Flexible **H**eat and **P**ower, connecting heat and power networks by harnessing the complexity in distributed thermal flexibility

D5.4 Report on Dissemination and Standardization activities

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[1] Disclaimer:

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Abbreviations

Abbreviation	**Full name**
CEM	Customer Energy Management
CEMS	Customer Energy Management System
DR	Demand Response
DSF	Demand Side Flexibility
EFI	Energy Flexibility Interface
EV	Electrical Vehicle
HP	Heat Pump
HVAC	Heat, Ventilation and Air Conditioning
RES	Renewable Energy Source
UC	Use Case

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1 Introduction

This document provides an overview of the FHP Dissemination and Standardization activities.

Specifically it lists the events, conferences, workshops where the project's objectives, activities and results have been disseminated. Next to that it contains a list of publications, both scientific and other. Besides these listed events and publications, there have been various – more informal – contacts with diverse stakeholders either through personal visits or at events that were attended that did not feature an FHP presentation.

From the outset of the project, the prime envisaged standardization focus has been on the interfacing between a BEMS and the Heatpump in relation to the proposed Grid Flex Heatpump concept. This is also what has been the main standardization focus, and various engagements have been held both with HP manufacturers as well as with the EEBus Initiative, which is seen as the most prominent initiative focussing on residential level flexibility enablement, including flex from heatpumps. In the course of the project, two additional areas for future standardization have been identified, namely for the interactions between the DCM (e.g. Aggregators/Community Managers) and DSOs (inspired by – but extending – the USEF interaction scheme), and the Flex Trading interactions between the DCM (e.g. Aggregators/Community Managers) and Active Connected Buildings. These latter two interfaces will be the focus of future projects, specifically the DT-ICT-10 InterConnect project.

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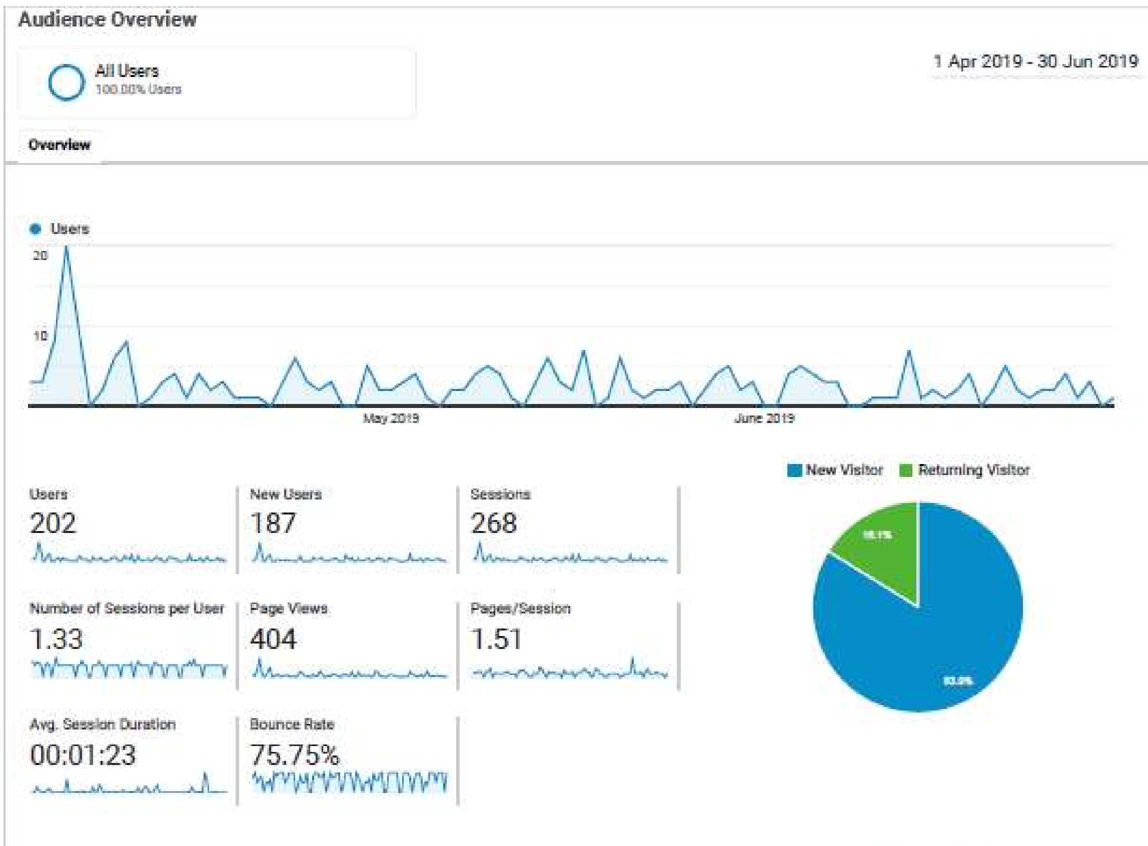
2 Overview of Dissemination Activities

2.1 Project website

See http://www.fhp-h2020.eu: created M3 and kept up to date with relevant information.

Most recent statistics:



	Country	Users	% Users
1.	Spain	35	17.24%
2.	Sweden	22	10.84%
3.	Netherlands	21	10.34%
4.	Belgium	18	8.87%
5.	Japan	16	7.88%
6.	United States	15	7.39%
7.	United Kingdom	7	3.45%
8.	Portugal	7	3.45%
9.	Germany	6	2.96%
10.	France	6	2.96%

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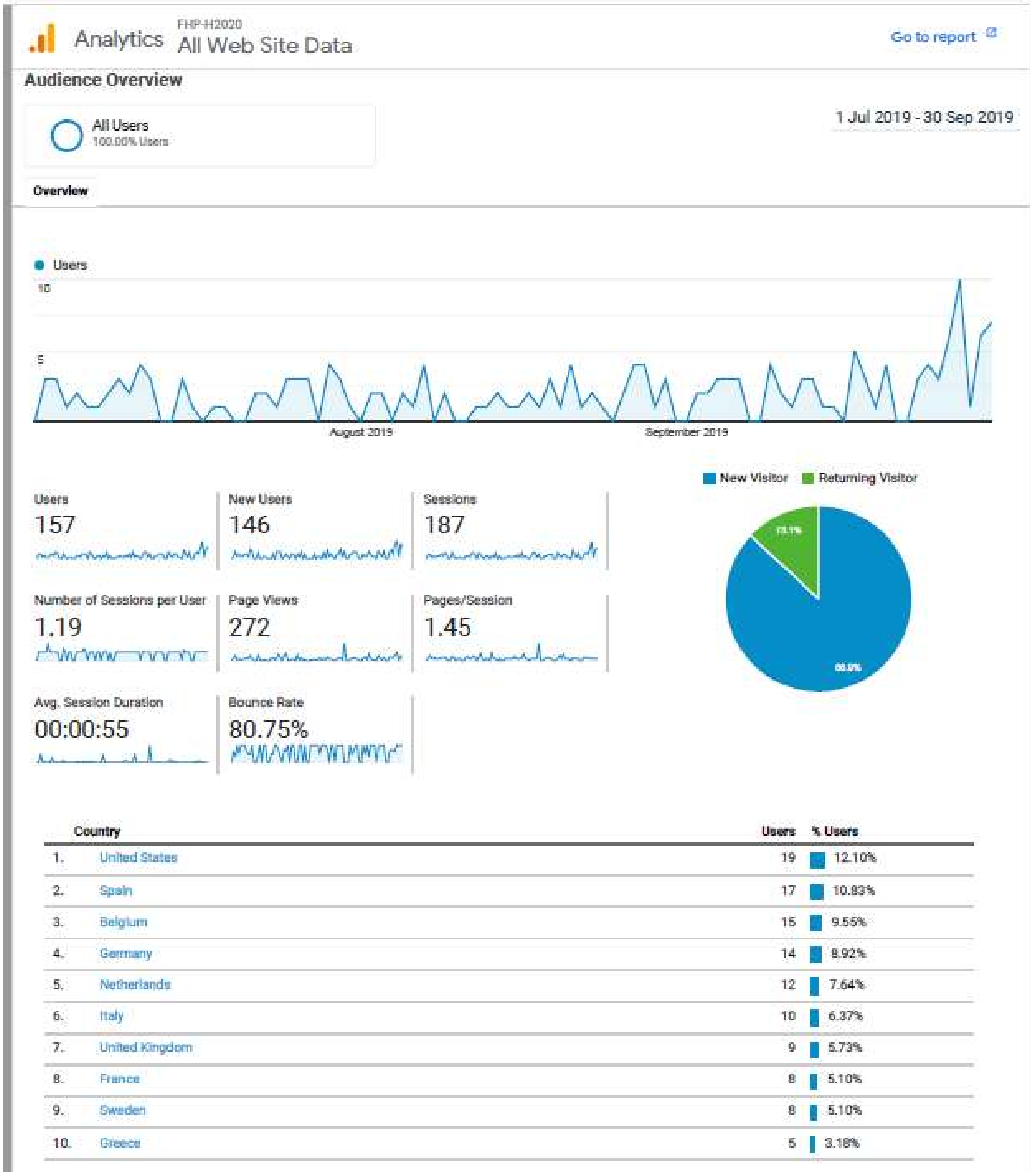

	Country	Users	% Users
1.	United States	19	12.10%
2.	Spain	17	10.83%
3.	Belgium	15	9.55%
4.	Germany	14	8.92%
5.	Netherlands	12	7.64%
6.	Italy	10	6.37%
7.	United Kingdom	9	5.73%
8.	France	8	5.10%
9.	Sweden	8	5.10%
10.	Greece	5	3.18%

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	Country	Users	% Users
1.	Sweden	33	29.73%
2.	Netherlands	10	9.01%
3.	Spain	9	8.11%
4.	Belgium	8	7.21%
5.	Austria	6	5.41%
6.	Germany	6	5.41%
7.	France	5	4.50%
8.	United Kingdom	3	2.70%
9.	United States	3	2.70%
10.	Switzerland	2	1.80%

2.2 Newsletters

Six newsletters were planned; five have been created.

- July 2018
- May 2019
- July 2019
- October 2019 (2)

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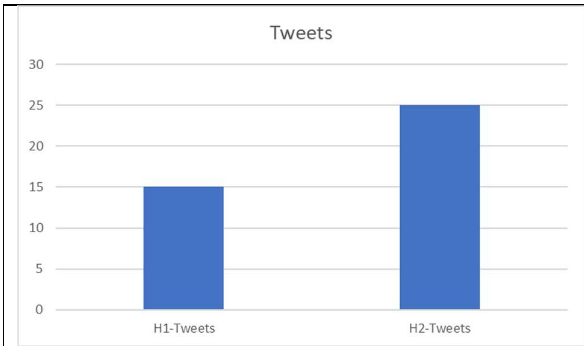
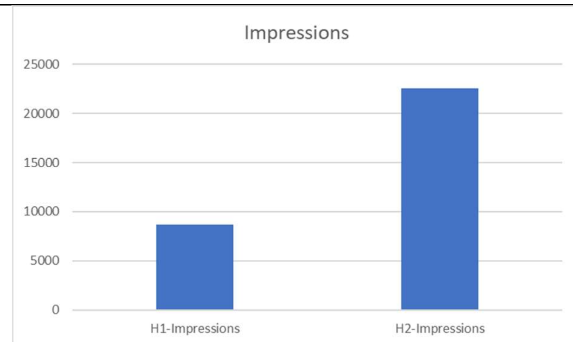
2.3 Social Media - Twitter





2.4 Workshops

Four national workshops were planned; two have been organized. A third one will be organized in November 2019.

The final conference that was planned for M36 has been organized as a side event to the Wind Europe 2019 event in Bilbao, Spain in M30.

More information pertaining to these workshops can be found in D5.3.

2.5 Dissemination through Events and Conferences

Event	Who	When
Energy Days 1710, The Netherlands	Wiet Mazairac (Ecovat)	October 26, 2017
SABINA project organized workshop, Denmark	Johan Van Bael (VITO)	November, 2017
EASME Contractors Meeting, Sustainable Places 2018 Conference, France	TECNALIA, HONEYWELL	2018
Energy Now conference, The Netherlands	Wiet Mazairac (Ecovat)	May 5, 2018
Energy Cluster conference, Netport Science Park, Karlshamn, Sweden	Jens Brage (NODA)	May 16, 2018
IEEE PES Conference, Portland, US	Shahab Shariat (VITO)	August 5-8, 2018
INEA H2002 Low TRL Smart Grids and Storage Projects clustering event, Brussels, Belgium	Chris Caerts (VITO), Dominic Ectors (VITO)	October 2, 2018

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workshop for knowledge exchange between projects, Malmö, Sweden	Jens Brage (NODA), Martin Borgqvist (NODA), Markus Lindahl (RISE), Marcus Steen (KEAB)	October 10, 2018
FlexCon – Flexibility Trading with distributed Power-to-Heat resources in local communities, Brussels, Belgium	Dominic Ectors (VITO)	November 26-27, 2018
Workshop jointly organised with the Moeebius and Sabina projects, Derio, Spain	TECNALIA (VITO)	January 30, 2019
Thomas Moore International Days, Geel, Belgium	Wiet Mazairac (Ecovat)	March, 2019
International Conference as Wind Europe 2019 side event, Bilbao, Spain	All	April 4, 2019
Local Energy Communities workshop co-organized by the European Energy Research Alliance, Nicosia, Cyprus	Chris Caerts (VITO)	May 8, 2019
Sustainable Places 2019, Cagliari, Italy (Distributed Schemes Cluster from Low TRL Smart Grids and Storage projects)	Davy Geysen (VITO)	June 6, 2019
Public workshop organised by ISGAN-SIRFN /EERA / MI, Montreux, Switzerland	Chris Caerts (VITO)	September 30, 2019
Public workshop organised by the FHP project, Gothenburg, Sweden	Jens Brage (NODA), Marcus Steen (KEAB) Markus Lindal (RISE)	October 9, 2019
public workshop organised by H2020 Magnitude project, Brussels, Belgium	Chris Caerts (VITO)	October 10, 2019
Heat Pump Summit, Nurnberg, Germany	Tommy Walfridson (RISE)	October 23, 2019
Future: 13th IEA Heat Pump Conference, Jeju, Korea (future: pending external review outcome)	Marcus Lindahl (RISE), Tommy Walfridson (RISE)	May, 2020

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2.6 Dissemination and Scientific Publications

What	Title	Main Author(s)	Where	When
Dissemination publication	FHP – Dynamic Coalitions of distribution grid connected Power to Heat resources providing local and system level services	Chris Caerts (VITO)	Article in Europe Energy Innovation digital publication	2017
Scientific publication	Flexibility quantification in the context of flexible heat and power for buildings	Javier Arroyo (KU Leuven), VITO	REHVA Conference	2018
Scientific publication	A dynamic coalition manager as a platform to characterize, control and trade electrical flexibility	Fjo De Ridder (VITO), Wiet Mazairac (Ecovat)	CDC (reviewed, not accepted)	2018
Scientific publication	A Python-based toolbox for model predictive control applied to buildings	Javier Arroyo (KU Leuven), VITO	5th Int. High Performance Buildings Conference	2018
Scientific publication	Optimal Flexibility Dispatch Problem using Second-order Cone Relaxation of AC loads	Shahab Shariat (VITO)	IEEE PES Conference, Portland, US	5-8 August, 2018
Dissemination publication	FHP (Flexible Heat and Power) – Dynamic Coalitions of distribution grid connected Power to Heat resources providing local and system level services	Chris Caerts (VITO)	Article in Open Access Government digital publication	October 2018
Dissemination publication	Karlshamn pilot description	Marcus Steen (KEAB)	Kyla & Värme (Industry Magazine in Swedish)	No. 2, 2019
Dissemination	Nätflexibel styrning	Markus	Kyla & Värme	no. 6,

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publication	av värmepumpar (In Swedish)	Lindahl (RISE)	(Industry Magazine in Swedish)	2019
Dissemination publication	Distributed Schemes, Innovative Solutions for Smart Grids: P2P, Multi-Agent Systems & Blockchain	Davy Geysen (VITO)	https://zenodo.org/record/3349684	July 2019
Scientific publication	Optimal Flexibility Dispatch Problem using Second-order Cone Relaxation of AC loads	Shahab Shariat (VITO)	IEEE Transactions on Power Systems (and also made available as an Open Access paper) https://ieeexplore.ieee.org/abstract/document/8767999	Accepted for publication July 2019
Scientific publication	Optimal placement of sensors for multi-zone building modelling	Javier Arroyo (KU Leuven), Gowri Suryanarayana (VITO)	Intelligent Building Operations Workshop, Boulder, US	August 2019
Future: Dissemination publication	Grid Flexible Control of Heat Pumps	Markus Lindahl, RISE	Heat Pumping Technology Magazine	*No 1. 2020 (preliminary, under review)*
Future: Scientific publication	Model based flexibility for energy markets	Borja Tellado, (TEC), Davy Geysen (VITO)	Building & Environment journal	*submitted October 2019 (under review)*
Future: Scientific publication	Possibilities and constraints of grid flexible control of todays and tomorrows heat pumps	Marcus Lindahl (RISE), Tommy Walfridson (RISE)	13th IEA Heat Pump Conference, Jeju, Korea	*May, 2020 (paper submitted for external review)*
Future: Scientific publication	A Model Free Method for Optimal Sensor Placement	Javier Arroyo (KU Leuven), Gowri	Applied Energy journal or Energy and Buildings	*Work in progress (will*

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	in Multi-Zone Buildings	Suryanarayana (VITO)	journal	*be finalized November 2019)*

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3 Overview of Standardization Activities and results

3.1 The context

This chapter maps the interface onto the FHP architecture, how the heat pump interacts with the FHP interaction flow. The building platform will be described in more detail to indicate what the options are for interfacing with the heat pump.

3.1.1 FHP architecture and de HP interface

The Dynamic Coalition Manager (DCM) platform was developed to forecast, manage and control flexibility of power to heat solutions, see deliverables D1.2, D3.1, D3.2 and D3.3. The DCM platform consists of a ‘forecaster’, ‘planner’, and ‘tracker’ to forecast flexibility from the flexible resources, and to plan and track the control signals to manage the flexibility of the different resources within one building or cluster of buildings. This DCM interacts, amongst others, with the distribution system operator to receive a plan on how to control the flexibility to avoid grid congestions. Figure 1 shows a schematic overview of the DCM platform and its interactions with the other stakeholders (DSO, BRP and flexible buildings)

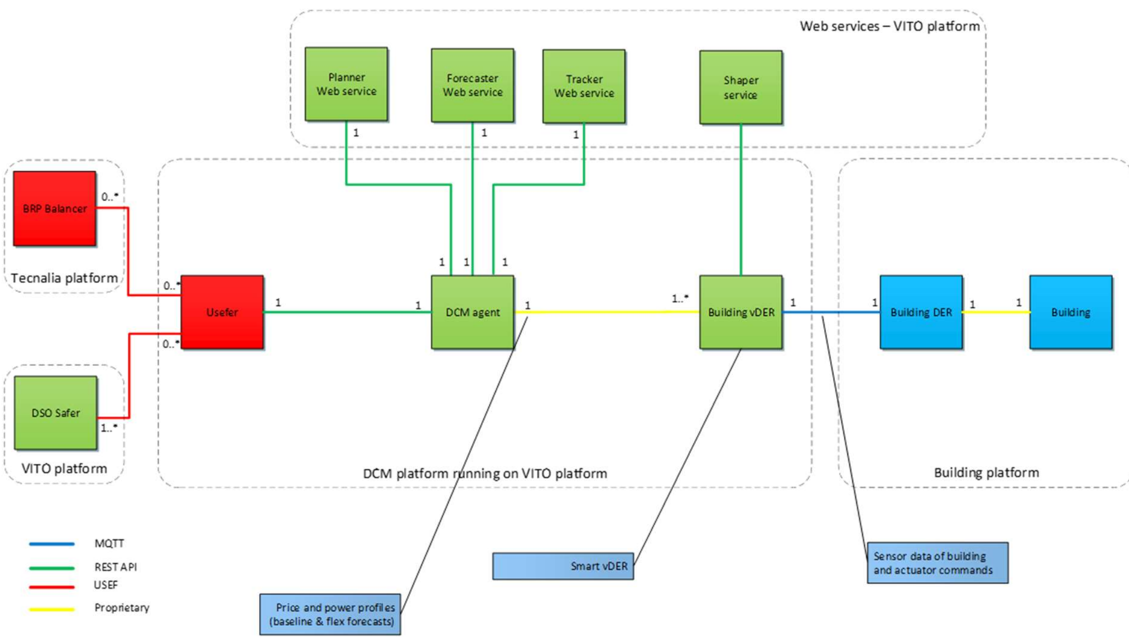

Figure 1 Overview of the DCM platform

The building DER in this figure represents either a pass-through gateway or a more intelligent component like an customer energy management system (CEMS) managing several devices in the building. In case of a pass-through gateway the DER component can be regarded as a IoT gateway forwarding capability and status data to the vDER, and forwarding control commands towards the building in the other direction. In case of a more intelligent DER, the vDER acts as a pass-through gateway. In this case the DER interacts with one or more systems or devices in the building providing

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energy flexibility. This is the interface that is described in this document. The next section sketches the context for this interaction in more detail for the case that one of these energy flexibility providing devices is a heat pump.

3.1.2 The HVAC context

Figure 2 shows the main functional components related to controlling a heat pump to harvest flexibility. These blocks have to be regarded as functional components. Functions can be implemented in one device or distributed over several devices. The scope of integration is mainly triggered by technical and commercial reasons. For instance to reduce costs it may be beneficial to have functionality distributed over several modules so that modules can be reused in other configurations.

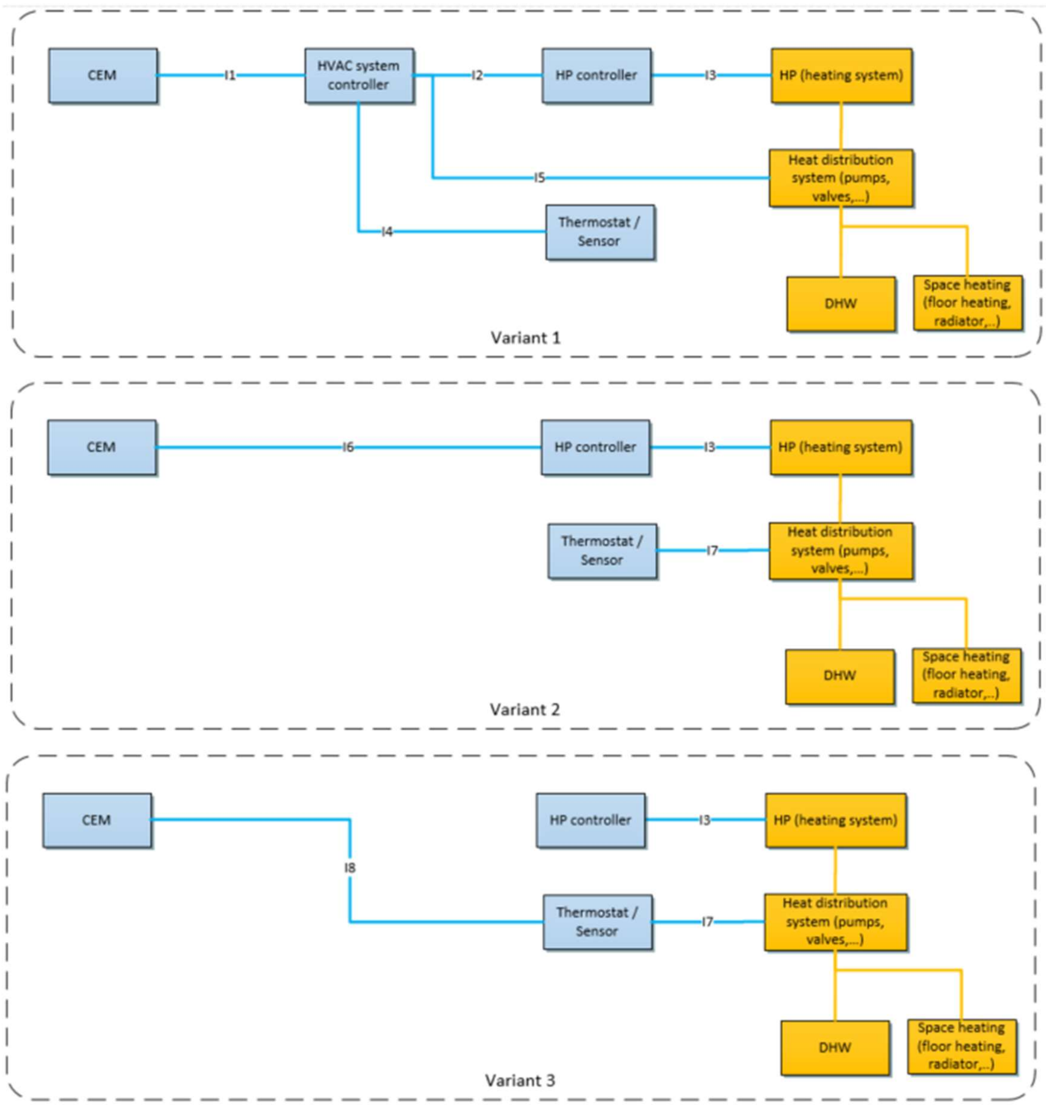

Figure 2 Variants of HVAC setups

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Table 1 provides a short description of these functional components.

Table 1: definition of the functional components in the building context

Component	Description
CEM:	the functionality to perform energy management operations (reference architecture …) not limited to HVAC (e.g. incl. batteries, smart appliances, …)
HVAC System Controller:	the functionality to control/manage the HVAC system (incl. DHW)
HP controller:	the functionality to control/manage the HP. Typically it is integrated with the physical HP heating system and offered as one product. It could be an internal module in the HP system or it could be an external module.
HP heating system:	all heat related components, except the HP controller, like the compressor, condenser, heat exchanger, pump, …

There are many ways to create/deploy a heating system. Some of these are shown as variants in Figure 2. In this set of variants, the CEM either communicates with the HVAC system controller, the HP controller or the thermostat to get the state of the heating system or to control the available flexibility.

The focus in this document is mainly on variant 1 and variant 2. In variant 1 a HVAC system controller acts as the central controller for the whole heating system and communicates with all relevant parts of the heating system. In variant 2 there is no overall controller. The HP system is controlled by the HP controller, mainly on system internal parameters and measurements. The thermostat controls the (heating) pumps and valves. Opening a valve or activating a pump to deliver heat will indirectly trigger the heat pump to produce heat.

The blocks in the Figure 2 describe pure functionality or logic and can be distributed over several devices or some functionality can integrated and implemented in one product. As a concrete implementation example Figure 3 shows two different constellations of variant 1 where the green blocks mark the devices. In variant 1a the HVAC system controller functionality is part of the CEM device. Or it could be a HVAC controller with additional energy management functions. The heat pump includes the HP controller. The thermostat device provides the thermostat functionality. In variant 1b the CEM device contains only the CEM functionality, and the HP device provides the HVAC system controller functionality and the HP controller functionality, besides the HP system components providing the heating function. From the outer view the thermostat communicates in this setup with the HP system.

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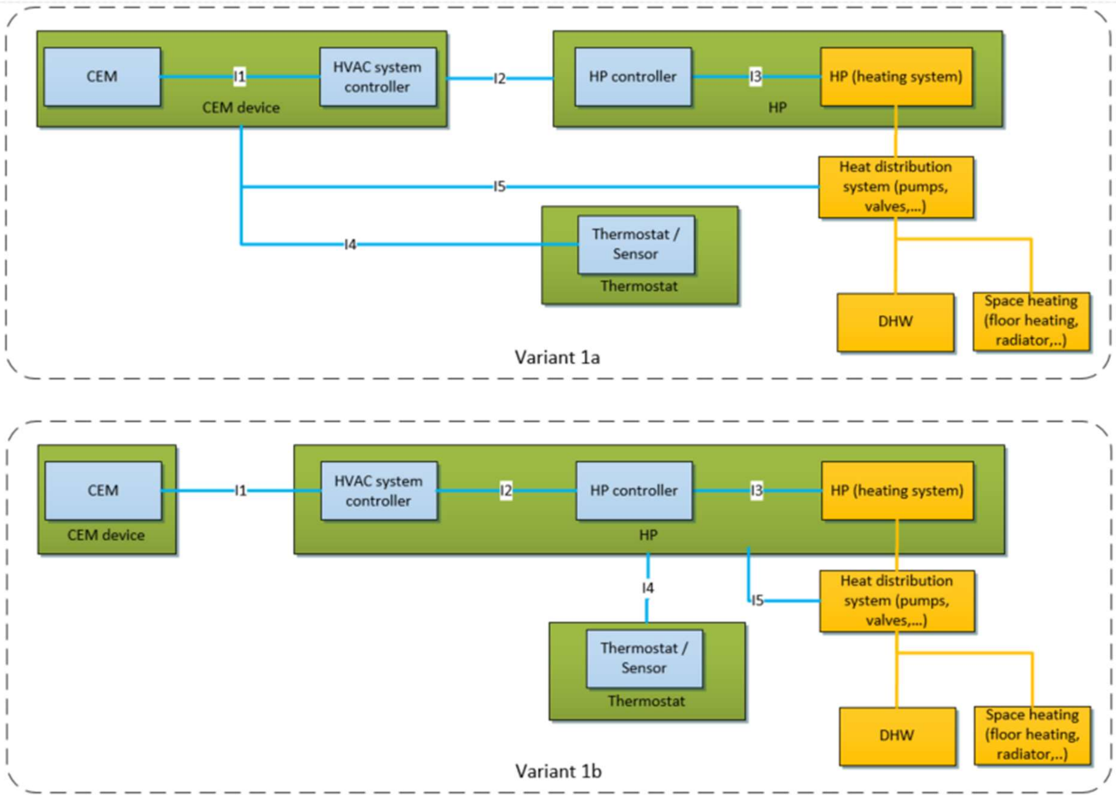

Figure 3 Two implementations of variant 1

With regards to the question how can the flexibility of the heat pump be enabled with the support of the manufacturers, chapter 3.5 looks at the above context with a more business view perspective. For instance Figure 3 shows how the functionality is integrated in one product or spread over several products, but it doesn't indicate the manufacturers of the products. Taking this into account variant 1b can show a completely different context if the CEM device and the HP device, including HVAC and HP controller, belong to the same manufacturer. In principle the applied interfaces can then be completely proprietary.

For all the Table 2 lists per interface, in the context of the FHP project, the options manufacturers have to implement an interface.

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Table 2 The interfaces and options to implement these interfaces

id	Interacting components	Interface options [2]	Comment
I1	CEM - HVAC System Controller	Proprietary	
		EEBus SPINE SG ready UC	
		EEBus SPINE thermostat setpoint override UC	Can be realized via the visualization and configuration of HVAC temperatures use case.
		EEBus SPINE outside temperature setpoint override UC	Currently not a EEBus UC
		EEBus SPINE heating curve adjustment UC	Currently not a EEBus UC
		EEBus SPINE Incentive-Table UC	On the EEBus roadmap
		(EEBus SPINE) direct control/advice UC	UC in discussion
I2	HVAC System Controller - HP Controller	Proprietary	
		EEBus SPINE	Several EEBus UC could be used to support this interface, but probably not all possibilities available in a proprietary interface will be in a standard use case.
I3	HP Controller - HP	Proprietary (digital communication or analogue control: relays, voltage,…)	Not in scope.
I4	HVAC System Controller – Thermostat / sensor	Proprietary analogue ON/OFF and/or modulation functionality	
		Proprietary Digital communication with status, ON/OFF and/or modulation functionality	
		EEBus SPINE visualization and configuration of HVAC temperatures UC	
I5	HVAC System Controller – Heat distribution system	Proprietary	Not in scope.

[2] In case of EEBus a reference is made to the use case. The EEBus SPINE data model and protocol together with an EEBus use case define the use of an interface. The EEBus use cases are listed in appendix 1.
Proprietary means that it is an interface defined by the manufacturer. It can be open (accessible to others) but it may also be closed. Even when it is proprietary it can still be based upon open protocols like Modbus for instance but with an manufacturer specific definition of the Modbus registers.

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id	Interacting components	Interface options [3]	Comment
I6	CEM - HP Controller	Proprietary	for instance controlling compressor speed via the test/support interface
		SG ready via 2 physical relays contacts	
		EEBus SPINE SG ready UC	
		EEBus SPINE outside temperature setpoint override UC	Currently not a EEBus UC
		EEBus SPINE heating curve adjustment UC	Currently not a EEBus UC
		EEBus SPINE Incentive-Table UC	On the EEBus roadmap
		(EEBus SPINE) direct control/advice UC	UC in discussion
I7	Thermostat / sensor – Heat distribution system	Proprietary	
I8[4]	CEM - Thermostat / sensor	EEBus SPINE visualization and configuration of HVAC temperatures UC	

Table 3 indicates the FHP flex functionality supported by each interface protocol.

Table 3 FHP flex functionality – interface protocol mapping

Supported functionality	SG ready (relays)	EEBus SG ready	Proprietary protocol implementation	EEBus HP direct control	Thermostat on/off/ modulating (0-10V)	Thermostat communication protocol.
Provide planned demand	No	?	Dependents on manufacturers' implementation	Yes	No	Dependents on manufacturers' implementation. Some thermostats may forecast user demand (Google Nest example).

[3] In case of EEBus a reference is made to the use case. The EEBus SPINE data model and protocol together with an EEBus use case define the use of an interface. The EEBus use cases are listed in appendix 1.
Proprietary means that it is an interface defined by the manufacturer. It can be open (accessible to others) but it may also be closed. Even when it is proprietary it can still be based upon open protocols like Modbus for instance but with an manufacturer specific definition of the Modbus registers.

[4] The I8 interface case assumes that the CEM communicates with the thermostat to get temperature info or to set/override the thermostat setpoint or program. This interface is not presenting the case that the thermostat is connected to a CEM acting as a HVAC controller. That interface case is presented by I4, where the HVAC controller functionality is part of the CEM system.

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Supported functionality	SG ready (relays)	EEBus SG ready	Proprietary protocol implementation	EEBus HP direct control	Thermostat on/off/ modulating (0-10V)	Thermostat communication protocol.
Provide flexibility forecast		?	Dependents on manufacturers' implementation	Yes	No	Dependents on manufacturers' implementation. Some thermostats may forecast user demand (Google Nest example?).
Respond to flex request with flex offer		?	Dependents on manufacturers' implementation	Yes	No	?
Indirect activation in real-time (1 point at a time)	Yes	Yes	Dependents on manufacturers' implementation	Yes	Yes	Yes
Indirect activation ahead via profile	No	?	Dependents on manufacturers' implementation	Yes	No	Could be
Direct activation in real-time (1 power point at a time)	No	No	Dependents on manufacturers' implementation	Yes	No	
Direct activation ahead via power profile	No	No	Dependents on manufacturers' implementation	Yes	No	

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Table 4 provides a map with the protocol options per interface.

Table 4 Interface – protocol mapping

Interface (protocol could be used at)	SG ready (relays)	EEBus SG ready	Proprietary protocol implementation	EEBus direct control HP (new UC)	Thermostat on/off/ modulating (0-10V)	Thermostat communication protocol.
I1	X	X	X	X		
I2	X	X	X	X		
I3			?			
I4					X	X
I5						
I6	X	X	X	X		
I7						
I8					X	X

This document looks into interfaces I1, I2 and I6, with the focus on a dedicated interface for flex management. The focus will be on 'direct' control (i.e. Grid Flex Heatpump concept) instead of 'indirect' control, as we want to exclude the use of 'setpoint or measurement overriding' solutions that can be considered as temporary solutions till commercially available products provide a dedicated direct flex management interface. These 'overriding' solutions generally deliver a less accurate, less predictable/reliable output compared to a dedicated interface. In some cases this may also be confusing to the end-user. For instance when a room temperature setpoint is lowered or increased by the energy management system, and the new value is visible on the display of the thermostat, the end-user may not be aware of the reason why this is happening. Also from system design viewpoint it is not good practice to misuse properties for not intended use cases. With some minor adaptations the room temperature setpoint overriding approach could be ameliorated by providing a 'delta setpoint' field indicating how much the user temperature setpoint setting is increased or lowered for energy management. This 'delta setpoint' field can be shown on the thermostats' display. This way there is a clear separation of functionality providing the end-user clear information.

I2 and I6 are the most likely interfaces to implement the Grid Flex Heat Pump concept described in chapter 3.3. I1 is not likely to be a candidate for this concept because the HVAC controller is the master of the heating system. It has all necessary information to define the thermal flexibility and can via the I2 interface make use of a direct control interface to instruct the heat pump very accurately and reliable.

Ideally, from the viewpoint of the CEM, the interface for energy management towards the heating system should be identical. It should not matter if the CEM is communicating with a HVAC controller or a HP controller, neither should it matter where (in which device) the functionality is situated. Despite the fact that the HVAC system controller may have additional options at its disposal to control the complete HVAC system (setpoint override, management of valves and pumps, …) this use case assumes that the HVAC system controller will use at least direct control of the HP via the HP controller.

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In case the HVAC system controller is part of the CEM the I1 interface could be implemented as a software interface and should be regarded as an API (application programming interface) in this case. The same is true for interface I2 when the HVAC system controller and HP controller are integrated in one device.

3.1.3 Determine the protocol/ information exchange for an interface

One way to determine the protocol for a certain interface is to look at the information the device or controller has. If a device has all the information to determine its flexibility one could implement a **flexibility protocol**, like for instance EEBus incentive-tables, to exchange information with the higher tier. If a device does not contain the necessary information to determine its flexibility then a **control/state protocol** is more appropriate. For instance a heat pump may not have the necessary information to determine its flexibility (e.g. it may not know the building's dynamic thermal behavior or weather forecast). A control/state interface with the HVAC controller is then the appropriate way to interact. The HVAC controller may be the master controller and have all the information to determine the thermal flexibility in the building. However, since there may be other devices with flexibility in the building, the HVAC controller may interact by means of a flexibility protocol with the controller one level up. This controller aggregates the flexibility offered by all the devices it interacts with (it does not control these devices, it interacts/negotiates with them to obtain its energy management objectives).

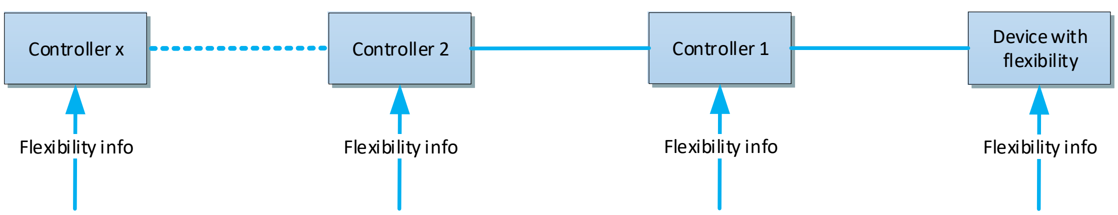

Figure 4 Control or flexibility exchange

3.1.4 Relation to the architecture proposed in CENELEC EN50491-12-1

In the architecture, described in CENELEC EN50491-12-1 and shown in Figure 5 and Figure 6, a new logical component, called the resource manager, is defined between the smart device and the CEM. The Resource manager provides the translation between the neutral (flexibility) Interface S2 (also called EFI) and the specific protocol used by a given smart device. The Resource manager presents a logical representation of the energy capabilities and properties of the devices to the CEM. The level of exposure of energy, capabilities and properties depends upon the configuration (and capabilities) of the Resource Manager. Being a logical function the Resource manager can be integrated in a controller, the device itself or a standalone device acting as a gateway. Applying the logic of section 3.1.3 it means that the Resource manager could talk to a smart device by means of a control/state interface, but it means also that it needs additional information from other sources to determine the flexibility so it can translate this control/state interface into a flexibility information exchange , what

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the neutral S2 interface is. This means that the RM is in that case part of a controller with the necessary sources of information to determine the flexibility.

In case the device already provides all the necessary flexibility information the Resource manager can act as a gateway/translator.

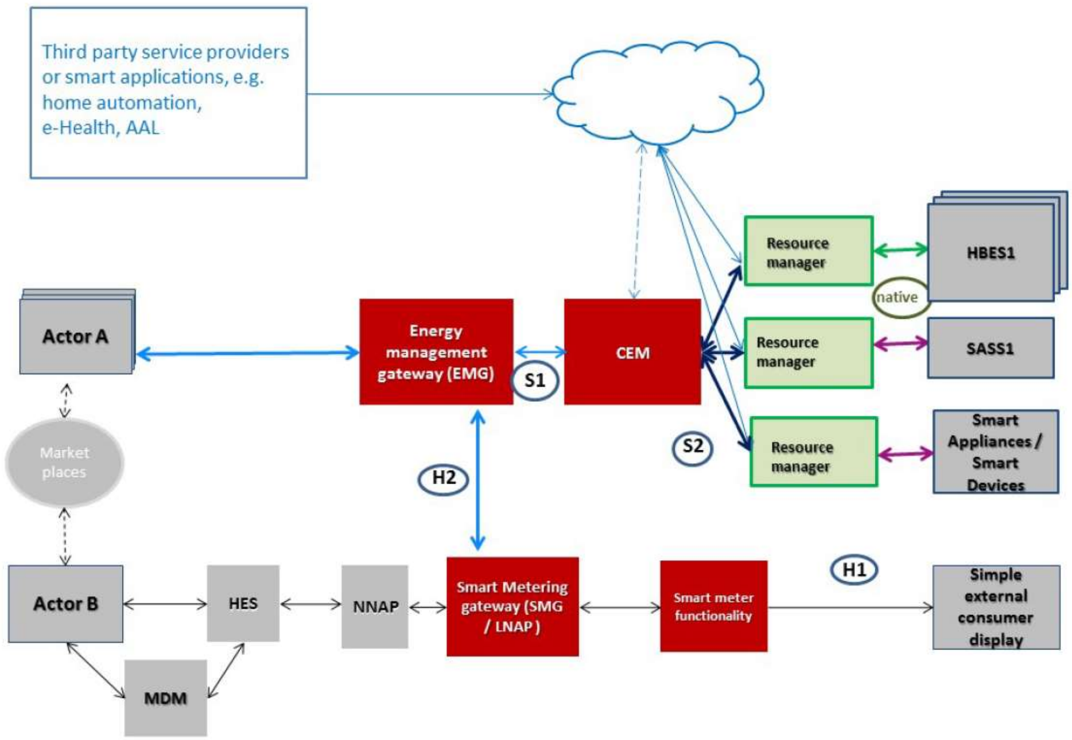

Figure 5 Architecture according to CENELEC EN50491-12-1

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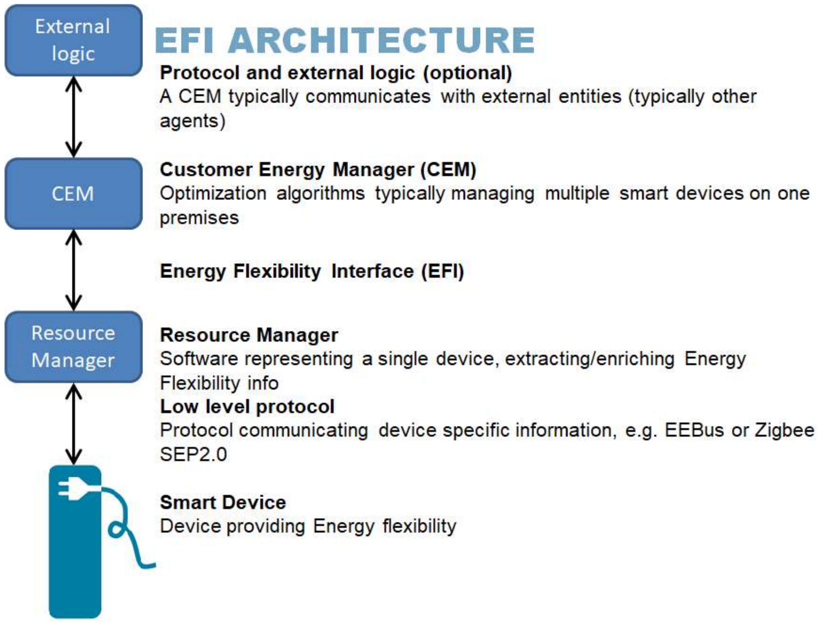

Figure 6 EFI Architecture

3.2 Communication with heat pumps

This chapter describes in general several communication options to interact with the heat pump and is a recap and continuation of section 3.9 of D2.3. The indirect control methods by means of overruling thermostat setpoints, modifying the measured outside temperature or influencing the heat curve are not part of the scope of this specification and are described in D2.3.

3.2.1 Modbus

Modbus is a communication protocol used by heat pumps and other devices to read or write data to the device. Modbus has become a standard communication protocol and is now commonly available for connecting industrial electronic devices. It was originally developed by Modicon (Schneider Electric) in 1979 for use with its programmable logic controllers (PLCs). The protocol makes communication among many devices connected to the same network possible. The protocol includes a Modbus Master, requesting information, and several Modbus slaves suppling information to the master. The Master can also write information to the slaves.

Modbus is an open protocol, meaning that it's free for manufacturers to build into their equipment without having to pay royalties. It has become a standard communications protocol in industry and is now commonly used for connecting industrial electronic devices. The protocol is often used to connect a supervisory computer with a remote terminal unit.

There are several versions of the protocol. The most relevant versions are Modbus for serial port and Modbus/TCP for communication over TCP/IP over Ethernet or other internet protocol suite compliant protocol.

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The main reasons for the use of Modbus in the industrial environment[5] are:

- developed with industrial applications in mind,
- openly published and royalty-free,
- easy to deploy and maintain,
- moves raw bits or words without placing many restrictions on vendors.

Although these reasons have made the protocol very attractive as a means for connecting industrial electronic devices and contributed to the interoperability of these devices, having a protocol with few restrictions, certainly on the data model level, has also negative implications. Every device manufacturer has its own definition of the registers, even for similar devices where the same definitions could be used.

Typically these electronic devices offer an Modbus based interface with hundreds or even thousands of registers. Each register can be seen as a parameter that can be set or read. The reason there are so many parameters is often the result from 'too much engineering' and the fact that the interface is not split up in a low level and high level interface. Actually all parameters are offered as a set, and it is up to the user of the interface to find out how to use these parameters.

To counteract this interface clutter one can define three versions of Modbus interaction from an information level perspective:

1. Modbus
2. Modbus + register definitions for a particular device
3. Modbus + register definitions based upon a data model for heat pumps.

Version 1 without any register definition is almost useless from the standpoint of interoperability. Implementors of a Modbus protocol endpoint would have to find out the meaning of the registers by reverse engineering (on the other hand machine learning/AI could support this).

Version 2 is the current state of commercial devices, meaning that implementors of a Modbus protocol endpoint have all the information to design such an endpoint. But a large shortcoming is that they have to do it for each manufacturer and potentially also for different device types of the same manufacturer. This is not a generic solution nor is it a plug and play solution. The interface may be open and well-documented, but a Modbus endpoint has to be implemented specifically per device type/version to communicate with these devices.

Version 3, the definition of 'Modbus for Smart Heat Pumps', is a potential path forward. This would mean that a **data model dedicated for controlling smart grid heat pumps** would be added to Modbus. This data model can be defined in an accompanying standard. Heat pumps supporting this version would be interoperable up to the SGAM information level (data model). At the SGAM functional level these heat pumps may not be interoperable, meaning they do not support the same (minimal) set of functions (for instance ON/OFF versus modulating heat pumps). To overcome this one could enhance the data model so also capabilities can be exchanged. For instance, a heat pump could indicate it can be modulated. The data model should be not too complex and still lean enough to support manufacturers that offer additional functionality not covered by the reference data model. This way manufacturers are not tempted to create their own branch of the standard and can still differentiate

[5] https://en.wikipedia.org/wiki/Modbus

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with other manufactures solutions by offering additional, manufacturer specific functionality without breaching the interoperability requirement.

A way to cope with interoperability at function level and related complexity could be the definition of a limited set of function groups. Devices would have to indicate which function sets, and therefore all related registers/data model parameters, are supported. The set of functions could be managed by an independent organization, being it the European heat pump association (HPA), ETSI workgroup for SAREF or other SDO.

From the market standpoint of heat pump manufacturers this could be their preferred solution: they don't have to implement a new protocol like SPINE (EEBus), instead they can rely on a mature protocol and engineers having years of Modbus experience.

This solution could also be a solution for integrating the installed base of heat pumps. By upgrading their firmware related to the Modbus communication with an additional abstraction/translation layer these devices could be made compliant with the new data model without having to alter the rest of the firmware logic (and the additional costs for testing).

3.2.2 Smart grid ready mode

Smart grid ready or "SG ready" is a standard for smart control defined by the German Bundesverband Wärmepumpe e.V. In the standard four different heat pump working modes are defined:

1. **Blocking mode**: HP is switched off, until storage reaches its lower allowed temperature level. (1:0)
2. **Normal mode:** HP operates with normal set-points (hysteresis controller). (0:0)
3. **Low price mode:** HP is switched on, hysteresis is increased. (0:1)
4. **Over-capacity mode:** HP is switched on, storage temperatures increased to the maximum temperature allowed by the HP. (1:1)

The activation of each mode is done based on how two terminals are open (0) or closed (1). The setting of the terminals activates a different setting of the heat pump. Heat pumps that have this function built in can get a "SG ready" label. Today over 1.000 heat pump models have the label already.

When one of the modes is activated (i.e. not Normal mode), the heat pump is programmed to respond in a certain way. As an example, the response of the heat pump CTC GSi 12 to the different modes is described below:

1. Blocking mode:
    a. The heat pump and auxiliary heater can be blocked in accordance with the settings in heat pump and auxiliary heater.
2. Normal operation:
    a. No specific changer to normal operation
3. Low price mode:
    a. With room sensor: Room temp. (setpoint) increased by 1ºC
    b. Without room sensor: Primary flow (setpoint) increased by 1ºC
    c. DHV tank: Setpoint increased by 10ºC
    d. Pool: Pool temp. increased by 1ºC

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   e. Cooling. Room temperature is reduced by 1ºC
4. Over-capacity mode:
   a. With room sensor: Room temp. (setpoint) increased by 2ºC
   b. Without room sensor: Primary flow (setpoint) increased by 2ºC
   c. DHW tank and immersion heater: Setpoint is increased by 10ºC. The immersion heater is permitted to run in parallel with the heat pump.
   d. Pool: Pool temp. increased by 2ºC
   e. Cooling. Room temperature is reduced by 2ºC

A disadvantage of the current Smart Grid ready v1.0 specification is that the required functionality behind each mode is not specified in such a way that all heat pumps would react in the same way. Every manufacturer can decide themselves how to implement each mode, resulting in different heat pump behaviour amongst heat pump types and brands. E.g. the example above illustrates that the Over-capacity mode is not guaranteeing that the HP and immersion heater are switched on unless/until there would be a comfort violation. It ressembles more a Low**er** price mode. In a recent meeting with heat pump manufacturers some indicated that the association was working on a new version of the Smart Grid ready specification, which might incorporate a well-defined and required action associated with each mode.

3.2.3 EEBUS

EEBUS is a standard based communications interface for energy management that can be used by different devices and technical platforms, regardless of manufacturer and technology.

EEBUS is developed by the EEBus Initiative e.V. which is an independent association with over 60 members, mainly from European manufacturers in the fields of smart home, connected home automation, electromobility and energy. The communication interface is a result of the German funding program E-Energy. The association and its members have developed the open EEBUS standard.

EEBUS aims for being a global language for devices to communicate with one another about energy. The background is that to make “Internet of Things” and “Smart Grids” work, devices needs to be able to communicate with each other. The core component of the technical specification is known as SPINE (Smart Premises Interoperable Neutral Message Exchange). SPINE provides a data model and a protocol to exchange this data. It can be regarded as an information level protocol. The most valued aspect of SPINE is its data model, and its neutral character. Although it has an associated protocol to transfer the data, this data model can also be incorporated in other protocols like the ones defined by the Open Connection Foundation (OCF). The EEBus organization is also working on an API interface based upon this data. Additionally a transporting protocol, named Smart Home Internet Protocol (SHIP), has been defined by the EEBus organization to exchange the SPINE data model on top of IP.

Although the SPINE specification describes the data model and the associated (application) protocol it is only in combination with specific use cases that a higher level of interoperability can be reached. The EEBus organization therefore is defining and describing several use cases in multiple domains, amongst others the HVAC domain. The next step under consideration is the definition of a smart grid or energy

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label indicating that the device is compliant with the EEBus specification and a (minimal) set of use cases.

The EEBus SPINE specification is open and publicly available on the organizations' website. It is also published as standard EN 50631-1. It is also SAREF4ENER compliant[6].

Chapter 3.4 describes the use of the EEBus SPINE option as the basis for an interface to enable the energy flexibility of a heat pump in more detail.

3.2.4 (Service) Web-interface / API

Nowadays most heat pump manufacturers offer some sort of web-interface/API, either integrated or as provided by an external box connected to the heat pump. Different levels of control are available, from few heating and DHW adjustments to entire control system parameter settings availability, see Table 5. Anyone having access to the API can use the interface, but the connection seems to need physical contact to the heat pump for the first-time setup.

Table 5 Control available for four different Swedish manufacturers of heat pumps.

Function*	Manufacturer 1	Manufacturer 2	Manufacturer 3	Manufacturer 4
Turn off heat pump completely	Yes	No	Yes	
Turn off heat pump, run aux heater	Yes	No	Yes	
Change heating curve	Yes	No	Yes	
Adjustment points of heating curve	Yes	No	Yes	
Change start of heating season	Yes	No	Yes	
Change room temp.	No	Yes	Yes	Yes
Schedule for room temp.	No	Yes	Yes	
Change DHW temp.	No	Yes	Yes	Yes
Schedule for DHW temp.	No	Yes	Yes	
Vacation (lower indoor temp.)	Yes	Yes	Yes	Yes

* No text in cell of table means information not found.

All heat pumps have the possibility to change the heating need of the building in at least one way, meaning all heat pumps having the web-interface/API can be controlled by indirect control. Only one of the manufacturers that were contacted in the project, is found outputting the speed of the

[6] Study on ensuring interoperability for enabling Demand Side Flexibility carried out by DNV-GL, TNO and ESMIG for the European Commission, Contract number: 30-CE-0837391/00-82

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compressor, an important parameter to control a VSD heat pump. That manufacturer claims to give access to all parameters except the parameters in the service menu.

In general, as of now the information and functionality that would be relevant for the flex control of heatpumps, is limited on many heat pump brands. Possibly a standardisation or manufacturer agreement is needed to get all needed parameters and interfaces for flexible control available. Today, for example, no heat pump makes available its electrical power consumption or its heating capacity.

The web-services are typically reach through addresses like: https://online.heat-pump-brand.com, where one must log in with a user name and password. All heat pump manufacturers (of the investigated four) have App-interfaces, on iOS or Android, as another way to communicate with and control the heat pump. There are different business models: the interface may be an add on option (extra cost) when purchasing the heat pump and/or a subscription may be needed to get full access to the interface.

In case of a larger building with a professional grade building automation system / building management system, this system will have some sort of web-interface and API, to get access to the heat pump controller. For private home automation the market is less mature, and we can see a growing flora of initiatives, products and services, including those from or supported by Apple, Google and Amazon. Smart thermostats like EcoBee and Nest are already here.

3.3 Definition of a direct control interface for the Grid Flex Heat Pump concept

As explained in chapter 3.1 this direct control concept applies primarily to interface I2 and I6. The focus of this interface is control by compressor speed variation.

To enable direct control of the compressor of the heat pump, the digital heat pump interface has to provide information about the capabilities of the heat pump and its compressor, return status information and provide commands to control the compressor.

The capability section of the interface provides information on how the heat pump can be controlled (constraints). These parameters together with the capacity parameters will provide the requester the necessary input to define an appropriate speed control profile and to estimate the consumption power profile based upon a compressor speed control profile. This part of the interface will be used by an energy management system or HVAC controller to discover and inquire for the devices ‘capabilities. Based upon this information energy management system or HVAC controller can decide how to encompass the heat pump in its energy or flexibility management.

Table 6. Heat pump capability parameters

Direction:	**From heat pump controller**		
Parameter	**Description**	**Type**	**Value/Unit**
Capacity	Electrical Power capacity	Integer	kW x 0.1
ControlType	Control type: ON-OFF or compressor speed control (modulating)	Enumeration	ONOFF or VARSPEED

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VARSPEED Control type	Varspeed option: stepless or discrete steps	Enumeration	Stepless/Discrete
Stepsize	Size of steps for a discrete varspeed heatpump	Integer	kW x 0.1
AuxiliaryHeater Present	Indicate if the heat pump system includes an auxiliary heater.	Enumeration	Yes/no
AuxiliaryHeater Controllable	Indicate if the auxiliary heater is separately controllable.	Enumeration	Yes/no
AuxiliaryHeater PowerCapacity	Electrical Power capacity of auxiliary heater	Integer	kW x 0.1

Table 7. Compressor capability parameters

Direction:	**From heat pump controller**		
Parameter	**Description**	**Type**	**Value/Unit**
SpeedControlType	Type of speed control: stepwise/stepless	Enumeration	stepwise/stepless
NumberOfSteps	Number of steps between minimum and maximum control range	Integer	0..n -1 in case of stepless
MinimumCapacity Interval	Control range minimum % capacity interval (see 3.6.1)	Integer	0 .. 100 %
RampingRate	Ramping rate in minutes from 0 to 100%, including start-up sequence.	Integer	Minutes
MaximumCompressor Speed	Maximum speed of the compressor in Hz or rps.	Integer	Hz or rps
RampUpSpeed	Ramp up speed: Hz/s or rps/s	Integer	Hz/s or rps/s
RampDownSpeed	Ramp down speed: Hz/s or rps/s	Integer	Hz/s or rps/S
SpeedUpAcceleration	Speed of change when increasing the speed, when the compressor is operating.	Integer	Hz/min or rps/min
SpeedDown Acceleration	Speed of change when decreasing the speed, when the compressor is operating.	Integer	Hz/min or rps/min
MinimumStart CapacityLevel	Speed level that has to be reached at ramp up before the compressor speed can be lowered. (start of operating phase)	Integer	0 … 100 %, 0 means there is no minimum speed level.
MaximumCompressor Power	Maximum power use of compressor	Integer	kW x 0.1
SpeedPowerFunction	Compressor/heat pump power consumption values, measured by manufacturer, for different speed settings. An array of {speed, power}	[{speed, power}], where speed and power are	Speed: Hz or rps Power: kW x 0.1

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	pairs, indicating the power for sufficient and relevant speed settings. Mandatory speed at minimum capacity interval and at maximum speed should be provided.	Integers	

The control parameters are used to provide a speed profile to the heat pump. A speed profile consists of speed levels in percentage and the duration the compressor should run at this speed. The requester can model the time it will cost to reach this speed based upon the capability parameters RampingRate (for first speed level), SpeedUpAcceleration and SpeedDownAcceleration. This way it will model a speed profile. The speedprofile can be converted to a power profile by means of the SpeedPowerFunction.

Table 8. Heat pump (Compressor) control parameters

Direction:	**To heat pump controller**		
Parameter	**Description**	**Type**	**Value/Unit**
Control speed profile	Array of control intervals. Each control interval is specified by a {speed, duration} pair. The duration indication the duration that the compressor should run at this speed. For each interval the duration starts when the compressor has reached the specified speed. In case of ON-OFF: max and min speed are the allowed values. Other values will be rounded up to maximum (100%) or rounded down to minimum speed (MinimumCapacity Interval). In case of stepwise (discrete values): speed will be adjusted to the nearest step value.	[{speed, duration}], where speed and duration are Integers	Speed: capacity interval (% of maximum speed) Duration: minutes

Table 9. Heat pump status information parameters

Direction:	**From heat pump controller**		
Parameter	**Description**	**Type**	**Value/Unit**
CoP	Coefficient of Performance function	Integer	x 0.1
ActualSupply Temperature	Temperature in degrees Celsius	Integer	°C
ActualPowerUsage	Actual power usage of the heat pump.	Integer	kW x 0.1

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Although the above defined interface exchanges information in terms of compressor speed, like MaximumCompressor Speed, ramp up speed, ramp down speed, or control speed profile, this information could also be exchanged as a power profile due to the compressor speed – power consumption correlation. This could make it easier to implement this functionality in for instance EEBus SPINE. EEBus SPINE does not provide by default the functionality to exchange compressor speed profiles, but it does provides the functionality to exchange power profiles.

Figure 7 shows the interaction between the controller and the HP controller.

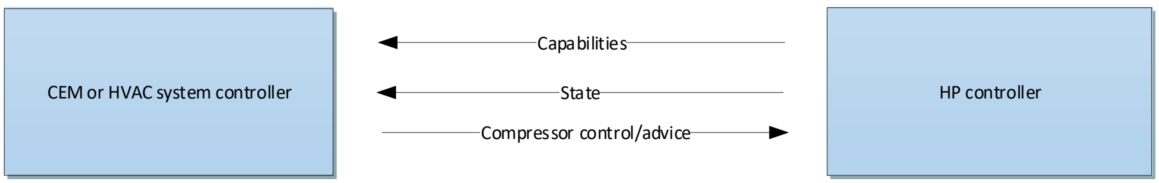

Figure 7 Direct interface interaction diagram (I2, I6)

3.4 EEBus SPINE interface to enable grid flexibility of heat pumps

3.4.1 The incentive-table based use case

The EEBus use case specification "Incentive-table based consumption management" provides a means to adjust the operation process of a device in such a way that higher-level constraints or optimization goals can be met. The use case is applicable to devices in the e-mobility domain as well as in the HVAC domain. Currently (October 2019) the e-mobility incentive-table based use case is specified and the HVAC incentive-table based use case is being specified. The plan is to have it released the first half of 2020 and tested in a plug-fest in the second half of 2020. The following section is based upon the general Incentive-table based mechanism, applied to the HVAC domain. The final HVAC incentive-table based use case may deviate from the deductions made in the next section. Some figures may indicate e-mobility or EV related terminology, but this can be replaced by HVAC terminology. For instance 'EV' can be replaced by 'heat pump', 'charging' by 'HVAC energy consumption', 'arrival time' by 'HVAC start phase', 'departure time by 'the end of the horizon', and so on.

Besides the energy consumer, which in this case is the heat pump, the use case defines two additional actors:

- The energy broker, which can influence the energy consumption of the energy consumer by means of incentives
- The energy guard, which provides a maximum power limitation as discrete power-time profile

The energy broker and energy guard are logical actors and can for instance be integrated in the same CEM device. As shown in Figure 8 the use case starts by the energy consumer sending an energy demand need (this could be considered the **baseline** consumption plan) for a certain horizon to the

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energy broker and energy guard. They respond with an incentive table and a maximum power limitation curve. As a result the energy consumer responds with an adjusted energy consumption plan.

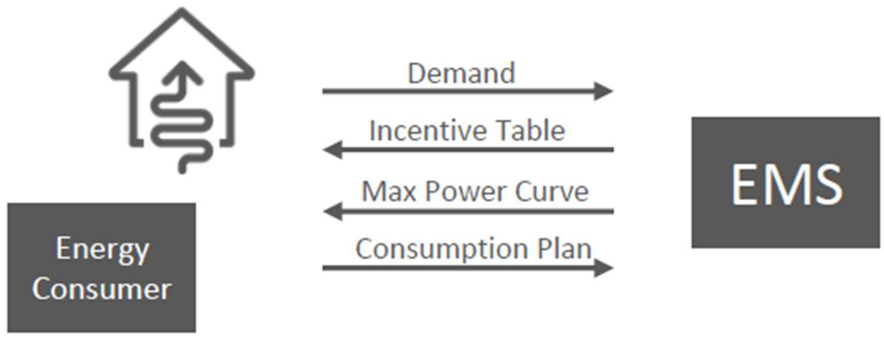

Figure 8 Coordinated energy consumer operation overview

With the energy demand profile (Figure 9) the energy consumer (a smart appliance, like HP) indicates the amount of energy needed to fulfil its foreseeable operation requirements (for a certain horizon). In this profile the energy consumer can specify the minimum energy it needs, the recommended amount of energy and the maximum amount of energy it could consume.

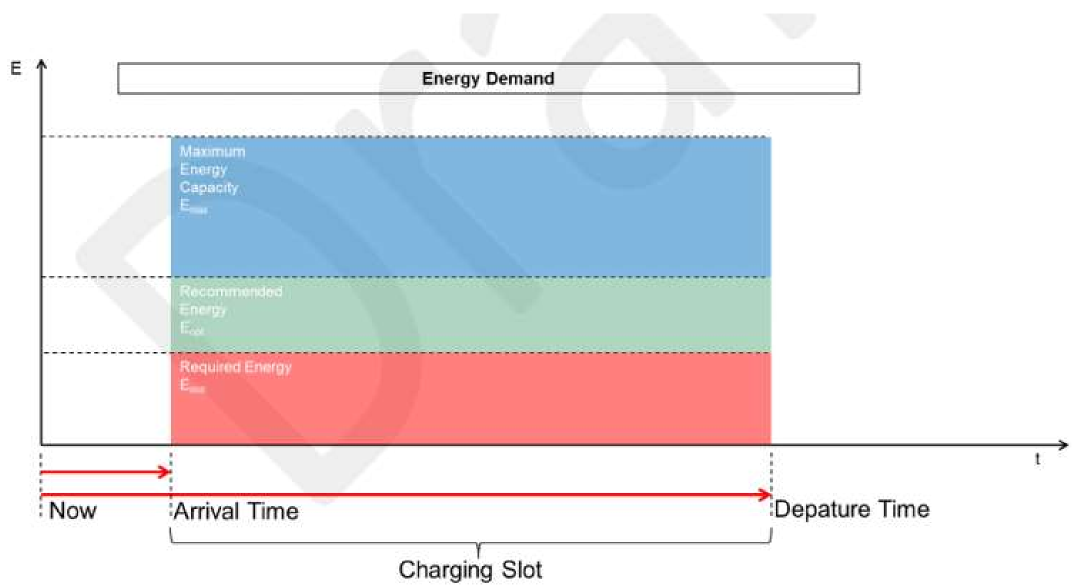

Figure 9 energy demand

The maximum power limitation curve (Figure 10) is sent by the energy guard and serves as a limit for the consumption. The consumption of the energy consumer should not surpass this limit. It is discrete and the horizon is matched with the energy demand horizon. Note: the EEBus organization is also

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considering a minimum consumption boundary, to indicate that the consumption should not fall below a certain threshold.

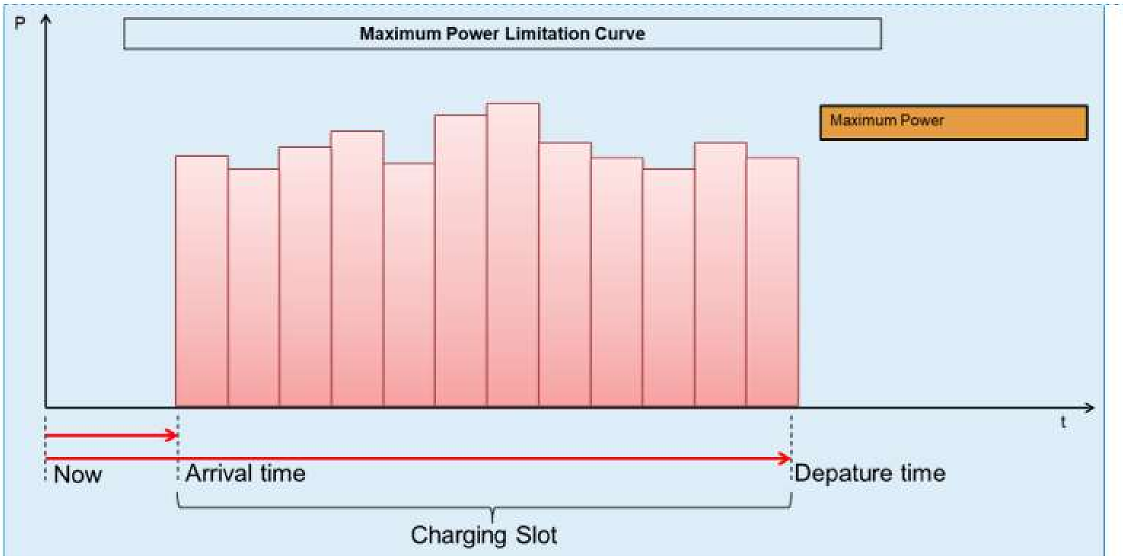

Figure 10 maximum power limitation curve

The Energy Broker sends a table with incentives (Figure 11) to the energy consumer. This way the energy consumer can create a (cost) optimized consumption plan. The incentive table communicates 3 different power levels (tiers) over time. For each power level (tier) the energy broker may communicate different incentives. The tiers should provide a realistic picture of the physical installation, meaning for example that PV power will be consumed before power from the grid is consumed.

The incentives can be based upon the absolute energy price but could for example also take into account CO_2 emission. However, the HVAC companies stressed the fact that the incentives should be realistic and not pure virtual. With virtual prices the CEM could almost take over heat pump control and force the consumption of the heat pump in a certain direction. With the virtual pricing mechanism the energy broker could also try to learn the behaviour of the energy consumer by sending different incentive tables in consecutive iterations. According the HVAC manufacturers this is not a use of the incentive mechanism that is allowed. They fear to lose control of the HVAC system, but still be held responsible for the performance of the system. There are some mechanisms built in the incentive-table process to counteract this 'misbehaviour'. For instance it is possible to start an incentive-table iteration several times, but the energy consumer can indicate that it will not respond anymore after a certain number of iterations.

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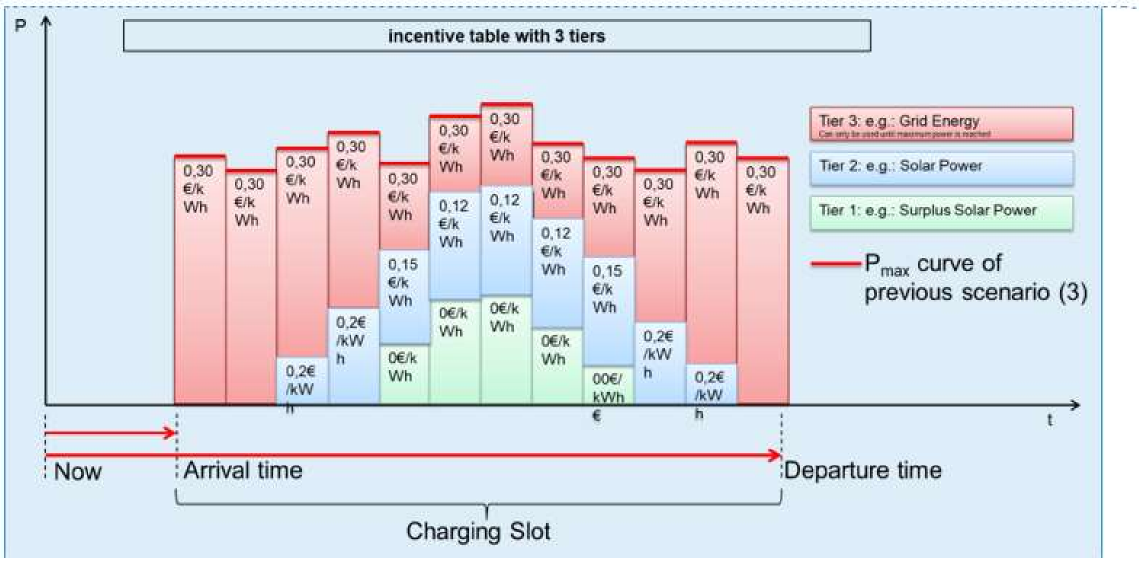

Figure 11 Incentive table example

This incentive-table mechanism can be used by the CEM (energy broker) to give priority to an EV charging session or to delay the EV charging session and let the HVAC system heat up the building. It can also be used in the FHP context to have heat pumps plan their consumption so to reduce RES curtailment. Although not as indirect as indoor temperature or outdoor temperature override, the incentive-table mechanism is still a kind of indirect method. It is the HVAC controller that decides how to react on the provided signals. The CEM may try to learn the behaviour of the HVAC controller to speed up the iteration process, but the final decision remains with the HVAC controller.

Looking from a systems perspective the Incentive table mechanism is similar to the ADMM interaction between the tracker and (v)DER.

This EEBus incentive-table use case is ideally for interface I1 . It could also be applied to interface I6, but in this case the heat pump controller has less information to determine its flexibility.

Analysis of the Incentive Table Based Approach

- It is basically support a myopic (per flex device) optimization. When there are multiple flex devices, one needs to determine per device what max power consumption parameter and what incentives (e.g in relation to Solar and Surplus Solar) each device receives.
- The approach to deal with multiple flex devices, is to prioritize them where the results of the first optimization constrain the second optimization.
- The proposal that we are pursuing from FHP, and will continue to pursue through the DT-ICT-10 InterConnect project, is a non-myopic holistic optimization, using a distributed optimization approach (like ADMM) to iteratively converge to an optimal solution, rather than a sequentialized approach.

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3.4.2 Alternative: direct control/advice interface based upon EEBus SPINE

The alternative is to use direct control as explained in chapter 3.3. A power (or compressor speed) profile is sent to the heat pump. And the heat pump is obliged to follow this suggested power profile as long as it doesn't infringe on the local (comfort and safety) constraints and preferences set by the installer and the user. Although the EEBus organisation has not described a use case based upon direct control via a power profile, this use case can be implemented by means of SPINE because all building blocks are available in SPINE. The SPINE resource (data model) specification 1.0.0 defines concepts like operating constraints, power sequences, direct control, smart energy management and others. One can already define and exchange capabilities and power profiles (power sequences) in SPINE, but it is the use case specification that defines how to interpret the information items like power profiles, and how an endpoint should act or react. The use case together with the SPINE data model and protocol specification (and certification tests) makes sure that devices are interoperable. Having a device with a SPINE protocol stack but not supporting the particular use case will not make it possible to interact with this device as set in the use case.

Having defined a use case not supported by the EEBus organization will provide the opportunity to test the whole concept, but the lack of support would make it less useable. It would also mean that the implementer has to write the use case code themselves and cannot rely on a commercially available SPINE stack library for that aspect. These commercial protocol stacks mostly provide a use case API to interact with the stack at use case level. They may also provide an API at SPINE protocol level but this API is more complex and a larger coding effort will be needed.

At this stage there is no added value in implementing the direct control interface use case by means of SPINE. Instead the use case can be implemented in any other protocol (REST API, Modbus, MQTT,…) to show the benefits of the use case. The results of that approach, the lab tests (see D2.3) and an added value analysis should be used to convince HVAC manufacturers to support this use case.

<u>From various contacts with HP manufacturers, two barriers can be observed:</u>

1. Fear of losing control cq. being blamed for comfort violations as the result of DR actions. The answer to this is to guarantee that any direct control advice shall take into account user-set comfort parameters, and the HP internal controller (as in the case for the SG Ready standard) can overrule requests if comfort would be at risk. I.e we need to create awareness that the risk is not higher than for the SG Ready standard, that already is supported by over 1,000 heatpump models.
2. Changing business models of HP manufacturers: moving from 'providing a device, i.e. the HP' to 'providing a heat service' in which they incorporate active control for flexibility/DR themselves.

3.4.3 Alternative: direct control/advice mode based upon EEBus SPINE

Instead of having an interface for direct control where the CEM actually has to guide the heat pump all the time via the direct control interface, one could define two modes: the normal operating mode and the slave operating mode.

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In the normal operating mode no direct control/advice commands from other controllers are accepted by the heat pump. The heat pump controller (or HVAC controller) has all control and optimizes for the best and most efficient performance.

In the slave operating mode the heat pump device is still in control, but the device is expected to take into account the direct control/advice commands from other controllers and to respect their intention as much as possible without violating the internal constraints (technical, lifetime, user preferences,…). To the HVAC manufacturers it may make sense that they can log how many times the slave mode is activated, how long this mode was activated and to indicate to the user what the impact is on the operation efficiency and lifetime of the device. This way the manufacturers do not lose control of the device, can fall back on logs in case of performance or lifetime disputes, and at the same time support the possibility to offer flexibility.

It can be agreed in sort of negotiation process ahead of the operational phase how many times or when a device can be switched to the slave mode, the maximum duration of the slave mode, the capability of the slave device to switch itself to normal mode, etc. These preferences can be set by the manufacturer, the installer or the end-user.

EEBus SPINE already has a mechanism and use case to switch modes, although the mode defined in this paragraph is not part of that use case. On top of that the mechanism described in section 3.4.2 would have to be implemented.

3.5 Business view

This section describes some business viewpoints. Business motives can influence the selection of certain interface implementations and offered functions via a particular interface. This section is the authors' interpretation, based upon discussions in the meetings mentioned in chapter 3.6. It by no means is a statement of the involved actors.

To analyze some aspects of interconnection of the systems involved in energy management and HVAC, the amount of potential configurations is reduced to the setups explained in the next sections.

3.5.1 Setup A: each system is supplied by a different manufacturer

In the setup shown in Figure 12 all components can be replaced by a similar component of another manufacturer. In the context of interoperability all interfaces should be well-defined up to the interoperability function level (SGAM function layer) and is inherently based upon open standards.

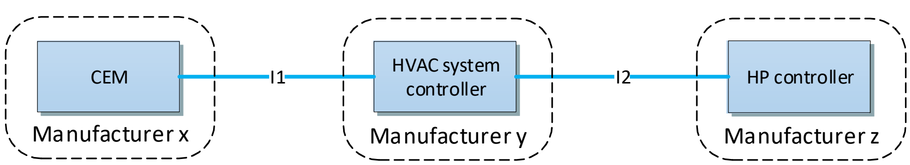

Figure 12 Setup A: each system is supplied by a different manufacturer

The benefits of this setup for the end-customer are:

- Freedom of choice: the ability to shop at different manufacturers and having more technological options in combining different components

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- Having more market competition resulting in lower prices per component
- Being less dependent on a specific manufacturer during the operation phase (lifetime of the component). A component of manufacturer A can be replaced by a component B.

Manufacturers could focus on just one market segment and on products for this segment. Because of this specialization the manufacturer may sell more products (when providing excellence), but the manufacturer could also be pushed out of the market by competitors offering one of the other setups (B,C,D).

The challenges of the setup are:

- Interoperability must be guaranteed up to the function level. It is up to the actor selecting the different components to assess this interoperability. No energy or smart grid ready label or certification is guaranteeing complete interchangeability yet.
- Responsibility and liability: having components from different manufacturers means the actor combining all components will be responsible for integrating, the commissioning and the well-operation of the system (maintenance, monitoring, performance, …). This actor can be:
    - The end-customer: in this case the end-customer must be technologically knowledgeable.
    - An independent third party: this actor acts as the integrator of the system and is responsible for the well-operating of the system once it is setup. The end-customer is shielded from the technological and operational aspects, but has to rely on the integrator. The services delivered by the integrator will introduce an additional cost for the end-customer. The integrator needs to have a good technical insight as well as a good business relation with the involved parties.
    - One of the involved manufacturers acts as the integrator: see previous point, except the fact that the integrator and other involved manufacturers are potential competitors could make the situation more complex.

3.5.2 Setup B: one manufacturer for the CEM, one manufacturer for the heat system

In the setup shown in Figure 13 one manufacturer is responsible for the whole HVAC system.

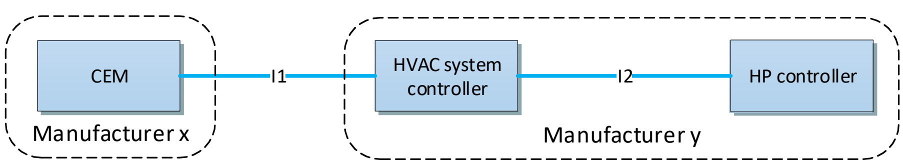

Figure 13 Setup B: one manufacturer for the CEM, one manufacturer for the heat system

Compared to the previous setup:

- There are less actors involved.
- The responsibility is clearly defined: manufacturer y is responsible for the well-operating of the HVAC system. A different manufacturer is responsible for the energy management of the

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whole system and relies on the HVAC energy and flexibility functionalities provided by manufacturer y.

- Since the HP controller and HVAC system controller belong to and are the responsibility of the same actor, the integration of both components can be closer, and the I2 interface does not have to be based on an open standard. It also means that some of the objections against a direct control/advice approach for interface I2 are not valid anymore in this setup. On the other hand having an open standard based interface for I2 could still be listed as one of the requirements when purchasing the system, in case the customer wants to switch to another setup at some point.

3.5.3 Setup C: one manufacturer for the CEM and HVAC controlelr, the heat pump is supplied by a second manufacturer

In the setup shown in Figure 14 the HP controller is just a smart appliance with an internal controller for the optimal functioning of the heat pump. The overall heat and cool management is the responsibility of the HVAC controller.

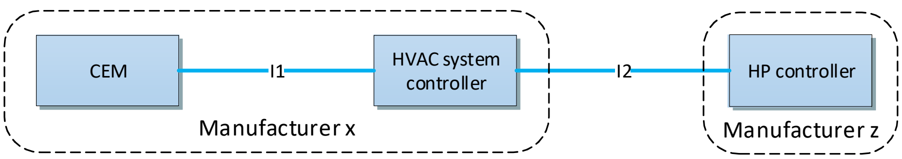

Figure 14 Setup C: one manufacturer for the CEM and HVAC controller, the heat pump is supplied by a second manufacturer

In fact the CEM and HVAC system controller functionality may be integrated into one physical box. For the I2 interface applies the same arguments as in setup A. Having the same manufacturer providing the CEM and the HVAC system means that the I1 interface could be a proprietary interface but also that there would be less opposition against a direct control interface.

3.5.4 Setup D: one manufacturer for all systems

In this setup shown in Figure 15 all components are supplied by the same manufacturer. Although the interfaces I1 and I2 are internal to the system and the manufacturer could make use of proprietary interfaces, unless an open standard based interface is requested by the end-customer, the manufacturer may still opt for an open standard based interface. For instance because the manufacturer may also sell these components as separate components (for the other setups).

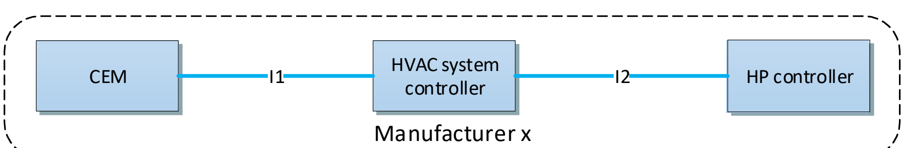

Figure 15 Setup D: one manufacturer for all systems

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Concerning responsibility, liability, complexity, performance, installation, integration and operation this the best setup. It is all handled by one party. On the other hand there is the vendor lock-in. At least the manufacturer operating the CEM should use open standard interfaces to communicate with other smart appliances in the building.

3.5.5 The manufacturer view of an open standard based interface

Unless it is a requirement, business-wise a manufacturer may opt not to provide an open standard interface, because of several reasons:

- The implementation cost to add this open standard interface to its systems.
- The loss of functionality of the overall system. The open standard interfaces may not support all functionality that can be realized when using proprietary interfaces.
- Management of the interface functionality. Compared to a proprietary interface it will be harder to add functionality to the interface when this functionality has been identified as crucial by a manufacturer.
- A manufacturer may opt not to use an open interface and to expose its technological lead, even when the standard supports proprietary extensions.
- The manufacturer believes he'll sell more components this way because components need to be sold in combination with components of the same manufacturer due to the proprietary interfacing.
- Supporting an open standard does not imply interoperability. Having a label that indicates that a device supports an open standard interface may even be counteracting if in the field it turns out that these systems do not interoperate or extra functionality or gateway has to be purchased.
- When the open standard protocol is designed to be generic and versatile, it may make the system more complex. And complexity makes a system more error-prone and security-wise more vulnerable. Installing and operating complex systems requires also well-educated installers and integrators having knowledge of the whole system.
- The manufacturer is dominating the market.
- The manufacturer may fear loss of control of the internal working of its components while still being hold responsible and accountable. The manufacturer may fear not to be able to guarantee quality of operation, performance, energy efficiency or lifetime commitments.

Potentially a manufacturer may implement a direct control/advice interface but not with the intention to open up this interface to other manufacturers. The manufacturer could make use of this interface when the EMS and /or HVAC controller and HP controller are provided by the same manufacturer. This would of course give them a technological advantage, resulting potentially in a higher performance. In discussions with HVAC manufacturers they indicated that they would not support an (open) direct control/advice interface for one or more reasons listed in the paragraph above. But informally they indicated that HVAC manufacturers are strategically purchasing other companies linked to energy management and EMS systems. This way there is a future for this direct control interface, but it might not be an open interface.

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3.6 Actions towards standardization

During the project is was decided that participating in the EEBus organisation was the best path to standardizing the heat pump direct control/advice use case. Afterwards it turns out that the process is quite slow and that it still may take several years to convince HVAC manufacturers and to have this use case standardized.

Actions towards the EEBus initiative:

- EnergyVille (VITO) joined the EEBus organisation in 2018.
- During the years 2018 and 2019, participating as member of the EEBus organisation in technical discussions. The EEBus organisation has several workgroups:
    - The HVAC workgroup
    - The e-mobility workgroup
    - The inverter workgroup
    - The EMS workgroup

  These workgroup have regular, typically two-weekly, teleconferences to discuss technical aspects.
- Participating in the EEBus member assembly meetings in Cologne in 2018 and 2019.
- Participating in the EEBus HVAC workgroup face-to-face meeting on September 26th , 2019 in Cologne. The outcomes of that meeting are integrated in this document. For instance the worries of the heat pump manufacturers to lose control of the device and still be responsible for its operational behaviour and lifetime. The proposed alternative by means of Incentive-Tables has been discussed. Also the intention to have a kind of direct interface for heat pumps on the EEBus HVAC roadmap was brought up by VITO and has been discussed. Notwithstanding the reluctance of the HVAC manufacturers the direct control/advise interface concept was in the end more or less categorized as grid support (in case of emergency for instance). At the end of the meeting three use cases has been selected and prioritized, including the grid support use case, and will be investigated further. The EEBus roadmap[7] shows the current (11/4/2019) state of the use cases and is summarized in Figure 16. The grey coloured use cases are upcoming use cases.

[7] EEBus overview of use cases, V1.24, 11/4/2019, https://www.eebus.org/download/8740/

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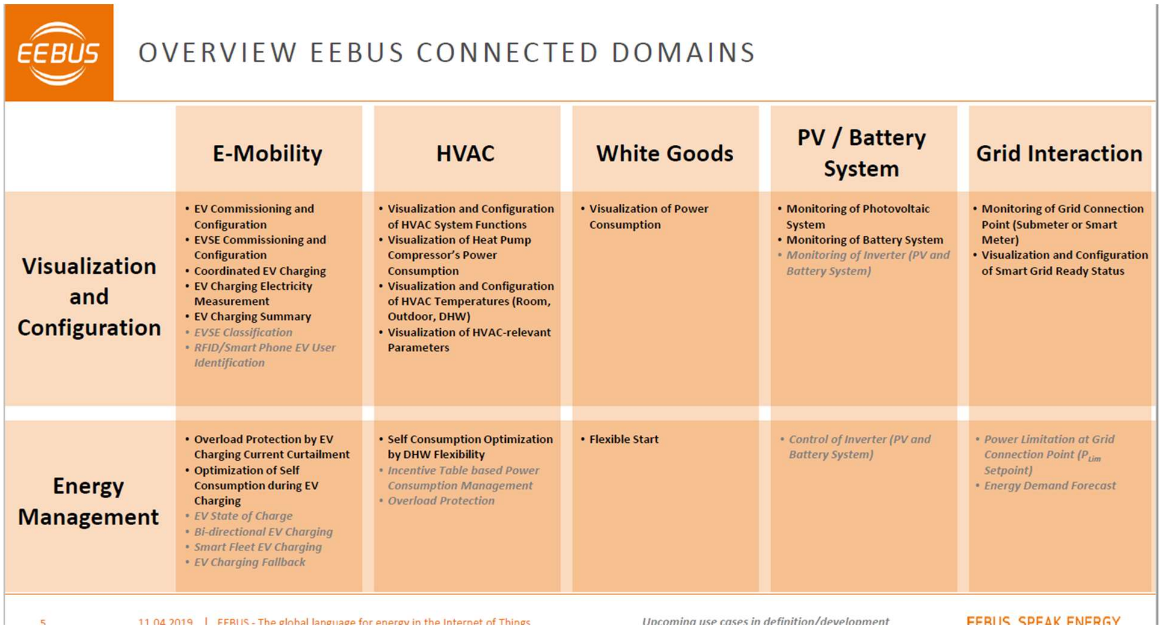

EEBUS OVERVIEW EEBUS CONNECTED DOMAINS

	E-Mobility	HVAC	White Goods	PV / Battery System	Grid Interaction
Visualization and Configuration	• EV Commissioning and Configuration • EVSE Commissioning and Configuration • Coordinated EV Charging • EV Charging Electricity Measurement • EV Charging Summary • *EVSE Classification* • *RFID/Smart Phone EV User Identification*	• Visualization and Configuration of HVAC System Functions • Visualization of Heat Pump Compressor's Power Consumption • Visualization and Configuration of HVAC Temperatures (Room, Outdoor, DHW) • Visualization of HVAC-relevant Parameters	• Visualization of Power Consumption	• Monitoring of Photovoltaic System • Monitoring of Battery System • *Monitoring of Inverter (PV and Battery System)*	• Monitoring of Grid Connection Point (Submeter or Smart Meter) • Visualization and Configuration of Smart Grid Ready Status
Energy Management	• Overload Protection by EV Charging Current Curtailment • Optimization of Self Consumption during EV Charging • *EV State of Charge* • *Bi-directional EV Charging* • *Smart Fleet EV Charging* • *EV Charging Fallback*	• Self Consumption Optimization by DHW Flexibility • *Incentive Table based Power Consumption Management* • *Overload Protection*	• Flexible Start	• *Control of Inverter (PV and Battery System)*	• *Power Limitation at Grid Connection Point (P_{Lim} Setpoint)* • *Energy Demand Forecast*

5 11.04.2019 | EEBUS - The global language for energy in the Internet of Things *Upcoming use cases in definition/development* EEBUS. SPEAK ENERGY

Figure 16 EEBus use cases

Participating in the workshop on smart home protocols organized by ElaadNL and TKI on September 9th 2019. The objective of this meeting by TKI and ElaadNL was to collect input on the current state of smart home protocols and on potential paths forward to have more interoperable solutions. For instance the concept of a standardized data model for heat pumps on top of Modbus was discussed in this meeting.

In the context of interoperability visions, teleconferences and meetings have been held throughout 2018 and 2019 with representatives of TNO and EEbus. TNO is responsible for the study on SAREF and SAREF4ENER. SAREF4ENER is a ETSI technical specification ETSI TS 103 410-1.

Participating at the Open Energy Marketplaces workshop on 8/3/2019 organized by DG ENER and DG CNECT.

Participating at the workshop on Platform Convergence for Smart Home Services for Health and Energy on 13/4/2018 organized by DG ENER and DG CNECT.

Participating at the Workshop on 'Digitalising the energy sector: standardisation and interoperability' on 28/11/2017. Amongst others SAREF has been discussed in this workshop.

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3.7 Conclusion

One of the conclusions is that going for the technically best performing/scoring solution may not always be the best path forward to market acceptance and thus installation base. A too complex solution may deter manufacturers from following the standard solution. Or a too strict solution can create the same effect because manufacturers may not be able to differentiate from competitors or be able to innovate. Also the liability aspect of who is responsible for the behavior of the overall setup or who is responsible for guaranteeing the lifespan of the device when control is moved to another actor has be taken into account.

Related to the direct control interface to the heat pump there are several options for the next steps to be taken:

- The most important step is to show the added value to the HVAC manufacturers. The results of the FHP project together with an economic business case calculation should be discussed with the HVAC manufacturer to take away their concerns. Their support to this interface and use case is needed.
- A prototype implementation based upon Modbus, a REST API or EEBus SPINE, with support of a HVAC manufacturer, could help to show the use case and convince the EEBus HVAC manufacturers.

In case of building on top of Modbus the potential next steps are:

1. Defining a minimal data model, based upon de functions in chapter 3.3, that can be applied to the register definitions.
2. Testing the concept with a Modbus implementation based upon the data model defined in step 1. If the test shows shortcomings in the data model, adapt the data model and retest.
3. Show the results to the HVAC alliance(s)
4. If accepted, initiate the standardization of this data model.

Note: although the aim is to include the necessary data items in the data model to support the direct control use case, having a standardized data model in Modbus for DSF interfacing with heat pumps would already be a great step forward to make these devices more interoperable.

To show the added value and to test the use case by means of SPINE the potential next steps are:

- Implement the direct control use case on top of SPINE
- Show the results to the EEBus HVAC consortium
- As an alternative the incentive-table based SPINE use case can also be implemented, and both solutions could be benchmarked.

An alternative is not to use Modbus or SPINE to implement the use case, but to define a REST API / web service to interact with the heat pump controller.

The final step would be to include this DSF data model for heat pumps as part of the SARE4ENER specification. This way the solution is agnostic of the underlying information and communication technologies.

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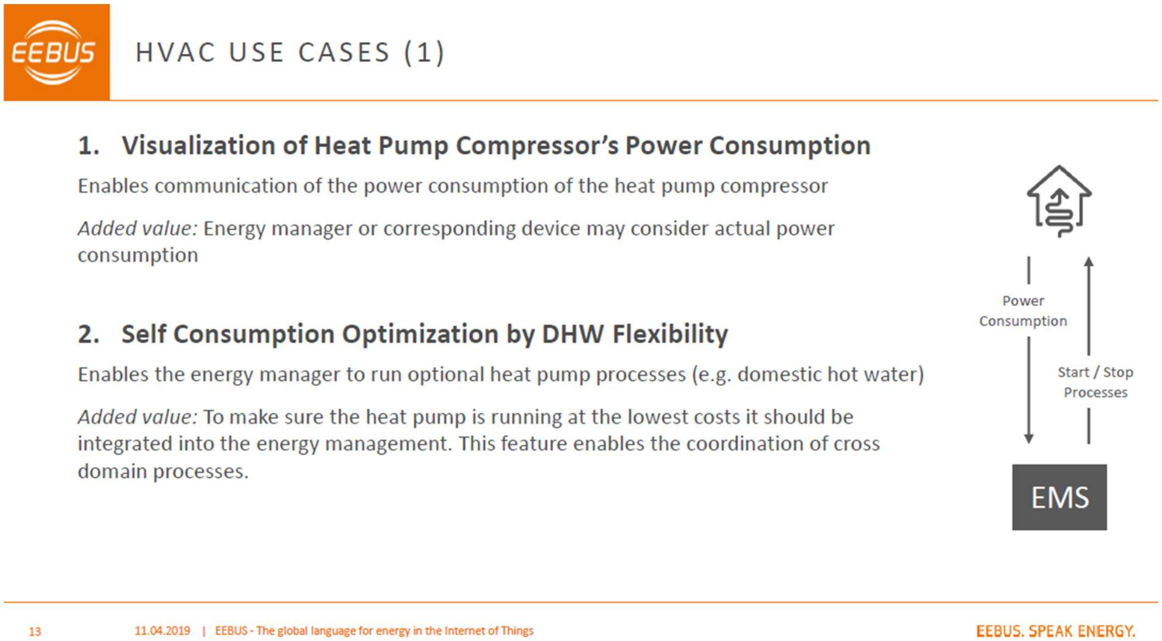
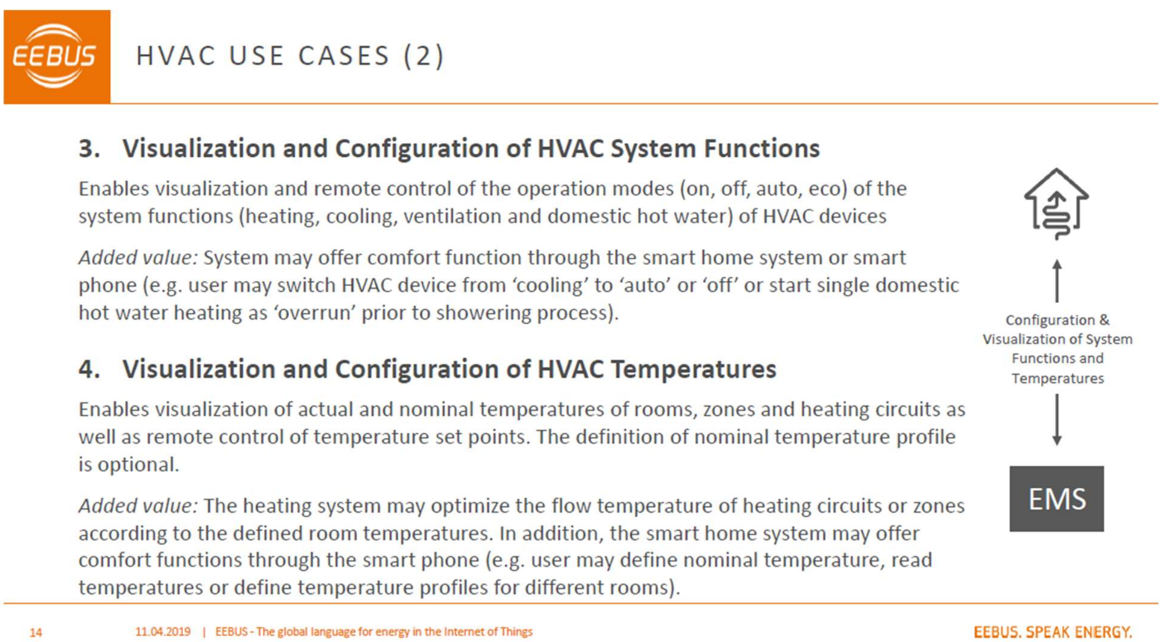
4 Annex I - EEBus HVAC use cases

The slides below from the EEBus overview of use cases document[7] summarizes the relevant HVAC use cases currently specified by the EEBus organization and also upcoming use cases.





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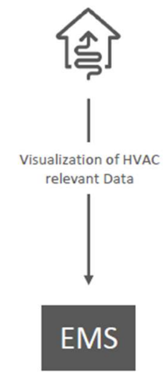
HVAC USE CASES (3)

5. Visualization of HVAC relevant Parameters

Enables system to communicate

- Heating circuit name
- Heating zone name

Added value: User may get additional information of the HVAC system



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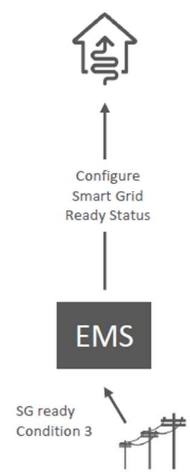
GRID USE CASES (2)

2. Visualization and Configuration of Smart Grid Ready Status

Enables system to read and write “SmartGrid-Ready Status”

Added value: Digitalization of relay contact. Set 1 of 4 different states, e.g. “SmartGrid-Ready Status” to “SG Ready Condition 3” digitally through EEBUS.



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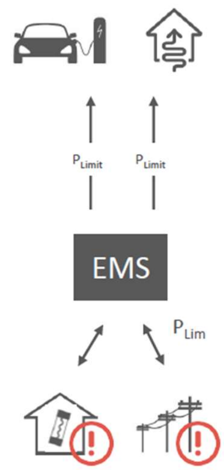
GRID USE CASES (3)

3. Power Limitation at Grid Connection Point (P_{Lim} Setpoint)

Enables the system to set the maximum power set point to a zone (e.g. smart home)

Added value: If the energy demand of a zone is too high and the network cannot provide this energy the energy manager can reduce the power consumption of the entire zone by sending power targets to the connected devices.



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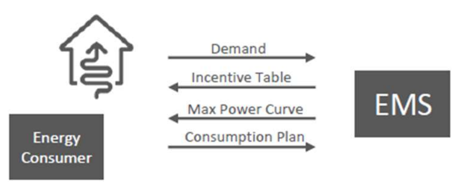
UPCOMING USE CASES (4)

7. Incentive Table based Power Consumption Management

Enables the energy manager to use of the devices' (e.g. heat pump) flexibility by influencing the operation process through the price of energy (incentive table) to optimize the total power consumption of the house or realize power set points from the grid.

Added value: Devices know about when green, cheap or costless energy is available and can change the operation mode accordingly. In case of PV curtailment, surplus costless energy can be used by the device. On the other hand, a device can operate without loss of comfort by accepting the energy price valid at that time.



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UPCOMING USE CASES (5)

8. HVAC Overload Protection

Enables the system to limit the maximum power consumption of an HVAC device and monitor the connection itself. In case there is no connectivity the HVAC device will only operate within defined safety parameters.

Added value: The power consumption of the HVAC device may be reduced to prevent grid issues or even fuse brake through limiting the maximum current.

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