Energy Research & Social Science 39 (2018) 12–18

Contents lists available at ScienceDirect

Energy Research & Social Science

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

Original research article

Sufficiency, change, and flexibility: Critically examining the energy consumption profiles of solar PV prosumers in Sweden

Jenny Palm[a,*], Maria Eidenskog[b], Rasmus Luthander[c]

[a] Lund University, International Institute for Industrial Environmental Economics (IIIEE), Box 196, SE- 221 00 LUND, Sweden
[b] Linköping University, Department of Thematic Studies − Technology and Social Change, SE − 581 83 Linköping, Sweden
[c] Uppsala University, Department of Engineering Sciences, Division of Solid State Physics, Built Environment Energy Systems Group (BEESG), P.O. Box 534, SE − 751 21 Uppsala, Sweden

ARTICLE INFO

Keywords:
Prosumer
Energy consumption
Photovoltaic (PV)
Flexibility

ABSTRACT

The number of consumers producing electricity at home, i.e., "prosumers", is rapidly increasing in many European countries. This article analyses the electricity consumption and energy-saving behaviours of households that own photovoltaic (PV) systems in Sweden. Earlier studies of how home production of electricity affects consumption patterns are few and their results are mixed. We interviewed prosumers in Sweden and collected electricity-consumption data one year before and after they installed PVs. The differences between households were large and no general behavioural change could be detected. The interviews indicated that awareness of the energy system increased among all prosumers, but led to no substantial changes in how or when activities were performed. Most prosumers thought that the benefits of shifting their electricity load to other times were too small. The changes prosumers did make mostly concerned smaller adjustments. Households that increased their consumption justified this by their access to "free" electricity. Automation, i.e., using a timer, was relatively unknown or not used when known.

1. Introduction

Micro-generation can create new opportunities for coordinating supply and demand in the electricity system. Microgeneration is a small-scale generation of electricity power and when households are both producers and consumers of electricity, they are called prosumers [1]. The number of consumers producing electricity at home, prosumers, is rapidly increasing in many European countries. This paper considers the case of Sweden, where the photovoltaic (PV) market share is so far not large, accounting for only 0.08% of electricity production in 2015 [2]. However, the Swedish PV market has developed fast in the recent years, with an increase in cumulative capacity as in Fig. 1 [2]. The yearly electricity production from Swedish PV systems are 800–1100 kWh per installed kW of peak PV power depending on location and orientation, which gives a yearly electricity production of 100–140 GWh with the installed capacity of 2015. This can be compared to the yearly electricity demand in Sweden of close to 140 TWh during the recent years, see Fig. 2. No data for the installed PV capacity in 2016 was available at the time of processing of this article.

As shown in Fig. 2 the residential and service sector is the one consuming most electricity in Sweden.

In Sweden, there are signs that prosumer participation in the energy system is increasing [2] and all future scenarios assume such an increase. There has also been a transformation in Swedes' minds, with PVs evolving from a technology for enthusiasts only to a technology many Swedes could see themselves adopting. For example, in a survey conducted by energy utility E.ON in April 2016, 73% of the respondents said that they wanted to install PVs [4].

In Sweden there has been some substantial changes in the policy support framework for PV panels. In 2009, a subsidy was introduced for the installation of PV panels for households. In the beginning, it was possible to get subsidies for 60% of the installation cost, including material and labor costs, but thereafter the subsidies have been stepwise reduced. Since 1 January 2015, the subsidies is 20% of installation cost [5]. Until April 2010, households had to pay for the costs of changing meters when installing PV panels. After that, the grid company had to make the change without charging the homeowner [6]. In 2015, a tax deduction of 0.06 EUR/kWh for sold electricity was introduced for micro producers of renewable electricity. This cannot, however, exceed 1800 EUR per year [2]. Sweden does not have feed-in tariffs, such as in e.g. Germany, where the prosumers receive a predefined price per kWh regardless of the buyer and the time.

* Corresponding author.
E-mail addresses: Jenny.palm@iiiee.lu.se (J. Palm), maria.eidenskog@liu.se (M. Eidenskog), Rasmus.Luthander@angstrom.uu.se (R. Luthander).

http://dx.doi.org/10.1016/j.erss.2017.10.006
Received 7 June 2017; Received in revised form 5 October 2017; Accepted 5 October 2017

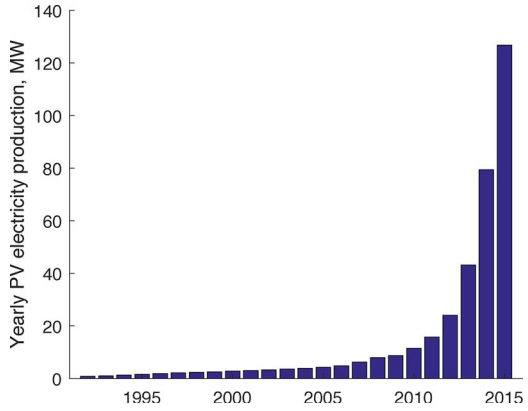

Fig. 1. Cumulative installed PV capacity in Sweden [2].

Developing a 100% renewable energy system would also require substantial changes in the structure of both supply and demand. A 100% renewable system requires that households engage in flexible energy consumption practices. Flexible electricity consumption relates to and relies on individuals' everyday household choices, routines, and activities. Electricity consumption needs to be understood in relation to households' daily activity patterns [7]. Activities are synchronized on a societal level [8], and to support consumption flexibility, it is necessary to understand the exact rhythms of people's everyday lives. This can be done by measuring the timing and duration of the energy-related activities in the complete daily sequences of activities performed by individuals. More knowledge is needed of the basic dynamics and temporalities of energy demand [8,9].

Few studies have addressed the electricity consumption and energy-saving behaviours of households that own PV systems. Most of these studies are from the UK [10]. This paper accordingly examines households in Sweden that have installed PV panels on their roofs to analyse the flexibility of their electricity consumption. Depending on the contracts with electricity companies, the most favourable use of self-generated electricity could be either to consume it directly or sell it to the grid. We will analyse if and in such case how home production of electricity affects households' electricity consumption patterns and if PV production influence awareness of energy.

2. Flexibility in energy use: earlier research

Household energy consumption is generally interwoven with everyday life, with its routines, meanings, social dynamics, and technical infrastructure [7,11–19]. Energy is required for the functions and conveniences it can provide in relation to, for example, preparing food, supplying heat and light, and maintaining health and sanitation. What people do in their everyday lives, i.e., their activities, is an important starting point for understanding energy use in a social context.

Household flexibility in energy use is of interest in relation to balancing supply and demand to facilitate increased renewable electricity generation [20]. Flexibility is usually defined as the capacity to increase or decrease the load within a certain timeframe. Powells et al. [21] defined flexibility as the ability of energy users to change how, when, and where they demand power. In a technological approach to flexibility, the consumer does not necessarily need to be involved, as domestic appliances can be turned on and off automatically. In a social science approach, the aim is to influence consumers' appliance use within a specific time-span [22]. For prosumers, the motivation for flexibility can lie in the benefits of using the electricity themselves, or in the benefits of selling self-produced electricity to the grid [23].

Micro-generation can create new opportunities for coordinating supply and demand and contribute to the rearrangement of household routines, for example, turning off unnecessary appliances and re-scheduling activities such as laundry to outside peak hours [24]. The role of consumers changes from that of passive recipients to co-managers of their own practices [25].

Earlier research has considered household energy-use flexibility mainly in relation to white goods, such as washing machines and dishwashers, as well as thermal appliances [20]. White goods use is often considered not to be time critical [26]. The effect of using the washing machine's automated function on load shifting was investigated by Kobus et al. [22]; regarding the increased self-consumption of PV-generated electricity, use of the automated function was found to have no significant effect. Anderson's [27] historical analysis of laundry practices discussed studies of home energy monitors that give feedback on energy consumption. Anderson [27] found that it can be difficult to shift laundry tasks, but that automation tools can contribute to more reflective planning of laundry practices to accommodate self-produced electricity.

Earlier studies found that home production of electricity can affect consumption patterns. Olkkonen et al. [28] discussed how the growth in energy prosumers is driven by a combination of lower-cost PVs and changing household practices, indicating that micro-generated electricity might influence how households consume energy. Olkkonen et al. [28] found that prosumers changed their consumption behaviour to consume as much as possible of their own electricity generated during daylight hours. Goulden et al. [29] also found that micro-generation triggered new habits, for example, checking the weather so that a timer could be set to schedule an automatic energy activity if the sun would be shining. Christensen et al.'s [30] study of Danish consumers

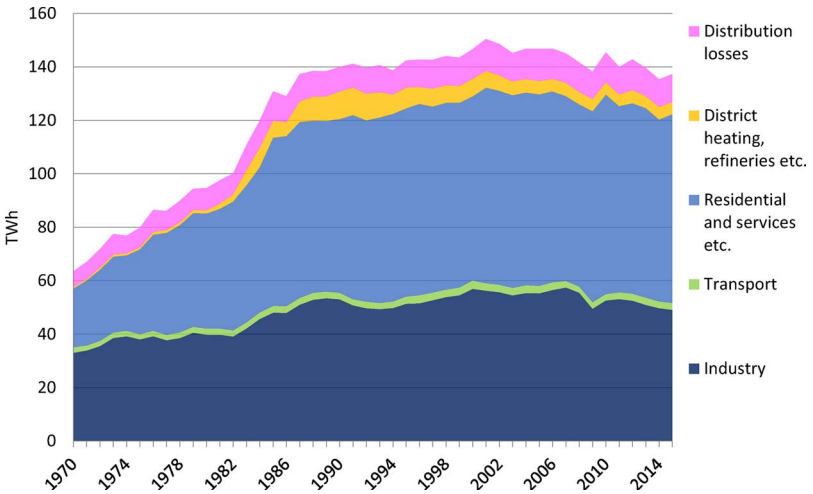

Fig. 2. Electricity use, by sector, from 1970, TWh [3].