MATCHING RENEWABLE ENERGY PRODUCTION AND CONSUMPTION BY MARKET REGULATED DEMAND SITE MANAGEMENT (DSM)

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Abstract

An important cornerstone to reach the goals of the Swiss energy turnaround is the consecutive addition of renewable electrical power sources in conjunction with efficient demand side management. This development implies shifts in the daily power production and changes in load-management. In the light of the future liberalization of the Swiss electrical market providers will have to search for new and different business models, which cope with these developments.

Such a new business model was developed by “Change38”. It sets local incentives to drive and accelerate the addition of electrical power supplies and storage systems. Its goal is to establish a local market for the ecological added value for renewable energy sources (producers) and to thrive the individual load management between the consumers, respectively prosumers. The model thereby follows a self-regulatory approach and merely gives the necessary framework. It sets monetary incentives for producers to produce and for consumers to consume energy at the right, most valuable time. The developed business model addresses the socio-economic trend of share-economy as well as the socio-technical trend of industry 4.0.

To evaluate and to refine this business model a simulation model was developed, which allows calculating all monetary flows and physical balances for every participant on the basis of time-series for power production and power demand.

Using Monte-Carlo simulations the model allowed the energy service provider “Change38” to estimate the risk of its new service and hence to design an economical business case.

Keywords:

Business models; start-up; share-economy, electricity; demand-site management; simulations; self-organization, industry 4.0

1 INTRODUCTION

Renewable energy systems were identified as a major key technology of the Swiss energy turnaround [1]. However, their integration in large quantities is a big challenge and although technical solutions themselves are available today [2], the monetarization of these solutions is often the critical barrier. National subsidies programs try to tackle these economic barriers, but even if they succeed, they are by design only an interim solution. A current example of such a program is the “KEV”[1], which helped to push the dissemination of photovoltaic systems in Switzerland, but is now financially depleted [3]. Business models, which incorporated the national subsidy, have therefore declined. In addition, the electrical power market is changing. National laws prohibiting the internal consumption of produced electricity were repealed and for the

[1] «Kostendeckende Einspeisevergütung» (=cost-effective feed-in remuneration)

coming years the liberalization of the market is imminent.

To cope with these changes new business models are in quest [4], [5]. Most business models for renewable energy sources trade the certified proof of origin (labelled electricity) as an indicator for its additional “ecological value” (EV). A business model that goes one-step forward was developed by “Change38” [6] and is already running in a small-scale pilot project in “Gachnang” (canton of Thurgau).

In this model producers and consumers are clustered in local pools and their production and demand is continuously monitored. Each participant has access to visualizations of his actual status within his pool. This business model can forgo any certified proof of origin; power is distributed directly and isochronally among the peers. An objective and core element of this model is to increase the self-sufficiency of each pool that directly addresses the socio-economical trend of sharing and the socio-technical trend of the industry 4.0 by matching demand and production [7], [8]. To reach this goal financial incentives are set for the participating producers as well as for the consumers. The consumer agrees on a small fee on each kWh, which he did not receive from a producer within the pool. The producer receives a financial reward on each kWh of his production, which is consumed within the pool – along with a small base rate for each produced kWh. While the consumers are handled equally in respect to the distribution of the pooled production, the model makes differentiates between the producers. Producers are distinguished by their pool entry date, such that a producer who joined early is more privileged in the distribution process (first come – first serve). This creates an incentive for producers to rather join unbalanced pools and fill in supply gaps, to invest in complementary technologies like storage systems or create additional pool that needs and attracts new costumers. The long-term perspective is to cluster local renewable energy sources and consumers such that most of the electricity is consumed locally (and thus on a low level of the electricity grid). The business model is shown in Fig 1. The three main actors are Change38, the producers and the consumers.

Consumers cannot be burdened with too high costs, while producers ask for an attractive additional income. Change38 needs to balance these contrary interests. A simulation tool was developed to investigate the interdependencies within the model and to find possible and for each stakeholder justifiable constellations. Ideally a high percentage of self-consumption and self-sufficiency is reached while satisfying producers and consumers’ monetary expectations.

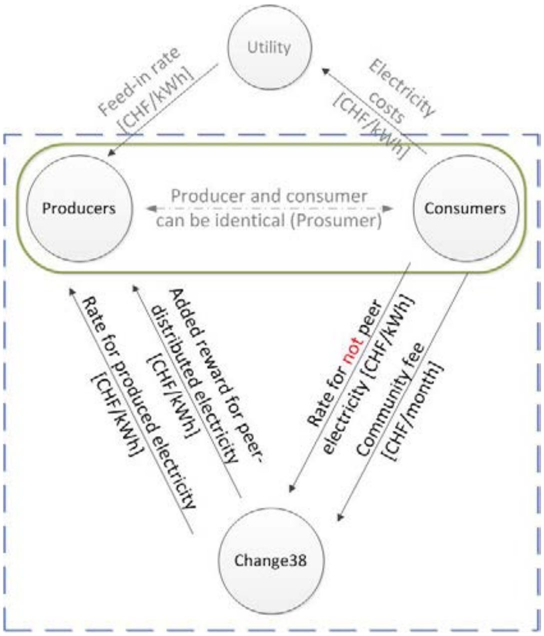

Fig 1: The business model «Change38» given in the blue frame. Producers and consumers are clustered in pools (green). The contracts to the utilities are kept outside the business model and are left untouched.

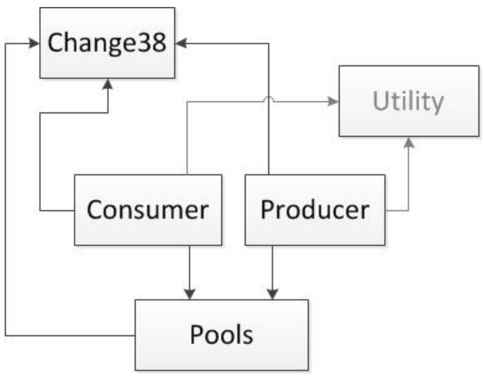

Fig. 2: Interrelations within the framework that was used to represent the business model. Each participants role equals an own class.

Tab.1 : In- and outputs of the simulation framework.

Inputs	Change38	Fees and rates (see Fig.1).
	Utility	Fees and rates (see. Fig.1).
	Consumer	Annual demand profiles with hourly resolution for: • Equipment, lighting, air-conditioning. (if applicable) • Heat pumps including seasonal performance. (If applicable)
	Producer	Nominal power. Annual production profiles with hourly resolution. Self-consumption rate. Entry date.
Outputs	Change38	Earnings and expenses.
	Utility	Earnings, expenses and back payments.
	Consumer	Power allocated from peers (hourly profile). Earnings and expenses (hourly profile).
	Producer	Power allocated to peers. Earnings and expenses.
	Pool	Percentage of self-consumption. Percentage of self-sufficiency.

Tab. 2: Parameters varied during the Monte-Carlo simulations.

Parameters	*From*	*To*	*Values*
Rate for not peer electricity [CHF/kWh]	Consumer	Change38	[0.02, 0.04, 0.06]
Community fee [CHF/month]	Consumer	Change38	[10, 14, 20]
Electricity costs [CHF/kWh]	Consumer	Utility	[0.2, 0.3, 0.4]
Feed-in rate [CHF/kWh]	Utility	Producer	[0.02, 0.04, 0.06]
Rate for produced electricity [CHF/kWh]	Change38	Producer	[0.01, 0.03, 0.05]
Added reward for peer distributed electricity [CHF/kWh]	Change38	Producer	[0.03, 0.06, 0.09]
Number of clustered producers			[15, 50, 100]
Number of clustered consumers			[30, 100, 200, 500]
Demand of consumers [kWh/a]			[2200, 3500, 5500, 7500]
Nominal power producers [kWp]			[10, 30, 100]
Percentage of self-consumption producer			[0.15, 0.3, 0.6]

2 METHOD

The business model was set-up in an object-oriented framework that allowed for the initialization of any arbitrary constellation of pools, consumers, producers and utilities. Fig. 2 shows the framework in principle and the underlying dependencies of the different classes.

Table 1 gives an overview about the in- and outputs of the framework. Consumers and producers are described by annual profiles (for residential use in this case). As comprehensive live data was not available at the time of writing, demand profiles from [9], [10] were aggregated that considered lightning, equipment and ventilations. The user's possible change in conduct was not taken into account. In cases of domestic heating using heat pumps typical demand profiles can be superposed.

In this study only photovoltaic systems (PV) were considered. Production profiles were generated [11] for the pilot area with different nominal power, ranging from 4 kWp to 100 kWp. The producers self-consumption is addressed in the simulation framework.

For each time step, the peer-distributed electricity of each pool member is calculated. All energy flows in and out of a pool are monitored, which – in its sum – gives the considered pools percentage of self-consumption and self-sufficiency. Based on these findings the earnings and expenses of each pool member are calculated.

To address the question what pool constellations are most favourable, a Monte-Carlo approach was chosen. About eleven parameters –listed in detail in table 2 – were varied. The Monte-Carlo simulation comprised about 2000 pool constellations that were randomly established.

The pool constellations then were reviewed and analysed in respect of the following main criteria:

- A positive and possibly high financial outcome for Change38 and the participating producers.
- Tenable costs for the consumers.
- No overproduction within the pool, i.e. the ratio of production and consumption is equal or less 1.
- A high percentage of self-consumption[2]
- A high percentage of self-efficiency[3]

The main idea of this business model is to support renewable energy sources utilizing economic means. Some constrains result from this approach, like balancing a pool: On the one hand, there should not much more produced electricity in a pool as actual needed by the pool members. On the other hand, a considerable amount of electricity should be supplied within the pool. Thus, at least half of the demand within a pool was expected to be produced within the pool itself and overproduction of a pool was prohibited.

3 RESULTS

Fig 3. and Fig. 4. show the ratio between production and consumption In relation to the pools self-sufficiencies and self-consumptions The profitability for Change38 is shown in colour and size. (The size of the scatter points indicates the magnitude of the earnings, respectively losses, and the colour if they were positive (blue) or negative (red)).

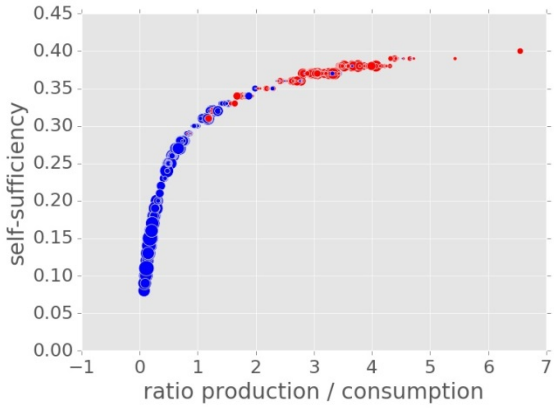

Fig. 3: The relation between self-sufficiency and the production/consumption ratio of the simulated pools. In blue financially profitable constellations for Change 38. In red unprofitable pools.

The additional income generated for participating producers is on average 0.127 CHF/kWh and varies between 0.042 CHF/kWh and 0.24 CHF/kWh. The expenses for the consumers vary between 0.034 CHF/kWh and 0.105 CHF/kWh. Note, that these expenses add to the regular costs charged by a consumers utility.

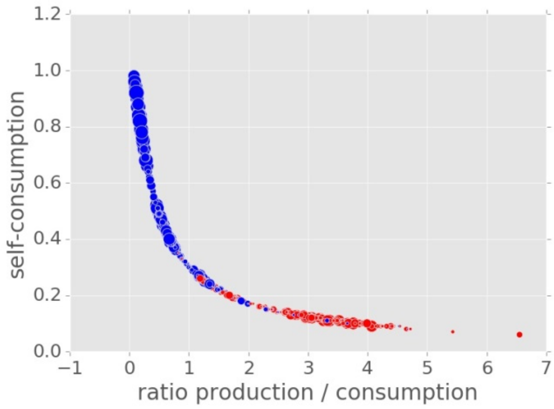

Fig 4: The relation between the self-consumption and production/consumption ratio of the simulated pools. In bluefinancially profitable constellations for Change 38. In red unprofitable pools.

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[2] Percentage of Self-consumption is the ratio of the total self-consumed energy per year to the total produced energy per year. For the sake of convenience, it will often be referred to as “self-consumption” throughout this work.

[3] Percentage of self-sufficiency (autarchy) is the ratio of the total self-consumed energy per year to the total consumed energy per year. For the sake of convenience it will often be referred to as “self-sufficiency” throughout this work.

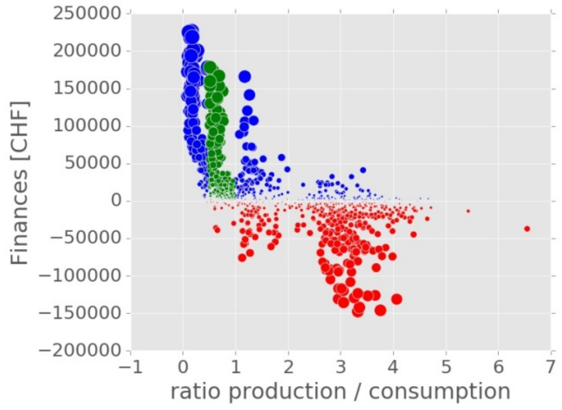

Fig. 5: The Ratio of production / consumption of the different pools against the financial balances of Change38. In red are unprofitable, blue profitable pools. In green the pools left after filtering for the given criteria.

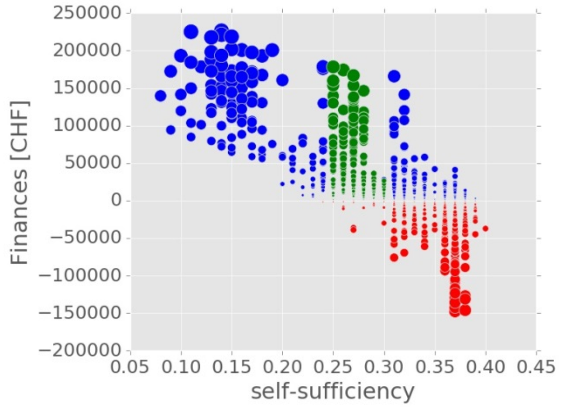

Fig. 6 : Self-sufficiency versus Change38 finances. Colouring similar to Fig. 5.

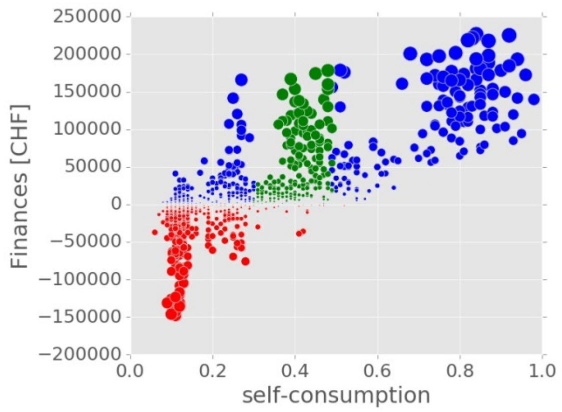

Fig. 7: Self-consumption versus Change38 finances. Colouring similar to Fig. 5.

For the consumers the resulting pricing structures of every pool constellation was found to be of tenable nature. The situation of the producers is not problematic. In any constellation the producer makes money and improves its investment.

However, the situation of Change38 is more sensitive. Some pool configurations are completely undesirable for the start-up company, other have the potential for high financial gains as can be seen in Fig. 5 to 7. The blue depicted pools show financially profitable configurations, while the red pools lead to losses throughout a year.

Filtering for pools that satisfyingly fulfill the economic and ecological criteria are shown in green. These pools produce at least 50% of their demand within themselves and do not overproduce. The pools self-sufficiency was found at about 25% and their self-consumption varying between 30% and 50%.

4 DISCUSSION

The chosen subsets of pools seem to be a valid compromise between the financial interests of Change38 and the ecological goals. The antagonizing behaviour of the self-consumption rate and the self-sufficiency rate dominates the systems behaviour. This contradictory behaviour becomes obvious when comparing Fig. 3 and Fig. 4. The self-sufficiency of the pools is highly correlated to the ratio of annual production to annual consumption (correlation factor of 0.87). Fig. 3 shows clearly, that an overproduction is needed for a reasonably high self-sufficiency. This reflects the circumstance that all production sites in this study were chosen to be photovoltaic systems. Technologies with more complementing production profiles should buffer and diminish this behaviour. Furthermore, the self-consumption is highly anti-correlated to the production-consumption-ratio (correlation factor of -0.84), which plainly states, that the more is produced the less can be used-up within the pool.

When focusing solely on the monetarisation and the optimization of profits for Change38 an arguable contradiction raises. If targets on self-consumption, self-sufficiency and production-consumption balancing are neglected or even dropped, earnings could be increased by 20% – plainly by setting up pools with only a few producers and many consumers (pools with low self-sufficiency, respectively high self-consumption. Compare with Fig. 5, 6 and 7). Such a development must be precluded by additional measures like a guaranteed self-consumption, a minimal production-consumption ratio or similar constrains.

5 SUMMARY AND OUTLOOK

In this study a business model to monetarize and strengthen the distribution of renewable energy sources was explored by means of computer modelling and simulation. The business model clusters producers and consumers in pools and sets financial incentives to consume from and produce for the pool. To gain an understanding of the business model's dynamics and the resulting consequences for the different actors a modelling framework was developed. The framework allows for the initialization of possible pool constellations and calculates the power distribution within the pool as well as the financial earnings and expenses of each participant. By means of Monte-Carlo simulations a set of 2000 pools was created and finally analysed on the basis on given criteria.

In a next step, the gained insights will be used to adapt and refine the business model as well as further development of the framework by adding additional models for e.g. storages, CHPs, heat pumps. Furthermore seasonal differences will be taken into account. Live-data from the pilot project will help to optimize the business case, but also to develop approaches to model the behavioural changes in customers conducts.

6 ACKNOWLEDGMENTS

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