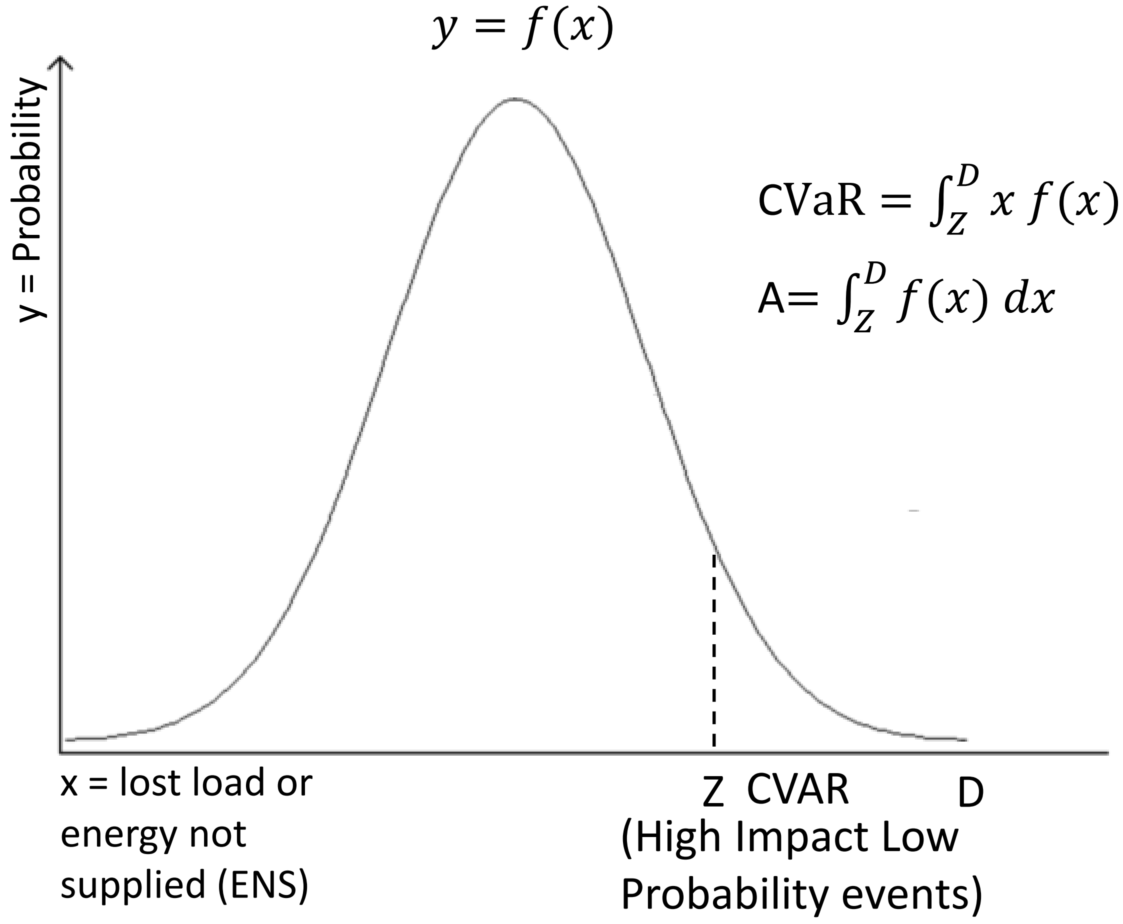
Are expected values adequate for resilience studies?



The statistician who drowned while fording a river that was, on average, only three feet deep.

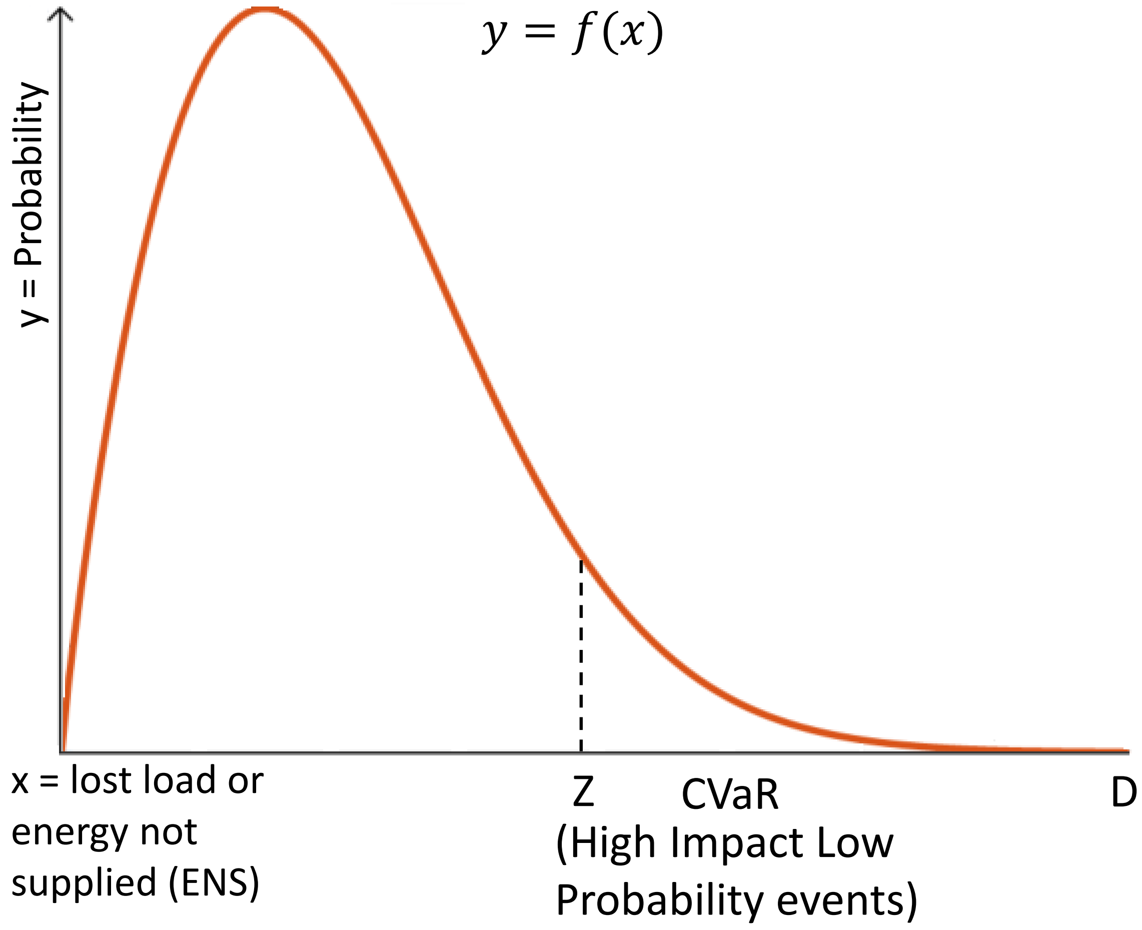
S, L, Savage, “The Flaw of Averages: Why We Underestimate Risk in the Face of Uncertainty,” Harvard Business Review, 2002.

Conditional values



$$\text{CVaR} = \int_Z^D x\, f(x)\, dx$$

$$\text{A} = \int_Z^D f(x)\, dx$$



Are Resilience and Reliability different?

CIGRE WG C4.47 – Resilience Definition

*the ability to limit the **extent, severity** and **duration** of **system degradation** following an **extreme event**.*

- In CIGRE definitions, the generic term "*magnitude*" usually used in resilience definitions is replaced by the two terms "***extent and severity***", which respectively refer to the *geographical extension* and the *intensity of the effects* of the event on the system.
- **"*Severity*"** in the present definition refers to the "*severity of the event consequences*", which must be kept separate from the "*severity of the event*" which in general does not imply any system degradations.
- The term "***degradation***" is intended as "*deviation from specified target performances*", both in system planning and operation as well as infrastructural and operational resilience.
- The term "***extreme event***" refers to high impact low probability (HILP) events, going beyond the "ordinary events" and referring to the "out of range type of contingencies" (ENTSO-E).

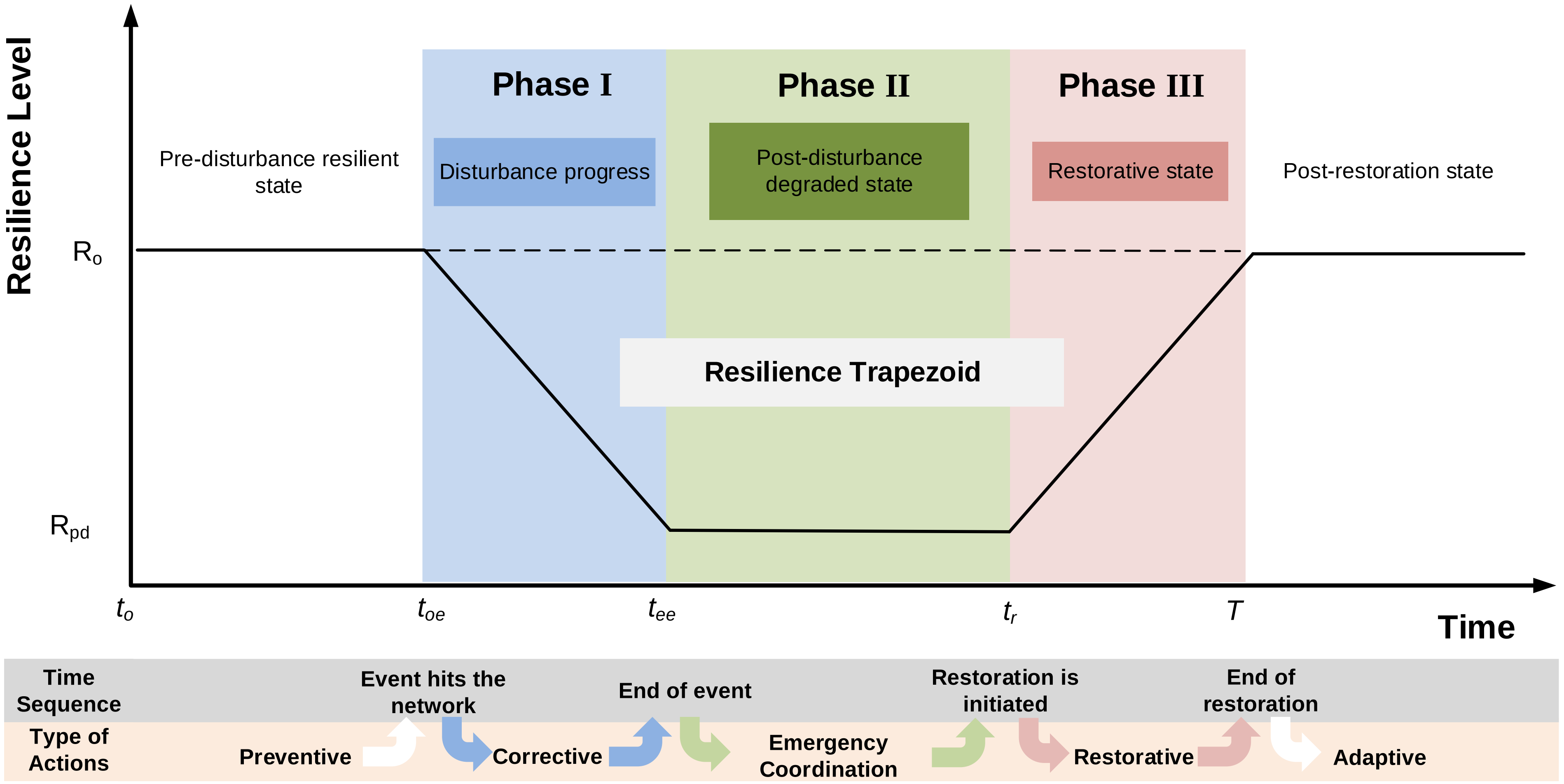
Acknowledgments: Emanuele Ciapessoni, Diego Cirio and Andrea Pitto, RSE, Italy

CIGRE WG C4.47 – Resilience measures

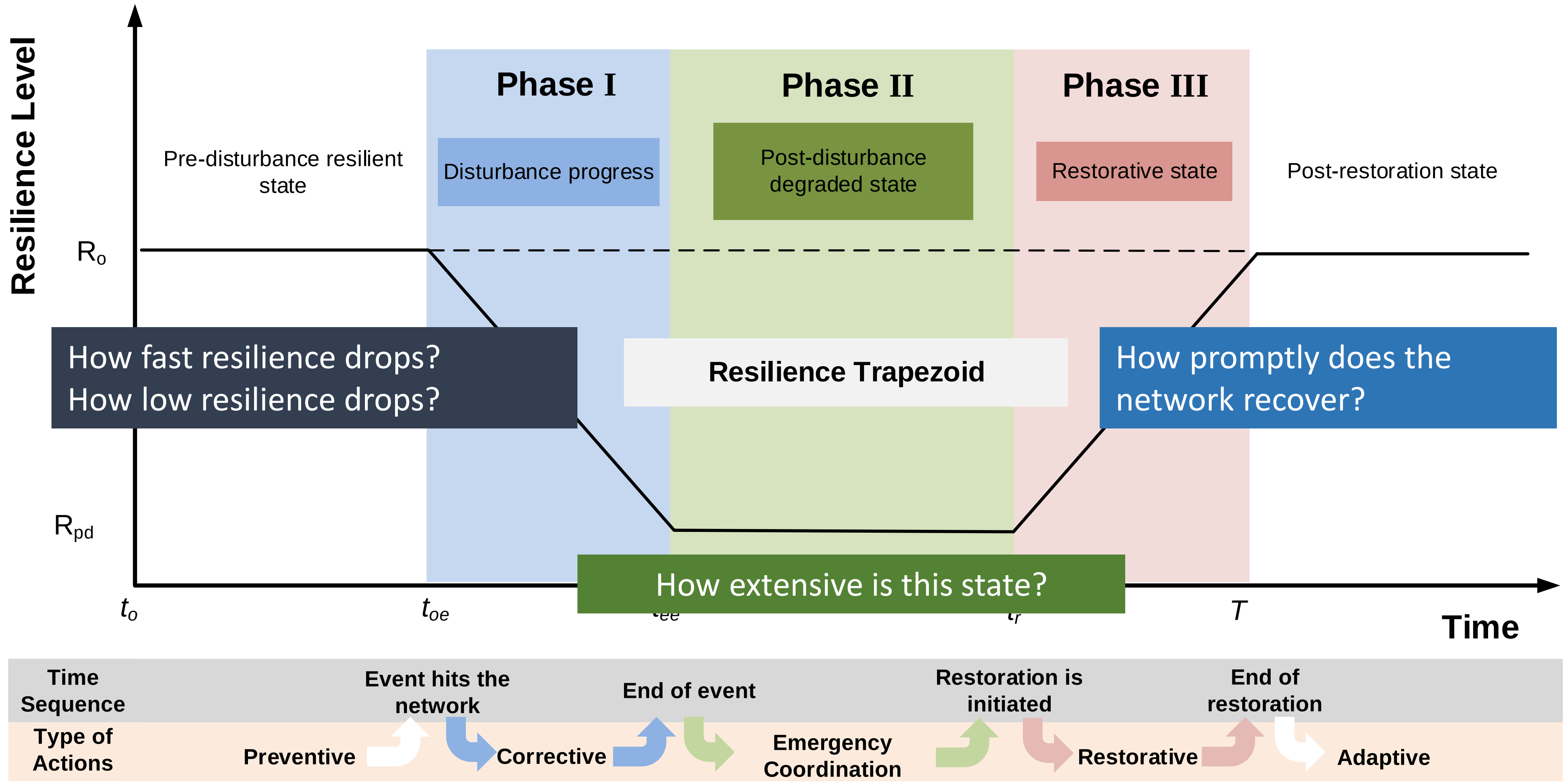
Resilience is achieved through ***key actionable measures*** to be ***taken*** before, during and after HILP, such as:

Anticipation	Preparation	Absorption	Adaptation	Rapid recovery	Sustainment of critical system operation
• the process by which newly incorporated knowledge gained is used to foresee possible crises and disasters	• the process through which grid operators establish a set of actions to be deployed in case the critical operating condition occurs	• the process through which a set of measures is deployed to limit the extent, the severity and the slope of the degradation of power system performance	• the process through which changes are carried out in the power system management procedures, on the basis of past disruptions, in order to adjust the system to undesirable situations	• the process through which the energy supply to the customers is restored and the damages to the grid infrastructure are repaired	• the process which deploys the measures allowing an impaired power system to supply a minimum system load level in order to maintain a reduced but acceptable functioning of everyday life

FLEP Resilience Metric System



FLEP Resilience Metric System



Techno-economic Modelling

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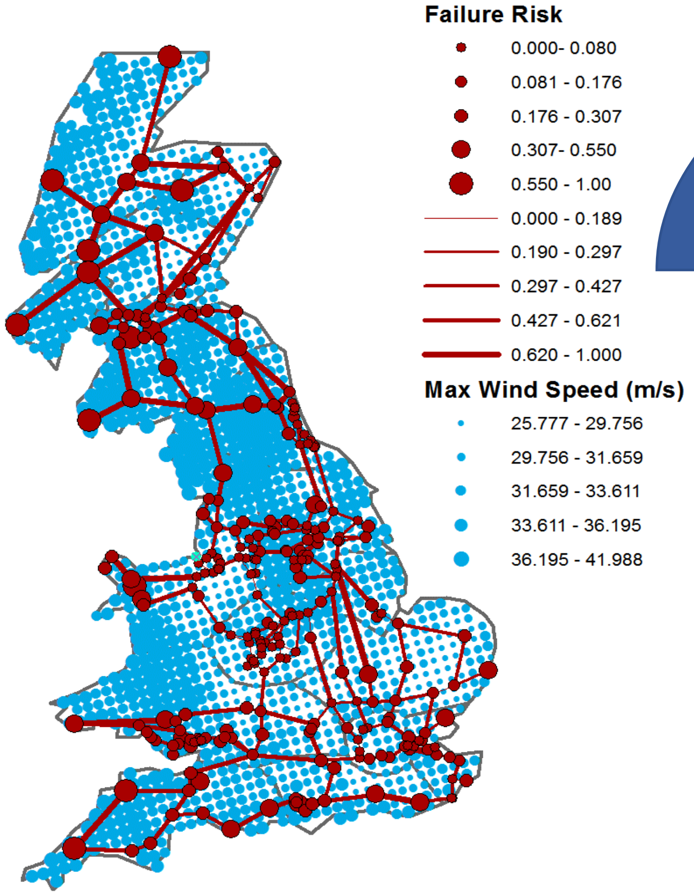
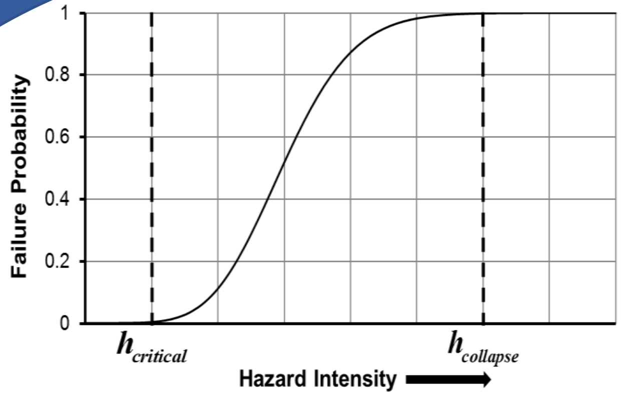
Example – Modelling the impacts of HILP

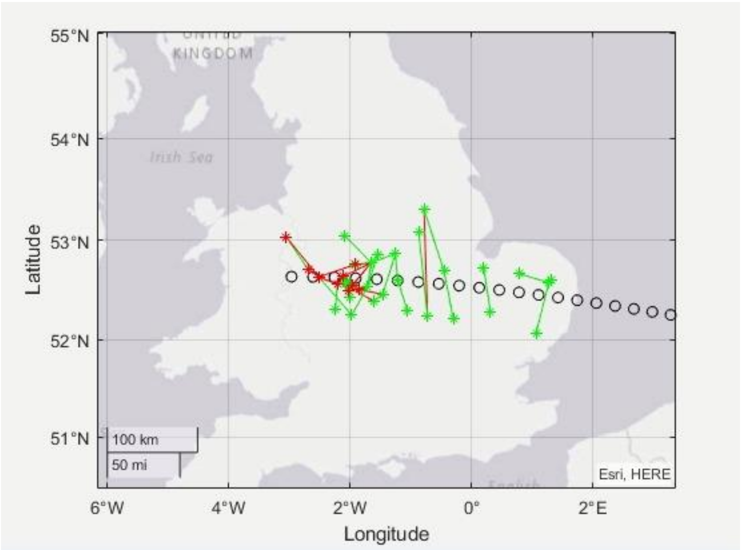


Modelling the network



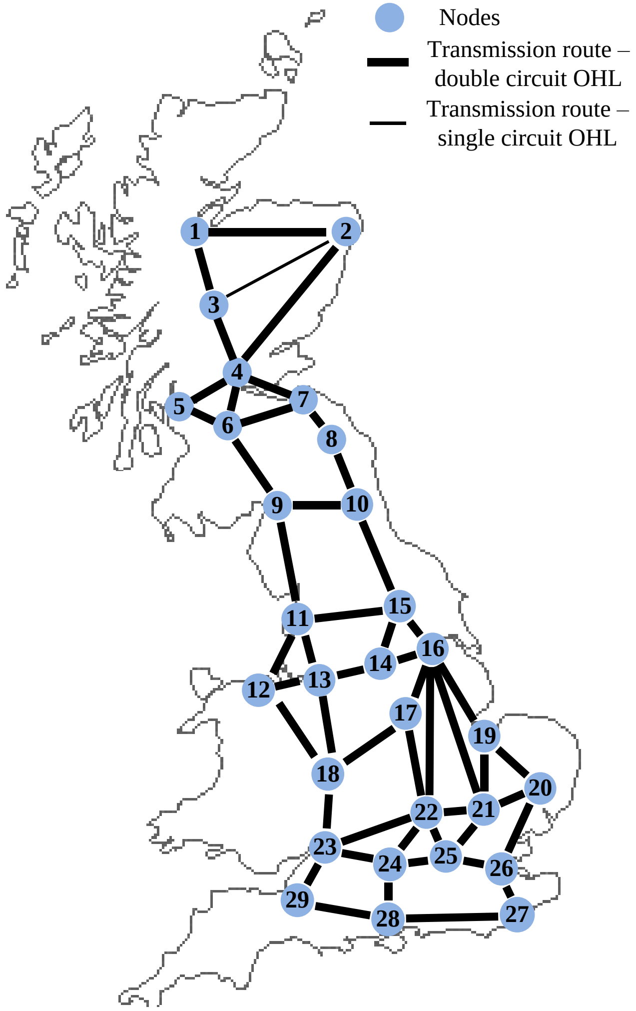
Modelling asset fragility

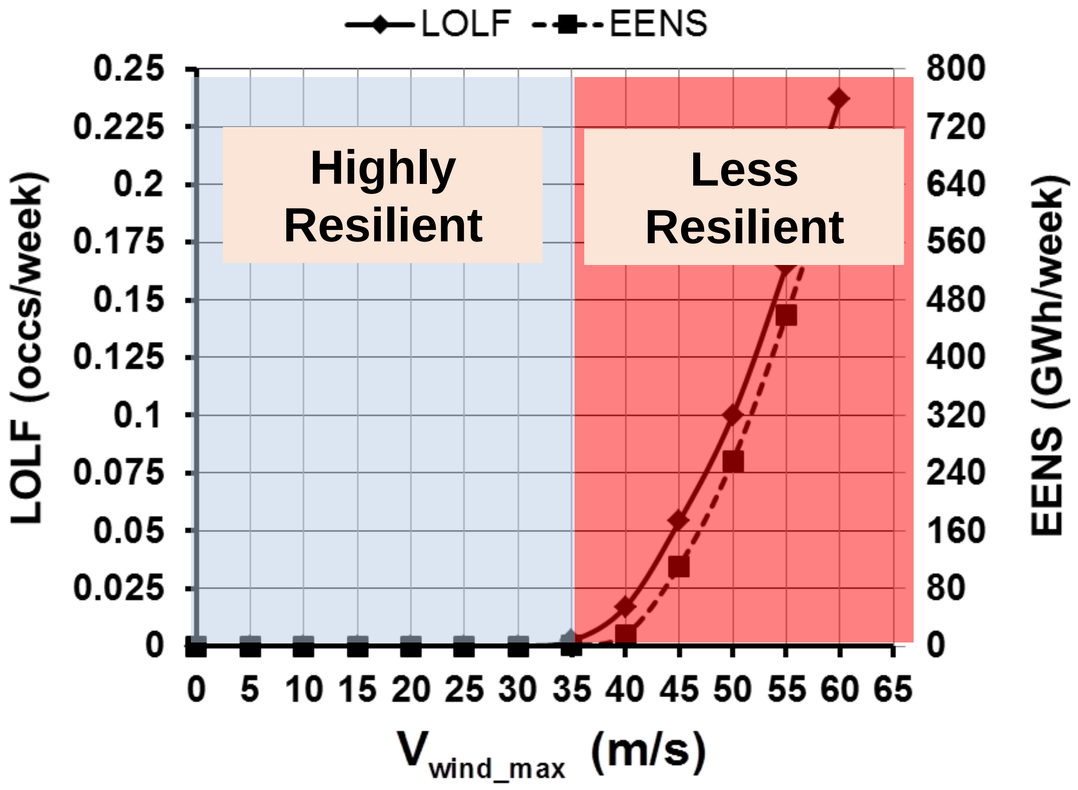
Modelling HILP



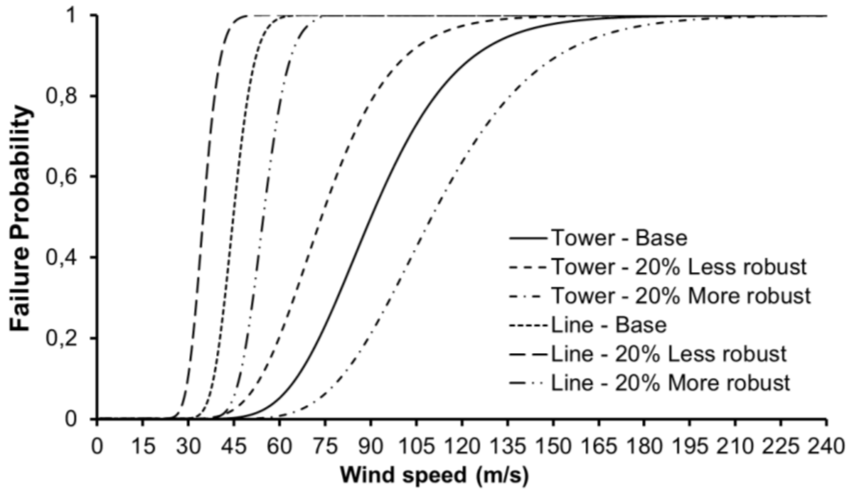
Modelling HILP impacts

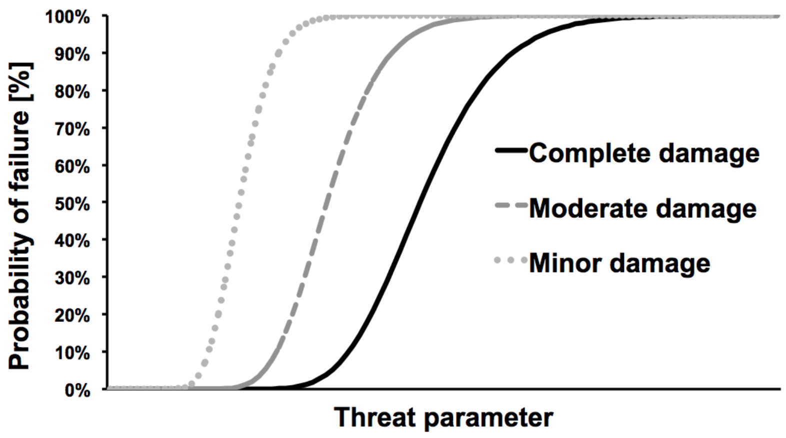
Example – Resilience assessment

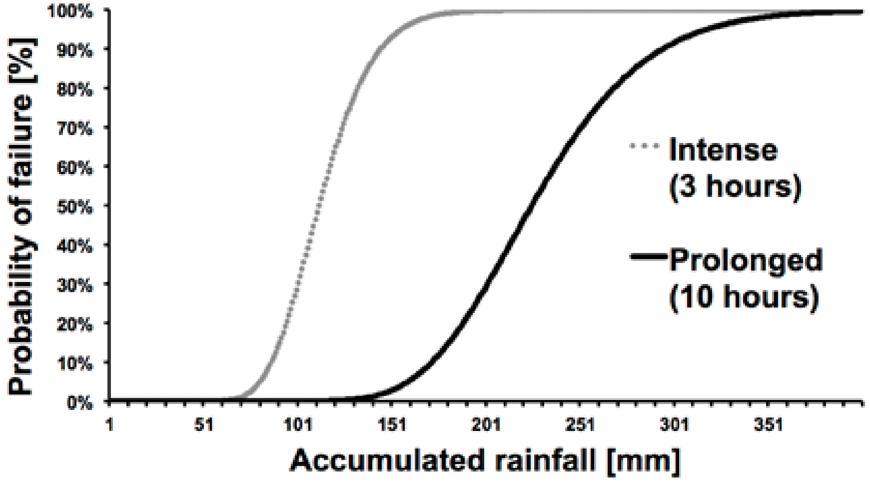


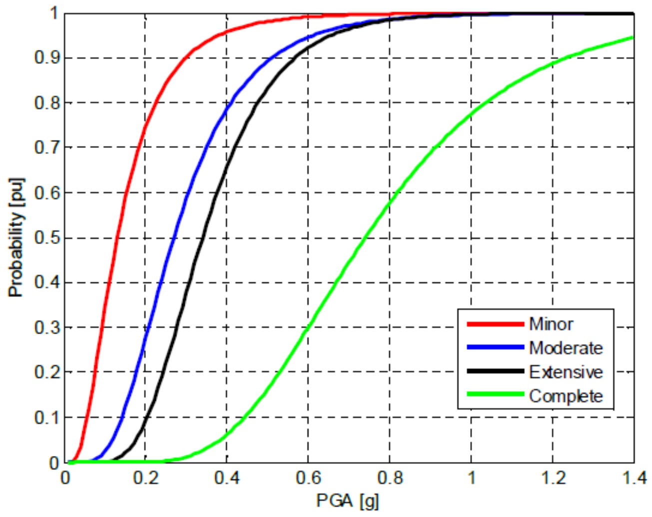


Investing in stronger assets?









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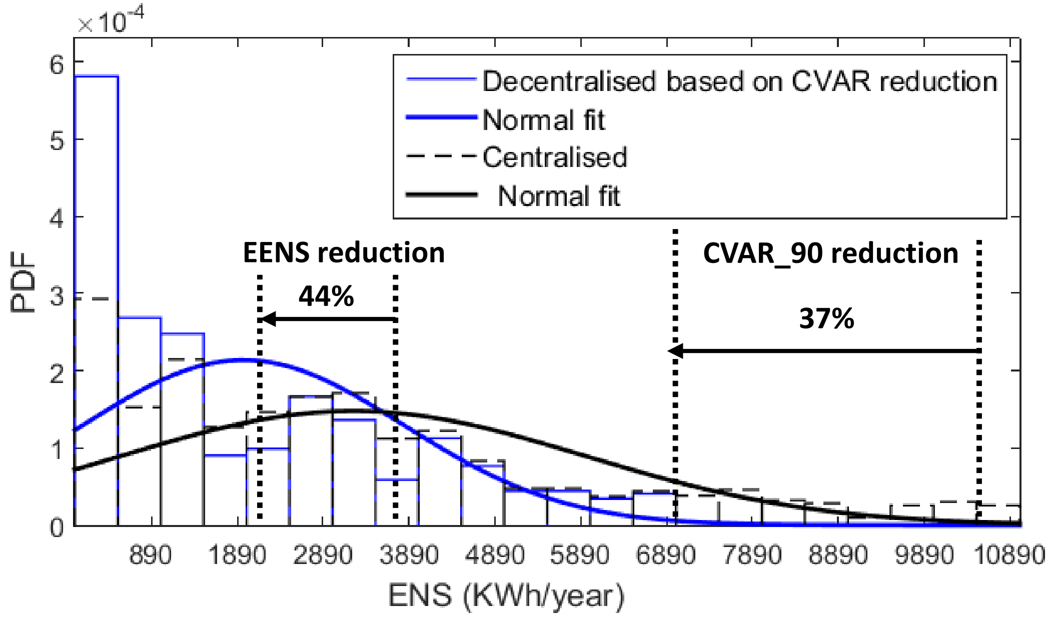
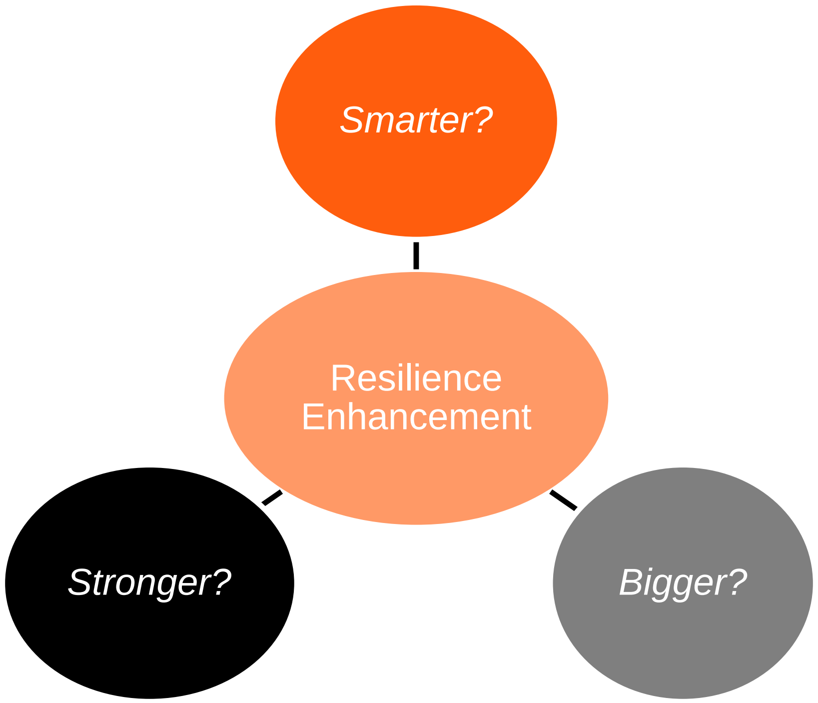
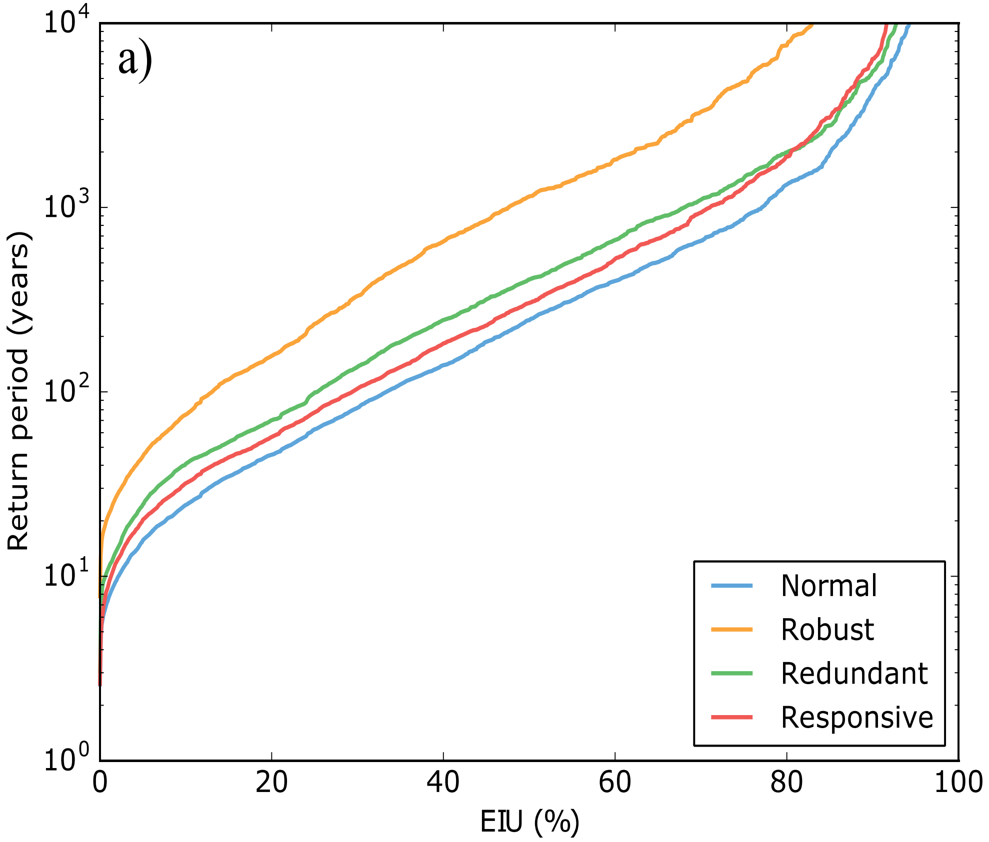
Investing in decentralised assets?



Architecture	LCOE ($/KWh)
Centralised	0.59
Decentr. – CVaR	0.42
Decentr - EENS	0.39

Investing in flexibility?





Flexibility might become more critical than redundancy in providing resilience to extreme events

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Your questions

Concluding remarks

- We need to consider resilience as a means to face Increasing uncertainties
- Resilience metrics should address HILP and the conditions before, during and after the events
- Investing in stronger assets, distributed resources and system flexibility are viable resilience measures

Relevant projects:

- Forward Resilience Measures (Stage 1): https://www.smarternetworks.org/project/nia_ngt0049
- TERSE: https://gow.epsrc.ukri.org/NGBOViewGrant.aspx?GrantRef=EP/R030294/1 funded by ESRC
- ATTEST: https://attest-project.eu/ funded by the EC
- FutureDAMS project: http://www.futuredams.org/ funded by EPSRC