Task 4.4

Title

Joint Activity Scenarios & Modeling (JA-S&M)

Project (presented on the following page)

Joint Activity Scenario & Modelling (JASM)
The JASM team

Are Interactive Web-Tools for Public Engagement Worth the Effort? An Experimental Study on the Swiss Electricity Supply Scenarios
Georgios Xexakis, Evelina Trutnevyte

Investment and generation cost trade-offs between cost-efficient vs. regionally equitable distribution of renewable electricity
Jan-Philipp Sasse, Evelina Trutnevyte

SCCER-SoE Annual Conference 2018

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Joint Activity Scenarios & Modelling

The JASM team representing all 8 SCCER
(Contact: gianfranco.guidati@sccer-soe.ethz.ch)

Our mission

The Swiss energy system supplies electricity, heat and mobility services to the domestic, commercial, industrial and transport sectors. The combustion of fossil fuels – mostly for heating and transportation – emits approx. **38 MT_{CO2}/a**. Following the objectives of the Energy Strategy 2050 and the Swiss INDC, we will create scenarios how to reduce emissions in 2050 down to **10 MT_{CO2}/a**.

Three questions shall be answered:
1. What technical means are most effective to reach the 2050 goals?
2. Which political instruments are needed to push this development?
3. What is the economical and social impact of this transition?

Our principle: Open team / Open data

Modelling teams from seven institutions – representing the eight SCCER – work together towards the objectives of JASM. Every other school, institute or company is invited to contribute with data and to profit from the combined knowledge of the JASM framework.

The idea is to agree on input data such as the future evolution of demand, supply potential and technology characteristics but to maintain the diversity of modelling approaches. All data is shared on the project website www.sccer-jasm.ch.

Elements of scenarios

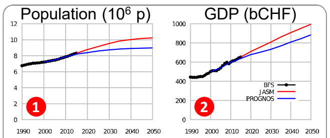
Major driver	
Population	1
GDP	2
Sectoral GVA	
Energy ref. area	
Climate change	
Energy intensity	

Yearly aggregate	Residential	Commercial	Industrial	Transport
Electricity	—	3	—	
Space heating	—	6	—	
Warm water				
Process heat				
Person-kilometer				
Ton-kilometer				

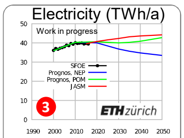
Hourly time series	Residential	Commercial	Industrial	Transport
Electricity				
Space heating	4			
Warm water				
Process heat				
Person-kilometer				
Ton-kilometer				

Generation technologies	Potential	Time series
Solar PV		
Solar thermal		
Hydro river	5	
Hydro storage		
Wind		
Geothermal		

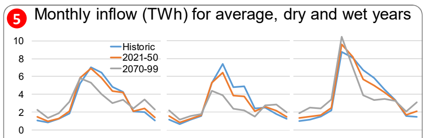
Technology characteristics	Invest. costs	O&M costs	Efficiency	CO2 intensity
Thermal power				
Renewable power				
Heat generation			7	
Efficiency measures				
Storage				
Fuels				



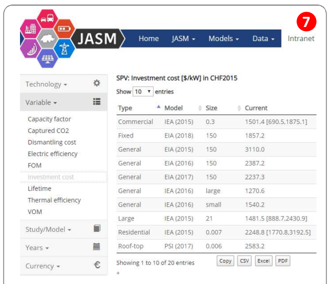
Higher expected population growth impacts extrapolation of future energy demand



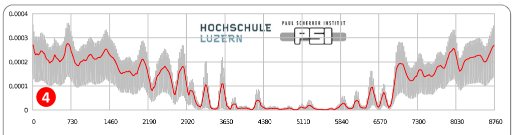
Updated future demand higher than Prognos



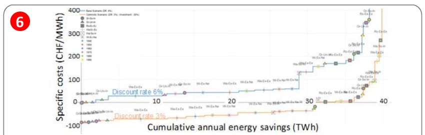
Swissmod estimates impact of climate change on hydro power production



Technology characteristics structured and published on www.sccer-jasm.ch

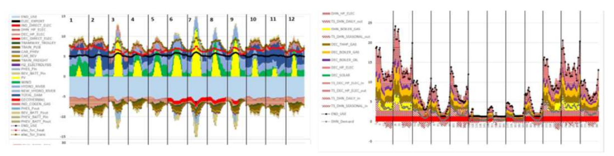


Synthetic heating demand time series using population-weighted daily temperature distribution and intra-day shape functions

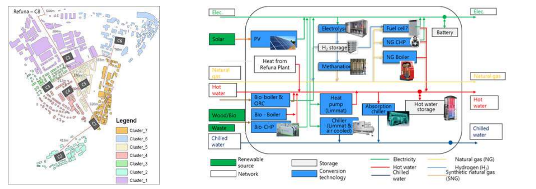


EECC tool ranks cost-effective renovation measures to reduce future heating demand

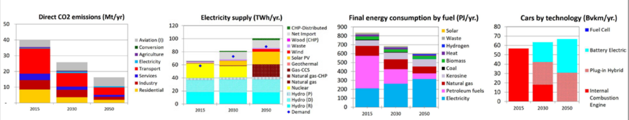
Selected results



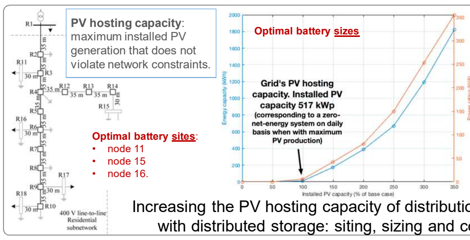
Update of SwissEnergyScope model to include typical days at hourly resolution; adds to the portfolio of full energy system models in JASM



Collaboration between EMPA and Regionalwerke Baden will result in scenarios for the future heat supply to Baden Nord



Preliminary results obtained with the Swiss TIMES Energy System Model (STEM) to test the quantification of the "Reference Climate Scenario" and the interfaces between STEM and the rest of the modelling frameworks employed in JASM



Battery costs

Installed capacity	Cost (CHF)
50%	0
100%	16k
150%	125k
200%	256k
250%	463k
300%	795k

Increasing the PV hosting capacity of distribution grids with distributed storage: siting, sizing and costs

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Panos, E., Kannan, R. (2018). Challenges and Opportunities for the Swiss Energy System in Meeting Stringent Climate Mitigation Targets, In Giannakidis G., K. Karlsson, M. Labriet, B. Ó Gallachóir (eds.) Limiting Global Warming to Well Below 2°C: Energy System Modelling and Policy Development, p. 155-172
Gupta, R., Sossan, F., Scolari, E., Namor, E., Fabietti, L., Jones, C., and Paolone, M. (2018). An ADMM-based coordination and control strategy for PV and storage to dispatch stochastic prosumers: Theory and experimental validation. 20th Power Systems Computation Conference, PSCC, 2018.

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Are Interactive Web-Tools for Public Engagement Worth the Effort? An Experimental Study on the Swiss Electricity Supply Scenarios

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Introduction and research questions

Interactive web-tools are often regarded as powerful methods to familiarize and engage the public with complex problems, such as those related with a national energy transition [1]. Nevertheless, including interactivity is much more resource-consuming than traditional methods and, in some cases, may even complicate communication [2]. Although studies exist on how to design and assess interactive web-tools [3], there is little empirical evidence whether they can be more effective in comparison with static methods [4]. We studied this in an experimental design survey with non-experts in the German-speaking part of Switzerland. As a case study, we used the Swiss electricity supply scenarios for 2035 and their environmental, health, and economic impacts.

Our study [5] aimed to address the following questions:

1. How do interactive and static web formats of scientific information perform in terms of making this information understandable, trustworthy and engaging for non-expert users?
2. How do the demographics, prior experience with the topic, numeracy, and website navigation skills of the non-expert users, influence this performance for each format type?

Methodology

We conducted a between-groups experiment online (N=313 total), where the two experimental groups differed in the format of scenario information they received: (a) an interactive web-tool that we have developed in a previous study [6] as an interface for exploring a large database of electricity supply scenarios and impacts (Figure 1), and (b) a static website presenting only four distinct electricity supply scenarios with their impacts (Figure 2). The selection of electricity supply technologies and impacts was informed by a series of non-expert interviews we did in a past study [7]. We compared the two groups in terms of (a) self-reported and tested understanding, (b) self-reported and tested engagement and (c) self-reported trust of information. The two groups of respondents were representative of the population in gender, age, and highest education level and with comparable previous experience with the energy subject, website-navigation skills, and numeracy.

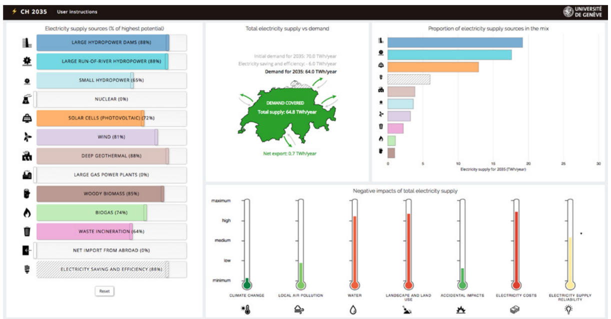

Figure 1. The interactive web-tool for exploring Swiss electricity supply scenarios for 2035 and related impacts.

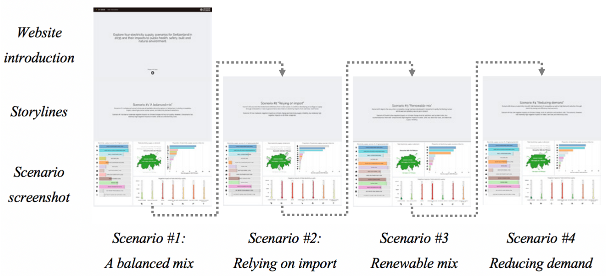

Figure 2. The static equivalent webpage, presenting four electricity supply scenarios along with short introductory storylines. The arrows show the order of the graphics and text in the website.

Results

We found that the interactive condition did not lead to a perceived advantage over the static one, as there were no statistically significant differences between the two groups in self-reported understanding, engagement and trust of the information (Table 1). In fact, it seems that the interactive web-tool may even complicate the usability because we observed that the interactive web-tool's users scored statistically significantly worse than the users in the static condition, when they had to answer a quiz that required to extract information from the scenarios ("Understanding – tested" in Table 1).

In both conditions, we found a low to moderate correlation of website-navigation skills and numeracy with tested understanding, suggesting that these skills are important but not imperative. Participants with higher prior experience with the energy subject were also more engaged in both conditions, while demographics did not have any effect. Although the effects of the control variables varied between the conditions, only one statistically significant difference was found: high website navigation skills increased self-reported understanding in the static condition but not in the interactive one. This suggests that another factor might have moderated the effects of these skills in the interactive condition, such as a possible overload of information from the interactive web-tool.

Dependent variables	Experimental conditions		Statistic
	Static (n = 157)	Interactive (n = 156)	
Understanding – tested *(quiz with 7 items, max. score: 7)*	4.03 ± 1.99	3.54 ± 1.66	t (311) = 2.318*
Understanding – self-reported *(6 items, 7-point Likert scale, max. score: 42)*	26.64 ± 5.50	25.88 ± 5.82	t (311) = 1.195
Trust – self-reported *(7 items, 7-point Likert scale, max. score: 49)*	32.56 ± 5.95	32.62 ± 6.04	t (311) = -.090
Engagement – self-reported *(7 items, 7-point Likert scale, max. score: 49)*	31.55 ± 8.36	31.76 ± 8.60	t (311) = -.218
Engagement – tested			
Time spent in website *(seconds)*	339 ± 273	366 ± 334	t (311) = -.806
Drop-out rates in website *(count)*	7	10	$\chi^2(1)$ = .504

Table 1. Dependent variables by experimental condition. *p < .05.

Conclusions

These results indicate that the interactive web-tools do not come automatically with the benefits of understanding and engagement claimed in the literature or believed by experts. In fact, they might lead to a discrepancy between the actual and perceived understanding in non-experts, making users believe they comprehend more than they actually do. As the trends of using such interactive web-tools for digital participation continue, more empirical research is needed to evaluate which formats meet the needs and abilities of the intended users.

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Investment and generation cost trade-offs between cost-efficient vs. regionally equitable distribution of renewable electricity

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Introduction

The Swiss Energy Strategy 2050 aims at drastically increasing electricity from renewable sources until the year 2035 [1]. Decentralised renewable electricity (solar PV, wind, biomass, small hydro power and enhanced-geothermal systems) is growing fast, especially solar PV, which grew by more than 500% in the last 5 years in Switzerland [2]. The appropriate spatial allocation of decentralised renewable electricity generators is highly controversial, because there is a trade-off between the most economically efficient distribution and a more regionally equitable distribution [3]. Investors prefer sites with good harvesting conditions (i.e. strong winds, high solar radiation) which leads to a concentration of renewable power plants to locations with the best conditions. Previous studies [4,5] have however shown the importance of a regionally even distribution in siting decentralised renewables. An uneven distribution of both negative consequences (i.e. noise, visual disturbance) and positive consequences (i.e. regional investments) can highly affect the public acceptance and therefore the successful diffusion of renewables.

This study is the first of its kind to study the economic and electricity generation trade-offs between the equitable and the cost-efficient spatial distribution of renewable generators in Switzerland. We use a bottom-up electricity generation model EXPANSE [6] with Modeling to Generate Alternatives (MGA) to assess the cost-optimal and 1'200 near cost-optimal spatial allocation scenarios of renewables in 2'258 Swiss municipalities.

Objectives

1. Develop a spatially-explicit electricity demand and supply database for 2'258 Swiss municipalities for the years 2016 and 2035.
2. Simulate the Swiss electricity generation at a municipal level with a spatially-explicit EXPANSE model to systematically explore cost-optimal and 1'200 near cost-optimal scenarios.
3. Assess trade-offs of cost-efficient vs. regionally equitable distribution of investments in renewables and the electricity generation cost.

Methodology

We simulate the Swiss electricity system with a spatially-explicit EXPANSE model [6] in order to assess the diversity of possible spatial allocation scenarios for decentralised renewables on a municipal level. The model integrates the electricity generation potentials for hydro power, gas, solar PV, wind, biomass and enhanced geothermal systems (EGS) as well as electricity savings and imports on a municipal level.

In order to assess the economic potential of each potential power generator, we incorporate the predicted future capital investment and O&M costs [7] to determine the levelized cost of electricity (LCOE) for each potential site. The additional economic potential of decentralised renewables until the year 2035 is shown in Figure 1.

With MGA methodology, the cost-optimal and 1'200 near cost-optimal scenarios of renewables were simulated for the year 2035, which provided the yearly electricity generation, installed capacity and cumulative investments per technology in each Swiss municipality. The simulation was conducted with yearly temporal resolution and municipal spatial resolution.

In order to assess the most equitable spatial allocation of decentralised renewables, we introduced a measure for regional equity which reflects the burden from decentralised renewable electricity generation across the Swiss population. Equity is defined as the even distribution of decentralised renewable electricity generated across the population and is measured using the Gini (G) coefficient [8]. The Gini coefficient measures the inequality of values of a frequency distribution, where the value of 1 stands for maximum inequality and the value 0 for maximum equality.

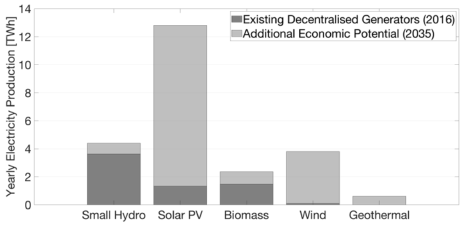

Figure 1. Current electricity generation (2016) and assumed additional economic potential (2035) of decentralised renewable electricity generation in Switzerland

Results

We find a moderate trade-off between efficiency and regional equity (Fig. 2). The difference in electricity generation cost between the most equitable and the cost-optimal scenario amounts to 1 Rp./kWh (8% above the generation costs in the cost-optimal case), while the regional equity (Equity = 100 - Gini coefficient [%]) applied on electricity generation more than doubles from 18% to 38%. An additional observation is that the share of electricity supplied from solar PV increases with increasing regional equity (Fig. 3), as the solar PV electricity generation potentials are proportional to the available rooftops and therefore also to the population size. In the cost-optimal scenario, up to 500MW in installed wind turbine capacity is concentrated in Vaud, Fribourg and Berne (Fig. 4a), where there are relatively strong winds and relatively low legislative land constraints for wind farm installations.

The cost-optimal scenario leads to distorted regional investments in the above mentioned three cantons, where 67% of all renewable investments are accumulated (Fig. 5a). With increasing equity, solar PV systems instead of wind turbines are installed evenly across all cantons (Fig. 4b), which in return leads to more spatially even investments (Fig. 5b). The cantons Zurich, Vaud and Berne together receive the highest share of investments of 38% even in the scenario of maximum equity.

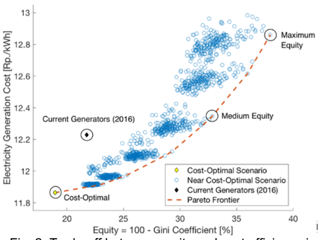

Fig. 2: Trade-off between equity and cost efficiency in spatial allocation of renewable generators

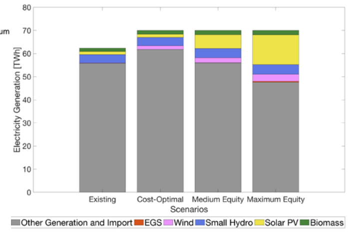

Fig. 3: Electricity generated from decentralised generators for various scenarios

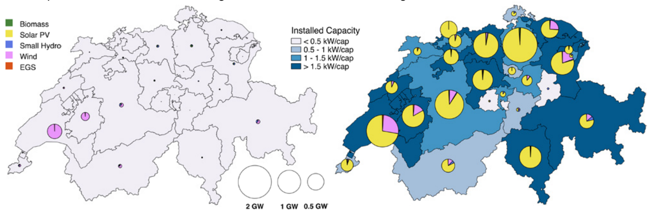

Fig 4a: Cost-optimal scenario (11.85Rp./kWh, G=82%) Fig. 4b: Maximum Equity Scenario (12.85Rp./kWh, G=62%)

Figure 4: Cantonal distribution of additionally installed capacity from decentralized renewables (2016-2035)

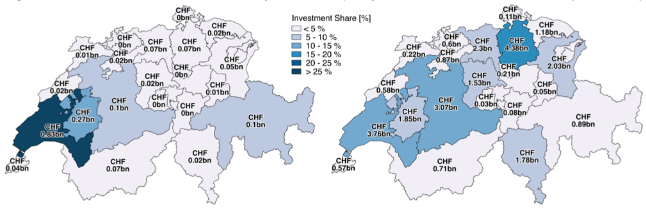

Fig. 5a: Cost-Optimal Scenario (CHF1.76bn in total) Fig. 5b: Maximum Equity Scenario (CHF28.62bn in total)

Figure 5. Cantonal distribution of additional cumulative investment in renewables (2016-2035)

Conclusions

We find a moderate trade-off between the cost-optimal and regionally equitable scenarios. Regional equity can be doubled with a moderate increase of 1 Rp./kWh in electricity generation costs, which is only 8% percent higher than the generation costs in the cost-optimal case. A cost-optimal spatial allocation leads to a concentration of 67% of renewable investments in Vaud, Fribourg and Berne (mostly wind), while equitable scenarios allow for more even renewable investments in all cantons (mostly in solar PV).

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