EFFECTS OF RESIDENTIAL CUSTOMERS' ENERGY EFFICIENCY ON ELECTRICITY DISTRIBUTION BUSINESS

Jussi TUUNANEN
LUT – Finland
Jussi.tuunanen@lut.fi

Samuli HONKAPURO
LUT – Finland
Samuli.honkapuro@lut.fi

Jarmo PARTANEN
LUT - Finland
Jarmo.partanen@lut.fi

ABSTRACT

Energy efficiency has been a topic of discussion for a long time, and now it seems to have effects on energy consumption. Energy efficiency actions will influence on customers' electricity usage. This can also be seen in the amount of transmitted electrical energy and power through distribution network. Total effects of energy efficiency on transmitted electrical energy and power are not known. Changes in transmitted energy through network will also have effects on distribution system operator's (DSO) business. This paper presents methodology for estimating effects of energy efficiency on electricity distribution. It is concluded that energy efficiency will have effects on transmitted electrical energy and power. Regionally those effects may differ. Finally, changes will happen also in electricity distribution business.

INTRODUCTION

Electricity distribution business is in a transition at the moment. Traditional electricity distribution will change to smart grids in the future. Smart grids will include e.g. micro generation, electric vehicles, energy storages and energy efficiency. International and national energy efficiency laws and decrees have had a great effect on energy efficiency. For instance, EU's energy efficiency directive orders to decrease electricity consumption by 20 % by 2020. [1] Also many parties, such as states, companies and private people, are already involved in energy efficiency. This proves that energy efficiency is an ongoing trend and it will also continue into the future. People have had a tendency to reduce electricity consumption, because they at least try to save in electricity fees. Great results and experiences have been achieved, e.g. from the energy efficiency pilot studies. In one pilot case in Finland, electricity consumption decreased from 45-49 MWh to 16,5-18 MWh in electric heating detached houses when ground source heat pumps had been installed. [2] In some scientific papers, [3] and [4], energy efficiency effects have already been analysed.

The biggest energy efficiency actions in buildings will probably be in lighting, heating and improvements in insulation. Lighting and insulation methods will decrease electricity consumption. In heating systems, heat pumps can increase electricity consumption in non-electric heating buildings and decrease electricity consumption in electric heating buildings. In spite of this, energy efficiency actions always decrease the amount of primary energy.

DSOs' customer groups can vary a lot. Typical customer groups in Finland are residential customers, service sector, industry and agriculture. These groups can be divided into more specific groups, such as residential customers to detached houses, row houses, block of flats and summer cottages. Residential customers have a considerable role in electricity distribution in Finland. In some DSOs residential customers can consume over half of all transmitted energy. The number of residential customers is the biggest and they have the most potential to perform energy efficiency actions in the near future, both economically and technically. In this study all customer groups have been taken into account, but residential customers are in a major role.

Chapter 2 presents methodology and Chapter 3 reviews results of the case study. The results are discussed in the 4th chapter and the final chapter presents conclusions of the paper.

METHODOLOGY

Energy efficiency effects are related to electrical energy and power. For example, air source heat pumps in residential customer's electric heating buildings decrease energy consumption, but it can increase power during the peak times. This is the reason, why energy and power consumption has to be researched separately. Energy calculations are not location dependent, but power calculations are. Basically, if power consumption increases, it means that costs increase too. This is because dimensioning of the network mainly depends on the power. In turn, changes in energy consumption have effects on DSOs' incomes with the present tariff structure.

The main criteria for energy efficiency calculations are:

- Insulation: on average buildings' heating demand will be 95 % by 2020 and 80% by 2050 compared to the present situation.
- Heating: the amount of heat pumps is based on an estimate of one million heat pumps in Finland by 2020. By 2050 it is assumed that the amount of heat pumps will increase from the level of 2020 and Seasonal Performance Factors (SPF) will be better on average.
- Lighting: assumptions are based on prohibition of incandescent lamps in EU 2012 and halogens are withdrawn from the markets. Individual lamp energy consumption will clearly decrease by 2020. By 2050 electricity consumption is even less.

These are initial and basic data and scenarios for the study.

Insulation scenarios are based on reference [5], heat pumps reference on [6] and lighting scenarios on reference [7]. To analyse different kinds of scenarios, simulation tools have been made. Parameters can be changed to simulate scenarios for the years 2020 and 2050. Electricity consumption data can be collected e.g. from Automatic Meter Reading (AMR) data.

Methodology for electrical energy

In electrical energy calculations it is important to know how much heating and electricity consumption is in an individual customer place. Each customer group needs to be studied separately, because consumption varies a lot. The effects can be calculated for all customers in the customer group, when the amount of customers in each customer group is known. Since scenarios have been made for each customer group, the total energy efficiency effects on the studied area can be solved.

A lot of information is needed from the research data: the amount of customers and how much each customer group uses electricity per year, the portion of electric heating buildings, approximations of space heating and water heating and cooling energy, the estimate of SPF and distribution of heat pumps in different kinds of buildings. Because all data is not always available, assumptions have to be made. If detached houses' space and water heating demand are not known, it has to be estimated. In this case, a good estimation could be that 50 % of the total energy consumption is used in space heating, the fifth for warm water heating and one third for electricity appliances.

Approximation of the amount of heat pumps in different types of buildings at the moment is based on the statistics of the national amount of heat pumps. Heat pumps increase electricity consumption in non-electric heated houses, and decrease consumption in electric heated houses. The methodology of the heat pump has been introduced on reference [6]. The insulation of buildings has been assumed to have an impact only on electric heating houses. Insulation and heat pumps interaction have been taken into account by calculating first changes in insulation and then the new heating demand has been used in heat pump calculations.

Methodology for power

In power calculations the electricity consumption during a specific time needs to be known. The basic principle is that the peak hourly power period is researched with all customers. The peak powers in Finnish conditions are usually during the coldest weather, which is typically during two weeks in the middle of February. The week, when peak hourly power exists, is chosen for researching. Hourly metered data, including 168 hours, is collected for scenarios. Energy efficiency analysis and calculations have to be done for each hour, see Figure 1.

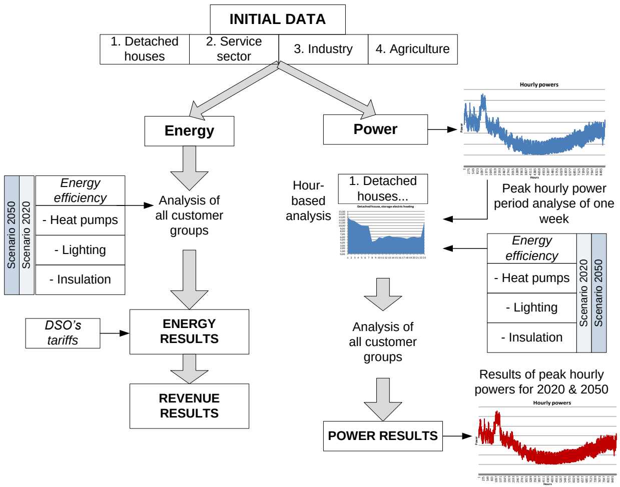

Figure 1. Methodology for energy power and revenue calculations.

The amount of customers and an average load curve for each customer group is needed. Each customer group and each energy efficiency action has to be evaluated individually. For instance, in detached houses lighting is on every day of the week: couple hours in the morning and 4-5 hours in the evening in winter time. In turn, lighting is on at different times at weekends. Estimations for all others customer types are needed: how much different kind of lighting use electricity at different times.

During the cold week, peak powers are clearly higher than in other weeks. During winter time and cold weather, additional heating is often needed and it is usually implemented by electric heating. Additional electric heating has been taken into account in insulation calculations. If building's insulation in non-electric heating houses and electric heating houses was better, the electric power would decrease.

Heat pumps increase power in non-electric heated houses and in storage electric heating buildings at day time. In turn, heat pumps decrease power in electric heated houses. When the average type of curve is known, the final scenarios for the years 2020 and 2050 can be obtained, when the curves are multiplied by the number of customers.

Methodology for revenue

When changes in transmitted energy have been solved, the effects on distribution business can be calculated. Information on the present distribution tariffs and electricity distribution revenue for one year is needed for this. Calculations can be done by using the DSO's tariffs and the results of electrical energy calculations.

RESULTS OF THE CASE STUDY

In this study small electricity customers have been analyzed, see Table 1.

Table 1. Initial data of the case area, power values are the highest hourly mean powers.

Customer group	Number	Energy [MWh]	Power [kW]
1. Detached house	381	6 443	2 273
1.1 Non electric heating	*205*	*3 007*	986
1.2 Direct electric heating	*125*	*2 402*	*902*
1.3 Storage electric heating	*51*	*1 034*	*517*
2. Agriculture	348	8 227	*2 455*
3. Service sector	219	6 440	1 506
4. Industry	88	3 182	1 145
TOTAL	**1 036**	**24 292**	**6 602**

AMR data was available from the all customers. In practise, the calculations have been made for one DSO in Finland, and its part of the network.

Effects on electrical energy

Results are very much dependent on the studied area. Residential customers are in the biggest role of all customer groups. Transmitted electrical energy from the distribution network to small customers will probably decrease from the level of the present situation by 2020, and effects will strengthen by 2050. From the Figure 2 can be seen that the total effects in energy consumption are -9 % by 2020 and -17 % by 2050 compared with present situation in this case study.

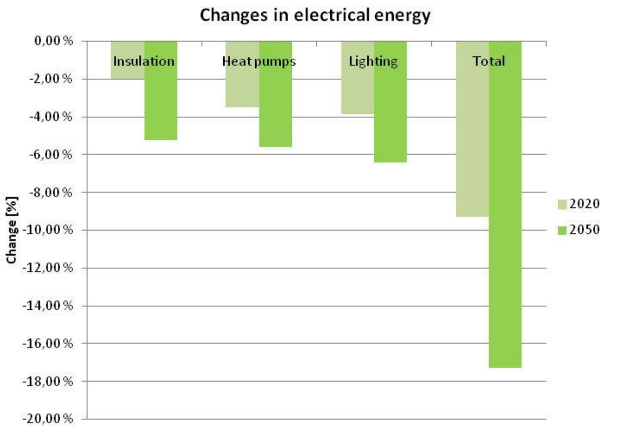

Figure 2. The total changes in electrical energy seem to be significant already by 2020.

In Figure 2 energy efficiency effects for all customers have been taken into account. Thereby, insulation result means, that all customers' insulation actions have -2 % effect on DSO's transmitted electrical energy through distribution network by 2020. Because the amount of electric heating houses is relatively low, the impacts of heat pumps on electrical energy are reasonable. Heat pumps are very popular in small buildings, but by 2050 heat pumps can also be popular in bigger buildings. The biggest saving potential will come from lighting. This can be explained by the amount of light energy consumed in Finland. Energy efficiency of lighting concerns all customers and all building types. For example lighting in detached houses normally use about 20 % of the total electricity usage.

Especially residential customers' electrical energy savings are significant by 2020. Almost 50 % of energy changes have been assumed to occur for residential customers. Service sector, agriculture and industry have bigger effects on electrical energy not until 2050. This is due to a fact that, the bigger building, the longer the time for renovation. Also technology has to be more developed in the future.

Effects on power

Traditionally electricity power has been thought to increase. But it seems that this trend will probably at least slow down in the case area. From Figure 3 can be noticed that in 2020 power can be higher than at the present. The reason is that the heat pumps can increase electricity consumption in non-electric heating buildings and in storage electric heating buildings at day time.

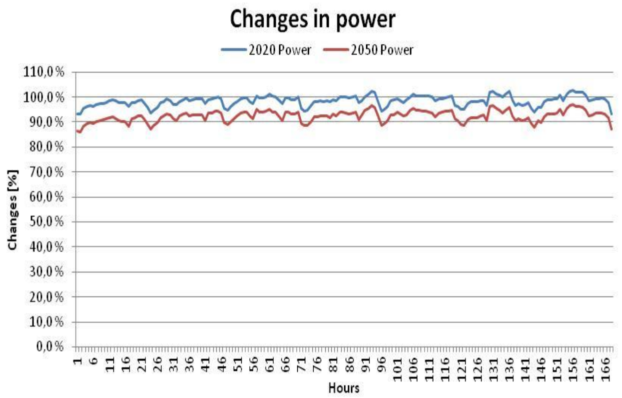

Figure 3. Changes in electrical power by 2020 and 2050, level of 100 % describe the present situation.

Generally power in this case study will be almost at the same level in 2020 that it is at the moment. If energy efficiency actions work as assumed, hourly peak power consumption could be about 95 % from the present situation by 2050. Lighting impacts on power consumption are small. Instead, heat pumps and insulation have considerable effects on power. Residential customers' energy efficiency actions have a relatively high impact on power.

Effects on DSOs' business

At the present distribution tariffs consist of fixed and energy based fees in Finland. Distribution between fixed and energy fee is about 50/50 % on average. Figure 4 show that energy efficiency would have -5 % effects on electricity distribution revenue by 2020 with the present tariff structure. Effects on revenue will be about -9 % by 2050 compared with the current situation. Distribution business is clearly dependent on transmitted energy through distribution network. In practise, this means that if DSO would like to keep revenue at the same level as previously, DSO's should increase distribution tariffs' prices.

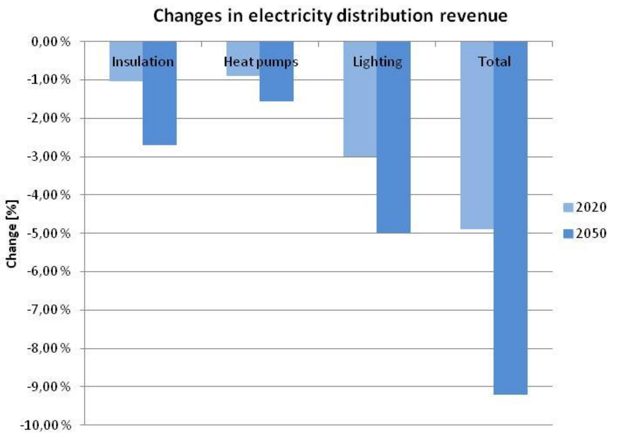

Figure 4. The total changes in electricity distribution revenue by 2020 and 2050.

DISCUSSION

The biggest part of electricity is consumed in buildings. In this study three remarkable energy efficiency actions in buildings have been taken into account. There are many energy efficiency actions, which are not included in this study. EU directives order appliances to be built more energy efficiently, such as refrigeration devices. On the other hand, the amount of buildings can increase in the future and also the number of appliances in single residences can increase. These will increase energy consumption, and it can be assumed that this will compensate energy efficiency actions.

The biggest changes in electricity consumption seem to occur for residential customers. The results of the case study show, that the impact on electrical energy can be remarkable by 2020 and even greater by 2050. The influence on power is insignificant by 2020, but by 2050 effects can be moderate. DSOs, at least in the countryside, need to prepare for changing conditions. The amount of electrical energy in the distribution network may change radically. The situation will probably be different in distribution companies in the urban area, where there are a lot of service sector and industrial customers. Moreover, new residential buildings are built in urban area all the time, which can increase electricity consumption in the low voltage network. It seems that the final changes are difficult to estimate accurately, but it is obvious that in residential customers' electricity usage there will appear changes during the next decades.

The biggest result might be that in the present building infrastructure electricity consumption will not increase necessary as previously, if operational environment in distribution system stay at the current level and technology will not change radically. Later on, e.g. electric vehicles will clearly increase electricity consumption and customers' own micro generation will decrease transmitted energy in distribution network. The same type of methodology as in energy efficiency can be applied to electric vehicle and micro generation calculations and scenarios.

CONCLUSIONS

The results of this study were methodology and tools to evaluate the effects of energy efficiency on electricity distribution. It is concluded that local effects on electricity consumption can be remarkable. Changes in electricity consumption and operational environment set challenges for DSOs and they have to accommodate the changing conditions. The result is that DSOs' revenue will change significantly with the present tariff structure. This means that with the present income formation DSOs' revenue will be jeopardised and become unstable. At the same time costs and demands for reliability are increasing. The final conclusion is that evidently new methods for electricity distribution business are needed.

Acknowledgments

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