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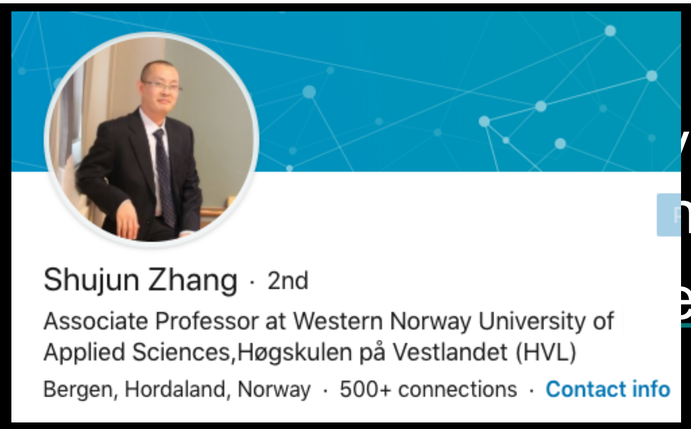
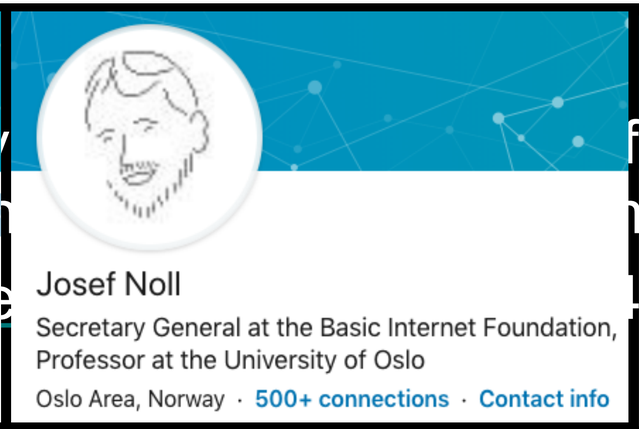
TEK5370 “Grid, Smart Grid and IoT” - L1 Intro

Norway CO_2 neutral in 2030

Knowledge for a CO2-neutral Society





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Disclaimer:
This presentation provides an overview for students on “what is the knowledge” you need to have to contribute to Norway 2030- Zero CO_2

United Nations
Sustainable Development Goals

TEK5370 - “Grid, Smart Grid and Internet of Things (IoT)”

- Motivation
  - Sustainable Developments
  - Renewable Energy
  - From Grid to Smart Grid
  - Secure and trusted IoT interaction

- Energy Group at ITS
  - head: Sabrina Sartori
  - Vision: “Transformation to affordable zero-ne

Vision and Mission

- Vision:
  “Transformation to affordable zero-net energy systems for All”
- Mission:
  - Research for modern and sustainable energy
  - Create the technology vision for a renewable energy systems
  - Empower the society for sustainable development through energy systems

Vision and Mission

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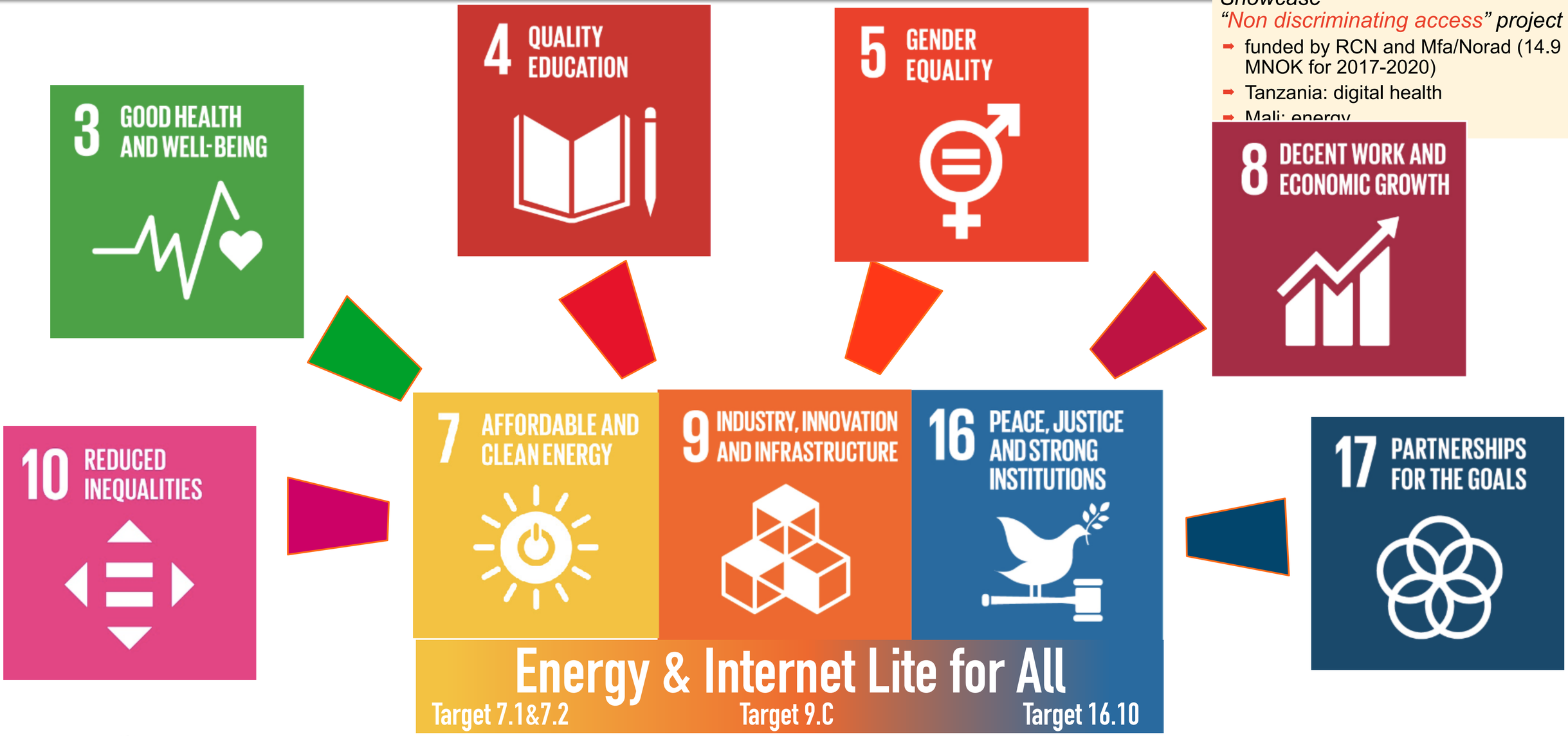
7 AFFORDABLE AND CLEAN ENERGY

- Answering SDG 7 targets:
- 7.1 By 2030, ensure universal access to affordable, reliable, and modern energy services
- 7.2 Increase substantially the share of renewable energy in the global energy mix by 2030
- 7.3 double the global rate of improvement in energy efficiency by 2030
- 7.a By 2030, enhance international cooperation to facilitate access to clean energy research and technologies, including renewable energy, energy efficiency, and advanced and cleaner fossil fuel technologies, and promote investment in energy infrastructure and clean energy technologies
- 7.b By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, particularly LDCs and SIDS

Affordable Energy & Internet Lite for All
the catalysts for the goals

Showcase
"Non discriminating access" project
- funded by RCN and Mfa/Norad (14.9 MNOK for 2017-2020)
- Tanzania: digital health
- Mali: energy



Goals Norway

- Climate regulation for Norway (Lov om klimamål, LOV-2017-06-16-60):
  - §3 “Goal of 40% reduction of climate gasses in 2030, as compared to reference year 1990"
  - §4 a.o. Goal of 80-95% reduction of climate gasses in 2050 (w.r.t. year 1990)
- 5 specific areas for Norway’s work on climate
  - ➡ Reduction in the transport sector
  - ➡ Low-emission technologies for industry
  - ➡ Carbon-capture and storage (CCS)
  - ➡ Increase Norway’s role as supplier for renewable energy
  - ➡ Environmental friendly ship transport

Energy balance Norway

- Calculate in %
  - production
  - industry
  - transport
  - households (see next page)
    - warming/usage
    - transport household

Energybalance Norway [TWh]	2017	2018	Change [%]
Production of primary energy	2483	2394	-3,6
Import	114	129	13,7
Export	2271	2186	-3,8
International Storage	9	9	6,8
Change in availability	11	-10	-184,9
Netto inland resources (SUM above)	**328**	**319**	**-2,8**
transformation	6	1	-76,6
own energy in energyproducing	76	76	0
losses	9	10	16,4
Netto inland incl. resources	**241**	**244**	**1,1**
	28	28	2
	213	216	1
Industry	**72**	**73**	**1,4**
Transport	**54**	**53**	**-0,8**
Other sectors (incl. households)	**88**	**89**	**1,8**
Statistical errors	8	-10	-223,3

https://www.ssb.no/energi-og-industri/statistikker/energibalanse

Energy Consumption Households Norway

- Calculate the % of usage for
  - heating
  - Electricity based heating
  - Transport

Energy consumption households Norway	2014	2015	2016	2017	2018
Electricity	36918	38690	40045	40442	40537
Coal	-	-	-	-	0
Oil	777	725	807	656	421
Parafin	226	187	174	124	112
LPG	78	57	97	90	103
Wood	5268	5620	5411	4981	5637
Natural Gass	44	39	42	89	9
Remote varm water	1000	1037	1212	1271	1284
Car Petrol (benzin)	10150	9537	8899	8524	8096
construction diesel	730	742	755	768	781
Car Diesel	10152	10654	10582	9270	9567
Bio petrol	611	682	1582	2357	1783
Total incl petrol/diesel [GWh]	65953	67971	69606	68574	68331
Total exclusive petrol/diesel [GWh]	45040	47098	48543	48422	48884
Energy/household [kWh]	28656	29138	29458	28849	28362
Energy/person [kWh]	12838	13097	13293	12995	12903
El. energy/household [kWh]	16040	16586	16948	17014	16825
El. energy/person [kWh]	7186	7455	7648	7664	7655
#people	5137429	5189894	5236151	5276968	5295619
#household	2301546	2332722	2362884	2376971	2409257

https://www.ssb.no/energi-og-industri/statistikker/energibalanse

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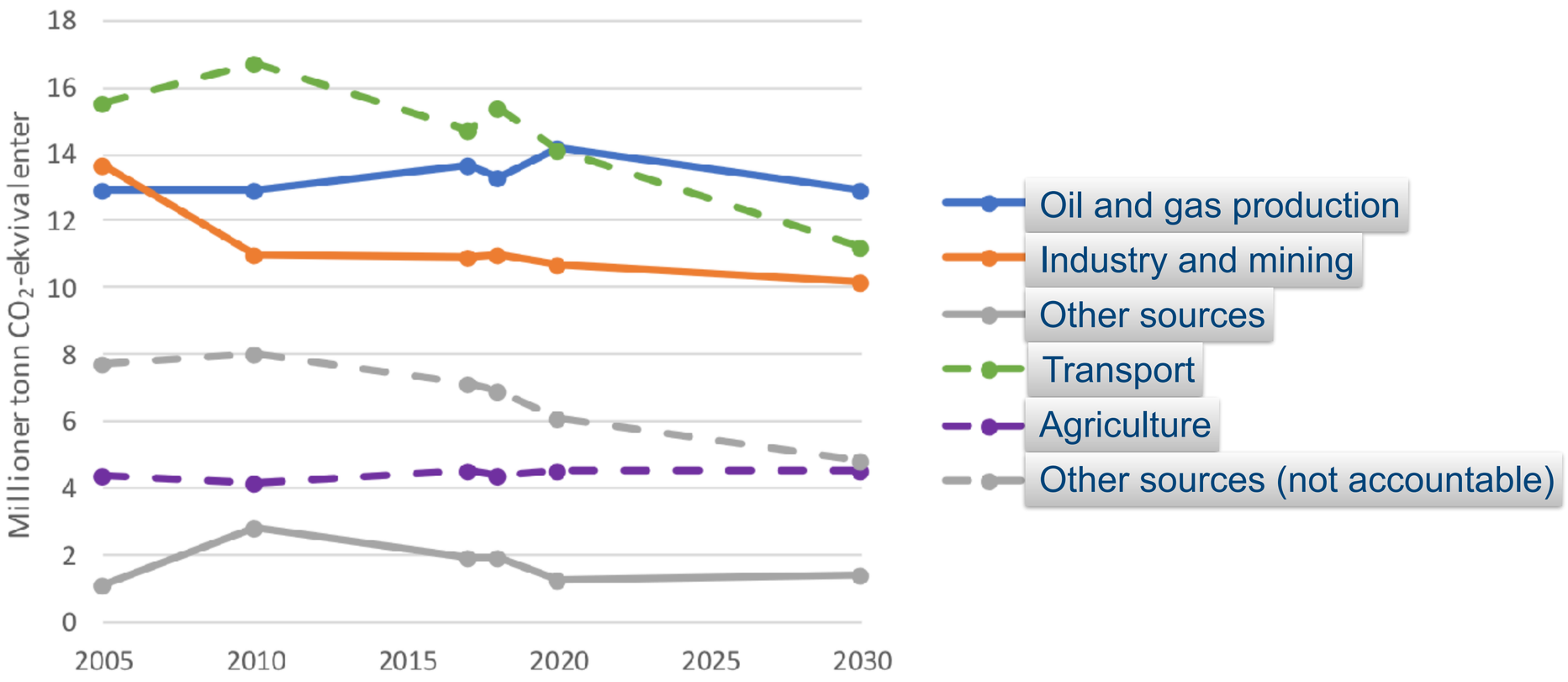
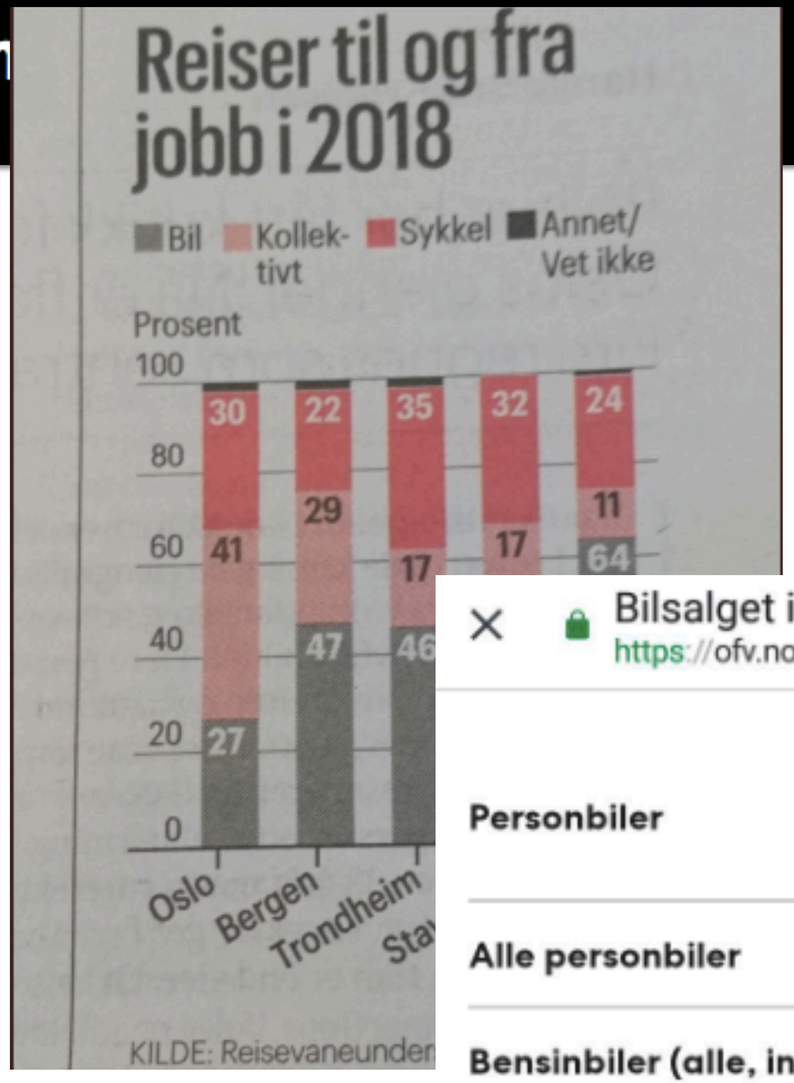
CO_2 equivalent climate gass emission Norway



[Fig1, L.E. Schäffer et al., “Veikart for energi i Norge mot 2050”, Report by Sintef, IFE, NTNU, 2019]

Challenge: Transport

- Transport (Example Norway, Feb2019):
- Petrol and Diesel **new** cars increased CO2 emission
  - ➡ due to ~50% electric cars, total of 64 g/km
  - ➡ Mar2019: >50% electric car sales + 18% hybrid
- Oslo: CO2 reduction by 8% (2015-2016)
  - ➡ 5% CO2 reduction in transport
  - ➡ Climate goals of 2017 reached in 2016
  - ➡ Travel to work: 30% bike + 41% public transport (only 27% car)



Bilsalget i februar ...
https://ofv.no
TWEET

Personbiler	CO2-utslipp februar 201
Alle personbiler	64 g/km
Bensinbiler (alle, inkludert bensin ladbare hybrider)	97 g/km
Dieselbiler (alle, inkludert diesel ladbare hybrider)	134 g/km
Varebiler klasse 2	155 g/km

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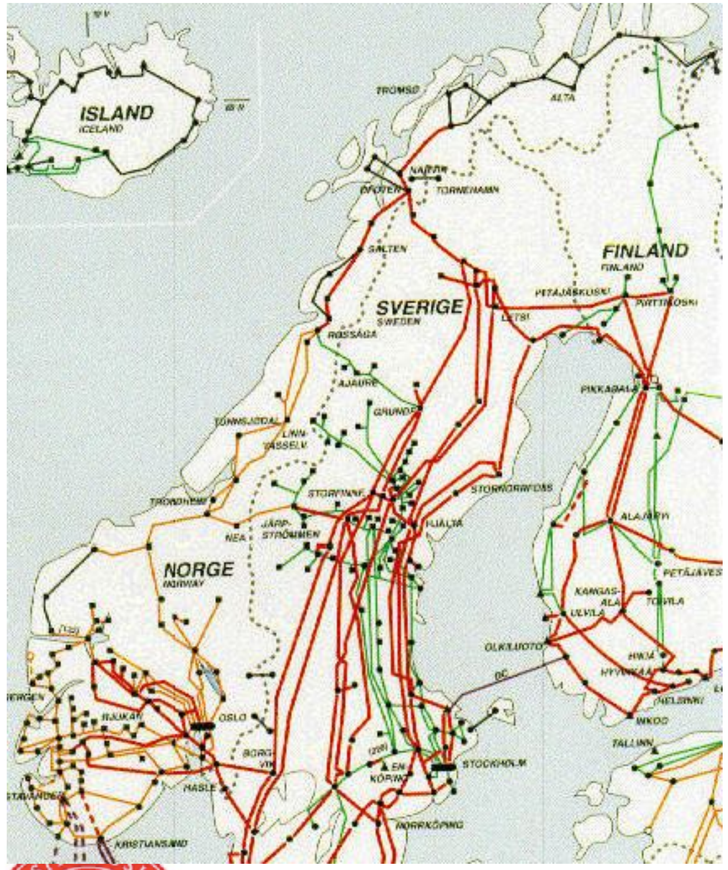
Competence Goal 1:
Energy usage and conversion to renewable energy

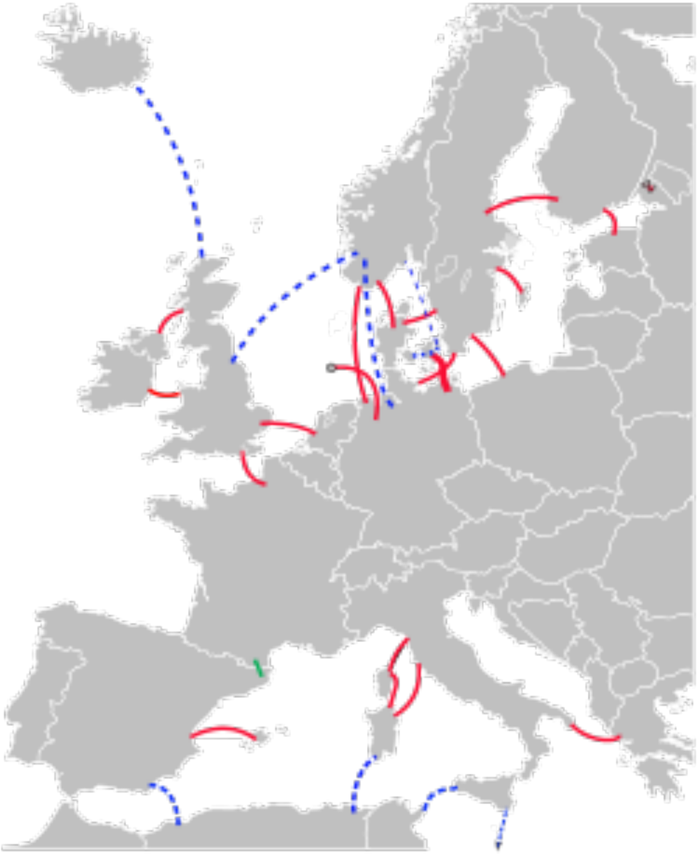
Most effective way to reduce CO_2

- You and me
  - Consumption
  - Transport
  - House/Appartment
- Industry
  - Electrical transport vs Methanol vs Hydrogen
  - Electrical construction
- Power companies
  - DSO
  - TSO

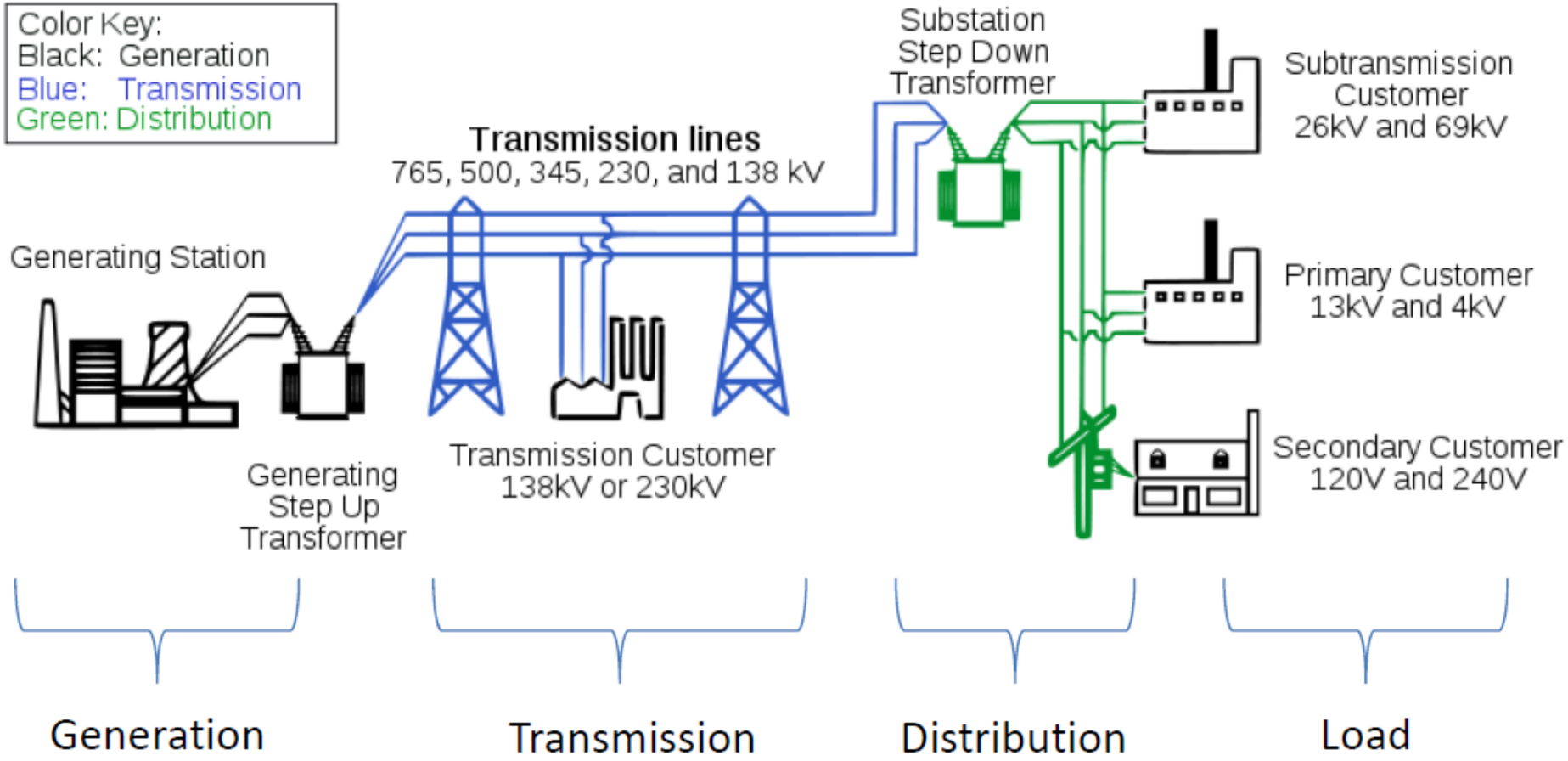
To understand:
- Energy balance, e.g. Hydrogen conversion
- Infrastructure costs (solar, batteries, …)
- Electrical grid enhancement vs methanol/hydrogen transport

The electrical grid - transport capacity and connections





Power system



Goal - a stable grid at minimal costs

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

Central grid 132-420 kV

Statnett is the Transmission System Operator

-Operates the central grid

-Owns ±90 % of the central grid, leases the remainder

Regional grid 33-132 kV

Around 90 network owners

-Most own distribution grids as well

-Licence for each individual network asset

Distribution grid <22 kV

Around 150 network owners

-Differ in size from 500 000 customers to a handful

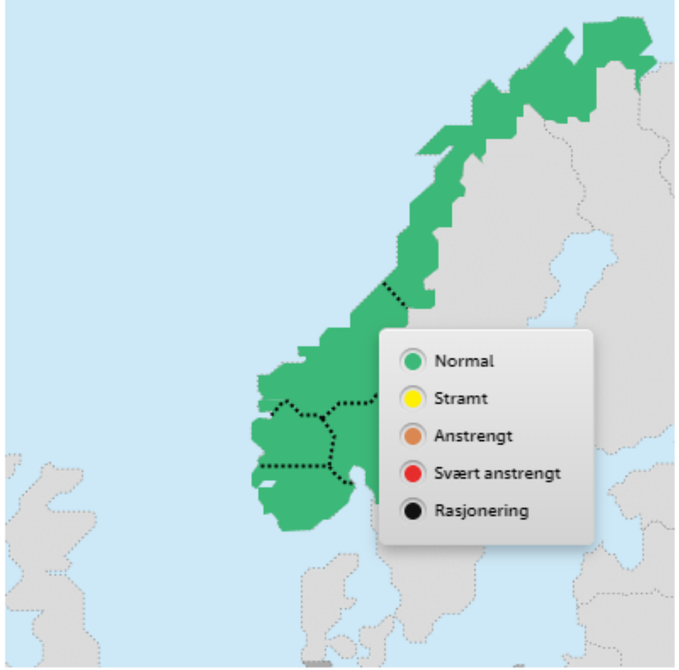
-Area licences with local grid monopoly

Source: NVE

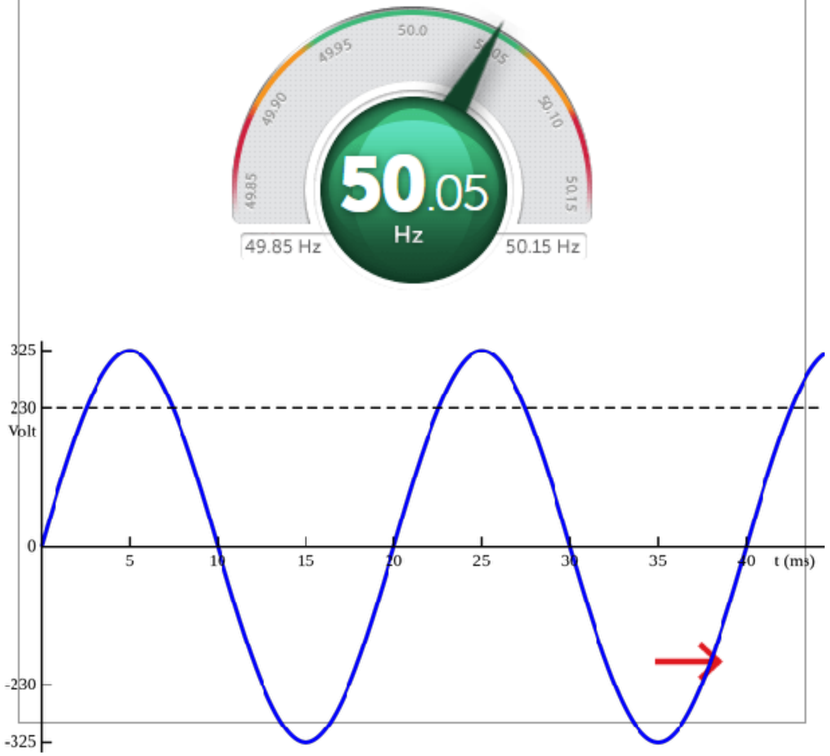
Norwegian grid

KRAFTSITUASJONEN AKKURAT NÅ

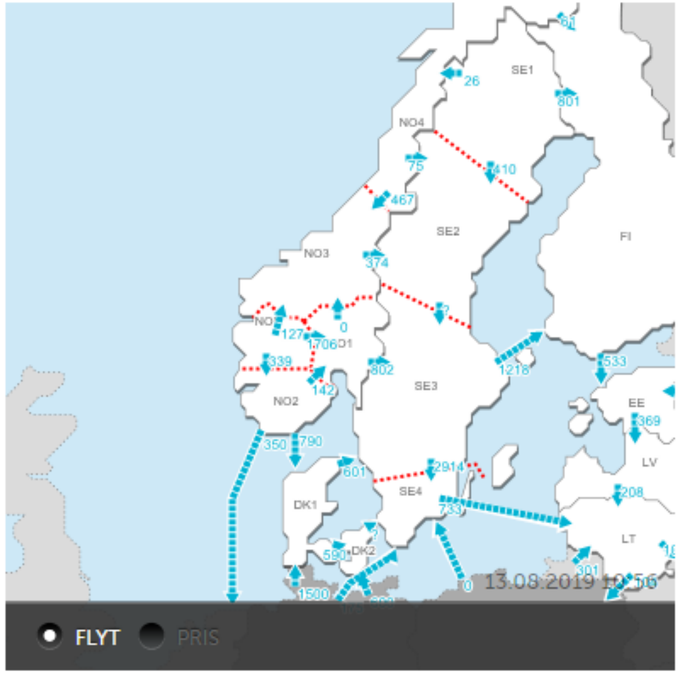
Kraftsituasjonen



Nordisk kraftbalanse

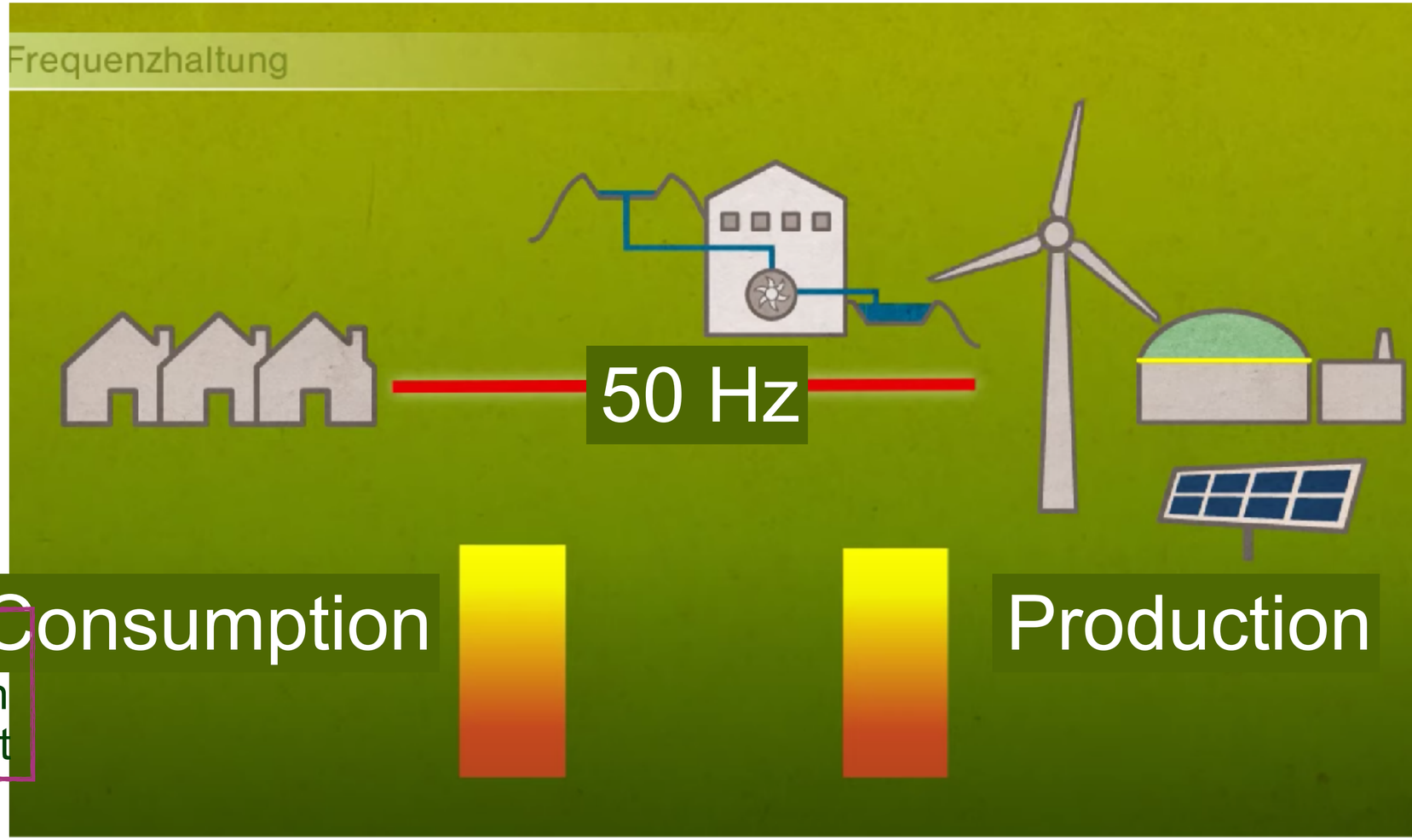


Nordisk kraftflyt



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



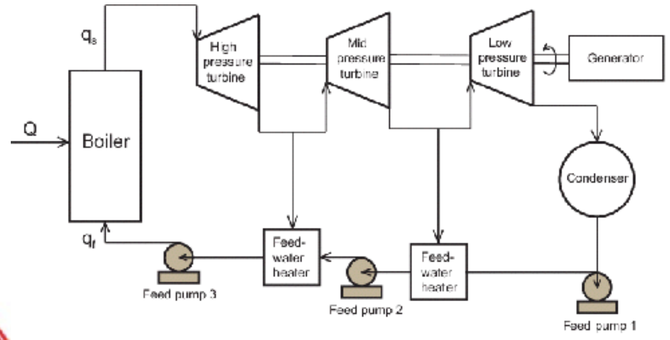
To understand:
- complexity of grid and grid regulation
- complex numbers Voltage vs Current

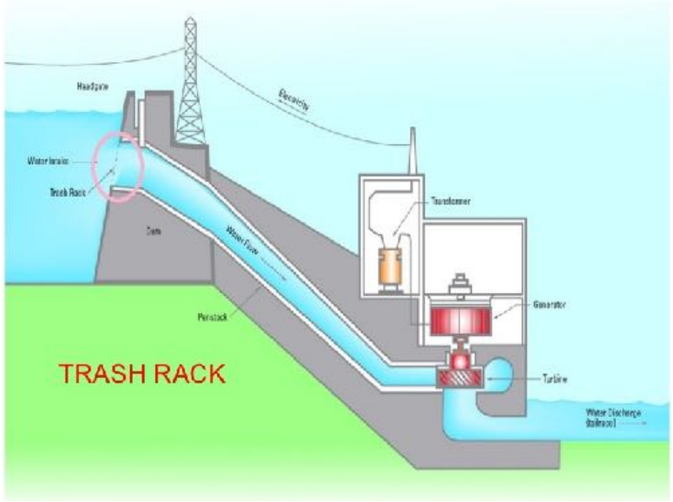
https://www.youtube.com/watch?v=xr76E9AmlaE

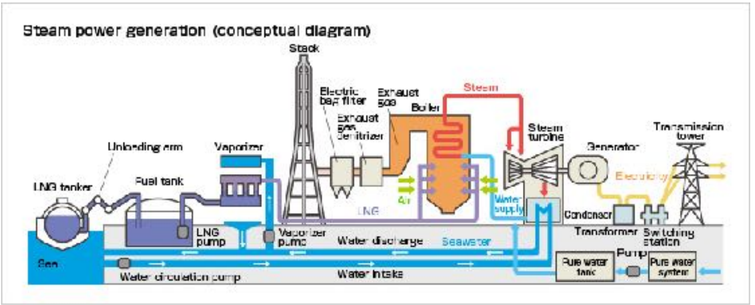
Actors and Functions

- 1. Production of energy- Power utilities, producing traditional and renewable elec- trical energy.
- 2. Transmission System Operators (TSO) - In Norway only Statnet can be classified as a member of this group by definition. However according to alternative defini- tion, owners of regional electrical network can be also considered as TSOs.
- 3. DistributionSystemOperators(DSO)-responsible for operation of local electrical grid between TSO and customers or prosumers.
- 4. Security companies – carrying out projects and developing solutions for security of smart grids. This includes security of individual households and grid operators.
- 5. Software development - companies providing different software and middle ware solutions. To limit the scope of the paper, we will focus only on software related to Smart Meter value chain.
- 6. Manufacturers of smart energy service devices -vendors providing smart meters, communication system modules, etc.
- 7. Consulting- companies providing advisory and consulting services for energy com- panies. Having best practices in place and list of reliable suppliers they take active participation in the projects launched by power companies.
- 8. Legislative- This group unites governmental companies, capable of creating new laws in power industry as well as companies working on promoting rights of their stakeholders in focus (trade unions and company unions).
- 9. Research- Research institutions take active part in various energy projects.
- 10. Prosumers and Customers - Customers and prosumers are end-users in electricity market. Naturally actors influencing this value chain should be also analyzed.

Power generation (traditional)

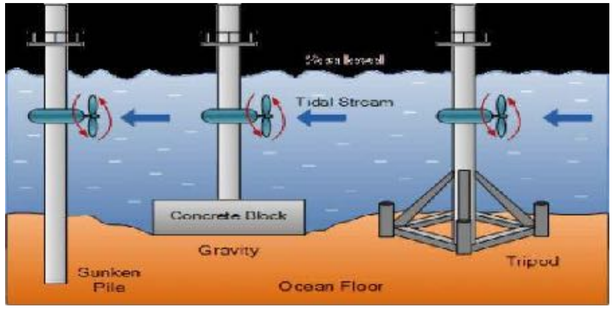


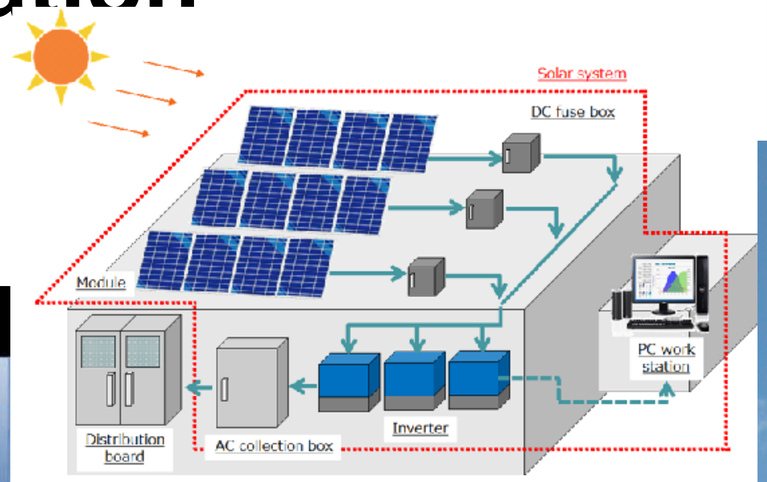




Power generation

- Renewable:





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

Power transmission

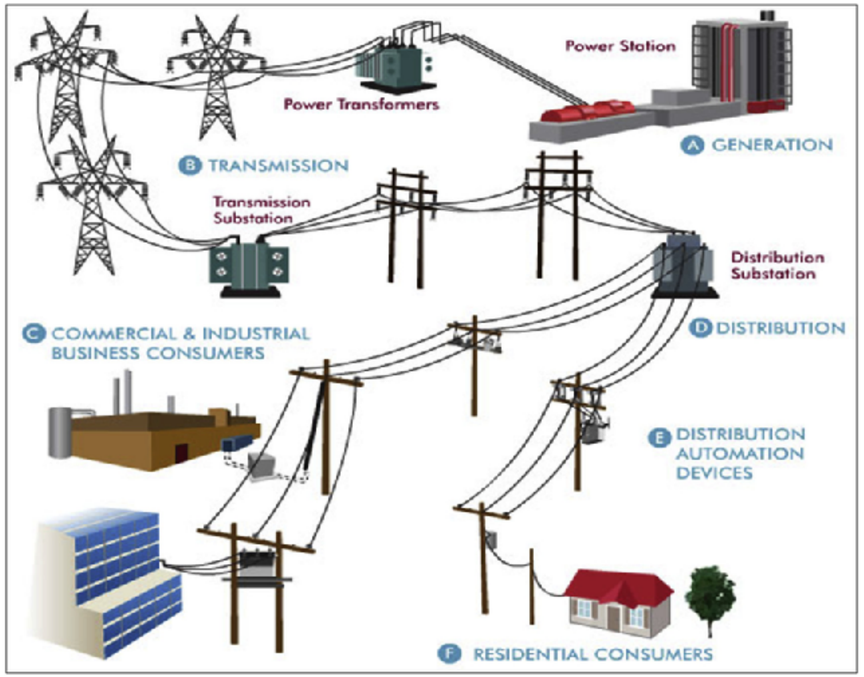
- High voltage transmission lines
- Several hundred kilometers

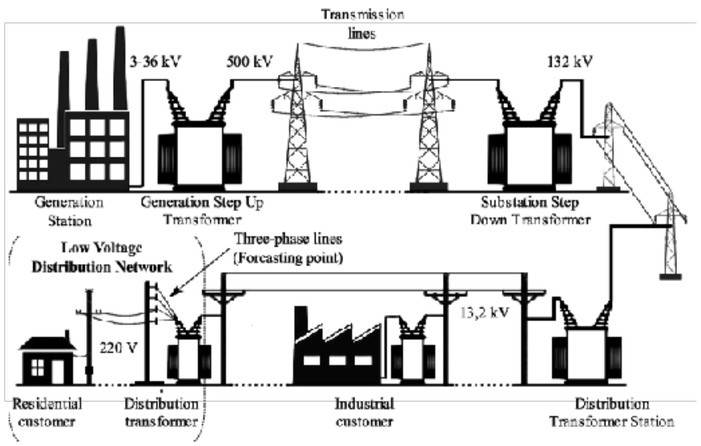
- Switching stations
  - ➡ Transformers
  - ➡ Circuit breakers

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

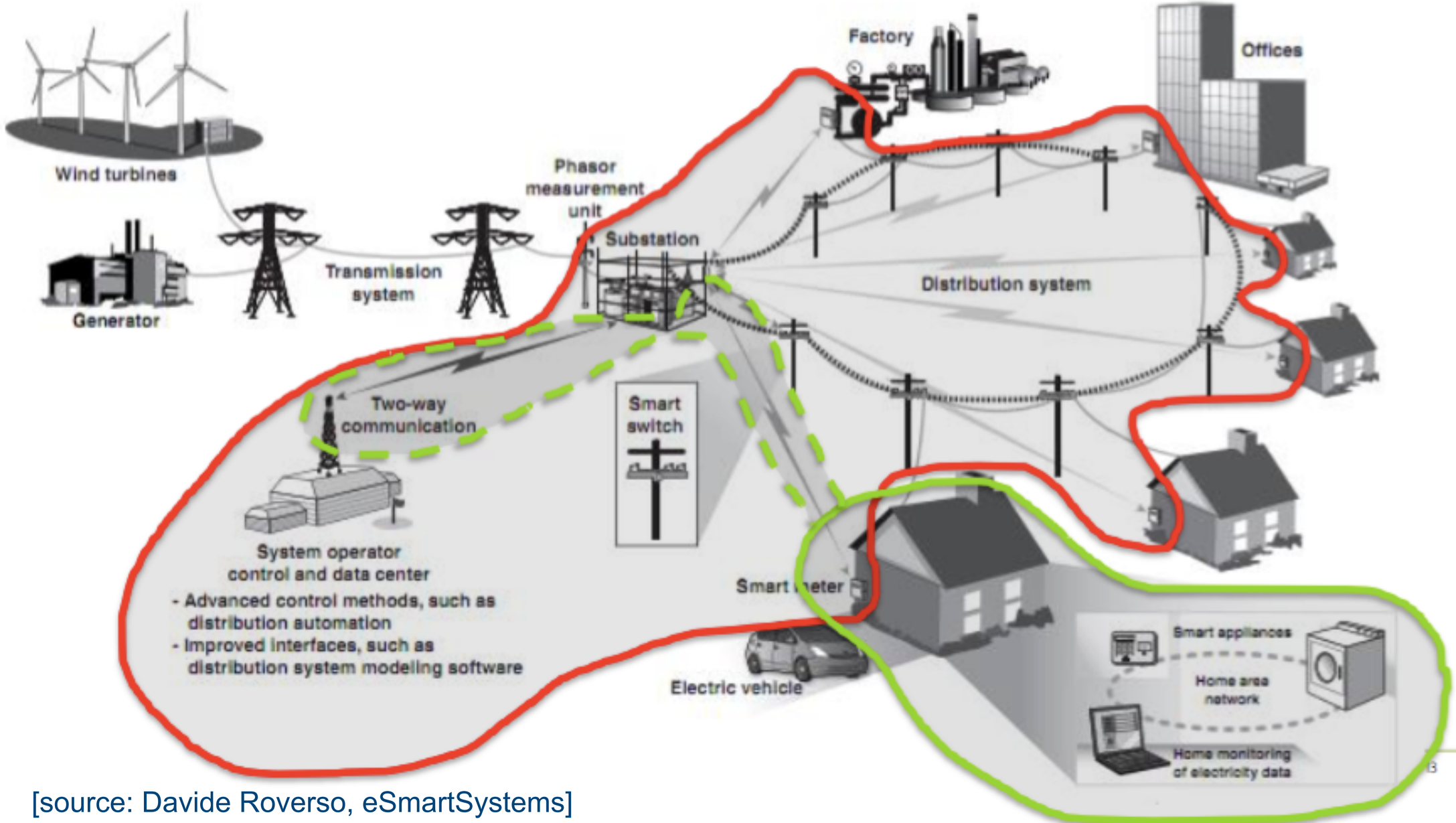
Power distribution

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





Smart Home vs Smart (Distribution) Grid focus



[source: Davide Roverso, eSmartSystems]

Load / Consumers

- Industry
- Commercial
- Residential

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Technology/Scientific Challenges

1) Grid- stability, security, privacy
2) Demand- Supply: Island, storage
3) Norway and Europe - manage the conversion, economics
4) Climate & Global aspects

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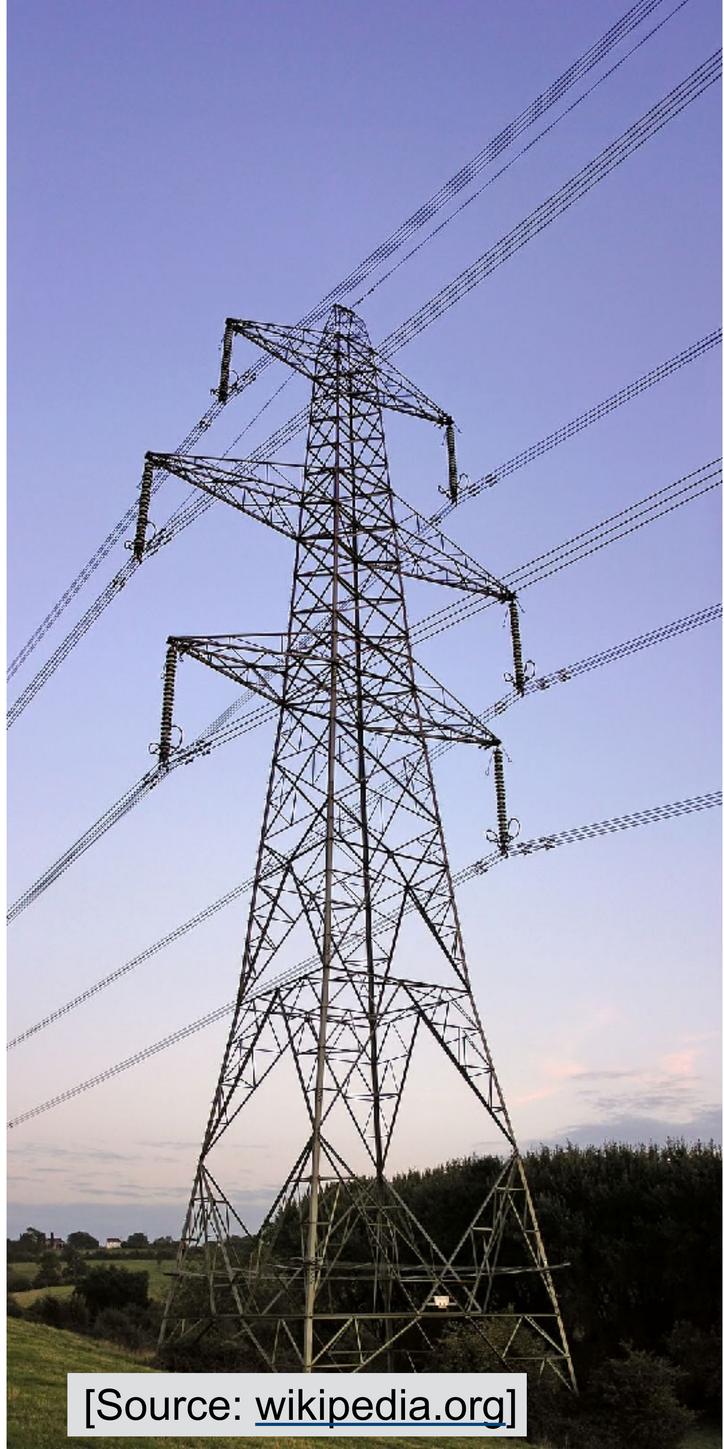
1) Grid- stability, security, privacy

- Stability- “how to measure”
- Security- resilience
- Privacy- “my life”

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

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



[Source: wikipedia.org]

Source: Davide Roverso, eSmart Systems

Smart Grid Actors

TSO: Transmission System Operator

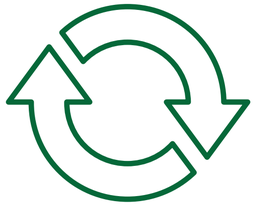
DSO: Distribution System Operator

- 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, ...

TEK5370 - Topics

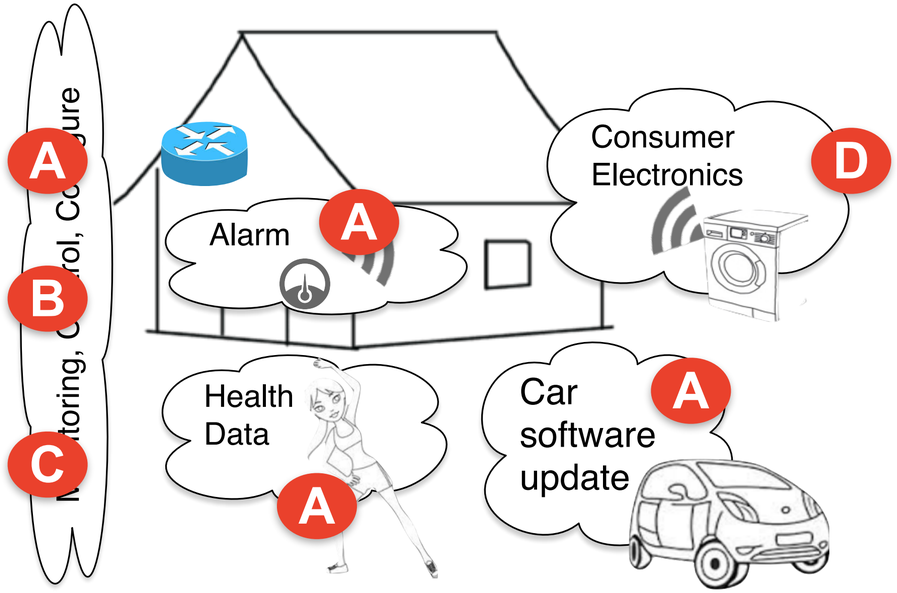
- 1. **Grid - physics** on how the grid is build, and how the balance between demand and supply is kept
  - ➡ from transmission to home distribution
  - ➡ challenges from renewable energies
  - ➡ power flow, voltage regulation
- 2. **Smart Grid** efficient energy systems
  - ➡ Advanced metering system (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

Security Paradigm for Home Control



IoT lifecycle

- Home Control - security and privacy
  - Regulating the energy consumption
  - Centralised solution (privacy, risk)
  - Decentralised/Home solution
- Security classes A B C D
  - Target security goals for design (home alarm = Sec Class A)
  - build the system, security enhancing technologies
    - link data from Class D (consumer electronics) into Class A operation
  - validation, check against threats (“continuous update”)
- Novel Risk Map for IoT - Impact and Exposure
  - Common weakness score system
  - Composite security metrics



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2) Demand- Supply
- variations (renewable)
- storage
- conversion loss

To understand:
- Energy balance, e.g. Hydrogen conversion
- Infrastructure costs (solar, batteries, …)
- Electrical grid enhancement vs methanol/hydrogen transpor

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

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3) Norway and Europe (Global)

- manage the conversion to CO_2
- economics
  - power lines
  - type of energy production (land-, ocean-wind,…)
- energy usage: DC, hydrogen, Methanol
- “North Pole as base for Wind Farms”

To understand:
- Energy balance, e.g. Hydrogen conversion
- Infrastructure costs (solar, batteries, …)
- Electrical grid enhancement vs methanol/hydrogen transport

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4) Climate & Global perspective

- Climate impact
- SDGs
- affordable energy

Climate Impact

- More rain, less snow
- high-intensity events
  - ➡ heavy rain-fall
  - ➡ high-wind speeds
  - ➡ gust winds
- storms taking down the grid
  - ➡ national cost of power outages in 2012, the year of Superstorm Sandy, was between $27 to $52 billion
-

Parameter	Value
Radius of wind part	600 km
Radius of precipitation part	300 km
Maximal gust wind	38 m/s
Maximal precipitation causing ice	10 mm/h

[https://www.eesi.org/articles/view/protecting-the-grid-from-the-impacts-of-climate-change]

[David M. Ward, The effect of weather on grid systems and the reliability of electricity supply, 2013]

Google translate

Partnership for Digital Africa

http://www.aftenposten.no/meninger/debatt/Kronikk-Som-gjesteland-pa-G20-toppmotet-ma-vi-bidra-til-a-endre-verden--Erna-Solberg-614076b.html

Comment: As a guest country at the G20 summit, we must help to change the world | Erna Solberg

ERNA SOLBERG (H), PRIME MINISTER

UPDATED: 30.JAN.2017 9:39 P.M. | PUBLISHED: 30.JAN.2017 7:58 P.M.

International Perspective

Climate migration (draught, flooding)

heat resistant crops

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TEK5370 - Grid, Smart Grid & IoT

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

To understand:
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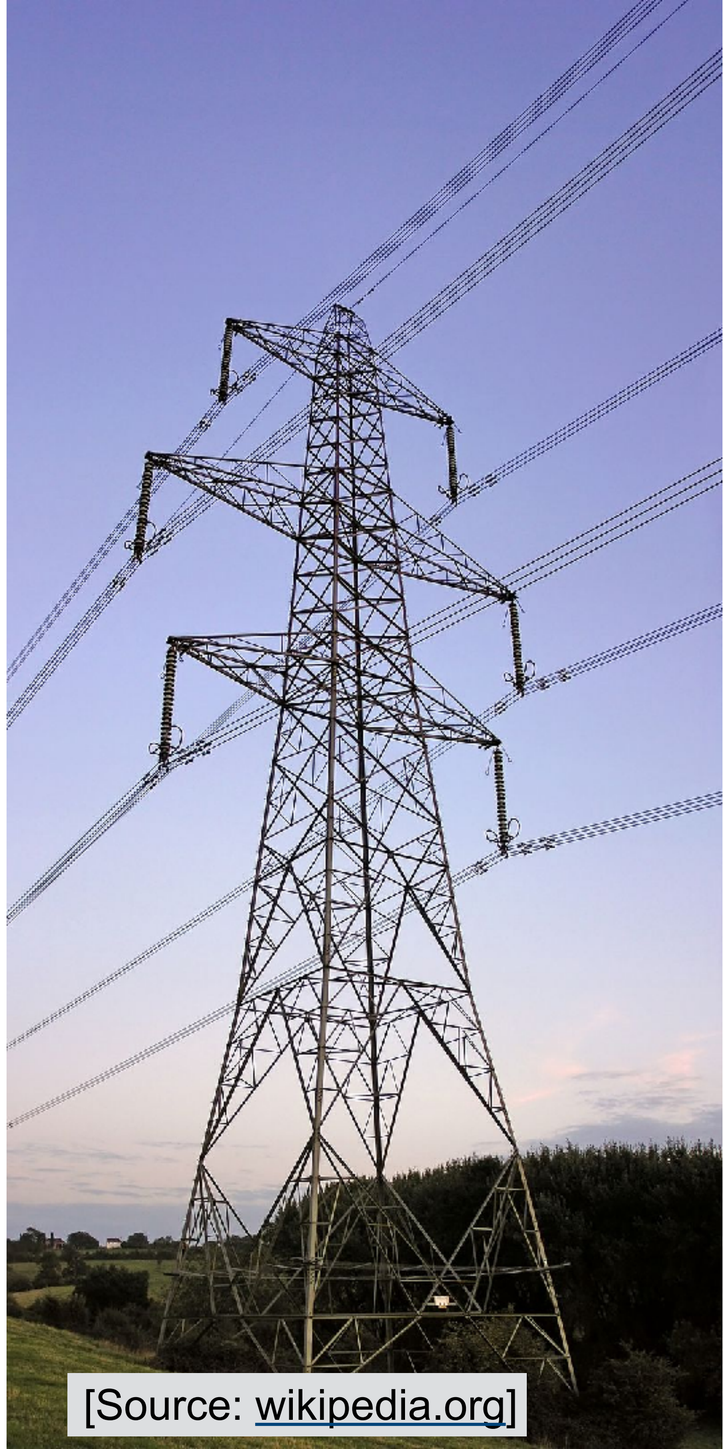

[Source: wikipedia.org]