5th International Conference on Smart Energy Systems
Copenhagen, 10-11 September 2019
#SESAAU2019

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Resilience metrics in energy master planning for communities

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Presented by

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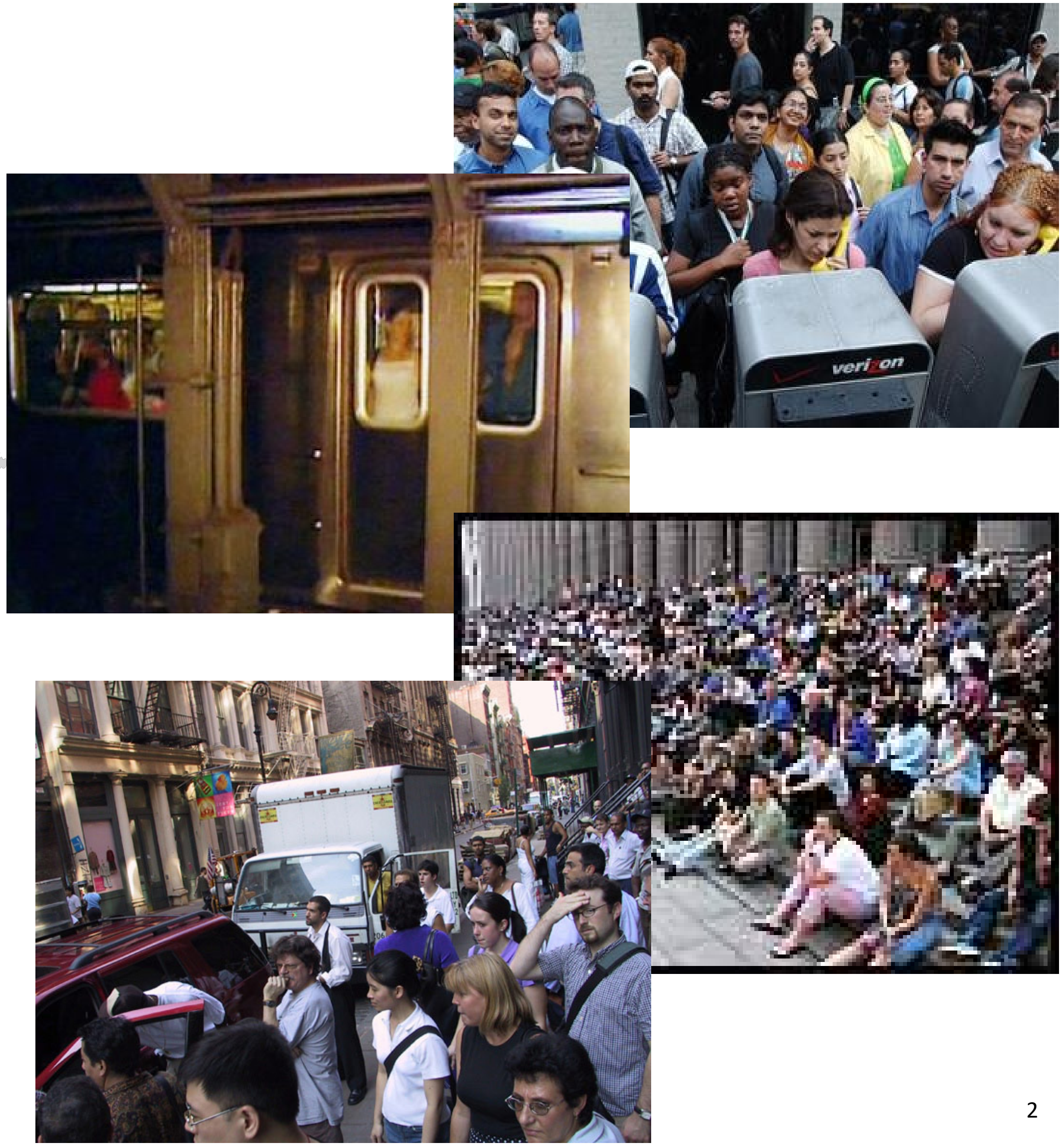
The 2003 US Northeast Blackout

- Parts of the Northeastern and Midwestern US, and the Canadian province of Ontario
- 4:10 pm August 14
- Some power was restored by 11 p.m. Most did not get their power back for 2 days, some areas for more than a week
- affected an estimated 10 million in Ontario, and 45 million in US
- The blackout's primary cause was a software bug in the alarm system at the control room
- What should have been a manageable local blackout cascaded into collapse of the entire Northeast region.



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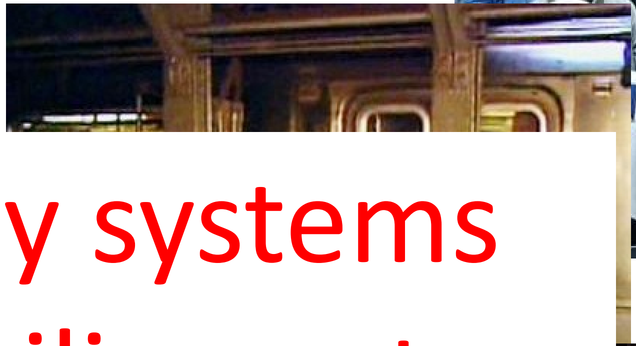
Is current energy systems designed for resilience to unexpected hazard?

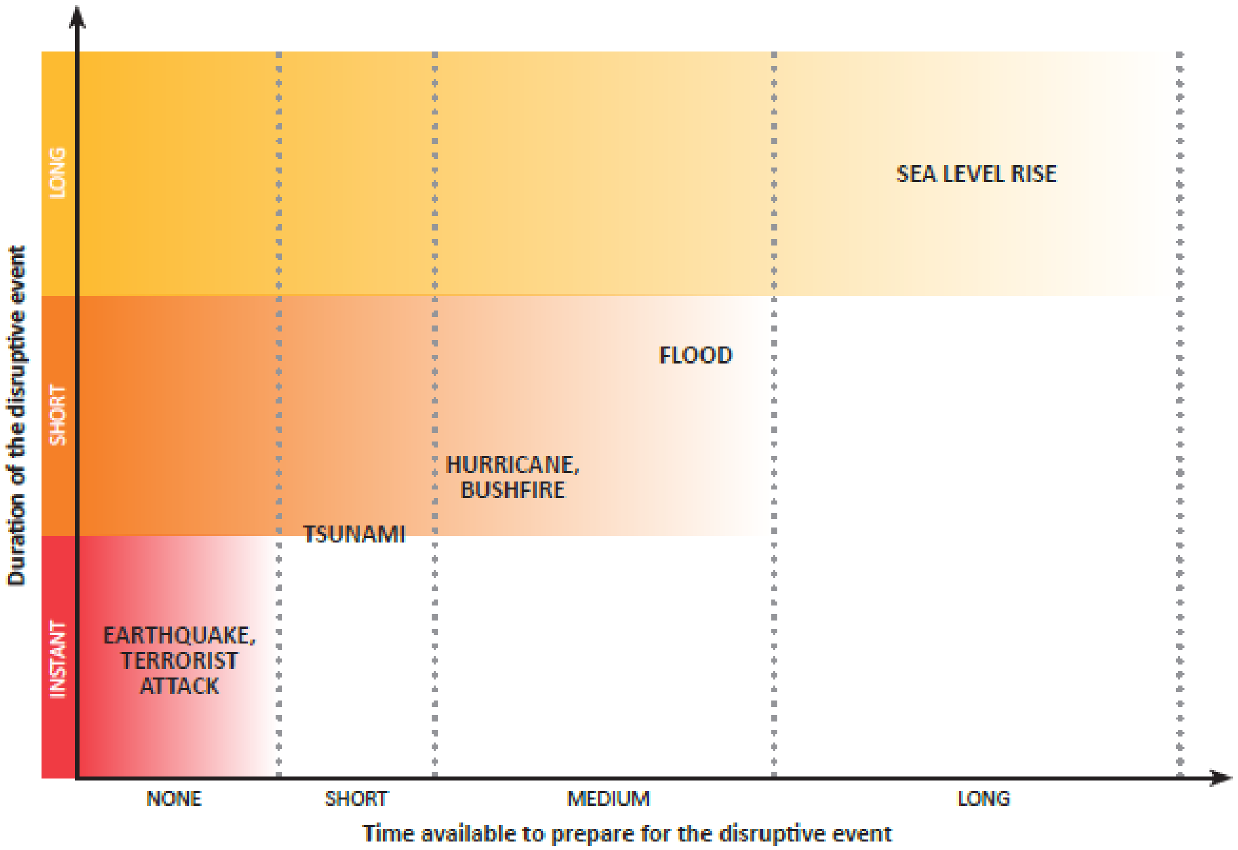



Introduction
various hazards with different impacts

- Hazards can be categorised based on their impact, frequency, duration of the event and the warning time.

- Under some circumstances, the combination of these events might create a high impact threat with different characteristics.

- To design an resilience energy system, it is critical to identify the threats and their potential impact on energy system, on environment and on the society.



various types of hazards based on their duration and warning time obtained from (Hasan & Foliente, 2015)

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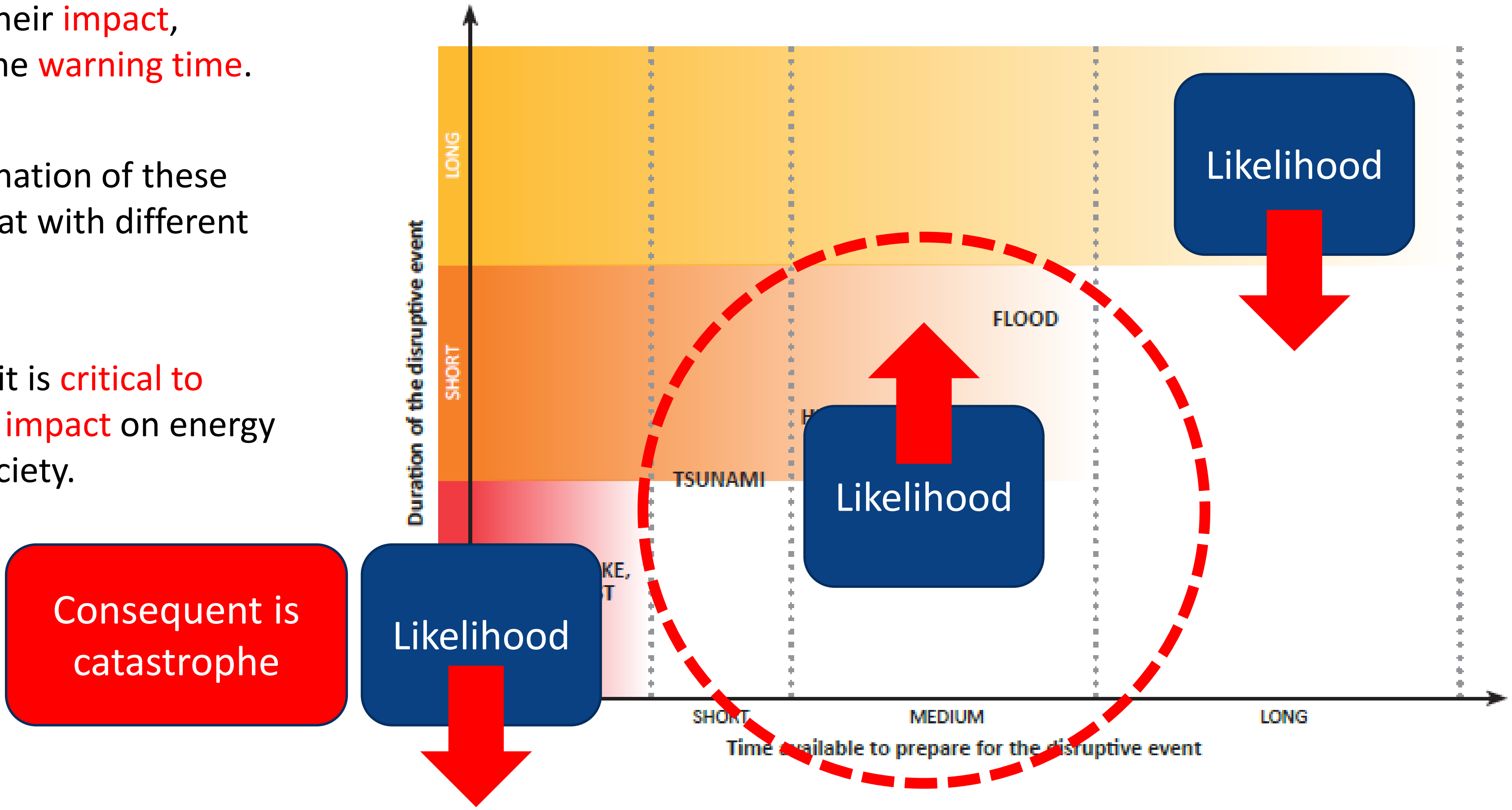

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Resilience energy master planning based on clear metrics is becoming more important

Defining physical and legal boundaries of an energy system

Single building:

- Considering resilience on the design of a single building could increase the cost significantly.

Cluster of buildings:

- Sharing the demand, resources and storage capability could justify the cost, but the legal issues due to multi ownership needs to be addressed.

3rd P, People

Single owner communities:

- Definition: a group of buildings with mixed-uses located in the vicinity of each other, connected internally as well as connected to the national energy grid. The entire system is considered as a whole with one owner (or organisation) in charge of decision-making.

- Although the term “community” in a social context has a different meaning, here by “community” the focus is on the medium scale energy system, precinct or campus both greenfield or brownfield.

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Community level system

- What types of communities?
  - University campus, military campus, large hospitals, or isolated communities in a remote area

2nd P, Policy

- When is the right design stage?
  - The impacts of disruptive events should be considered in early stages of design and planning, that’s when energy master planning is needed.

- In the design and planning of these communities, explicit considerations of system resilience and component reliability are necessity.

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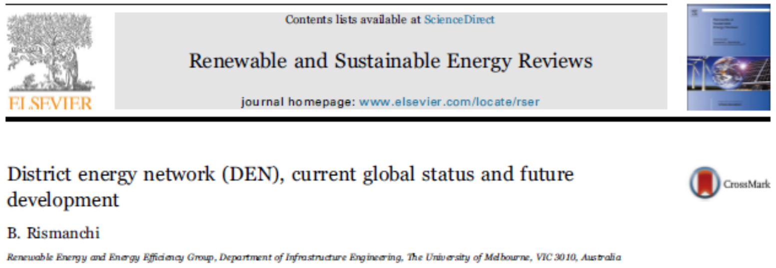
Community level energy system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Renewable and Sustainable Energy Reviews

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District energy network (DEN), current global status and future development

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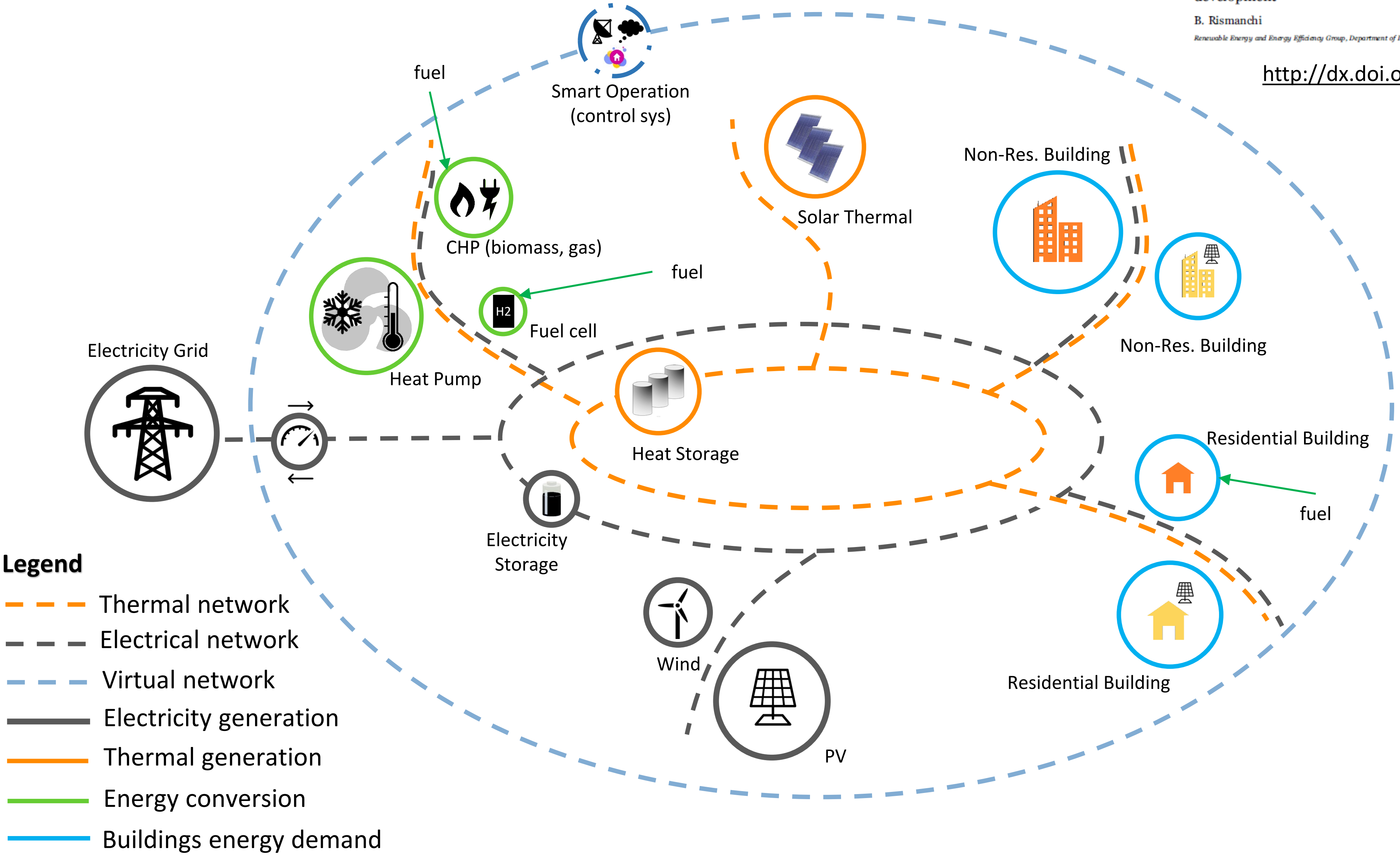
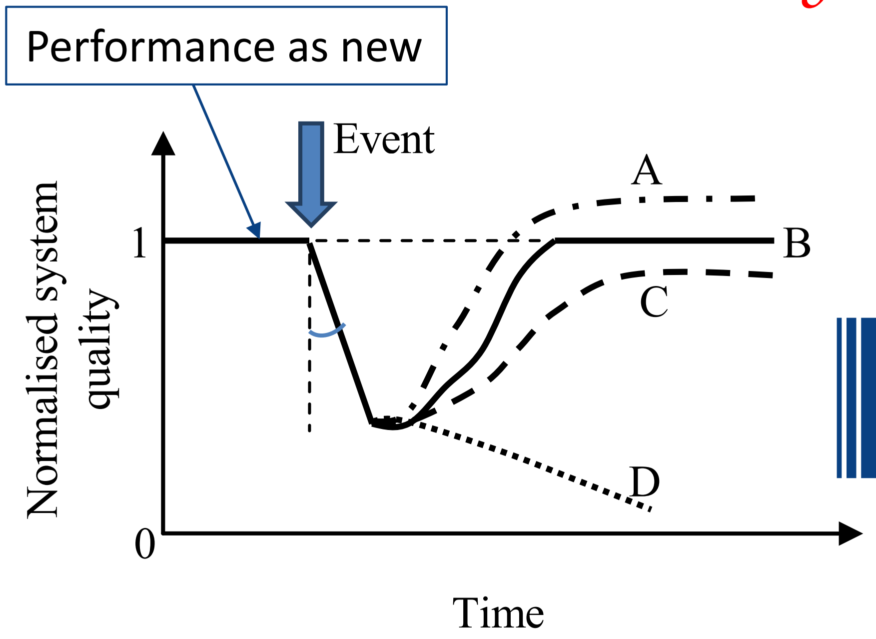
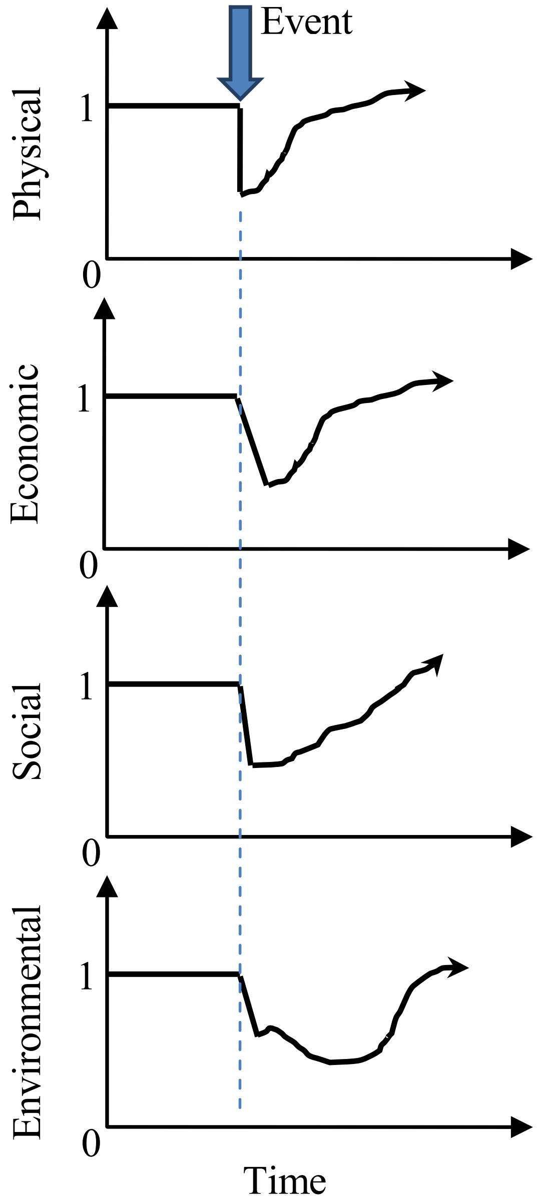


What is Resilience?

"Bounce-back-ability"



Ability to prepare for, withstand, and recover from disruptions caused by major accidents, attacks, or natural disasters.



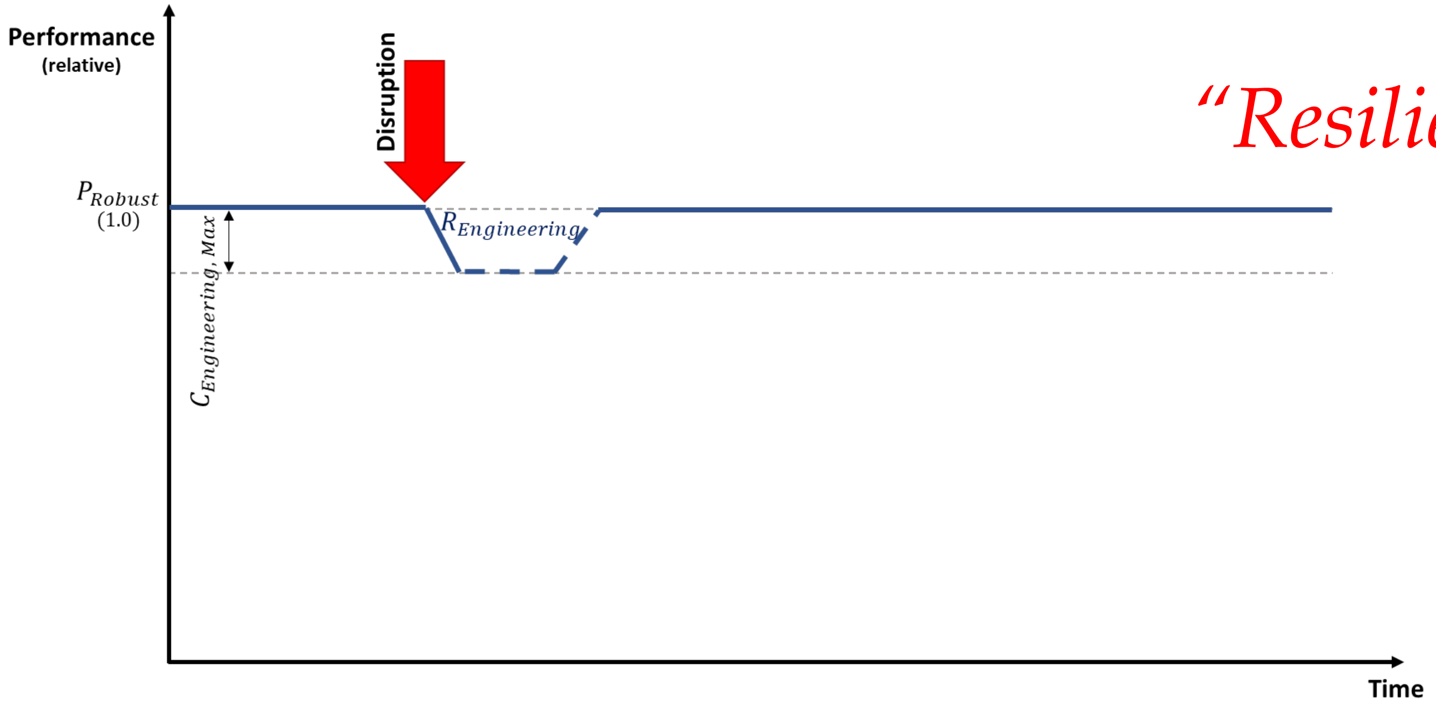
Resilience is contextual – defined in terms of threats or hazards

- A system resilient to hurricanes may not be resilient to earthquakes

Resilience includes hazards with low (no) probability but potential for high consequence

- Naturally fits within a risk-based planning approach or disaster management but it is difficult to capture this type of risk with high confidence

Engineering-designed Resilience ($R_{Engineering}$)



"Resilience trapezoid"

The first layer is the built-in or "engineering-designed resilience" ($R_{Engineering}$).

In this approach, the energy system may be designed in such a way that normal services can be restored after a short disruption.

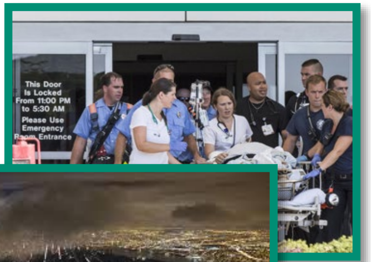
In some sense, this may be seen as an extension of a system designed for reliability and redundancy. But it also provides the opportunity for other or new innovative solutions (e.g. self-healing systems) that is activated when the primary system fails

How are Resilience and Reliability Related?

Resilience

Includes ***low probability, high consequence*** events.

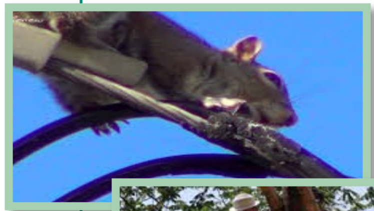
Not widely adopted. Still working on ***methods, metrics, and tools***



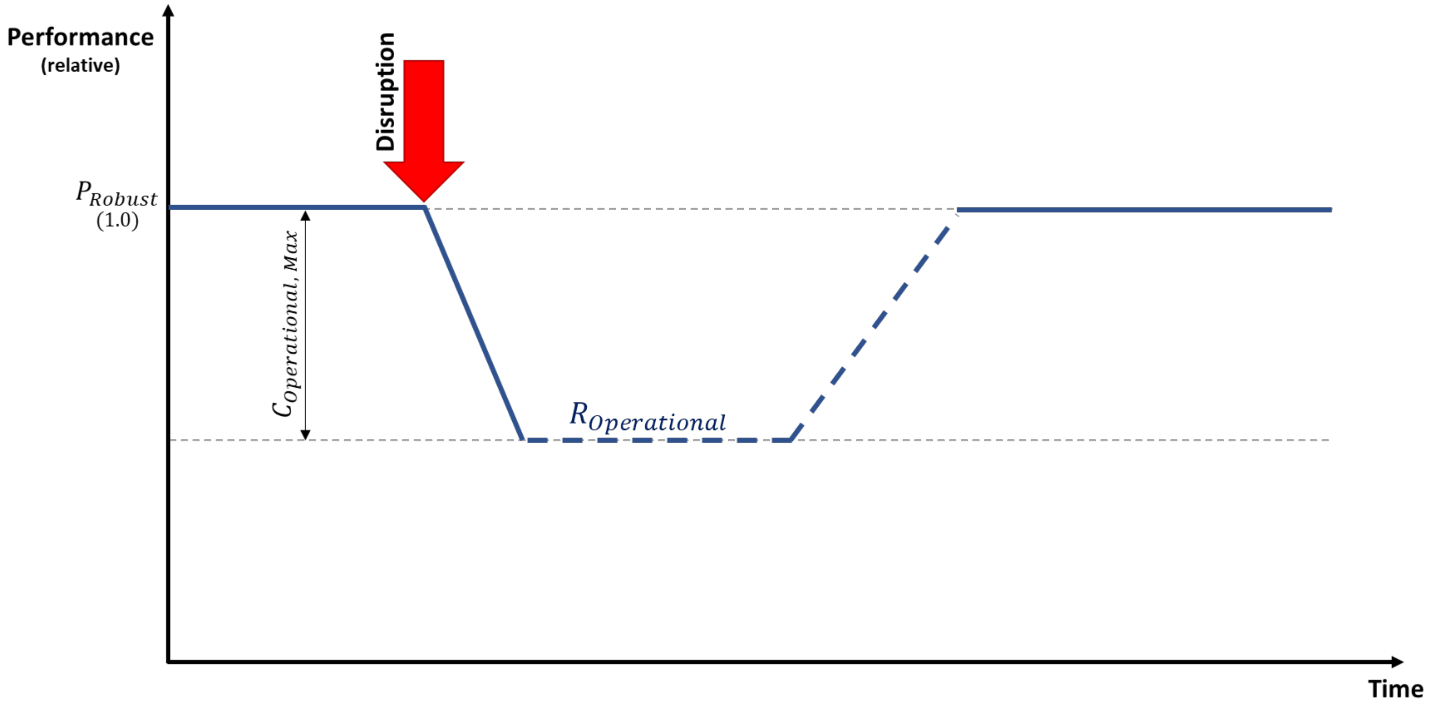
Reliability

Focuses on system performance with respect to **commonly expected events** (component failure, etc.)

Widely adopted for infrastructure investment decision-making



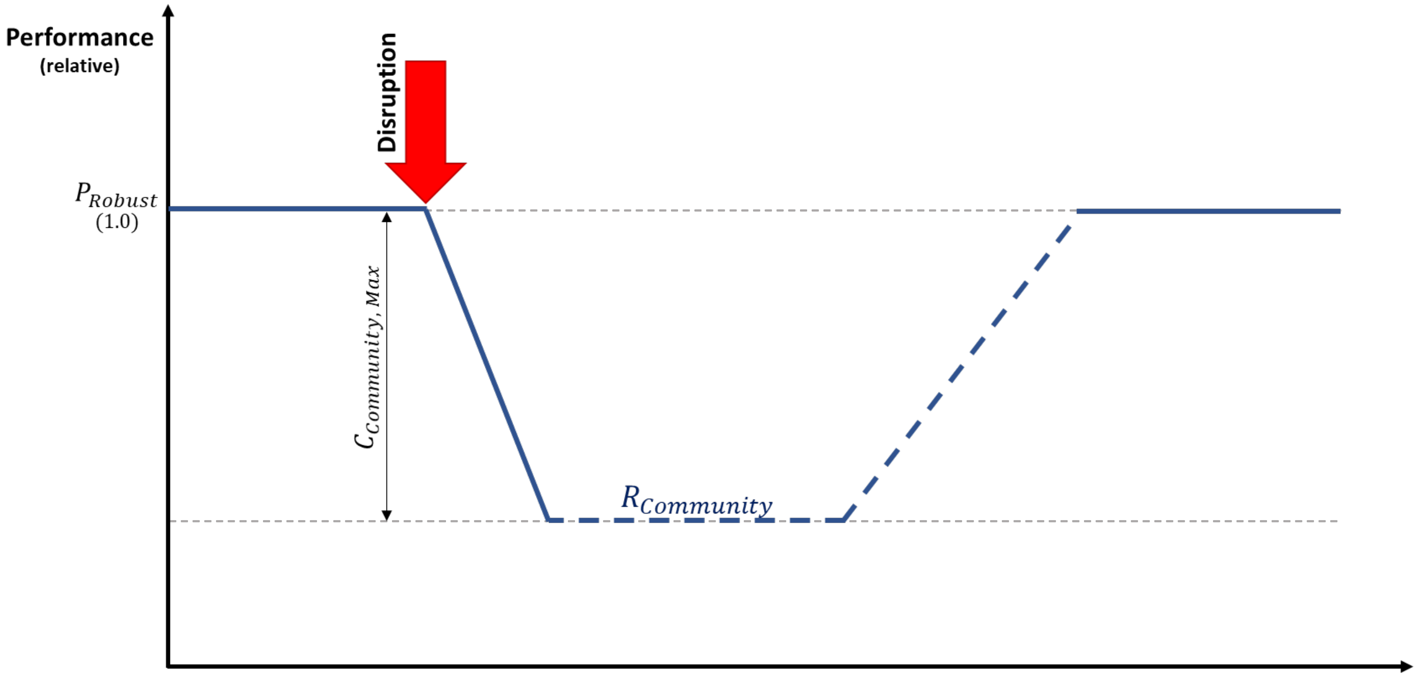
Operational Resilience ($R_{Operational}$)



The next layer is “operational resilience” ($R_{Operational}$), which is the set of technological and organisational measures that should be employed when the disruption goes beyond the maximum capacity of the built-in or engineering-designed resilience.

This also includes the process of decision-making required to restore services (from the team or organisation level to the whole energy sector in a region).

Community-societal Resilience ($R_{Community}$)



The next layer is the "community-societal resilience" ($R_{Community}$), which needs to be invoked as part of the solution as appropriate especially when operational resilience alone is not sufficient to address the disruption.

There is a broad range of stakeholders within the community and/or society, whose cooperation and contributions to bring the service back will be critical.

Energy resilience layers at community level

Example metrics φ :

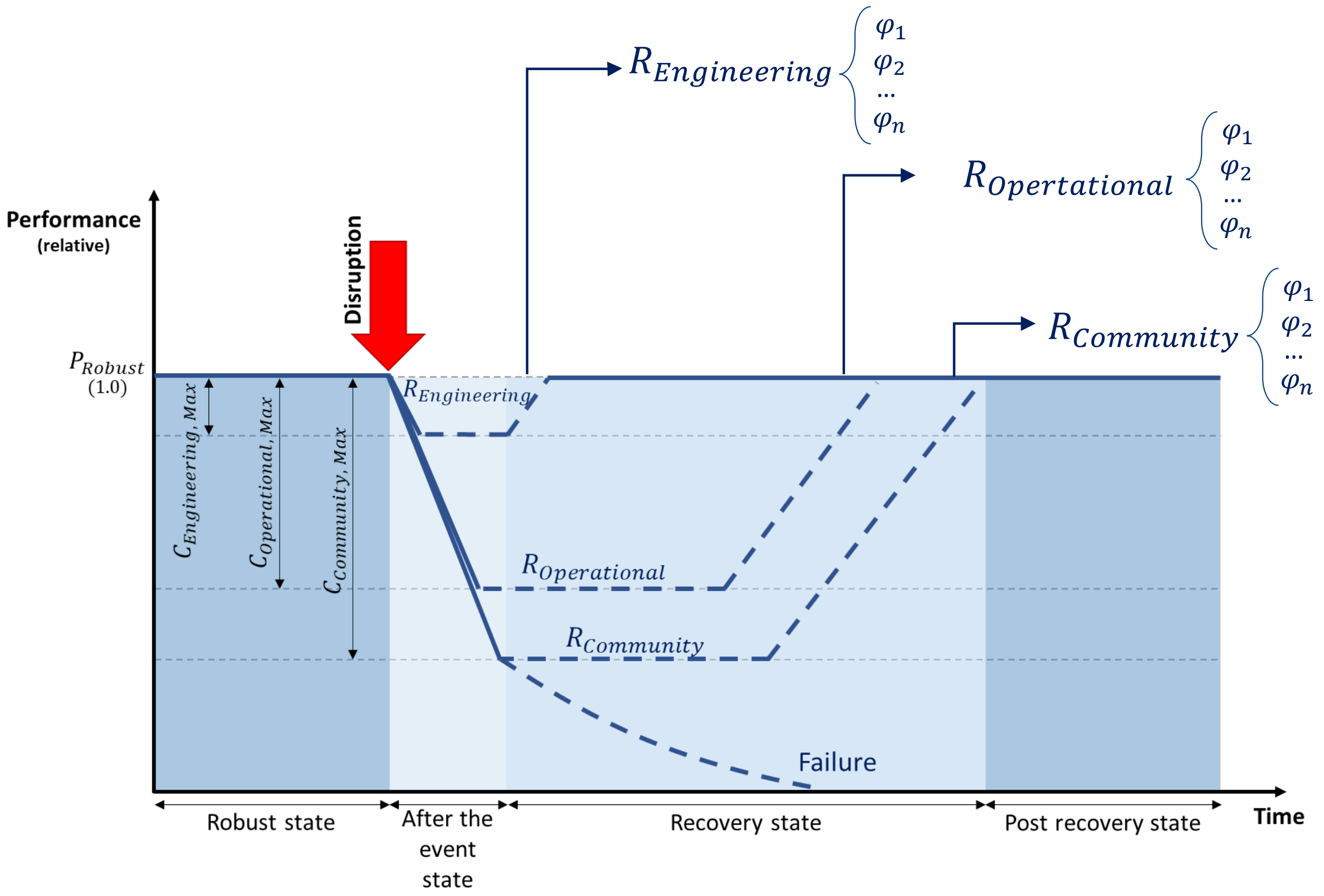
- Slope and extent of the edges for each trapezoid
- Integral under the curve (area of each trapezoid)

Primary metric:

- kWh not served energy for intended system performance

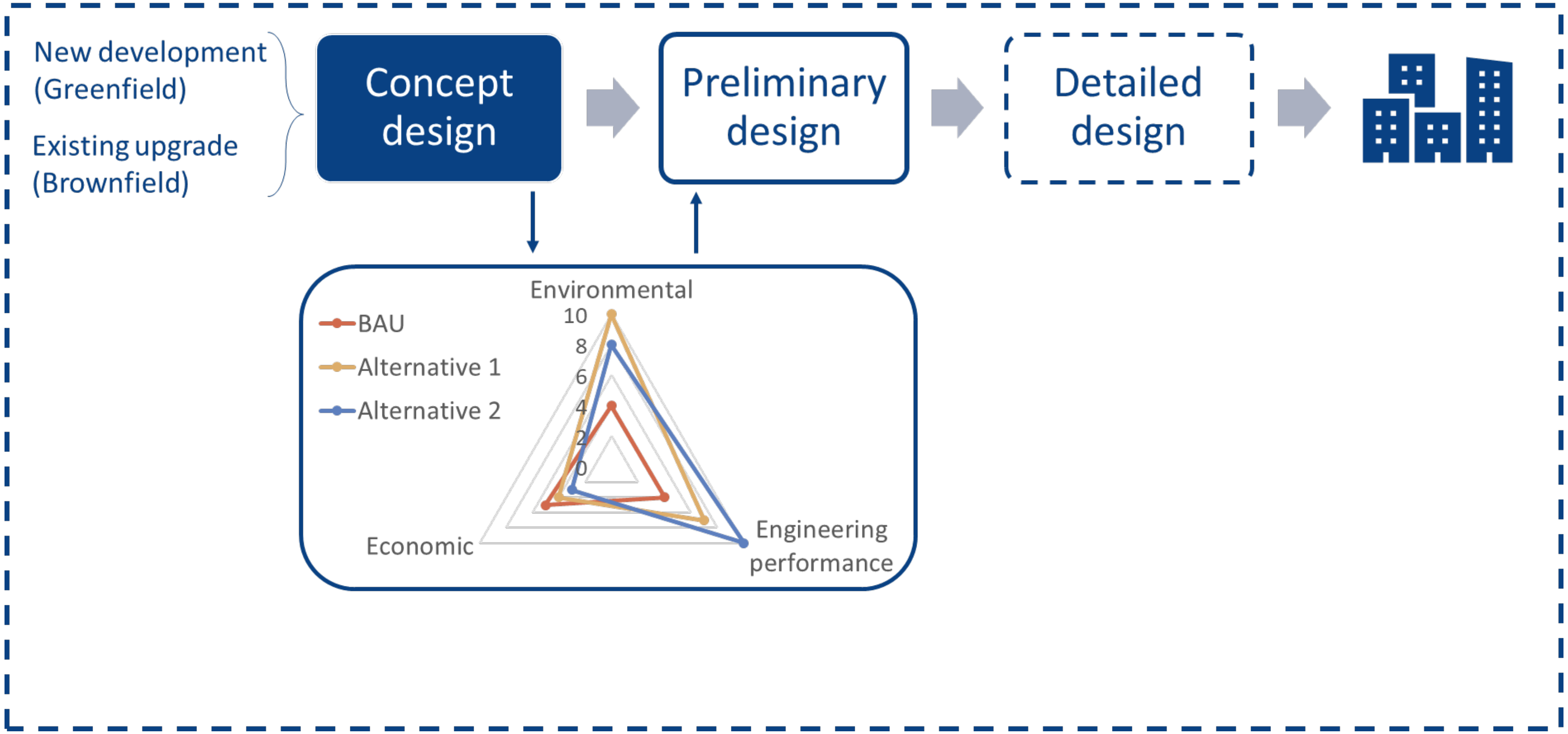
Consequence metrics:

- The economic ($) loss of performance disruption
- The environmental impact (GHG) due to unusual performance during the disruption



Conceptual multi-phase energy resilience trapezoid, revised based on (Panteli et al., 2017)

An example of energy resilience assessment in community energy master planning



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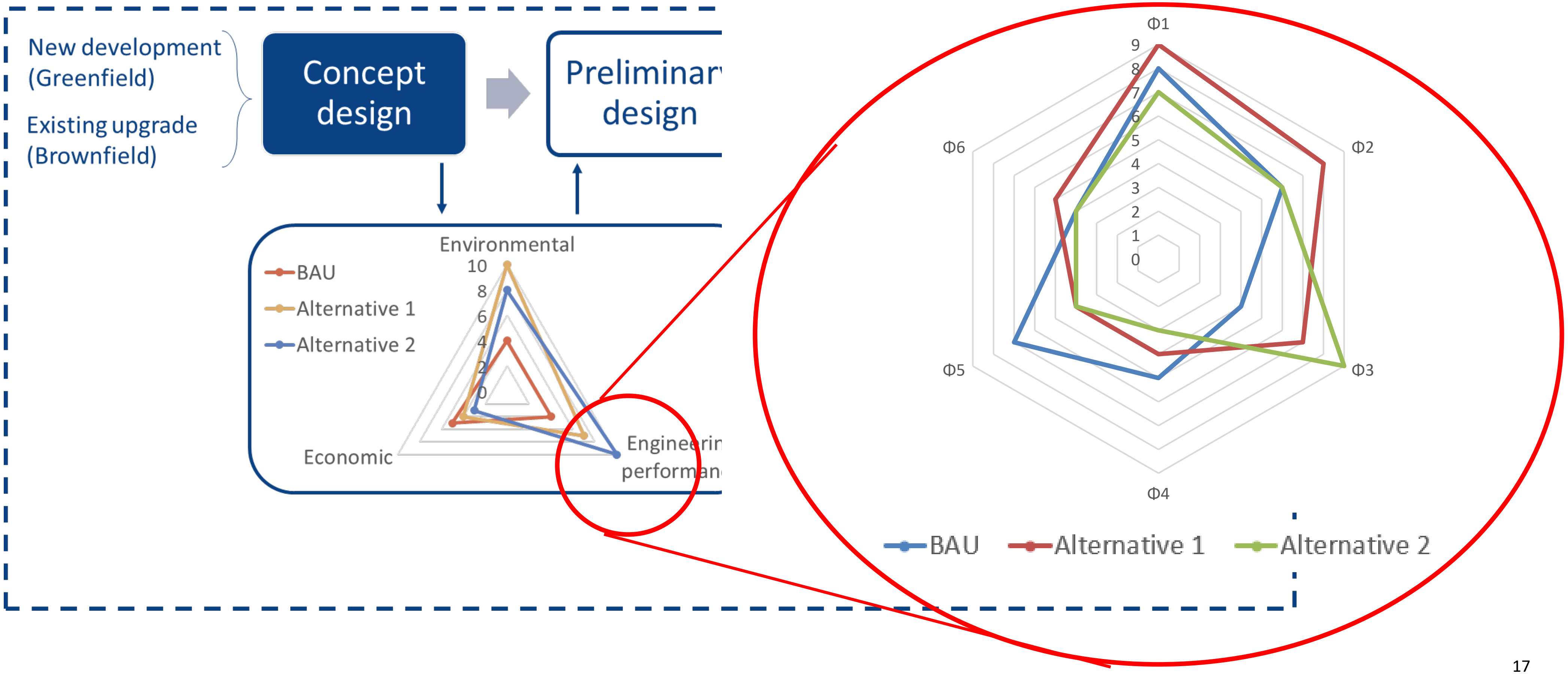

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Summary

- The importance of the resilience in the energy master planning of communities is highlighted.
- A general resilience framework to understand and design a community level system is proposed.
- Three layers of energy resilience metrics are presented, namely engineering-designed resilience, operational resilience and community-societal resilience.
- In future work, the practical application and implication are explored.
- Detailed metrics for each layers are discussed in the full paper.

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Thank you

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