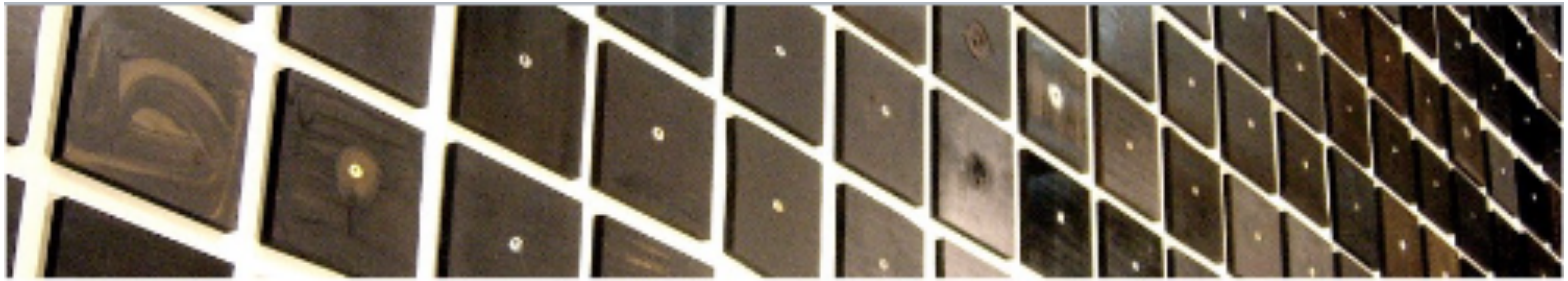


UiO : Universitetet i Oslo

TEK5370: L1 Introduction

Grid, Smart Grid and Internet of Things (IoT)

Shujun Zhang · 2nd
Associate Professor at Western Norway University of Applied Sciences,Høgskulen på Vestlandet (HVL)
Bergen, Hordaland, Norway · 500+ connections · Contact info

Josef Noll
Secretary General at the Basic Internet Foundation, Professor at the University of Oslo
Oslo Area, Norway · 500+ connections · Contact info

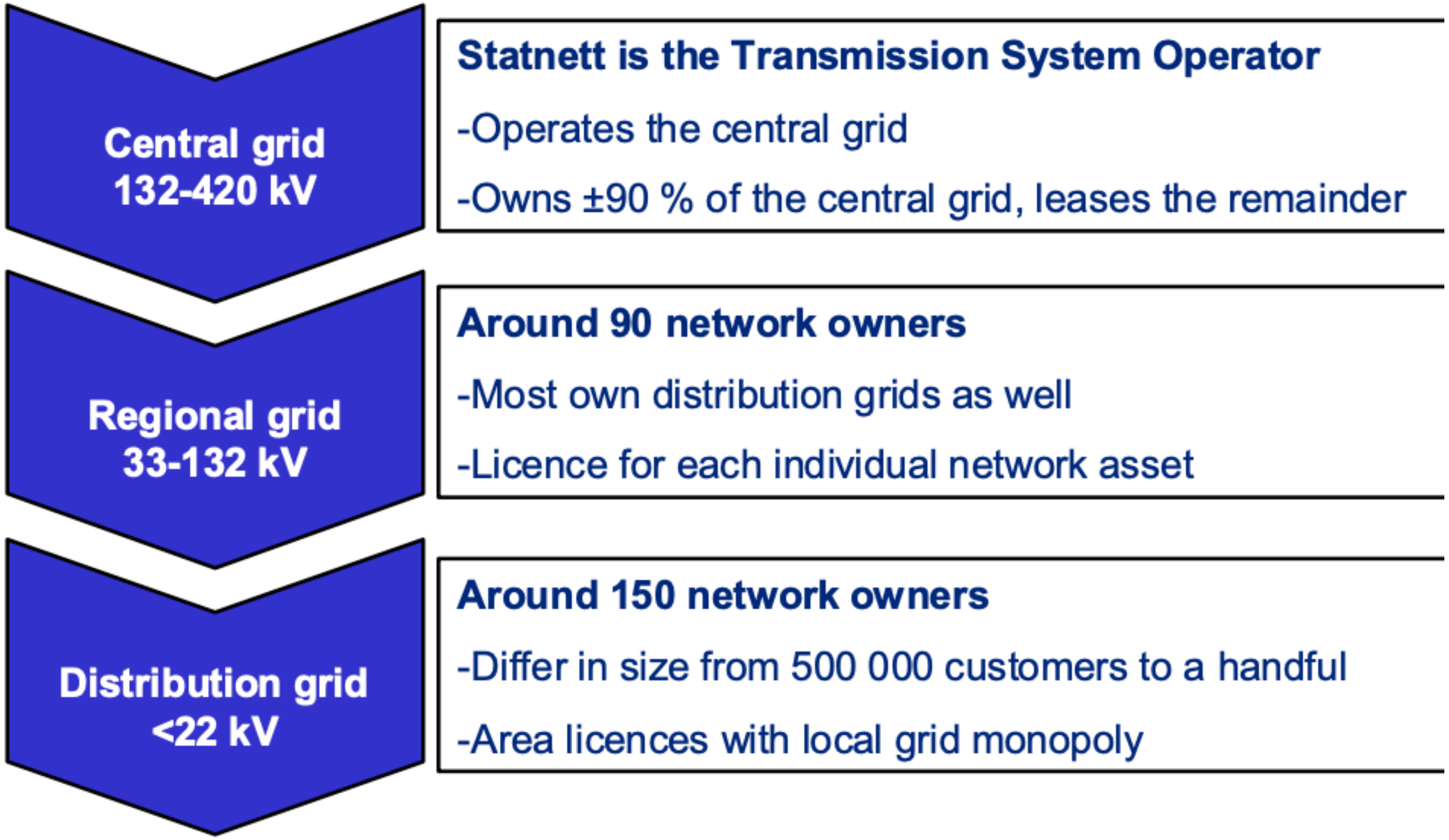
György Kálmán, Ph.D., CISM, CCSP · 1st
Technical Information Security Officer (TISO) at DNB Retail and Corporate
Nordby, Akershus, Norway · 497 connections · Contact info

Lecturers

- Professor Josef Noll
  - Research Interests: Digital Inclusion, Microgrid, Security & trust in IoT, Sustainable Development
  - Ongoing projects:
    - Security in IoT for Smart Grids (IoTSec.no),
    - Secure connected Things (SCOTT.IoTSec.no)
    - Digital Inclusion (DigI.BasicInternet.no)
- Associate Professor Shujun Zhang
  - Research interests: Power system, Microgrid, Power Electronics,Electric Drives
  - Ongoing projects:
    - Electric Actuator for subsea applications, industry project, pre-project, master project
    - Stability study of DC microgrid for diesel electric propulsion systems, research project, PhD project
- Associate Professor György Kálmán
  - Research interests: smart grid, critical infrastructure protection, financial systems

Goal - a stable grid at minimal costs

- TSO - Statnet
- Regional Grid (Hafslund, BKK)
- DSOs



Source: NVE

TEK5370 - Topics

- 1. **Grid - physics** on how the grid is build, and how the balance between demand and supply is kept
  - ➡ from transmission to home distribution
  - ➡ challenges from renewable energies
  - ➡ power flow, voltage regulation
- 2. **Smart Grid** efficient energy systems
  - ➡ Advanced metering system (AMS)
  - ➡ Automatic Meter Reader (AMR)
  - ➡ Control
- 3. **Internet of Things (IoT)**, providing the capabilities to control appliances
  - ➡ Interconnected power systems
  - ➡ Smart Home, home automation, augmented living
  - ➡ Cloud

TEK5370 - Expectations “Grid, Smart Grid, IoT”

- What is your background, what do you expect?
  - ➡ Discuss with your neighbours – 7 min
  - ➡ tell

- Goal of the course,
  - ➡ what to achieve
  - ➡ how to achieve it

About the course

- Course description:
- https://www.uio.no/studier/emner/matnat/its/TEK5370/index-eng.html
  - Credits: 10
  - Teaching: 15 lectures + 1 repetition, 0900-1200 + 1300-1600 (draft schedule)
  - Examination: 3Dec2020
    - one mandatory assignment must be approved in order to take the final examination. The final exam counts 100% of the final grade.
    - Grading scale: From A to F, A is the best grade and F(<40%) is a fail, E(>=40%) is the minimum pass.

Forelesninger - tor. 09:15-16:00

Dato	Tid	Aktivitet
to. 20. aug.	09:15–16:00	Forelesning
to. 3. sep.	09:15–16:00	Forelesning
to. 17. sep.	09:15–16:00	Forelesning
to. 1. okt.	09:15–16:00	Forelesning
to. 15. okt.	09:15–16:00	Forelesning
to. 22. okt.	09:15–16:00	Forelesning
to. 5. nov.	09:15–16:00	Forelesning
to. 19. nov.	09:15–16:00	Forelesning

What is a power system

- Every large-scale power system has three major components:
  - ➡ **generation**: source of power, ideally with a specified voltage and frequency
  - ➡ **load** or **demand**: consumes power; ideally with a constant resistive value
  - ➡ **transmission system**: transmits power; ideally as a perfect conductor
- Additional components include:
  - ➡ **distribution system**: local reticulation of power (may be in place of transmission system in case of microgrid),
  - ➡ **control equipment**: coordinate supply with load.

Complications

- No ideal voltage sources exist.
- Loads are seldom constant and are typically not entirely resistive.
- Transmission system has resistance, inductance, capacitance and flow limitations.
- Simple system has no redundancy so power system will not work if any component fails.

Power & Energy

- Power
  - Instantaneous rate of consumption of energy,
  - How hard you work!
  - Power = voltage x current for dc
  - Power Units:

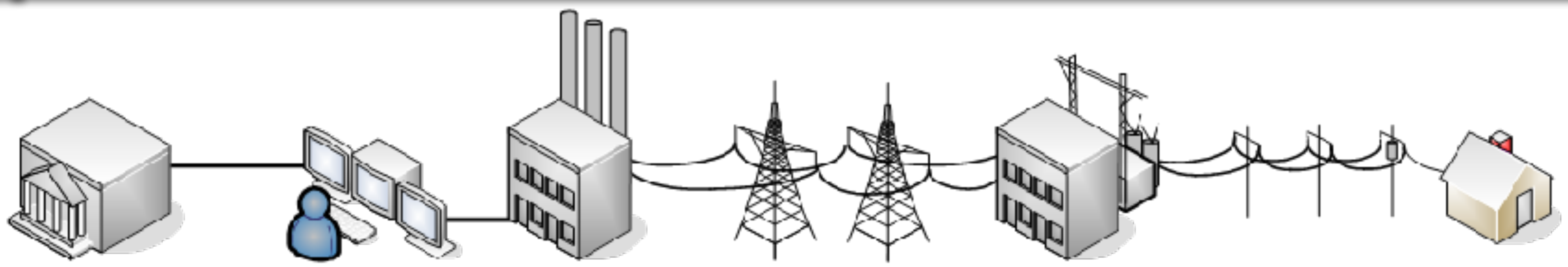
Watt	=	Volt times Ampere (W)
kW	–	1 x 10^3 Watt (1E3 W)
MW	–	1 x 10^6 Watt (1E6 W)
GW	–	1 x 10^9 Watt (1E9 W)

- Energy
  - Integration of power over time,
  - Energy is what people really want from a power system,
  - How much work you accomplish over time.
  - Energy Units:

Joule	=	1 watt-second (J)
kWh	–	kilowatthour (3.6 x 10^6 J)
Btu	–	1055 J; 1 MBtu=0.292 MWh
(British thermal unit)		

$$U = R \times I$$
$$P = U \times I$$

Power system



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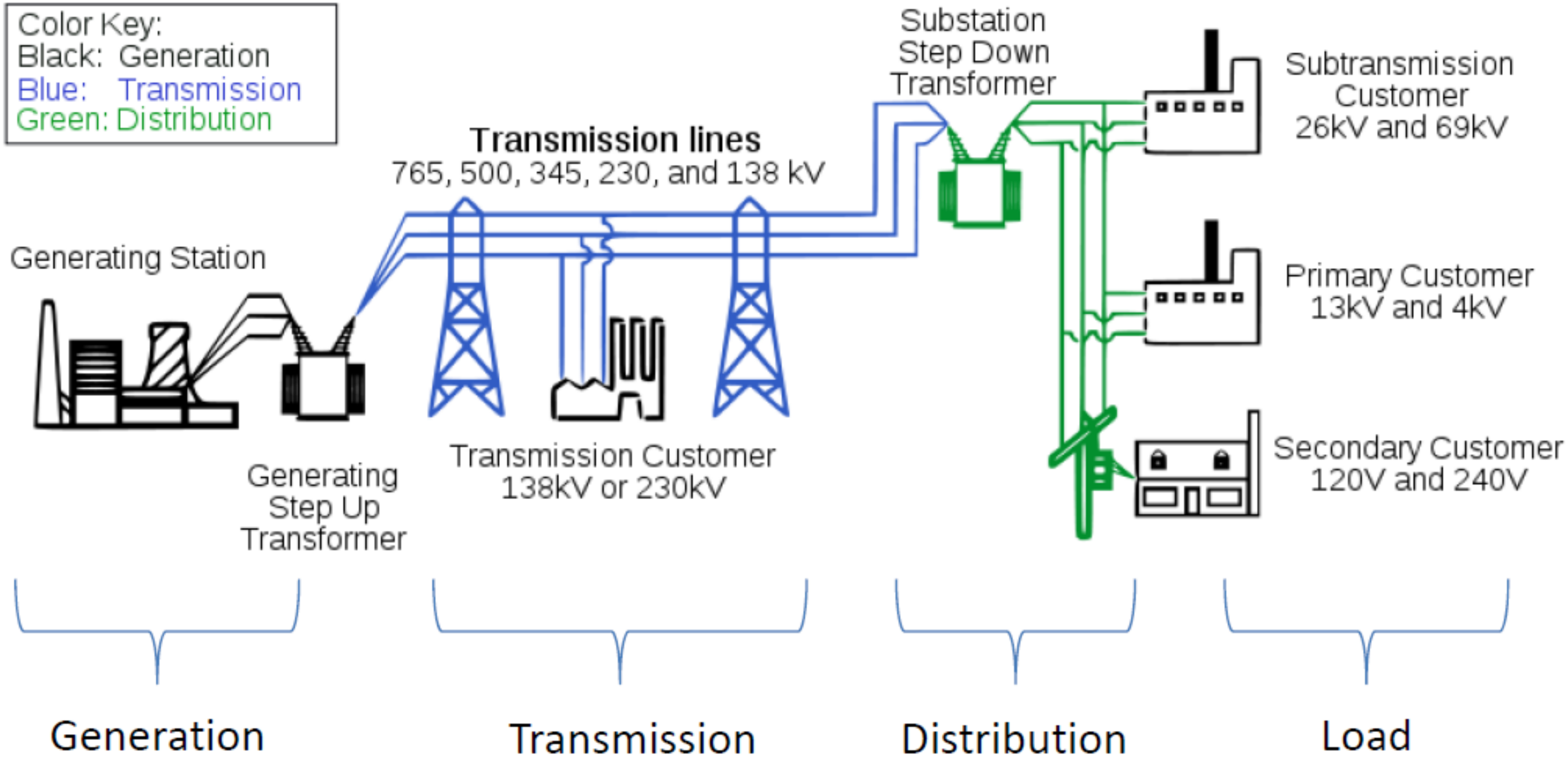
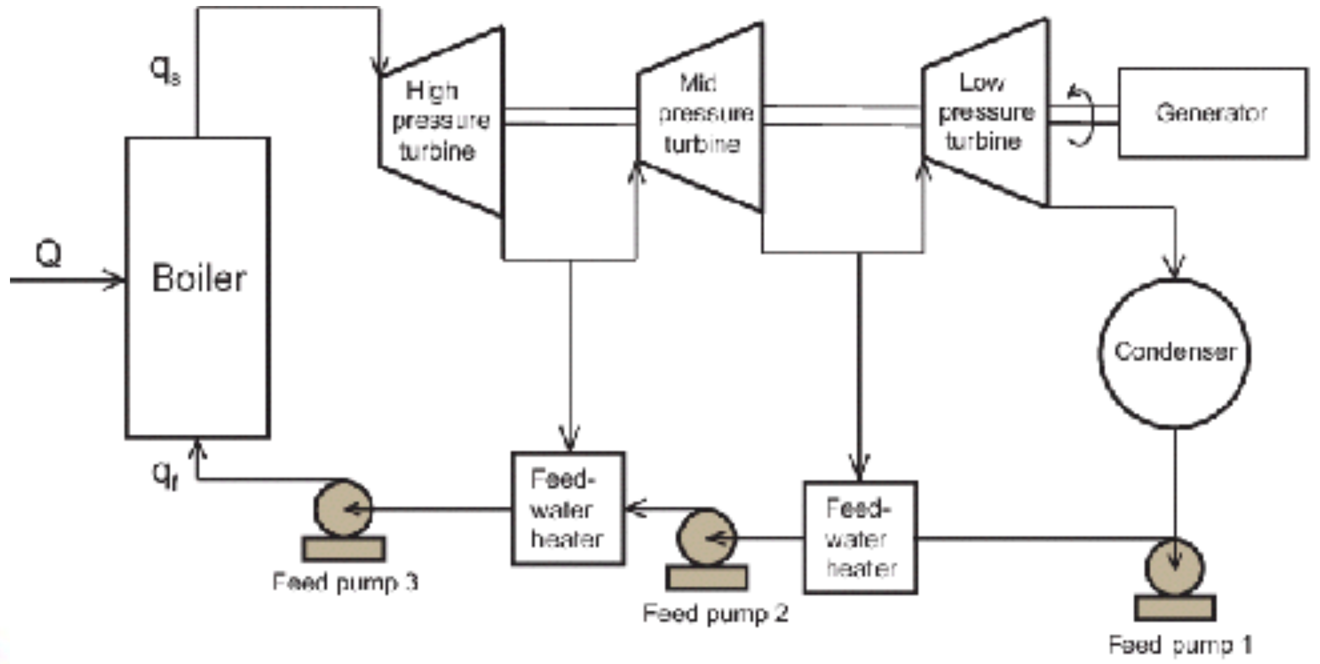


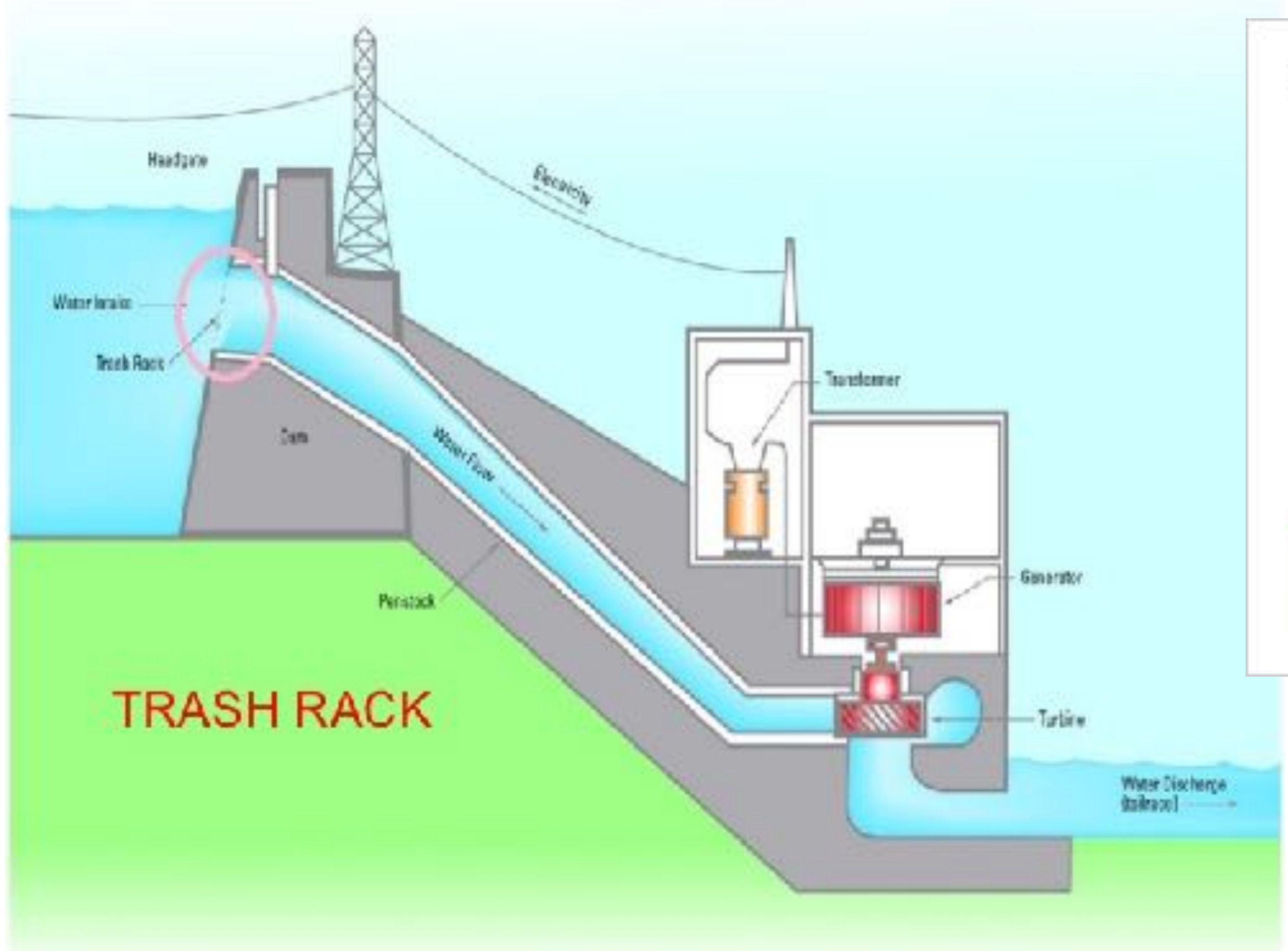
Power Systems – the four main elements

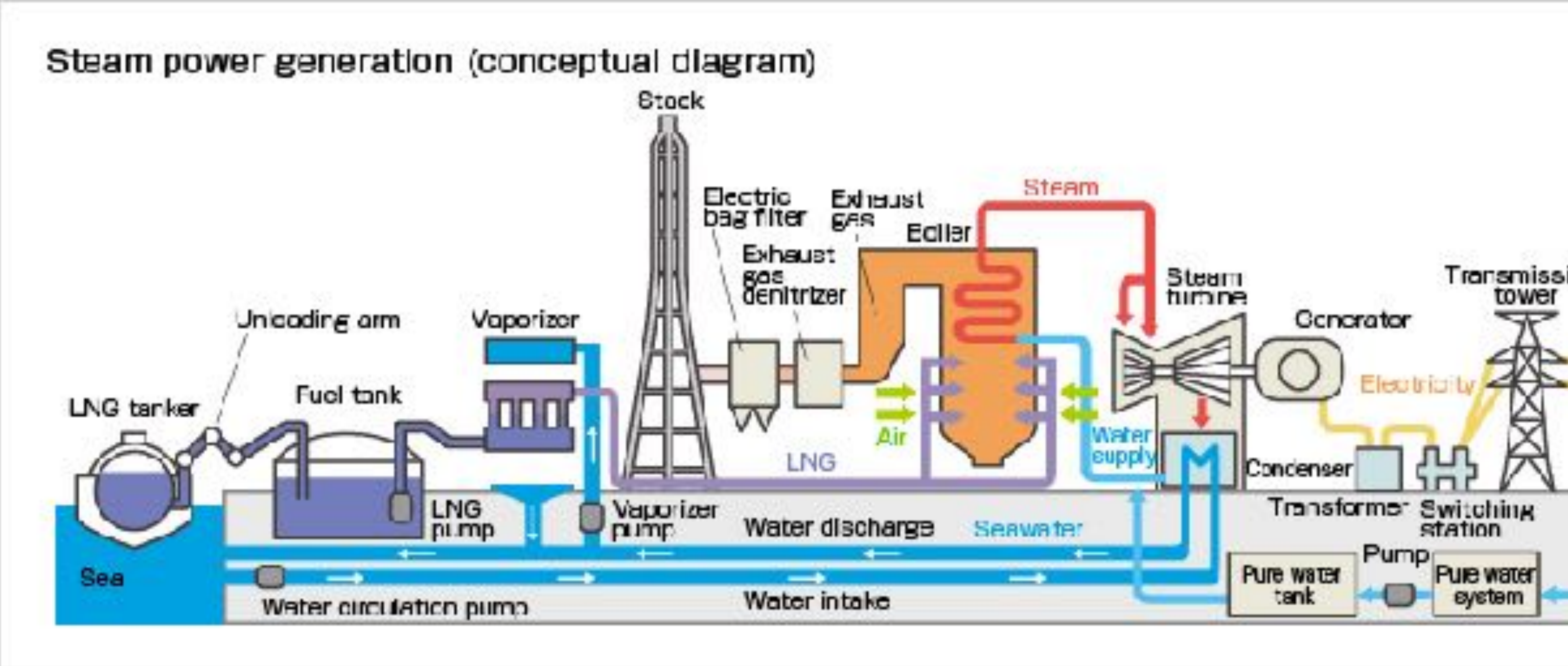
- Power Production / Power Generation
- Power Transmission
- Power Distribution
- Power Consumption / load
- Control systems, condition monitorning system, communications, etc. are needed in order to have a robust and reliable power system.

Traditional Power generation

Nuclear $\Delta t = 12h$ Cole $\Delta t = 6h$ Water $\Delta t = 3min$ Gas $\Delta t = 15min$

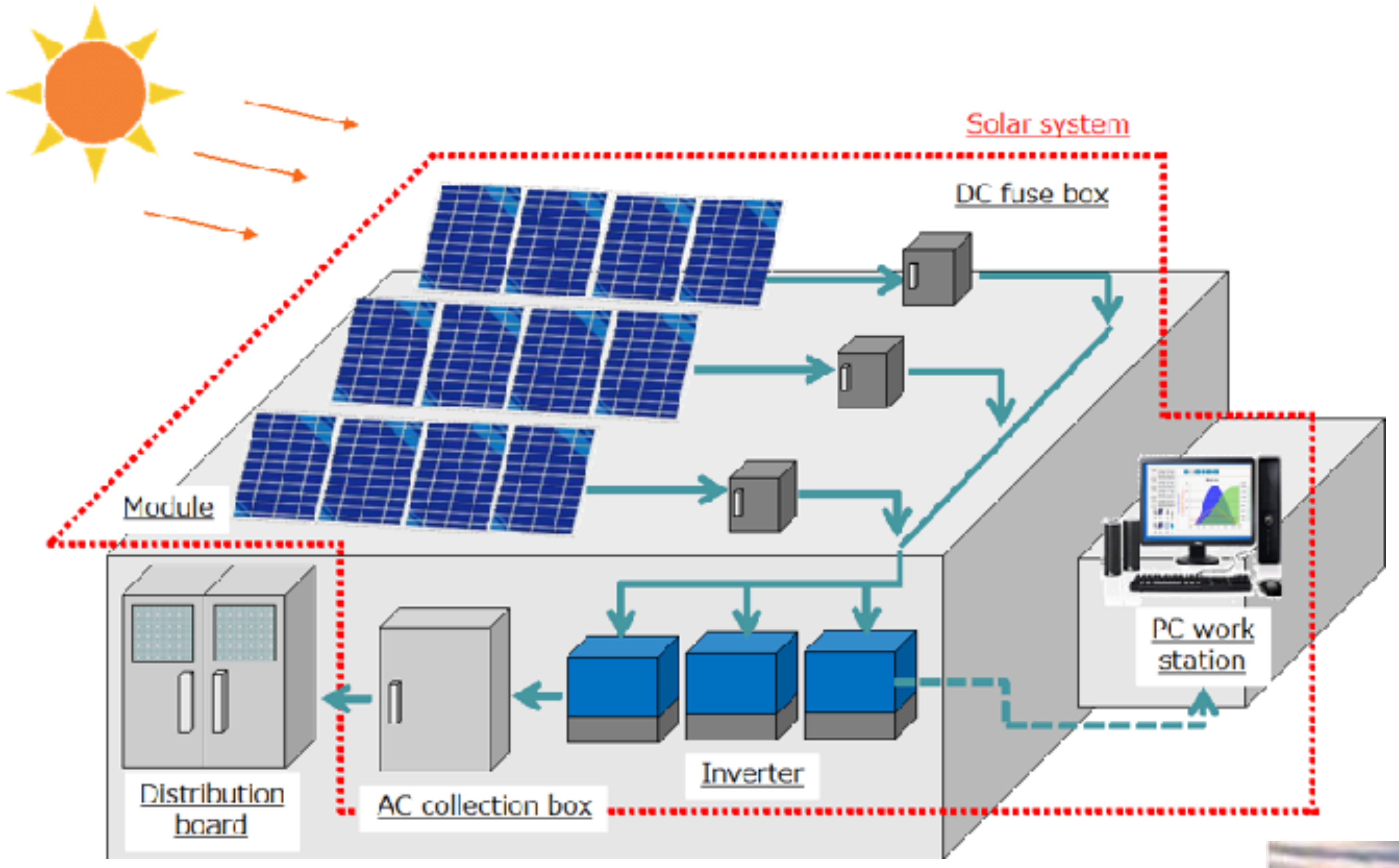


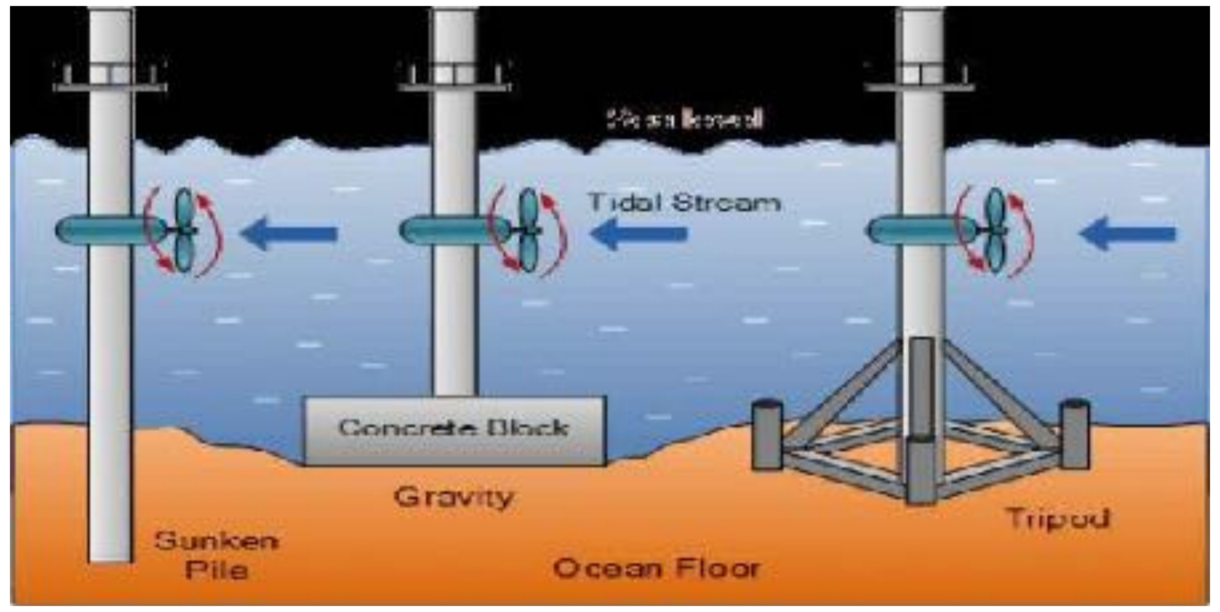




Renewable Power generation

Renewable $\Delta t = 30sec...2min$





Power transmission

- High voltage transmission lines
- Several hundred kilometers

- Switching stations
  - ➡ Transformers
  - ➡ Circuit breakers

Cable resistance and head dependence

$$\text{Resistance } R_{20} = \rho \frac{L}{A}$$

$$L = \text{Length in } km$$

$$A = \text{size in } mm^2 \text{ e.g. } 2.5mm^2$$

$$\text{copper (CU): } \rho_{20} = 17,241\Omega mm^2/km$$

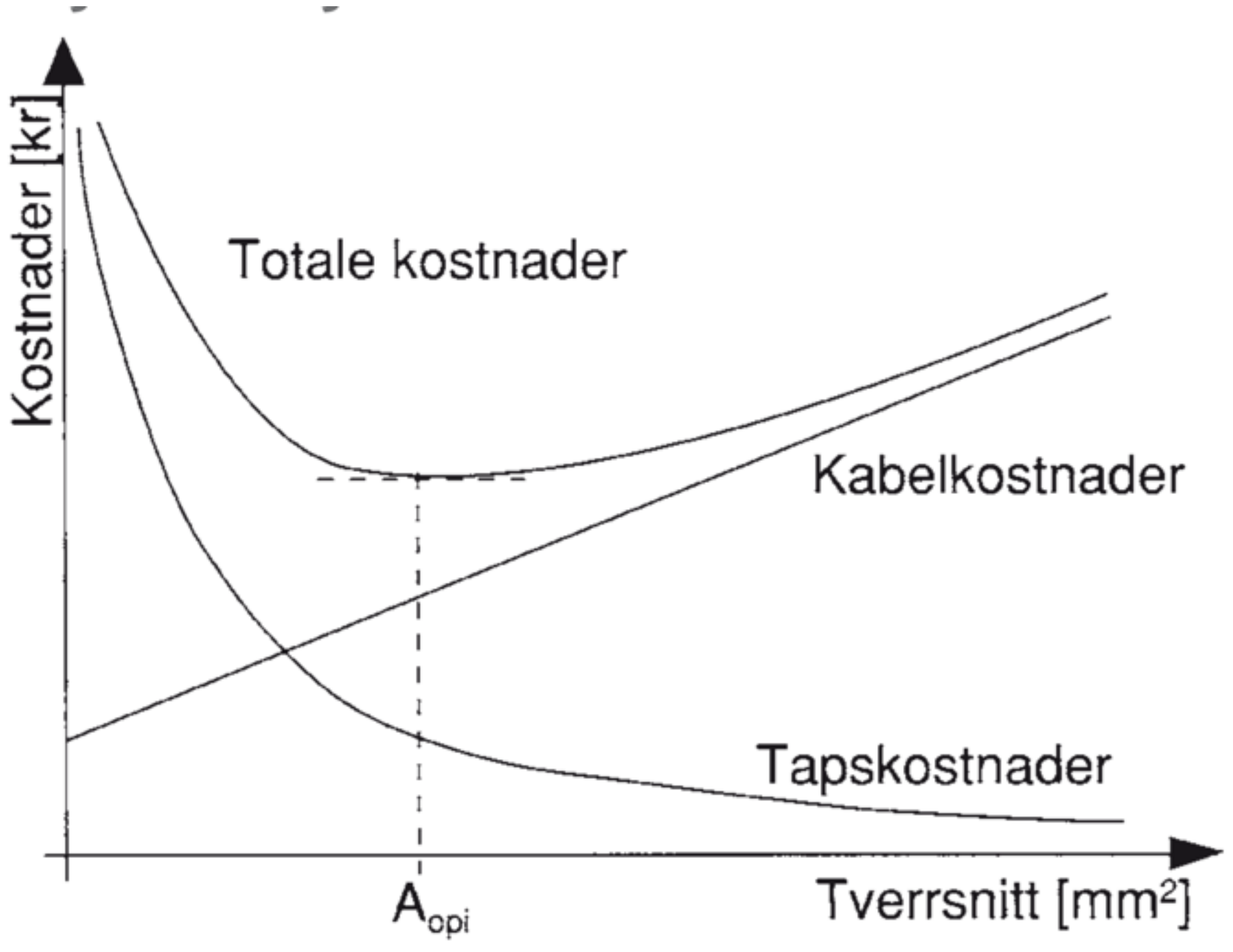
$$\text{aluminium (AU):} \rho_{20} = 28,264\Omega mm^2/km$$

$$R_t = R_{20}(1 + \alpha(t - 20))$$

$$t = \text{temp in deg C}$$

$$\alpha_{CU} = 0,00393$$

$$\alpha_{alu} = 0,00403$$



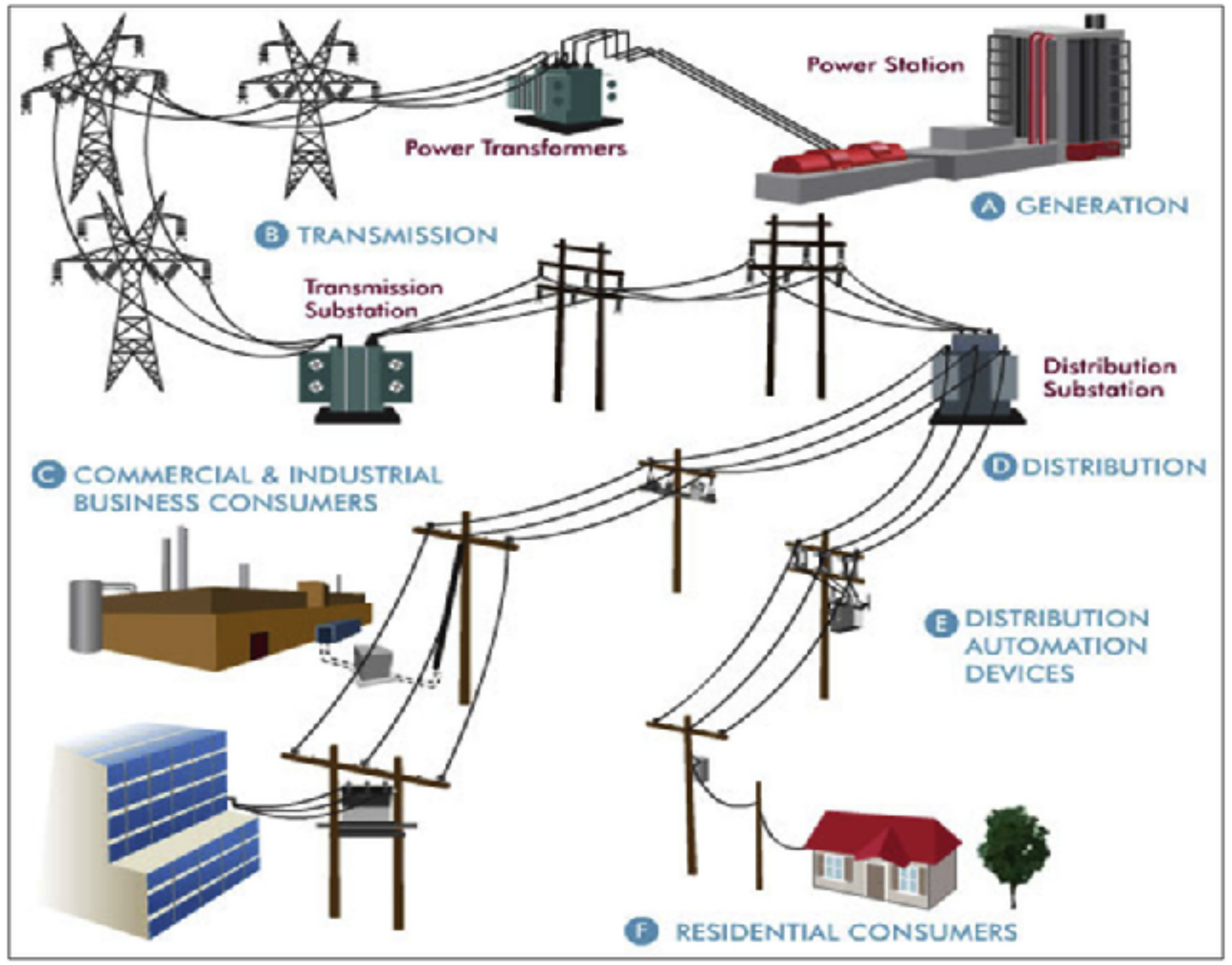
Kostnader som funksjon av ledertverrsnitt

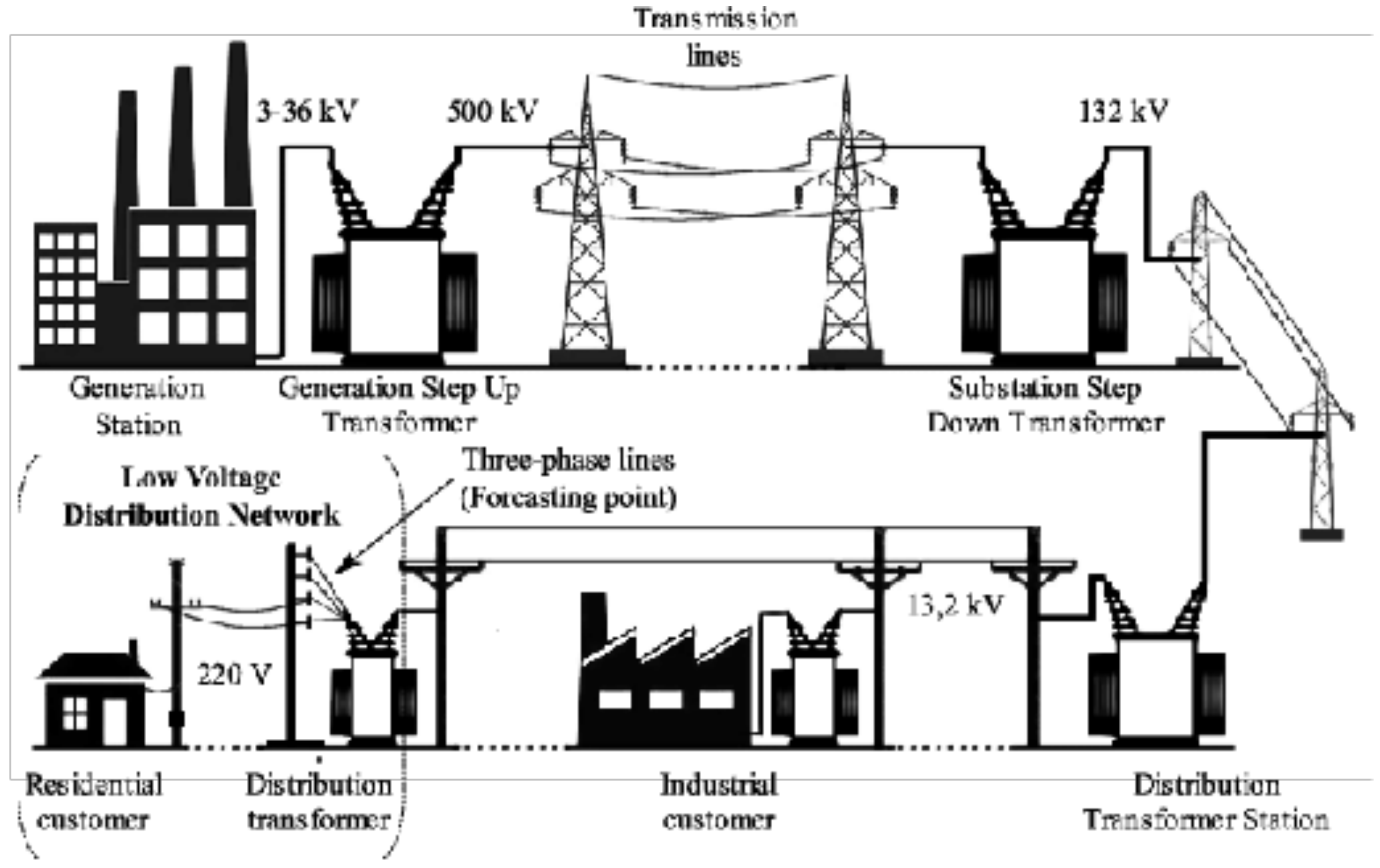
Calculate the resistance of a 22 mm^2 cable, being 100 km long
- how much more is the restistance at max temperature of 70 deg?

http://media.draka.no/2016/07/Teknisk-Handbok-

Power distribution

- Medium voltage transmission lines (<50 kV)
- Power deliver to load locations
- Interface with consumers
- Distribution substations
  - ➡ Step-down transformers
  - ➡ Distribution transformers

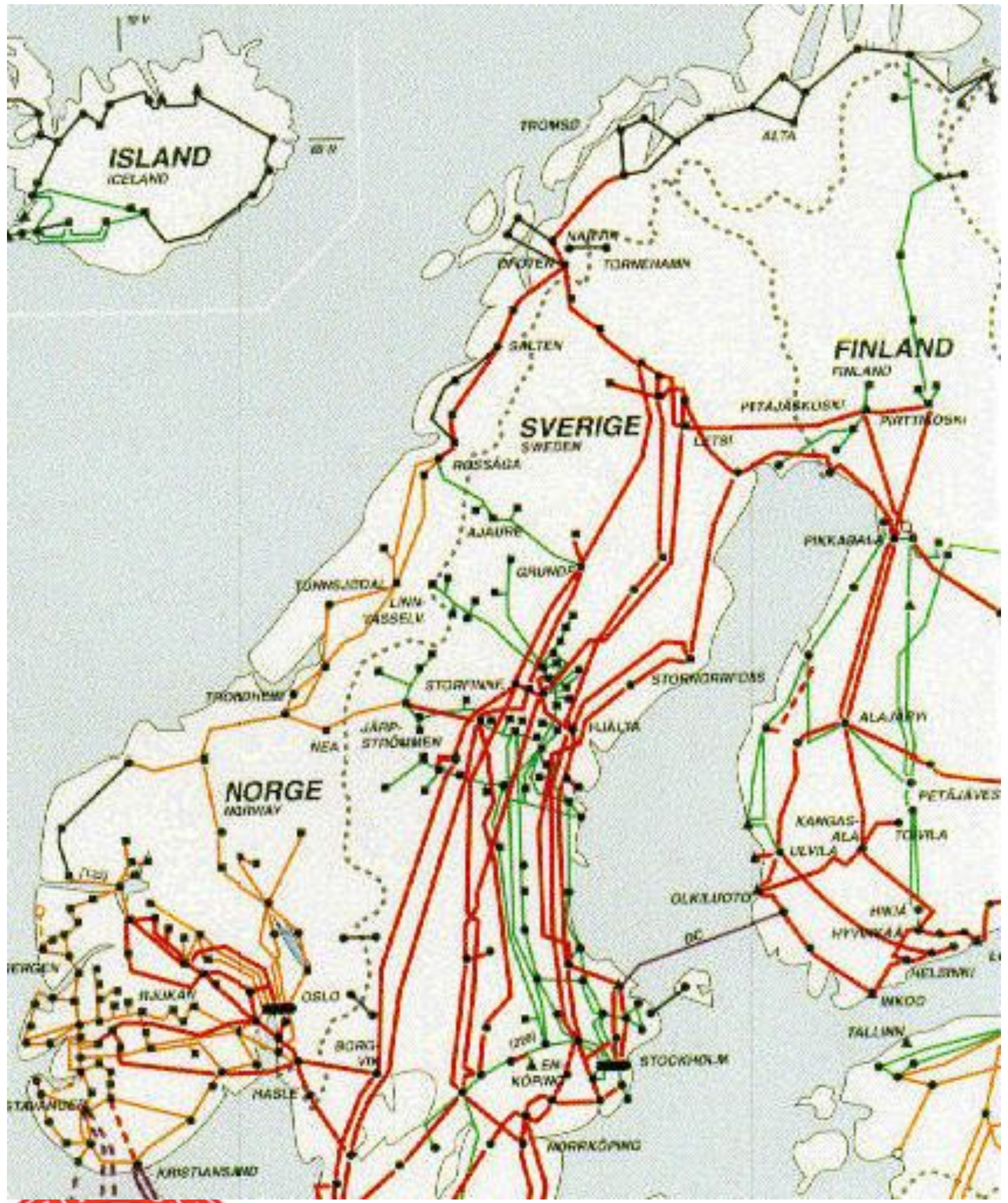


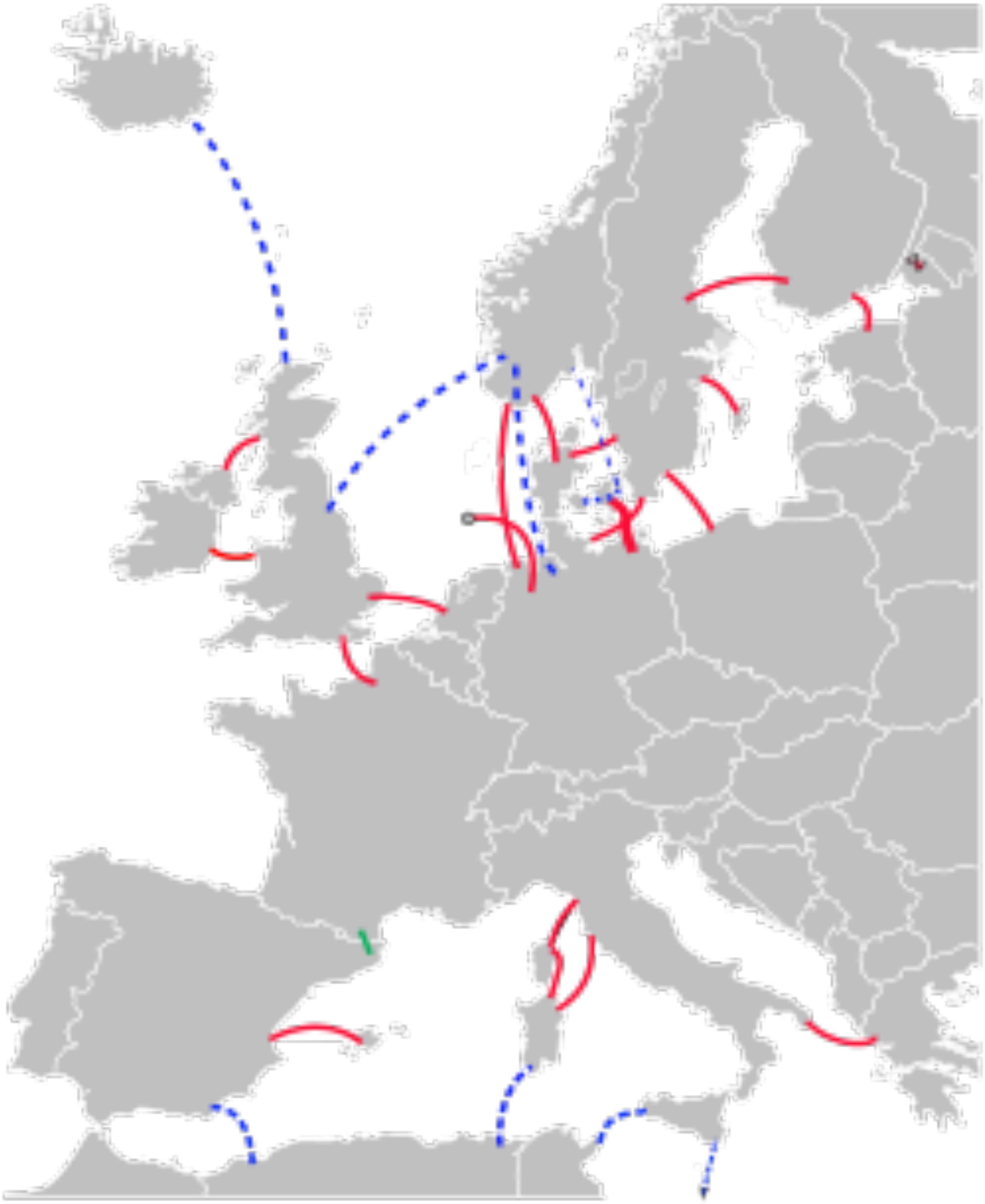


Load / Consumers

- Industry
- Commercial
- Residential

Norwegian grid



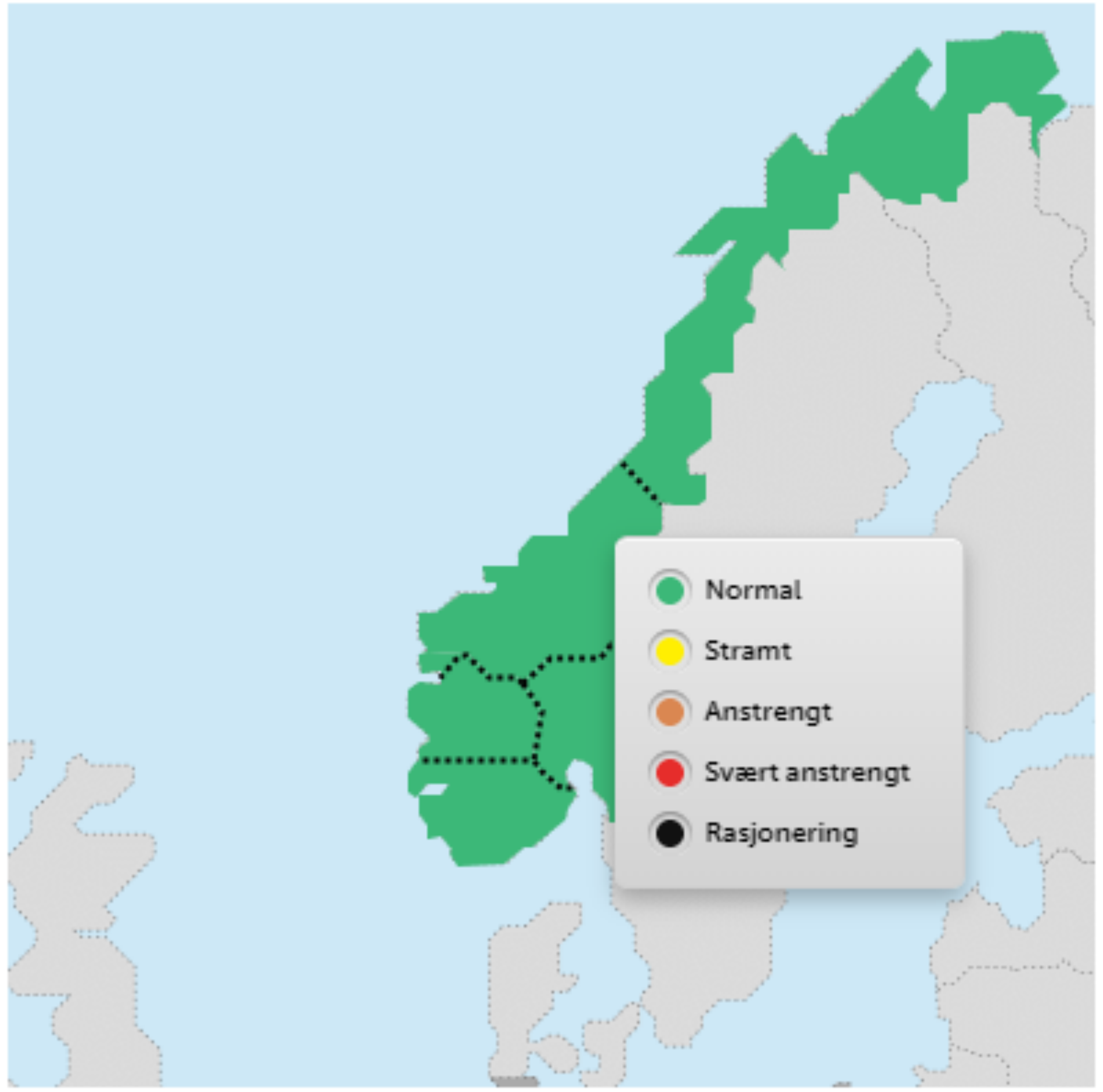


Using the NordNed cable with a diameter of 50 mm^2, 580 km long, 450 kV and 700 MW - how big are the losses?

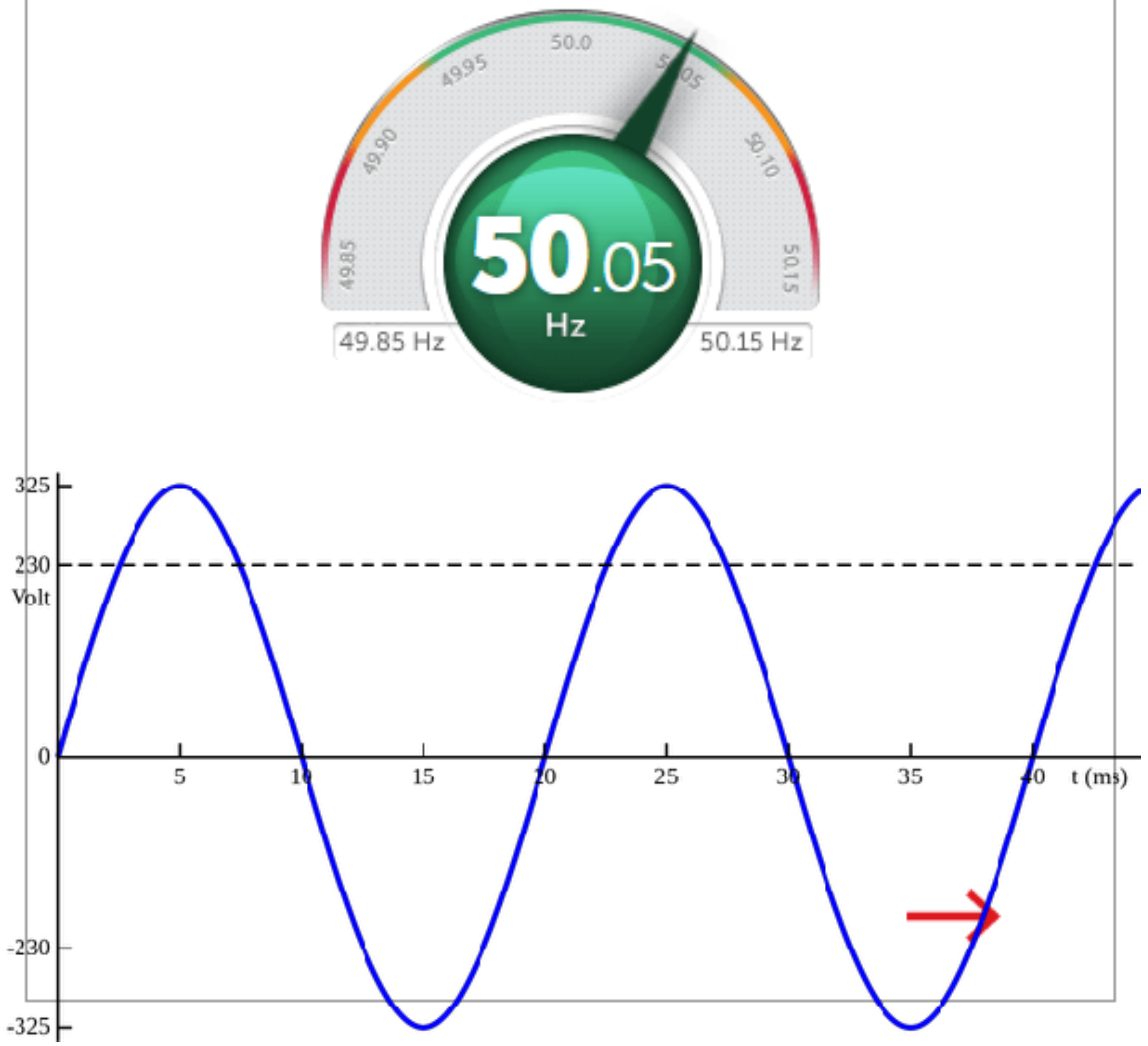
Norwegian grid

KRAFTSITUASJONEN AKKURAT NÅ

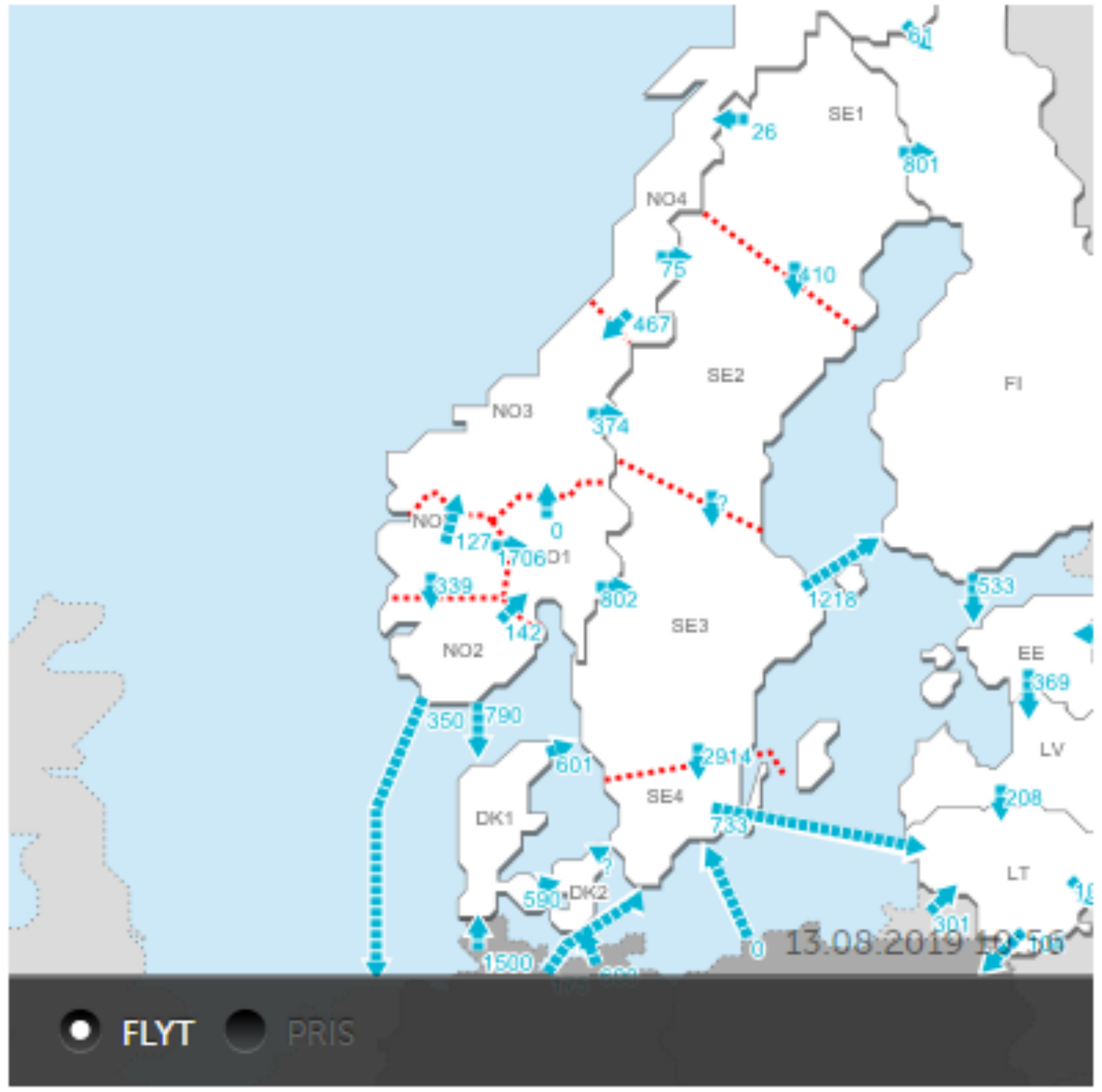
Kraftsituasjonen



Nordisk kraftbalanse

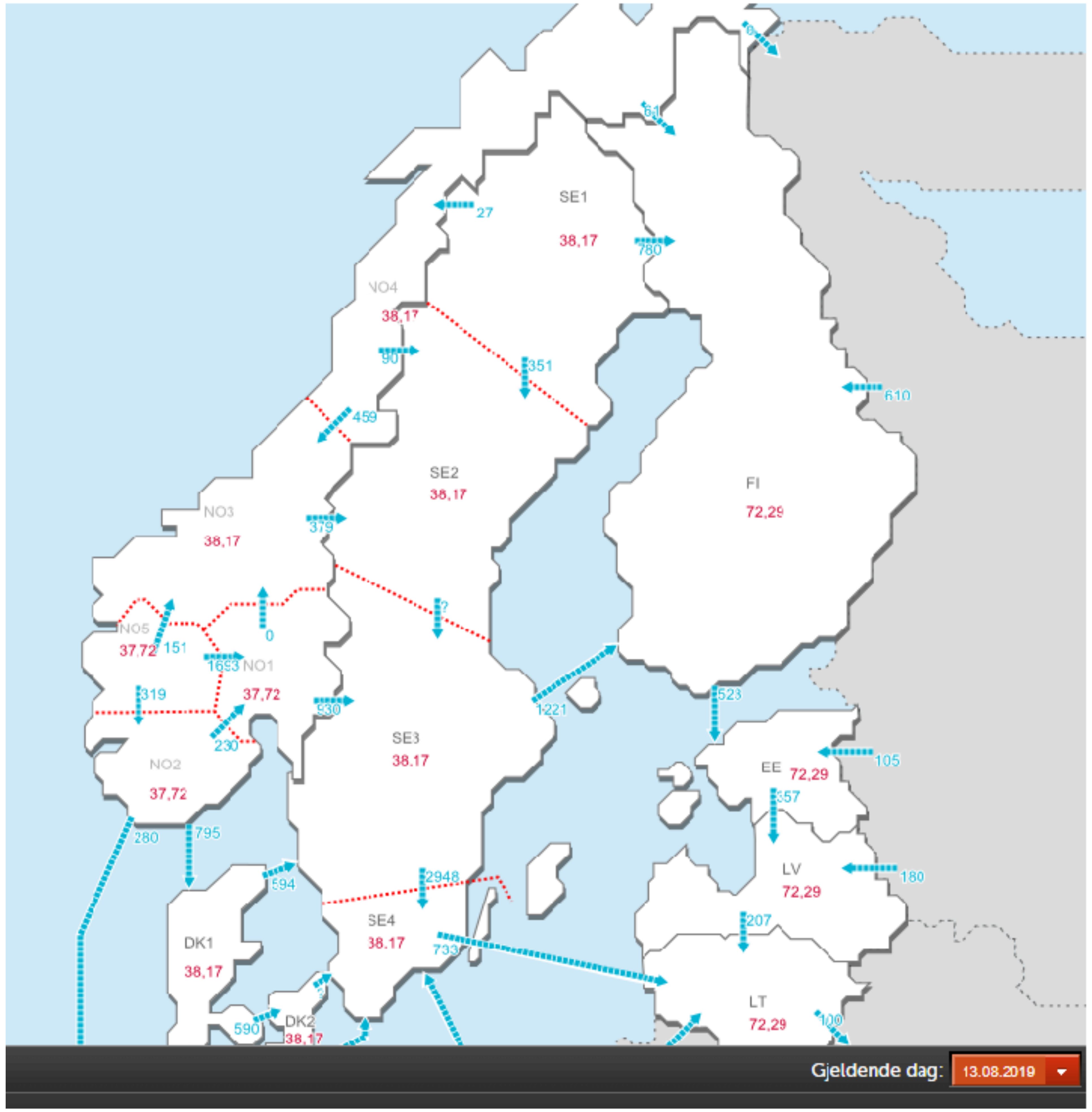


Nordisk kraftflyt



Norwegian grid

- nordpoolgroup.com
  - ➡ showing current flow of energy



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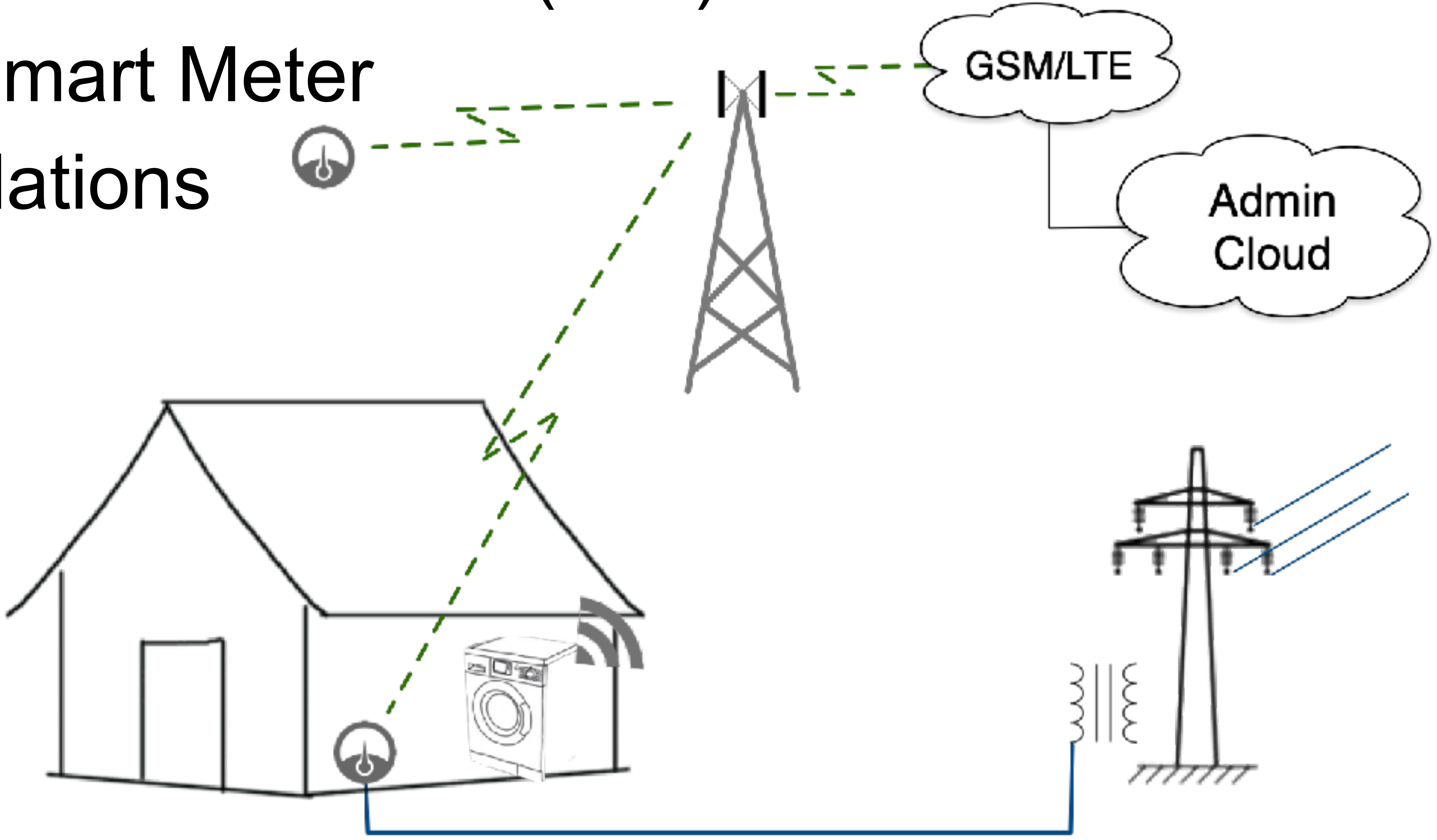
Smart Grid

Smart Grid - efficient energy systems

- Advanced metering system (AMS) / infrastructure (AMI)
- Automatic Meter Reader (AMR) /Smart Meter
- AMS motivation, capabilities, regulations
- AMS systems and components
- Home integration



Source: Davide Roverso, eSmart Systems

Smart Grid Actors

TSO: Transmission System Operator

DSO: Distribution System Operator

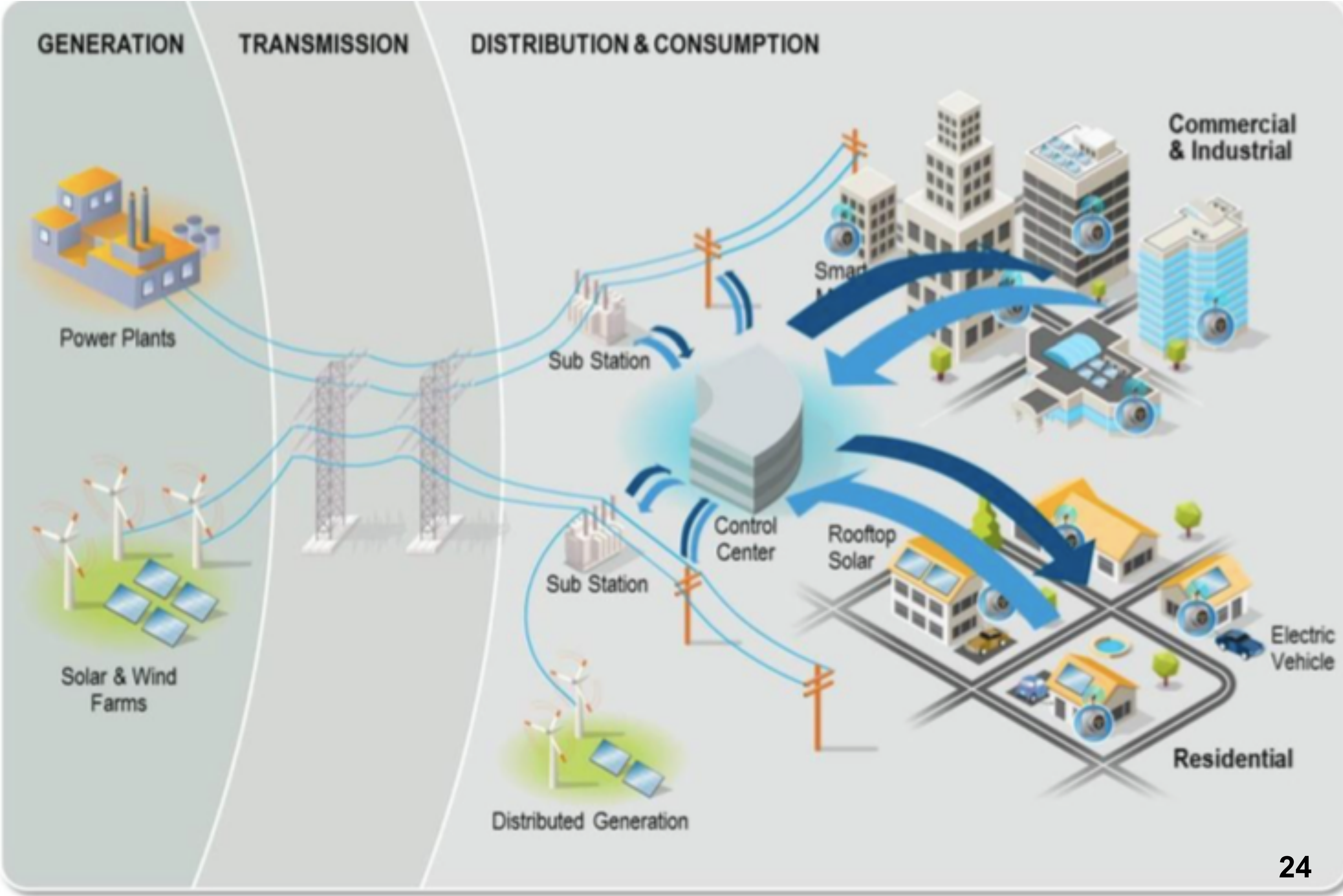
- The TSO perspective – IoT in the Smart Transmission Grid
  - IoT security of the Smart Grid critical infrastructure (devices/communication/...) at the transmission network level
- The DSO Perspective – IoT in the Smart Distribution Grid
  - IoT security of the Smart Grid critical infrastructure (devices/communication/...) at the distribution network level,
  - included privacy issues
  - Smart Meters, Concentrators, Automated Substations, ...
- The end-user perspective – IoT in the Smart Home
  - IoT security of Smart Home related devices/communication, mainly related to home automation and its relation
  - with smart metering infrastructure, including privacy issues
- Other perspectives - Service Provider, Producer, Prosumer, Aggregator, ...

Specific challenges of the DSO

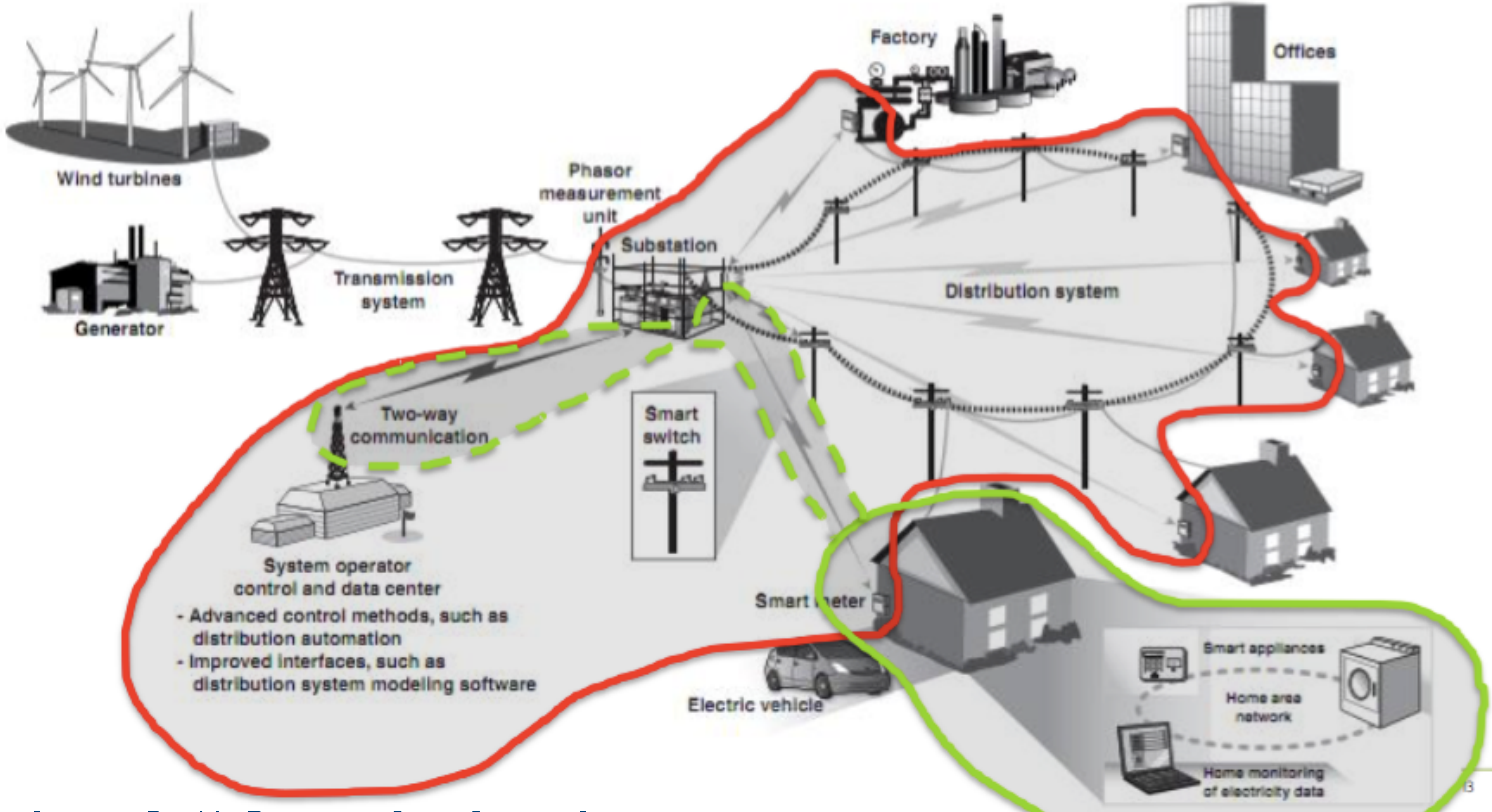
Powered by penalties of not-delivered energy

- Quality-adjusted income for non-delivered energy//Kvalitetsjusterte inntektsrammer ved ikke levert energi (KILE)

- short-time (< 3 min) and long-time (> 3 min) disturbances, both planned and not planned (U > 1kV)
- Total amount ca 800 MNOK/år in Norway
- Costs related to societal costs
- Related to build, operate, maintain the distribution grid in an economic-optimal way for the society



Smart Home vs Smart (Distribution) Grid focus



[source: Davide Roverso, eSmartSystems]

Smart Meter and HAN Port

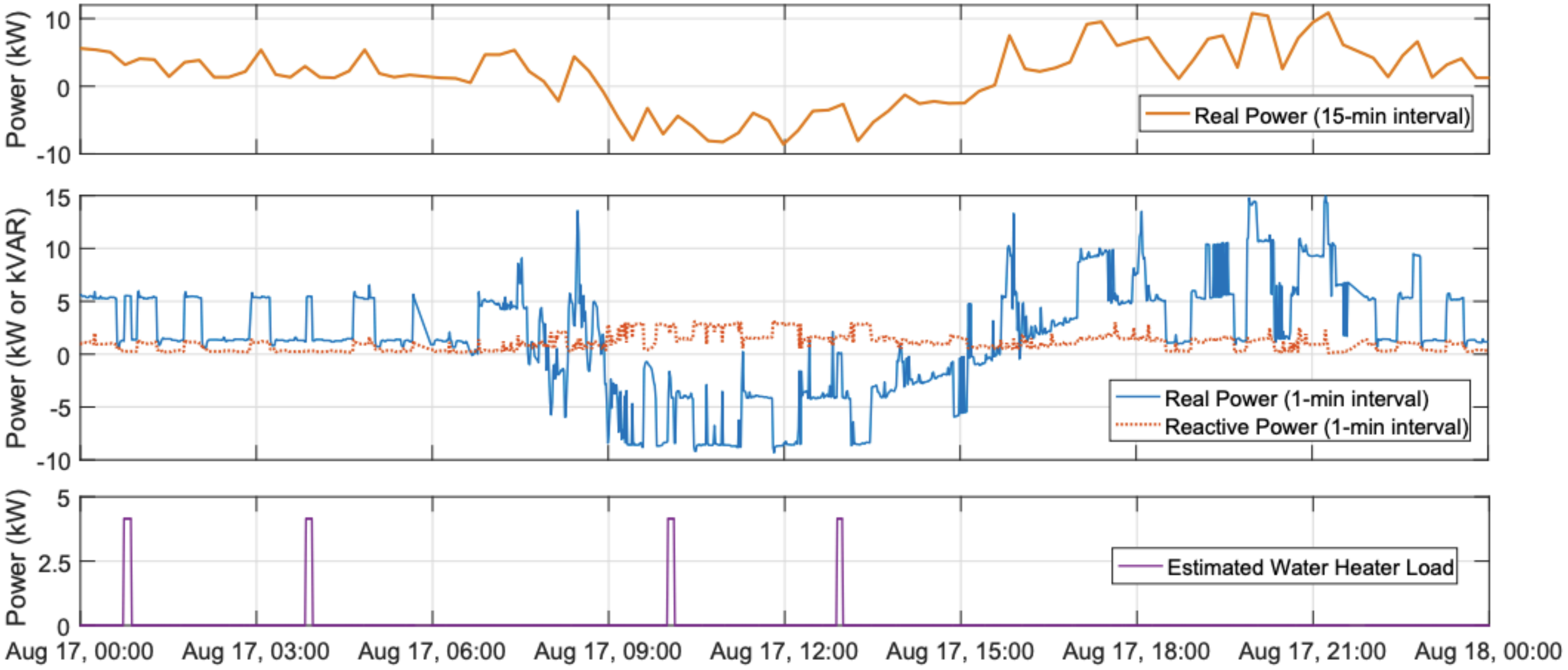
- HAN Port
  - ➡ energy usage
  - ➡ online monitoring (1/s … 1/min)
- Typical Norway
  - ➡ Power (every 2.5s)
  - ➡ Current (every 10s)
  - ➡ Voltage (every 10s)
- Connected devices
- Security

physical security, encryption

AMS HAN port (NEK)
https://www.nek.no/info-ams-han-brukere/

Meter analysis - knowledge about you

- Security
  - ➡ (unencrypted) wireless data
  - ➡ Cloud computing
  - ➡ “is my HAN port open?”
- Information & control
  - ➡ energy saving (water heater)
  - ➡ load control
  - ➡ Fridge, freezer, heat pump,…
  - ➡ usage pattern, “door is open”
  - ➡ “which TV channel do you watch” (every 2s)



http://nilmworkshop.org/2018/proceedings/Poster_ID17.pdf

https://www.cnet.com/news/researchers-find-smart-meters-could-reveal-favorite-tv-shows/

"Amazon Echo" in your smart meter

- Amazon/Google/Apple home control
  - ➡ works on your command
- "Amazon HAN connect"
  - ➡ works all the time
  - ➡ brings all your information to the cloud

Amazon Echo/ Alexa

Apple Home Kit

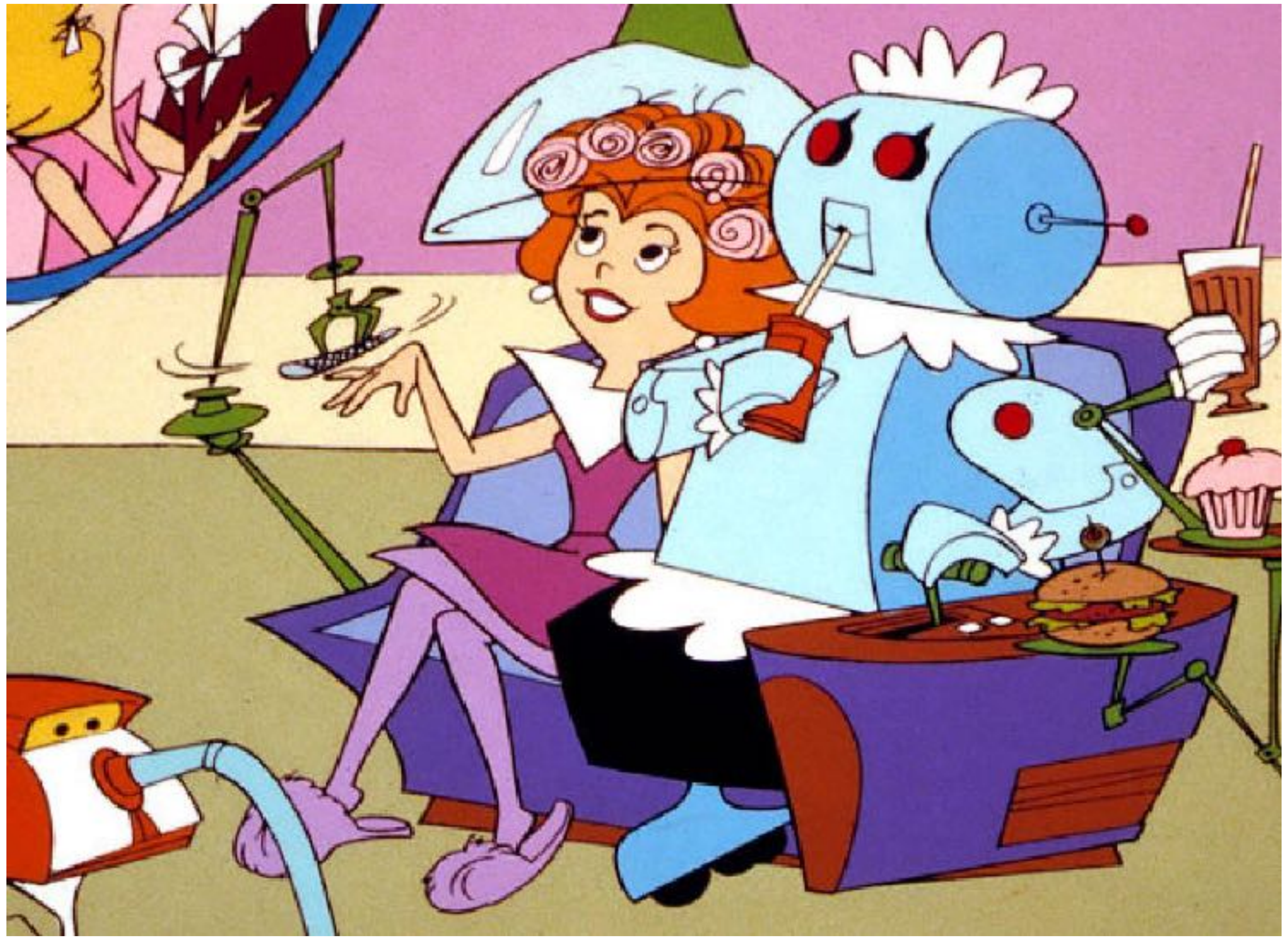
Google Home/Nest

UiO : University of Oslo

Internet of Things

Internet of Things (IoT)

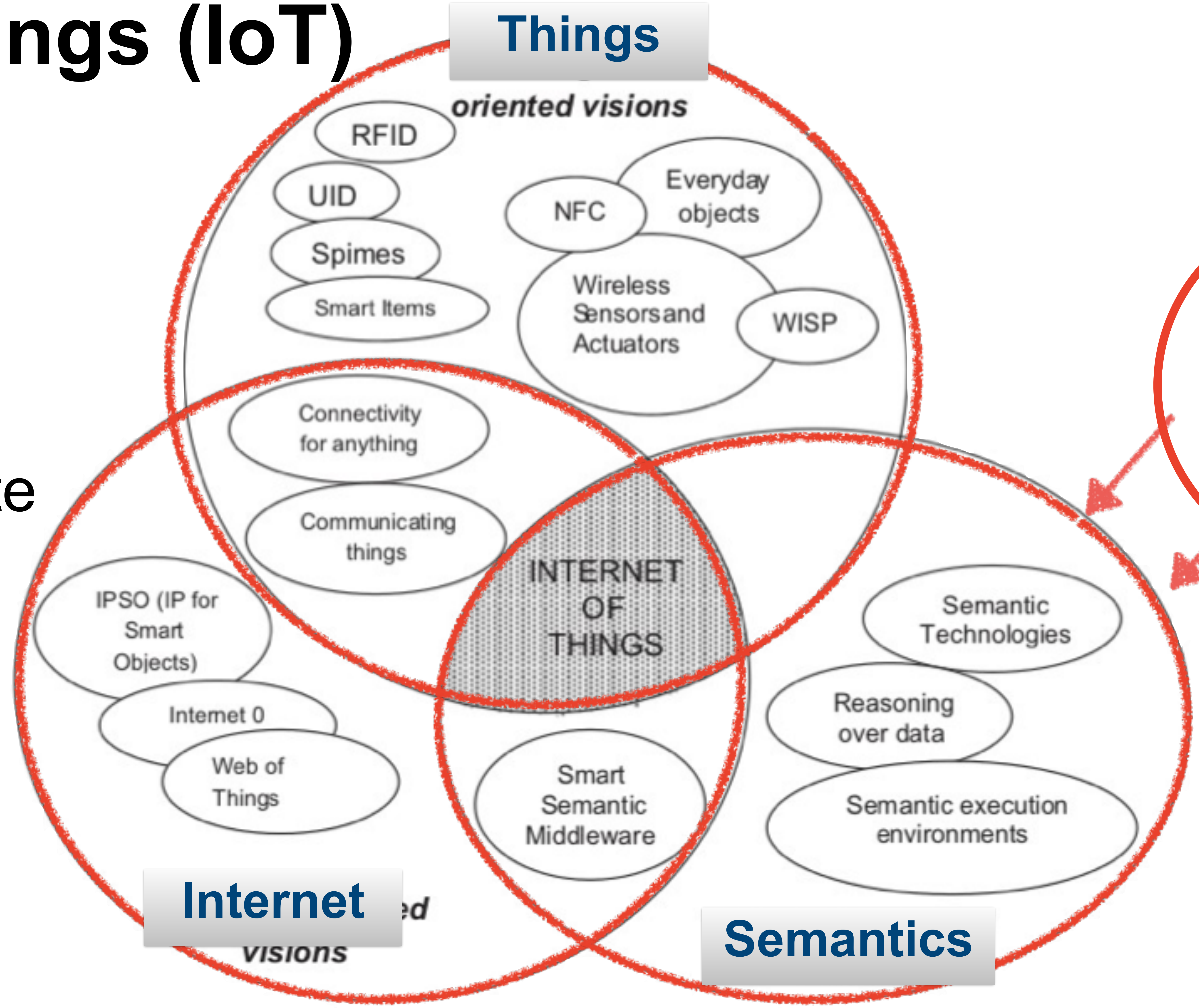
- Interconnected power systems
  - ➡ Enabling the modern life
  - ➡ Critical infrastructure
- Smart home: Life, Jetsons style:
  - ➡ Complexity hidden from user
  - ➡ «Seamless» operation
  - ➡ Adaptive and personal

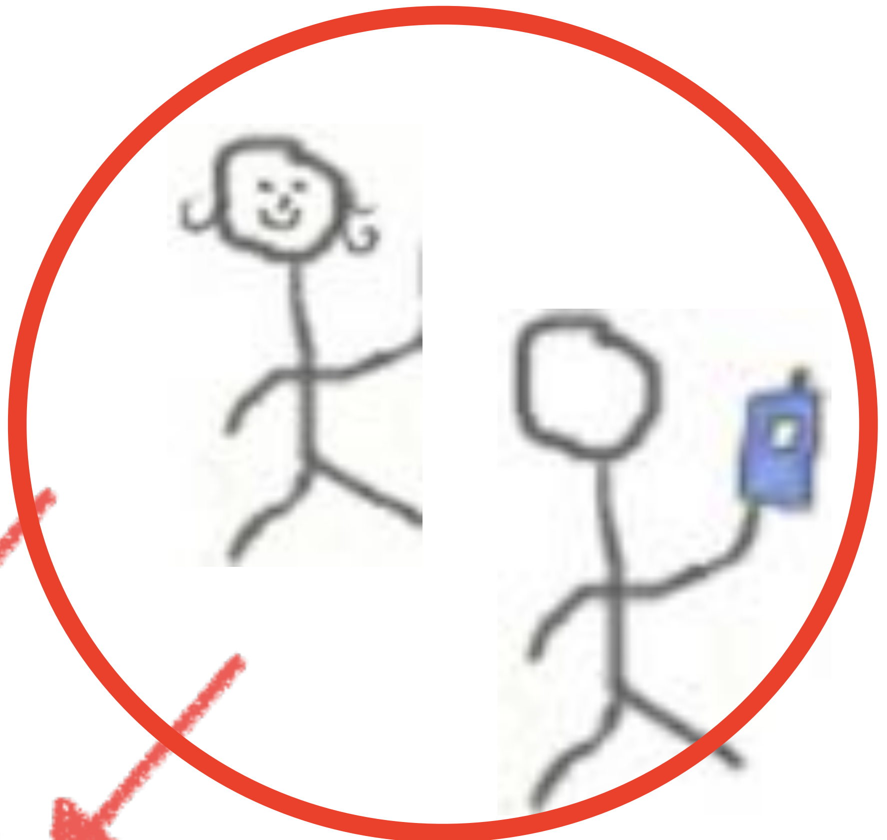


Source: L. Atzori et al., The Internet of Things: A survey, Comput. Netw. (2010), doi:10.1016/

The Internet of Things (IoT)

- IoT =
  - ➡ Things +
  - ➡ Internet +
  - ➡ Semantics
- Things that communicate
  - ➡ with Things: computer,
  - ➡ understand the meaning,
  - ➡ takes own decisions





* security
* privacy
* dependability
* context-aware
* personalised

Fig. 1. "Internet of Things" paradigm as a result of the convergence of different visions.

IoT Life cycle

Industrial Example – E2U Home Management

GATEWAY FIRMWARE

EDGE COMPUTING - SENSOR INTEGRATION

CLOUD INTERFACE

(EVENT HUB)

USER INTERFACE by Partner

(WEB BASED)

WEB TOOLS /APIS (IoT Management)

Installation | Monitoring | Logistics

Industrial Automation

- Main Objective of an automation system: maintain the integrity of its production process and the availability of its components
- Has a physical dimension, bridges the gap between the imaginary IT world and real physical processes
- Maps to:
  - ➡ Network redundancy
  - ➡ Software and hardware requirements
  - ➡ Device redundancy
  - ➡ As a result: security focus in automation translates to:

Caution
The functions and solutions described in this article confine themselves to the realization of the automation task predominantly. Please take into account furthermore that corresponding protective measures have to be taken up in the context of Industrial Security when connecting your equipment to other parts of the plant, the enterprise network or the Internet. Further information can be found under the Item-ID 50203404.

http://support.automation.siemens.com/WW/view/en/50203404

teach our sensors and Smart Grid to talk Norwegian

Summary: TEK5370

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