



Grid of the Future 2022



Resilience of Power Grids to Catastrophic Cascading Failures

(With an example application of NetResilience to the Brazilian Interconnection)

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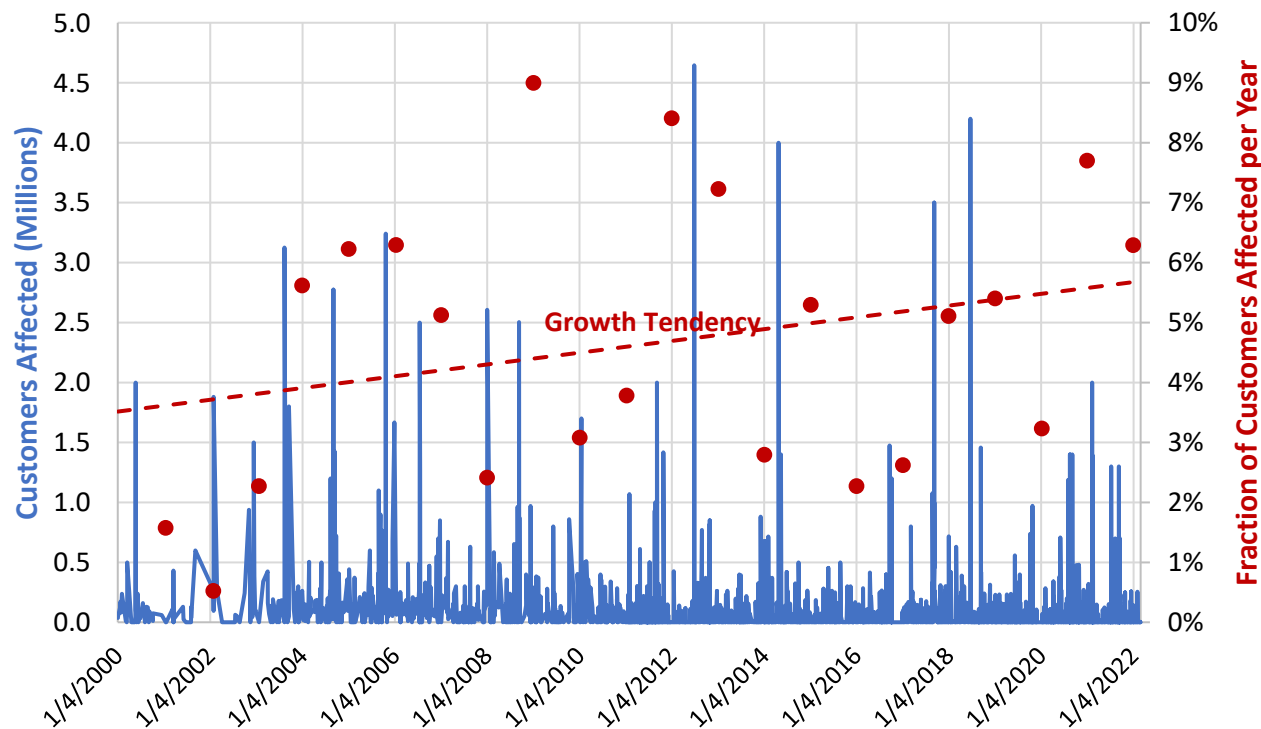
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Purpose: Power System Resilience

Power Outages, USA, 2000-2022



Source: DOE (https://www.oel.netl.doe.gov/OE417_annual_summary.aspx)

Technology advances provide:

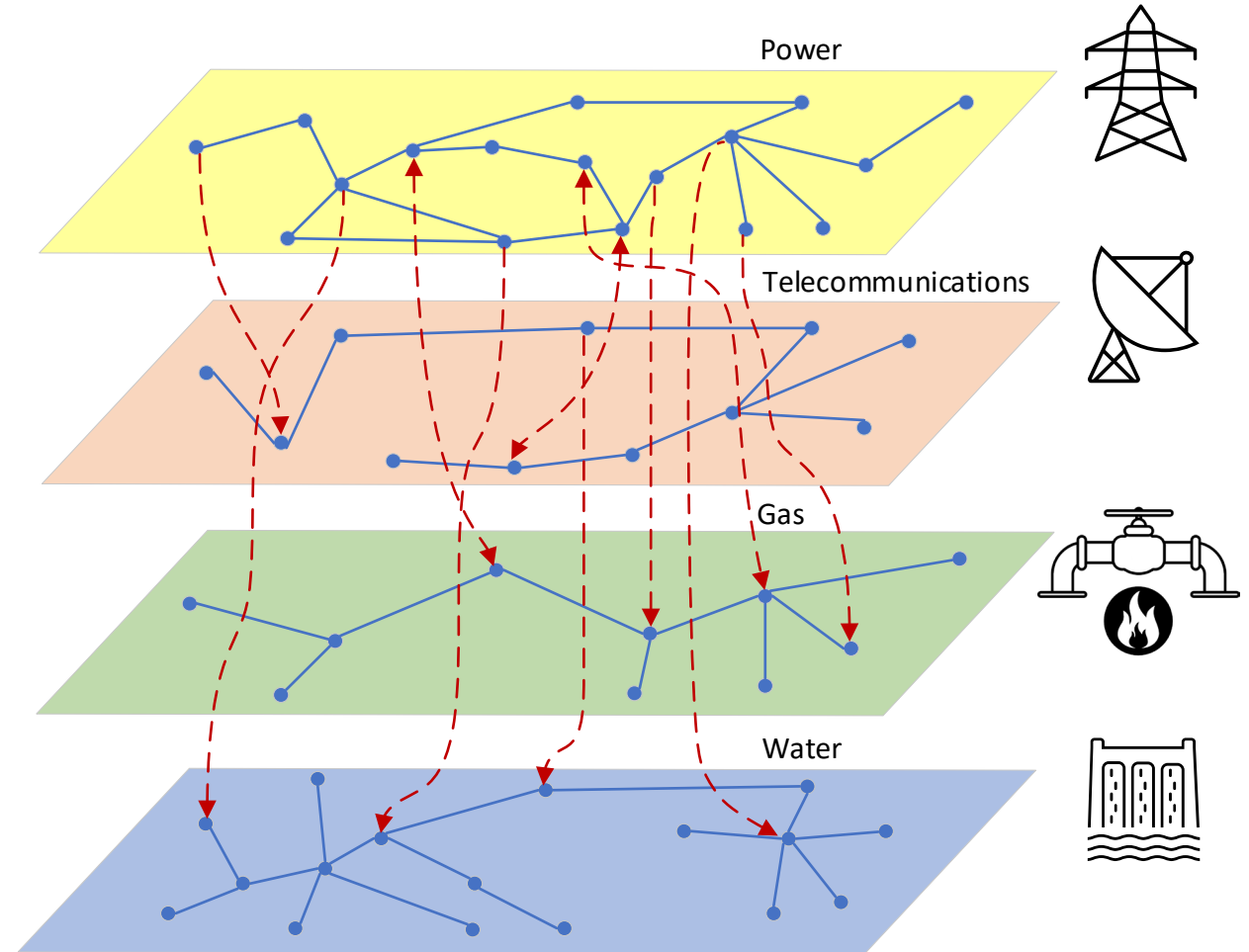
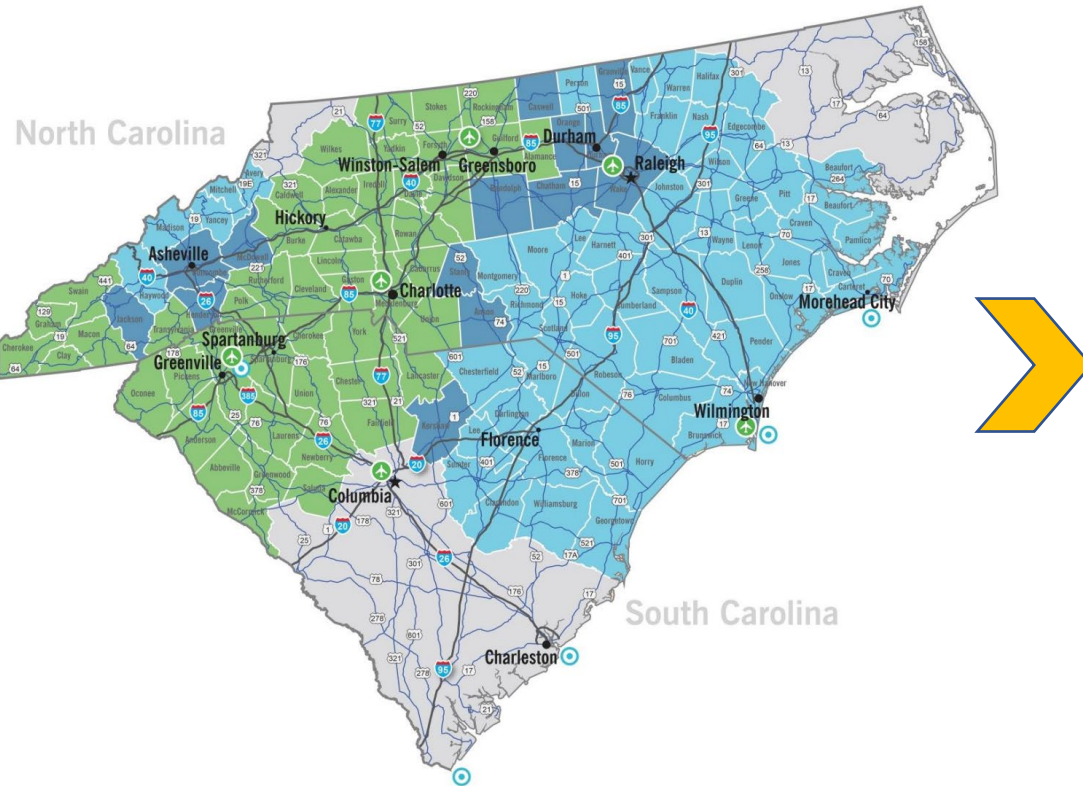
- More reliable equipment
- Better protection technology
- Hardening against more threats
- Virtually unlimited processing power for simulations and analyses.

But we have a problem!

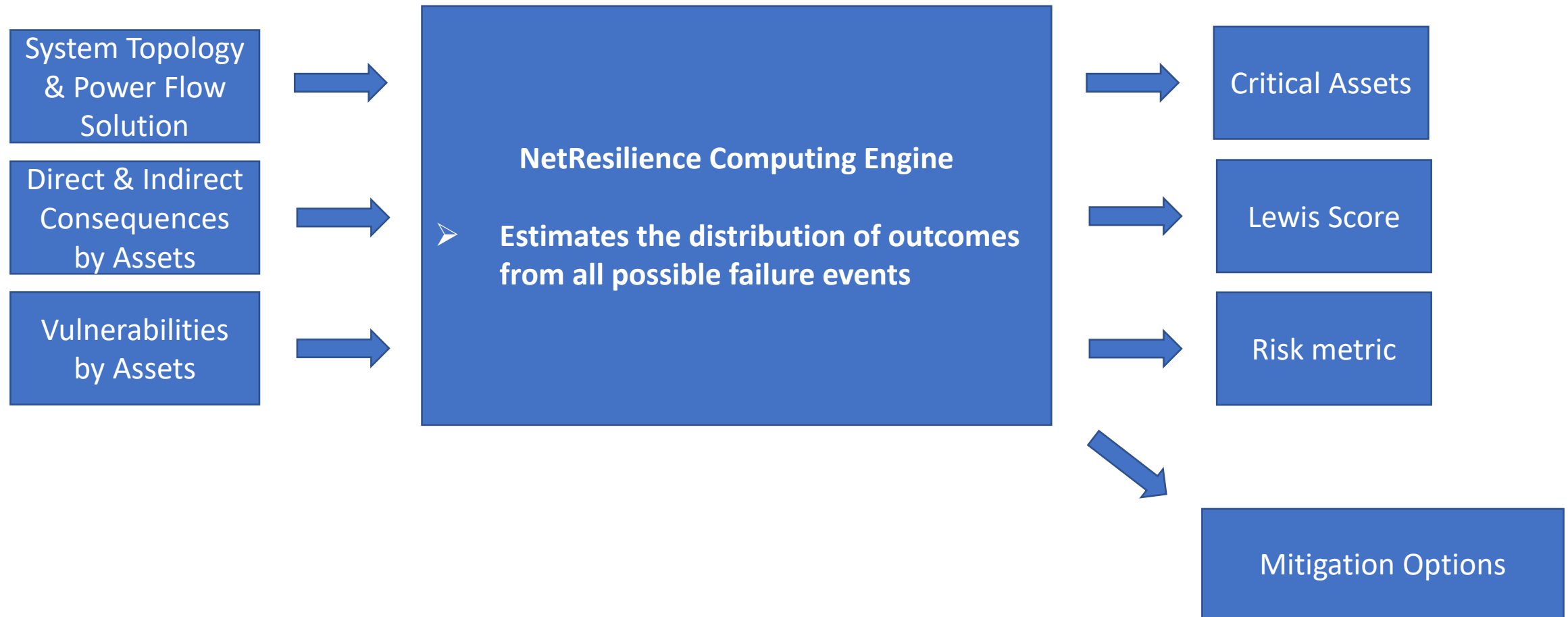
- Power system infrastructure is still becoming more unreliable!
- *High Impact Low Probability* (HILP) events including cascading network failures contributing to unreliability.

We need cost effective solutions for HILP.

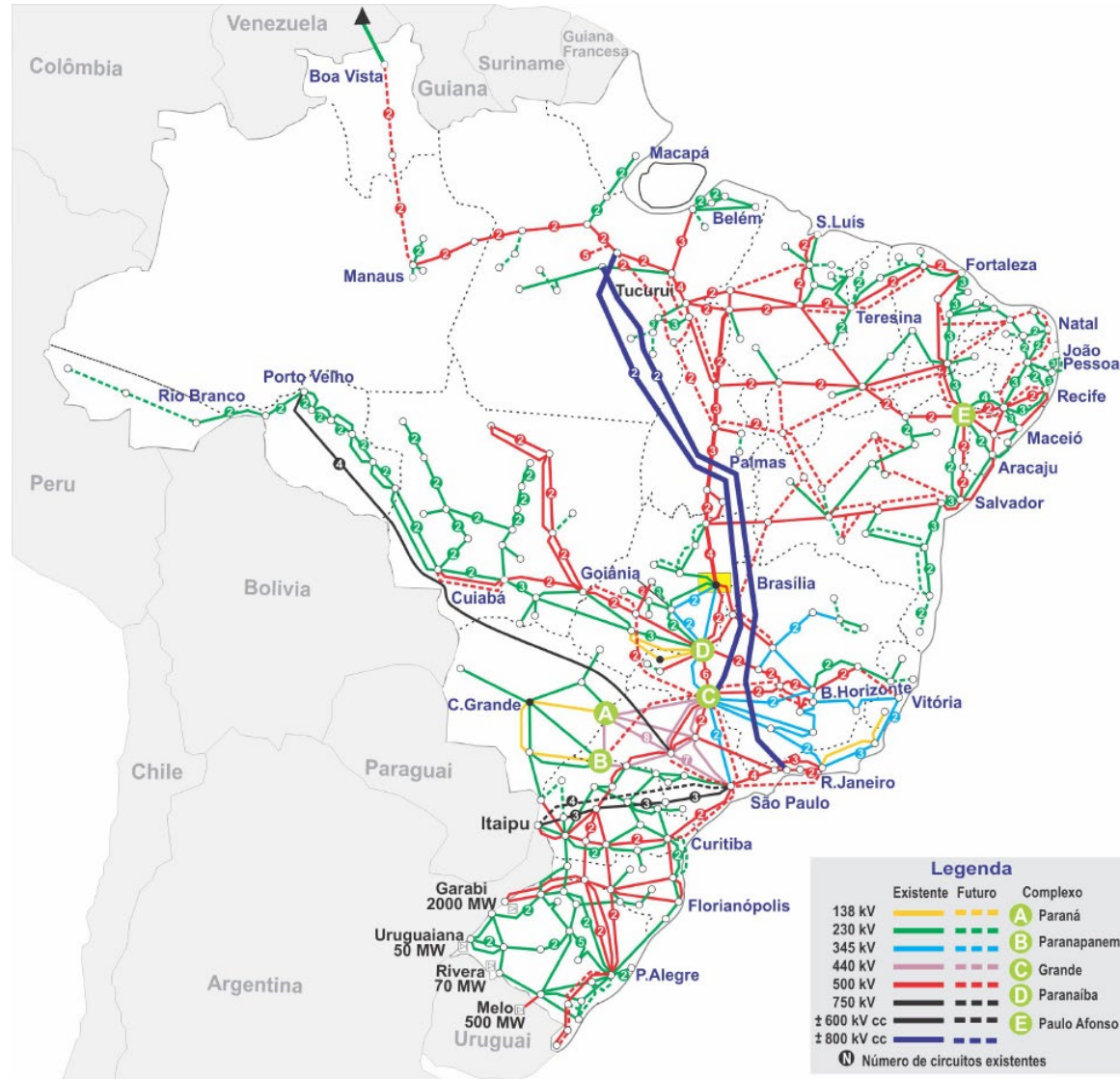
Cross sector interdependencies are problematic



The NetResilience process for cascade risk and resilience in interdependent networked infrastructures



Application example: Brazilian Interconnection

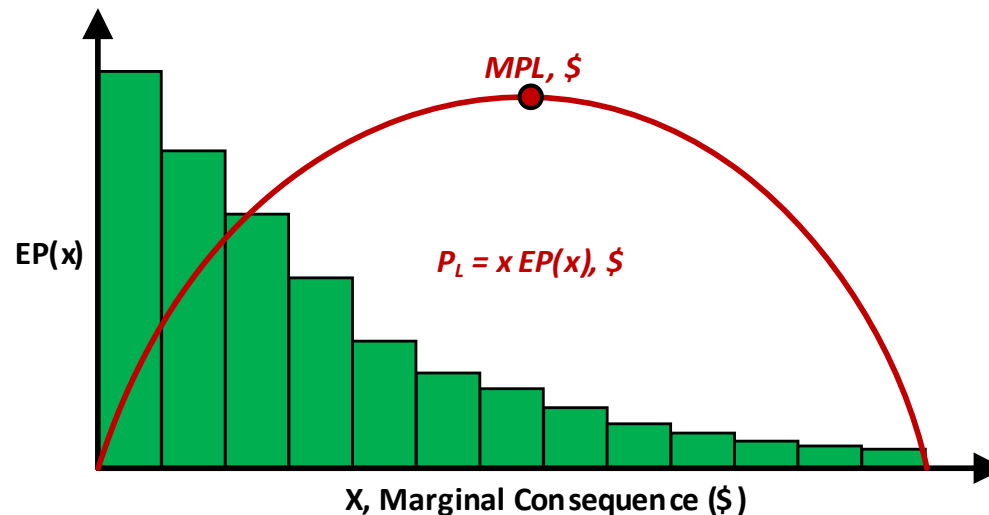


System Overview

- 213 Million Served
- 170 000 km Transmission Lines
- 4 HVDC Bipoles
- 1783 Power Plants
- 176 GW Installed Capacity

Brazilian Interconnection: Cascade Risk, \$/hr

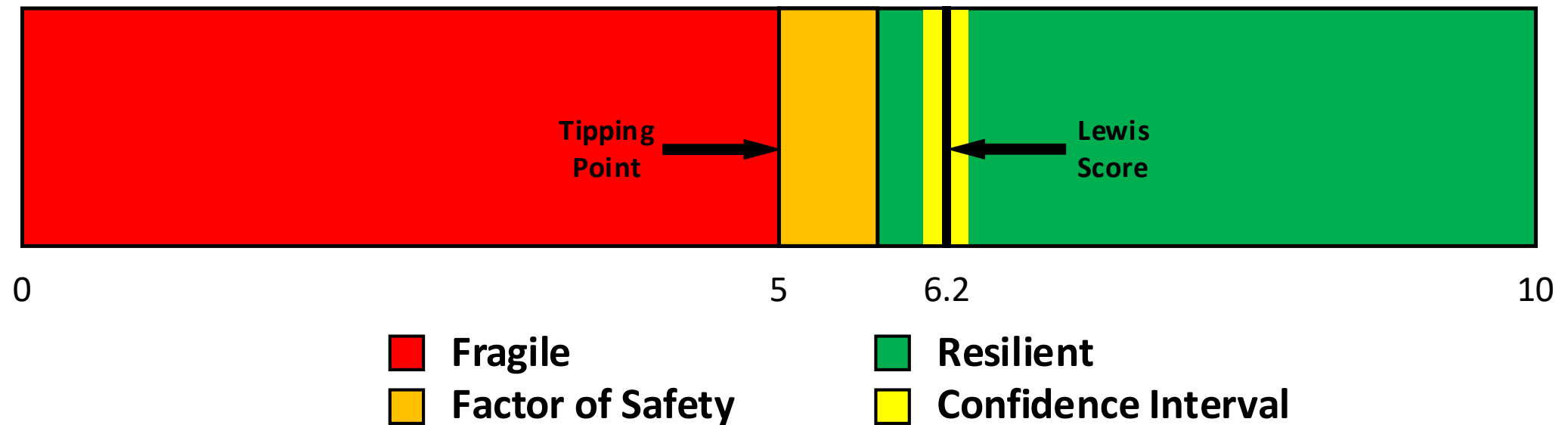
SYSTEM	SCENARIO		RISK			RESILIENCE	
	Failure Mode	Consequence	Total Static Risk (\$/h)	Maximum Probable Loss (\$/h)	+/-	Lewis Score (0-10)	Reserve (aim for >15%)
Power System	All-Hazard	Direct	\$55,759,419	\$12,549,323	3.5%	6.2	69.5%



The Maximum Probable Loss (MPL) is a statistic of the consequence distribution: a loss that is both likely and consequential.

MPL for the Brazilian System is Approx. 23% of the Total Static Risk.

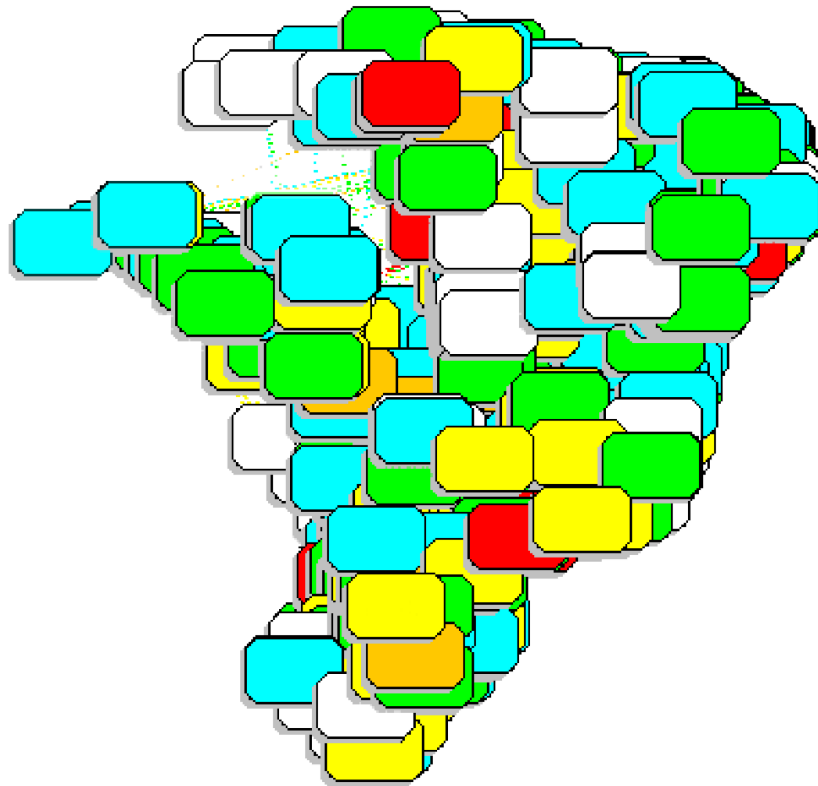
Brazilian Interconnection: Resilience Score



What does the Lewis Score mean?

Brazilian Interconnection: Ranking Critical Assets

Node & Link property intensity: Low->High.



Critical Assets related to Cascading Failure Risk

NetResilience™ Critical Assets	Critical Asset Ranking	Cascade Risk
Substation 1262	1	1
Substation 442	2	0.94
Substation 282	3	0.916
Substation 443	4	0.905
Substation 533	5	0.891
Substation 115	6	0.837
Substation 583	7	0.819
Substation 723	8	0.818
Substation 887	9	0.804
Substation 808	10	0.797

Power Systems Infrastructure

- More fragile
- More unreliable
- More interdependencies
- More HILP events

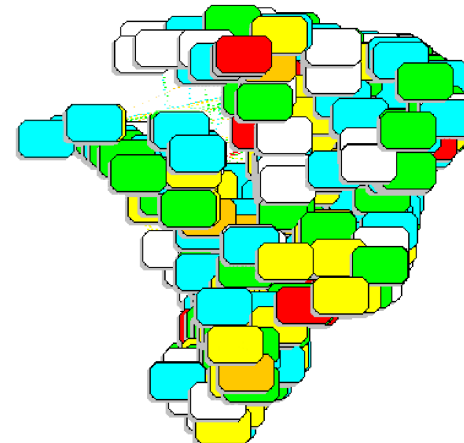
NetResilience

- Engineering + Network Science
- Power System Resilience Analysis
- Benchmark cascade risk and resilience
- Rank & mitigate resilience issues
- Relate investment to resilience score

Results for Brazil

- Ranked Critical Assets
- Lewis Score
- Risk measure
- Priorities for cost-effective mitigation

Node & Link property intensity: Low->High





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I'll be happy to answer your
Questions

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