Reliability standards and generation adequacy assessments for interconnected electricity systems

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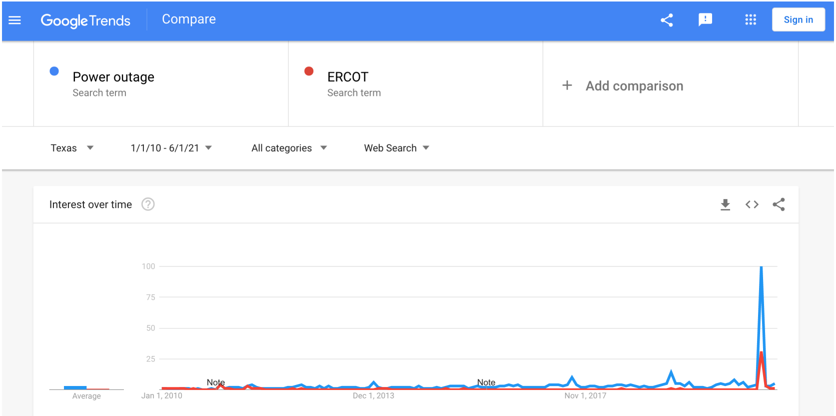
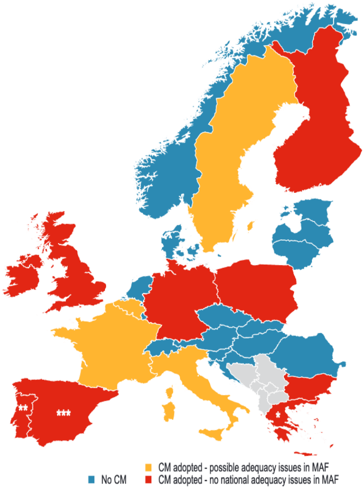
Power outages are one of the main sources of public and political attention to the electricity sector



(source: Google trends)

Heavy-handed policies that aim at ensuring *generation adequacy* are often implemented



Source: ACER based on ENTSO-E's 2019 MAF.

Reliability standards

Generation adequacy assessments consist in determining how much electricity generation capacity should be installed to meet a **national reliability standard** (or whether a prospective generation fleet meets the standard).

If we define:

$$\text{Loss of load expectation (LOLE)} \quad \equiv \Pr\left[\text{load} > \text{available capacity}\right]$$

then, a reliability standard is generally specified as:

$$\text{LOLE} \quad \leq \hat{\alpha}$$

$$= 2.4/3/4/8 \text{ hours/year}$$

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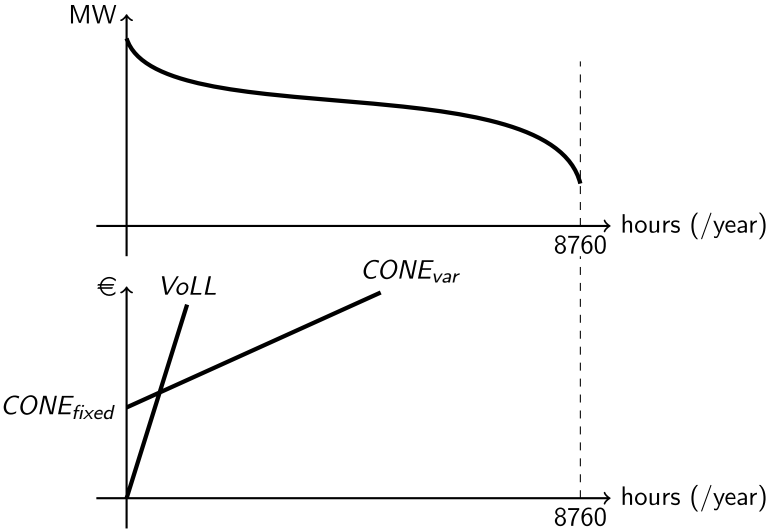

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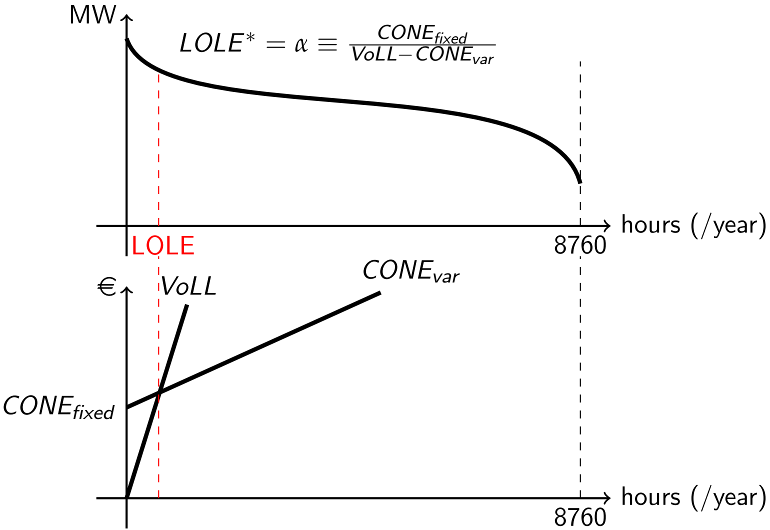

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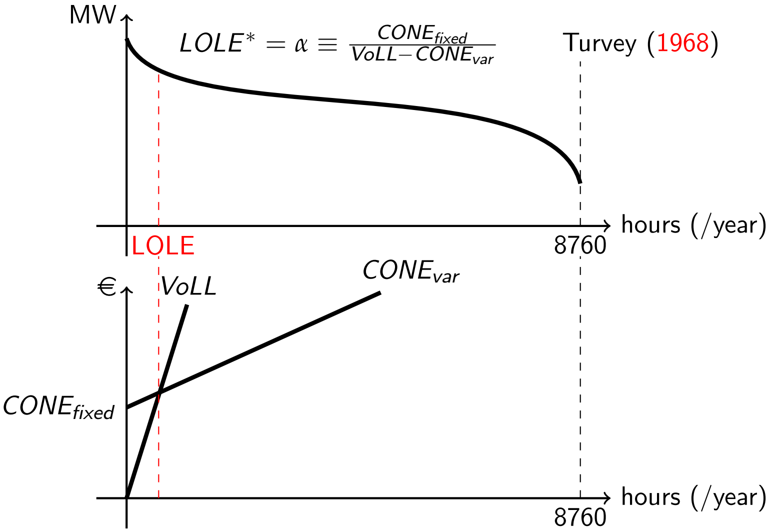

Research question

Does/can the enforcement of a national reliability standard still make sense in an interconnected power system?

In particular:

- Should we update/replace the national reliability standard?
- How should countries coordinate their adequacy assessments?

Summary of results

- We show theoretically that the social optimum may still be reached with national reliability standards under **two conditions**:

  1. Optimal installed generation capacity for each country should be determined jointly, while considering the full power system;
  2. LOLE calculations in generation adequacy assessments should fully internalize external adequacy benefits occurring throughout the full power system.

- We run a numerical application for Europe that suggests that regional coordination matters the most.

Generation adequacy assessments approaches

- **Current approach:** each country determines how much it will install, making assumptions on available imports from neighbors in times of scarcity.
- **Optimal approach:** determine jointly how much capacity to install in every sub-region, taking into account the full power system.

However national decision makers may be reluctant to transfer this responsibility to a supra-national level, because of the high economic, social, and political stakes.

Example of Europe

- Following the adoption of the Clean Energy Package (Regulation (EU) 2019/943), a regional adequacy assessment has to be implemented by the European Network of Transmission System Operators by the end of 2023.
- This single assessment will determine the need for generation capacity investments in the different countries simultaneously, based on national LOLE targets provided by Member States.

⇒ Does/can such a hybrid approach remain consistent with social welfare maximization?
⇒ In the European context, can ACER's current proposal for generation adequacy assessments be improved?

Framework

Demand:

$D_i \equiv$ hourly electricity demand in country i.
$V \equiv$ value of lost load (VoLL).
Assumptions: inelastic with a known distribution. Symmetric VoLL.

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Interconnection:

$L_{ij} \equiv$ interconnection capacity from country i to j (can vary across hours).
Assumption: NTC model (no power flow modeling), lossless exchanges.

Autarky reliability standard

We define:

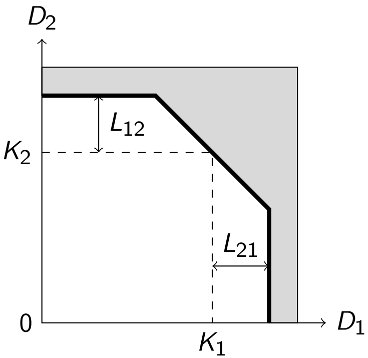
$$\alpha \equiv \frac{CONE_{fixed}}{VoLL - CONE_{var}}$$

For a power system in autarky, welfare maximization/cost minimization is achieved when:

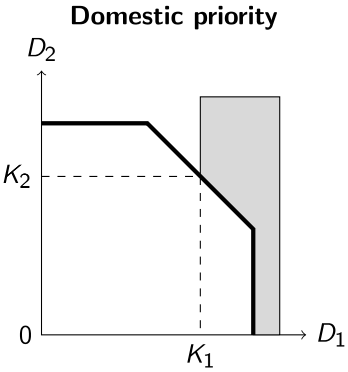
$$LOLE = \alpha$$

$\Rightarrow$ We refer to α as the autarky reliability standard.

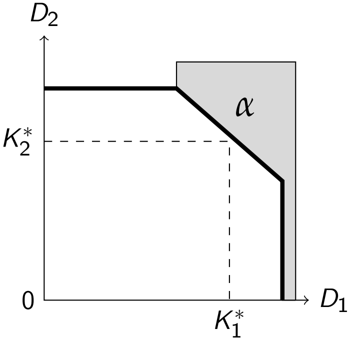
Lost-load region



How should one assess LOLE in country 1?



First-order condition w.r.t. K_1 for optimality



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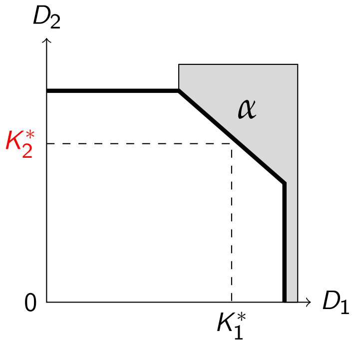
Take away 1: Regional coordination



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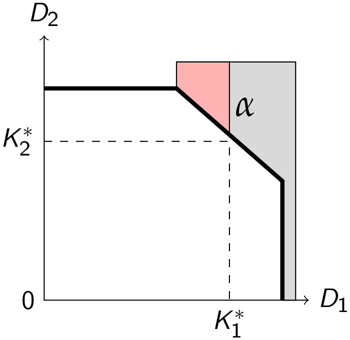
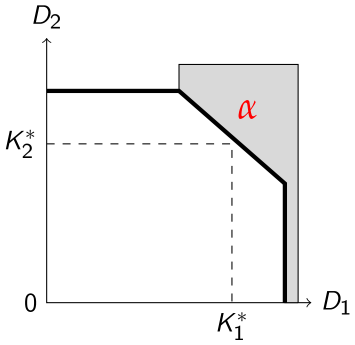
Take away 2: Need to internalize external adequacy benefits



First-order condition w.r.t. K_1 for optimality

Take away 3: Autarky reliability standard need not be removed



Application to Western Europe: scenarios

We compare 4 approaches to generation adequacy assessments in an interconnected power system:

	Neighbor contribution considered	Capacity determined jointly	Internalize external adeq. benefits
Autarky			
National	✓		
Regional	✓	✓	
Optimal	✓	✓	✓

Data - Load (1/2)

Hourly load and NTC data for 2015-2018 is retrieved from ENTSO-E Transparency Platform.

Table: Summary statistics of hourly load [MW] in the 11 studied countries.

Country	Observations	Mean	P95	$K^*_{autarky}$	Maximum
Belgium	35,064	9,973	12,216	13,506	13,670
Denmark	35,057	3,740	4,997	5,638	5,819
France	35,040	54,040	75,280	92,433	94,492
Germany-Austria-Luxembourg	35,064	70,037	89,770	96,788	98,259
Great Britain	35,058	35,893	48,360	56,544	57,388
Ireland	34,899	3,132	4,077	4,798	4,901
Italy	35,064	33,096	45,077	53,212	55,157
Netherlands	35,064	12,557	16,686	18,692	19,272
Portugal	35,064	5,669	7,283	8,500	8,732
Spain	35,047	28,684	36,084	40,232	41,015
Switzerland	34,990	6,697	8,474	9,826	9,968

Note: Germany load is aggregated with Austria and Luxembourg. Some observations are missing or where ignored because they differed more than 50% from their day-ahead forecast.

Data (2/2) - NTC

Table: Median NTC [MW] for each border between the 11 studied countries.

From \ To	BE	DK	FR	DE-AT-LU	GB	IE	IT	NL	PT	ES	CH
Belgium			800					1,300			
Denmark				885							
France	2,100			1,800	2,000		2,686			2,400	3,000
Germany-AT-LU		2,090	1,400				275	1,468			2,336
Great Britain			2,000			780		1,016			
Ireland					750						
Italy			995	100							1,810
Netherlands	1,200			1,468	1,016						
Portugal										2,900	
Spain			2,050						2,000		
Switzerland			1,200	5,200			2,961				

Note: missing observations were replaced by the median value of NTC for the corresponding interconnection.

Results

	Autarky	National	Regional	Optimal
Total costs (M€/year)	23,395	24,590	22,446	22,436
Total installed capacity (GW)	389.9	361.3	372.2	372.3
Average realized LOLE	0.1	15	3	2

Main take-aways:

- In the absence of regional coordination, national adequacy assessments can backfire (i.e. yield a worse outcome than just installing autarky capacities);
- In terms of getting total system costs right, regional coordination appears to be more important than correctly internalizing external adequacy benefits in national LOLE computations.

Conclusion

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