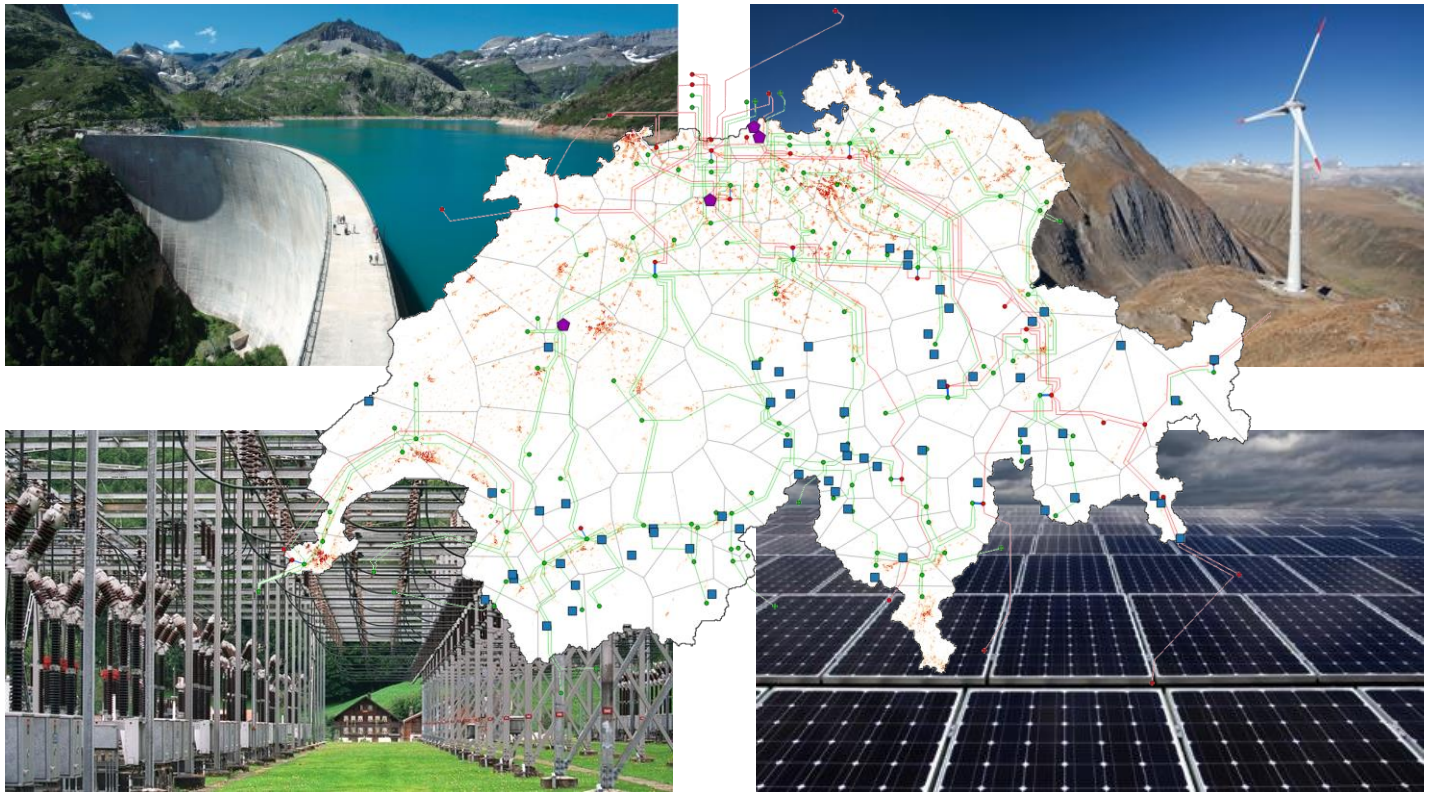
The role of Mountain PV and Wind in a fully renewable Swiss Energy World



Annelen Kahl, Jérôme Dujardin, Bert Kruyt, Stuart Bartlett, Michi Lehning

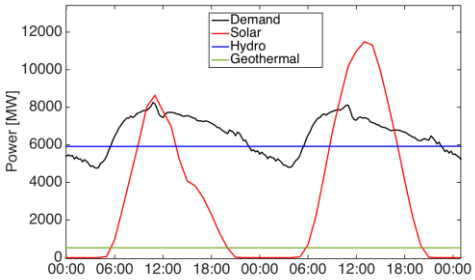
SCCER – WSL - Conference

Challenges:
Mismatch in supply and demand

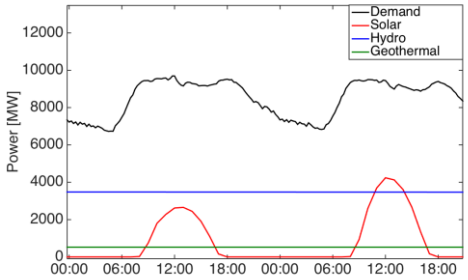
Mismatch in time:

1. Throughout the day

Swiss-wide production and demand, Summer



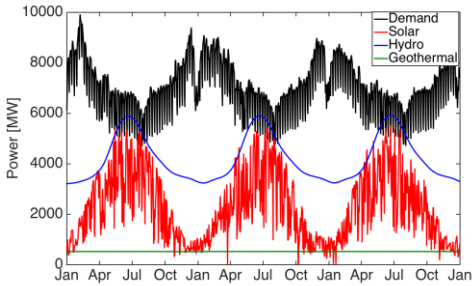
Swiss-wide production and demand, Winter



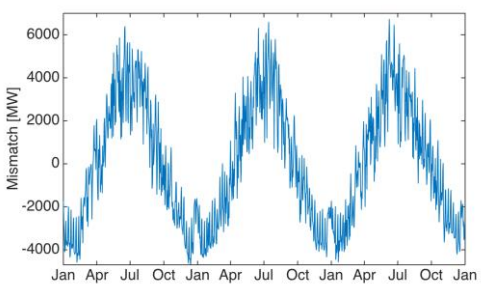
Can be alleviated by conventional and pumped hydropower

2. Throughout the year

Swiss-wide production and demand for 2012- 2014



Resulting mismatch



Critical to penetration of RES in the future energy market – Needs to be addressed!

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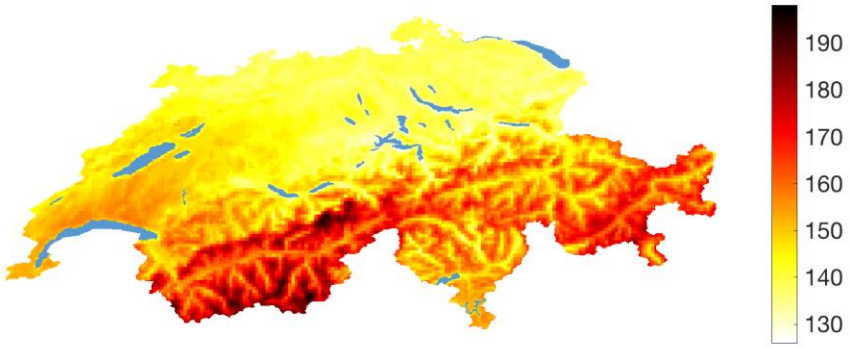
Three Main Points

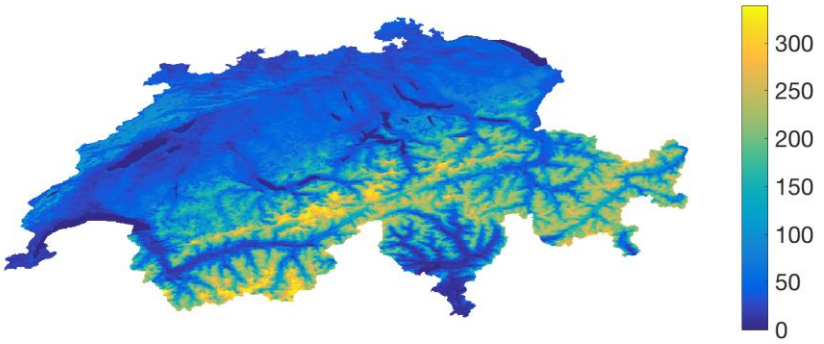
- Potential of PV in (Snowy) Mountains
- Potential of Wind in Switzerland (Mountains)
- Integration in the Swiss Power System

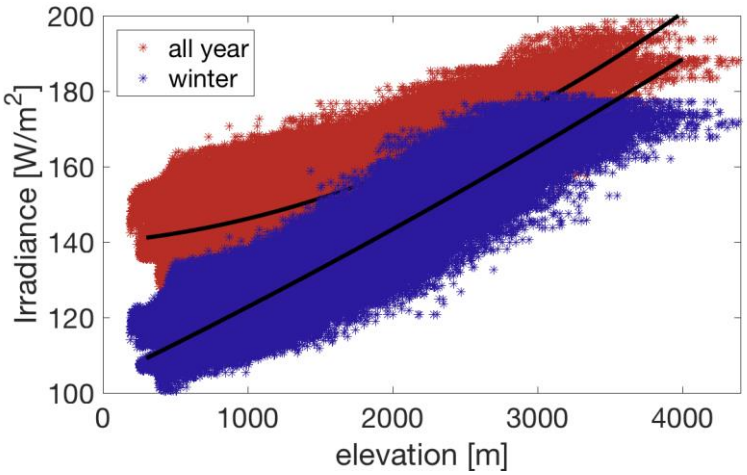
The Environmental Drivers (Solar)

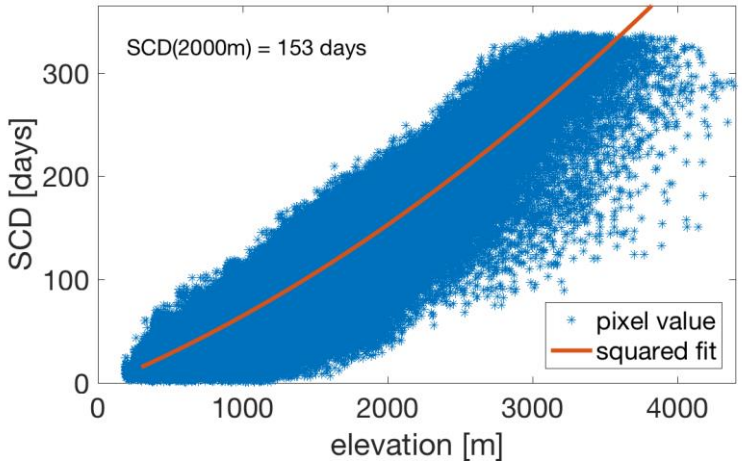
Irradiance [W/m^2]



Snow Cover Duration (SCD)

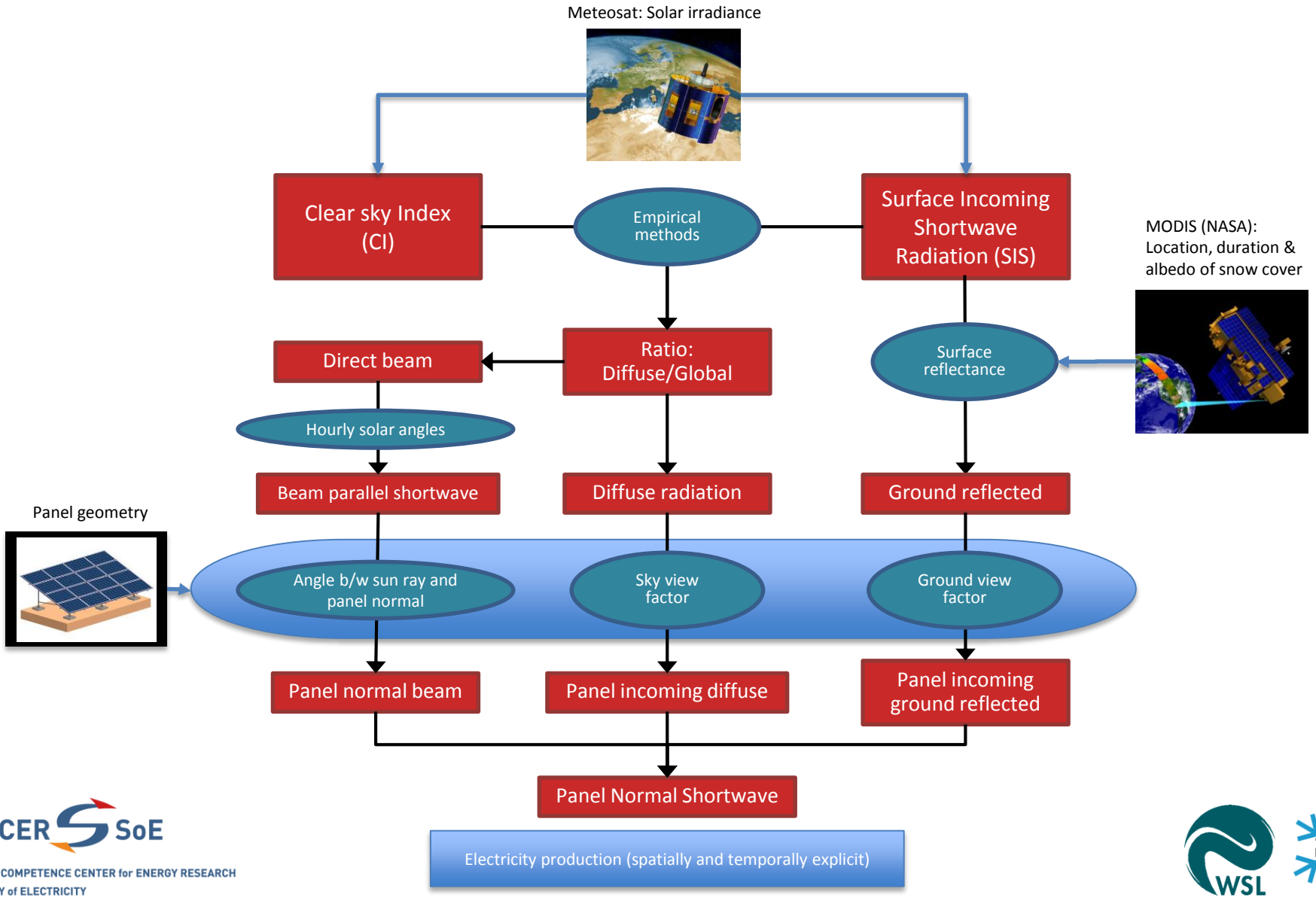






The higher the better !!

PV - Method: Model production potential based on satellite-derived information and panel tilt



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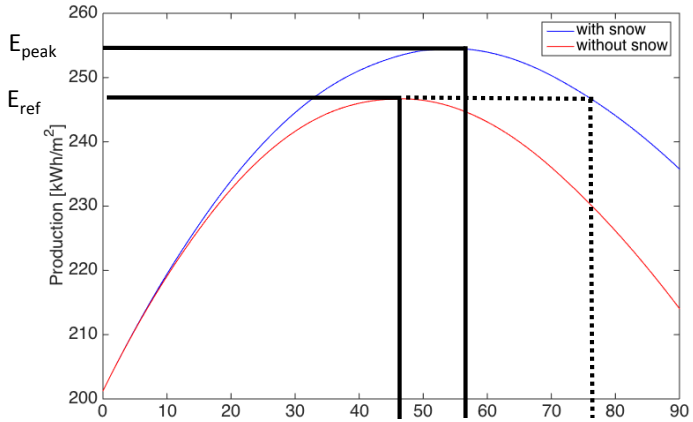
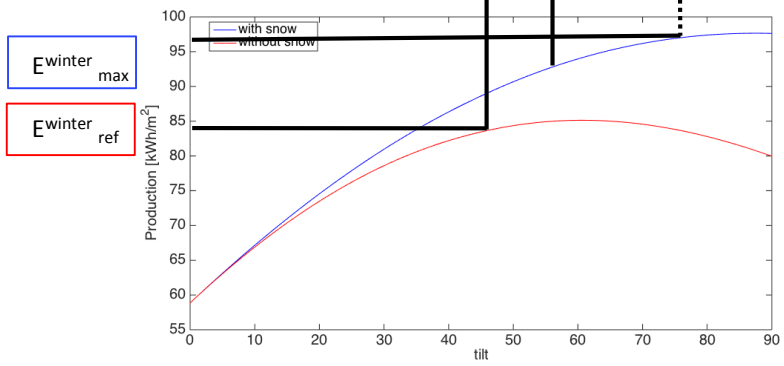
The technical dial: Panel tilt

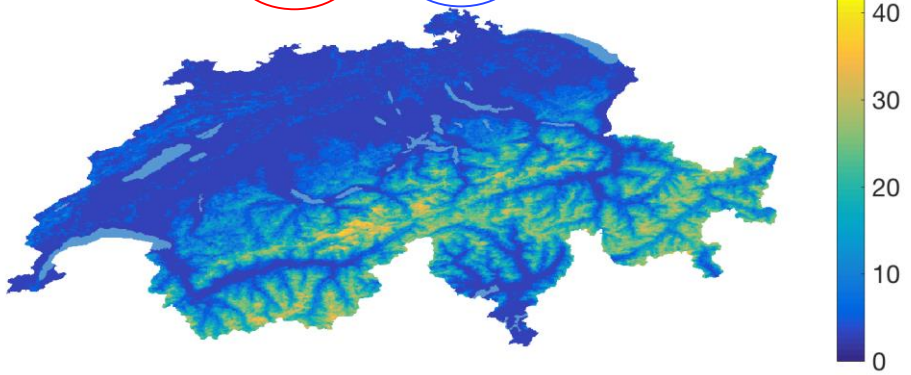
Annual total production



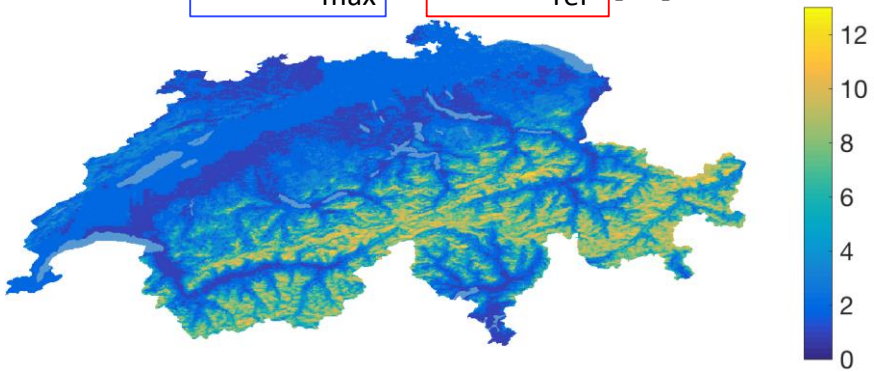


Winter production (1st Jan – 30th April)

$tilt_{max}$ - $tilt_{ref}$ [degree]



E^{winter}_{max} - E^{winter}_{ref} [%]



Steeper tilts allow gain in winter production without loss in annual total

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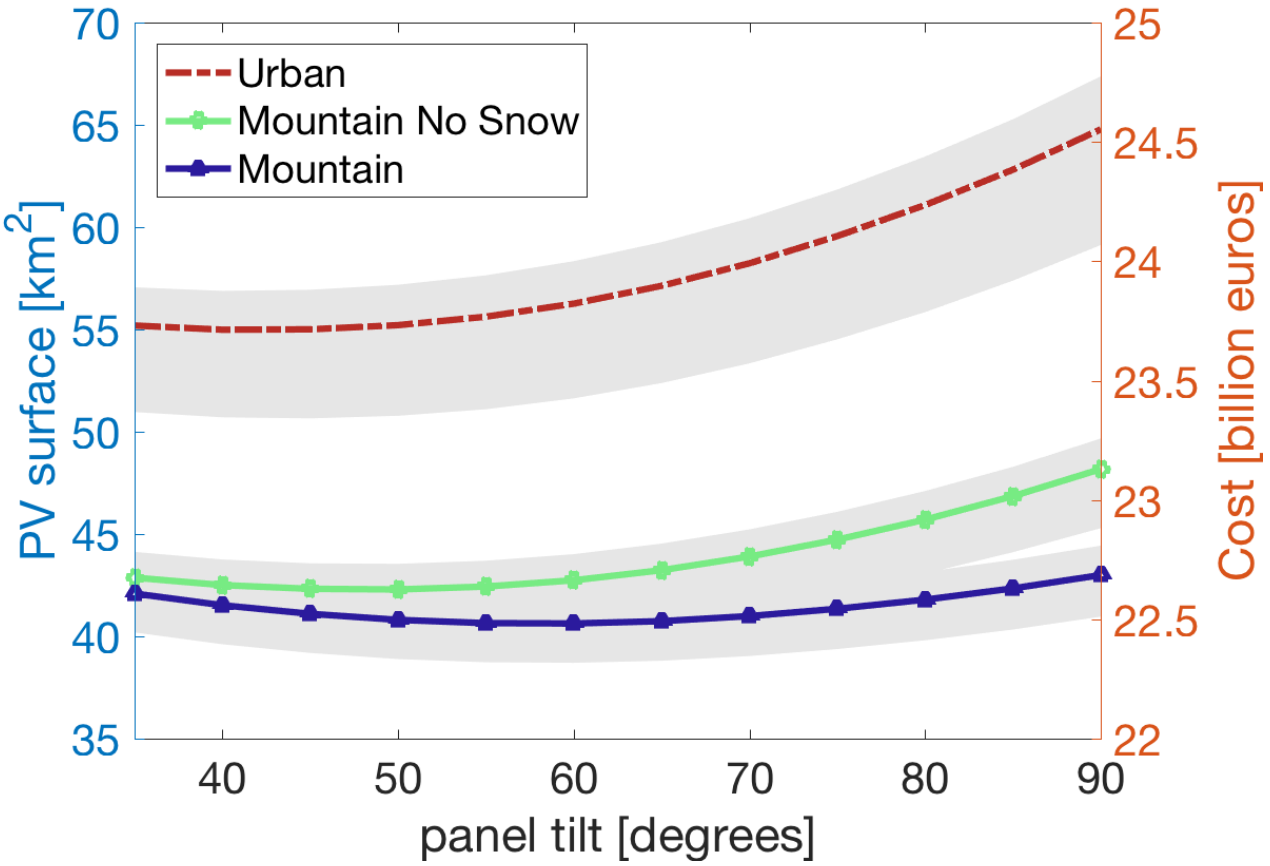
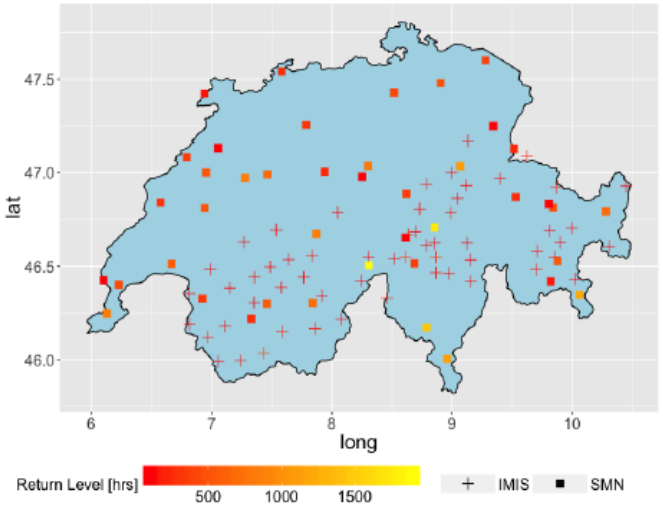
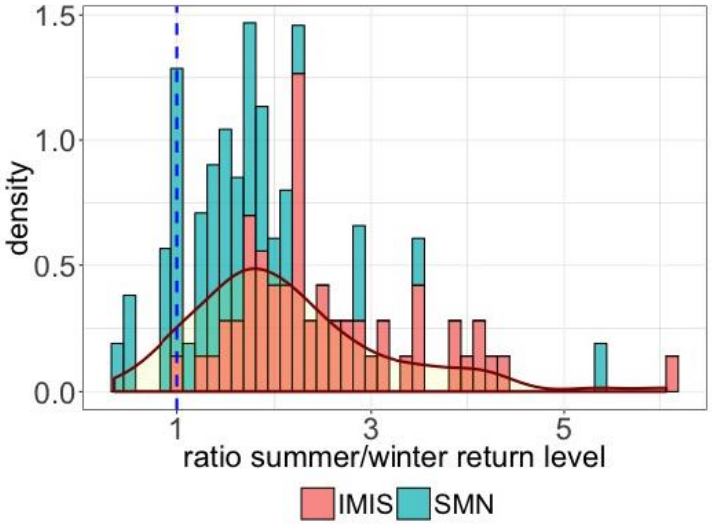
Scenario Comparison
Urban, Mountain Snow, No Snow

Required surface area to produce 12 TWh



Wind:
Intermittent Wind Resources:
Potential and Potential Risk

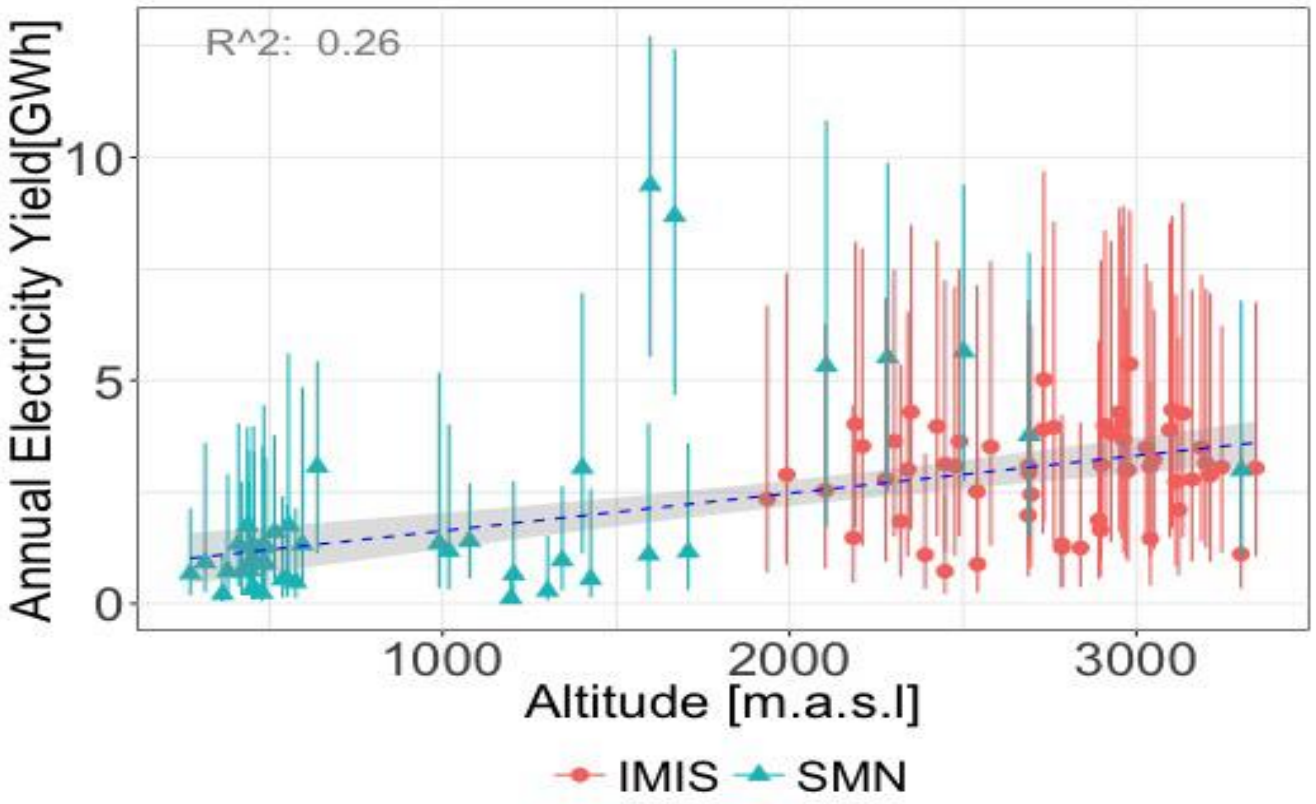




- The risk of “no wind power” for extended time periods is very variable across Switzerland and can be minimized by a good choice of location (high elevations).
- Winters (when there is an energy gap) are more productive and less risky

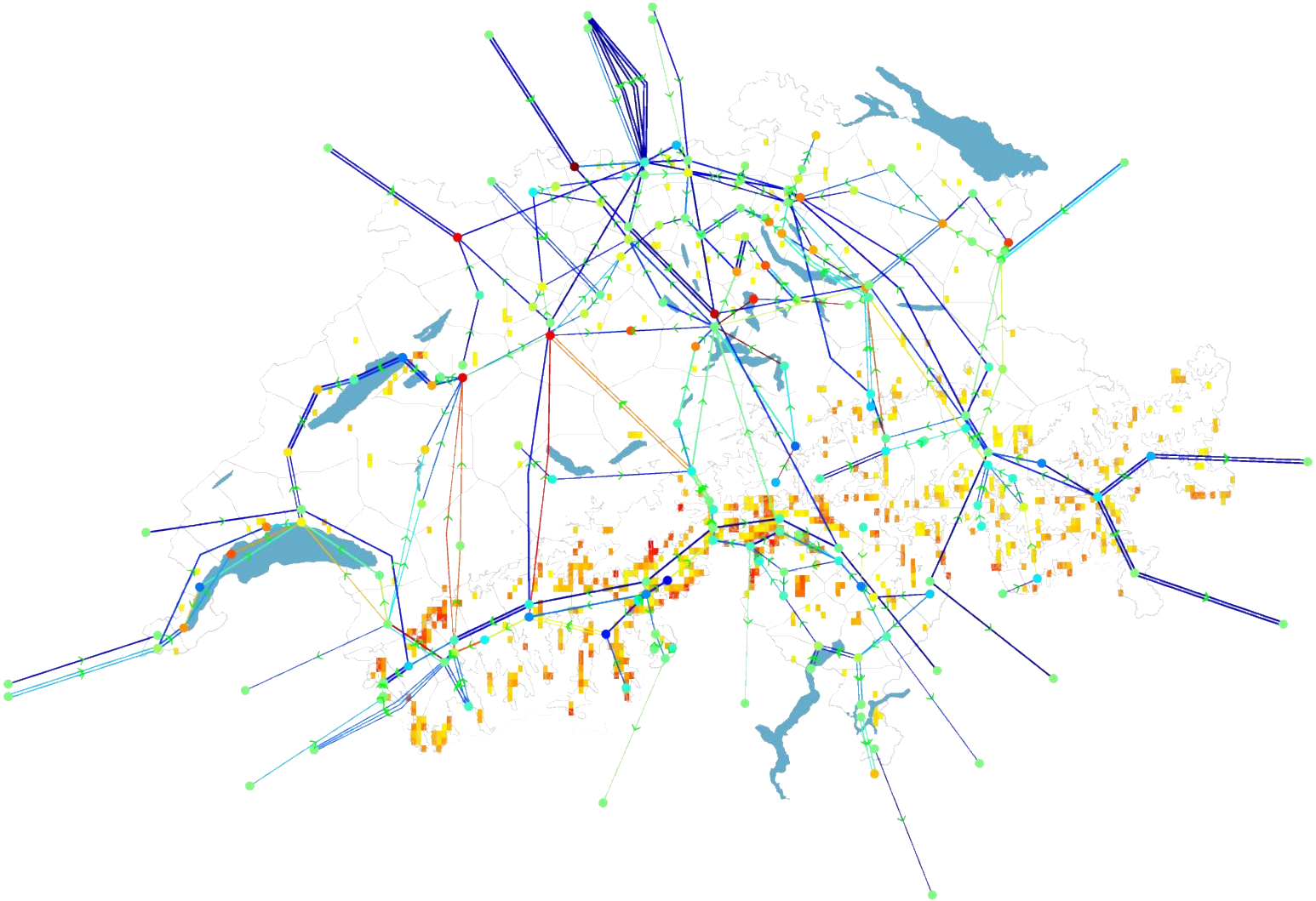
Kruyt et al., Applied Energy, 2017

Wind Energy Yield increases with Elevation



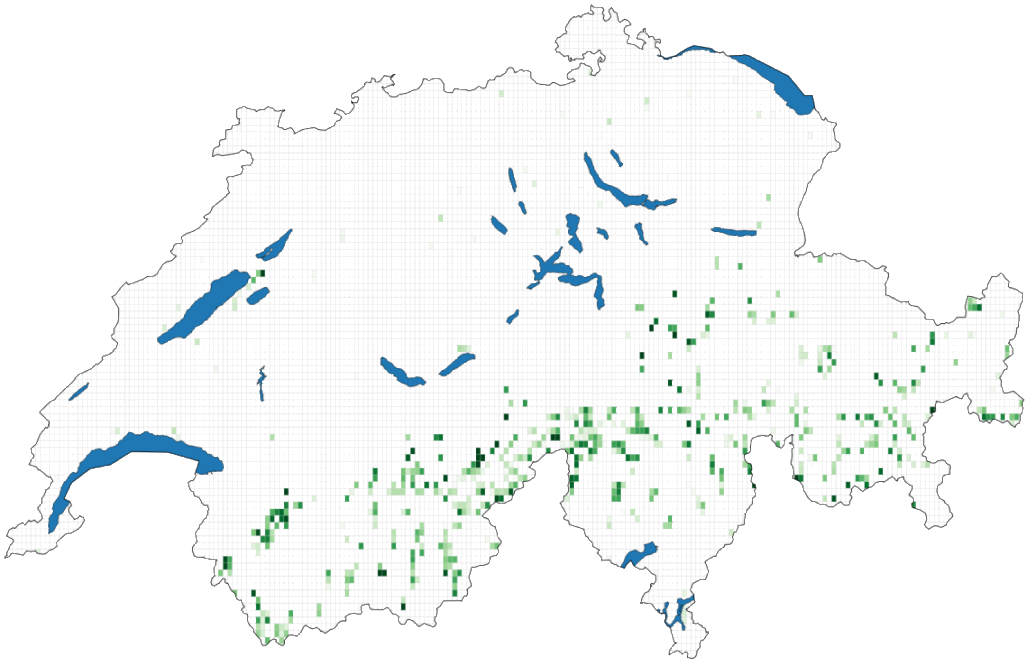
Applied Energy, 2017

Optimization of PV Placement with Power Flow Model



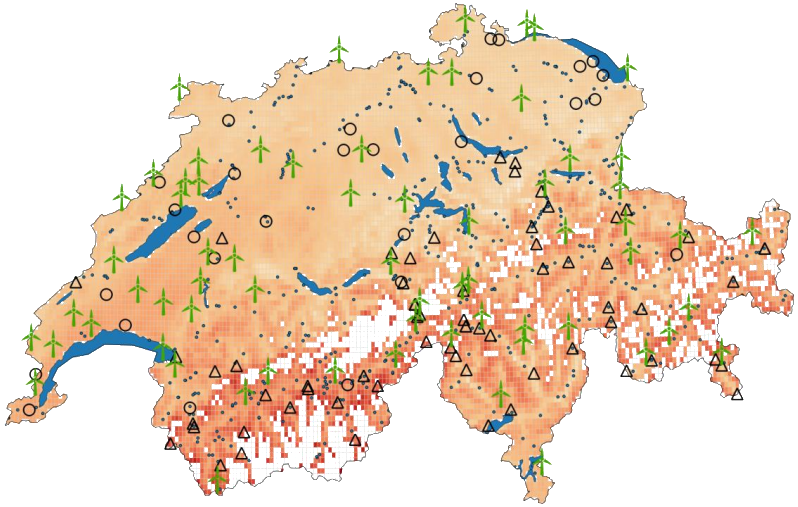
Line use, import – export, water management,

Where we should build PV



- Increased Yield (+ 18%)
- Decreased interannual variability (ca. 60% in Winter) and therefore less import
- No grid overload, in fact smaller average load than today

Conclusions



- Replacement of Nuclear with Wind (40%) and Solar (60%) is technically feasible and realistic
- High elevation locations facilitate energy change – let it snow!
  - More and more stable winds
  - Reduce the winter gap with PV siting and larger tilt
- No grid overload, in fact smaller average load than today
- Import / Export at current level

Steeper tilts allow gain in winter production without loss in annual total

Future - Solution

- PV on mountain buildings and other infrastructure, e.g. avalanche defense structures (St. Antönien)
- Find best locations for mountain wind installations – and then “Good Luck”
- Storage?
- Move PV and Wind (not Hydro) into the mountains – this helps close the winter gap