Interreg North-West Europe
HeatNet NWE
European Regional Development Fund

Guide to home and building energy management

Researched by	Checked by	Reviewed by	First Draft	Final Draft
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Deliverable: WP.T3 D1.5 Guide to home and building energy management

Date: October 2019

About HeatNet NWE

This document has been developed as part of the HeatNet NWE project, which is part-funded through the Interreg NWE programme and aims to increase the uptake of 4DHC networks across North-West Europe. As part of this project, the partners are developing the HeatNet Model, which will help the public sector to begin implementing 4DHC networks, and the Transition Roadmaps, which will outline the partners' experience in developing six district heating pilots across North-West Europe. The HeatNet Guide to Financing is also currently being developed and will give a broad overview of the various sources available to finance district heating schemes.

For further information on these reports and on the HeatNet NWE project, please visit www.nweurope.eu/heatnet.

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Introduction

Fourth generation district heating and cooling is an open door to provide low-carbon energy to the buildings or facilities that are part of the network, by using renewable energies as a heat and cool supply. This system is altogether an advance on highly carbonated heating systems using conventional energy sources; but the way the provided energy is used is also an important point in making 4DHC an even more environmental-friendly system.

Energy management consists in implementing direct or indirect solutions in order to decrease the energy consumption of a building. These solutions include both technical solutions, such as improving the insulation of the building or managing the temperature in the network according to the outside temperature, and behaviour change solutions, that is, involving the user in that dynamic.

Apart from the environmental gains that a proper energy management provides, it includes direct economies. The building's user will reduce his energy bill, the network manager will pay for less fuel, have less maintenance costs, for example. However, some of the technical solutions presented below can be costly: for instance, installing a performant substation or a high-volume buffer system. However, the balance might be positive when comparing these investments to the short and long-term economies achieved throughout the lifetime of the buildings and network.

This guide is a tool destined to stakeholders developing 4DHC, either from scratch or in a retrofitting approach, aiming for an energy-efficient network, and to building owners or users who want to make the most of it.

It is meant to provide guidance to local authorities, building managers and building users on the subject of energy management.

This task is part of the *HeatNet Model* work package of the Interreg project *HeatNet NWE* and was led by Cerema.

General information

What is energy management?

As was pointed out above, energy management consists in the reasoned use of energy within the DHC network. Two different concepts can be included there:

- Using appropriate constructive methods and materials, which is often referred to as energy efficiency;
- Regulating and efficiently using the provided energy, commonly called energy management.

Both concepts are close, but energy efficiency consists more in technical solutions, while energy management consists more in organisational solutions.

For instance, from the **network manager's** point of view, energy management refers to adapting the heat and cool production to the actual heat demand, while cutting down the losses. The possible solutions are forecasting the demand, using buffer systems to shave demand peaks, and decreasing the losses in the network.

From the **building manager's** point of view, energy management consists in choosing the most adapted solution for the substations during the conception phase, and implementing an Energy Management System (in the case of a business building or facility) during the utilisation phase, which includes raising awareness and motivation.

Lastly, for the **building user**, energy management consists in using and regulating the heating and cooling devices according to the occupation of the building.

Current situation and stakes in the European Union – Overview

Economic context

Due to the approaching scarcity of fossil fuels, an increase in energy prices and a threat of energy shortage is part of the future of energy worldwide. The British Standard Institution (BSI) predicts that energy costs will increase by 25% in the next ten years.

This observation is felt in households; in a report addressed to the European Parliament, entitled *Energy prices and costs in Europe*, the European Commission notes that although household electricity and gas consumption declined (respectively by 1% and 15% between 2008 and 2011), **household energy costs** have increased [1].

The decrease in gas and electricity consumption observed is due to building refurbishment, and deployment of buildings that are more efficient, as well as heating appliances. However, this rate of refurbishment and replacement is too low to balance the increase of energy prices (see Figure 1 and Figure 2 below).

From this statement, BSI notes that energy management ensures cost savings and improves energy security. It is also important since energy efficiency and energy management are registered in the European law (see Energy Performance of Buildings Directive[1] and Energy Efficiency Directive[2]).

[1] Energy Performance of Buildings Directive (2018/844), https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2018.156.01.0075.01.ENG

[2] Energy Efficiency Directive (2018/2002), https://eur-lex.europa.eu/legal-content/en/TXT/?uri=celex%3A32012L0027

In this constrained context, the response to energy costs increase holds in using renewable energy sources and optimizing it as much as possible. District heating and Cooling, and even more fourth generation DHC holds a great potential to cut expenses for end-users.

According to the European Investment Bank, energy efficiency and energy management can save European consumers around 78 billion EUR per year, considering all economic sectors. The beneficiaries of these savings are all energy consumers (vulnerable households, professionals and large businesses). As an order of magnitude, the French Energy and Environment Agency (ADEME), states that reducing the heating temperature by 1°C allows saving 7% on the final energy bill [2].

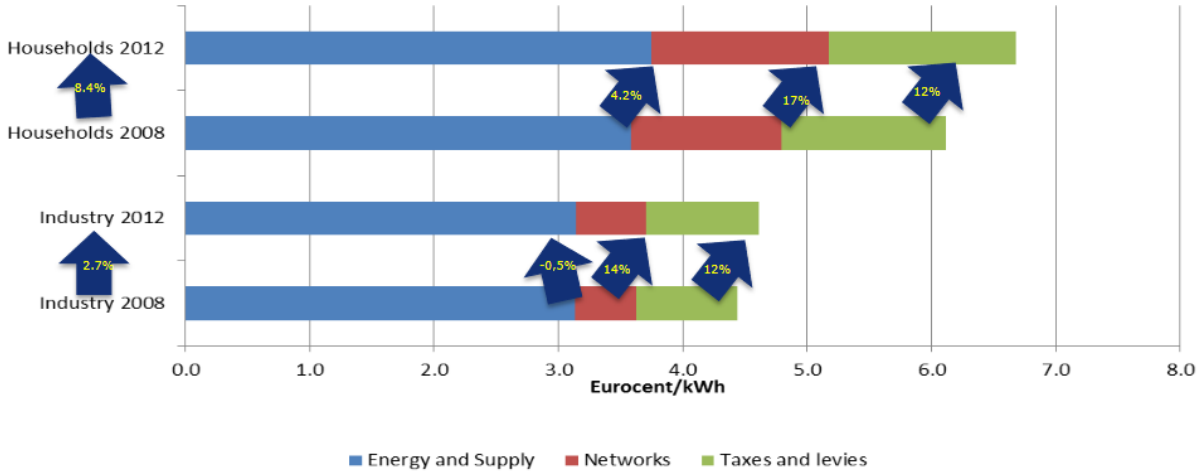


Figure 1: Gas prices evolution between 2008 and 20122. Source: Eurostat (includes taxes for households, excludes VAT and other recoverable taxes for industry)

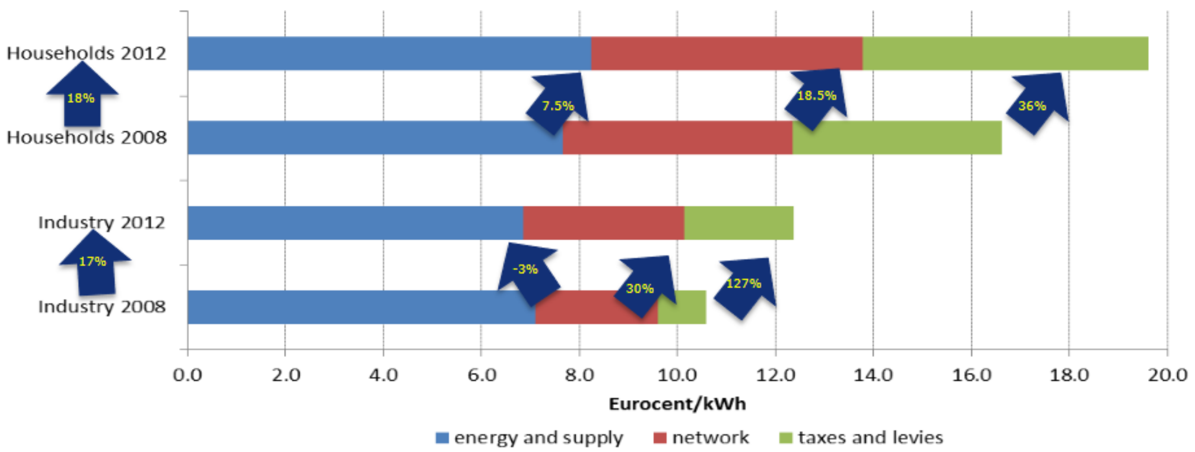


Figure 2: Electricity prices evolution between 2008 and 2012. Source: Eurostat (includes taxes for households, excludes VAT and other recoverable taxes for industry)

Political context

With the intention of fulfilling the European Union's commitment to the Paris agreement, the European parliament and the European Union Council drafted the **Energy Efficiency Directive** (2012/27, amendment 2018/2002). This directive sets that energy efficiency should be considered as an engine for the European economy, and by that, that it should be a priority concern regarding the investments on the energy infrastructure (considering the whole chain, from production to consumption).

Now focusing on the case of District Heating and Cooling and buildings, the directive influenced especially the use of Energy Performance Contracting (EPC), making it easier and less blurry; and the implementation of financing tools to promote energy efficiency. As of today, the countries taking part in the HeatNet NWE project have all implemented such financial incentives, directed towards different sectors (public buildings, social lodgings, private and individual housing, co-ownership housings, and business buildings). These financial incentives, presented in the Table 1 below, are often consisting of soft loans, zero interest loans and tax credits. Table 1 is a non-exhaustive and indicative list of the public financing instruments currently in force in the countries participating in the HeatNet project.

Country	Financial incentive
Belgium	**Wallonia region:** Subsidy scheme for households supporting energy saving measures and housing refurbishment [3]: a scheme dedicated to households, granting them a grant for insulation and heating devices works. UREBA subsidies (publics buildings renovation) [4]: the scheme grants support to public organisations undertaking energy performance works (e.g. renewable energy systems, insulation, lighting)
	Brussels region: Green loan scheme [5]: a zero interest loan dedicated to private housing (owners and tenants), and allows them to undertake energy efficiency measures with a loan of an upper limit of €20.000 with zero interest. Subsidy scheme for energy efficiency measures [6]: dedicated to individuals, businesses and collective housing, the scheme covers energy efficiency investments, of which: audits, insulation and ventilation, heating devices, heating controls, renewable energies.
	Flanders region [7]**:** Property tax reduction for drastic energetic renovation (concerning only insulation). Tax reduction from 50 to 100% depending on the case. Reduction of the registration fees if one buys a house and intends to refurbish it efficiently. The works included are boilers, insulation, ventilation and renewable energy sources.
France	'Eco prêt à taux zéro' [8]: zero interest loan, concerning insulation works, or space heating or domestic hot water devices replacement. There is no requirement for income. Tax credit for energetic transition [9], which allows deducting 30% of the eligible spending from the tax income. Amongst the equipment that can be installed: high efficiency boilers, insulation, heat pumps, and heating control devices (non-exhaustive). Connection to a highly-effective district heating, powered by more than 50% renewable and recovery energy is also eligible to tax credit.
Ireland	The Sustainable Energy Authority of Ireland (SEAI) implemented the Home Energy Grants [10]. This device helps households who initiate the installation of heat pumps, solar water heating, and insulation. The Home Energy Grants also offers a grant for homeowners wishing to install heating controls in their homes. This grant represents €700. For companies and public sector bodies, the SEAI offers Project Assistance Grants [11] in order to build good procurement practices and achieve energy savings. The grant concerns feasibility studies, energy audits and business cases.

Netherlands	The EIA (Energie-investeringsaftrek) [12]is a tax reduction plan for investments in energy saving equipment and sustainable energy; it is dedicated to companies, and allows them to deduct 41.5% of the investments from their taxable profit. Government campaign 'Save Energy Now' [13], aims to encourage people to make their homes more energy efficient. Grants and low-interest loans are available under some eligibility criteria for insulations improvements, installation of heat pumps, solar thermal, and solar panels. The Green Fund Scheme is a tax incentive instrument, in which private investors lend their money to banks at a low interest rate, but compensated by a tax credit. Further, banks offer cheaper loans to environmental sound projects.
United Kingdom	Energy Company Obligation (ECO) [14]: device in which medium and larger energy companies fund the installation of energy efficiency measures in households. Each obligated company has a target based on its share of the domestic energy market. The works concerned in this device are for example loft or wall insulation, and other heating measures. The eligibility criterion is based on income requirements. For social housing, it is based on the Energy Performance Certificate (E, F, and G).

Table 1: Existing financial incentives in participating countries

While these economic instruments are numerous, there still exist some barriers to spreading them even more. The report of the Concerted Action Energy Efficiency Directive entitled Funds and financing for energy efficiency, highlighted that both recipients and financers were facing difficulties to using these tools. Recipients accentuate the lack of awareness and knowledge of energy efficiency and of the economic instruments, the understanding of these instruments and of their application processes, and the long payback period (around 20 years). On the other hand, financers give prominence to the small size of the projects, the lack of standardisation, and the return on investments that is less profitable than other investments.

The content of Table 1 suggests that while there are many economic instruments directed toward energy efficiency (that is, constructive methods), energy management as an improvement of energy use and behavioural change is rarely presented (except the Home Energy Grants, Ireland).

However, energy management holds a lot of potential to reduce energy consumption in Europe. For example, the Cube 2020 challenge (organised in France and Belgium), has allowed building managers to reduce their heating by up to 20% over a whole year without any major investment. Thus, energy management is a link in the chain leading to a better energy future, by helping to integrate more renewable energy sources, fight fuel poverty and increase the fuel safety of European countries.

Legislative context

- Energy metering:

The Energy Efficiency Directive (2012/27 and amendment 2018/2002) sets that buildings connected to a district heating or cooling network must be equipped with an **energy meter**, either at the substation, or at the delivery point. For housing buildings, every unit (*i.e.* each housing) should be connected to an energy meter, allowing the end-users to access their consumption data.

All member states have transcripted this Directive in their texts of law by 2014, and set objectives of energy savings and obligations on energy efficiency. The achievements of these objectives are available in the progress reports every member state publishes.

An accurate energy metering allows accessing both historical and real time data on energy consumption (electricity, gas and water for example).

Also, if the pricing structure allows it, it is possible to manage the energy consumption according to the peak and off peak tariff. That sort of pricing structure is not available for all energy providers; but it is quite current for the electricity market.

For example, in the United Kingdom, most households have a single set tariff structure. Only households that have an Economy 7 pricing structure, with a peak and off-peak pricing structure can benefit from such management.

On the contrary, in Aberdeen, the City Council and Aberdeen Heat & Power chose to set a fixed charge per month for the heating consumption in its multi-storey properties, with no metering devices in such properties. This follows the principle of alleviating the fuel poverty in the city. On the other hand, newer properties, which are more performant, are provided with individual metering devices.

- ISO 50 001: Energy Management Systems (EnMS):

For businesses and facilities, there exist an international norm, **ISO 50 001**, that sets a pathway to implementing an EnMS. This norm is not compulsory, but is applicable to both energy-intensive facilities (foundry industries, agri-food for instance), and business or buildings (for instance, social property owners). This ISO certification is often in the continuity of the norms ISO 9 001 (Quality Management Systems) and ISO 14 001 (Environmental Management Systems).

In order to encourage businesses to undertake the implementation of an EnMS, the French association ATEE (technical association for energy and environment) launched an incentive device entitled Pro-SMEn[3]. Started in 2016, about 130 businesses have acquired it.

- Energy Performance Contracting (EPC):

The European Commission defined **Energy Performance Contracting** as a mechanism allowing organizing financing for energy efficiency. The contract states that an ESCO provides services such as finances and guaranteed energy savings; the ESCO remuneration will depend on the achievement of said guaranteed savings. The ESCO will handle the project from beginning to end, and provide a full building retrofit (replacement of boilers, cooling systems, insulation), which can include temperature automation controls, and energy data management.

The form of the contract may vary between all member states, and solutions to finance the EPC as well. It is possible that the whole EPC be financed by the owner, or by the ESCO; but some complementary financing is possible, through third-party financing (bank, funds, other entity), and through grants, loans and financial incentives provided by governments.

For example, the Sustainable Energy Authority of Ireland ([11]) provides companies project assistance grants regarding energy savings; this grant is upgraded if an Energy Performance Contracting is used, up to €37.500. In France, the energy and environment agency provides a subsidy of at most 50 k€ on the project management services, provided the required specifications be used ([15]).

[3] Visit http://atee.fr/c2e/pro-smen-pour-aider-les-entreprises-et-collectivites-mettre-en-place-la-norme-iso-50001

Social stakes
The economic context of energy markets tends to affect first **vulnerable households**: energy insecurity, expensive energy supply bills due to the poor quality of the heating equipment and the use of fossil fuels. This situation is a factor of social exclusion and causes a decrease in purchasing power.

Despite the pros for energy management and energy efficiency in general, and given that energy management approaches require assessing and changing the user's behaviours, it might generate **resistance to change**. The contributions of an adequate communication strategy allow creating awareness and motivation for the users to take part in the approach, and using this motivation to the fullest of its potential.

This report describes later on the ins and outs of the social and communication levies. Refer to the third part: *Energy management from the building manager's point of view*, subpart *Raising awareness and motivation*.

Energy management from the network manager's point of view

Demand forecasting

Since DHC networks are **demand-driven**, the ability to forecast the heating or cooling load is an essential step to increasing the energy efficiency of the overall system. In addition to that, given the time delay in heat delivery, the possibility to anticipate a peak demand (for example in the morning) represents an additional energy management advantage.

Heat or cold demand in a DHC comes from two different demands: space heating or cooling and Domestic Hot Water (DHW). The first, space heating, is weather dependant; the second, DHW, depends on social behaviour. The addition of both curves is a stochastic system, which forecasting requires complex mathematical models.

Researchers through time have developed different approaches in order to tackle demand forecasting. Such approaches range from simple statistical models to more complex, machine learning models.

These tools often also comprise with a control system that handles the arbitration of the different production systems, thermal energy storages, energy prices and flexibility with the electricity grid.

Advanced demand forecasting requires the installation of connected metering devices on all buildings part of the network. The data collected by these devices will later form historical data for each building, thus making the demand-forecasting model more accurate.

- STORM project: Self-organising Thermal Operational Resource Management

The STORM project, funded under the European Union H2020 program[4], aims at improving the energy efficiency of District Heating and Cooling networks using waste heat, renewable energy sources and storage systems. Pilot partners are Mijnwater BV in Heerlen (Netherlands) and Växjö Energi in Rottne (Sweden).

The research launched by the project partners consists in developing an innovative controller for District Heating and Cooling networks. This controller is able to balance supply and demand for a cluster of producers and

[4] Visit https://cordis.europa.eu/project/rcn/194614/factsheet/en

consumers, and integrating multiple renewable energy sources, waste heat and storage systems, and including three control strategies:

- Peak shaving: reducing the use of fossil back-up devices;
- Market interaction: the controller deploys devices connected to the electric grid (heat pumps or CHP) at interesting power prices;
- Cell balancing: optimizing the heat and cold supply and demand for a cluster of buildings.

The **controller** is made of three different modules:

- Energy forecaster: forecasts the energy consumption of the network for the next 24 hours;
- Operational Optimisation planner: associates the forecast and the chosen strategies and produces an optimal cluster consumption;
- Demand-side management tracker: sends control signals to achieve this consumption profile.

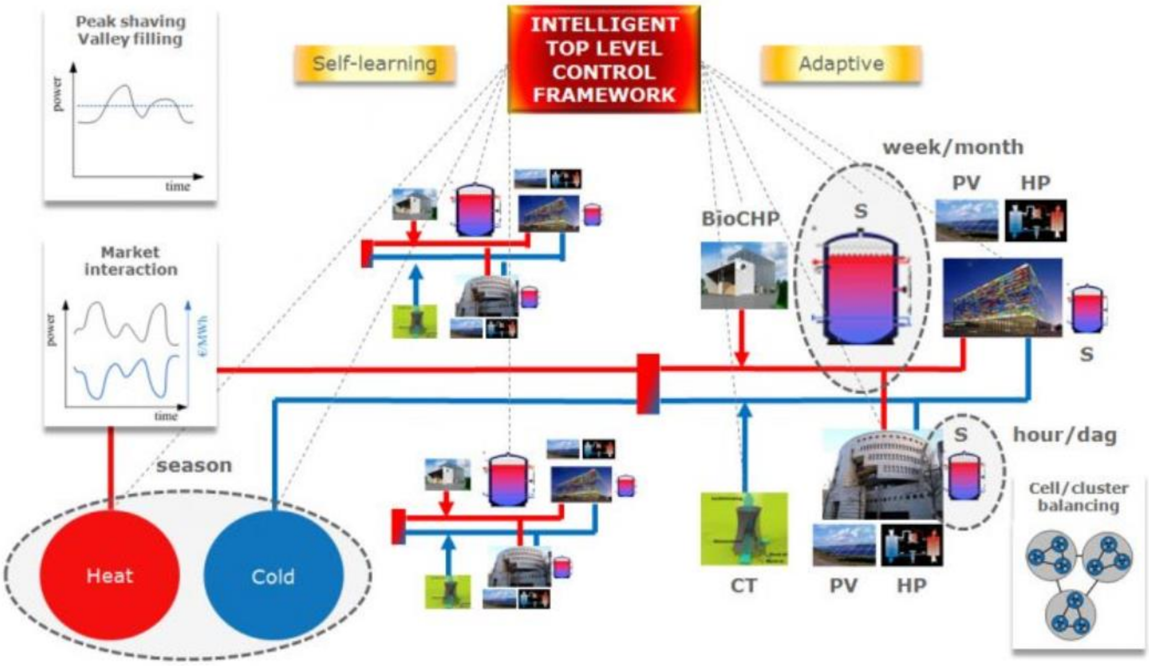


Figure 3: Conceptual overview of the STORM controller, based on the Heerlen demo site (Source: STORM project website)

Heat and cold sales pricing: the example of the Paris Saclay 4DHC

The public planning institution of Paris Saclay[5] implemented a District Heating and Cooling project for its urban campus, which is part of the Grand Paris project. The heat and cold network is resolutely a **4th generation network**. The principal heat source is the Albien aquifer, which provides water at an average temperature of 31°C. This water circulates in the moderate temperature loop. Some gas boilers complete the geothermal heat pumps. In the future, waste heat from data centres and industrial processes will be recovered.

[5] Visit https://www.epaps.fr/projets/tous-les-projets/reseau-de-chaleur-et-de-froid/

The buildings that are part of the network, organised as clusters, get heat through the islet substation, consisting of heat exchangers with the moderate temperature loop, and thermos-fridge pumps that can simultaneously produce heat and cold (see Figure 4).

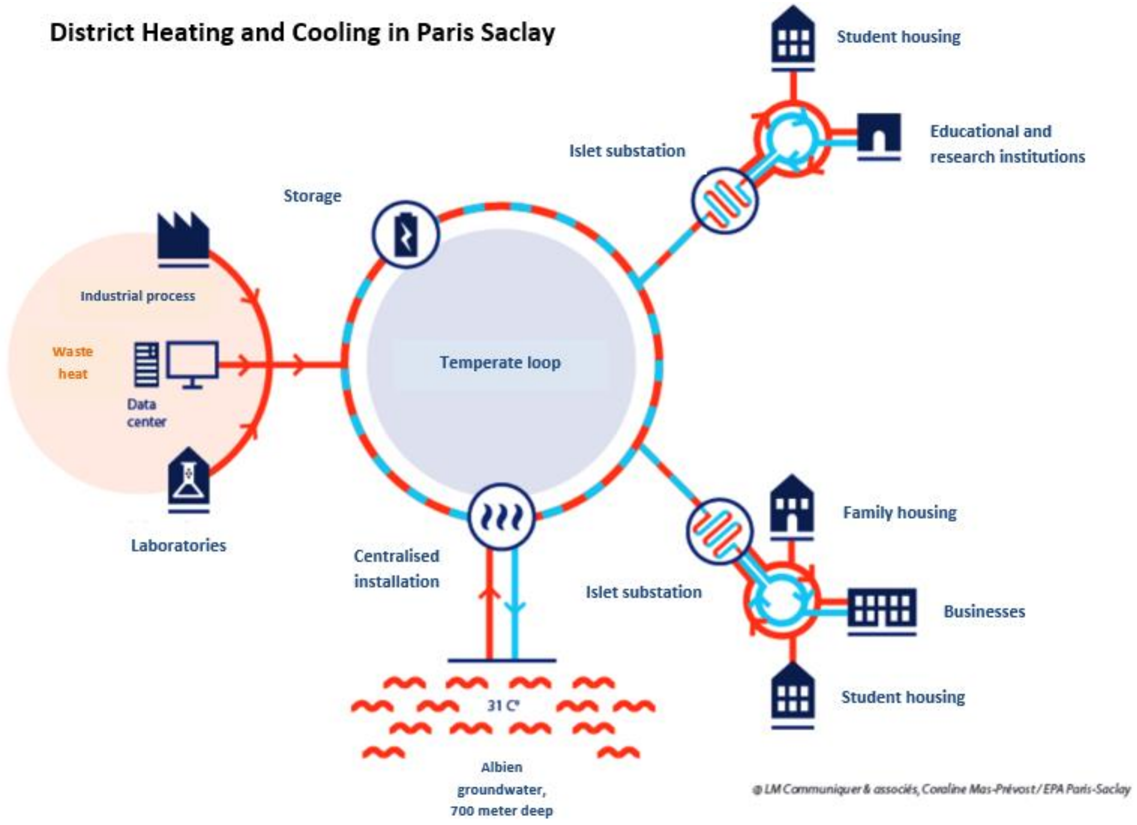


Figure 4: Scheme of the Paris Saclay 4DHC (Translated from EPAPS)

With the diversity of connected buildings, the pricing applied by the DBOM Company is **seasonal and incentive**. Firstly, since some of the buildings have a prosumer profile, the pricing privileges the use of energy at the scale of the building. In addition, to incite energy management in the buildings, a bonus is applied on th e pricing if the temperature difference is great, and if the building installed its own heat storage. Finally, the pricing of cold, heat and heat for domestic hot water is seasonal; its value differs depending on the time of the year (winter, summer and mid-season). For example, the price of cold is set at zero during winter time, because it optimizes the overall system. Buildings that benefit from this are the data centre and laboratories.

Seasonality in the pricing of heat and cold is beneficial for the network users, allowing them to reduce their bills and taking part in the good and performant running of the network. Another possibility is to implement peak time and off-peak time tariffs, which can smooth the demand curve on a daily or even weekly basis. This, on the other hand, requires that building managers be aware of the running of the network and the flexibility the buildings offer (especially regarding its heating time and inertia).

Energy efficiency measures

Low temperature regime on the network

4DHC networks usually have low temperature regimes, due to the fact that the buildings linked to the network have low heating or cooling needs and low temperature heating devices; and also because a number of low temperature energy sources can be used (solar thermal and heat pumps for example).

Consequently, it is possible to lower the departure temperature for heating to **50 – 60 °C**. This is advantageous because it is then possible to reduce the diameter of the pipes, and so to reduce the heat losses in the network, and the costs related to the pipes themselves and the digging. Likewise, this allows reducing the investments, operation and maintenance costs (both for the pipes and for the auxiliary equipment).

This low temperature regime is compatible with Domestic Hot Water production; the adapted preparation methods are described in Deliverable 1.2 *Guide to integrating 4DHC with energy efficiency retrofitting*. They are Instantaneous Heat Exchange Units and District Heating Storage Units.

In the aim to reduce even more the temperature of the networks, research is being conducted to pave the way towards ultra-low temperature networks.

- RELaTED project: Renewable Low Temperature District

This project, funded under the European Union's Horizon 2020 research and innovation programme[6], aims at developing a decentralized ultra-low temperature network solution. The four network pilots of the project – Belgrade (Serbia), Vinge (Denmark), Iurreta (Spain), and Tartu (Estonia) – are looking to convert the district heating temperature regimes from high or low temperature to ultra-low temperature, which is **45/30°C.**

In the project, each building connected to the network has a prosumer profile, since a heat pump (District Heating integrated Renewable Heat Pump, DHRHP) and/or a solar thermal system (Building Integrated Low Temperature Solar Thermal, BILTST) is implemented.

This ultra-low temperature regime is consistent with Domestic Hot Water preparation. Indeed, if the substation's design does not include any storage, and a small volume between the exchanger and the water taps, the legionella development risk is minimised. If the project concerns a very large building, this is still possible, if local heat exchangers are installed to minimize the volume.

Nowadays, connected systems allow to monitor the temperature levels at each substation of a district heating network. This kind of synoptic graph allows to monitor the performance of the substations of the network, especially regarding the return temperature of the water running in the network.

Figure 5 gives an example of such monitoring synoptic graphs. The figure displays the substation of an ensemble of individual housing in the city of Helsingborg, in Sweden. The connection is made via an indirect two-stage connection; so that the domestic hot water is preheated by the surface heating return flow. A set of temperature meters and valves allows to control and monitor the functioning of the substation.

[6] Visit http://www.relatedproject.eu/

For example, if a high return temperature is observed, it can be assessed that there might be a technical problem on this particular substation; this may lead to conducting preventive maintenance works on the equipment.

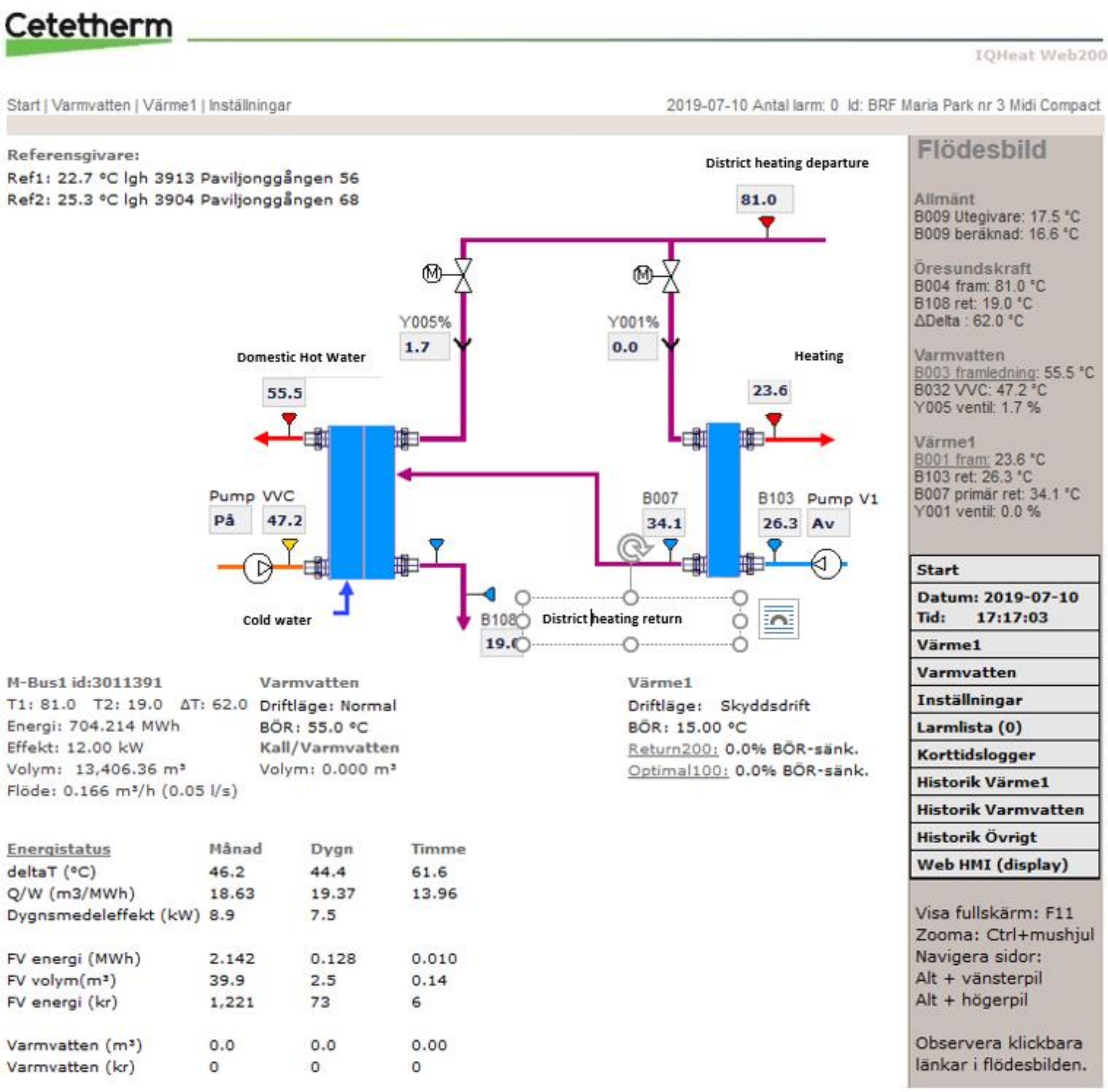


Figure 5: Screenshot of a control synoptic of a heat network in Sweden (source: Cetetherm)[7]

Pipe design and insulation

Through time, improving the energy efficiency of District Heating and Cooling networks went through reducing the heat losses in the district pipes as much as possible. The first generation of District Heating and Cooling networks was made of concrete ducts, and the use of steam water as an energy carrier resulted in very high heat losses. The third generation of DHC used pre-insulated pipes and insulated substations; associated with using water with a temperature below a 100°C allowed reducing these heat losses.

Further improvements for 4DHC may be about the choice of the pipe systems. The traditional pipe system is made of two single pipes, one for the supply, and the other for the return. Newer systems consist in twin pipes,

[7] This synoptic is accessible via : http://demo1.iqheat.com/pub/flowchart.asp

in which supply and return pipes are placed in the same insulation casing. Different designs for the twin pipes were developed: circular or egg-shaped casing, horizontal twin pipes or vertical twin pipes (see Figure 6).

For service pipes (which is the pipe linking the main grid to a building), another design was created, the triple pipe (see Figure 7). In the triple pipe design, there are two forward (or supply) pipes, and one return pipe. If the heat demand is normal, the smallest forward pipe supplies heat. In the case of a large heat demand (DHW for example), the second forward pipe supplies the heat.

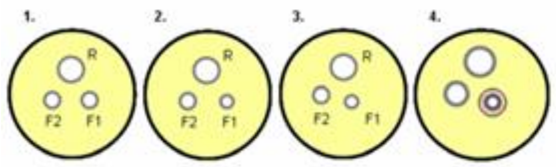


Figure 6: Triple pipe designs. F1: first priority supply pipe; F2: second priority supply pipe; R: return pipe. Design 4 has an increased insulation on F1 (source: Danfoss)

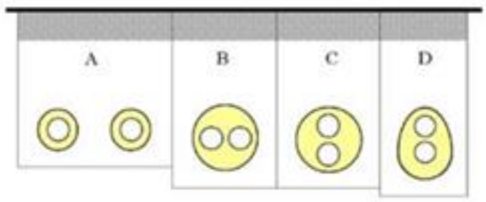


Figure 7: Single pipe design (A) and twin pipe designs: horizontal twin pipes (B), vertical twin pipes (C) and egg-shaped twin pipes (D)(source: Danfoss)

The heat losses in the different designs depend on many different variables: operational data (supply, return, soil temperature), heat conductivity of the soil and the insulating material, and geometry of the pipes.

Concerning the insulation of the district ducts, nowadays most of the installed ducts are pre-fabricated and pre-insulated pipes. The insulation material is usually polyurethane foam, which has very good thermal properties, with a thermal conductivity equal to 0.023 W/ (m.K).

Buffer systems

For small to large size renewable heating systems, such as biomass boilers, heat pumps and solar thermal, the installation of a buffer system is highly recommended. These buffer systems, ranging from 1000 m3 to larger volumes depending on the nominal power of the system, allow storing energy in the form of hot water.

For a wood boiler, which is more efficient under its nominal power, and that cannot easily modulate its power (contrary to the network load) the buffer system is important. With the buffer, the boiler will work under its nominal power for a large amount of time, excess energy being stored in the tank, which will lead to the following improvements:

- Increase of the life time;
- Decrease of the maintenance costs;
- Increase of the average efficiency;
- Increase of the biomass-covering rate (if another source of energy is used).

Buffer systems of this size are also commonly used to store thermal energy produced by solar thermal plants. Since the energy production profile of such plants is linked with the solar irradiation, and so is disconnected with the actual heat load of residential buildings, the implementation of buffer systems allows to integrate solar energy to DHC networks.

A magnitude order of the sizing of these buffer tanks is 1 to 2 cubic meters every 100 kW of heat power (indicative value). These systems cost around 1000 €/m3 (tax-free).

Such buffer systems are also interesting for district cooling networks. During the night, when the cooling demand is at its lowest, the refrigerating machines keep on working, and so the cooling production is stored. The buffer systems usually consist of tanks of water or ice.

For example, the district cooling network of Paris, operated by Climespace (a subsidiary company of Engie), stores the cool production with both icy water and ice. The storage facility at the Tour Maubourg contains 13 ponds of icy water at 3 °C, adding up to 12.000 m^3 and 90 MWh. The storage facility near the Opéra contains a pond of ice adding up to 320 m^3 and 20 MWh.

Figure 8: The cool production and storage facility of the Opéra, district cooling of Paris (Source: Climespace)

High volume buffer systems
High volume buffer systems should be considered if the network includes waste heat recovery or a large amount of heat from renewable sources (such as high scale solar thermal). As will be shown with the two examples below, this approach to store heat can have a daily time scale, or seasonal time scale.

Daily thermal energy storage is implemented using tanks containing high volumes of water. These tanks can be partly buried in the ground, thus allowing reducing the amount of insulation that is necessary; but it is also possible to install the tank on the ground. It is also possible to use an existing infrastructure such as ancient mines.

Seasonal thermal energy storage is possible using different technologies: tank thermal energy storage (TTES), pit thermal energy storage (PTES), borehole storage (BTES) and aquifer storage (ATES). The technical parameters of these technologies will not be detailed here. However, it should be noted that the decision for a certain type of storage is linked to local conditions (for example hydrogeological situation).

- <u>Example 1: heat storage in Borås, Sweden</u>

The DHC network in Borås provides heat to about 30,000 households, with 300 km of pipes running in the city. The energy sources are wood pellets, with two boilers of 60 MW each, and household waste, with 2 waste to energy boilers of 20 MW each. Some supplementary fossil fuels are also used. The district heating network operator, Borås Energi och Miljö, invested 10.5 million euros in a high volume thermal energy storage, in order to reduce even more the share of fossil fuels, and ensure a more stable and flexible heating production.

This thermal energy storage consists in an over-insulated steel tank of 37,000 cubic meters, which can contain up to 1,900 MWh. The total autonomy of the storage is 3 days; however in usual conditions the tank charges and discharges with an hourly time scale.

The thermal energy storage system comes with a tool to drive the energy storage and energy production in relation with the electricity process, heating load on the grid, fossil fuel costs and storage capacity.

Figure 9: Borås thermal energy storage (source: Veolia)

- <u>Example 2: heat storage in Friedrichshafen, Germany</u>

The thermal energy storage within the district heating network of Friedrichshafen is a 12,000 cubic meters buried tank, made of isolated and reinforced concrete. The tank stores heat produced by 4,300 m² of solar panels and an additional condensing gas boilers. The network provides heat to 390 apartments and a day-care. The solar input represents about 26 % of the total heat demand.

Given that the storage is linked with solar panels, it has a seasonal time scale: the tank charges during the summer, and discharges during the winter.

Energy management from the building manager's point of view

Substation efficiency

Since the global performance of a DHC does not only depend on the collective amenities, the owner of a building connected to a DHC or intending to connect a future building, should be able to choose the most energy efficient substation technologies, in agreement with the district heating and cooling operator.

In order to take part into the global performance of the network, the technological choices should be made according to different points:

- Does the considered solution allow a low return temperature, to ensure the global performance of the network?
- Is the solution cost-effective (i.e. do the investments costs allow avoiding indirect investments, maintenance costs, and energetic costs)?
- Is metering the energy consumption per lodging possible?

Different technologies are now available on the market, each displaying different advantages and disadvantages. The next paragraph suggests some definitions on the different substation technologies:

- Direct vs indirect connection: this characterizes whether the surface heating network on the customer building is connected to the network via a heat exchanger or not (in any case, domestic hot water circuit is always indirectly connected):
    - Indirect connections include at least one heat exchanger in the substation, whose role is to transfer calories from the district network circuit to the building water circuit.
    - Direct connections, on the other hand, do not comprise a heat exchanger. This causes issues regarding the pressure control: an excessively high pressure may be source of leakages and damages on the customer side.
- Indirect domestic hot water preparation[8]:
    - Instantaneous Heat Exchange Units (IHEU):
    - District Heating Storage Units (DHSU):
- One-stage and two-stage connection of DHW: two-stage DHW connection consists in a pre-heating performed by the return flow from the surface heating, and an after-heating performed by the supply flow from the DHN.
    - Two-stage connection allows decreasing the return temperature of the network, which, as was mentioned above, is a key point for the DHN efficiency. This solution is recommended[9] for housing buildings, and even more if the return temperature is high.
    - One-stage connection, or parallel connection, is recommended for other buildings.

These different solutions allow thinking of a large diversity of substation connections, each having their own advantages and disadvantages.

Figure 10: Demonstration copy of a substation, District Heating of Roubaix, France

Whatever the chosen technology, carrying out preventive maintenance on a district heating network and the substations may recognize developing malfunctions, and allow correcting those.

[8] These devices are described in Deliverable 1.2 of the HeatNet Model work package.

[9] See « Guidelines for District Heating substations » Euroheat and Power, https://www.euroheat.org/wp-content/uploads/2008/04/Euroheat-Power-Guidelines-District-Heating-Substations-2008.pdf

The inspector should be checking for leaks, noise behaviours, and check the absence of corrosion and the good condition of insulation. This concerns the pipes, the filling pump and circulation pump, the regulation, control, safety and non-return valves, the heat exchangers, storage tanks if there is one, the dirt traps and the metering devices.

In general, the substation represents where the responsibility of the network operator ends and where the building manager's starts; this is also called the primary network (district heating) and secondary network (in the building). Depending on the contracts, the boundary between the primary and secondary network can be set before or after the heat exchanger. Finally, this defines which stakeholder must handle the maintenance of which equipment.

Regarding the building manager, the maintenance of the equipment is often entrusted to a specialised company. In order to improve the efficiency of the substation, it is possible to include the maintenance of the substation in an Energy Performance Contract (EPC).

Energy efficiency in the building

Deliverable 1.2 of the HeatNet Model, *Guide to integrating 4DHC with energy efficiency retrofitting* describes the appropriate heater technologies associated with district heating. The water-based systems described are the following: radiators, large surface emitters and forced air heating.

Despite the energy supply of the systems by Low Temperature District Heating (LTDH) water, the global energy efficiency of the building ensures the user's comfort.

Comfort in a building depends on the operating temperature. This temperature is the average of the wall temperature and the ambient temperature. For instance, if we consider a room with an ambient temperature of 20°C:

- If the wall temperature is of 14°C, the operative temperature is 17°C, which is not enough to ensure the thermal comfort of the occupants;
- If the wall temperature is of 18°C, the operative temperature is 19°C, which is usually enough to ensure the thermal comfort (depending on activities, and individual parameters).

Making sure that the wall temperatures (mostly windows) are consistent with this consists in refurbishing or constructing buildings with good thermal characteristics (double and triple glazing).

Likewise, air infiltration and humidity tend to modify the operative temperature. Indeed, the limit values of air humidity are 35 and 60%; any air humidity rate above or below these values bring discomfort. Limiting the air infiltration is possible with insulation and proper implementation of doors and windows; air renewal or an air treatment station control the air humidity.

Regarding domestic hot water, deliverable 1.2 of the WP3 of HeatNet NWE project makes a list of the possible methods that can be used to prepare DHW (this can be found in the 'thermal storage in buildings' part). These methods are:

- Instantaneous heat exchanger units;
- District heating tank unit.

Implementing an Energy Management System (ISO 50 001)

Energy Management Systems, abbreviated EnMS, is a way for businesses and industrials to take control of the energy post in the business. From thinking to acting, the EnMS will allow decision makers to implement an efficient politic line in order to reach the goals that they have set. Let us note that EnMS concerns all types of energy flows, not just heating and cooling.

Let us note that the implementation of an EnMS is a voluntary approach, which can lead to an ISO 50 001 certification (replacing ISO 16 001 certification).

What are the steps to implementing an Energy Management System?
The implementation of the system includes three different steps:

- Analysing the current state in the business/facility;
- Mapping the actions;
- Enforcing these actions.

Step 1: diagnosis of the technical/operational conditions

The energetic diagnosis of the business/facility should include both a technical and operational part.

The technical diagnosis will focus on the installations (computers, machinery, and lighting, heating systems...) and their consumptions. The questions that should be answered are:

- What are the significant uses in the building?
- How performant are the machines and equipment?
- What performance indicators are currently used?
- Do some improvements appear at this stage of the diagnosis?

On the other hand, the operational diagnosis will focus on the organisation of the business. Likewise, we are looking to answer the following questions:

- Are there any procedures, instructions concerning energy uses?
- Are the employees aware of the possible energy savings at work?
- Who is in charge of energy, and what are the responsibilities of every one regarding energy use?
- Are there any existing legal requirements?
- Do some improvements appear at this stage of the diagnosis?

Step 2: planning all the actions

For a business, a very important point is to plan the energetic politic that will be applied. This politic allows to define the motivations of the leaders (reduce functioning costs, improve the brand image), what objectives will be reached, and what means will be put in place.

The hierarchy might consider hiring an Energy Manager, qualified on this subject, who will be given the means (regarding legitimacy and authority, budget, and staff members) to carry out the EnMS.

All the foreseen actions are then listed and described in a complete program, stating which actions are more important, and what is the expected return on investment. All staff member should have access to such a document.

Step 3: enforcing the actions
First, the staff members should be sensitized and trained to the measures that will be put in place. Sensitization concerns mostly daily-life practices, such as turning the lights off, managing the thermostatic radiator valves for example, while training concerns machinery use, or any technical movements. A regular communication is also important to keep the staff going. The energy consumptions should be measured, collected, and analysed, in order to assess the savings made on a period of time. Depending on the case, a certain amount of investments should be made, for instance installing energy-metering equipment, or hiring an energy accountant. During the implementation of the EnMS, the goals are updated, and the precedent reached goals should be communicated on.

Table 2: Steps to implementing an Energy Management System

Examples of Energy Management System implementation

It is possible to find many different examples of implementation of Energy Management Systems, mostly coming from industry (petrochemicals, manufactory). However, the ISO standard can also be applied to office buildings and social housing.

- Sheffield Hallam University (United Kingdom)

The Sheffield Hallam University started the ISO 50 001 approach in 2015 [16]. Since the University already had an operational energy team, applying the certification allowed formalising best practices. With the help of consultants, working on the gap between ISO 16 001 and ISO 50 001, and training their energy team employees to perform internal energy management audits, the university was able to successfully implement the EnMS.

The benefits of the certification are the following: reduction of 11% of carbon emissions due to total energy use of the university, based on 2005 emission levels. The amount of energy savings is up to £10,000 per year.

- LogiRep (France)

In France, the social property owner LogiRep (managing around 80,000 lodgings) started the ISO certification in 2015 [17]. In order to build their approach, the property owner got help from an Assistant Project Manager that handled the audit of the real estate, the choice of consistent monitoring indicators, and support on the sensibilisation actions that would be put in place towards the building managers and tenants.

Following the certification process, LogiRep established an energy team that structured the approach, and followed up on the monitoring indicators. The objectives that were set are:

- Reduction of the Energy Performance Diagnosis from 165 kWhEP/m²/year in 2016 to 150 kWhEP/m²/year in 2020;
- Reduction of the heating consumption of 6% between 2016 and 2020;
- Reduction of the domestic hot water consumption of 6% between 2016 and 2020.

The social property owner acquired financial support from the ATEE for the certification costs, which convinced the manager to take on the approach.

Raising awareness and motivation

Given that implementing an EnMS within a business, or push people into consciously managing the heating load at home, is deeply bound to their ability to change, it requires to raise motivation and awareness.

The steps to implementing the EnMS within a business presented above already detail the communication requirements for the measure. On the other hand, considering tenants in a housing building, the private aspect makes the task all the more complex to implement.

Compared to individual heating systems, the tenants actually have much less control systems to focus on; however, studies on certain populations have shown that some people just do not know about the existence of these systems (timer for the boiler, thermostats for the rooms, TRVs for the radiators…).

The French energy and environment agency gathered data and advice from three different awareness campaigns [18]; the Department for Energy and Climate Change of the United Kingdom [19] has led a trial on the use of heating controls with tenants of social housing in Newcastle. Both these studies highlight three different levers that can ensure or maximize success of such campaigns.

The first of these levers is **cognitive**: access to consumption data and technical knowledge. The consumption data should be easy to grasp, not restrictive to access, and refer to immediate consumption. For this part, smart meters are the best solution to implement. The technical knowledge refers to getting to know the way some equipment work (for example thermostats and thermostatic radiator valves), and what behaviours regarding them is actually energy saving.

The second lever is **material**, which is providing tools such as thermostats. These tools should ask little effort in their daily use.

The last lever is **social**. The studies emphasize that being part of a group is a source of motivation that is even stronger than the prescriptions given by the organizers. The discussions among participants allow exchanging knowledge, and changing some domestic practices. In the case of social housing, a personalised accompaniment, consisting of home visits, diagnosis of the equipment, and adapted counsel regarding each person's situation, was considered by the tenants the best way to provide information compared to explanation sheets or group meetings.

These studies also focused on the motivation levers: what drives people into taking the first step to energy savings? While the environmental benefits are clear to all, it is not the source of these actions. The top motivation driver is actually the feeling to be part of a social group (neighbours, business teams etc.). As was mentioned above, group dynamics enables people to share information and practices, but it is also a great way to initiate and perpetuate energy savings behaviours and dynamics.

Two others motivation levers are comfort improvement and possible money savings that are possible with the approach. Stating that energy management is the solution to cut short discomfort situations (too warm during the night for instance) and giving examples of how much energy can be saved by reducing the temperature, and how much money this actually represents is a tool to motivate people into changing their habits.

Contractual relationships

Within a district heating and cooling scheme, the roles are distributed between:

- The public body, usually at the initiative of the DHC network;
- The network operator, which is often a public service delegate, but can also be the public body in some cases;
- The contract subscribers, social landlords or condominium syndicates;
- The secondary network operator, the whom the efficient operation of the building's internal network has been delegated;
- Finally, the end-users that beneficiate from the service.

Figure 11 describes the links between all these stakeholders; a more thorough description of the contractual relationships is available in the *Business Case to energy companies* of the HeatNet NWE Interreg project.

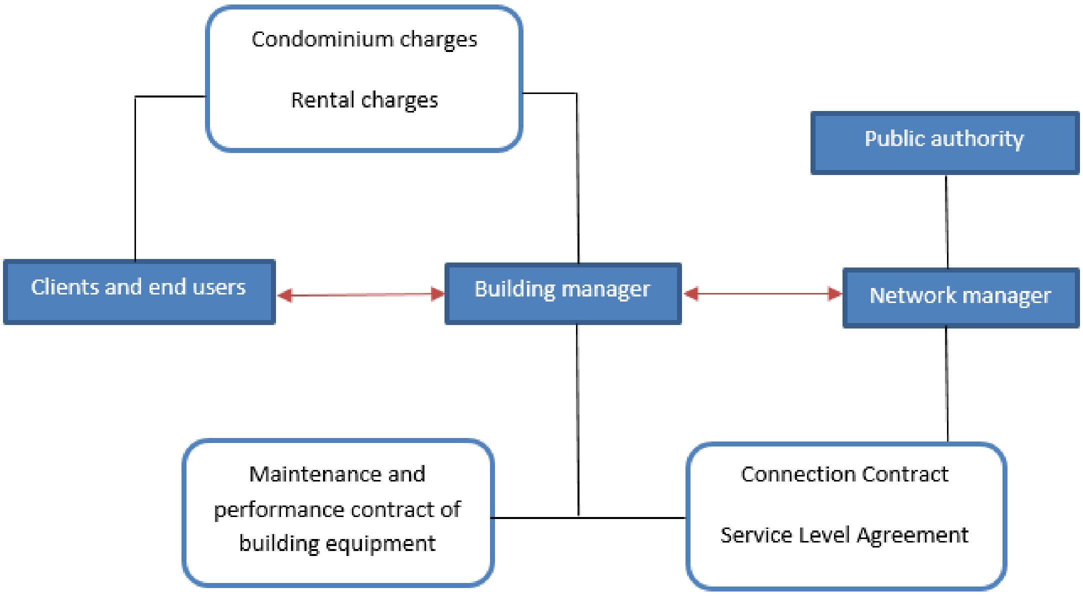


Figure 11: Actors and contracts in DHC networks (example)

To sum up, there are a number of different contracts between all stakeholders; this complicates the global management of the buildings and the efficiency of the communication between all actors. This bears consequences on energy management at the scale of a building, especially when considering the role of the building manager in all energy management procedures (as a leader of the procedure).

To thwart these problems, setting up a subscriber committee, and including the end-users in the operation of the network is a good point. For example, the district heating in Clermont-Ferrand (France) set up a website dedicated to its users, allowing them to track dashboards related to the installation, track their consumption and bills, and to view the requests for any maintenance intervention.

In addition, resort to Energy Performance Contracting (EPC) is a way to make sure that the performance and the efficiency of the substation (and any equipment on the secondary network) is taken into account during its maintenance and operation.

Building instrumentation – Dalkia Energy Saving Centres

The installation of metering devices is called **building instrumentation**. It aims to pursue an energy **accounting**, be it to check the energy consumption at the scale of one lodging, or to exercise a contractual follow-up as part of an operating contract or an Energy Performance Contracting.

Energy metering devices can be implemented at any moment of the lifetime of a building; however, it is cheaper to install them during the construction of the building.

The metering devices are many and diverse: temperature, hygrometry, volumetric, electric energy, thermal energy, sunshine, etc. The data is then concentrated in a central data logger, and finally transmitted.

In Toulouse, France, Dalkia implemented an Energy Saving Centre[10]: a **remote driver** for building and industry energy performance. Using a number of metering devices, and setting alerts, an information system collecting the data allows following up on the evolution of the consumption in real time.

In the contract between Dalkia and the building manager, Dalkia is contractually engaged to attain a **target consumption**; any drift from this level of consumption, observed in the Energy Saving Centre, is analysed and corrected by Dalkia.

Additionally, Dalkia can share this data with the building's users. For example, a housing building will be provided with a collective screen that will display the energy consumption of the overall building, with educational information. This holds the potential to change behaviours and empower the users.

To go even further, at the scale of a district heating and cooling network, in which individual energy metering must be implemented, according to the Energy Efficiency Directive, using instrumentation and smart metering in the connected buildings can be seen as a strong levy for energy management.

Feedback from Cerema: Cube 2020 challenge

Based on energy savings, the Cube 2020 Challenge aims to oppose different tertiary buildings (offices, education buildings, state buildings…) regarding their approach to energy use. The arbitration is made on the amount of energy savings throughout a whole year, compared to the yearly consumption of the last three years.

The challengers are assisted with a database on communication strategies, materials that can be used to improve it (flyers, posters), counsel regarding animation, technical guides and a list of referenced providers.

The Cerema building in Lille started taking part in the challenge in 2018, at the beginning of the heating season. The building is connected to the district heating network owned by the Metropolis of Lille, who delegated its management to Dalkia. Currently, the heat network provides heat to 60.000 housing mostly from coal and wood

[10] Visit : https://www.dalkia.fr/fr/besoins/performance-energetique/pilotage-energ%C3%A9tique

biomass. In the coming year, the network will connect to the waste-to-energy plant located in the city of Halluin, thus allowing to recover the waste heat from the plant.

The Cube 2020 challenge management was entrusted to a dedicated project team. As part of the project, the team made a diagnosis of the building's technical heating installations: substation, regulation, heating devices.

It was observed:

- The aging of the substation and the absence of regulation according to the different wings in the building (oriented North / South), and the absence of insulation around the distribution pipes (see Figure 11);
- The inefficiency of some heating equipment and the inconstancy of the insulation refurbishment;
- A general discomfort of the users (some too warm, others too cold), and the aging of the regulation of the radiators (thermostatic radiator valves).

The actions undertaken in order to improve the comfort of the users and to reduce the energy bill are the following:

- Reducing the water temperature in the secondary network;
- Renew the thermostatic radiator valves for the radiators;
- Implementation of thermometers to study the daily temperatures in the offices, and so to get to know the building better;
- Informing all personnel on thermal comfort, energy savings and the use of regulation devices installed in the offices. These meetings helped to raise questions, misunderstandings and common bad practices from the employees;
- Installation of electric heaters in offices that are particularly cold during winter time;
- Meeting with a technical team from Dalkia (network operator) in order to assess the possible improvements in the substation.

Figure 12: Absence of insulation on the secondary network's pipes

Some difficulties were encountered during the challenge:

- **Relationship with the network manager** and limits of the **responsibilities** of each partners, more particularly regarding the maintenance of the heat exchanger;

- Overall lack of **motivation** from the users, mostly due to the general discomfort and the contrast with the efforts that the users were asked to make for the challenge, and the lack of investments to improve the situation.

Feedback from Habitat du Littoral

Habitat du Littoral is the main social landlord of the city of Boulogne-Sur-Mer. Some of his buildings are connected to the district heating network of the city, managed by Ecoliane.

Habitat du Littoral highlighted that energy management in the form of implementing a set of energy meters at the delivery points should be consistent to a logical path:

Figure 13: Typical real estate in Boulogne-sur-Mer (Source: Ecoliane)

- A first round of **metering** should be launched, as a way to gain knowledge on the building (energy consumption, use, weaknesses regarding insulation, windows and heat emitters as a matter of example);
- With regard to this diagnosis, it is then possible to undertake **renovation works**, that can take the opportunity for national or regional subsidies, since its energy label is low;
- Finally, the **connection to the heat network** is relevant, and be followed by a second round of energy meters to allow a follow-up on the building behaviour.

This is also relevant when considering the energy rating expectations of the different available funding. For example, in Boulogne-Sur-Mer, the DHC network was deployed before the urban renewal scheme was finished, and so the buildings that needed retrofitting improved their energy rating, and so the funding were not available or with a lower quantity.

Energy management from the user's point of view

What means of action for the user?

At the scale of an accommodation, the user focuses on adjusting the global thermostat and/or thermostatic radiator valves, since he has no control on the boiler settings (especially water law).

The means of action, or regulatory bodies, depend on the heating and cooling technologies chosen in the accommodation. Heating technologies that can be associated with district heating are:

- Radiators;
- Large surface emitters: for example, floor heating, wall heating;
- Forced-air heating.

Cooling technologies that can be associated with district cooling are:

- Air conditioning, with a Central Air Treatment device, that allows to control the air temperature, air humidity, and to control the air quality;
- Water-based systems, such as radiators and large surface emitters, in which cold water is running.

The table below summarizes the regulatory bodies associated with these heating and cooling technologies:

Heater / cooling technology	**Radiators**	**Large heat emitters (e.g. floor heating)**	**Forced-air heating and air conditioning**
Regulatory body	Thermostatic radiator valves + thermostat	Thermostat	

Table 3: Heater and cooling technologies and associated regulatory bodies

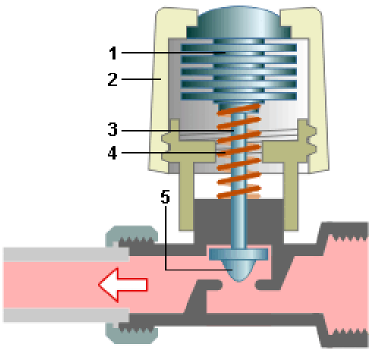
Thermostat
A thermostat usually drives the heating system according to the temperature measured in the room. Should this temperature be below the threshold settled by the user (or above, when considering cooling), the thermostat will 'ask' for heat; on the other hand, when the threshold temperature is reached in the room, the thermostat will stop the heating inflow (or cooling inflow).

Nowadays the best solution is the programmable thermostat, which is more specific. With this device, it is possible to program heating or cooling schedules, according to the usual occupation of the house. Most devices allow programming daily or weekly schedules, including reduced temperature during absence periods. For instance, in a business building, it is possible to program the thermostat according to the working hour range.

Commercial solutions also comprise multi zone thermostats, which allow driving the heating load in each room. This is a perfect solution for houses heated or cooled with surface heaters; instead of setting one comfort temperature, it is possible to set different temperatures for each room, which is called zoning.

With the increase of connected tools, room thermostats are now available with connected option, allowing driving the heating and cooling from afar. This device can prove to be interesting if a tenant has variable working hours.

Thermostatic radiator valves
The thermostatic radiator valve is composed of a temperature sensor, made out of a liquid or gas that expands or contracts according to the room temperature (see Figure 14). The changing volume of the liquid or gas is then affecting the transmission shaft, which will regulate a valve, thus adapting the water inflow in the radiator. If the set point temperature is reached, the liquid or gas will expand, thus closing the regulation valve and stopping the water inflow.



Legend:
1: Temperature sensor
2: Regulation handle
3: Transmission shaft
4: Return spring
5: Regulation valve

Figure 14: Thermostatic radiator valve (source: energie-plus)

- Set point temperature

The user can choose the set point temperature using the handle of the thermostatic radiator valve. Usually, the valve is gradated from 1 to 5, with an additional * symbol. The gradations correspond to the following temperatures:

- gradation 1: 15 to 16°C;
- gradation 2: 16 to 17 °C;
- gradation 3: 19 to 20 °C;
- gradation 4: 21 to 22 °C;
- gradation 5: 23°C;
- * refers to frost free (used for long period of absence).

The temperature setting with mechanical thermostatic radiator valves using liquid or gas bulbs is about a half degree or degree accurate; nowadays it is possible to install electronic radiator valves that are more accurate, with a setting ranging from a half degree to a tenth degree. Moreover, electronic radiator valves make it possible to adjust hourly or weekly time slots, although this option might not be relevant if the housing is already equipped with a thermostat.

- Common handling mistakes

Experience shows that there are some **common handling mistakes**: for example, if we consider a room whose comfort temperature is reached if the TRV is set on three (around 19°C).

- After a long period of absence, the TRV was set on * or one. When the inhabitants are back, they set the TRV on five instead of the usual three, hoping that the temperature will increase faster.
  - This is wrong, since the temperature gap measured by the sensor is important (i.e. set point temperature - comfort temperature), so the valve is fully opened. Setting the TRV on 5 will not speed up the temperature recovery;
  - The risk with this setting is to heat up the room to 23°C, which will put the inhabitants in a discomfort situation.

- Likewise, if the room is currently occupied, and that the ambient temperature decreases, setting the TRV on four or five will not permit to improve the situation.
  - Since the ambient temperature is below the set point temperature, the valve in the TRV is opened. The problem does not come from the TRV itself, but rather from the central heating, which is not sending water at the appropriate temperature.

- On the other hand, if it gets too warm in the room (sun shining for example), setting the TRV on one will not change the situation.
    - Since the ambient temperature is above the set point temperature, the valve is closed.
    - The risk is to prevent the morning temperature recovery, if the TRV is not reset.

These examples show that the lack or absence of knowledge on the operation of the thermostatic radiator valves leads people to think that TRVs are switches, which may lead to overconsumption and discomfort. The operation of TRVs should be clearly explained by building managers, network managers, or even the public actor owning the DHC, thus preventing such handling mistakes.

- Combination of room thermostat and thermostatic radiator valves

Assuming that a lodging is equipped with radiators, it is possible to implement both a room thermostat and thermostatic radiator valves. The combination of these devices will allow adjusting the heating load in the complete lodging more accurately.

The room thermostat can be set on a maximum temperature for the whole lodging; the TRVs on every radiator can then be set according to the use of every room (bedroom, living room etc.).

Efficient regulation

In the case of a building connected to a DHC network, the user/owner has no mean of action on the delivered temperature in the heating devices. The energy management on that level consists in **adapting the heating load to the current use** of a room/building, if these actions are fully part of their behaviour and understanding.

Zoning

The ability to separate a building/lodging in separate zones is a great step in improving the heating regulation in the building. Depending on the heater technology, this is made possible by installing the following equipment:

- With radiators: using TRVs on each of them (associated or not with a thermostat);
- With large surface emitters: using a smart thermostat.

Separating the building in **different heating zones** consists in setting different comfort temperatures depending on the use and occupancy of each room. Usually, it is advised to set the following temperatures for improved comfort in housing buildings (these values may vary depending on individual characteristics):

- Bedroom: 17°C;
- Living room, office: 19°C;
- Bathroom: 21°C;
- Unoccupied room: 17°C.

In offices and scholar buildings, the following temperatures are advised (or set as an average value by the regulation):

- Offices: 19 °C[11];

[11] These temperatures are not compulsory; energy-related associations or even local authorities sometimes advise them. The most important parameter in every building is the comfort temperature. This temperature depends on a number of different factors: air temperature and humidity, wall temperature, clothing, metabolism, physical activity, etc.

- Gymnasiums: 14 °C;
- Classrooms: 18 °C[12].

Other buildings, such as retirement homes or establishments receiving children often have higher temperatures due to the fragility of these populations (22°C for retirement homes, and 21 °C for children).

Reduced temperature

In general, the set comfort temperature in housing is around 19°C (this value may vary on inter-individual criteria). Applying a reduced temperature during absence periods (work time, holidays…) allows adjusting the indoor temperature to the actual use of the building.

The regulation devices described above (electronic thermostatic radiator valves and room thermostats) make it possible to apply a temperature reduction during said absence periods. According to the duration of the user's absence, the following temperature reduction are applied:

- Reduction to 18°C during night time and temporary absence (working hours);
- Reduction to 16°C for 24 to 72 hours of absence;
- Reduction to 14 to 16°C for absence periods exceeding 3 days.

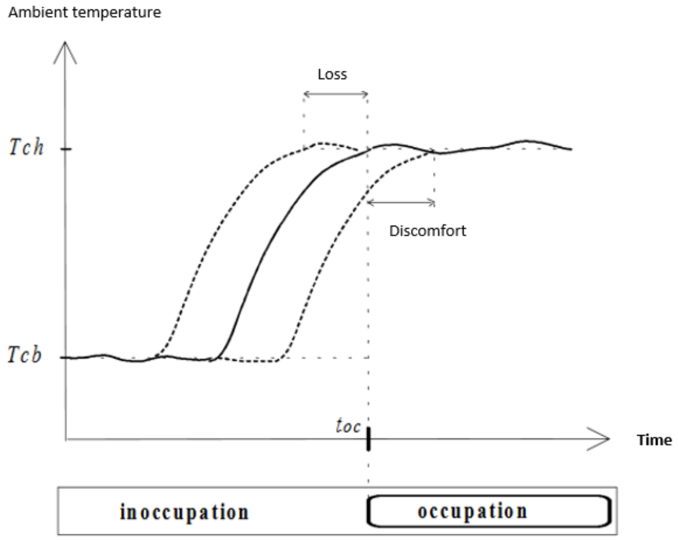
When programming the temperature reduction, one should keep in mind that a building possesses two major characteristics: its inertia and its heating time. Taking in account both of these parameters, and adding that water based heating systems are slow to heat the space, the regulation of hourly or weekly heating schedules is somewhat affected:

- It is possible to program a **temperature reduction** before actually leaving the place (inertia will keep the building warm);
- The user should program the **temperature recovery** (i.e. after a period of absence) before actually arriving at home (because of the heating time).

In offices and scholar buildings, which are unoccupied during night time, it is also possible to set a low set point temperature, or to simply cut the heating or cooling after the usual using times, and to anticipate the start of the day by reviving the heating systems earlier.

Nonetheless, programming a temperature reduction and a temperature recovery requires determining the optimum time to boost or shut the heating input. Setting an improper time will result either in energy losses or in user discomfort, as is presented in the Figure 15 below.

[12] Classrooms can be lowly heated because the people in the room will serve as heat sources.



Legend:

Tch: high set temperature

Tcb: Low set temperature

Toc: time at which the building is occupied

Figure 15: Setting the correct time during intermittence periods. Translated from 'La régulation thermique des bâtiments tertiaires', doctoral thesis of G. Fraisse (1997)

Conclusion

Energy management in the context of 4th generation District Heating and Cooling is possible via a set of different technical solutions that allow monitoring and controlling the operation and performances at the network and building level. While some of these solutions are implemented at the scale of the network, and so are performed by its operator, others depend on the building owner or manager. This allows following the energy consumption of the building, and understanding where the possible improvements stand.

Nonetheless, the end-user of a 4DHC, and so the final energy consumer is an important link in the chain, and should not be left behind. Educating the end-users to the operation of the network, and the management of his energy consumption according to his needs is important. Past experiences show that integrating the consumers into a larger social group, with a particular care to communication and training is the right path to succeeding.

References

[1]. European Commission 2014, *Energy prices and costs in Europe*, European Commission.

[2]. Agence de l'Environnement et de la Maîtrise de l'Energie 2019, *Le chauffage et la climatisation*, ADEME, viewed August 2019, https://www.ademe.fr/particuliers-eco-citoyens/habitation/bien-gerer-habitat/chauffage-climatisation

[3]. Le droit en Wallonie 2015, *Arrêté du Gouvernement wallon instaurant un régime de primes aux particuliers favorisant les économies d'énergies et la rénovation des logements*, viewed 1st April 2019, https://wallex.wallonie.be/index.php?doc=29199&rev=30705-20417

[4]. Wallonie Energie SPW 2017, *Rénovation énergétique des bâtiments*, viewed 1st April 2019, https://energie.wallonie.be/fr/amelioration-de-la-performance-energetique-des-batiments.html?IDC=8969&IDD=83066

[5]. Energy Cities 2014, *The Brussels green loan scheme*, viewed 1st April 2019, http://www.energy-cities.eu/db/Brussels_green_loans_infinite_2014_en.pdf

[6]. IEA 2012, *Brussels, subsidy schemes for energy efficiency measures*, viewed 1st April 2019, https://www.iea.org/policiesandmeasures/pams/belgium/name-24681-en.php

[7]. Vlaanderen is energie, *Vlaanderen is energie, Ondersteuning door de Vlaamse overhead*, viewed 1st April 2019, https://www.energiesparen.be/ondersteuning-door-de-vlaamse-overheid

[8]. Ministère de la Cohésion des Territoires et des Relations avec les Collectivités Territoriales 2018, *Le Crédit d'impôt transition énergétique*, viewed 1st April 2019, http://www.cohesion-territoires.gouv.fr/le-credit-d-impot-transition-energetique

[9]. Ministère de la Cohésion des Territoires et des Relations avec les Collectivités Territoriales 2013, *Tout sur l'Eco-Prêt à Taux Zéro*, viewed 1st April 2019, http://www.cohesion-territoires.gouv.fr/tout-sur-l-eco-ptz

[10]. Sustainable Energy Authority of Ireland, *Heating Control Grants*, viewed 1st April 2019, https://www.seai.ie/grants/home-energy-grants/heating-upgrade-grants/

[11]. Sustainable Energy Authority of Ireland, *Project Assistance Grants*, viewed 1st April 2019, https://www.seai.ie/grants/business-grants/project-assistance-grants/

[12]. International Energy Agency 2012, *Tax reduction for investments in energy saving equipment and sustainable energy*, viewed 1st April 2019, https://www.iea.org/policiesandmeasures/pams/netherlands/name-23861-en.php?s=dHlwZT1lZSZzdGF0dXM9T2s,&return=PG5hdiBpZD0iYnJlYWRjcnVtYiI-PGEgaHJlZj0iLyI-SG9tZTwvYT4gJnJhcXVvOyA8YSBocmVmPSIvcG9saWNpZXNhbmRtZWFzdXJlcy8iPlBvbGljaWVzIGFuZCBNZWFzdXJlczwvYT4gJnJhcXVvOyA8YSBocmVmPSIvcG9saWNpZXNhbmRtZWFzdXJlcy9lbmVyZ3lIZmZpY2llbmN5LyI-RW5lcmd5IEVmZmljaWVuY3k8L2E-PC9uYXY-

[13]. Government of Netherlands 2016, *Central government promotes energy savings*, viewed 1st April 2019, https://www.government.nl/topics/renewable-energy/central-government-promotes-energy-savings

[14]. Ofgem, *Energy Company obligation*, viewed 1st April 2019, https://www.ofgem.gov.uk/environmental-programmes/eco

[15]. ADEME Rhône Alpes 2015, *Contrat de Performance Energétique*, viewed 1st April 2019, http://www.rhone-alpes.ademe.fr/sites/default/files/files/mediatheque/publications/contrat-performance-energetique-retour-experiences.pdf

[16]. BSI, *Sheffield Hallam University case study*, viewed 1st April 2019, https://www.bsigroup.com/Documents/iso-50001/case-studies/BSI-ISO-50001-case-study-Sheffield-Hallam-University-UK-EN.pdf

[17]. Groupe Polylogis 2018, *Logirep et Trois Moulins Habitat certifiés ISO 50 001*, viewed 1st April 2019, http://blog.polylogis.fr/nos-engagements/2018/03/30/logirep-trois-moulins-habitat-certifies-iso-500001/

[18]. ADEME 2014, *Des ménages acteurs de la gestion de l'énergie dans leur logement*, Agence de l'environnement et de la maîtrise de l'énergie, viewed August 2019, https://www.ademe.fr/ademe-lettre-strategie-ndeg-39

[19]. Department of Energy and Climate Change 2014, *Advice on how to use heating controls, evaluation of a trial in Newcastle*, Department of Energy and Climate Change.