UNIVERSITY OF OSLO

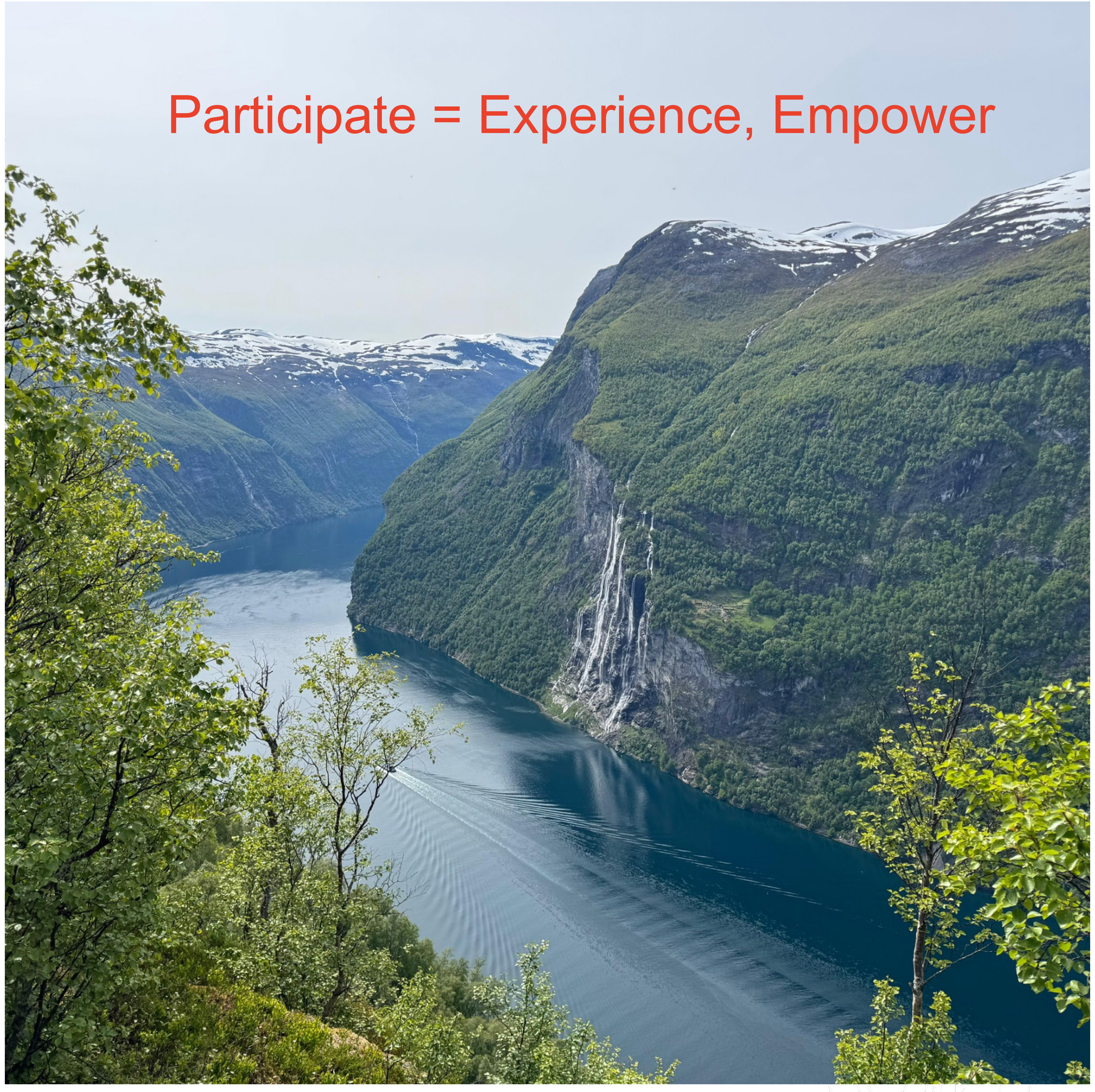
Noble Banadda International Sustainability Summer School, Rappersvill, 8-13Sep2025

Participating Energy Transition, Opportunities for Municipalities

Josef Noll

Professor, University of Oslo,
Department of Technology Systems

Kjeller, Norway, m: +47 9083 8066, e: josef@jnoll.net



Our journey for the Smart Energy Transition

1) Grid - principles, stability
2) Demand - Supply: “freshware”
3) Norway: manage the conversion
4) Use case: Lillestrøm Municipality
5) Energy Security, Monitoring and Control
6) The opportunity for Municipalities

TEK5370 - Grid, Smart Grid & IoT

To understand:
- complexity of grid and grid regulation
- complex numbers Voltage vs Current

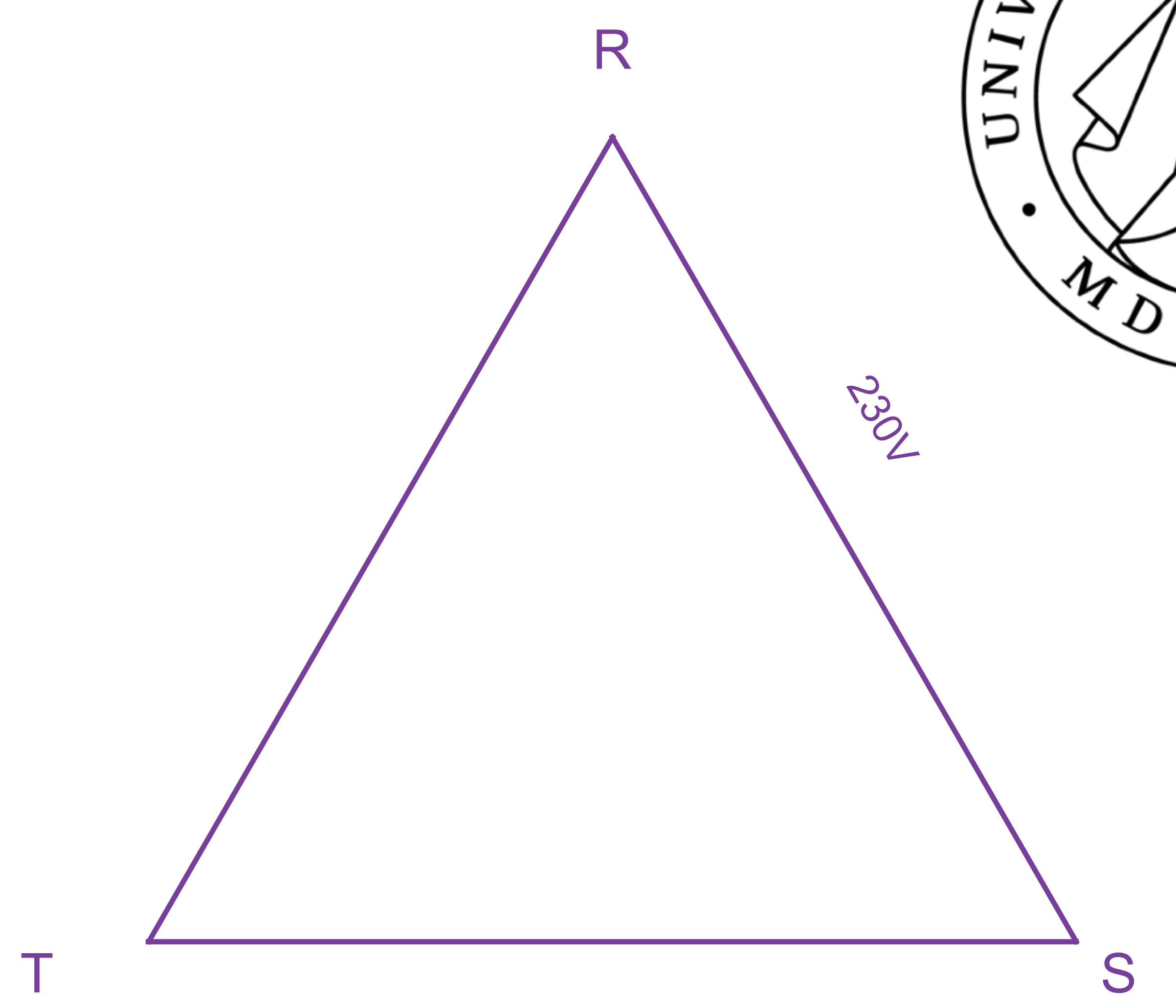
To understand:
- Energy calculation in a transformator
- Real and imaginary energy

To understand:
- impact of renewable energy on the grid, e.g.
- variation in frequency (time)
- variation in amplitude

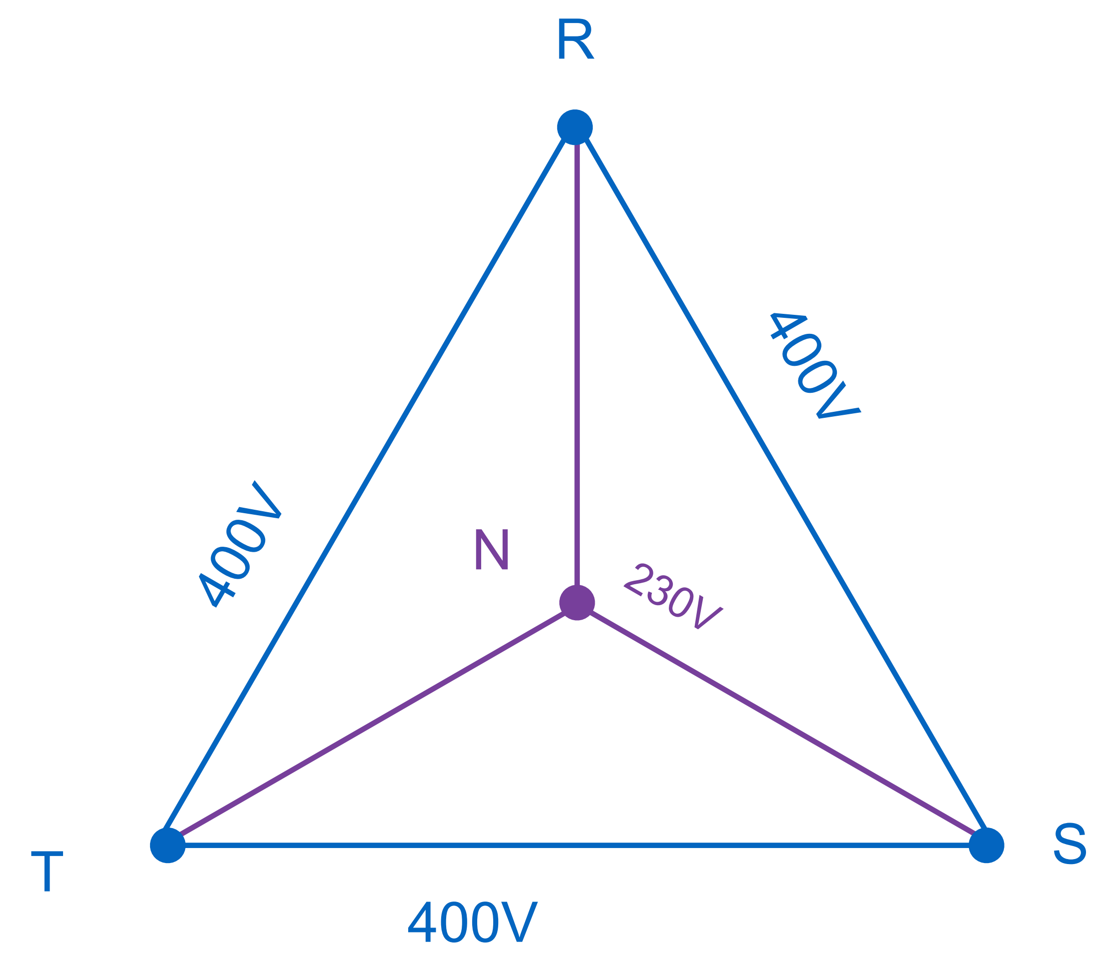
Power & Energy - AC - alternate current

$$U = R \times I$$

$$P = U \times I$$



- "Norway and Albania"
  - floating network - no earth
  - IT network
-
- Europe (and rest of world)
  - N = neutral
  - TN network



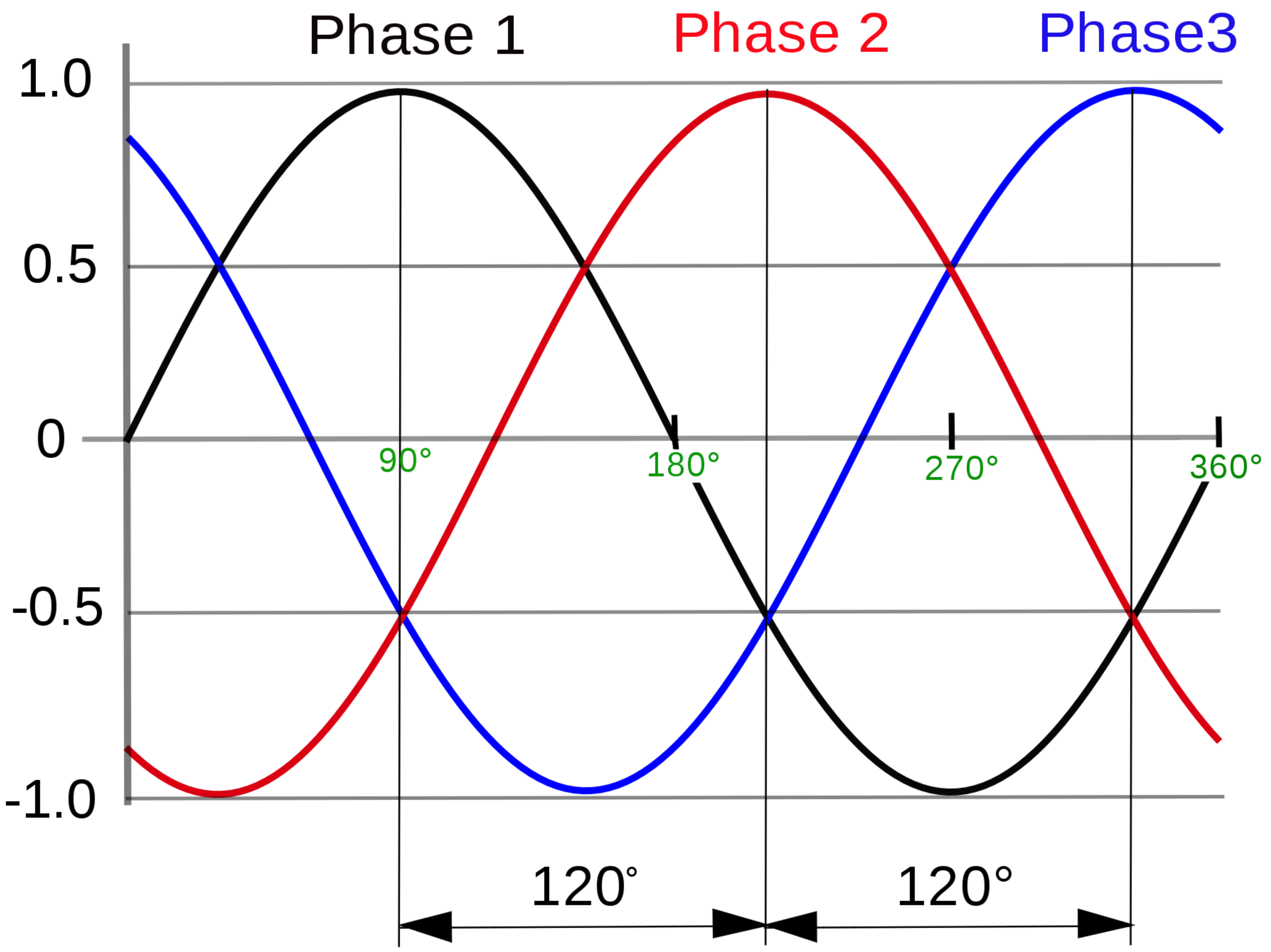
Example: Home

230 V AC
Heat pump 6 kW

how much current?

discuss the effects of 3 phases

3-phase system



https://en.wikipedia.org/wiki/Polyphase_system#/media/File:3_phase_AC_waveform.svg

Line Model representation

- What is happening?
- Series inductance $z = R + jwL$
- Shunt admittance: $y = jwC + G$

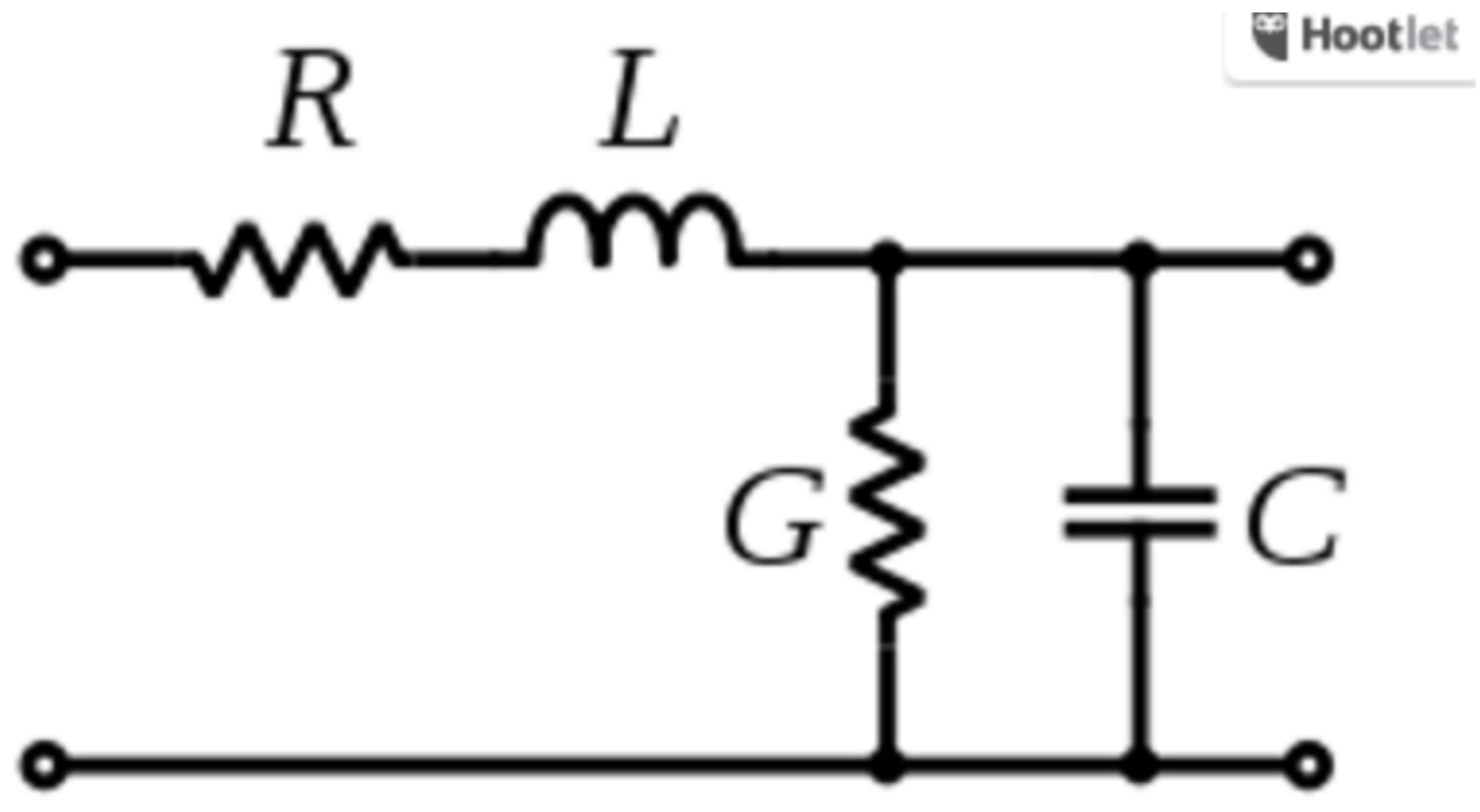


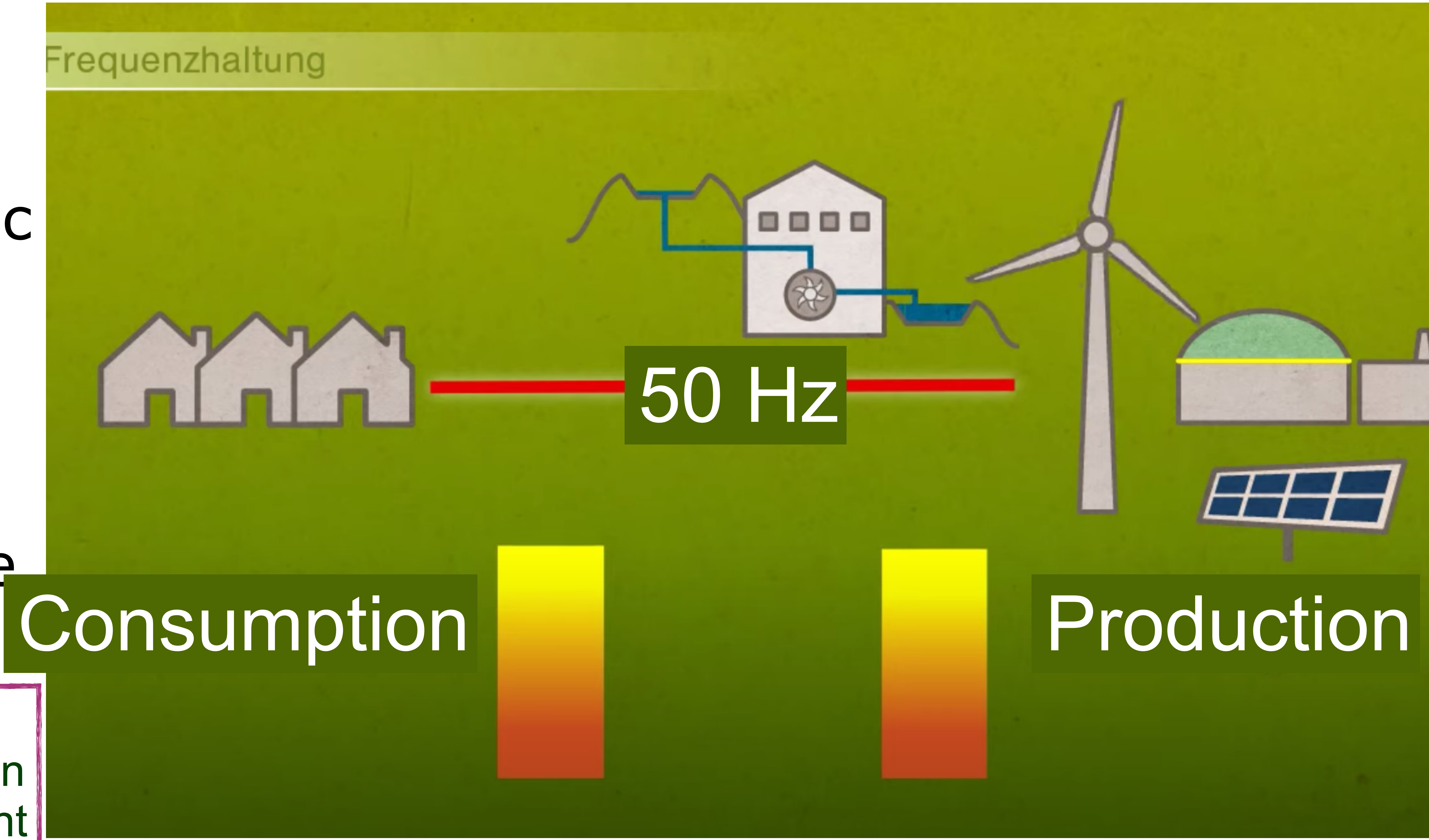
Figure 1: Lumped elements of an arbitrary section of transmission line.

https://www.allaboutcircuits.com/technical-articles/transmission-lines-from-lumped-element-to-distributed-element-regimes/

Frequency and Voltage - control and stabilisation

- ➡ 50,2 Hz too much energy
  - switch off photovoltaic
- ➡ 49,8 Hz too little energy
- ➡ 230 V (400 V)
  - drop due to resistance in the line

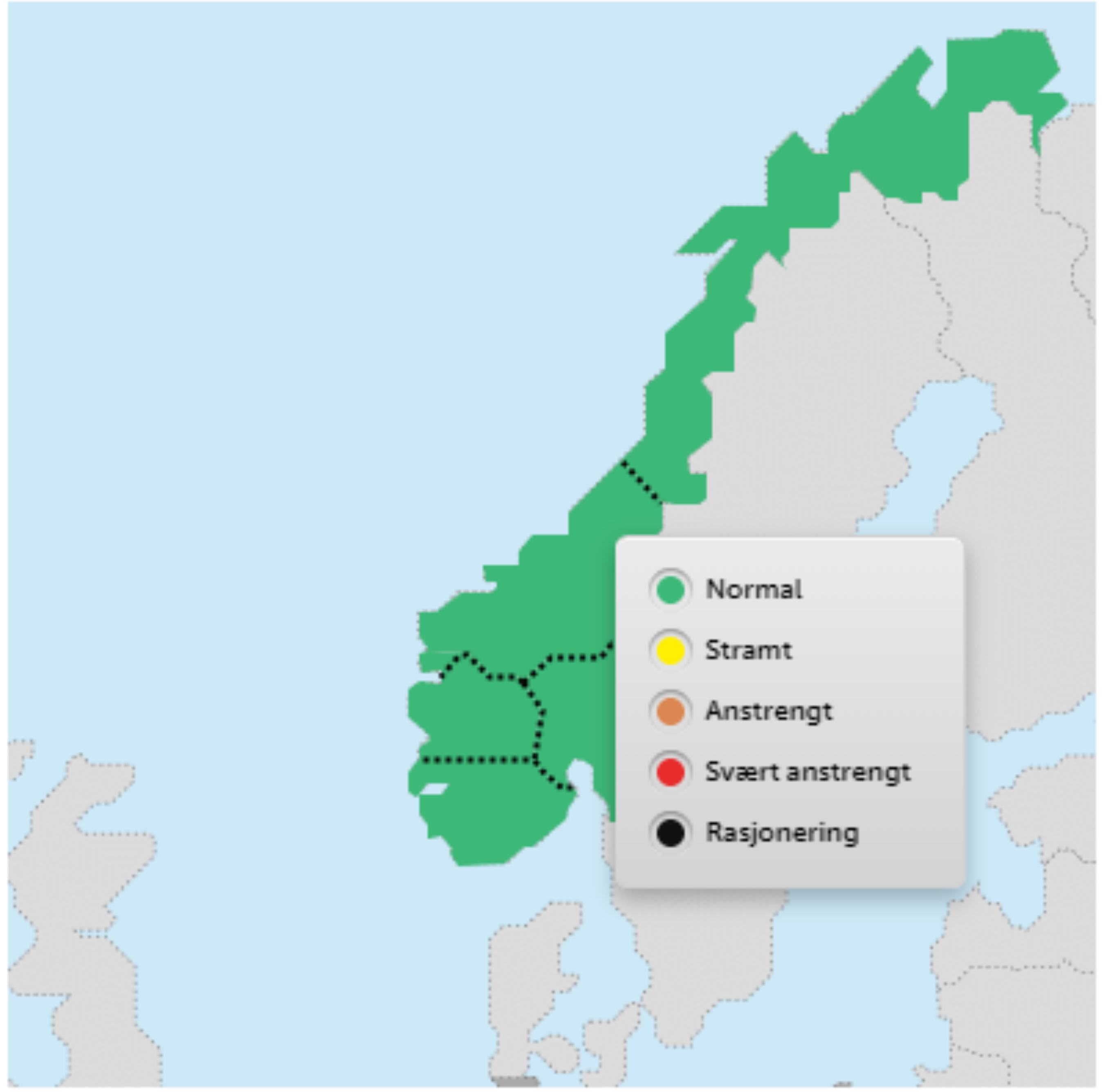
To understand:
- complexity of grid and grid regulation
- complex numbers Voltage vs Current



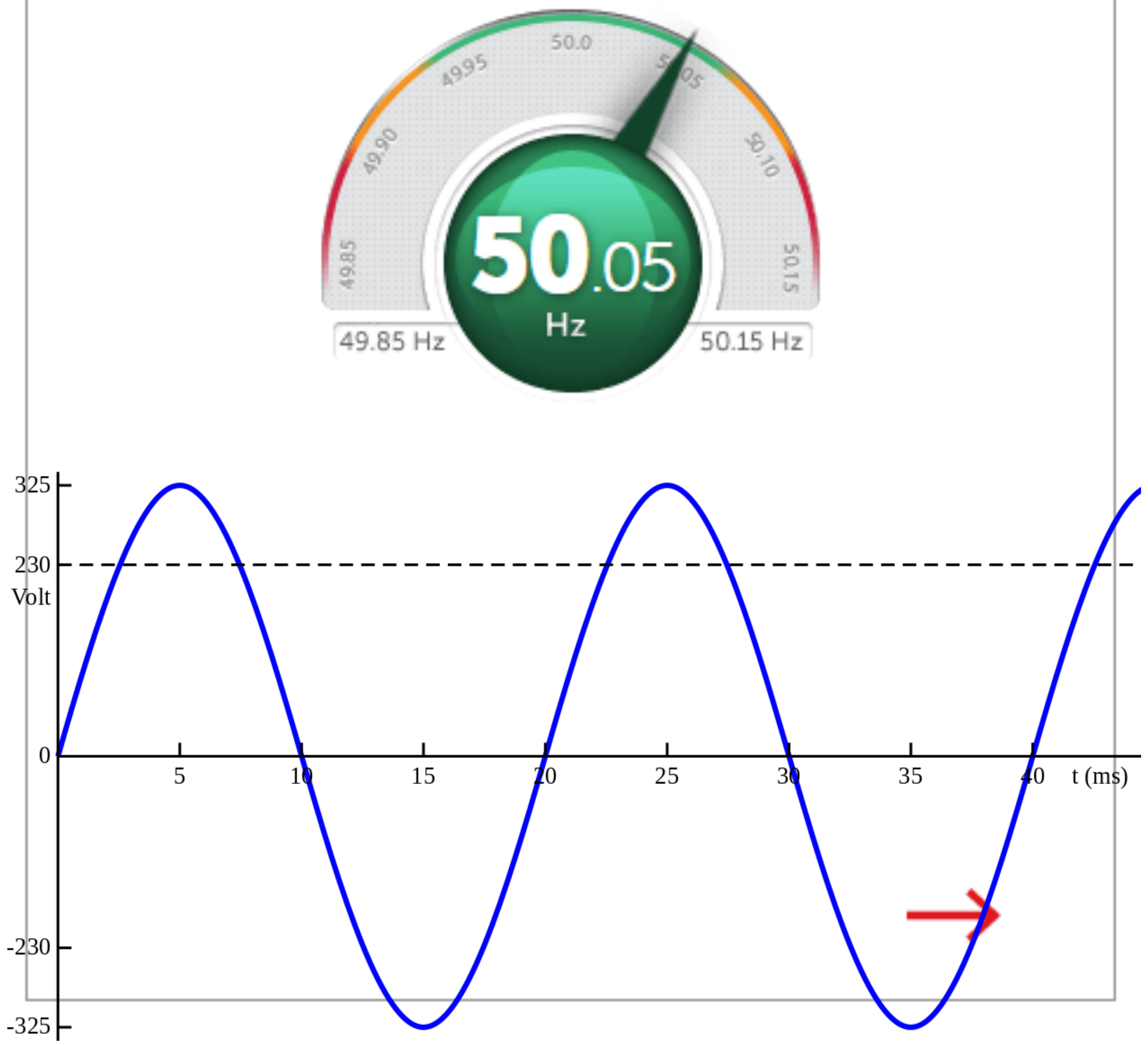
Norwegian grid

KRAFTSITUASJONEN AKKURAT NÅ

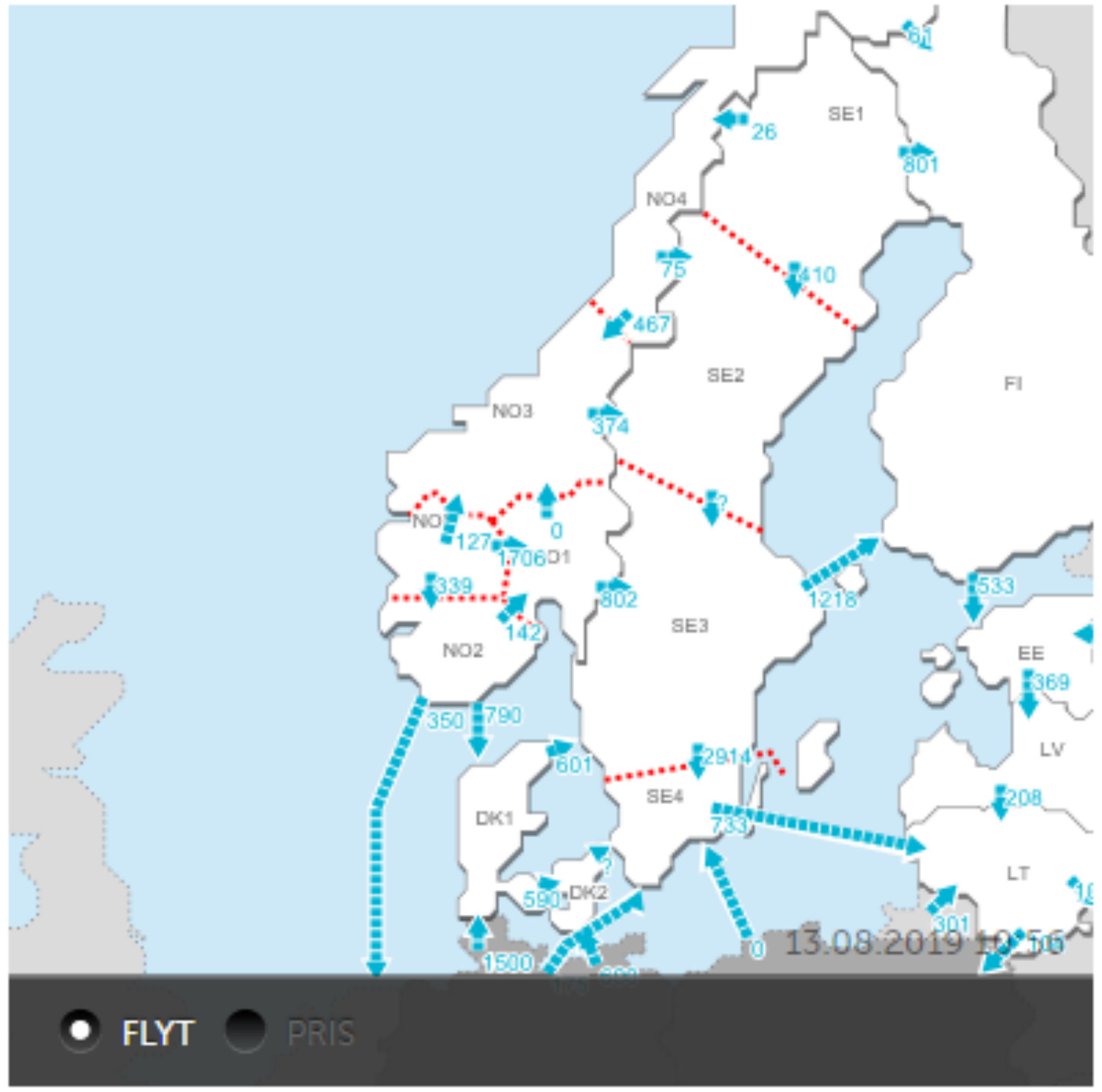
Power situation (arbitrary day)



Nordic Power Balance



Nordic Power Flow



Power balance
Norwegian Grid

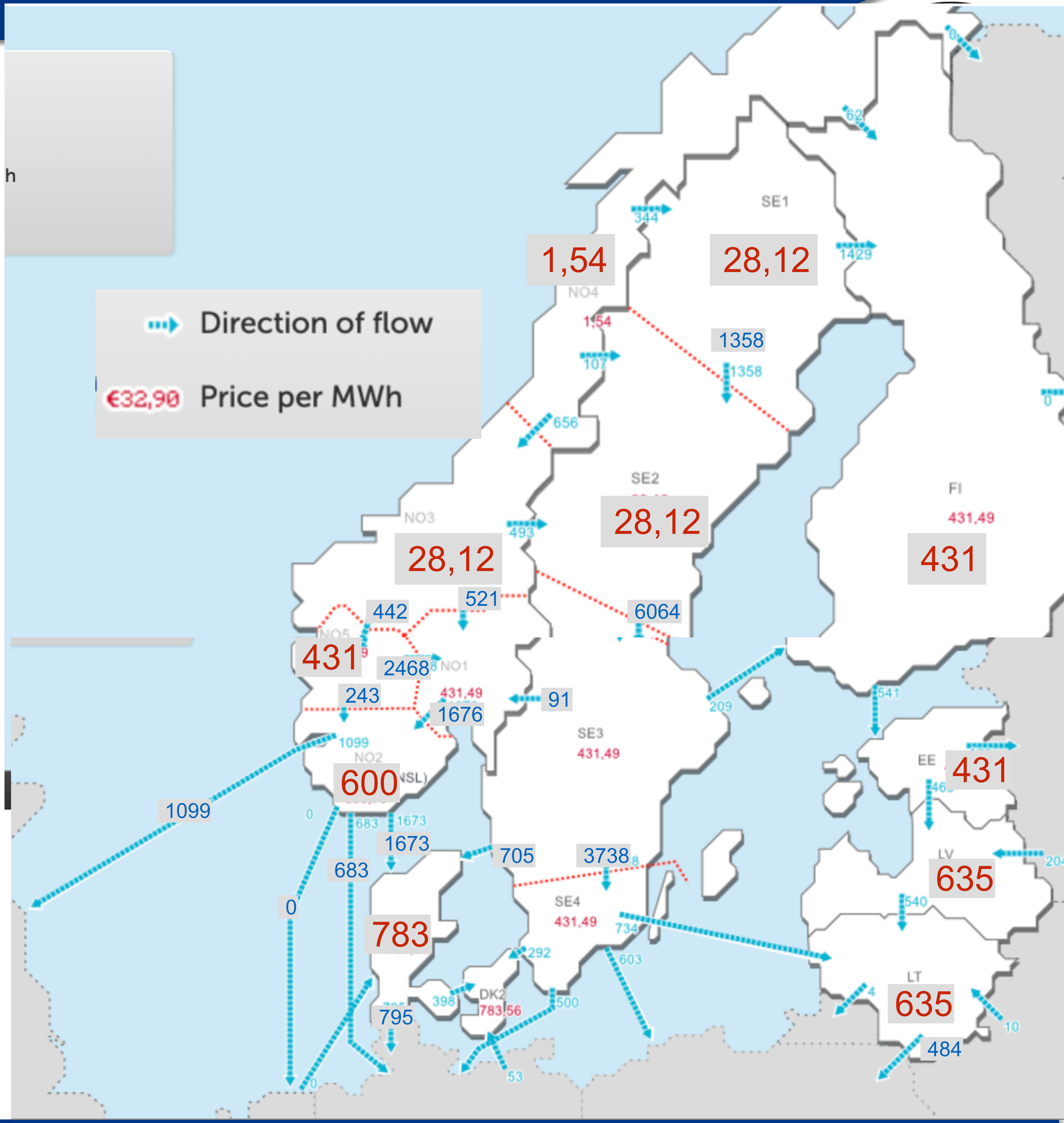
Difference: ~500 000 MWh
why?

Statnett Data 31Aug2025-7Sep2025

Norway exchange 24Aug2022

Did Norway manage the transition?

Challenges
- A: Grid capacity
- B: Transition to renewable
- C: Novel industries

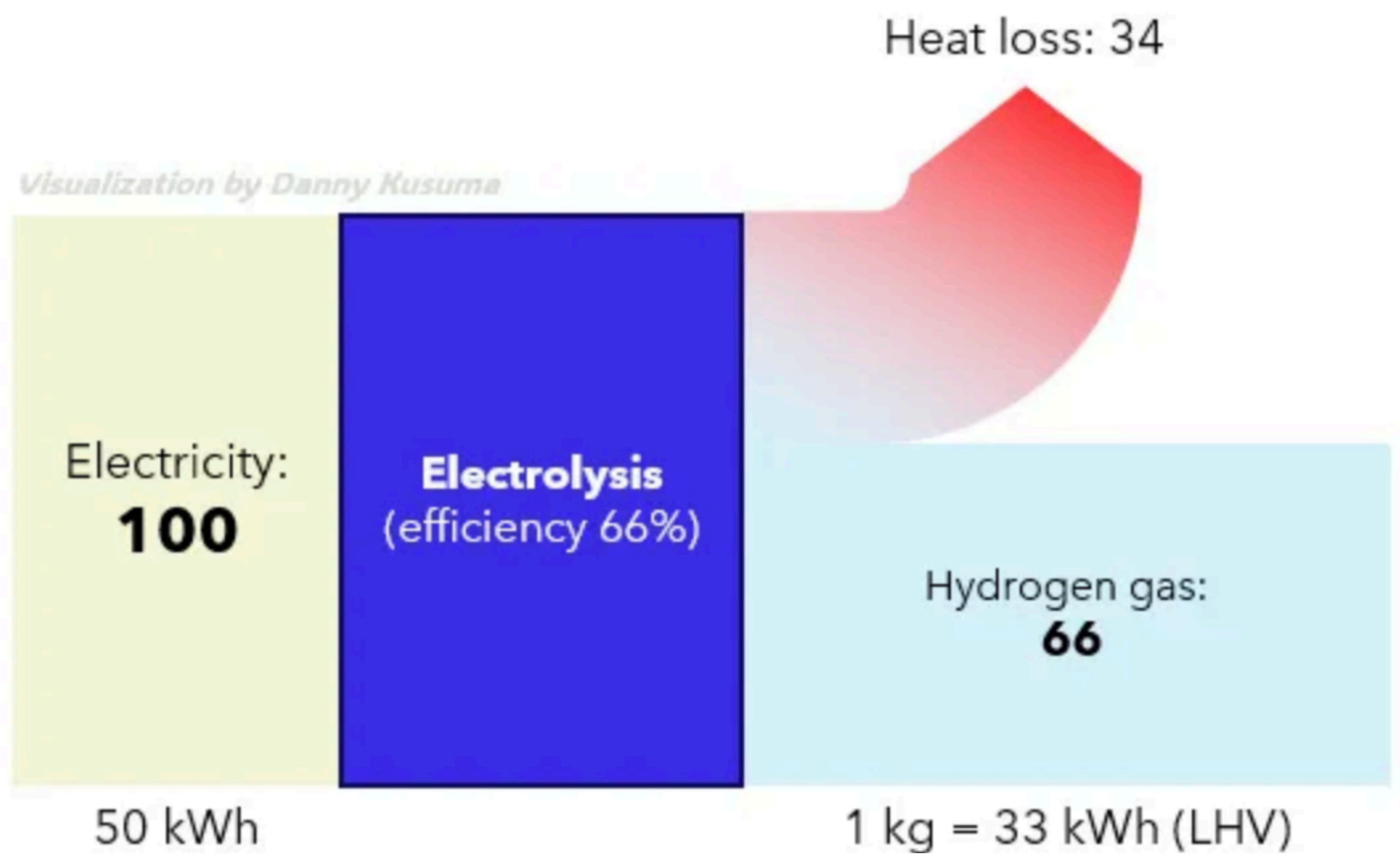


A) Grid capacity

https://atlas.nve.no/Html5Viewer/index.html?viewer=nveatlas

B) Transition to electrical energy case: Norway

- ➡ Yearly total energy: 230 TWh
- ➡ Yearly electrical energy: 150 TWh
- ➡ Need for transition: 80 TWh



- ➡ Efficiency of conversion?
  - e.g. wind energy > hydrogen > electrical energy (23%)
  - e.g. wind energy > Ammonia NH_4 (61%) > engine efficiency 35%, total 21%
- Comparison: heat pump 300% efficiency (COP=4)

https://dannykusuma.medium.com/hydrogen-hype-a-story-of-energy-loss-f37a592331c8

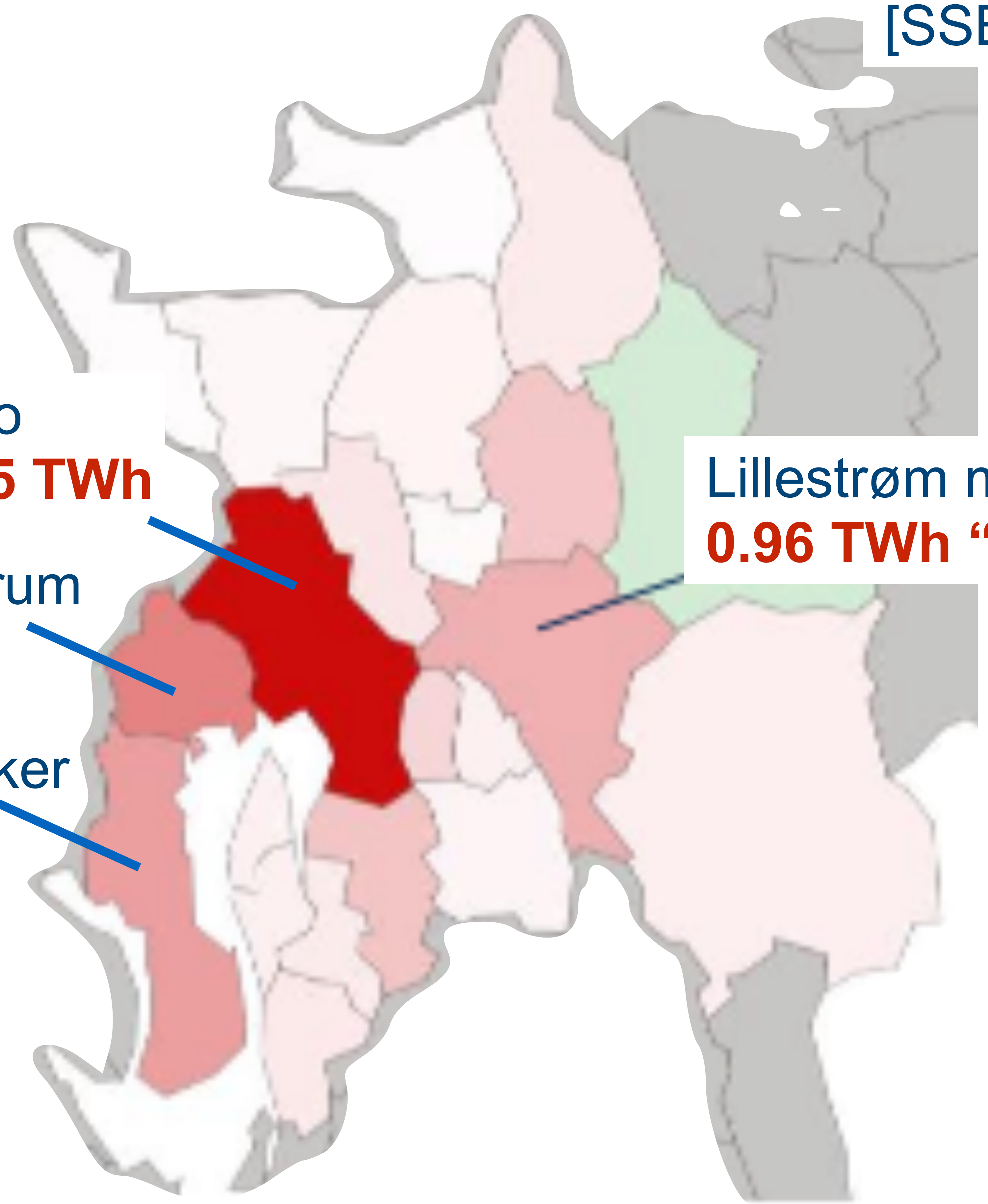
C) new business (AI, battery production,…) Energy balance towards 2030 (NHO & LO)

https://www.nho.no/tema/energi-miljo-og-klima/kraftloftet/kraftloftet-pbi/

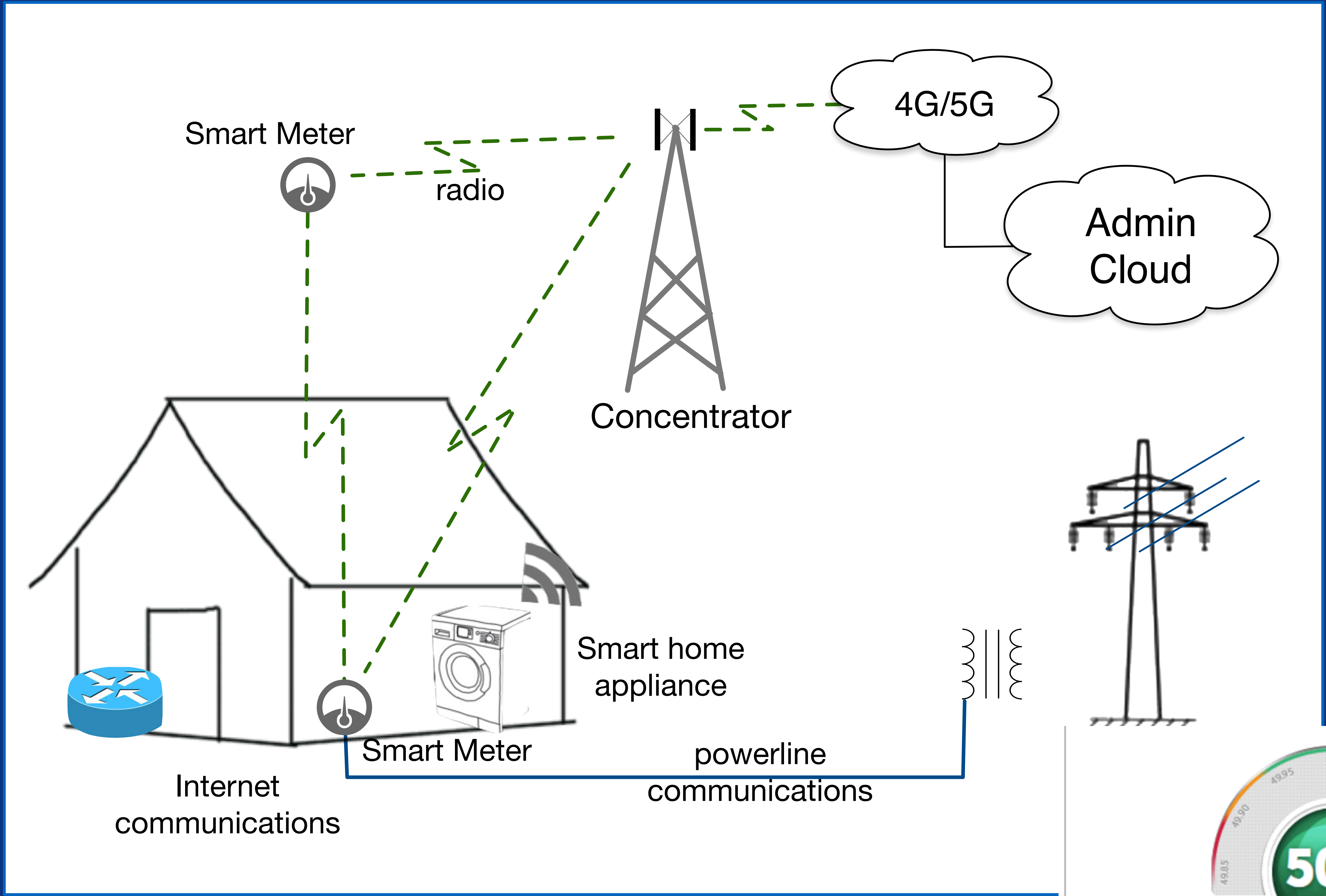
Akershus	
Eksisterende kraftbalanse (TWh)	-8.38
Kraftbalanse reservert (TWh)	0.11
Kraftbalanse tilknyttet (TWh)	0.00
Forventet kraftbalanse (TWh)	-8.27

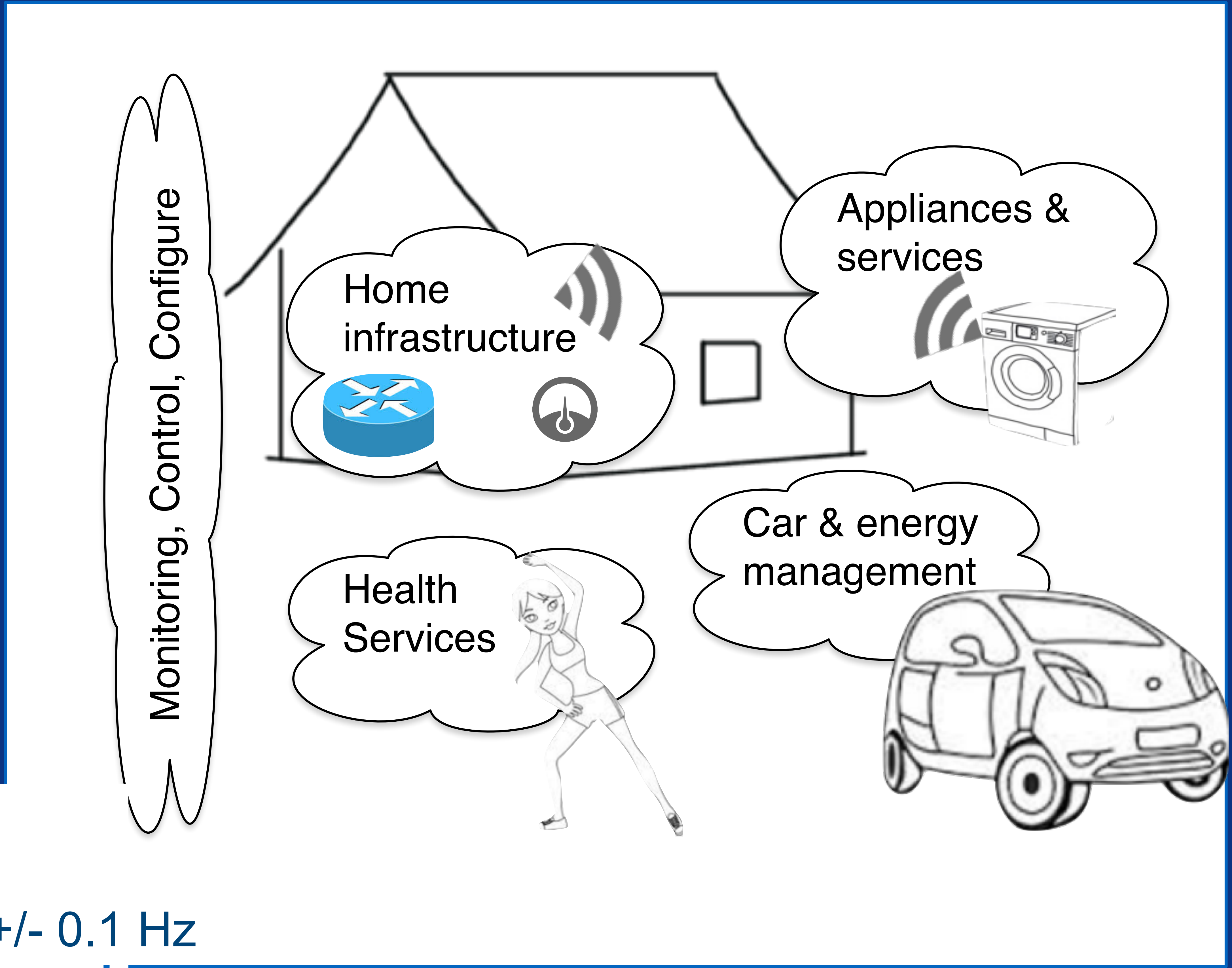
Oslo (724 k people) and
Akershus (728 k people, 21 municipalities)

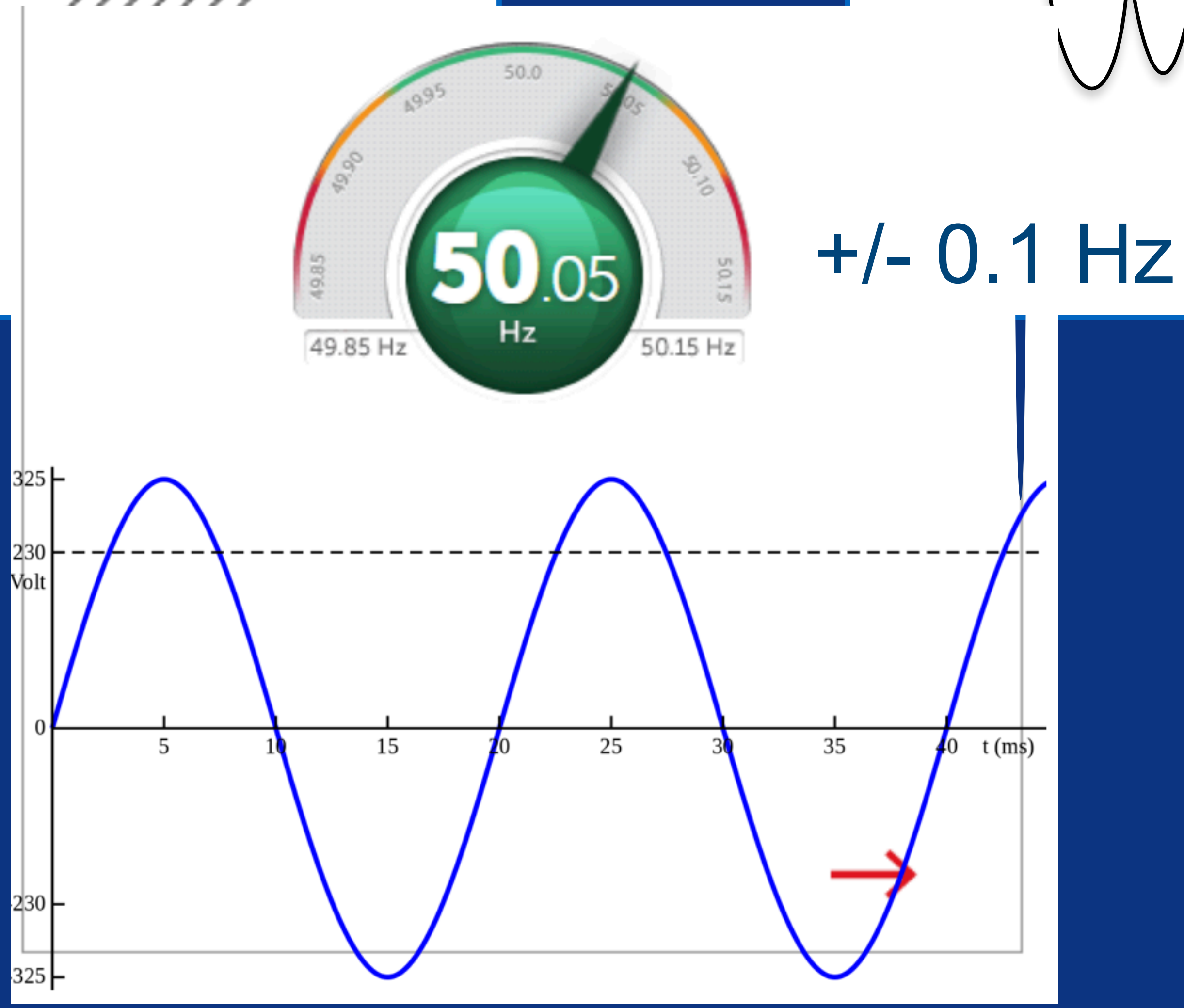
[SSB, Jan 2025]



5) Energy Security, Monitoring and Control

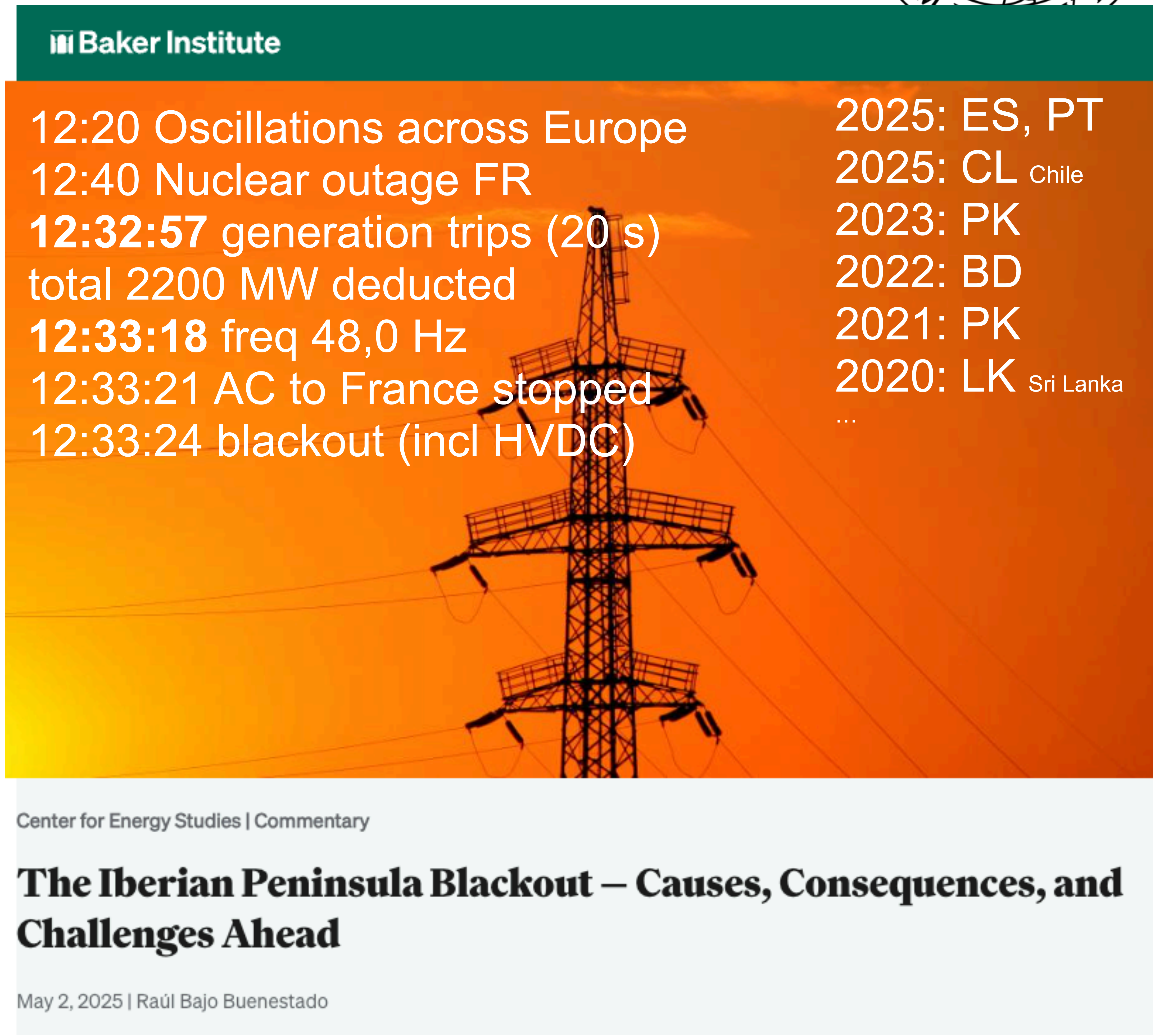






28Apr2025 Spain & Portugal blackout

- Cause:
  - 60% solar energy,
  - 1. solar park switched off, 1.5 s later 2. solar park
  - interconnection to France stopped (f < 48,0 Hz)
- Conventional: inertia (rotating generators)
- Solar: sudden death (DC/AC converters)
- Challenge:
  - distributed respond to grid fluctuations



https://www.entsoe.eu/news/2025/05/09/entso-e-expert-panel-initiates-the-investigation-into-the-causes-of-iberian-blackout/

https://www.bakerinstitute.org/research/iberian-peninsula-blackout-causes-consequences-and-challenges-ahead

https://en.wikipedia.org/wiki/List_of_major_power_outages

Power Grid 2024

US electric grid growing more vulnerable to cyberattacks, regulator says

By **Laila Kearney**

April 4, 2024 11:48 PM GMT+2 · Updated 9 months ago

Aa

A local resident walks by the power grid towers at Bair Island State Marine Park in Redwood City, California, United States, January 26, 2022. REUTERS/Carlos Barria/File Photo Purchase Licensing Rights

https://www.reuters.com/technology/cybersecurity/us-electric-grid-growing-more-vulnerable-cyberattacks-regulator-says-2024-04-04/

Ukraine blackouts caused by malware attacks warn against evolving cybersecurity threats to the physical world

May 17, 2024

By Emily Cerf

SHARE THIS STORY:

On a cold winter night in 2016, Ukrainians experienced the first-ever known blackout caused by malicious code (malware) designed to autonomously attack the power grid. One-fifth of Kyiv's citizens were plunged into darkness as attackers used malware to target the capital city's power grid. Six years later, in the early months of the ongoing Russia-Ukraine war, a second attack attempted to combine kinetic and cyber attacks to take down Ukraine's power grid.

Power lines in Ukraine. Photo credit: Mny-Jhee, iStock.

Malware attacks against physical infrastructure have long been a looming threat in the realm of cybersecurity, but these two in Ukraine were the first attacks of their kind, and have received little attention from the academic community. Carried out by a Russian intelligence agency against Ukraine, they warn of the evolution of cyber attacks to the built world, and highlight the need to better understand and defend against this type of malware.

https://news.ucsc.edu/2024/05/ukraine-cybersecurity.html

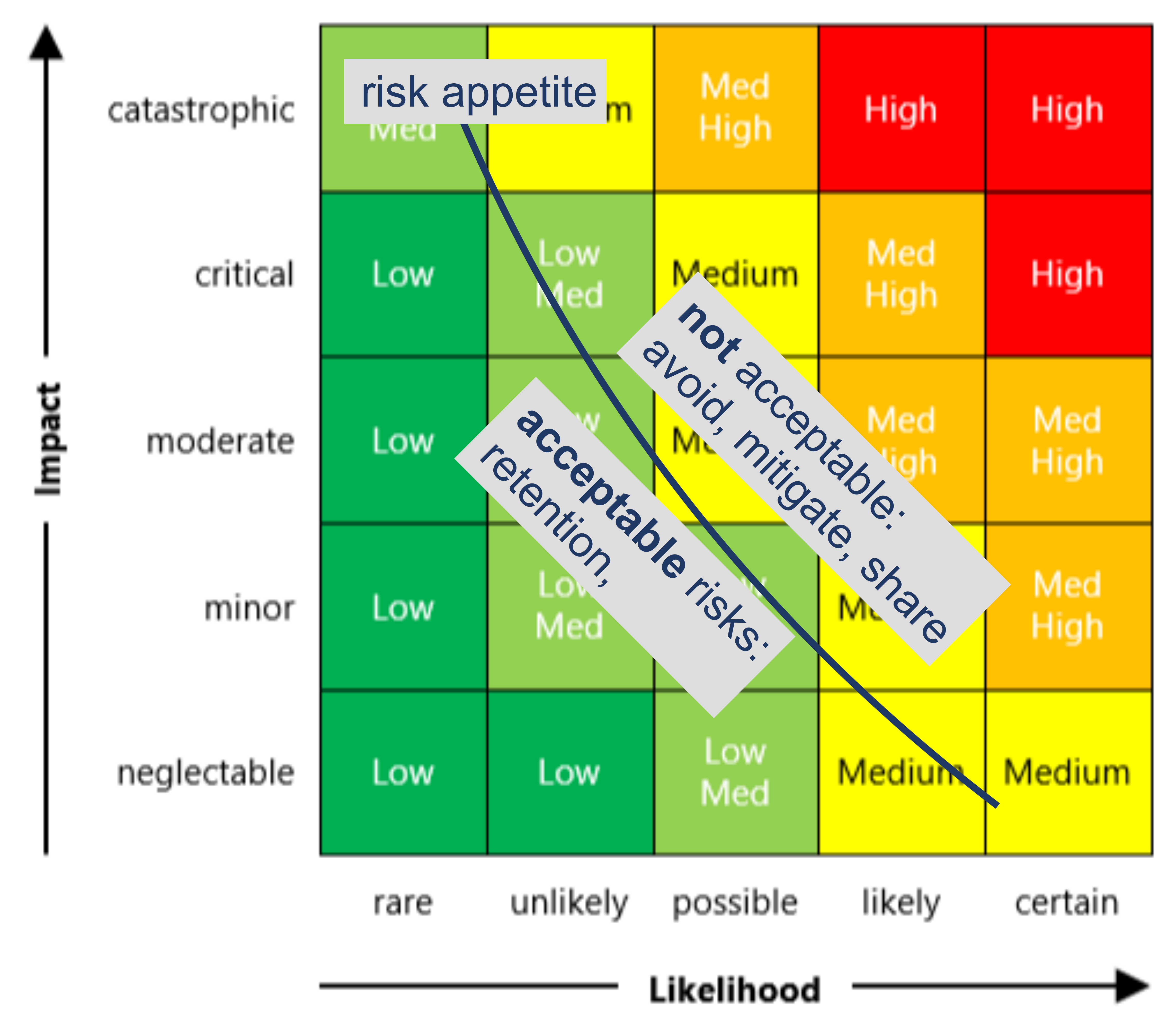
Resilient Societies

- Resilience to threats
  - Pandemics: COVID-19,
  - natural disaster
  - external threats: terrorism, fake news,
- Self-sustained communities
  - job-creation
  - educating, information,
  - Dugnad: value creation
- Value-based
  - “alle er med” (everyone is included)
  - Trust

- “Digital Participation in the society”

Markus Brunnermeier, Princeton University

Risk Analysis for IoT

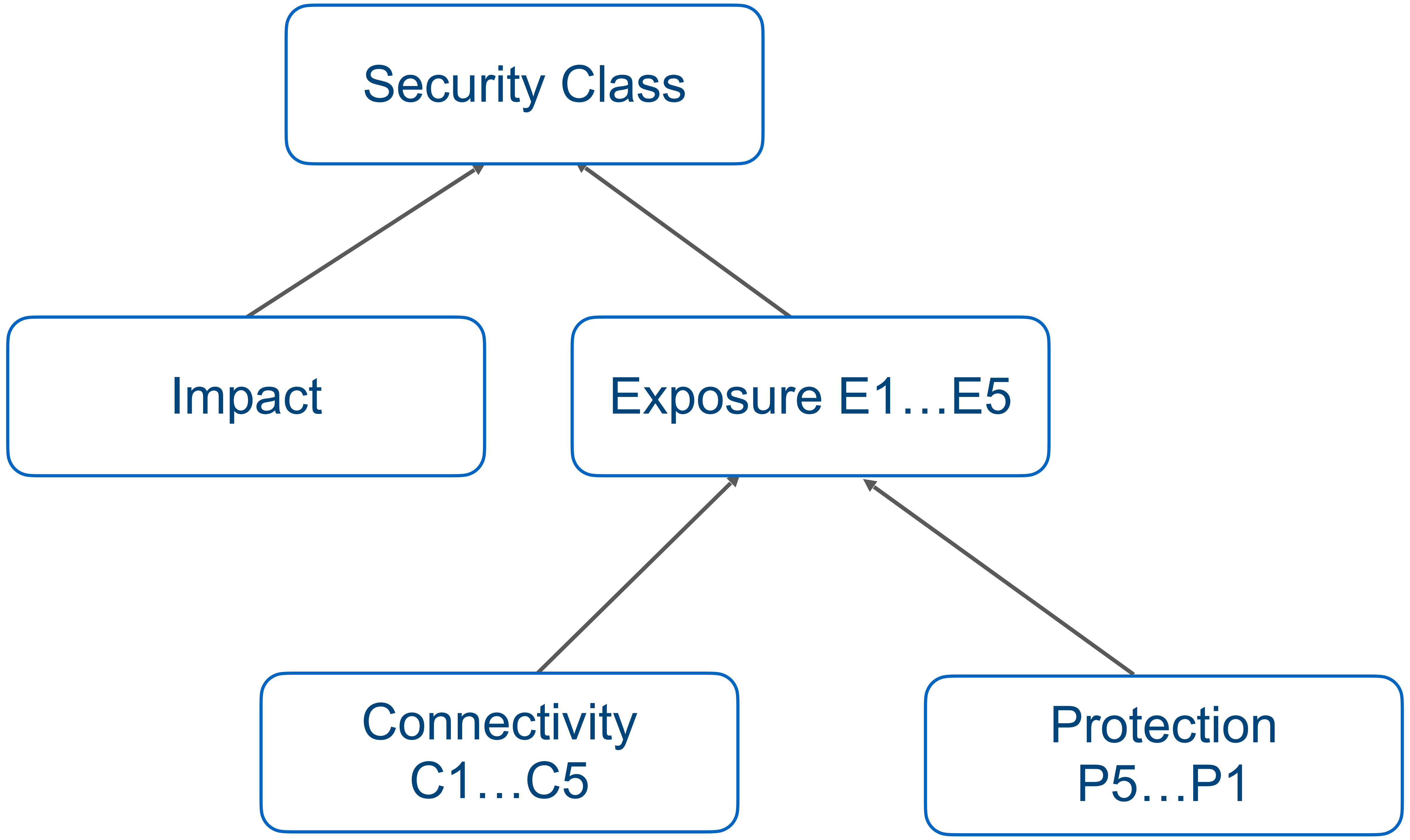


Applicable to IoT?

https://www.nrk.no/trondelag/historien-om-containerskipet-som-grunnstotte-i-hagen-til-johan-pa-byneset-gar-verden-rundt-1.17429973

Risk Exposure Model for IoT

- "you have been hacked"
- Exposure
  - Connectivity
  - Protection Level



Lowest Protection

P1	E4	E4	E5	E5	E5
P2	E3	E4	E4	E5	E5
P3	E2	E3	E3	E4	E4
P4	E1	E1	E2	E2	E3
P5	E1	E1	E1	E1	E2
Protection/ Connectivity	C1	C2	C3	C4	C5

Highest Protection

Isolated

Wireless connectivity

Internet

Manish Shrestha https://its-wiki.no/wiki/Smart_ICT_2019

Exposure Risk Model

Increased Security through decentralisation

decentralised
Sec. Class = A

centralised
Sec. Class = D

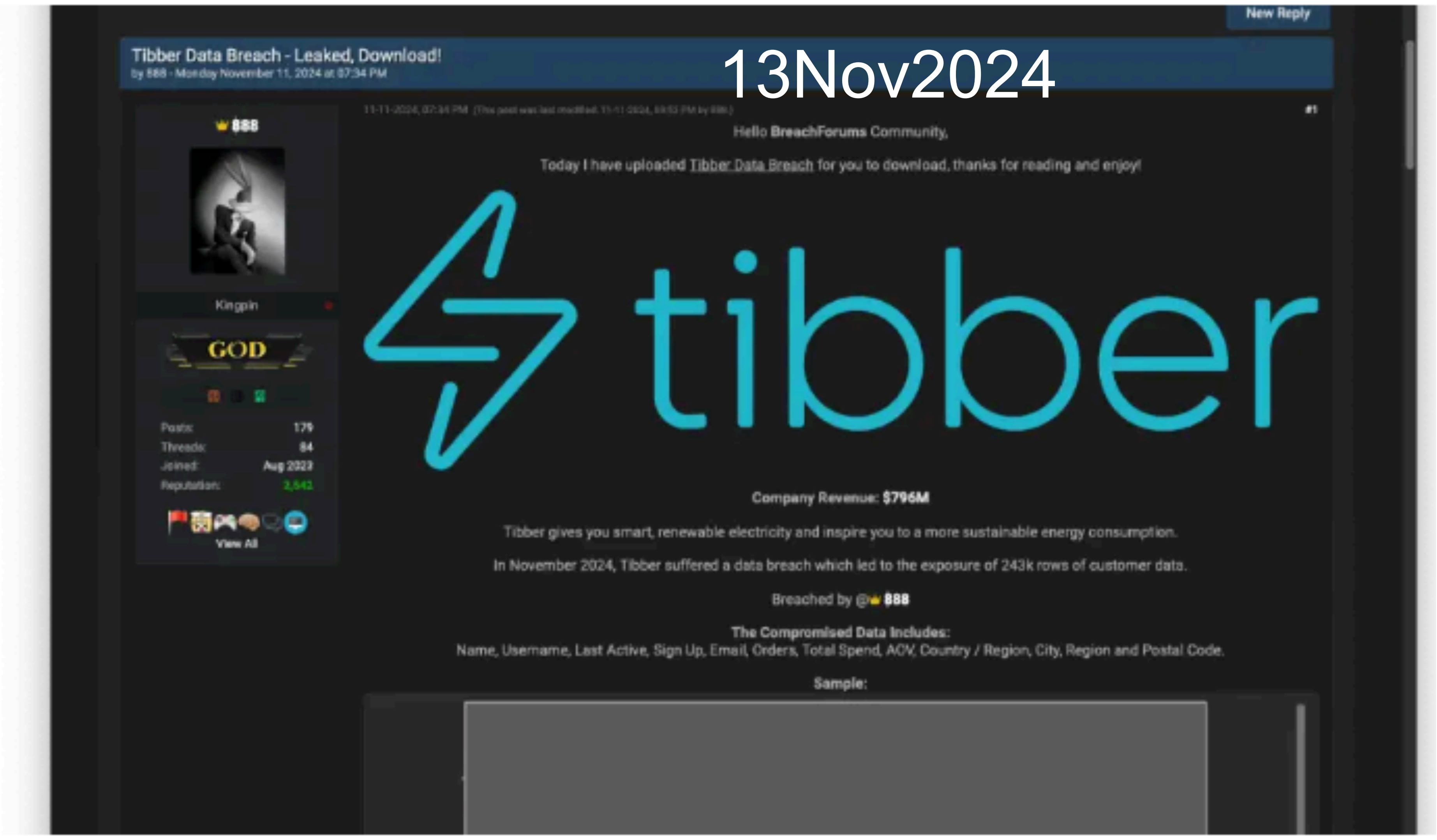
Catastrophic	A	C	E	F	F
Major	A	B	D	E	F
Moderate	A	B	C	E	E
Minor	A	A	B	D	D
Insignificant	A	A	A	C	C
Impact/ Exposure	E1	E2	E3	E4	E5

Smart Meter Regulations

[Courtesy: Manish Shrestha, UiO, 2019]

Threat landscape

- Supply chain attacks
- Ukraine grid hack (2015)



(Image: heise online)

Nov 13, 2024 at 4:35 pm CET 2 min. read | Security

By Dr. Christopher Kunz

Hackers have attacked electricity provider Tibber and stolen data. The company confirmed this to heise security. Over 50,000 customers are apparently affected, all of them from Germany. The attackers are offering their prey for sale on the Darknet.

July 2023 - June 2024

1. Ransomware 25.8%
2. Malware 5.2%
3. Social Engineering 6.1%
4. GDPR threat 19%
5. DDoS 41.1%
6. Information manipulation ~1%
7. Supply chain attacks ~1%

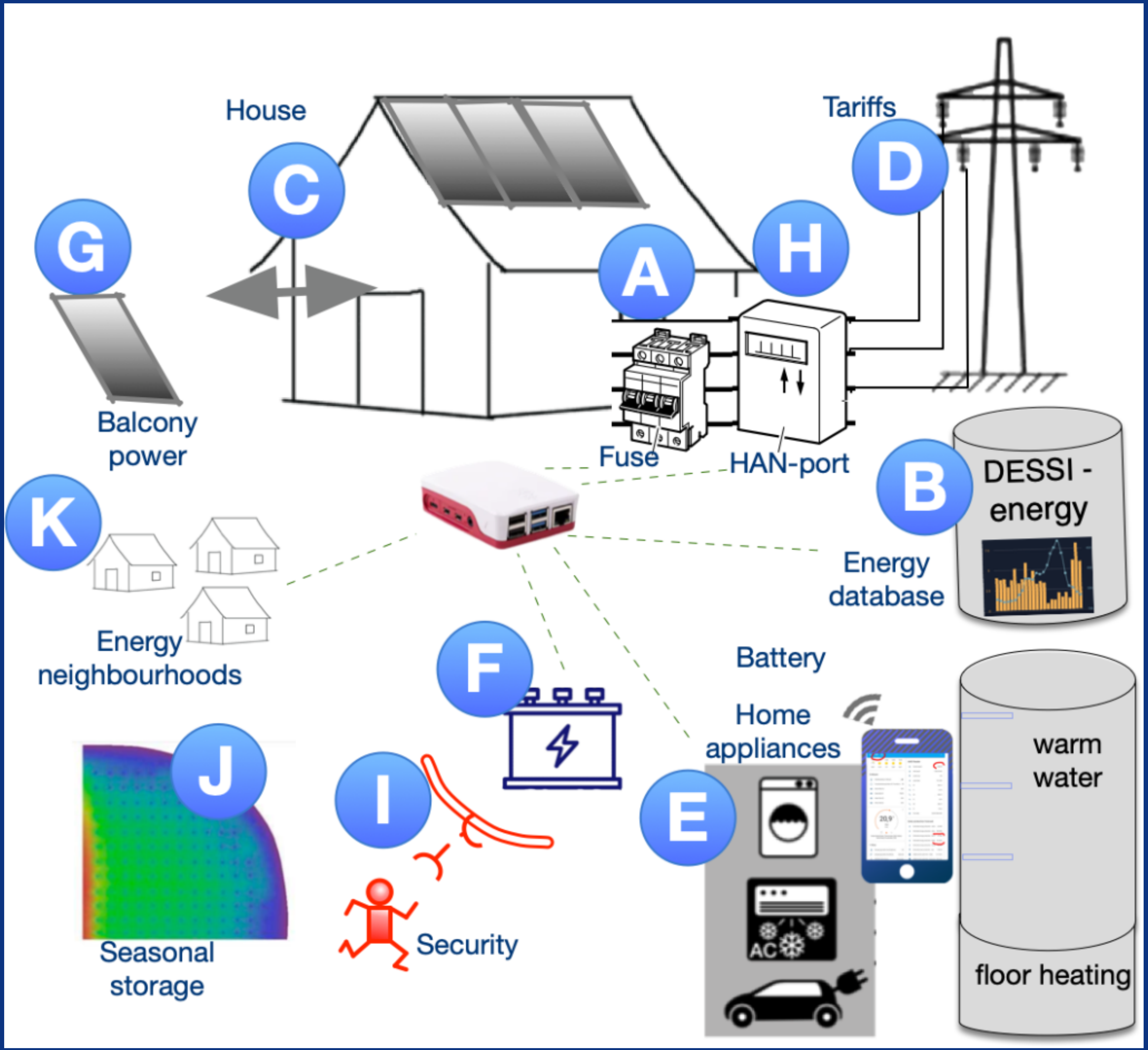
Examples Supply Chain

- Discord (Mar2024)
- Okta (Oct2023 - authentication)
- JetBrains (Sep2023 - TeamCity)
- MOVEit (Jun2023 - transfer tools)
- Microsoft (Feb2023 - code sign)

https://www.heise.de/en/news/Electricity-provider-Tibber-hacked-50-000-German-customers-affected-10031690.html

https://www.enisa.europa.eu/publications/enisa-threat-landscape-2024

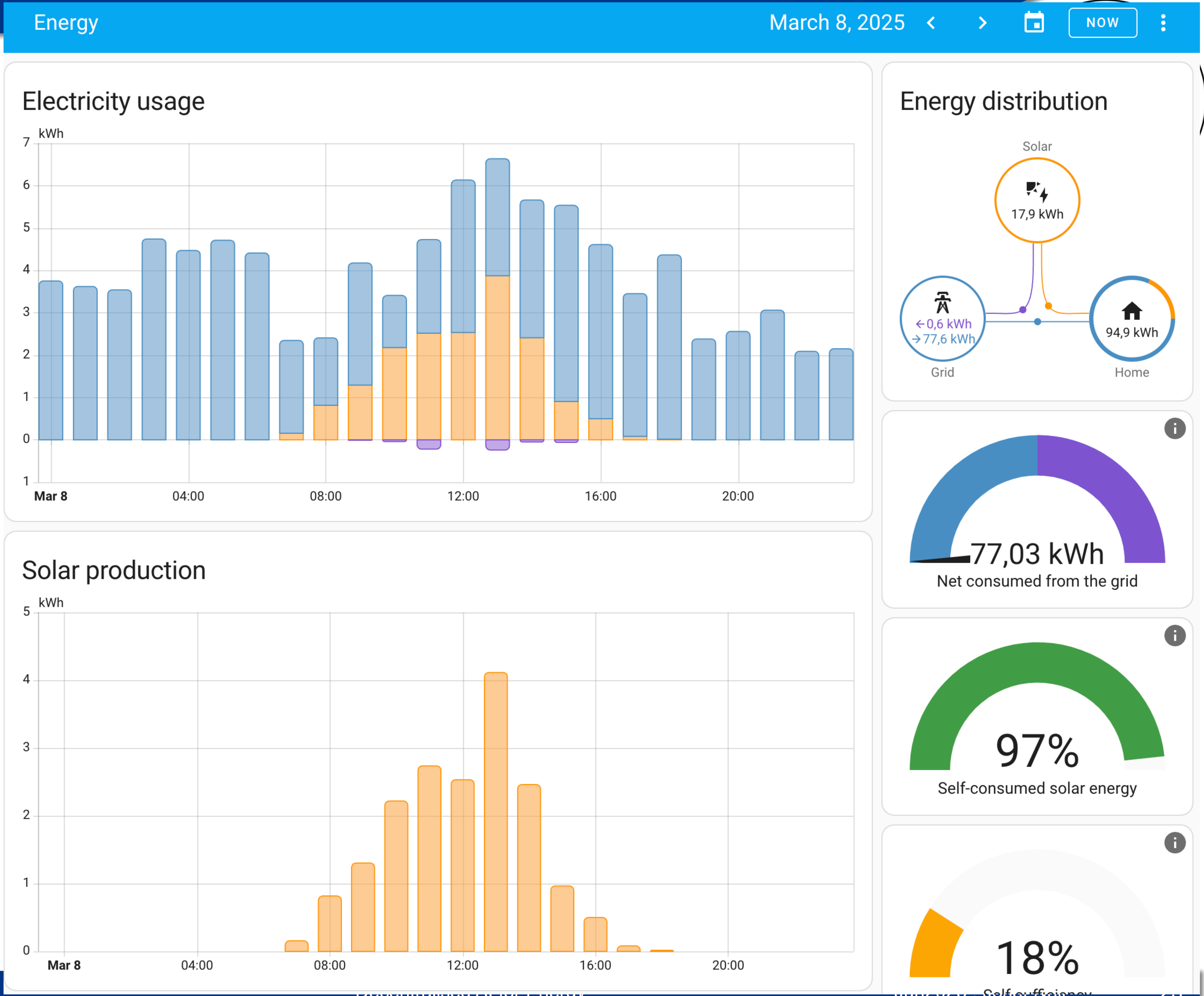
Energy monitoring and control



DESSI - Distributed Energy System and Security Infrastructure
https://www.mn.uio.no/its/english/research/projects/dessi/

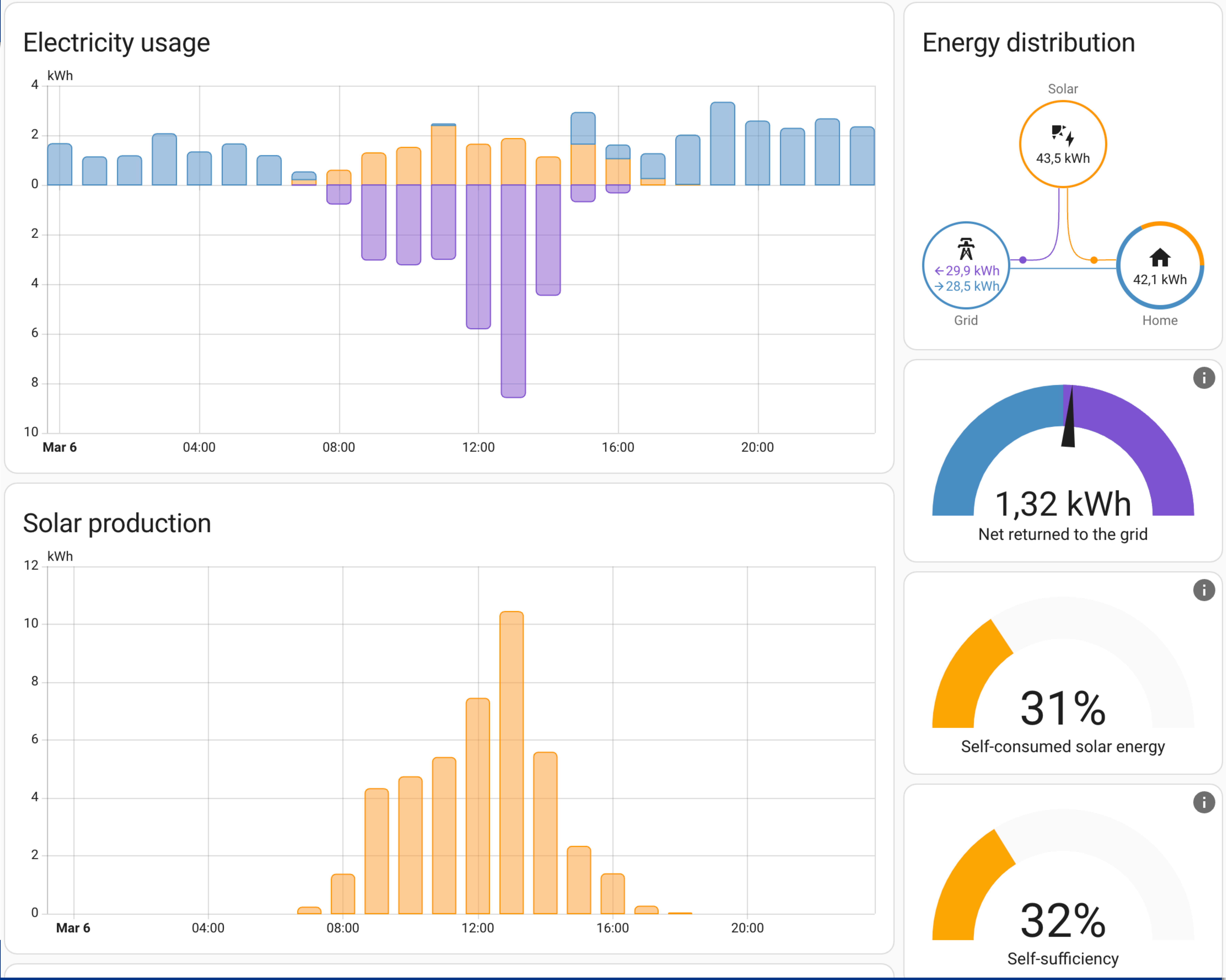
Energy dashboard 8 Mar 2025

- Energy dashboard
  - blue: from grid
  - orange: from solar
  - ping: to grid
- Solar production
- Energy distribution



6Mar2025

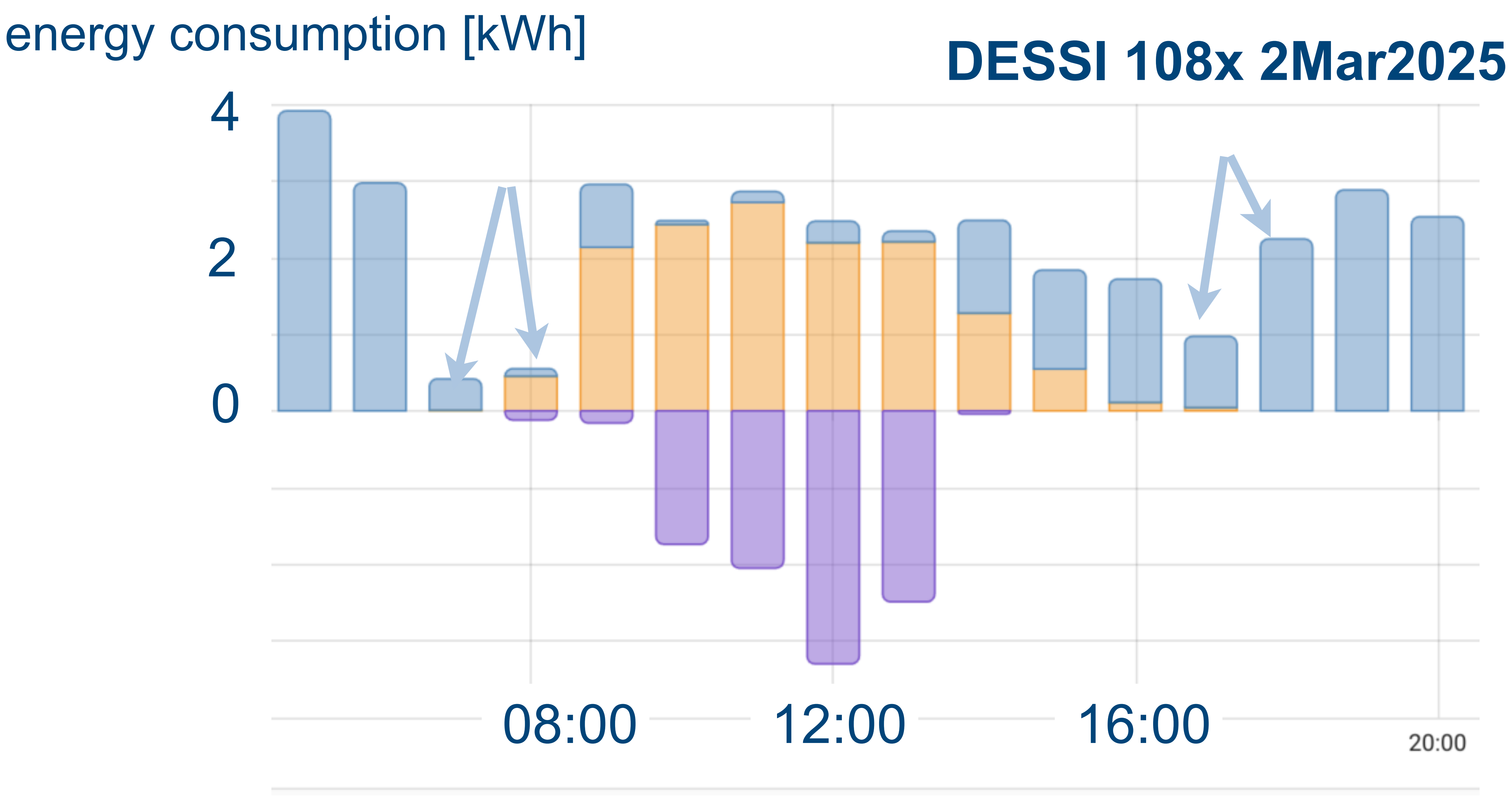
- typical situation
  - 31% self consumed
  - 43,5 kWh produced (orange)
  - 29,9 kWh to the grid (pink)

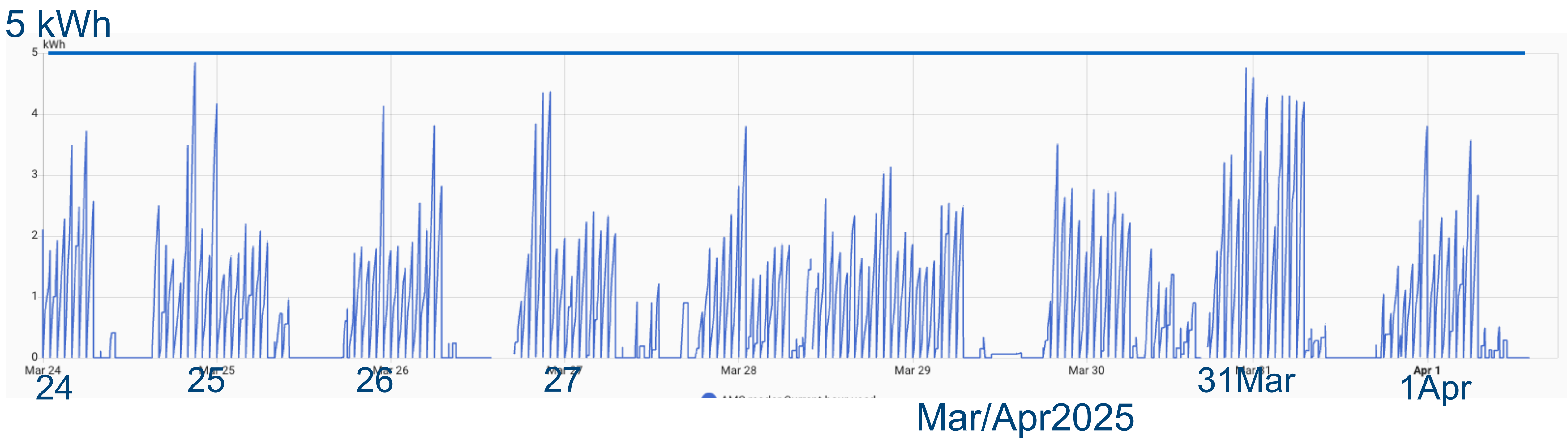


DESSI energy control “busy hour”

- busy hour reduction
  - 0700-0900: 84%, 96%
  - 1700-1900: 69%, 25%

- Peak shaving
  - below 5 kWh/h

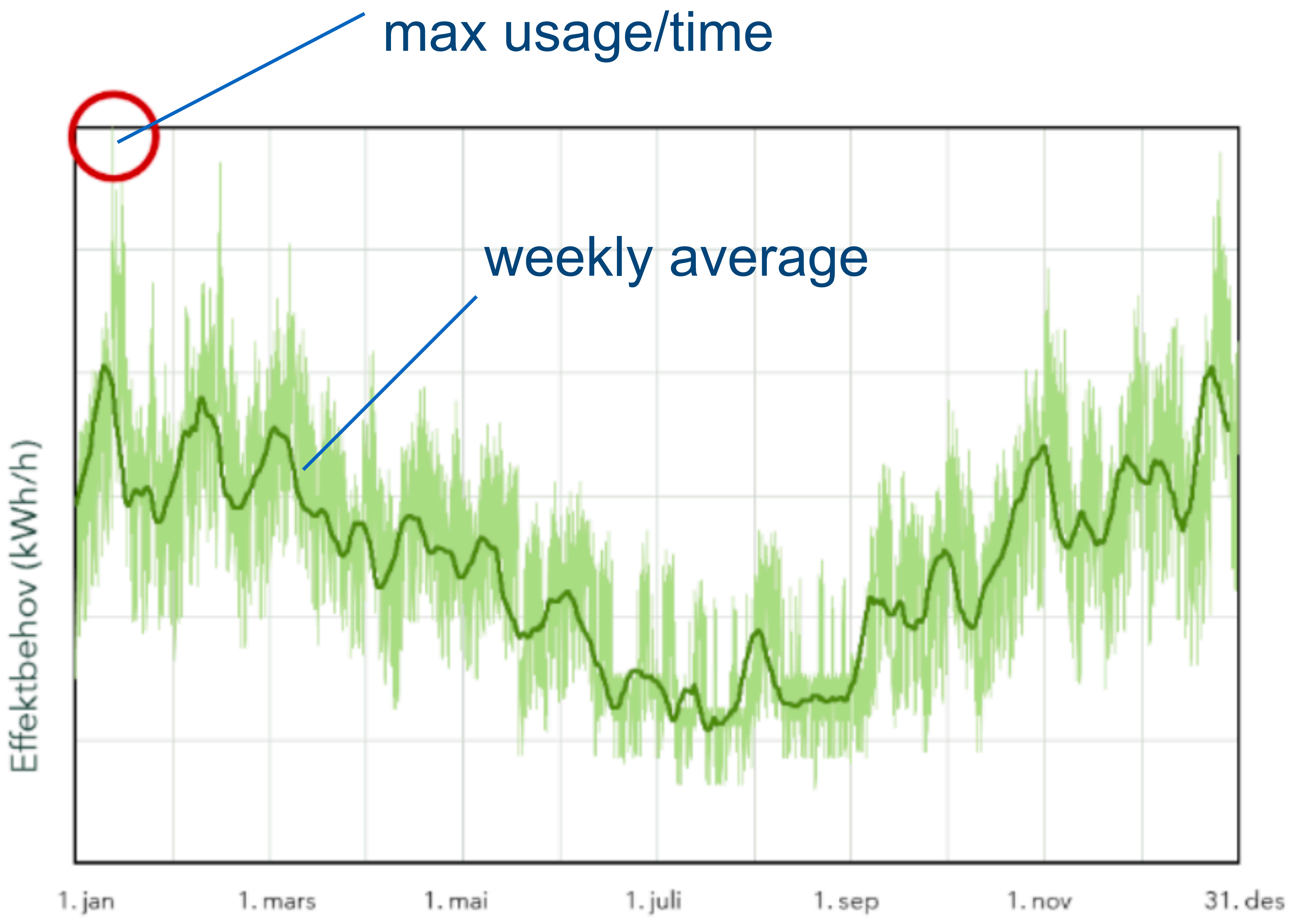




https://www.mn.uio.no/its/english/research/projects/dessi/

Electrical Energy usage in Norwegian households

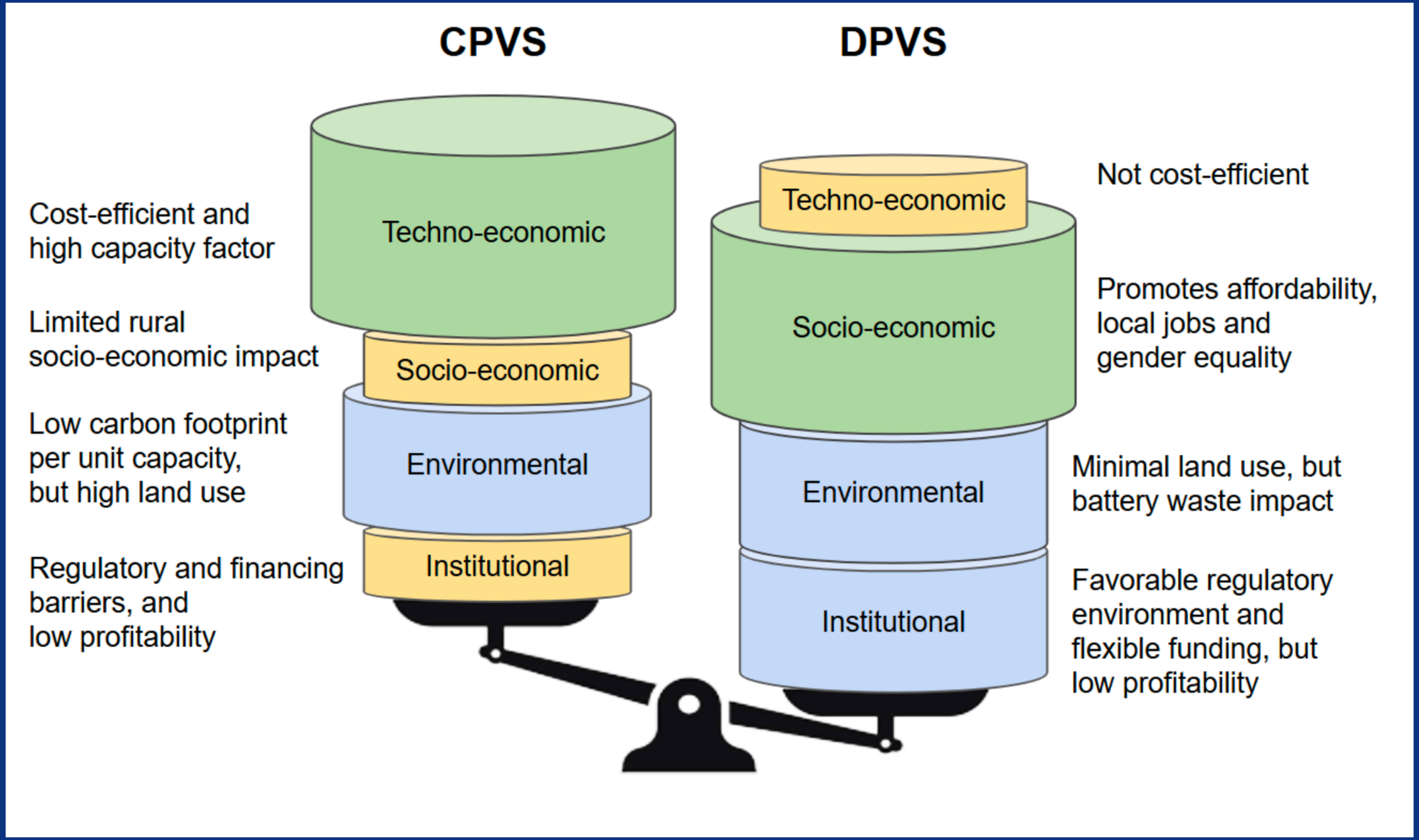
- Electrical energy usage per unit
  - 1995: 18 537 kWh
  - 2022: 14 964 kWh (war in Ukraina)
  - roughly 50 TWh (1/3 of total) for heating
- 4-5 TWh reduced energy for heating gives 2 GW more energy (Statnet)



https://www.asplanviak.no/content/uploads/2025/05/Kostnader-for-konvertering-fra-elektrisitet-til-vannbaren-varme-i-bygg_Asplan-Viak.pdf

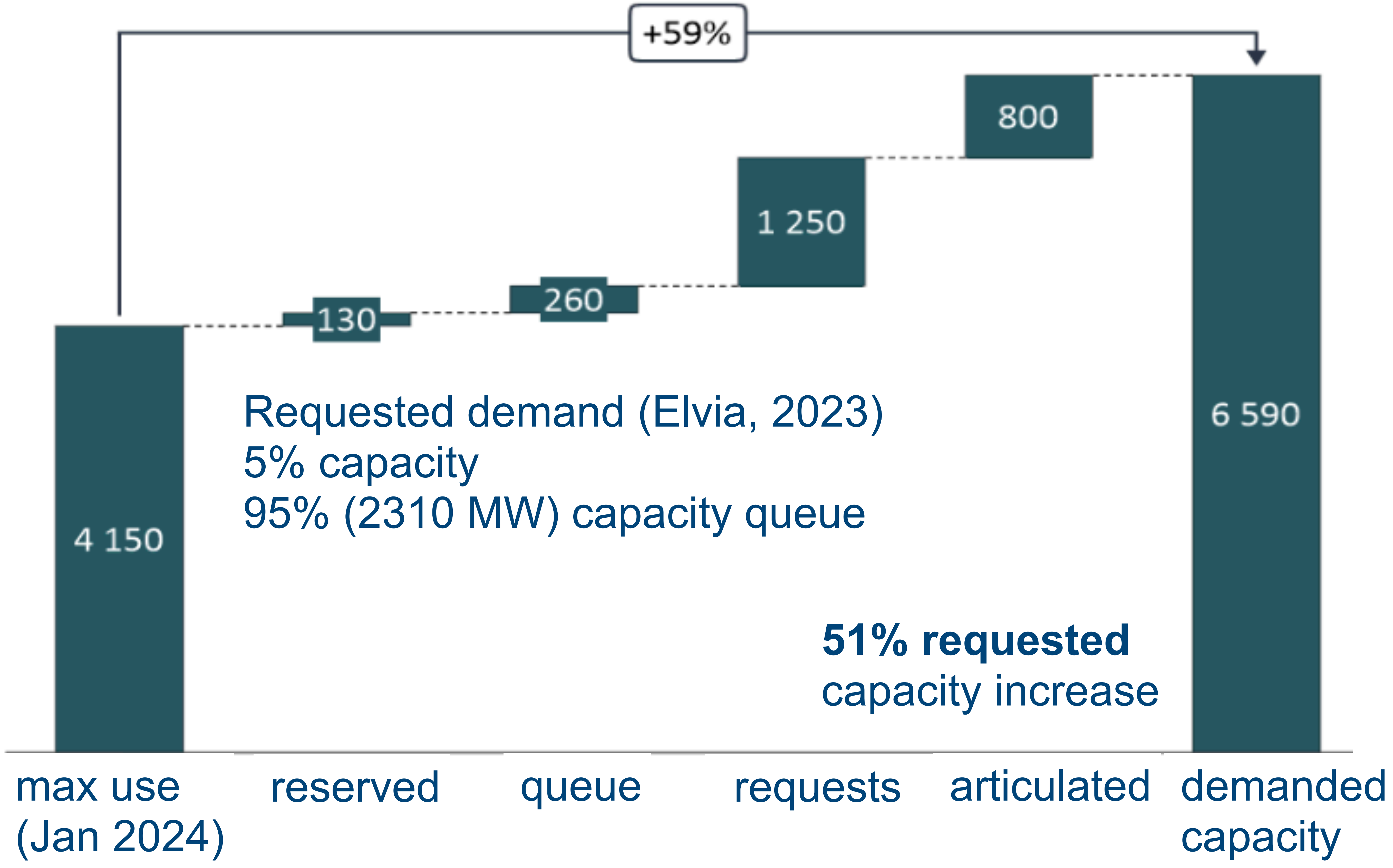
https://www.ssb.no/energi-og-industri/energi/statistikk/energibruk-i-husholdningene

6) Opportunities for Municipalities



Limited Grid-capacity

- "No capacity for new usage in Oslo, Østfold and Akershus until 2030-2035"
- Green business development?

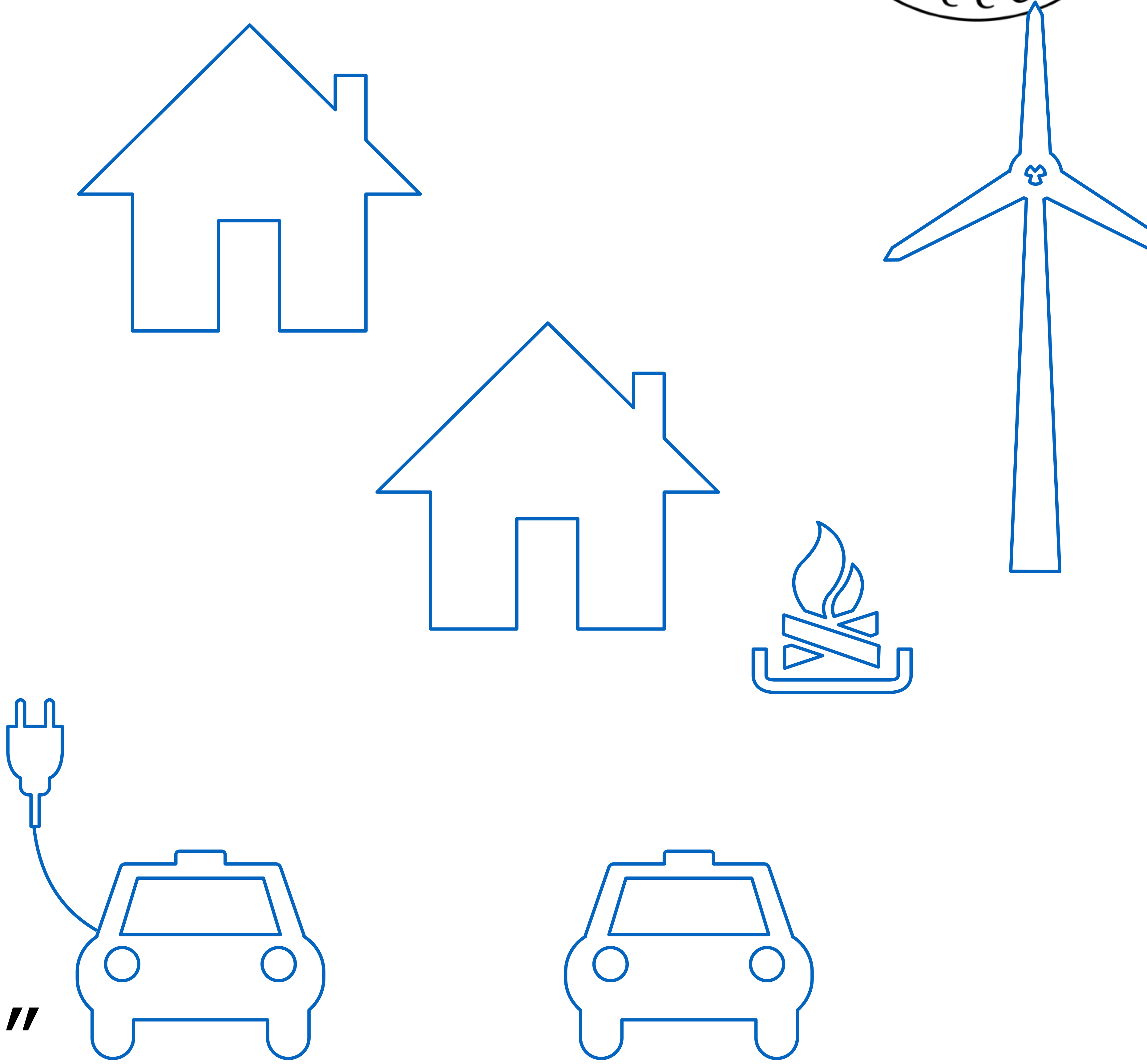


[Kraftløftet Oslo Akershus, LO & NHO, 2023]

Municipalities, e.g. Lillestrøm

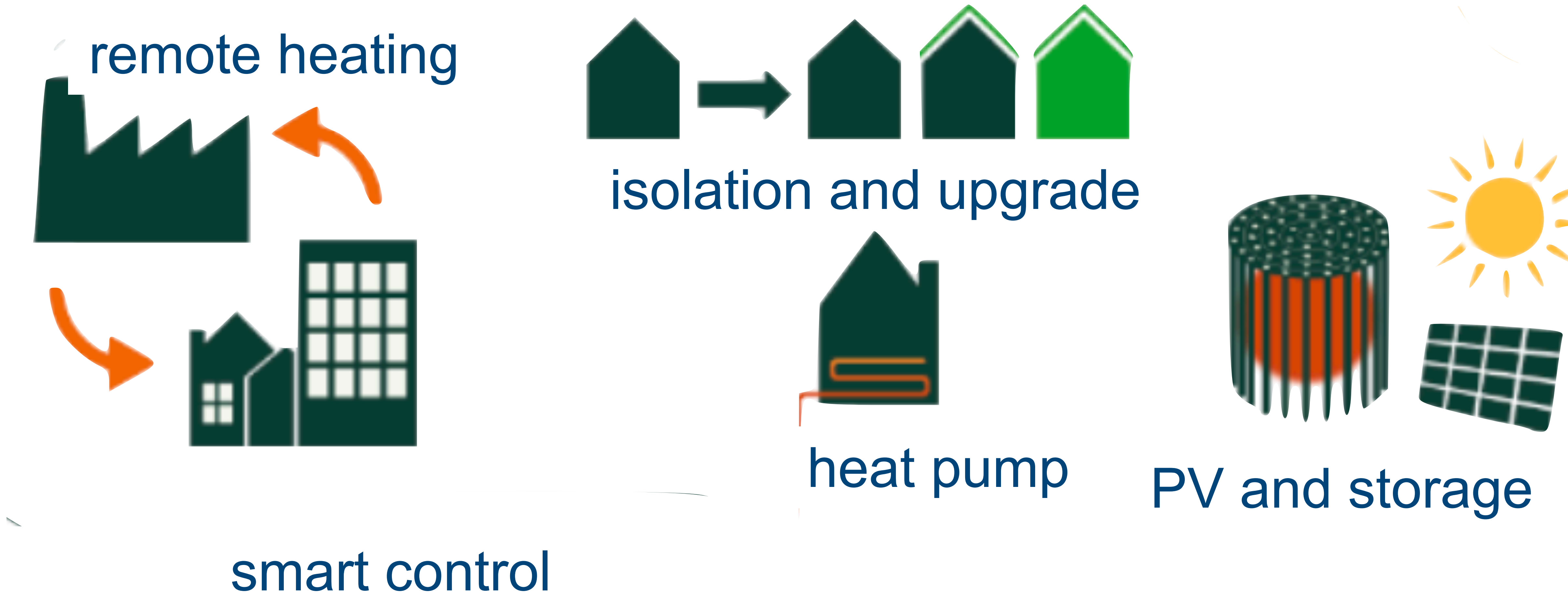
- Upgrade of lines & transformators
  - "we can't wait"

- Energy control
  - 241 buildings, 19 swimming pools, 750 car chargers
  - "Municipality as a battery"
  - "Municipality as actor in the energy market"



Opportunities for Municipalities

- Responsible for CO_2 reduction
- Integrate energy
  - car charger,
  - heating, swimming pools
- aggregator in the energy market
  - foster building conversion
  - mediator for private households



https://www.asplanviak.no/content/uploads/2025/05/Kostnader-for-konvertering-fra-elektrisitet-til-vannbaren-varme-i-bygg_Asplan-Viak.pdf

And where does AI come in?

Decentralised and distributed AI (D-AI)

- Installed on RPI 5 with 4 GB RAM
  - tinnyllama: 1.1b
  - deepseek-r1:1.5b
  - llama3.2:1b
- Limitations:
  - recommended 8 GB RAM for models
- Next steps
  - training local models

Department of Technology Systems
TEK5530 - Measurable Security for IoT-Based Systems

Local Language Models in Rasperry Pi

Stian Østgaard, Ulrik Sand

Screenshot from the Ollama website

Take away

- Grid principles
  - stability: 50 Hz +/- 0.1 Hz
- Demand - Supply: “Energy is freshware”
- Norway, Germany, Sweden,…
  - growth in grid capacity is too slow
- Lillestrøm Municipality use case
  - Demand for 50% increase in electricity, not
  - New jobs not provided
- Energy Security, Monitoring and Control
  - Security: Risk - Exposure model
  - Decentralised control
  - Control: 25%-90% reduction of electricity in busy hour
  - Conversion to ground source heat pump (>70% savings)
- The opportunity for Municipalities
  - integration of energy systems
  - actor in the grid stability market
  - driver of the change of buildings
  - mediator for private households

Security Class A

Catastrophic	A	C	E	F	F
Major	A	B	D	E	F
Moderate	A	B	C	E	E
Minor	A	A	B	D	D
Insignificant	A	A	A	C	C
Impact/ Exposure	E1	E2	E3	E4	E5