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Requirements for system adaptation to intermittent generation

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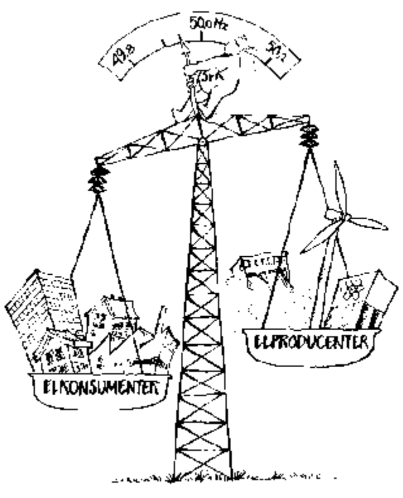
Physical prerequisite 1 in any electrical power system

The generation must follow and be exactly equal to the consumption

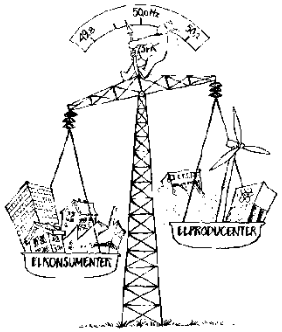


….at all times !

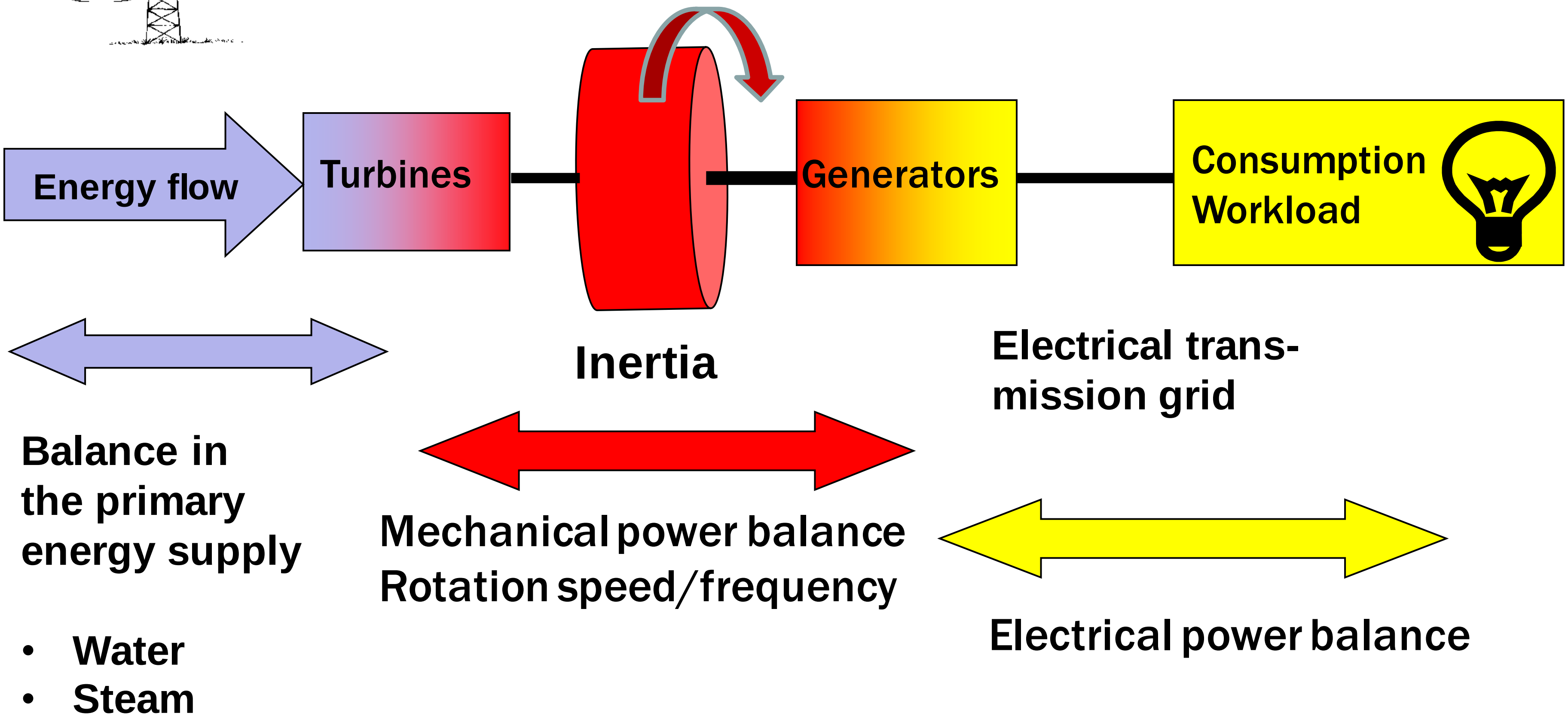
Physical prerequisite 2 in any electrical power system

Generation that is located far away from the consumption must be transmitted over the distance

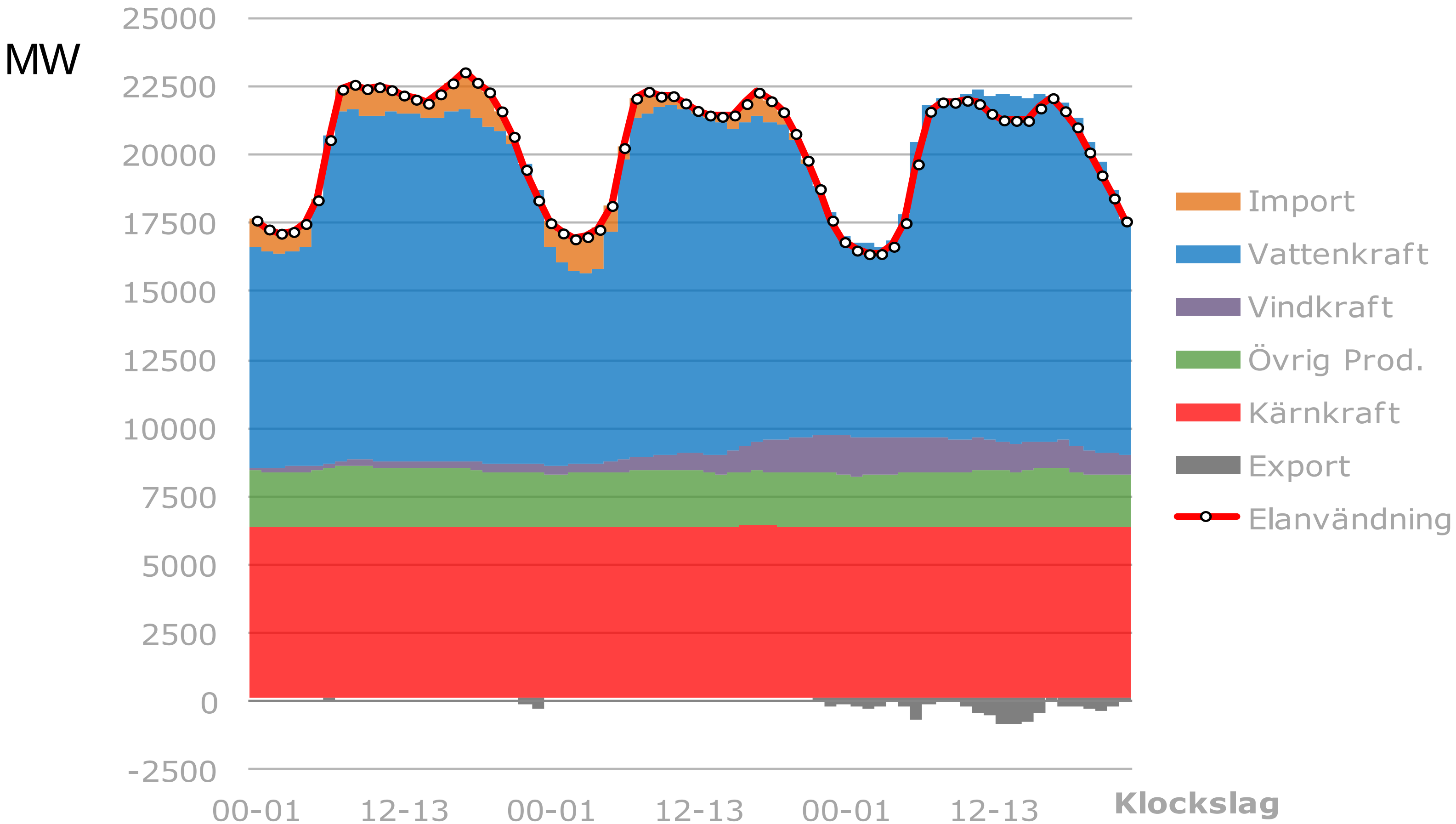
…the longer distance, the higher voltage!



Physical balance in a synchronous power system (AC-interconnected)



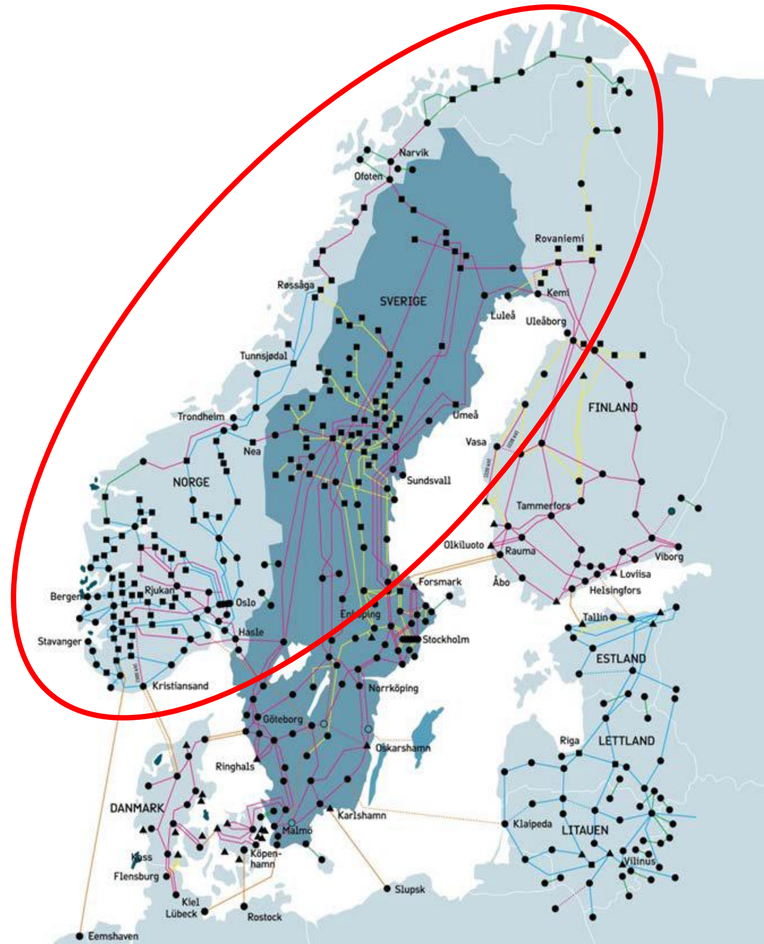
Power balance in Sweden three winter days



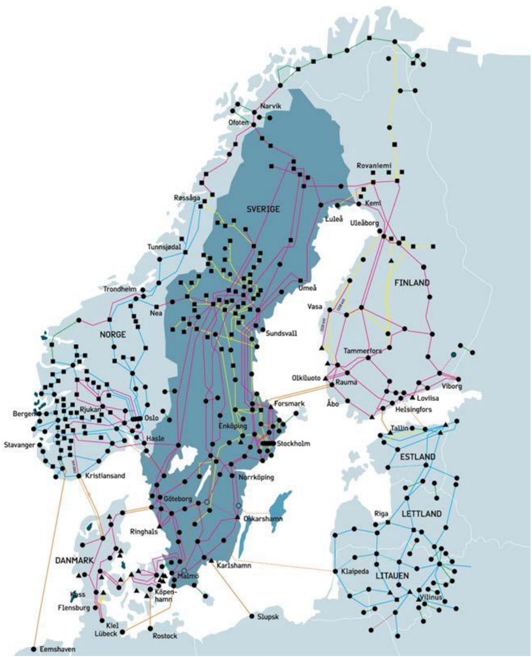
Transition from night to day 5000-6000 MW within 4 h

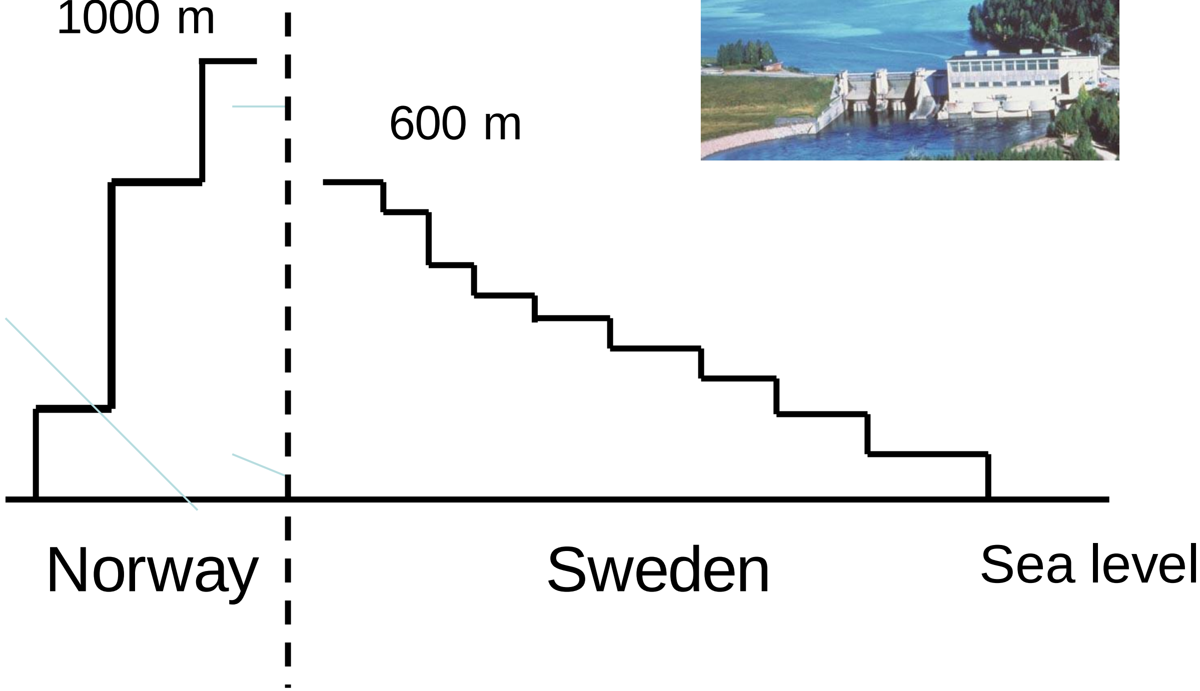
Nordic Hydro Power Resources

- Norway 30 000 MW, 125 TWh
- Sweden 16 000 MW, 65 TWh
- Finland 3 000 MW, 15 TWh

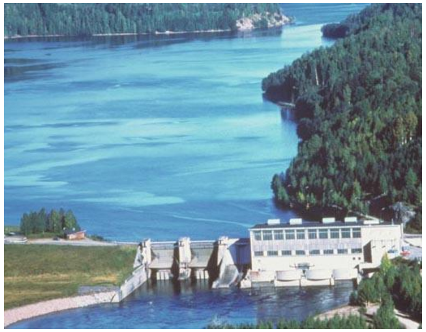


Principal difference between Norwegian and Swedish Hydro Power

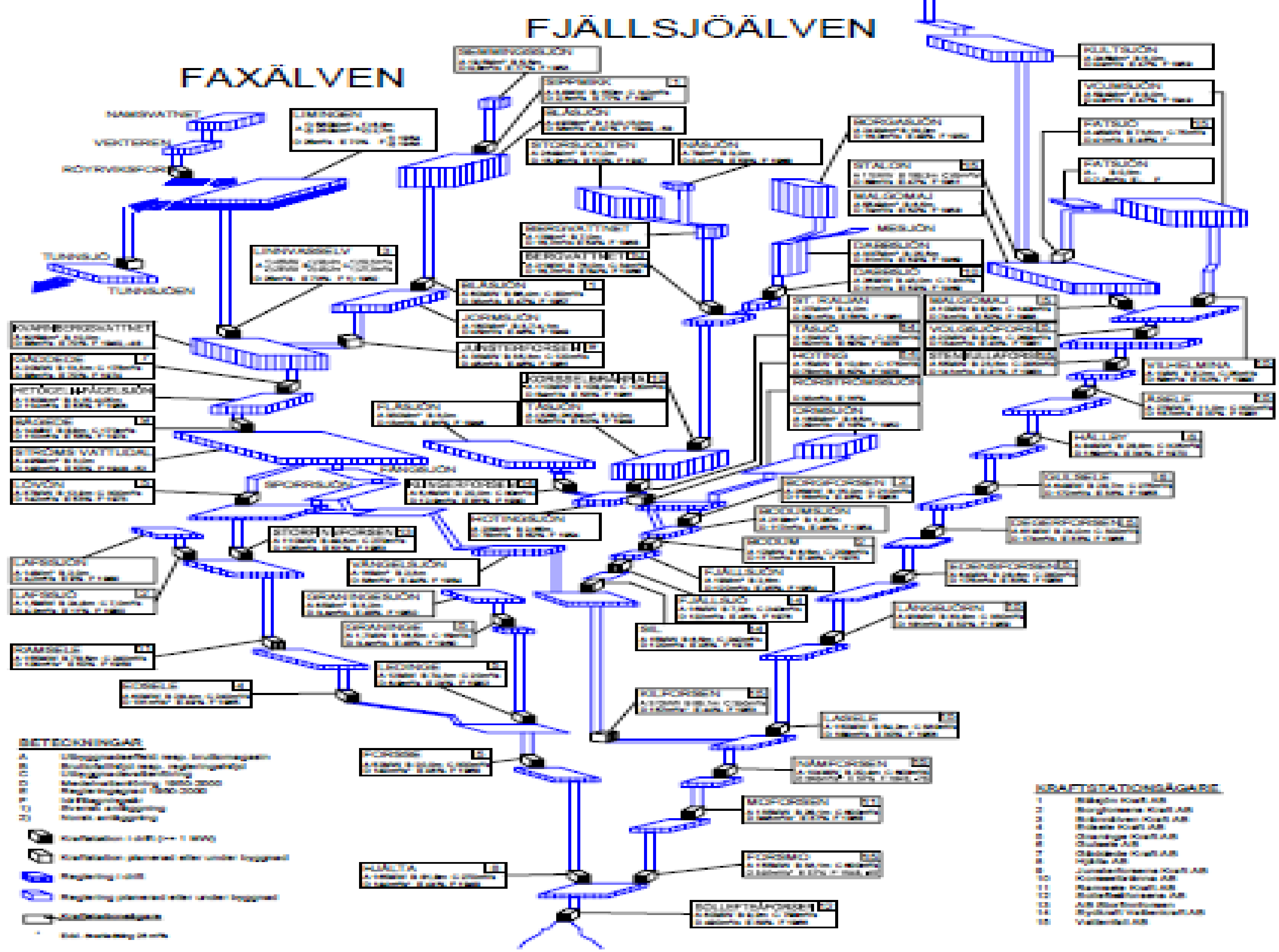




National border along the mountain ridge

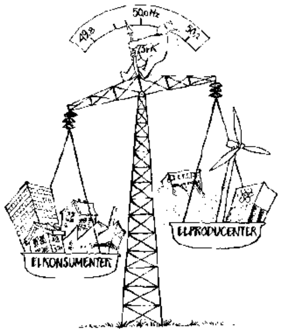


SCHEMATISK BILD AV ÅNGERMANÄLVEN



VATTENREGLERINGSFÖRETAGEN

UMEÄLVEN - ÅNGERMANÄLVEN - INDALSÄLVEN - LJUNGAN - LJUSNAN - DALÄLVEN



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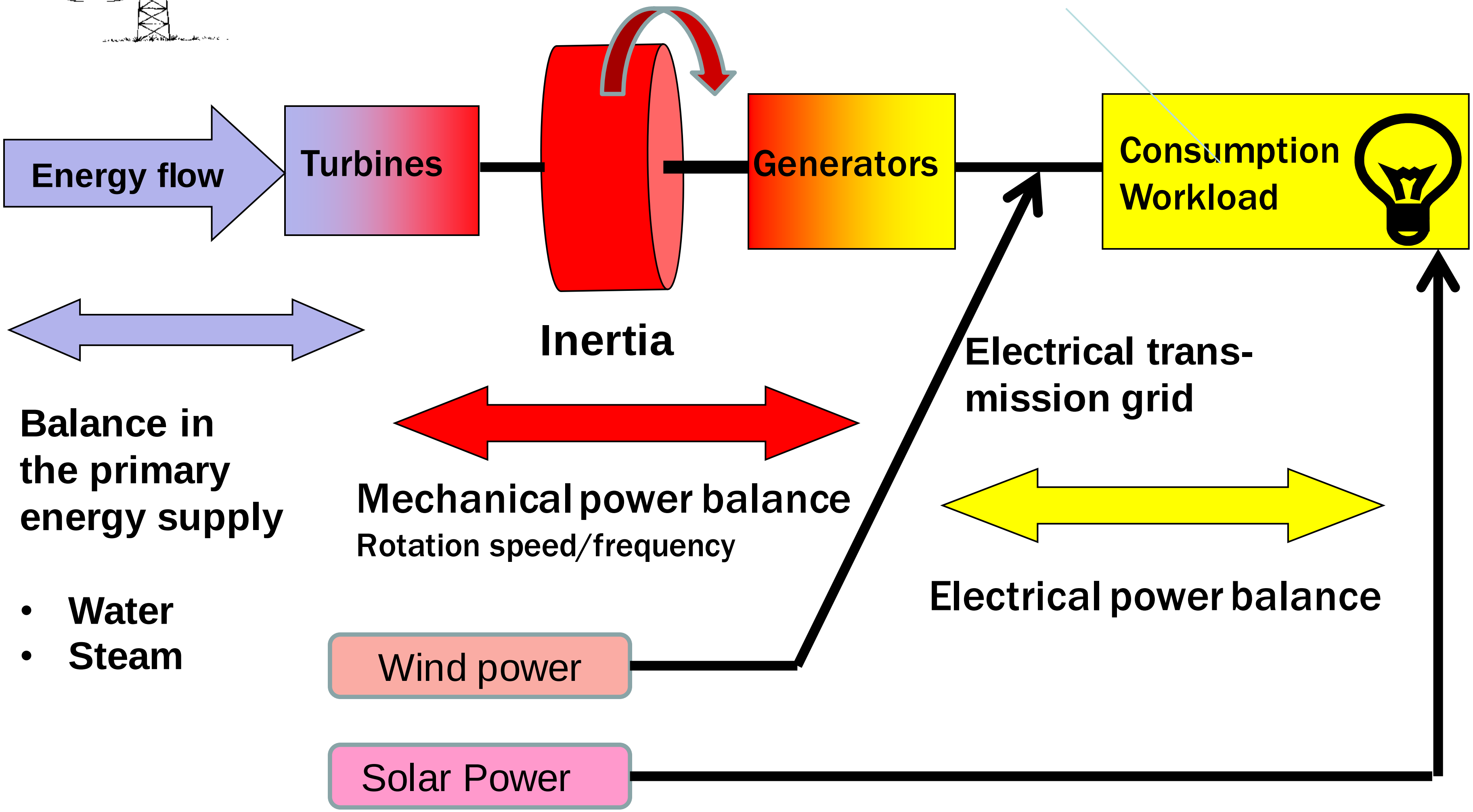
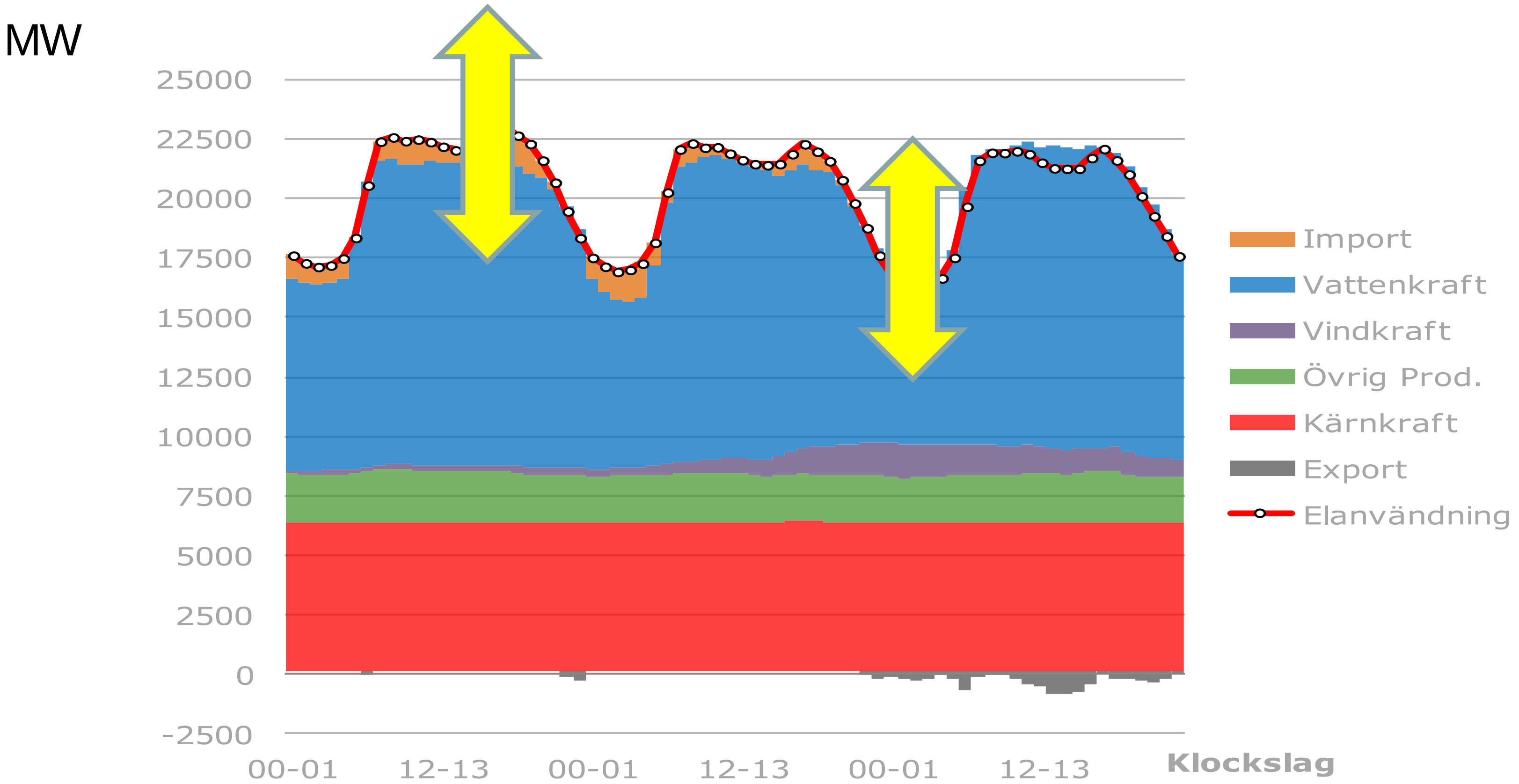


Power balance in Sweden three winter days

Balancing needs from intermittent generation



Wind power variations do not occur regularly in daily cycles

Problem distinction

- The additional **need** to balance the variations of the intermittent generation

- The **ability** to balance the variations from the intermittent generation and the consumption

…..given the reduced share of controlable, synchronized generation in the power balance!

Intermittent generation
Inherent implication

To reach high shares of the annual energy supply, the intermittent generation will be dominant in the power balance during periods of high wind and solar inflow.

During such periods there will be little room for ”conventional”, controlable generation in the power balance.

The dynamic characteristics of the power system will thus be substantially different.

Insufficient inertia for balancing
in the time domain of seconds

Consequences:

- Unstable balancing process
- Large frequency deviations
- Enhanced risk for system disturbances and black-outs

Remedial measures:

- Synchronization of idle generators
- Installation and activation of HVDC-links to external systems
- Development of fast power activation from storages (seconds)

Insufficient access to suitable capacity for balancing the system

in the time domain of minutes, hours and days

Consequences:

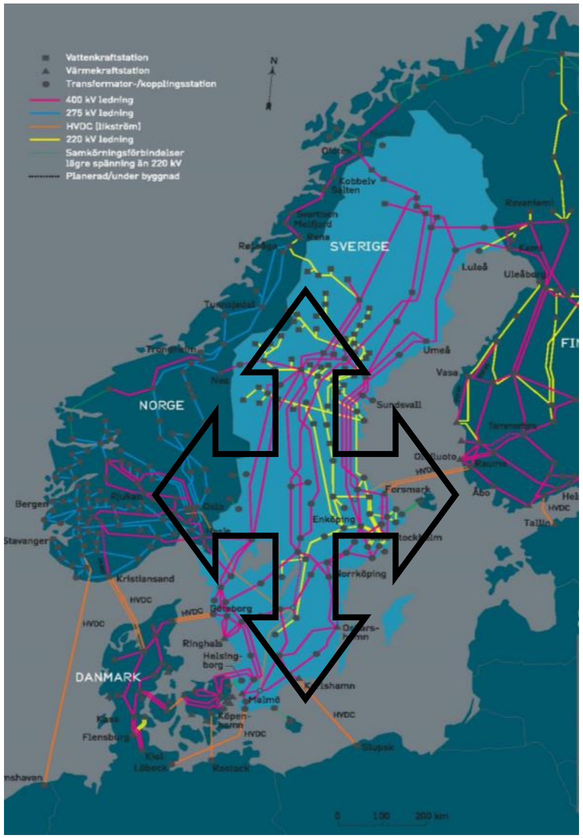
- CO_2-emitting power stations must run for balancing purposes
- Enforced ecological strain in the hydro systems
- Renewable energy must be curtailed and spilled away
- Risks for shedding of demand, local black-outs

Remedial measures:

- Installations for ecological protection in waterways
- Development of demand flexibility, ’Smart Grids’
- Reinforcements within and between national grids
- Pumped storage

  (20-25% energy losses)

Enhanced transmission capacity needs



- > Facilitate use of efficient and sustainable sources of balancing capacity
- > Transport of large volumes of renewable generation
- > Equalize wind generation over large areas

The transmission capacity is depending on voltage support from synchronous generators

Insufficient access to synchronous generators

Consequences:

- Reduced transmission capacity
- Non-optimal use of available generation
- Reduced equalization of wind-power over large areas
- Inadequate mitigation of grid faults, endangered system stability

Remedial measures:

- ”Must-run” of generators not needed in the power balance
- Installation and operation of reactive power compensation devices
- Grid reinforcements
- Advanced system protection schemes

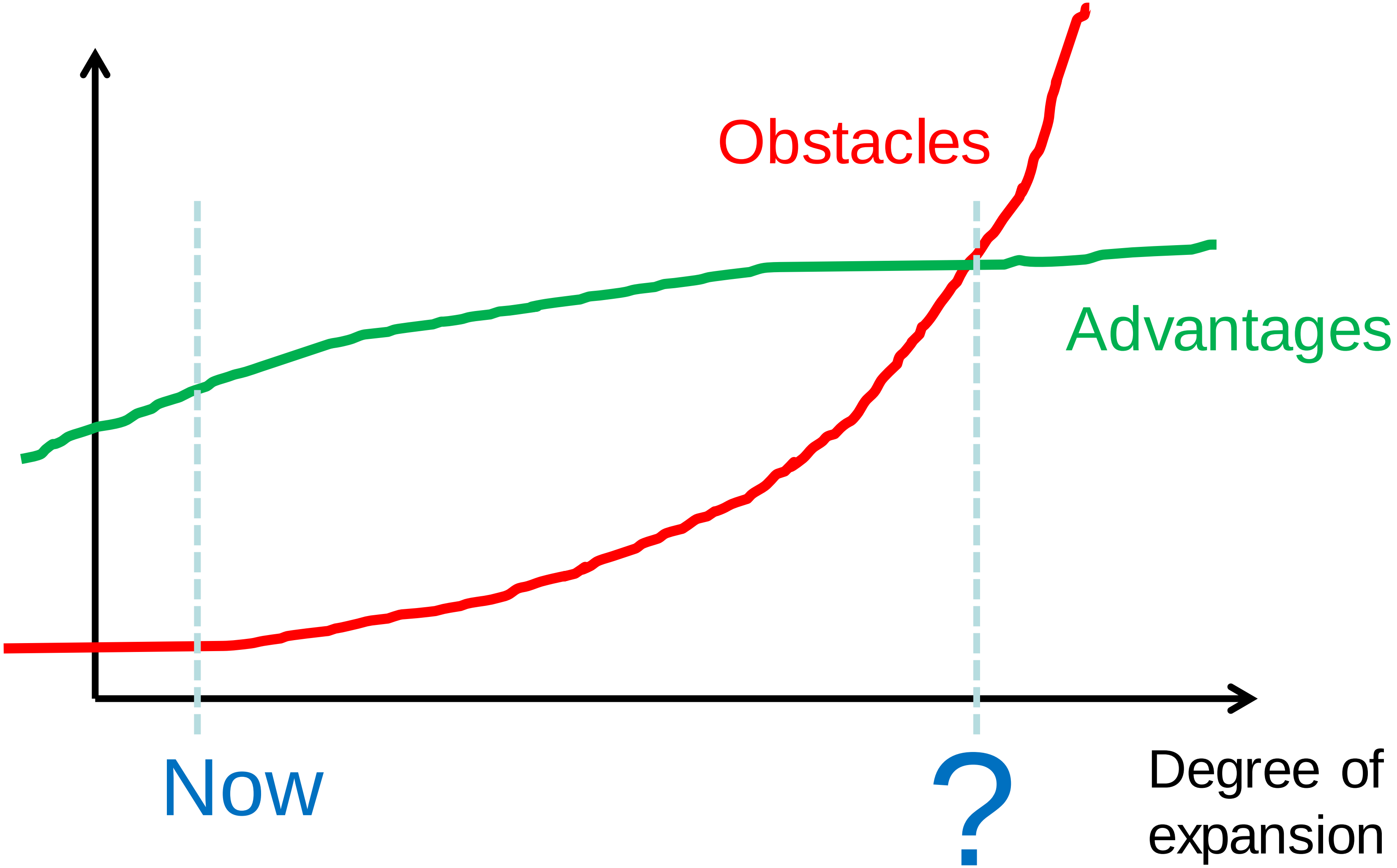
Conclusion:

Extensive integration of intermittent generation is mostly possible

Gradually emerging obstacles must be observed at an early stage

- Investment costs for remedial measures
- Operational complexity and costs
- Environmental side effects
- Public acceptance

Reasonable expansion of renewable intermittent generation



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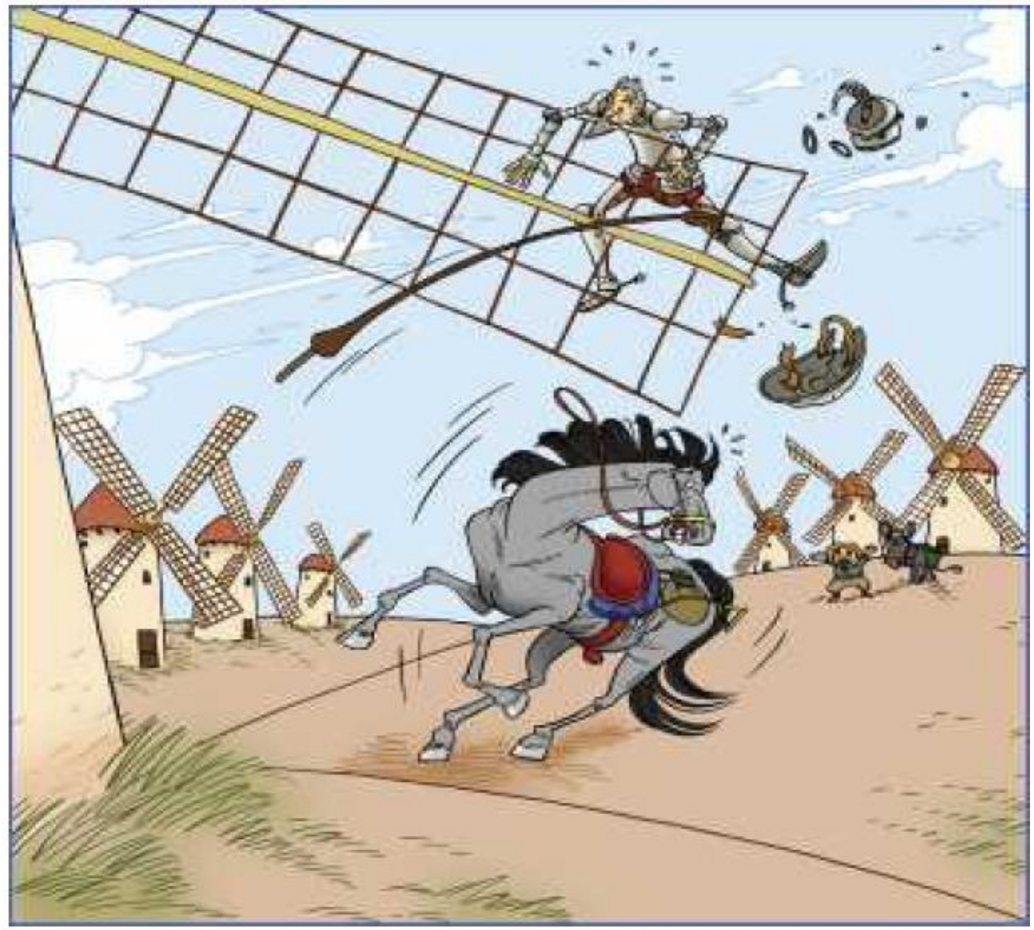

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