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# Linking business model innovation with energy system optimization

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**Abstract**. There are dedicated computational models and platforms to facilitate the design and planning of multi-energy-systems. However, the widespread adoption of new technological solutions largely depends on the right business models. Whilst there exists a list of possible business opportunities emerging with a multi-energy-system, there is lacking guidance on how to match their design with business models. A close fit could possibly increase the speed of implementation of a new energy solution. This study describes and tests a methodology to evaluate and improve the match between business models of selected companies and planned multi-energy-systems. A total of six districts with planned energy systems as well as six companies were assessed for their matching potential. Then, mutual adaptation between the business model and the further energy system optimization was tested as a way to improve the match.

## 1. Introduction

The future of energy systems will likely be decentralized, renewable and interconnected [1]. To facilitate the design and the planning of such multi-energy-systems, dedicated optimization software programs exists that are capable of finding the optimal configuration and operation of technologies under objectives defined in earlier work [2]. However, the widespread uptake of such multi-energy systems is lacking, partly due to limited interest from businesses [3,4].

   This study presents and evaluates a methodology to assess the match between an optimized energy system from a district and the business model (BM) of a company. A good fit between the BM and the intended energy system indicates that the objectives of the district's stakeholders, the district's characteristics as well as the competencies and interests of the company are well aligned. This facilitates the implementation of the planned system by pairing up with a respective business partner that has interest to make business through the optimized energy system. Whilst a list of possible business opportunities for an energy hub is available [5], there is a research gap on how to match and adapt both, energy hub design and business model [6]. Please note that each company features a BM. However, several companies could utilize the same or a similar one [7]. The present study introduces a methodology to identify the best BM (from a pool of alternatives) and respective companies for an optimized energy system.

The widespread adoption of new technological solutions largely depends on the right business model which balances the values generated with the cost structures [4,7]. In general, a business model can be described as "the rationale of how an organization creates, delivers, and captures value" [8]. The business model can and should adapt to the specific circumstances [9]. The method presented hereafter allows to clearly identify the elements of the business model that would need to be innovated for a better match with the intended energy system. This facilitates the search for required analogies and hence, the method directly links to business model innovation [7,10]. In analogy finding, other business models are screened for elements that could be transferred to another business model. As a consequence, in this study, we present a methodology to not only identify the best BM, but integrate as well a BM innovation approach with currently existing tools for the planning and design of multi-energy systems.

## 2. Methods

Figure 1 gives a graphical overview of the methodology. Each of the steps outlined is presented in more detail subsequently.
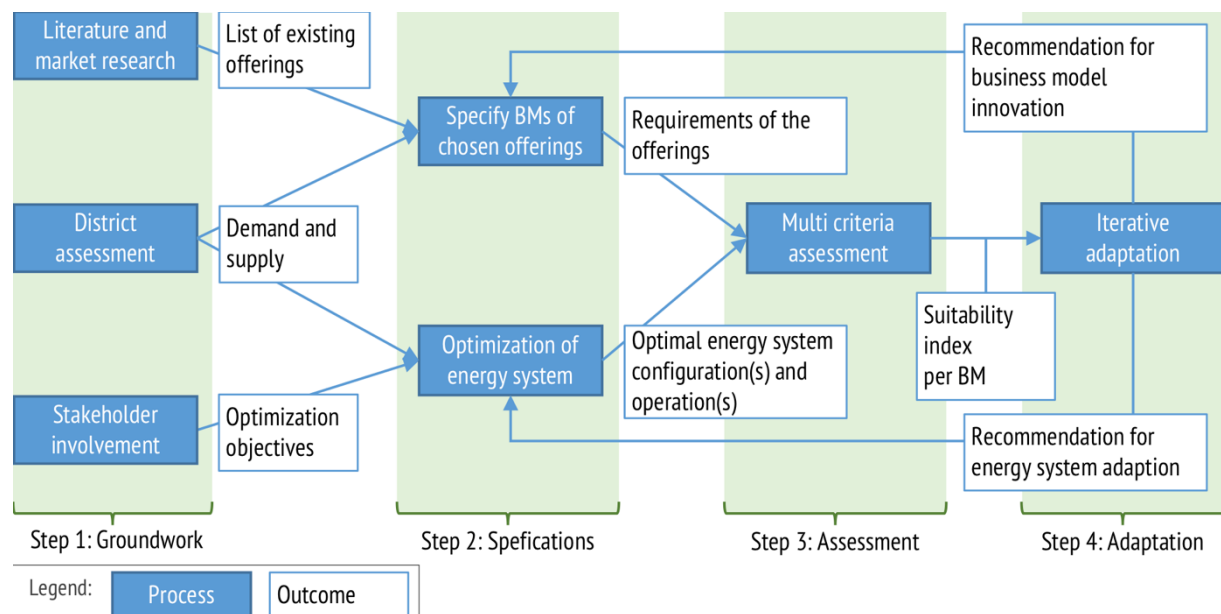


**Figure 1.** Graphical overview of the proposed methodology

### 2.1. Step 1: Groundwork

For illustration of the different steps, an example is introduced. Imagine a district located in the suburbs of a larger city. The local government of this district decides to foster the transition of the energy system towards a more cost efficient and environmentally friendly solution. After discussions with several stakeholders the objectives and boundary conditions are defined. For energy planning, the future current demand and supply of energy is estimated and, in this line, a list of promising business approaches to manage this transition compiled (Step 1).

In this study, districts serving as case studies were chosen from the pool of research objects from research groups from Swiss universities. Literature and market research to identify candidate companies was done through expert interviews and internet search engines. A geographical focus was set to companies operating in Switzerland as the districts serving as case studies are located in Switzerland. The selection of companies was aiming at maximum diversity of offerings.

*2.2. Step 2: Specifications*

In Step 2 the optimal operation and configuration of the energy system is computed. In the example above, this would yield proposed dimensions for each technology, such as 900 m$^2$ of PV-panels, and 700 kWh of electricity storage in Li-ion batteries. Hence, a company operating a BM relying on batteries for a virtual powerplant is more closely analyzed and through questionnaires other requirements as well as the optimal size of the battery capacity for the BM are identified.

In this study, the optimizations of the energy systems were done by a dedicated software, as described in the references in Table 1. The BM of the companies were analyzed by a multi criteria assessment. Based on the literature, a list of 26 key-criteria were identified. In line with the Analytic Hierarchy Process (AHP) [11] they were organized in a hierarchical tree, shown in Figure 2. Then a questionnaire was designed and tested to elicit utility functions as well as the weights per criterion. The utility curves were estimated by optimal and acceptable boundary conditions, as described by Rohrbach et al. [12]. Instead of the originally proposed step-wise functions, fuzzy membership functions were used as utility curves [13]. The weights of the criteria were then calculated making use of the online AHP calculator by Goepel [14]. However, instead of the standard linear scale, the balanced scale was used as it provides higher consistency [15] and better reflects human perception of the verbal expressions [16].

*2.3. Step 3: Assessment*

Step 3 then is the comparison of the calculated optimal configuration of the energy system with the optimal conditions of the BM. To this end, the energy system of the cases was translated into utility per company, multiplied by the companies' weights (= weighted utility) and summed up. A matching weighted utility indicates synergies when a stakeholder pairs up with a business.

*2.4. Step 4: Adaptation*

In Step 4, both the BM and the energy system are adapted to better match each other. In the initial example, this could translate into choosing a battery capacity that is slightly higher than initially thought of. But as the company would profit from this through a virtual powerplant, the operation and maintenance of the batteries would be taken care of by the company and the total costs of the system hence reduced. In this study, the iterative adaption was only performed exemplarily by looking for possibilities to adjust the non-matching conditions.

**3. Experiments**

**Table 1.** Description of the case studies analysed

| Case and reference | Short description | #of buildings | Energy optimisation scenarios considered |
|---|---|---|---|
| **Altstetten** [17] | Optimized energy system considering decentralized short and long-term storage systems as well as the introduction of heat networks. | 77 | Global sustainable development with new policies |
| **Brig-Glis** [18] | Whole city optimized for an updated energy master plan aiming at a more sustainable energy supply. | 1,112 | Impacts of a new energy policy |
| **Cartigny** [19] | Suburbian area. Aims to improve sustainability and efficiency. | 370 | PV, wind turbines, batteries, CHP plant |
| **EPFL** [20] | Large university buildings, optimized under climate change and when installing PV plants and storage. | 5 | Renovation and energy hub |
| **Hemberg** [21] | Rural area. Energy system optimized for improving energy sustainability. | 150 | Renovation, PV and wind turbines |
| **Zernez** [22] | Mountain village, optimized for the aim of achieving zero $CO_2$-emission. | 309 | Renovation, PV installation, CHP plant |

For the experiments, six case studies of energy systems optimizations were analysed as shortly described in Table 1. The six companies shown in Table 2 were surveyed with questionnaires covering all the 27 criteria. The criteria were sorted in a hierarchical tree as shown in Figure 2, yielding a questionnaire with a total of 40 questions.

**Table 2.** Companies surveyed in this study

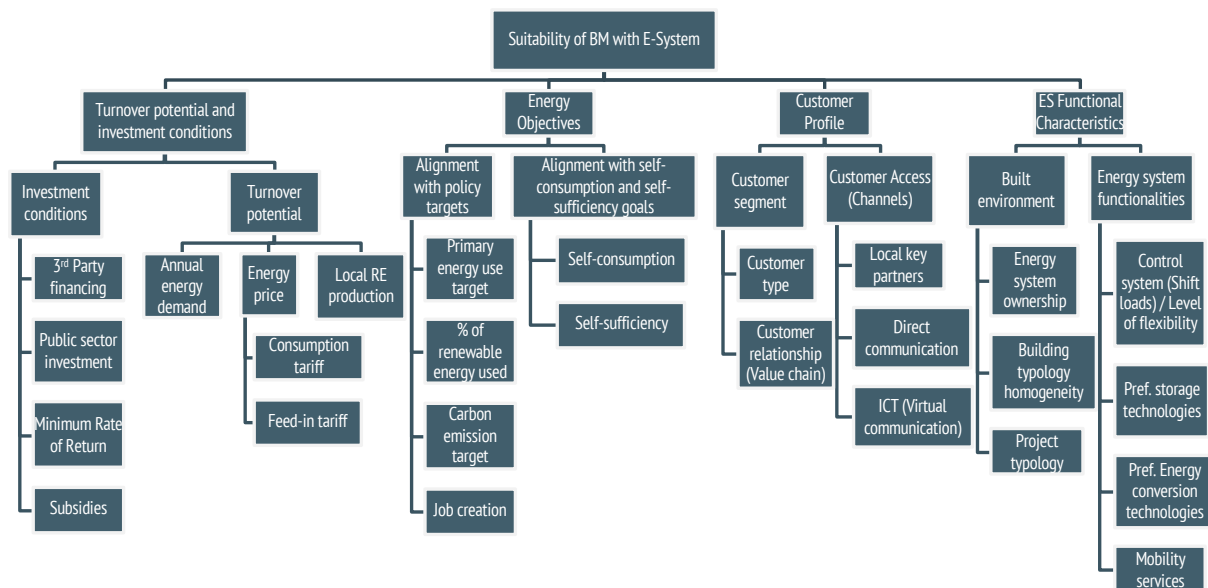| Company | Short description of the company and its business model |
| --- | --- |
| **A** | Team of engineers for sustainable housing, including control systems. Strong when targeting high autarky, high self-consumption and low greenhouse gas emissions. |
| **B** | Software developer for the planning and optimization of power grids dealing with decentralized power generation. Addresses B2B customers. |
| **C** | Provides an energy management system that reduces consumption by anticipating weather conditions. Provides contracting solutions with the system's user. |
| **D** | Installer for heat pumps, solar collectors and other heating systems. Requires thermal storage systems to be installed, but otherwise has few requirements. |
| **E** | HVAC-installation company. Scores with scale and hence addresses B2B customers with particular high buildings homogeneity. |
| **F** | Solar system installer including energy management systems. Addresses mainly residential customers with demands for high levels of autarky and self-consumption. |



**Figure 2.** Hierarchical tree of the used criteria

## 4. Results

Figure 3 displays the results among the six case studies. It clearly shows that the uncertainty associated to this approach is considerable. However, there are visible differences among the case studies and companies. For example in Brig-Glis, all companies can reach similar suitability levels, while in case Cartigny, company C is clearly the least suitable. However, in no case a single company was clearly the most suitable. Uncertainty is the result of ambiguities in either the company's requirements or the district/energy system characteristics. So uncertain matching potential could be move either way, as explained subsequently.
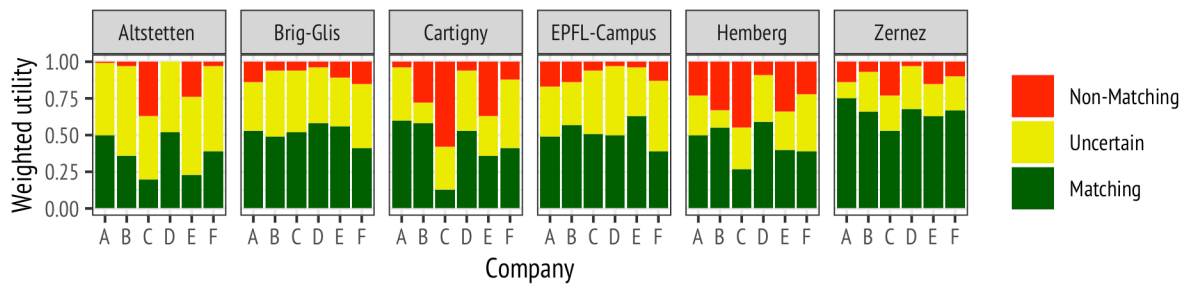
**Figure 3.** Matching potential between the six case studies and the six analysed companies

Figure 4 shows how the match of company B and the case Zernez could be either improved by a) changing the local conditions or b) by changing the energy system. The local conditions could be improved by providing a local key partner (in this case a local GIS operator), which would increase the weighted utility of the match by 0.18. Additionally, by adding battery storage to the energy system, the matching weighted utility would increase by 0.02.
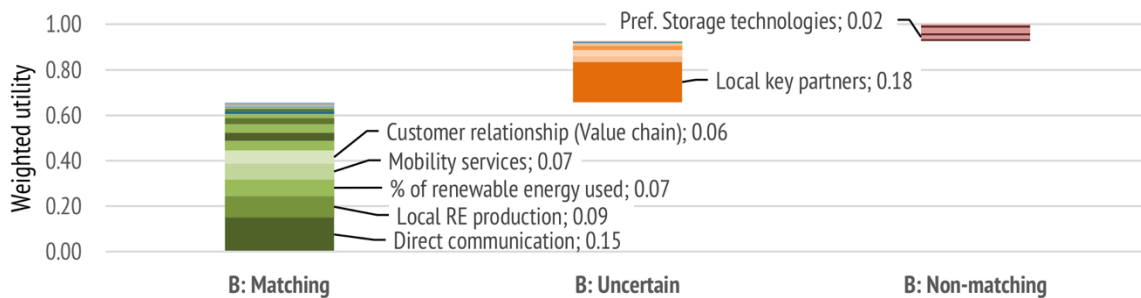


**Figure 4.** Example of company B and the energy system of Zernez. Highlighting criteria with a weighted utility >0.05 or with particular suitability for adaption

## 5. Discussion

In the outlined methodology, a company's BM is characterized by a set of pre-defined criteria. A further extension of this methodology could inspire the developers of optimization software to include business model approaches within their software. However, as the market continuously evolves, additional criteria might then be required in the methodology to distinguish yet unforeseen business models. In this work, the chosen criteria have shown to be suitable to analyze the matching potential between companies and an energy system. However, this methodology does not provide guidance on how to find promising existing companies in the first place, and might be extended in this respect. Further work should investigate the combined matching potential of two or more companies, as they might tackle different business opportunities. Nevertheless, the methodology introduces approaches for business model innovation, such as analogy seeking. The process of mutual adaptation could be informed by the identification of non-matching elements between energy system and business model, as shown for the Zernez case.

## 6. Conclusions

The results show a working example of the integration between modelling and optimization of district level energy systems and business model thinking. To the best of our knowledge, this is the first time those two formerly independent streams of research are combined. This approach helps to assess the compatibility of a business model and a business opportunity emerging from a proposed energy system. This assessment further triggers innovation since the energy system might be adapted to strengthen business interest in its implementation. The case studies showed proof that the presented procedure is able to indicate a selection of best suited business models within the initially considered universe of business models.

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