The Nordic Perspective

Hydropower Summit

Trondheim February 5th 2020

Mats Billstein
Vattenfall AB – R&D

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The 17 goals defined by UN

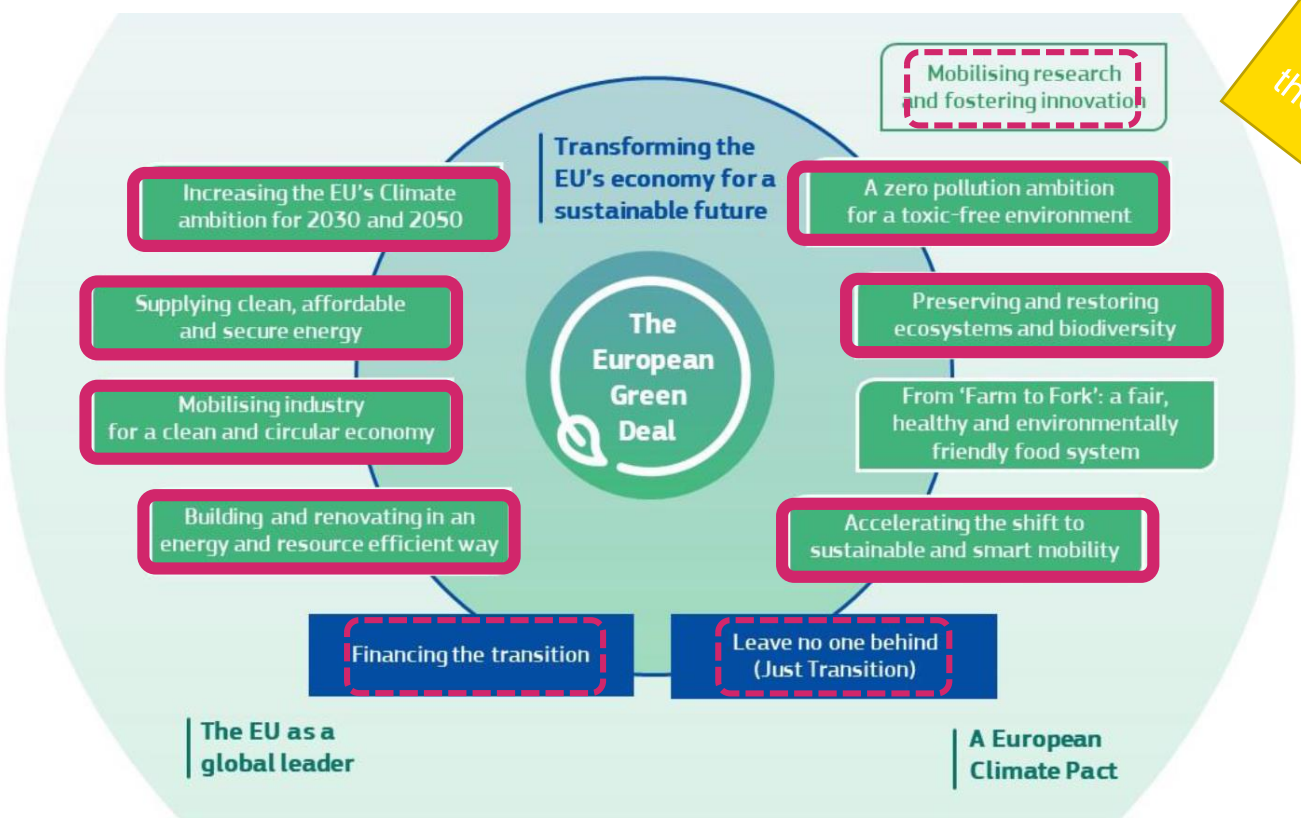
Electrification is the key

… together with education and innovation

The European Green Deal: a roadmap for actions

Key topics for power sector

Topics to monitor



"Europe's man on the moon moment"

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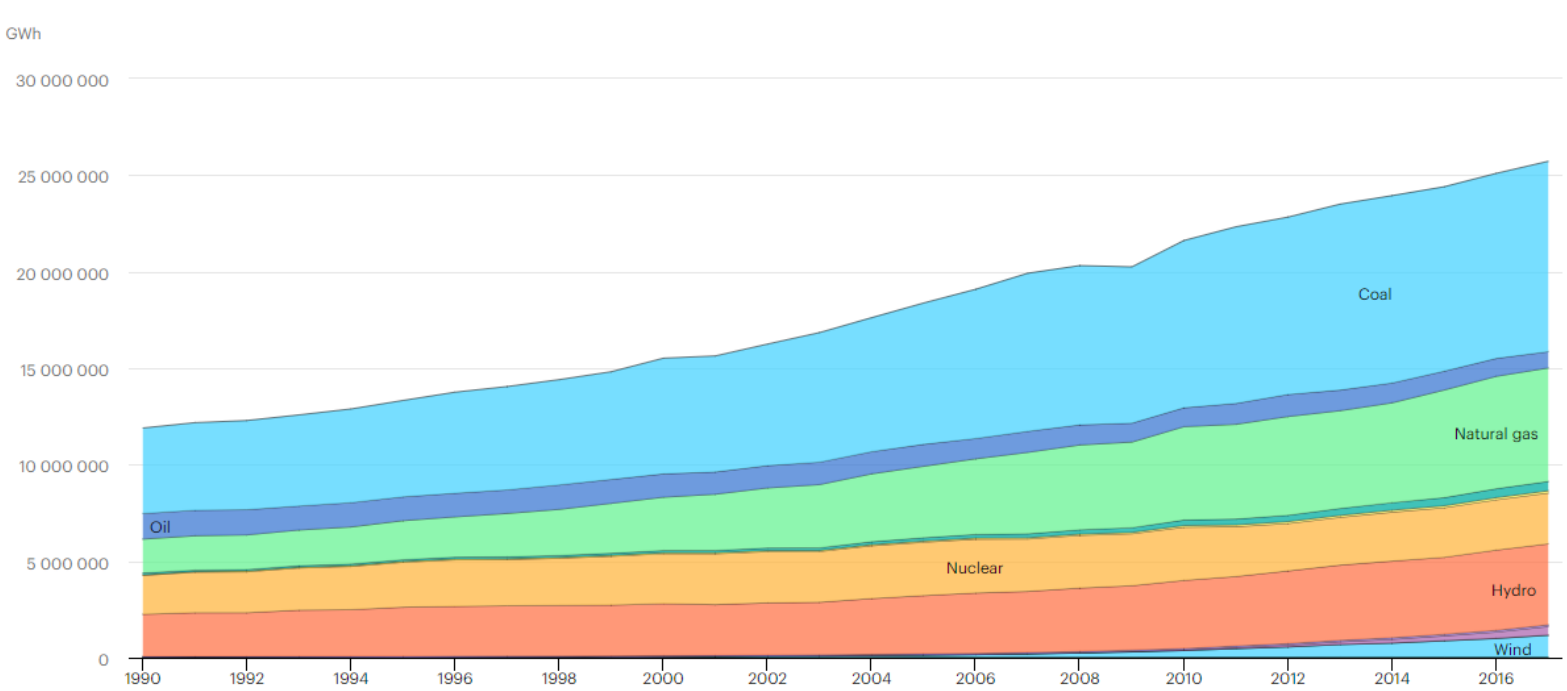
Source: European Commission; Communication "The European Green Deal" – 11.12.2019; COM(2019) 640 final

Electricity generation, World 1990-2017



*) Biofuels and waste **) Geothermal, solar PV, solar thermal and tide

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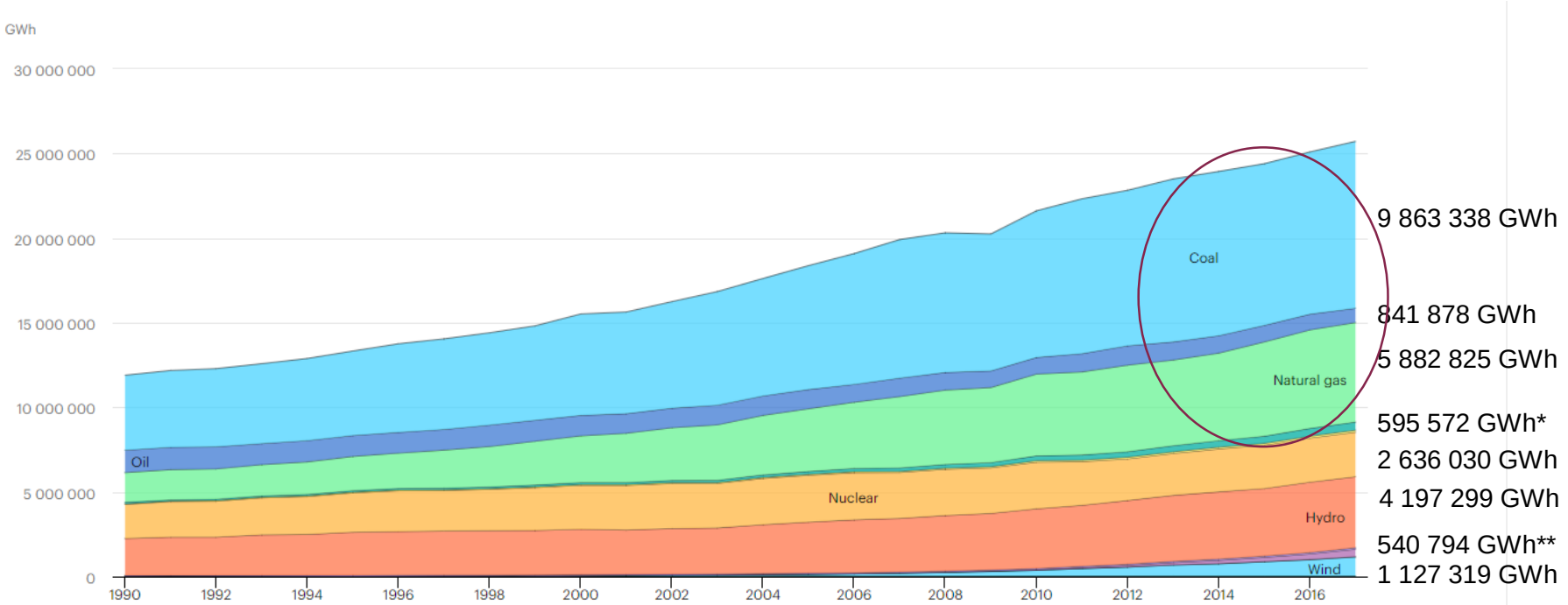
Electricity generation, World 1990-2017



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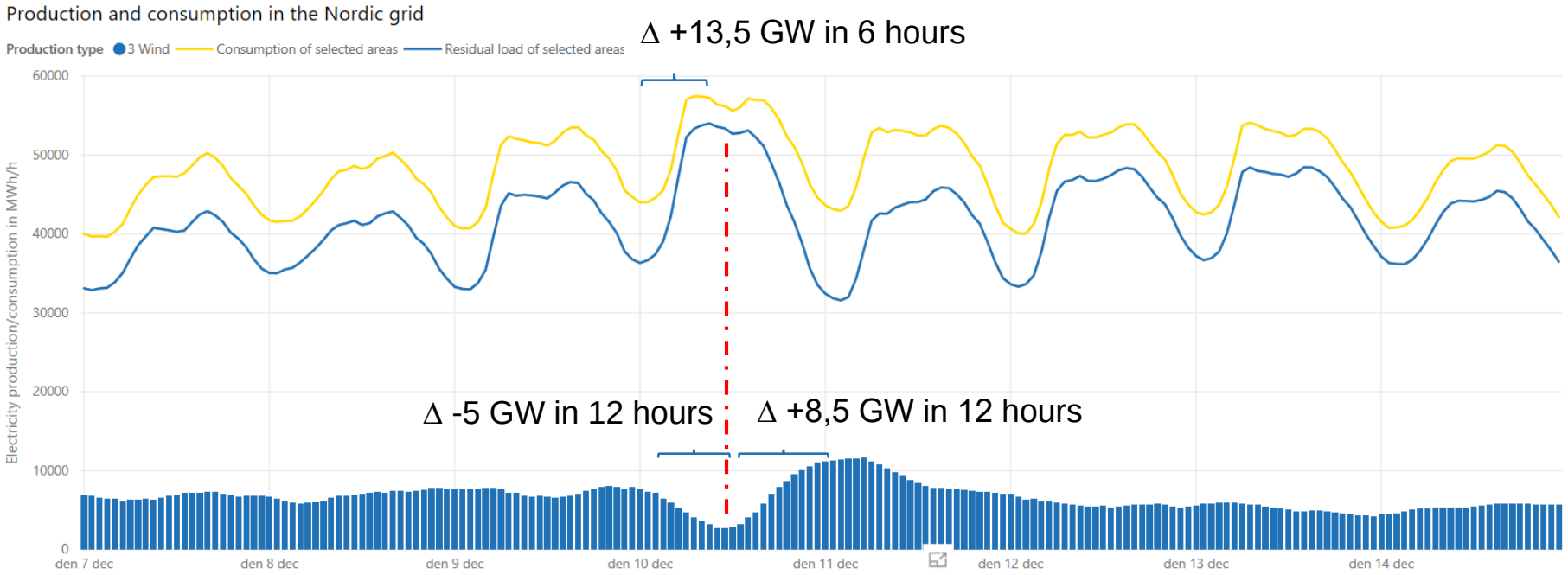
Need for transition

Thermal based → renewable energy system



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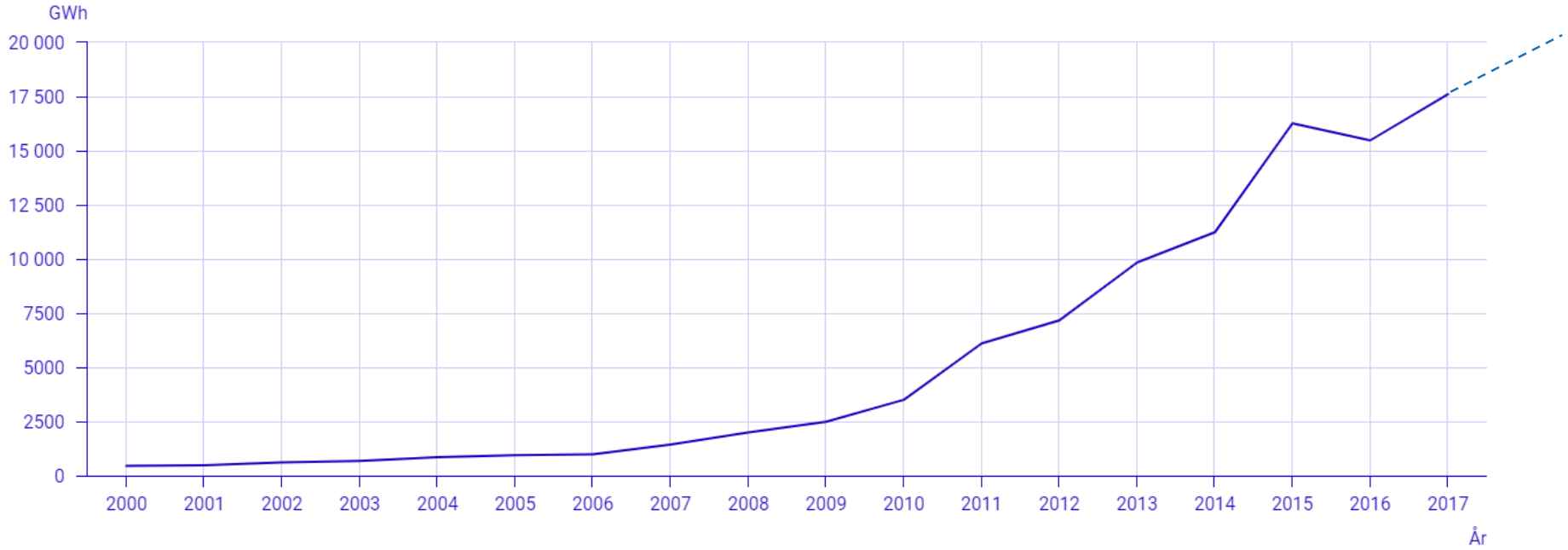
Electricity generation from Wind in Sweden



Requirements for transition

Available power/capacity/flexibility:

- Stabilization of the grid frequency and voltage
- Energy storage
- Sustainable, reliable and secure energy supply

Nordic power system

Installed capacity in MW (2017)

	Nordic
Nuclear	11 400
Hydro	51 100
Wind	15 200
Heat	25 800
Solar	900
Total	**105 300**

Potential additional hydropower generation in TWh

	Nordic
Norway	30
Sweden (and Finland)	15
Total	**45**

Electricity generation in TWh (2017)

	Nordic
Nuclear	84
Hydro	221
Wind	39
Heat	53
Solar	1
Total	**394**

Storage capacity in Nordic reservoirs in TWh (2019)

	Nordic
Norway	86
Sweden and Finland	34
Total	**120**

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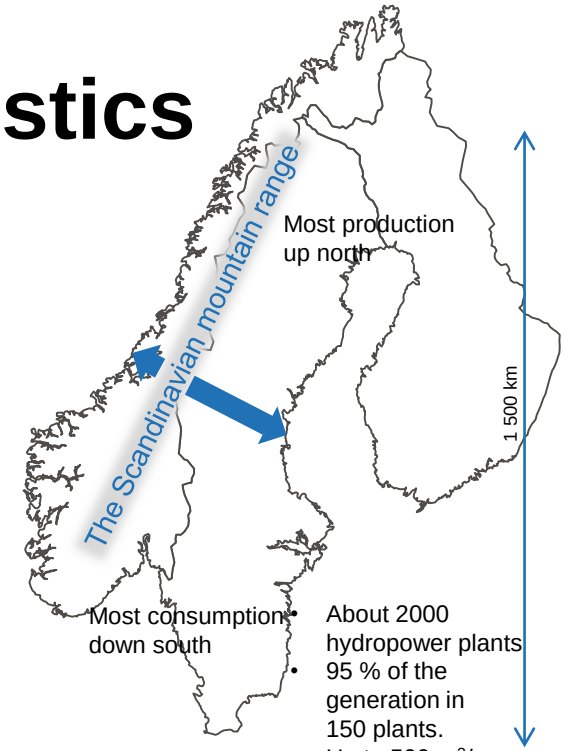
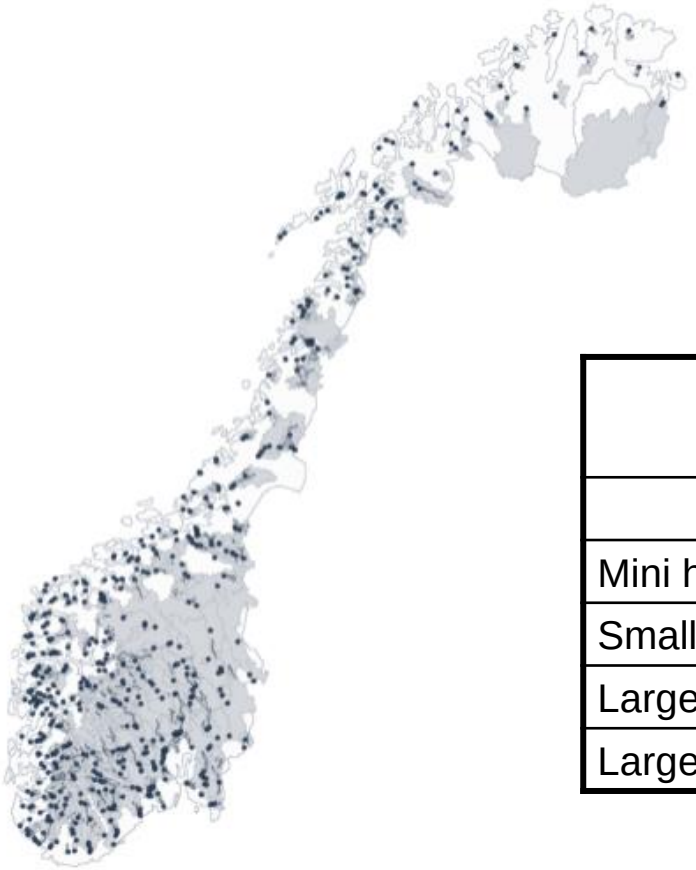
Swedish hydropower characteristics

Majority of large-scale hydropower developed in the 1950-1970s. Situated in long-stretching rivers in primarily Northern Sweden.	• Large reservoirs in the mountains, run-of-river closer to the coast. • Long cascades of plants to reach the coast, typically 10-35 plants. • Lower heads than Norwegian and Alpine plants. • Property rights along rivers yield perpetual generation permits with conditions. Dictates water management.
Annual average generation 65 TWh, 40-45 % of Sweden's demand.	• Snow in the winter yields runoff mainly in the spring flood, stored in reservoirs. • Deregulated market for electrical energy (Nordpool), no subsidies for hydro.
The major flexible generation resource in the Nordic synchronous system on all time scales.	• Storage in Swedish reservoirs: 34 TWh (120 TWh in SE, NO, and FI). • Very few pumped-storage powerplants, no significant volumes.
No new builds to expect – major remaining rivers are protected by environmental laws.	• Potential ~15 TWh additional generation. • Oversupply (energy) in the Nordic market.
Differences to Continental hydropower	• Less hydropeaking in Sweden – naturally damped in the river stretches. • Less/no dissolved oxygen issues. • Fewer concrete dams – more earth-filled dams. • Few rivers used for navigation and irrigation. • Less sedimentation issues.



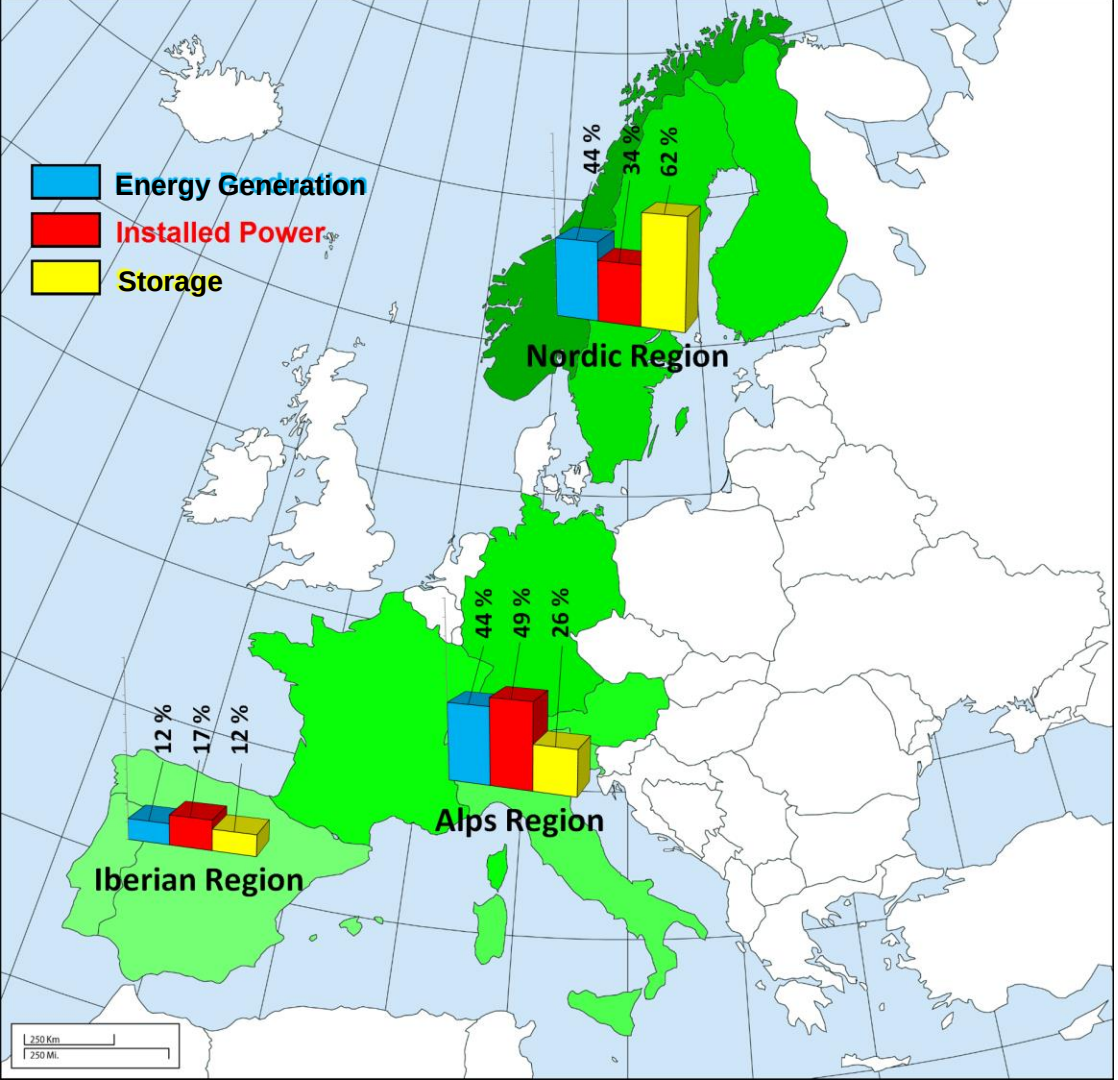
- About 2000 hydropower plants
- 95 % of the generation in 150 plants.
- Up to 500 m^3/s.
- Typically 4-5000 full-load hours.
- Several starts/stops per day for the most flexible units.

Norweigan hydropower characteristics



- More than **1600 power plants**
- Installed capacity of ~**32 300 MW**
- Mean annual generation of **~135 TWh**
- More than **800 water reservoirs**
- Close to **3500 dam constructions**
- More than **5000 km** of water tunnels

	Size	Number	Total Power	Annual generation
	[MW]	[-]	[MW]	[GWh/år]
Mini hydro	0 - 1	571	184	790
Small hydro	1 - 10	715	2.518	9.910
Large hydro	10 -100	257	9.545	42.250
Large hydro	> 100	83	20.010	82120



~50% of European renewable electricity comes from hydropower

Nordics and Alps have huge potential for increased flexibility in its hydropower systems

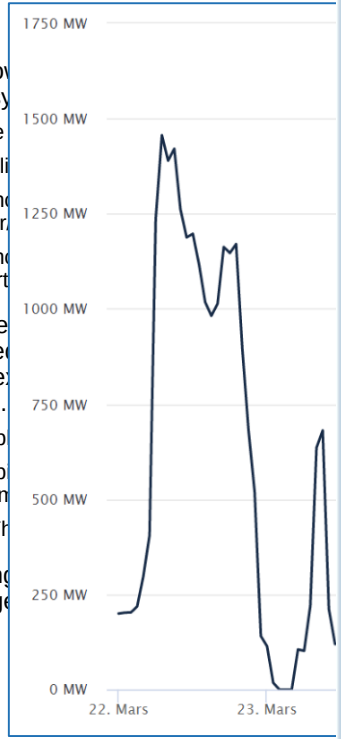
Nordics have majority of storage, and large potential for expansion of power

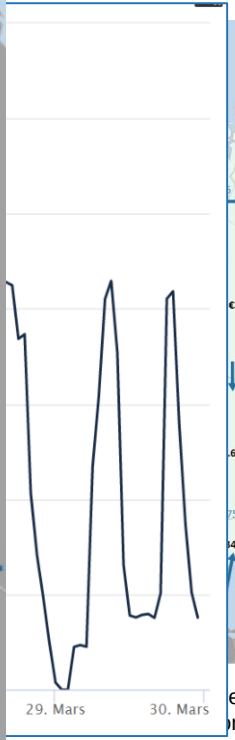
Alps have majority of installed capacity/power

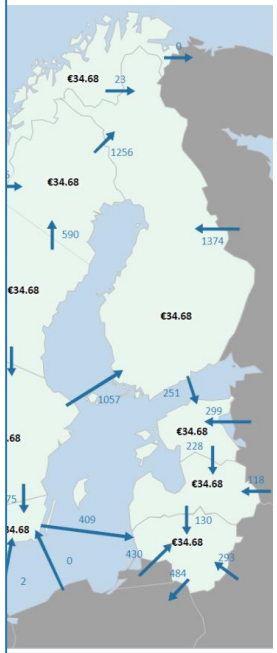
Hydropower has a unique position as system enabler for Europe

Flexibility

- Hydropo
  Nordic sy
  - Large
  - Suppli
  - Balanc
    winter
  - Balanc
    export
- Cascade
  combine
  hydro fle
  duration.
  - Flexib
  - Flexib
    transm
    - Th
- Changing
  challenge







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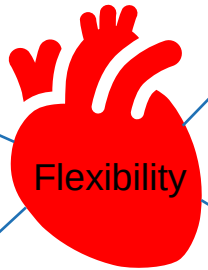
ntinental Europe.

Research and development – Nordic perspective



Dam Safety and Infrastructures

- Critical flows, spillways, ice loads, green concrete
- Condition monitoring, identification/localization/ repair of damages, life time expansion
- Climate impact, runoff forecasts, snow mapping

New Markets

- More wind, less nuclear
- Demand response
- Changing prerequisites in the market and the financial and technical consequences for Nordic hydropower
- Battery in combination with hydro

Environment

- Understanding measures in main streams and tributaries, fish migration tests, modelling
- Balance between environmental measures and important flexible fossil-free production
- Implementation of new environmental law coordinated with WFD, Habitat directive, Eel regulation and transition to fossil free power production
- Social acceptance and license to operate

Units and Turbines

- Rotor dynamics, vibrations, transients, modelling, life time expansion
- ODC, wear & tear
- New technology preferably proven during several years of operation

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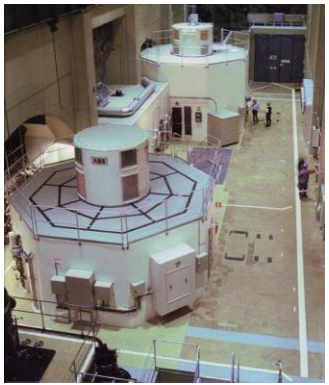
Nordic perspective - collaboration

HydroCen



The Porjus R&D units
2×10 MW

Dam safety
models

Fish test
facility

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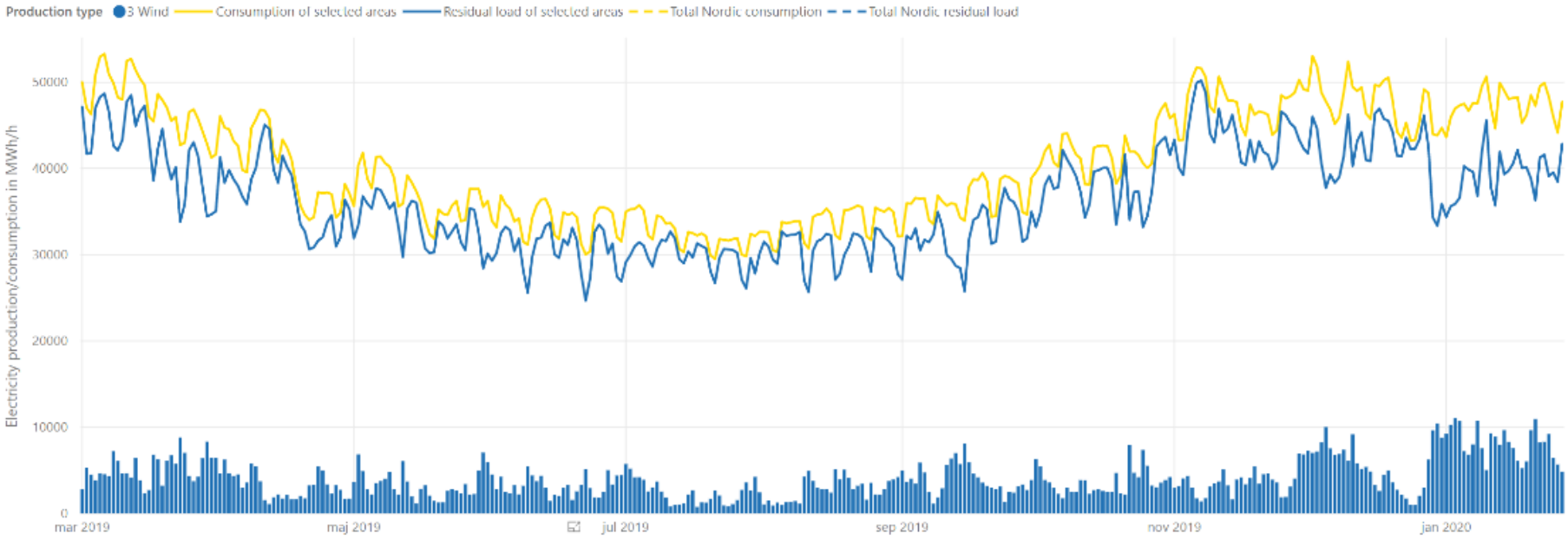
Thanks

Additional slides

Production and consumption in the Nordic grid



FUTURE GLOBAL UNCERTAINTIES

UNMATURITY

TIME

KNOWN CHALLENGES
Nordics

- Lifetime >50 years
- Investment cycles 20-100 years
- Ageing work force
- Low energy prices
- Production overflow
- Water Framework Directive
- Dam safety restrictions

- **New, intermittent electricity production**
  - Balancing, storage, regulation
- **Changed and new markets**
  - Power/capacity, frequency and energy
  - Industrial vs. end user (large-small)
  - International development
  - Blockchain, microgrids (emerging tech)
- **Changes in consumption and demand**
  - Electrification of transport, smart-grids
  - Clean energy-intensive industries
  - Local production and distribution (prosumers)
- **Climate change and environmental issues**
  - Multipurpose, water management, security
- **New competence needs**
  - Digitalization, big data, automation

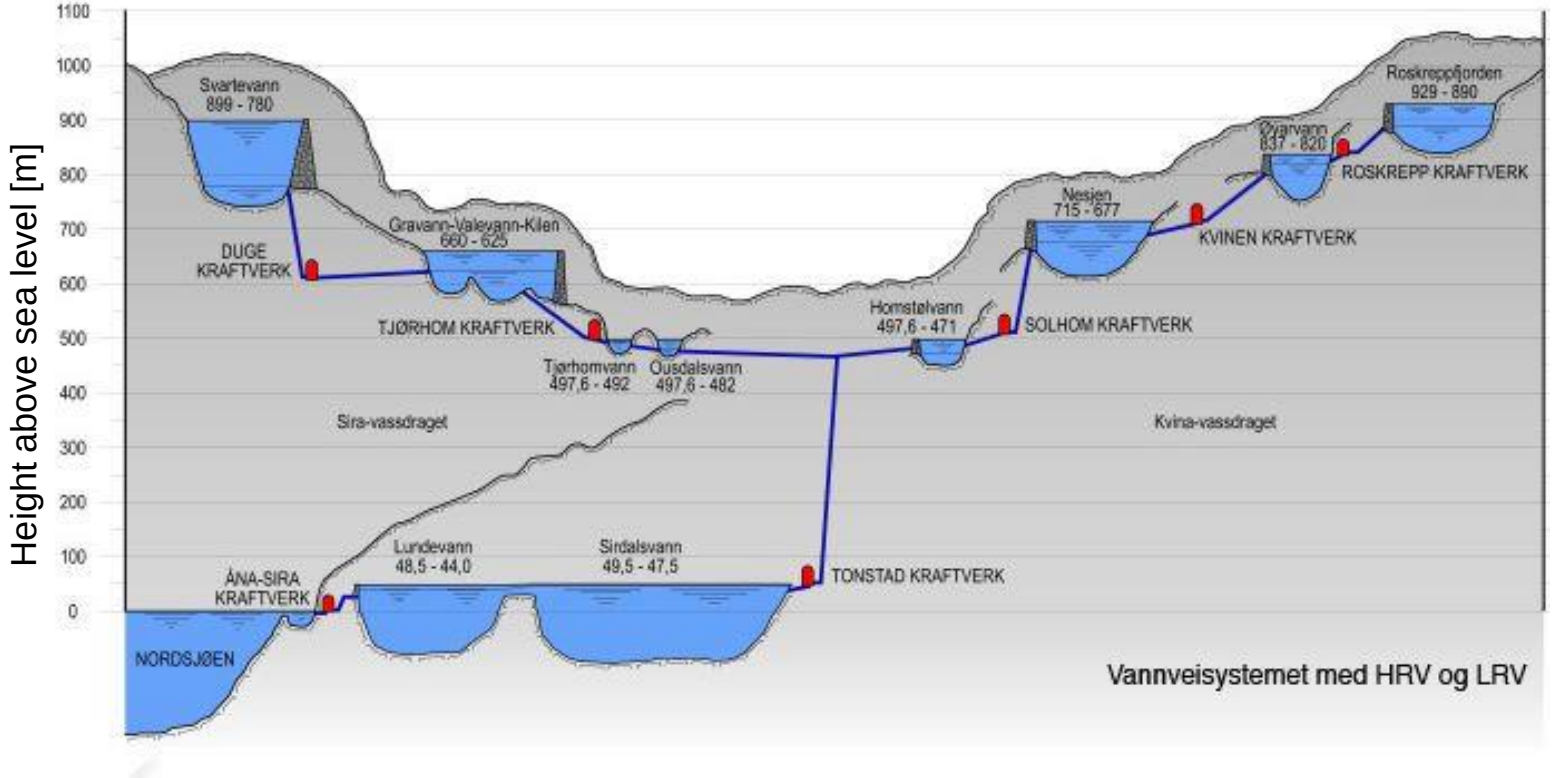
Environmental adaptation – company funded

- Sweden now starts to implement new environmental legislation reviewing permits for all hydropower coordinated with the EU Water Framework Directive, the Habitat Directive and the Eel regulation.
- A 20-year effort to modernize environmental conditions in permits and corresponding mitigation measures in powerplants and dams.
  - To be funded and executed by the industry through the Vattenkraftens Miljöfond AB.
  - A result from the Energy Agreement in the Swedish parliament.
- Research and development needed to support and understand the measures.
  - Fish ways
  - Environmental flows by changed production patterns and bypass flows.
  - To improve environmental conditions while maintaining enough flexible capacity in the system including managing increased wind and solar power.

Fish ladder at the Stornorrfors powerplant in the Ume river.

Hydropower system in Norway

Sira-Kvina



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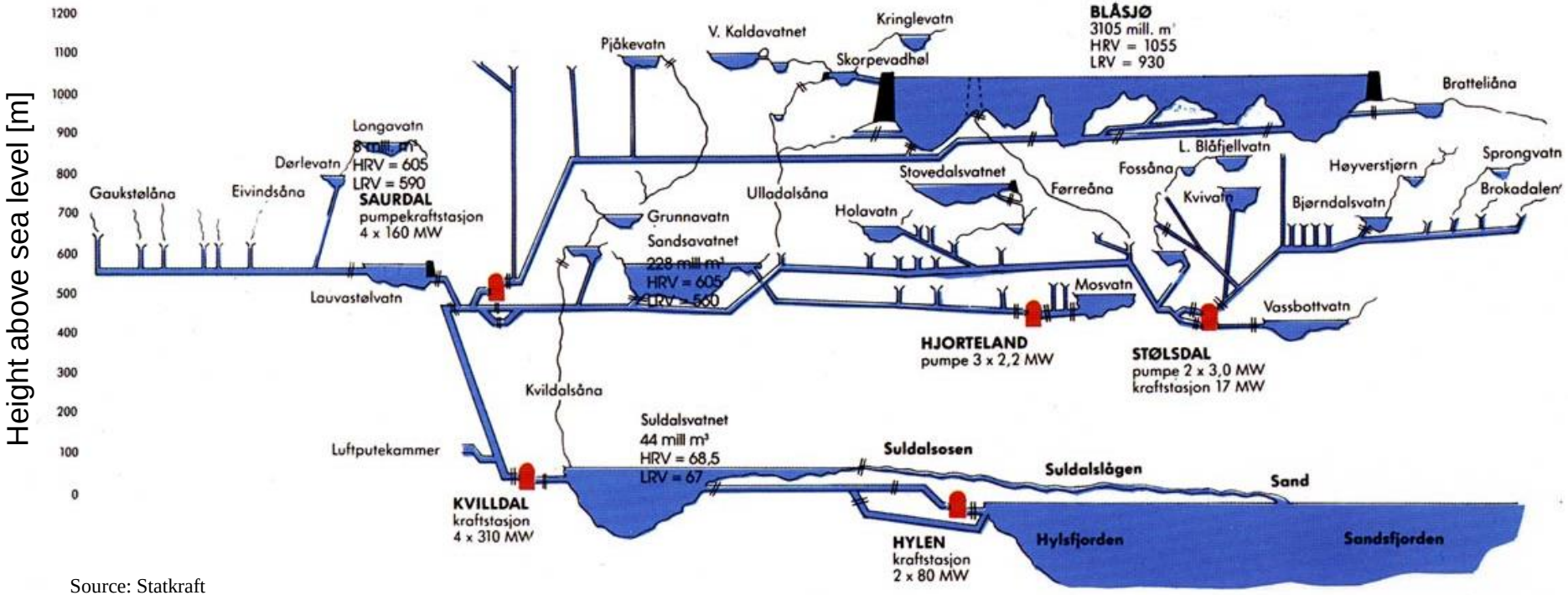
Hydropower system in Norway

Ulla-Førre



Source: Statkraft

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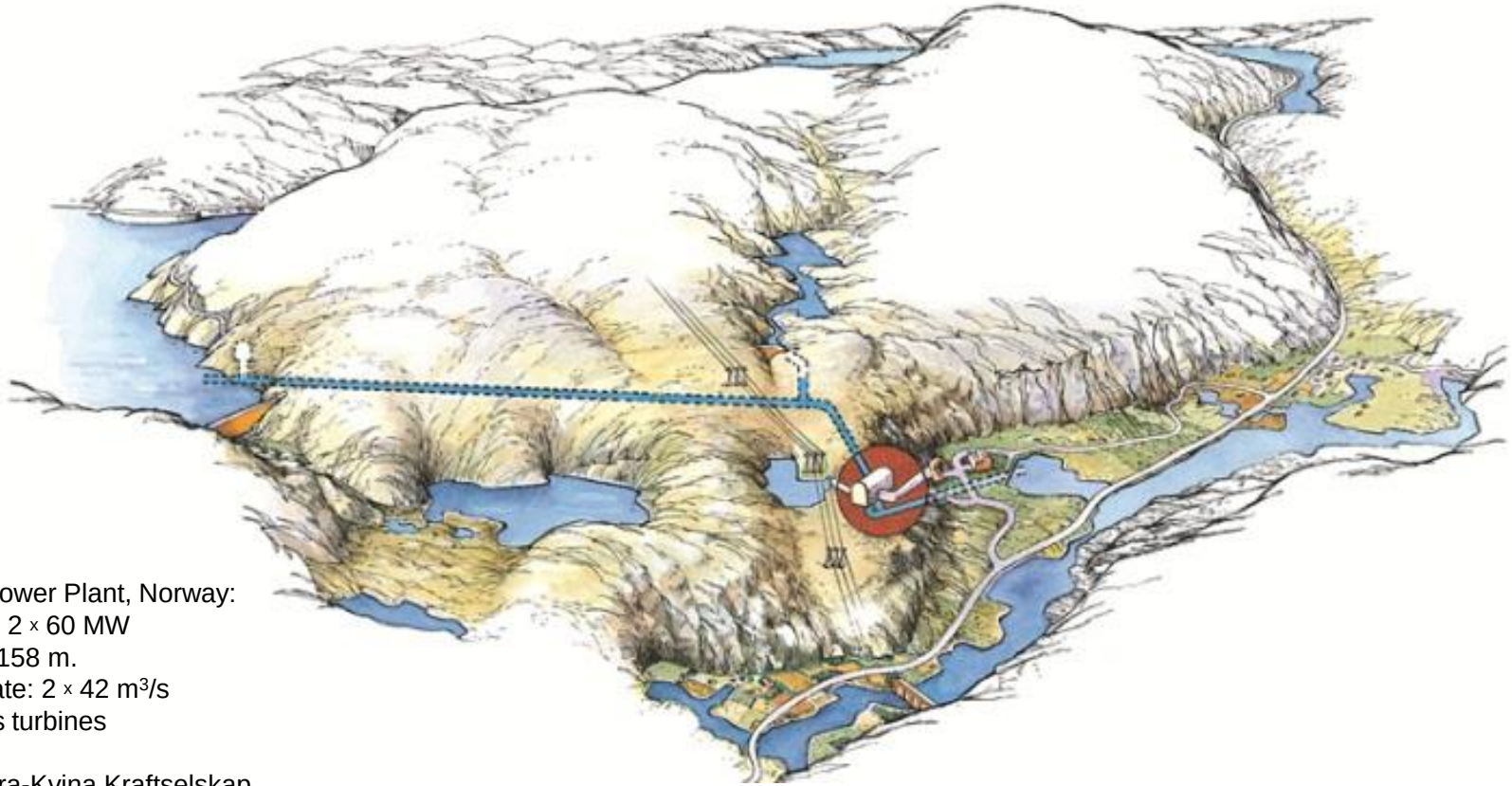
Hydro Power Plant



Tjørhom Power Plant, Norway:

- Power: 2 × 60 MW
- Head: 158 m.
- Flow rate: 2 × 42 m^3/s
- Francis turbines

Source: Sira-Kvina Kraftselskap

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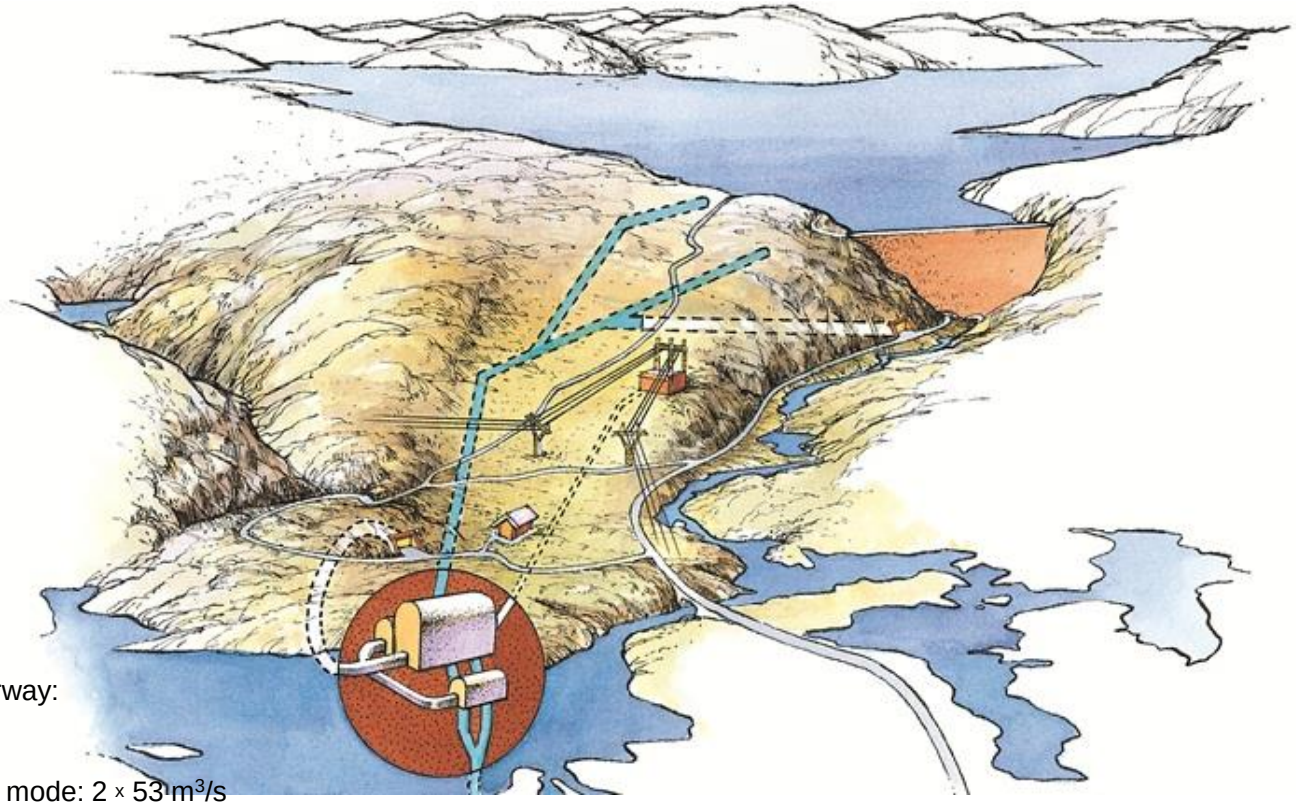
Pump-turbine power plant



Duge Power Plant, Norway:

- Power: 2 x 100 MW
- Head: 215 m.
- Flow rate in turbine mode: 2 x 53 m^3/s
- Flow rate in pump mode: 2 x 42 m^3/s

Source. Sira-Kvina Kraftselskap

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