E. HEAT PUMPS MODELLING

Heat pumps are seen as one of the main technologies to decarbonise the heating sector. Indeed, their high COP (Coefficient of Performance) allow to consume much less final energy than other heating systems as most of the energy is taken from the ambient air or ground. The heat pumps can both provide Space Heating (SH) as well as sanitary Hot Water (HW). As heating represents the largest share of energy use in the residential sector, this potentially represents an important increase of electricity use in the long-term.

These two end-uses could be flexibilised under certain conditions. For space heating, there is a need to define a tolerance around a temperature setpoint. Imagining a range of +-2°C, the house temperature could vary and thus the house could be pre-heated to flatten the load. However, thermal inertia cannot be overestimated and consumer's comfort needs to be ensured by respecting the defined temperature range. Regarding hot water, with a large enough water tank, daily energy needs could be completely flexibilised. However, its total contribution to flexibility is limited due to the low energy it represents.

The methodology and nomenclature to model HPs is similar in most ways than since the previous AdeqFlex'23 study. **However, a notable improvement is included in this AdeqFlex'25 study (further described later in this document)**

- Consideration of regional tariffs, and PV self-consumption, for locally optimised heating (HP1H)

This appendix first explains how the daily energy needs are computed. Then, an overview of the operation mode of heat pumps is given. As heat pumps concern both the ones providing hot water and space heating, and that these can be operated in different ways, a zoom is made on the different ways possible to model this load.

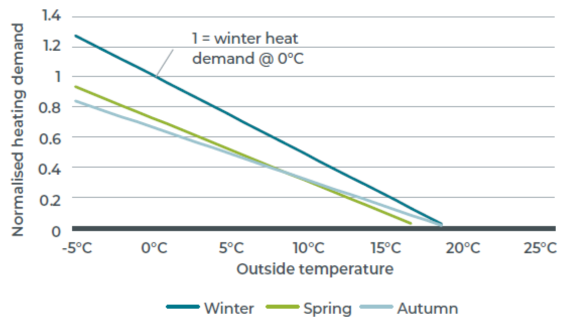
E.1. DEFINITION OF ENERGY NEEDS

The construction of hourly profiles for heat pumps consists of a set of steps as shown in Figure E-4.

- In a first phase the evolution of the number of heat pumps is determined per sector and type. A distinction is made per sector (residential, tertiary), type of heat pump (ground-water, air-water, air-air, HP with back-up) and per status of the building (new, renovated). Note that heat pumps are assumed not to be installed in buildings with poor insulation levels. For other countries than Belgium, no distinction is made between new/renovated buildings and residential/tertiary sector as those assumptions are not available data collected by ENTSO-E or in national reports.
- The primary heating need of a building equipped by a space heating heat pump is specified using a normalised annual heating demand is specified per type of building (new/renovated) and per sector (residential/tertiary).

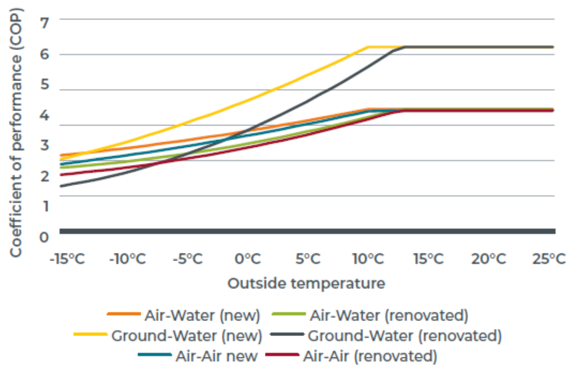
- Finally, daily heating demand is determined assuming a linear relation with outside temperature. Different linear relations are assumed per sector (residential, tertiary), month and type of day (weekday, weekend). These linear relations are obtained via residential and tertiary metering data of the gas operator Fluxys and are presented in Figure E-1. As a consequence, two days with the same daily average temperature could result in a different heating demand; for example a day in May with an outside temperature of 10°C will lead to a lower heating demand than a day in January with the same temperature, because the majority of buildings have switched to non-space heating mode and due to inertia in buildings. These linear relations are computed for each day of the year and are normalised across the 200 climate years. Finally, this normalised series is multiplied with the yearly heating demand, in this way each climate year has a different annual heating demand while the average of the 200 climate years aligns with the specified heating demand per type of building.

FIGURE E-1 — NORMALISED HEATING DEMAND IN FUNCTION OF OUTSIDE TEMPERATURE – RESIDENTIAL SECTOR, AGGREGATED PER SEASON



- Subsequently, daily heating demand is translated into daily electricity demand by applying the coefficient of performance curves (COP) per type of heat pump and building. HP efficiency depends on the delta between outside temperature and flow temperature within the heating system. As shown Figure E-2 (based on data from [NAT-1]), it is assumed that flow temperatures in renovated buildings are higher than in new builds, with a reduced efficiency as a consequence. At the same time the steering method for each heat pump is taken into account. For heat pumps which have a non-electric back-up and/or are used as secondary heating unit, it is assumed that from 5°C a back-up heating system is activated which delivers the residual heat (Figure E-3), while the contribution diminishes to become 100% from -15°C.
- In the final step the daily electricity demand per heat pump is translated into hourly electricity demand profiles using an intraday scaling profile. Those profiles depend on the flexibility assumed in the system, for which the methodology is explained in the following sections of this appendix.

FIGURE E-2 — COP CURVES IN FUNCTION OF OUTSIDE TEMPERATURE



Data based on Nature paper 'Time series of heat demand and heat pump efficiency for energy system modeling', Ruhnau et al., 2019.

FIGURE E-3 — SHARE OF HEAT DELIVERED IN FUNCTION OF OUTSIDE TEMPERATURE – HEAT PUMP WITH BACK-UP

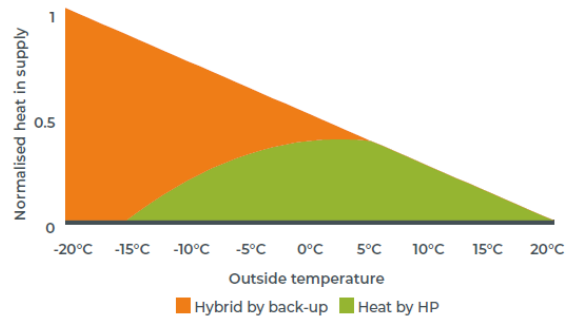
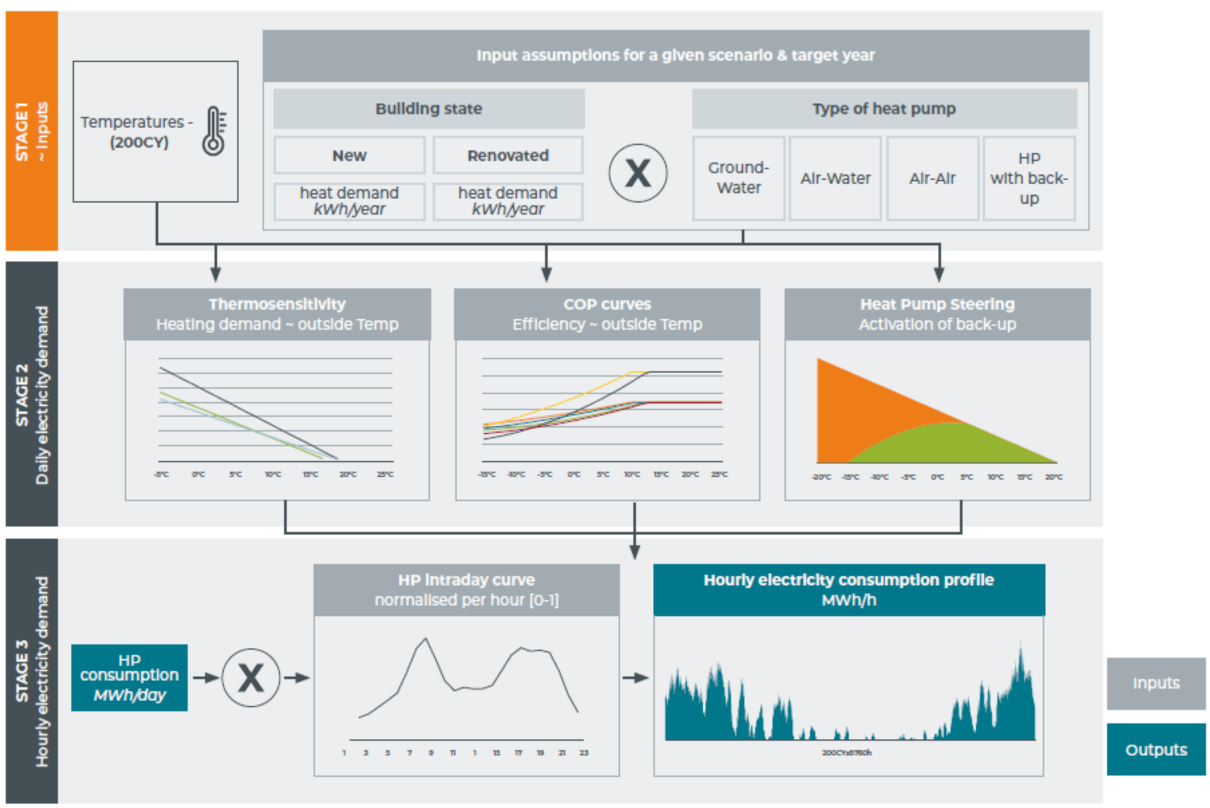


FIGURE E-4 — CONSTRUCTION OF HOURLY PROFILE FOR HEAT PUMPS



E.2. HEAT PUMP – SPACE HEATING – MODES OF OPERATION

Space heating represents the largest energy demand in the residential sector. Hence with growing electrification, there is a growing need to flexibilise this load. This part of the appendix describes the different ways of modelling heat pumps providing space heating.

A heat pump can be operated in different ways. The Table E-1 summarises the way Elia models heat pumps.

	No Flex	Local Flex (H)	Market Flex (M)
Heat pumps	Natural charging: Heating your home regardless of financial incentives	Optimised at Home: Minimise your costs following regional tariffs, or maximise PV self-consumption	Optimised in the Market: Minimise your costs following market signal based on merit-order dispatch
Rationale	HP0 Normal heating	HP1H HP load locally optimised	HP1M HP load optimised by the market (load shifting)
Modelling	Pre-defined time series	Pre-defined time series	Dispatched by the model following energy and power constraints

Table E-1 – list and description of the different ways to operate a heat pump providing space heating.

A HP providing space heating can thus be operated in the following ways:

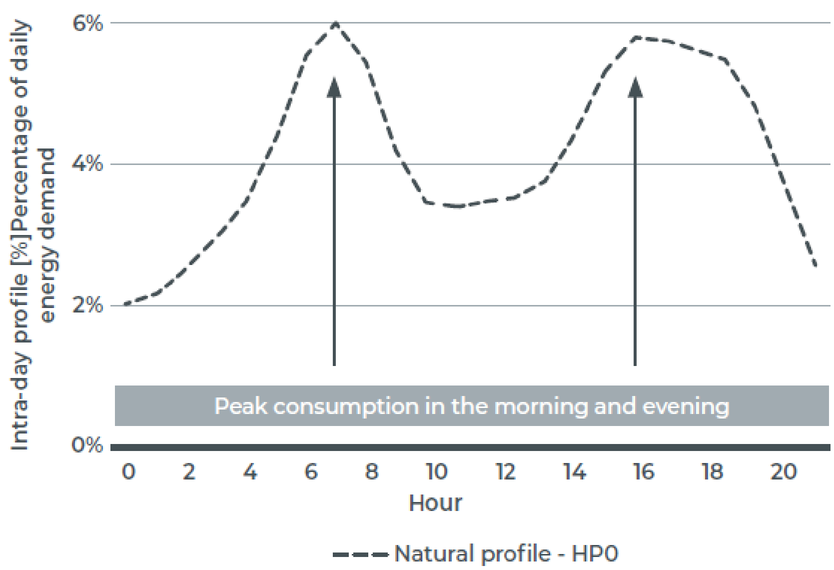
- **Natural Load (HP0):** the heat profile corresponds to the average occupation of the home. The heating peaks happen in the morning before waking up as well as in the evening, when houses are most occupied. During the day, the setpoint is set to a lower temperature, and during the night, the setpoint is even lower.
- **local optimised heating (HP1H):** just like HP0, this is a pre-fixed load time-series. This profile corresponds to an optimization based on a local signal (in opposite to a centralised market signal). This signal could be grid tariff (capacity, time of use), or incentivised PV self-consumption. For the next AdeqFlex'25 study, this profile has been improved to consider PV self-consumption and regional tariffs. Indeed, tariff differs in regions: there is a capacity tariff in Flanders (which aims to minimise peak) since 2023, and time of use tariff in Wallonia (incentivises consumption in certain periods of the day) expected by 2026. More details are given in the associated section of this appendix.
- **Smart heating – market optimisation (HP1M):** the load is dispatched when it best fits the market, while respecting constraint of power and energy. To avoid impacting consumer comfort, the maximum and minimum power is set by the respective maximum and minimum power attained by the HP0 and HP1H load profiles. For the energy constraint, the model ensures that the same daily energy needs are met for each HP.

E.2.1. HP0 – NATURAL LOAD

This load profile corresponds to the average space heating behaviour. The house is heated when most occupied, meaning no pre-heating happens. The intra-day daily profile is shown on Figure E-5. This profile shows how the daily energy demand is spread through the day. The need is slightly lower during the day, and lowest during the night. The peak consumption happens around 7 AM and 5 PM. The load is lower during the day, and evening lower at night when occupation is at the lowest point.

In the model, heat pumps associated with this operation mode have a pre-defined time-series for their load. An example is given in Figture E-5, however note that this profile represents only residential heat pumps. Different profiles are available for each sector (residential, and tertiary), are different per season, and different if it's a weekday, or the week-end.

FIGURE E-5 — NATURAL SPACE HEATING PROFILE FOR A HEAT PUMP



E.2.2. HP1H – PRE-HEATED PROFILE

Assuming that for most houses, temperature setpoint should be reached when people wake up, and come home from work in the evening, this will lead to the two peaks presented on Figure E-5. This situation is not ideal for the grid as it puts more pressure on the two already existing peaks.

Different local signals (in opposition to market signals), exist to incentivise HP owners to heat their home differently. For the next AdeqFlex'25 study, major improvements have been included in the study for the HP1H profile. Notably, the profile now considers regional differences in Belgium both in terms of (i) tariff and (ii) PV self-consumption.

Regarding the first improvements, it is known that regional tariffs are either already or planned to be implemented in Belgium. In 2023 the capacity tariff started in Flanders[1], and a Time-of-Use tariff is expected in Belgium by 2026[2]. These two tariffs will impact the way people charge their cars, giving them incentives to charge in a way that is best for the grid (i.e.: minimising peak, or outside peak hours). However, both tariffs will not impact charging behaviour in the same way. For this reason, the next AdeqFlex'25 study, includes profiles for each tariffs / region.

These profiles were developed by minimising the consumer bill. Starting from a synthethic load profile (representative of a residential load curve or a user across Belgium) from Synergrid[3], an algorithm dispatched the energy demand of the HP. The energy to be dispatched depends on the heating degree days (as explained earlier in this methodology appendix), and the algorithm does so to minimise cost (considering energy costs as well as an estimate of tariff costs).

Changing the way people heat their home will have an impact on the inside temperature. Hence, in this study we make the conservative assumption that only 10% of the daily energy consumption can be shifted through the day.

Also, the locally optimised profile now considers PV self-consumption. With greater and greater PV penetration in the residential and tertiary sector, it is expected to have flexible electrified assets (like HP) integrate renewable energy directly where it is produced. These profiles then consider the different climate years (and related local PV production) run in the study.

Hence, there are different profiles for the region of Flanders and Wallonia, and this profile differs for each day of each climate year. An illustrative example for a day in winter, with PV self-consumption is given on figure E-6. The figure depicts averaged HP profile for each region, in winter, with and without PV self-consumption.

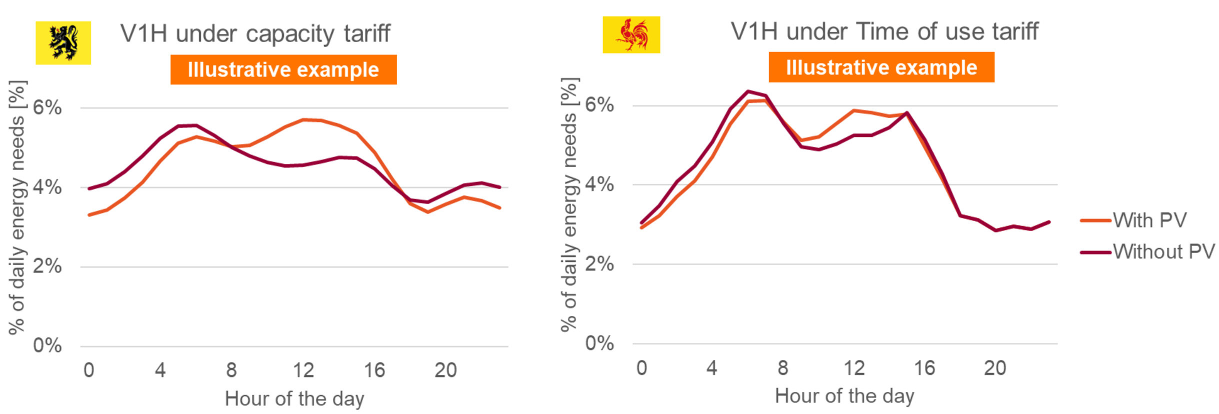


Figure E-6: local charging profile (HP1H) for two different tariffs (capacity tariff, and time of use tariff), with and without PV production.

[1] The capacity tariff | Flanders.be
[2] Méthodologie tarifaire 2025-2029 | CWAPE
[3] Profils de charge synthétiques - Profils de production synthétiques - Profils de charge réels - Synergrid

E.2.3. HP1M – MARKET DISPATCH OF HEAT-PUMPS

With each day comes variability in load profiles as well as RES generation. For this reason, a dispatchable load is a valuable asset to operate for the model in order to minimise system costs but also the final consumer's bill. With the right financial incentives and easy platforms, as well as sufficient house insulation and a connected and steerable device, space heating could be flexible. The model however needs constraints within which to dispatch the load. There are thus two constraints considered in this study: (i) one on the power, and another (ii) on daily energy needs.

The first constraint is simply set by the maximum and minimum power set by the HP1H profile. It is assumed that to ensure the consumer's comfort, the power of a heat pump could not go beyond or under the power delivered in a 'normal operation' of the heat pump.

Then, the model ensures, as second constraint, that the average daily energy needs for space heating needs to be answered for each heat pump. Note that these change for every day, for every climate year, as heating degree days (serving as basis for computing heating needs) change every day. For more info on this, see Appendix B on electricity consumption).

In conclusion, given an amount of energy to be answered every day and limits on power rate, the model dispatches this load through the day, at moments where residual load and electricity prices are the lowest.