TU Delft

Algorithmic Fairness in Electrical Distribution Grids

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Alliander - AI for Energy Grids Lab

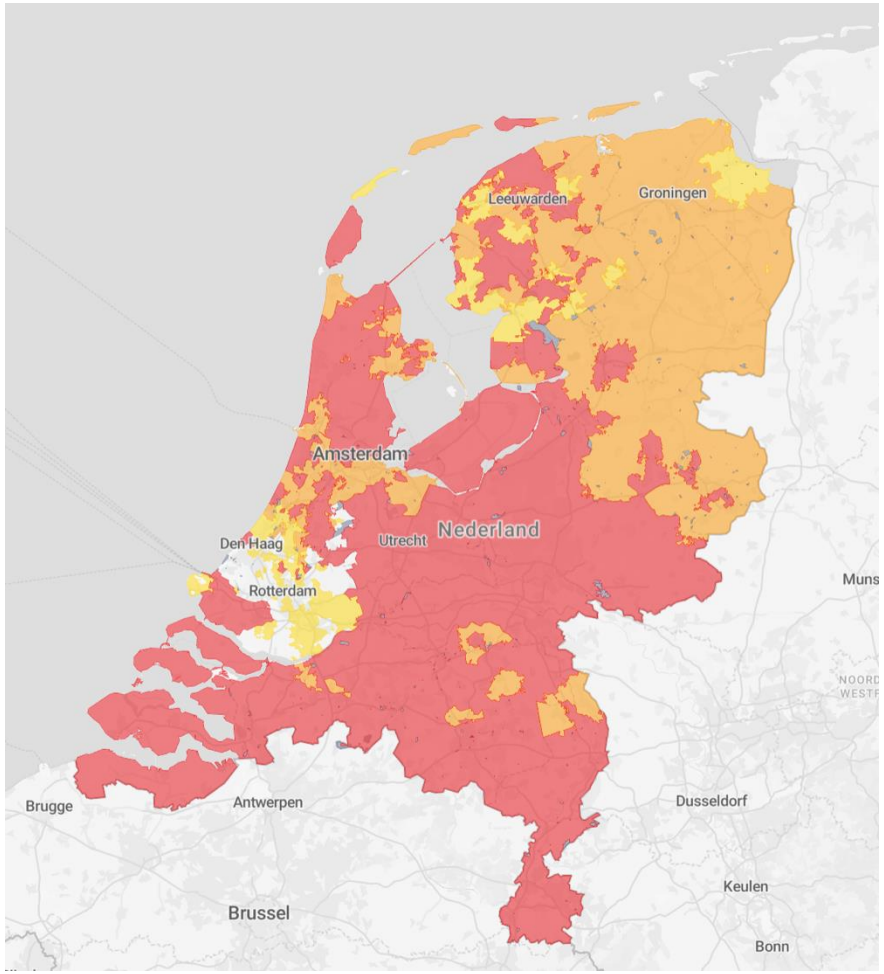
01

Introduction

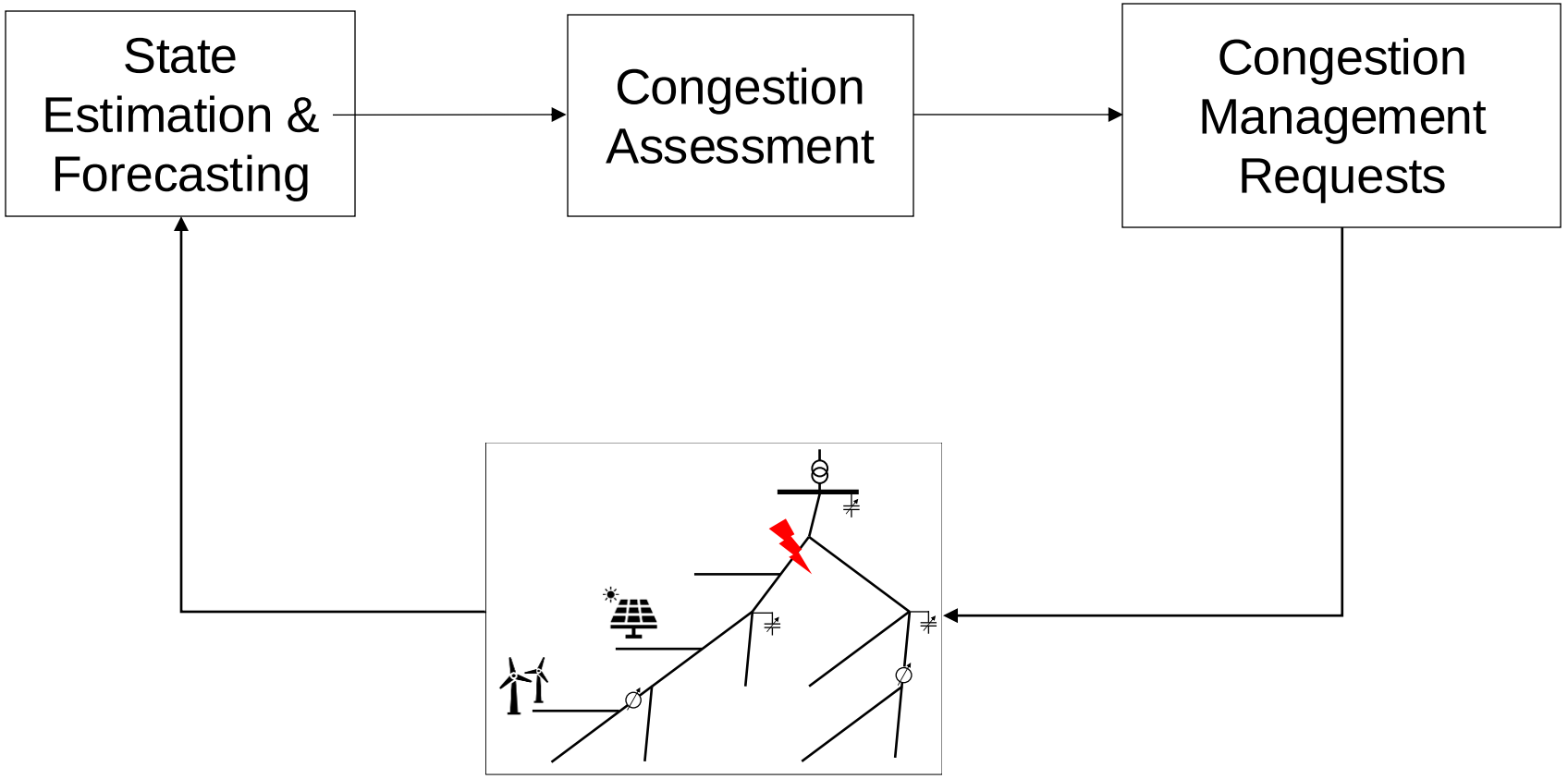
Increasing grid congestion

Main causes:
- Increased electrification
- Increased distributed generation
- Lagging grid investments (in some countries)

Potetial solutions:
- Grid expansion
- Congestion management

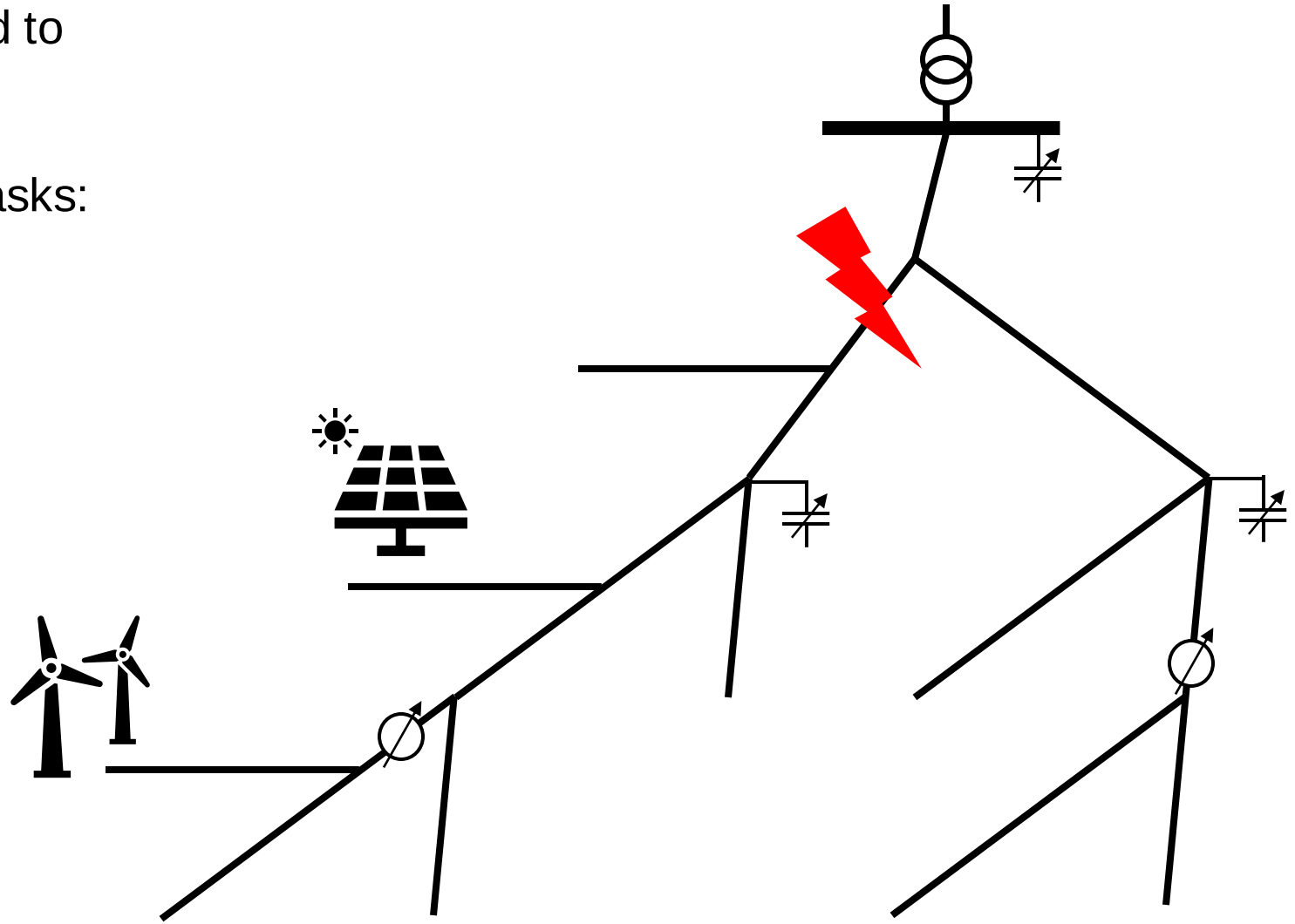


Simplified congestion management process

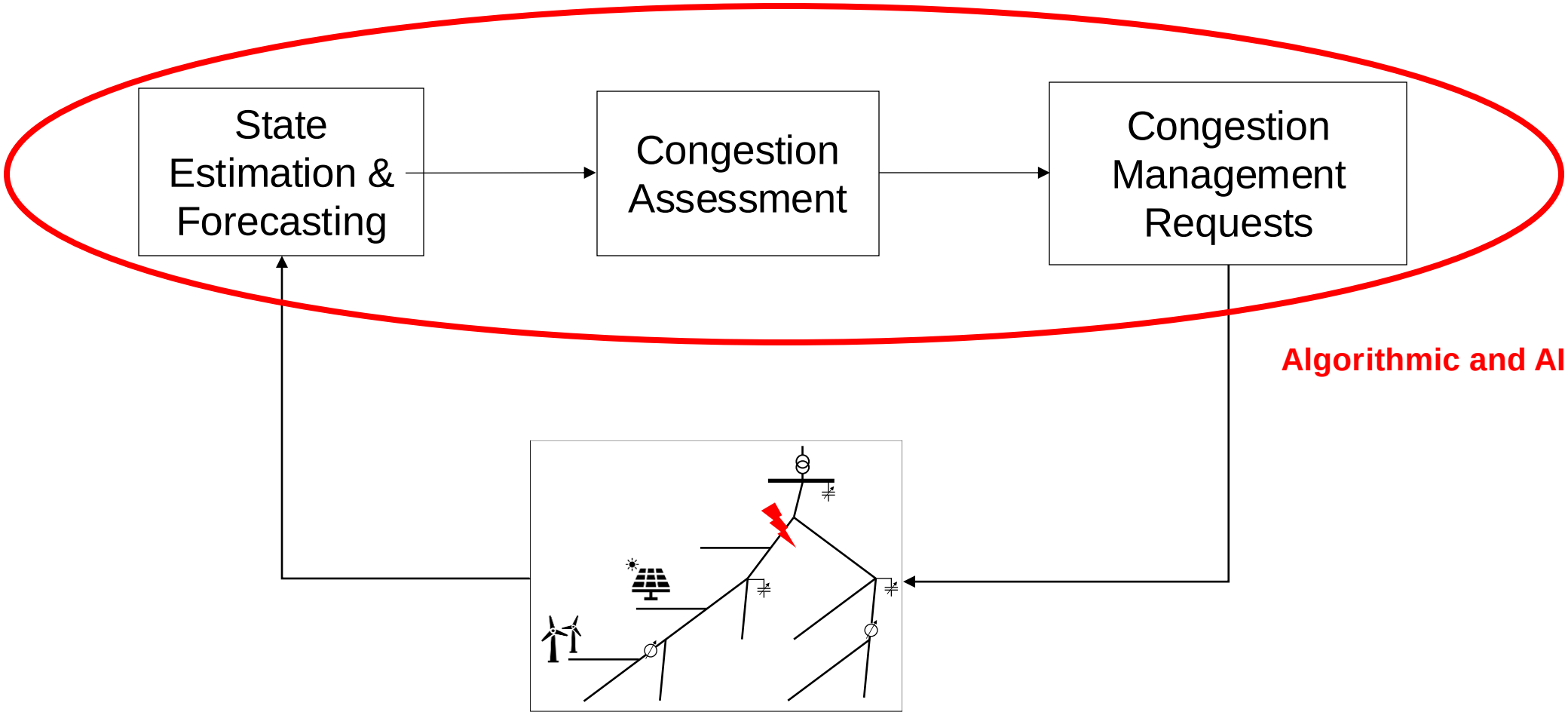


Congestion management has distributive effects

- Solar farm is asked to reduce production
- Solar farm owner asks: *”Why me?”*



Simplified congestion management process



Algorithmic and AI systems!

MIT News
ON CAMPUS AND AROUND THE WORLD

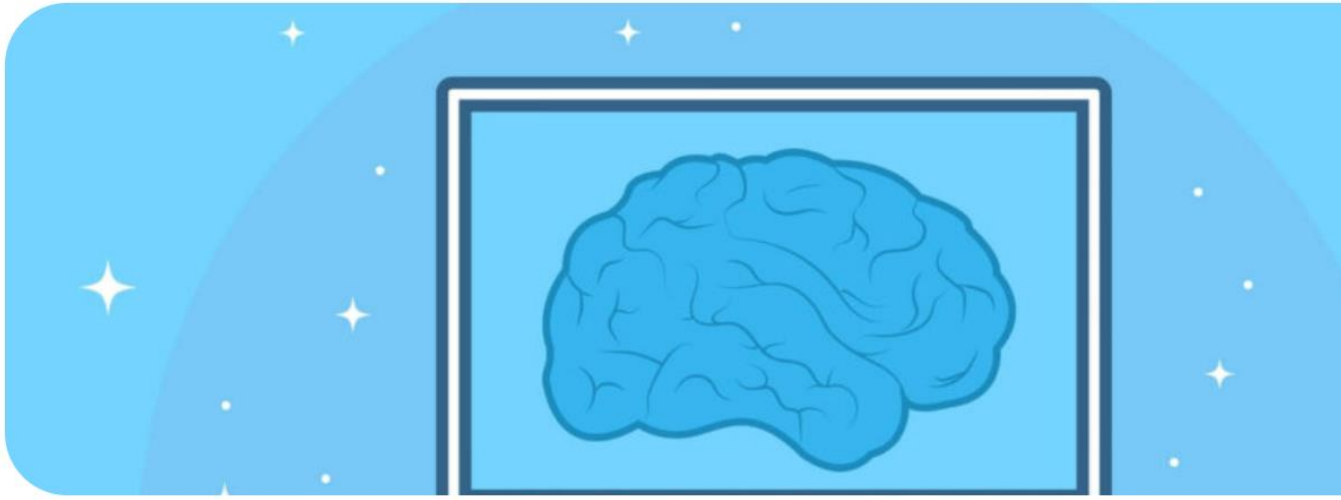
How machine-learning models can amplify inequities in medical diagnosis and treatment

MIT researchers investigate the causes of health care disparities among underrepresented groups.

Steve Nadis | MIT CSAIL
August 17, 2023

Volgsystemen

De rol van Artificial Intelligence-algoritmes bij de toeslagenaffaire



In de toeslagenaffaire werden naar schatting 26.000 ouders in Nederland slachtoffer van onterechte fraudeverdenkingen met de kinderopvangtoeslag en/of slachtoffer van een harde fraudeaanpak door de Belastingdienst. Wat was de rol van Artificial Intelligence (AI) hierbij?

Geautomatiseerd risicoselectiesysteem

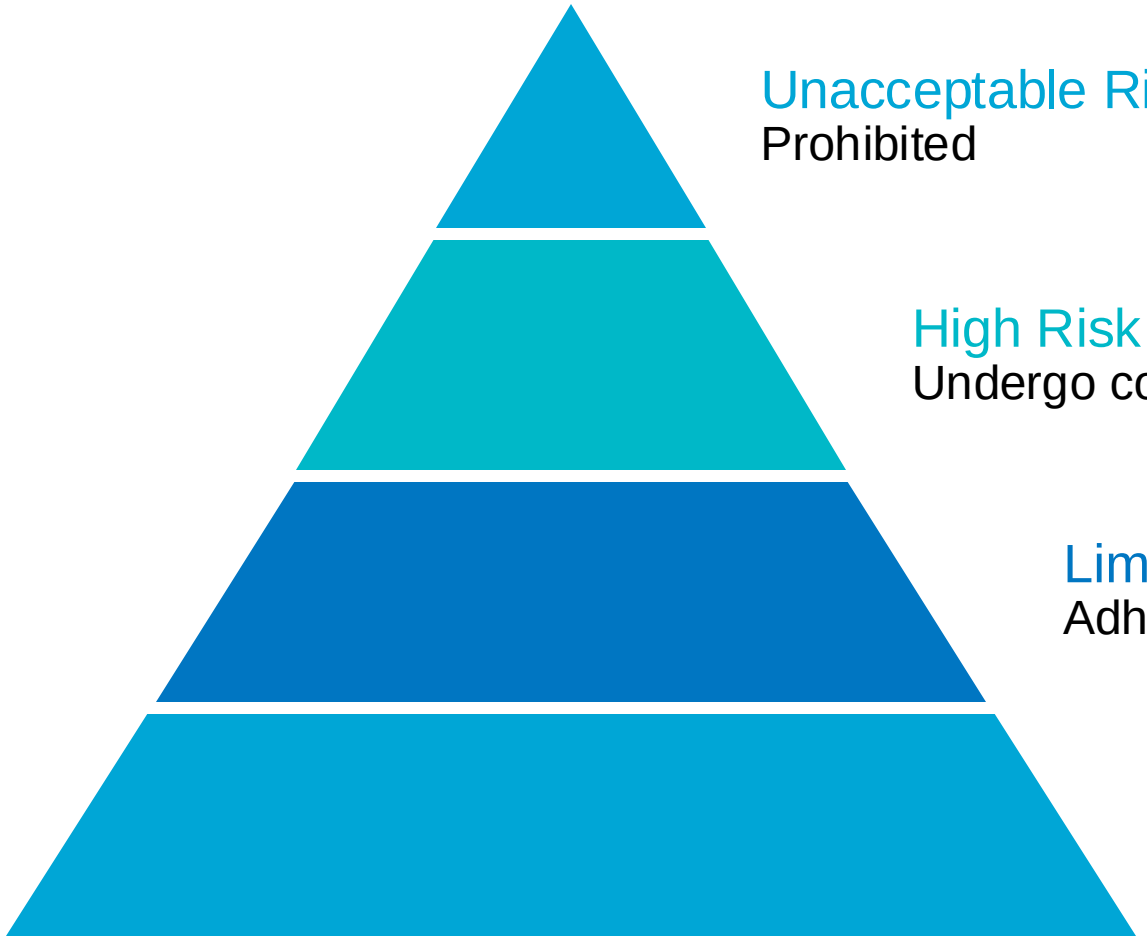
De Belastingdienst werkte in het geval van de toeslagenaffaire met een geautomatiseerd risicoselectiesysteem op basis van Artificial Intelligence (AI), dat bepaalde welke toeslagaanvragen extra gecontroleerd moesten worden. Hierbij was 'dubbele nationaliteit' bijvoorbeeld een van de selectiecriteria. Het resultaat was dat toeslagaanvragers met een tweede nationaliteit meer kans liepen om eruit gepikt te worden door het AI-algoritme.

Een gevaar van AI: data met bias

NEWS ARTICLE | 1 August 2024 | Directorate-General for Communication | 2 min read

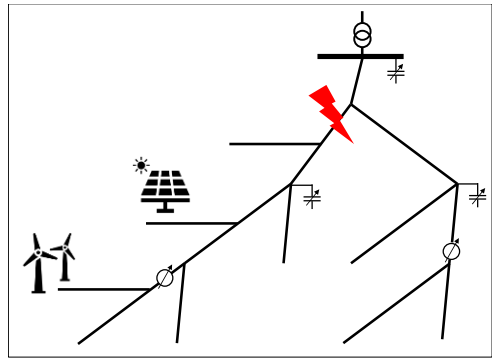
AI Act enters into force

EU AI Act: Risk Levels



Unacceptable Risk (e.g. social scoring by governments)
Prohibited

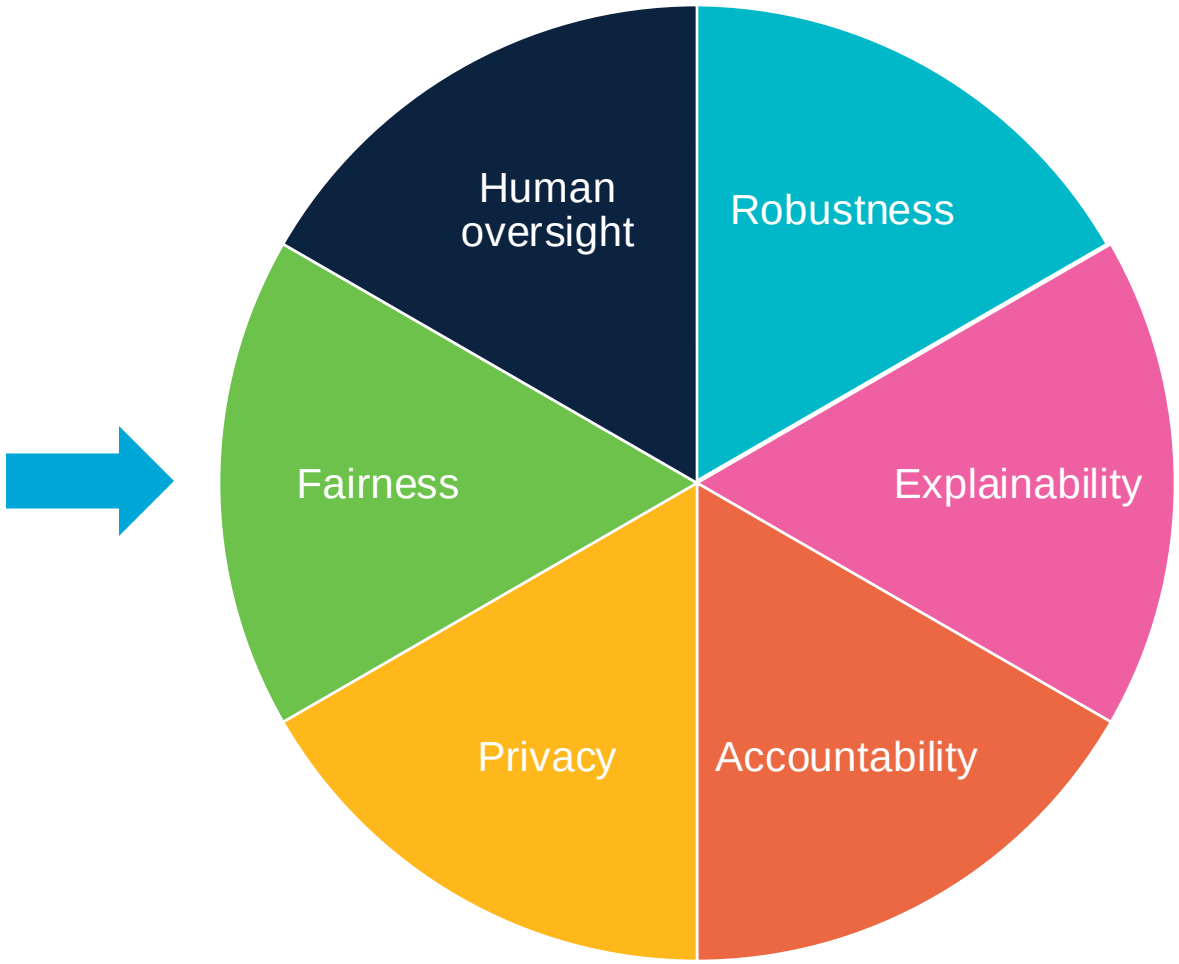
High Risk (e.g. critical infrastructure)
Undergo conformity assessments



Limited Risk (e.g. chatbots)
Adhere to transparency requirements

Minimal Risk (e.g. spamfilters, videogames)
No obligations

The Field of Responsible AI



02

Research Aim

Aim of my PhD research

My PhD research aims to study how distribution system operators can safeguard fairness for affected parties in their transition to active distribution grids, specifically with the increasing use of algorithmic and AI systems.

03

Ongoing Work

Project 1: Actors' Perceptions

What injustices do actors experience or anticipate with congestion management in the Netherlands?

- *Under review*

Emerging injustice perceptions in congestion management: Lessons from The Netherlands

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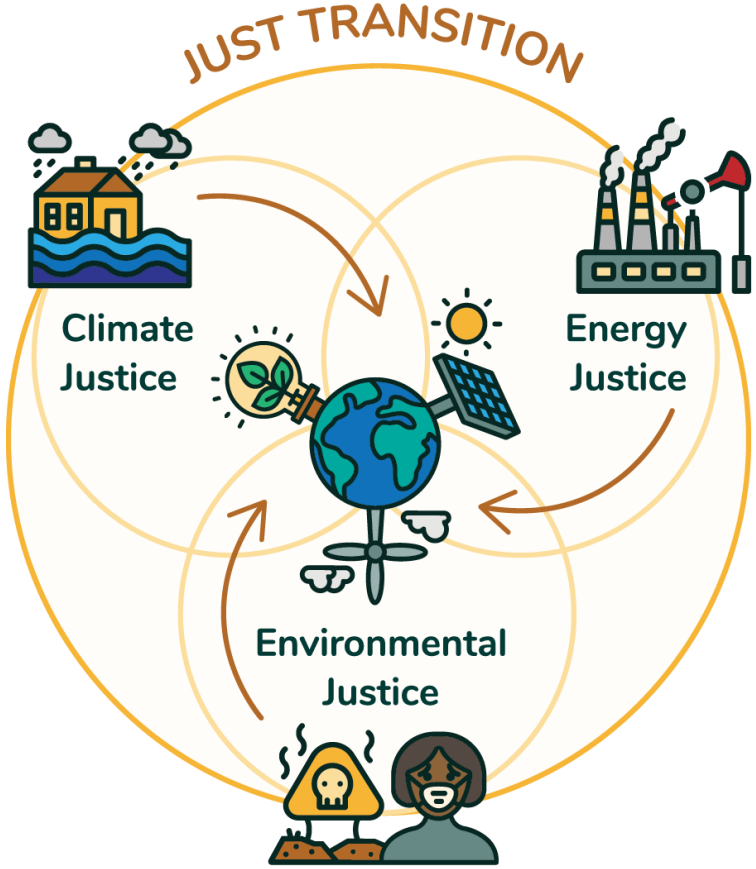
Abstract

As distributed renewable energy generation and electrification expand rapidly, electrical distribution grids face significant challenges with increasing grid congestion. Traditionally, distribution system operators have mitigated congestion through asset reinforcement, but constraints such as technician shortages, lengthy spatial procedures, and limited financing impede timely expansions. An alternative approach involves leveraging grid flexibility to shift loads, requiring active consumer and producer participation in what is known as congestion management.

Energy Justice

- **Triumvirate of tenets (McCauley, 2013):**
  - Distributive justice + Restorative justice
  - Procedural justice + Cosmopolitan justice
  - Recognition justice

- **Applied principles (Sovacool, 2015):**
  - Availability
  - Affordability
  - Due process
  - Transparency
  - Accountability
  - Sustainability
  - Intra & Intergenerational equity
  - Responsibility

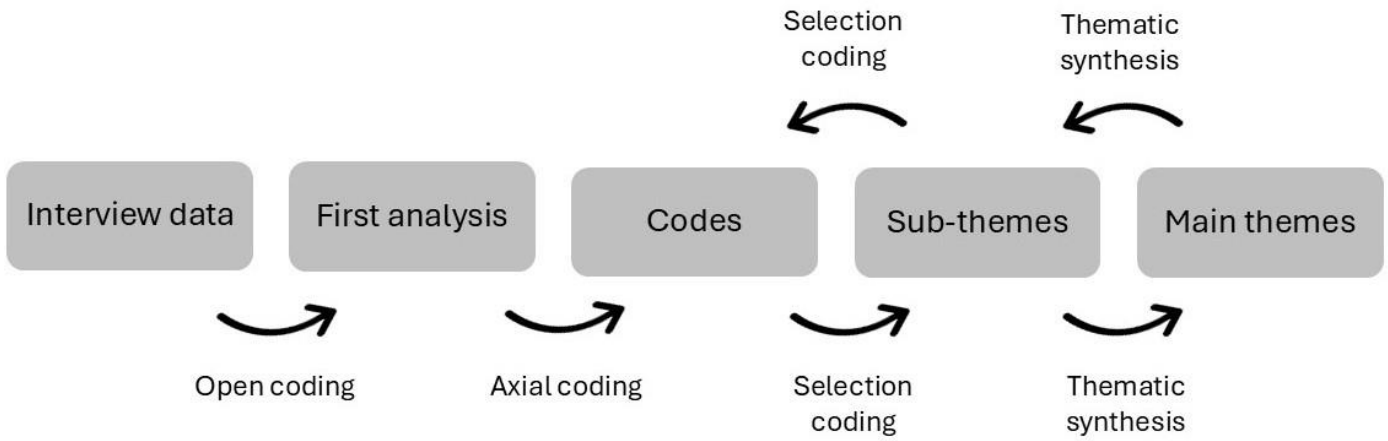


Source: The Energy Justice Workbook

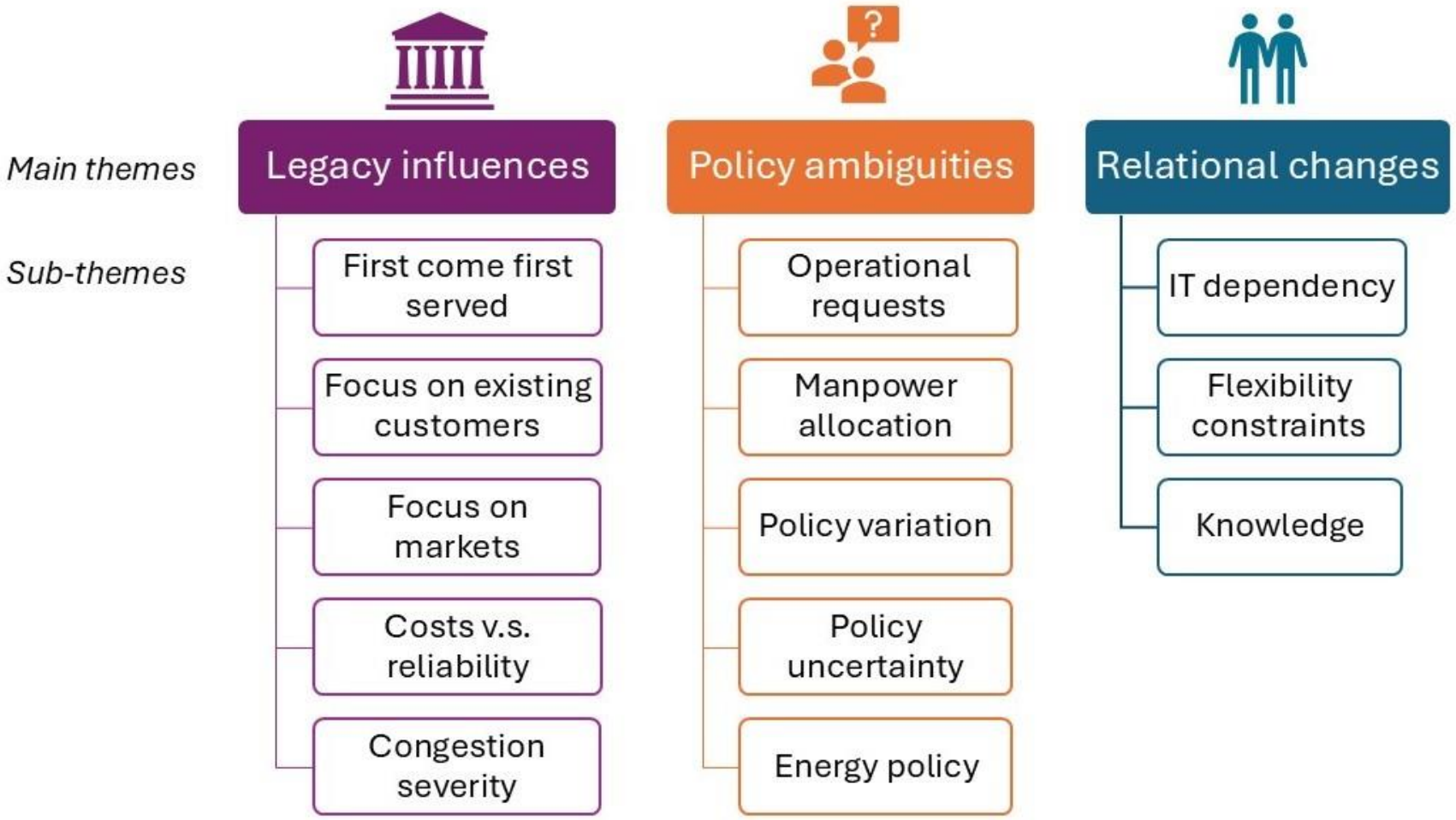
Methodology

Semi-structured interviews:

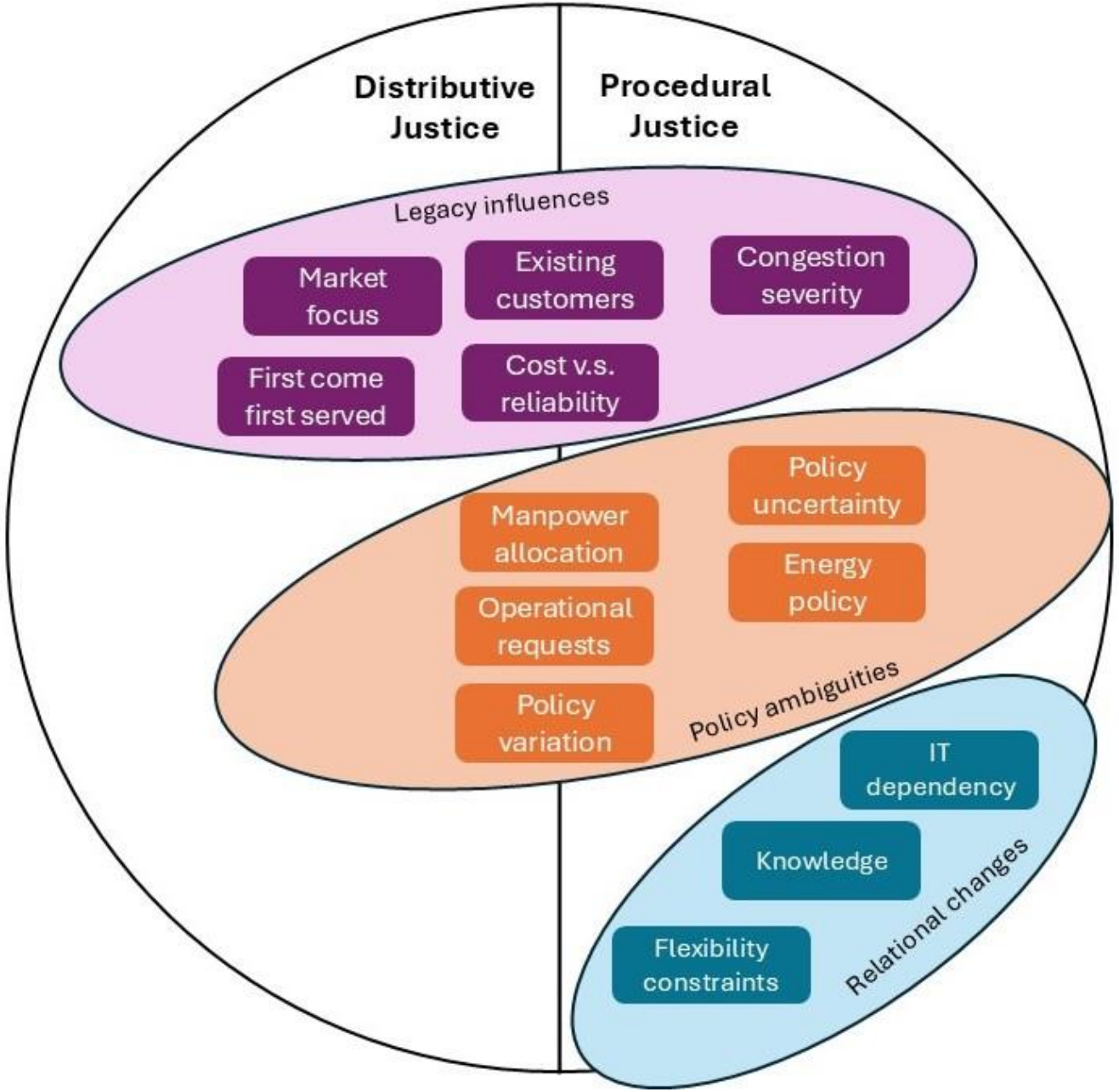
- System operators
- Clients on waiting list
- Clients providing congestion management
- Grid operator associations
- Trade associations
- Research institutes
- Non-profit organizations
- National government



Main Findings



Discussion


Distributive Justice
Procedural Justice
Legacy influences
Market focus
Existing customers
Congestion severity
First come first served
Cost v.s. reliability
Policy uncertainty
Manpower allocation
Energy policy
Operational requests
Policy variation
Policy ambiguities
IT dependency
Knowledge
Flexibility constraints
Relational changes

Conclusion

Grid congestion is a *socio-technical* problem:

Technology

Actors

Institutions

Policy recommendations:

Revising legacy law and policies

Reconsidering fundamental trade-offs

Improving information provision

Integrating justice in IT systems

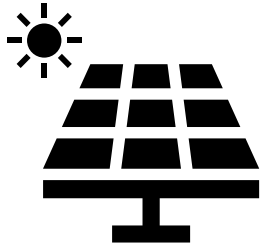
Project 2: Literature Review

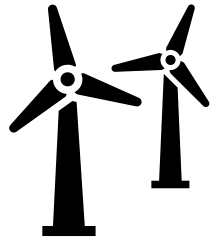
What normative assumptions underly the variation of fairness concepts used in congestion management literature?

- *Conference paper presented at ISGT*

The literature uses different fairness definitions

Required curtailment: 1 MW

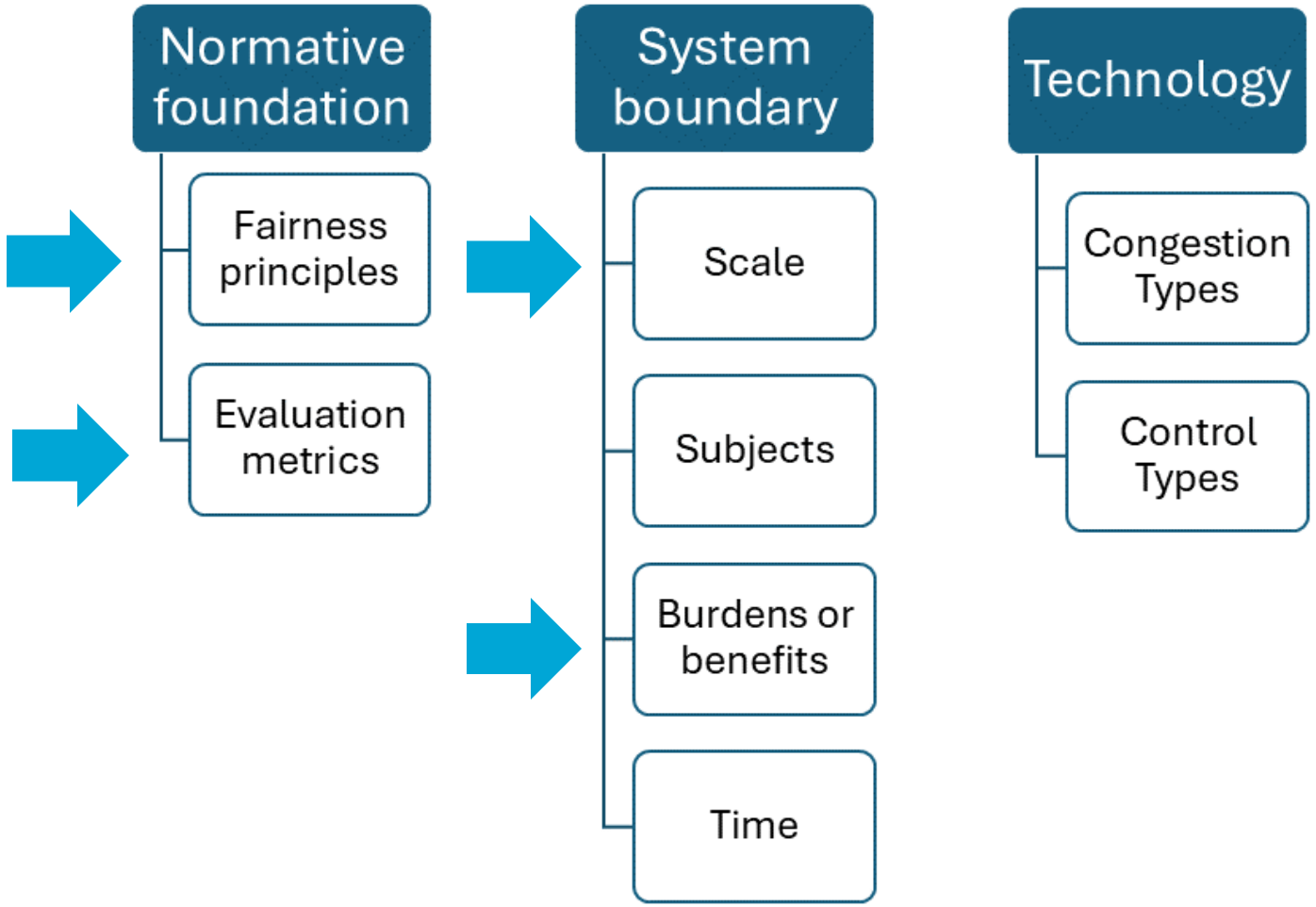




Installed capacity:	2 MW	20 MW
1. Equal curtailment:	0.5 MW	0.5 MW
2. Proportional to installed capacity:	0.09 MW	0.91 MW

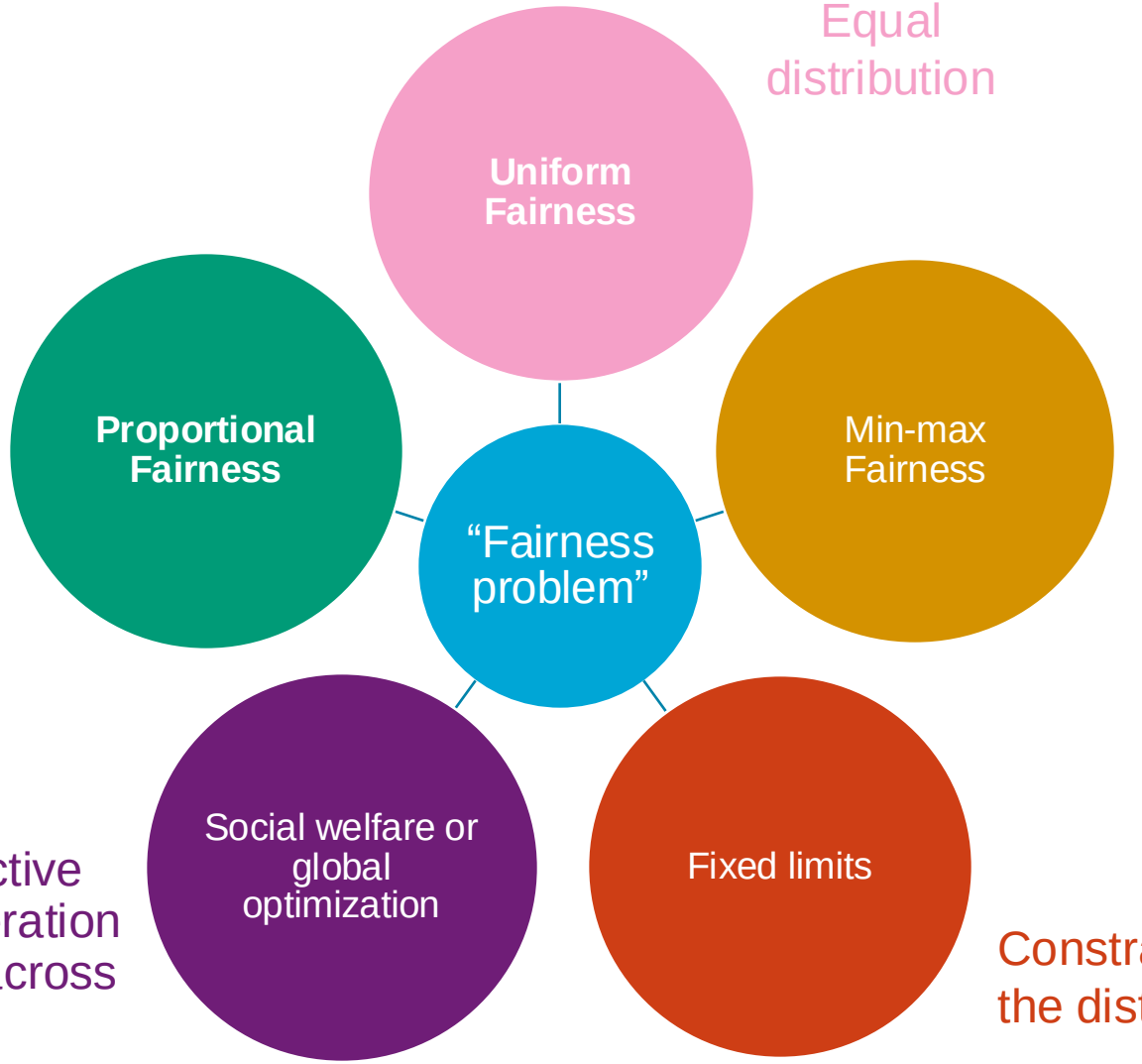
And many more!

Findings – Normative Assumptions



Normative foundation

Five main categories of fairness principles



Equal distribution

Distribution based on parties' properties

Minimize the maximum burden or benefit among parties

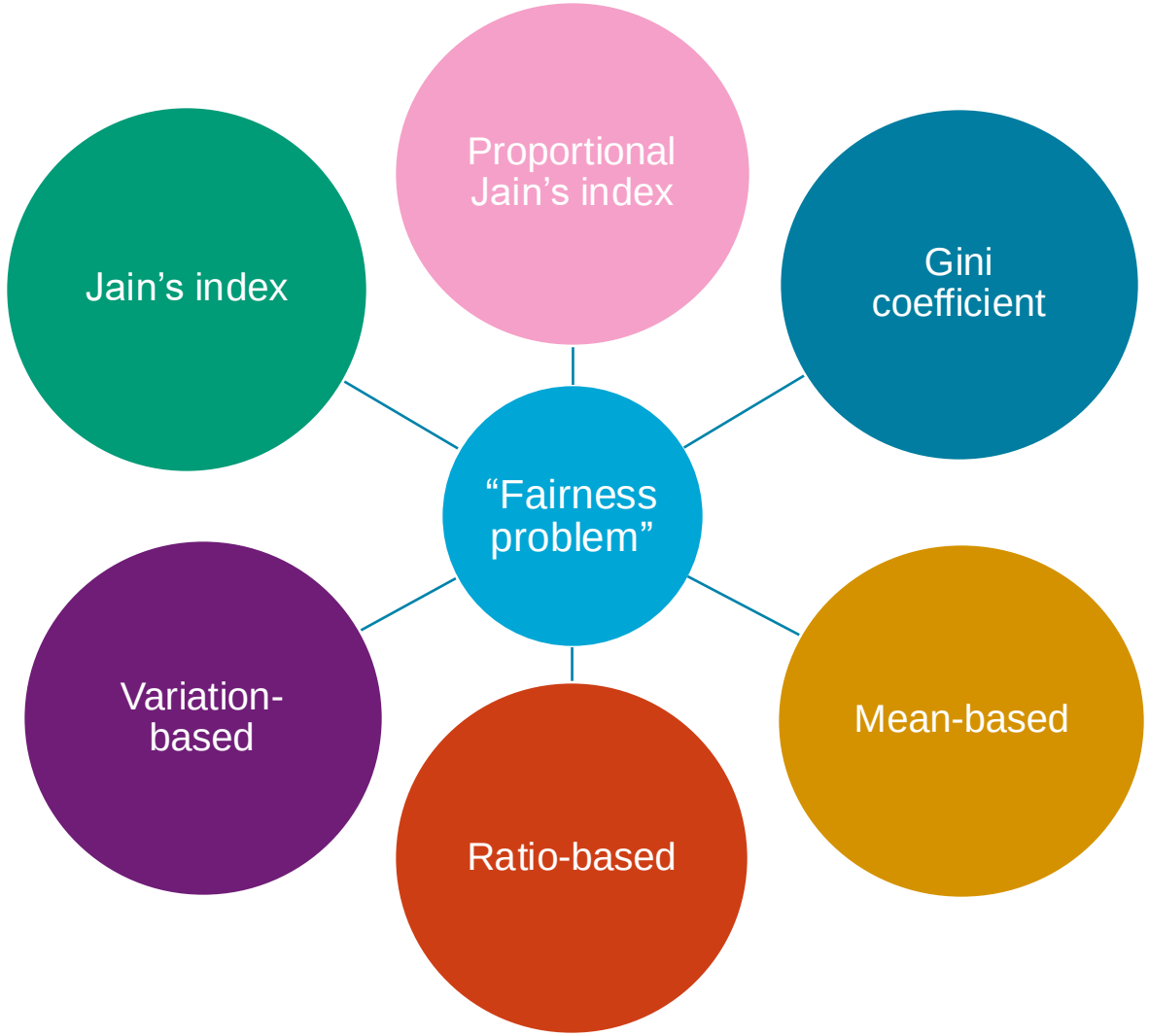
A global objective without consideration of differences across groups

Constraints on the distribution

Normative foundation

Six main categories of evaluation metrics

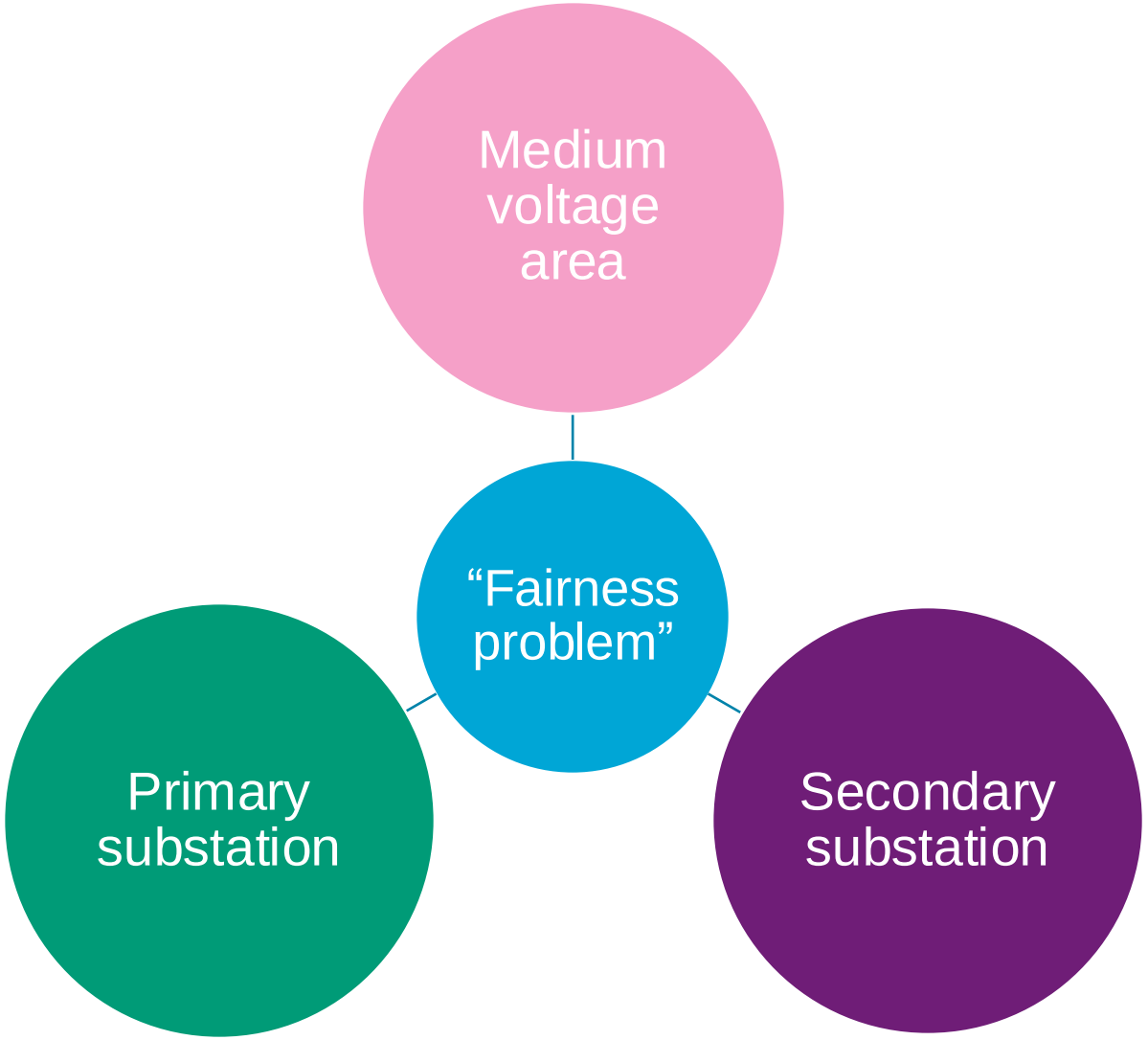
$$JI = \frac{\left(\sum_{n \in N} u_n\right)^2}{|N| \cdot \sum_{n \in N} u_n^2}$$



$$G = \frac{\sum_{i=1}^{|N|} \sum_{j=1}^{|N|} |u_i - u_j|}{2 \cdot |N| \cdot \sum_{n \in N} u_n}$$

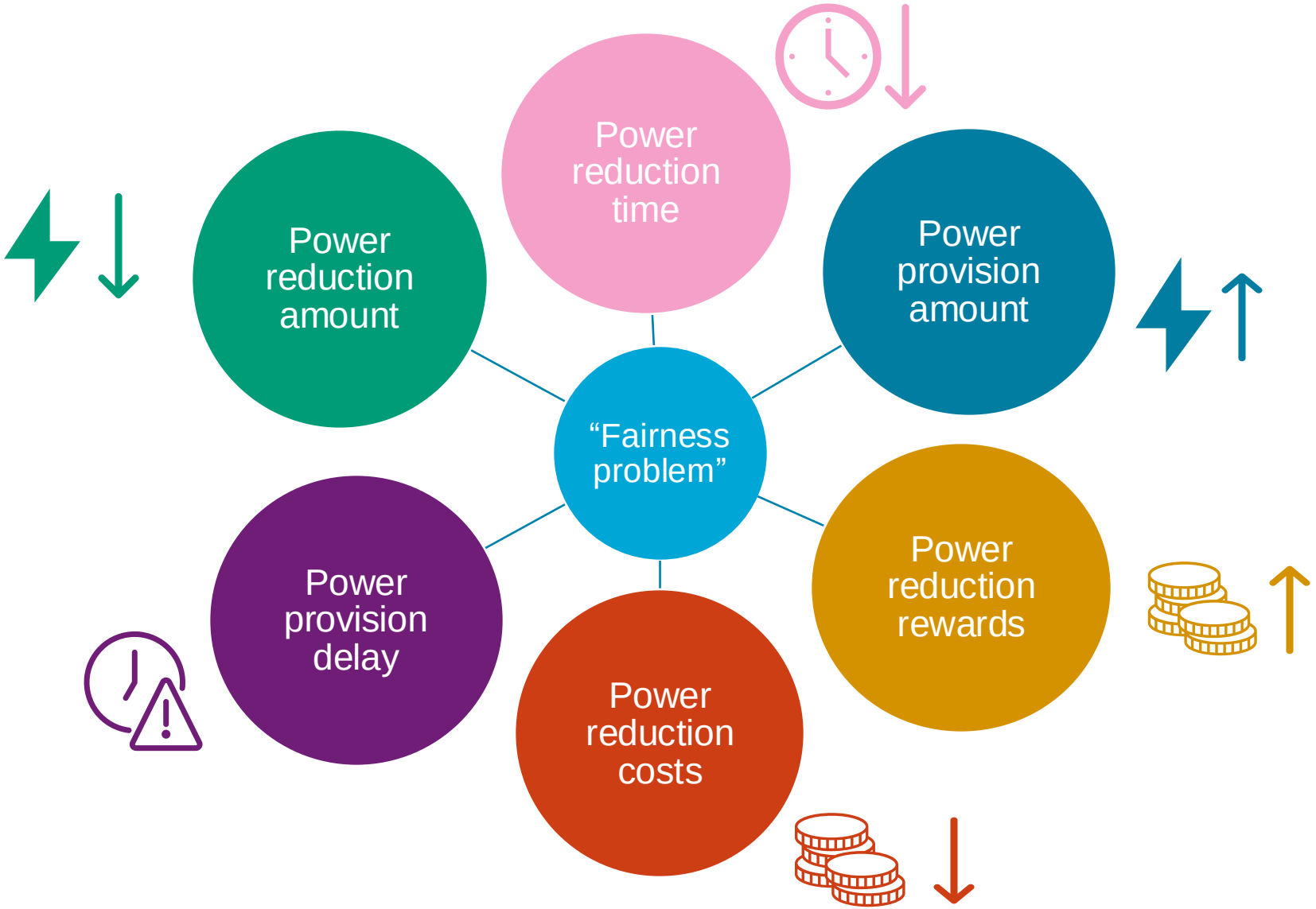
System boundary

Three main categories of scale

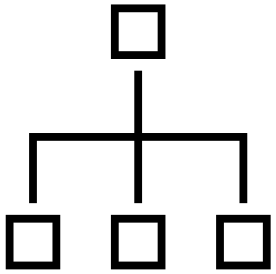


System boundary

Six main categories of burdens and benefits

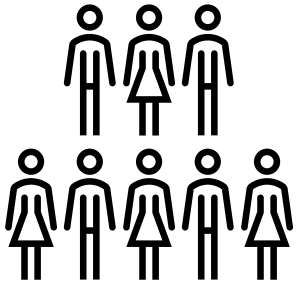


Research agenda

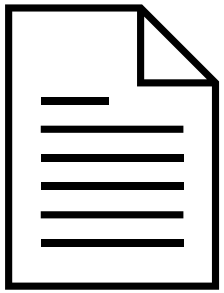


System level?

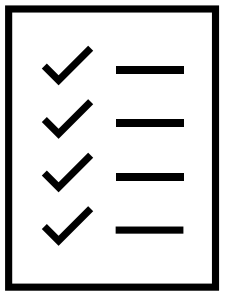
Performance indicators?



Empirical studies?



Reporting?



Verification?

04

Questions and Discussion

Thank you!

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13-3-2025