

Integrating intermittent renewables into electric power systems

A systemic, multi-scale approach

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Energy promotion in Switzerland

- Action plan

"Coordinated Energy Research Switzerland"

- 202 mios CHF for energy research 2013-2016
- 24 mios -> promotion of individual scientists in research domains relevant to energy issues (via Swiss NSF)

- Three instruments NSF

1 Ambizione Energy

2 SNSF Professorships

3 AP Energy Grants (NEW)



SCHWEIZERISCHER NATIONALFONDS
ZUR FÖRDERUNG DER WISSENSCHAFTLICHEN FORSCHUNG

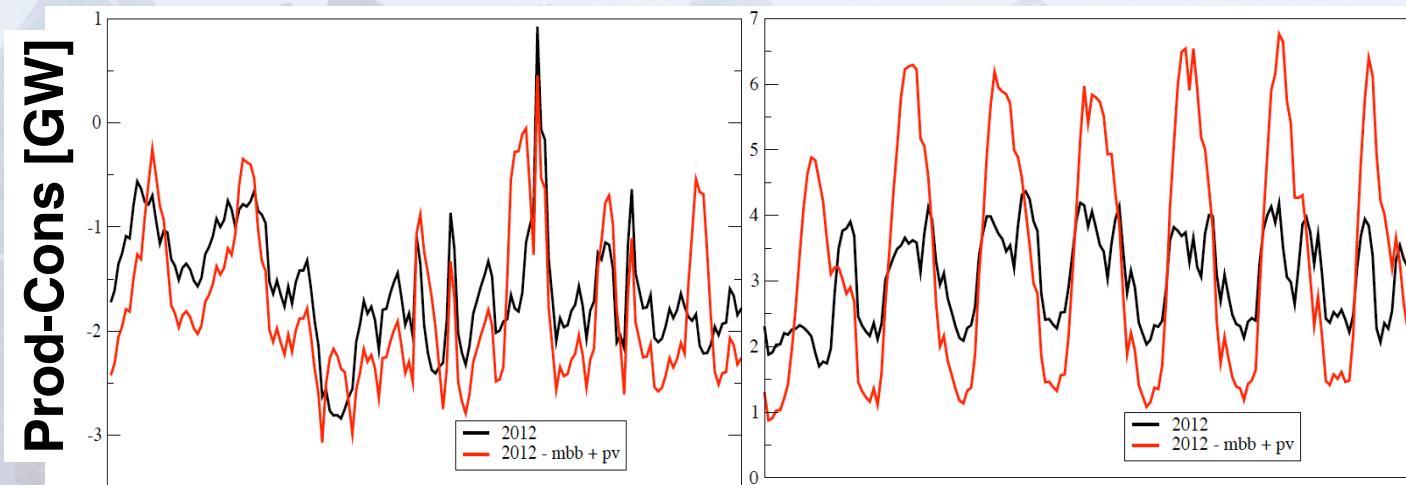


Problem formulation - Energy strategy 2050

ENERGY TRANSITION IN SWITZERLAND

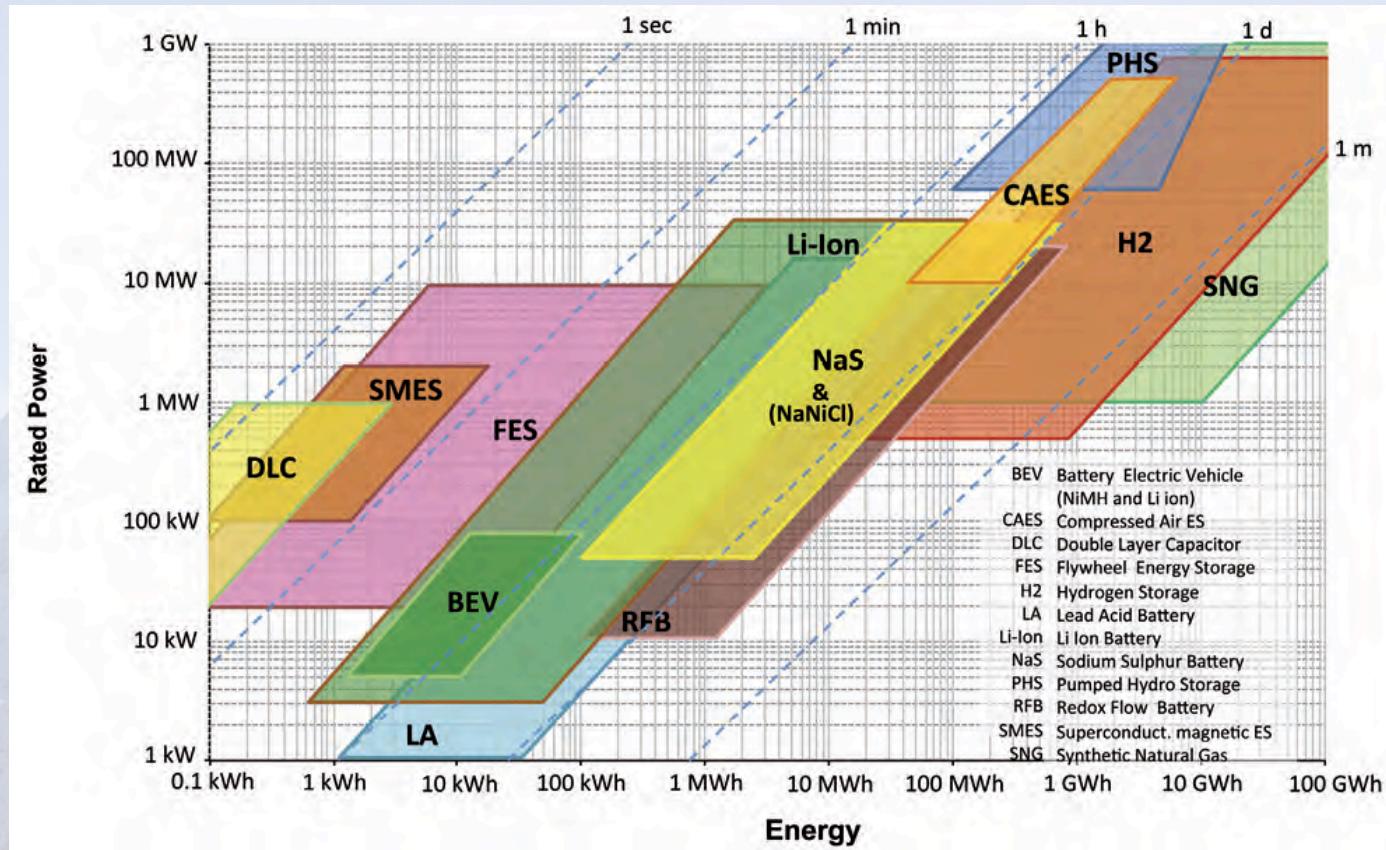
decommissioning of nuclear power plants
+ reducing greenhouse gas emission

= increasing penetration of renewables



"How can we absorb/mitigate daily and seasonal
fluctuations of production???"

General solution : play with electrical energy storage



"Which type of storage ? How much ? Where ?"

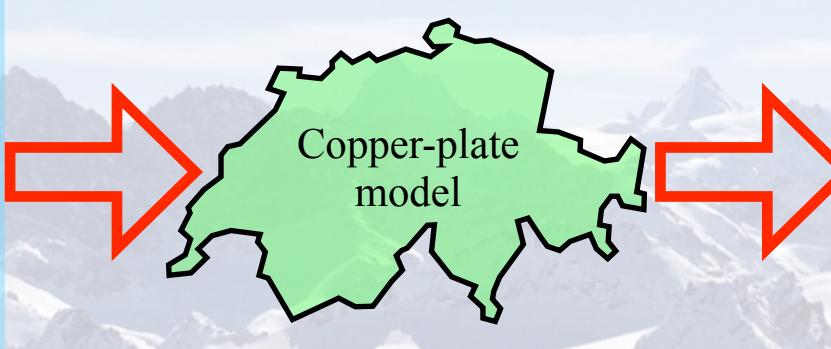
Multi-scale approach : phase I

Inputs :

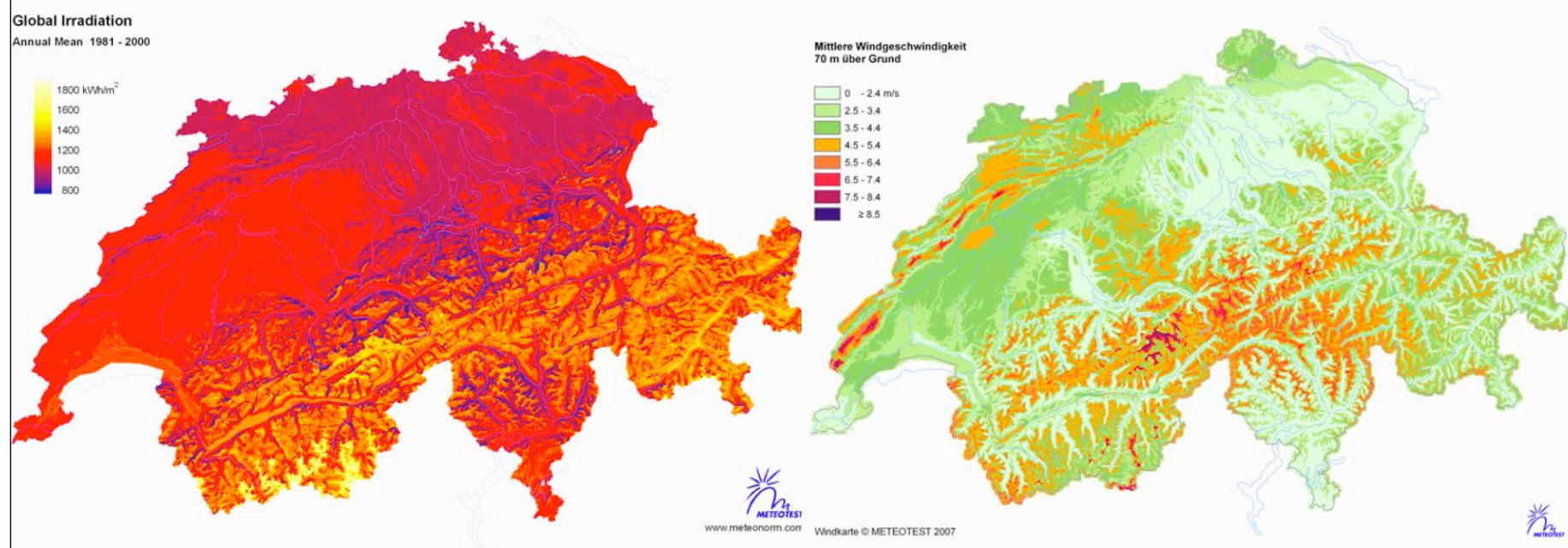
- annual energy productions (scenarios of Table II)
- geographic distribution of PV+WP
- meteorological data (hour-to-hour wind and insulation)

Outputs :

- peak power for PV + WP
- optimized geographic distribution of PV + WP (mitigating meteorological fluctuations)
- total storage power
- total storage energy, given tolerated dumping %-age



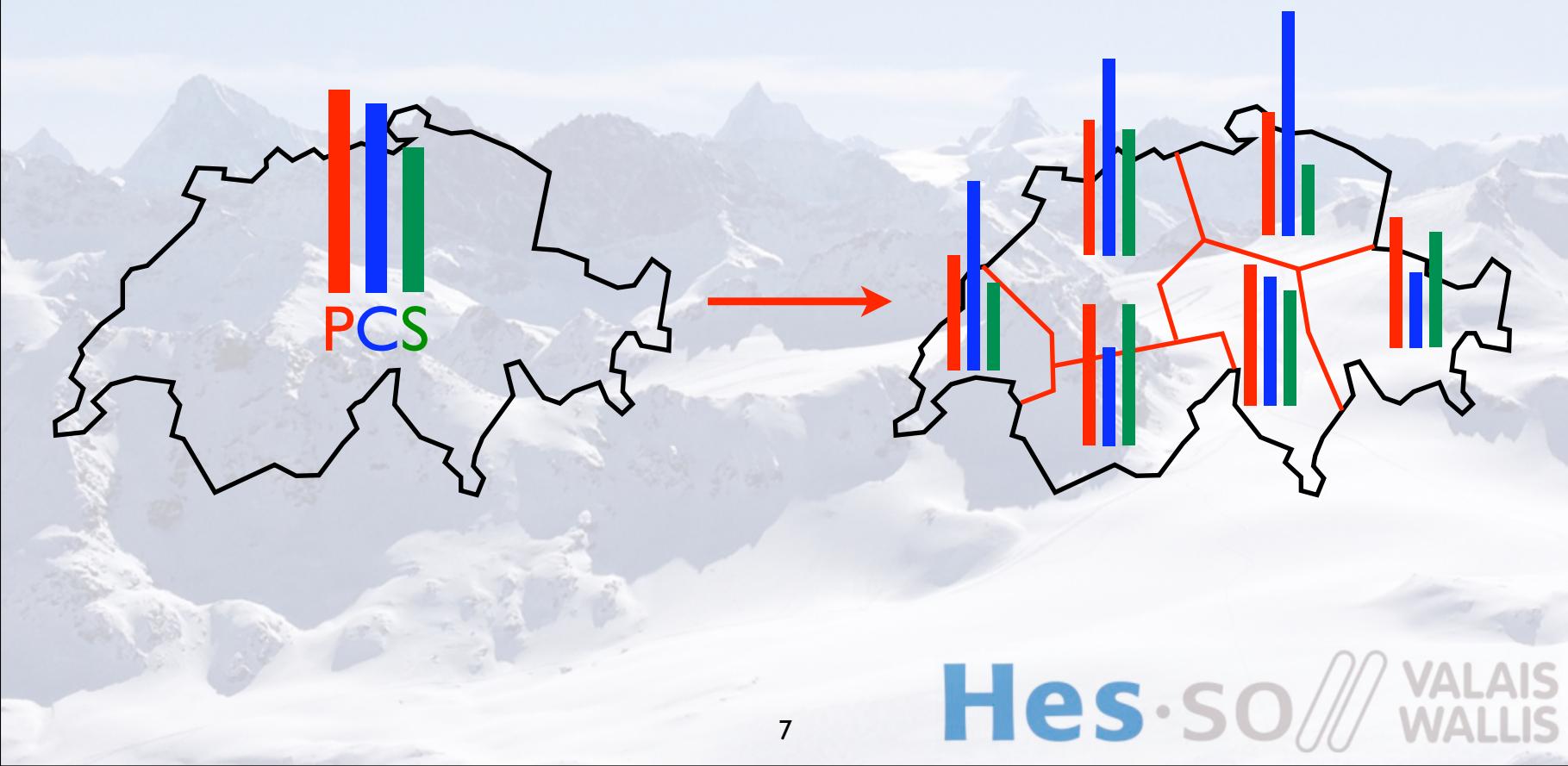
Geographical distribution of PV and Wind turbines



Put PV on roofs (high population density) ~ close to consumption
Put wind turbine on mountain ridges (not too high potential...)

Multi-scale approach : phase II

- Subdivide CH into regions (demography; economy; energy prod/cons...)
- Each region characterized by **Production**, **Consumption**, **Storage capacity**
- Determine **Storage** in each region by minimizing power flows



Multi-scale approach : phase II

Inputs :

- PV+WP+storage power in each region in previous step

- hour-to-hour meteorological data (wind and insulation)

- phase I : current grid



Outputs :

- optimized geographic distribution of PV + WP + storage (power and energy) with increased spatial resolution

- minimized power flows between regions (from storage distribution)

- phase II : guidelines for grid optimization

Iterate - go to more regions, increase spatial resolution

Goals:

- determine optimal production mixes
- determine geographic storage distribution
- investigate load on grid

Multi-scale approach : phase I - year 2025

2025:

-political boundary condition:

Three nuclear reactors of Mühleberg, Beznau 1+2 are phased out
~30% less (8-9TWh/yr) electricity production

-our scenario:

Nuclear production is replaced by PV (80%) and wind (20%)

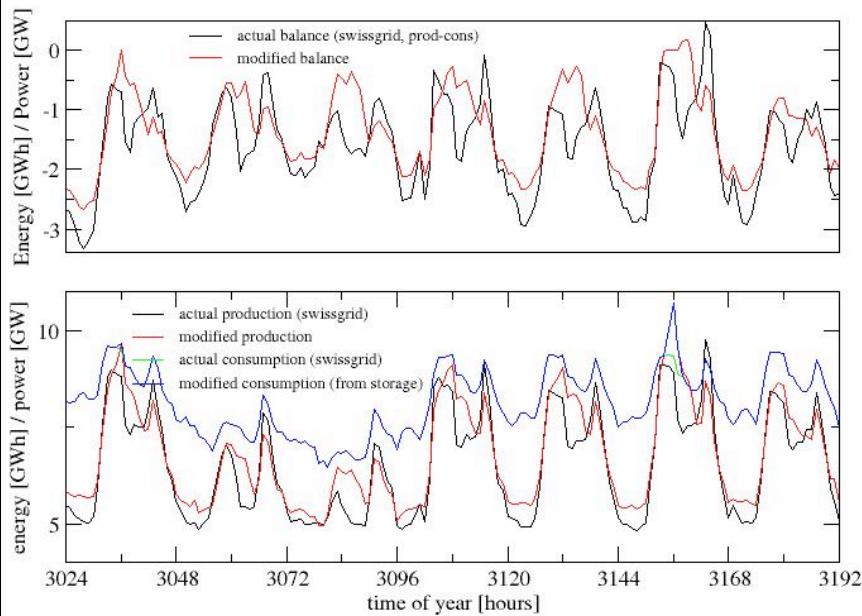
Hydro-electric production modified

Dam hydro as in 2013 (max energy content 9 TWh; power 17 GW)

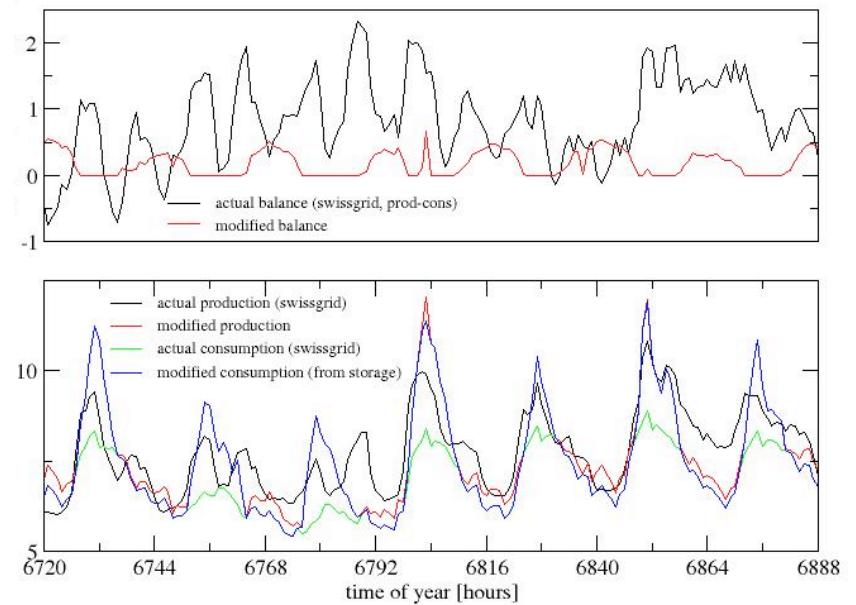
Storage power @ 3.5 GW; energy content @ 200GWh

2025 : evolution of production-consumption balance

Winter



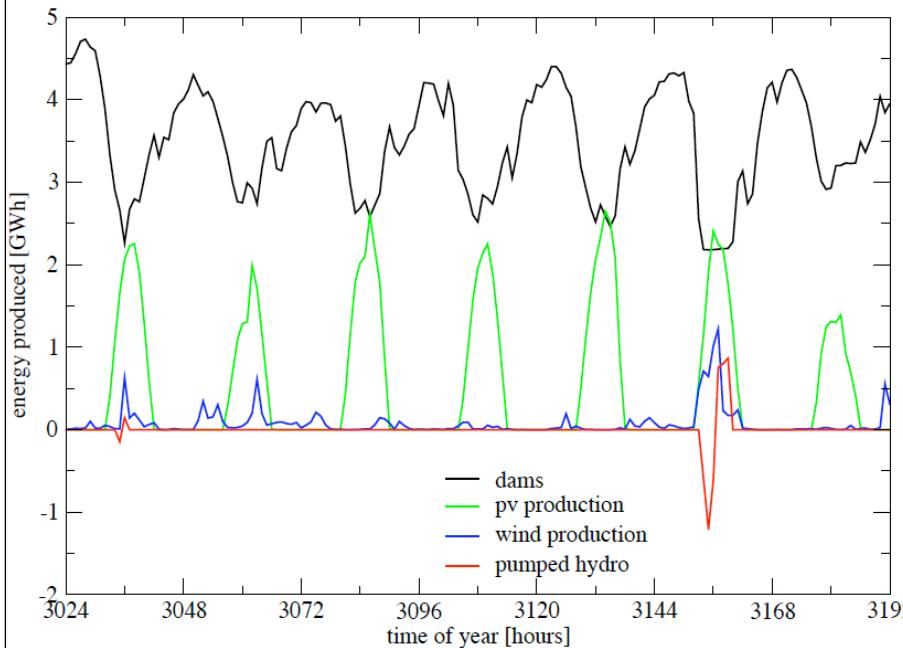
Summer



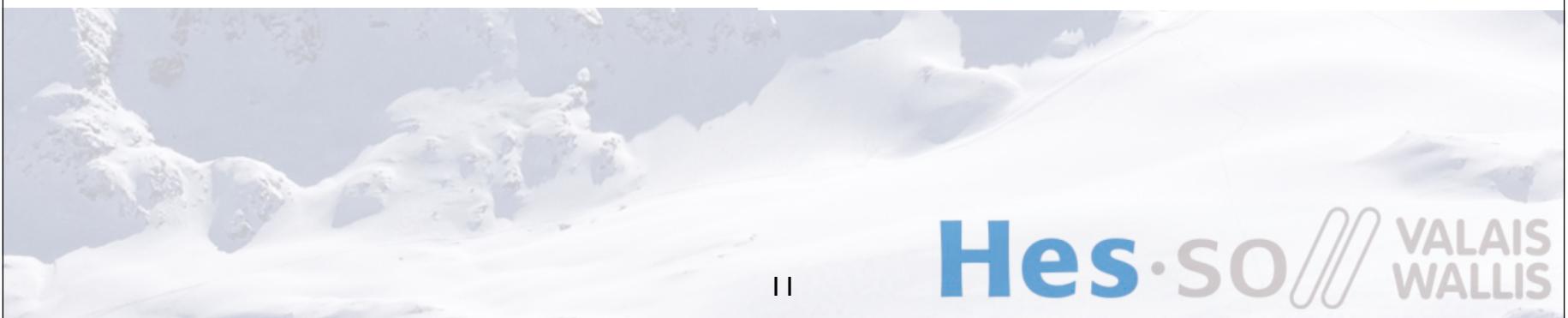
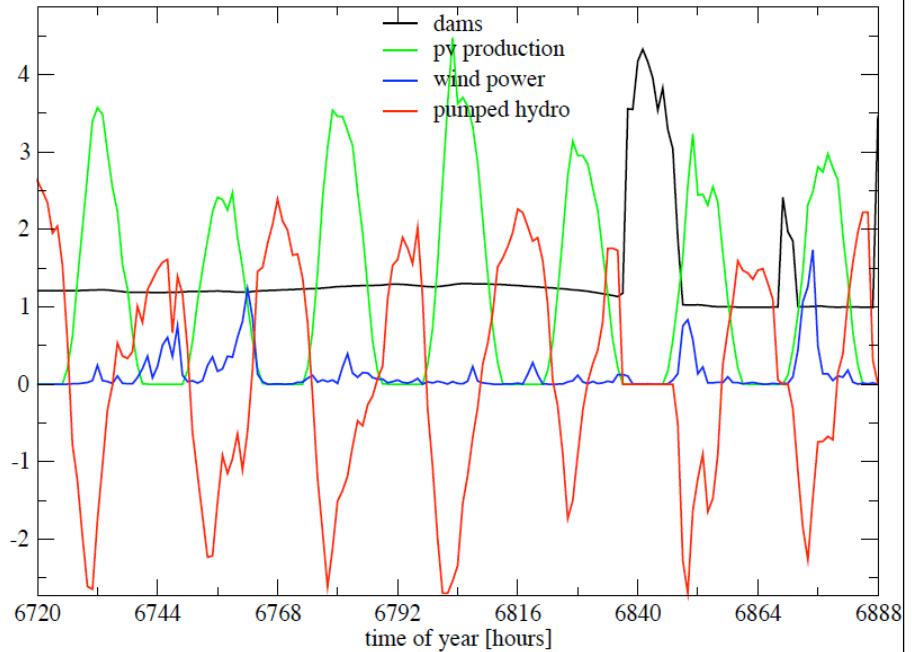
-smoothing of balance in summer thanks to storage
-not much change in winter

2025: evolution of hydro and pumped-hydro production

Winter



Summer



Multi-scale approach : phase I - year 2030

2030:

-political boundary condition:

Four nuclear reactors :Mühleberg, Beznau 1+2, Gösgen phased out
~65% less (18TWh/yr) electricity production

-our scenario:

Nuclear production is replaced by PV (80%) and wind (20%)

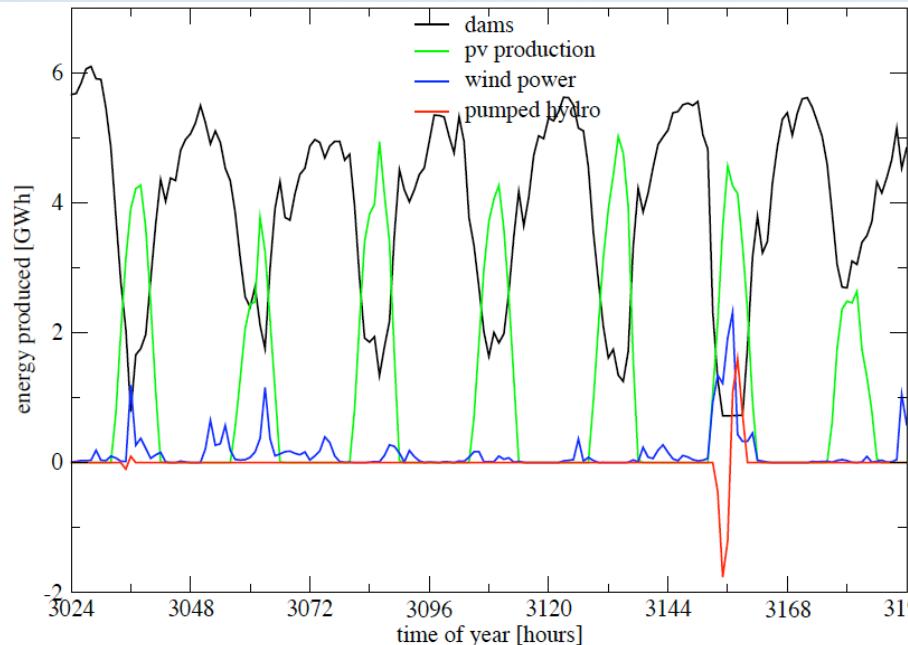
Hydro-electric production modified

Dam hydro as in 2013 (max energy content 9 TWh; power 17 GW)

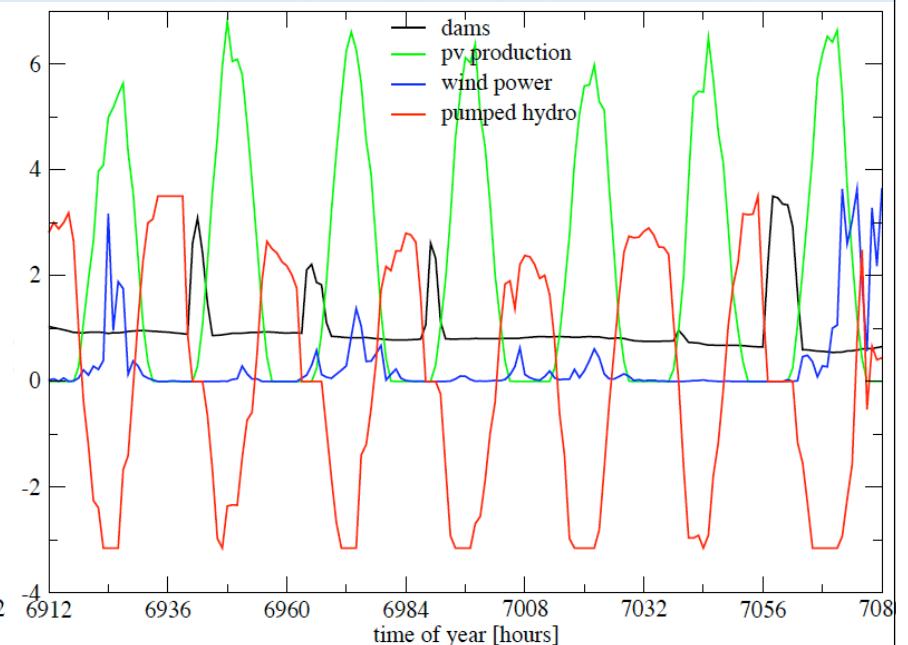
Storage power @ 3.5 GW; energy content @ 200GWh

2030: evolution of hydro and pumped-hydro production

Winter



Summer



Multi-scale approach : phase I - year 2035

2035:

-political boundary condition:

All nuclear reactors phased out

~25TWh/yr of electricity production missing

-our scenario:

Nuclear production is replaced by PV (80%) and wind (20%)

Hydro-electric production modified

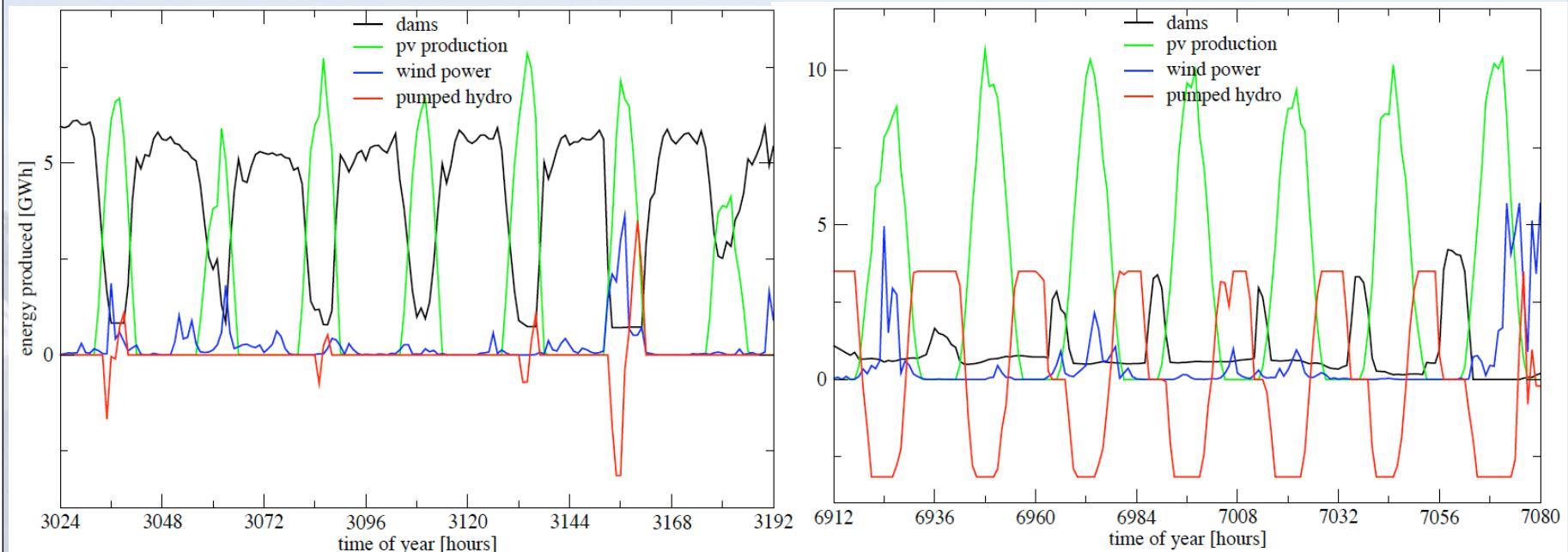
Dam hydro as in 2013 (max energy content 9 TWh; power 17 GW)

Storage power @ 3.5 GW; energy content @ 200GWh

2035: evolution of hydro and pumped-hydro production

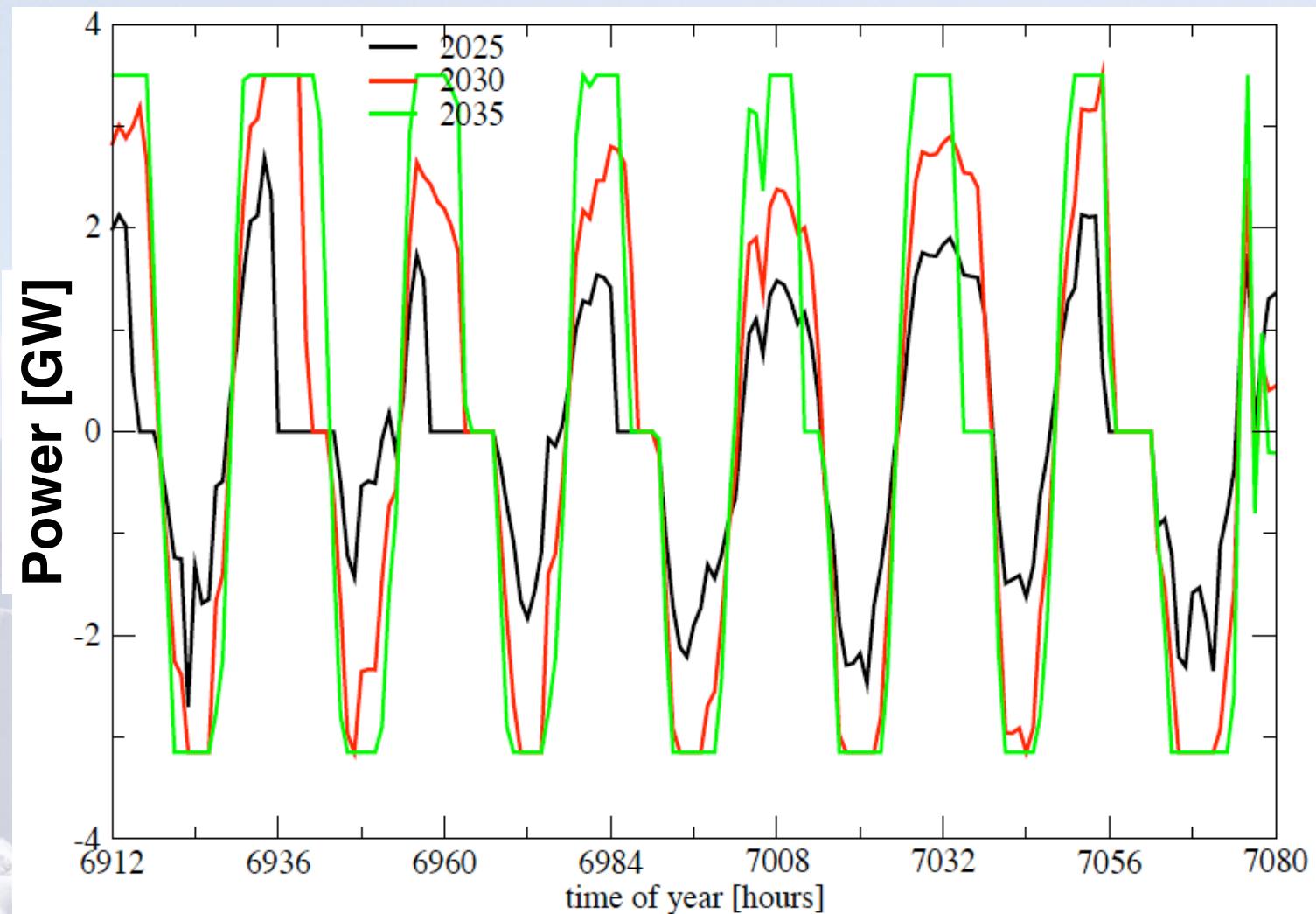
Winter

Summer

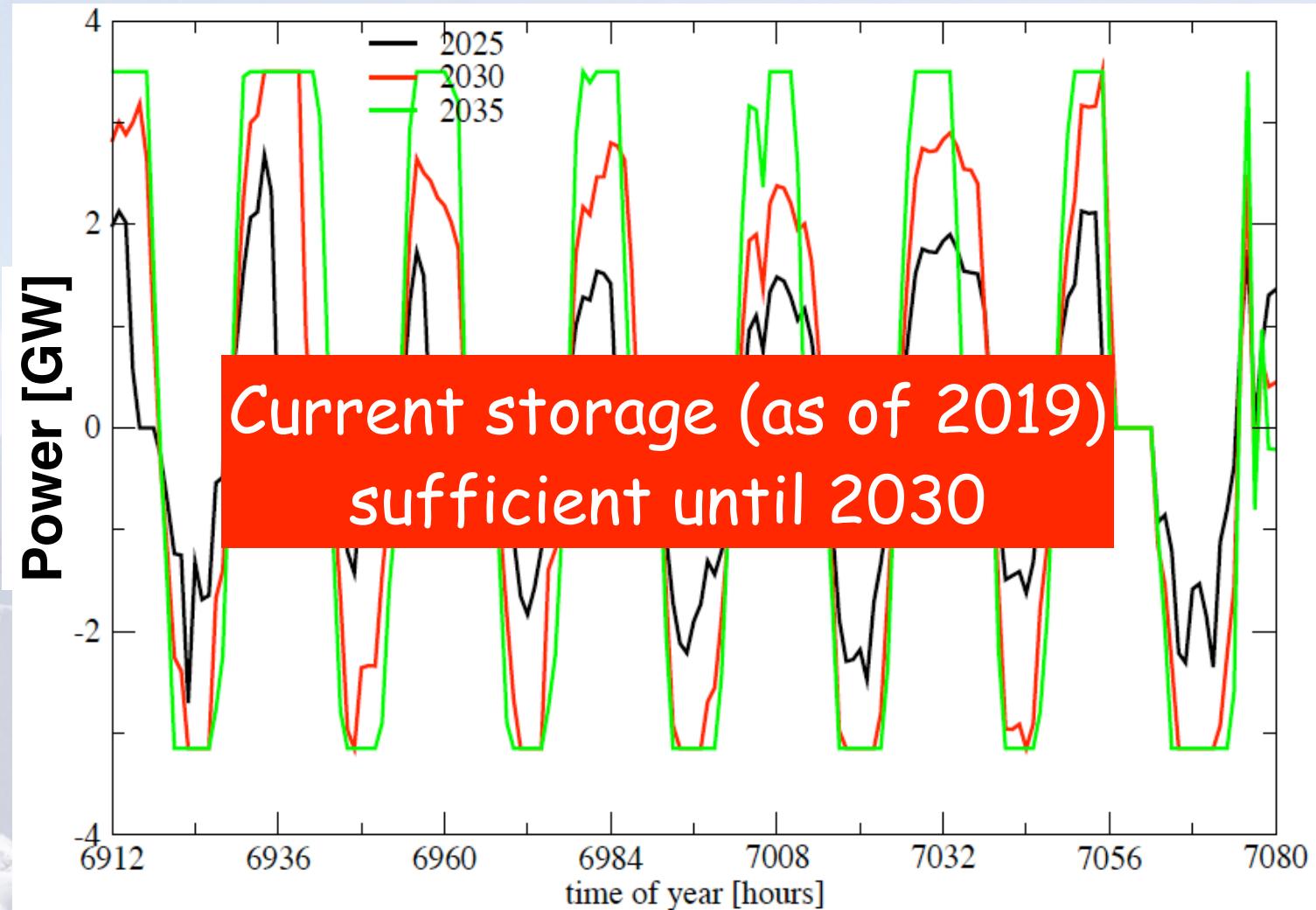


Storage saturates almost daily in summer

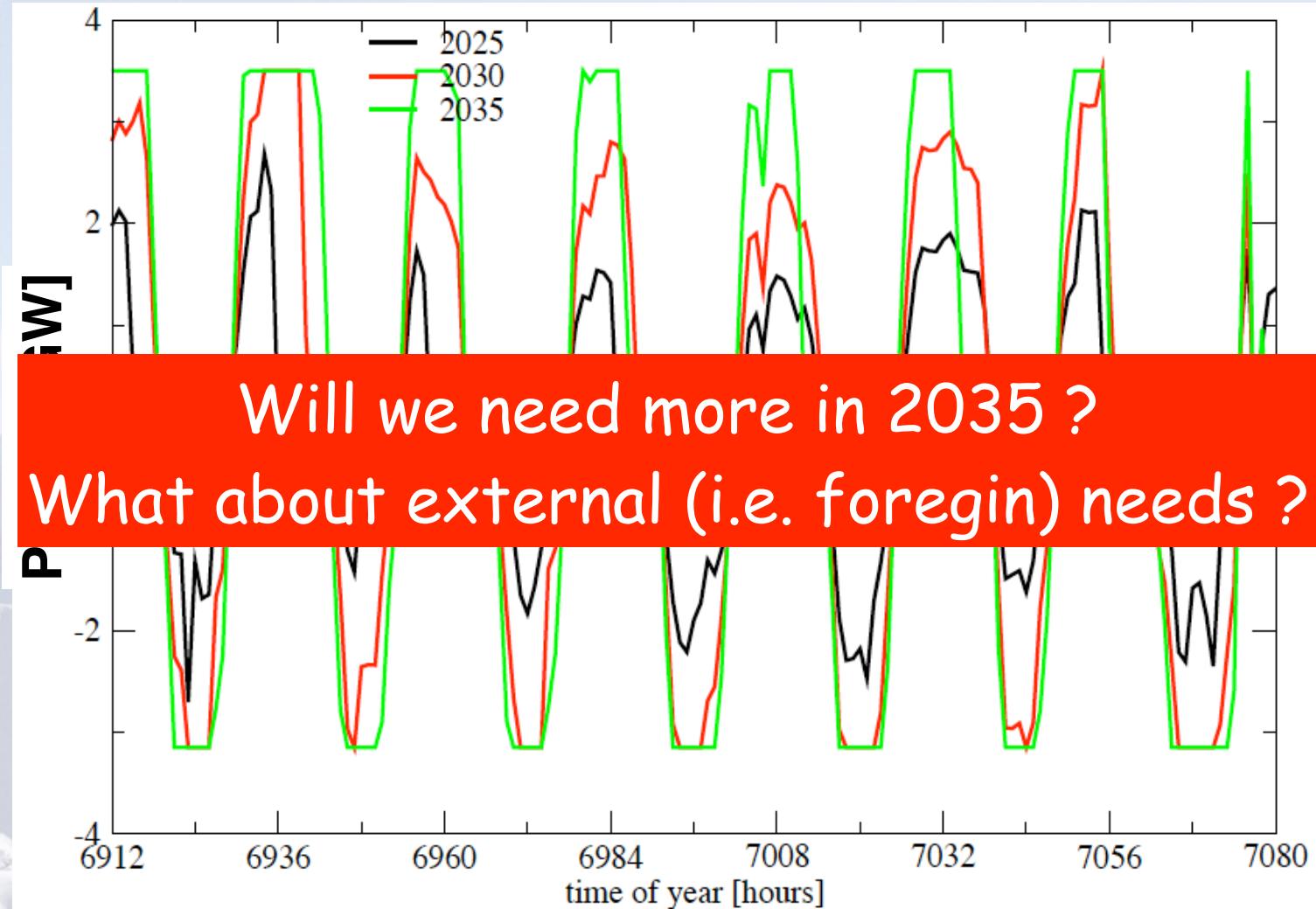
Storage usage : mostly in the summer (high PV production)



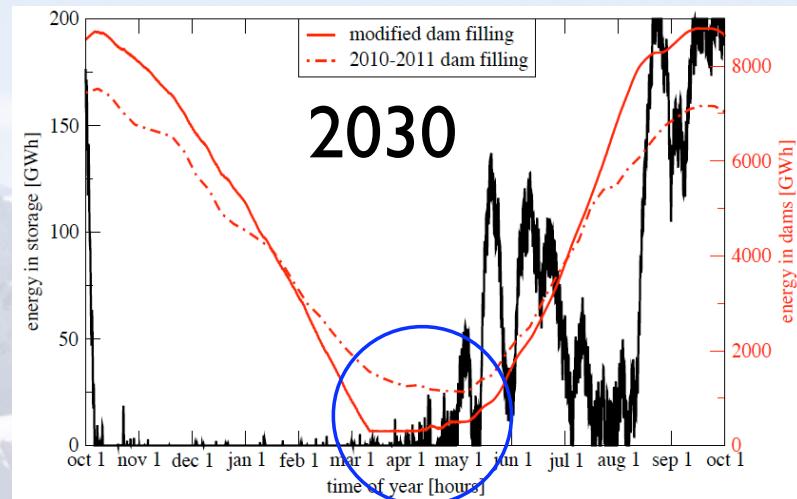
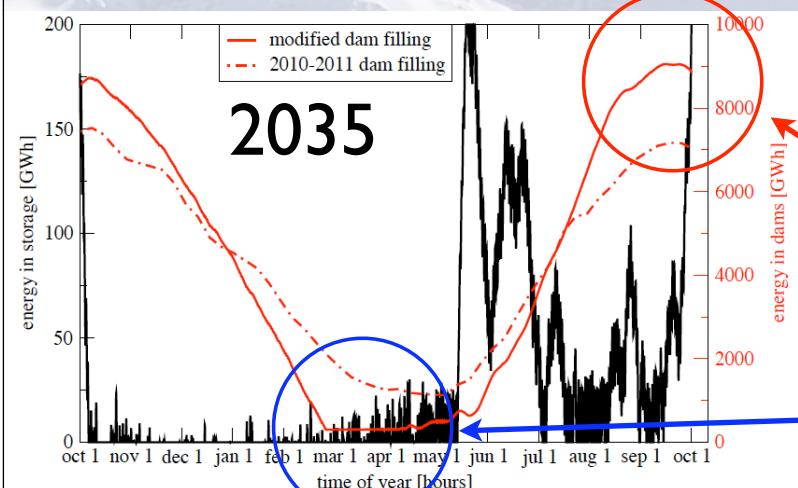
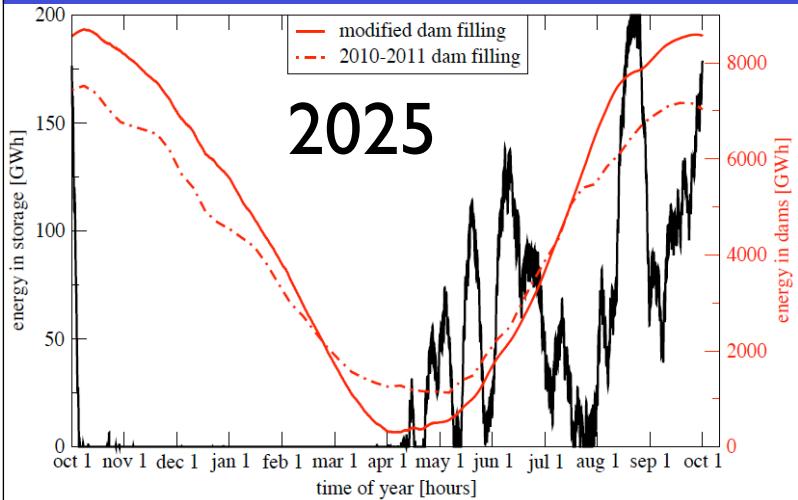
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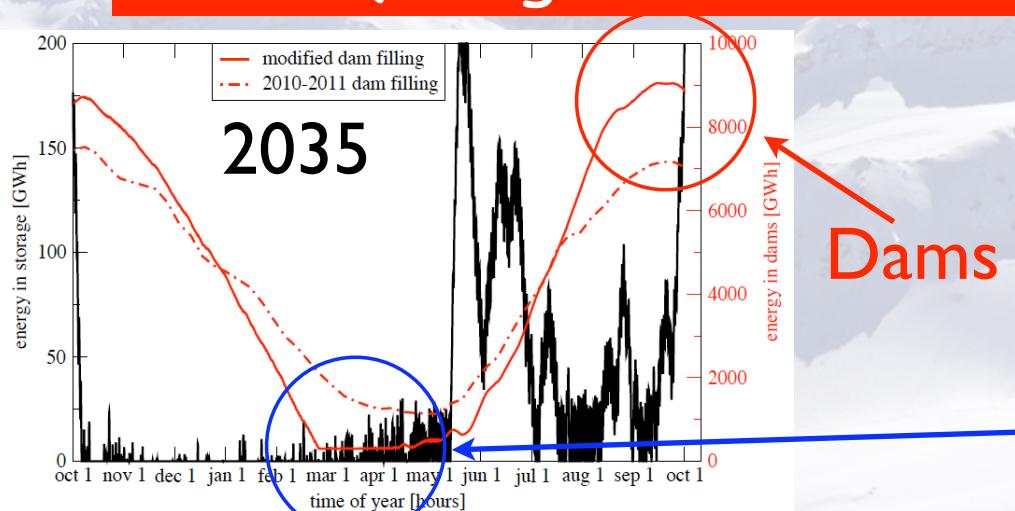
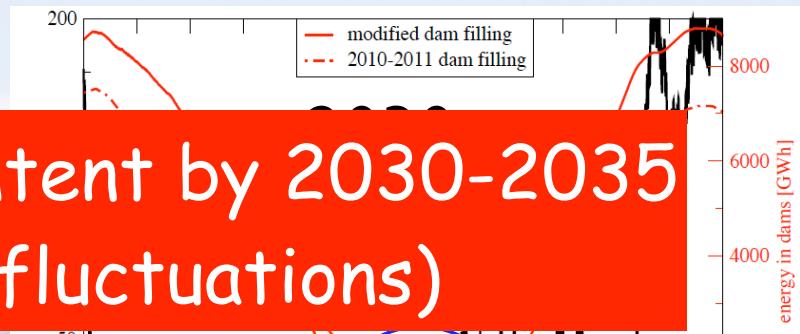
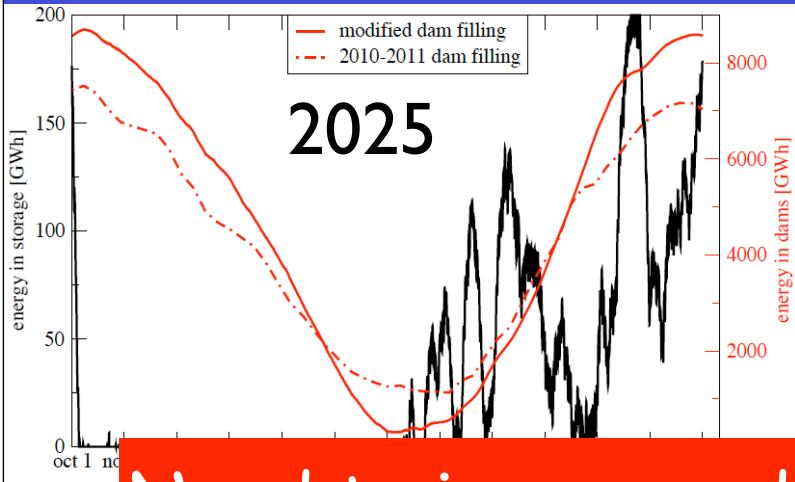
Dam and storage energy content



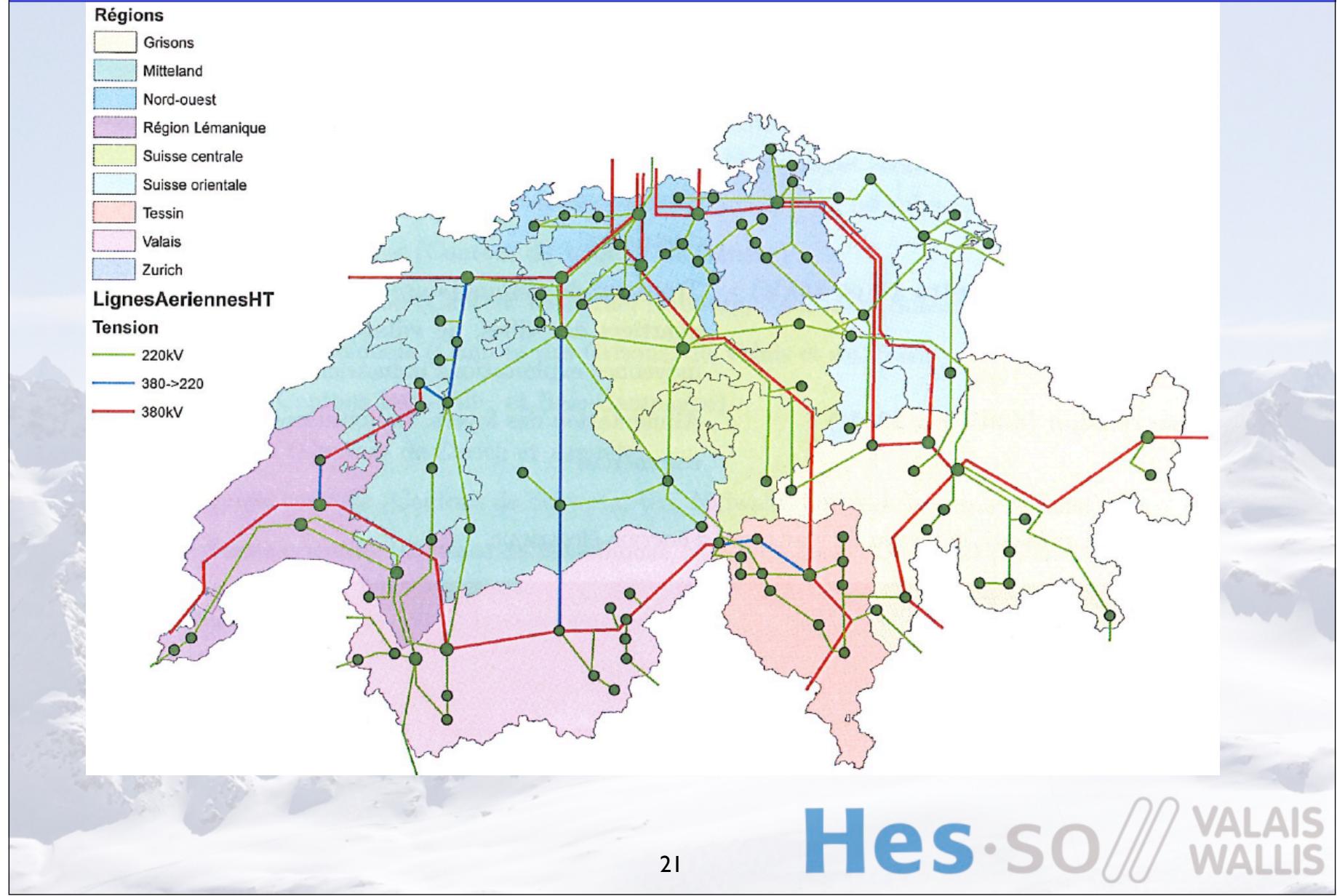
Dams full

Dams empty

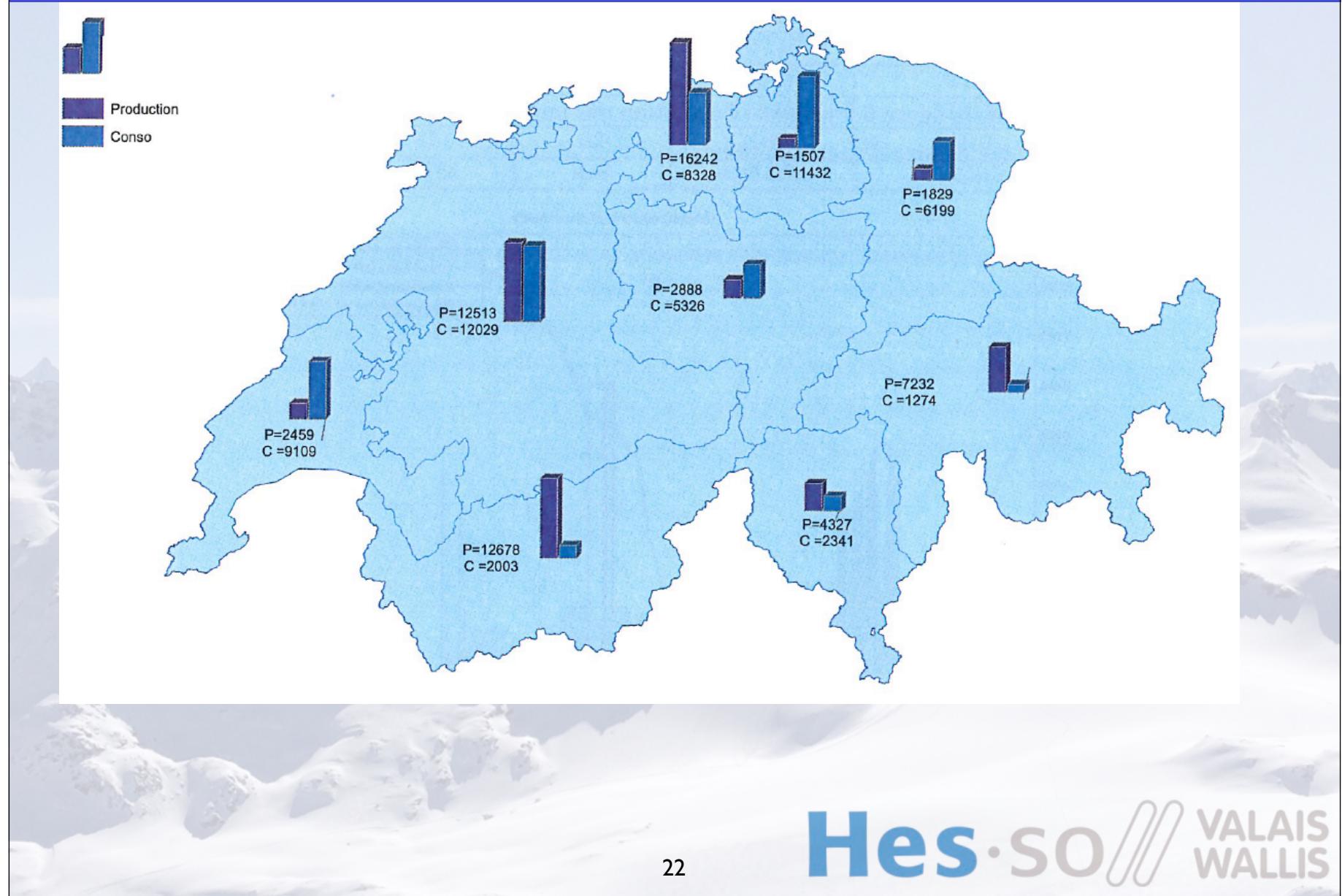
Dam and storage energy content



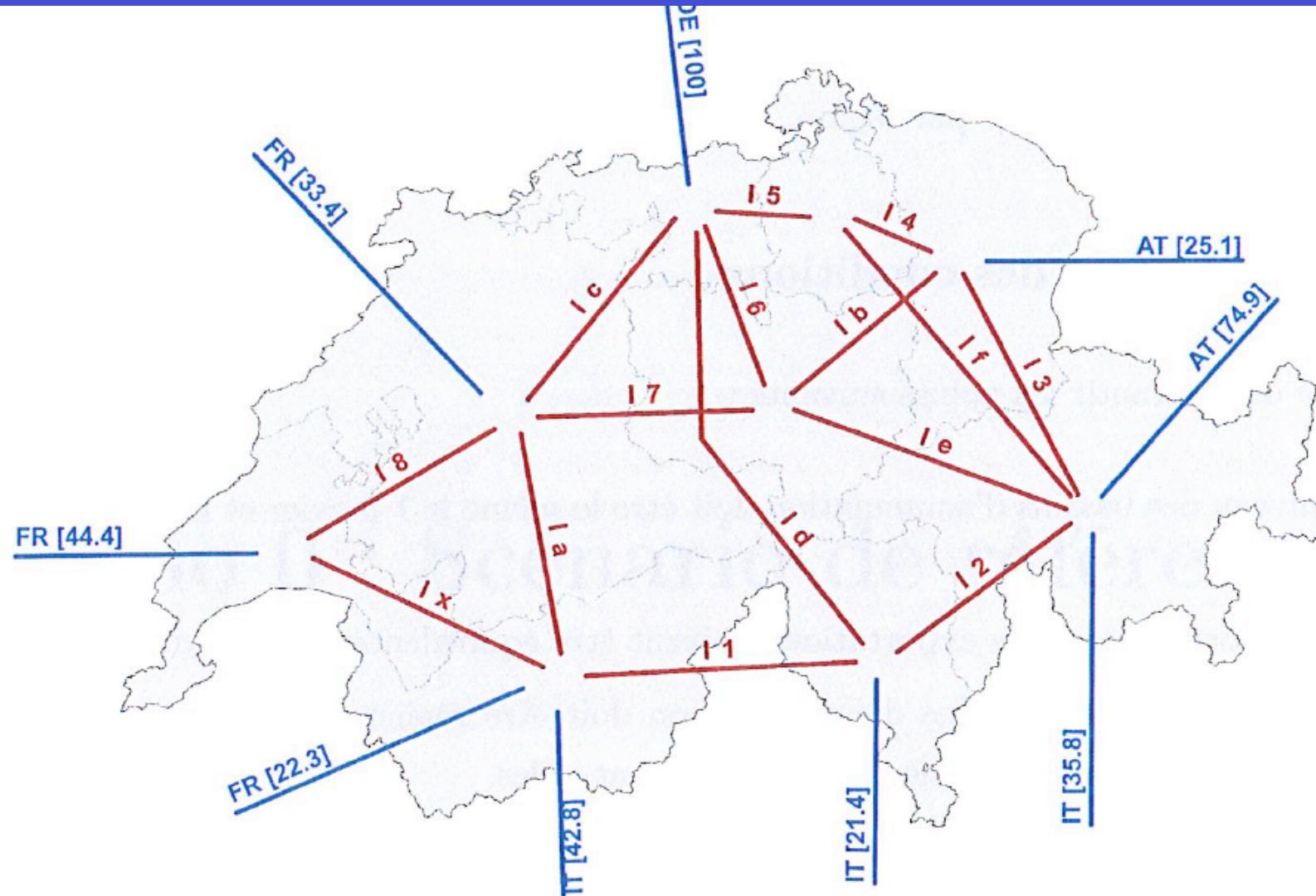
Multi-scale approach : phase II



Multi-scale approach : phase II



Multi-scale approach : phase II



Thank you for your attention

