Energy 162 (2018) 20–34

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

# Sociotechnical transition to smart energy: The case of Samso 1997–2030

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A R T I C L E I N F O

*Article history:*
Received 30 December 2017
Received in revised form
5 June 2018
Accepted 26 July 2018
Available online 3 August 2018

*Keywords:*
Smart islands
Civic engagement
Commons
Renewable energy systems
Energy policy
Energy planning

A B S T R A C T

This case study analyses an ongoing practical transition to a smart energy system. The Danish island of Samso, with 3700 inhabitants, aims for a fossil fuel free energy system in the year 2030. Owing to natural limitations, it is necessary to exploit the available energy sources in a manner, which requires careful planning. Furthermore, civic engagement is necessary for a democratic transition to a smart energy system. Therefore the transition has a social side and a technical side, which is analysed. The analysis applies the causal loop diagram of an urban model in order to explain the inner workings of the island community. The analysis illustrates many planning elements, such as political energy targets, socio-technical priorities, energy vision, energy balance, energy action plan, and examples of demand-side management. The analysis shows that the current municipal plan is comprehensive, but not coherent. It will be necessary to consider trade-offs, that is, set a goal that would balance housing, jobs, agriculture, tourism, biomass and energy. An open question for further research is whether this insight from Samso can be scaled or replicated to other regions.



## 1. Introduction

A *smart energy* system combines the heating sector with the other sectors of the energy system in order to focus on how the sectors may assist one another (Lund 2017) [1]. Smart energy is especially relevant for an island – or an islandlike system – that experiences bottlenecks in the internal electricity network, an external cable connection, or if the energy production is insufficient to meet the demand. Furthermore, electricity consumers may be billed on an hourly basis, with a high price during peak hours, and it is therefore of interest for a consumer to shift the electricity consumption away from expensive periods of the day. Smart energy concerns not only the electricity supply, but also other energy products such as oil, gas, coal, and biomass. It is *smart* to combine the electricity sector with the heating sector whenever there is an abundance of electricity from renewable energy sources.

The Danish island of Samso promises to rid the island of fossil fuels by the year 2030 – twenty years ahead of Denmark – as a pilot case for the rest of the country. The island is already a renewable energy island with respect to the annual energy balance. Sea cables connect Samso with the mainland, and electricity flows both ways, but mostly in the export direction. Smart energy is part of the overall energy plan for the year 2030 [2]. The objective is to minimise the electricity export by maximising the internal use of renewable energy. The plan includes a biogas plant, which will convert biomass to gas, electricity, heat, and fertilizer. The island already has a ferry fuelled by liquid natural gas. The idea is to produce fuel for the ferry, and other means of transportation, on the island instead of buying it from outside of the island.

In 1997 the Danish government appointed Samso as Denmark's renewable energy island. This entailed a commitment to work towards a 100% renewable community in the sense that the renewable energy production should balance the energy consumption, when calculated at the end of the year. Cooperatives, farmers, and the municipality installed district heating plants fuelled by biomass, as well as wind turbines on land and in the sea [3]. Private house owners invested in hot water solar collectors, heat pumps, and biomass heating units. The island started to produce electricity in the year 2001, and a few years later the electricity production was up to three times larger than the electricity consumption. The

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https://doi.org/10.1016/j.energy.2018.07.174
0360-5442/

electricity export compensated for the fossil fuels consumed by tractors, buses, cars, and ferries, and by the year 2007 the island achieved its 100% target.

The present-day energy plan requires a further sociotechnical transition, and one challenge is whether the citizens will accept more changes. This article's objective is to analyse the Samso case from a sociotechnical point of view in order to review policies for its transition to smart energy. The existing policies in the EU, the nation, and the region are more or less fixed, or they change slowly. The article focuses therefore on the more agile local policies formulated by the municipal politicians and the citizens.

Energy transition requires an approach that includes several disciplines within the humanities and the sciences.

*Social approaches*. With respect to the European energy transition Sarricaa, Brondia, Cottoneb & Mazzaraa propose a cultural approach to overcome the separation between the technical and the human sides of energy transition [4]. Their approach focuses on the interactions between the citizen and the society. They consider norms, material culture, and energy practices which lead to their identification of four main challenges:

> The need for further integration towards shared interpretative frameworks, the quest for a constructive and future-oriented research attitude, the importance of connecting different planes of analysis to foresee alternative scenarios, and the need for proposals and solutions to be addressed to decision makers [4].

The concept of a *common* is central in this context, as Melville, Christie, Burningham, Way and Hampshire recognised [5]. Hermansen and Nørretranders provide examples of successful commons as well as threats to commons, such as centralisation [6]. A common is a resource owned and managed by a community with a system of rules, norms, and values regulating its use. An island can be regarded as a common, where the community or the municipality administers the limited land in such a way that no single interest jeopardizes the wealth of the community. It also applies to a suburb, a city, or more generally to an area that can be regarded as an island. Local ownership is of primary concern, often practised under the legal construction of a cooperative.

*Technical approaches*. Smart energy is a technical extension of a smart grid; it widens the focus from the electricity sector to the whole energy sector, including heating and transport. It is introduced in the book by Lund (2014) [7] and in the same book, the chapter by Hvelplund et al. [8]. Smart energy is an intelligent combination of various energy sectors in order to optimise some criterion. For example, the use of electricity for heat pumps is a way to combine the electricity sector and the heating sector. That could result in economic savings, because the cost of thermal storage per energy unit is two orders of magnitude smaller than electrical storage [1]. Although a simulation of a smart energy system requires many detailed input data, which can be difficult to procure, it is a well defined engineering activity in contrast to understanding the causes and effects in the surrounding society.

*Sociotechnical approaches*. A new energy system affects the society, and vice versa, and attempts have been made to understand the socioeconomic interactions. Mathiesen, Lund & Karlsson point out that a Danish national smart energy system can have positive socioeconomic effects, create jobs, and lead to earnings on export [9]. Lund and Hvelplund also focus on job creation, in this case by means of so-called *concrete institutional economics* in relation to sustainable development as a whole [10]. Those authors base their conclusions on a computer simulation of the present and future energy systems. Timma, Blumberga, Bazbauers and Blumberga take this a step further by proposing tools to study sociotechnical transitions [11]. They try to link engineering and social sciences. They start their approach by means of social psychology and *system dynamics* models, and their next step is *statistical data analysis*. They studied energy efficiency and storage in households.

Also, the sociotechnical approach is common for studies of energy transitions within the Science and Technology Studies (STS) field, where the social and the technical are perceived as closely intertwined and interdependent entities as demonstrated in the article by Skjølsvold, Ryghaug & Berker [12] and the book by Strengers [13]. An example is the study of how time-shifting electricity consumption in households depends on the design of technologies as well as existing everyday practices of families [14].

*Our approach*. An introductory paper to a special journal issue by Clark and Lund advocate a description of practical cases in order to illustrate sustainable developments [15]. The Samso energy system is one such case, because it spans both the past, the present, and the future. It appears there is a need for all of the previously mentioned approaches, and possibly more, in order to understand the transition to smart energy adequately. To come to grips with the sociotechnical causes and effects of a transition, system dynamics, or more precisely, Alfeld and Graham's *urban dynamics* model provides a useful framework [16]. Urban dynamics tries to simulate the long term, time dependent (dynamic) developments in a city or an urban area. Dynamic simulation is beyond the scope of this article, but the model is general, and it can be adapted to the workings of an island community. As with an urban model, the population level, the amount of enterprises, and the amount of housing are three so-called *level variables* (or stock variables, integrators, state variables) of interest. In an urban area, the growing population is usually a cause for concern. Oppositely, the *decline* of the population is often a cause for concern in an island community. This is the case in areas, or countries, where urbanization is a general trend.

This article presents the case of Samso based on the theoretical elements presented in the following section. In order to structure the analysis, the methodology follows a list of eight general planning elements ranging from political energy targets and energy visions to policy implications. The case is described with reference to the theory and the planning elements. The policies are then reviewed with respect to the overall goals, resulting in a recommendation to balance the policies toward the limitations in land use on an island.

## 2. Theory

Hardin, a biologist, pointed out long ago, that “freedom in a common brings ruin to all” (1968) [17]. Each individual will try to maximise his return. Some form of corrective feedback and regulation is necessary for it to work. A modern common thus becomes “a resource + a community + a set of social protocols” (Bollier in Melville et al., 2017) [5]. An example is a dairy cooperative of cattle farmers or a wind turbine cooperative of citizens [6]. Melville et al. propose to trial a common based local electricity institution [5]. Furthermore, large systems should be organised as “multiple layers of nested enterprise” according to the political economist Elinor Ostrom (in Melville et al., 2017) [5]. Such an organisation already exists, namely the following regional hierarchy: the European Union -> the nation -> the region -> the municipality, and -> the citizen.

Urban dynamics is an application of system dynamics. A system dynamics model simulates a nonlinear system over time using level variables, flows, and feedback loops. Alfeld and Graham constructed such a model to portray the behaviour of an urban area [16]. The model is quite general. Later, other researchers published a simplified version together with its programming code [18]. Fig. 1 shows an adaptation with three level variables and their