Using GIS data and satellite-derived irradiance to optimize siting of PV installations in Switzerland

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Background
- Swiss Energy 2050 strategy: Phase-out of remaining nuclear power plants
- Demand in electricity production covered by renewables
- Challenges: Solar energy highly variable (diurnally, annually and due to cloud cover)

Goal 1: Study different siting scenarios for PV installation and assess their impact on the power flow of the Swiss Electricity System

Goal 2: Exploit spatial and temporal correlation of irradiance and demand under existing constraints to enable most robust production

Challenges in a renewable Switzerland

Mismatch in space:
- Demand centers in the north
- Hydropower production and solar potential primarily in the south
- High regional residual demand
- Demand – Production

Mismatch in time:
1. Throughout the day
- Swiss-wide production and demand, Summer
- Swiss-wide production and demand, Winter

2. Throughout the year
- Annual total residual demand [TWh/cluster]

Assessment tool: Model of the Swiss electricity system
- Resolved for clusters, associated to transmission network substations
- Demand proportional to population density
- Model interval: flexible down to 15min
- Storage hydro: smart turbines & pumping
- Production from all renewables
- Import/Export balanced

Different PV siting scenarios

to produce the 20TWh/year of electricity needed to satisfy current demand

Potential annual production [TWh/km²]

Annual demand scaled with population density [TWh/km²]

Solar irradiance to electric power: 15% panel efficiency & different placement constraints

- Constraint 1: 15% of surface area in urban and 10% in industrial zones (total = 198km²)
- Constraint 2: Constraint 1 + 2% of agricultural and pastures (total = 530km²)
Always excluded: Lakes and zones above 2500m

Reactions of the Swiss electricity system: Power flow in time and space

Pumping
Storage
Hydropower
Solar
Transmission lines

Conclusions & Outlook:
- Siting and siting of PV installations to satisfy annual average demand is possible using available data, but temporally variable demand-supply mismatch remains.
- Next step: Include wind generation as additional resource to balance the intermittent production
- Investigate scenarios to stabilize the residual demand:
  - Increase pump storage capacity
  - Raise dams and explore other storage alternatives
  - Optimize Import/Export

Paper has too few dimensions: please check out our movies!!!

Data

Solar irradiance from satellite imagery
- 2004-2015, daily
- Surface incoming shortwave radiation (SIS)
- SEVIRI imagery using HeliosMont algorithm (Meteoswiss)
- Snow-cloud discrimination
- Probabilistic cloud mask
- 2.4km x 2.3km resolution
- Self and terrain-shading

SRTM DEM – 30m resolution
- 105.5km
- 103.5km
- 95.0km
- 99.6 km
- 101.9 km
- 101.2 km
- 96.7 km
- 82.9 km

Corine Landsurface Cover – 200m resolution
- 105.0 km
- 101.3 km
- 95.0 km
- 101.1 km
- 95.0 km
- 103.5 km
- 101.9 km
- 99.6 km

Additional data:
- Population density (SFIO)
- Swiss electricity demand + infrastructure (swissgrid)
- Hydropower information (SFIO/AVASTA, PRIVAM)

Annual demand
- Provisionally scaled by population density

Required surface area of installed PV for the different scenarios.

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Summit pixels</th>
<th>Uniform</th>
<th>Cluster-wise scaled by population density</th>
<th>Cluster-wise scaled by residual demand</th>
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<td>82.9 km²</td>
<td>101.3 km²</td>
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<td>-</td>
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