Open Flexibility Alliance

Toward Flexible Control of Heat Pumps in Two Steps

A blueprint for a (rudimentary) smart grid protocol for heat pumps that can be implemented rapidly

With a look ahead at a more extensive protocol with more advanced functionalities

- Final report -

This project was carried out by Technolution, Business Development Holland (BDH), and Silentric commissioned by the Flexiblepower Alliance Network (FAN), TKI Urban Energy, and the Netherlands Enterprise Agency (RVO).

Redefining **solutions**

Colophon

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Summary

Context
The drive to heat homes sustainably is picking up in residential development and heat pumps are a major part of this. The number of heat pumps installed is growing by 30–40 % every year and this growth is accelerating. It will result in a significant rise in electricity consumption in residential development, beyond the capacity of the power grid in its current dimension. The application of (both hybrid and fully electric) heat pumps and electric vehicles are driving up the demand and peak load on the power grid; over time, this may lead to network congestion on the low-voltage networks.

The growing number of heat pumps, in combination with dynamic energy prices, can help to partially absorb to excess supply of (sustainable) electricity. Flexibility from heat pumps, once available, also helps to facilitate consumers who are keen to respond to dynamic energy prices, or to prevent their PV system from switching off during congestion (for example by proactively warming the boiler tank at that time), etc.

There is therefore a growing need for flexibility in the network, both in respect of power generation and of consumers. Growth is currently forecast to reach up to 300,000 installed heat pumps per year by 2029–2030 at the latest. This means that a realistic estimate of the installed base of heat pumps will be more than 1.5 million in 2030, which creates a real need for network operators to have the possibility to switch heat pumps on or off to avoid congestion. Not just at outdoor temperatures far below zero °C, but even, for example, at temperatures such as 8 °C, when large numbers of installed (hybrid) heat pumps together demand greater quantities of electrical energy than we have been used to.

Heat pumps as a source of flexibility
The currently installed base of heat pumps is not scalable because there is no standard protocol to control them and no infrastructure that can apply such a protocol. Suppliers can distinguish themselves for future clients by supplying heat pumps that are switchable.

In addition to being substantial consumers of electricity, heat pumps are a demonstrable potential source of flexibility, because heat pump technology is such that the electrical power of heat pumps can be switched on or off for periods of time. The thermic mass of homes (homes can do without heat supply for a while without loss of comfort) and possibly other forms of thermic energy storage (such as the hot water buffer) that are connected to the heat pump make heat pumps a shiftable load from the perspective of grid management. A reasonably to well-insulated home can do without heat supply for a few hours; and this period can be extremely valuable for congestion reduction.

To determine this flexible load and actually realize it, a uniform heat pump control system needs to be put in place. Heat pumps can be made flexible in four ways:

1. by switching heat pumps on or off (avoiding grid load or reducing input locally),
2. by switching heat pumps on later or earlier (shifting net load in time),
3. by increasing, reducing, or switching on capacity by changing the heating curve (modulating the grid load),
4. in the case of hybrid heat pumps: by switching to natural gas as a source of energy (avoiding grid load).

Project goal
Under the title Open Flexibility Alliance (OFA), Flexiblepower Alliance Network (FAN) is committed to realizing a communication standard for heat pumps. TKI Urban Energy and RVO recognize the importance of interoperability and support this initiative.

The greatest challenge in developing this kind of protocol is that it must factor in, on the one hand, the technical wishes and possibilities of the stakeholders for whom flexibility has direct added value, and, on the other, the (as yet non-existent) knowledge, expertise, and possibilities of chain partners, such as heat pump suppliers and installation companies. We know already that heat pump manufacturers require a substantial lead time to implement a new and more extensive protocol in the way their products are controlled. The danger is that it would take years of fine-tuning to reach agreement on a widely accepted protocol and then to implement it, while thousands of non-smart heat pumps are being installed in the meantime.

> **The organizations who commissioned this report want to solve this impasse. They are calling for the development of a widely accepted blueprint for a rudimentary and – above all – easily implementable smart grid protocol for heat pumps ('version 1.0'), with a look ahead at the development of a more advanced protocol ('version 2.0').**

Version 1.0 is a first step; its most important function is simply to attain flexibility in the short term, and it should be up and running for the 2024–2027 period. This version should allow the grid operators to create switchable power rapidly, enabling them to keep the network stable and prevent congestion. To be able to use heat pump technology as adequately as possible, and in view of the future technical demand for switchable power, a more extensive protocol will be necessary. This is version 2.0, which will be introduced in mid-2026 as version 1.0 is implemented.

The goal of this project is to draw up a widely accepted blueprint for 'version 1.0', and to offer a look ahead at the development of a more advanced protocol ('version 2.0'). This has been done in concert with the relevant stakeholders in the field. Our approach is based on interviews with experts, a limited literature review, and on the combined expertise of the teams at Technolution, BDH, and Silentric, followed by a peer review round and workshops with experts and other stakeholders.

Conclusions
The technology that is currently available for version 1.0 of the protocol is a further development of the existing Smart Grid Ready (SGR) control system. This is a rudimentary control system that many heat pump manufacturers already use and that is very suitable for a possible development and demonstration phase. This solution can also be used in situations in which there is an urgent need, because of local congestion, to use the flexibility of already installed heat pumps. The current state of technology makes it possible to create switchable capacity (i.e., flexibility) with large numbers of heat pumps in residential development in the foreseeable future (a few years).

During their exploration of the subject for this report, the authors gradually abandoned the idea of turning version 1.0 of the protocol into a 'precursor' that could later be developed into a version 2.0. It became clear to them that this is technically unfeasible, because SGR has no development potential.

The EU's upcoming Code of Conduct for Electric Smart Appliances means that our look ahead at a version 2.0 of the protocol will present the possibility to use the S2 and/or EEBUS protocols. Other options are less interesting due to their technical possibilities/specifications and their acceptance in the field, which depends on these. Open ADR, for example, is focused on North America and much less on the European situation. Furthermore, a number of large European heat pump manufacturers have a certain preference for EEBUS as standard due to its availability, whereas the set-up of S2 appears to make it the preferred option from the perspective of the energy system. This report recommends starting by studying/developing both options together.

Ready for scale-up
Creating flexibility for heat pumps is a matter of aggregating large numbers of devices. An important factor in addressing network congestion and aggregating flexibility is registration of installed heat pumps, as this gives insight into the geographical spread of these devices. Aggregating flexibility requires the organization in question to possess high-grade knowledge (technical, organizational but also with regard to intellectual property and cybersecurity), financial stamina, and a robust integration into the process of grid management.

<u>We believe the following route is the most appropriate one</u>: It should be left to the market to assume the commercial aggregator role, with the government (legislation) and grid operators playing a distinct role in setting out the framework for how the aggregator role should be performed. History has shown that the response time and innovative capabilities of private enterprise in the role of aggregator are sufficient, and that a large market player operating in the background as the owner of the aggregator can safeguard the financial wherewithal and stamina. We have compiled the following recommendations as preconditions for successful implementation:

1. Implement the SG-Ready 2 protocol and make it digitally approachable
2. Work toward implementation of S2 and EEBUS
3. Implement a flexibility identification or connection identification for heat pumps
4. Research switching between energy sources (electricity and gas) for hybrid heat pumps
5. Adopt a standard method for verification and validation of flexibility from heat pumps
6. Cloud or local? Make both options possible
7. Adopt basic conditions for the regulation of heat pumps
8. Register installed heat pumps
9. Stimulate – or provide norms for – the implementation of the correct standard protocols
10. Ban electrical resistance heating in heat pumps
11. Develop greater knowledge and conduct more research concerning the flexible use of heat pumps

These recommendations have been further detailed in the last chapter.

Contents

1. Introduction

1.1 Context

The drive to heat homes sustainably is picking up in residential development and heat pumps are a major part of this. The number of heat pumps installed is growing by 30–40 % every year and this growth is accelerating. It will result in a significant rise in electricity consumption in residential development, beyond the capacity of the power grid in its current dimension. The application of (both hybrid and fully electric) heat pumps and electric transport are driving up the demand and peak load on the power grid; over time, this may lead to network congestion on the low-voltage networks.

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1.2 Heat pumps as a source of flexibility

The currently installed base of heat pumps is not scalable because there is no standard protocol to control them and no infrastructure that can apply such a protocol. Suppliers can distinguish themselves for future clients by supplying heat pumps that are switchable. We define flexibility here as:
'The measure in which the connected load value of the home at any time can be varied relative to the normal or current value in response to market signals, but also in response to dynamic tariffs for network and/or supply, or other specific financial incentives.'

In addition to being substantial consumers of electricity, heat pumps are a demonstrable potential source of flexibility, because heat pump technology is such that the electrical power of heat pumps can be switched on or off for periods of time. The thermic mass of homes (homes can do without heat supply for a while without loss of comfort) and possibly other forms of thermic energy storage (such as the hot water buffer) that are connected to the heat pump make heat pumps a shiftable load from the perspective of grid management. A reasonably to well-insulated home can do without heat supply for a few hours; and this period can be extremely valuable for congestion reduction.

To determine this flexible load and actually realize it, a uniform heat pump control system needs to be put in place. Heat pumps can be made flexible in four ways:

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The box below offers background information about conditions that demonstrably influence the actually attainable flexibility from heat pumps:

Conditions for flexibility from heat pumps

1. **Hot water generation:** By advancing or delaying the generation of hot tap water in time, this process can be made to contribute to flexibility. However, once a heat pump has begun to generate hot tap water, this process cannot be interrupted for technical reasons that might affect end user comfort.
2. **Preventing Legionnaires' disease**: By law, every heat pump capable of generating hot tap water must perform a high-temperature cycle every week to prevent Legionnaires' disease in the hot tap water system. Legionnaires' disease cycles require the heat pump to operate at maximum capacity and they cannot be interrupted for technical reasons.
3. **Volume of boiler tank:** On the one hand, the greater the volume of a boiler tank (i.e., the hot water supply), the more space there is for flexibility. On the other hand, a large boiler tank also requires longer heating time and thus longer operating time for the heat pump, during which the heat pump should preferably not be stopped. A fully empty hot water boiler is normally a 'must run' situation due to various comfort requirements, and the heat pump cannot be switched off during this time.
4. **Reducing the domestic heat demand**:
So-called heating curve adjustments are used for this, i.e., the adjustment of the heating settings of the heat pump that modulate grid load. However, this generates only very limited possibilities for switching. The current electronic control/inverter settings of heat pumps translate heating curve adjustments into electrical power used over a relatively long period, which is clearly longer than the response time required to create flexibility.
5. **Switching between gas and electricity (in hybrid heat pumps)**: Hybrid heat pumps use the heat pump part for space heating, the boiler for tap water, and the auxiliary heating during low outside temperatures. Hybrids have the option of temporarily switching between the two energy carriers (natural gas and electricity) that are both used for this configuration. This offers significant possibilities for flexibility without technical repercussions, including for comfort.

FAN recently asked LCPDelta to draw up an overview of the status of the currently installed base of heat pumps in the Netherlands with regard to connectivity. The main conclusions of the resulting report can be found in the diagram below.

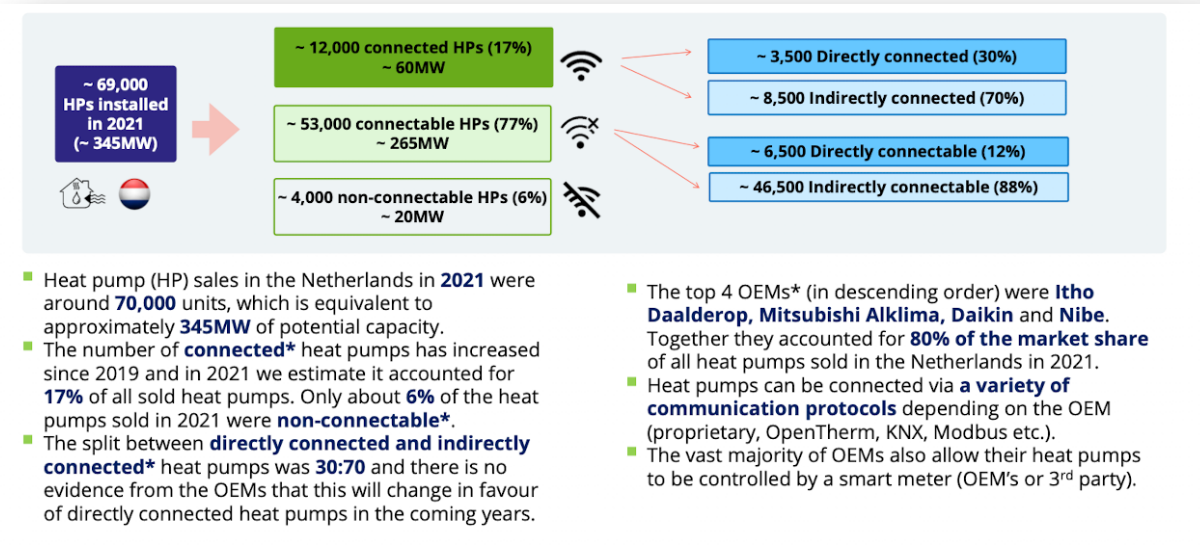


Figure 1. Executive summary of 'Aan Internet verbonden warmtepompen in Nederland' (Heat pumps connected to the Internet in the Netherlands) (source: LCPDelta 2022).

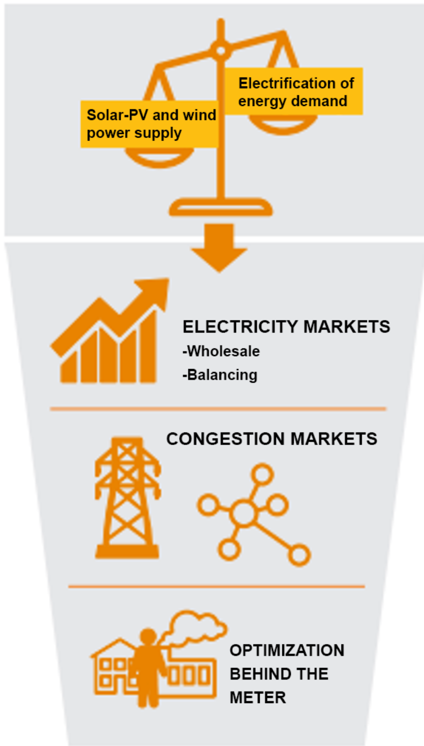
1.3 The value of flexibility from heat pumps

Due to the electrification of the energy demand and the increasing supply of non-dispatchable energy sources (such as solar-PV and wind power) the demand for flexibility in our electricity systems is growing. This demand represents an explicit value, which can be monetized in various electricity markets by offering flexibility. The relevant markets include the wholesale electricity market, the balancing market (FCR, aFRR, mFRR), and congestion markets (GOPACS).

In addition, flexibility has an implicit value. This is value that is created by optimizing electricity consumption behind the meter, for example by responding to variable supply rates, by boosting self-consumption, or by avoiding the cost of greater connected load. The implicit value of flexibility depends on legislation, tariff systems, and types of energy contract.

All this means that flexibility is an instrument that can be used for different goals and that represents a financial value for the end user. However, the currently installed base of heat pumps is not switchable due to the lack of a standard. From the perspective of society, network congestion is the greatest reason to move more rapidly toward flexible control of heat pumps. Preventing and solving network congestion is possible through a combination of implicit and explicit flexibility. Creating proposals with regard to implicit flexibility that are financially attractive to end users is a crucial focus point for the stakeholders in explicit flexibility.

From the perspective of the end user, there are currently three use cases why end users might wish to have their heat pump controlled flexibly: to benefit from dynamic energy prices, to maximize self-consumption, and to prevent grid operator fees. For the grid operators there is also a use case: creating a technical safety net for network congestion. These four uses cases are explained in the box on the next page.



The energy transition is increasing the need to balance the demand for and supply of electricity. The value of flexibility can be monetized in several ways.

Figure 2. Explicit and implicit flexibility (source: TKI Urban Energy)

The large-scale roll-out of heat pumps is currently underway. However, because only a small percentage of the installed heat pumps are directly connected or directly connectable, and because control requires a large variety of protocols, flexible control of heat pumps has barely taken root. It needs a great deal of customization, which means no viable use case is emerging for control of heat pumps in homes. In the meantime, the reality is that local power networks are increasingly experiencing shortages.

Three use cases for flexible deployment of heat pumps for the end user

1. **Benefit from dynamic energy prices:** It can be expected that consumers will increasingly use dynamic energy prices, and if their homes are fully electrified, they will use it even more. Gas prices are more or less stable at a relatively high level compared to the average over the last 5–8 years, but, interestingly for end users, the electricity price is volatile, and they can benefit from this. More so, if a heat pump can be switched off or reduced in capacity whenever the grid load is at its highest (high demand).

   NOTE: it should be mentioned that dynamic electricity prices are based on the (national) APEX, whereas network congestion is a local or regional problem for the grid operator. Seeking to solve network congestion as a local/regional problem by influencing the behavior of users of dynamic energy prices runs into the difficulty that these are not always parallel and/or synchronous. The two developments could possibly even counteract each other.

2. **Maximizing 'self-consumption':** The penetration of solar PV panels in the housing stock is growing fast. One of the driving forces behind this development (aside from rising electricity prices) is the current system of net metering. This system will be gradually be scaled down in the future, which means consumers will be looking increasingly at the possibility of consuming the energy generated by their PV panels themselves. Heat pumps can be used to consume as much privately generated solar energy as possible.

   NB on average, a heat pump in a home fitted with PV panels can use electricity generated by these PV panels for at most c. 30 % of the time, depending on the heating threshold of the home (source: Installatiemonitor 3.0 – BDH). The yield from the panels will be too low during the rest of the time, which means that the heat pump will rely fully on the power grid during these periods. During the summer months, PV-generated energy can be used to generate hot tap water or active cooling in the case of a reversible heat pump.

3. **Preventing grid operator costs:** We are working on the assumption that the consumer wants a stable energy supply at the lowest possible cost (network and supply). The stability of the physical power grid is outside the consumer's control. But consumers can strongly influence the use of the grid for the connection of their home, and thus save money on grid operator costs.

   NB consumers can currently save money on grid operator costs by preventing excessively large grid connections. But this is only a limited incentive to prevent large peaks of electricity use. Grid operators are currently working on a plan for a new tariff structure under which consumers will be charged more for peak consumption; in other words, permitting consumers to save money by preventing large power peaks.

4. **Technical safety net:** The grid operators regard the possibility of having control as a necessary part of future grid management, to prevent critical situations from arising on the power grid. Grid operators are therefore considering introducing a 'technical safety net'. The purpose would be to continue to facilitate new devices but simultaneously prevent outages. This buys them more time to reinforce the power grid.

   NB this is a policy that is being developed, but is not yet ready. The German example is being studied, where there is a legal obligation as of January 1, 2024 for grid operators to be able to control heat pumps, EV charging stations, and energy storage in excess of 3.7 kW. This is known as 'Paragraph 14a'. For more information, please visit this page of the Bundesnetzagentur.

1.4 Changes to legislation

Legislation has an impact on the desirability of control of heat pumps, and can influence the time at which energy is consumed. The box below discusses both current and proposed legislation that affects heat pumps and the desirability of having controllable heat pumps. Specifically, it addresses the ban on gas connections in newly constructed homes introduced in 2018, the obligation to install hybrid heat pumps by 2026, the rise of dynamic energy tariffs, the phasing out of net metering for solar PV, and the considerations underlying the decision to organize grid connections differently.

1. **No natural gas connections in newly built homes as of 2018:** As of July 1, 2018, new residential developments can no longer be fitted with gas connections. The legal obligation for grid operators to connect new homes expired on that date. See this announcement in the official gazette of the Netherlands, the Staatscourant. This means homes must be heated in some alternative way; usually through installation of a heat pump. The number of heat pumps that is being installed in residential developments is therefore increasing strongly. It is estimated that some 50,000 heat pumps were installed in new developments by mid-2023, and that this figure will remain the same for 2024.

2. **Obligation to have hybrid heat pumps by 2026:** The government has announced that, as of 2026, hybrid heat pumps will be the standard type for heating existing homes. This means that when home owners seek to replace their central heating system, they are obliged to switch to a more sustainable alternative – in most cases this will be a (hybrid) heat pump. This is further driving up the growth of the number of (hybrid) heat pumps. See also this announcement from the government.

3. **Dynamic delivery tariffs:** Since January 1, 2017, it has become possible for small consumers to sign contracts with dynamic energy prices. The ACM issued clear guidelines for energy contracts with dynamic tariffs in 2021. Since then, consumer interest in such contracts with dynamic energy prices has grown strongly, as a result also of the recent hike in energy prices. Contracts with dynamic prices provide an immediate financial incentive to consumers to use their heat pump at times when electricity is cheapest. This device will most likely be able to influence the market for energy suppliers.

4. **Phasing out of net metering for solar PV:** Due to the strong growth of the number of households with PV installations, the current system for net metering for solar PV-generated electricity will probably be phased out in the near future; see also this announcement by the government. This will give consumers who own a PV installation an immediate financial incentive to operate their heat pump at times when their own PV installation is generating electricity. It should be noted, however, that the peak in electricity generation from PV panels and the peak in demand for electricity for heat pumps are strongly asynchronous. The period during which heat pumps are demonstrably operational coincides only to a very limited extent with the time that electricity is actually being generated privately (source: Installatiemonitor 3.0 – BDH).

5. **Reconsidering the costs of grid connection:** Currently, the costs of grid connection are determined by the technical connection capacity, the so-called capacity tariff. The idea of introducing an alternative tariff model for residential developments has been under study for some time now; in this alternative model, the costs for the consumer depend on the time and maximum consumption (or feed-in) capacity. It is expected that in this model, the consumer will pay for demand peaks; any excess consumption will incur additional costs per connection and/or per kWh. If a consumer fears that the capacity is insufficient, they can negotiate higher capacity against additional cost. If this, or a similar, system is introduced, it will create an immediate financial incentive for consumers to avoid using devices that require a lot of energy simultaneously, such as a heat pump or an electric vehicle charging station, and to use private PV-generated energy as much as possible.

1.5 Question

Under the title Open Flexibility Alliance (OFA), Flexiblepower Alliance Network (FAN) is committed to realizing a communication standard for heat pumps. TKI Urban Energy and RVO recognize the importance of interoperability and support this initiative. The greatest challenge in developing this kind of protocol is that it must factor in, on the one hand, the technical wishes and possibilities of the stakeholders for whom flexibility has direct added value, and, on the other, the (as yet non-existent) knowledge, expertise, and possibilities of chain partners, such as heat pump suppliers and installation companies. We know already that heat pump manufacturers require a substantial lead time to implement a new and more extensive protocol in the way their products are controlled. The danger is that it would take years of fine-tuning to reach agreement on a widely accepted protocol and then to implement it, while thousands of non-smart heat pumps are being installed in the meantime.

The organizations who commissioned this report want to solve this impasse. They are calling for the development of a widely accepted blueprint for a rudimentary and – above all – easily implementable smart grid protocol for heat pumps (‘version 1.0’), with a look ahead at the development of a more advanced protocol (‘version 2.0’). Version 1.0 is a first step; its most important function is simply to attain flexibility in the short term, and it should be up and running for the 2024–2027 period. This will allow heat pumps to make an important contribution to grid management in the energy transition and to build awareness within households that flexibility is a important precondition for a stable power grid. This version 1.0 should give the grid operators the possibility to create switchable power through aggregators, allowing them to keep the network stable and prevent congestion.

To be able to use heat pump technology as adequately as possible, and in view of the future technical demand for switchable power, a more extensive protocol will be necessary. This is version 2.0, which will be introduced in mid-2026 as version 1.0 is implemented.

1.6 Scope of the report van het rapport

This report outlines the contours of a 1.0 protocol that is suitable to be used as a first standard protocol for the flexible use of heat pumps; this protocol will have to be further elaborated and defined depending on the existing protocols. The report does not contain the specifications and does not define the protocol messages: that is a task for the next phase, if the decision is made to carry out specific demonstration projects.

2. What the industry is asking for

2.1 Developments in dialog with the industry

In researching a suitable protocol for making heat pumps flexible, two things are particularly important when determining the protocol. The first are the wishes and possibilities of heat pump suppliers; the second is the required functionality (use cases) in the market.

If a standard for control is to be developed successfully, it is necessary, therefore, to involve various stakeholders from the field in its development. Relevant stakeholders include heat pump suppliers, grid operators, market players (suppliers/developers of smart energy services such as Home Energy Management Systems), innovative energy suppliers (such as energy companies, aggregators), and other participants in the energy system.

We also gathered input from a wide spectrum of heat pump suppliers during a number of workshops. Through interviews, we gauged various aspects such as expectations regarding the use and deployment of flexibility, response time, communication preferences, risks, obstacles, and value drivers in the process. This created a firm footing to determine whether existing protocols can be used to perform these functions.

We interviewed the following persons from the following organizations:

Marijn Beekman	VWP
Marco Bijkerk	NVI
Leonie Boelens	Alliander
Peter Cool	Intergas
Henk Fidder	Stedin
Sjors Geraedts	iWell (battery storage)
Brendan de Graaf	Lyv
Thijs de Graaf	NieuweStroom
Erwin Janssen	Nathan (AlphaInnotec)
Edwin van Kessel	BeNext
Casper Koldewee	Samsung
Erik Nagelkerken	Alklima (Mitsubishi Electric)
Rens Schoorl	Tibber
Elbert Stoffer	IthoDaalderop

2.2 Results of the interviews

The following sections summarize the essence of the information we acquired during the interviews.

Concerning **the expectations of flexibility**:

- Heat pump suppliers have an interest in the continuous roll-out of heat pumps in residential developments, and avoiding obstacles in the electricity network is of immediate and essential interest to them. These companies are currently convinced of the necessity of making heat pumps switchable and of implementing a switch option for hybrid heat pumps. Nonetheless, the manufacturers' current focus is strongly on customer value and on costs for the customer.
- The industry benefits from clear legislation so that product development can be adjusted accordingly. Manufacturers are reluctant to take on a leadership role here, but are willing to cooperate to expedite the roll-out.
- The relevance of optimization, the reduction of grid load, and switchable capacity are understood, but these things currently constitute 'bycatch' for the stakeholders.
- For the grid operators, it is essential that the electricity consumption of heat pumps and electric transport can be removed from the grid load peak. This buys respite time to work on further reinforcing the networks.

Concerning **using the flexibility**:

- From the perspective of (dynamic) energy suppliers: control of heat pumps makes it easier to operate in the balancing market and to realize benefits for the end users. The capacity to regulate congestion is becoming increasingly important and valuable (including on the intraday market).
- From the perspective of one grid operator (Stedin): deployment depends on where the problems in the grid are located. An indication for low-voltage networks: control per 200–300 connections behind the transformer (per 200–300 connections) with control at postal code 6 or postal code 5 level.
- From the perspective of one grid operator (Alliander): focus on using the right energy carriers at the right moment (as seen from the system). Deployment depends on the geographical location. It is necessary to determine per location, per neighborhood what the most cost-effective and future-oriented way is to organize the energy supply properly. Hybrid plays a role in this; it is not just about the option of an on-off switch, but also about the possibility of switching between energy carriers (electricity/natural gas).

Concerning **applying flexibility:**

- Application of preferably one or at most two protocols to access the available installed base of heat pumps. Once the market has been defined with the aid of a protocol, market players can quickly begin to service it.
- There is no appetite for focusing on the development of yet another protocol. Instead, focus on existing developments; preferably something that has a high international adaptation.
- The protocol should factor in developments such as the upcoming EU *Code of Conduct on energy management related interoperability of Energy Smart Appliances*, which formulates requirements for the controllability of devices.
- Dynamic energy suppliers do <u>not</u> want to be able to control heat pumps at a low level (i.e., within the operating system of the heat pump), but are currently trying to influence the heating curve setting. The manufacturer's heat pump setting, the internal operating system of the heat pump, is not affected by this, which is likely to make controlling it much less complex and less prone to error. Heating curve adjustments will take place only with the user's consent.
- There is a preference for solving problems as close to the source as possible, i.e., on location in homes. For example, by using a HEMS to control the PV, EV, storage and heat pump at once.

Concerning **the response time** for flexibility of heat pumps (reaction speed):

- This depends in part on the possibilities/technology (connectivity and controls in the heat pump).
- This depends on the goal: a response time of 1 hour suffices for day-ahead pricing, but there is only 15 minutes at most on the balancing and intraday market.
- A quick response time should be facilitated by the development of AI and algorithms that should also especially give insight into '<u>what parts can't be switched off</u>'.
- At system level, response is valuable only if we are talking about being able to switch large numbers of heat pumps.

Concerning the **communication preference for control** of heat pumps:

- This domain is legally inaccessible to grid operators. It must fall therefore to a third party in the role of aggregator.
- The market then faces the choice whether or not to install devices in homes and how to contact the heat pump (via HEMS or cloud)?
- However, given the huge efforts required to keeping a large installed base of devices in homes up to date and functioning, an EMS device might prove less interesting than a cloud solution from the perspective of cost. Management of a cloud solution could be entrusted to an aggregator.
- It seems attractive to combine cloud solutions into one coherent solution, but compared to a local solution using a physical EMS device, this requires very robust cybersecurity measures.

- Experience in the field from a possible demonstration phase for switching heat pumps will hopefully provide clarity on which solution is the easiest to operate, the most reliable, and the most cost-effective.

With respect to **concerns of interviewees regarding** control of heat pumps:
- Liability in case of damage to the heat pump because external control can contribute to a higher number of start/stops, which could have a negative impact on life span.
- How to involve end users in the process in a scalable and cost-effective manner.
- The role of aggregator will become difficult for large, established players (i.e., the energy suppliers) due to the complexity of organizing the process appropriately. The organization of the aggregator will need to be able to deal with the required innovative power, complexity, and scalability.
- The risk that the end user will not have/develop confidence in the solutions and the technology involved and will pull out at the first glitch.

Concerning **possible obstacles for flexible control** of heat pumps:
- Risks concerning the reliability of the technology and management (privacy).
- This is new and unfamiliar to the end user, who will possibly act in a risk-avoiding way.
- The client-specific economic benefit is difficult to communicate/demonstrate.
- The current legislation is outdated. There is still a great deal of uncertainty about new tariff structures and the phasing out of net metering.
- The lack of standardization is an obstacle for possibilities for cost-effective control of heat pumps.
- There is limited insight into the commercial benefits of potential aggregators.
- Dynamic tariffs facilitate flexibility, but conversely, fixed tariffs (i.e., conservative energy suppliers but also conservative consumers) will become an obstacle to flexible heat pumps.
- There is a risk that flexibility with EVs will begin to compete with flexibility from heat pumps; cars are much smarter already than heat pumps and have a much greater electricity impact.
- Heat pump manufacturers may refuse to facilitate control out of fear that it will shorten the life span of their heat pumps.
- Lack of smart European batteries (some Chinese home energy storage batteries have Modbus).

Concerning **value drivers** for interviewees:
- Reliability for aggregator, grid operator, but also for the end user, and sensitivity to technical and security risks with regard to the home, installation, and heat pump.
- Raising consumer awareness, on the one hand focusing on ease of use (flexibility is not a direct concern for consumers), and on the other empowering end users by permitting them to adjust settings in a comprehensible way, for example through an app. This requires the development of the right kind of services.
- Servicing the Tennet balancing market and at the same time helping to realize added value for the party that ultimately creates the flexibility: the end user.
- Subsidies to stimulate flexibility, for example by adopted a rule banning subsidies for heat pumps without flex options (as is the case in England).
- Normative policies that do not give consumers a choice as to whether they wish to participate in the flexible use of heat pumps.

<u>A widely shared insight for all parties is that a future system that does not have flexibility from switchable capacity is no longer an option.</u>

2.3 Criteria for versions 1.0 and 2.0 of the protocol

On the basis of these insights, the following criteria were formulated for a blueprint/design for version 1.0 of the protocol:
1. The protocol should take account of the current technological state of installed heat pumps and heat pumps that are now being sold.
2. It should require minimal effort to realize, preferably without a visit to the end user at home.

3. It should be possible to control the heat pump as a black box (without knowledge of its internal functioning).
4. The home comfort levels that the heat pump provides should not be noticeably affected.

On the basis of these insights, the following criteria were formulated for a blueprint/design for version 2.0 of the protocol:

1. The protocol should make it possible to implement the entire functionality (use cases) required. This means it should be able to work in two ways: not only can it control the heat pump, but it also provides insight into the current availability of the device and available flexibility (switchable capacity).
2. The protocol should be based on modern and generally accepted technology and should not require extra (local) hardware.
3. The protocol should preferably be based on an existing protocol as its starting point.
4. The protocol should preferably be able to evolve according to future developments, i.e., its most important requirement is to be open and independent of heat pump type and brand.
5. The protocol should be able to be used in combination with an additional HEMS.
6. The various elements within the heat pump that consume energy should be controlled in a 'modulating' fashion, for example the frequency control of the compressor, and, if applicable, the stepwise switching on of electric auxiliary heating.
7. The comfort that the user experiences may be impacted in some cases. This should happen only at the user's request, and because there is some economic advantage.
8. The protocol should take account of developments such as the upcoming EU *Code of Conduct on energy management related interoperability of Energy Smart Appliances*.

3. Existing protocols

Various protocols have been developed over the past years to enable the flexible use of domestic appliances, including heat pumps. This chapter offers an overview of these existing protocols.

4.1 SG-Ready 2.0

This is the existing (German) standard for controlling electrical heat pumps for heating and hot water and for compatible system components. This standard works with two physical relays which can be switched to four operation modes. See the official specification for the formal definition (in German): 2020_SG-ready_Regularien_2.0_NEU.pdf. The shortened summary of the operation modes is as follows:

- Operation mode 1: Blocked mode: (Smart A: closed, Smart B: open).
- Operation mode 2: Normal mode: (Smart A: open, Smart B: open).
- Operation mode 3: Recommendation on (low price) (Smart A: open, Smart B: closed).
- Operation mode 4: Forced on (overcapacity): (Smart A: closed, Smart B: closed)

The box provides more background information on these four operation modes.

Background information for SG-ready 2.0's four operation modes

- **Operation mode 1**: This operation mode is compatible for frequency-switched EVB blocks at fixed times and encompasses a maximum of two hours of 'fixed' blocked time.
- **Operation mode 2**: In this mode, the heat pump will operate in the energy efficient normal operation mode to fill the heating boiler before the EVB block of at most two hours.
- **Operation mode 3**: In this mode, the heat pump will run intensively within the adjustment range for space heating and hot water generation. This is not a positive start command, but a switch-on recommendation in line with the greater demand.
- **Operation mode 4**: This is a positive start command; as far as possible within the framework of the control settings. This mode requires that it is possible to configure the various tariff and utility models of various control models on the controller:
  Variant 1: The heat pump (compressor) is actively switched on.
  Variant 2: The heat pump (compressor and additional electrical heating) is (or are) actively switched on, optionally: higher temperature in the heating boilers.

Optionally, the room temperature can be used as reference for controlling the system temperatures (supply and return temperature). It is not enough for the heat pump to be blocked by a room thermostat depending on the room temperature.

4.2 EN50631 'Household appliances network and grid connectivity' (EEBUS)

EN50631 is the formal norm that defines EEBUS. For more information, please refer to the EEBUS website. This is sometimes seen as the digital successor to SG-ready, but this is mainly because both were initiated in Germany and both are being promoted there. The EEBUS spec (in the use case 'Monitoring and Control of Smart Grid Ready Conditions', see section 7.9 in EN 50631-1.PDF) does use the SG-Ready possibilities of heat pumps.

4.3 EN50491-12-2 'S2'

The S2 protocol is also known as 'Working Group 18'. S2 is a European standard in which abstraction is applied according to energy flexibility. It is a device-agnostic protocol. For more information, see the website s2standard.org. Various types of abstractions can be applied within S2. Two of these can probably be applied to heat pumps: FRBC (fill rate-based control) and PEBC (power envelop-based control). Of the two, PEBC is the simpler type, but it has fewer possibilities to optimally use the available flexibility. We recommend beginning with PEBC, and applying the more advanced FRBC at a later stage.

4.4 Matter

Matter is a smart home standard introduced in 2019. Matter is driven by Connectivity Standards Alliance (CSA), formerly Zigbee Alliance. This standard is royalties-free and supports interoperability between devices and platforms. Matter officially started in November 2022. It is a recent development that is not yet widely supported by manufacturers, but that does have great potential. For more information about Matter, see this video on Tweakers.

The Matter smart home standard is a local protocol. This addresses another well-known problem with current IoT devices: these devices require a constant internet connection. IoT devices have so far usually used the cloud as a solution for everything, which means devices become unusable without internet.

The current version contains support for 'HVAC thermostats'; energy management features are being developed. The Matter Application Cluster Specification Version 1.2 shows that control and read-out are currently limited to typical thermostat functions, such as configuring a setpoint and requesting the current temperature.

4.5 Modbus

Modbus is a concept used in building management systems; a communication protocol based on master-servant architecture. Ethernet and RS485 are used as transfer technology. Modbus is applied quite widely in industrial and building management systems. It is used frequently as a communication protocol for the low-level control of heat pumps (and other devices). There are two variants:

- **Modbus RTU:** Communication via RS485; can only be connected using a cable.
- **Modbus TCP**: Communication via TCP/IP; can be connected through existing Ethernet or WiFi.

However, there is no standardization of the register mappings (also known as device profiles) and the available functionality, which means that device-specific implementations will still have to be made.

4.6 'Code of conduct'/'Interconnect'

This is a project of the European Commission for Smart Appliances. See this webpage of the European Commission's Joint Research Centre. It is an initiative to achieve interoperability between the various protocols through semantic models, so that a hard standard is not required. The project focuses on white goods and HVAC. Any manufacturer that signs the code of conduct commits to bringing a device to market within one year that supports the use cases 'Monitoring of Power Consumption' and 'Limitation of Power Consumption'.

In the CoC, Saref is used as ontology, to achieve compatibility between various standards in this way. This means that a Saref mapping has to be available for the standard in question. Such mappings have been made both for EEBUS (see section 4.1.2) and for S2 (see section 4.1.3), and the expectation is that this will be able to function for the use cases that have to be supported initially. This has in part already been demonstrated in the TNO Reflex report 'Flex in toekomstbestendige energienetten' ('Flexibility in future-proof power grids') and GO-e. It will be more complicated, however, for more complicated use cases.

5. Currently applied protocols

This chapter describes protocols that are currently used to control heat pumps. It subsequently looks at the possibilities and limitations of applying these as a basis for a widely accepted protocol.

FAN recently asked LCPDelta to draw up an overview of the status of control options for heat pumps and of available control protocols. The most important conclusions of this report are presented in the diagrams below.

This table summarizes the connectability of the OEM's heat pumps, i.e. it shows the ways their heat pumps can be connected to the internet: via Wi-Fi that is integrated in the HP, via OEM specific hardware, via OEM Smart thermostat or 3rd party thermostat.

OEM	Wi-Fi integrated in HP	Via OEM hardware	Via OEM smart thermostat	Via 3rd party smart themostat	Comments
Itho Daalderop					▶ Spider WP Climate Thermostat are compatible with all models and available for an additional price. ▶ The Gateway has a wired connection to the WiFi router and smart meter. The thermostat has a wired connection to the HP and wireless connection to the gateway.
Mitsubishi Electric					▶ MELCloud app allows heat pump operation from any device (phone, tablet, PC). ▶ The WiFi interface uses wireless connection with the home router and wired connection with the HP. ▶ Any thermostat with on/off signal can be used with Ecodan.
Daikin					▶ Daikin Onecta app is available for all Altherma heating systems and air conditioning systems. Control is available via WLAN adapter either integrated, included as standard or optionally available. ▶ All new 3rd generation systems sold from 2020 are compatible with Onecta.
Nibe					▶ Online software platform (and app) NIBE myUplink specially developed for smart NIBE S series heat pumps. There is an option to choose between the WIFi connection or direct operation on heat pump touchscreen. ▶ Different levels/types of subscription allows different levels of control.

Figure 3. Status overview (1/2) (mid-2022) of connectability options per heat pump manufacturer (source: LCP Delta 2022).

This table summarizes the connectability of the OEM's heat pumps, i.e. it shows the ways their heat pumps can be connected with the internet : via Wi-Fi that is integrated in the HP, via OEM specific hardware, via OEM Smart thermostat or 3rd party thermostat.

OEM	Wi-Fi integrated in HP	Via OEM hardware	OEM S.T.*	Via 3rd party S.T.*	Comments
Inventum					▶EVA smart thermostat (and app) ensure optimum operation of Inventum's heat pumps.
Bosch					▶Bosch EasyRemote smart thermostat & app capable of remotely controlling ground source heat pump with an integrated gateway. ▶HomeCom Easy app operates all Nefit Bosch heat pumps remotely. ▶Bosch heat pumps can be used with all smart thermostat except for Nest.
Vaillant					▶Consumer apps: sensoApp & myVAILLANTapp (depending on gateway used). ▶Installers use myVAILLANTapp for remote access maintenance. ▶Unique to Vaillant: Smart Home API (used mostly by larger installer companies).
Remeha					▶Smart Remeha eTwist or wireless eTwist RF thermostat and eTwist app can control (hybrid) heat pumps and boilers. ▶Connectivity via MODBus gateway and remote connection network.
Intergas					▶No smart thermostat developed yet. All Intergas boilers and heat pumps come with a regular Comfort Touch (and app) thermostat, connected to the heat pump.

Figure 4. Status overview (2/2) (mid-2022) of connectability options per heat pump manufacturer (source: LCP Delta 2022).

This table provides an overview of communication protocols used in connectable heat pumps by key manufacturers (blue shaded cells).

OEM	Proprietary	OpenTherm	KNX	Modbus	Other
Itho Daalderop					
Mitsubishi Electric	(MELCloud)				
Daikin					iFTTT compatible
Nibe	(their own API)				iFTTT compatible
Inventum					
Nefit/Bosch					EMS-BUS
Vaillant	eBUS*	(only for boilers)			Smart Home API
Remeha	eSmart inside platform				
Intergas					

Figure 5. Status of communication protocols (source: LCPDelta 2022).

The installed heat pumps and heat pumps currently on the market are not fitted with a universal protocol. The most common protocols for external control are:

- SG-Ready;
- Modbus;
- Manufacturer-specific cloud solution.

The diagram below explains the possibilities and limitations of this with regard to applying these protocols as a basis for a widely accepted protocol.

SG-Ready	**Possibilities:** The four operation modes defined by SG-Ready can be used to realize – to a certain extent – the four use cases defined and the wishes for OFA version 1.0. In the use cases in which the consumer obtains some benefit, it is to be expected that the consumer will also purchase the hardware required for control. There are, for example, converters that can control SG-Ready heat pumps on the basis of PV generation. For use case 4, in which the grid operator is the party to derive benefit, the grid operator will have to provide the required hardware.
	Limitations: This is an 'analog' solution. Additional hardware is required locally (in the home) to permit control, and this means extra costs. This product ('PowerDetector') is an example of hardware specifically made for this purpose. According to this description, control via a 'standard' relay is also possible; in that case the Shelly Plus 2PM, for instance, could also be used, because it has an immediate Rest API. In this description, a Shelly 1 is used to switch on the 'overcapacity' mode. This document by SMA prescribes using a Moxa E1214. The cost of this device is approximately € 250, which is not realistic for large-scale roll-out. It is one-way traffic; there is no possibility to request the status of the heat pump and no feedback is possible. This means only blind control is possible, without any information on the ability of the heat pump to respond to the control. It is also unknown whether the heat pump has responded to the control and for what length of time.
Modbus	**Possibilities**: Modbus is a relatively simple, low-level product that is familiar to most manufacturers. It is used 'internally' in the heat pump by manufacturers, and sometimes also for low-level integration into a building management system.
	Limitations: The available functionality may differ per device; the use of Modbus in itself says little about the possibilities for flexible use that the device offers. Because there is no standardization of the register mappings (also known as device profiles), device-specific implementations would still have to be made. Modbus is intended for local communication. In the case of the RS485 variant, an additional box is required in the home to establish the serial connection with the heat pump. In the case of the Modbus TCP variant, the heat pump can theoretically be accessed through the internet, but this raises concerns due to the lack of security. Modbus TCP messages are not sent encrypted (i.e., they are readable and can be manipulated). A secure variant of Modbus TCP has been defined (mbaps) that would solve this specific problem. Furthermore, firewall/port forwarding settings in the router of the connected homes are required, because a TCP connection has to be established with the heat pump.
Manufacturer -specific cloud solutions	**Possibilities**: Various manufacturers offer brand-specific solutions to control heat pumps. For example, Nibe has a RestAPI via myUplink. This can be configured to optimally control the heat pump according to the EPEX prices. Moreover, a REST interface is available via the cloud, which can adjust the room temperature setpoint. This allows only for a rudimentary form of control.
	Limitations: The great drawback of manufacturer-specific solutions is that they are not standardized and a separate implementation is thus necessary per manufacturer and even sometimes per product series. The possibilities vary per case, so that it is impossible to judge a priori to what extent the available flexibility can be used.

6. A blueprint for protocols

We have concluded that it is impossible to try to immediately define a full protocol and implement it in the field. It is clear from the interviews that heat pump suppliers prefer – and are obliged to – build on existing protocols. This is why this project has focused, on the one hand, on the '1.0 protocol' whose most important function is to facilitate any kind of flexible use in the short term (albeit in rudimentary form). On the other, it also mapped whether this can serve for the '2.0 protocol', which offers more advanced control possibilities, and is to be introduced in mid-2026. The criteria for versions 1.0 and 2.0 of the protocol have been defined at the end of chapter 2.

6.1 Proposal for version 1.0: Use digitally available variant of SG-ready 2

Our proposal is to use already existing switching options, which ensures that the installed base of heat pumps and the heat pumps that are currently being installed and will continue to be installed over the coming few years can be controlled. If we apply this criterion to the protocols described in the previous chapter, there is one protocol that clearly stands out as regards standardization and support: Smart Grid Ready 2.0 (SGR). None of the other protocols meet the required criteria.

As indicated in the previous chapter, one limitation of SGR is that it is a hardware-based standard. This means that physical hardware will always have to be present in the vicinity of the heat pump, hardware fitted with the two required relays to be able to switch between the four operation modes. In order to obviate these limitations as much as possible, we are proposing making SGR functionality digitally accessible via a REST API at the lowest possible cost. We think there are two ways to realize this API:

- Manufacturers of 'connected' and 'connectable' heat pumps (see introduction) have an existing proprietary connection with the manufacturer's central environment; this is used for example for service and for remote control. The manufacturer could access this REST API using this existing cloud connection. If the heat pump is SG-Ready, it would require limited effort on the part of the manufacturer to access this in its central environment through an API; the existing connection could then be used to send commands to the heat pump in question. Figure 6 shows this scenario in a diagram.

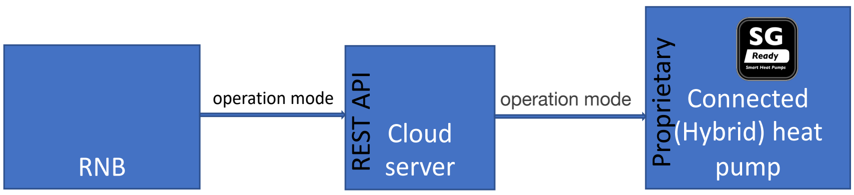


Figure 6. Display of the set-up of connected heat pumps (source: Technolution).

- For 'non-connected' heat pump, this could be done using a box (in concept, a cheap Raspberry Pi with an RPi Relay Board), which supplies the REST API via WiFi or LoRa and which encompasses the two relays to offer SG-ready input to the heat pump. Control would then happen via LoRa from the transformer station, via WiFi, or from the NextGen smart meter.

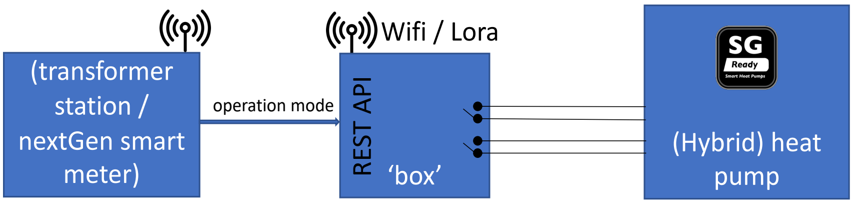


Figure 7. Display of the set-up of 'non-connected' heat pumps (source: Technolution).

A concept proposal for the definition of this API has been included in the appendix. In summary, this offers one endpoint with which the operational status can be set through a POST request and the current operational status can be requested via a GET request.

6.2 Proposal for version 2.0: Use S2 and EEBUS

The second limitation of SGR is the fact that it provides only one-way traffic; there is no possibility to request the status of the heat pump and no feedback is possible. This means it cannot know what the availability and available flexibility of the heat pump is at any given time; nor is there any feedback on the command given. This functionality does not seem viable within version 1.0.

Two-way traffic is an explicit criterion for version 2.0 of the protocol. This allows the heat pump to indicate what the possibilities (e.g., adjustable capacity) and limitations (e.g., maximum number of compressor starts per 24-hour time period) are, what the current availability is, and how much flexibility is available and when. This will also make it possible to give feedback on the possibilities or limitations of a particular command. If a command cannot be carried out, for example because it would cause too many compressor starts within a particular time period (anti-pendulum software will counteract this), then the heat pump can report back on this and the energy management application can factor it in. Because the available flexibility for the coming period is known, it will also be possible to take account of the flexibility (or lack thereof) of other smart devices (EV, PV, storage). The input from all devices, together with the signals of an external aggregator, grid operator, or energy supplier for example, then forms the input for the algorithm that determines the optimal deployment within the defined framework.

At the moment, EEBUS and S2 are the best options, because they are existing protocols that access flexibility in its entirety, and they are technically built in such a way as to allow for each roll-out scenario (fully local, fully cloud, or a hybrid).

It is to be expected that both EEBUS and S2 will be permitted as protocols under the code of conduct (CoC) of the EU, i.e., EU policy for all HVAC and white goods manufacturers that sets requirements for the energy management of devices.

Manufacturers and players in the energy system have a role to play in deciding which protocol will become dominant in the future. Given the large share of heat pumps manufactured outside the Netherlands, certain manufacturers appear to have a certain preference for EEBUS. However, EEBUS intervenes deeply in the firmware of devices, and focuses on optimizing the device itself, whereas S2 offers better phasing of implementation, and focuses on integration with EV, storage, and PV systems.

The boxes on the following page offer background information on the architecture of these protocols.

Architecture of the S2 and EEBUS protocols

Figure 8 shows the global architecture of the S2 protocol. Every device has its own resource manager. This manager translates device-specific information into generic S2 information. The resource manager can be a separate device or a software module, but preferably it is an integral part of the device to be controlled.

Figure 9 shows a broad 'home energy' architecture that could be applied. It shows a local HEMS that communicates with devices. One of these devices would then be the heat pump. Devices communicate their flexibility to the HEMS via a protocol, in this case S2. On the basis of the information received from the devices and other sources of information, the HEMS can then set the most optimal status of the heat pump.

Figure 10 shows how EEBUS could be used to control various devices, including a heat pump.

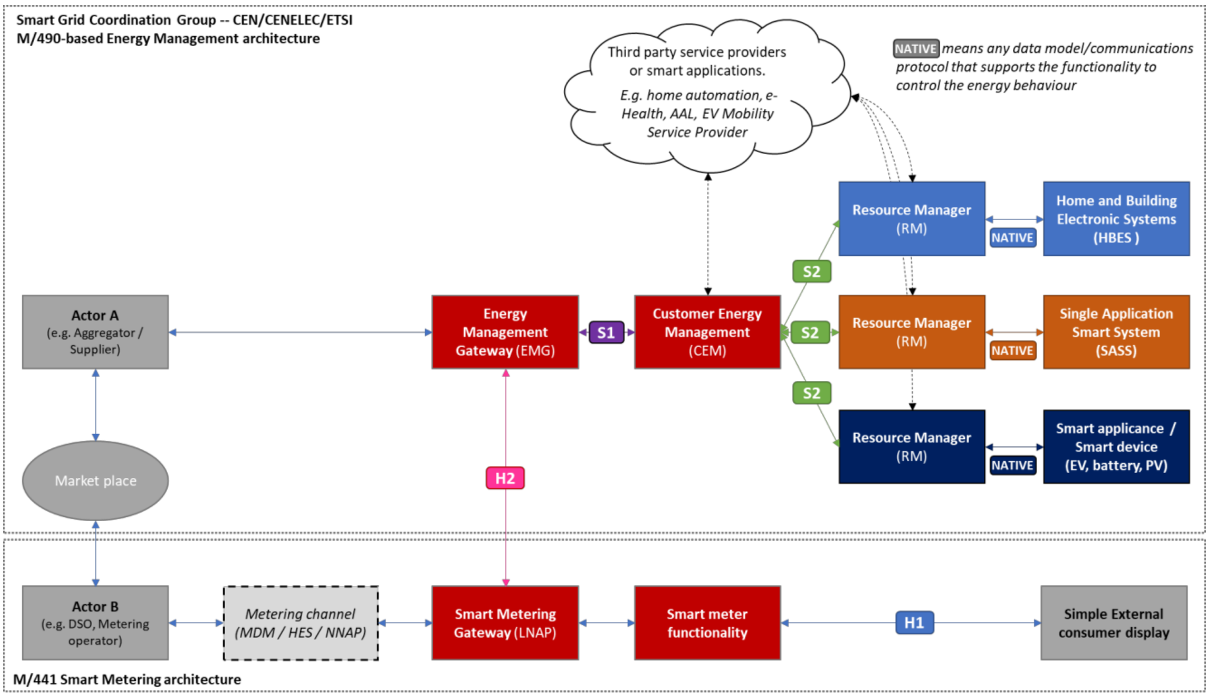


Figure 8. S2 global architecture (source: EN50491-12-2)

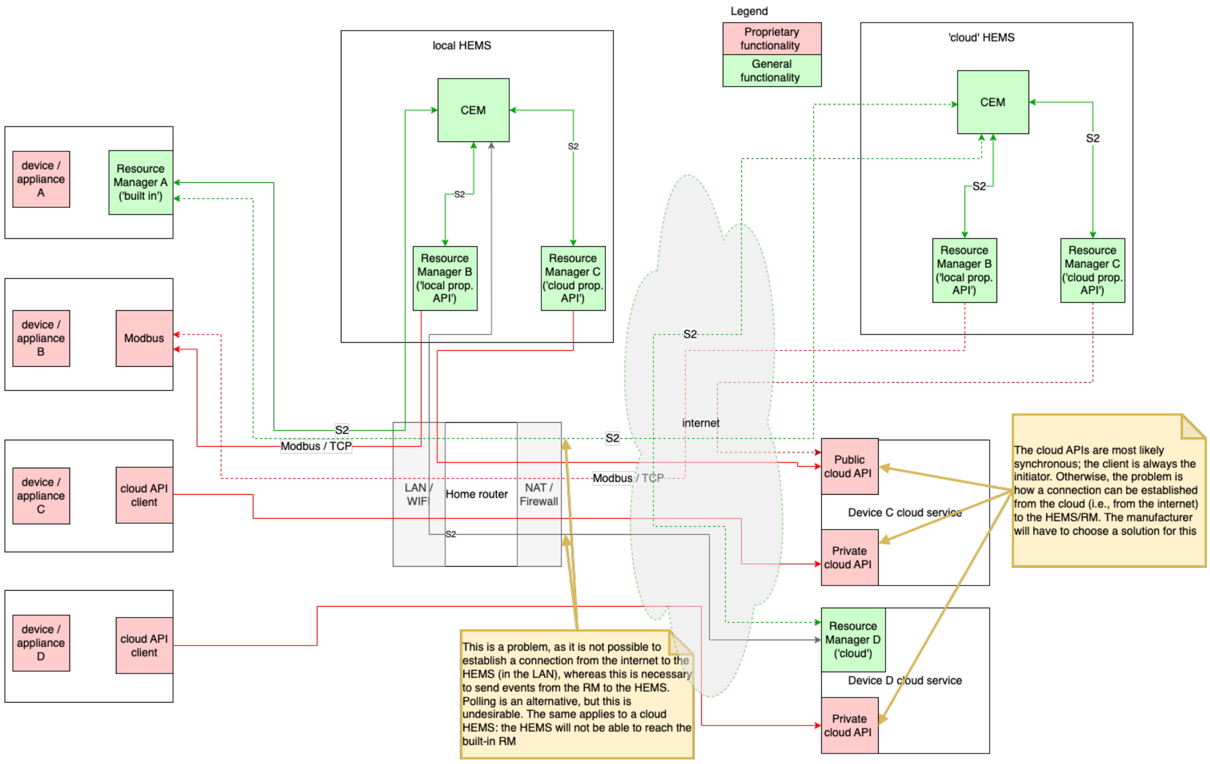


Figure 9. Sample architecture based on S2

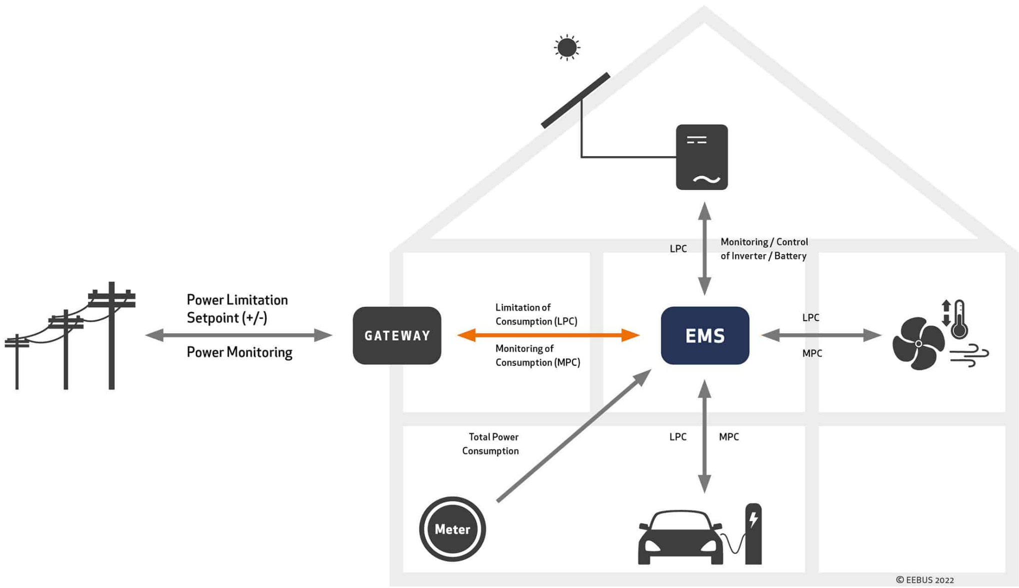


Figure 10. EEBUS global architecture (source: https://www.EEBUS.org/solutions-examples/).

7. Recommendations

Creating flexibility with heat pumps is a matter of aggregating large numbers of devices. An important factor in addressing network congestion and aggregating flexibility is registration of installed heat pumps, as this gives insight into the geographical spread of these devices. Aggregating flexibility requires the organization in question to possess high-grade knowledge (technical, organizational but also with regard to intellectual property and cybersecurity), financial stamina, and a robust integration into the process of grid management.

We believe the following route is the most appropriate one: It should be left to the market to assume the commercial aggregator role, with the government (legislation) and grid operators playing a distinct role in setting out the framework for how the aggregator role should be performed. History has shown that the response time and innovative capabilities of private enterprise in the role of aggregator are sufficient, and that a large market player operating in the background as the owner of the aggregator can safeguard financial wherewithal and stamina. We have compiled the following recommendations as preconditions for successful implementation:

Recommendations for heat pump manufacturers

1. Implement the SG-Ready 2 protocol and make it digitally approachable
   This report offers a description of how heat pumps can be made controllable quickly and simply. Implement the method proposed.

2. Work toward implementation of S2 and EEBUS
   Manufacturers and players in the energy system have a role to play in deciding which protocol will become dominant in the future. Choosing either S2 or EEBUS will have consequences once the future European legislation that sets requirements for heat pumps is enacted. Given the large share of heat pumps manufactured outside the Netherlands, certain manufacturers appear to have a certain preference for EEBUS. However, EEBUS intervenes deeply in the firmware of devices, and is focused on optimizing the device itself, whereas S2 offers better phasing of implementation, and focuses on integration with EV, storage, and PV systems.

3. Implement a flexibility identification or connection identification for heat pumps
   Heat pumps should be given a flexibility identification by brand/type (Flex ID) that indicates what kind of flexibility the heat pump in question is capable of providing: To what extent can the heat pumps be switched on or off? What is the minimum and maximum switch-off period? Is it possible to switch between energy carriers? This could be made part of future certification such as CE marking.

4. Research switching between energy carriers in hybrid heat pumps
   Research the conditions, possibilities, and effects of switching between energy carriers (natural gas and electricity) in hybrid heat pumps.

Recommendations for the energy sector (energy suppliers, aggregators, installation companies)

5. Adopt a standard method for verification and validation of flexibility from heat pumps
   A standard or definition (in addition to the switch protocol) should be adopted for the verification of flexibility from heat pumps. What can we expect of the devices? What switch-off period and what flexibility capacity does a specific class of heat pumps have? To 'validate' the flexibility that a heat pump has actually delivered, we recommend exploring cooperation with players such as Equigy (an initiative of Tennet and three other European TSOs). These

actors are working on a single European standard for validation of decentralized flexibility transactions. This is relevant when flexibility also has to be used on balancing markets and for system services.

6. Cloud or local? Make both options possible
   One thing to factor in when deciding on the protocol is that both central (Cloud) and local access (using a device) should be possible.

7. Adopt basic conditions for the regulation of heat pumps
   Define technical criteria for the degree of intelligence that the heat pump control must have to be able to connect with a HEMS.

Recommendation for grid operators and national government

8. Register installed heat pumps
   Registration of heat pumps is an explicit requirement for grid operators and for the aggregator role, among other things to be able to identify geographical clustering of heat pumps. The following things would need to be registered: geographical location, whether the heat pump is hybrid or all-electric, the electrical connected load value, and the volume of the hot water buffer. Also register whether the heat pump can be used for cooling, to be able to allocate flexibility in the cooling function in summer if required. The registration process could start by looking at the ISDE subsidy applications, which contain data on the location of installed heat pumps for many of them.

Recommendations for the national government

9. Stimulate – or provide norms for – the implementation of the correct standard protocols
   The national government has a strong instrument in the form of legislation, together with financial incentives, to gradually stimulate or compel heat pump users and heat pump suppliers to implement flexibility. The application of standard protocols could be stimulated, for example, through the ISDE subsidy or other economic incentives, and/or controllability can be enforced through setting norms. This will enhance the participation of end users in offering flexibility. Any measures would have to be compliant with developments at EU level and with the upcoming Code of Conduct.

10. Ban electrical resistance heating in heat pumps
    Although this subject also falls under network congestion, auxiliary electrical resistance heating should be banned for devices with a maximum power in excess of, for example, 3.7 kW-Elec (Compressor Plus resistance heating). This should perhaps be permitted through software only in the back-up function in case the compressor fails.

Recommendation for the entire sector

11. Develop greater knowledge and conduct more research concerning flexible use of heat pumps
    Begin a partnership between heat pump manufacturers, installation companies, energy suppliers or aggregators, grid operators, the government, and knowledge institutions to acquire greater knowledge concerning the flexible use of heat pumps. This study has mapped the various questions that require further research, elaboration, or study. They are listed in the box on the next page.

Questions for further research

- What precise possibilities and limitations does hot water generation offer in a flexibility context that seeks compromise as little as possible on comfort?
- Together with heat pump manufacturers, implement the Smart Grid Ready 2.0 TCP variant and a simple form of S2 (as is currently happening with IthoDaalderop within GO-e), to have as many experiences (as to content and as to process) in demonstration projects. Alternatively, choose a medium-term solution and continue with S2 and EEBUS; it will become clear progressively which option is the most practical and viable for market players, particularly heat pump manufacturers.
- Study the Smart Grid Readiness Indicator (SRI) from the EPBD to see whether entire homes can be assigned a so-called flexibility ID. Given that heat pumps have a life span of 15–20 years, any flexibility management system and its successors would have to be backwards compatible.
- Reducing power for inverter-driven heat pumps as a result of heating curve reduction through the room thermostat can take more than 10 minutes (Source: RISE report Sweden), which essentially rules out capacity reduction on the basis of the heating curve because it is too slow. Further study is required of the precise response times of the various heat pump types and their operation when given flexibility commands to switch off or on, to increase or reduce the heating curve, to switch between energy carriers (for hybrid heat pumps), or to fill the buffer. Does this mean that switching the heat pump on or off are the two preferred options? Then study how a flexibility protocol could work around this.
- One-way communication with heat pumps offers very limited control possibilities with regard to flexibility. Two-way communication offers more options; the details of this should be further elaborated, including criteria for two-way communication.
- Further research of the flexibility potential that is actually available in real time: How do you determine the current connected value and power consumption of the heat pump? For how long is this potential available? What response will the installed base give if we want to realize an increased or reduced demand for electricity or connected value? What interaction and dynamic are feasible (time-wise and/or as a peak in connected value or consumption) by combining dynamic energy tariffs (network and delivery) with technically viable flexibility options with heat pumps? What precision can be attained through aggregation of flexibility from heat pumps?
- Study relevant and required legislation with regard to creating flexibility from heat pumps in residential development.
- Given that there are currently no standards for flexibility from heat pumps in residential development, and given that there are high standards for availability and the precision of availability, the playing field for aggregators should be further explored and organized. What conditions should aggregators comply with?
- Inventory cybersecurity standards for online devices; what standards do the heat pump manufacturers currently comply with?
- Creating flexibility from heat pumps means operating in a complex playing field with many stakeholders with different interests. It is particularly advisable therefore to acquire experience through demonstration trajectories; experiences that can then be used during scale-up. To start the learning curve, launch demonstration projects as soon as possible, initially using the installed base. After these demonstration projects, a scalable process including feasible protocol should be available.

8. References & bibliography

EU Code of Conduct: EU DRAFT Code of Conduct on energy management related interoperability of Energy Smart Appliances

EHPA

- EHPA WS Slides Interoperability June 2023.pdf
- EHPA Interoperability WS Briefing June 2023.pdf

RISE / IEA

- SLAV final report 230621draft.pdf (Energymindigheten report)
- IEA RISE Lindahl Grid Flexible Control of Heat Pumps_NY.pdf

EDNA docs

- BEIS UK - smart-secure-energy-system-consultation
- EDNA report - Energy-Protocol-Report-Release

Smart Grid Ready 2.0

Appendix: SG-Ready REST API

SG-Ready REST API 0.1 OAS 3.0

REST API for controlling heatpumps that support SG-Ready

Some useful links:

- The SG-Ready Version 2.0

todo

Servers

todo

SG-Ready SG-Ready modes

POST /sgready Set operation mode

Parameters

Try it out

No parameters

Request body required

application/json

New operation mode

Example Value | Schema

```
{
  "mode": "MODE_2_NORMAL"
}
```

Responses

Code	Description	Links
200	Successful operation	*No links*
405	Validation exception	*No links*

GET /sgready Get operation mode

Parameters

Try it out

No parameters

Responses

Code	Description	Links
200	Successful operation	*No links*

Media type

application/json

Controls Accept header.

Example Value | Schema

```
{
  "mode": "MODE_2_NORMAL"
}
```

Schemas

```
OperationMode {
   mode*                string
                        example: MODE_2_NORMAL
                        Operating modes
```

- Betriebszustand 1 (1 Schaltzustand, bei Klemmenlösung: 1:0): Dieser Betriebszustand ist abwärtskompatibel zur häufig zu festen Uhrzeiten geschalteten EVUSperre und umfasst maximal 2 Stunden „harte" Sperrzeit.
- Betriebszustand 2 (1 Schaltzustand, bei Klemmenlösungen: 0:0): In dieser Schaltung läuft die Wärmepumpe im energieeffizienten Normalbetrieb mit anteiliger Wärmespeicher-Füllung für die maximal zweistündige EVU-Sperre.
- Betriebszustand 3 (1 Schaltzustand, bei Klemmenlösung 0:1) In diesem Betriebszustand läuft die Wärmepumpe innerhalb des Reglers im verstärkten Betrieb für Raumheizung und Warmwasserbereitung. Es handelt sich dabei nicht um einen definitiven Anlaufbefehl, sondern um eine Einschaltempfehlung entsprechend der heutigen Anhebung.
- Betriebszustand 4 (1 Schaltzustand, bei Klemmenlösung 1:1) Hierbei handelt es sich um einen definitiven Anlaufbefehl, insofern dieser im Rahmen der Regeleinstellungen möglich ist. Für diesen Betriebszustand müssen für verschiedene Tarif- und Nutzungsmodelle verschiedene Regelungsmodelle am Regler einstellbar sein: a. Variante 1: Die Wärmepumpe (Verdichter) wird aktiv eingeschaltet. b. Variante 2: Die Wärmepumpe (Verdichter und elektrische Zusatzheizungen) wird aktiv eingeschaltet, optional: höhere Temperatur in den Wärmespeichern

```
                        Enum:
                        [ MODE_1_BLOKKED, MODE_2_NORMAL, MODE_3_RECOMMENDED_ON, MODE_4a_FORECD_ON MODE_4b_FORECD_ON_WITH_BH ]
}
```

YAML file:


```yaml
openapi: 3.0.3
info:
  title: SG-Ready REST API
  description: |-
    REST API for controlling heatpumps that support SG-Ready

    Some useful links:
    - [The SG-Ready Version 2.0
](https://www.waermepumpe.de/fileadmin/user_upload/bwp_service/Guetesiegel/2020_SG-
ready_Regularien_2.0_NEU.pdf)
  license:
    name: todo
    url: todo
  version: '0.1'
servers:
  - url: todo
tags:
  - name: SG-Ready
    description: SG-Ready modes
paths:
  /sgready:
    post:
      tags:
        - SG-Ready
      summary: Set operation mode
      requestBody:
        description: New operation mode
        content:
          application/json:
            schema:
              $ref: '#/components/schemas/OperationMode'
        required: true
      responses:
        '200':
          description: Successful operation
        '405':
          description: Validation exception
    get:
      tags:
       - SG-Ready
      summary: Get operation mode
      responses:
        '200':
          description: Successful operation
          content:
            application/json:
              schema:
                $ref: '#/components/schemas/OperationMode'

components:
  schemas:
    OperationMode:
      type: object
      properties:
        mode:
          type: string
          enum: [
              MODE_1_BLOKKED,
              MODE_2_NORMAL,
              MODE_3_RECOMMENDED_ON,
              MODE_4a_FORECD_ON,
              MODE_4b_FORECD_ON_WITH_BH
          ]
          example: MODE_2_NORMAL
          description: >
            Operating modes
```

```
        * Betriebszustand 1 (1 Schaltzustand, bei Klemmenlösung: 1:0):
          Dieser Betriebszustand ist abwärtskompatibel zur häufig zu festen Uhrzeiten geschalteten
          EVUSperre und umfasst maximal 2 Stunden „harte“ Sperrzeit.
        * Betriebszustand 2 (1 Schaltzustand, bei Klemmenlösungen: 0:0):
          In dieser Schaltung läuft die Wärmepumpe im energieeffizienten Normalbetrieb mit anteiliger
          Wärmespeicher-Füllung für die maximal zweistündige EVU-Sperre.
        * Betriebszustand 3 (1 Schaltzustand, bei Klemmenlösung 0:1)
          In diesem Betriebszustand läuft die Wärmepumpe innerhalb des Reglers im verstärkten Betrieb
          für Raumheizung und Warmwasserbereitung. Es handelt sich dabei nicht um einen definitiven
          Anlaufbefehl, sondern um eine Einschaltempfehlung entsprechend der heutigen Anhebung.
        * Betriebszustand 4 (1 Schaltzustand, bei Klemmenlösung 1:1)
          Hierbei handelt es sich um einen definitiven Anlaufbefehl, insofern dieser im Rahmen der
          Regeleinstellungen möglich ist.
          Für diesen Betriebszustand müssen für verschiedene Tarif- und Nutzungsmodelle verschiedene
          Regelungsmodelle am Regler einstellbar sein:
          a. Variante 1: Die Wärmepumpe (Verdichter) wird aktiv eingeschaltet.
          b. Variante 2: Die Wärmepumpe (Verdichter und elektrische Zusatzheizungen) wird aktiv
          eingeschaltet, optional: höhere Temperatur in den Wärmespeichern
required:
  - mode
```