Nordic Hydropower - The European Battery

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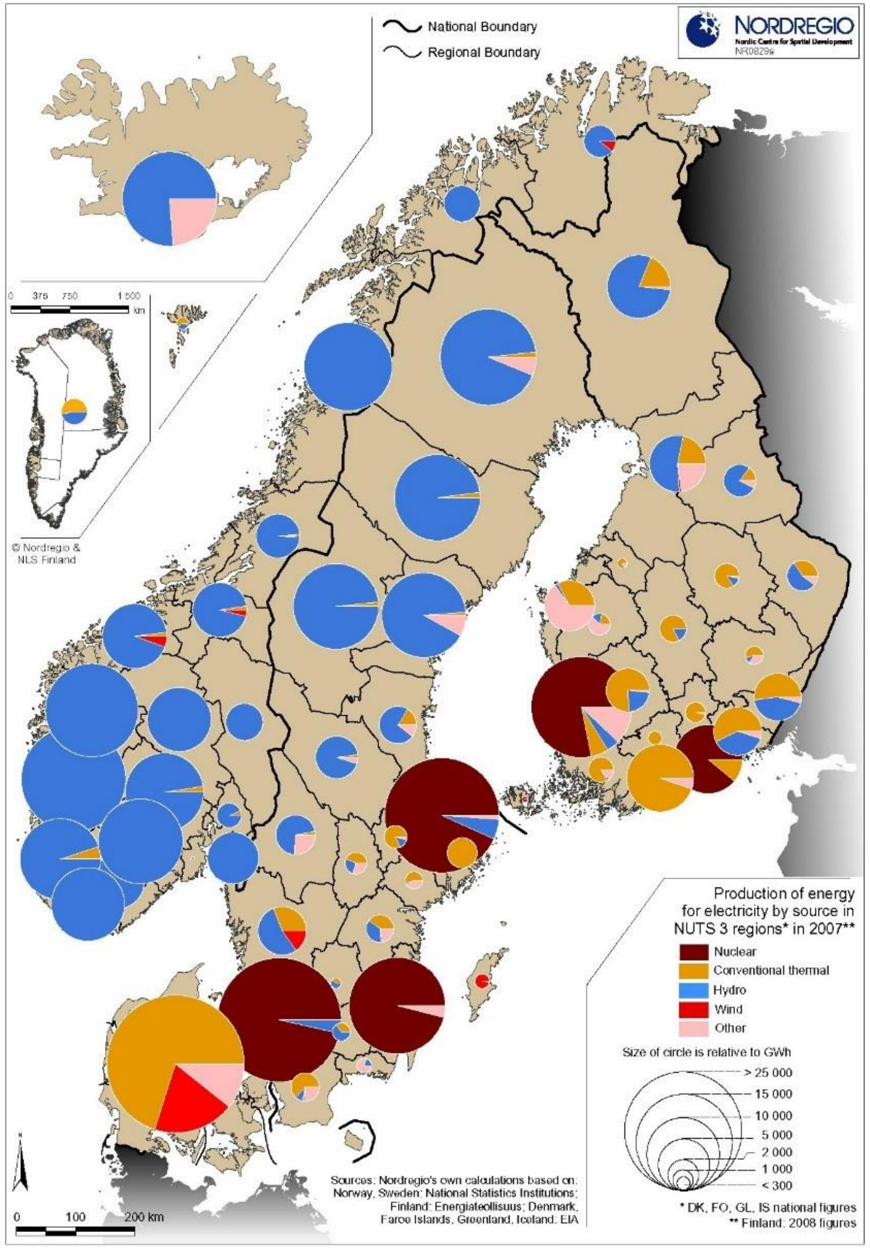
Basic facts (Sweden)

- Large scale development started in 1910
- Most plants built 1950-1970
- Total installed power today is 16.2 GW
- 700 plants larger than 1.5MW
- 1800 plants smaller than 1.5 MW
- Very few pumped-storage powerplants.
- Annual production 65TWh (~45 %)
- Most capacity is located far up North
- No new builds to expect – major remaining rivers are protected by environmental laws.



Map shows production of energy for electricity by source in Nordic NUTS 3 regions in 2007.

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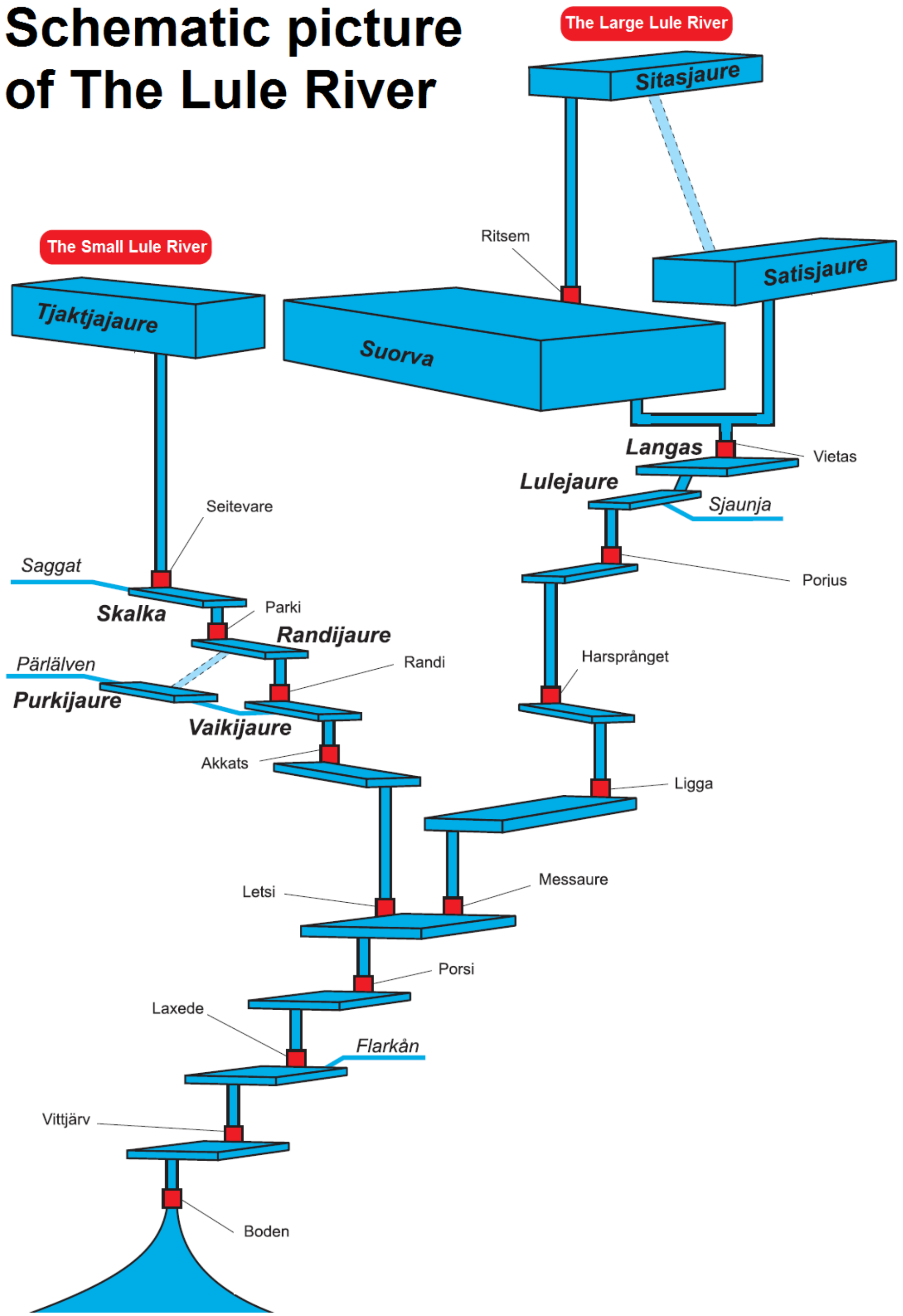
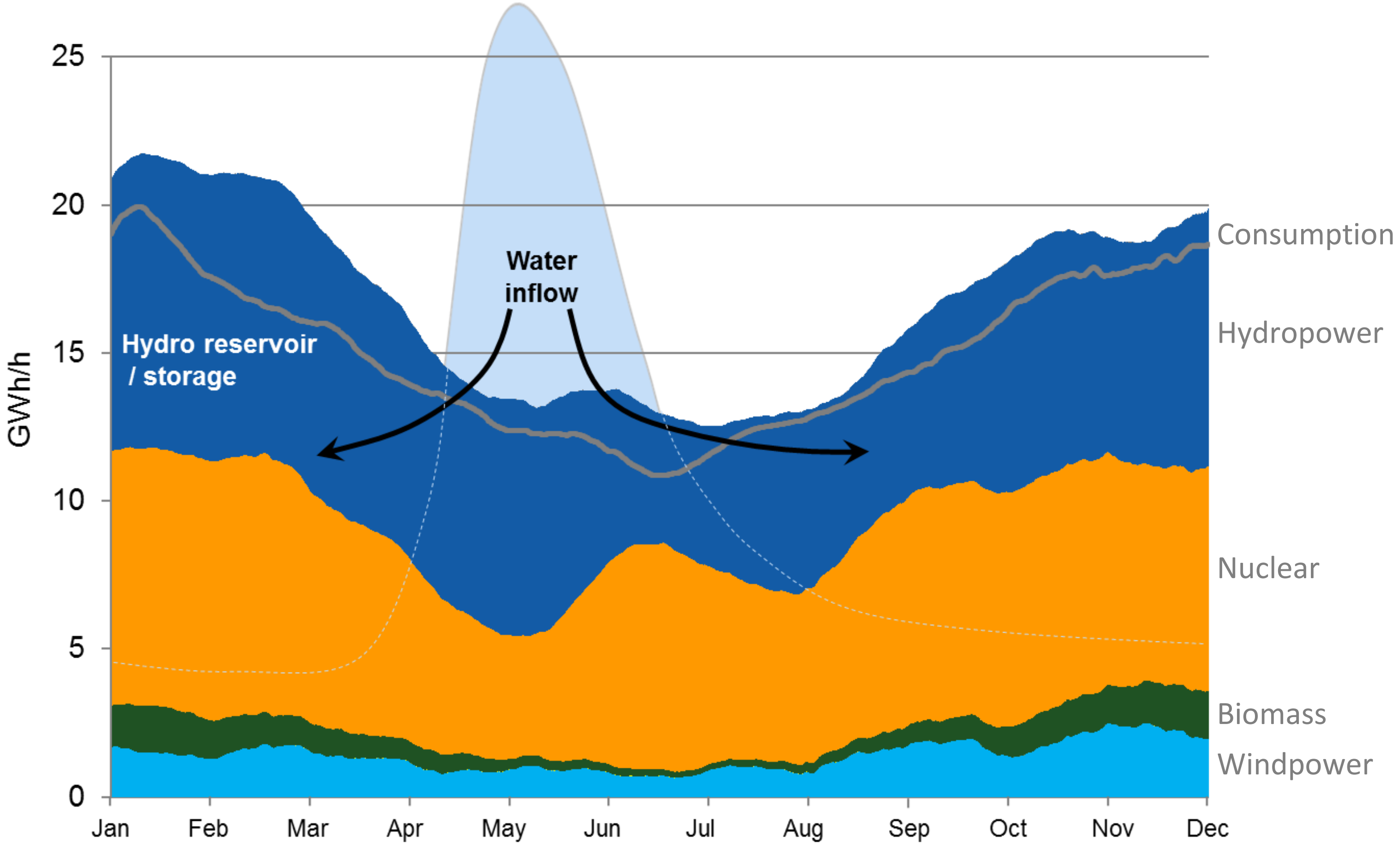
Flexibility

- Nordic hydropower systems are mixed reservoir-type and cascading schemes.
- Flexibility through large power-to-energy ratio (low utilization) and intermediate reservoirs.
- Large ability to balance net load variations on all time scales from seconds to seasons and years.
- N.B. no pumping involved!

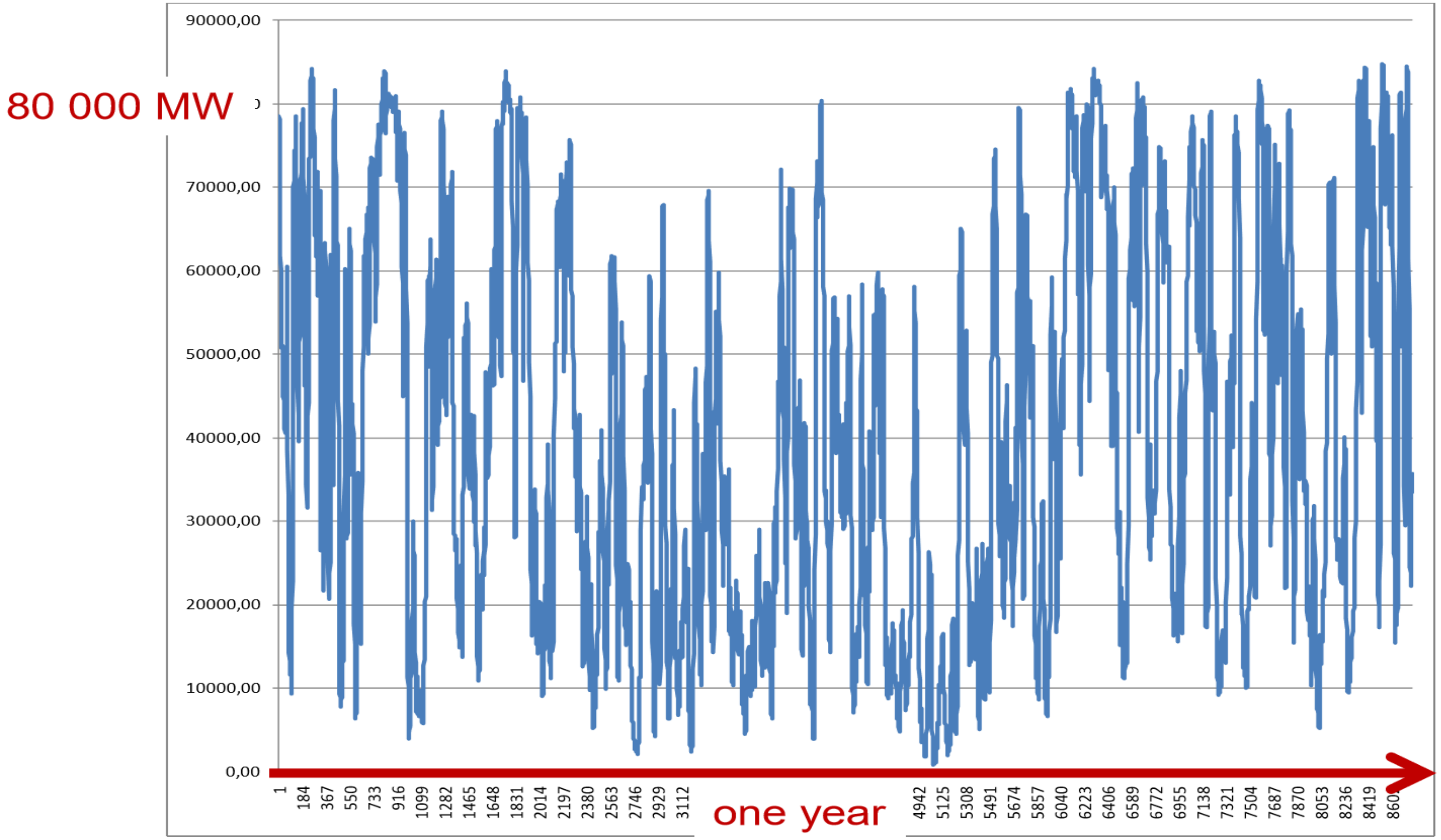


Capturing the fuel

- The spring flood (snow melting) is stored in very large reservoirs (lakes) at high altitude.
- Large storage volumes needed.
- Total storage capacity in Sweden, Norway and Finland is 120 TWh.



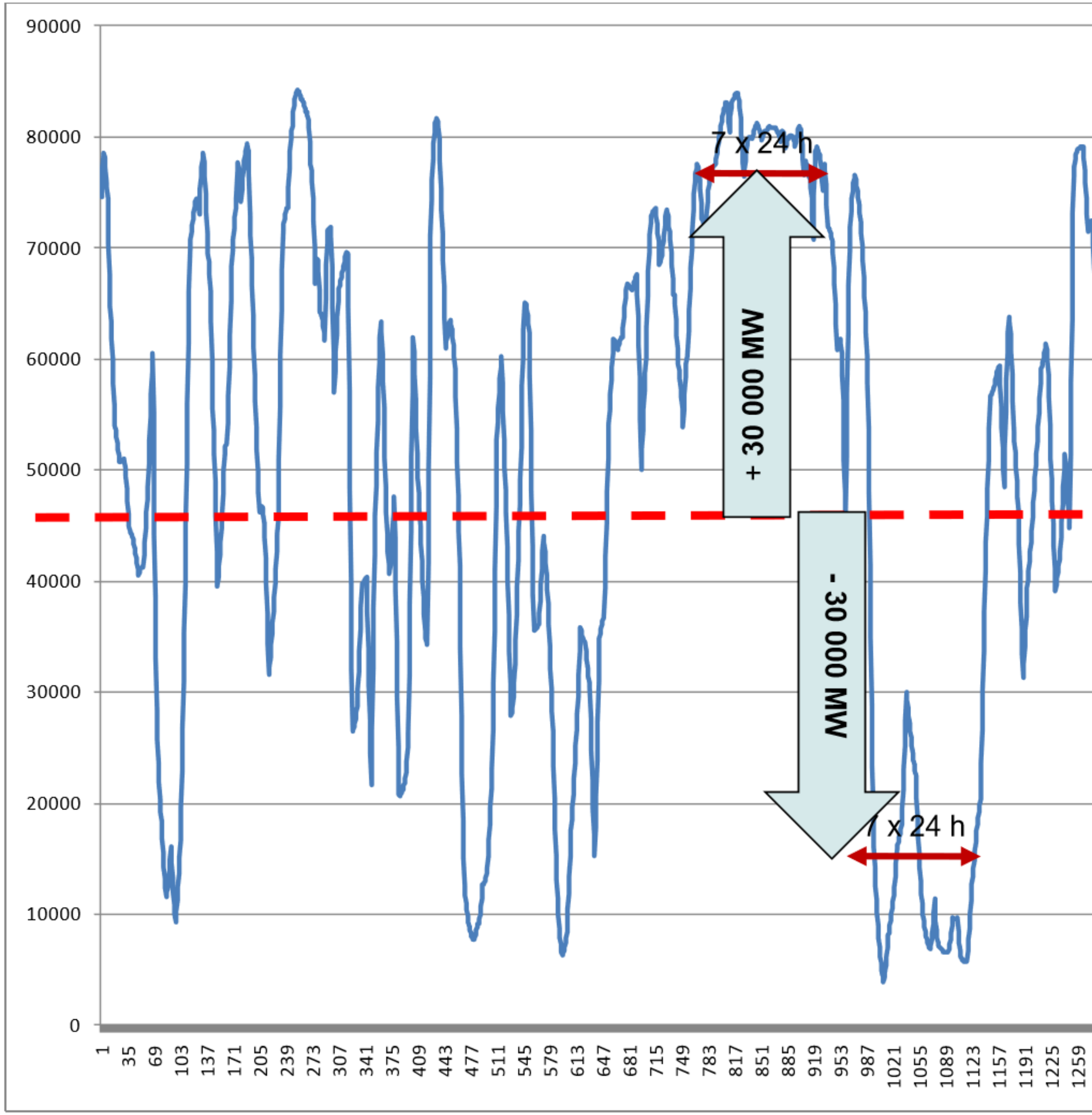
Simulated 95 GW wind power in the North sea area



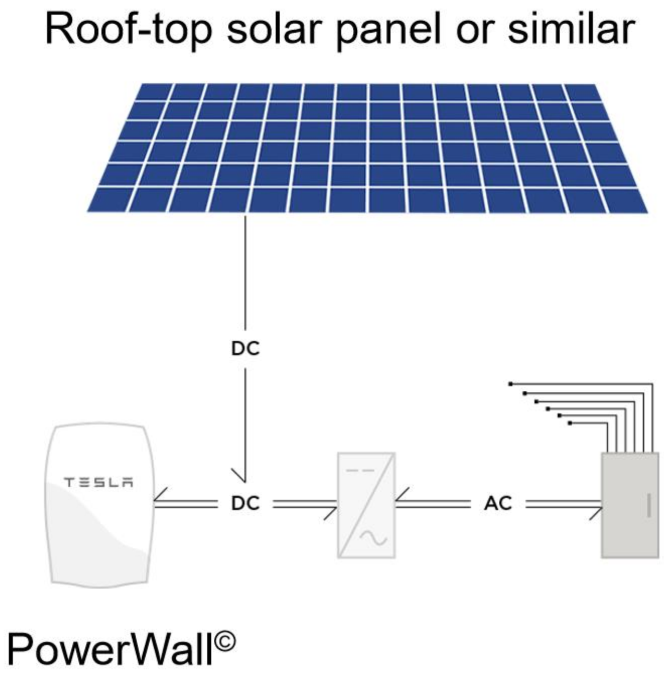
How much energy storage capacity do we need to balance this?

Two quite normal weeks require approximately 5 TWh of storage (30 GW x 7 days x 24 h)

Comparable to 1000 pump-storage plants



Tesla PowerWall

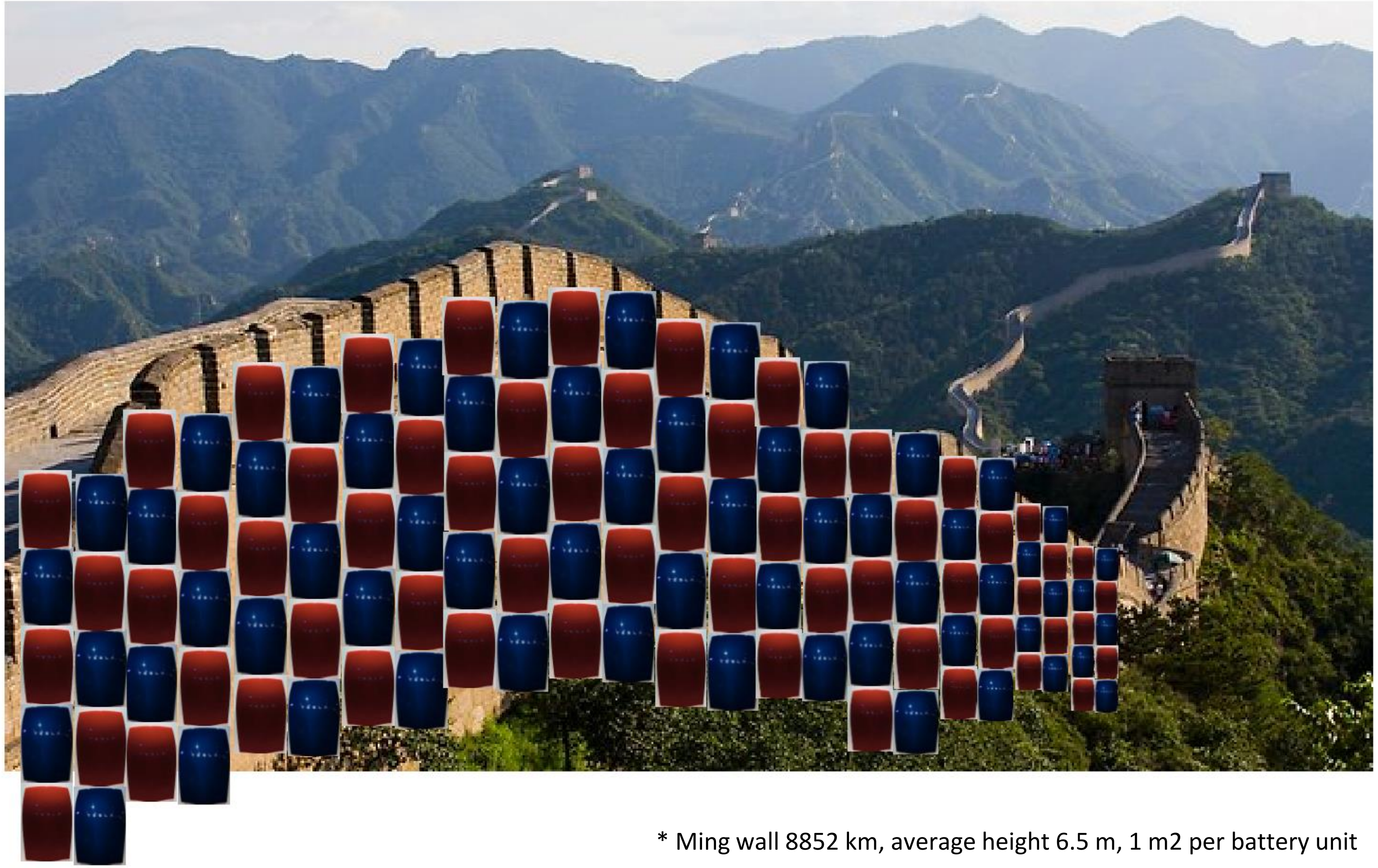


- Balancing solar energy
- Energy security
- Off-grid solutions

Chineese PowerWall

Covering both sides of the Great wall of China* with Tesla batteries would give ~1.2 TWh of energy storage

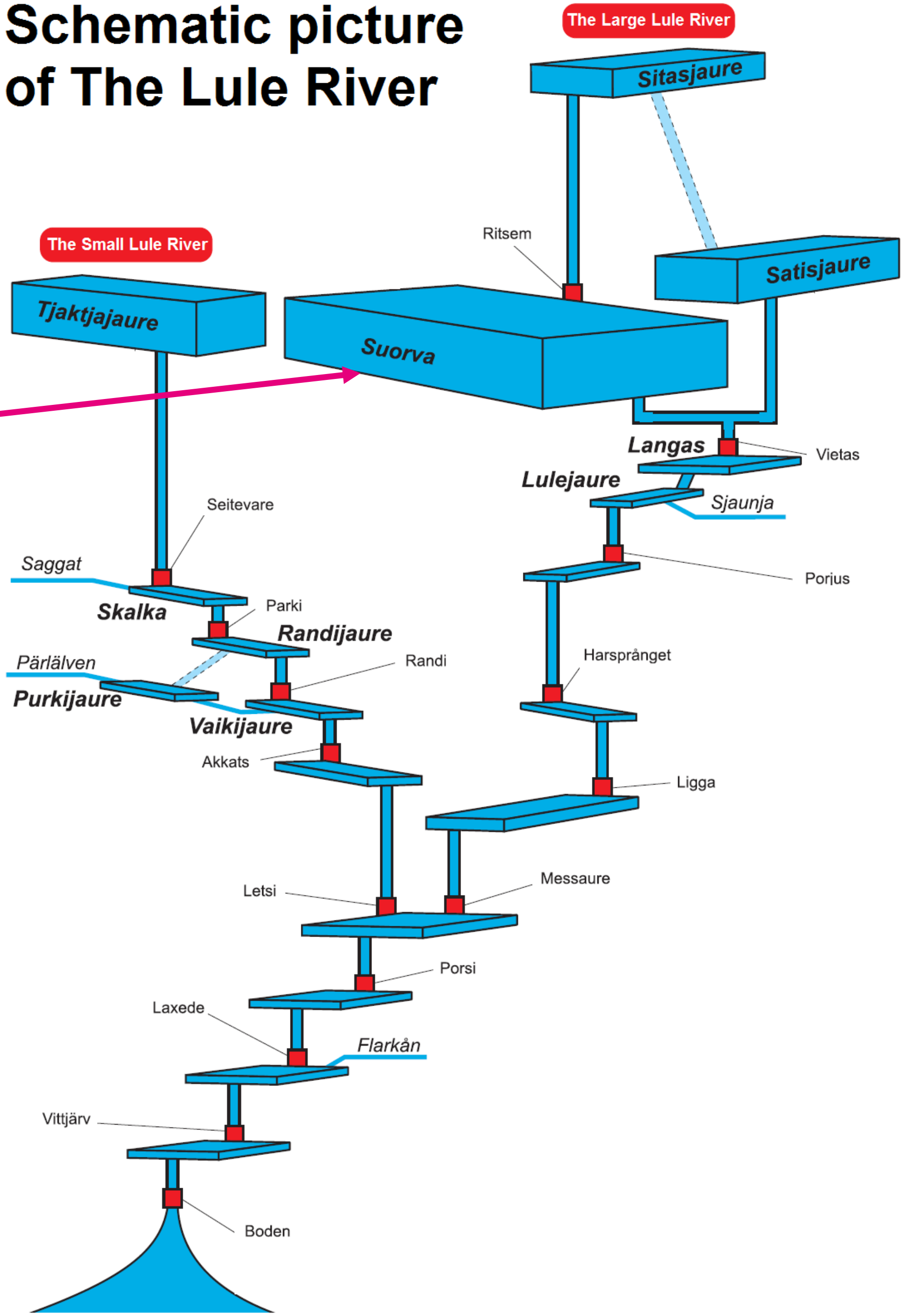
Only 1 % of the Nordic storage capacity

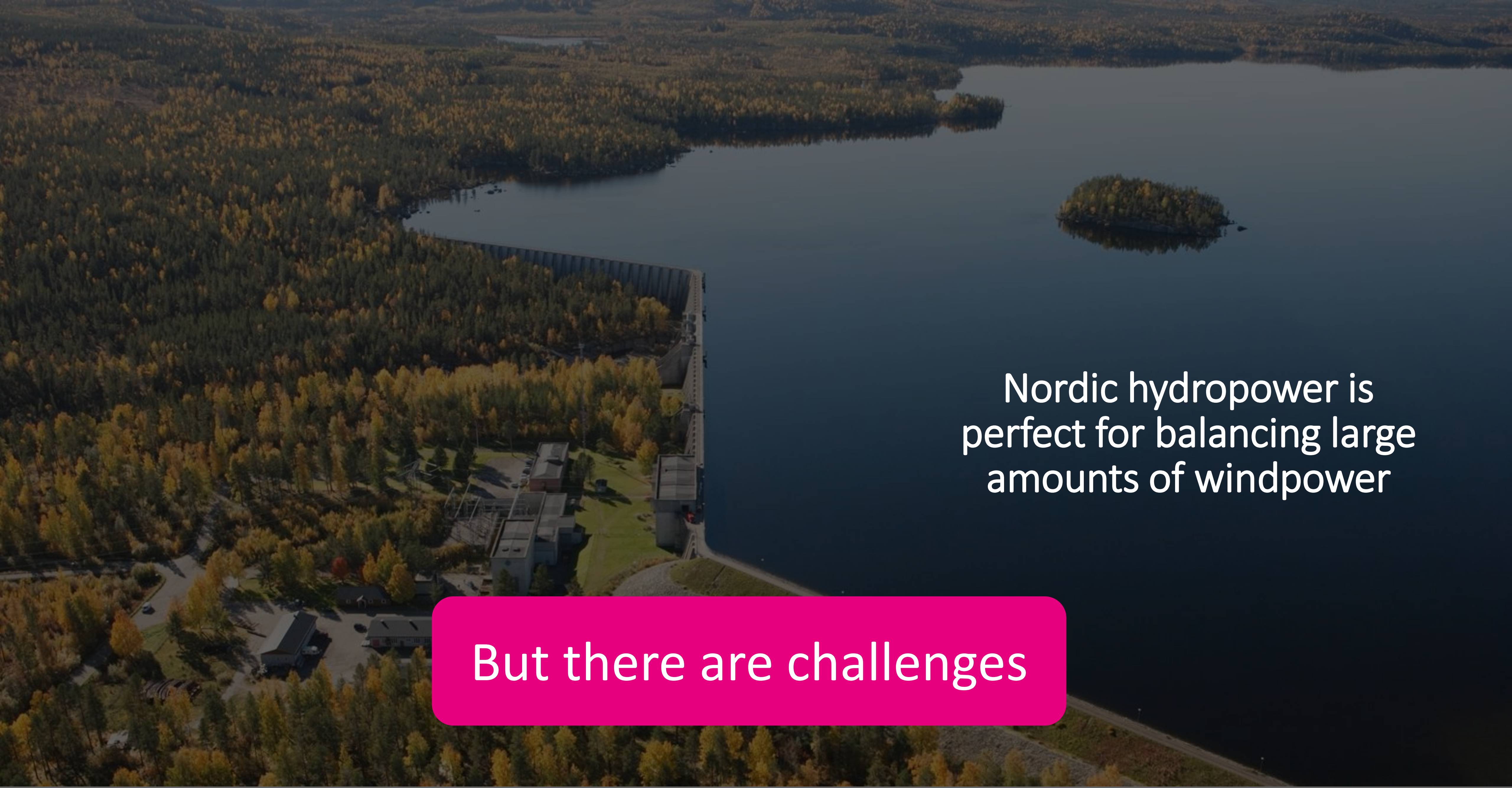


* Ming wall 8852 km, average height 6.5 m, 1 m2 per battery unit

The Suorva reservoir

7 TWh

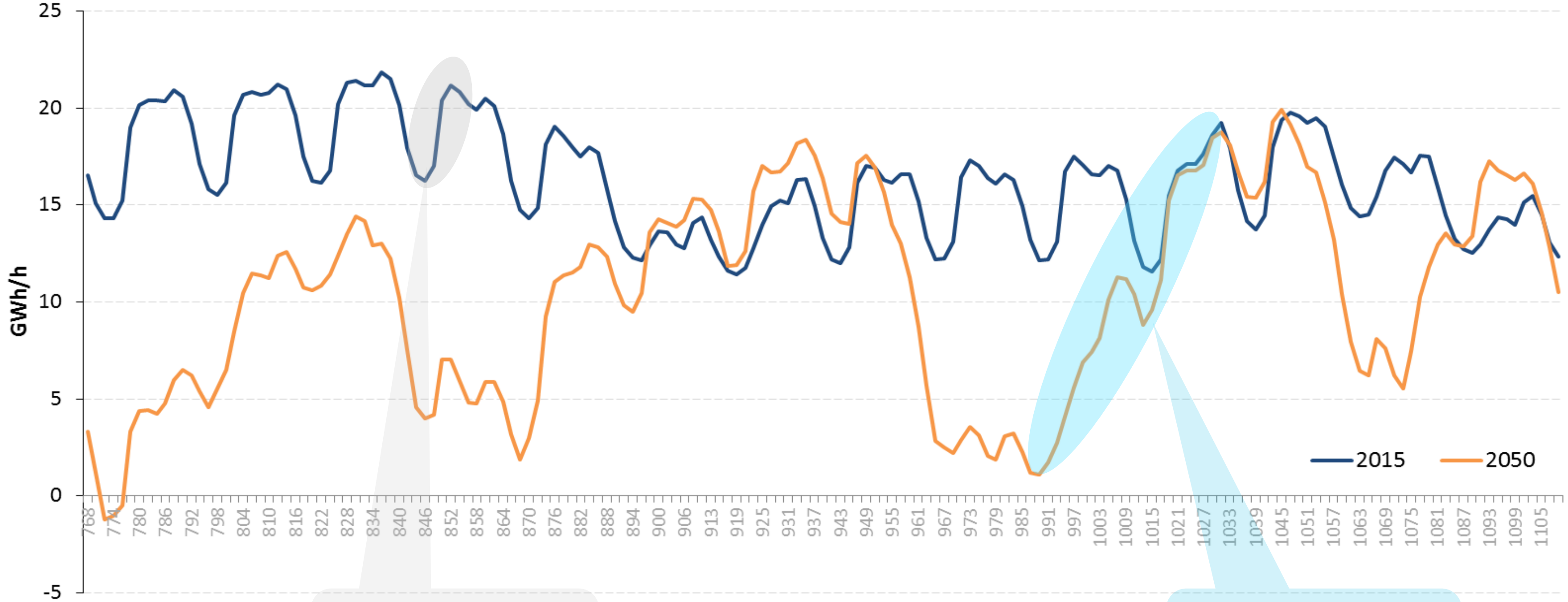



Nordic hydropower is perfect for balancing large amounts of windpower
But there are challenges

New operation pattern

Load variations are relatively small and predicable

Windpower variations är larger (in GW), longer (multiple days) and do not follow any predictable pattern.



6 GW ramp 2015

20 GW ramp 2050

Environmental adaptation necessary

- Sweden just started a 20-year effort to modernize environmental conditions in permits and corresponding mitigation measures in powerplants and dams.

- Fully funded by the industry through the Vattenkraftens Miljöfond AB, owned by the eight largest hydropower producers.

Fish ladder at the Stornorrfors powerplant in the Ume river.

R&D is key to find a suitable balance between conflicting objectives

R&D areas of interest

Environmental adaptation

Fish passage solutions

Ecological flows

Habitat restoration

Dam safety implications

Hydrology

Increasing flexibility

Understanding future operations patterns

Extending the operation range

Understanding wear and tear mechanisms

Integrating new technology and new methods, e.g.,

Digitalization

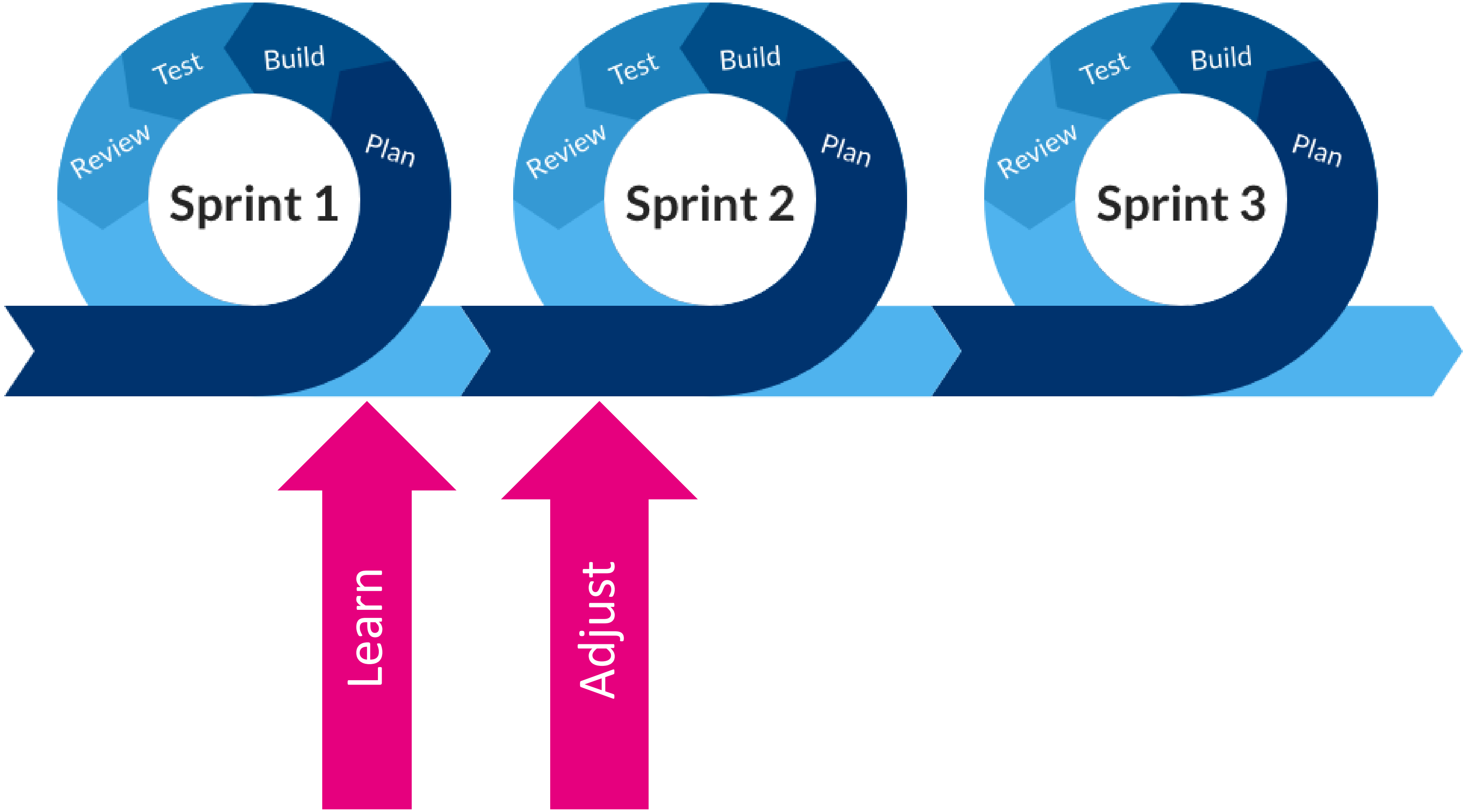
Power electronics

New materials

And much more…

Cross-disciplinary projects have a large potential!

We need to learn as we go!



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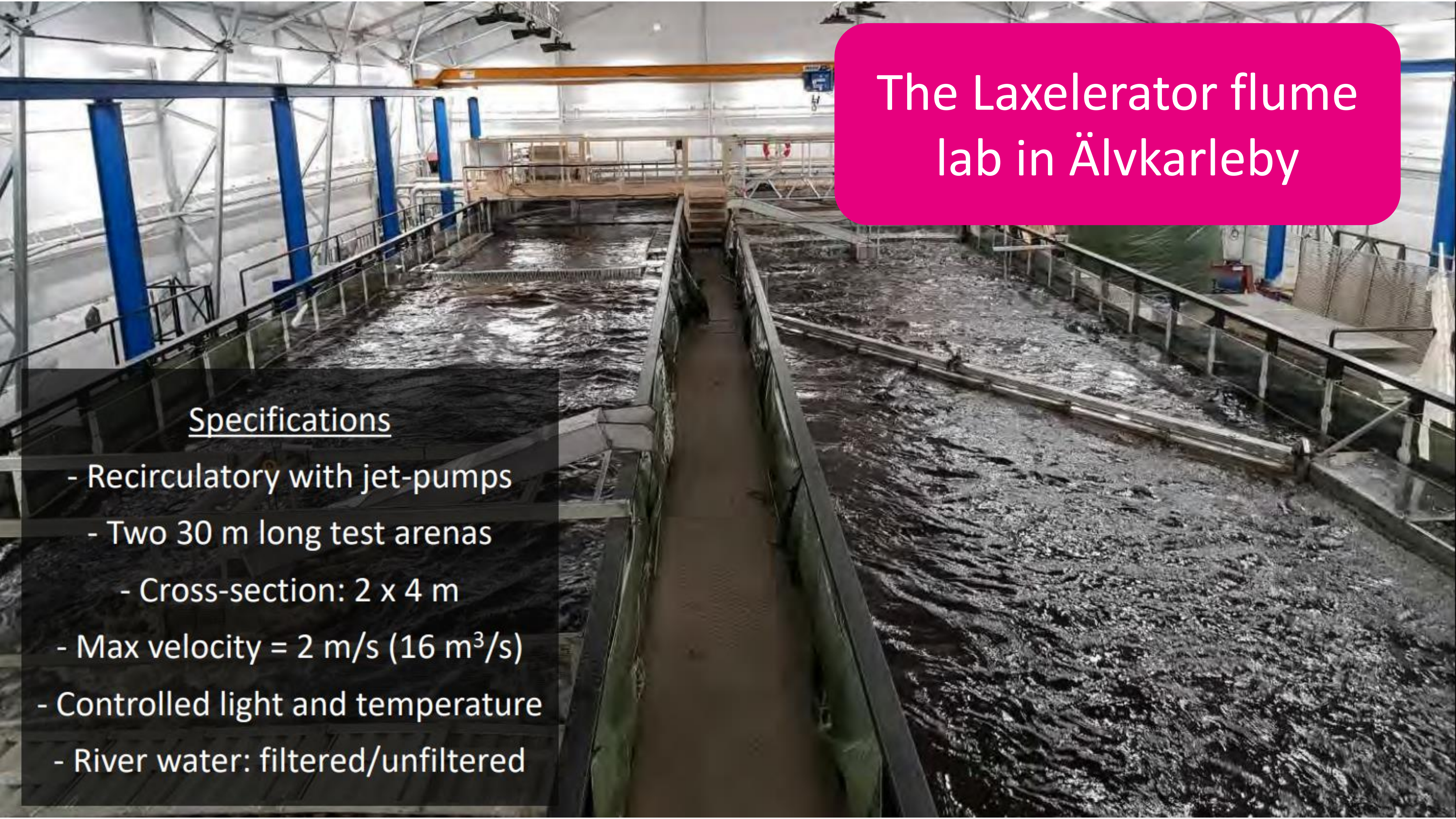
Additional challenges

- Capital intensive investments
- Long investment cycles (20-100 years)
- Rapid technical development
- Political uncertainties
- Very conservative industry

We need a plan to get the good stuff out there!

Demonstration is very important!

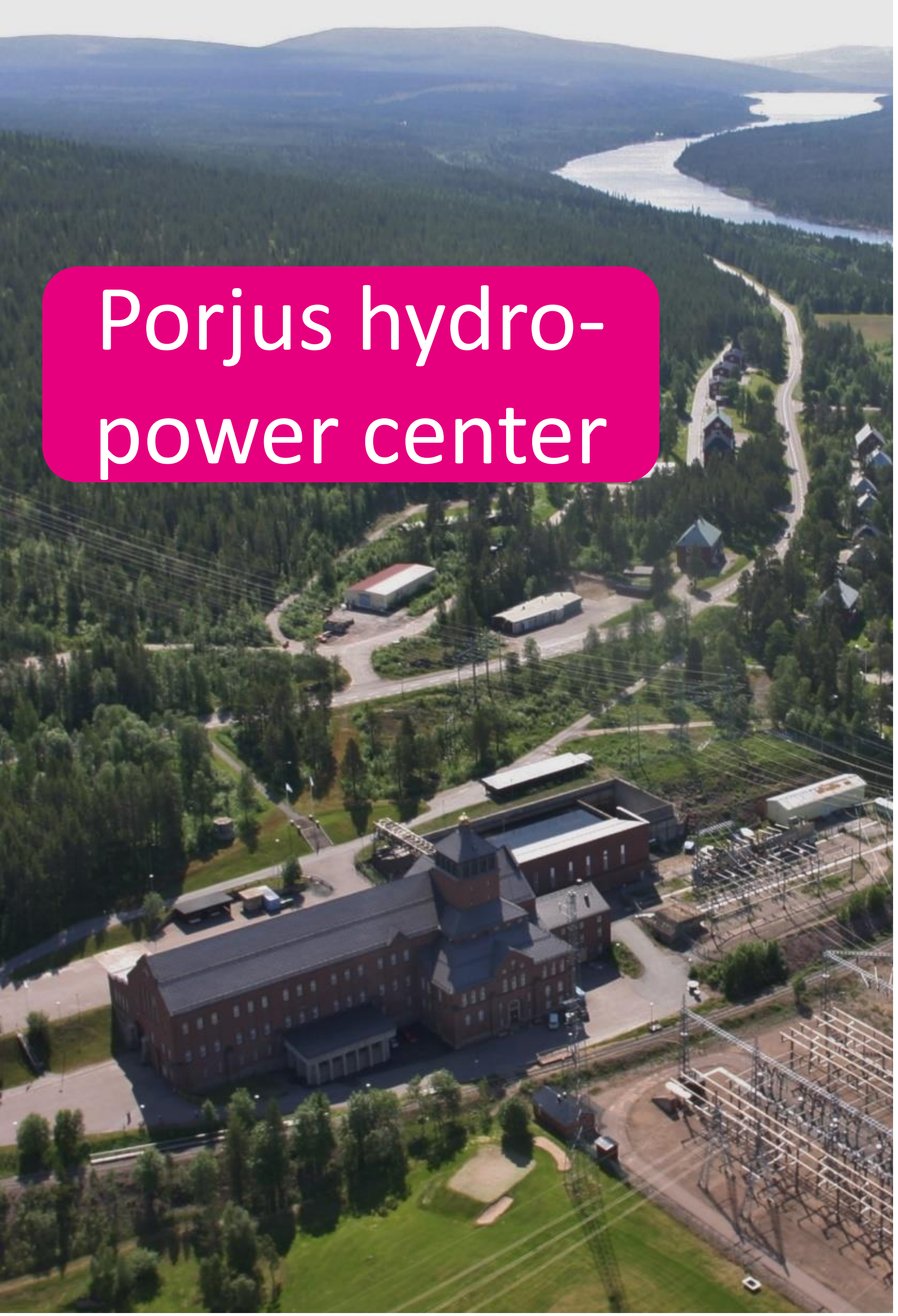
The Laxelerator flume lab in Älvkarleby



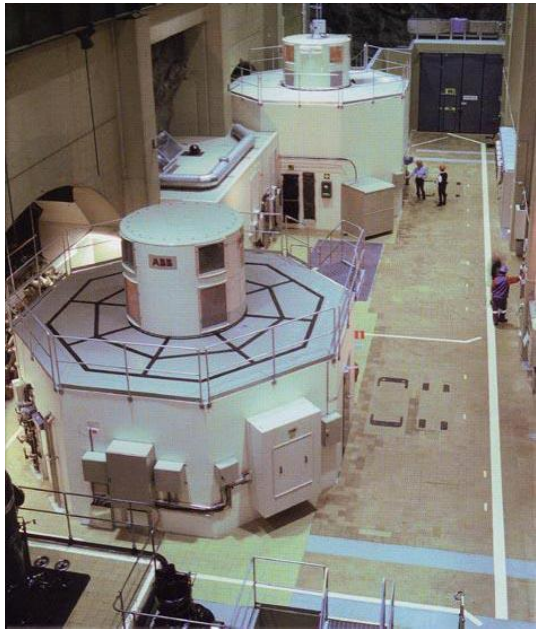
<u>Specifications</u>

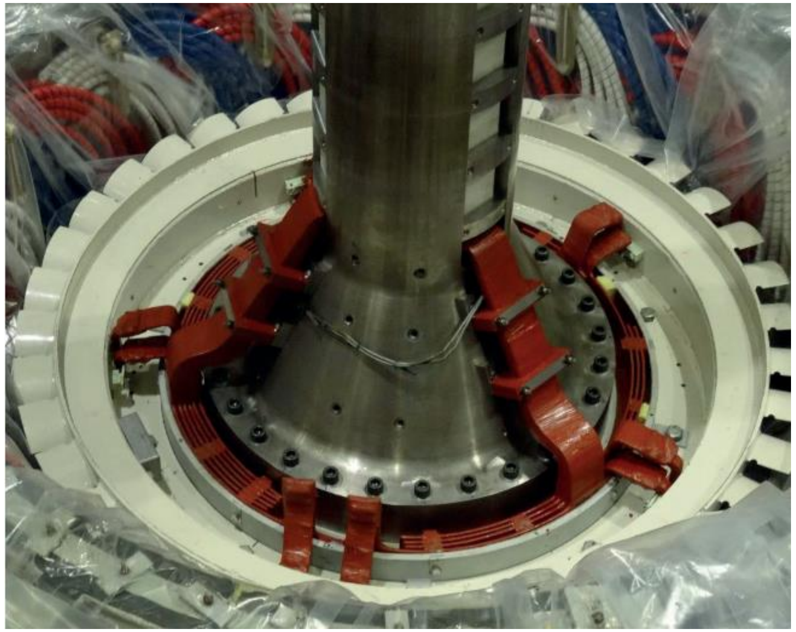
- Recirculatory with jet-pumps
- Two 30 m long test arenas
- Cross-section: 2 x 4 m
- Max velocity = 2 m/s (16 m^3/s)
- Controlled light and temperature
- River water: filtered/unfiltered

Porjus hydro-power center



2 × 10 MW units for R&D purposes and education






Thank you!