Articulating qualitative vulnerabilities beyond quantitative vulnerabilities in resilience assessments for a human-centric energy policymaking

Management of Disaster Risk and Societal Resilience (MADIS) Conference

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Structure of presentation

- ESR and its use in energy system design

  State of the art of energy system resilience (ESR) assessments
- The centrality of quantitative vulnerabilities in PRA-based ESR assessments
- Quantitative vulnerabilities amidst vulnerabilities at large

  Qualitative vulnerabilities behind quantitative ones

  Policy relevance of framing quantitative vulnerabilities with qualitative vulnerabilities

Defining ESR

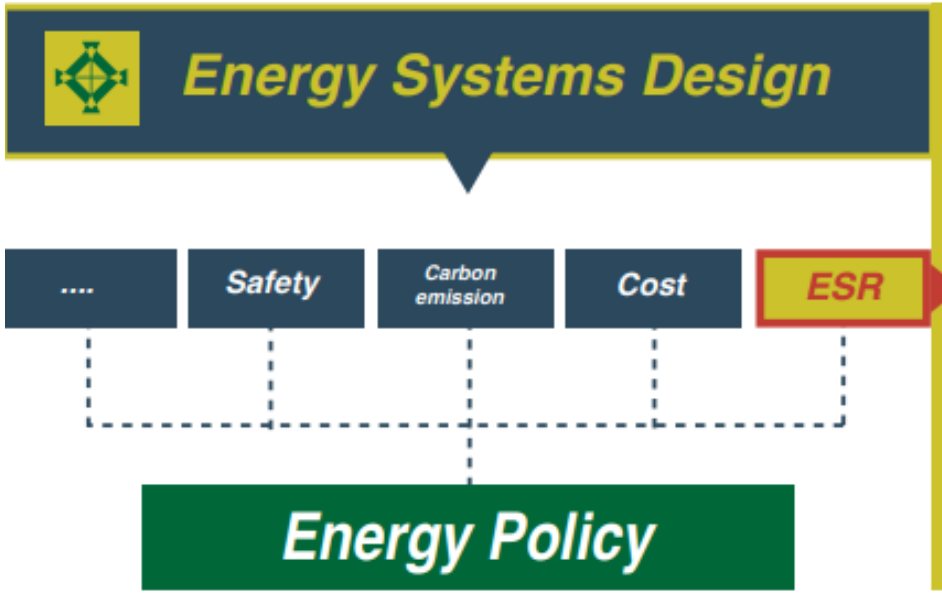
Energy systems' readiness to bounce forward amidst anticipated and unanticipated disruptions in order to provide sufficient and stable energy supply through reliable engineering technique, efficient management, and conducive social institutions

Indicates having the means and being disposed to deal with disruptions such as blackouts-brownouts, grid collapse, data breacing (for virtual grids), etc.

sufficient-stable energy supply is the normative goal of ESR

Social and technical means to achieve resilient energy systems

ESR guides energy policy makers in designings energy systems



Readiness against (un)anticipated disruptions

From blackouts and brownouts, natural disasters, physical and cyber attacks, material supply, etc., not all disruptions can be anticipated. Readying energy systems to bounce back amidst disruptions require factoring in uncertainties and ignorance about such events

Ensuring sufficient energy supply

The normative purpose of readying energy systems to bounce back amidst (un)anticipated disruptions is to provide sufficient energy supply to the poor. Sufficient energy allows the poor a higher overall living standard which lead to a better life.

Technical-management-social strategies

In building, maintaining, and improving resilient energy systems, policy makers and engineers need to consider capabilities of existing energy technologies in both commercial and developmental stages, how to manage them, and link technical vulnerabilities to vulnerable socieities.

1. State of the art of ESR assessments

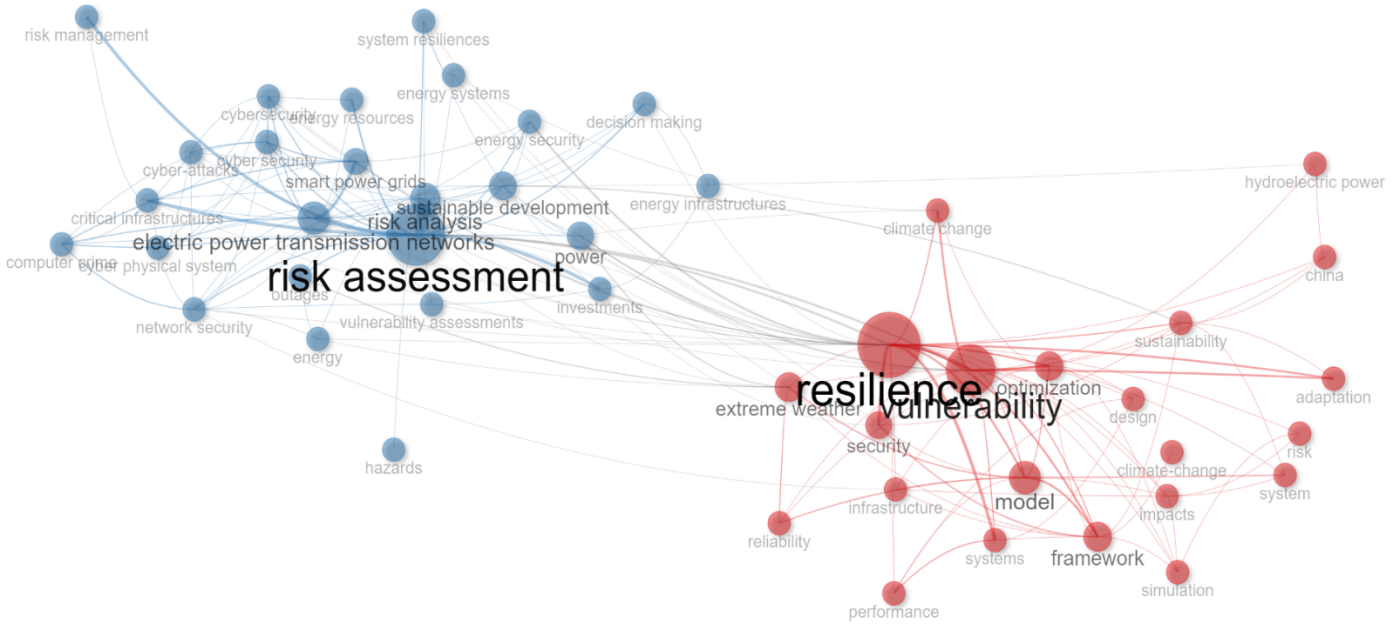


Figure 1. Co-occurence keywords on 145 studies using bibliometrics analysis via R software on January 3, 2024. There are 247 studies gathered selected by inputting 'resilience assessments, 'energy systems', and 'vulnerabilities' under 'topic' in Web of Science and 'article title, abstract, keywords' in Scopus. After removing duplicates, further removing conference proceedings and selecting only studies which talk about energy systems bring the number down to 145. Visualisation is done using the 'keyword plus' function to include not only words in the authors' keywords list, but also words within the titles and abstracts.

State of the art of ESR assessments: most frequent co-occuring keywords

Including resilience, risk assessment, vulnerability	Excluding resilience, risk assessment, vulnerability
Resilience	Model
Risk assessment	Electric power transmission networks
Vulnerability	Risk analysis
Model	Framework
Electric power transmission networks	Optimisation
Risk analysis	Extreme weather
Framework	Sustainable development
Optimisation	Power
Extreme weather	Security
Sustainable development	Smart power grids
Power	Cyber security

State of the art of ESR assessments literature: wrap-up

- There is an overlap between ESR assessments and probabilistic risk assessments (PRA) for electric grids.
- PRA for electric grids generally examines the likelihood of disruptive events occuring towards the grid e.g. weather events and cyberattacks.
- ESR assessments for electric grids examines the likely performance of a grid given the occurence of disruptive events.

  The likely performance of a grid given disruptions occuring is labelled ‚vulnerability‘.

2. Centrality of quantitative vulnerabilities in PRA-based ESR assessments

- Case in point: publicly accessible resilience assessments online tool from the United States' National Renewable Energy Laboratory (NREL)
- Value of Resilience (VoR): "…the value of risk, given the probability of a hazard or threat, vulnerability, and consequence over time, where consequence can be considered as monetary and non-monetary costs associated with a realized hazard or threat."

Centrality of quantitative vulnerabilities in PRA-based ESR assessments

Monetary or not, a grid's resilience is quantifiable by considering 1) the likelihood of hazard, 2) the grid's likely performance, and 3) the likely consequence of such performance during the hazard.

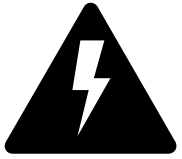
Centrality of quantitative vulnerabilities in PRA-based ESR assessments: wrap-up

- Quantitative vulnerabilities allow stakeholders a clearer, more laid-out investment strategies in electric grids.
- E.g. quantified vulnerabilities help opting between fossil fuelled, renewables fuelled, or nuclear fuelled grids; which safety or stability features on which to invest more money; which grid designs to implement, etc.

3. Qualitative vulnerabilities beyond quantitative ones

- Quantitative vulnerabilities‘ output: dollar lost per probable hour-long outages.
- Qualitative vulnerabilities‘ output: possible crucial human activities hindered by outage lasting for certain period and happening in certain frequency.

Qualitative vulnerabilities beyond quantitative ones: example



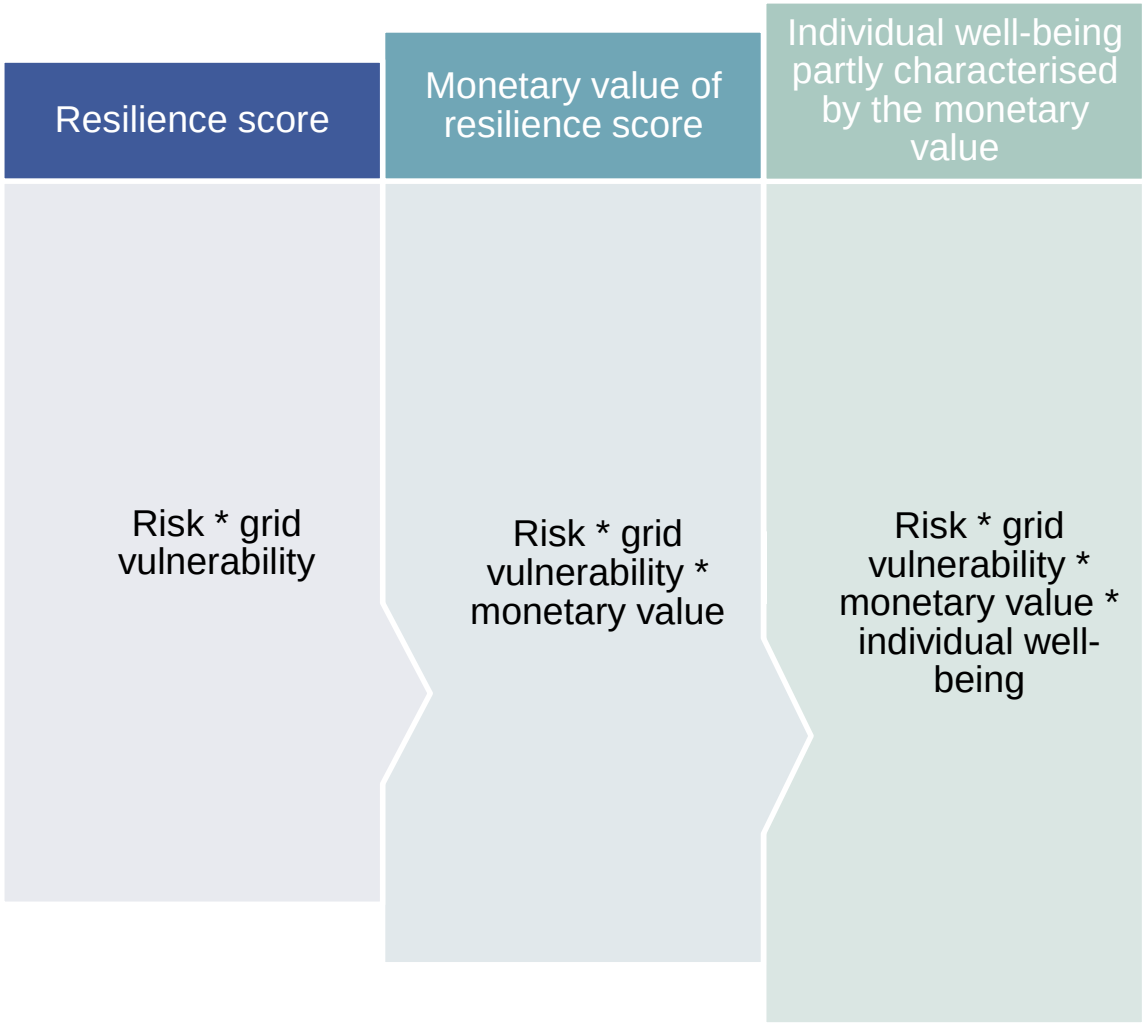
- We can quantify the resilience of a solar-and-wind-only grid powering an area with several hospitals with low probability of occasional low-sun days and low-wind days and nights.
- The number assigned to indicate grid resiliency can further be assigned monetary value.

  However, beyond the X degree of resiliency and Y amount of monetary value, exist critical infrastructures (hospitals) in which lives are treated regularly.

Qualitative vulnerabilities beyond quantitative ones: reflection

- Resiliency score/value of a grid is a numerical characterisation of how the grid‘s likely performance during disruptions.
- This score/value is but a partial indicator of the ones affected by the grid‘s affected performance: individuals who use the electricity.

Qualitative vulnerabilities beyond quantitative ones: wrap-up



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4. Policy relevance: framing quantitative vulnerabilities with qualitative vulnerabilities

Quantitative vulnerabilities in ESR assessments are useful indicators to examine grids‘ capabilities when disrupted.

Quantitative vulnerabilities in ESR assessments can also detail technical indicators for grids‘ performance such as capacity factors, for instance.

However…

Policy relevance: framing quantitative vulnerabilities with qualitative vulnerabilities

Behind quantifiable and/or monetisable grid performance during probable disruptions, there are individuals affected by it.

Qualitative characterisation for vulnerabilities such as disrupted life-saving medical procedures, for example, are why we employ quantitative characterisation of vulnerabilities in the first place.

- Qualitative vulnerabilities are thus the frame for quantitative vulnerabilities and not the other way around.

Framing quantitative vulnerabilities with qualitative vulnerabilities: policy aims

Qualitative vulnerabilities are important in policymaking to integrate qualitative measures such as individual well-being, value assessments, vision assessments, etc., into quantitative ESR assessments.

Main policy question: how likely would the society be able to maintain their activities when the grid is disrupted?

Thank You

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- I need your input, please…

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