Flex4RES

Flexible Nordic Energy Systems

Framework conditions for flexibility in the individual heating-electricity interface

DTU

NMBU Norges miljø- og biovitenskapelige universitet

KTH VETENSKAP OCH KONST

RTU

TUT

Aalto University

Stockholm School of Economics

NIFU

norden

Nordic Energy Research

Flex4RES project summary

The Flex4RES project investigates how an intensified interaction between coupled energy markets, supported by coherent regulatory frameworks, can facilitate the integration of high shares of variable renewable energy (VRE), in turn ensuring stable, sustainable and cost-efficient Nordic energy systems.

Through a holistic system approach based on coupled energy markets, we identify potentials, costs and benefits of achieving flexibility in the Nordic electricity market created by the heat, gas and transport sectors as well as by electricity transmission and generation. Flex4RES develops and applies a multidisciplinary research strategy that combines technical analysis of flexibility needs and potentials, economic analysis of markets and regulatory frameworks, and energy system modelling that quantifies impacts.

Through the development of a coherent regulatory frameworks and market designs that facilitate market interactions, which are optimal for the Nordic conditions in an EU context, transition pathways to sustainable Nordic energy systems are identified. Flex4RES will comprehensively discuss and disseminate the recommended pathways and market designs for achieving a future Nordic sustainable energy solution with a variety of stakeholders from government, industry and civil society.

More information regarding the Flex4Res project can be found at www.Flex4RES.org or by contacting project manager Klaus Skytte at klsk@dtu.dk

Acknowledgement

The Flex4RES is supported by Nordic Energy Research for which we are very grateful. The opinions expressed in this report do not represent the Nordic Energy Research's official positions, but are entirely attributable to the authors.

WP2 Framework conditions, May 2017

Framework conditions for flexibility in the individual heating-electricity interface

Authors: Daniel Møller Sneum (DTU), Dagnija Blumberga (RTU), Jonas Katz (DTU), Ole Jess Olsen (DTU)

With contributions from: Hardi Koduvere (TTU), Eli Sandberg (NMBU) and Erik Trømborg (NMBU)

Reviewed by: Emilie Rosenlund Soysal (DTU) and Klaus Skytte (DTU)

ISBN: 978-87-93458-49-9

Results at a glance

- This study reviews framework conditions for energy system flexibility within individual heating, defined as heating and hot water in households not connected to district heating,
- Except for Norway and Sweden, where deployment of power-to-heat is significant, inflexible fuel-based technologies are dominant in individual heating of the Nordic and Baltic countries. This means that there is a *large technical potential for conversion to flexible power-to-heat* technologies, in case flexibility from this part of the energy system is desired.
- Flexibility requires an incentive to invest in flexible technologies, and to operate these flexibly. I.e. the right incentives regarding fixed as well as variable costs. Norway and Denmark, as the only countries, have a potentially flexible heat technology – air-water heat pump – as the most economical alternative to invest in, while Sweden provides hourly based contracts for flexible operation. *None of the countries reviewed offer ideal conditions for investment in flexible individual heating technologies, together with conditions for flexible operation* of these.
- *Biomass-based individual heating is generally the most economically attractive option* to invest in, apart from Denmark and Norway.
- *Flexible operation is dependent on hourly metering, and subsequently on contracts for this*, and technologies and consumers, who will respond to price signals. Under current conditions, *smart electricity consumption has a very limited effect towards improving the business-case for flexible heat production technologies*
- *Incentives for investment in power-to-heat can be increased along several paths*, where these are the main: Decreasing the cost of operation of flexible technologies; increasing the cost of operation of inflexible technologies; or decreasing the investment cost for flexible technologies and vice versa for inflexible technologies. The first could be achieved by a reduction in levies on electricity; the second by increasing levies on use of particularly biomass; and the third could address high capital costs of flexible technologies by subsidising, or providing low or no interest loans.

Executive summary

As part of the Flex4RES project, this study explores the current framework conditions for flexibility in the individual heating-electricity interface, in the Baltic and Nordic countries. Based on these findings, opportunities for increasing the flexibility are explored.

Flexible technologies are in this study considered to be heat pumps and electric resistance-based electric heating, i.e. power-to-heat technologies in the interface between heat and electricity. Conversely, *inflexible technologies* comprise of fuel-based heating, which does not contribute to integration of variable renewable energy. The study does not advocate a complete transition from inflexible to flexible technologies, but explores the framework conditions for increasing the flexibility.

The review of national statistics shows that individual heating, i.e. provision of heat and hot water in households not connected to district heating, consumes considerable amounts of energy in all countries. In Norway and Sweden, deployment of power-to-heat technologies is significant, while fuel-based technologies are dominant in the remaining countries. This leaves a considerable potential for increasing the share of power-to-heat in the Baltic and Nordic countries.

Reviews of national barriers and drivers reveals that support for flexible technologies can be in shape of subsidies or reduced levies, and can be provided for investment as well as operation. Regarding flexible operation, the review shows a more limited set of experiences. All countries have or are deploying smart meters, but the use of these for hourly pricing is limited to Sweden.

In addition to the review of drivers and barriers, an extensive review has been conducted on national regulation of levies, subsidies, fuel prices, and tariffs. These have provided input for analysis of the annual costs and heat production costs for selected flexible and inflexible technologies. Except for Denmark and Norway, where the air-water heat pump is the most economically attractive alternative, biomass-based heating is generally the most attractive solution in all countries.

If provision of flexibility from individual heating is desired, this situation needs to change.

Flexible operation is dependent on hourly metering, and subsequently on contracts for this, and technologies and consumers, who will respond to price signals.

Economic investment in flexible technologies can be improved along four paths:

1. Decreasing the variable costs of flexible technologies
2. Increasing the variable costs of inflexible technologies
3. Decreasing the fixed cost for flexible technologies
4. Increasing the fixed cost for inflexible technologies

The first could be achieved by reduction in levies on electricity; the second by increasing levies on use of particularly biomass; the third could address high capital costs of flexible technologies by subsidising, or providing low or no interest loans; the final could be addressed by adding levies on the investment cost of fuel-based technologies.

CONTENT

1 Introduction

Residential heating is an important part of the energy demand in the Baltic and Nordic countries, and can be an important contributor to a flexible energy system. Conversely, residential heating can be a barrier, if not interacting with the rest of the energy system, or if operated inflexibly. Within the Flex4RES project, the subject of flexibility in district heating has been explored in *Framework conditions for flexibility in the district heating- electricity interface* [1], and the subject of electricity system flexibility in *Framework Conditions for Flexibility in the Electricity Sector* [2]. This report on residential heating focuses on individual heating, i.e. heating and hot water for households which are not connected to district heating systems. The geographical scope is the Baltic (Estonia, Latvia, Lithuania) and Nordic (Denmark, Finland, Norway, Sweden) countries.

1.1 Research questions

The study is based in the following questions:

- *What are the current framework conditions for flexibility in the individual heating-electricity interface?*
- *If we want increased flexibility in the individual heating-electricity interface, how can this be achieved?*

This study reveals tools for increased flexibility. Like any other tools, these should be reviewed in their concrete context (e.g. by energy system analysis and/or economic analysis), before being applied. Such analyses are conducted in the Work Package 3 of the Flex4RES project. Findings from these analyses will be a good starting point for implementation.

1.2 Report contents

The methodology is described in Section 2. Section 3 outlines the technological scope of the study, and relates the technologies to flexibility. Section 4 outlines good and historical practice in incentivising flexibility in individual heating. Section 5 presents the review of barriers and drivers for flexibility in individual heating in the Baltic and Nordic countries, including the annual cost of heat from selected technologies. In Section 6 the results from Section 5 are collected, discussed and concluded upon. References are found in Section 7. Appendices with the country-specific data are found in Section 8.

2 Methodology

2.1 Focus: Incentives for investment and flexible operation

The study reviews the conditions for investing in potentially flexible technologies, i.e. power-to-heat (P2H) technologies, and operating such technologies flexibly. This provides an overview of important barriers for flexibility. The analyses of the annual cost of heat, and annual costs for each technology, shows which technologies are most economically attractive, when investing in a new technology for individual heating. The terms *fixed costs* and *variable costs* could equally well apply for the terms mainly used in this study, respectively *investment costs* and *operation costs*.

2.2 Flexibility: Definition and application

Flexibility has been defined in two other studies within the Flex4RES project [1,2], as the ability of shifting either production or consumption between hours (inter-hour shifting). Thematically, the flexible consumption takes the main share of this study, since prosumers are outside the scope. To operate flexibly, i.e. performing shifts in consumption, technologies must be physically present in the system; they must be invested in. These two key elements are illustrated in Figure 1, where the overlap is the ideal situation for flexibility.

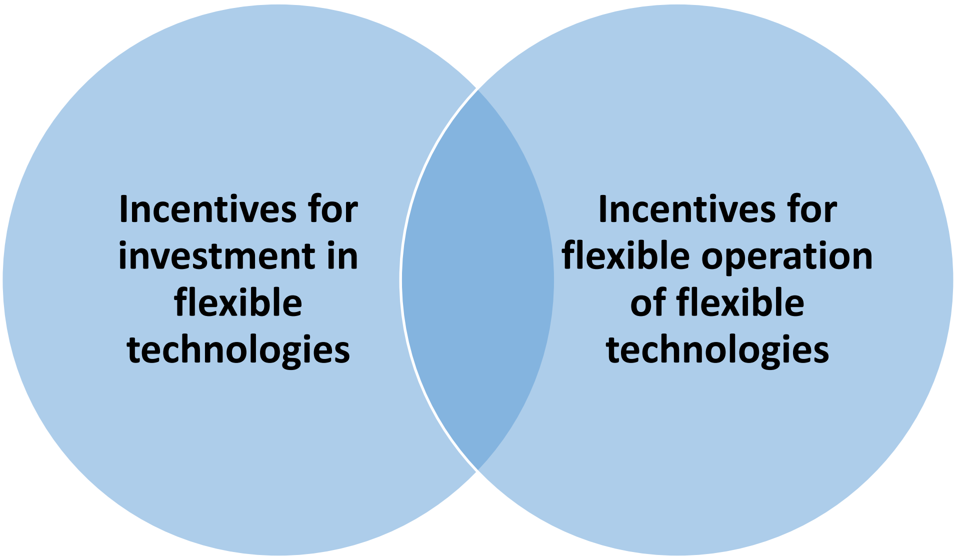


Figure 1 Overlap: Ideal conditions for flexibility.

This study should not be interpreted as an advocacy for a full electrification of individual heating, but as an investigation of the drivers and barriers for increasing flexibility. The distinction is relevant, since it is likely that individual heating based on e.g. biomass would be a better option than P2H in some cases. For instance, when the marginal energy production comes from fossil sources, when the distribution grid is too limited to handle increased electrification, or when socio-economic analysis shows that P2H would not be preferable for other reasons.

2.3 Definition of individual heating

In this study, individual heating describes residential heating without connection to a common heat provider, i.e. district heating. We limit the study to household consumers, focusing on the regulatory frameworks related to this consumer group. Other types of regulation and heat demand, which applies to commercial and industrial heat consumers, are not considered. Although heat pumps (HP) are usually able to provide cooling as well as heating, cooling is not addressed in the study.

2.4 A typical household

For the review and analysis of levies on different heat sources in Section 5, the following assumptions were made for the analyses of annual cost of heat and annual cost of heating technology:

- The heat source is installed in an existing house with waterborne system, a chimney and no existing heat source installed. Payment for energy (electricity and other fuels) is based on annual average prices from 2016.
- Heat demand is based on the standard house, as defined by the Danish Energy Agency: "*An existing one-family house is defined to have an annual heat demand of 16.8 MWh and a peak demand of 7 kW.*" [3]
- Investment period is 15 years with a 5% interest rate. No discounting is done. Technologies with a lifetime of more than 15 years are assumed decommissioned at a scrap value which is subtracted from the cost. Investment costs are based on the Danish Energy Agency [3].
- It is assumed that firewood is bought according to national prices. If gathered for free or in other ways obtaining wood materials at a lower cost, this will decrease the cost of firewood-based heating.

2.5 Review of national regulation

An extensive review of the subsidies, taxes, tariffs, and energy costs have been conducted for the Baltic and Nordic countries. This review is, to the best of the authors' knowledge, exhaustive as of 2016.

3 Individual heating technologies

3.1 Technologies in review

In Section 5, seven different technologies for individual heating are analysed regarding their annual costs and heat production costs. This section provides a brief description of these technologies regarding flexibility.

3.1.1 Heat pump air-water

HPs are the most energy efficient source of heating among the two P2H types, since heat pumps use electricity for extraction of heat from an external source. In the case of the air-water HP the efficiency used is 325% [3], and the heat source is ambient air.

3.1.2 Heat pump liquid-water

The same characteristics apply as for the air-water HP described in 3.1.1, with exception of the efficiency of 360% and a heat source based on liquid. Liquid-water based HPs utilises heat from a liquid, which in turn extracts heat from rock, ground or water.

3.1.3 Resistance-based electric heating

As the name indicates, resistance-based electric heating generates heat by utilising the resistance in the material that electricity is passed through. This happens in electric radiators and electric floor heating.

3.1.4 Natural gas boiler

Natural gas boilers generate heat by combustion of natural gas. Natural gas boilers are dependent on a natural gas grid, which is deployed at no or limited extent in Finland and Norway. Hence, natural gas boilers are not included in the review for these countries. In this configuration, they offer no flexible operation in regard of the energy system. They are hence not considered a flexible individual heating option in this study.

3.1.5 Oil boiler

Oil gas boilers generate heat by combustion of oil. The oil is usually stored in tanks, refuelled by lorries. In this configuration, they offer no flexible operation in regard of the energy system. They are hence not considered a flexible individual heating option in this study.

3.1.6 Wood pellet boiler

Wood pellet boilers generate heat by combustion of wood pellets. The pellets are stored in a local store and automatically (assumed in this study) or manually fed to the wood pellet boiler. In this configuration, they offer no flexible operation in regard of the energy system. They are hence not considered a flexible individual heating option in this study.

3.1.7 Firewood and electric water heater

While firewood stoves might be the oldest and least efficient (65% efficiency [4]) among the technologies reviewed for individual heating, they persist in residential heating, often in combination with other technologies. For this study, the configuration is assumed to be firewood stove (79% of total heat demand) and electric water heater (21% of total heat demand).

3.2 Flexible operation of individual heating technologies

P2H can be operated as a flexible or inflexible part of the energy system. When it is inflexible, it operates according to pre-set operation cycles or solely according to heat demand. Conversely, flexible operation satisfies the heat demand while offering flexibility in the energy system. In this case, the ability to store heat is essential, either in the form of an actual heat storage (e.g. hot water tank), or as the inertia of the heat capacity of the building's physical mass. The benefit of a hot water storage tank, is that it maintains comfort for the user, regardless of operation of the flexible technology. The drawback is that a storage takes up space, which might not be available or prioritised for other needs.

Since P2H, and HPs in particular, is not flexible per se, making the technology flexible can have higher investment costs than e.g. inflexible HPs. Whether this additional flexibility adds value to the heat consumer, determines the incentive to choose between the flexible and inflexible alternatives.

3.3 Technologies beyond the review

As in the rest of the energy system, individual heating is subject to constant change and development. This section reflects on this, by addressing technologies of relevance, which are not addressed in the review in Section 5.

3.3.1 Air-air heat pumps

Since this study focus on individual heating technologies with the ability to cover the full heat demand for a household, air-air heat pumps are not included. This type of heat pump is very similar to the air-water heat pump in the study, with the exception that air-air heat pumps heats the air in the house, instead of water as part of a waterborne system. Air-air heat pumps have relatively low investment cost, and are assumed to have relatively high deployment already.

3.3.2 Blockchain and peer-to-peer energy trading

Whereas the blockchain and peer-to-peer trading presently appear to be centred on electricity mainly, they might equally well extend into individual heating, particularly P2H.

Among its many applications, the blockchain technology provides the opportunity of contracting energy consumption and production on the prosumer level. Among the potential consumer benefits, are reduced transaction costs and more flexible switching among suppliers [5]. The latter would potentially mean that P2H consumers could contract directly with the source of electricity of choice, which inevitably adds an additional layer of complexity to obtaining a balanced energy system, all things being equal. The technology is in its infancy, and can take different paths, some of which might be disruptive to the traditional provision of energy and flexibility in the energy system.

Peer-to-peer energy trading can happen through blockchain as described above, but does not have to. There are already facilitators of regional markets, who provide contact between local providers and consumers. The difference to the blockchain approach is that peer-to-peer trading functions more like a virtual power plant, where utilities and facilitators can play a role in ensuring a balance between producers and consumers.

The pragmatic perspective on both blockchain and peer-to-peer trading is that the physical infrastructure sets natural limits on the use of the electricity grid, regardless of contracting. From this follows that the grid providers will maintain their need for financing for the infrastructure, which in turn means that the issue regarding tariff design for grid use persists.

3.3.3 Hybrid heat pumps

Existing boilers can be supplemented with a HP, allowing an interchange of production, and possibly simultaneous operation during cold periods. The hybrid HP can potentially be operated flexibly, adding flexibility to the energy system. E.g. by turning off and replacing with boiler production in periods with electricity scarcity and high electricity prices.

3.3.4 Prosumers

Prosumer is a collective term for the several different opportunities of consuming and producing residential energy. The considerable cost reductions in photovoltaic panels and batteries in the recent decade have made these a significant part of the prosumer category. However, dark and cold Baltic and Nordic winters will require very large capacities of batteries, if wanting to be truly independent of the grid, with or without P2H. Assuming such a setup, and a flexible operation of P2H, batteries might contribute to flexibility by *valley-filling and peak-shaving*, i.e. consuming when electricity prices are low, and producing when high.

Micro CHPs are another option, and can be based on e.g. natural gas or hydrogen fuel cells. If operated according the energy system needs, they have a similar flexibility potential as batteries, by valley-filling and peak shaving. Except for micro CHPs based on a regular gas engine, the technology is not yet commercial. Their relatively high costs mean that further technological development is needed, to make these a viable alternative [6].

Solar heating is presently relatively limited in individual heating. The use of solar heating in combination with a heat storage provides a potentially significant contribution to flexibility, in case it is combined with a P2H unit, which has access to this heat storage.

4 Review of common practice regarding the regulation of individual heating

With respect to an improvement of flexibility in the electricity system, the impact of the regulatory framework is primarily of importance in relation to two aspects: 1) the choice of technology; 2) the daily operation of it in order to achieve the intended effect. There are various kinds of instruments that may be used for affecting both the adoption of technologies and the operation of them. One may distinguish between direct load control measures and indirect attempts to control load by price or other informational feedback [7]. The latter type is mostly aimed at the operation of appliances, but attractive pricing schemes may also have an influence on the adoption of technologies. Moreover, utilities have been very active in promoting technologies that would have a positive impact on the load shape and thus on the utilisation of assets. Utility activities may include financing of appliances, cooperating with manufacturers in the design of new appliances and marketing such appliances themselves [8].

In the residential sector focus has long been on electric heating in the form of both storage and direct electric heating – this is particularly the case for European countries, such as France, Germany, UK and the Scandinavian countries. Individual electric heating has been promoted by utilities throughout Europe since the 1960s to fill the valleys in the load shape. They have been promoted with attractive tariffs linked to the condition of off-peak use. Traditionally two approaches have been used to ensure that heat customers are charged at favourable rates. The first is a time-of-use tariff granting a reduced price during off-peak periods during which hot water storage tanks are charged. As the remaining non-heat related consumption is billed under the same tariff, it would be possible to reduce costs for the use of other appliances as well by shifting the loads to the low-price periods. Another approach is to install a separate meter for consumption for electric heating. In this way it is possible to isolate the use for heating and offer specific rates. An advantage of the separate approach is that the utility can better control the amount of load that is shifted to off-peak periods. With increasing installations of electric heating in some countries it became important to avoid that new peaks are created causing capacity problems.

Besides the mere price, various approaches were implemented to control the use of devices. Most often the heating systems were installed with a simple form of automation. The operation could be based on a timer that could turn appliances on or off at a specific point in time. To avoid that all devices start at the same time, groups of appliances start at shifted points in time, resulting in a rolling connection of the additional load. In addition to this timer-based operation there are examples of remote control by radio signals or signals sent through the electric network itself. Such signals have been used since the 1930s for the control of large industrial loads. As well as with the timer-based model, it is possible to group the devices such that they respond to a specific signal, and the groups are controlled differently according to system needs.

It had been envisaged that similar price incentives could be applied to other kinds of loads. The French system of dynamic tariffs has been developed very early to cover for the full consumption of households. In many other countries pricing pilots have been initiated to test the responsiveness of household consumption. Electric heating, however, remained the most effective form of responsive demand for household consumers -a major reason being that small thermal storage elements made it possible to control the loads without affecting the comfort of consumers.

Besides the rather static tariff systems based on time-of-use, the 1980s saw the discussion, testing and introduction of more dynamic rates to control loads [9]. These incorporate real-time aspects into the tariff structure to achieve a more cost-efficient demand management. A simple form of dynamic schemes are interruptible load contracts that include the option for the utility to curtail load at critical points in time, rather than implementing a regular control based on a static structure. The most complex schemes reflect real-time system conditions in the form of spot prices to the consumers. Although such pricing schemes have been implemented to some extent throughout the past, most dynamic pricing schemes contain only some real-time elements [10]. Critical peak day pricing could, for example, result in exceptionally high prices during a short period of the day at short notice. Also dynamic time-of-use structures have been implemented. In such schemes price levels and the overall number of hours per price level can be predetermined, however, the exact timing is only notified in real-time. A recent example for tariff design proposed by Skytte et al. [11] (yet to be published by primo 2017), focuses on an increased fixed charge and a relatively smaller variable charge, which can be dynamic.

5 Review of framework conditions for flexibility in individual heating

In this section, present deployment, barriers and drivers are described for flexible individual heating solutions in each country. Background data for the analyses of annual heat costs, and a detailed comparative overview of the shares of heat production costs are found in the appendix, Section 8.

Data on the distribution of energy for heating and consumption in households varies in format by country, since this is compiled in different ways. Moreover, the statistics does generally not distinguish between different types of heat pumps. Thus, air-air heat pumps are likely to be part of the number on heat pumps, where these numbers are provided.

5.1 Denmark

5.1.1 Current distribution of heating: Denmark

Table 1 2014 data on energy demand for individual heating in Denmark

TYPE	ENERGY [GWh]
Natural gas	6 513
Oil boilers	2 282
Biomass	10 230
Resistance-based electric heating	570
Heat pumps	411

Sales of HPs have been almost constant for a decade, and the current number of HPs is estimated to 70 000. The Danish TSO Energinet.dk has in a projection estimated the need for HPs to be 350 000 by 2035, in order to reach a fully renewables-based heating sector. [12]

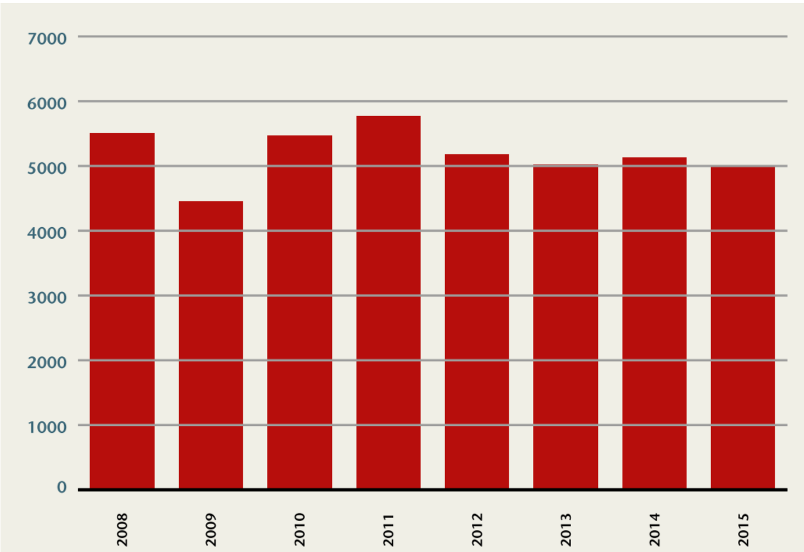


Figure 2 Sales of heat pumps in Denmark. Figure from Nyhedsbladet Dansk Energi [12].

5.1.2 Barriers and drivers for flexibility in individual heating: Denmark

Investment

The drivers for investment in P2H identified in Denmark:

- *Scrap your oil boiler* (Skrot dit oliefyr, discontinued). Subsidies for exchanging oil boilers with e.g. district heating or HPs. An evaluation showed that approximately 1/3 of those who invested, would not otherwise have done so [13]
- Reduced electricity tax (0.12 EUR/kWh to 0.05 EUR/kWh) for electricity consumption more than 4 MWh. Consumption beyond this level is assumed to derive from electric heating
- Heat pump list, maintained by the Danish Energy Agency. Provides information on efficiencies, capacities etc. on the HPs on the market
- Public subsidy for companies who develop business models for leasing or renting of HPs [14]
- Preparing new building plots for HPs, by drilling wells for ground-source HPs [15]. A similar service is seen for district heating
- *Craftsman deduction* (håndværkerfradrag), where expenses for craftsman salaries can be deducted from the tax payment of the household [16]. This subsidy is included in the analyses in Section 5
- Energy companies are obliged to perform energy savings, which they among other sources can ensure but subsidising or buying energy savings in households. For heating in individual households, the savings are realised by changing heat supply from a less efficient or older heat source. Since the analyses in Section 5 assume no existing heat source, this subsidy is not included. [17]

A recent analysis calculates the annual socio-economic cost of damages by emissions from wood stoves to 800 MDKK (107 MEUR) [18]. While this could provide incentive for taxation on biomass or wood stoves, this has per primo 2017 not attracted a political majority.

Operation

There are technical solutions for varying production in existing heat pumps according to electricity price, but Danish research shows that presently the costs for installing such solutions, are higher than the economic benefits. [19]

Generating benefits from the flexible operation of P2H depends on the implementation of hourly settlement procedures (so called flex-afregning). Preconditions in terms of regulation and infrastructure (metering, communication, data management etc.) is already in place for many residential consumers. At present, however, further implementation is hampered by outstanding issues regarding the handling of consumers with solar PV installations that are guaranteed annual net-metering arrangements. Therefore, dynamic retail pricing in Denmark is limited to products following spot prices on an aggregated basis. That is, customers are billed according to the monthly spot market procurement costs of their suppliers [20]. Besides the pure energy price, Denmark has opened for distribution grid companies charging time-of-use tariffs to residential consumers. The design is not dynamic, though, and the differences between base load and peak load tariffs are moderate.

5.1.3 Annual individual heat production costs – 2016: Denmark

The impact of investment costs, taxes, tariffs, energy costs and subsidies on heat cost for individual heating in Denmark is illustrated in Figure 3 and Figure 4. It is seen that the air-water HP and the wood pellets-based biomass boiler are the least cost solutions. The liquid-water HP is less competitive, explained by the relatively higher investment costs. For resistance-based electric heating, taxes and tariffs on electricity use is the determining factor for its lack of competitiveness. Whereas subsidies (embedded in the capital costs) improve the competitiveness of the natural gas boiler and the heat pumps, the wood pellet boiler remains among the most economical solutions, due to the absence of levies, and its relatively low investment costs.

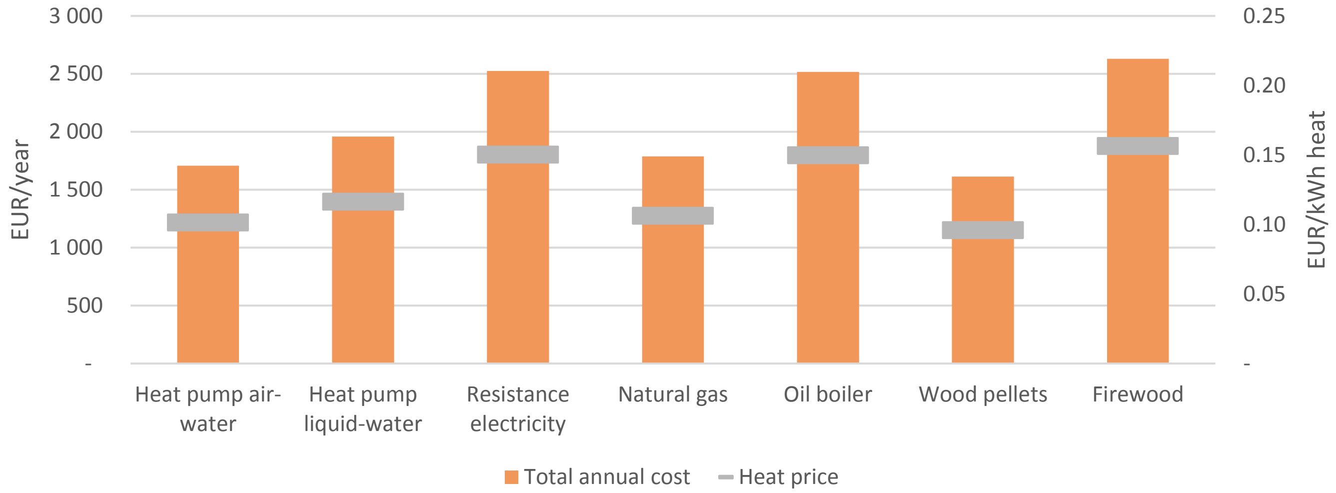


Figure 3 Total annual costs and heat price per kWh for individual heating in Denmark. Left axis shows total annual heat price in the lifetime of the investment, including levies, fuel, maintenance, and capital costs, but excluding scrap value. Right axis shows the cost per kWh of heat, including levies, fuel, maintenance, capital costs, and scrap value.

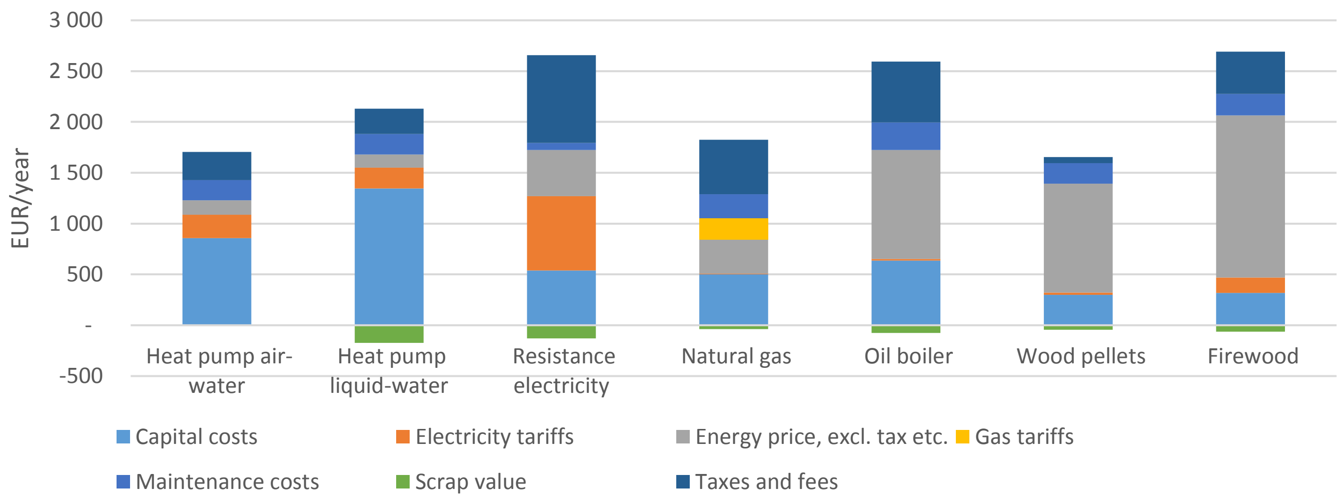


Figure 4 Annual costs divided on levies, subsidies, energy costs and scrap value of individual heating in Denmark.

It should be noted that the figure is shown without the Danish PSO tariff, since this is to be phased out towards 2022. Whereas the absence of PSO increases the competitiveness of the electricity-based heat sources, the overall picture remains the same.

5.2 Estonia

5.2.1 Current distribution of heating: Estonia

Exact statistics on heat demand in different individual heat sources are not available. Instead, Table 2 shows fuel consumption in private households. Because private households use most of the fuel for heat production, it can be assumed that the fuel consumption corresponds to the type of technology it is most typically used in. The exception here being electricity. It is generally not known how much residential electricity is consumed for heating. However, the largest and dominant distribution grid operator, Elektrilevi has analysed electricity consumption change according to the ambient temperature, and estimated that in the distribution grid, about 20%, or 800 GWh of electricity is used for electric heating (HPs and heaters combined). Thus, the number in the table for electric heaters and HPs is (Electricity use in residential buildings) x 0.2. This is an extremely rough measure, but no better one has been found.

Table 2 2015 data on energy demand for residential heating in Estonia

TYPE	ENERGY [GWh]
Natural gas	577
Oil boilers	956
Wood pellet boilers	48
Firewood stoves	4 144
Biomass total	4 192
Resistance-based electric heating and HP	346

5.2.2 Barriers and drivers for flexibility in individual heating: Estonia

Investment

Using firewood in wood stoves is considered more cost effective than electric heating devices in rural areas.

Operation

A barrier for flexible operation is the relatively high grid tariffs. Consumers rarely see a significant change in end-consumer prices because the energy price in the overall cost of electricity is quite low.

Among the drivers is that the installation of smart meters in all residential consumers is near completion.

5.2.3 Annual individual heat production costs – 2016: Estonia

Generally, the regulation of individual heating is quite liberal in Estonia, with very few restrictions or specific taxes. Investment costs, taxes, tariffs, energy costs and subsidies for individual heating in

Estonia are illustrated in Figure 5 and Figure 6. It is seen that the flexible technologies are generally more expensive than inflexible technologies, where natural gas, wood pellets and firewood can provide heat for 0.07 EUR/kWh. Of particular relevance for this difference is the relatively high investment costs of HPs, and the distribution grid tariff. The sole exception is oil boilers, where the energy tax drives a significant increase in cost.

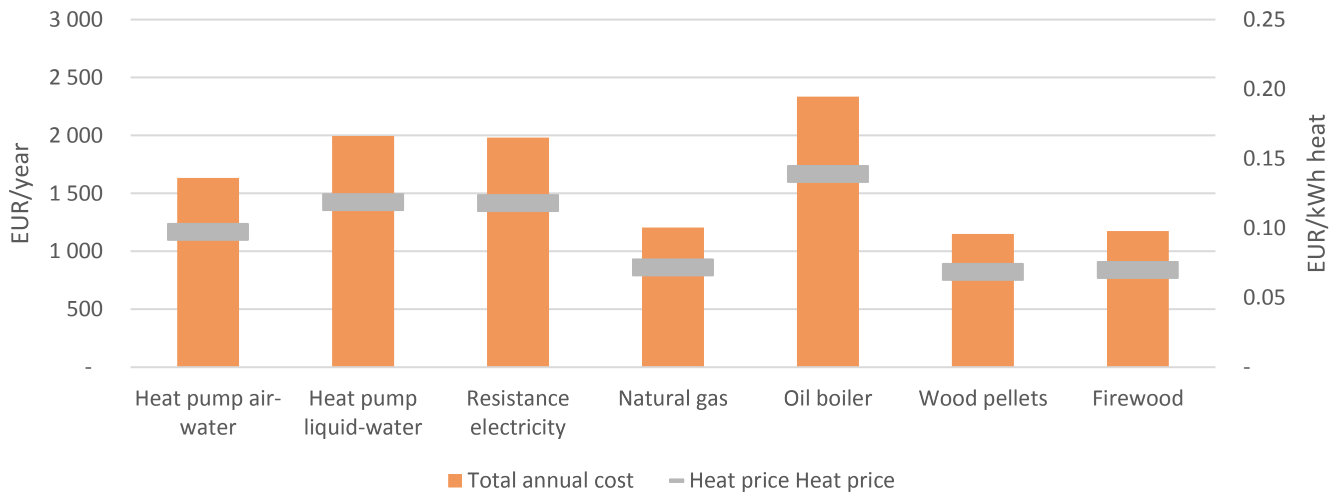


Figure 5 Total annual costs and heat price per kWh for individual heating in Estonia. Left axis shows total annual heat price in the lifetime of the investment, including levies, fuel, maintenance, and capital costs, but excluding scrap value. Right axis shows the cost per kWh of heat, including levies, fuel, maintenance, capital costs, and scrap value.

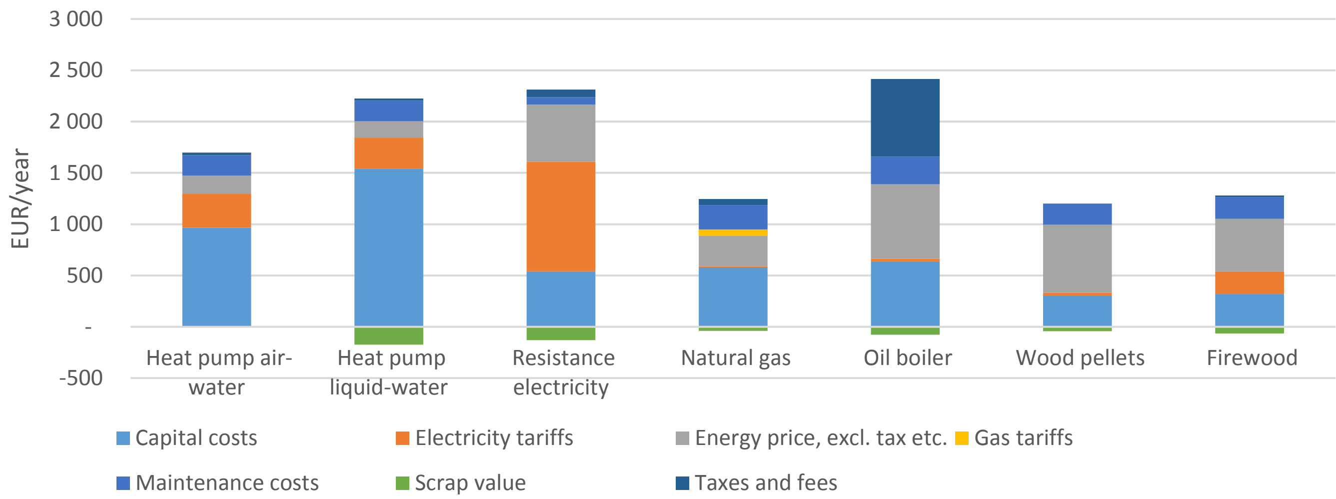


Figure 6 Annual costs divided on levies, subsidies, energy costs and scrap value of individual heating in Estonia.

As an additional fact regarding heat prices, district heating has lower prices than the combined cost of grid tariffs, electrical energy price and other taxes for most of the individual heating options. For example, in the largest distribution grid operator's area, the grid tariff for regular residential consumers is presently around 0.054 €/kWh. The price for district heat can be as low as 0.052 €/kWh in Tallinn without VAT. [21]

5.3 Finland

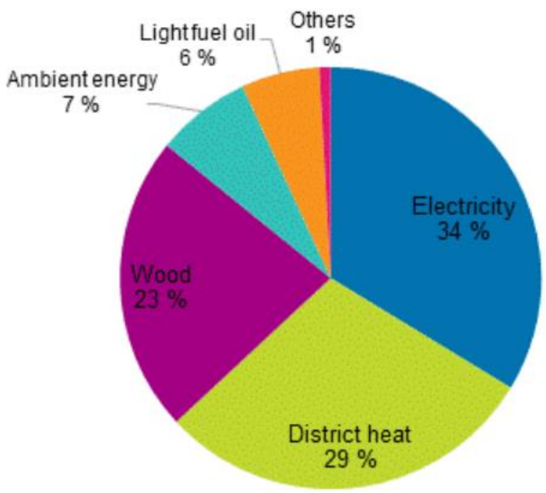
5.3.1 Current distribution of heating: Finland

Exact data on fuel consumption on different types of individual heating technologies in Finland has not been identified. Instead, Table 3 and Figure 7 indicate the amount and distribution of energy used in households, and the energy sources used for satisfying this demand.

Table 3 Data on energy demand for residential heating in Finland. Table from [22]

Corrected on 8 December 2016. The corrections are indicated in red.						
	2010	**2011**	**2012**	**2013**	**2014**	**2015**
Heating of spaces	48 765	41 419	45 928	42 739	42 831	40 804
Residential buildings proper, total	46 365	39 339	43 663	40 643	40 690	38 760
- Detached houses	29 101	25 091	27 641	25 595	25 967	24 507
- Terraced houses	4 462	3 767	4 215	3 972	3 925	3 816
- Blocks of flats	12 802	10 481	11 807	11 076	10 798	10 437
Free-time residential buildings	2 399	2 080	2 265	2 097	2 140	2 044
Household appliances 1)	9 092	8 320	8 856	8 395	8 099	7 886
- Lighting	2 702	2 482	2 349	2 115	1 919	1 876
- Cooking	826	799	714	697	689	680
- Other electrical equipment	5 564	5 039	5 793	5 583	5 491	5 330
Heating of saunas	2 880	2 871	2 894	2 902	2 924	2 920
Heating of domestic water	9 522	9 584	9 658	9 727	9 789	9 850
Housing, total	70 259	62 194	67 336	63 763	63 643	61 460

1) Apart from electricity consumption, consumption of household appliances includes use of natural gas and liquid gas in cooking.
Electricity consumption also covers solar power produced by households.



Used energy sources 61 TWh. The group Others contains the following energy sources: natural gas and liquid gas 0.7 %, peat 0.1 %, heavy fuel oil 0.1 % and coal 0.005 % of energy consumption in households.

Figure 7 Data on energy demand for residential heating in Finland. Figure from [22]

5.3.2 Barriers and drivers for flexibility in individual heating: Finland

Investment

Biomass-based heating is generally applied in rural areas, often preferred by house owners who have access to biomass from forests. Additionally, local/individual heat producers or *heat entrepreneurships* are progressing in rural areas. Heat entrepreneurship is mainly based on bioenergy use, supplying heat to smaller rural consumer groups, e.g. municipal buildings; the scheme is forestry bioenergy-driven, and incentives for P2H may not yet be there.

Heat pumps gain popularity, both in new buildings but also in retrofitting old oil boilers. Heat pumps are particularly applied in urban areas. Heat pumps also start to penetrate to larger buildings and high rise buildings, also in district heating areas, although the amounts in the latter are still small.

Moreover, in 2010, the government of Finland introduced a supportive package for deployment of renewable energy with emphasis, among others, on the wood-based bioenergy through feed-in tariffs and financial support for investments in biorefineries. Individuals do not directly get subsidies for their heating system investment. However, they receive a so-called household tax deduction on the installing work; the deduction per person is 45% of work costs up to 5,000 euro. If two persons are in the household, then the subsidy doubles.

Finally, the goal is to increase the current share of wood-based bioenergy as a source of total energy consumption to 30% by 2020. Currently, 85 TWh (about 20%) of Finnish energy consumption is based on wood-based bioenergy and it is aimed to extend that to 99 TWh (about 30%) of the total energy consumption.

Operation

Smart meters are being deployed throughout Finland, but has not reached all households as of primo 2017. Time of use-payment is possible, split on day/night, which has incentivised P2H in combination with heat storage. In practice a water storage has been charged with cheaper night-electricity. As the tariff difference between day and night was significant, many consumers had an incentive to invest in a water tank with electric resistance. These schemes have typically been driven by municipal utilities.

5.3.3 Annual individual heat production costs – 2016: Finland

Investment costs, taxes, tariffs, energy costs and subsidies for individual heating in Finland are illustrated in Figure 8 and Figure 9. It is seen that air-water HP is rather competitive against all technologies, while liquid-water HP and resistance-based electric heating are the most expensive options, together with the oil boiler. Wood pellets are by a small margin the least cost option. Of particular relevance for the higher costs of flexible technologies are the investment costs.

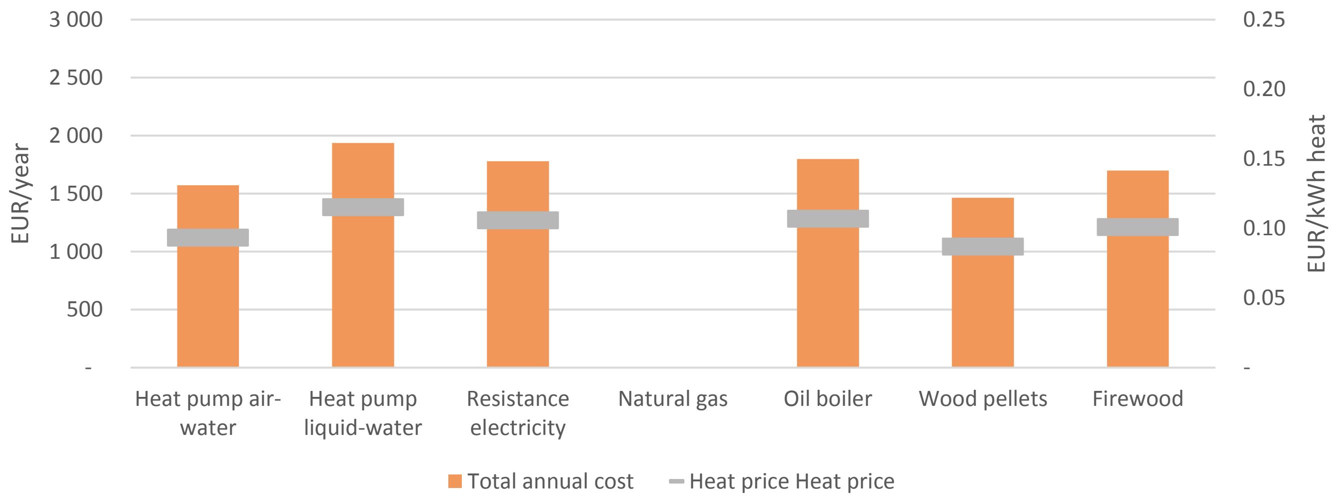


Figure 8 Total annual costs and heat price per kWh for individual heating in Finland. Left axis shows total annual heat price in the lifetime of the investment, including levies, fuel, maintenance, and capital costs, but excluding scrap value. Right axis shows the cost per kWh of heat, including levies, fuel, maintenance, capital costs, and scrap value.

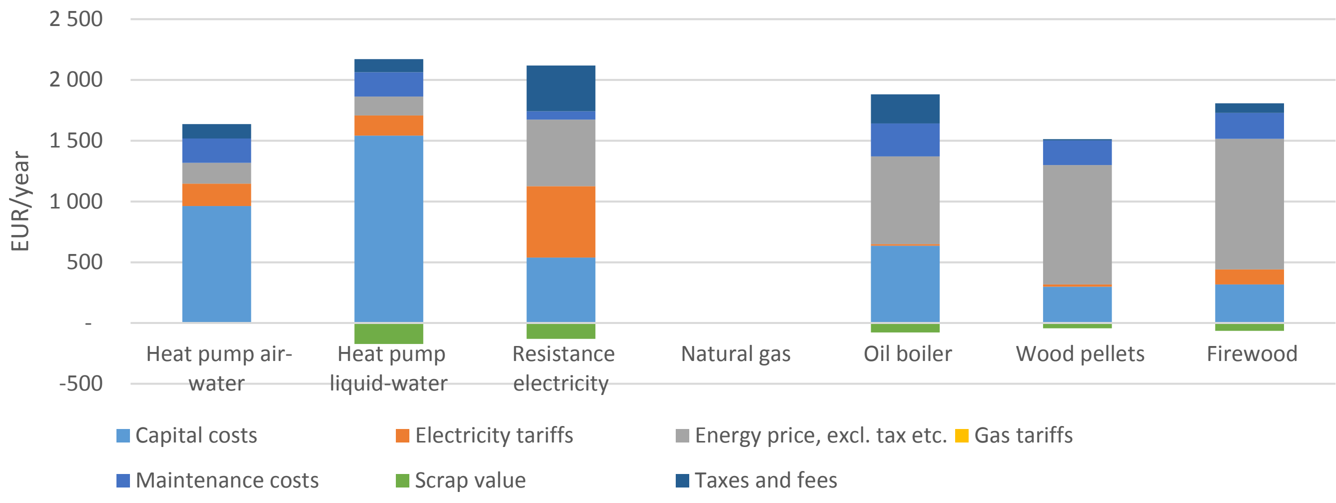


Figure 9 Annual costs divided on levies, subsidies, energy costs and scrap value of individual heating in Finland.

5.4 Latvia

5.4.1 Current distribution of heating: Latvia

Exact data on fuel consumption on different types of individual heating technologies in Latvia has not been identified. Instead, Table 4 indicates the amount of energy used.

Table 4 Data on energy consumption in households in Latvia. Note that this includes "consumption in agricultural holdings and for other economic activities". [23]

TYPE	ENERGY
Electricity (GWh)	1 758
Natural gas, (GWh)	1 298
Liquefied petroleum gas (LPG) (t)	16 617
Fuel oil for heating and hot water (t)	2 093
Hard coal (t)	20 900
Fire wood (thousand m3 solid)	2 441
Wood briquettes (t)	23 337
Wood pellets (t)	115 012
Wood wastes (t)	36 254
Charcoal (t)	1 517
Heat (heating and hot water) (GWh)	3 917

5.4.2 Barriers and drivers for flexibility in individual heating: Latvia

No recent data has been identified regarding the deployment of smart meters in Latvia. A report from the European Commission from 2014 found a negative result from a cost-benefit analysis of a large-scale roll-out of smart meters by 2020 for Latvia. Furthermore, the study pointed towards an absence of legislation for deployment of smart meters in Latvia. [24] Both characteristics are considered to be barriers. Since the study is from 2014, conditions might have changed since then.

Operation

As *Investment*.

5.4.3 Annual individual heat production costs – 2016: Latvia

Investment costs, taxes, tariffs, energy costs and subsidies for individual heating in Latvia are illustrated in Figure 10 and Figure 11. It is seen that the flexible technologies are generally not competitive with inflexible technologies. Of relevance for this difference are the significant electricity tariffs, in particular the distribution grid tariff of 5.6 EURc/kWh. Air-water HP and oil boiler are on par under current levels of levies.

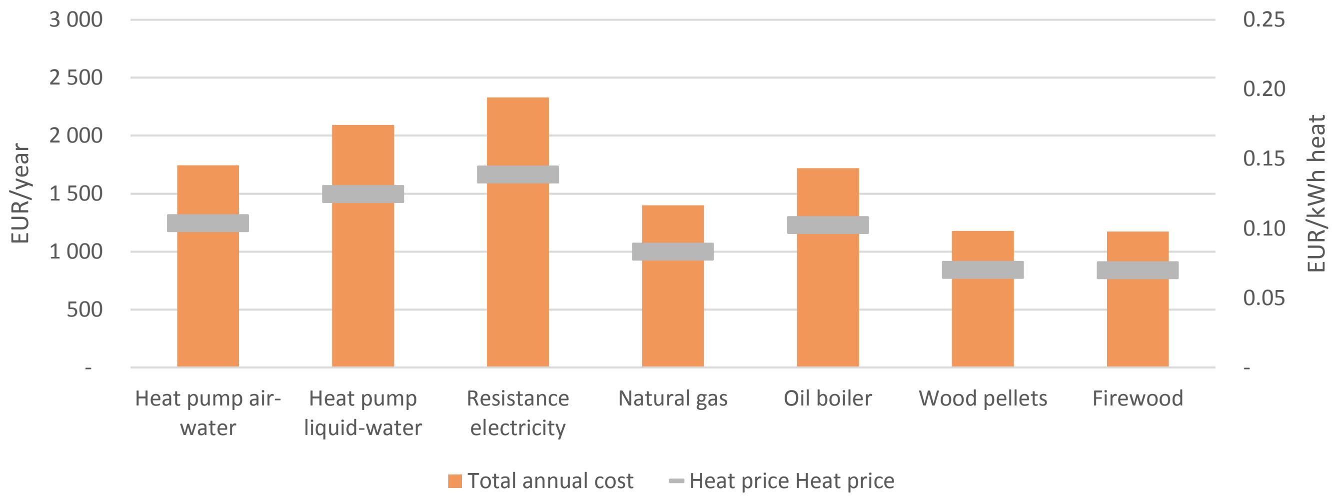


Figure 10 Total annual costs and heat price per kWh for individual heating in Latvia. Left axis shows total annual heat price in the lifetime of the investment, including levies, fuel, maintenance, and capital costs, but excluding scrap value. Right axis shows the cost per kWh of heat, including levies, fuel, maintenance, capital costs, and scrap value.

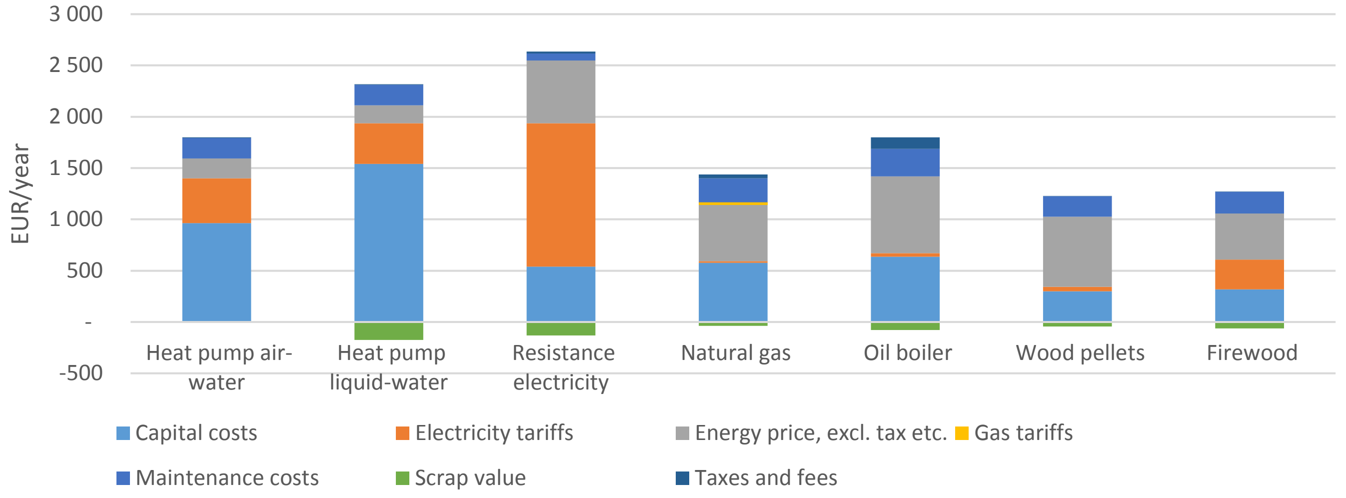


Figure 11 Annual costs divided on levies, subsidies, energy costs and scrap value of individual heating in Latvia.

5.5 Lithuania

5.5.1 Current distribution of heating: Lithuania

Table 5 indicates the amount and distribution of energy used in households. The distribution allows insight in the types of energy that satisfies the demand, but not in the types of technologies in which the energy is converted.

Table 5 Data on energy consumption in households in Lithuania 2015. [25]

TYPE	SUBTYPE	Fuel and energy consumption in households by type of end use [natural units]
Hard coal, thous. tonnes	Total by end use	58.1
	Space heating	53.7
	Water heating	4
	Cooking	0.4
Peat and peat briquettes, thous. tonnes	Total by end use	37
	Space heating	34
	Water heating	2.3
	Cooking	0.7
Firewood, wood and agricultural waste, thous. cubic metres	Total by end use	2505.1
	Space heating	2324.7
	Water heating	132.8
	Cooking	47.6
Liquefied petroleum gases, thous. tonnes	Total by end use	28.5
	Space heating	0.8
	Water heating	0.1
	Cooking	27.6
Heating gasoil, thous. tonnes	Total by end use	9.5
	Space heating	7
	Water heating	2.5
	Cooking	
Natural gas, GWh	Total by end use	1585.4
	Space heating	995.6
	Water heating	187.1
	Cooking	402.7
Electricity, GWh	Total by end use	2660
	Space heating	141
	Water heating	151.6
	Cooking	175.6
Heat, GWh	Total by end use	4997.9
	Space heating	4173.2
	Water heating	824.7
	Cooking	

5.5.2 Barriers and drivers for flexibility in individual heating: Lithuania

Investment

No recent data has been identified regarding the deployment of smart meters in Lithuania. A report from the European Commission from 2014 found a negative result from a cost-benefit analysis of a large-scale roll-out of smart meters by 2020 for Lithuania. Furthermore, the study pointed towards an absence of legislation for deployment of smart meters in Lithuania. [24] Both characteristics are considered to be barriers. Since the study is from 2014, conditions might have changed since then.

Operation

As *Investment*.

5.5.3 Annual individual heat production costs – 2016: Lithuania

Investment costs, taxes, tariffs, energy costs and subsidies for individual heating in Lithuania are illustrated in Figure 12 and Figure 13. It is seen that the flexible technologies are generally not competitive with the inflexible technologies. Of relevance for this difference are the investment costs and electricity tariffs.

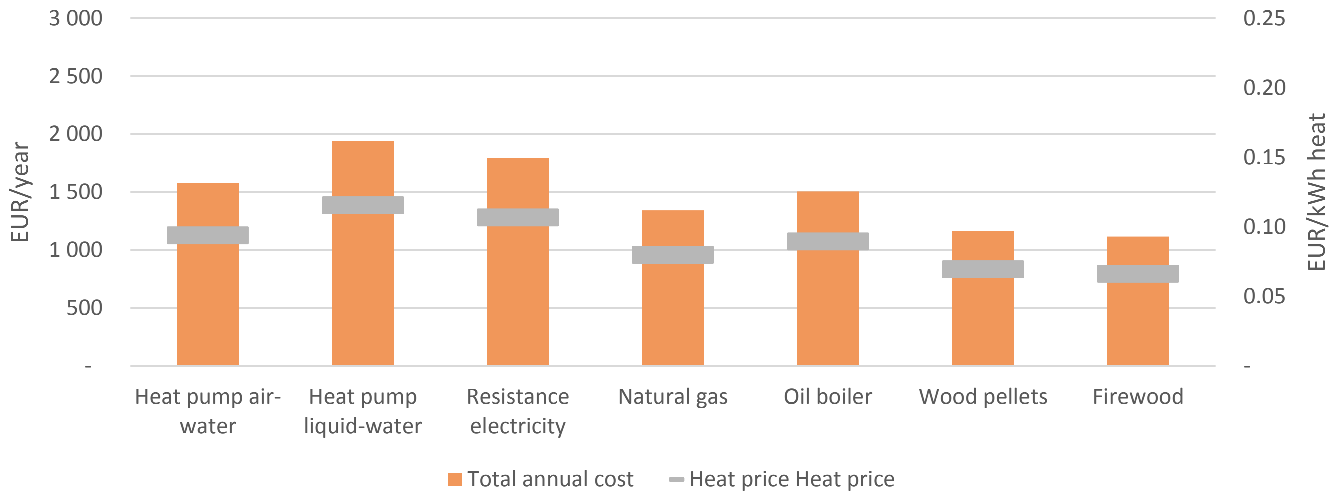


Figure 12 Total annual costs and heat price per kWh for individual heating in Lithuania.

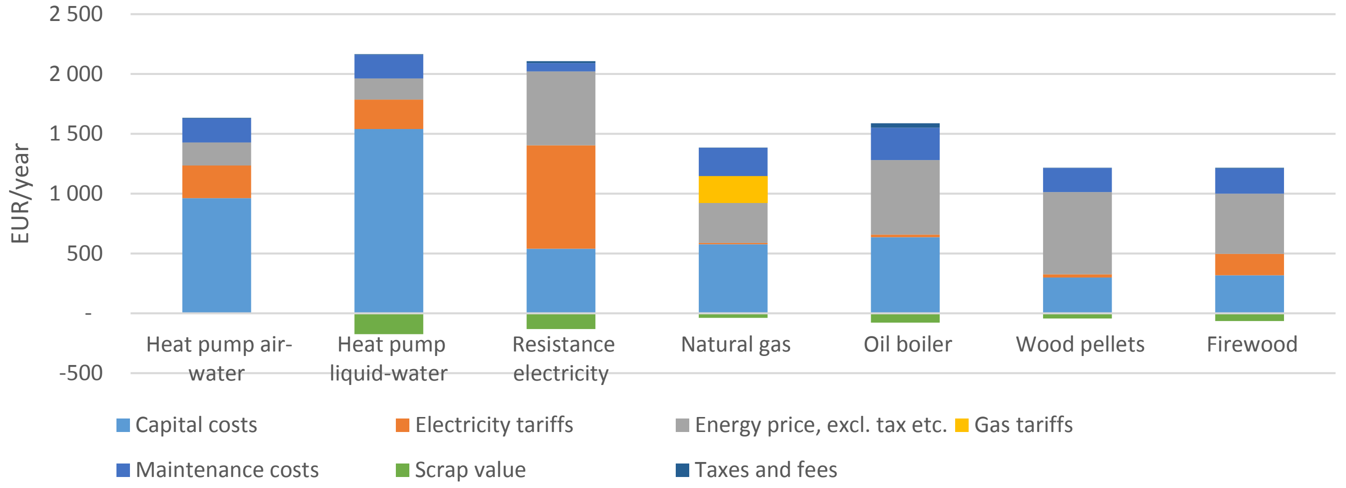


Figure 13 Annual costs divided on levies, subsidies, energy costs and scrap value of individual heating in Lithuania.

5.6 Norway

5.6.1 Current distribution of heating: Norway

Electrical energy in Norway is broadly used for space and domestic water heating, which explains typically high electricity shares in total consumption especially in households and service sector. In recent years, the use of HPs for space heating purposes has increased significantly. While in 2004 HPs were installed in only 4% of dwellings, the share was 27% in 2012 and even 44% in single family houses. Table 6 shows the distribution of energy consumption in households, while Table 7 shows the distribution of heat sources.

Table 6 Energy consumption in households in Norway 2015. [26]

TYPE	ENERGY [GWh]
Coal, coke and petrol coke	4
Biofuel and waste	6 139
Crude oil	0
Natural gas/LNG	39
Other gases and LPG	101
Petrol and kerosene	9 108
Middle distillates, heavy fuel etc.	8 915
Electricity and district heating	38 419

Table 7 Share of heating sources in Norwegian households. Numbers can exceed 100%, since a household can have more heating sources. [27]

TYPE	Row house, linked house and house with 3 or 4 dwellings	Multi-dwelling building	Detached house	Farmhouse
Electric space heaters or electric floor heating	97%	89%	96%	94%
Gas stove	3%	4%	3%	4%
Stove for oil or kerosene	2%	2%	7%	3%
Stove for oil or kerosene and/or combined stove for fuel wood and oil	6%	3%	15%	11%
Stove for solid fuels and/or open fire place	65%	22%	86%	98%
Stove for solid fuel or open fire place and/ or combined stove for fuel wood and oil	65%	23%	89%	99%
Open fire place	9%	4%	17%	19%
Fireplace and similar	6%	3%	7%	1%
Closed stove for fuel wood	58%	19%	80%	98%
Stove for pellets	0%	0%	1%	0%
Combined stove for fuel wood and oil	4%	1%	10%	9%
Common or individual central heating, excl. district heating	5%	18%	8%	8%
Common central heating, excl. district heating	2%	18%	0%	0%
Individual central heating	3%	0%	8%	8%
District heating	2%	13%	1%	0%
Heat pump	16%	6%	44%	30%
Ambient-air heat pump	15%	2%	39%	27%
Geothermal or ground-source heat pump	1%	4%	6%	4%
Heat recovery	8%	8%	10%	6%

A few studies regarding the share of energy consumption for heating have been conducted, but they all provide different conclusions depending on the method used. Estimates of the share of the electricity consumption used for heating purposes ranges from 20-30% [28] over 41% [29] to approximately 50% [30]. The method used in the latter study is temperature corrected, and dependent on the energy source per building. However, in that study the efficiencies of different fuels are not considered. Factors as building types and isolation also matter, and leads to differences between the estimates.

5.6.2 Barriers and drivers for flexibility in individual heating: Norway

Investment

- Energy requirements for new buildings [31]
- Prohibited to install heating systems for fossil fuels

- From 2016, resistance-based electric heating has been allowed in all buildings
- Investment subsidies are provided for air-water and liquid-water heat pumps, and for biomass boilers. The subsidy is 25% of the investment cost, subject to a cap which varies between the technologies [32]

Operation

Although hourly metering is not yet fully rolled out to all residential consumers, the majority of consumers already buys electricity on the basis of spot prices [20]. While at present consumers are billed based on average spot prices (typically monthly) or a mix of short-term forward products, this is expected to change, as hourly metering is deployed. While individual consumers in theory have had the opportunity for hourly-based contracts, the absence of smart metering has limited this option. Grid tariffs can already hold a capacity component. It is being discussed, whether to increase the capacity component and reduce the energy component, thus establishing an increased incentive for peak shaving.

5.6.3 Annual individual heat production costs – 2016: Norway

Investment costs, taxes, tariffs, energy costs and subsidies for individual heating in Norway are illustrated in Figure 14 and Figure 15. It is seen that air-water HP has the lowest heat cost (0.08 EUR/kWh), followed by the wood pellet boiler and resistance-based electric heating. Worth noticing is that the CO_2- and energy tax on oil makes this the costliest alternative. Subsidies are applied on HPs and the wood pellet boiler, resulting in the air-water HP becoming more competitive than resistance-based electric heating and wood pellet boiler. A removal of subsidies for the wood pellet boiler would make the liquid-water HP a competitive alternative.

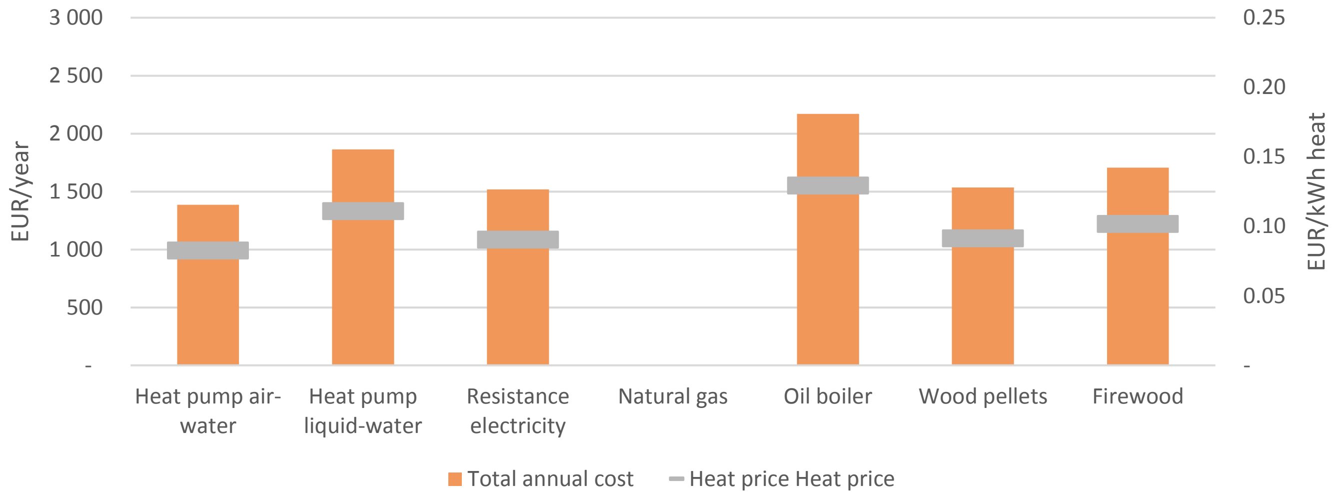


Figure 14 Total annual costs and heat price per kWh for individual heating in Norway. Left axis shows total annual heat price in the lifetime of the investment, including levies, fuel, maintenance, and capital costs, but excluding scrap value. Right axis shows the cost per kWh of heat, including levies, fuel, maintenance, capital costs, and scrap value.

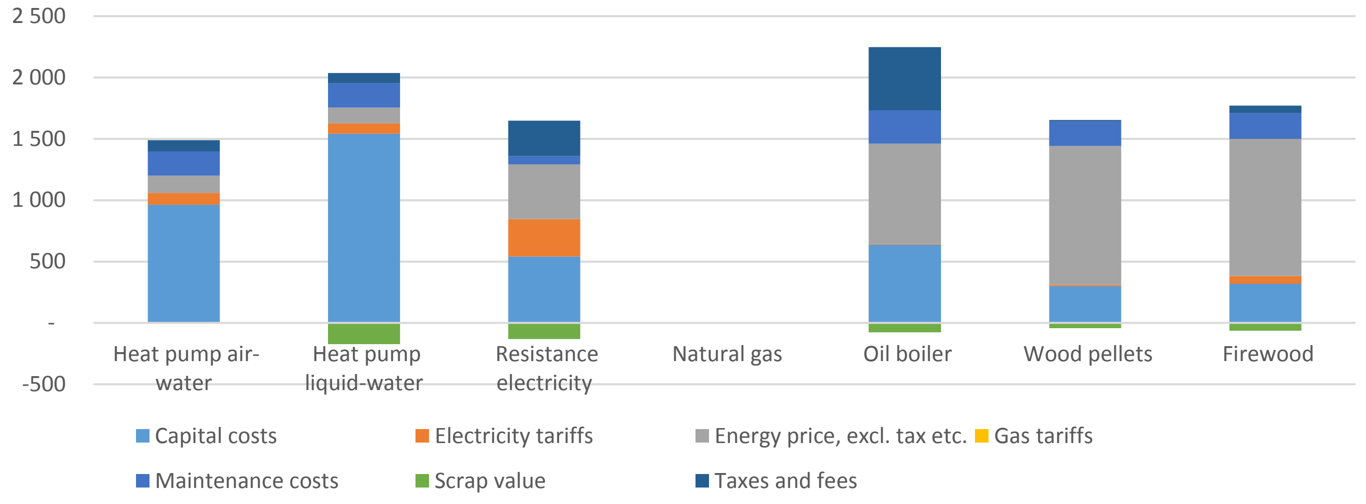


Figure 15 Annual costs divided on levies, subsidies, energy costs and scrap value of individual heating in Norway.

The use of wood pellets in households is presently marginal, as indicated in Section 5.6.1. It will be relevant to follow the development of wood pellet boilers, since these appear to be competitive with the alternatives within P2H.

5.7 Sweden

5.7.1 Current distribution of heating: Sweden

Table 8 shows the amount of energy used in households, and the distribution of technologies in which the energy is converted.

Table 8 Data on energy consumption in households in Sweden 2015. "Total use of energy for heating and hot water in one- and two-dwelling buildings in 2015, by use of fuels and type of heating system used, GWh". [33]

Type of individual heating	Oil	District heating	Electricity (incl. non-heating purposes)	Electricity (excl. non-heating purposes)	Natural gas	Local heating systems	Biomass
TOTAL	751	5 587	22 486	13 852	245	146	10 351
Electric heating (direct heating)	–	–	4 456	2 769	–	–	18
Electric heating (water-based)	–	–	5 474	3 570	–	–	23
Only oil	377	–	–	–	–	–	–
Oil and electricity	123	–	120	74	–	–	–
Biomass and electricity	–	–	5 270	3 051	–	–	3 950
Only biomass	–	–	–	–	–	–	4 944
Heat pump with heat source rock/ground/water and electricity	–	–	1 003	676	–	–	3
Heat pump with heat source rock/ground/water and biomass	–	–	936	599	–	–	495
Heat pump with heat source rock/ground/water	–	–	3 835	2 419	–	–	12
District heating	–	4 514	–	–	–	–	4
Other types of individual heating	251	1 073	1 392	693	245	146	900

5.7.2 Barriers and drivers for flexibility in individual heating: Sweden

Investment

Up to 30% of the installation cost for all types of heating analysed in this study can be deducted from the tax payment of the household [34]. This subsidy is included in the analyses in Section 5

Operation

DSO-monitored smart meters have been mandatory in Sweden for several years. Contracts based on electricity spot prices are possible for individual households. Taxes and grid tariffs are mainly based on energy (i.e. kWh), independent of time. This provides no incentive for flexibility. Possibility for customer monitoring of spot prices are provided in multiple ways.

5.7.3 Annual individual heat production costs – 2016: Sweden

Investment costs, taxes, tariffs, energy costs and subsidies for individual heating in Sweden are illustrated in Figure 16 and Figure 17. It is seen that the flexible technologies are generally in the mid-range regarding cost, compared to inflexible technologies, where biomass-based heating is the least cost option. The significant CO_2 tax means that natural gas and oil becomes the costliest options. The relatively limited subsidies, in form of a deductible share of 30% of installation cost for all technologies, does not affect the outcome regarding the relative costs among the technologies.

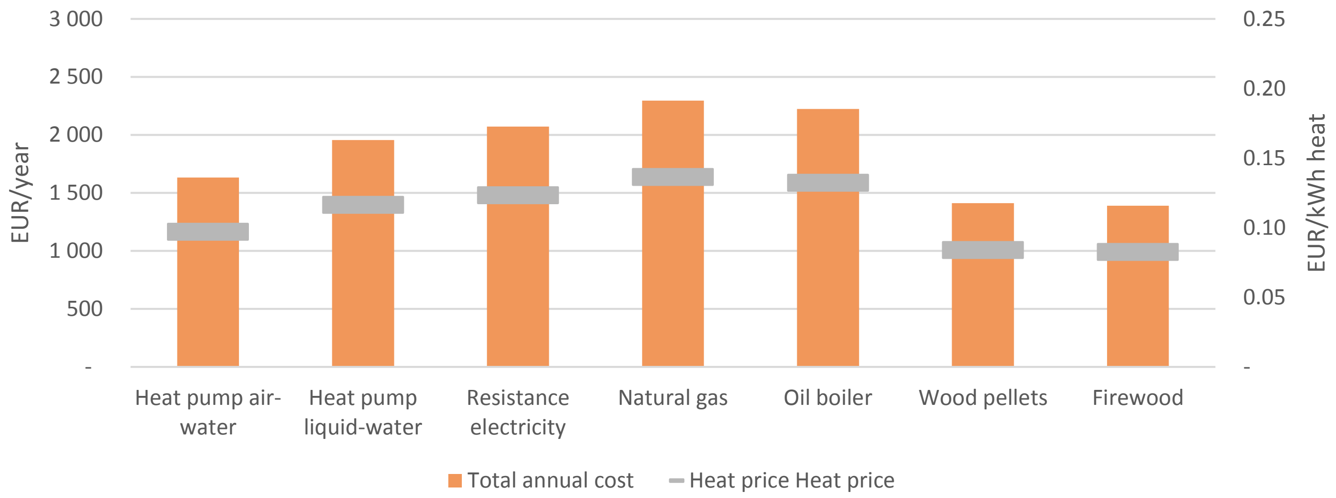


Figure 16 Total annual costs and heat price per kWh for individual heating in Sweden. Left axis shows total annual heat price in the lifetime of the investment, including levies, fuel, maintenance, and capital costs, but excluding scrap value. Right axis shows the cost per kWh of heat, including levies, fuel, maintenance, capital costs, and scrap value.

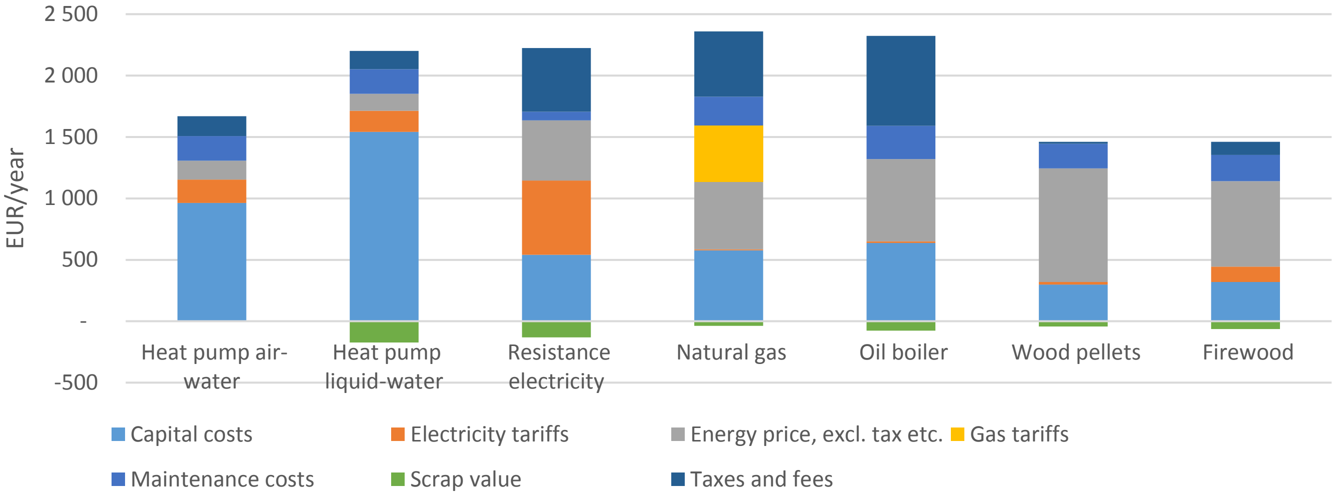


Figure 17 Annual costs divided on levies, subsidies, energy costs and scrap value of individual heating in Sweden.

6 Discussion and conclusion

The review of regulatory framework conditions for individual heating in Section 5 provides the background for a discussion and conclusion on the results in this section.

6.1 Potentials for power-to-heat

Except from Norway and to some degree Sweden, there is a limited deployment of power-to-heat in the reviewed countries.

- Denmark: HP sales are constant. 2.3 TWh of oil boilers are to be phased out. Significant shares of biomass and natural gas as well.
- Estonia: Biomass is dominant. Oil boilers of approximately 1 TWh.
- Finland: Use of natural gas and fuel oil is less than 1/10 of household energy use. Around ¼ of household energy consumption is covered by biomass, whereof heating is assumed to be dominant.
- Latvia: Coal, biomass and natural gas all holds significant shares of household energy use.
- Lithuania: Biomass, natural gas and coal use are significant.
- Norway: Oil and biomass both takes up considerable shares.
- Sweden: Biomass is the only heat source with considerable potential for conversion.

In summary, all countries have considerable technical potential for power-to-heat, since they all show a large deployment of inflexible fuel-based technologies. For concrete estimates of numbers and amounts of energy, more detailed data is needed for some of the countries.

6.2 Drivers and barriers for flexibility in individual heating

Investment

- No direct investment- or operation subsidies have been identified for heat storage-options for individual heating.
- Denmark: A now discontinued subsidy scheme has incentivised switching from oil boilers. Reduced tax for electric heating. Business models for leasing and renting are under development. Preparing building plots for HP, like what is done for DH.
- Norway: Prohibition of oil boilers. Resistance-based electric heating allowed in all buildings. Investment subsidy for heat pumps and biomass boilers.
- Finland, Denmark and Sweden: Expenses for investment in heating technologies can be deducted from the taxable income.

Both carrot (subsidies) and stick (prohibition of oil boilers) have thus been, or are applied. The study shows that oil boilers are commonly among the most expensive options, but since not all investments are based on an economic incentive, a ban on certain technologies might be necessary as well.

Operation

Flexible operation is here reduced to the technical issue of smart meters allowing for hourly settlement, combined with contracting models for providing price signals to the electricity consumer. The deployment of these elements is illustrated in Table 9.

Table 9 Deployment of smart meters and contracts for flexible demand.

COUNTRY	SMART METERS	CONTRACTS FOR FLEXIBLE DEMAND
DENMARK	Presently being deployed	Implementation of regulation hampers actual hourly electricity prices for individual consumers
ESTONIA	Almost fully deployed	Unknown
FINLAND	Presently being deployed	Day/night time of use tariffs
LATVIA	No legislation for smart meters. No status on deployment	Unknown
LITHUANIA	No legislation for smart meters. No status on deployment	Unknown
NORWAY	Presently being deployed	Absence of smart meters has halted spot-price contracts, but these are expected to come. Capacity component in grid tariffs incentivises peak shaving.
SWEDEN	Smart meters are mandatory and deployed	Spot market-based contracts are available

While the deployment of smart meters seems to be increasing, the opportunity for contracting for flexible demand appears more limited. The study has not enquired into the reasons for this, but causes might be lack of economic incentive due to relatively small gains from offering flexibility, lack of technological know-how, and regulatory bottlenecks. An additional challenge not addressed in this study, is the potentially minor share that the variable payment makes up of the total electricity bill. Variable pricing might thus be hampered by the dampening effect provided by the fixed charges that consumers face in their invoicing. The latter aspects of low private economic benefit are indicated in the following section on investment incentives.

6.3 Investment incentives

Table 10 displays the heat prices for each of the technologies analysed. Biomass-based heating stands out as the generally most economical option. This can be explained by low investment costs, absence of levies, and relatively low fuel costs. Resistance-based electric heating, oil boilers and liquid to water HP are seen in the other end of the spectrum. This is for the HP caused by high investment cost and levies on the electricity consumption, while for oil boilers, this is caused by the fuel cost and levies. Generally, power-to-heat is not the most economical option. All things being equal, this means that the economic incentive drives individual heating towards inflexible, biomass-based heat production technologies.

Table 10 Annual heat production costs per kWh, utilising average electricity prices. Green indicates lowest; red highest. Colour scale applies horizontally per country.

	Heat pump air-water	Heat pump liquid-water	Resistance-based electric heating	Natural gas	Oil boiler	Wood pellets	Firewood
Denmark	0.10	0.12	0.15	0.11	0.15	0.10	0.16
Estonia	0.10	0.12	0.13	0.07	0.14	0.07	0.07
Finland	0.10	0.12	0.12		0.11	0.09	0.10
Latvia	0.11	0.13	0.15	0.08	0.10	0.07	0.07
Lithuania	0.10	0.12	0.12	0.08	0.09	0.07	0.07
Norway	0.08	0.10	0.09		0.13	0.09	0.10
Sweden	0.10	0.12	0.12	0.14	0.13	0.08	0.08

In a simple analysis of the impact of smart use of electricity, it is assumed that the electricity consumption is based only on the average of the lowest 25% of 2016-electricity prices, where the analysis so far has assumed average 2016-electricity prices. This analysis is optimistic in assuming that these low prices are distributed evenly, allowing for utilisation over the full year. As seen in Table 11, the consumer benefit of smart electricity consumption is limited, when comparing to the average prices seen in Table 10. As could be expected, due to the relatively large electricity consumption, the difference is largest in resistance-based electric heating. It can be concluded that smart electricity use alone under current conditions is insufficient to shift incentives from inflexible to flexible individual heating.

Table 11 Annual heat production costs per kWh, utilising the average of the lowest 25% of electricity prices. Green indicates lowest; red highest. Colour scale applies horizontally per country.

	Heat pump air-water	Heat pump liquid-water	Resistance-based electric heating	Natural gas	Oil boiler	Wood pellets	Firewood
Denmark	0.10	0.12	0.15	0.11	0.15	0.10	0.16
Estonia	0.10	0.12	0.12	0.07	0.14	0.07	0.07
Finland	0.09	0.12	0.11		0.11	0.09	0.10
Latvia	0.10	0.12	0.14	0.08	0.10	0.07	0.07
Lithuania	0.09	0.11	0.10	0.08	0.09	0.07	0.07
Norway	0.08	0.10	0.08		0.13	0.09	0.10
Sweden	0.09	0.11	0.11	0.14	0.13	0.08	0.08

The effect of subsidies in making power-to-heat competitive has been shown by especially the Danish and Norwegian schemes. While there are several alternatives to shift the investment incentives, two are briefly discussed in the following.

- A tax on biomass, by metering the use of wood stoves and biomass boilers, has been proposed by The Danish Ecological Council among others [35]. This would, in a similar fashion as reducing electricity levies, increase the competitiveness of power-to-heat.

- Providing loans with 0 or very low interest (5% is used in this study) for preferred technologies, here exemplified with liquid-water heat pumps, would improve the investment incentive for preferred technologies. Liquid-water heat pumps, which are otherwise challenged by their high investment costs, would with 0% interest be significantly more attractive, as seen in Table 12.

Table 12 Liquid-water heat pumps with 0% interest becomes more competitive.

	Heat pump air-water	Heat pump liquid-water	Resistance-based electric heating	Natural gas	Oil boiler	Wood pellets	Firewood
Denmark	0.10	0.09	0.15	0.11	0.15	0.10	0.16
Estonia	0.10	0.09	0.13	0.07	0.14	0.07	0.07
Finland	0.10	0.09	0.12		0.11	0.09	0.10
Latvia	0.11	0.10	0.15	0.08	0.10	0.07	0.07
Lithuania	0.10	0.09	0.12	0.08	0.09	0.07	0.07
Norway	0.08	0.07	0.09		0.13	0.09	0.10
Sweden	0.10	0.09	0.12	0.14	0.13	0.08	0.08

6.4 Conclusion

As presented in the introduction, this study has addressed two research questions. The answers provided by the study, are summarised in this section.

- *What are the current framework conditions for flexibility in the individual heating-electricity interface?*

The study shows that Norway and Sweden presently have the largest deployment of power-to-heat. The technical potential for increasing the share of power-to-heat, is significant in all countries, since fuel-based heating serves large shares of the heating demand.

Furthermore, flexibility within individual heating in the Baltic and Nordic countries, is currently limited by two things. First is that, except from Denmark and Norway, the deployment of potentially flexible heating options based on power-to-heat, is limited by lack of economic incentives for investing in these for the household. Second is that the flexible operation of power-to-heat is hampered by the absence of contracting for flexibility, e.g. by electricity prices that reflect the spot market in real time – except for Sweden. As shown in Figure 18, the ideal situation is the overlap between the two circles. None of the countries satisfies this condition, and only three qualifies in either of the two categories.

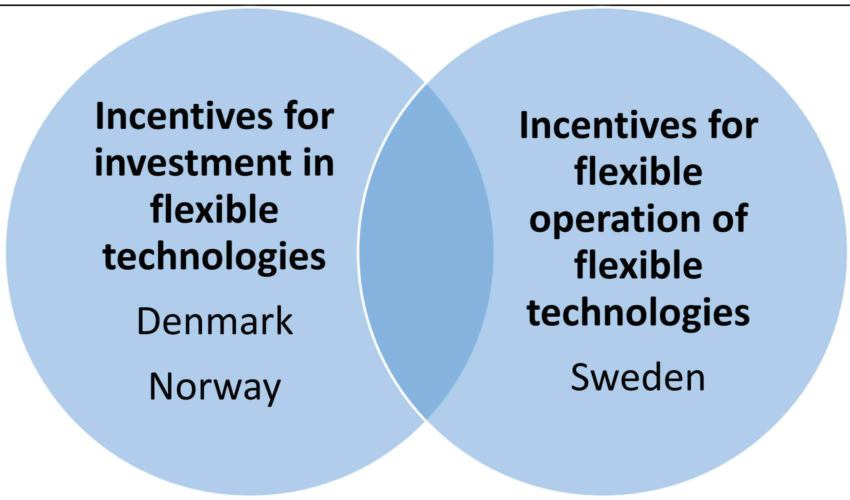


Figure 18 The ideal conditions for offering flexibility are in the overlap.

- *If we want increased flexibility in the individual heating-electricity interface, how can this be achieved?*

Full electrification of all individual heating might not necessarily be the most beneficial solution for society, or for the energy system. With this caveat in mind, increased shares of power-to-heat can, simply put, be achieved by either decreasing heat production costs of power-to-heat or increasing those in non-flexible technologies. Expanding on this, economic investment incentive for flexible technologies can be improved along four paths:

1. Decreasing the variable costs of flexible technologies
2. Increasing the variable costs of inflexible technologies
3. Decreasing the fixed cost for flexible technologies
4. Increasing the fixed cost for inflexible technologies

The first could be achieved by reduction in levies on electricity; the second by increasing levies on use of particularly biomass; the third could address high capital costs of flexible technologies by subsidising, or providing low or no interest loans; the final could be addressed by adding levies on the investment cost of fuel-based technologies.

The analysis shows that competitiveness of power-to-heat can be improved by subsidies, or by extending levies on particularly biomass. Along this path, 0 interest loans have been analysed. They proved to be efficient for making the annual cost of heat competitive of the otherwise uncompetitive liquid-water heat pump. Under current conditions, the benefit from flexible electricity demand is in itself insufficient to shift the incentive for investment in power-to-heat.

The above approaches have not been weighed or analysed regarding socio-economy or energy system, which is why recommendations of one over the other are not provided.

While the study has not addressed the specific capabilities for flexibility of each technology, perhaps electric resistance-based electric heating is presently the most well-suited technology for provision of flexibility, since it without significant challenges can be turned on and off. The challenge here is to provide a solution which is economically attractive, and which does not impede comfort for the consumers. Regardless of technology, the flexible operation is highly dependent on the ability to store heat. While the study has not identified special incentives for individual heat storage, such ability to store should be an important part of the deployment of power-to-heat.

6.5 Further work

This section contains an array of options which will be relevant to address and include, if analysing this subject further.

Further studies would benefit from more detail on the time of life of individual heating installations. This would provide a better estimate of the real potential of a shift from inflexible to flexible individual heating. This due to the unlikeliness of people decommissioning e.g. a well-functioning biomass boiler, before it is at the end of its lifetime.

Spot prices have been used to represent the cost of electricity. Consumers are under current conditions likely to pay a premium on the variable part of this price, which is not reflected in the study. A more detailed study could include this, which would further reduce the investment incentive of power-to-heat.

Same investment costs are used for all technologies. More context specific costs, e.g. including labour costs, might show different results, particularly for the liquid-water heat pump, since this is impeded by its large capital costs.

Regarding subsidies, the Danish subsidy on exchanging existing heat sources is not included in the study, due to the assumption of having no existing heat source in the analysis. Since the subsidy is not insignificant, it would in most Danish cases provide a better business case for heat pumps, gas boilers and biomass-based boilers.

Analysing technologies described in Section 3.3, in a similar way as done in the present study, would provide an indication of how these would be impacted by present regulation. And, perhaps equally important, what degree of technological maturity and cost reductions would be necessary, before they would have significant impacts on competitiveness with existing technologies. Air-air heat pumps are technologically mature, and further studies would benefit from determining flexibility-potentials from this type of heat source.

Additionally, a separate analysis would shed light on the impacts of peer-to-peer trading, blockchain and similar new business models, which can impact flexibility.

The question of time and frequency is also important to address: Will the flexibility be activated few or many times/year, and for how long? The common denominator is that comfort should be maintained for the consumer.

District heating has been addressed separately in the Flex4RES project. Bringing this together with present and future results from individual heating, would provide estimates for the competitiveness between the technologies, and ultimately, an estimate of the costs and benefits of applying either technology to increase flexibility in the energy system.

7 References

[1] Møller Sneum D, Sandberg E, Emilie Rosenlund S, Klaus S, Ole Jess O. Framework conditions for flexibility in the district heating- electricity interface. Lyngby: 2016.

[2] Bergaentzlé C, Boscán L, Skytte K, Rosenlund Soysal E, Olsen OJ. Framework Conditions for Flexibility in the Electricity Sector. Lyngby: 2016.

[3] Danish Energy Agency, Energinet.dk. Technology data for energy plants - individual heating plants and energy transport - Updated chapters, August 2016. Copenhagen: 2016.

[4] Energistyrelsen, Energinet.dk. Technology data for energy plants - individual heating plants and energy transport. Copenhagen: 2013.

[5] PWC. Blockchain – an opportunity for energy producers and consumers ? Düsseldorf: 2017.

[6] Mathiesen BV, Lund H. Comparative analyses of seven technologies to facilitate the integration of fluctuating renewable energy sources. IET Renew Power Gener 2009;3:190–204. doi:10.1049/iet-rpg:20080049.

[7] Bergaentzlé C, Clastres C, Khalfallah H. Demand-side management and European environmental and energy goals: An optimal complementary approach. Energy Policy 2014;67:858–69. doi:10.1016/j.enpol.2013.12.008.

[8] Mitchell BM, Manning Jr. WG, Acton JP. Electricity pricing and load management: Foreign experience and California opportunities. Santa Monica, CA: 1977.

[9] Edvinsson MJ. Load Management in Europe - Marketing Aspects. IEEE Trans Power Syst 1986;1:83–9. doi:10.1109/TPWRS.1986.4335021.

[10] Sanghvi AP. Flexible strategies for load/demand management using dynamic pricing. IEEE Trans Power Syst 1989;4:83–93. doi:10.1109/59.32461.

[11] Skytte K, Bergaentzlé C, Rosenlund Soysal E, Olsen OJ. Design of Grid Tariffs in Electricity Systems with Large Shares of Variable Renewable Energy. EEM17, Eur. Energy Mark., Dresden: Chair of Energy Economics at the Technische Universität Dresden; 2017.

[12] Schalburg R. Salg af varmepumper i bakgear. Nyhedsbl Dansk Energi 2016.

[13] Danish Energy Agency. Vurdering af den umiddelbare effekt af oliefyrsskrotnings - ordningen. Copenhagen: 2013.

[14] Danish Energy Agency. Varmepumper på abonnement er en håndsrækning til stavnsbundne ejere af oliefyr 2017. http://www.efkm.dk/aktuelt/nyheder/nyheder-2017/februar-2017/varmepumper-paa-abonnement-er-en-haandsraekning-til-stavnsbundne-ejere-af-oliefyr/ (accessed February 26, 2017).

[15] Danish Energy Association. Dansk Energi | Middelfarts parcelhusgrunde er ”varmepumpe-ready” 2017. http://www.danskenergi.dk/Aktuelt/Arkiv/2017/Januar/17_01_24A.aspx (accessed February 26, 2017).

[16] SKAT. SKAT: Håndværkerfradrag (servicefradrag). Website 2016. http://www.skat.dk/SKAT.aspx?oId=2234759&vId=0&search=h%E5ndv%E6rkerfradrag* (accessed

April 28, 2017).

[17] Danish Technological Institute. Standardværdikatalog for energibesparelser. Standardværdikataloget 2017. http://svk.teknologisk.dk/Pages_open/Default.aspx (accessed April 28, 2017).

[18] Sekretariatet for afgifts- og tilskudsanalysen på energiområdet. Afgifts- og tilskudsanalysen på energiområdet Delanalyse 3. Copenhagen: 2016.

[19] L. Stærmose H, S. Poulsen C, G. Würtz J. Varmepumper reagerer ikke som forventet. #Smart Energi 2016.

[20] ACER, CEER. ACER/CEER Annual Report on the Results of Monitoring the Internal Electricity and Gas Markets in 2015: Retail Markets. Brussels: 2016.

[21] The Competition Authority. A coordinated network charges n.d. http://www.konkurentsiamet.ee/index.php?id=18292 (accessed February 27, 2017).

[22] Finnish Central Statistical Office. Official Statistics of Finland (OSF): Energy consumption in households [e-publication]. Helsinki: 2016.

[23] Central Statistical Bureau of Latvia. epm3.3. Energy consumption in households including consumption in agricultural holdings and for other economic activities (in physical units) 2016. http://data.csb.gov.lv/pxweb/en/vide/vide__energ_pat/0303.px/table/tableViewLayout2/?rxid=a79839fe-11ba-4ecd-8cc3-4035692c5fc8 (accessed February 27, 2017).

[24] European Commission. Benchmarking smart metering deployment in the EU-27 with a focus on electricity. Brussels: 2014.

[25] Statistics Lithuania. Fuel and energy consumption in households by type of end use. Mod Lith 2016. http://osp.stat.gov.lt/en/statistiniu-rodikliu-analize?epoch=ML (accessed February 27, 2017).

[26] Statistics Norway. Table: 10776: Energy accounts. Energy use for Norwegian economic activity, by industry and energy product (GWh). Emiss from Nor Econ Act n.d. https://www.ssb.no/statistikkbanken/SelectVarVal/saveselections.asp (accessed February 27, 2017).

[27] Statistics Norway. Energy consumption in households 2012. https://www.ssb.no/statistikkbanken/selecttable/hovedtabellHjem.asp?KortNavnWeb=husenergi&CMSSubjectArea=energi-og-industri&PLanguage=1&checked=true (accessed February 27, 2017).

[28] Dalen HM, Larsen BM. Formålsfordeling av husholdningenes elektrisitetsforbruk i 2006. Oslo: 2009.

[29] Statistics Norway. Energy Statistics 2000. Oslo: 2000.

[30] Statistics Norway. Energibruk i husholdningene - SSB. Energibruk I Husholdningene, 2009 2011. https://www.ssb.no/energi-og-industri/statistikker/husenergi/hvert-3-aar/2011-04-19 (accessed February 27, 2017).

[31] Direktoratet for byggkvalitet. Byggteknisk forskrift (TEK 10). Byggtek Forskr (TEK 10) 2016. https://dibk.no/byggeregler/tek/ (accessed February 27, 2017).

[32] ENOVA. Alle energitiltak | Enova 2017. https://www.enova.no/privat/alle-energitiltak/ (accessed May 2, 2017).

[33] Statistics Sweden. Energistatistik för småhus, flerbostadshus och lokaler 2016. http://www.scb.se/hitta-statistik/statistik-efter-amne/energi/tillforsel-och-anvandning-av-energi/energistatistik-for-smahus-flerbostadshus-och-lokaler/ (accessed February 27, 2017).

[34] Swedish Tax Agency. Lista över rotarbeten i bostadsrätt 2017. https://www.skatteverket.se/foretagochorganisationer/skatter/rotochrutarbete/rotarbeten/rotarbetenibostadsratt.4.5c1163881590be297b55977.html (accessed May 2, 2017).

[35] Danish Ecological Council. Forureningsafgifter: Det skal din brændeovn koste 2017. https://www.ecocouncil.dk/en/udgivelser/artikler/trafik-og-luft/2898-forureningsafgifter-det-skal-din-braendeovn-koste (accessed February 27, 2017).

[36] Videncenter for energibesparelser i bygninger. Valg af varmekilde i en- og tofamiliehuse med oliefyr. Taastrup: 2012.

[37] Videncenter for energibesparelser i bygninger. Udskiftning af gaskedel. Taastrup: 2015.

8 Appendices

8.1 Data used in the analyses of annual heat cost

Table 13 Costs (EUR/kWh) related to the use of electricity. References are national statistics on tariffs, spot market prices, and taxes. Colours indicate level, and are read vertically: red is high; green is low.

Country	Electric grid tariff	Electric trans-mission tariff	Electricity price	Energy tax	Energy tax - electric heating	PSO (or similar elec. tariff)
DK	0.032	0.011	0.027	0.119	0.051	-
FI	0.019	0.003	0.033	0.022	-	0.013
NO	0.017	-	0.026	0.017	-	0.001
SE	0.036	-	0.029	0.031	-	-

Table 14 Costs (EUR/kWh) related to the use of firewood. References are national statistics on fuels. Colours indicate level, and are read vertically: red is high; green is low.

Country	Fuel price
DK	0.073
FI	0.047
NO	0.050
SE	0.029

Table 15 Costs (EUR/kWh) related to the use of natural gas. References are national statistics on tariffs, gas prices, and taxes. Colours indicate level, and are read vertically: red is high; green is low.

Country	CO_2 tax	Energy tax	Fuel price	Gas distribution tariff
DK	0.005	0.027	0.020	0.013
FI	-	0.015	0.027	0.010
NO	0.009	-	0.022	0.002
SE	0.023	0.009	0.033	0.028

Table 16 Costs (EUR/kWh) related to the use of oil. References are national statistics on oil prices, and taxes. Colours indicate level, and are read vertically: red is high; green is low.

Country	CO_2 tax	Energy tax	Fuel price
DK	0.006	0.027	0.063
FI	0.007	0.007	0.042
NO	0.013	0.017	0.048
SE	0.034	0.009	0.039

Table 17 Costs (EUR/kWh) related to the use of wood pellets. References are national statistics on fuels. Colours indicate level, and are read vertically: red is high; green is low.

Country	Fuel price
DK	0.050
FI	0.046
NO	0.053
SE	0.043

8.2 Subsidies

Subsidies are applied in Denmark, Norway and Sweden. In Denmark, the subsidy for conversion from older heat sources to e.g. heat pumps. In Norway, the subsidy is provided for heat pumps and biomass boilers, whereas subsidy for all technologies is provided in Sweden. The Norwegian subsidy provides a 25% cost-refund of the total investment, while the Swedish subsidy comes as a deductible amount equivalent to the labour cost of the investment. Both subsidies are subject to a price cap.

8.3 Costs and characteristics for individual heating technologies

Table 18 Technological data based on [3,36,37]. Assumed to be the same for all countries. Auxiliary electricity is electricity used for operation of the unit. In the case of the firewood stove and electric heater, this category also covers electricity used for water-heating. Annual efficiency describes the average efficiency. Heat pumps have >100%, due to the utilization of ambient heat. The natural gas boiler utilizes condensation, whereby the higher heating value is >100%.

Technology	Annual efficiency	Auxiliary electricity [kWh/year]	Technical lifetime [years]	Heat demand [kWh/year]	Heat capacity [kW]	Variable maintenance [EUR/kWh]	Fixed maintenance [EUR/year]	Investment – Hardware cost [EUR]	Investment – Connection costs and other hardware costs [EUR]	Investment – Installation costs [EUR]
Heat pump air-water	325%	100	15	16 800	7	-	200	7 000	-	3 000
Heat pump liquid-water	360%	100	20	16 800	7	-	200	10 400	-	5 600
Resistance-based electric heating	100%	-	30	16 800	7	-	70	3 920	-	1 680
Natural gas boiler	102%	176	22	16 800	7	-	235	1 800	2 000	2 200
Oil boiler	100%	406	20	16 800	7	-	270	4 620	-	1 980
Wood pellet boiler	80%	526	20	16 800	7	-	201	2 571	-	536
Firewood stove and electric water heater	65%	3 500	24	16 800	7	-	212	2 540	-	762

8.4 Heat production costs between countries

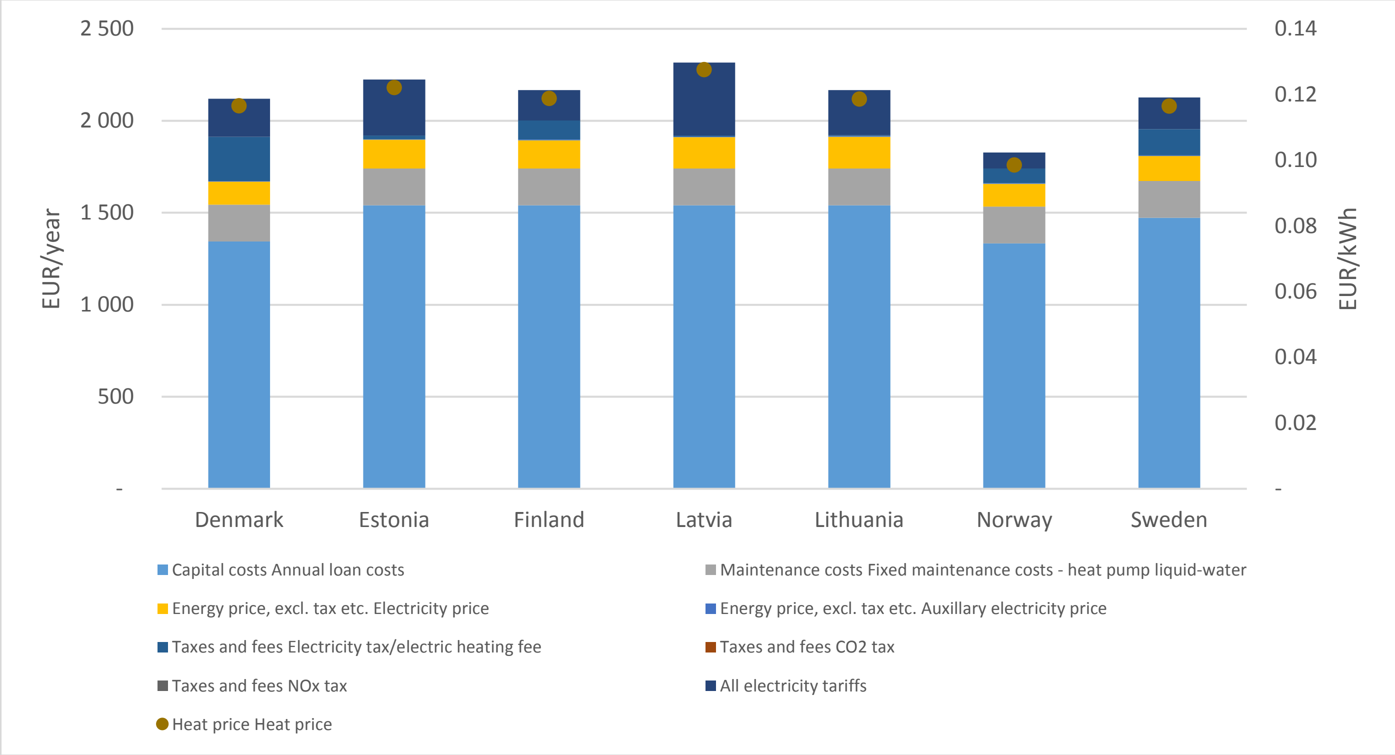


Figure 19 Annual consumer costs, and heat cost for liquid-water heat pump.

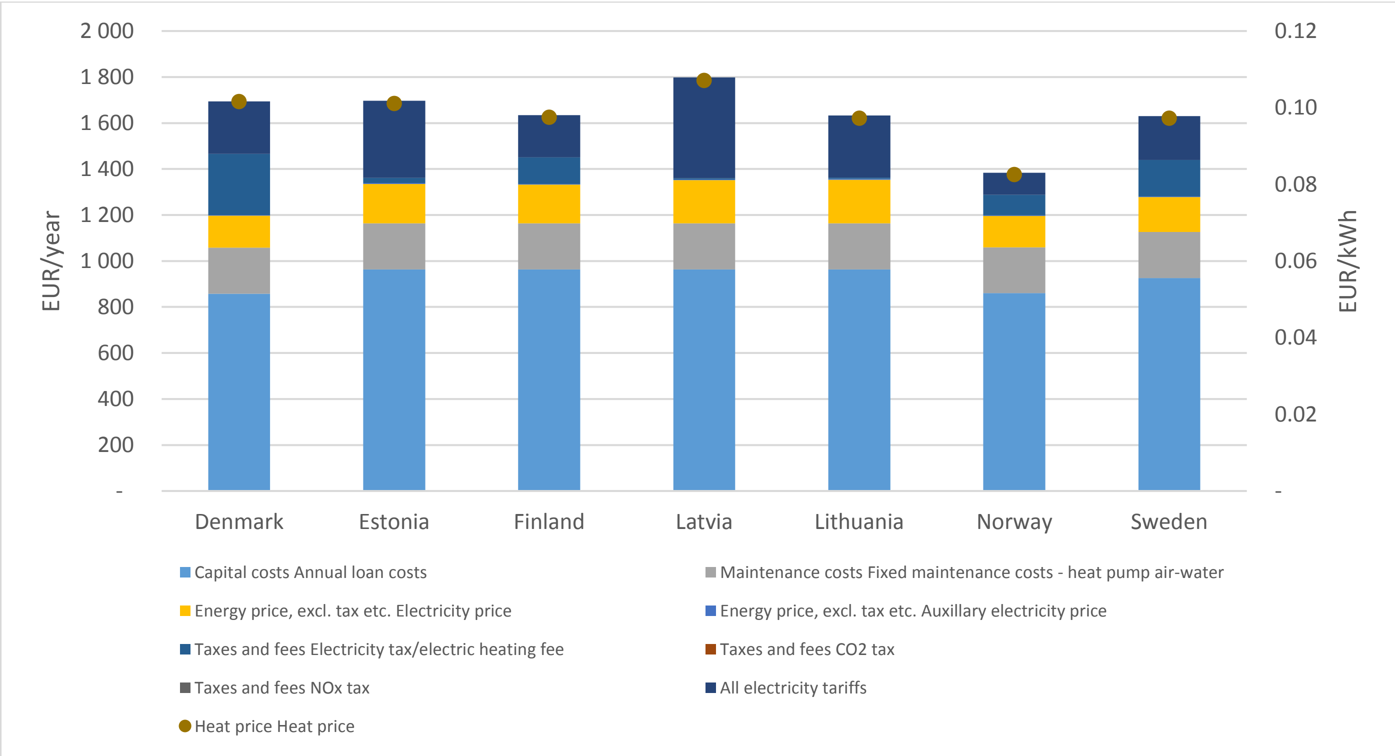


Figure 20 Annual consumer costs, and heat cost for air to water heat pump.

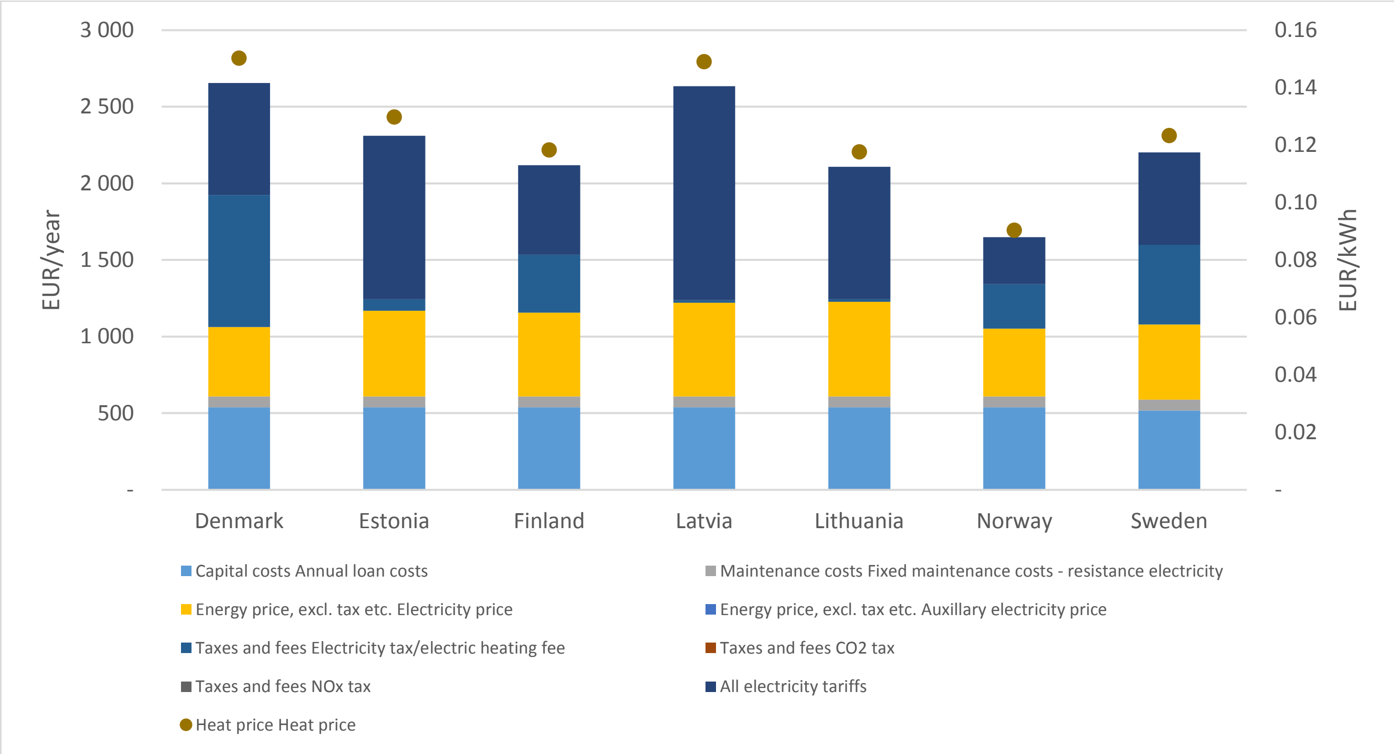


Figure 21 Annual consumer costs, and heat cost for resistance-based electric heating.

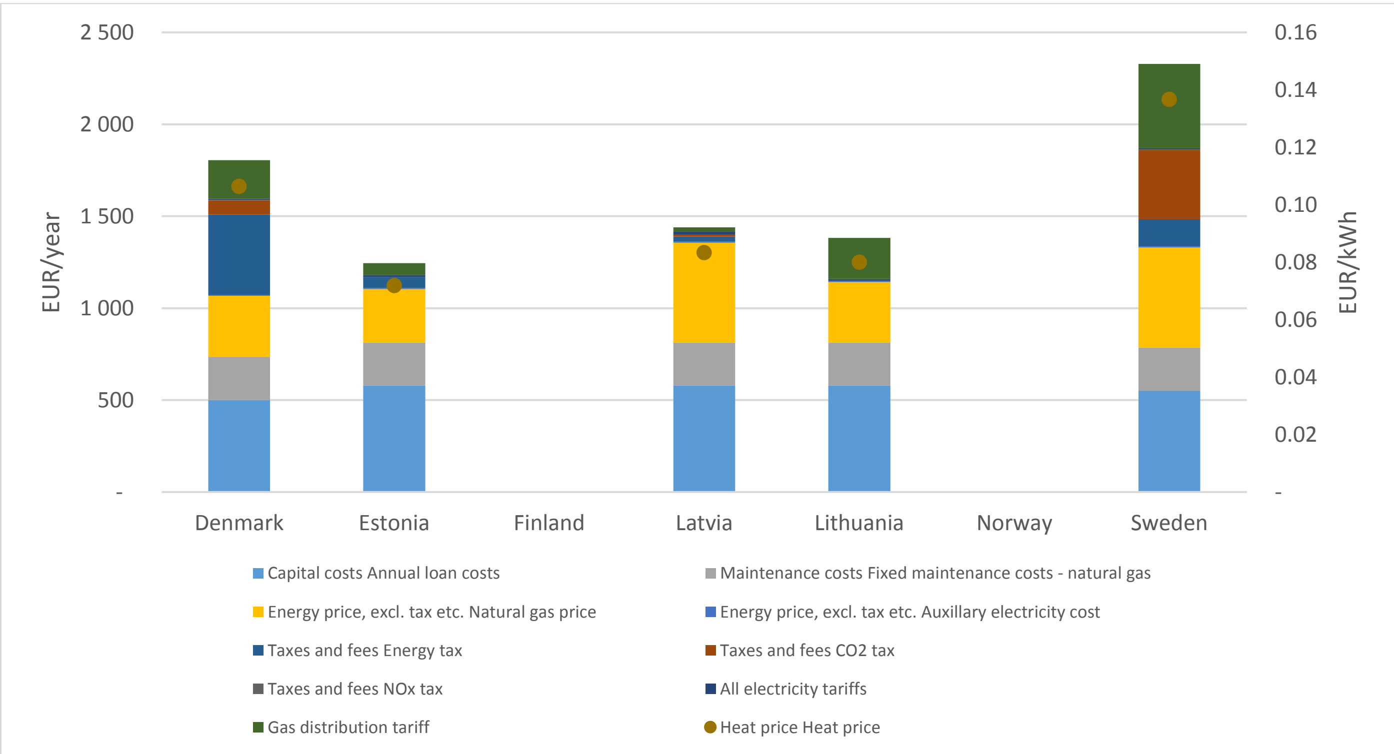


Figure 22 Annual consumer costs, and heat cost for natural gas boiler.

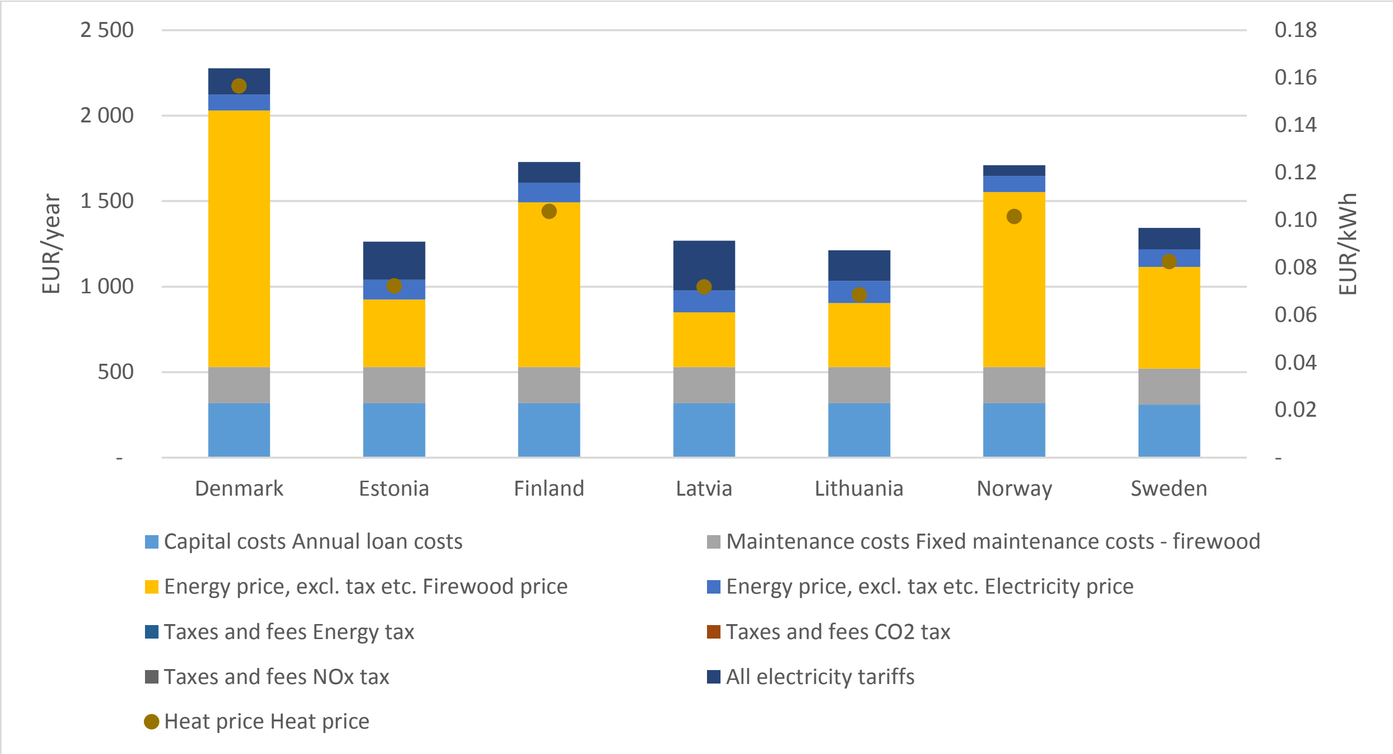


Figure 23 Annual consumer costs, and heat cost for wood stove and electric water heater.

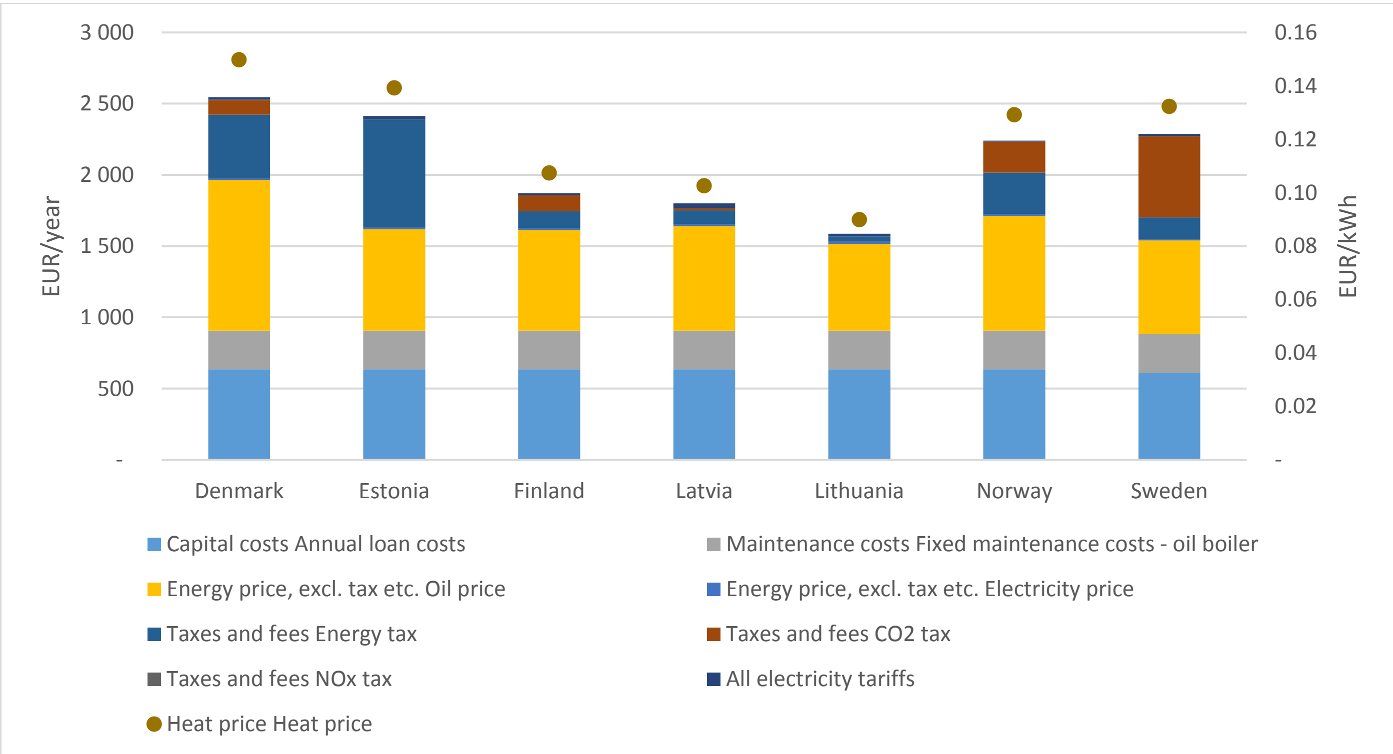


Figure 24 Annual consumer costs, and heat cost for oil boiler.

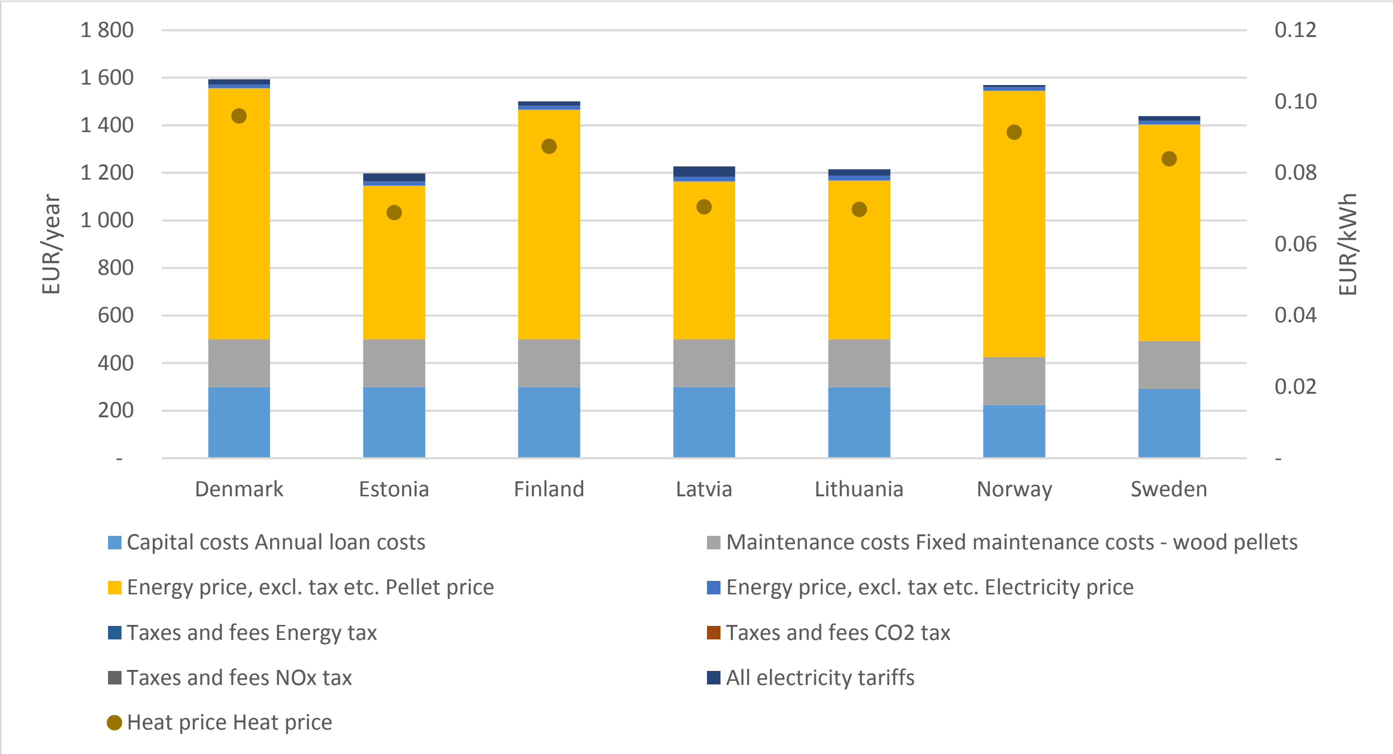


Figure 25 Annual consumer costs, and heat cost for wood pellet boiler.

8.5 Liquid to water heat pump

Levies, subsidies and energy price 2016	Category	Unit	Denmark	Estonia	Finland	Latvia	Lithuania	Norway	Sweden
Subsidies:	None		-	-	-	-	-	-	-
Taxes and fees:	Electric heating fee	EUR/kWh	0,05	-	-	-	-	-	-
	Energy tax	EUR/kWh	0,12	0,00	0,02	0,00	0,00	0,02	0,03
	CO2 tax	EUR/kWh	-	-	-	-	-	-	-
	NOx tax	EUR/kWh	-	-	-	-	-	-	-
Tariffs:	PSO (or similar tariff) for subsidy of other electricity production	EUR/kWh	0,03	0,01	0,01	0,03	0,02	0,00	-
	Electricity local grid tariff	EUR/kWh	0,03	0,05	0,02	0,06	0,04	0,02	0,04
	Electricity system/transmission tariff	EUR/kWh	0,01	-	0,00	-	-	-	-
Energy price, excl. tax etc.:	Electricity price	EUR/kWh	0,03	0,02	0,02	0,03	0,03	0,02	0,02
	Electricity price	EUR/kWh	0,03	0,02	0,02	0,03	0,03	0,02	0,02

Technology costs	Category	Unit	Denmark	Estonia	Finland	Latvia	Lithuania	Norway	Sweden
Maintenance costs:	Variable maintenance costs - heat pump liquid-water	EUR/kWh	0	-	-	-	-	-	-
	Fixed maintenance costs - heat pump liquid-water	EUR/unit/year	200	200	200	200	200	200	200
Capital costs:	Hardware costs - heat pump liquid-water	EUR/unit	10400	10.400	10.400	10.400	10.400	10.400	10.400
	Connection costs and other hardware costs - heat pump liquid-water	EUR/unit	0	-	-	-	-	-	-
	Installation costs - heat pump liquid-water	EUR/unit	5600	5.600	5.600	5.600	5.600	5.600	5.600
	Total cost	EUR/unit	16000	16.000	16.000	16.000	16.000	16.000	16.000
Loan:	Loan period	years	15	15	15	15	15	15	15
	Annual loan costs	EUR/year	1.541	1.541	1.541	1.541	1.541	1.541	1.541
Remaining technical lifetime	Remaining technical lifetime	years	5	5	5	5	5	5	5
Scrap value:	Revenue	EUR	-2.600	-2.600	-2.600	-2.600	-2.600	-2.600	-2.600

Technical characteristics	Category	Data	Denmark	Estonia	Finland	Latvia	Lithuania	Norway	Sweden
Technical characteristics	Annual efficiency - heat pump liquid-water		360%	360%	360%	360%	360%	360%	360%
	Auxillary electricity consumption - heat pump liquid-water	kWh/year	100	100	100	100	100	100	100
	Technical lifetime (years) - heat pump liquid-water	years	20	20	20	20	20	20	20
	Annual heat demand - individual house	kWh/year	16800	16.800	16.800	16.800	16.800	16.800	16.800
	Effect need	kW	7	7	7	7	7	7	7
	Electricity consumption for heat	kWh/year	4666,666667	4.667	4.667	4.667	4.667	4.667	4.667

Ground source HP - annual consumer cost 2016	Cost category	Denmark	Estonia	Finland	Latvia	Lithuania	Norway	Sweden	Unit
Capital costs:	Annual loan costs	1.541	1.541	1.541	1.541	1.541	1.541	1.541	EUR/year
Maintenance costs:	Variable maintenance costs - heat pump liquid-water	0	0	0	0	0	0	0	EUR/year
	Fixed maintenance costs - heat pump liquid-water	200	200	200	200	200	200	200	EUR/unit/year
Energy price, excl. tax etc.:	Electricity price	126	100	94	121	121	85	85	EUR/year
	Auxillary electricity price	3	2	2	3	3	2	2	EUR/year
Electricity tariffs:	All electricity tariffs	363	303	166	397	245	87	172	EUR/year
Subsidies:	Subsidies	0	0	0	0	0	0	0	None
Taxes and fees:	Electricity tax/electric heating fee	240	21	105	5	5	80	144	EUR/year
	CO2 tax	-	-	-	-	-	-	-	EUR/year
	NOx tax	-	-	-	-	-	-	-	EUR/year
	Electricity tax on auxillary electricity	12	0	2	0	0	2	3	EUR/year
Scrap value:	Revenue	-173	-173	-173	-173	-173	-173	-173	EUR/year
Total cost		2.311	1.995	1.937	2.093	1.942	1.824	1.973	
Heat price:	Heat price	0,14	0,12	0,12	0,12	0,12	0,11	0,12	EUR/kWh

8.6 Air to water heat pump

Levies, subsidies and energy price 2016	Category	Unit	Denmark	Estonia	Finland	Latvia	Lithuania	Norway	Sweden
Subsidies:	None		-	-	-	-	-	-	-
	Electric heating fee	EUR/kWh	0,05	-	-	-	-	-	-
Taxes and fees:	Energy tax	EUR/kWh	0,12	0,00	0,02	0,00	0,00	0,02	0,03
	CO2 tax	EUR/kWh	-	-	-	-	-	-	-
	NOx tax	EUR/kWh	-	-	-	-	-	-	-
	PSO (or similar tariff) for subsidy of other electricity production	EUR/kWh	0,03	0,01	0,01	0,03	0,02	0,00	-
Tariffs:	Electricity local grid tariff	EUR/kWh	0,03	0,05	0,02	0,06	0,04	0,02	0,04
	Electricity system/transmission tariff	EUR/kWh	0,01	-	0,00	-	-	-	-
Energy price, excl. tax etc.:	Electricity price	EUR/kWh	0,03	0,02	0,02	0,03	0,03	0,02	0,02
	Auxillary electricity price	EUR/kWh	0,03	0,02	0,02	0,03	0,03	0,02	0,02

Technology costs	Category	Unit	Denmark	Estonia	Finland	Latvia	Lithuania	Norway	Sweden
Maintenance costs:	Variable maintenance costs - heat pump air-water	EUR/kWh	0	-	-	-	-	-	-
	Fixed maintenance costs - heat pump air-water	EUR/unit/year	200	200	200	200	200	200	200
	Hardware costs - heat pump air-water	EUR/unit	7000	7.000	7.000	7.000	7.000	7.000	7.000
Capital costs:	Connection costs and other hardware costs - heat pump air-water	EUR/unit	0	-	-	-	-	-	-
	Installation costs - heat pump air-water	EUR/unit	3000	3.000	3.000	3.000	3.000	3.000	3.000
	Total cost	EUR/unit	10000	10.000	10.000	10.000	10.000	10.000	10.000
	Loan period	years	15	15	15	15	15	15	15
	Annual loan costs	EUR/year	963	963	963	963	963	963	963
Remaining technical lifetime	Remaining technical lifetime	years	-	-	-	-	-	-	-
Scrap value:	Revenue	EUR	-	-	-	-	-	-	-

Technical characteristics	Category	Data	Denmark	Estonia	Finland	Latvia	Lithuania	Norway	Sweden
	Annual efficiency - heat pump air-water		325%	325%	325%	325%	325%	325%	325%
	Auxillary electricity consumption - heat pump air-water	kWh/year	100	100	100	100	100	100	100
Technical characteristics	Technical lifetime (years) - heat pump air-water	years	15	15	15	15	15	15	15
	Annual heat demand - individual house	kWh/year	16800	16.800	16.800	16.800	16.800	16.800	16.800
	Effect need	kW	7	7	7	7	7	7	7
	Electricity consumption for heat	kWh/year	5169,230769	5.169	5.169	5.169	5.169	5.169	5.169

Air to water HP - annual consumer cost 2016	Cost category	Denmark	Estonia	Finland	Latvia	Lithuania	Norway	Sweden	Unit
Capital costs:	Annual loan costs	963	963	963	963	963	963	963	EUR/year
Maintenance costs:	Variable maintenance costs - heat pump air-water	0	0	0	0	0	0	0	EUR/year
	Fixed maintenance costs - heat pump air-water	200	200	200	200	200	200	200	EUR/unit/year
Energy price, excl. tax etc.:	Electricity price	139	111	104	134	134	94	94	EUR/year
	Auxillary electricity price	3	2	2	3	3	2	2	EUR/year
Electricity tariffs:	All electricity tariffs	401	335	184	438	271	96	190	EUR/year
Subsidies:	Subsidies	0	0	0	0	0	0	0	None
	Electricity tax/electric heating fee	266	23	116	5	5	89	159	EUR/year
Taxes and fees:	CO2 tax	-	-	-	-	-	-	-	EUR/year
	NOx tax	-	-	-	-	-	-	-	EUR/year
	Electricity tax on auxillary electricity	12	0	2	0	0	2	3	EUR/year
Scrap value:	Revenue	-	-	-	-	-	-	-	EUR/year
Total cost		1.984	1.635	1.571	1.744	1.576	1.446	1.611	
Heat price:	Heat price	0,12	0,10	0,09	0,10	0,09	0,09	0,10	EUR/kWh

8.7 Resistance-based electric heating

Levies, subsidies and energy price 2016	Category	Unit	Denmark	Estonia	Finland	Latvia	Lithuania	Norway	Sweden
Subsidies:	None		-	-	-	-	-	-	-
Taxes and fees:	Electric heating fee	EUR/kWh	0,05	-	-	-	-	-	-
	Energy tax	EUR/kWh	0,12	0,00	0,02	0,00	0,00	0,02	0,03
	CO2 tax	EUR/kWh	-	-	-	-	-	-	-
	NOx tax	EUR/kWh	-	-	-	-	-	-	-
Tariffs:	PSO (or similar tariff) for subsidy of other electricity production	EUR/kWh	0,03	0,01	0,01	0,03	0,02	0,00	-
	Electricity local grid tariff	EUR/kWh	0,03	0,05	0,02	0,06	0,04	0,02	0,04
	Electricity system/transmission tariff	EUR/kWh	0,01	-	0,00	-	-	-	-
Energy price, excl. tax etc.:	Electricity price	EUR/kWh	0,03	0,02	0,02	0,03	0,03	0,02	0,02
	Auxillary electricity price	EUR/kWh	0,03	0,02	0,02	0,03	0,03	0,02	0,02

Technology costs	Category	Unit	Denmark	Estonia	Finland	Latvia	Lithuania	Norway	Sweden
Maintenance costs:	Variable maintenance costs - resistance electricity	EUR/kWh	0	-	-	-	-	-	-
	Fixed maintenance costs - resistance electricity	EUR/unit/year	70	70	70	70	70	70	70
Capital costs:	Hardware costs - resistance electricity	EUR/unit	3920	3.920	3.920	3.920	3.920	3.920	3.920
	Connection costs and other hardware costs - resistance electricity	EUR/unit	0	-	-	-	-	-	-
	Installation costs - resistance electricity	EUR/unit	1680	1.680	1.680	1.680	1.680	1.680	1.680
	Total cost	EUR/unit	5600	5.600	5.600	5.600	5.600	5.600	5.600
	Loan period	years	15	15	15	15	15	15	15
	Annual loan costs	EUR/year	540	540	540	540	540	540	540
Remaining technical lifetime	Remaining technical lifetime	years	15	15	15	15	15	15	15
Scrap value:	Revenue	EUR	-1.960	-1.960	-1.960	-1.960	-1.960	-1.960	-1.960

Technical characteristics	Category	Data	Denmark	Estonia	Finland	Latvia	Lithuania	Norway	Sweden
Technical characteristics	Annual efficiency - resistance electricity		100%	100%	100%	100%	100%	100%	100%
	Auxillary electricity consumption - resistance electricity	kWh/year	0	-	-	-	-	-	-
	Technical lifetime (years) - resistance electricity	years	30	30	30	30	30	30	30
	Annual heat demand - individual house	kWh/year	16800	16.800	16.800	16.800	16.800	16.800	16.800
	Effect need	kW	7	7	7	7	7	7	7
	Electricity consumption for heat	kWh/year	16800	16.800	16.800	16.800	16.800	16.800	16.800

Resistance electricity - annual consumer cost 2016	Cost category	Denmark	Estonia	Finland	Latvia	Lithuania	Norway	Sweden	Unit
Capital costs:	Annual loan costs	540	540	540	540	540	540	540	EUR/year
Maintenance costs:	Variable maintenance costs - resistance electricity	0	0	0	0	0	0	0	EUR/year
	Fixed maintenance costs - resistance electricity	70	70	70	70	70	70	70	EUR/unit/year
Energy price, excl. tax etc.:	Electricity price	453	360	338	436	436	305	305	EUR/year
	Auxillary electricity price	-	-	-	-	-	-	-	EUR/year
Electricity tariffs:	All electricity tariffs	1.279	1.068	586	1.398	864	307	605	EUR/year
Subsidies:	Subsidies	0	0	0	0	0	0	0	None
Taxes and fees:	Electricity tax/electric heating fee	864	75	376	17	17	289	518	EUR/year
	CO2 tax	-	-	-	-	-	-	-	EUR/year
	NOx tax	-	-	-	-	-	-	-	EUR/year
	Electricity tax on auxillary electricity	-	-	-	-	-	-	-	EUR/year
Scrap value:	Revenue	-131	-131	-131	-131	-131	-131	-131	EUR/year
Total cost		3.074	1.982	1.779	2.330	1.796	1.380	1.907	
Heat price:	Heat price	0,18	0,12	0,11	0,14	0,11	0,08	0,11	EUR/kWh

8.8 Natural gas boiler

Levies, subsidies and energy price 2016	Category	Unit	Denmark	Estonia	Finland	Latvia	Lithuania	Norway	Sweden
Subsidies:	None		-	-	-	-	-	-	-
Taxes and fees:	Energy tax	EUR/kWh	0,027	0,004	-	0,00	-	-	0,009
	CO2 tax	EUR/kWh	0,005	-	-	0,00	-	-	0,023
	NOx tax	EUR/kWh	0,000	-	-	0,00	-	-	-
	Electricity tax	EUR/kWh	0,119	0,004	0,022	0,00	0,001	-	0,031
Tariffs:	PSO (or similar tariff) for subsidy of other electricity production	EUR/kWh	0,033	0,010	0,013	0,03	0,016	-	-
	Electricity local grid tariff	EUR/kWh	0,032	0,054	0,019	0,06	0,035	-	0,036
	Electricity system/transmission tariff	EUR/kWh	0,011	-	0,003	-	-	-	-
	Gas distribution tariff	EUR/kWh	0,013	0,004	-	0,00	0,014	-	0,028
Energy price, excl. tax etc.:	Natural gas price	EUR/kWh	0,020	0,018	-	0,03	0,020	-	0,033
	Electricity price	EUR/kWh	0,027	0,021	0,020	0,026	0,026	-	0,018

Technology costs	Category	Unit	Denmark	Estonia	Finland	Latvia	Lithuania	Norway	Sweden
Maintenance costs:	Variable maintenance costs - natural gas	EUR/kWh	-	-	-	-	-	-	-
	Fixed maintenance costs - natural gas	EUR/unit/year	235	235	235	235	235	235	235
Capital costs:	Hardware costs - natural gas	EUR/unit	1.800	1.800	1.800	1.800	1.800	1.800	1.800
	Connection costs and other hardware costs - natural gas	EUR/unit	2.000	2.000	2.000	2.000	2.000	2.000	2.000
	Installation costs - natural gas	EUR/unit	2.200	2.200	2.200	2.200	2.200	2.200	2.200
	Total cost	EUR/unit	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Loan:	Loan period	years	15	15	15	15	15	15	15
	Annual loan costs	EUR/year	578	578	578	578	578	578	578
Remaining technical lifetime	Remaining technical lifetime	years	7	7	7	7	7	7	7
Scrap value:	Revenue	EUR	-573	-573	-573	-573	-573	-573	-573

Technical characteristics	Category	Data	Denmark	Estonia	Finland	Latvia	Lithuania	Norway	Sweden
Technical characteristics	Annual efficiency - natural gas		102%	102%	102%	102%	102%	102%	102%
	Auxillary electricity consumption - natural gas	kWh/year	176	176	176	176	176	176	176
	Technical lifetime (years) - natural gas	years	22	22	22	22	22	22	22
	Annual heat demand - individual house	kWh/year	16.800	16.800	16.800	16.800	16.800	16.800	16.800
	Effect need	kW	7	7	7	7	7	7	7
	Natural gas consumption	kWh/year	16.471	16.471	16.471	16.471	16.471	16.471	16.471

Natural gas boiler - annual consumer cost 2016	Cost category	Denmark	Estonia	Finland	Latvia	Lithuania	Norway	Sweden	Unit
Capital costs:	Annual loan costs	578	578		578	578		578	EUR/year
Maintenance costs:	Variable maintenance costs - natural gas	-	-		-	-		-	EUR/year
	Fixed maintenance costs - natural gas	235	235		235	235		235	EUR/unit/year
Energy price, excl. tax etc.:	Natural gas price	332	290		544	329		544	EUR/year
	Auxillary electricity cost	5	4		5	5		3	EUR/year
Tariffs	All electricity tariffs	13	11		15	9		6	EUR/year
	#REF!	209	64		24	225		459	EUR/year
Subsidies:	Subsidies	-	-		-	-		-	None
Taxes and fees:	Energy tax	437	61		26	-		148	EUR/year
	CO2 tax	78	-		12	-		379	EUR/year
	NOx tax	2	-		0	-		-	EUR/year
	Electricity tax on auxillary electricity	21	1		0	0		5	EUR/year
Scrap value:	Revenue	-38	-38		-38	-38		-38	EUR/year
Total cost		1.871	1.206		1.399	1.343		2.321	
Heat price:	Heat price	0,11	0,07		0,08	0,08		0,14	EUR/kWh

8.9 Firewood stove and electric water heater

Levies, subsidies and energy price 2016	Category	Unit	Denmark	Estonia	Finland	Latvia	Lithuania	Norway	Sweden
Subsidies:	None		-	-	-	-	-	-	-
Taxes and fees:	Energy tax	EUR/kWh	-	-	-	-	-	-	-
	CO2 tax	EUR/kWh	-	-	-	-	-	-	-
	NOx tax	EUR/kWh	-	-	-	-	-	-	-
	Electricity tax	EUR/kWh	0,12	0,00	0,02	0,00	0,00	0,02	0,03
Tariffs:	PSO (or similar tariff) for subsidy of other electricity production	EUR/kWh	0,03	0,01	0,01	0,03	0,02	0,00	-
	Electricity local grid tariff	EUR/kWh	0,03	0,05	0,02	0,06	0,04	0,02	0,04
	Electricity system/transmission tariff	EUR/kWh	0,01	-	0,00	-	-	-	-
Energy price, excl. tax etc.:	Firewood price	EUR/kWh	0,07	0,02	0,05	0,02	0,02	0,07	0,03
	Electricity price	EUR/kWh	0,03	0,02	0,02	0,03	0,03	0,02	0,02

Technology costs	Category	Unit	Denmark	Estonia	Finland	Latvia	Lithuania	Norway	Sweden
Maintenance costs:	Variable maintenance costs - firewood	EUR/kWh	0	-	-	-	-	-	-
	Fixed maintenance costs - firewood	EUR/unit/year	212,1422819	212	212	212	212	212	212
Capital costs:	Hardware costs - firewood	EUR/unit	2540	2.540	2.540	2.540	2.540	2.540	2.540
	Connection costs and other hardware costs - firewood	EUR/unit	0	-	-	-	-	-	-
	Installation costs - firewood	EUR/unit	762	762	762	762	762	762	762
	Total cost	EUR/unit	3302	3.302	3.302	3.302	3.302	3.302	3.302
Loan:	Loan period	years	15	15	15	15	15	15	15
	Annual loan costs	EUR/year	318	318	318	318	318	318	318
Remaining technical lifetime	Remaining technical lifetime	years	9	9	9	9	9	9	9
Scrap value:	Revenue	EUR	-953	-953	-953	-953	-953	-953	-953

Technical characteristics	Category	Data	Denmark	Estonia	Finland	Latvia	Lithuania	Norway	Sweden
Technical characteristics	Annual efficiency - firewood		65%	65%	65%	65%	65%	65%	65%
	Auxillary electricity consumption - firewood	kWh/year	3500	3.500	3.500	3.500	3.500	3.500	3.500
	Technical lifetime (years) - firewood	years	24	24	24	24	24	24	24
	Annual heat demand - individual house	kWh/year	13300	13.300	13.300	13.300	13.300	13.300	13.300
	Effect need	kW	7	7	7	7	7	7	7
	Firewood consumption	kWh/year	20461,53846	20.462	20.462	20.462	20.462	20.462	20.462

Wood stove and electric water heater - annual consumer cost 2016	Cost category	Denmark	Estonia	Finland	Latvia	Lithuania	Norway	Sweden	Unit
Capital costs:	Annual loan costs	318	318	318	318	318	318	318	EUR/year
Maintenance costs:	Variable maintenance costs - firewood	0	0	0	0	0	0	0	EUR/year
	Fixed maintenance costs - firewood	212,1422819	212,1422819	212,14	212,14	212,1423	212,142	212,14	EUR/unit/year
Energy price, excl. tax etc.:	Firewood price	1.500	395	962	320	373	1.355	595	EUR/year
	Electricity price	94	75	70	91	91	64	64	EUR/year
Electricity tariffs:	All electricity tariffs	266	223	122	291	180	64	126	EUR/year
Subsidies:	Subsidies	0	0	0	0	0	0	0	None
Taxes and fees:	Energy tax	-	-	-	-	-	-	-	EUR/year
	CO2 tax	-	-	-	-	-	-	-	EUR/year
	NOx tax	-	-	-	-	-	-	-	EUR/year
	Electricity tax on auxillary electricity	416	16	78	4	4	60	108	EUR/year
Scrap value:	Revenue	-64	-64	-64	-64	-64	-64	-64	EUR/year
Total cost		2.743	1.175	1.700	1.172	1.114	2.010	1.359	
Heat price:	Heat price	0,16	0,07	0,10	0,07	0,07	0,12	0,08	EUR/kWh

8.10 Oil boiler

Levies, subsidies and energy price 2016	Category	Unit	Denmark	Estonia	Finland	Latvia	Lithuania	Norway	Sweden
Subsidies:	None		-	-	-	-	-	-	-
Taxes and fees:	Energy tax	EUR/kWh	0,03	0,04	0,01	0,01	0,00	0,02	0,01
	CO2 tax	EUR/kWh	0,01	-	0,01	0,00	-	0,01	0,03
	NOx tax	EUR/kWh	0,00	-	-	0,00	-	-	-
	Electricity tax	EUR/kWh	0,12	0,00	0,02	0,00	0,00	0,02	0,03
Tariffs:	PSO (or similar tariff) for subsidy of other electricity production	EUR/kWh	0,03	0,01	0,01	0,03	0,02	0,00	-
	Electricity local grid tariff	EUR/kWh	0,03	0,05	0,02	0,06	0,04	0,02	0,04
	Electricity system/transmission tariff	EUR/kWh	0,01	-	0,00	-	-	-	-
Energy price, excl. tax etc.:	Oil price	EUR/kWh	0,06	0,04	0,04	0,04	0,04	0,05	0,04
	Electricity price	EUR/kWh	0,03	0,02	0,02	0,03	0,03	0,02	0,02

Technology costs	Category	Unit	Denmark	Estonia	Finland	Latvia	Lithuania	Norway	Sweden
Maintenance costs:	Variable maintenance costs - oil boiler	EUR/kWh	0	-	-	-	-	-	-
	Fixed maintenance costs - oil boiler	EUR/unit/year	270	270	270	270	270	270	270
Capital costs:	Hardware costs - oil boiler	EUR/unit	4620	4.620	4.620	4.620	4.620	4.620	4.620
	Connection costs and other hardware costs - oil boiler	EUR/unit	0	-	-	-	-	-	-
	Installation costs - oil boiler	EUR/unit	1980	1.980	1.980	1.980	1.980	1.980	1.980
	Total cost	EUR/unit	6600	6.600	6.600	6.600	6.600	6.600	6.600
Loan:	Loan period	years	15	15	15	15	15	15	15
	Annual loan costs	EUR/year	636	636	636	636	636	636	636
Remaining technical lifetime	Remaining technical lifetime	years	5	5	5	5	5	5	5
Scrap value:	Revenue	EUR	-1.155	-1.155	-1.155	-1.155	-1.155	-1.155	-1.155

Technical characteristics	Category	Data	Denmark	Estonia	Finland	Latvia	Lithuania	Norway	Sweden
Technical characteristics	Annual efficiency - oil boiler		100%	100%	100%	100%	100%	100%	100%
	Auxillary electricity consumption - oil boiler	kWh/year	406,4	406	406	406	406	406	406
	Technical lifetime (years) - oil boiler	years	20	20	20	20	20	20	20
	Annual heat demand - individual house	kWh/year	16800	16.800	16.800	16.800	16.800	16.800	16.800
	Effect need	kW	7	7	7	7	7	7	7
	Oil consumption	kWh/year	16800	16.800	16.800	16.800	16.800	16.800	16.800

Oil boiler - annual consumer cost 2016	Cost category	Denmark	Estonia	Finland	Latvia	Lithuania	Norway	Sweden	Unit
Capital costs:	Annual loan costs	636	636	636	636	636	636	636	EUR/year
Maintenance costs:	Variable maintenance costs - oil boiler	0	0	0	0	0	0	0	EUR/year
	Fixed maintenance costs - oil boiler	270	270	270	270	270	270	270	EUR/unit/year
Energy price, excl. tax etc.:	Oil price	1.059	713	708	734	610	808	658	EUR/year
	Electricity price	11	9	8	11	11	7	7	EUR/year
Electricity tariffs:	All electricity tariffs	31	26	14	34	21	7	15	EUR/year
Subsidies:	Subsidies	0	0	0	0	0	0	0	None
Taxes and fees:	Energy tax	446	755	118	96	36	291	151	EUR/year
	CO2 tax	103,02	-	112,17	15,66	-	217,64	570,75	EUR/year
	NOx tax	2,04	-	-	0,15	-	-	-	EUR/year
	Electricity tax on auxillary electricity	48	2	9	0	0	7	13	EUR/year
Scrap value:	Revenue	-77	-77	-77	-77	-77	-77	-77	EUR/year
Total cost		2.529	2.334	1.798	1.719	1.506	2.167	2.243	
Heat price	Heat price	0,15	0,14	0,11	0,10	0,09	0,13	0,13	EUR/kWh

8.11 Wood pellet boiler

Levies, subsidies and energy price 2016	Category	Unit	Denmark	Estonia	Finland	Latvia	Lithuania	Norway	Sweden
Subsidies:	None		-	-	-	-	-	-	-
Taxes and fees:	Energy tax	EUR/kWh	-	-	-	-	-	-	-
	CO2 tax	EUR/kWh	-	-	-	-	-	-	-
	NOx tax	EUR/kWh	-	-	-	-	-	-	-
	Electricity tax	EUR/kWh	0,12	0,00	0,02	0,00	0,00	0,02	0,03
Tariffs:	PSO (or similar tariff) for subsidy of other electricity production	EUR/kWh	0,03	0,01	0,01	0,03	0,02	0,00	-
	Electricity local grid tariff	EUR/kWh	0,03	0,05	0,02	0,06	0,04	0,02	0,04
	Electricity system/transmission tariff	EUR/kWh	0,01	-	0,00	-	-	-	-
Energy price, excl. tax etc.:	Pellet price	EUR/kWh	0,05	0,03	0,05	0,03	0,03	0,05	0,04
	Electricity price	EUR/kWh	0,03	0,02	0,02	0,03	0,03	0,02	0,02

Technology costs	Category	Unit	Denmark	Estonia	Finland	Latvia	Lithuania	Norway	Sweden
Maintenance costs:	Variable maintenance costs - wood pellets	EUR/kWh	0	-	-	-	-	-	-
	Fixed maintenance costs - wood pellets	EUR/unit/year	201,3422819	201	201	201	201	201	201
Capital costs:	Hardware costs - wood pellets	EUR/unit	2571,428571	2.571	2.571	2.571	2.571	2.571	2.571
	Connection costs and other hardware costs - wood pellets	EUR/unit	0	-	-	-	-	-	-
	Installation costs - wood pellets	EUR/unit	535,7142857	536	536	536	536	536	536
	Total cost	EUR/unit	3107,142857	3.107	3.107	3.107	3.107	3.107	3.107
Loan:	Loan period	years	15	15	15	15	15	15	15
	Annual loan costs	EUR/year	299	299	299	299	299	299	299
Remaining technical lifetime	Remaining technical lifetime	years	5	5	5	5	5	5	5
Scrap value:	Revenue	EUR	-643	-643	-643	-643	-643	-643	-643

Technical characteristics	Category	Data	Denmark	Estonia	Finland	Latvia	Lithuania	Norway	Sweden
Technical characteristics	Annual efficiency - wood pellets		80%	80%	80%	80%	80%	80%	80%
	Auxillary electricity consumption - wood pellets	kWh/year	526	526	526	526	526	526	526
	Technical lifetime (years) - wood pellets	years	20	20	20	20	20	20	20
	Annual heat demand - individual house	kWh/year	16800	16.800	16.800	16.800	16.800	16.800	16.800
	Effect need	kW	7	7	7	7	7	7	7
	Pellet consumption	kWh/year	21000	21.000	21.000	21.000	21.000	21.000	21.000

Wood pellet boiler - annual consumer cost 2016	Cost category	Denmark	Estonia	Finland	Latvia	Lithuania	Norway	Sweden	Unit
Capital costs:	Annual loan costs	299	299	299	299	299	299	299	EUR/year
Maintenance costs:	Variable maintenance costs - wood pellets	0	0	0	0	0	0	0	EUR/year
	Fixed maintenance costs - wood pellets	201,3422819	201,3422819	201,34	201,34	201,3423	201,342	201,34	EUR/unit/year
Energy price, excl. tax etc.:	Pellet price	1.056	646	965	663	668	1.120	910	EUR/year
	Electricity price	14	11	11	14	14	10	10	EUR/year
Electricity tariffs:	All electricity tariffs	40	33	18	44	27	10	19	EUR/year
Subsidies:	Subsidies	0	0	0	0	0	0	0	None
Taxes and fees:	Energy tax	-	-	-	-	-	-	-	EUR/year
	CO2 tax	-	-	-	-	-	-	-	EUR/year
	NOx tax	-	-	-	-	-	-	-	EUR/year
	Electricity tax on auxillary electricity	62	2	12	1	1	9	16	EUR/year
Scrap value:	Revenue	-43	-43	-43	-43	-43	-43	-43	EUR/year
Total cost		1.631	1.151	1.464	1.179	1.167	1.606	1.412	
Heat price:	Heat price	0,10	0,07	0,09	0,07	0,07	0,10	0,08	EUR/kWh

8.12 Technological assumptions

	Category	Data	Unit	Reference	Note
Technical characteristics	Annual efficiency				All heating hardware is assumed to be new; not existing
	Annual efficiency - heat pump air-water	325%	PCT	P41 - https://ens.dk/sites/ens.dk/files/Analyser/update_-_technology_data_catalogue_for_individual_heating_plants_and_energy_transport_-_aug_2016.pdf	Assuming an existing one-family house with radiators
	Annual efficiency - heat pump liquid-water	360%	PCT	P45 - https://ens.dk/sites/ens.dk/files/Analyser/update_-_technology_data_catalogue_for_individual_heating_plants_and_energy_transport_-_aug_2016.pdf	Assuming an existing one-family house with radiators
	Annual efficiency - resistance electricity	100%	PCT	P84 - https://ens.dk/sites/ens.dk/files/Analyser/old_technology_data_for_individual_heating_plants_and_energy_transport_aug2016.pdf	Assuming one-family house, new building. 5 kW unit scaled to 7 kW
	Annual efficiency - natural gas	102%	PCT	P32 - https://ens.dk/sites/ens.dk/files/Analyser/old_technology_data_for_individual_heating_plants_and_energy_transport_aug2016.pdf	Assuming one-family house, existing building
	Annual efficiency - oil boiler	100%	PCT	P21 - https://ens.dk/sites/ens.dk/files/Analyser/old_technology_data_for_individual_heating_plants_and_energy_transport_aug2016.pdf	Assuming an existing one-family house with radiators, 15 kW oil boiler (smallest in catalogue)
	Annual efficiency - wood pellets	80%	PCT	P46 - https://ens.dk/sites/ens.dk/files/Analyser/old_technology_data_for_individual_heating_plants_and_energy_transport_aug2016.pdf	Assuming automatic stoking - one-family house, existing building
	Annual efficiency - firewood	65%	PCT	P62 - https://ens.dk/sites/ens.dk/files/Analyser/old_technology_data_for_individual_heating_plants_and_energy_transport_aug2016.pdf	Assuming one-family house, existing and new building, share of 100% of heat demand covered by firewood, while tap water is covered by electric water heater
	Auxillary electricity consumption				
	Auxillary electricity consumption - heat pump air-water	100	kWh/year	P41 - https://ens.dk/sites/ens.dk/files/Analyser/update_-_technology_data_catalogue_for_individual_heating_plants_and_energy_transport_-_aug_2016.pdf	Assuming an existing one-family house with radiators
	Auxillary electricity consumption - heat pump liquid-water	100	kWh/year	P45 - https://ens.dk/sites/ens.dk/files/Analyser/update_-_technology_data_catalogue_for_individual_heating_plants_and_energy_transport_-_aug_2016.pdf	Assuming an existing one-family house with radiators
	Auxillary electricity consumption - resistance electricity	0	kWh/year		Not found. Assumed 0
	Auxillary electricity consumption - natural gas	176	kWh/year	P3 - http://www.byggeriogenergi.dk/media/1710/udskiftning-af-gaskedel_ok.pdf	
	Auxillary electricity consumption - oil boiler	406,4	kWh/year	P17 - http://www.byggeriogenergi.dk/media/1718/guide-valg-af-varmeforsyning.pdf	Assuming an existing one-family house with radiators, 15 kW oil boiler (smallest in catalogue). Electricity demand assumed to be 20% less in new oil boiler
	Auxillary electricity consumption - wood pellets	526	kWh/year	P22 - http://www.byggeriogenergi.dk/media/1718/guide-valg-af-varmeforsyning.pdf	
	Auxillary electricity consumption - firewood	3500	kWh/year	P62 - https://ens.dk/sites/ens.dk/files/Analyser/old_technology_data_for_individual_heating_plants_and_energy_transport_aug2016.pdf	Assuming one-family house, existing and new building, share of 100% of heat demand covered by firewood, while tap water is covered by electric water heater. Tap water included here, and calculated based on P12 https://ens.dk/sites/ens.dk/files/Analyser/old_technology_data_for_individual_heating_plants_and_energy_transport_aug2016.pdf
	Technical lifetime (years)				
	Technical lifetime (years) - heat pump air-water	15	years	P41 - https://ens.dk/sites/ens.dk/files/Analyser/update_-_technology_data_catalogue_for_individual_heating_plants_and_energy_transport_-_aug_2016.pdf	Assuming an existing one-family house with radiators
	Technical lifetime (years) - heat pump liquid-water	20	years	P45 - https://ens.dk/sites/ens.dk/files/Analyser/update_-_technology_data_catalogue_for_individual_heating_plants_and_energy_transport_-_aug_2016.pdf	Assuming an existing one-family house with radiators
	Technical lifetime (years) - resistance electricity	30	years	P84 - https://ens.dk/sites/ens.dk/files/Analyser/old_technology_data_for_individual_heating_plants_and_energy_transport_aug2016.pdf	Assuming one-family house, new building. 5 kW unit scaled to 7 kW
	Technical lifetime (years) - natural gas	22	years	P32 - https://ens.dk/sites/ens.dk/files/Analyser/old_technology_data_for_individual_heating_plants_and_energy_transport_aug2016.pdf	Assuming one-family house, existing building
	Technical lifetime (years) - oil boiler	20	years	P21 - https://ens.dk/sites/ens.dk/files/Analyser/old_technology_data_for_individual_heating_plants_and_energy_transport_aug2016.pdf	Assuming an existing one-family house with radiators, 15 kW oil boiler (smallest in catalogue)
	Technical lifetime (years) - wood pellets	20	years	P46 - https://ens.dk/sites/ens.dk/files/Analyser/old_technology_data_for_individual_heating_plants_and_energy_transport_aug2016.pdf	Assuming automatic stoking - one-family house, existing building
	Technical lifetime (years) - firewood	24	years	P62 - https://ens.dk/sites/ens.dk/files/Analyser/old_technology_data_for_individual_heating_plants_and_energy_transport_aug2016.pdf	Assuming one-family house, existing and new building, share of 100% of heat demand covered by firewood, while tap water is covered by electric water heater
	Energy supply				
	Annual heat demand - individual house	16800	kWh/year	P17 - https://ens.dk/sites/ens.dk/files/Analyser/update_-_technology_data_catalogue_for_individual_heating_plants_and_energy_transport_-_aug_2016.pdf	"An existing one-family house is defined to have an annual heat demand of 16.8 MWh and a peak demand of 7 kW."
	Effect need	7	kW	P17 - https://ens.dk/sites/ens.dk/files/Analyser/update_-_technology_data_catalogue_for_individual_heating_plants_and_energy_transport_-_aug_2016.pdf	"An existing one-family house is defined to have an annual heat demand of 16.8 MWh and a peak demand of 7 kW."

Maintenance costs	Variable maintenance costs				
	Variable maintenance costs - heat pump air-water	0	EUR/kWh	P41 - https://ens.dk/sites/ens.dk/files/Analyser/update_-_technology_data_catalogue_for_individual_heating_plants_and_energy_transport_-_aug_2016.pdf	Assuming an existing one-family house with radiators
	Variable maintenance costs - heat pump liquid-water	0	EUR/kWh	P45 - https://ens.dk/sites/ens.dk/files/Analyser/update_-_technology_data_catalogue_for_individual_heating_plants_and_energy_transport_-_aug_2016.pdf	Assuming an existing one-family house with radiators
	Variable maintenance costs - resistance electricity	0	EUR/kWh	P84 - https://ens.dk/sites/ens.dk/files/Analyser/old_technology_data_for_individual_heating_plants_and_energy_transport_aug2016.pdf	Assuming one-family house, new building. 5 kW unit scaled to 7 kW
	Variable maintenance costs - natural gas	0	EUR/kWh	P32 - https://ens.dk/sites/ens.dk/files/Analyser/old_technology_data_for_individual_heating_plants_and_energy_transport_aug2016.pdf	Assuming one-family house, existing building. 100 EUR/year assumed to be a simplification. Added under fixed cost
	Variable maintenance costs - oil boiler	0	EUR/kWh	P21 - https://ens.dk/sites/ens.dk/files/Analyser/old_technology_data_for_individual_heating_plants_and_energy_transport_aug2016.pdf	Assuming an existing one-family house with radiators, 15 kW oil boiler (smallest in catalogue)
	Variable maintenance costs - wood pellets	0	EUR/kWh	P46 - https://ens.dk/sites/ens.dk/files/Analyser/old_technology_data_for_individual_heating_plants_and_energy_transport_aug2016.pdf	Assuming automatic stoking - one-family house, existing building
	Variable maintenance costs - firewood	0	EUR/kWh	P62 - https://ens.dk/sites/ens.dk/files/Analyser/old_technology_data_for_individual_heating_plants_and_energy_transport_aug2016.pdf	Assuming one-family house, existing and new building, share of 100% of heat demand covered by firewood, while tap water is covered by electric water heater
	Fixed maintenance costs				
	Fixed maintenance costs - heat pump air-water	200	EUR/unit/year	P41 - https://ens.dk/sites/ens.dk/files/Analyser/update_-_technology_data_catalogue_for_individual_heating_plants_and_energy_transport_-_aug_2016.pdf	Assuming an existing one-family house with radiators
	Fixed maintenance costs - heat pump liquid-water	200	EUR/unit/year	P45 - https://ens.dk/sites/ens.dk/files/Analyser/update_-_technology_data_catalogue_for_individual_heating_plants_and_energy_transport_-_aug_2016.pdf	Assuming an existing one-family house with radiators
	Fixed maintenance costs - resistance electricity	70	EUR/unit/year	P84 - https://ens.dk/sites/ens.dk/files/Analyser/old_technology_data_for_individual_heating_plants_and_energy_transport_aug2016.pdf	Assuming one-family house, new building. 5 kW unit scaled to 7 kW
	Fixed maintenance costs - natural gas	235	EUR/unit/year	P32 - https://ens.dk/sites/ens.dk/files/Analyser/old_technology_data_for_individual_heating_plants_and_energy_transport_aug2016.pdf	Assuming one-family house, existing building. Fixed and (fixed annual) variable cost added together.
	Fixed maintenance costs - oil boiler	270	EUR/unit/year	P21 - https://ens.dk/sites/ens.dk/files/Analyser/old_technology_data_for_individual_heating_plants_and_energy_transport_aug2016.pdf	Assuming an existing one-family house with radiators, 15 kW oil boiler (smallest in catalogue)
	Fixed maintenance costs - wood pellets	201	EUR/unit/year	P22 - http://www.byggeriogenergi.dk/media/1718/guide-valg-af-varmeforsyning.pdf	Assuming automatic stoking - one-family house, existing building. This value used, since the one in the DEA's was considered unrealistic
	Fixed maintenance costs - firewood	212	EUR/unit/year	P22 - http://www.byggeriogenergi.dk/media/1718/guide-valg-af-varmeforsyning.pdf	Assuming one-family house, existing and new building, share of 100% of heat demand covered by firewood, while tap water is covered by electric water heater. Assumed the same as with wood pellets. This value used, since the one in the DEA's was considered unrealistic. Water heater costing 540 EUR assumed with maintenance 2%/year

Capital costs	Hardware costs				
	Hardware costs - heat pump air-water	7000	EUR/unit	P41 - https://ens.dk/sites/ens.dk/files/Analyser/update_-_technology_data_catalogue_for_individual_heating_plants_and_energy_transport_-_aug_2016.pdf	Assuming an existing one-family house with radiators. 70% of total costs are equipment
	Hardware costs - heat pump liquid-water	10400	EUR/unit	P45 - https://ens.dk/sites/ens.dk/files/Analyser/update_-_technology_data_catalogue_for_individual_heating_plants_and_energy_transport_-_aug_2016.pdf	Assuming an existing one-family house with radiators. 65% of total costs are equipment
	Hardware costs - resistance electricity	3920	EUR/unit	P84 - https://ens.dk/sites/ens.dk/files/Analyser/old_technology_data_for_individual_heating_plants_and_energy_transport_aug2016.pdf	Assuming one-family house, new building. 5 kW unit scaled to 7 kW. 70% of total costs are equipment
	Hardware costs - natural gas	1800	EUR/unit	P32 - https://ens.dk/sites/ens.dk/files/Analyser/old_technology_data_for_individual_heating_plants_and_energy_transport_aug2016.pdf	Assuming one-family house, existing building. 45% of total costs are equipment
	Hardware costs - oil boiler	4620	EUR/unit	P21 - https://ens.dk/sites/ens.dk/files/Analyser/old_technology_data_for_individual_heating_plants_and_energy_transport_aug2016.pdf	Assuming an existing one-family house with radiators, 15 kW oil boiler (smallest in catalogue). 70% of total costs are equipment
	Hardware costs - wood pellets	2.571	EUR/unit	P22 - http://www.byggeriogenergi.dk/media/1718/guide-valg-af-varmeforsyning.pdf	Assuming automatic stoking - one-family house, existing building.
	Hardware costs - firewood	2540	EUR/unit	P62 - https://ens.dk/sites/ens.dk/files/Analyser/old_technology_data_for_individual_heating_plants_and_energy_transport_aug2016.pdf and https://www.billigvvs.dk/Varmesystemer-Varmtvandsbeholdere-El-Vandvarmer--Metro-El-vandvarmer-model-110-173057.html	Assuming one-family house, existing and new building, share of 100% of heat demand covered by firewood, while tap water is covered by electric water heater. This value used, since the one in the DEA's was considered unrealistic. Water heater costing 540 EUR assumed.
	Connection costs and other hardware costs				
	Connection costs and other hardware costs - heat pump air-water	0	EUR/unit	P41 - https://ens.dk/sites/ens.dk/files/Analyser/update_-_technology_data_catalogue_for_individual_heating_plants_and_energy_transport_-_aug_2016.pdf	Assuming an existing one-family house with radiators
	Connection costs and other hardware costs - heat pump liquid-water	0	EUR/unit	P45 - https://ens.dk/sites/ens.dk/files/Analyser/update_-_technology_data_catalogue_for_individual_heating_plants_and_energy_transport_-_aug_2016.pdf	Assuming an existing one-family house with radiators
	Connection costs and other hardware costs - resistance electricity	0	EUR/unit	P84 - https://ens.dk/sites/ens.dk/files/Analyser/old_technology_data_for_individual_heating_plants_and_energy_transport_aug2016.pdf	Assuming one-family house, new building. 5 kW unit scaled to 7 kW.
	Connection costs and other hardware costs - natural gas	2000	EUR/unit	P32 - https://ens.dk/sites/ens.dk/files/Analyser/old_technology_data_for_individual_heating_plants_and_energy_transport_aug2016.pdf	Assuming one-family house, existing building
	Connection costs and other hardware costs - oil boiler	0	EUR/unit	P21 - https://ens.dk/sites/ens.dk/files/Analyser/old_technology_data_for_individual_heating_plants_and_energy_transport_aug2016.pdf	Assuming an existing one-family house with radiators, 15 kW oil boiler (smallest in catalogue)
	Connection costs and other hardware costs - wood pellets	0	EUR/unit	P22 - http://www.byggeriogenergi.dk/media/1718/guide-valg-af-varmeforsyning.pdf	Assuming automatic stoking - one-family house, existing building. Assumed that chimney and central heating system is already present
	Connection costs and other hardware costs - firewood	0	EUR/unit	P62 - https://ens.dk/sites/ens.dk/files/Analyser/old_technology_data_for_individual_heating_plants_and_energy_transport_aug2016.pdf	Assuming one-family house, existing and new building, share of 100% of heat demand covered by firewood, while tap water is covered by electric water heater. Assumed that chimney is already present
	Installation costs				
	Installation costs - heat pump air-water	3000	EUR/unit	P41 - https://ens.dk/sites/ens.dk/files/Analyser/update_-_technology_data_catalogue_for_individual_heating_plants_and_energy_transport_-_aug_2016.pdf	Assuming an existing one-family house with radiators. 30% of total costs are installation
	Installation costs - heat pump liquid-water	5600	EUR/unit	P45 - https://ens.dk/sites/ens.dk/files/Analyser/update_-_technology_data_catalogue_for_individual_heating_plants_and_energy_transport_-_aug_2016.pdf	Assuming an existing one-family house with radiators. 35% of total costs are installation
	Installation costs - resistance electricity	1680	EUR/unit	P84 - https://ens.dk/sites/ens.dk/files/Analyser/old_technology_data_for_individual_heating_plants_and_energy_transport_aug2016.pdf	Assuming one-family house, new building. 5 kW unit scaled to 7 kW. 30% of total costs are installation
	Installation costs - natural gas	2200	EUR/unit	P32 - https://ens.dk/sites/ens.dk/files/Analyser/old_technology_data_for_individual_heating_plants_and_energy_transport_aug2016.pdf	Assuming one-family house, existing building. 45% of total costs are equipment
	Installation costs - oil boiler	1980	EUR/unit	P21 - https://ens.dk/sites/ens.dk/files/Analyser/old_technology_data_for_individual_heating_plants_and_energy_transport_aug2016.pdf	Assuming an existing one-family house with radiators, 15 kW oil boiler (smallest in catalogue). 30% of total costs are installation
	Installation costs - wood pellets	536	EUR/unit	P22 - http://www.byggeriogenergi.dk/media/1718/guide-valg-af-varmeforsyning.pdf	Assuming automatic stoking - one-family house, existing building.
	Installation costs - firewood	762	EUR/unit	P62 - https://ens.dk/sites/ens.dk/files/Analyser/old_technology_data_for_individual_heating_plants_and_energy_transport_aug2016.pdf	Assuming one-family house, existing and new building, share of 100% of heat demand covered by firewood, while tap water is covered by electric water heater. Installation for water heater assumed to be 30% of hardware cost

www.Flex4RES.org