Energy Conversion and Management 103 (2015) 259–265

Contents lists available at ScienceDirect

Energy Conversion and Management

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

Energy saving synergies in national energy systems

Jakob Zinck Thellufsen *, Henrik Lund

Aalborg University, Deparment of Planning and Development, Vestre Havnepromenade 9, 3, 9000 Aalborg, Denmark

ARTICLE INFO

Article history:
Received 13 April 2015
Accepted 17 June 2015
Available online 3 July 2015

Keywords:
Heat savings
Electricity savings
Energy system analysis
System dependent energy savings
Energy saving synergies

ABSTRACT

In the transition towards a 100% renewable energy system, energy savings are essential. The possibility of energy savings through conservation or efficiency increases can be identified in, for instance, the heating and electricity sectors, in industry, and in transport. Several studies point to various optimal levels of savings in the different sectors of the energy system. However, these studies do not investigate the idea of energy savings being system dependent. This paper argues that such system dependency is critical to understand, as it does not make sense to analyse an energy saving without taking into account the actual benefit of the saving in relation to the energy system. The study therefore identifies a need to understand how saving methods may interact with each other and the system in which they are conducted. By using energy system analysis to do hourly simulation of the current Danish energy system, the combination of reductions in heat and electricity demands is analysed within the Danish district heating sector to show the benefits of coordinating savings in the electricity and district heating sectors.

1. Introduction

In the transition to future 100% renewable energy systems, many aspects have to be included, among others: introducing new energy technologies, dealing with large amounts of intermittent resources, and energy savings. Energy savings is often identified as a key element in transitioning to future energy systems. This is the case in [1] that combines district heating with heat savings in the case of the European Energy System, and [2] that investigates the role of heat savings in a European Energy System without the focus on district heating and combined heat and power. Other examples are the Coherent Energy and Environmental System Analysis report that investigates a future 100% Renewable Smart Energy System of Denmark [3], and [4] that investigates a possible path to a future Energy System in California. In both of these energy savings play an important role but are not investigated in relation to the energy system. Heat Roadmap Denmark [5] investigates the expansion of district heating in Denmark in relation to energy savings, and [6] investigates the cost optimal level of saving in relation to future Danish energy systems.

In all these studies, energy savings are and play an important role in the conclusions. However, the studies have different levels of savings, for instance [1] suggests 34% reduction in heat demand, whereas [2] suggests 61% and [3] suggests 50% reduction. The three studies have different energy systems and emphasises different technologies. These differences seems to influence the amount of energy savings needed, indicating that savings are dependent on the system layout, and that some kind of understanding of the dependency exists; however, the studies do not investigate or quantify this system effect.

These plans for future energy systems therefore apply an overall approach to energy savings appreciating the need for savings and better efficiency in both heating and electricity sectors. However, they do not focus on the specific performance of specific technologies. Other studies focus on specific technologies to reduce demands or increase efficiencies within a certain part of the energy systems such as electricity or heating. For instance by improving the building stock in either Denmark [7] or Greece [8], with the focus on lowering energy demands for buildings, or introducing better appliances such as refrigerators, freezers and coolers [9], and better air conditioning [10]. Other specific studies investigate effect of energy efficiency in lightning, for instance through the development of new technology [11], and the actual implementation scheme of lightning in office buildings [12]. Common for these studies is they discuss the lowering of the demand by different technologies and schemes, but they do it in a closed environment, thus omitting a system perspective.

What becomes apparent is that energy savings are essential, but there is no investigation of the energy system's effect on the performance of the savings initiatives. Either, analyses are so specific that they do not take into the energy system into account. Alternatively, analyses are broad and investigate transitions of whole energy systems, where energy savings are only a part of

* Corresponding author. Tel.: +45 9940 8289.
E-mail address: jakobzt@plan.aau.dk (J.Z. Thellufsen).

http://dx.doi.org/10.1016/j.enconman.2015.06.052
0196-8904/

the study, thus making it hard to identify the specific effect of the energy system on the performance of energy savings. This study therefore separates itself from these previous analyses, by focusing specific of this relation between energy savings and the energy system to quantify this interaction.

Thus, there is a lack of knowledge about interaction between energy savings and the energy system. This also omits the possible synergies between, for instance, heat and electricity savings and the system.

With the introduction of the concept of Smart Energy Systems [13], it becomes increasingly important to understand the connection between energy savings and the energy system. Smart Energy Systems push towards higher integration between the various parts of the energy system, and are defined as:

> *"an approach in which smart electricity, thermal, and gas grids are combined and coordinated to identify synergies between them to achieve an optimal solution for each individual sector as well as for the overall energy system."*
>
> [14]

Thus, Smart Energy Systems avoid isolating parts of the energy system for themselves, but instead take an approach where all parts have to be connected. Connecting the Smart Electricity Grid with the Smart Thermal Grid through heat pumps enables storage for excess electricity in terms of access to thermal storage. Furthermore, using excess electricity to create synthetic fuels enables a link between the Smart Electricity Grid and the Smart Gas Grid. By creating and storing gas, the system achieves a higher degree of flexibility, enabling production of heat and electricity in hours with little intermittent renewable energy [14].

This indicates that a Smart Energy System should be able to achieve close to 100% renewable energy with large amounts of intermittent resources such as wind and solar power, as demonstrated for the case of Denmark in the Coherent Energy and Environmental Systems Analysis Study [3]. Smart Energy Systems find the necessary flexibility of an energy system through the interconnection between each grid, instead of through the fuel as is the case in current fossil-based systems [14]. Fig. 1 illustrates the concept of Smart Energy Systems and highlights the main points of interconnection between the different grids.

It is clear that in systems with no connection between the thermal, electrical, and gas grids there is very little to no system dependency and almost no achievable synergies. In these cases, the expectation is a linear relation between reduced demand and reduced fuel use.

However, in Smart Energy Systems and other integrated energy systems, which emphasise the combination of and coordination between different parts of the energy system, the system influences the performance of the energy savings initiatives. Here, it becomes important to identify the energy system's effect on savings, and possible synergies between various types of savings across different sectors.

This paper focuses on these system effects and synergies in integrated energy systems. It seeks to identify the possibility of obtaining better performance of energy savings across different parts of the energy system, when these parts are connected. Currently, no mapping of the effect of synergies between savings exists. As identified earlier, studies that investigate the benefit of savings either focus on a specific technology and investigate the benefit of this, or see savings in a larger picture in combination with the installation of other technologies. Even though both types of studies might inherently appreciate or acknowledge possible system dependent synergies between savings, none of them study the possible effects of such system dependency and synergies between, for instance, reduction in heat and electricity demands. This paper therefore seeks to investigate the synergies of coordinating savings in highly integrated systems. The goal is not to specify specific targets for savings but instead to see the effect of coordinated savings. This is done by developing a methodology for exploring the area and applying it to the case of the current

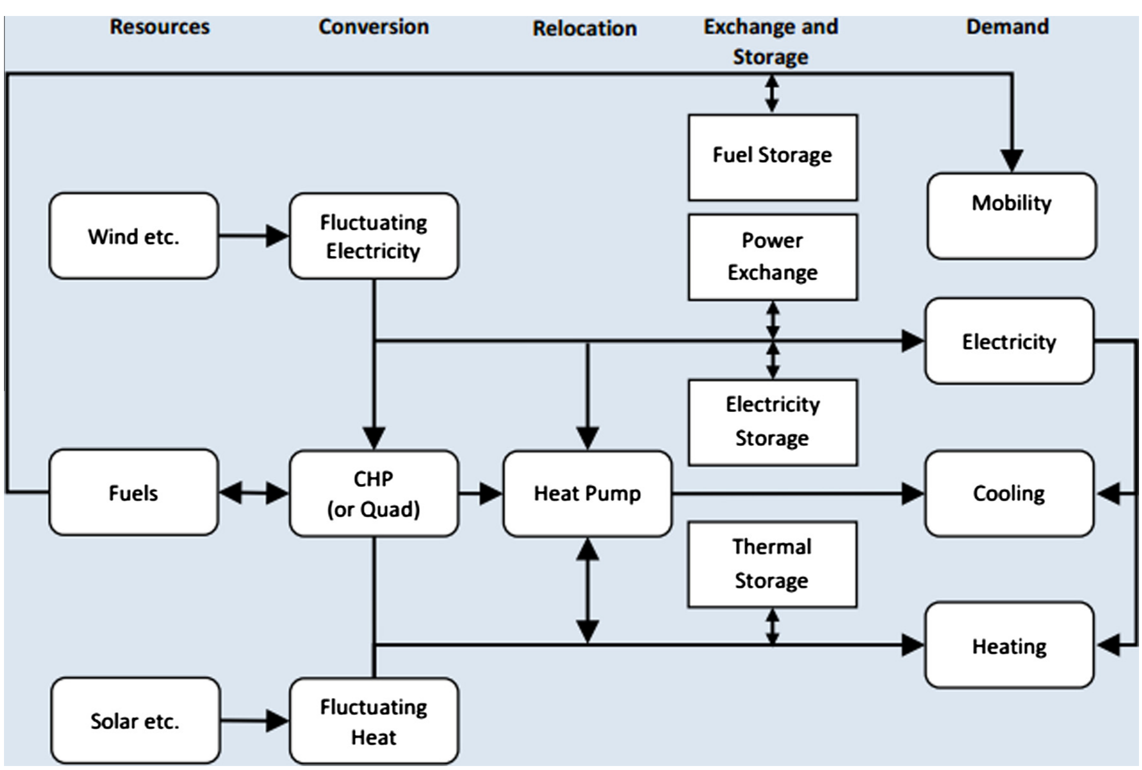

Fig. 1. Illustration of smart energy systems [15].