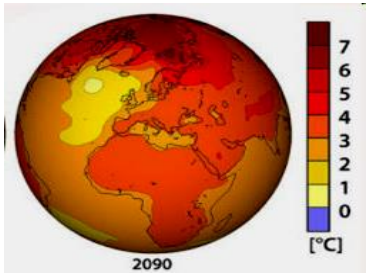
Awareness about the relevance of cascading effects in urban critical infrastructure networks under climate change – a participatory impact matrix approach

Markus Groth, Steffen Bender, Peer Seipold, Elisabeth Viktor

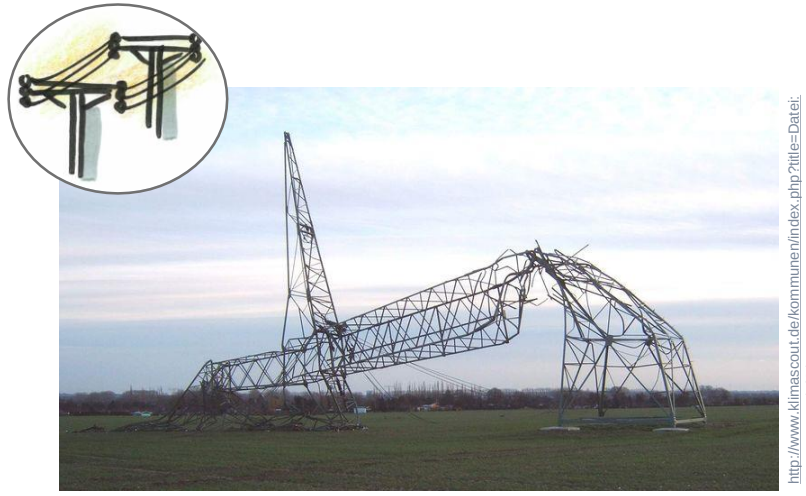




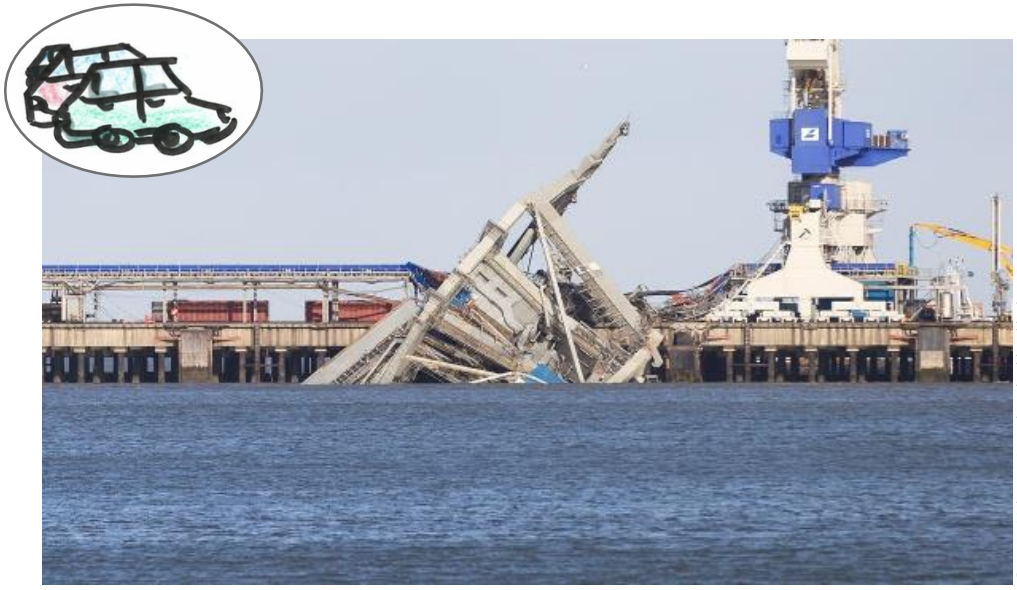

(Quellen: fotolia, GERICS)

Impacts of extrem weather events on critical infrastructure

http://news-dig.de/sturm-orkan-xavier-in-berlin-oktober-2017-folgen-video-foto/



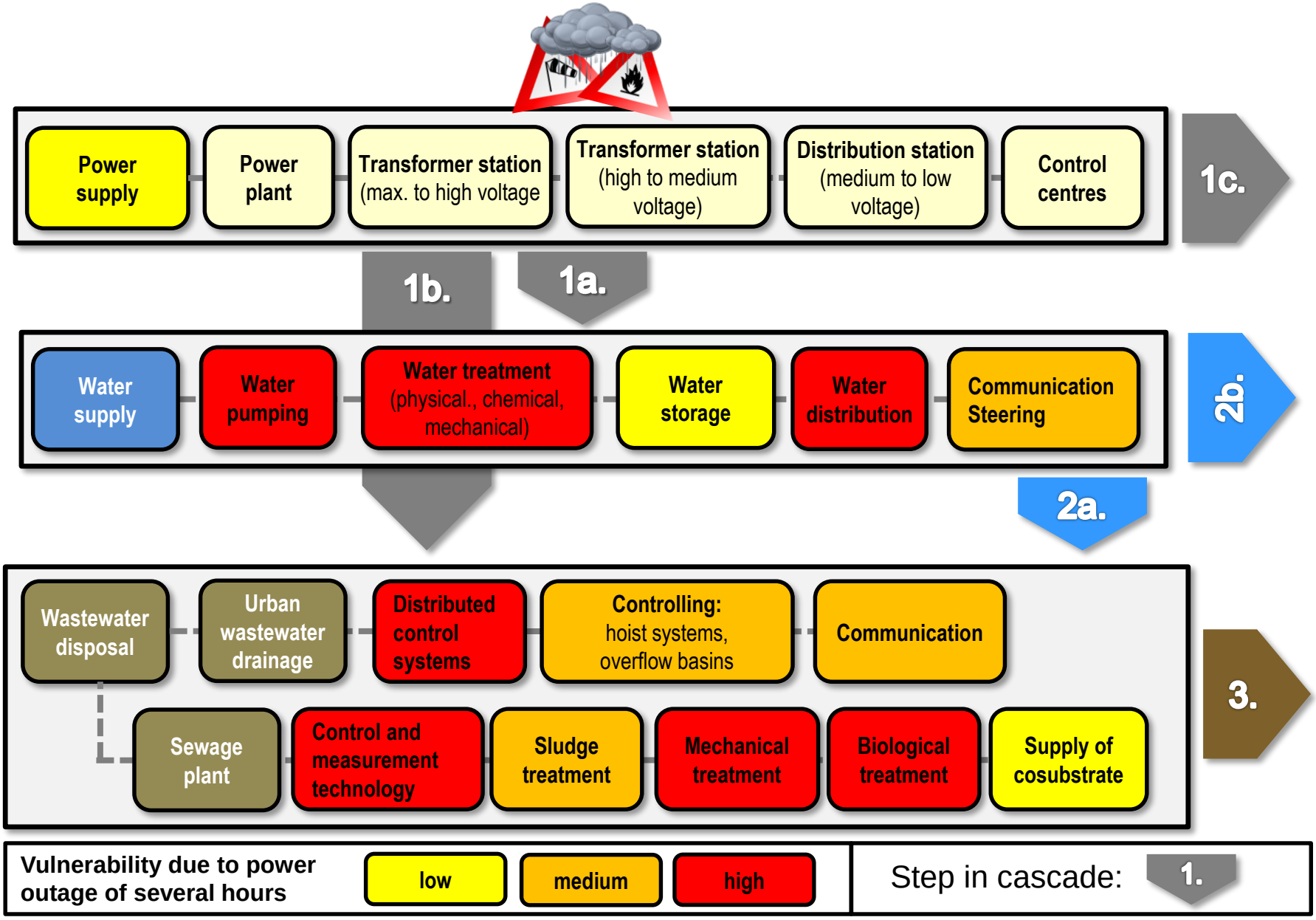
http://www.klimascout.de/kommunen/index.php?title=Datei:Strommast_olaf2.jpg



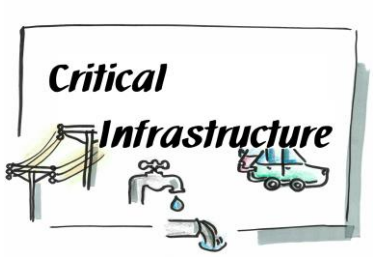
Source: Mohssen Assanimoghaddam/dpa)
https://www.t-online.de/nachrichten/panorama/id_82397488/toedlicher-orkan-xavier-wuetet-ueber-deutschland.html

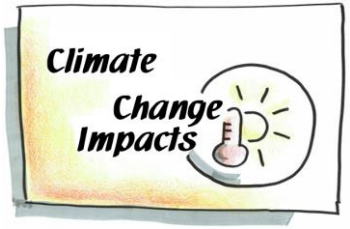
http://www.trp1.de/hochwasserschutz-1uer-trinkwasserversorgung/
https://www.passau.de/Aktuelles/Pressearchiv.aspx?rssid=36f2e42c-8db9-42fa-8a11-f7a38a1eb243

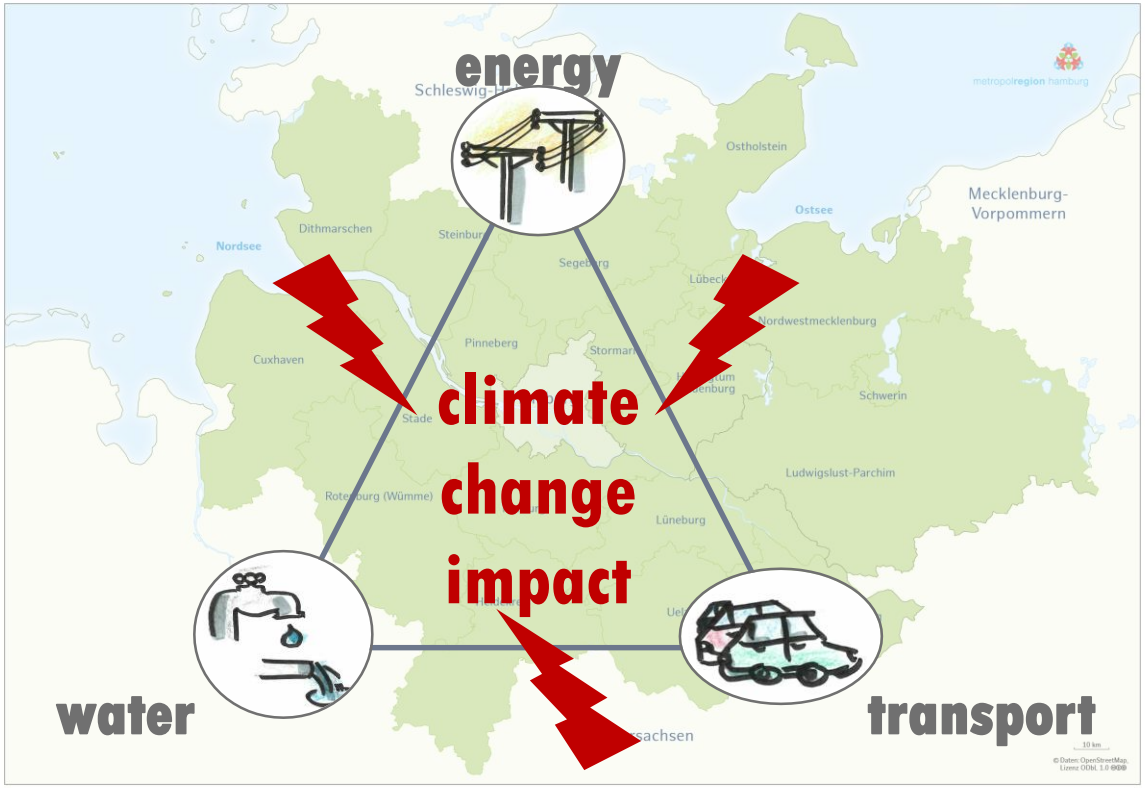
Climate change, critical infrastructure and cascading effects



Case-study: effects of climate change on critical infrastructure

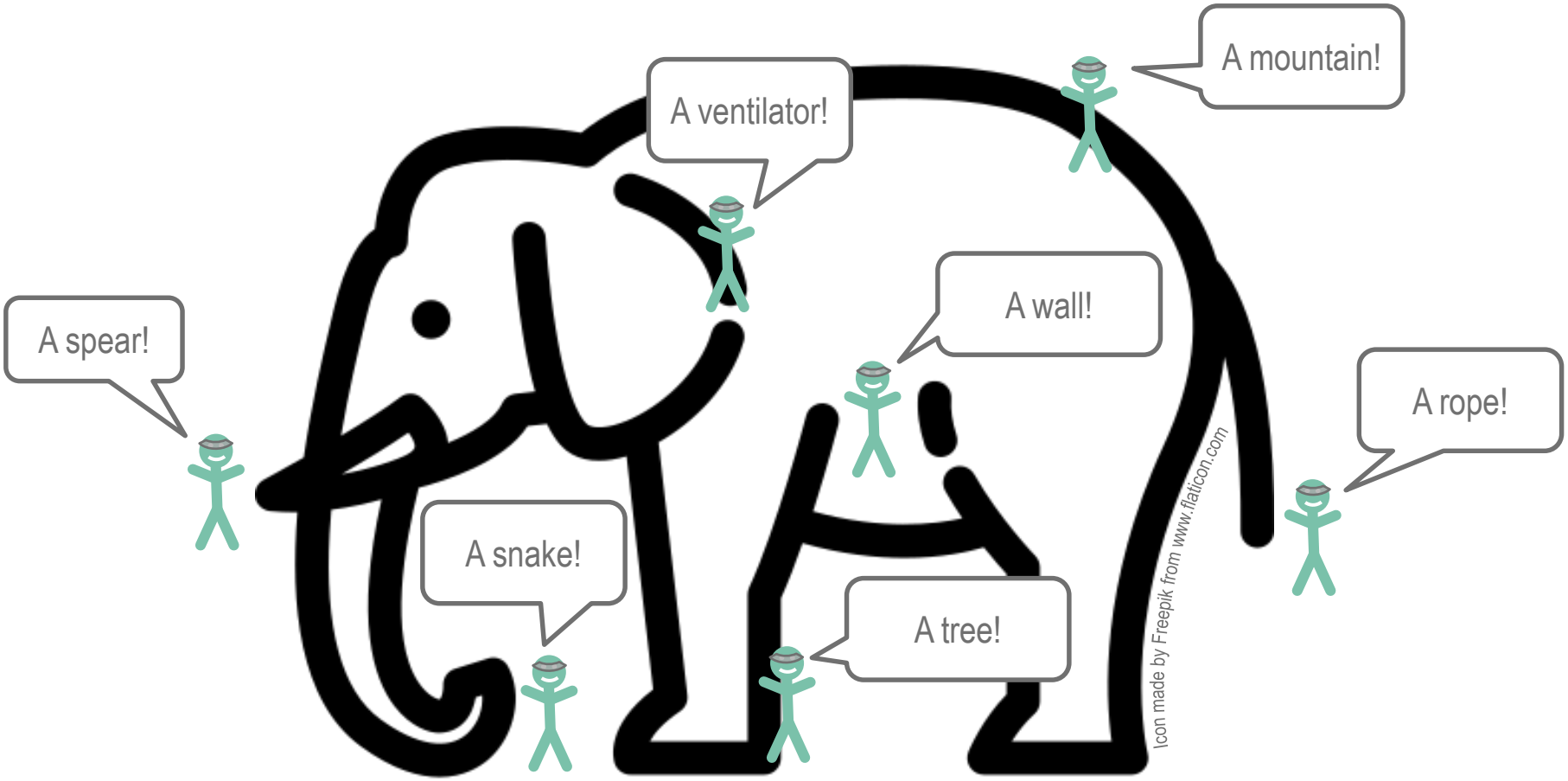






- Identification of key variables for cascading effects, regarding the infrastructure for energy, water and transport in the metropolitan area of Hamburg (Germany), caused by impacts of climate change.
- Based on the transdisciplinary interaction with expert stakeholders.

System thinking



Stakeholder Analysis

25

Stakeholders contacted

13

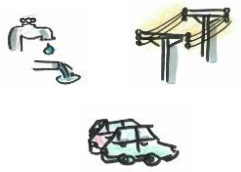
Interviews

10	7	1	7
8	2	1	2

Overall interview topics

Organisation and core business

Loss experience due to (extreme) weather events



Organisation‘s tasks regarding critical infrastructure

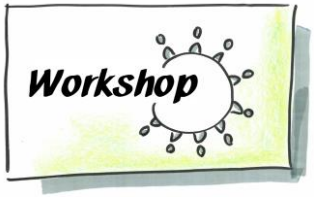
Indirect damages and cascading effects

Risk management (extreme weather, gradual changes)

Connections with and interdependencies from other sectors

Adaptation

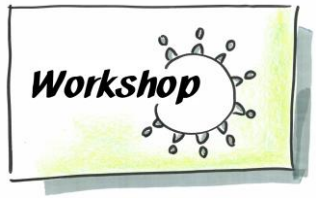
Stakeholder Workshop // Most relevant variables



Variables chosen by the participants (3 variables per person) to be the most relevant for their work based on all variables mentioned in the interviews

- Share of electric vehicles (2x)	- Road/railway capacity	- Grid stability (4x)
- Specialists	- Road capacity (2x)	- Precipitation (2x)
- European Network of Transmission System Operators for Electricity (ENTSO-E)	- Communication	- Provision of public services
	- Types of mobility	- Volatility of renewable energy (2x)
- Regulation (e.g. EEG) (2x)	- Grid expansion	- Wind speed (2x)
- Flood risk	- Network load	- Maintenance (2x)

Stakeholder Workshop // Impact matrix



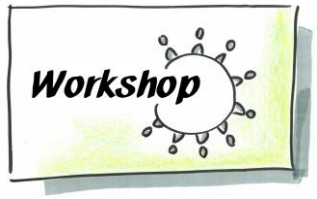
- Direction of impact (x influencing y, or y influencing x)
- Strength of relationship:
  - 0: No relationship
  - 1: Weak relationship
  - 2: Medium relationship, proportional
  - 3: Strong relationship, disproportionate

Impact of ↓ on →	Influencing factor A	Influencing factor B	Influencing factor C	Influencing factor D
Influencing factor A		1	1	…
Influencing factor B	2		…	2
Influencing factor C	…	0		…
Influencing factor D	3	…	…	

Impact Matrix = basis to define roles of individual influencing factors

Source: Vester (2003)

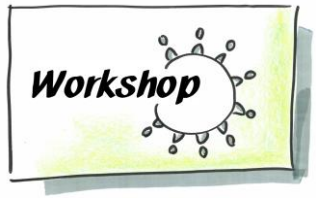
Stakeholder Workshop // Impact matrices



Impact matrix of the "blue" group, mostly representing experts of municipal companies

Impact by ↓ on →	Road/railway capacity	Wind speed	Grid stability	Provision of public services	Precipitation	Maintenance	Share of electric vehicles	Volatility of renewable energy	European transmission network
Road/railway capacity		0	0	2	0	2	0	0	0
Wind speed	3		2	2	0	2	0	3	2
Grid stability	3	0		3	0	2	2	1	2
Public services	2	0	2		2	2	2	0	1
Precipitation	2	0	1	0		2	0	0	0
Maintenance	3	0	3	2	0		2	1	2
Share of electric vehicles	2	0	2	1	0	2		0	1
Volatility of ren. energy	0	0	3	3	0	2	0		3
European transmission	0	0	3	3	0	2	0	2	

Stakeholder Workshop // Impact matrices

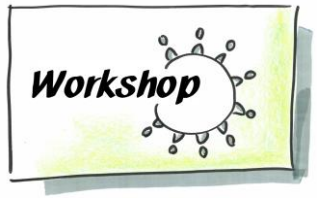


Impact matrix of the “yellow" group, mostly representing experts from the private sector

Impact by ↓ on →	Share of electric vehicles	Network load	Grid expansion	Flood risk	Grid stability	Road capacity	Maintenance	Precipitation
Share of electric vehicles		2	2	0	2	0-1	0-1	0
Network load	-2*		0-1	0	-3	0	0	0
Grid expansion	3	-2		0	3	0-1**	0	0
Flood risk	0	0	0		0*	0-1	0	0
Grid stability	0	0	0	0		0	0	0
Road capacity	0	0	0	0	0		0	0
Maintenance	0	0	0	0	0	1		0
Precipitation	0	0	0	0-1	0	-2	1	

*load too high → less electric vehicles; **number of vehicles exchanged by same number of electric vehicles.

Stakeholder Workshop // Impact matrices

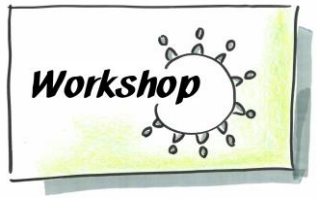


Impact matrix of the “green" group, mostly representing experts from the areas of administration and associations

Impact by ↓ on →	Grid stability	Communication	Wind speed	Regulation (e.g. EEG)	Volatility of renewable energy	Specialists	Types of mobility
Grid stability*		3	0	1	0	3/1	3
Communication**	3		0	0	0	3/2	3/2
Wind speed	2	1		1	3[1]	0	2
Regulation (e.g. EEG)	3	2	0		0	2	2
Volatility of renewable energy	3	1	2	2		1	2
Specialists***	3	2	0	2	0		2
Types of mobility****	2	2	0	1	0	3/1	

The fields with two numbers (distinguished with /) first show the intensity of impact during a crisis situation and secondly in a normal situation. *electricity/heat/transport; **using technological devices; ***not just general availability, but also availability at the right time at the right place; ****in a crisis situation, without electricity grid. 1 no sun, no wind (“Dunkelflaute”).

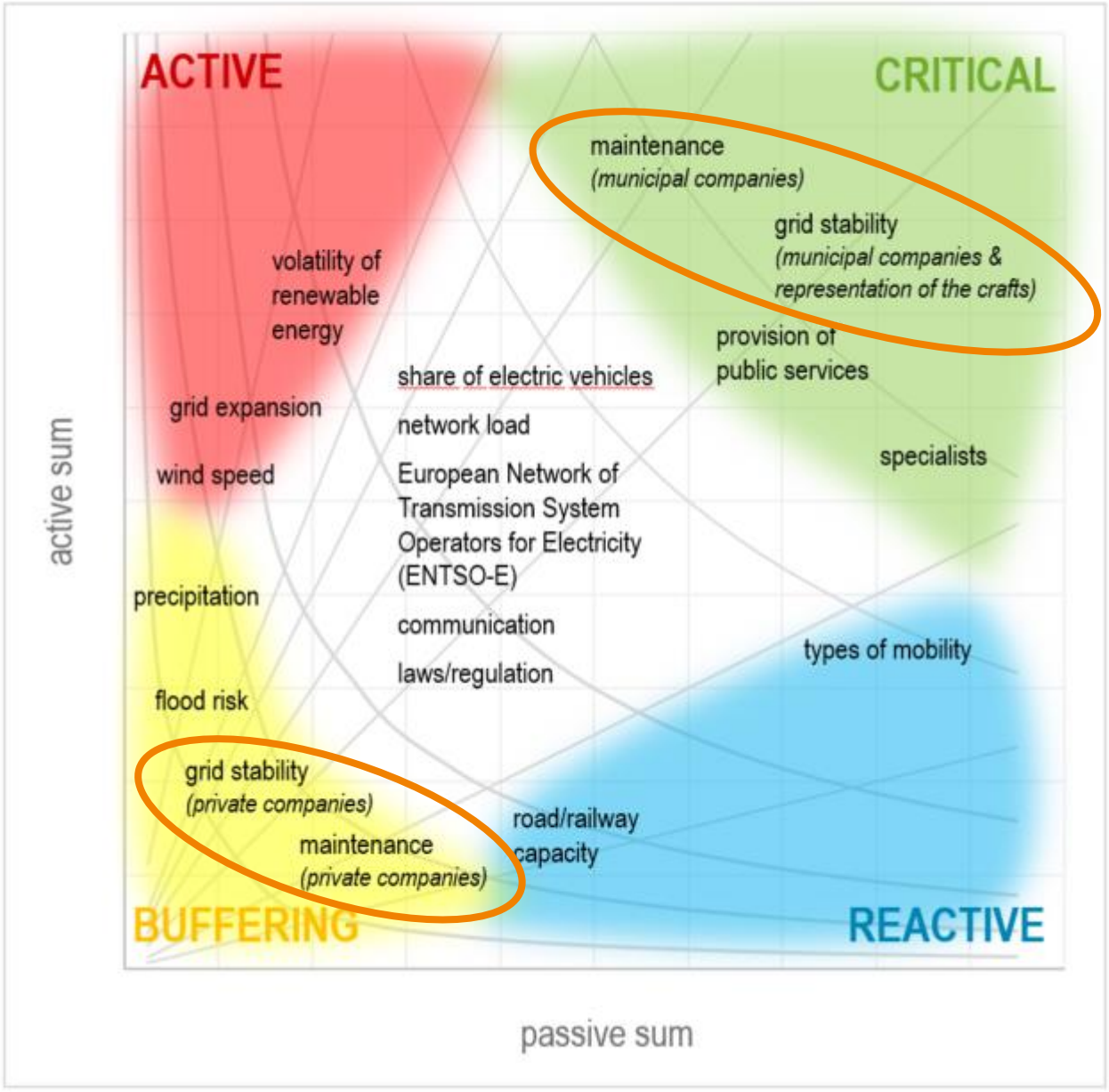
Stakeholder Workshop // Summarizing impact matrix



Impact by ↓ on →	Grid stability	Share of electric vehicles	European transmission grid	Specialists	Regulation (e.g. EEG)	Flood risk	Maintenance	Railway capacity	Road capacity	Communication	Types of mobility	Grid expansion	Network load	Precipitation	Public services	Volatility of ren. Energy	Wind speed	Active sum
Grid stability		0/2	2	2	1	0	0/2	3	0/3	3	3	0	0	0	3	0/1	0	7-11
Share of electric vehicles	2		1	-	-	0	1/2	2	1/2	-	-	2	2	0	1	-/0	-/0	8
European transmission grid	3	0		-	-	-	2	0	0	-	-	-	-	0	3	2	0	4
Specialists	3	-	-		2	-	-	-	-	2	2	-	-	-	-	0	0	4
Regulation (e.g. EEG)	3	-	-	2		-	-	-	-	2	2	-	-	-	-	0	0	4
Flood risk	0	0	-	-	-		0	-	1	-	-	0	0	0	-	-	-	1
Maintenance	0/3	0/2	2	-	-	0		3	1/3	-	-	0	0	0	2	-/1	-/0	4-7
Railway capacity	0	0	0	-	-	-	2			-	-	-	-	0	2	0	0	2
Road capacity	0	0	0	-	-	0	0/2			-	-	0	0	0	2	-/0	-/0	1-2
Communication	3	-	-	2	0	-	-	-	-		2	-	-	-	-	0	0	3
Types of mobility	2	-	-	2	1	-	-	-	-	2		-	-	-	-	0	0	4
Grid expansion	3	3	-	-	-	0	0	-	1	-	-		2	0	-	-	-	4
Network load	3	2	-	-	-	0	0	-	0	-	-	1		0	-	-	-	3
Precipitation	0/1	0	0	-	-	1	1/2	2	2	-	-	0	0		0	-/0	-/0	4-5
Public services	2	2	1	-	-	-	2	2	2	-	-	-	-	2		0	0	7
Volatility of ren. energy	3	-/0	3	1	2	-	2	0	-/0	1	2	-	-	-/0	3		-/0	8
Wind speed	2	-/0	2	0	1	-	-/2	3	-/3	1	2	-	-	-/0	2	3		8-10
Passiv sum	**11-13**	**3-5**	**6**	**5**	**6**	**1**	**6-9**	**6**	**6-8**	**6**	**6**	**2**	**2**	**1**	**8**	**2-4**	**0**	

Mentioned one-time
Mentioned two-times
Mentioned three-times

Roles of different variables in the system



Active Variables

the cause of many effects in the system, only slightly impacted by anything in the system.

Reactive Variables

strongly impacted by the system, have only very little impact on the system.

Critical Variables

many interconnections within the system.

Buffering Variables

only impacting the system marginally and only impacted by the system in a minor way.

Neutral Variables

work well to self-regulate the system.

Source: Vester (1991; 2003)

Conclusion

- Both the interviews as well as the workshop provided valuable insights regarding the specific practical relevance of cascading effects for the sectors energy, water and transport.
- Grid stability is the only variable mentioned in every group.
- Different assessments regarding specific variables -> e.g. grid stability and maintenance:
  - “Blue” group (municipal companies): often responsible for maintenance and grid stability; estimate both as crucial elements of a functioning critical infrastructure and therefore impacting many other variables strongly.
  - “Yellow” group (private sector): consumers/user of a solid grid stability and well maintained critical infrastructure, without experiencing main interruption so far; estimating the impact on other variables of the system as week or not existing.
- Case-study as a promising starting point for a further integration of stakeholders addressing the growing need to better understand and manage systemic climate change risks regarding critical infrastructures and cascading effects in urban areas.

Stakeholders' reactions

„Loss experience due to extreme weather events can provide arguments to strengthen our adaptation policy."

Environmental agency

„Those kinds of things are super interesting for us. We're happy that someone is looking into all these interdependencies."

Public utility company

„Adaptation to climate change is a relatively new topic for the sector."

Local public transport association

The quotes are idiomatic translations of the original statements in German.

Kontakt:

Dr. Markus Groth

Climate Service Center Germany (GERICS)
Fischertwiete 1, 20095 Hamburg
Email: Markus.Groth@hereon.de

http://www.climate-service-center.de