Local energy communities in rural Switzerland: national-level scalability under different incentive schemes and economic scenarios

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Séminaire Energie-Environnement

E.Romano (UniGE)

Renewable Systems Group – Energy Systems Group

UNIVERSITÉ DE GENÈVE

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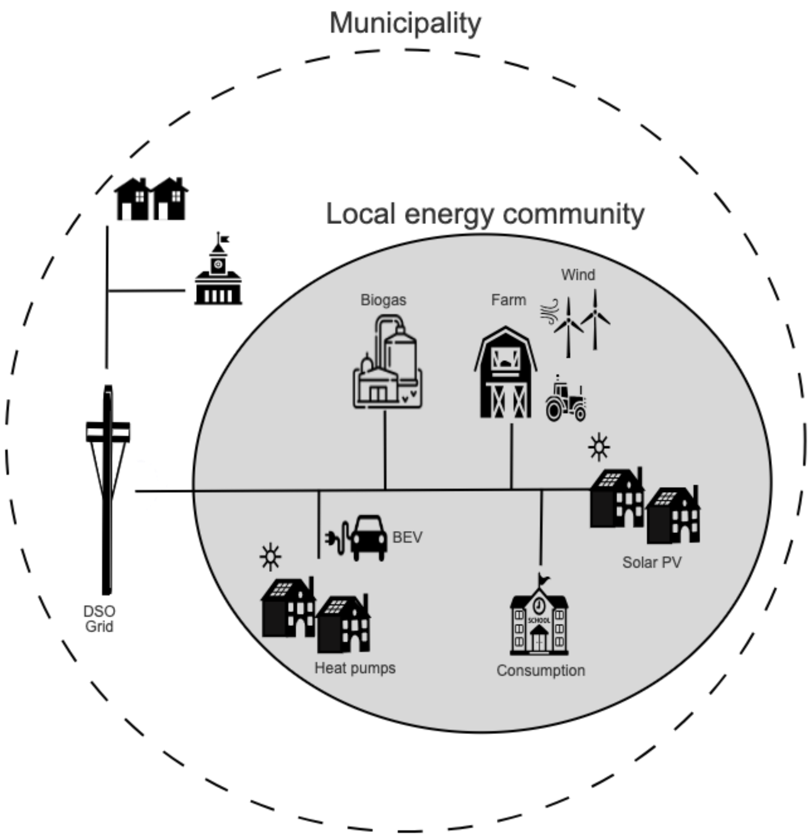
EDGE

New legislative framework

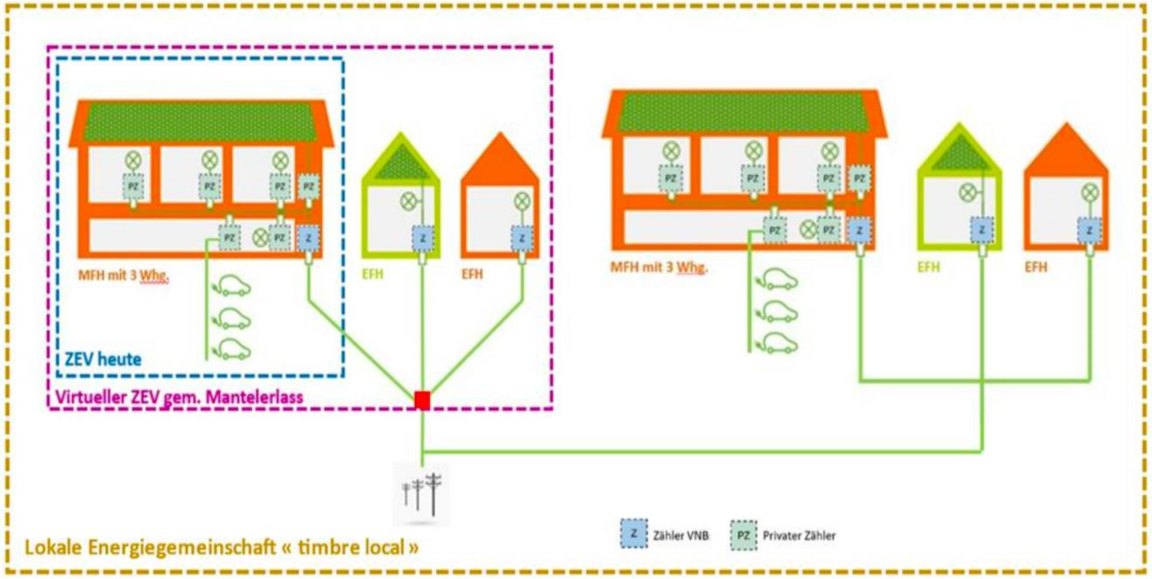
- Self-consumption is one of primary driver for new investments in renewable energy technologies in Switzerland.

- The **Mantelerlass (2023)** or **New Energy Act** introduces new business models for local energy communities (LECs).
  - Based on similar concept at the EU level, where citizens are actors.
  - LECs can operate within municipal boundaries, as long as the generated electricity is self-consumed.
  - LECs are allowed to use the local DSO (Distribution System Operator) grid for a reduced fee (ex 30% or 40%).
  - LEC might act as alternative suppliers to the DSO.
  - LEC generation capacities must be at least 5% of the total subcribed power capacity of all participating consumers.



LEC community

LEC & RCP



Source:
J.Grossen

Aspect	LEC (Local Electricity Community)	RCP (Regroupement de Consommation Propre)
Legal Scope	Broad concept aligned with EU/Swiss energy policy	Specific legal construct in Swiss law
Geography	Can include multiple buildings or even municipalities	Limited to one building or closely connected units
Energy Sharing	Diverse sources (PV, wind, hydro), flexible sharing using the DSO grid	Mostly solar PV, shared behind one grid connection

Research questions

- Which renewable energy portfolios are suitable for LECs?
- How much of the renewable energy potential in rural areas can be utilized by 2035 under the self-consumption models ?
- Which levels of self-sufficiency can be achieved (with and without battery storage)?
- How can LECs contribute to the 35 TWh target of new renewables set by the Mantelerlass ?
- Can LECs offer competitive costs?

LEC goals

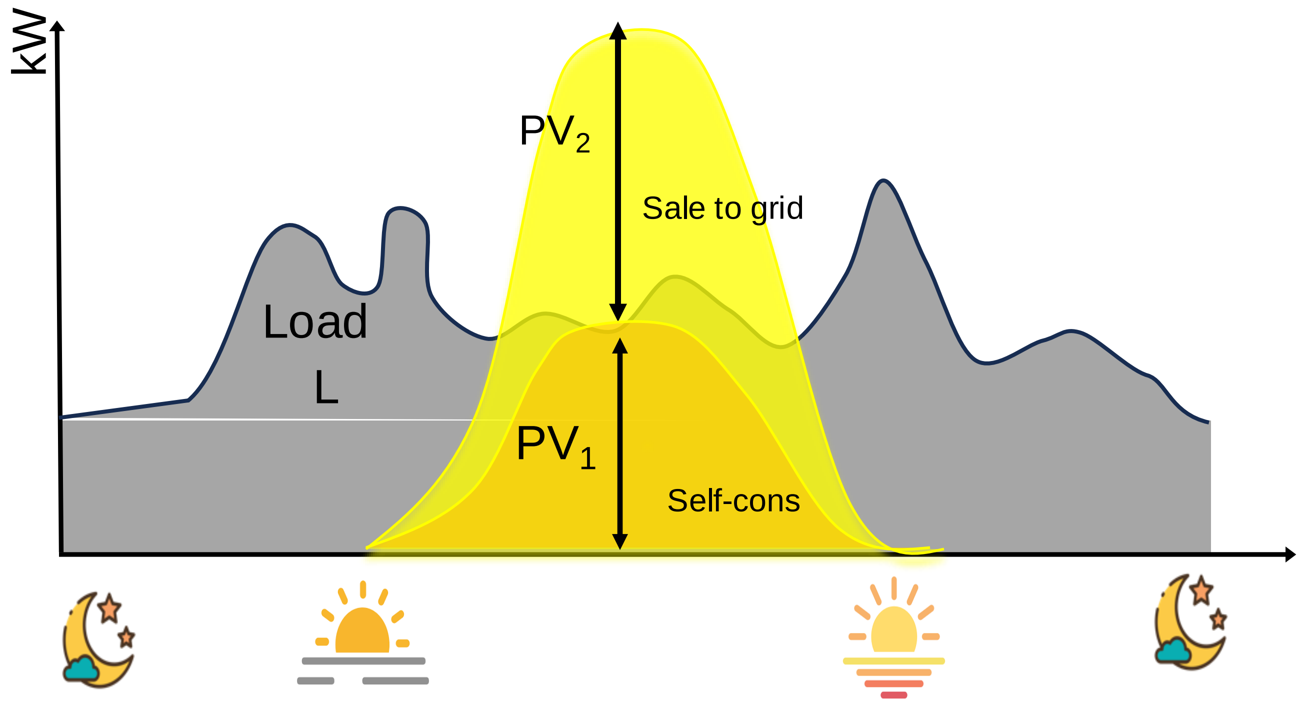
- Different goals for LECs
  - Depends on LEC governance form…
    - …cooperatives, non-profit organisation,
  - Depends on local context and local policy

  ➔ goals : environnemental, social, economic, technological or a mix of them

- This paper : LECs can have two different goals
  - **Private** : maximizing the return on investments (ROI) for LEC investors
    ➔ among different projects choose the one which provides the highest return.
  - **Social** : maximize the energy self-sufficiency
    ➔ minimizing the cost of electricity purchases for community members

- How do renewable portfolios differ according to the goals ?

Private objective



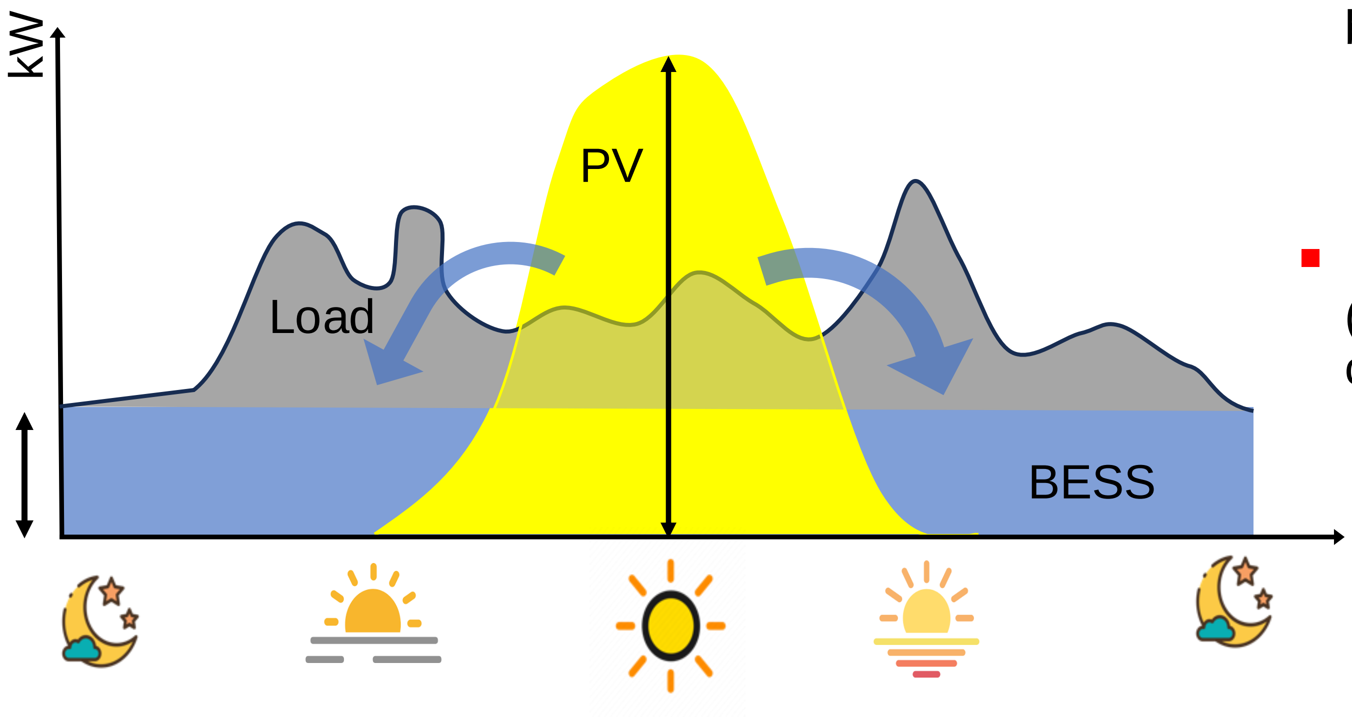
* **Example for only portfolio made of Solar PV.**

- Which renewables technologies and their sizing (kW) does the LEC choose to maximize ROI for its members?

- Trade-off in sizing :
  - **PV_1: increased capacity due to self-consumption benefits**
  - **PV_2: benefits from feed-in tariffs or market resale (direct marketing) (which can be less attractive than self-consumption benefits).**

- LECs seek for the optimal capacities of renewable technologies, considering the trade-off in capacity sizing, and interactions among technologies.

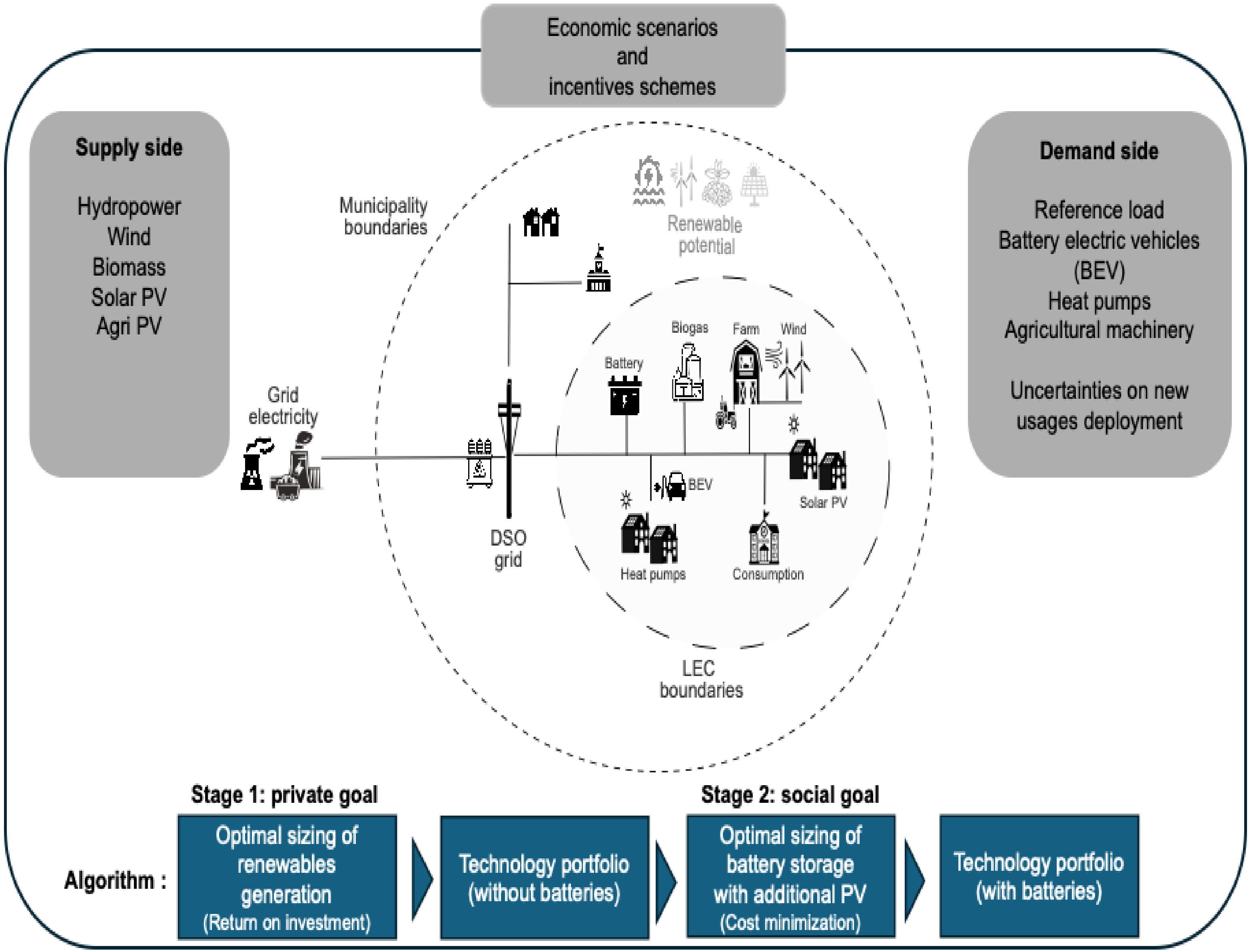
Social objective



- Which technologies and installation sizes does LEC choose to minimize electricity bills for its members ?

- LEC seeks for the optimal capacities (PV and batteries) for minimizing the cost of electricity procurement.

Methodology

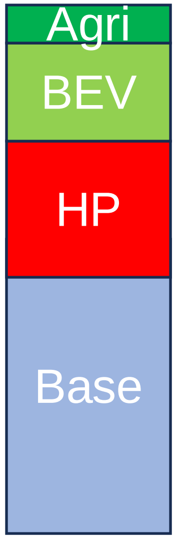


- Simulate investment decisions by LEC, within a two-stage algorithm…
  - 1st Stage : Private goal
  - 2nd Stage : Social goal
- …considering at local level:
  - consumption projections for 2035
  - available renewable energy potentials
  - current incentive schemes
  - different economic inputs (retail and feed-ins tariffs)
- …where LEC acts as price-takers agents.

Modelling 2035 electricity consumption

- Municipal level approach
  - 730 municipalities in rural areas
- Aggregation of electricity demand by use (bottom-up approach)
  - Reference (Base)
  - + Heat pumps (HP)
  - + Electric vehicles (BEV)
  - + Electrification of agricultural machinery (Agri)

  - = Consumption (annual 2035)
- Load profiles at a high-granularity : hourly values
- Uncertainty over the adoption of new usages (BEV, HP)
  - Different scenarios for the adoption of electric vehicles or heat pumps up to 2035
  - D1 : Low adoption
  - D5 : Median adoption
  - D9 : High adoption



Aggregation of reference load with new usages

Reference load model for municipalities

- Municipality consumption model
  - Based on oberved consumption and economic activities (nb of firms, nb of workers,…)
  - R^2 : 84.6%
  - 2-stage least square to eliminate potential endogeneity between independent variables and error term

- Data collection
  - Historical annual consumption at municipality level (2021)
  - 407 Municipalities consumption in BL, SG, AG, LU.
  - Activities based on BFS data

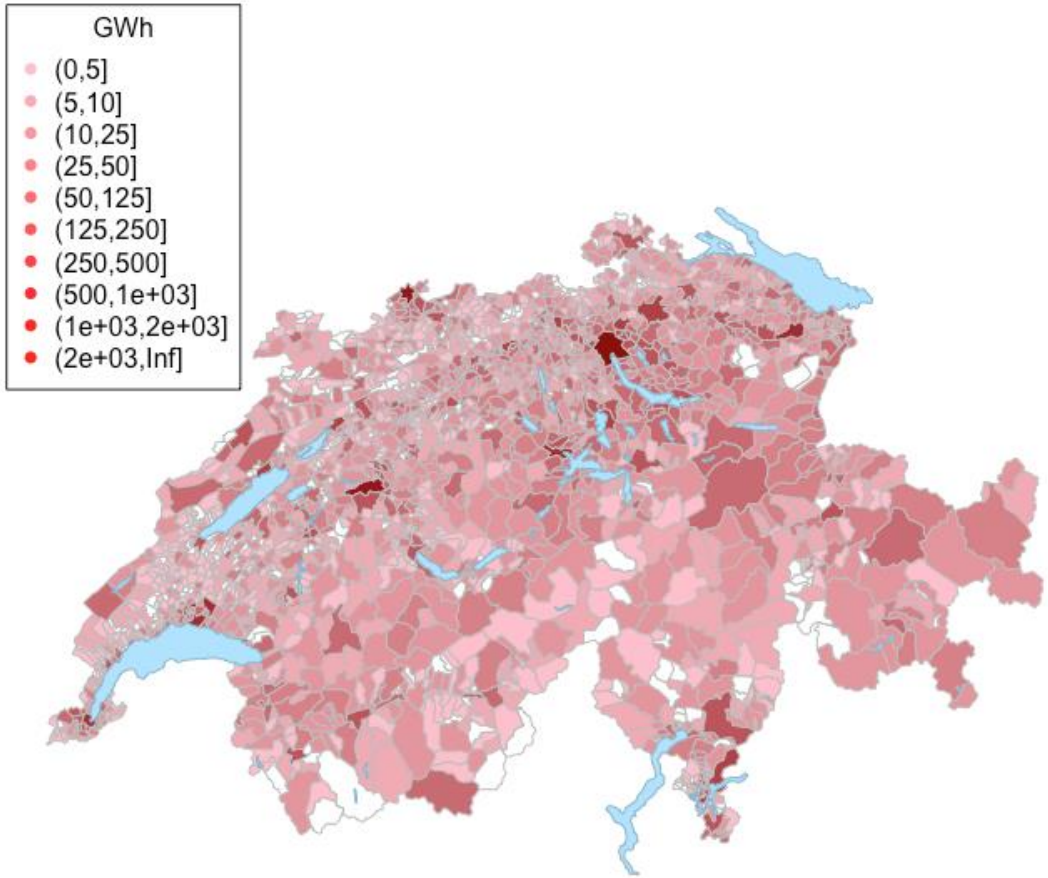
- Methodology inspired by SWEET-EDGE work (1)
  - Projection for a reference year

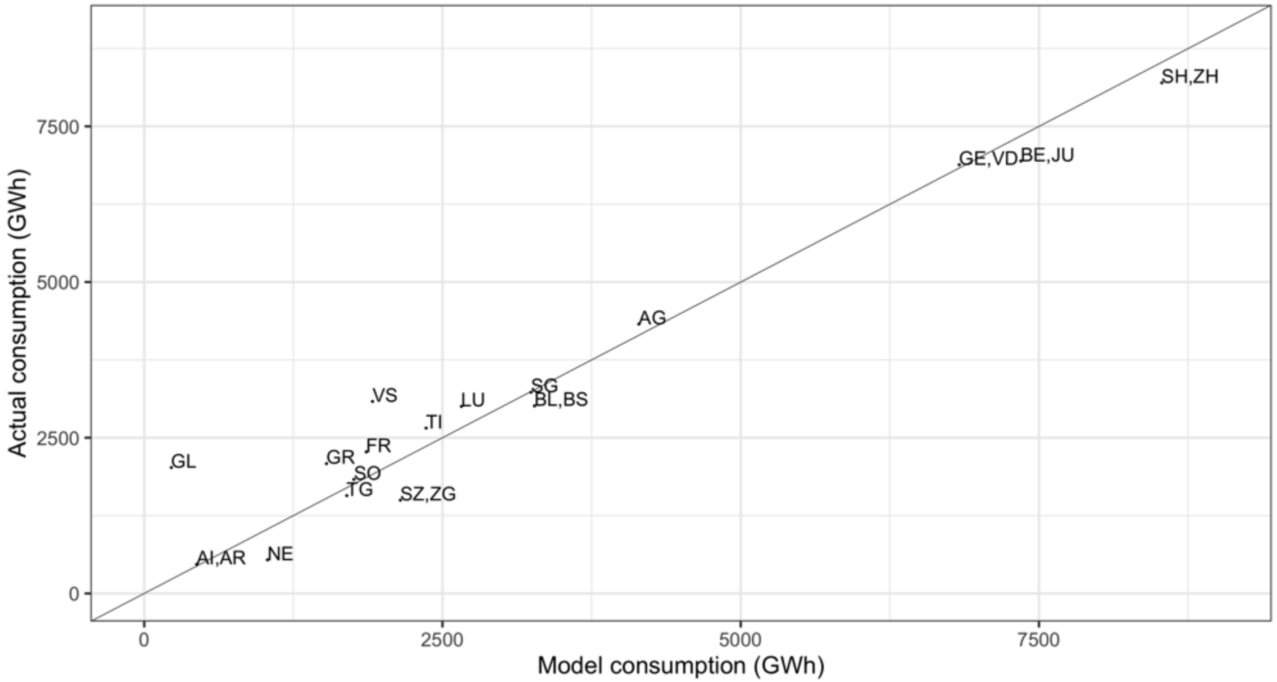
	Dependent variable:
	log(TOTAL_MWh)
log(`BeschÃ¤ftigte von aktiven Unternehmen` + `BeschÃ¤ftigte Vollzeit (ab 75%)`)	0.905***
	(0.161)
log(`Bestand aktiver Unternehmen` + Betriebe)	-0.143
	(0.240)
Constant	4.359***
	(0.229)
Observations	407
R^2	0.846
Adjusted R^2	0.846
Residual Std. Error	0.454 (df = 404)
Note:	*p<0.1; **p<0.05; ***p<0.01

(1) Stocker N. et al. (2023), "*Need for energy balancing by region for renewable energy system scenarios of Switzerland*", *SWEET-EDGE*.

Reference load estimates

- Estimate for all CH municipalities by 2018 (2151)
- Consistency check between Swissgrid actual and model estimate





Actual Cantonal consumption (Swissgrid) vs. model

Aggregate consumption : 52 TWh

Reference load profiles from…

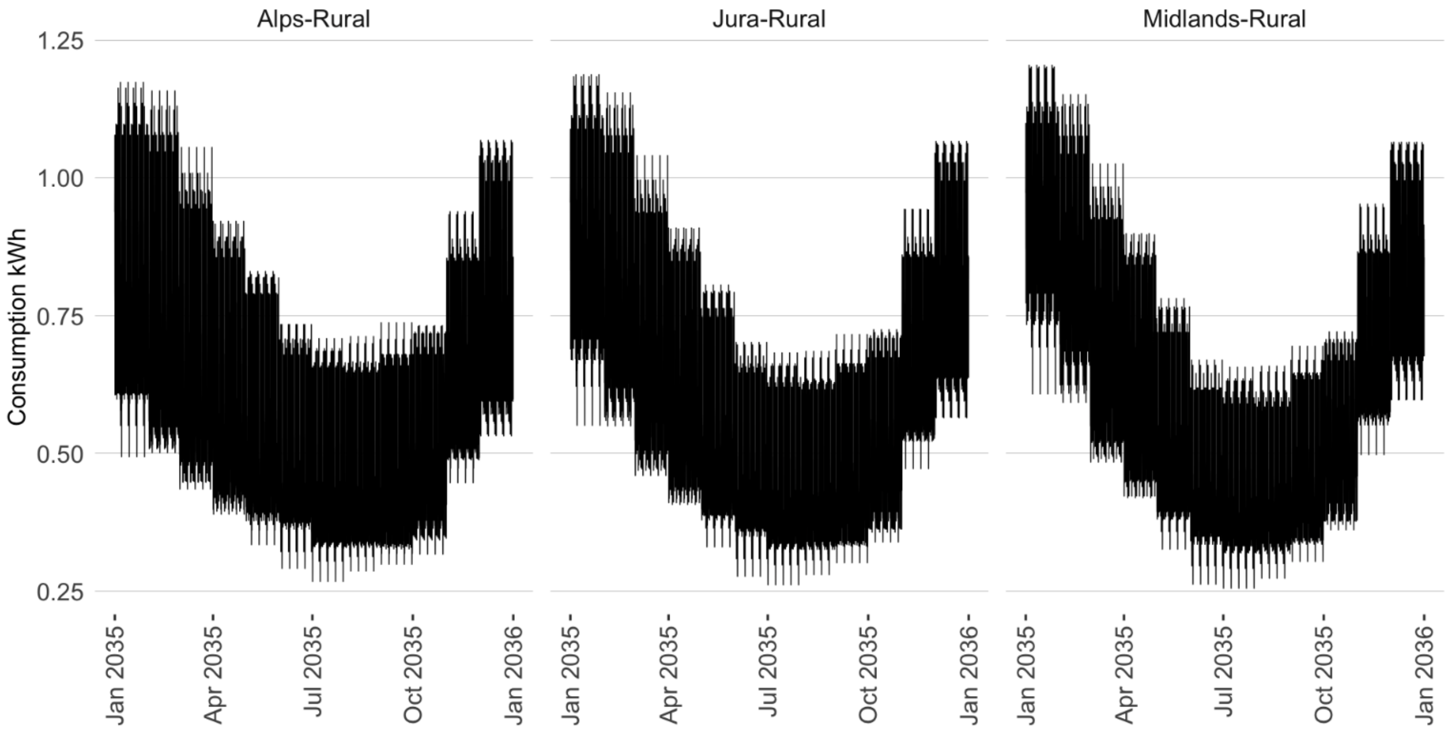


Figure S 3: Normalized consumption profiles for the different rural areas. The Alps and Midlands profiles are built from smart-meter data from the CKW distribution system operator. For Jura, the consumption profile is modeled by combining data from the two existing profiles and adjusting for the average altitude of municipalities in this area

- **CKW data**
  - Number of meters : > 100k smart-meters.
  - Cleaned over the period 2021-2023.
  - ~80 municipalities (covering midlands and alps areas).

- **3 rural hourly profiles**
  - Standard profiled based on the collected years
  - Midlands-rural
  - Alps-rural
  - Jura-rural (composite profile based on 2 previous depending on altitude)

Electrification of heat demand…

Building stock (1)

12 age-dependent categories

- <1919
- 1919 - 1948
- 1946 - 1960
- ⋮
- 2010-2015
- >2015

Heat demand (SH + DHW)

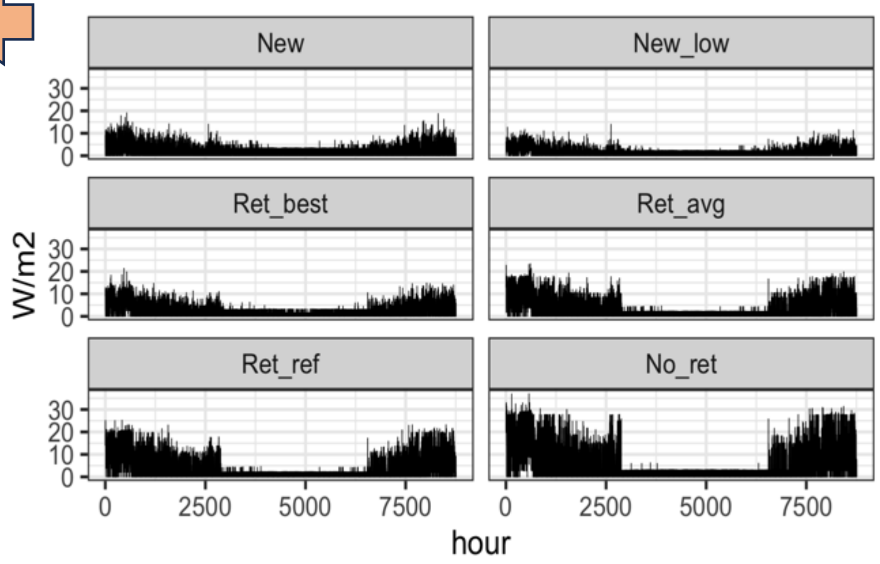
SRE (m2)

1. Compute consumption per m² (W/m²) for each category in each municipality
2. Associate a HP load profile to a building category based on consumption (W/m²) and estimate demand for heat
3. Aggregate HP load by municipality

Full electrification in CH : 30.1 TWh

Heat-pumps load curves for each municipality

Heat-pumps load curves (in W_{elec}/m^2) for different buildings with different heat demand (W/m²) (2)



(1) SCHNEIDER, S. et al. A Heat Demand Load Curve Model of the Swiss National Territory. In: IOP Conference Series: Earth and Environmental Science doi: 10.1088/1755-1315/290/1/012107

(2) FRAGA C. et al. (2018). Heat pump systems for multifamily buildings: Potential and constraints of several heat sources for diverse building demands. Applied Energy 225, 1033-1053.

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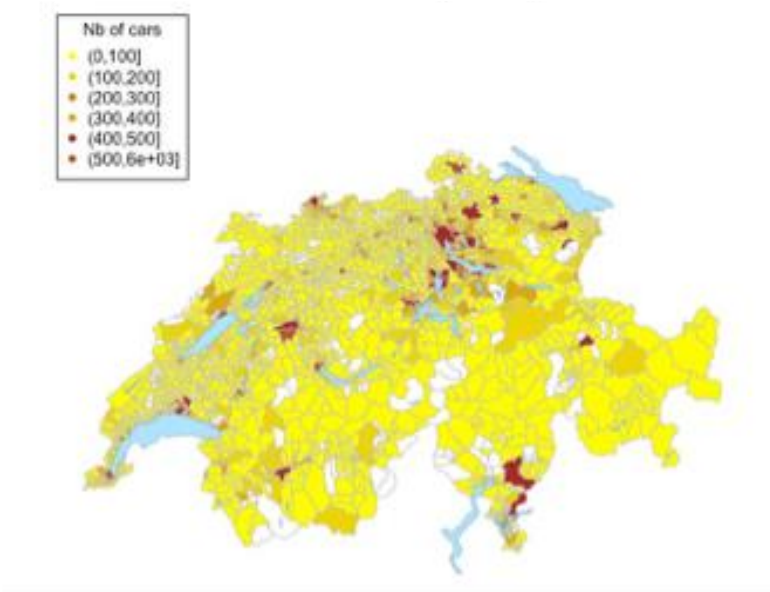
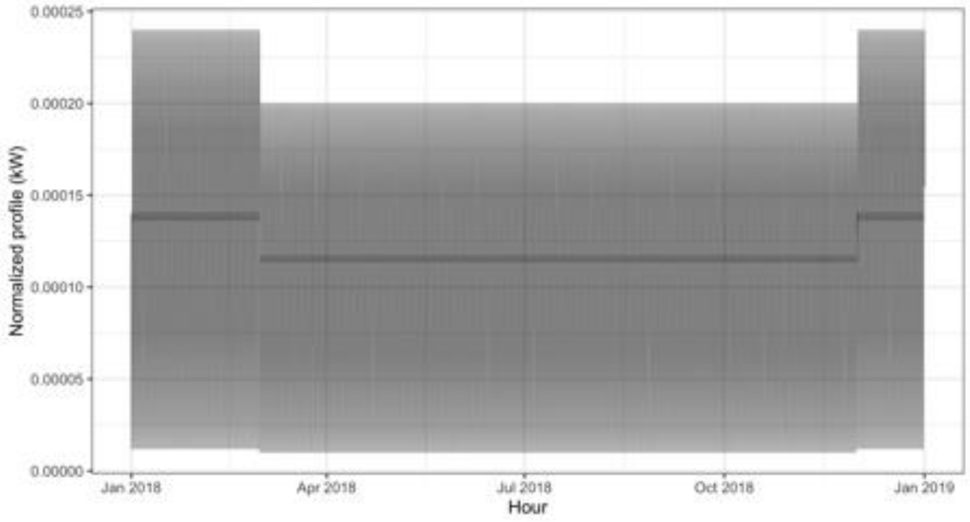
Electrification of vehicles…





1. Historical sales of BEV per municipality in 04/2024
2. Apply deployment path for BEV in municipalities up to 2035 (1)
3. Estimate electricity demand based on OFEN estimate on electricity demand (12.6TWh) for 4.6 millions BEV
4. Use load profile for BEV from literature (2)

(1) Zielonka N, Wen X, Trutnevyte E. Probabilistic projections of granular energy technology diffusion at subnational level. PNAS nexus. 2023 Oct;2(10):pgad321.

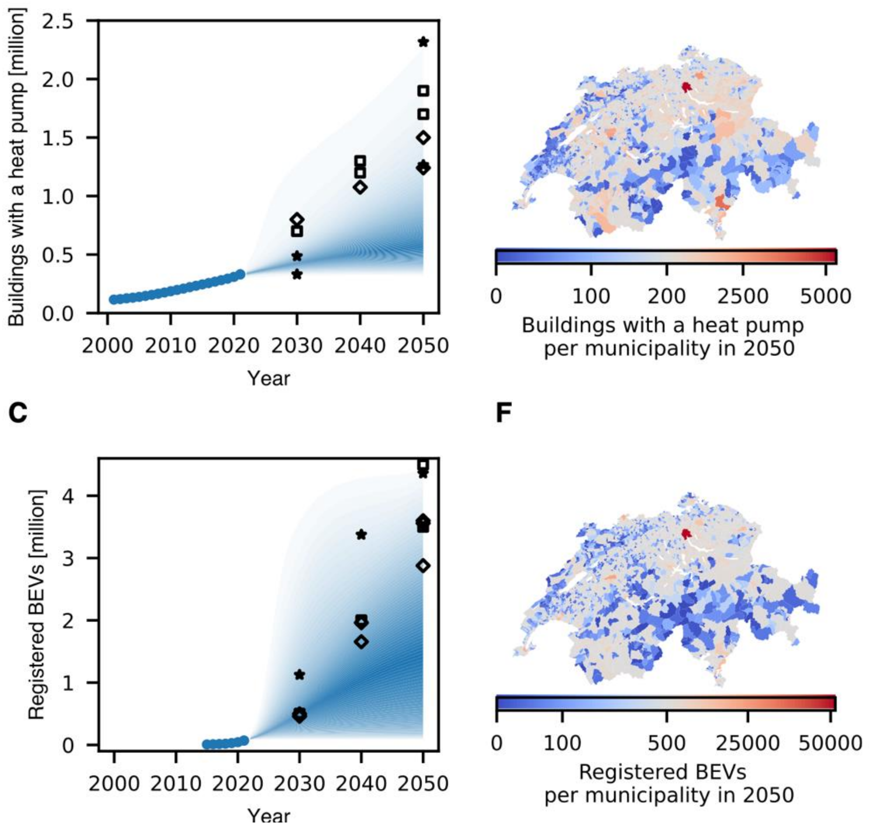
(2) Robinson, A.P., Blythe, P.T., Bell, M.C., Hübner, Y., Hill, G.A., 2013. Analysis of electric vehicle driver recharging demand profiles and subsequent impacts on the carbon content of electric vehicle trips. Energy Pol. 61, 337–348. https://doi.org/10.1016/ J.ENPOL.2013.05.074.

Uncertainty on deployment based on…

… probabilistic projections of energy technology diffusion at municipality level [(1)]

Heat-pumps

BEV



- Projection spatially for 2035 on the basis of heat-demand potential (30.4 TWh) by 2050
- Projection spatially for 2035 on the basis of historic BEV sales
- **3 diffusion pathways :**
  - D_1 : Low adoption
  - D_5 : Median adoption
  - D_9 : High adoption

(1) ZIELONKA, Nik, WEN, Xin, TRUTNEVYTE, Evelina. Probabilistic projections of granular energy technology diffusion at subnational level. In: PNAS Nexus, 2023, vol. 2, n° 10, p. pgad321. doi: 10.1093/pnasnexus/pgad321

Demand & load scenarios

Usage	Demand Scenario	Rural				National	Potential
		Alps TWh/year in 2035	Jura TWh/year in 2035	Midlands TWh/year in 2035	Total TWh/year in 2035	TWh/year in 2035	TWh/year
Reference Load	D_5	4.5	1.1	2.9	8.6	52.0	52.0
Heat pumps	D_1	0.3	0.1	0.3	0.7	3.6	30.1
	D_5	0.4	0.1	0.4	0.9	4.7	
	D_9	0.6	0.2	0.5	1.3	6.7	
BEVs	D_1	0.05	0.02	0.03	0.1	0.6	12.3
	D_5	0.2	0.1	0.2	0.4	2.6	
	D_9	0.5	0.1	0.3	0.9	5.4	
Agricultural transport	D_1	0.00	0.00	0.00	0.00	N/A	0.18
	D_5	0.01	0.00	0.01	0.02		
	D_9	0.03	0.01	0.02	0.05		
Total	D_1	4.9	1.2	3.3	9.4	56.2	94.5
	D_5	5.1	1.3	3.5	9.9	59.3	
	D_9	5.5	1.5	3.8	10.8	64.1	

- National demand by 2035.
  - D_1 : 56.2 TWh
  - D_5 : 59.3 TWh
  - D_9 : 64.1 TWh
- Rural communities by 2035 :
  - Total : 9.4 to 10.8 TWh
  - Reference load : 8.6 TWh
  - Heat–pumps : 0.7 to 1.3 TWh
  - BEVs: 0.1 to 0.9 TWh
  - Share of rural : 16 to 17%
- In line with other estimates in SWEET-EDGE studies.

Generation potential & profiles

	Rural areas					National
Technology	Alps (GWh/year)	Jura (GWh/year)	Midlands (GWh/year)	Total (GWh/year)	Number of municipalities (nb of profiles)	Potential (GWh/year)
Solar PV	9'194	1'908	6'038	17'140	730	65'872
Apri PV	2'896	951	2'279	6'126	730	13'100
Wind power	6'701	4'263	3'571	14'535	378	29'454
Biomass	542	113	283	938	714	3'070
Small hydro	561	30	60	651	118	3'762

Table S 4 :Renewable electricity generation potentials for the different technologies in the 730 Swiss rural municipalities and the national level.

- Technologies :
  - Building-integrated PV,
  - Agri PV,
  - Wind,
  - Biomass (woody and non-woody)
  - Small hydro (end of concession < 2035)
- National generation potential

  116 TWh
- Rural municipalities potential

  40 TWh

- Spatio-temporal profiles are used to reflect both the geographic distribution and time-varying availability of the various renewable resources.

Incentive schemes

<table>
<tr><th>Technology</th><th colspan="3">Investment
grants</th><th colspan="4">Per kWh
payments</th></tr>
<tr><td>PV</td><td colspan="3">Unique Retribution (Pronovo, 2023)
(CHF/kW)</td><td colspan="4">Municipality level
Feed-in tariff from distribution system operators
or market reference price if direct marketing for large installations (>100kW)</td></tr>
<tr><td>Agri PV</td><td colspan="3">Up to 60%
(if without self-consumption)</td><td colspan="4">Direct marketing with market reference prices</td></tr>
<tr><td>Wind</td><td colspan="3">Up to 60%</td><td colspan="4">Direct marketing with market reference prices</td></tr>
<tr><td rowspan="5">Biomass</td><td colspan="3">Investment
lump-sum grants</td><td colspan="4">OPEX contributions
(Swiss cents/kWh)</td></tr>
<tr><td>Biogas</td><td>Woody biomass</td><td>Sewage sludge</td><td>Capacity (kW)</td><td>Biogas</td><td>Woody biomass</td><td>Sewage sludge</td></tr>
<tr><td rowspan="3">Up to 50%</td><td rowspan="3">Up to 40%</td><td rowspan="3">Up to 20%</td><td>< 50</td><td>30</td><td>16</td><td>market</td></tr>
<tr><td>< 500</td><td>19</td><td>13</td><td>market</td></tr>
<tr><td>< 5000</td><td>10</td><td>11</td><td>market</td></tr>
</table>

Table 1: Incentive mechanisms considered for the renewable generation investments in rural local energy communities, split between investments grants and per kWh payments.

- Variety of incentives in CH.
  - Federal incentives
  - Local incentives (Cantonal or DSO)
- Some federal subsidies are lower or not applicable if part of the generation is self-consumed within LEC.
  - Ex. Agri PV or wind
- Identify incentive schemes at the national and local level, which are available for renewable investments by a LEC, with self-consumed generation or not.

Model & economic scenarios

- Computation of optimal investment decisions with :
  - varying load demand (D_1,D_2, D_3)
  - varying economic scenarios
  - cost assumptions from literature
  - WACC varying with technology.
- 7 economic scenarios based on historical data (2017-2023), capturing key economic inputs at municipal level.
- Key economic inputs includes
  - Retail tariffs at municipal level (ELCOM H4)
    - ➔ Valuation of self-consumption
  - Feed-in tariffs at municipal level
    - ➔ Local subsidies scheme
  - Direct marketing
    - ➔ Reference market prices (EPEX)

For each demand scenario (D_1,D_2, D_3)
7 Outputs

Results
expected value of simulations outputs

Sensitivity analysis
extreme values

Results – demand scenarios

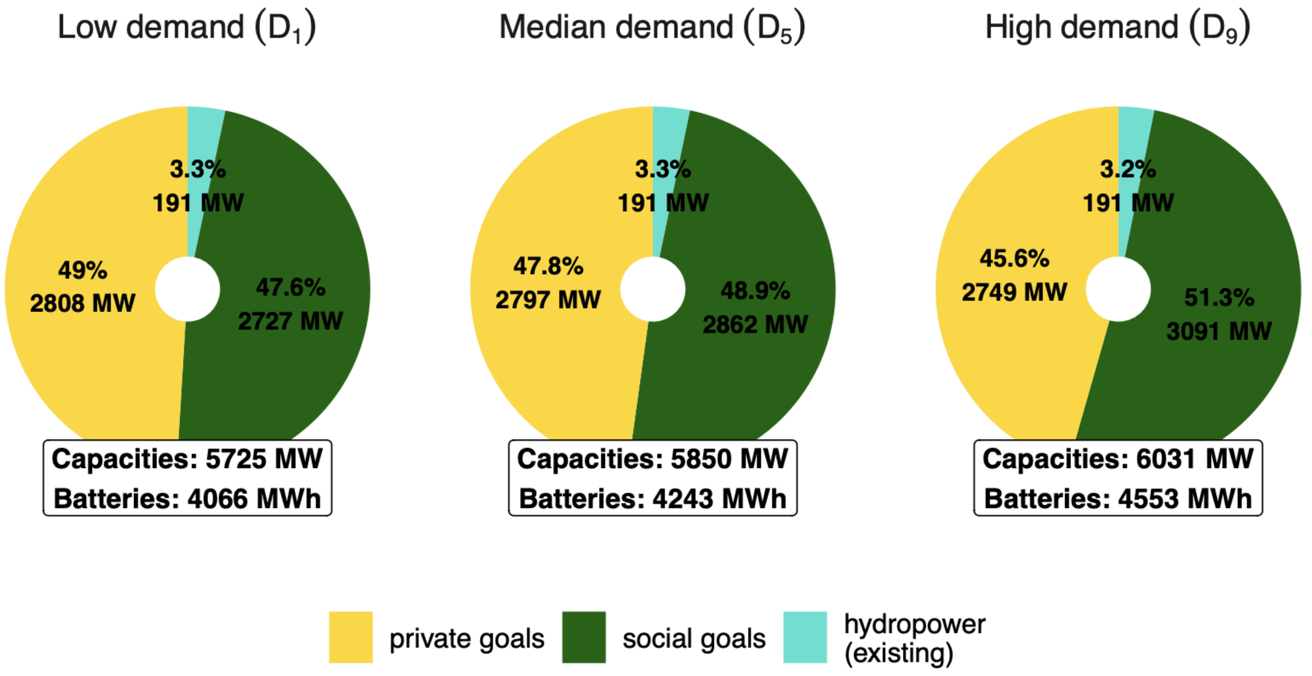


Figure 2: Optimal renewable generation capacities and batteries storage in 2035 for each of the demand scenarios (D_1, D_5, and D_9) in 730 Swiss rural communities, resulting from the two-stage algorithm. The yellow color represents the share of capacities derived from the private objective of return on investment (first stage of the algorithm), while the green color depicts the share of additional capacities added under the social objective (second stage of the algorithm).

- Capacities resulting from the first-stage of the model algorithm are very similar through the different demand scenarios (D_1 to D_9)
  - half of the generation capacities are deployed (average : 2794 MW) in the first stage
  - additional usage (HP, BEV) have little impact on the sizing decision by the LEC in the first stage
- LECs optimizing for social goals for the community, additional solar PV capacities (2909 MW, +51% on average) are additionally installed, as batteries complement the investment decision.

Results - economic scenario

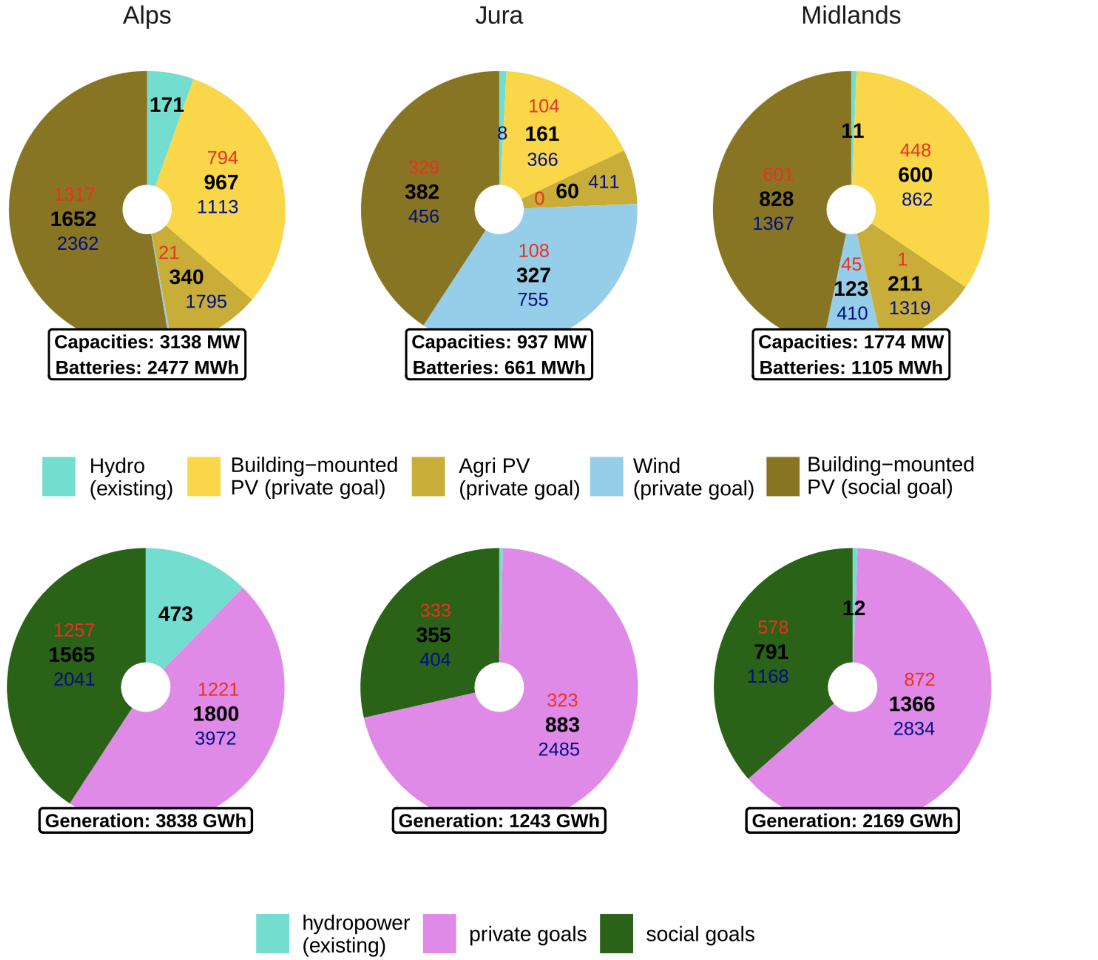


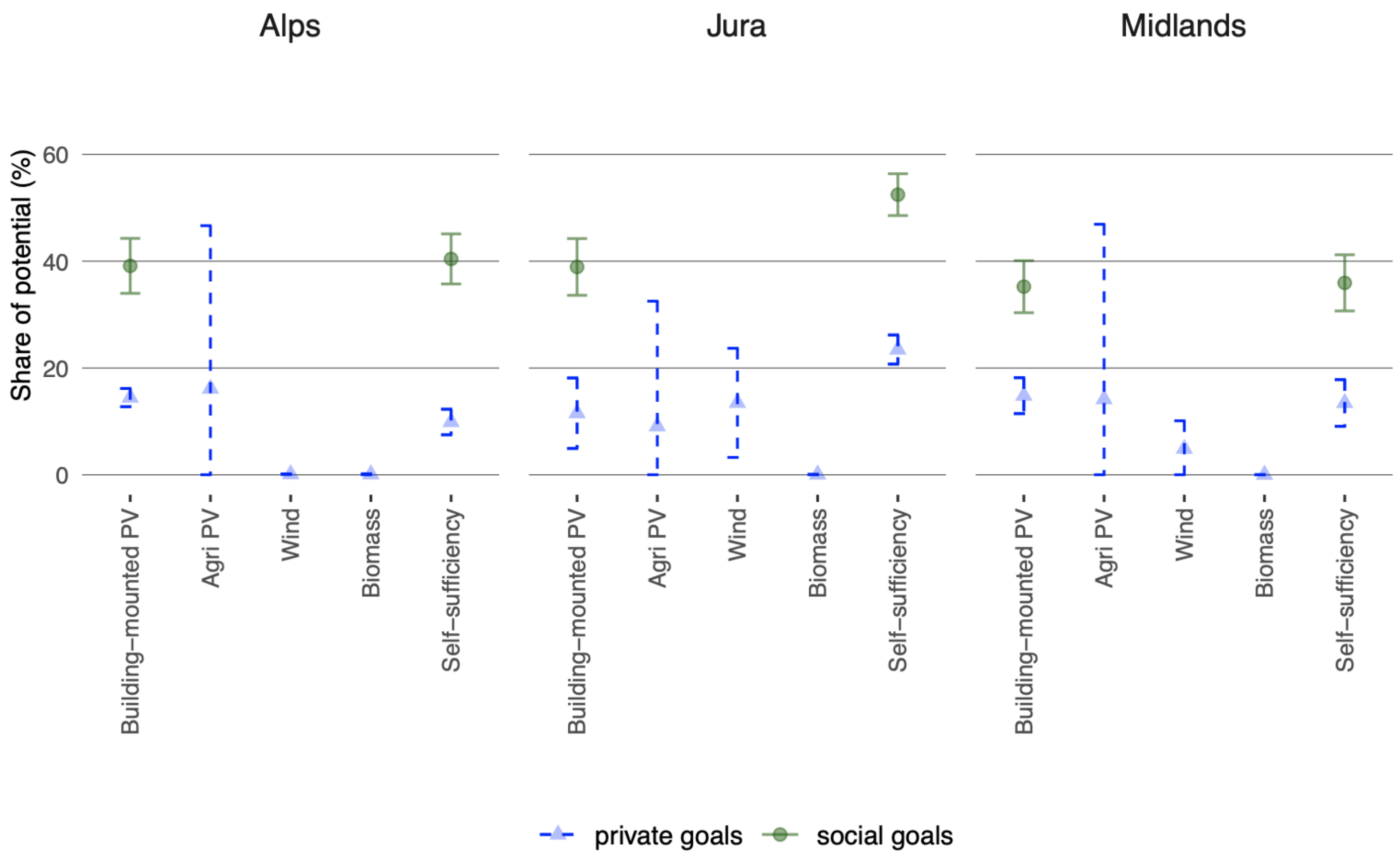
Figure 3 : Optimal renewable generation capacities and storage (top) and expected generation outputs (bottom) from rural LECs in 2035 in the Alps, Jura and Midlands for the median demand scenario. The distinction is made between capacities and generation from optimizing the private objective of return on investment (first stage of the algorithm), and the additional generation capacities and storage added under the social objective (second stage of the algorithm). Blue and red figures represent the extreme values, with blue indicating the most favorable economic scenarios and red the least favorable.

- Portfolios (MW) - aggregated by areas
  - Alps : Building-mounted PV and Agri PV
  - Jura : More diversified portfolio with wind
  - Midlands : Building-mounted PV and some Wind
- Generation (MWh) - aggregated by areas
  - Private goal : 4’049 GWh,

    contribution: 12% of 2035 target (35 TWh)
  - Social goal : 8’505 GWh

    contribution: 23% of 2035 target (35 TWh)
- Economic context (ie. market prices) and incentive scheme : decisive parameter for the deployment of generation technologies, especially for Agri PV and Wind.

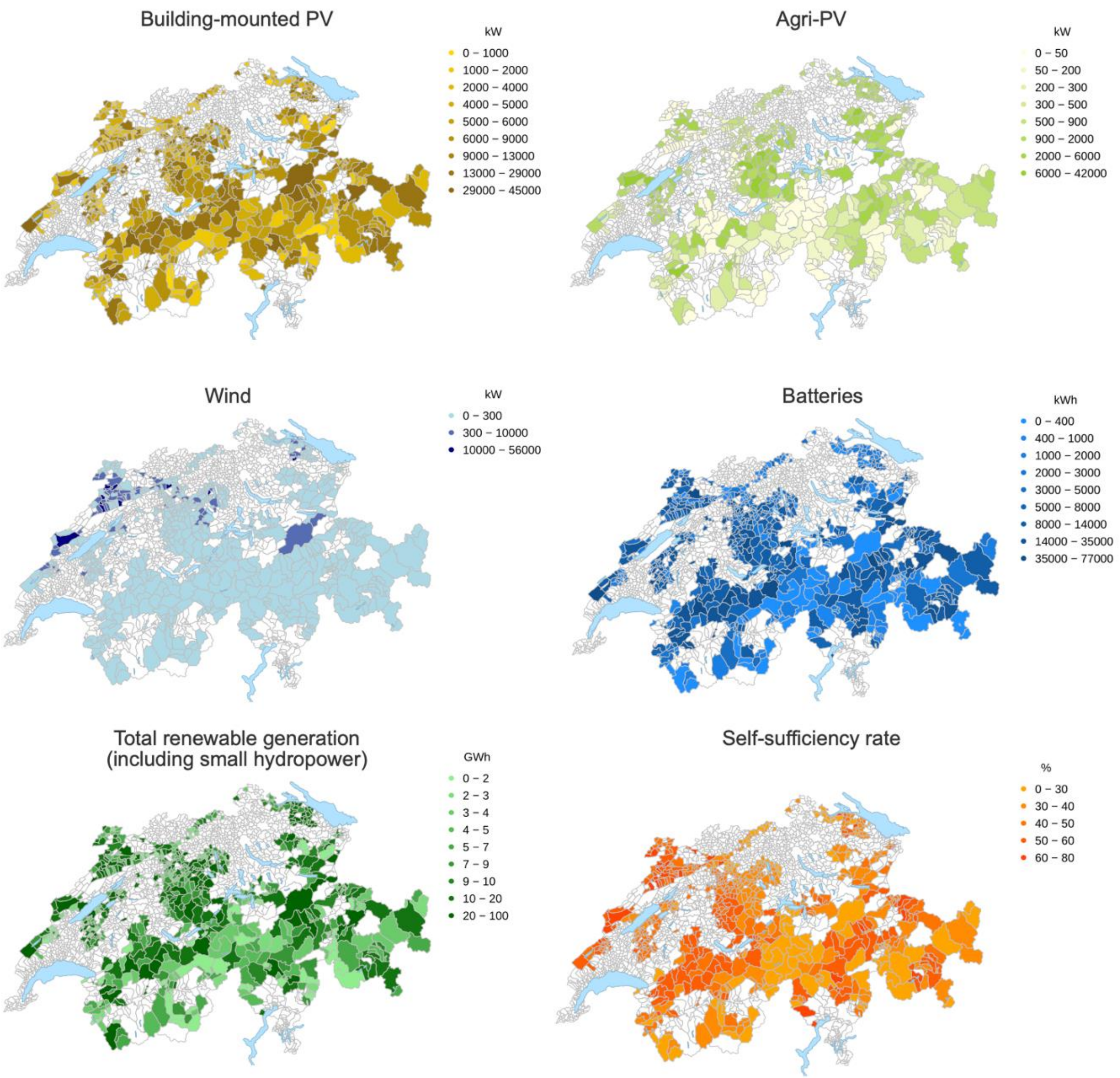
Results - Potential usage



- Private goal:
  - Solar PV : 18%
  - Agi PV : 14 %
  - Wind : 9%
  - Self-sufficiency: 17 %
- Social goal:
  - Solar PV : 38%
  - Self-sufficiency : 41%
- Uncertainty higher for wind and Agri-PV
- Low uncertainty on self-sufficiency ➔ better sale to market instead of consuming when prices are high

- Share of the potential which can be used by LEC in rural areas are limited
  ➔ how the remaining potential could be used for the non-rural areas (peri-urban, and urban) ?

Results - Spatial analysis



- Spatial analysis provide :

- View of technology portfolio for municipalities

  Building-mounted PV
  Agri PV
  Wind
  Batteries

- Distribution of capacities among them

- Variation of self-sufficiency rate

- But last not least ….

Results - LEC competitiveness

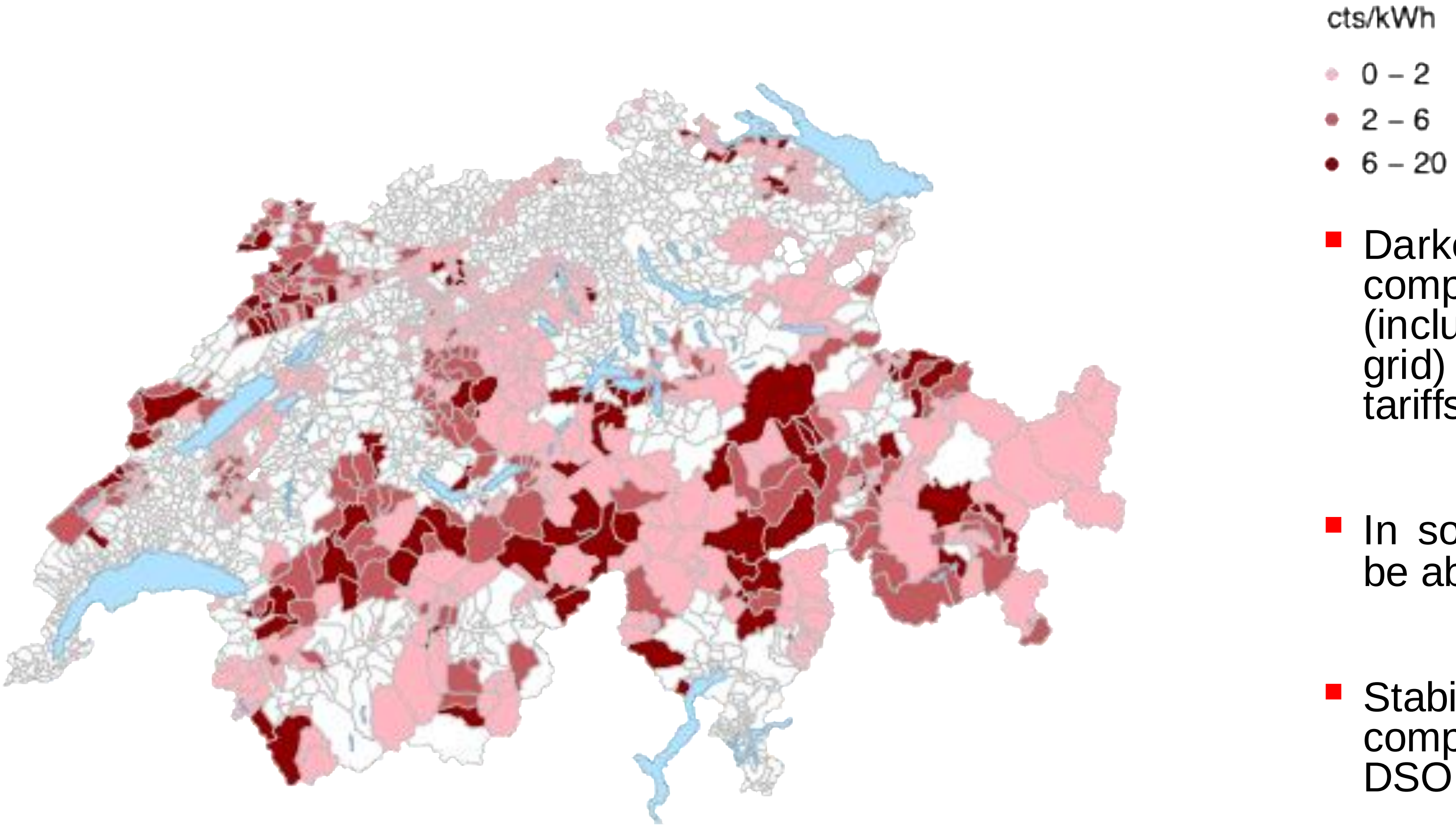


Figure 6 : Competitiveness of LECs, measured as a difference between the costs of LECs (which include costs for generation, batteries and the fees charged by the local distribution system operator for using its grid as a microgrid) as compared to grid tariffs.

- Darker colors depicts higher competitiveness of LEC costs (including reduced fees for using the grid) in comparison to DSO retail tariffs (ELCOM H4)
- In some municipalities the gap can be above 6 cts/kWh
- Stability of LECs costs in comparison to procurement costs of DSO.

Conclusions

- LEC can help to achieve 8TWh or 23% of the 2035 target (35TWh)
- Local generation can meet 4 TWh (41%) of rural electricity demand by 2035
  - → 6 TWh (59%) of imports from outside the municipalities.
- However, if LEC strategy is driven purely by return on investment
  - → underutilization of the renewable generation potential in the communities
  - → generation drop to less than 12% of the 2035 target
  - → misses opportunities for the LECs to contribute to the national taget.
- Economic parameters (ie. market prices) and incentives schemes are decisive parameters
  - → Specially for some generation technologies (Agri PV and wind power)
- Targeted policy adjustments are needed for fully harnessing the available renewable energy potential by LECs.
  - → policy frameworks must be adapted to enhance scalability and reduce investment risks for some technologies.
- LEC can offer competitive electricity to members in comparison the the DSO supply tariffs.

REGISTRATION OPEN

SECOND SWISS CONFERENCE ON DECENTRALIZED ENERGY

22 May 2025

In Bern

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Picture credit: Sorell Hotel Ador

More information

elliot.romano@unige.ch

Romano E. et Trunevyte E. 2025, Local energy communities in rural Switzerland: national-level scalability under different incentives schemes and economic scenarios, SWEET-EDGE, Working paper

Economic Inputs overview