Summer School

Gent, Sept 2, 2015

How to calculate the cost of a blackout?

Quantitative assessment of the economic costs of a national blackout

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plan.be

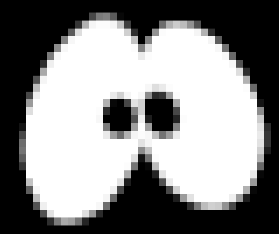
Agenda

- Blackouts: what, where and why?
- Societal importance of power

  Sensitivity of (critical) infrastructures
- Electrification of Final Energy Demand
  - Current/future situation
  - Investments necessary to safeguard lights staying on
- What if… things go (terribly) wrong?

  Estimation of the economic losses due to a national blackout
    - Methodology
    - Results
- Discussion

What, where and why?



Large-scale blackouts

November 2006

German-triggered blackout exposes fragile European power network

E-mail | Print | RSS

Updated 11/5/2006 7:23 PM ET

BERLIN (AP) — A German electric company said Sunday a high-voltage transmission line it shut down over a river to let a ship pass could have caused the chain-reaction power outages that left about 10 million people in the dark across Europe.

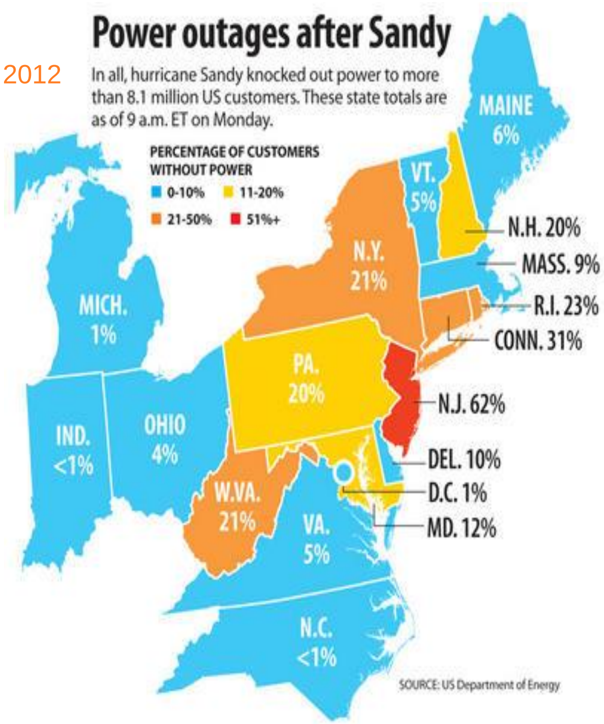
The blackouts Saturday night briefly halted trains in Germany and trapped dozens of people in elevators in France and Italy. Austria, Belgium and Spain were also affected, though supplies to most regions were quickly restored. No injuries were reported.

The outages raised fresh questions about the reliability of Europe's interconnected power grids and drew an immediate call for stronger coordination.

FRANCE GOES DARK: Blackout hits 15 regions, parts of Paris

September 2003

October 2012



STATE	CURRENT CUTOMER OUTAGES
1. New Jersey	2,498,447
2. New York	1,967,874
3. Pennsylvania	1,267,512
4. Connecticut	626,440
5. Maryland	311,020
6. Massachusetts	298,072
7. Ohio	254,207
8. West Virginia	212,183
9. Virginia	182,811
10. New Hampshire	141,992
11. Rhode Island	116,308
12. Maine	90,727
13. Michigan	68,619
14. Delaware	45,137
15. Vermont	17,959
16. Indiana	7,537
17. North Carolina	4,005
18. District of Columbia	3,583

Definition of blackout

- A blackout is defined as a *complete interruption of power in a given service area*. It comes without warning, lasts for indeterminate periods, and is typically caused by catastrophic equipment failure or severe weather.
- Rolling blackouts are controlled and usually preplanned interruptions of service. They typically occur with at least some advance warning, normally last for a fixed length of time, and are deliberately produced by utility companies. They can be used as a means of coping with peak power demands that cannot be met from existing supply.
- A brownout is a partial, temporary reduction in system voltage or total system capacity. In most cases, brownouts are deliberately produced by energy providers as an emergency measure to prevent the system from failing completely (blacking out).

Causes

- Consumption
  - Fluctuating demand: (quasi) non-storability
  - Error margins on demand forecasts

  e.g. France: 2300 MW/°C
  Belgium: 100 MW/°C

- Climatological variables
  - Heat waves, floods, storms, …
  - Can lead to short circuits and systems not functioning properly/defecting

- Outages
  - Unforeseen system failure of critical components
  - External aggressions on the system
    - (Un)visible damage by contractors, terrorist attacks (e.g. Stuxnet), …

- Human factor
  - Human errors while starting up or maintaining certain components
  - Erroneous forecasts
  - Non-appropriate actions during exploitation

Types of outages

Grid related

- Power cannot be transported from producer to consumer
- Both producer and consumer are affected by the power outage

Production related

- Within the network, insufficient power is produced to satisfy demand
- Typically, producers do not suffer consequences, they may even (during a limited period of time) raise prices to sell scarce electricity

*) Unexpected disturbances, usually on the wires, that cause almost every blackout
*) Transmission reliability is much more complex than the adequacy of the generation fleet

- Power cannot be transported from producer to consumer

- Both producer and consumer are affected by the power outage

The specific needs of Europe and North America

What causes blackouts in North America and Europe is not what gets the most attention. The power grid systems, not a shortage of power plants, are the problem. Take a look at the 13 major power outages that have occurred across the globe over the years, and see that the problems we face are not because we aren't building enough power plants.

Only one of the outages, July 2012 in India, was due to more electricity demand than could be supplied by existing resources. In the industrialized economies of North America andEurope, people more often lose power due to a subtle and difficult challenge: the electrical grid is prone to system failures and needs modernization.

Source: www.livescience.com

*) Raising the price is a desirable element of any strategy to deal with a temporary shortfall (*scarcity pricing*).
*) Getting the price right early on may eliminate the crisis altogether

- Within the network, insufficient power is produced to satisfy demand
- Typically, producers do not suffer consequences, they may even (during a limited period of time) raise prices to sell scarce electricity

TOT 8.000 BEDRIJVEN TIJDELIJK AFGESCHAKELD VAN HET NET

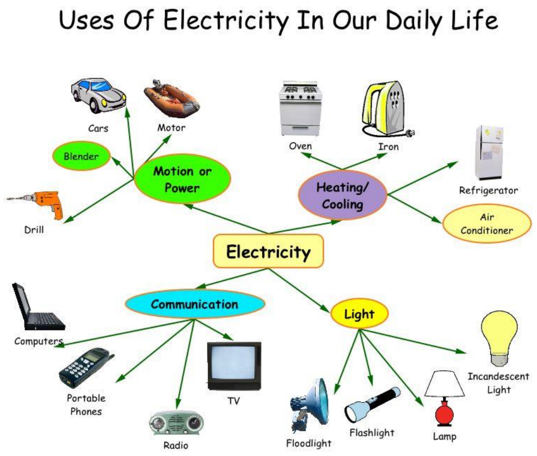
Poolse hitte leidt tot stroomtekorten

13 AUGUSTUS 2015 | Van onze medewerker Joris Moorthamers

Polen kreunt onder een hittegolf. Door de aanhoudende droogte hebben de elektriciteitscentrales niet genoeg koelwater, wat in het hele land tot afschakelingen van het elektriciteitsnet heeft geleid.

Source: De Standaard.

Societal importance of power



Triple vulnerability paradox

- Sustained technological development -> more vulnerable to power disruptions
  - Less dependent on 'coincidences' like good weather (dry year, hot year, …) -> each disruption hits disproportionally hard
- Larger penetration of electrical equipment and electronical measurement, control and operating devices (ex. SCADA)
- Other infrastructural systems also dependent on power:
  - Water distribution, communication, transport, …

Triple vulnerability paradox

Every critical infrastructure is built on it and every important business function is completely dependent on it

- Sustained technological development -> more vulnerable to power disruptions

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Google Compute Engine Incident #15056

Google Compute Engine Persistent Disk issue in europe-west1-b

Incident began at **2015-08-13 09:25** and ended at **2015-08-16 09:35** (all times are **US/Pacif**

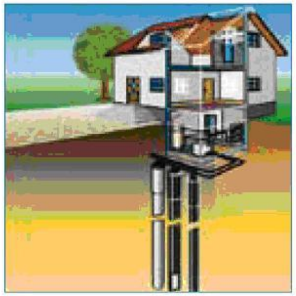
DATE	TIME	DESCRIPTION
Aug 18, 2015	02:18	SUMMARY:

ROOT CAUSE:

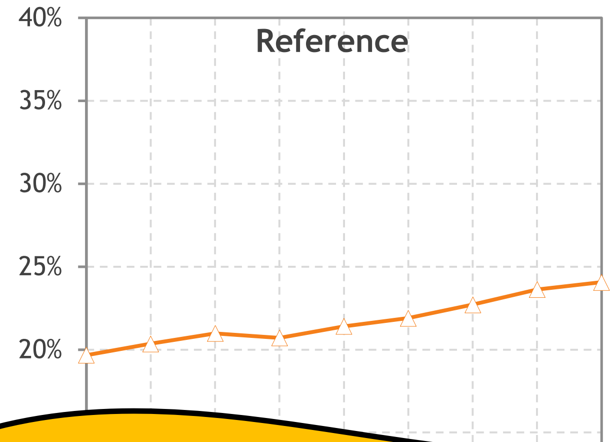
At 09:19 PDT on Thursday 13 August 2015, four successive lightning strikes on the local utilities grid that powers our European datacenter caused a brief loss of power to storage systems which host disk capacity for GCE instances in the europe-west1-b zone. Although automatic auxiliary systems restored power quickly, and the storage systems are designed with battery backup, some recently written data was located on storage systems which were more susceptible to power failure from extended or repeated battery drain. In almost all cases the data was successfully committed to stable storage, although manual intervention was required in order to restore the systems to their normal serving state. However, in a very few cases, recent writes were unrecoverable, leading to permanent data loss on the Persistent Disk.

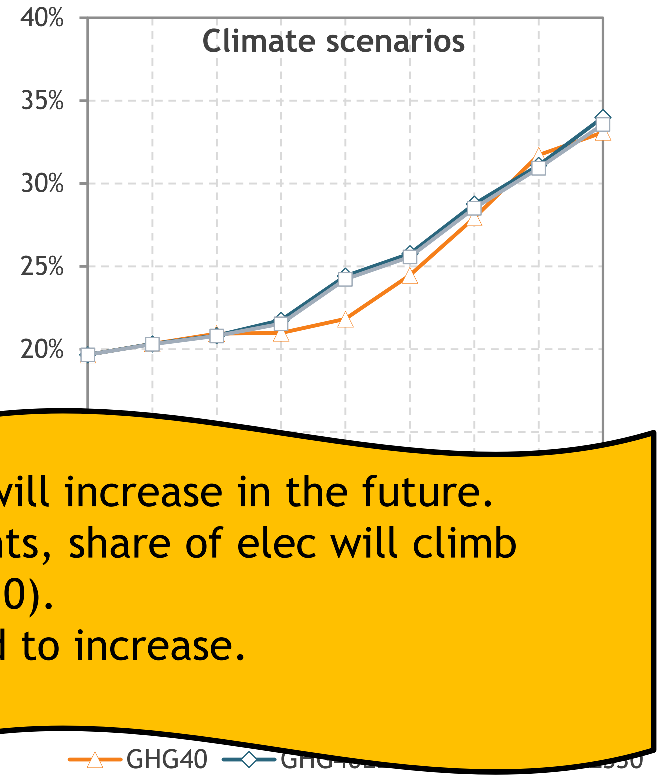
Google verliest data door bliksem in Belgisch datacenter

Electrification of final demand



Penetration of electricity in Final Energy Demand





1) Whatever we do, share of elec in FED will increase in the future.
2) In GHG emission restrained environments, share of elec will climb towards 1/3 of FED (up from 1/5 in 2010).
3) Vulnerability to power outages is bound to increase.

Source: FPB, 2015.

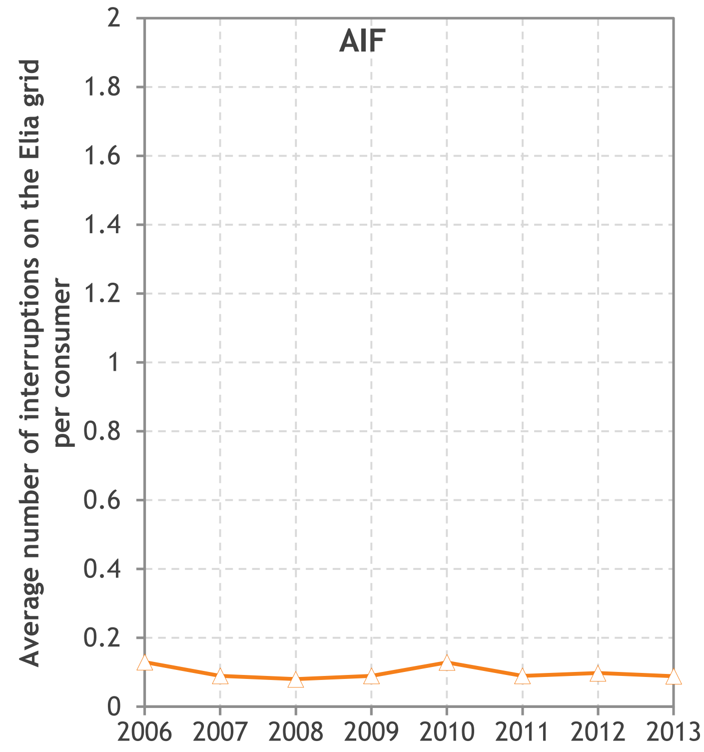
Belgian context

Reliability

Continuity of supply in Belgium remained at a high level in 2013, among the best in Europe.

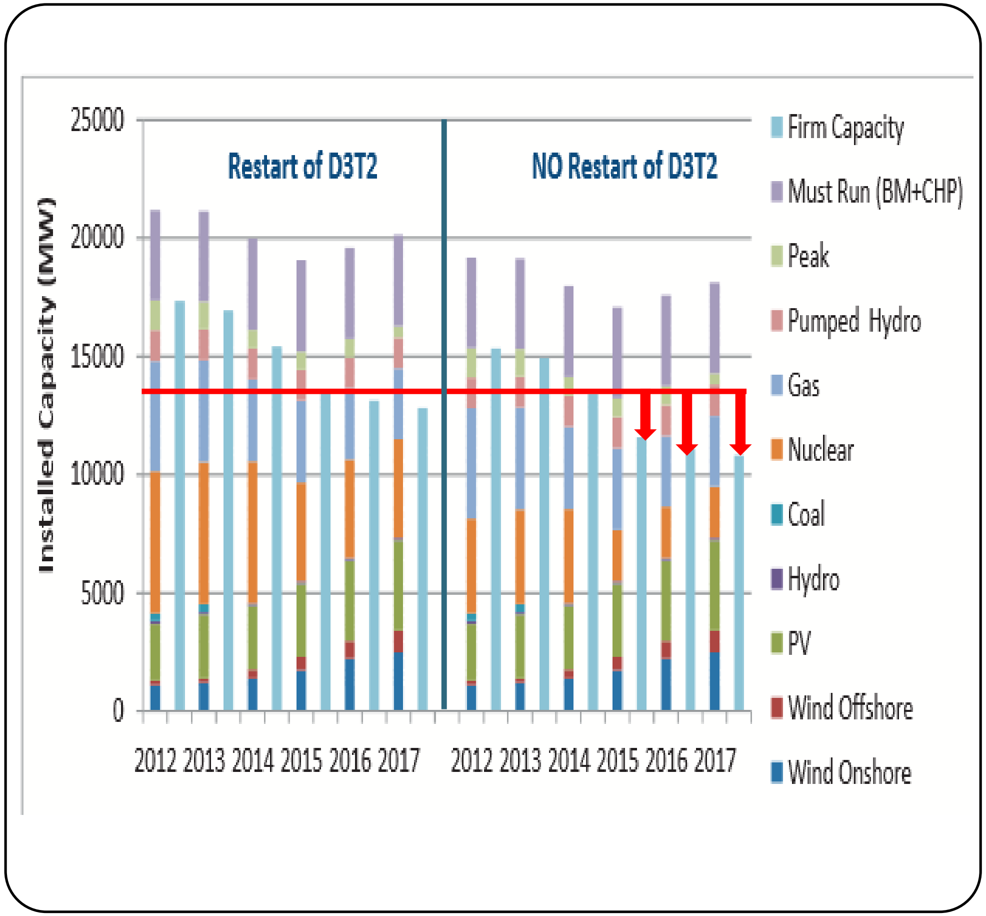
The average number of interruptions on the Elia grid per consumer (Average Interruption Frequency) was 0.0891, equivalent to one interruption per customer every 11.2 years. The average duration of interruptions was 27 minutes and 50 seconds. Across all customers, the average duration of interruptions was 2 minutes and 29 seconds per customer (Average Interruption Time), equivalent to an average availability of more than 99.999%, which is higher than the average for the last decade.

Source: Elia, Facts & Figures 2013.



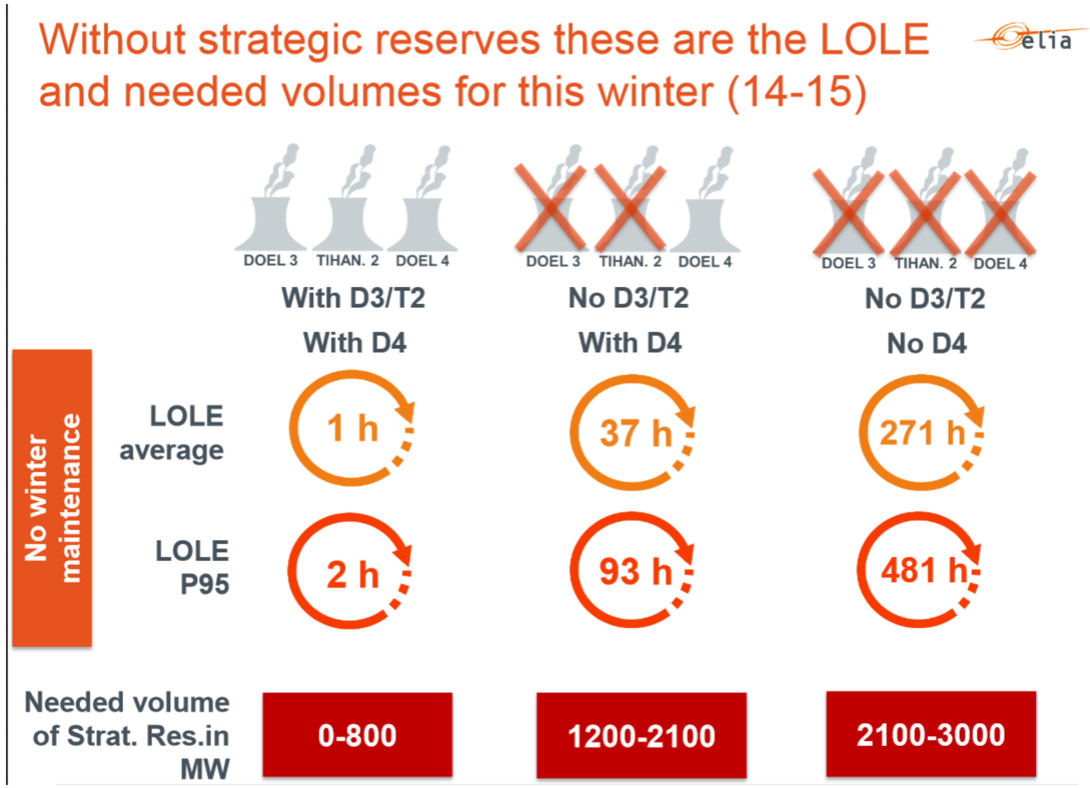
Belgian context (2)

- Generation problem
- Critical situation this (and next) winters
- Difference between Installed and Reliable Available Capacity
- N-2/N-3: generation adequacy@stress



Source: Itinera Institute, 2014.

Probabilistic estimation of number of (winter)hours that available sources are not capable to cover demand



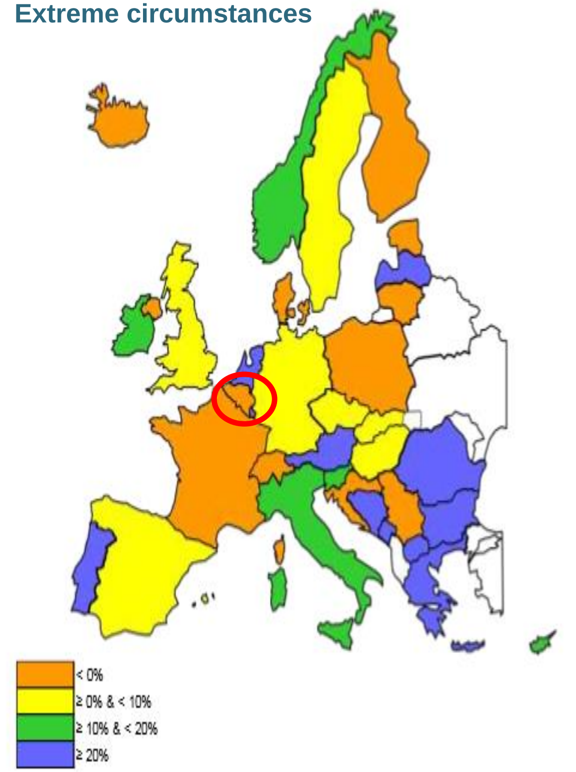
Source: Elia, 2014.

Deterministic estimation of generation adequacy

Normal circumstances

F 4.1.3 – RC as a part of NGC per country in January 2020, Scenario B

Extreme circumstances



F 4.1.8 – Remaining Capacity minus Adequacy Reference Margin as a part of Reliably Available Capacity per country, Scenario B, January 2020, 7 p.m.

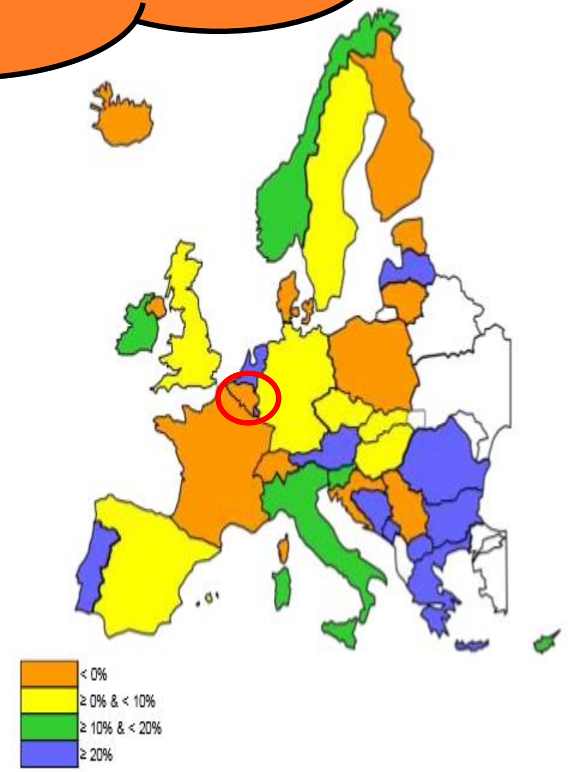
Source: ENTSO-E, SO&AF2014-2030.

Determinis … acy

PLEF probabilistic adequacy assessment:
Most often BE & FR would experience adequacy risk simultaneously

Normal circumstances

F 4.1.3 – RC as a part of NGC per country in January 2020, Scenario B



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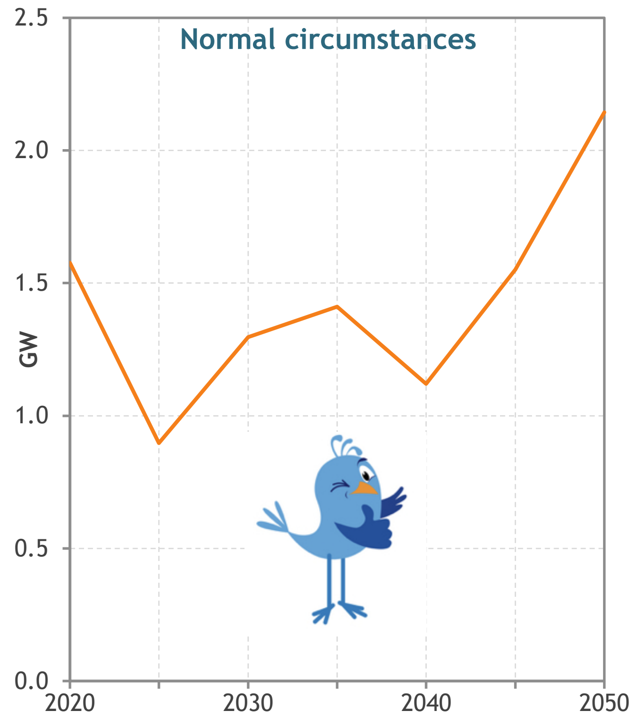
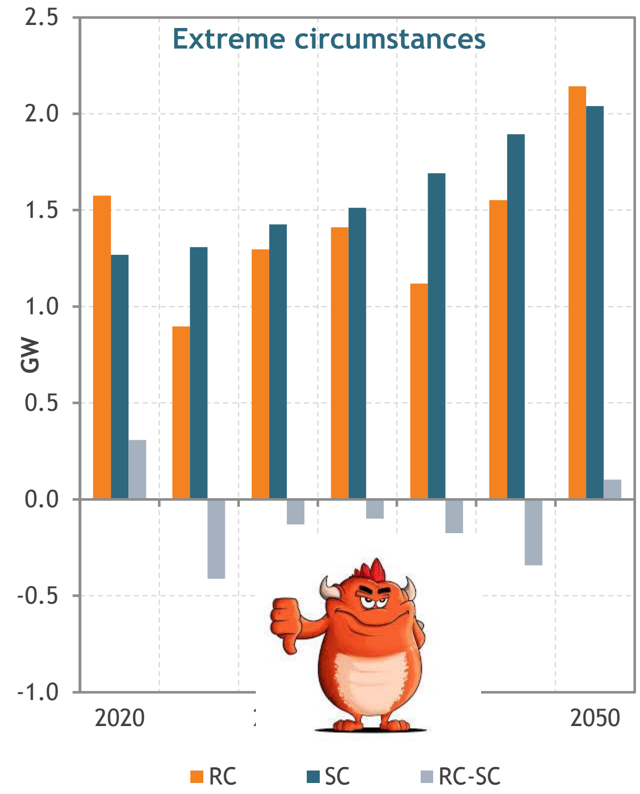
Source: ENTSO-E, SO&AF2014-2030.

Deterministic estimation of generation adequacy in a Reference scenario



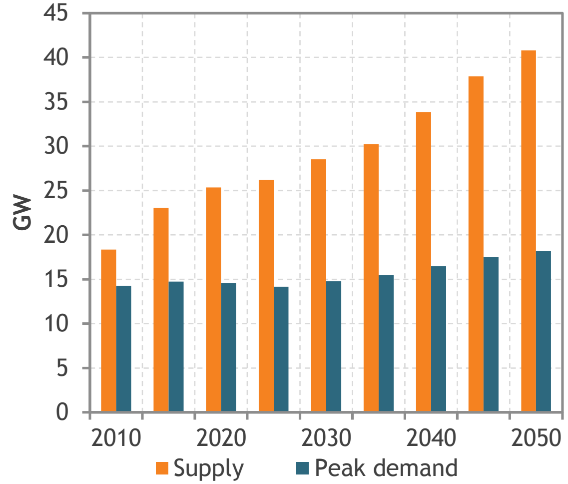


Source: FPB, 2014.

Generation adequacy in a Reference scenario

Impact on generating facilities:

- Increase in installed capacity largely surpasses demand increase
  +123% vs. +28% (2010-2050)



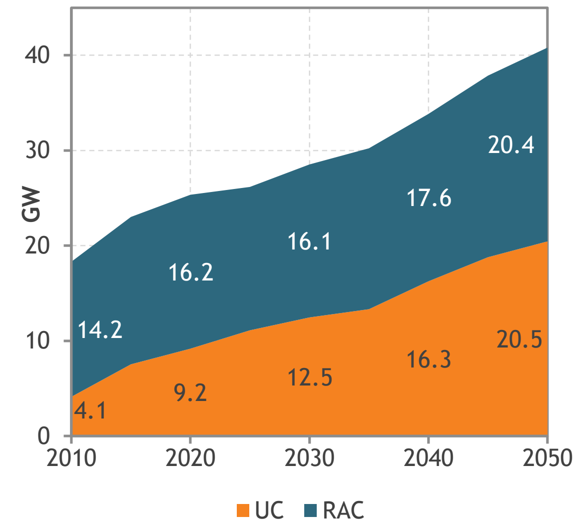
Source: FPB, 2014.

Generation adequacy in a Reference scenario

Impact on generating facilities:

- Increase in installed capacity largely surpasses demand increase
  +123% vs. +28% (2010-2050)

  Because of strong growth in Unavailable Capacity



Source: FPB, 2014.

- Required investments in generating facilities are enormous
  - 31 billion € 2010-2030
  - 31 billion € 2030-2050

What if… thing go WRONG!

How to estimate this cost?

Different methods

- Case studies
  - Rich detail
- Indirect analytical assessments
  - Proxy
    - Observable variables
    - Quantify the costs of back-up generation or insurance purchases
  - Market-based valuation
    - Observable consumer decisions
    - ICH
- Contingent valuation (CVM)
  - Define some hypothetical scenarios in which electricity supply is interrupted to, subsequently, provide monetary quantification of damage that would ensue (WTA/WTP)

Valuation is inferred using data related to observed consumer behaviour

Involves use of survey and experimental settings to reveal consumer valuation

Potential problems

- Data availability

  One blackout is not the other: Using case studies might give biased impression (difficult to generalize results)

  - Different types of users
  - Perceived reliability level
  - Moment of interruption
  - Length of interruption
  - Prior notification
  - Source of the outage

> "Without modernising the energy infrastructure the country will keep on running into trouble, and that simply does not attract investors"
> H. Kalis, ArcelorMittal Poland, August 2015

- Surveys
  - Questionnaire design: making trade-offs between details and response rates, framing, …
  - Censoring outliers: zero and extreme responses due to a.o. strategic responses
  - Answer questions about trade-offs they rarely make
  - People prefer status quo, not more or less interruptions
- High reliability level in BE

  In countries with few interruptions, firms and HH are not always willing to pay (much) for a higher level of SoS than is provided by the network
- Macro-economic impact

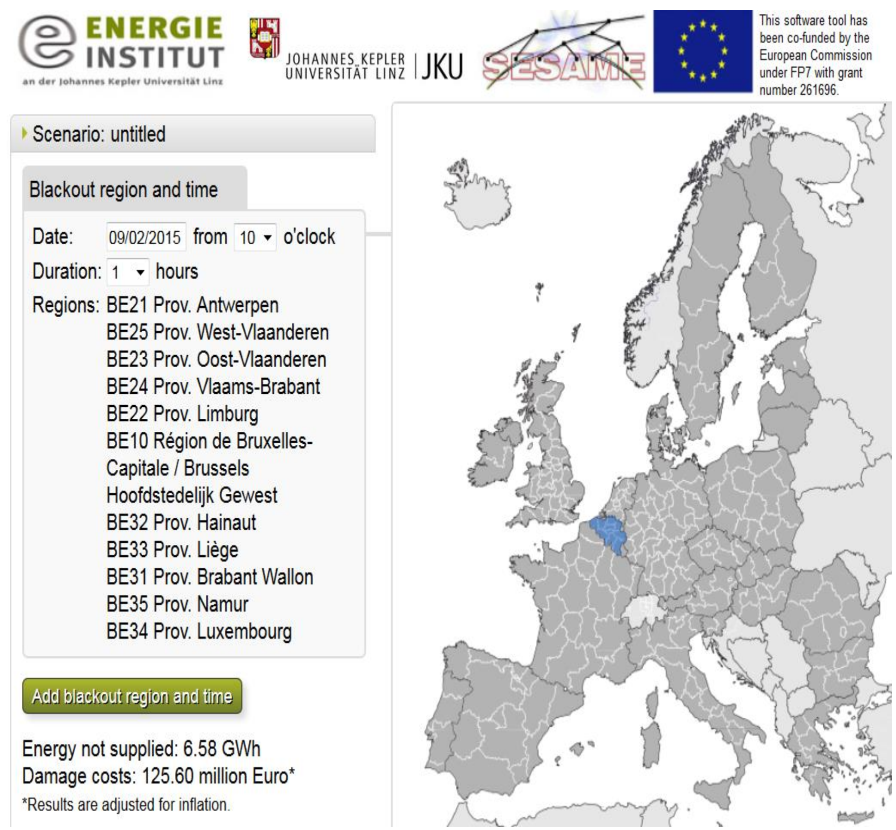
  Difficult to assign to individual event ex. new Google server station in Kronsdorf

Blackout simulator

- One of the main outputs of the EU FP 7 project SESAME

  Securing the European Electricity Supply Against Malicious and accidental thrEats

- Collaborative research effort performed by 9 project partners from various European countries including regulatory authorities



Blackout simulator (2)

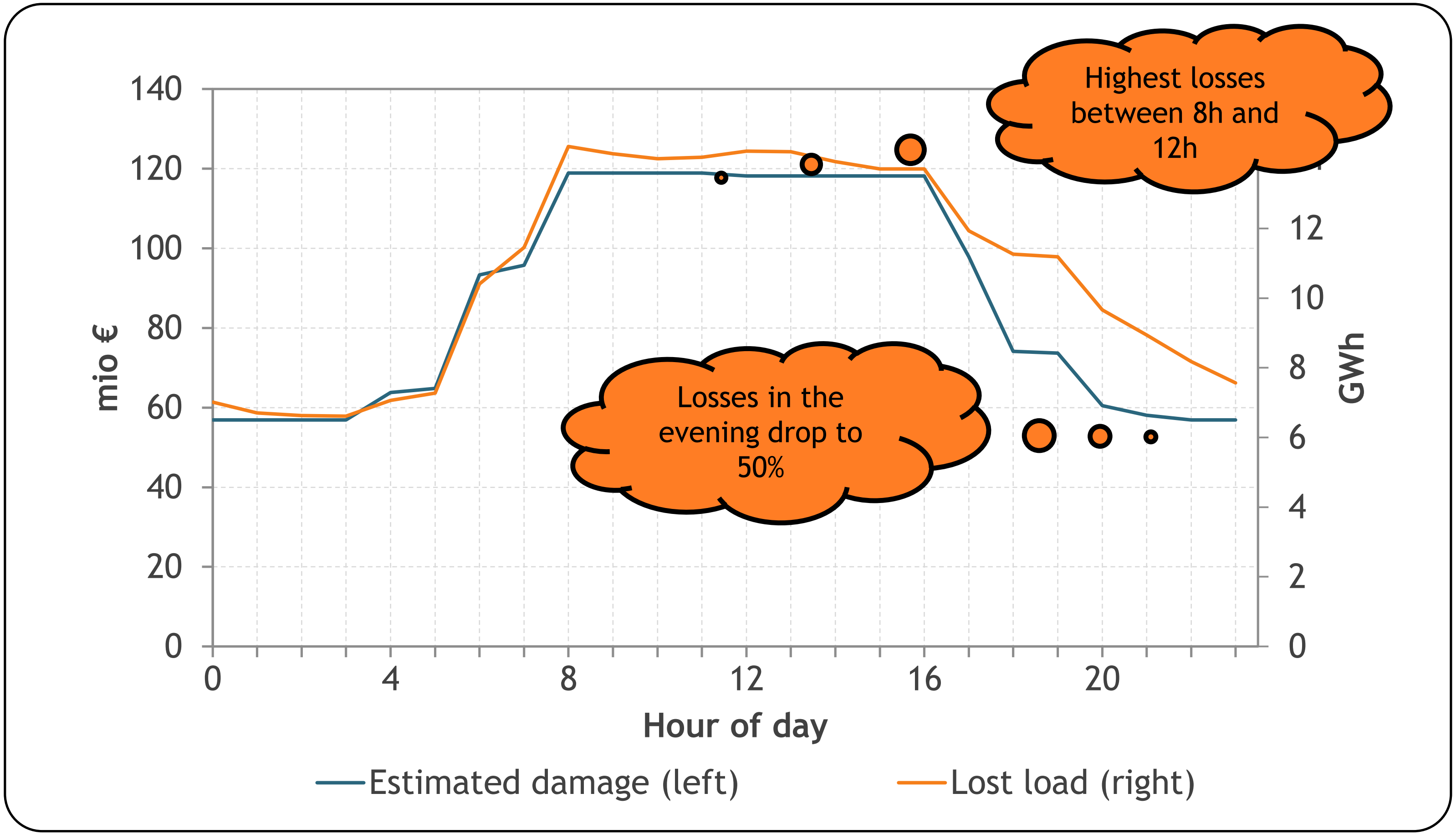
Non-households

- Exclusively monetary losses
- Lost-value added regression model and data on economic activities
    - All key activities analysed wrt elec dependence and impact on VA process
    - Minus portion of VA which can be recovered later (at certain costs, which have to be added)
    - Plus costs of idle staff
    - Plus value of inputs lost

Households

- Immaterial (inconvenience, fear, …) and material losses
- Surveys: Face-to-face + web-based
- Discrete choice model

Economical damage and Energy Not Supplied (ENS) during a Belgian blackout



Source: Devogelaer, 2014.

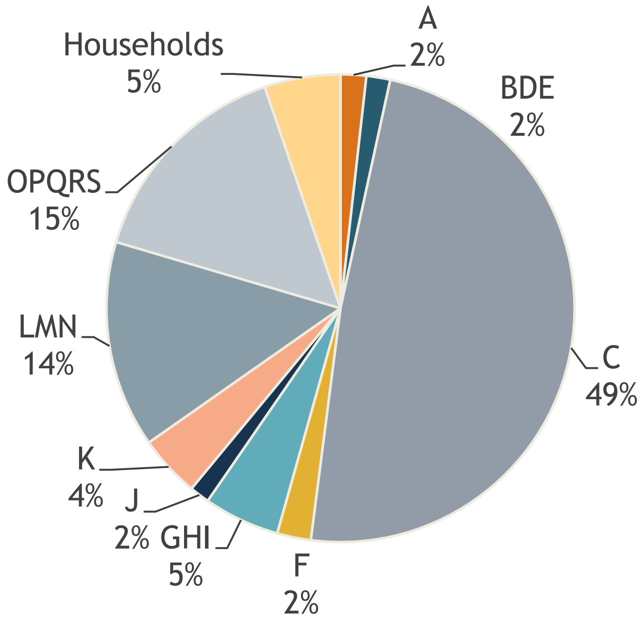
Allocation of damage per consumer category

- Households: 5%
- Firms: 95%

  Industry most heavily hit: 49%

  Tertiary sector: 40%
- Allocation not uniform to ENS
- VOLL: 8.3 €/kWh <> mean HH power price: 0.22 €/kWh

Damage distribution during working day (8AM-4PM)



Source: Devogelaer, 2014.

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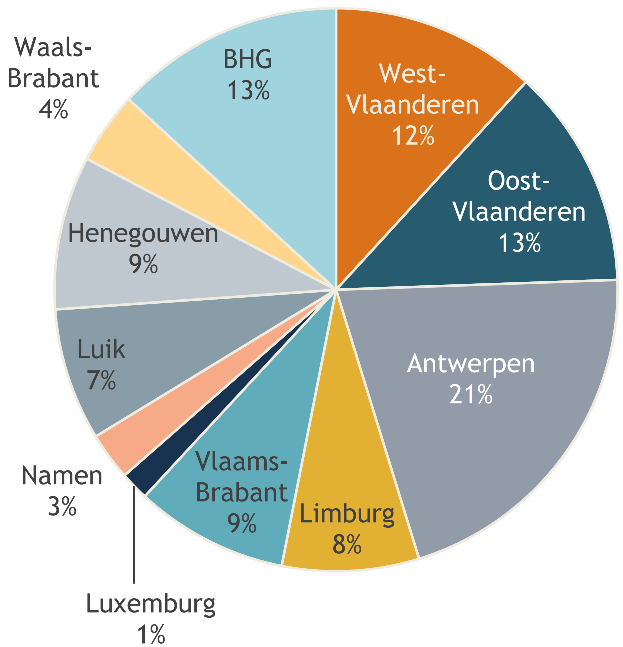
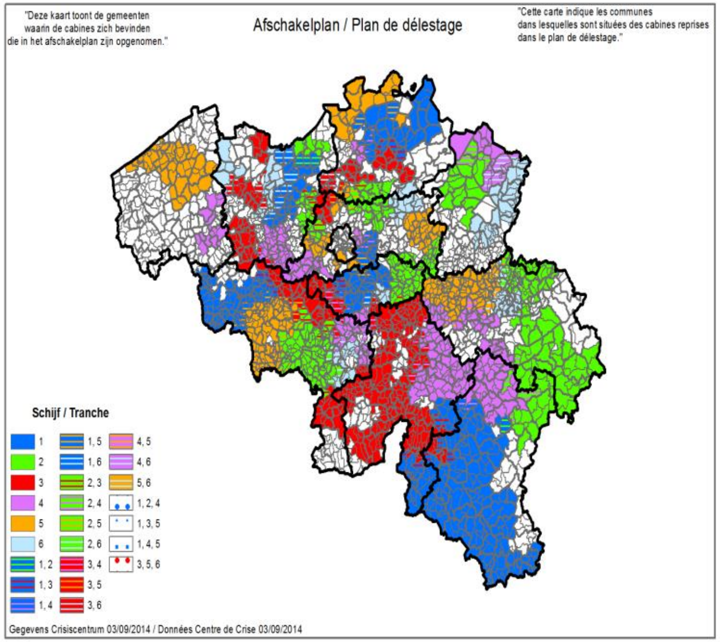
Geographical (NUTS2) damage allocation





Source: Blackout Simulator.

Source: FPS Economy.

What if… thing go terribly **WRONG!**

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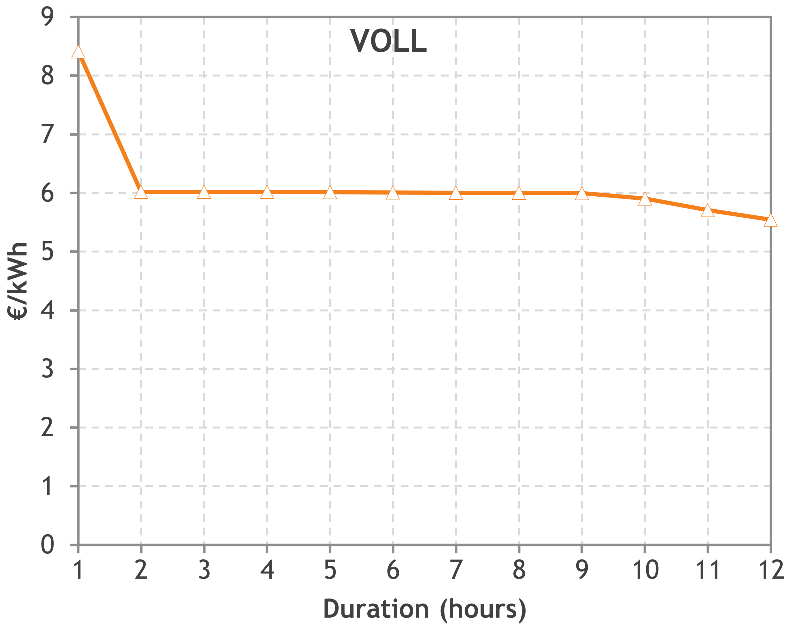
Power outages of long duration

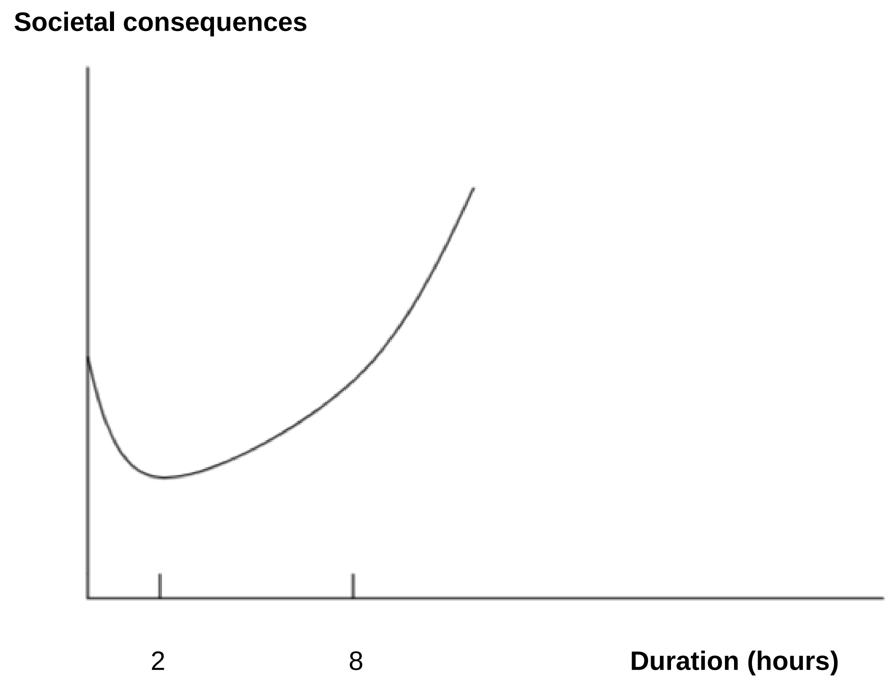
VOLL shows negative correlation wrt duration of the power cut, implying declining marginal outage costs



Source: Blackout simulator.

Power outages of long duration

- Not necessarily linear effect
  - Saturation (<2h)
  - (Quick) deterioration (>8h)
- LT effects
  - Public order (looting, rioting, …)
  - Communication
  - Food chain
  - Water distribution (+hygiene)
  - Hospitals
  - Gas stations
  - Distribution of medicines
  - Nuclear PP (back-up)
- Cascade effect towards other regions/MS?



Source: Rathenau Institute, 1994.

Reference

- Good feeling of the impact of a blackout of long duration
- Fiction, but thorough research

Discussion