Space heating measurement in apartment buildings

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VTT TECHNOLOGY 305

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Teknologian tutkimuskeskus VTT Oy

ISBN 978-951-38-8563-2 (URL: http://www.vttresearch.com/impact/publications)

VTT Technology 305

ISSN-L 2242-1211
ISSN 2242-122X (Online)
http://urn.fi/URN:ISBN:978-951-38-8563-2

JULKAISIJA – UTGIVARE – PUBLISHER

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Cover image: Typical Finnish new apartment building (larger photo); Typical old, renovated 70's building (smaller photo)

Contents

Summary

The aim of the Energy Efficiency Directive (EED) is to improve energy efficiency by means of consumption-based cost allocation, e.g. in multifamily apartments. The main idea is to give information and incentives to users, and by that to encourage energy saving behaviours.

This project focused on determining out the costs and benefits achieved through: a) heating cost allocators; b) building energy management systems and c) comparing them with benefits achieved by other energy improvement measures both in the existing building stock and future new construction.

In multi-apartment buildings with a central heating, individual consumption meters or heat cost allocators shall be installed as stipulated by the Energy Efficiency Directive, which came into force in December 2012. The introduction of individual billing of heat cost is justified by energy savings. Measuring heat energy consumption as such obviously does not save energy, but it effects residents' behaviours, e.g. by avoiding window ventilation during the heating period.

In Finland, apartment buildings are typically equipped with ventilation, either by natural or mechanical exhaust or mechanical supply and exhaust ventilation. Opening windows for long-term ventilation purposes seldom occurs. The predominant share of space heating is represented by old building stock, which has not gone through major renovations. In the new and renovated building stock, the share of space heating is decreasing due to improved thermal insulation, airtightness and ventilation heat recovery.

According to this study, heat cost allocators indicate an increase in the billing and equipment costs associated with a central heating in new and renovated buildings in Finland. The cost increase compared to the present situation in old, non-renovated buildings is about 10%, after renovation 20–30% and after major renovation 40–50%. In new, very efficient buildings the cost allocation can be as much as the energy cost of space heating itself. It is very unlikely and sometimes even impossible that energy-saving behaviours could compensate the additional cost of a measuring system. Therefore, heat cost allocators can counteract out savings achieved by ordinary or advanced building energy management systems.

As the share of intermittent renewables increases flexible demand, the demand side of management becomes important. Therefore, it is beneficial to invest in active energy management systems which are able to react to changes in energy supply, but at the same time also maintain good-quality thermal comfort and indoor climate.

Recent research on demand side management in heating has shown good potential in shifting and reducing peak energy demands to avoid increased costs and CO_2 emissions. In addition, demand side management can lead to energy savings. Different studies have shown clear reductions in back-up oil boiler start-ups. Additional savings could be realised if the building stock thermal capacity could be used to optimise demand side management.

1. Introduction

1.1 Energy Efficiency Directive

The aim of the Energy Efficiency Directive, EED, is to improve energy efficiency by means of consumption-based cost allocation, e.g. in multifamily apartments. The main idea is to give information and incentives to users and by that to encourage energy saving behaviours.

The new Energy Efficiency Directive's Article 9 Section 3 states the following:

Where heating and cooling or hot water are supplied to a building from a district heating network or from a central source servicing multiple buildings, a heat or hot water meter shall be installed at the heating exchanger or point of delivery. In multi-apartment and multi-purpose buildings with a central heating/cooling source or supplied from a district heating network or from a central source serving multiple buildings, individual consumption meters shall also be installed by 31 December 2016 to measure the consumption of heat or cooling or hot water for each unit where technically feasible and cost-efficient. Where the use of individual meters is not technically feasible or not cost-efficient, to measure heating, individual heat cost allocators shall be used for measuring heat consumption at each radiator, unless it is shown by the Member State in question that the installation of such heat cost allocators would not be cost-efficient. In those cases, alternative cost-efficient methods of heat consumption measurement may be considered.

Where multi-apartment buildings are supplied from district heating or cooling, or where own common heating or cooling systems for such buildings are prevalent, Member States may introduce transparent rules on the allocation of the cost of thermal or hot water consumption in such buildings to ensure transparency and accuracy of accounting for individual consumption. Where appropriate, such rules shall include guidelines on the way to allocate costs for heat and/or hot water that is used as follows:

a) *hot water for domestic needs;*
b) *heat radiated from the building installation and for the purpose of heating the common areas (where staircases and corridors are equipped with radiators);*
c) *for the purpose of heating apartments.*

1.2 Project goals

The project goal is to clarify in regards to both the existing building stock and future new construction costs and benefits achieved through a) heating cost allocators and c) building energy management systems and compare them with benefits achieved by other energy improvement measures.

1.3 Implementation

Energy consumption measurement and energy management technologies and their assessment are done by literature survey and interviews. Besides technology, also the building management culture is taken into account. Economic feasibility is assessed by life cycle cost calculations. Input data is adopted from statistics and studies.

2. Apartment blocks in Finland

2.1 Management of buildings

Most apartment houses (69%) are owned by private households (Table 1). The shares are the same calculated from houses and residential units. Approximately 10% of dwellings do not have permanent residents.

Table 1. Multi-unit residential buildings according to type of ownership. Source: Statistics Finland, Buildings and free-time residences.

	Apartment buildings (2017)	
Total	63 760	100%
Buildings containing owned and rental apartments	44 260	69%
Subsidised rental houses	15 060	24%
Other rental houses	4 440	7%

The private ownership (69% of buildings) is organised via a limited liability housing company system. The responsibility of maintenance is divided between company and households. The company is responsible for building structures and technical service systems. In other words – all structures that play a role in terms of energy consumption. This motivates shareholders to make energy performance upgrades together.

Energy savings as well as energy bills are divided between owners in relation to each apartment's floor space. Common guidelines for building management provided by the Ministry of the Environment instruct taking into account a building's physical behaviour. Otherwise, there is a risk of moisture condensing on the structures and even water freezing. Typically, the internal walls between apartments are uninsulated and the dimensioning of the heating devices is based on the assumption that the neighbouring spaces are kept within normal temperature ranges. If this is not happening, the heating power capacity in the smaller apartments may be insufficient to reach targeted indoor air temperatures.

The current Limited Liability Housing Company Act enables apartment-specific billing of heat energy consumption, but it has not been well-liked. In the introduction of apartment-specific measuring and billing, the topic of discussion in Finland has indeed been inequality due to the location of the apartments and the impact of heat flows between apartments on energy consumption. The great changes in outdoor temperatures in Finland emphasise the significance of the location of the apartment.

Discussion has also been brought about by heat not coming through the radiator network, such as warm air coming through mechanical air conditioning and electric floor heating. In the future, the share of these and free energies in the heating of apartments and spaces will be emphasised when the thermal losses of the structures decrease.

In rental housing (31% of buildings) the rent always includes heating. Cold and hot water may be separated from the rent if it is metered. Usually an electricity supply agreement is made by the tenant. Exceptions are special groups, like students. Low-income residents can get a rent subsidy from Kela – the

Social Insurance Institution of Finland. This subsidy contains only fixed costs mentioned in the rental fee agreement. Fees determined according to consumption are excluded from the subsidy (Kela, 2013).

This social security system guarantees acceptable living conditions to all who want live decently. Finland is one of a few European countries, where energy poverty does not exist. According the Ministry of the Environment (2016), the only people who are at risk of suffering from energy poverty, are low-income people living in single-family houses heated with oil.

2.2 Energy consumption in Finnish apartment blocks

District heating is the dominant heat source in apartment blocks (Figure 1). Until the 1990's the heat was distributed only by water circulation in central heating system. Due to the use of mechanical supply and exhaust ventilation, the role of distribution by water circulation has been reduced.

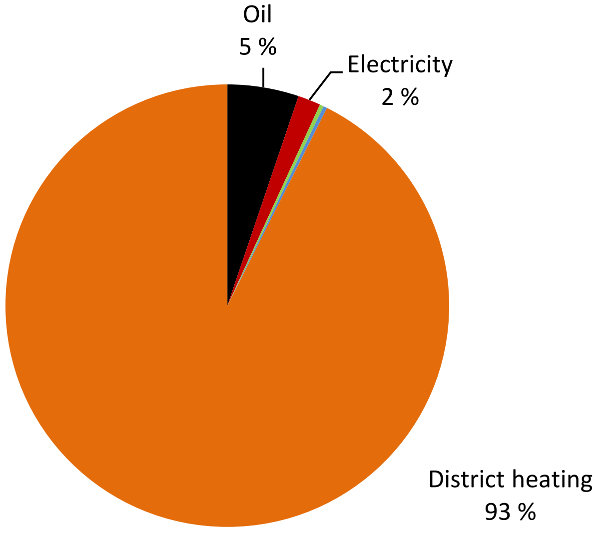

Figure 1. Source of heat in apartment blocks.

The shares of space heating, supply air heating, domestic hot water and electricity are shown in Figure 2. The given years refer to the dates when new guidelines (1940, 1962, 1969) or construction requirements (1976–1985, 2003–2012) were given. In 1990, no new orders were given, but mechanical ventilation had already become a business-as-usual solution and it is therefore added as a separate case. All the cases are calculated with an equal amount of controlled ventilation (0.5 dm^3/m^2s). For the oldest cases that is natural ventilation, then mechanical exhaust starting from the seventies and finally mechanical supply and exhaust with heat recovery since 1990's. Therefore, all the cases are equal in terms of indoor air quality. Also, the appliance, lighting and occupancy loads are equal in the cases. Only the envelope heat transfer coefficients, infiltration and ventilation system implementations vary in the cases.

Figure 2 shows how the share of space heating has decreased from 73% in the 1940's to 12% in buildings permitted in 2012. In most buildings that is the part of the delivered energy that can be affected by installing heat cost allocators or individual measuring and billing. Supply air heating is typically implemented by a water-based heating coil in a centralized unit and it is very unlikely that it could be included into an individual measuring and billing scheme.

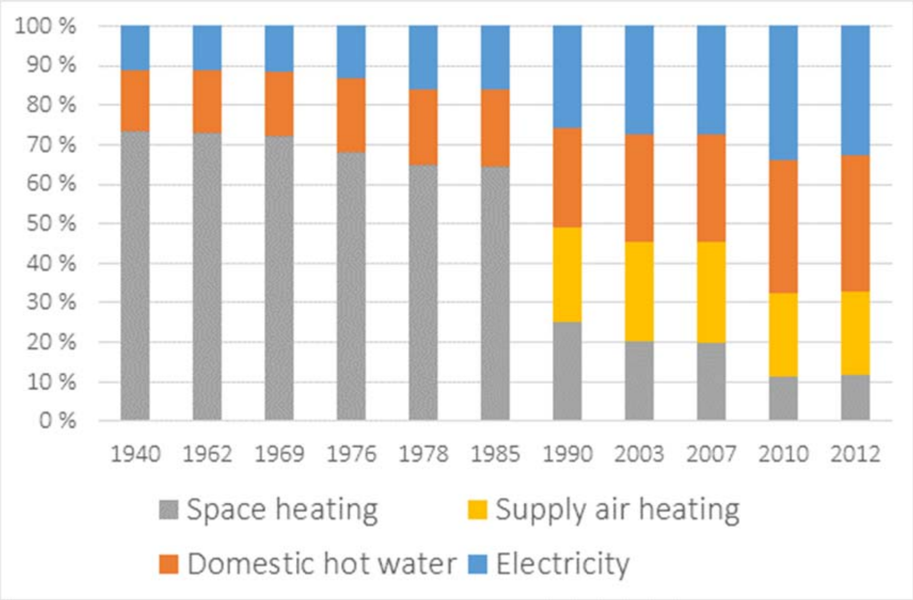

Figure 2. The shares of space heating, supply air heating, domestic hot water and electricity in apartment buildings.

2.3 Building technical systems in apartment blocks

2.3.1 Ventilation

Finland has a long tradition in combining good indoor air quality and energy efficiency. All Finnish apartment buildings have ventilation channels. The oldest buildings, built before the 60s, have natural ventilation. After the 60s, buildings have been equipped with mechanical ventilation. Since the 90s, buildings have been equipped with two pipe supply and exhaust air ventilation with heat recovery. The supply air is heated by the warmer exhaust air.

In connection with renovations, natural ventilation has been changed to mechanical ventilation. To upgrade the energy efficiency of mechanical ventilation, tailor-made heat harvesting technology has been developed. In this technology, recovered heat is transferred by heat pump either to the heating system or to hot water.

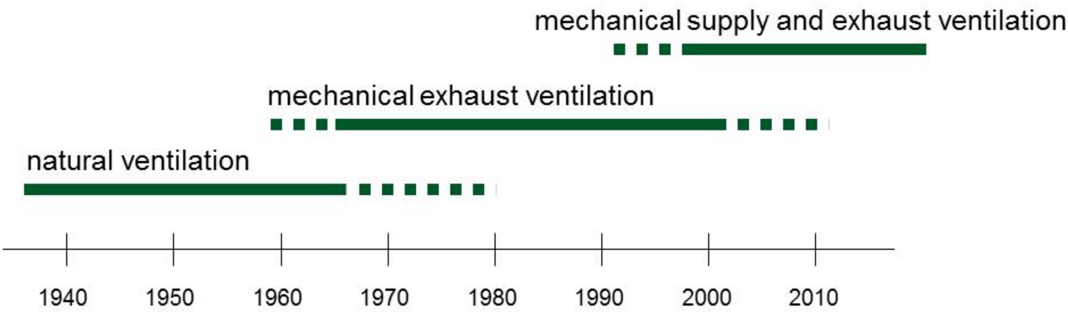

Figure 3. The evolution of ventilation technology in apartment blocks.

Supply air is taken in through ventilation inlets. In the oldest buildings, ventilators may exit through outside walls or in masonry channels. Mechanical ventilation is typical for prefabricated apartment buildings. They can have ventilators built in window frames or in flues. The newest buildings have a mechanical supply and exhaust ventilation system where fresh air is supplied via heat recovery to pre-heat the supply air.

As supply air is arranged in ventilation channels, window ventilation is limited to the warm months. In Finland, windows have typically two parts – large and small (Figure 4). The large part is locked, and it is opened only for washing. For ventilation, the smaller part is used.

Figure 4. Typical Finnish windows. This is a year 2013 model which replaced a similar window from 1972.

The prevalence of window ventilation during the heating season has been studied by photographing facades of 434 buildings during 23 February 2016–5 April 2016 by random sampling. The outside temperature was between -5 – +5 °C and the weather was cloudy. The amount of open windows was 3.3% of all 20,757 studied windows.

Table 2. Window ventilation in Finland (Helsinki, Espoo, Seinäjoki, Kuopio).

Photographed buildings	434 st
Windows – total	20 757 st
Open windows	685 st
Share	3.3%

2.3.2 Heating

In Finland, nearly all apartment blocks are connected to a district heating system and have centralised heat distribution (Statistics Finland, buildings and free-time residences). The heating network piping in the buildings has mainly been implemented so that rooms have facade-specific vertical piping lines. Many vertical piping lines run through each apartment (Figure 5).

Apartment-specific measuring would be cheaper if the radiator circulation would be centralised – like floor heating – and could be metered at one point (Figure 6). Within many vertical pipes, also many metering points are needed, and this weakens the measuring accuracy and increases installation and maintenance costs.

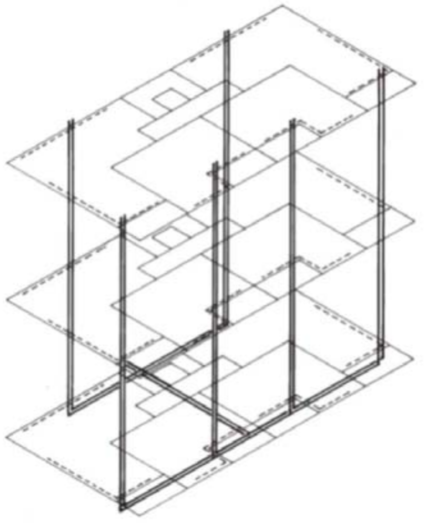

Figure 5. Distributed heating network frame lines. Source: Woodfocus (2005).

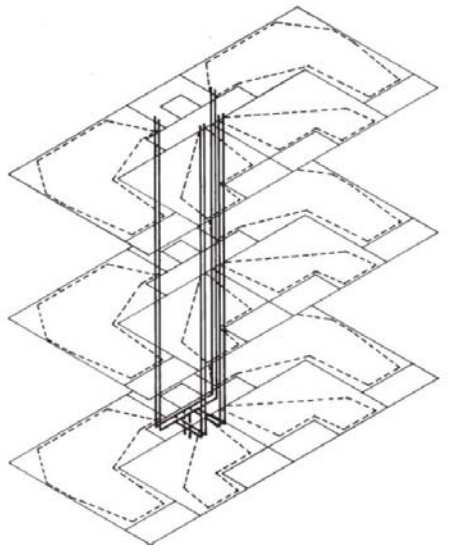

Figure 6. Centralised heating network frame lines. Source: Woodfocus (2005).

Performance of the heating system has a very significant effect on indoor comfort in a Nordic climate where heating has been and is still required even in the latest NZEB buildings throughout the year, excluding a couple of months in the summer. In the Finnish limited liability housing company model, as well as in rental houses, heating systems are maintained by professionals and not by individual occupants.

Heating systems are controlled on the building level. The supply water temperature to radiators or floor heating is based on outdoor air temperature (Figure 7). The temperature is either the same for the whole building or there are different temperature measurements and supply temperatures for northern and southern facades. In a typical existing building with radiators, the supply water temperature in the dimensioning temperature (-26 °C in Helsinki) would be 70 °C and decrease close to linearly until the outdoor temperature reaches 20 degrees and supply water temperature is 20 degrees, which is the lower limit.

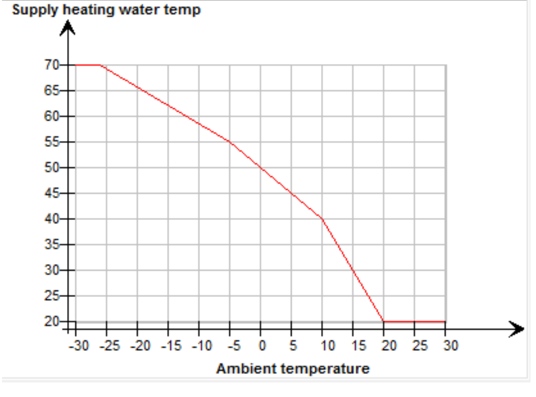

Figure 7. Supply heating water dependence on outdoor temperature.

The valves in the radiators only have a minor ability to control and limit the heat flow. If the valves are thermostatic they automatically change the flow to reach the given temperature set point. The set point can be adjusted by the occupant, but only within given limits. Typically, the allowed variation is a couple of degrees. If the valves are not thermostatic, but manually controlled, the user can adjust the flow in a given range, but the valve itself does not change the flow according to the temperature.

The described control method effectively prevents energy waste. At an average temperature of 5 °C, the supply water temperature is around 45 °C in the described setting. If the occupant opens a window, but does not close the radiator valves, the thermostatic valves open as much as they are allowed, but thanks to low supply temperature, the energy loss is much less than it would be if the supply temperature would be constant all year.

Figure 8 presents the performance of this procedure. The specific heating energy consumption has been decreased year after year thanks to advances in technology.

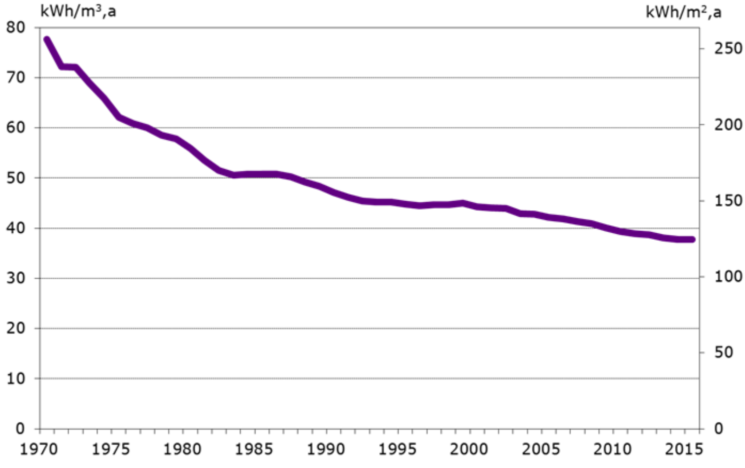

Figure 8. Specific energy consumption for central heating, including both space heating and domestic hot water, in buildings heated by district heating. Figure includes both older buildings with weak energy performance and newer buildings with good energy performance. Source: Finnish Energy, 2016.

3. Heating energy saving

3.1 Measure options

There are basically five options to save in space heating:

1. Making building envelope and technical building systems more energy efficient.
2. Affecting user behaviour through information campaigns.
3. Affecting user motivation through measuring and billing (more in Chapter 3.2).
4. Reducing reasons for occupants’ energy waste, i.e. improving user comfort by improving technical building systems (more in Chapter 3.3).
5. Reducing occupants’ possibilities for energy waste.

The first option is about improving the building itself. Even though the targeted consumption in the building is different, the wider target to improve the efficiency is still the same. The renovation of the building and systems should not be forgotten. Renovation is the most guaranteed way to achieve energy savings and can be done at a reasonable cost within upkeep of a building.

In Finland, option two has been effectively used in national-level campaigns. Option three has been widely used with electricity, but not with heat, since the risks have been seen as too high. Option four is the one that probably has the highest potential for improvement. Option five is the traditional approach, which is certainly required at a reasonable level, but will lead to increased complaints if it is taken too far, i.e. even with a well-working ventilation system complaints are expected if the occupants are not able to open their windows.

Technical solutions to space heating are assessed in Figure 9.

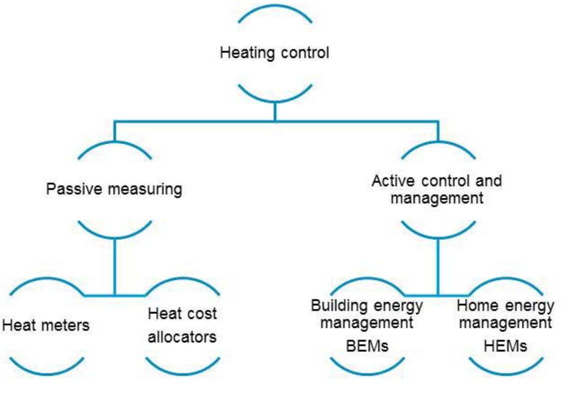

Figure 9. Heat energy measuring devices and heat cost allocators.

A holistic view is important in developing building energy management and should include all the topics in the energy use of a building such as maintenance issues and practices, control strategies, sequences of operation and how well the mechanical equipment, lighting, building envelope and related controls perform together. Separating only one topic from the others can lead to partial optimisation which may not be cost-efficient and can lead to higher risk of problems in other topics. (CaCx, 2006.)

3.2 Passive measuring

3.2.1 Heat meters

Heat energy meters are similar as used for metering district heating. In calorimetric metering, the water volume flow rate and the supply and return water temperature difference is metered, and with these the heat consumption is calculated (Figure 10).

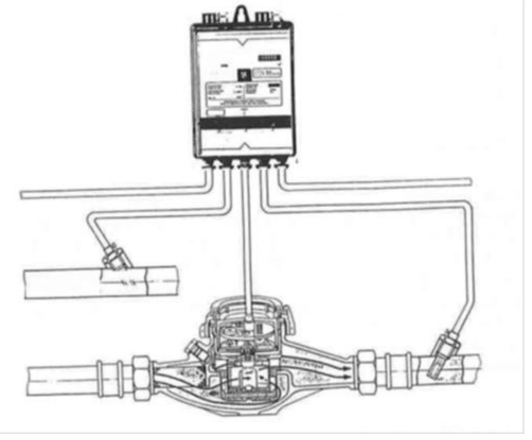

Figure 10. Heat meter.

3.2.2 Heat cost allocators

Through heat cost allocators, apartment-specific heat energy consumption shares are estimated. The devices are used, for example, in Denmark, Germany, Austria and some other countries in central Europe. In Finland, heat cost allocators have been installed at research sites and a limited number of rental houses. Case 1 at the end of this chapter is a description of a system at a housing company owned by the city of Berlin.

The most common method is to install a separate device into each radiator and other structures (e.g. pipes) bringing heat into the apartment (Figure 11, Figure 12). Heat cost allocators can be divided into evaporative and electronic ones. The electronic models have in practice displaced the evaporative models. The latest electronic models can be read remotely (Figure 13) – the same kind of radio and Internet technology that is used in the electricity grid.

Figure 11. The heat cost allocator on a radiator.

Figure 12. Heat cost allocator on radiator pipes.

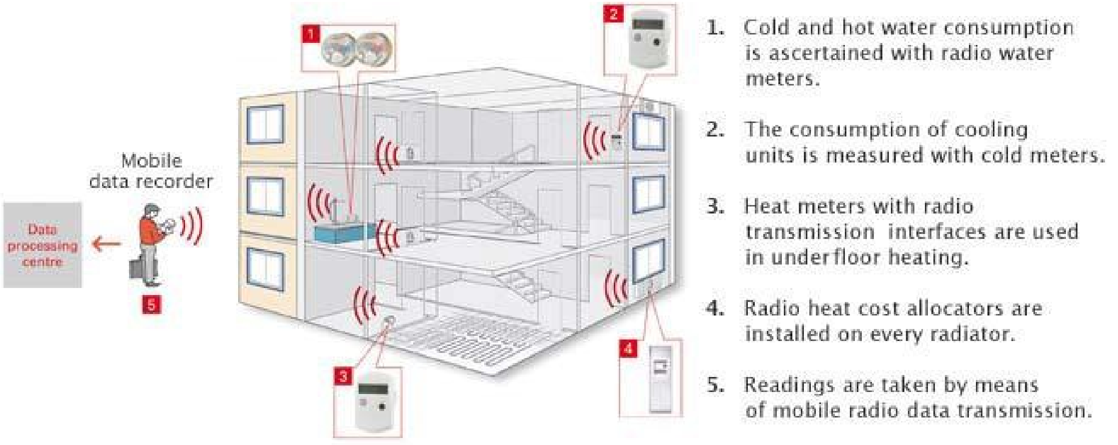

Figure 13. Illustration of a remote reading.

Case 1. DEGEWO - housing company owned by the city of Berlin

- The company owns 73 000 apartments in East Berlin and is transferring the measuring and billing of heat consumption from an external supplier to an own subsidiary (Gewobe) that has been established founded especially for this task
- The subsidiary has developed its own heat and water measuring, remote reading, and billing system from components bought from the market. The operating life of the heat cost allocator is 10 years (operating life of the radiator), and after that the whole instrument is exchanged.
- The instrument is installed into radiators and other building blocks providing heat, e.g. radiator and hot water pipes. Based on the values of the allocator, the divisible share of the heat costs varies building-specifically from 30 to 70%. The share is smaller in newer than older buildings.
- Residents pay 50–70 € / year rent for the system. In order to pay merely for the instrument rent, the residents should be able to save 15–25% of their heating costs
- Residents pay a monthly estimate fee for heating. The estimate is levelled once a year.
- The system fulfils the obligation regarding the fair distribution of heat costs. This is seen as important in Germany, especially regarding low-income residents.
- There are no air shafts in the houses of this company, rather in the rental agreement there is an obligation to air out the apartment at least 10 minutes a day.
- The requirements set by the city of Berlin for energy savings and the use of renewable energy are fulfilled by the dynamic direction of the heating system, outer sheath repairs, solar energy or like procedures.

Source: Gewobe 2013

3.2.3 Impact on energy consumption

International studies argue that by taking into use an apartment-specific heat energy and water consumption billing system, we can achieve savings compared to previous energy consumption. For example, according to Abrahamsson (2012), the savings are usually 10–20%. In some old studies concerning a central European building stock, even bigger savings percentages than this have been achieved.

In Finland, this matter has been investigated most thoroughly in the 1980s and 1990s. Also, Finnish studies have concluded that an apartment-specific measurement usually lowers consumption, although not as much as in international studies. Kimari (1994) states that energy savings produced by the measuring will remain under 10%. These thoughts presented by Kimari are supported, for example, by studies done by Aho et al. (1995) using extensive material. According to the results of this study, at the time when energy and water consumption was measured and billed apartment-specifically, the total energy consumption remained at a level of about 2% lower than at the time when there was no apartment-specific measuring. Regarding heat energy consumption, the difference was only 1%. Then again, the energy consumption of warm water billed according to apartment-specific consumption was at an approx. 6% lower level than when the apartment-specific measuring and billing were not used. Indeed, the essential factor in the formation of the total consumption difference seems to have been the difference in the consumption of warm water.

Actions by which residents may decrease their heat energy consumption are lowering the inside temperature of dwellings and decreasing the duration of window ventilation and other user-controlled ventilation. According to Motiva and Finnish Energy Industries, lowering the inside temperature by one degree means a five per cent savings in annual heat energy consumption. Following this, a 10% heat energy consumption savings would require a drop of two degrees in the inside air in all areas of the building. Since the use of window ventilation during the heating period in Finland is very slight, achieving a 10% savings with these methods is very difficult.

Lowering the indoor temperature and decreasing the ventilation rate, whether through windows or through the actual ventilation system should always reflect the actual use of the building. The thermal comfort of the people depends on body composition and activity of the occupants (Tuomaala et al., 2013). Motivating people to save energy is naturally recommendable, but doing this using too strict methods may lead to energy poverty where people are forced to lower the temperature and ventilation rate to a level that is lower than what is comfortable and healthy. Trying to generate regulation that prevents energy poverty by setting clearly defined minimum requirements may lead to complex specifications (Brunner et al., 2011).

3.2.4 The cost impact of heat cost allocation in Finland

The annual costs of apartment-specific heat cost allocators depend on the number of radiators in the dwelling. Typically, for example, a dwelling with three rooms and a kitchen has four radiators with pipelines into which the instruments are installed. The annual cost for this kind of measuring system for an apartment is estimated to be 70 euros per year (Table 3).

Table 3. Apartment-specific heat cost allocators' average taxable annual cost in profitability calculations for a three-room apartment with a kitchen. Building has 20 apartments. The basic price level of the service depends on the number of radiators. Single payments are written off in 30 years. Discount rate is excluded.

	€	€/apartment per year (2013 price level)	€/apartment per year (2017 price level)
Legal services (changes to house rules)	250	0.42	0.43
Change to the by-laws	380	0.63	0.64
Taxable basic price level of service (4 radiators)*		55	56
Additional cost/billing (4 x year)**		12	12
Total		68	70

* investment share 15 €/ apartment yearly, use costs 40 €/apartment yearly.

** billing is done by the building manager or service provider

The following annual costs depending on the number of rooms in a dwelling are used in the profitability calculations of this study for apartment-specific heat cost allocators:

- Two-room apartments: 55 €/ apartment per year
- Three-room apartments: 70 €/ apartment per year

Heating costs in multifamily residential buildings

The specific space heating energy consumption depends on both the construction year and what renovations have been carried out during a building's lifespan. By renovations, the space heating energy need can be decreased from an initial 135 kWh/m^2 to 40–85 kWh/m^2 (Table 4; Table 5). The impact of renovation measures is based on cost optimality study of the Energy Performance of Buildings Directive (EPBD) national implementation (Ministry of the Environment, 2013).

The consumptions are priced by using the unit price of 60 €/MWh (incl. all taxes) for CHP district heating (Energiateollisuus, 2017) and 63 €/MWh (incl. all taxes) for heat pump electricity (Energiavirasto, 2017). Annual heating costs are calculated for a two-room apartment (56 m^2) and three-room apartment (70 m^2). As can be seen in Table 4 and Table 5, the cost of heat cost allocation is unreasonably too high compared to the present heating cost of apartments. It is unlikely and sometimes even impossible that energy-saving behaviours could compensate the additional cost caused by a measuring system.

Calculations presented in tables are made without an interest component. If the discount rate is taken into account in the calculations, economic viability changes for the worse. In comparison, we can state that through basic regulation of the heating network an energy savings of 15% can be achieved (Virta & Pylsy, 2011). Costs of the basic regulation of the network and the change of the thermostatic radiator valves vary case-specifically. In terms of magnitude, the costs of these procedures are 50–100 euros per radiator. Through these single investments, it is possible at one time to achieve many years of energy savings.

Table 4. An analysis of how much a heat cost allocation system can raise the space heating cost in a two-room apartment. Acronyms: DH = district heating; HP = heat pump; GHP = ground heat pump; Deep renovation = structural improvements and HP.

		Space heating kWh/ floor-m^2; y	Space heating €/ floor-m^2; y	Space heating €/ flat 56 m^2;y	Heat cost allocation €/ flat 56 m^2; y	Cost pressure due the heat cost allocation %
Old building	initial state, DH	135	8.1	454	55	12%
Old building	after structural improvements; DH	85	5.1	286	55	19%
Old building	after installing the exhaust air HP; DH	65	3.9	221	55	25%
Old building	after GHP	55	3.5	194	55	28%
Old building	after deep renovation; DH	40	2.4	137	55	40%
New building	2012 requirements, DH	35	2.1	118	55	47%
New building	2017 requirements, DH	20	1.2	67	55	82%
New building	2012 or 2017 requirements, GHP	15	0.9	50	55	109%

Table 5. The analysis of how much a heat cost allocation system can raise the space heating cost in a three-room apartment. Acronyms: DH = district heating; HP = heat pump; GHP = ground heat pump; Deep renovation = structural improvements and HP.

		Space heating kWh/ floor-m^2; y	Space heating €/ floor-m^2; y	Space heating €/ flat 70 m^2;y	Heat cost allocation €/ flat 70 m^2;y	Cost pressure due the heat cost allocation %
Old building	initial state, DH	135	8.1	567	70	12%
Old building	after structural improvements; DH	85	5.1	357	70	20%
Old building	after installing the exhaust air HP; DH	65	3.9	276	70	25%
Old building	after installing GHP	55	3.5	243	70	29%
Old building	after deep renovation; DH	40	2.4	171	70	41%
New building	2012 requirements, DH	35	2.1	147	70	48%
New building	2017 requirements, DH	20	1.2	84	70	83%
New building	2012 or 2017 requirements, GHP	15	0.9	63	70	111%

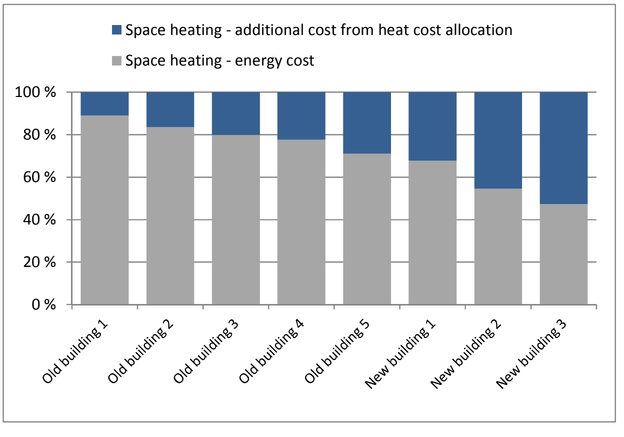

Figure 14. Annual cost of heat cost allocation compared with energy cost in a three-room apartment.

Case 2. The city of Helsinki's reasons for why its housing companies do not measure heat consumption apartment-specifically.

Case 2. Why not apartment-specific heat billing, City of Helsinki

1. THE RESIDENT CAN IMPACT HEAT ENERGY CONSUMPTION IN F INLAND ONLY SLIGHTLY

The energy amount needed for the heating and ventilation of buildings depends on the quality of the heating, ventilation and regulation instruments, their condition and use and the quality of the structures. In Finland, the responsible party for all of these is usually the owner of the building, not the resident. The resident may impact his or her heat consumption mostly by regulating the inside temperature of the apartment and consuming water economically at those sites where the use of warm water is measured apartment-specifically.

2. HEATING IN FINLAND IS THE RESPONSIBILITY OF THE PROPERTY OWNER

In Finland the owner of the property, i.e. also the apartment housing company, is responsible for both the property's structural and technical total condition and the heating costs so that the resident always has in his or her use adequately warm and sanitary spaces. Thus, the heating costs are fairly included in the maintenance fee or rent independent of the apartment's location, wall insulations or condition of the devices.

3. IN FINLAND, THE REGULATION SYSTEMS USUALLY TAKE INTO ACCOUNT CHANGES IN OUTDOOR TEMPERATURE AND INTERNAL HEAT LOADS

In Finland, regulation of the temperature of radiators is always done centrally at the lowest level possible according to the outside temperature. Practically all radiators have thermostatic radiator valves, with which internal heat flows can be utilised and also the inside temperature regulated within certain limits. However, the ventilation amount of the apartments must in all conditions be over the minimum norm level at local conditions, and the resident may not change these basic settings.

4. THE APARTMENT'S LOCATION IMPACTS CONSUMPTION SIGNIFICANTLY – HOW IS THAT TAKEN INTO ACCOUNT?

Apartments situated in different parts of the building are not in an equal position thermally. The larger the part of the apartment's structures that is defined against outside air, the more heating is needed. Also, apartment's orientation in relation to compass points impacts the need for heat. If the heat consumption and costs want to be distributed among the apartments exactly according to measurements, also the unequal location of the apartments must be compensated for and the transfer of heat among apartments taken into account. Instruments that are able to take into account the aforementioned factors are currently so expensive and complex that their use has to be justified even in new construction properties. Additionally, the reliability of the measurements, operating life of the measurement and costs due to billing have not corresponded to even the achievable theoretical future benefits.

5. GENERAL GROUNDS

The Technical Board of Helsinki believes that through current solutions, in most of the Helsinki building stock a good and economical energy economy, a healthy inside air and a fair distribution of costs have been achieved. The apartment-specific energy consumption focused on heating is small and the external and internal situation-specific variables related to it big. Understanding the external let alone the internal changes related to the heating of one apartment, and reacting to them correctly, is almost impossible with the measurement information. Unreliable measuring and the difficult interpretation of the final result is a drawback, not a benefit, for the sensible use of energy, especially if the arrangement increases costs in all cases.

Source: Technical Board of Helsinki City 1.4.2008 (City of Helsinki, 2008)

3.2.5 Legal environment

Features of evaporative devices are discussed in the Standard SFS-EN 835 and features of electronic models are reviewed in the Standard SFS-EN834. Requirements have not been harmonised on the EU level, because heat cost allocators do not fulfil the description of a measuring device.

In many European countries, the calibration of heat meters is guided through regulations. The calibration periods set for the meters in the regulations vary usually from two to ten years, depending on the country. Some countries do not have separate regulations concerning the calibration of heat meters (Euroheat & Power, 2011).

In Finland, regarding legislation concerning measuring, the Finnish Measuring Instruments Act 707/2011 replacing the old Act on Inspection of Weights and Measures 219/1965 came into effect starting on 1.7.2011. The goal of the Act is to guarantee the reliability of measuring instrument functions and measuring methods and results. In the legislative reform, the regulations of the Act on Inspection of Weights and Measures have been updated to correspond to the requirements of the new constitution. At the same time, the Measuring Instruments Directive (MID) was transposed into Finnish legislation. Along with the reform, the concept of calibration is replaced with certifying the measuring instrument. Measuring instruments used in trade must during use be certified by the inspection agency at specified intervals. In consumption measurements (electricity, gas, heat and water), the operator ensures that the reliability of the measuring instrument is certified at set intervals. The Finnish Safety and Chemicals Agency (Tukes) and regional administration offices will also in the future monitor adherence to the law.

3.3 Active control and management (system level)

3.3.1 Building and home energy management

In the large scale, building automation in Finnish building stock is still at a basic level. In a 2012 study (Ministry of the Environment 2012), it was estimated that the typical new building made according the requirements would be in the EN15232 class C. It is reasonable to assume that also the buildings that have gone through extensive renovation would fall in the same class.

The best class A corresponds to high-energy performance building automation and control system (BACS) and technical building management (TBM). Class B corresponds to advanced BACS and some specific TBM functions. Class C corresponds to standard BACS. Class D corresponds to non-energy efficient BACS. Building with such systems shall be retrofitted. New buildings shall not be built with such systems.

The standard lists required system properties for each of the technical building systems. For the heating emission control, for example, there are four recognised levels

- Level 0 – no automatic room temperature control
- Level 1 – central automatic control on distribution or generation, e.g. supply water temperature control based on outdoor temperature
- Level 2 – room control, e.g. by thermostatic valves or electronic controller
- Level 3 – room control with communication to building automation and demand control, e.g. demand control performed by occupancy

The energy performance classes are defined by checking the level of automation in the building. The standard defines which level of automation is required for each part of the system. The requirements are different for residential and non-residential systems. For the heating emission control, level 3 is required for class A in both building types. Figure 15 illustrates the definition.

			Definition of classes							
			Residential				Non residential			
			D	C	B	A	D	C	B	A
AUTOMATIC CONTROL										
1	HEATING CONTROL									
1.1	Emission control									
		The control system is installed at the emitter or room level, for case 1 one system can control several rooms								
	0	No automatic control								
	1	Central automatic control								
	2	Individual room control								
	3	Individual room control with communication and demand control								
1.2	Emission control for TABS									
	0	No automatic control								
	1	Central automatic control								
	2	Advanced central automatic control								

Figure 15. A part of the class definition in EN15232.

The standard has two methods to estimate the savings due to improved automation. The simpler method is based on efficiency factors, which show that improving a residential building from class C to class A will result in an estimated 19% savings in heating. It is interesting to notice that this is actually the same saving percentage that is reported in a number of European studies on heat cost allocators and/or individual billing. A quick conclusion could be that in a large scale the same saving potential can be reached either by implementing state of the art building automation or by changing occupant behaviour by using money as a motivator. The choice between the two should be based on analyses of costs, indoor comfort and risks to a building itself. The other way round, it could also be said that if state of the art building automation is already installed, there will be much less saving potential due to heat cost allocators – or vice versa.

Carefully designed and implemented automation does not make human mistakes or waste energy and is typically less risky to a building, but probably a more expensive option. It also enables better indoor comfort. Whereas the occupants must be guided regularly in a manually controlled building, the automation must be regularly commissioned in a technical building. It is difficult to estimate which effect lasts longer without refreshing.

A complete traditional building automation system is not necessarily a requirement for getting the savings promised in the standard. New cloud and Internet-of-Things technology has enabled smart control systems that for some years only existed in large building automation systems in commercial buildings. They are easy and cost-effective to install also into existing residential buildings. For space heating, these systems can, e.g. measure the room temperatures in each room wirelessly, check the energy price or renewable generation status, check the weather forecast and optimize the heating power in each heating unit based on the given criteria. The consumption and status of the system can be monitored in the web and professional maintenance staff can control the system remotely.

3.3.2 Demand-side management at apartment and building level

Demand side management is widely used in industrial systems and it has been focusing mainly on electricity use. However, currently there are many ongoing activities focusing on the space heating demand side of management. The focus in demand side management is primarily to shift and decrease the peak energy demands to avoid increased costs and CO_2 emissions, and it can also lead to energy savings.

In a previous study by Sipilä and Kärkkäinen (2000), it was shown that the peak demand of buildings can be reduced without customers noticing the reduction in heat quality. Stang et al. (2002) found that there is only a small potential to reduce the heat load of domestic hot water and some potential in the preheating of mechanical ventilation air (e.g. in commercial buildings, schools, etc.), by using different control algorithms. That obviously requires close co-operation and synchronisation between the end user and district heating supplier. The largest potential for peak load reductions was seen in space heating having a negligible effect on end user comfort if applied for short periods of time. Stang et al. (2002) pointed out that there is still need for further expertise on temperature reduction control and demand side management in district heating systems.

Wiegbels et al. (2005) found many potential benefits in demand side management (DSM). The savings in a case study in Finland (Jyväskylä CHP), showed emission reductions of 84 t CO_2 yearly and the estimated savings of DSM for the whole Finnish district heating market was 3 million US$. They stated also that the savings are smaller for district heating systems without electricity production.

Wernstedt et al. (2008) found a 7% reduction in energy consumption when indoor temperature was not affected. The study concluded also that the indoor thermal comfort satisfaction was considers as typical.

In a recent Finnish study (Salo, 2016) it was found that 11% of the variable space heating costs can be reduced in heavy-mass buildings. In addition, that study found that the variable production costs during the heating season can be reduced by 1.1 €/MWh, which equals 6% of the total variable costs through demand side management. In addition, more than 40% of the oil boiler start-ups could be avoided during a year. If the building stock (offices and commercial buildings) thermal capacity could be used to optimise demand side management, the total potential with dynamic pricing could be 10–25% of the peak demand.

From a comprehensive market review on Demand Response, under four criteria – enabling consumer participation and aggregation, appropriate programme requirements, fair and standardised measurement and verification requirements – some relevant findings were extracted and summarised into an overall score. Figure 16 presents the situation of the EU countries in 2015 with respect to explicit DR markets. Finland is among those countries able to adapt demand response technology.

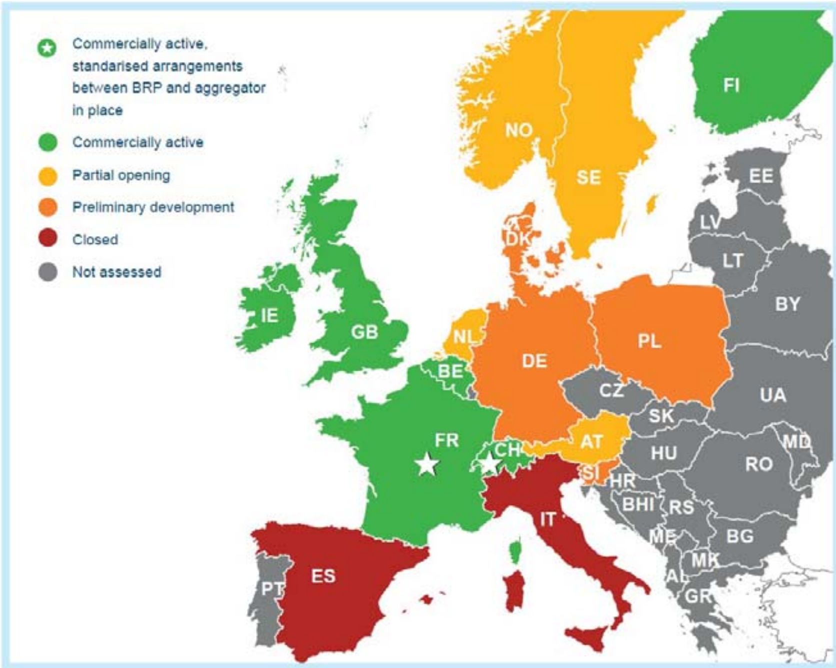

Figure 16. Demand Response scenario in Europe. (Source: SEDC 2015, Mapping Demand response in Europe today.)

3.3.3 Smart energy management and control systems

The increasing share of intermittent renewables on the supply side has increased the desire of flexible demand. Energy efficient buildings generally have lower peak loads compared to standard buildings, but the difference is much higher in energy consumption than in peak loads, e.g. (Rijksen et al., 2010). In addition, specific technical and management factors within each building significantly affect its peak load in real use of the building.

By introducing domotic technology, the actions and processes in the system are executed automatically based on given parameters. Smart building automation technology offers an easy way to control and monitor building conditions. In addition to possibilities to optimise system performance, domotic technology can increase comfort and security.

Even though there are already existing solutions for smart energy management in buildings, there are still quite a lot of traditional building energy management systems relying on static set-point temperatures, e.g. for heating. By using intelligent systems the operations of, e.g. heating can be adjusted based on changing needs. A Swedish study of offices and shopping centres indicated that heating demand can be reduced by over 40% by relying on dynamic temperature set points for the heating equipment (Lindén et al., 2009).

Groissböck et al. (2014) demonstrated that space heating and ventilation energy consumption can be reduced over 10% by using responsive systems. The buildings were located in Austria and Spain and they applied a dynamic temperature set point method, which allows zonal temperatures to fluctuate in a user-specified range.

Rocha et al. (2015) found that using smart building energy management systems resulted in higher energy savings than conventional building energy management systems with policy measures. The studied cases were located in Austria and Spain.

Intelligent energy management systems have also been a focus of the EU H2020 programme, with a total of 27 related calls in the last four years within the programmes of Energy-efficient Buildings (EeB), Energy Efficiency (EE), Smart Cities (SCC) and Low Carbon Energy (LCE) in H2020 focused on smart energy management or intelligent/self-learning energy systems and demand response.

3.4 National-level promotion for improved energy efficiency

3.4.1 Energy efficiency agreements

The Energy Efficiency Agreements 2008−2016 (Motiva, 2008) and the new agreements signed in October 2016 for the period 2017−2025 (Motiva, 2016) are an important means of furthering energy efficiency in Finland. The agreement scheme serves implementation of the Energy Efficiency Directive (EED) 2012/27/EU. Finland has chosen alternative measures to fulfil EED Article 7, such as binding energy savings targets and extensive energy efficiency agreements, which have an important role in the implementation. Voluntary Energy Efficiency Agreements covering the following sectors are in force until 2025:

- industries (industry, private service sector, energy sector)
- municipal sector
- oil sector (oil-heating and distribution of liquid fuels)
- property and building sector (housing properties, commercial properties)

The agreements are a means of improving energy efficiency in different sectors with voluntary measures without enacting any new legislation. When joining companies and municipalities commit to improving the efficiency of their energy use in order to achieve objectives they have set by 2025. The use of these agreements will speed up improved energy efficiency and support the mitigation of climate change and success in achieving national objectives for the use of renewable energy, as well as establish green growth and markets for cleantech solutions. The agreements will also increase Finland's security of supply and energy self-sufficiency.

The calculation of energy savings from energy efficiency agreements is based on energy-saving measures reported as implemented in the annual reports of companies and municipalities who have joined the agreements. Companies and communities have reported a total of approximately €1.050 million to be used to implement these energy savings measures. Annual total impact of implemented measures at the end of 2015 are the following:

- heat and fuel savings 10.6 TWh
- electricity savings 3.6 TWh
- savings in energy costs approx. €500 million
- CO_2 emissions reduced nearly by 4.3 million tonnes

Savings reported in industry cover 69% of the realised energy savings, energy production 21% and other sectors 10%. Energy savings related to the energy sector are important for EED overall energy efficiency targets but not eligible to be claimed for the EED Article 7 implementation.

3.4.2 Inspection of boiler – alternative method

Finland has a effective scheme for EED energy efficiency agreements, which is one of the reasons why Finland has chosen alternative methods instead of mandatory EPBD boiler inspections (Ministry of the

Environment, 2013). It has been proven that the alternative methods are more effective than mandatory inspections would have been.

One of the aims of the energy efficiency agreements linked to heating systems is to include a voluntary inspection corresponding to the mandatory ones and advice on energy efficiency as part of the periodic service and maintenance procedures. This achieves cost-effective results, though without any obligation to conduct statutory inspections, as is the case with the inspection procedure. Furthermore, the aim is to increase the number of yearly maintenance contracts for boilers so that the energy efficiency of heating systems remains at the best possible level and boiler operators regularly receive advice and information on energy efficiency. The energy savings achieved are compared to the savings estimated for the inspection procedure.

In the follow-up period 9 January 2013–30 June 2014, the alternative procedure used with boilers in Finland achieved at least the same effect in terms of volume of energy savings as the mandatory inspection procedures were predicted to achieve (Table 6). Estimates suggest that savings with the alternative procedure total 141–288 GWh. If the mandatory inspections had been conducted, the figure would have been around 291–271 GHw in the follow-up period. The alternative procedure used by Finland under Article 14(4) of the Directive therefore corresponds to the inspection procedure referred to in paragraphs 1–3 of the Article.

Table 6. Overall savings effects of the inspection procedure for the period 2013–2014 (Ministry of the Environment, 2014).

	Energy saving effects of the inspection procedure	Energy saving effects of the alternative procedure
Oil-fired boilers	58–86	90–132
Biomass boilers	70–182	51–156
Gas-fired boilers	1–2	–
Total	129–271	141–288

4. Conclusions

The aim of the Energy Efficiency Directive, EED, is to improve energy efficiency by means of consumption-based cost allocation, e.g. in multifamily apartments. The main idea is to give information and incentives to users and by that to encourage energy saving behaviours.

This project focused on determining the costs and benefits achieved through: a) heating cost allocators; b) building energy management systems and c) comparing them with benefits achieved by other energy improvement measures both in the existing building stock and future new construction.

In multi-apartment buildings with central heating, individual consumption meters or heat cost allocators shall be installed as per the Energy Efficiency Directive, which came into force in December 2012. The introduction of individual billing of heat costs is justified by energy savings. Measuring heat energy consumption, as such, obviously does not save energy. It effects residents' behaviours, e.g. by avoiding window ventilation during the heating period.

In Finland, most of the apartment buildings (69%) are owned by private households. Apartment buildings are typically equipped with ventilation, either by natural or mechanical exhaust or mechanical supply and exhaust ventilation. Opening windows for long-term ventilation purposes very seldom happens. Old buildings which have not gone through major renovations comprise the majority of space heating needs. In the new and renovated building stock, the share of space heating is decreasing due to improved thermal insulation, airtightness and ventilation heat recovery.

According to this study, the heat cost allocators increase the equipment and billing costs of central heating in new and renovated buildings in Finland. The cost increase compared to the present situation in old, non-renovated buildings is about 10%, after renovation 20–30% and after major renovation 40–50%. In new, very efficient buildings the cost allocation can be as much as the energy cost of space heating itself. It is very unlikely and sometimes even impossible that energy-saving behaviours could compensate the additional cost associated with a measuring system. Therefore, heat cost allocators can counteract savings achieved by ordinary or advanced building energy management systems.

As the share of intermittent renewables increases, flexible demand and demand side management become important. Therefore, it is beneficial to invest in active energy management systems which are able to react to changes in energy supply, while at the same time maintain good-quality thermal comfort and indoor climate.

Recent research on demand side management in heating has shown good potential in shifting and reducing peak energy demands to avoid increased costs and CO_2 emissions. In addition, demand side management can lead to energy savings. Different studies have shown a clear reduction in back-up oil boiler start-ups. In addition, building stock thermal capacity could be used to optimise demand side management.

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Series title and number

VTT Technology 305

Title	**Space heating measurement in apartment buildings**
Author(s)	Terttu Vainio, Miimu Airaksinen & Teemu Vesanen
Abstract	This project focused on determining the costs and benefits achieved through: a) heating cost allocators; b) building energy management systems and c) comparing them with benefits achieved by other energy improvement measures both in the existing building stock and future new construction. In multi-apartment buildings with central heating, individual consumption meters or heat cost allocators shall be installed as per the Energy Efficiency Directive, which came into force in December 2012. The introduction of individual billing of heat costs is justified by energy savings. Measuring heat energy consumption, as such, obviously does not save energy, but it effects residents' behaviour e.g. by avoiding window ventilation during the heating period. In Finland, apartment buildings are typically equipped with ventilation, either by natural or mechanical exhaust or mechanical supply and exhaust ventilation. Opening windows for long–term ventilation purposes very seldom happens. The dominant share of space heating occurs is old building stock that not experienced major renovations. In the new and renovated building stock the share of space heating is decreasing due to improved thermal insulation, airtightness and ventilation heat recovery. According to this study the heat cost allocators increase the equipment and billing costs of heating in new and renovated multi-apartment buildings in Finland. The cost increase compared to the present situation in old, not-renovated buildings is about 10%, after renovation 20-30% and after major renovation 40-50%. In new, very efficient buildings the cost allocation can be as much as the energy cost of space heating itself. It is very unlikely and sometimes even impossible that energy-saving behaviours could compensate the additional cost associated with a measuring system. Therefore heat cost allocators can counteract savings achieved by ordinary or advanced building energy management systems.
ISBN, ISSN, URN	ISBN 978-951-38-8563-2 (URL: http://www.vttresearch.com/impact/publications) ISSN-L 2242-1211 ISSN 2242-122X (Online) http://urn.fi/URN:ISBN:978-951-38-8563-2
Date	August 2017
Language	English, Finnish abstract
Pages	27 p.
Name of the project	
Commissioned by	Ministry of Economic Affairs and Employment
Keywords	Measurement of space heating; Heat cost allocation
Publisher	VTT Technical Research Centre of Finland Ltd P.O. Box 1000, FI-02044 VTT, Finland, Tel. 020 722 111

Julkaisun sarja ja numero

VTT Technology 305

Nimeke	**Asuntokohtainen lämpömäärän mittaus Suomessa**
Tekijä(t)	Terttu Vainio, Miimu Airaksinen & Teemu Vesanen
Tiivistelmä	Kulutukseen perustuva lämmityskustannusten jakaminen monen käyttäjän vanhoissa ja uusissa rakennuksissa on kirjattu joulukuussa 2012 voimaan tulleeseen EU:n energia-tehokkuusdirektiiviin. Direktiivin perusteluissa oletetaan, että energiankäyttöön perustuva laskutus ohjaisi asukkaiden ja tilojen käyttäjien energiankäyttötottumuksia ja saisi aikaan energiansäästöjä. Suomessa on niukasti tarjolla kokemuksia ja kustannustietoja vaaditusta kulutukseen perustuvasta menettelystä, koska lämpöenergian kustannukset jaetaan asuntokunnille tyypillisesti huoneistoalojen suhteessa. Kirjallisuustutkimuksen perusteella näytöt saavutettavissa olevasta energiansäästöstä perustuvat siihen, että asukkaat vähentäisivät ikkunatuuletusta lämmityskauden aikana. Useasta syystä Suomessa ei ole samanlaista tuuletuskulttuuria. 1960-luvun loppupuoliskolta lähtien suomalaiset usean asunnon asuinrakennukset on varustettu koneellisella poistolla. Lisäksi 1990-luvulta lähtien ilmanvaihtoon on asennettu lämmöntalteenotto. Suomessa ei myöskään ole samanlaisia, helposti aukeavia isoja ikkunoita, vaan pienemmät tuuletusikkunat tai -luukut. Koneellisen sisään-ulos-ilmanvaihdon takia merkittävä osa lämmityksestä jaetaan tiloihin ilman, ei vesipattereiden, välityksellä. Nämä seikat huomioon ottaen lämmityskustannusten jako asuntokohtaisen lämmityksen kiertoveden luovuttaman energian mittaamisen perusteella ainoastaan nostaisi asumiskustannuksia. Energiansäästö jäisi kyseenalaiseksi, koska mittauslaitteet itsessään eivät säästä energiaa vaan niiden kautta saatavalla informaatiolla pyritään vaikuttamaan asukkaiden käyttäytymiseen. Asuntokohtaisen lämpömäärän mittaamisen sijaan Suomi ehdottaa vaihtoehtoista menettelyä, jossa vaadittu säästö saataisiin aikaan lämmityksen ja ilmanvaihdon edistyneellä ohjaamisella.
ISBN, ISSN, URN	ISBN 978-951-38-8563-2 (URL: http://www.vtt.fi/julkaisut) ISSN-L 2242-1211 ISSN 2242-122X (Verkkojulkaisu) http://urn.fi/URN:ISBN:978-951-38-8563-2
Julkaisuaika	Elokuu 2017
Kieli	Englanti, suomenkielinen tiivistelmä
Sivumäärä	27 s.
Projektin nimi	
Rahoittajat	Työ- ja elinkeinoministeriö
Avainsanat	Asuntokohtainen lämpömäärän mittaaminen, lämmityskustannusten jakaminen
Julkaisija	Teknologian tutkimuskeskus VTT Oy PL 1000, 02044 VTT, puh. 020 722 111

Space heating measurement in apartment buildings

ISBN 978-951-38-8563-2 (URL: http://www.vttresearch.com/impact/publications)
ISSN-L 2242-1211
ISSN 2242-122X (Online)
http://urn.fi/URN:ISBN:978-951-38-8563-2