How to accelerate the heat transition:

a guide for local government and actors

Module 4

Technology choices,

data, and mapping for sustainable heating

Interreg
2 Seas Mers Zeeën
SHIFFT

CONTENTS

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INTRODUCTION:

This is the fourth part of a series exploring how municipal efforts can accelerate the decarbonisation of heating at the community level.

This is an output of the EU Interreg 2 Seas funded project SHIFFT – Sustainable Heating: Implementation of Fossil Free Technologies. This module is concerned with the technical basis of how cities and local governments, citizens and stakeholders can work on visions and plans for zero carbon heating.

In this module the technical and physical aspects of the transition from fossil to renewable heating are emphasised. In the first section the reader is informed about the reasons why we need to transition our heating systems in the built environment to renewable sources. The second section provides the reader with an overview of technology choices and strategies, and is aimed at helping you make technical decisions.

This document is one of a four-part guide on how to accelerate the heat transition in cities. Module 1 in this series is concerned with the role of communities and the need for citizen engagement and a co-creation process which can ensure that community views are a central part of any municipal planning for the shift to zero carbon heating. Module 2 covers the range of financial instruments and their application. Module 3 focuses on city heat strategies, regulation, and other non-financial policy instruments. All of the other modules are available from the SHIFFT website: https://shifftproject.eu

1.1 WHAT ARE WE HEATING?

In the temperate climate of North West Europe, buildings require a heating system for two end uses: thermal comfort and domestic hot water (DHW).

Thermal comfort keeps the indoor spaces of the building at a comfortable temperature level. This includes both heating, and due to climate change, increasingly some cooling as well. In this module, however, we will focus on heating.

Domestic Hot Water is generally used for cleaning, washing dishes and taking showers or baths. Because legionella bacteria thrive in warm-but-not-too-hot environments, the temperature of a DHW system has to be kept above a certain temperature level. This is usually defined by national law. In the Netherlands for example, water temperature has to be either below 25°C for cold water or above 65°C for hot water, in the UK these limits are below 20°C and above 50°C. Temperatures lower than the hot water limit might be possible if a regular thermal pulse (for example raising the temperature above 60°C once a week) is allowed by law.

Seasonal changes: Of these two, thermal comfort requires the most energy over a year, however its demand changes with the seasons. For most buildings, heat demand for thermal comfort will be zero in summer and will be high in winter. Figure 1 shows space heating and DHW usage for a home in the southern part of the Netherlands.

The length of the heating season and the daily heat demand pattern depend on the (type of) building: homes, offices, hospitals, and factory halls will all be different from one another in these regards.

DHW demand is usually far more constant. For instance, the number of showers taken and dishes washed will not vary much over the seasons as space heating does.

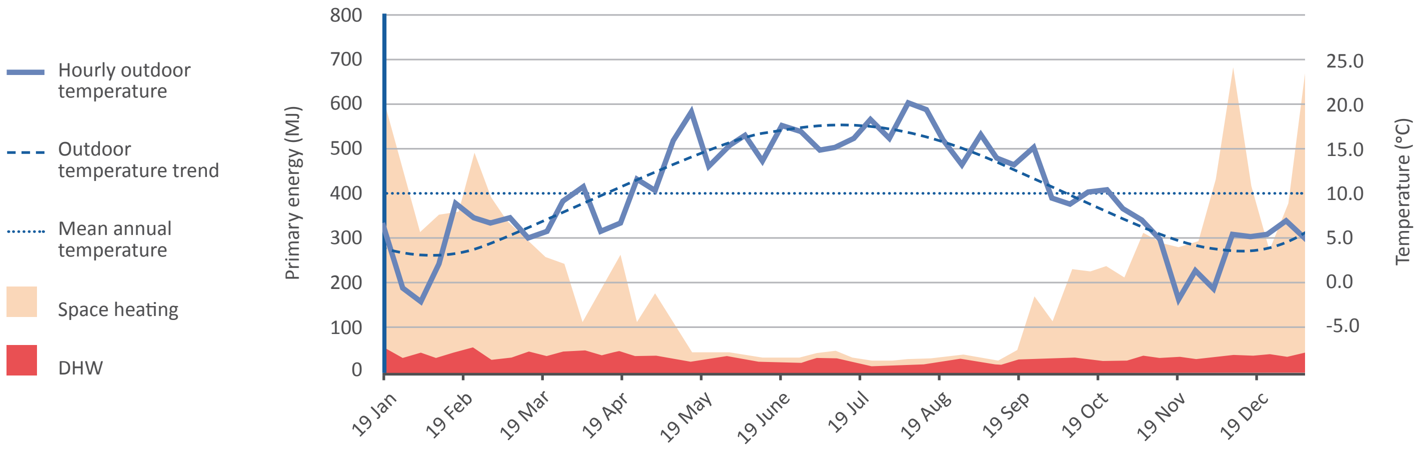


Figure 1 Space heating and DHW demand. Heat demand and outdoor temperature are roughly mirrored. (PLANHEAT, 2018)

Building use also matters. Homes will, for example, have a different kind of usage from offices, care homes, hospitals, or factory halls. How much space heating and DHW are used, and when throughout the year will be different for each of these.

Heat demand may also change over time. Current heat demand is the starting point, but renovation, behavioural change, demolition, and climate change may reduce it, and new construction may increase it. See section 2.3.2 for more details on this.

1.2 WHY THE TRANSITION TO RENEWABLES?

Although most of us are familiar with the reasons a transition to a fully renewables-based heating system is necessary, this section provides a short primer on the main drivers. Heating technologies for buildings play an important part in both causing and preventing climate change. Because both the Earth's climate, and human fossil energy supply chains are global, zooming out to the proverbial big picture is needed. In short: act global by acting local.

Earth's climate is changing faster than it should

Over long periods of tens to hundreds of thousands of years, climate change is considered normal, and this slow pace has allowed life to evolve and cope with these changes. However, because of human activities, this same change now happens at a speed of a few hundred years, and the speed of change continues to accelerate. This, combined with a growing human population, and our reliance on safe living space, abundant food production and clean water, makes it increasingly difficult for the Earth's ecosystems to support themselves and us people living off them.

BOX 1: HUMAN INFLUENCE HAS WARMED THE CLIMATE AT A RATE THAT IS UNPRECEDENTED IN AT LEAST THE LAST 2000 YEARS

Changes in global surface temperature relative to 1850-1900

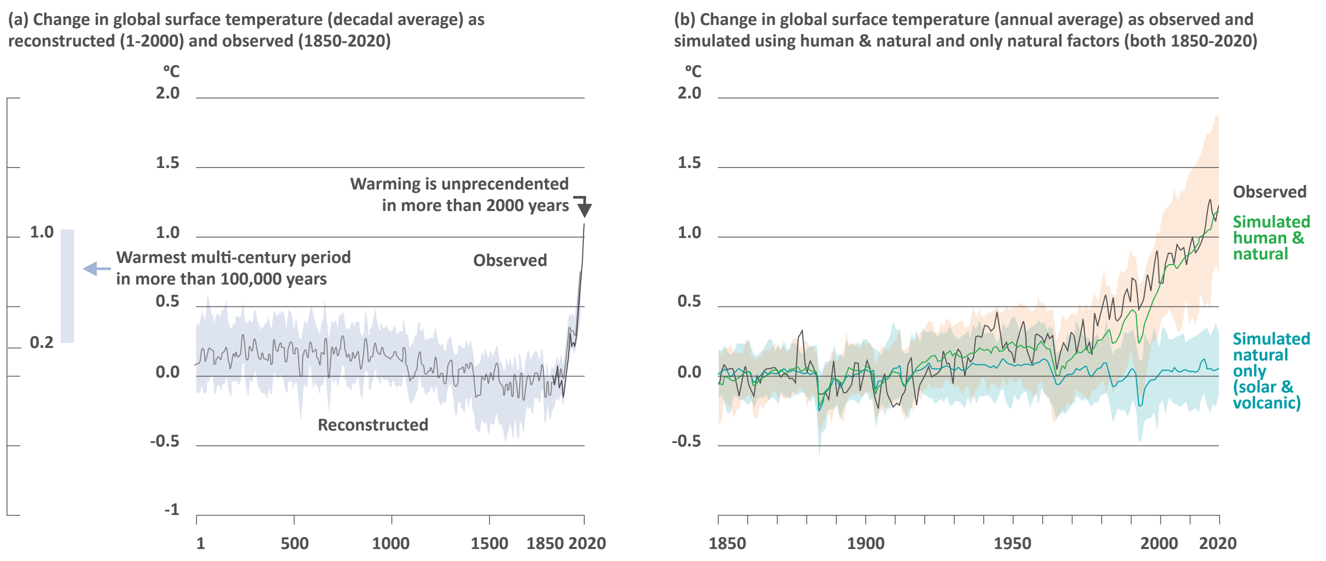


Figure 2 The latest IPCC report directly ties abnormally fast global surface temperature rise in the past 150 years to human activities. (IPCC, 2021)

Human activities are the main cause

The United Nations Intergovernmental Panel on Climate Change (IPCC) brings together several thousand experts in many different fields, and assesses the state of climate change every six to seven years. In their most recent reports, they state that the accelerated climate change as we are experiencing it is overwhelmingly caused by human activities: primarily greenhouse gas emissions from burning fossil fuels. We therefore also have the ability to strongly reduce our impact on the climate, by moving away from those and towards clean energy sources.

The built environment can play an important role

Heating and cooling make up about half of the energy demand in the EU. The built environment uses 45% of that (European Commission, 2016), and a lot of it is still fossil fuel based (causing 37% of greenhouse gas emissions). Changing heating and cooling sources in the built environment therefore can have a large impact.

And it's a matter of trust (or: energy security)

Although in the past coal was mined in many places (and the Netherlands still sits on top of the largest gas bubble in Europe), right now most non-renewable fuels used in the Netherlands, Belgium, France and the UK are imported. Most of the world's oil, gas, uranium and coal reserves are outside of Europe!

The 2022 energy crisis, and a dozen other regional and global ones, since at least 1973, have made very clear that this makes Europe vulnerable to both price fluctuations, supply embargoes, wars and even sabotage. More local sources, including almost all renewable sources, can help strongly reduce this dependence and make energy supply both secure and affordable on the long term.

The Netherlands, furthermore, has over the past decade experienced an issue with energy extraction safety – decreases in pressure in the massive Slochteren gas field, due to half a century of natural gas extraction, are increasingly causing earthquakes (live map here: https://www.knmi.nl/nederland-nu/seismologie/aardbevingen, there will be a cluster in the north east). Geological instability in abandoned coal mines is also causing earthquakes in the province of Limburg (the southwestern-most province of the country), although much less frequent and intense. The gas field-related earthquakes have damaged homes, reduced property values, and generally had a negative effect on mental health of residents. For these main reasons, the Slochteren gas field will be scaled down to zero over the next few years, well before economic reserves have been exhausted.

2 TECHNOLOGY STRATEGIES

This module is intended to give you a primer on what technologies and information to consider when starting or accelerating your local heat transition. There are a lot of technology options to choose from, and a lot of sustainable heat sources to use.

Which one works best depends on what you need (demand), what's available (supply), when heat is needed and provided and how close to each other sources and sinks are. Although in a lot of places we are used to having one (gas) valve to turn, to make our homes comfortable in winter, and the sustainable heating transition may look daunting because of this, heating technology itself should not be considered a problem anymore. Figuring out which technology options are available to your area will help inform local citizens, develop business cases and generally accelerate the process.

When it comes to heating systems, we come from a world where the required heat is available at the turn of a dial, regardless of the characteristics of your home or personal preferences. This has come at the cost of accelerating climate change (see chapter 1). The post-fossil world is different. In this chapter we therefore take a broad look at the technologies involved in the heating transition, and what choices are available.

There is a need to identify and evaluate the available resources, to choose the most appropriate technologies to convert these into energy or heat, and to decide whether to choose collective or individual distribution systems.

Which ones are useful for you, will depend on a few things: both on the demand and supply side, and heat transport and storage in between.

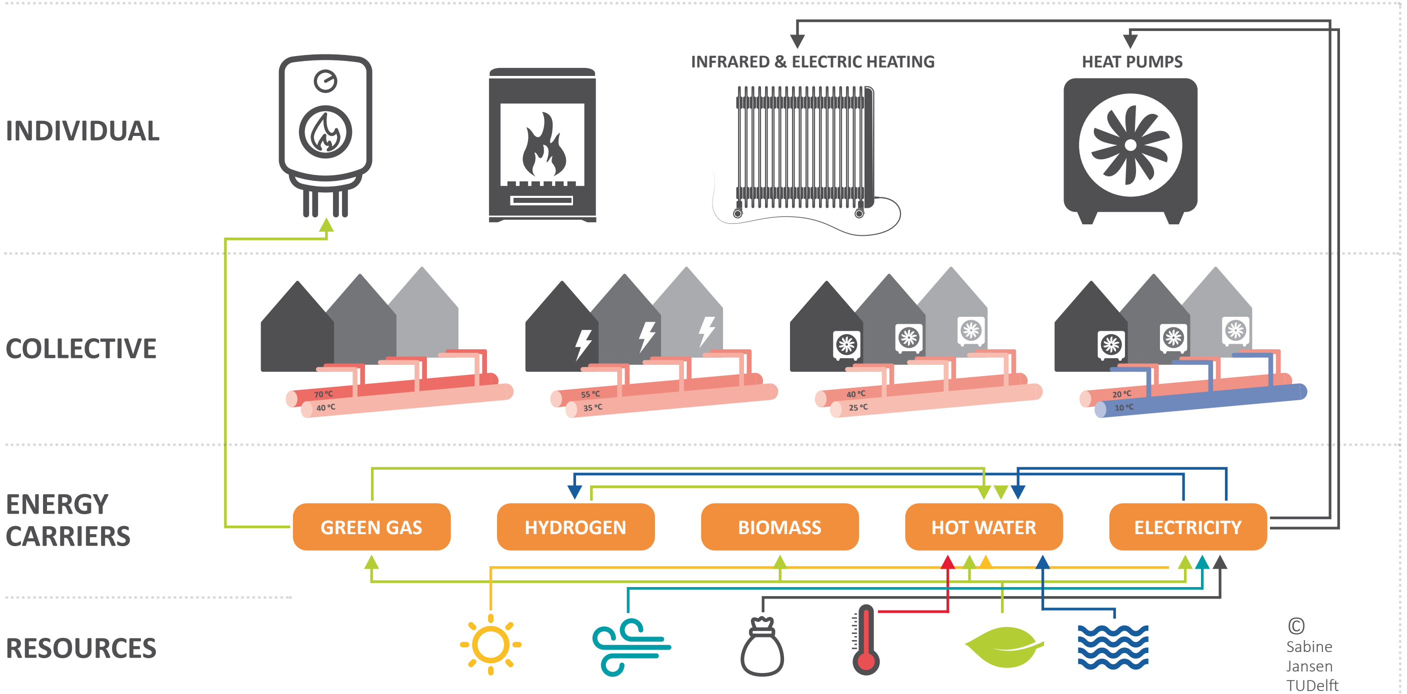
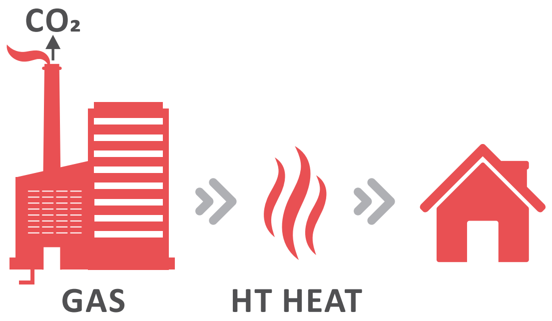


Figure 3 Alternative solutions for heating in the built environment (Jansen, 2018)

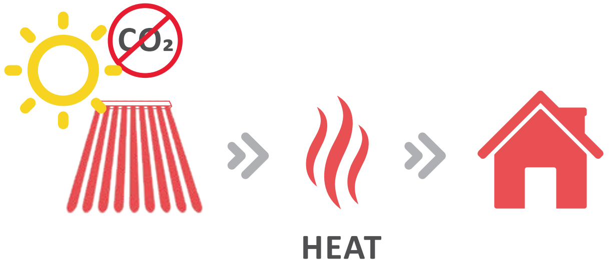
2.1. SUSTAINABLE?

Heat sources can roughly be divided in three categories: non-renewable, residual, and renewable.

Non-renewable heat generally involves burning fuels, which creates CO_2 emissions (and frequently other pollutants). Although nuclear power (and its waste heat, see below) may have low CO_2 emissions compared to oil and gas, the supply of uranium is finite and often mined abroad, therefore it behaves more like a fossil fuel (that can provide residual heat, see below).



Residual heat is the waste flow of another system, for example exhaust heat from a coal fired power plant (which of course uses fossil fuels) or a waste incinerator. Although these reduce emissions by reusing existing 'waste' heat, this in itself is not renewable, but rather increasing the efficiency of the system that originally generated the heat. Residual heat can only be labelled 'renewable' if the ultimate source (in the example above, gas) is fully replaced by a renewable heat source itself.



Fully renewable heat sources regenerate over time, and therefore do not run out, meaning they can be used indefinitely. Furthermore, any CO_2 released when used to generate heat (for example with biofuels) can theoretically be reabsorbed when the biofuel source grows back. Other renewable heat sources rely on solar or geothermal heat, or ambient local sources like aquathermal energy.

BOX 2: COMMON TERMS

Decarbonisation:
Reducing CO_2 emissions into the atmosphere. This is about establishing a downward trend.

(Net) zero carbon, carbon neutral, climate neutral:
Over a year the (net) greenhouse gas emissions are zero. Carbon emissions may be compensated, for example by carbon trading (e.g., by using CO_2 certificates), CO_2 storage, or CO_2 uptake by forests (note that carbon trading and certificates are not always credible or reliable). Since the goal of becoming (net) zero carbon or carbon neutral is related to climate change mitigation it can also be called climate neutral.

(Net) zero energy, energy neutral:
The amount of energy used is equal to the amount of renewable energy produced over a year. The use of fossil fuels is still allowed but should be compensated by on-site renewable energy production. Therefore, energy neutral does not necessarily mean an energy system is fossil free. Where more energy is produced then used within the same system over a year, the system can be called energy positive.

Fossil free:
Being completely fossil free means operating with zero fossil fuels; fossil resources are not allowed anywhere within a given energy system. Compensation of carbon emissions is not allowed.

Circular:
Circularity or Circular Economy refers to an alternative model of production and consumption, a strategy which theoretically contributes to both economic growth and sustainable development. Although it is often only connected to the use of natural resources and products, with a focus on avoiding waste and spillage by reusing, recycling and reprocessing materials, circularity can also include energy, water and nutrient cycles. For example, by focusing on energy savings to avoid energy loss. A circular energy system reuses all waste flows and resources with only the input of renewable energy. A circular system functions by itself; it is self-sufficient. It is difficult to measure to what extent a system is circular, there are no numeric indicators.

2.2 HOW TO START?

With a reduced demand, less supply is needed. Less supply also means a smaller, less expensive energy system – both at the city level and within buildings. Therefore, it helps to know how well your buildings can be insulated. New buildings will also have to be connected (which would increase heat demand in the area again), therefore future construction plans in the area should be included. Figure 4 shows the energy hierarchy of steps that can be followed to optimise local heat systems: Reduce, re-use, generate sustainably, and generate cleanly with fossil fuels (this final step is ultimately phased out).

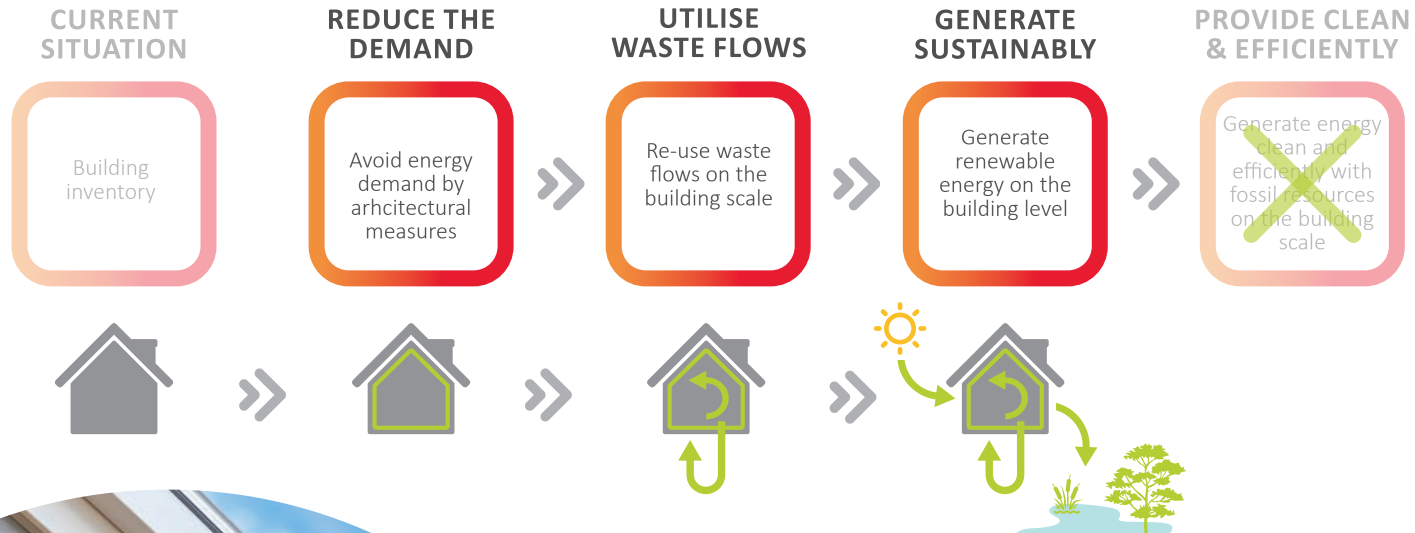


Figure 4 The New Stepped Strategy (Dobbelsteen, 2008)

You will also need to investigate which sustainable heating sources are available in the area. Unlike electricity heat cannot economically be transported over long distances, especially not low temperature (LT) heat (which is what a lot of sustainable sources provide).

Some sustainable heating sources may be able to provide a lot of energy, but only in summer. For these having the ability to seasonally store this is very important in being able to use them. Some large-scale seasonal storage technologies use aquifers, others use constructed water pits.

Long term planning is needed throughout these steps, so you know what the end situation will be in, for example, 2050. This end situation should reflect a desired situation in which a law carbon or net zero goal is to be achieved. In order make this more tenable and transparent a vision should be created. After a vision and goals have been set, a pathway and roadmap can be developed on how to achieve these goals.

However, achieving the strong carbon reduction targets that have been set by the European Commission and governments of European countries, means that they should all be executed simultaneously! If that comes down to installing a heat pump system first, and using a peak gas boiler (to cope with the coldest days) for a while, this will still have a short term partial impact and allow that home to go fully sustainable afterwards.

The next section applies the SHIFFT structured approach (this approach is described in more detail in Module 3) and shows a few examples of tools and strategies that can help plan your heating transition.

2.3. DEVELOPING A RENEWABLE ENERGY SYSTEM

2.3.1. Context

Large-scale fossil fuel-based heating followed the industrial revolution. We are burning gas and oil (as well as, coal, lignite, peat, and other types of energy carriers) at a temperature of hundreds to thousands of degrees Celsius. Many renewable sources provide renewable heat at a much lower temperature; however, as the goal is to create an indoor temperature of only around 20°C (and a much smaller amount of energy for DHW at about 65°C), this is not a problem.

Exergy is a measure of how much useful work you can get out of a type of energy. Fuel sources that burn at a very high temperature can be used to heat homes, but also to melt steel or run cars. Low temperature renewable heat sources are usually far more abundantly available, and/or require shorter and cheaper supply chains than high temperature ones (like hydrogen production and various kinds of biomass). Therefore, in general it is better to use the latter for higher quality work. Figure 5 gives an idea of what can be done at different temperatures.

Heat generation and applications

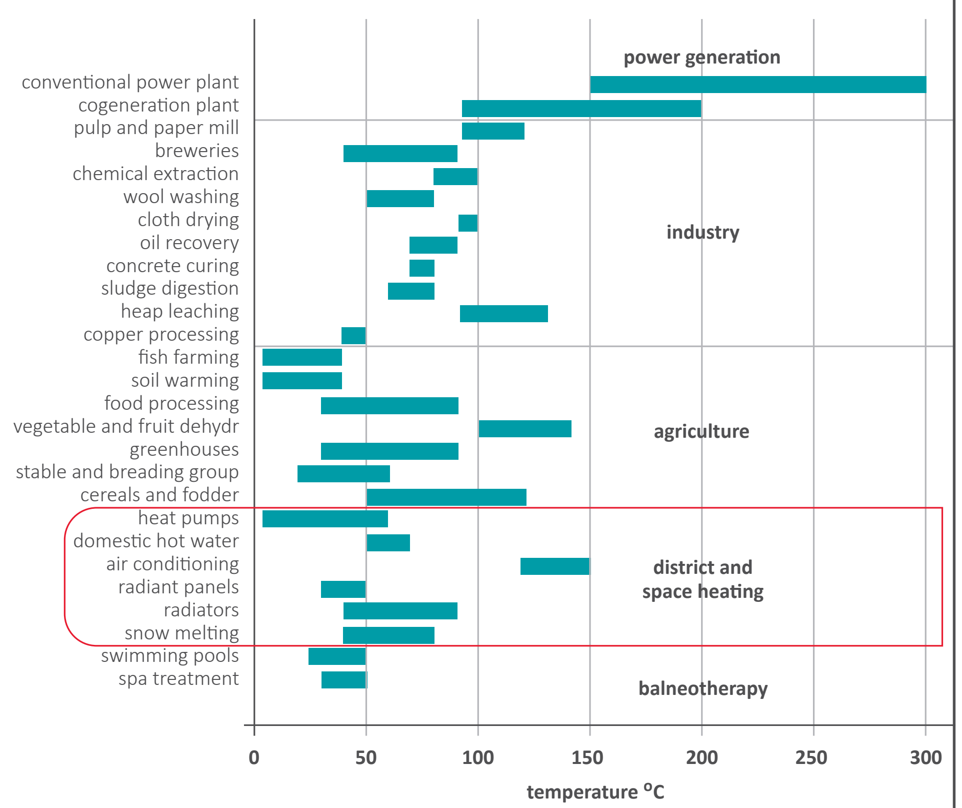


Figure 5 This Lindal diagram shows heat generation and applications by temperature range, buildings in red (Hurter & Schnellschmidt, 2003)

The **Coefficient of Performance (COP)** is an important efficiency term (related to heat pumps). This provides the ratio between electricity going in and heat coming out. A simple electric resistance heater consumes electricity and converts 100% of it into heat. For the same amount of electricity however, a ground source heat pump (GSHP) can usually produce 3-4 times as much heat! The difference is that the GSHP additionally draws in ambient heat from, in this case, the ground, and gives it a temperature bump. The Seasonal Performance Factor (SPF) is the average COP over a full (heating) season.

Figure 6 Coefficient of performance of an electric heater on the left, heat pump on the right. The 3kW of ambient heat from the ground heat exchangers (here in orange) makes the difference.

2.3.2. The current (and future) situation

When making heating transition plans, your first step should be to map and understand the state of the current local built environment and energy system.

How much energy is required? At every step of the energy chain, only part of the energy we start out with is converted into the energy we need. As each kind of heating system has a unique different energy supply chain, it is important to consider these steps. Figure 7 below shows that what we measure is what comes out of the national/global energy system, and then gets converted into what we need locally (i.e., inside the building). Practically, we tend to work with final energy, as this is almost always measured for billing purposes and therefore more easily available.

Energy consumption data can usually be obtained from a local (distributed) system operator. Sometimes there only is a single heat source (gas, district heating) available in an area (like a neighbourhood), whereas in other areas there might be a mix of sources available. Although annual figures are commonly the default, monthly figures help a lot, this will give you a better idea of peak heat demand.

Comparing primary energy flows and conversion rates between non-renewable and renewable systems is less useful (for example solar thermal panels vs coal fired power plants). However, this is important in measuring the CO_2 impact of each system.

As energy consumption is directly related to each individual, this information is considered privacy sensitive and subject to the GDPR (General Data Protection Regulation). In Flanders this also applies to energy labels (see section 2.3.3 below). The solution is aggregation, asking the grid operator for the average consumption of whichever minimum number of houses is considered anonymised according to national law (for example 50 dwellings).

If there are already plans to demolish, renovate or develop new buildings, these should be included in your planning efforts. They will influence heat demand in the area one way or another, and may for example result in a heat grid becoming an economic option, or to be expected to turn unprofitable after losing part of its customers. These should be mapped and taken into consideration.

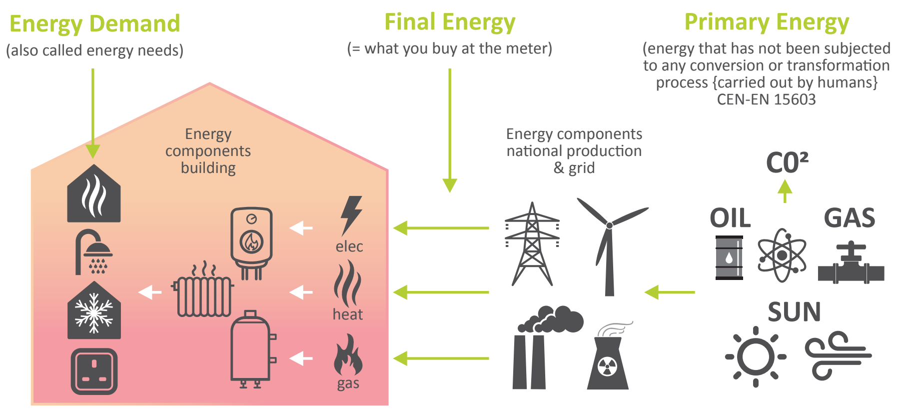


Figure 7 The energy chain (Smart Urban Isle, 2017)

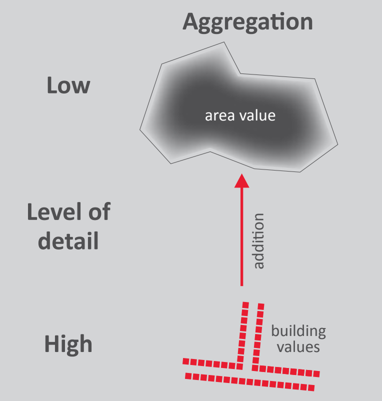


Figure 8 Aggregating data from individual buildings to meet privacy requirements (PLANHEAT, 2017)

2.3.3. Reducing demand

Reducing heat demand falls in two categories: the building and user behaviour.

In general, the lifespan of a building ranges anywhere from 30 to 50 years to hundreds of years. No matter which source you choose for a building, neighbourhood or entire city, thermal insulation of walls, windows, roofs and crawlspaces will both reduce heating demand, and hence the energy bill over that lifespan, and allow your energy system that supplies this heat to be smaller and therefore cheaper. Furthermore, better thermal insulation allows the temperature in the heating system to go down as well, making it possible to use low(er) temperature sources.

The heat delivery system inside the buildings also influences your choices. Examples are:

- **Radiators and convection heater:** the most common type of heat delivery. These are water-air heat exchangers that generally operate at higher temperatures (50-90°C), depending on how well the building is thermally insulated. Efficiency can be slightly increased with forced convection by means of a small fan.
- **Underfloor heating:** heating coils built into the floor that operate on a low temperature (LT) (for example 35-40°C). Suitable for LT heat sources.
- **Air heating (HVAC):** air is heated centrally and distributed through the building.
- **Electric heating:** uses resistance to turn electricity into heat. The Coefficient of Performance (COP) is 1, whereas heat pumps have a COP of 2-4.
- **Infrared panels:** these can provide heat to your body directly rather than indirectly (by heating up the space and walls). This can be favourable if the space in question is large and only partially used, poorly insulated, or sees only short periods of use over time. They do increase tension on the electricity grid capacity when used in large quantities.

Figure 9 Energy labels for the historic centre of Middelburg (NL), status July 2022. Source: (Nationale Energie Atlas: RVO 2022)

Legenda:

Green label	Klasse A++	Klasse C
Klasse A+++++	Klasse A+	Klasse D
Klasse A++++	Klasse A	Klasse E
Klasse A+++	Klasse B	Klasse F
		Klasse G

BOX 3: BUILDING ENERGY PERFORMANCE LABELS

Due to the European EPBD (Energy Performance of Buildings Directive), building energy labels are becoming more easily available right now. When projected on a map (like for Middelburg in Figure 9), these should give you an idea of how good (or bad) the buildings in the area are performing and, if detailed inspections are available, what kind of energy systems they currently have.

The existing energy system of a building (for example the gas boiler) can be made more efficient, by:

- Optimising system settings (including thermostatic radiator valves);
- Using one's boiler more efficiently: e.g. reducing the flow temperature;
- Keeping the radiator water pressure sufficient;
- Performing annual check-ups for the above;
- Using radiator fans to improve heat circulation;
- Applying radiator foil behind the radiators.

Which options work best depend on the energy system present. As with user behaviour below, informing people that these simple options are available, may help to bring heat usage down.

People can also play a large role in energy savings by adjusting their behaviour. Space and hot water heating for example can be made more efficient by:

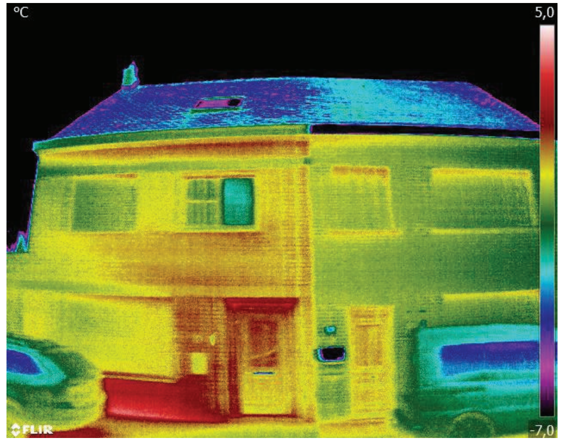
- Turning down the thermostat a few degrees during the day (for example 19°C instead of 20°C);
- Turning off heating at night (by turning down the thermostat even further);
- Keeping windows closed when the heating is on;
- Heating fewer rooms (just the living room for example);
- Keeping doors closed (so hallways and bedrooms aren't also heated);
- Having shorter showers (even 1-2 minutes is already noticeable on the annual heating bill);
- Taking showers rather than baths (less heated water required).

There are numerous ways to do this, however not everyone is aware of these. Informing citizens can therefore go a long way in both helping them to reduce their heating bills and helping the city to reduce its heat demand.

The UK based Heating Hub lists a wide range of boiler setting optimisations: https://www.theheatinghub.co.uk/mission

Thermographic facade scans in Bruges

The City of Bruges (BE) is investigating the insulation quality of its buildings at a large scale. A car, equipped with a thermal camera, has covered the 10,000 homes in the Assebroek neighbourhood during a cold day. The resulting infrared photos show facade (and roof) performance and help determine the state of thermal insulation for both the homeowners and the city. Inhabitants are informed about the infrared photos of their homes and offered accompanying appointments to receive energy advice.



Top photo: thermographic facade scan: the house on the left loses more heat than the one on the right; Bottom photo: scan vehicle

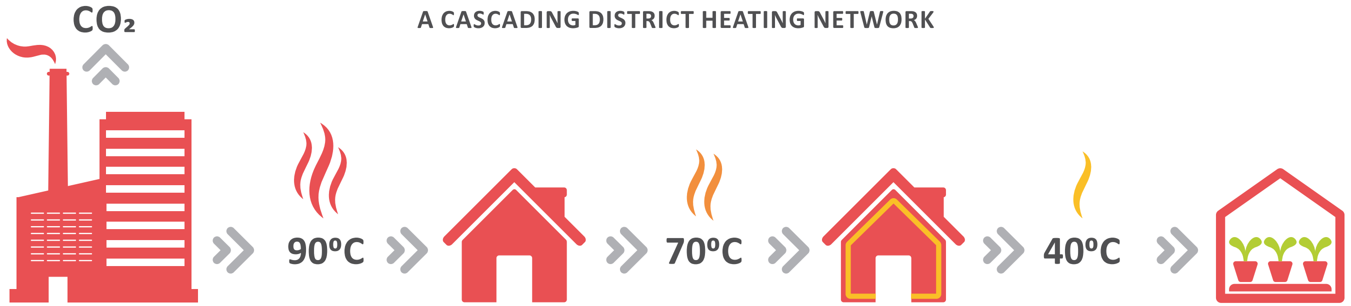
2.3.4. Supply potential

As the objective of the energy transition is to phase out the non-renewable heat sources, two types of heat source are considered: residual and renewable.

Residual sources can be waste heat from a power plant, factory, or waste incinerator. These are usually high temperature sources. Unless the source of that heat is renewable, these only mean that fossil fuels (at the source) are used more efficiently. Although using these will in the short term reduce CO_2 emissions of your neighbourhood or city, and for the longer term will need replacing with a suitable high temperature renewable source.

High temperature sources can be used for a cascading district heating (DH) network. The 'waste' heat from a factory could be used to heat buildings with a high energy demand. Well insulated homes can then use the return pipe as a heat source. In this example the return pipe of those is then used for a greenhouse.

A CASCADING DISTRICT HEATING NETWORK



Renewable sources can indefinitely produce net zero carbon heat (see 2.3.6). Examples are solar thermal, geothermal, aquathermal and biomass. Some sources are low temperature and require a heat pump, others are large scale and require a heat grid. For both of these technologies, the source of the electricity consumed during operation should also be renewable. Heat sources are usually tied to a specific technology, as mentioned in this overview. Examples are:

- **Solar thermal:** Seasonal source. Can be panels on roofs, but also covering large open spaces.
- **Aquathermal:** Seasonal source. Involves heat exchangers (and heat pumps) in surface water.
- **Shallow geothermal:** Utilised with Ground Source Heat Pumps (GSHP).
- **Deep geothermal:** Constant, high-volume source. Best paired with a steady heat demand (from multiple buildings) and/or a seasonal store. Multiple wells can interfere with each other, so underground spatial planning and coordinated action is important.
- **Biomass:** Can be dedicated production forests or fields (e.g., for straw), but also waste streams like clippings from public green spaces. Dry biomass can be stored over time and provide on demand high temperature heat but is usually very limited in supply. Quality of biomass matters.
- **Biogas:** Almost always a result of (co-)fermentation of a waste product. Biogas can also be stored, but is usually limited in supply, can be expensive, and requires attention with regard to distribution and use.
- **Hydrogen:** Not a heat source but a carrier. Requires electricity for production, which needs to be renewable for the hydrogen itself to be labelled renewable or 'green hydrogen'.

As mentioned above, in Europe seasonal heat demand does not always match renewable seasonal heat supply. For seasonally fluctuating renewable sources, storage availability is therefore important to be able to fully use the available potential. Without storage, most of the heat in the summer season cannot be used, and conversely, in winter you may not be able to supply enough (see also Figure 10).

CALCULATION METHOD FOR INTERMITTENT LOW TEMP THERMAL SOURCES: DIRECT VS STORED ENERGY

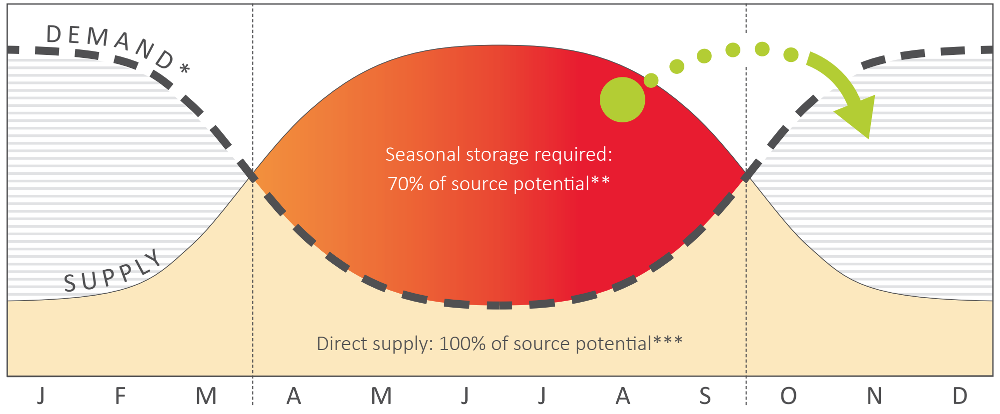


Figure 10 Seasonal storage is required to make full use of a seasonal heat source (PLANHEAT, 2018)

* Demand is only needed for the share of direct vs indirect, assumed to follow an inverse curve, DHW being the base load.

This roughly translates to 20% of the combined technical potential of an unconventional source of the summer months without storage, up to 80% with sufficient storage and 100% of the combined potential of the winter months.

These numbers are then added up to a single GJ number for each cell on the resulting raster.

** Seasonal storage efficiency factor (estimate)

*** For some sources and locations, thermal supply in the high demand season might be zero, which means all potential energy available will require seasonal storage.

Examples of seasonal thermal storage are:

- **Aquifer Thermal Energy Storage (ATES):** Uses a suitable water carrying underground layer. As with geothermal sources, multiple systems can interfere with each other, so underground spatial planning is important.
- **Borehole Thermal Energy Storage (BTES):** As the name implies, this relies on a borehole to act as a heat exchanger with the surrounding soil. It can be applied in far more places than ATES (and can be placed much closer to neighbouring systems) but provides less storage capacity.
- **Cavern thermal energy storage (CTES):** Relies on large volumes of encapsulated water, either in caverns or abandoned mines. Eliminates digging cost (see PTES below), but requires either of these to be nearby, accessible, and suitable.
- **Pit thermal energy storage (PTES):** This involves a man-made pit that is lined and filled with water/gravel, then covered. There are a few projects in Europe (for example Vojens in Denmark) that use simple water in very large volumes (hundreds of thousands of m³) to provide a seasonal heat store. For these to be successful the required soil plot needs to be very low cost, and preferably with a very low ground water table so that the soil can provide additional insulation.

Energy Potential Mapping is very important in understanding which options you have, and how much they can provide. In short, this involves mapping where heat sources are, and how much they can provide (and at which temperature category). For this you will need:

- Suitable spatial indicators;
- A map that shows their spread on your area of interest;
- Conversion technology efficiency per m².

This is for example how **solar thermal potential of roofs** can be calculated:

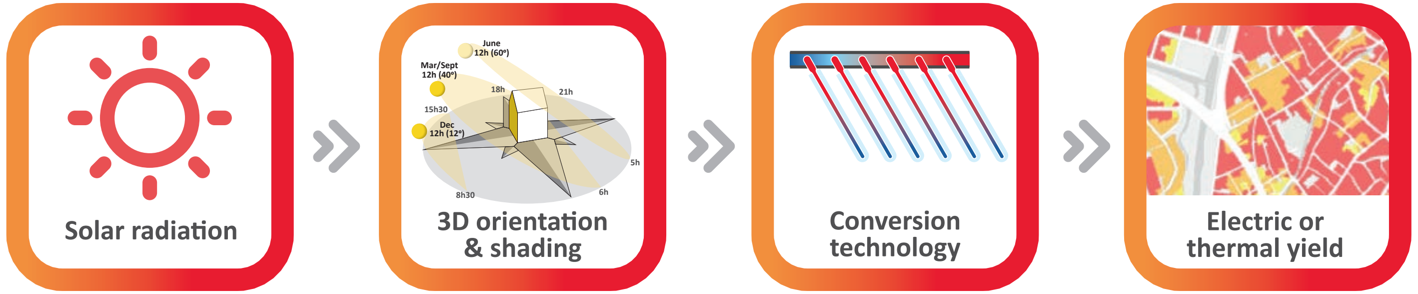


Figure 11 Solar thermal potential of roofs (Fremouw, 2011)

The national meteorological institute can provide solar radiation in your selected area (this will vary relatively little over shorter distances, so for small to medium sized towns you can usually use a single figure). If available, a 3D building model (such as the Dutch 3DBAG model - https://3dbag.nl/) can provide a far more accurate picture. For flat roofs, simple building footprints can get you started, otherwise modelling the most common building types and their orientations will be required. The last variable is which conversion technology you use. In this case, a solar thermal panel can convert roughly 35% of the incoming radiation over a year into useful heat. Multiplying all these with each other results in a solar thermal technical potential map.

More constraints can be added of course, to make the estimated potential even more realistic, consider the addition of economic constraints in Figure 14 for example. Additional technical constraints are, for example, if the roofs are favourably oriented, if they have enough loadbearing capacity, and what kind of ownership or occupancy they have. Adding these will help improve the quality of the initial planning, before informing the decision-making process.

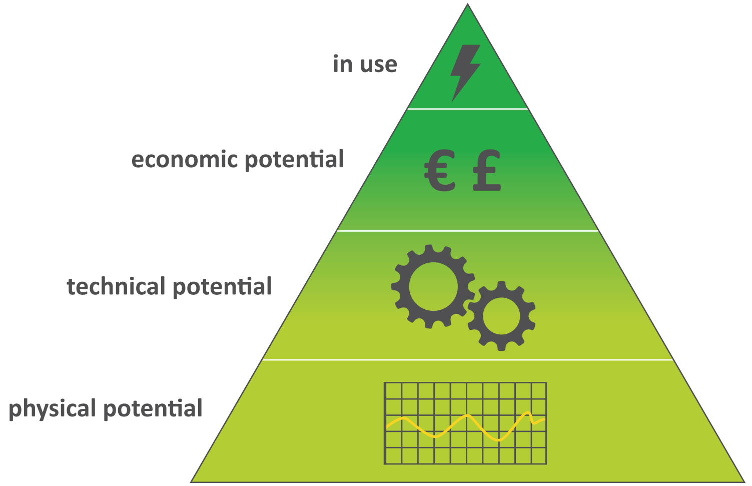


Figure 12 Energy potential levels (Fremouw, 2012)

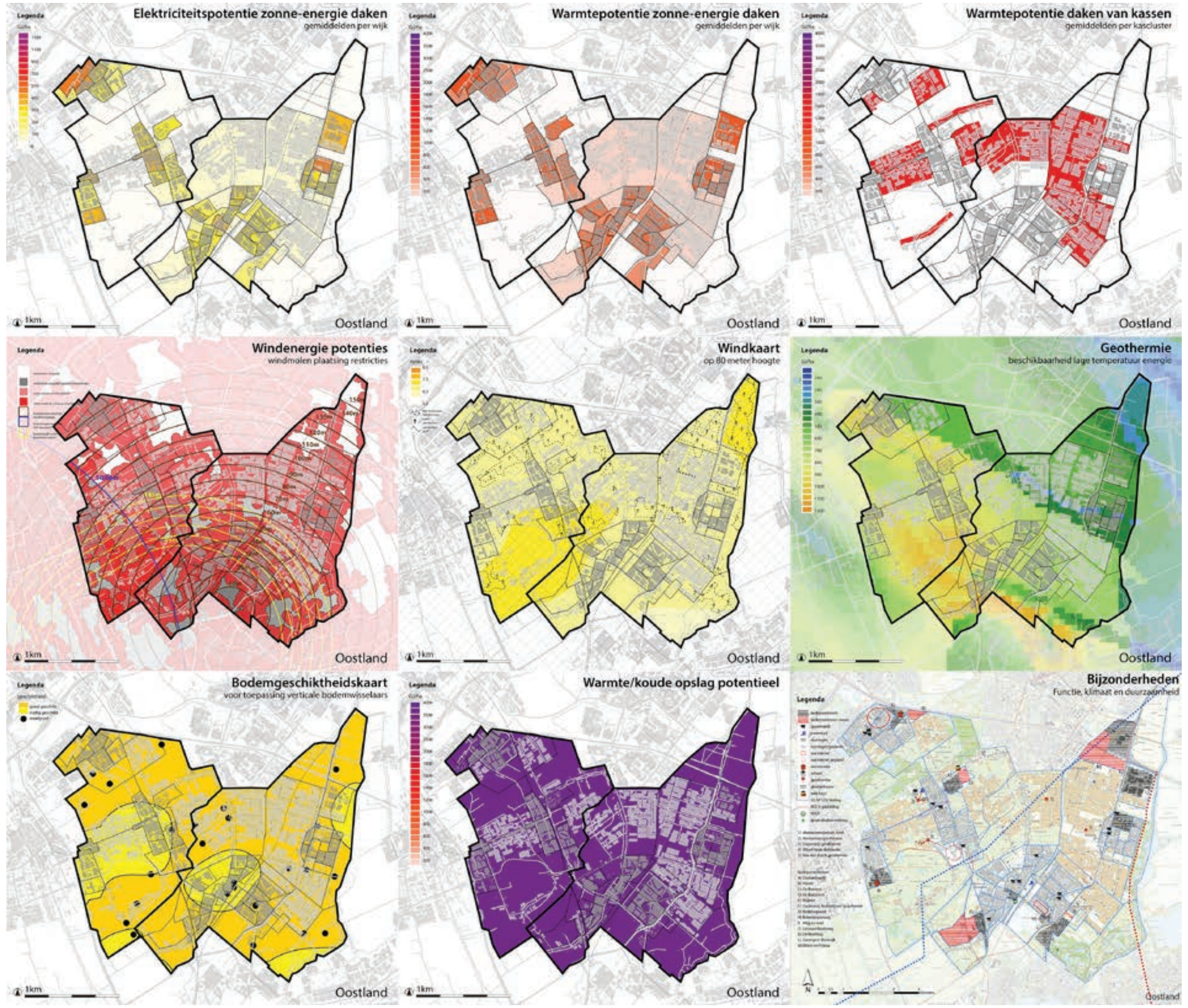


Figure 13 Demand map, supply and underground storage potentials for the Oostland region. Source: Broersma et al., 2013.

Evaluating the realistic potential of a heat source means analysing and incorporating as broad a range of relevant factors or constraints as possible. Figure 14 shows nine potential maps for the Oostland region in the Netherlands. From top left to bottom right: PV potential of roofs, solar thermal potential of roofs, solar thermal potential of greenhouses, wind turbine placement potential (including turbine height restrictions resulting from an airport south), wind speed at 60 metres altitude, deep geothermal potential, GSHP suitability, and ATES potential and particularities (for example: waste heat from supermarkets and swimming pools).

BOX 4: WOODY BIOMASS POTENTIAL IN FOURMIES

The City of Fourmies (France) is situated in a forested region and is therefore planning to construct a wood fired district heating (DH) network to heat its public buildings. Not only the forests are considered as biomass sources, residual industrial and construction wood are also included. In order to determine how much wood could be supplied locally, an inventory was made of the different types of green areas within the city limits, using the TOPO and SIGNALE databases.

Figure 14 Land use map of Fourmies, vegetation areas highlighted in green

The potential for combustible wood was estimated to be between 19.5 and 32.8 GWh/year. The next steps are identifying ownership of the individual plots and investigating storage capacity for harvested wood.

For supply potential it makes sense to also consider the surrounding region. Perhaps a large heat source is located just beyond the municipal borders, or cooperation with a neighbouring city may improve the business case for a DH network.

Regional Energy Strategies

In 2018 the Dutch national government negotiated the national ‘Climate Agreement’, in close collaboration with societal partners from the public, private and civic sectors. It included a regional governance approach that foresaw thirty Dutch energy regions (the Netherlands having over 340 municipalities), contributing a fair share to the national renewable energy goal of at least 35 TWh in wind and solar energy production, which would help reach the CO_2 emission reduction goal of 49% by 2030 (using the 1990 level as a baseline).

The Climate Agreement and the related 2019 Climate Law would pave the way for the organisation and implementation of so-called ‘Regional Energy Strategies’ (RES), giving regional energy transition governance a concrete and visible character. Next to a focus on solar and wind power, RES also address heat (yet to a limited extent). This concerns developing Regional Heat Structures which particularly concerns heat sources and infrastructure that go beyond municipal jurisdictional boundaries, and require inter-municipal coordination (Hoppe, 2021).

The province of Zeeland (in which Middelburg is located) forms one of these regions, and was the first to complete and approve its RES in 2020. You can read more here: https://www.zeeuwsenergieakkoord.nl/

2.3.5. Strategic choices

Mapping supply and demand is fundamental but practically only manifests the start of the process. Strategy development and (to differing degrees) operational decision-making will need to meaningfully involve stakeholders (see Module 1) and consider socio-economic, political, and other factors (see Module 3). In this section, we will explore how consideration of these wider factors may affect technology choices and describe some options that may be available as solutions.

When it comes to deciding on strategies, the first question is:

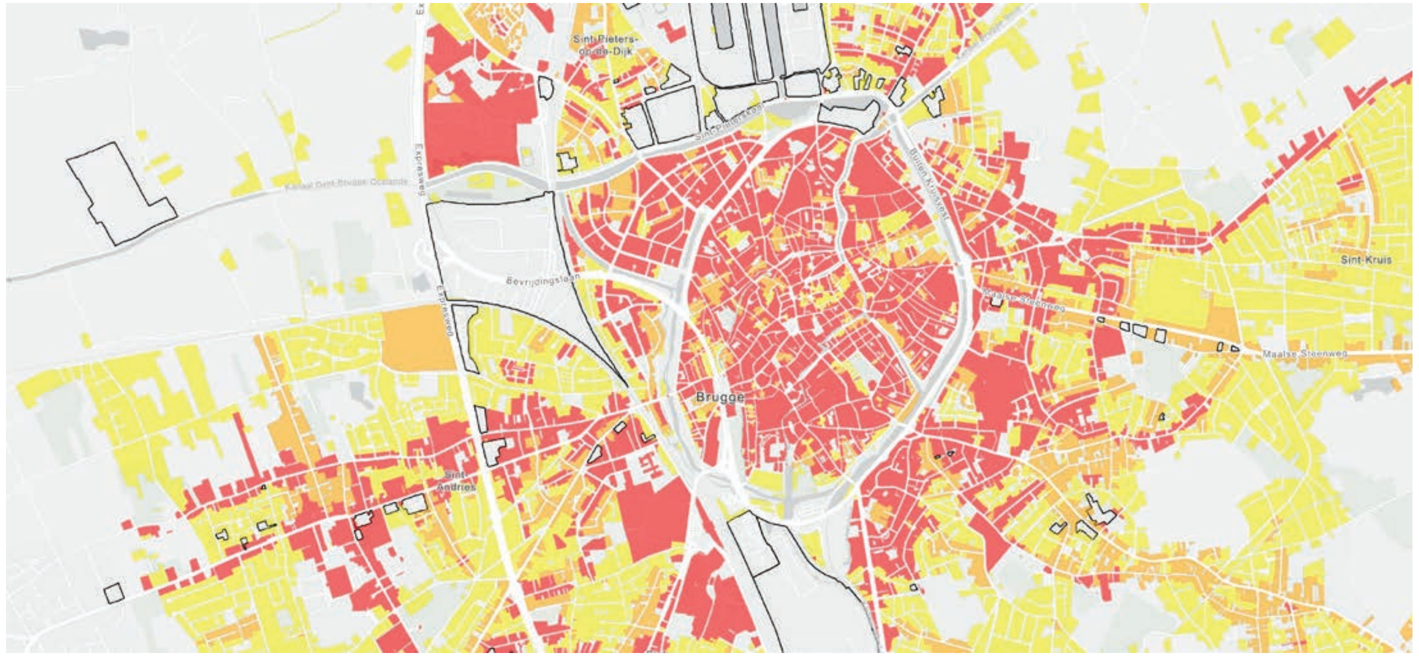
“ What goal do you want to achieve?”

For this you need to inform yourself about the current and future situation of the area you want to address (see 2.3.2), how much more efficient it can be made (2.3.3) and what kinds of renewable energy supply there are in the area and surrounding region (2.3.4).

When these are known, it becomes much easier to decide which pathways best lead to that desired situation, and which choices you have to make, when and where. This is where energy potential mapping transitions into heat zoning, making high level system choices by including not just technical, but also socio-economic, governance and other factors.

Heat zoning plans in Bruges

The City of Bruges (BE) has studied its building stock and the available heat sources, and in 2021 presented its heat zoning plan (available online at https://www.brugge.be/warmtekaart2050).



Proposed solution

Individual | Context dependent | Collective | Commercial & industrial zones

Figure 15 Heat zoning plan for Bruges: proposed solutions per neighbourhood. Source: https://www.brugge.be/warmtekaart2050

The factors included largely follow the steps described in section 2.3: current heat demand (linear demand density), future heat demand, renovation policies (socio-demographic context), long term renovation strategy (national goals), other socio-economic factors (such as age, income level, ownership and monument status) and the rebound effect (where increased efficiency inadvertently enables people to use more energy than the expected savings would suggest).

A single neighbourhood does not have to end up with the same energy system throughout. Some neighbourhoods have a more diverse building stock (for example clusters of pre 1945 buildings surrounded by 1960s apartment complexes and a few 1990s buildings). In others ownership can be diverse; a mixture of owner-occupied homes (which may include condominium associations when apartment complexes are involved), social housing organisation owned homes, and private landlord owned homes, which may complicate the adoption of a single type of heating solution, and require the use of different strategies (tailored to different groups of ownership). It may therefore make sense looking at how similar buildings are grouped in your area. Perhaps clusters can be found that can share an energy system, or there are isolated buildings that will have to be equipped with an individual one.

Temperature is an important consideration (see also 2.3.1). Although poorly thermally insulated buildings may require high temperature heat running through their radiators in order to stay comfortable, this does not mean the heating source also has to be high temperature. A low or medium temperature source can locally be boosted with a suitable heat pump (or a peak gas boiler as a transitional measure).

Furthermore, buildings can be insulated and radiators can be replaced. This will not only make the building suitable for lower temperature heating, these measures will also vastly decrease heat demand (and therefore the heating bill).

Because not all buildings can be renovated simultaneously, transitional solutions could be:

- Equipping buildings with a heat pump and a peak (gas) boiler: the latter only kicks in during the short period of the year that the heat pump cannot meet the full heat demand. The peak boiler can be decommissioned once the home is sufficiently insulated.
- Building a Low Temperature District Heating (LTDH) network, supplemented where necessary by heat pumps that increase the temperature for specific buildings.
- Designing the DH network so that it is suitable for lower temperature circulation, starting high and lowering the temperature when a) lower temperature sources are connected, and b) the buildings are ready for it.

System scale is also important; whether it makes sense to apply individual heating systems or build heat networks is partly a technical and partly an economic choice. The technical choice is about which supply sources are available and how much they can provide, and what your buildings need now and later (after renovation). The economic choice is usually determined by demand density. If there is a lot of heat demand in an area, a network might provide this heat more cheaply than a series of individual systems. On the other hand, if there are only few, thermally insulated buildings in an area, it might be easier to give them individual systems (for example a GSHP or ASHP, or a wood boiler). Figure 17 presents an overview of sustainable heating systems.

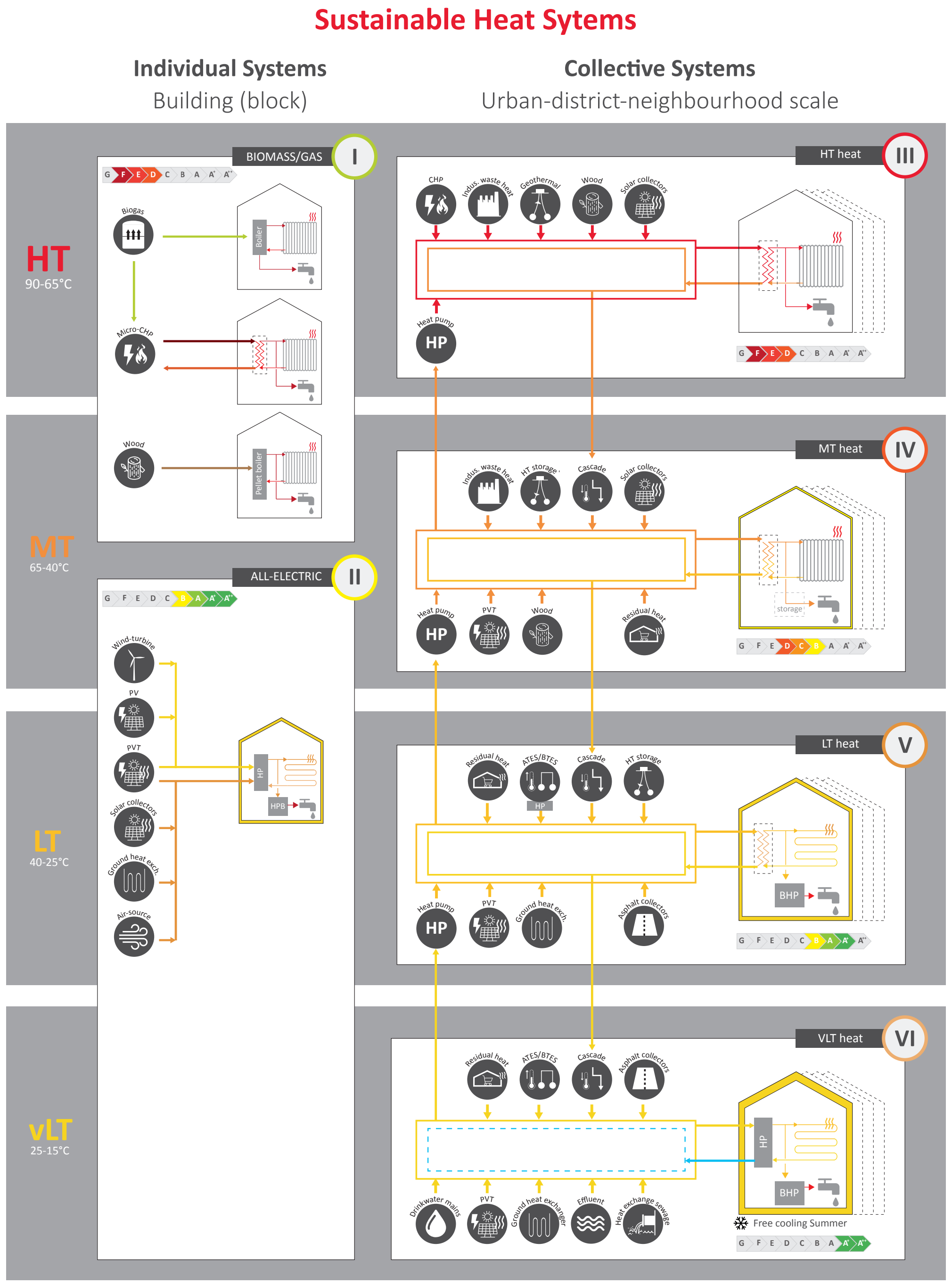


Figure 16 Sustainable heat systems diagram (City-zen 2019)

2.3.6. Measuring your impact

All these plans and choices are meant to have an impact: for that you must have a 'baseline'. Energy usage needs to be measured before measures are taken, so you can compare this to the new situation and see how much it has improved.

Section 2.3.2 describes this in more detail. Important are:

- **Which heating sources** are used (for a heat pump, that includes both the ambient heat source and the electricity required to run it)?
- **How much energy** is used from each of them (or which share of an energy source is used for heating, for example from electricity)?
- **How much CO_2** do they exhaust per unit of heat (if the electricity for a heat pump comes from the national grid rather than a renewable source, there will be CO_2 emissions)?

Sometimes national statistics are available on CO_2 footprint per household that you can use as a start. As some of these figures include everything (so also electricity consumption by lighting and appliances, and sometimes things like food consumption and family vehicle emissions), you need to make sure they are specifically on the heating system.

For the new situation, the same needs to be done. You can then compare how much CO_2 has been saved. Keep in mind that even though waste heat sources will reduce CO_2 emissions (see 2.1), they should not be considered sustainable unless the ORIGINAL heat source is sustainable! This also applies to using hydrogen (which could be generated with "grey" grid electricity) and the electricity requirements of heat pumps (although for heat pumps, the ambient energy used is of course renewable).

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