A Swiss Electrical Model
 stil nameless)
Without nuclear and gas: production deficit of 27.5 TWh/year (average 2009-2016)

→ 3.14 GW continuously, or 370 W/person

But what does it represent?
370 W/person is like:

- ½ horse
- Michi at full power
- Enough charge of my e-bike to go 10 times around the globe per year
What do we need to produce so much?

- **140 km²** of PV panels (15% efficiency)  
  now: **11 km²**

  → All Swiss roofs  
  or 9000x EPFL solar park

- More than **6000** wind turbines (2MW each)  
  now: **37**

  → 10x the largest US wind farm
Seasonality and variability

What does the production look like?

Mean and std 2009-2015

Moving average of 0.010417 days
Spatial variability

Annual solar irradiance [kWh/m²]
- 1300
- 1400
- 1500
- 1600
- 1700
- 1800
- 1900
- 2000

Long term average

Spatially distributed

time series

2017/12/07 - Jérôme Dujardin: Description of the Swiss electrical model
• 2025 grid (Swissgrid snapshot)
  (246 lines, 169+6 nodes, 25 transformers, 37 tie nodes/lines)
• 100 m area clustering based on geodesic distance with forbidden areas
  (Mountains above 2500 m.a.s.l, major lakes, borders)
Power generation data

- 513 run-of-river plants (WASTA 2016) → Annual production from WASTA + monthly river flow rate from PREVAH (200m)
- 69 storage hydropower plants (with 67 reservoirs) → Characteristics from WASTA + monthly reservoirs’ inflows from PREVAH
- Spatially distributed solar irradiance (Meteoswiss) → Hourly (1.6 x 2.3 km)
- Spatially distributed wind (Modeled, from COSMO 1 or 2) → Hourly (1.1 x 1.1 or 2.2 x 2.2 km) or from measurement (Meteoswiss, SwissMetNet network) → Hourly, 117 locations
- Geothermal projects (28 plants, constant production, 4.4 TWh/yr), current nuclear power plants (monthly aggregated production)
Modeled storage hydropower

- 92% of the national energy storage (8.8 TWh)
- 96% of the total installed capacity (12.25 GW)
- ~91% of the production (~20 TWh)
Water inflows (run-of-river, reservoirs)
Reservoir level management

- Mismatch between all sources and demand.
- Use of short-term storage (~ pumped hydropower)
- Accumulation of the mismatch through time

- Energy deficit in winter, surplus in summer
- Partially alleviated by the reservoirs
- Some deficit covered by import
- Some surplus (water) to export

→ Optimal times for the reservoirs to be full or empty
→ Shape of the reservoirs’ filling will impact the import behavior
Architecture of the model

- Import grid characteristics (Lines, nodes, transformers, area of interest)
- Clustering of the area
- Reservoirs’ filling fraction optimization
- Set the grid with generators
- Import inbuilt data (Demand, stor.hydro, RoR, PV, wind, geothermal, nuclear)
- Pairing the generation (geo-located) and the grid (clusters)
- Aggregation of generation: residual demand and dispatchable generators
- Selection of the period of interest
- Cost for stor.hydro vs import/export
- Optimal power flow (AC or DC) at a given time step
- Update water level (Stor.hydro use + inflow)
- Max power for stor.hydro and batteries (empty/full)
- Loop through the selected period
Outputs

Spilled water (energy): 0.43%
Max negative total volume: 0.00 m³
Storage Hydro production: 489.73 GWh
Non modeled stor.Hydro production: 8.26 GWh
Pump consumption: 7.89 GWh
Run-Of-River production: 212.66 GWh
Solar production: 161.45 GWh
Wind production: 130.77 GWh
Geoth production: 84.45 GWh
Surplus production (free disp.gen): 0.00 GWh
Surplus potential: 0.00 GWh
Curtailment: 0.00%
Swiss demand: 1316.59 GWh
Swiss residual demand: 711.11 GWh
Portion of residual demand: 54.01%
Import: 229.27 GWh
Export: 0.00 GWh
Net import: 229.27 GWh
Swiss production (with pumping): 1087.52 GWh
Losses: 0.00 GWh
Losses portion of demand: 0.00%
LineLosses: 0.00 GWh
EnergyStoredDiff: -99.88 GWh
TransmittedEnergy: 3708.62 GWh
Outputs

Spilled water (energy): 0.00%
Max negative total volume: 0.00 mio m³
Storage Hydro production: 3.62 GW
Non modeled stor Hydro production: 0.00 GW
Pump consumption: 1.32 GW
Run-Of-River production: 2.93 GW
Solar production: 0.00 GW
Wind production: 0.10 GW
Geoth production: 0.50 GW
Surplus production (free disp.gen): 0.10 GW
Surplus potential: 0.10 GW
Curtailment: 0.00%
Swiss demand: 7.12 GW
Swiss residual demand: 2.36 GW
Portion of residual demand: 33.21%
Import: 0.03 GW
Export: 0.00 GW
Net import: 0.03 GW
Swiss production (with pumping): 7.15 GW
Losses: 0.06 GW
Losses portion of demand: 0.88%
Line_losses: 0.06 GW
EnergyStoredDiff: 854.93 GW
TransmittedEnergy: 23.79 GW
Future

- More detailed PV production (higher spatial resolution → topographic shading)
- Spatially distributed wind energy → COSMO 2 and 1

Wind turbine capacity factor [%]

Required annual import [GWh]
THANK YOU FOR YOUR ATTENTION