The bright side of snow cover effects on PV production - How to lower the seasonal mismatch between electricity supply and demand in a fully renewable Switzerland

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Switzerland’s path a fully renewable electricity production

Large existing hydropower production including pumped-hydropower

Good potential for “New Renewables”
Challenges remain:
Mismatch in supply and demand

Mismatch in time:

1. Throughout the day

Can be alleviated by conventional and pumped hydropower

2. Throughout the year

Critical to penetration of PV in the future energy market – Needs to be addressed!
How to address the seasonal energy gap in PV production?

1. Install a lot of storage

2. Change the production profile to have higher production in winter and lower in summer

   How?

3. Steeper panel tilt

1. More radiation in winter

2. More ground reflection in winter

Goal: Quantify impact of these 3 measures
Method: Model production potential based on satellite-derived information and panel tilt

- Clear sky Index (CI)
- Empirical methods
- Surface Incoming Shortwave Radiation (SIS)
- Direct beam
- Ratio: Diffuse/Global
- Surface reflectance
- Beam parallel shortwave
- Diffuse radiation
- Sky view factor
- Ground reflected
- Angle b/w sun ray and panel normal
- Diffuse radiation
- Ground view factor
- Panel normal beam
- Panel incoming diffuse
- Panel incoming ground reflected
- Panel Normal Shortwave

Electricity production (spatially and temporally explicit)
The environmental drivers

Irradiance [W/m²]

Snow Cover Duration (SCD)

The higher the better !!
The technical dial: Panel tilt

Annual total production

Winter production (1st Jan – 30th April)

Steeper tilts allow gain in winter production without loss in annual total
PV Placement Scenarios – 12TWh/year

Urban scenario:
- Conventional
- Roof-top installation
- Close to demand
- Lowest productivity

Mountain scenario:
- Innovative
- PV farms/mountain infrastructure
- Far from demand
- Highest productivity

Pixel Selection:
- With population
- Max. cover fraction (0-8%) per pixel

Pixel Selection:
- Below 2500m
- Max. cover fraction (0-8%) per pixel

Mountain No Snow:
- Re-run at constant surface reflectance of $r=0.2$
Scenario Comparison
Urban, Mountain Snow, No Snow

Required surface area to produce 12 TWh/year

Winter production [per scenario]

Winter production [per unit area]
Import reduction for mountain scenario (with respect to urban)
Shift from summer to winter production

Difference in production profile between urban and mountain

1. More radiation in winter
2. More ground reflection in winter
3. Steeper panel tilt

Panel tilt & location

<table>
<thead>
<tr>
<th></th>
<th>Panel tilt</th>
<th>PV area</th>
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</thead>
<tbody>
<tr>
<td>urban</td>
<td>40°</td>
<td>53km²</td>
</tr>
<tr>
<td>mountain</td>
<td>90°</td>
<td>42km²</td>
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</tbody>
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Tilt & location

snow