UGent review of Elia heat pump method and assumptions

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1. Introduction

Ghent University (UGent) was requested by Elia to review a number of specific assumptions used in the modelling of heat pump electricity demand. More specifically, the assumptions related to:

1) Which share of the air-to-air heat pumps that are known to be installed in Belgium are only used as 'secondary' heating systems, and which share of building heat demand do they cover.
2) What is the annual heat demand of residential buildings that are heated with a heat pump
3) Which COP curves should be used for different types of heat pumps
4) How should electric back-up resistance heaters be considered

In this document, UGent reflects on each of these matters, indicating whether or not the assumptions and approaches considered by Elia are valid, given the inevitable uncertainties involved and Elia's use-case in particular, namely the biennial "*Adequacy and Flexibility*" studies. In addition, UGent has taken the liberty to additionally reflect on:

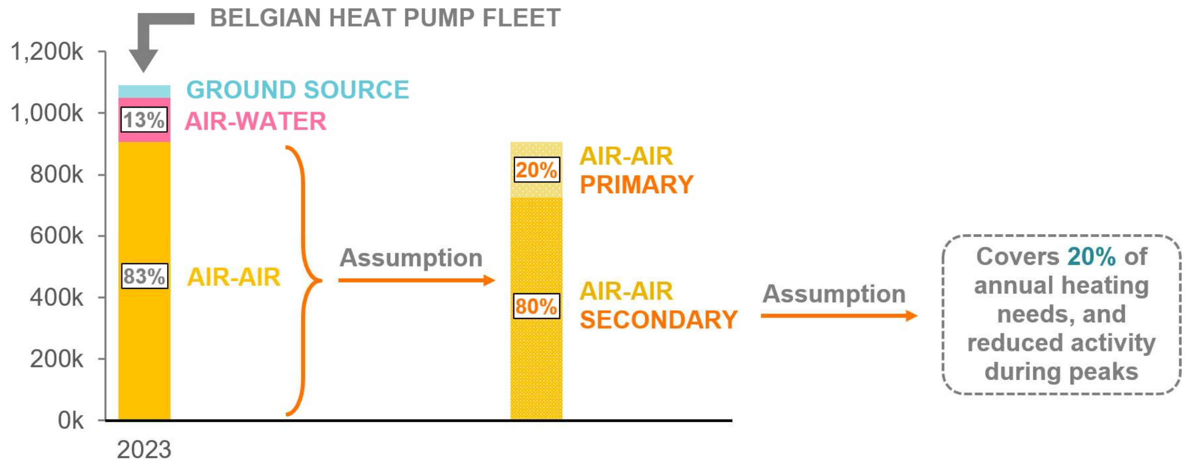
5) The approach taken by Elia in terms of how secondary air-to-air heat pumps transition to a non-electric back-up heating system as outside temperatures decrease
6) The fact that Elia choses for a top-down approach as opposed to bottom-up
7) The number of building archetypes used by Elia to resemble the Belgian building stock

Our goal was limited to reflecting on specific elements of the current approach taken, refraining from any suggestions about how we as academic researchers would design the entire modelling pipeline ourselves (for the Ad&Flex use-case). Neither did we review Elia's modelling of heat pump *flexibility*, which is an entirely different subject in and of itself.

2. Remarks UGent

2.1. Determining the Belgian heat pump asset-mix and dealing with air-to-air

Elia estimates how many heat pumps are currently installed in Belgium – per heat pump type – based on the best available data. Approximately 80% of the total number of heat pumps in Belgium are of the type air-to-air, and it is unclear to which degree these heat pumps are used for space heating, as many of them are supposedly installed primarily with a cooling use-case in mind. UGent recognises this problem, although it is clear from contacts with the sector itself that manufacturers do have the usage-data necessary to remove this uncertainty. However, these fleet-monitoring data have so far not been made available to Elia or UGent due to commercial sensitivities.



Elia's best estimate of the current Belgium heat pump fleet[1], visualised by UGent

As UGent understands, Elia will assume in the 2025 Ad&Flex study that 80% of the air-to-air heat pumps in Belgium are "secondary" heat pumps, which cover 20% of a building's annual heat demand. Lacking any formal data sources to contradict these assumptions, UGent views these values are reasonable estimates. In **section 2.4.3**, we reflect on Elia's modelling of how exactly these secondary air-to-air heat pumps are operated.

2.2. Annual heat demand of buildings heated with a heat pump

To estimate the hourly electricity consumption of the Belgian residential heat pump fleet in the next 10 years, Elia uses a step-wise approach that begins with assumptions about the annual space heating demand of two types of residential buildings. These two types are "New" and "Renovated", resembling the two major categories of residential buildings that can be heated with a heat pump. The assumed space heating demands for these two types are 4400 kWh/year and 8000 kWh/year, respectively. As UGent understands it, Elia has received these values from

[1] As currently planned for the upcoming 2025 version of the biennial Elia Adequacy & Flexibility study.

Fluvius, which has based them on metered gas consumption data for buildings with an energy label A and C, respectively. To split gas consumption data into gas consumed for space heating versus domestic hot water (DHW), Fluvius considered the level of gas consumption taking place outside of the heating season. The remaining gas consumption used for space heating was translated into building heat demand by taking into account the efficiency of a typical gas boiler.

Building Type		Heating requirements	
		Space heating (kWh/yr)	Water heating (kWh/yr)
Residential	New	4400	1800
	Renovated	8000	
Tertiary	New	17 000	3600
	Renovated	25 500	

Reviewed by UGent

Elia assumptions about the annual space heating demand of buildings that are heated with a heat pump[2]

UGent can review the assumed values to check whether they are in the right order of magnitude according to our own estimate. We do this by considering the metered Fluvius data that was published in a recent report written by UGent for VEKA[3].

We use this report as a reference to review Elia's assumptions because, unfortunately, VEKA, VREG or Fluvius do not publicly share any average metered energy consumption data for the categories of residential buildings that are required here. To UGent's knowledge, the only relevant datapoint made publicly available by VREG is the fact that an average Flemish household consumes 17.000 kWh/year of natural gas for space heating[4]. However, this includes *all* homes, which are predominantly poorly insulated in Flanders. Therefore, this figure cannot be used as a proxy for the heat demand of newly built or renovated homes that are heated with a heat pump.

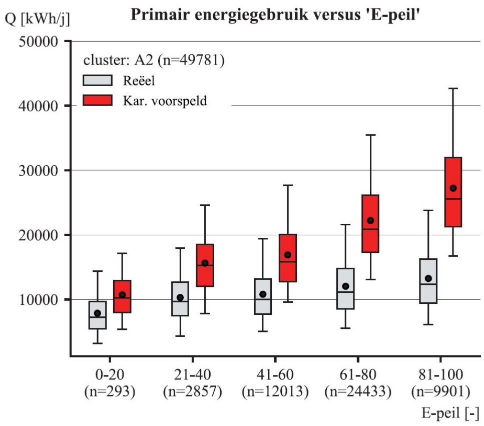
In the 2021 UGent report written for VEKA, Figure 2.12 (p. 77) considers single-family homes (i.e. detached, semi-detached and terraced buildings, but – unlike Elia' figures – excluding apartments) that use natural gas both for space heating and DHW. In this figure, shown below, the grey boxplots show the metered total gas consumption of these buildings, as measured by

[2] Elia (2023) *Adequacy & flexibility study for Belgium (2024-2034), p. 100,* *https://www.elia.be/en/electricity-market-and-system/adequacy/adequacy-studies*

[3] *Analyse naar de haalbaarheid van statistische modellen die energiegebruik in woningen kunnen voorspellen op basis van gebouwparameters (2021) Matthias Van Hove, Marc Delghust, Arnold Janssens.* *https://assets.vlaanderen.be/image/upload/v1665674115/Analyse_haalbaarheid_statistische_modellen_die_energiegebruik_woningen_voorspellen_obv_gebouwparameters_quxvuv.pdf*

[4] https://www.vreg.be/nl/energieverbruik

Fluvius in the period 2012-2019. Buildings are categorized according to E-peil, covering a range of energy performance levels from very high (0-20) to mediocre (80-100).



E-peil	Gas consumption kWh/year	Space heat demand kWh/year	
0-20	7 800	5 220	New
21-40	10 200	7 380	
41-60	10 700	7 830	Renovated
61-80	12 000	9 000	
81-100	13 200	10 080	

Translating measured gas consumption data of dwellings in different E-peil categories (grey box plots)[3], into estimates for the space heating demands of new and renovated buildings that are heated with a heat pump

When we manually extract the values of the averages shown in the figure (black dots in the grey box plots), we get the values shown in the table on the right-hand side. These total gas consumption figures can be translated into space heat demands by subtracting an assumed 2000 kWh/year of DHW and multiplying the remainder by 0.9 to reflect the losses of the gas heating system. This way, we can deduce that the average space heat demand in "**new**" residential buildings (E-peil 0-40) is **5220-7380 kWh/year**, while it is **7830-9000 kWh/year** in the case of "**renovated**" buildings (E-peil 40-80). This aligns rather closely to the assumptions taken by Elia (4400 and 8800 kWh/year, respectively). The fact that Elia's assumptions are lower – especially for 'new' – can be explained by the fact that apartments, which often have a high energy performance, are not included in the UGent figure. In conclusion, UGent can thus confirm that Elia's assumptions appear to be reasonable.

2.3. From annual building heat demand to daily building heat demand

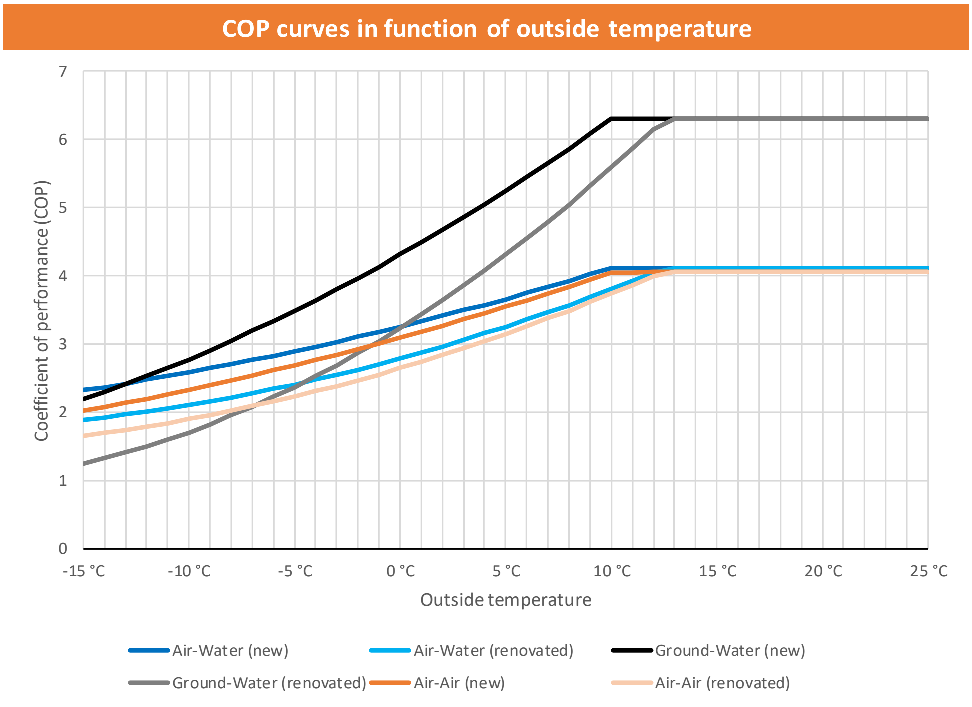
Operators of the gas grids in Belgium know how much gas is being consumed at the distribution level from month to month. These data show clear peaks in the winter months, due to increased heating requirements. As UGent understands it, these data are used to approximate a linear relationship between outside temperatures and space heating demands. This relationship is subsequently used by Elia to translate the assumed annual heat demands of their different building types into daily heat demands. More specifically, the daily temperatures in their '200 future climate years' dataset are translated into 365 individual percentages – together summing up to 100% – to divide the annual heat demand number (e.g. 4400 kWh/year) into heat demands for each day of the year. UGent believes this approach is reasonable.

2.4. From daily building heat demand to daily heat pump electricity demand

2.4.1. COP curves

General reflection on COP curves

In its 2023 Ad&Flex report, Elia presents the following COP curves used for the three different types of heat pumps (air-to-air, air-to-water and ground-to-water), across the two types of buildings that are distinguished (new and renovated):



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

Heat pump COP curves assumed by Elia in the 2023 Adequacy and Flexibility report[2]

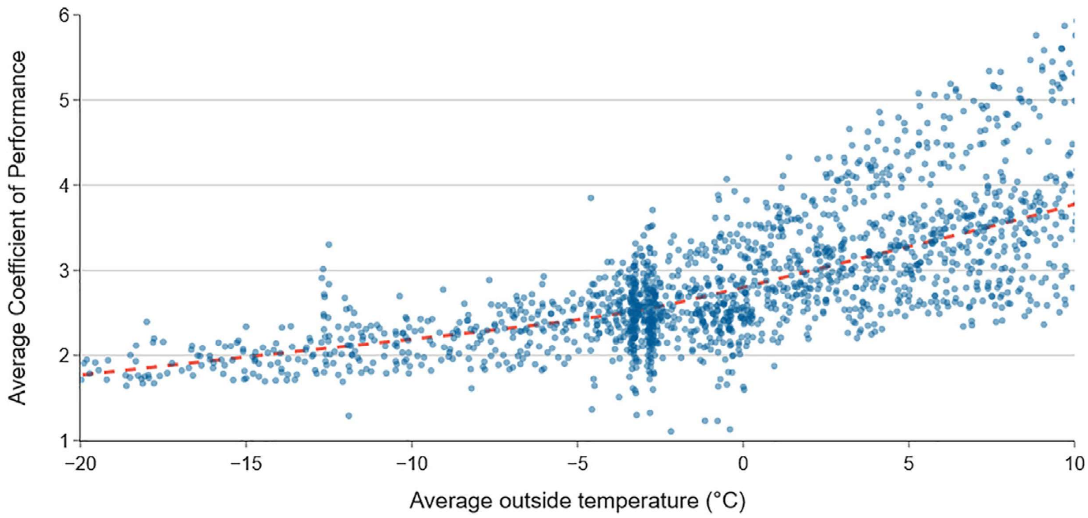
It is unclear to UGent *how exactly* the COP values presented in the referenced Nature article were translated into the COP-curves shown in the Elia figure. Presumably, this was done by (first) formulating specific assumptions about the supply temperatures[5] that are required in the case of 'new' and 'renovated' buildings.

UGent is currently not aware of any 'better' sources for heat pump COP assumptions, given the fact that data about measured (real-world) COP's are only scarcely available. Heat pump manufacturers presumably have large amounts of such data, retrieved over the internet from

[5] I.e. the temperature to which the heat pump heats the water that is sent to the underfloor heating system or radiators/convectors. Elia could for example have assumed that heat pumps in newly built homes with underfloor heating operate with a supply temperature of 30°C, while those in renovated homes with radiators operate with a supply temperature of 50°C.

their fleet of installed assets, but they currently have not (yet) shared these data with Elia or UGent due to commercial sensitivities.

Third-party initiatives collecting real-world COP data do exist, but there are relatively small in size[6]. However, a recent academic study did perform a best-effort to collect as much real-world COP data as possible (see figure below). While the COP curve presented in this study only covers air-source heat pumps (ASHPs), it does appear to align quite closely with the corresponding curves in the Elia figure, leading UGent to conclude that the continued use of these curves (based on the 2019 Nature publication) appears reasonable.



Real-world measured COP's from a variety of data sources[7]

What is also unclear about the COP curves used by Elia, is whether or not the effect of an electric back-up resistance heater is included in it or not. To the best of our knowledge, the use of electric back-up heaters is typically *not* included in heat pump COP curves, unless explicitly stated otherwise. For example, the COP curves made public on official heat pump "product spec sheets" typically do not include the effect of an electric back-up heaters[8]. We delve further into the specific aspect of electric back-up heaters in the next subsection (**2.4.2**).

It should also be noted that – strictly speaking – real-world heat pump COPs are almost never truly measured. Heats pumps do typically report their own estimated COP (e.g. on the unit's display), but these estimates are based on underlying models, the accuracy of which is unclear. For a reliable and accurate measurement of a heat pump's COP, the electricity consumption of the entire machine needs to be measured, as well as the heat delivered to the home. Such

[6] See, for example, https://heatpumpmonitor.org/

[7] Gibb, D., Rosenow, J., Lowes, R. and Hewitt, N. (2023) Coming in from the cold: Heat pump efficiency at low temperatures. Published in *Joule*. https://www.janrosenow.com/uploads/4/7/1/2/4712328/coming_in_from_the_cold_final.pdf

[8] When the effect of an electric resistance back-up heater is included on a heat pump spec sheet, it is typically only included in the annual value for the seasonal performance factor (SPF).

measurements require a MID-certified electricity meter and a calory meter measuring the flow of water going towards the heat emission system (e.g. underfloor heating). Due to the extra costs related to these measurement devices, they are rarely included by heat pump OEMs in the machines themselves. In principle, a large-scale measurement campaign is required to accurately inform modelling such as Elia's, which would entail the installation of all the correct measurement equipment on hundreds or even thousands of real-world heat pump installations.

COP curves assumed for ground-source heat pumps

It is surprising that the "worst" COP shown in the Elia figure is reached by the heat pump type "ground-water (renovated)" (grey line). Typically, one would expect ground-source heat pumps (GSHPs) to have a higher (not lower) COP compared to ASHPs. Especially when the outside temperature is low – given the fact ASHPs need to extract heat from this outside air. Meanwhile, a GSHP extracts its heat from its underground source, which is typically 10-12°C.

The underground depth of GSHP systems is typically 70-90 meters, and while the first few meters are subject to seasonal fluctuations in temperature, everything below 10 meters is rather constant in temperature. That it, until the heating season begins and the GSHP starts extracting heat from its source. Depending on the size of the system, how it is configured, and how cold the outside temperatures gets during the heating season (i.e. how much space heating is required), the source will cool down by several degrees. By the end of the heating season, the source has typically cooled down to e.g. 5°C, although this could be as low as 1-2°C depending on circumstances.

After a heating season has ended (in spring), the underground surrounding the system has the time to naturally return to its standard temperature of 10-12°C. However, many GSHPs help restore this temperature and can even exceed it, by cooling the building in summer. As heat is transferred from the home to the underground, the temperature increases. Depending on how much cooling occurs during the summer[9], it is possible for the underground to be heated to several degrees above its standard temperature, thereby allowing the heat pump to start off the new heating season with a higher COP.

UGent suggests Elia to update the COP curves for GSHPs, which could be done in a number of ways. The simplest method would be to assume an underground source temperature which linearly decreases from 10-12°C in the beginning of the heating season to 0-5°C at the end of the heating season. In a more advanced alternative, fluctuating heat demands occurring from month to month could be used to model a non-linear decrease. While the underground temperature at the start of the heating season would remain the same, it would decrease according to heat demands as they occur in the heating season, i.e. faster when it's colder outside and slower when outside temperatures are mild.

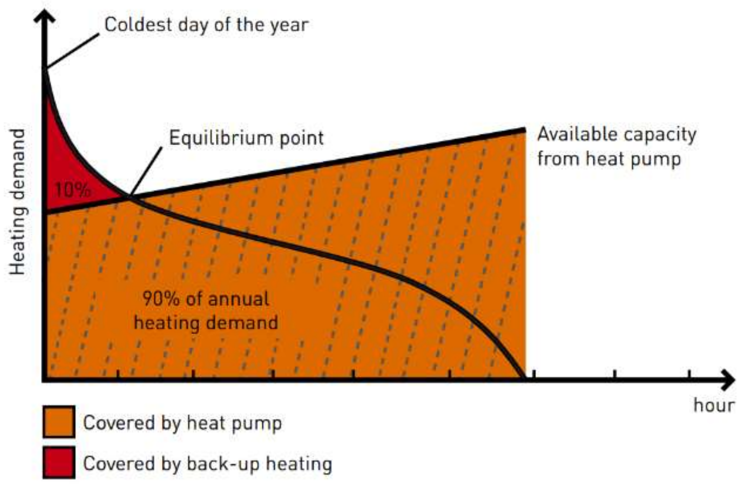
At the same time, any newly made COP curves for GSHPs should still bend downwards as outside temperatures drop (i.e. when plotted on a graph with COP on the Y-axis and outside temperature

[9] And other parameters like the field configuration, thermal conductivity of the soil and the ground water movement, etc.

on the X-axis). However, unlike the ASHPs (air-to-water and air-to-air), this is an indirect effect – given the fact that the outside air is not the heat source in the case of a GSHP and the time lag between the change in outdoor and ground temperature. Instead, the reason for the downwards bend is the increase in the heat demand of the building, which coincides with an increase in the building's heat loss. As the heat loss increases, the flow temperature – i.e. the temperature supplied to the underfloor heating or radiators – needs to be higher. For example, in a newly built home the flow temperature may be 30°C on mild days, but 35°C on colder days. The reason being that more heat needs to be transmitted to the home, to maintain the same user setpoint temperature (e.g. 21°C) given the higher heat loss caused by lower outside temperatures. For a given source temperature, a higher flow temperature means that the COP will be lower – as it is the delta between source and supply temperatures that fundamentally determines the COP of a heat pump.

2.4.2. Electrical resistance back-up heating

Some heat pumps include back-up resistance heaters to assist the heat pump in producing a sufficient amount of heat under rare extreme circumstances. The figure below indicates how this works, considering an ASHP. As the outside temperature drops and the heat demand of the building increases, the amount of heat that can be delivered by the heat pump itself decreases ("*Available capacity from heat pump*"). In a very limited amount of hours per year, this results in the heat pump being unable to meet the building's heat demand. During these rare moments, the electrical resistance back-up heater turns on to generate a supplementary amount of heat. This way, the sum of the heat generated by the heat pump itself and the back-up heater covers the total heat demand.



Purpose of an electric resistance back-up heater integrated into a heat pump[10].

[10] Daikin Altherma Technical Catalogue For Installers. Air to water heat pumps. https://www.daikin.eu/content/dam/document-library/catalogues/heat/air-to-water-heat-pump-high-

Although not all heat pumps necessarily include an electrical back-up heater, both the installer and the user are often incentivized to include it. Back-up heaters are relatively cheap, which means that including them allows the heat pump itself to be somewhat smaller, and thereby cheaper overall. Instead of having to choose for a more expensive heat pump of a bigger size – which could still cover the building heat demand even during the coldest hours of the year – a smaller heat pump can be chosen in combination with a built-in back-up heater. This can be interesting from the perspective of an installer, who wants to attract business by offering an attractive price for the heating system he installs, and from the perspective of the user, who wants a heating system that can cover his heating needs as affordably as possible. Since the back-up needs to be used in only the rarest, most extreme moments, its impact on the annual running costs of the heat pump are negligible.

In practice, an installer installing heat pumps of a certain brand typically only has a few discrete options in terms of the size (exact model) of the heat pump. This means that the reasoning explained above applies mostly when the heat demand of the building is slightly higher than what the closest-matching heat pump model can deliver on its own (i.e. without an electric back-up heater). In such cases, adding an electric back-up is a financially attractive way to ensure comfort during the coldest moments. Conversely, when a heat pump model is chosen that has a higher capacity than what is needed to meet the building heat demand during the coldest hours of the year, adding a back-up is unnecessary and therefore unlikely.

Several additional complexities arise in practice. First of all, it is sometimes up to the installer to determine the power capacity of a back-up unit. Options may exist to pick an electric resistance heater with a capacity of 1 kW, 2 kW, 3 kW, etc., and not every installer may pick the exact same option. Secondly, it is a known phenomenon that back-up units that are included in a heat pump are sometimes completely turned off (software wise) or simply not connected to a power supply[11]. Finally, even when a back-up heater is included in the heat pump and is allowed to function, the user or installer may introduce – through the system's configuration – specific 'rules of thumb' about when the back-up actually activates. These conditions for activating the back-up heater can be specified in a variety of ways.

As far as UGent knows, insufficient real-world data is available to know exactly...

- Whether heat pumps are typically somewhat under- or over-sized
- Which share of heat pumps have a back-up heater to deal with being undersized
- What the capacity of back-up heaters is (1 kW, 2 kW, 3 kW,...)
- Which share of installed back-up heaters are actually allowed to function
- How the conditions for activating back-up heaters are configured in practice

Trustworthy large-scale data about these elements is simply unavailable. The only way to reduce these uncertainties is to regularly survey large groups of heat pump installers and/or OEMs.

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temperature/ekhbh-a/Altherma%20technical%20catalogue%20for%20installers_EPCEN08-721_Catalogues_English.pdf

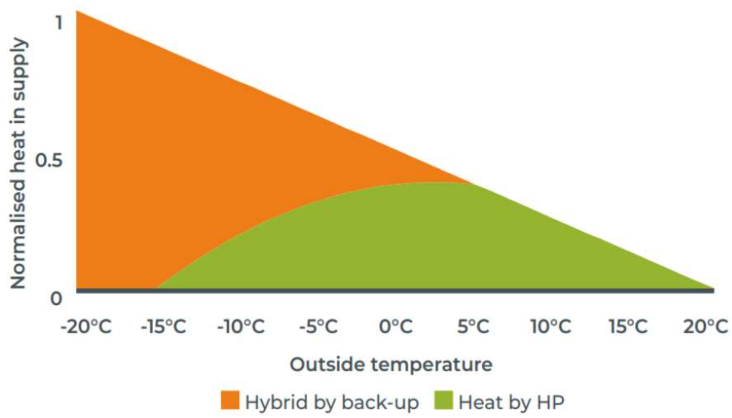
[11] In certain cases, the manufacturer requires the electric back-up heater to receive its own separate power supply, with its own cable connecting to the building's electrical panel. This causes a need for additional work performed by an electrician, the extra cost of which may not be deemed worthwhile.

As long as these uncertainties persist, it is extremely challenging to make any strong claims about the role of back-up resistance heaters in the future Belgian heat pump fleet, and how they may impact the electricity demand we should expect from this fleet during the a rare cold-spell with extreme sub-zero temperatures.

UGent recommends that Elia runs a sensitivity simulation in which it is assumed that a high share of the heat pump fleet has electric back-up heaters which actually activate when the coldest temperatures occur. After all, if a million Belgian heat pumps increase their electricity demand by a single kilowatt due to the activation of a back-up heater, an additional gigawatt of electricity supply needs to be available to meet this load.

2.4.3. Non-electric back-up heating

In the 2023 Ad&Flex report, Elia explains how the assumed fleet of secondary air-to-air heat pumps is operated in the simulation model. Given the fact that these heat pumps do not cover 100% of the building's annual heat demand, a certain heuristic has to be modelled to determine when they heat and to which degree. Here Elia has chosen for an approach whereby the outside temperature determines which percentage of the total heat demand is covered by the heat pump, as illustrated in the figure below. As the figure indicates, a secondary air-to-air heat pump is assumed to cover the full building heat demand during all moments when the outside temperature is above 5°C. When the outside temperature drops below this threshold, the share gradually decreases until it reaches 0% at -15°C. The heating system that takes over is called the 'back-up system', which is explicitly non-electric (e.g. heating fuel, gas, wood,...).



Operation of secondary air-to-air heat pumps
as assumed by Elia in the 2023 Adequacy and Flexibility report[2]

As mentioned before, heat pump manufacturers have the necessary fleet monitoring data to confirm or correct this assumed mode of operation, but they have (so far) not yet made these data available to Elia or UGent. Given these uncertainties, the abovementioned approach appears to be reasonable, although a few supplementary remarks can still be formulated:

1) In principle, it is possible that secondary air-to-air heat pumps are *not* used when temperatures are mild, if users feel like "supplementary heating" is not required then. Perhaps these heat pumps are activated as soon as temperatures drop below a certain point, and are used *increasingly* as it gets colder. Namely, if the "problem being solved" is the fact that the "primary" heating system (e.g. a wood stove) is insufficient to reach comfort in all rooms when outside temperatures are exceptionally low. It should be noted however that – without any fleet monitoring data – this remains a matter of pure speculation.

2) To achieve the goal of eliminating the carbon emissions associated with the fossil-fuelled heating of buildings, policymakers will need to implement the actions necessary to reduce the household-level price ratio between electricity and gas. Assuming that the ratio will be decreased from current levels around 4-to-1 to a new level of 2-to-1, it will become financially attractive for those with a secondary air-to-air heat pump to cover 100% of their heating needs with it. This would have two implications. First, a number of air-to-air heat pumps that are currently assumed to be "secondary" would instead become "primary" (i.e. used to cover the entire building heat demand). Second, the air-to-air heat pumps that would still be labelled as "secondary" would likely cover more than the currently assumed 20% of annual heat demands.

3) In practice, air-to-water heat pumps are also sometimes combined with a gas-boiler in so-called "hybrid" systems. Depending on the configuration of such installations, 100% of heating may switch over to the gas boiler as soon as a specific outside temperature threshold is reached. However, given the lack of data on how such hybrid systems are configured exactly, combined with the fact that these type of installations are quite rare, UGent believes they can be safely ignored.

4) UGent understands from Elia that the smooth "transition to back-up heating" depicted in the figure above could in principle also be used to explicitly model electric resistance back-up heaters. However, UGent would advise against this. While there are many uncertainties regarding the presence and use of electric back-up heaters in the installed heat pump fleet (*cf.* ***section 2.4.2*** *above*), it is nonetheless certain that they are not intended to fully replace the heat delivered by a heat pump from a certain outside temperature onwards (e.g. at every temperature below -15°C, as depicted in the figure). Heat pumps used for space heating still produce far more than 0% of the required heat during moments of exceptionally cold temperatures. Although the thermal capacity of an air-source heat pump can decrease somewhat when outside temperatures drop, it does not at all 'disappear' completely. Ideally, electric resistance back-up heaters should therefore be modelled as devices which *supplement* the output of the heat pump when needed, and only to the degree necessary. Again, taking into account the remarks formulated in the previous subsection, namely, that hardly any data is available today about the presence and use of electric back-up heaters.

2.5. Top-down versus bottom-up

The stepwise approach used by Elia to estimate the hourly electricity consumption profile of the future Belgian heat pump fleet can be described as a “top-down” approach. It focusses on leveraging a number of high-level datapoints to piece together an estimate of heat pump electricity consumption at the aggregate level. Real-world measurement data is favoured over data coming out of (building) simulations, the diversity of existing buildings is aggregated into only a very limited number of building types, and the detailed dynamics of heat pump operation at the individual building level are not thoroughly considered.

This stands in contrast to the approach taken by UGent in the recent FlexSys research project[12]. In it, 66 types of individual residential buildings were distinguished and simulated thoroughly to investigate heat pump operation and the electricity consumption that results from it. Furthermore, the heat pump electricity consumption results coming from these thousands of individual building simulations were subsequently aggregated to arrive at the fleet-level electricity consumption profile in future years. This approach can be described as bottom-up, and relies more heavily on the accuracy of the underlying building simulations, as opposed to relying on measured energy consumption data.

For Elia’s use-case of estimating the Belgian fleet-level heat pump electricity consumption, UGent thinks a top-down approach relying on real-world measurement data is reasonable. Using average measured energy consumption data guarantees that any conceivable feature of the underlying reality is “captured”. For example, the average measured energy consumption data includes whichever heating related habits and behaviours users have in practice – which may not always be fully or accurately captured by simulation models like those used by UGent. Similarly, such averages also include the very low energy consumption of certain building types that may not be considered by models, like secondary homes (which are only heated when the owner occasionally resides there) or student occupancies (which often remain unheated during the weekends).

2.6. Number of building archetypes

When modelling the Belgian residential building stock, UGent distinguishes between 66 different archetypes of buildings. Namely:

- Detached (3 size variants)
- Semi-detached (3 size variants)
- Terraced (3 size variants)
- Apartment corner (1 size variant)
- Apartment enclosed (1 size variant)

For each of these 11 types of buildings, 6 further variations are made, varying their thermal insulation characteristics from labels A to F, thereby resulting in 66 archetypes in total.

[12] https://www.flexsys-project.be/project/#goal

While this thorough disaggregation into so many different types of buildings is important when the research goal is to study the dynamics of heat pump electricity consumption at the individual building level, it is less important when the goal is to estimate the future electricity consumption at the national heat pump fleet level.

It remains an open question whether distinguishing between only two types of residential buildings (‘new’ and ‘renovated’) is sufficient, even for Elia’s use case focussed on the national fleet-level. However, it is not possible for UGent to make any strong statements about what the minimum level of disaggregated building types needs to be to enable a sufficiently-accurate estimate of heat pump electricity consumption at the Belgian level. Continuing with the current building types used by Elia can therefore be considered a reasonable approach.

3. Conclusion

UGent’s review of the specific elements considered in this document can be summarized as follows:

1) Elia’s approach requires explicit assumptions about the annual space heating demands of buildings with a heat pump. Direct measurements of such space heating demands are only scarcely available, so estimates need to be made on the basis of the historically metered gas consumption of buildings that are thought to be a good proxy (e.g. on the basis of energy labels). While imperfect, this approach is reasonable given the boundary conditions in terms of limited data availability and Elia’s specific use-case. The values used by Elia are also in line with the values found in a study performed by UGent (for VEKA).

2) The COP curves used by Elia can be slightly updated, in particular with respect to ground-source heat pumps, but are generally speaking in line with the best available COP data in the literature. A real-world measurement campaign would be beneficial to further improve the accuracy of the COP’s used in Elia’s simulations, but this could take a significant amount of time and resources.

3) Electric resistance back-up heaters should be explicitly modelled by Elia, in order to perform a sensitivity analysis indicating the potential impact on Belgium’s electricity generation requirements in the future. Unfortunately, there is a lot of uncertainty about the reality on the ground in terms of how frequently heat pumps are equipped with such back-up units, and how exactly they are used. This implies that the aforementioned sensitivity will necessarily be speculative in its nature.

4) Air-to-air heat pumps make up the vast majority of the Belgian heat pump fleet, and it remains unclear to which degree they are used as a primary space heating device. Out of necessity, Elia makes assumptions about which share of the air-to-air heat pump fleet should be modelled as “secondary heating” – and choses for a specific approach in terms of modelling how exactly they are operated. UGent recommends further efforts to obtain

real-world data about these assets from the heat pump manufacturers, which are known to monitor their fleets. This way, the huge uncertainties about air-to-air heat pumps can be reduced and Elia will get a more reliable sense of how these hundreds of thousands of assets can be expected to impact the Belgian electricity system.

5) For Elia's use-case of estimating the electricity demand of the entire national heat pump fleet, UGent recognises that it is reasonable to use a top-down approach combined with a limited disaggregation of different types of buildings.