IN-HOME ENERGY FLEXIBILITY PROTOCOLS

TKI URBAN ENERGY
Topsector Energie

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commissioned by RVO.nl
at the request of
TKI Urban Energy

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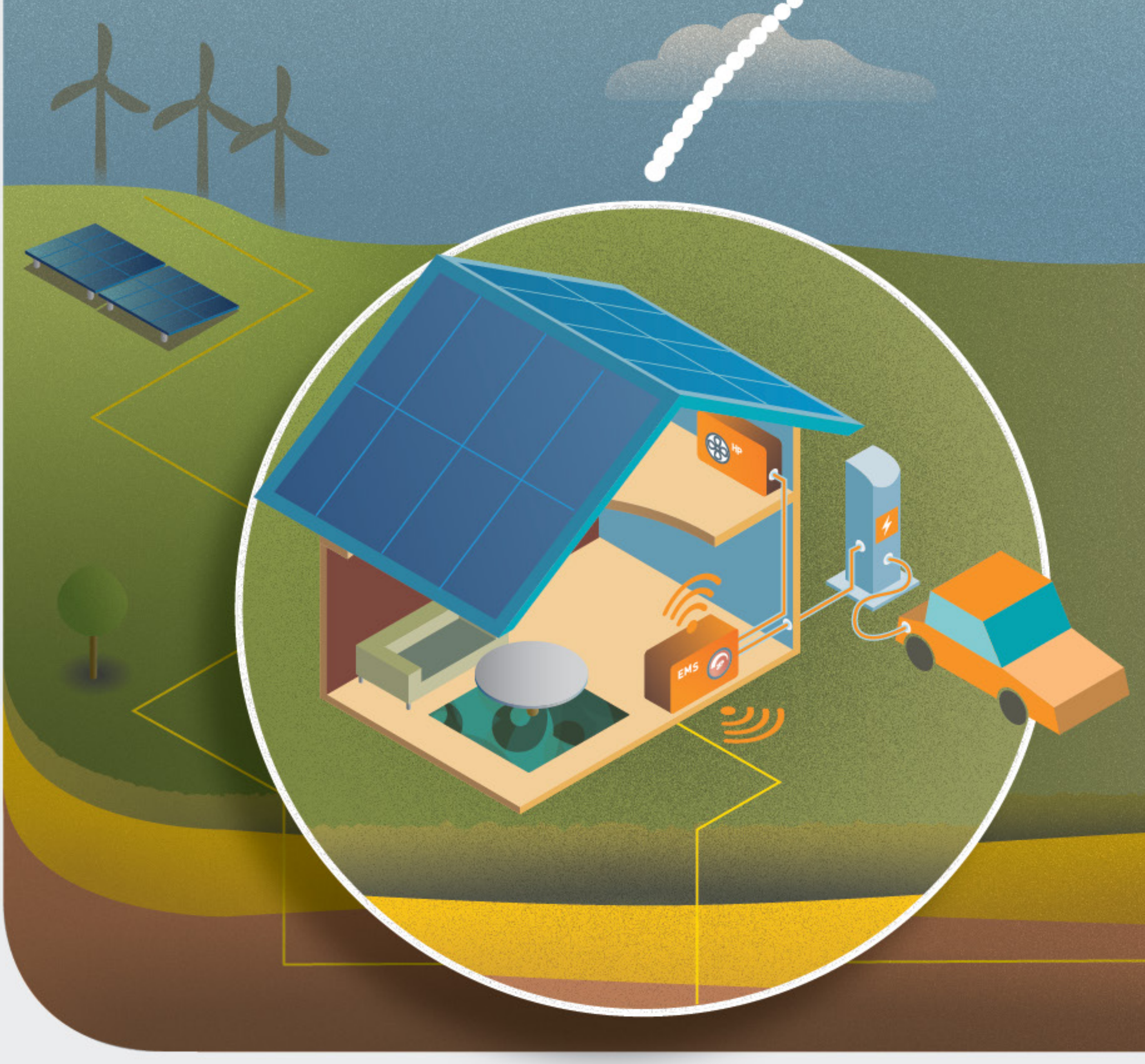

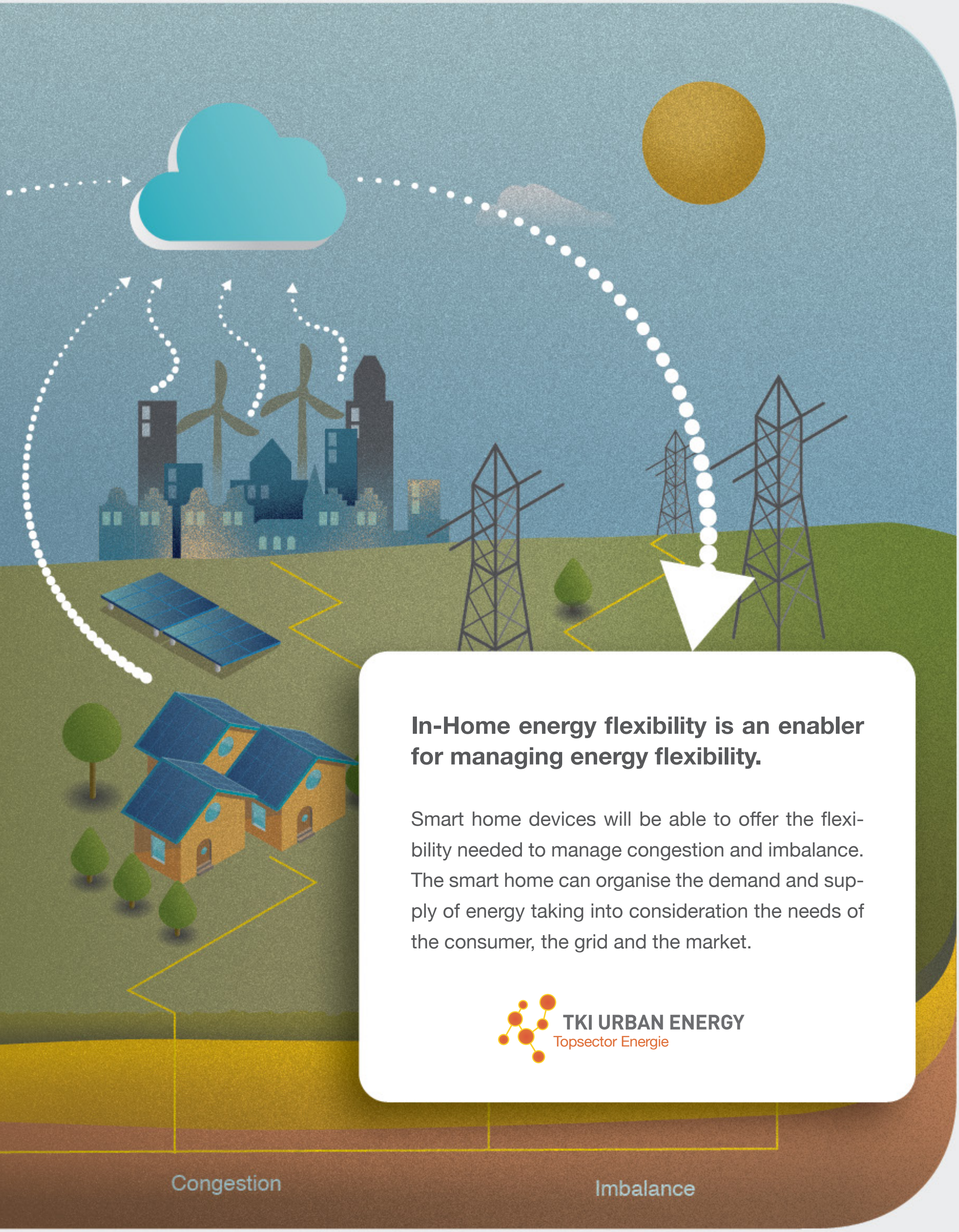

In-Home energy flexibility is an enabler for managing energy flexibility.

Smart home devices will be able to offer the flexibility needed to manage congestion and imbalance. The smart home can organise the demand and supply of energy taking into consideration the needs of the consumer, the grid and the market.

TKI URBAN ENERGY
Topsector Energie

Preface

Electrification of the built environment

The energy transition is slowly but surely putting pressure on the electricity infrastructure. Electrification of heating and mobility leads to increased electricity consumption and creates peak demand for energy on the electricity grid. The rise of the electric car in particular is increasing the demand for electricity in the built environment. In 2030 there will then be an estimated 2 million (plug-in hybrid) electric vehicles and 1.8 million charging points. Charging an electric car at home has an impact on the electricity system in the built environment. When electric cars are charged at full capacity, this requires around 11 to 22 kW of power, while a household usually does not need more than 5 kW of power.

Moreover, this demand for electricity is not nicely spread throughout the day, but large peak demands arises at certain times; for example when many people plug in the electric car around dinner time when they come home after a working day. As a result, the balance of supply and demand for electricity is disrupted and the electricity grid can become locally overloaded. At the same time the EV itself (and other flexible devices) can offer an enormous amount of flexibility to cope with the sketched grid- and balancing challenges.

ELECTRIC TRANSPORT AS THE DRIVING FORCE BEHIND ENERGY FLEXIBILITY

An important solution is the use of "flexibility" - adjusting or shifting the demand or supply of electricity. With the use of flexibility, it becomes possible to peak-shave and balance the supply and demand for electricity. This contributes to a reliable, efficient and affordable electricity supply.

Smart Charging of electric transport is seen as a promising development in this area. Many experiences have already been gained with smart charging in the public space, while smart charging behind the meter is only slowly taking shape. However, that world is evolving now that the netting scheme (in Dutch: saldeerregeling) is being abolished, some energy companies started offering electricity to small-scale consumers at varying market rates and consideration is being given to alternative capacity rates, creating more financial incentives. In recent years the Topsector Energy has supported various innovation projects that focus on storage of electrical energy in battery systems. Notable projects are: ‘Slim laden met dynamische nettarieven’, ‘OROSL’, ‘JEDaFRR’, ‘Smart Charging’, ‘SlimFlex’, ‘B-DER’, ‘BlauFlex’, ‘Slim met Trafo’, ‘DC Laadplein’ and ‘ECISS’.

← See appendix for links

TKI Urban Energy predicts that the rise of electric transport will be an important accelerator to unlock flexibility behind the meter for citizens and businesses. Because smart charging has relatively little impact on consumer comfort, while the electric car can deliver much more flexibility than, for example, a heat pump. Moreover, there are widely accepted protocols for smart charging, such as OCPP. Electric transport, can therefore pave the way for other sources of flexibility such as heat pumps and batteries.

AIM OF THIS STUDY: THE USE OF OPEN STANDARDS AND PROTOCOLS FOR “IN HOME” FLEXIBILITY

TKI Urban Energy and RVO call for the use of open standards/protocols to be used for the flexible control of various devices (such as heat pumps, electric cars and battery systems). This ensures interoperability. This means that it is possible to easily incorporate different brands, types and kinds of devices (plug & play) into a control circuit and change them along the way. Owners and users of these assets then have the opportunity to switch between suppliers of "flex services", which prevents a lock-in situation. In this way standards contribute to the scaling up and reusability of results.

In recent years, much attention has been given to standardization of communication protocols within the domain of smart charging, especially with regard to public charging infrastructure. It is expected that the charging infrastructure in the private domain (residential, non-residential construction) will grow enormously in the coming years. "behind the meter" the charging point is often "connected", but often not (yet) integrated in a smart control with other flexible devices, such as PV panels, batteries and heat pumps. That is why there is also added value from standardization of communication protocols "behind the meter". In the private domain, however, the starting points are slightly different: different protocols, different considerations, different stakeholders, different configurations, different devices and a different division of roles apply.

That is why TKI Urban Energy and RVO have asked ElaadNL to investigate suitable protocols to further shape smart charging within the home in relation to other flexible assets. This is a unique opportunity to guarantee open standards for smart charging "behind the meter" in the coming years and to investigate what these changes mean for the requirements and functionality of the protocols.

ABOUT TKI URBAN ENERGY AND NETHERLANDS ENTERPRISE AGENCY (RVO)

TKI Urban Energy is part of the Topsector Energy. The organization encourages companies, knowledge institutions, social organizations and governments to work together in the field of energy innovations. TKI Urban Energy promotes, together with RVO, research and development into energy innovations for a rapid transition to a sustainable, reliable and affordable energy system in the built environment and infrastructure by financially supporting initiatives, bringing stakeholders together and sharing knowledge. This strengthens the economic competitiveness of the Dutch companies and knowledge institutions involved.

Do you have innovative ambitions in the field of flexibility? TKI Urban Energy and RVO might be able to support you in your ambitions. The employees of TKI Urban Energy are ready to assay your ideas and help you find cooperation partners and set up a consortium. You can also contact RVO if you want to explore whether your ideas are eligible for funding (co-financing) from one of the many innovation schemes from the Dutch Government.

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About ElaadNL

ElaadNL explores, tests and develops the possibilities of smart charging. There is a considerable grid-impact of in-home charging to be expected. Therefore it is important to know the (technical) possibilities of smart charging 'in-home'. Besides that, not only the EV can offer flexibility. Other devices, like heat pumps and local storage units can also provide this flexibility.

In addition the "flexibility deployment" is developing. All these developments create incentives for energy flexibility. The private domain differs from the public domain because there are different challenges, protocols, considerations, stakeholders, configuration, devices and division of roles. It is worth investigating this area specifically. ElaadNL also wants to know the technical possibilities for unlocking flexibility from these devices.

Summary

BALANCING SUPPLY & DEMAND

Due to the energy transition we have to find ways to cope with the strong growth of sustainable and decentralized generation. This development entails intermittent electricity production, fluctuating due to the weather-conditions. At the same time electrification of heat demand and mobility increase this challenge, resulting in the need for finding a balance between supply and demand, within the available grid capacity. This balance and the capacity challenge can be improved by using the flexibility of devices, by modifying the (distributed) generation and / or consumption patterns which can be provided a service within the energy system.

UNLOCKING IN-HOME FLEXIBILITY IS KEY

In this study, unlocking flexibility is studied for the in-home situation using an Energy Management System (EMS). The goal is to gain insight in the way flexibility can best be unlocked.

BASED ON CONCEPT OF ENERGY FLEXIBILITY

The concept of energy flexibility is further elaborated on, looking at energy optimization, device categories and functions. Unlocking of flexibility can only be done when optimization is done by taking into account device integrity, user comfort and user integrity first. Furthermore, unlocking of flexibility depends on the available devices, that can be categorized as inflexible, shiftable, adjustable or storage device. The category determines whether a device can offer flexibility at all and what the impact is on the energy consumption / generation at a later point in time. For example, curtailment of solar energy has no impact on future energy consumption / generation, storage of energy from solar panels does have impact. To be able to influence energy generation / consumption, a number of functions has to be supported, such as adjusting the capacity of a device. These functions are described and used as a basis for considering the protocols during the protocol exploration.

EMS CAN COMMUNICATE WITH DEVICES

When using an EMS for the in-home domain, this EMS can communicate directly to devices by using one single protocol or multiple protocols to communicate to the in-home devices. In the latter case the EMS has to implement different protocols (“polyglot approach”). A second architectural approach is an indirect approach, where the energy related functions are standardized and an intermediate software com-

ponent converts these to device specific commands. This means the EMS itself only has to implement one protocol to communicate to all in-home devices. A standard for this indirect approach is under development and the approach seems promising from a theoretical point of view. However, no practical experiences with this approach are available yet. The practical experiences shared by a number of companies in the EMS domain, show that currently device manufacturers are not looking at this approach. Most device manufacturers look at a direct approach. In general (potential) EMS manufacturers express more interest in energy flexibility than manufacturers of flexible devices itself. When manufacturers of devices realize the connectivity of these devices, it mostly is done with the use of lower level protocols such as Modbus.

STANDARDS & PRACTICAL EXPERIENCE NEEDED

The protocol exploration shows that most protocols in the scope of this study support the functions necessary for unlocking flexibility, although for some protocols the use of customization or extensions are necessary to support all functions. It can be concluded that many protocols exist, too many to discuss these all in this exploration. Besides these various protocols, different views exist on how to use these protocols in the market.

MOST PROTOCOLS SUPPORT FLEXIBILITY

We therefore conclude that there is a strong need for coordination in order to take the next step in unlocking flexibility. To determine the best way forward, the indirect approach that seems promising, must be further investigated to test the technical feasibility and acceptance of this approach by manufacturers. This can be done by applying this indirect approach to a domain where a de facto standard is already available, for electric vehicle charging stations.

Finally this study presents some considerations for further research, such as quantifying energy flexibility per device type, which can be used to prioritize devices on the roadmap for improving interoperability.

FURTHER STUDY NEEDED

Content

Colofon

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We would like to thank all the people from the utilities companies who worked with us on this study. For all parties concerned 'Flexibility behind the meter' is a new area. The relevance of this area for utilities companies became more and more apparent in our meetings with them. We hope this study will help them further address the possibilities for managing the grid.

Thank you for your contribution to this publication.

The editorial team

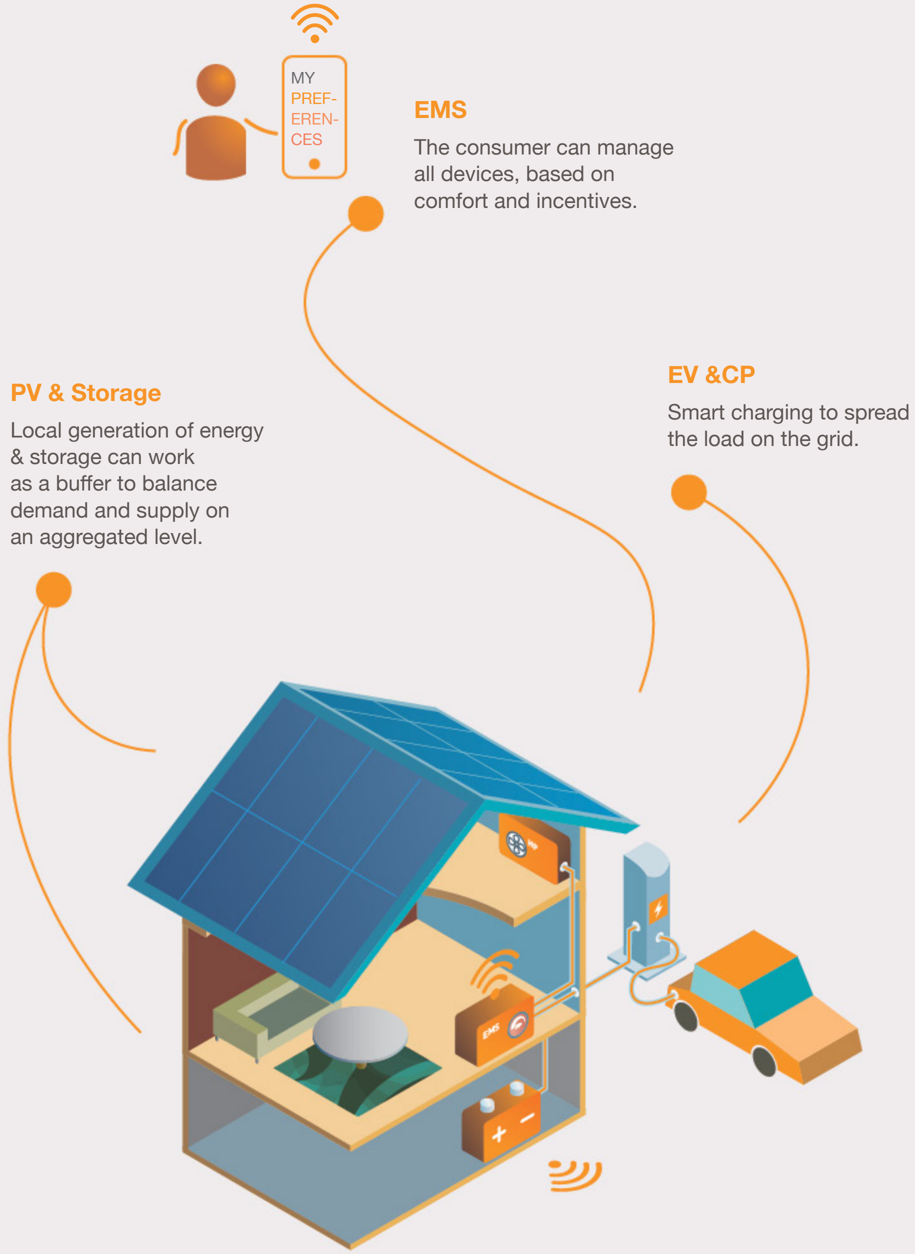
1 Introduction

The electricity system is slowly but surely coming under pressure due to the energy transition. The strong growth of sustainable and decentralized generation entails intermittent electricity production, for instance due to the weather.

As a result, the balance between supply and demand is increasingly challenged. A number of related developments specifically reinforce this challenge within the local electricity networks:

- **Decentralized and sustainable generation**
- **Electrification of heat demand**
- **Electrification of mobility**

> These devices offer possibilities of unlocking energy flexibility



A dense installation of solar panels in a neighborhood cause peaks in local electricity generation, electric cars cause a simultaneous and substantial power demand. And other devices, such as heat pumps and inductive cooking, can also cause a simultaneous peak demand. However, many of these devices also offer control possibilities; unlocking flexibility from these devices.

1.1. The use of flexibility

Flexibility can be defined as:

> **"the modification of generation injection and/or consumption patterns in reaction to an external signal (price signal or activation) in order to provide a service within the energy system"**
> *(Eurelectric, 2014)*

← definition

When using flexibility, it becomes possible to flatten peaks in energy demand and to better balance supply and demand. This contributes to a reliable, efficient, affordable and smart electricity supply. The smart use of flexibility prevents the energy transition from reaching limits, such as the physical and financial limits of network expansion, limits on security of supply and on the affordability of the electricity system. This flexibility can come from different sources:

- **Demand-side management** (changing the energy demand of existing devices)
- **Curtailment** (the temporary limitation of connection capacity (for sustainable generation))
- **Storage** (the temporary storage of energy surpluses in, for example, batteries or flywheels)
- **Conversion** (for example, converting electricity to heat)

Flexibility can be used for different purposes by multiple stakeholders in the energy system. The regional network operator, responsible for the low and medium voltage electricity networks, has an interest in deploying flexibility to keep the demand for power within the network's limits. The end user can optimize its usage (avoid peaks) and can therefore contract a smaller capacity value at a lower cost. It is possible that in the future the network operators will modernize the system of transport rates and introduce several capacity tables with corresponding costs.

THE BENEFITS OF ENERGY FLEXIBILITY

DSO:
Keep demand within limits

TSO:
Keep frequency stable

Consumer:
Low energy cost

This also applies to the high-voltage grid operator (in the Netherlands, Tennet). In addition; flexibility also offers the possibility to contribute to the grid balance, to keep the frequency stable (at 50Hz or 60 Hz, depending on the network), which is an increasing challenge with the growth of intermittent production.

> „ When using flexibility it becomes possible to better balance supply and demand

The flexibility of devices offers the energy supplier various technical possibilities to use electricity simultaneously with the production/purchase of electricity. In addition to being explicitly asked by external parties for flexibility, it is also conceivable that new capacity rates to level off peak loads will be used in the future.

It is quite possible that the flexibility for the benefit of several energy stakeholders is made available by specific service providers, aggregators or energy service companies (Escos), who provide these services to the aforementioned parties.

The idea is that the flexibility of the various devices can be used in such a way that the joint power demand remains below the contracted capacity limit, without the consumer having to sacrifice comfort.

Different devices in a building offer the possibility to provide flexibility by shifting or reducing energy demand ("demand-side management"). This is possible, for example, by not charging electric cars at full capacity when everyone comes home in the evening, but at a lower capacity during the entire night (smart charging). Another example is by allowing heat pumps to heat earlier than necessary, at a time sufficient electricity is available.

This study focuses on the technical (im)possibilities for unlocking the flexibility of various potentially flexible devices. The distinction between the different objectives of the "energy stakeholders" regarding the use of flexibility and the way this is "requested" is not in scope of this study.

← the objective of this study

Relevant stakeholders

In the in-home domain, next to the most important stakeholder, the user, multiple stakeholders play an important role in creating this ‘in-home interoperability’. The manufacturers and operators of flexible devices, like for example charging stations, heat pumps and solar panels are stakeholders in this domain. Furthermore, developers and operators of Energy Management Systems (EMS) play a role. Multiple parties must be able to perform this role.

Together they have the task to connect the devices and deliver energy flexibility to the discussed ‘energy stakeholders’, within the limits set by the consumer.

For the energy stakeholders it is important to gain insights in the current state of technology of in-home interoperability and possibilities for further development. This will help to deduct a timeframe in which flexibility from (smart) homes can be utilized on a large scale. To companies this gives insight in potential commercial opportunities and to policymakers it provides relevant insights to scale up energy flexibility potential.

A summary of the needs and challenges related to energy flexibility of the different involved stakeholders can be found in the figure below.

The value of flexibility grows when it can be made available to all the different stakeholders in combination. There are many different systems for unlocking flexibility and many applications for flexibility. When these applications can be combined, this provides the most added value.

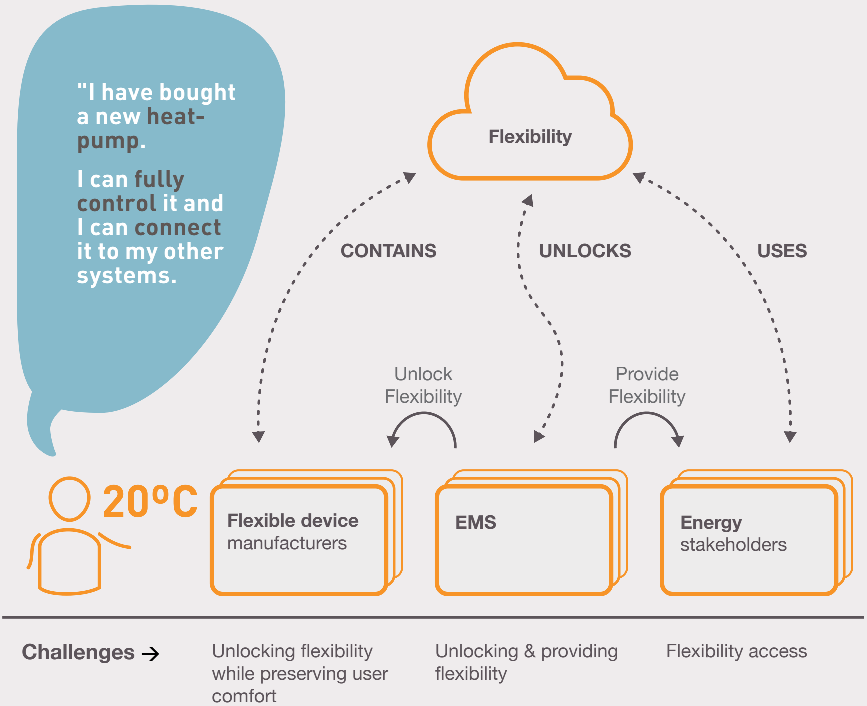
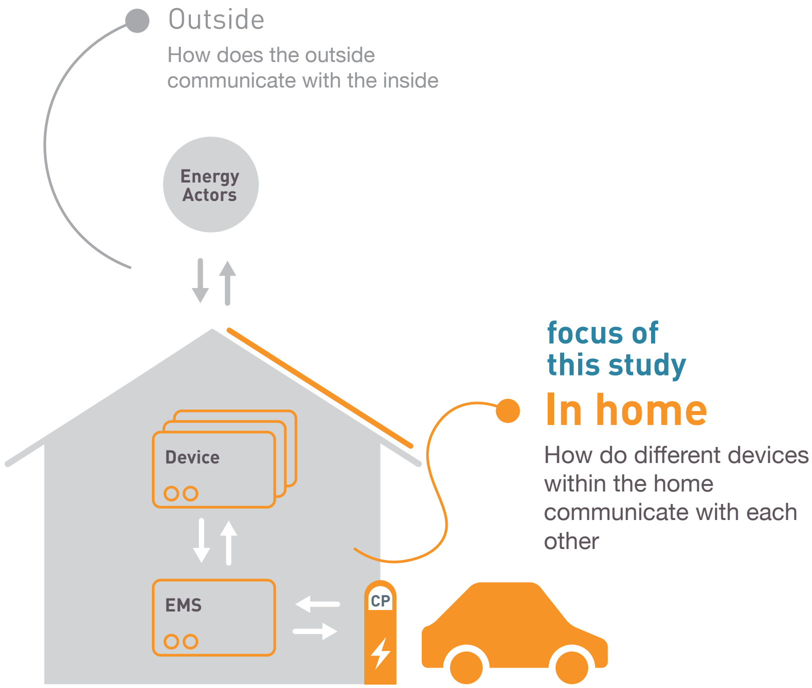


Figure 1: Challenges and needs of energy flexibility stakeholders

1.2. Unlocking of flexibility

To make the deployment of flexibility possible, insight is needed in the possibilities to unlock the flexibility from the variety of devices within buildings. TKI Urban Energy anticipates that the rise of electric transport will be an important accelerator to unlock flexibility among citizens and businesses. Smart charging, which is defined as energy flexibility within the EV domain, has relatively little impact on consumer comfort, while the electric vehicle (EV) can deliver much more flexibility than, for example, a heat pump. And with a very short response time. Also, within the EV domain there is a high degree of connectivity / interoperability. Electric mobility can therefore pave the way for other sources of flexibility such as heat pumps and batteries.

In order to unlock flexibility of a device, a communication channel between the device and the external party that asks for this flexibility is required. This connectivity is a precondition for energy flexibility. It is not yet self-evident for many devices that they can be controlled to unlock energy flexibility.



The focus of in this study is on the in-home domain and thus on the EMS model

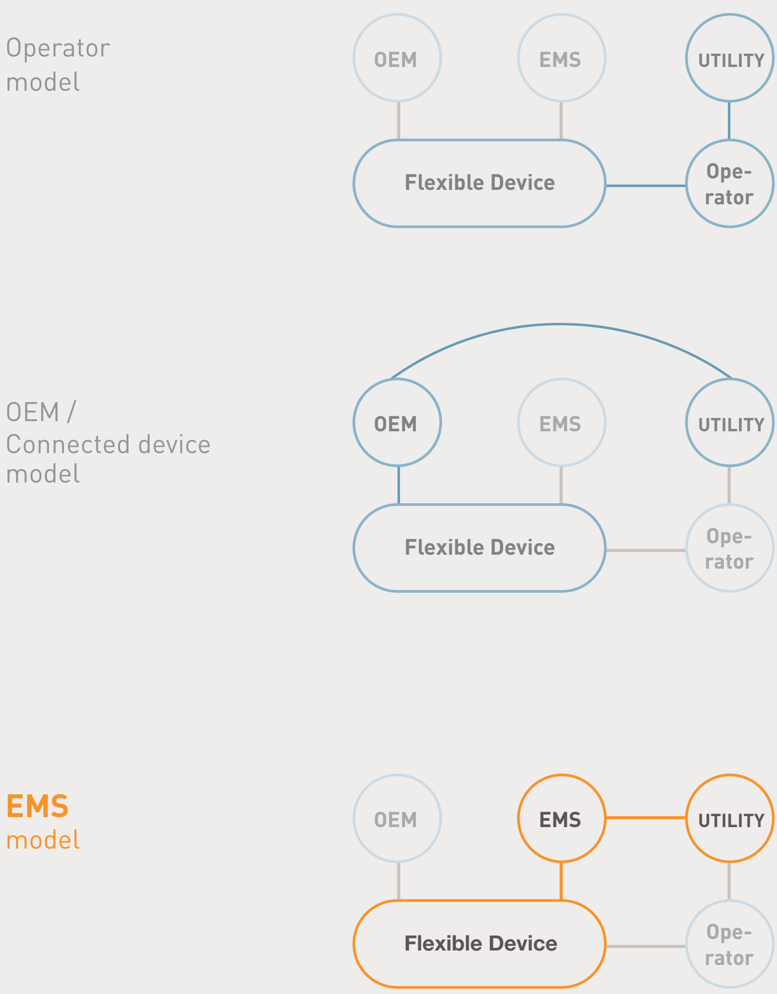
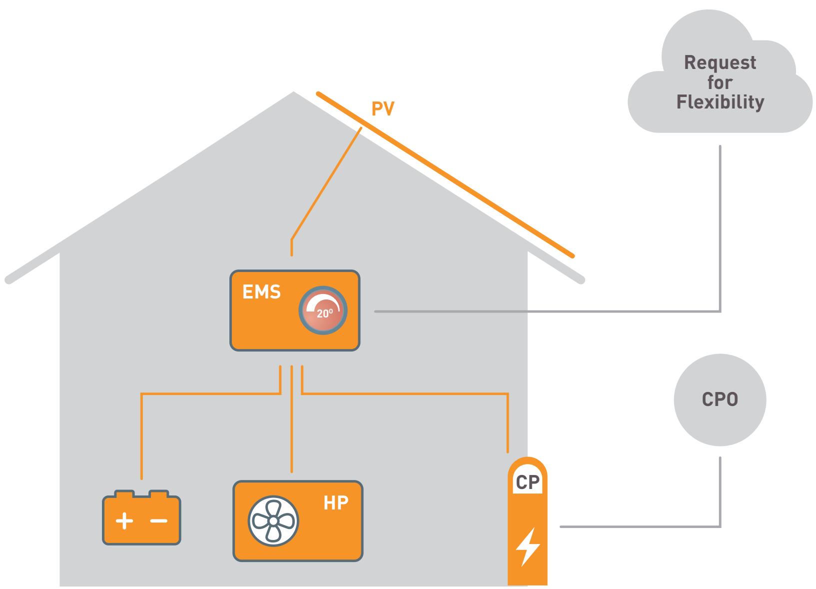


Figure 2: Overview of information exchange options

1.2.1 Interoperability & information options

Even when devices can be controlled in a smart way, lack of interoperability, i.e. being able to work with other products or systems, can be an additional reason why it is difficult to control flexibility: various services for controlling flexibility have been developed for only one specific (type and brand) device. When an energy actor wants to use flexibility (on a aggregated basis), either all devices have to be of the same type/brand or it has to create a separate communication/control channel for each type/brand of device.



Combining different devices is a good strategy to deliver the requested flexibility. The dominant idea for unlocking flexibility from in-home devices is that devices are not controlled individually, but that an Energy Management System (EMS) in the home ensures connectivity with the devices. An EMS “interconnects” the devices and provides flexibility access to the requesting parties.

The different possibilities (without attempting to be exhaustive here) derived from the EV domain can be seen in **Figure 2**. In the EV domain, different topologies are possible, where the flexibility is unlocked via the manufacturers (“OEMs”) of the flexible device (EV), via the operator of the Charging Station (CSO) or via a separate Energy Management System. In this study we focus on the in-home domain and thus the Energy Management System Model (EMS) model.

THIS STUDY:
TECHNICAL EXPLORATION

Routes:
See paragraphs 3.1 & 3.2

Context / location:
See paragraph 3.2

Despite the focus on this “route” in this study, this does not mean a preference for a particular route. In this study a technical exploration is being done of the (im)possibilities to unlock flexibility via this route. We are however aware that there are several routes and that these may differ per context/location (also see the last chapter).

1.2.2 Interoperability as starting point

In this study, interoperability is considered from the perspective of integrateability and interchangeability. Integrateability is the term used for the extent to which different devices can easily be integrated/functionally connected, simply referred to as "plug and play". Interchangeability refers to the degree of unambiguous exchange of messages, meaning that a device can be replaced by another device, resulting in the same functionality. Both aspects are important and are included in the assessment of the various protocols.

The starting point for interoperability is different per domain and type of device. In the EV domain, interoperability was an important design principle from the beginning of the development of charging infrastructure. This led to the implementation of a limited number of protocols on the different interfaces. The openness of these protocols and standardization that has been achieved within this context has ensured that connections were made relatively quick and that various parties can play a good role within this domain, also in the area of flexibility.

Within the domain of other flexible devices interoperability was not an explicit precondition during the development of the various products. Device integrity and user comfort were main drivers and the need for interoperability was added at a later stage.

In anticipation of the study, the question is whether developments and learning experiences within the EV domain can also lead to acceleration in flexibility access of other devices in a building.

1.3. Goal and approach

The goal of this study is to provide insight in the ways in which flexibility can be unlocked from different flexible devices within a building. For this purpose we analyse a number of existing protocols that can be used for different in-home devices. We investigate to what extent these protocols are suitable to unlock flexibility.

Within the in-home domain we investigate the flexibility access via an EMS, which is one of the starting points of this study.

The core of this study is the communication between an EMS and flexible devices to unlock energy flexibility.

THE GOAL

The goal is to gain insight in the way in which flexibility can best be unlocked on devices. An exploration of the technical possibilities, "the ins & outs of in-home flexibility":

- Functions per device type (which we hope the OEMs will facilitate in their devices);
- Architecture options (2 models related on how to unlock flexibility);
- The protocols themselves;
- An overview of practical experiences;
- Conclusions and recommendations.

In the introduction the definition and use of energy flexibility was explained. In the following chapters the core of this study is presented: an overview of a subset of the current protocols used for energy flexibility for in-home applications and how they relate to openness, interoperability, maturity and a list of energy flexibility functions.

> How can flexibility be unlocked from different devices within the home ”

The approach that has been followed is two-fold. On the one hand, a theoretical study has been conducted into the various protocols that can contribute to unlocking energy flexibility from the home. This is presented in chapter **4** “**Protocol exploration**”. On the other hand, various experts and companies have been consulted that are working on the development of flexibility access from different devices and thus have practical experience. This is presented in chapter **5** “**Practical experiences**”. Chapter 6 presents the conclusions and recommendations of this study.

As part of the approach, a supervisory committee has been organized. The committee has given direction to the development of this study. The direct involvement of this committee was shaped by several meetings in which guidance and feedback was received.


HP
EMS

2 Energy flexibility of devices

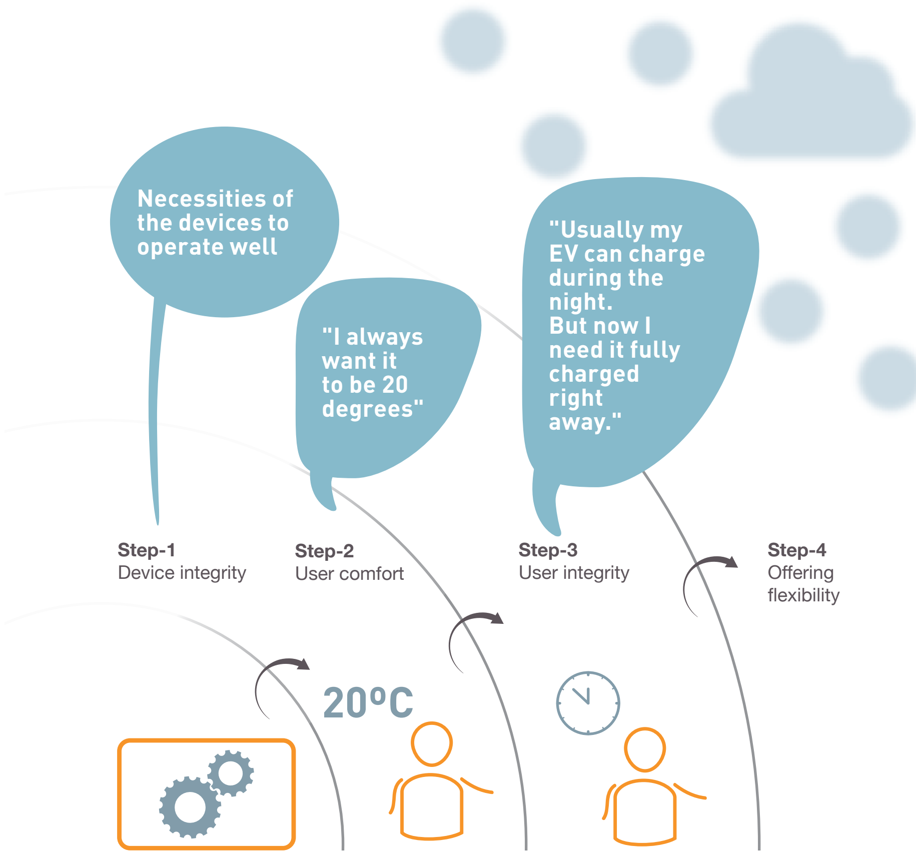
This chapter explains the various elements of energy flexibility in more detail. This increases understanding of the concept and this generalization in our opinion also helps with the actual technical accessibility of energy flexibility.

Energy optimization in an ‘in-home’ situation is explained in the next paragraph. Thereafter is explained that unlocking energy flexibility can be done in four categories. A definition of how this energy flexibility can be unlocked (functions) is given in the last paragraph. The functions will serve as guidelines in the protocol exploration chapter.

2.1. Energy optimization

Energy optimization precedes unlocking energy flexibility. Energy optimization can be considered as using both ‘internal’ (in-home) as well as ‘external’ flexibility for optimizing energy usage. After ‘internal’ energy needs are covered, the remaining (explicit or implicit) energy flexibility of the in-home devices can be unlocked and offered to ‘external’ requesters as mentioned in the introduction chapter.

The following diagram illustrates the steps as part of the energy optimization. The individual steps are described below.



Step 1: device integrity

First ensure that proposed optimization does not get in the way of the correct operation of the smart device, taking into account the technical requirements as prescribed by the manufacturer of the smart energy devices. For instance, every device requires a minimum amount of energy to function and not every device is able to instantaneous adjust its power. When composing an optimization the device integrity conditions should be taken into account. For example, incorrect usage of a smart device, like very frequent turning it on and off, can have a negative effect in the long term. This will affect the intended result of the energy optimization.

Step 2: user comfort

Optimizing energy should not have any (or little) effect on the comfort that is experienced by the user of the smart energy devices. The amount of energy that is needed to cover user comfort and device integrity (step 1), is what is defined as ‘Energy flow reservation’. In this study this is considered the starting point for quantifying the energy flexibility[π].

User comfort preferences can be embedded in both the smart energy devices as well as in the EMS. For instance a rule in the EMS can be that the fact that the Electric Vehicle is ‘charged on time’ is more important than the energy costs for charging. The specific means how to provide the user settings and the willingness of the consumer to do so calls for further research.

Step 3: user integrity

The end user should be able to state under which circumstances energy flexibility can be offered to ‘outside use’. It is likely that the user should give explicit permissions to the EMS.

Step 4: unlocking flexibility

Given the energy flow reservations, internal metering data and parameters like internal and external constraints the EMS should be able to determine the ‘in-home’ energy flexibility. The energy flexibility can then be unlocked for ‘outside use’ by one of the other relevant stakeholders.

π Although in some parts of e.g. North America in some flexibility schemes user comfort is violated.

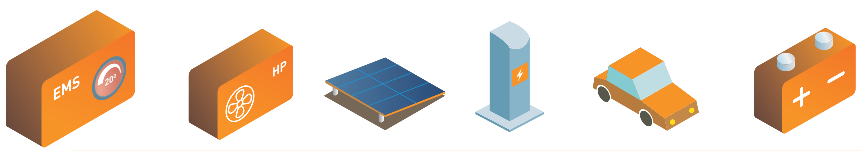
2.2. Functions

The value of flexibility grows when it can be made available to all the different stakeholders in combination. There are many different systems for unlocking flexibility and many applications for flexibility. When these applications can be combined, this provides the most added value. Some applications and protocols already make choices in how flexibility is unlocked. For example, by sending a price profile to a device. With such a solution, it becomes impossible to subsequently use the flexibility for balancing services or congestion management. This reduces the value of flexibility. This should be taken into consideration.

To abstract and clarify the way in which flexibility is addressed, the general functions of unlocking flexibility are given below.

The amount of energy flexibility is determined by the EMS. It therefore interprets, for every smart energy device, what tasks it can perform **(registration**) and what it needs in terms of energy (**energy flow reservation**). Also real-time measurements (**metering**) can be used by the EMS as an input to determine the energy flexibility. Whenever the energy flexibility is captured by the EMS it can optimize energy usage by adjusting the energy consumption/generation of smart energy devices (**adjust capacity**).

In order to describe and define how this energy flexibility can be unlocked a couple of functions were derived from literature review. These functions represent the basic information exchange between EMS and smart energy devices. The functions are necessary to support certain energy flexibility use cases related to energy flexibility as described further on in this chapter. The functions are illustrated in the following diagram.



Function	Definition
Registration	This function is used to register a smart energy device and its potential flexibility at the EMS. Registering a smart energy device can include: • Indicating which tasks a device can perform (incl. category) • Indicating the maximum amount of available flexibility • Indicating the device limits (minimal power, maximum power, ramp up, ramp down etc)
Energy flow reservation	This function enables a smart energy device to reserve a certain amount of energy in a specific time frame. It indicates it's needs. Through this reservation the smart energy device assures that the functionalities can be performed according to the user's needs. Typical elements an energy flow reservation can contain are available consumption/generation energy and minimum/maximum consumption/generation power given a time frame. The registration must be done prior to the energy flow reservation. This functionality contains communication from the smart energy device to the EMS. **Paragraph 2.4.1** describes the energy flow reservation in more detail.
Metering	This function is used to verify if the smart energy device does what it should do. Metering might not be part of the smart energy device itself. It is possible that metering is done by a separate metering device that measures the device's energy production/consumption and communicates this to the EMS. Metering can serve several purposes. Metering can aim to steer quickly (eg prevent exceeding connection capacity), metering can be used to verify / learn behavior (is this device reliable in its stated energy flexibility options?) Or as a basis for billing.
Adjust capacity	This function is used by the EMS to adjust the capacity of a smart energy device. Depending on the registration besides the basis 'Turn on/off' more variable adjustments can be communicated. Typical examples are increasing or decreasing power of consumption or generation of a smart energy device. The amount of energy that can be adjusted depends on the energy flow that is reserved by the smart energy device. The way of adjusting depends on the registration by the smart energy device. Both should have been completed before the capacity of the smart energy device can be adjusted. **Paragraph 2.4.2** describes the function in more detail.

This diagram positions the functions and visualises the scope of the study.

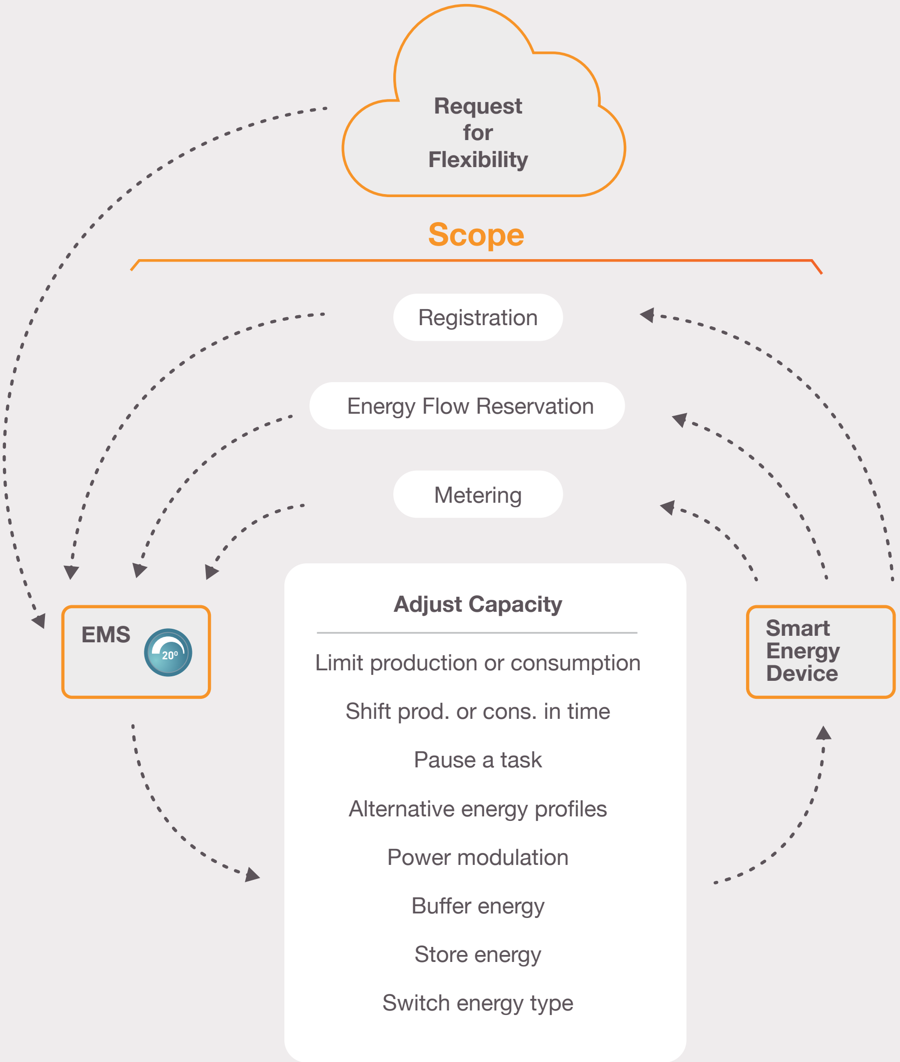


Figure 3 Overview of functions

The function Adjust capacity can thus be used to communicate different flexibility patterns. Depending on the chosen architecture (next chapter) these patterns can be implemented in the EMS, the smart energy device or in an adaptor/convertor module between the EMS and the flexible device. In the next chapter this will elaborated on.

The flexibility patterns support in standardising the communication between EMS and smart energy devices. These patterns are not further assessed in this protocol study.

2.2.1 Energy flow reservation

The energy flow reservation function is one of the functions mentioned above and needs a more in-depth explanation. Sequentially it comes after registration and before 'adjust capacity' and 'metering'. The function describes the need for energy by a smart energy device given a time period. It does not describe flexibility. It consists of the forecasted energy consumption/generation over time. Based on this forecast an EMS should be able to request the smart energy device to perform one or more flexibility patterns.

It is possible for smart energy devices to actually consume more (or less) than estimated in the energy flow reservation. Unmanageable and unpredictable circumstance like user interference (increase consumption, unplugging, etc.) is typically not part of the energy flow reservation. A user interference is an event that causes a recalculation of the energy flow reservation.

2.2.2 Adjust capacity

The adjust capacity function is briefly described above and contains the actual adjustment of power demand of the smart energy device. As mentioned earlier many types of smart energy devices can be identified. Because of the categorization of each smart energy device various flexibility patterns can potentially be unlocked by sending the right commands to the right devices. Flexibility patterns are patterns of commands that an EMS can send to a flexible device, which can process these commands to unlock the requested energy flexibility.

Flexibility patterns will help in imagining what the communication between the EMS and smart energy devices should look like. In this study energy flexibility meets the following patterns:

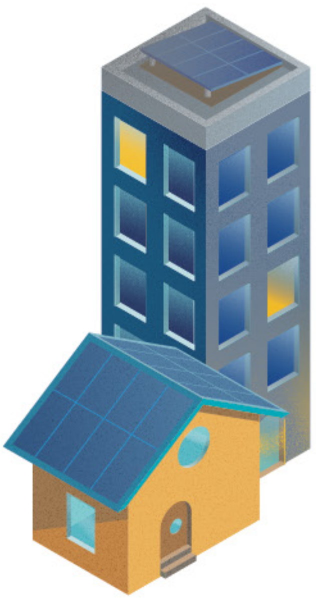
- Limit production or consumption (adjustable)
- Shift production or consumption in time
- Pause a task
- Alternative energy profiles
- Power modulation
- Buffer energy
- Story energy
- Switch energy type *Hybrid energy type*

Inflexible Shiftable Adjustable Storage Hybrid

Patterns typically do not occur in isolation, but have an effect on each other. The categories mentioned are further explained in the next paragraph.

Implementing one or more flexibility pattern gives the smart energy device the ability to effectuate flexibility request from the EMS and makes it easier/clearer for the EMS to communicate certain standardised flexibility commands.

> Implementing one or more flexibility patterns will give smart energy devices the ability to effectuate any request from the EMS



2.3. Categories

Smart energy devices can be categorized in terms of flexibility, based on the characteristics of the specific device. This categorisation makes it easier to connect a smart energy device to a flexibility need. It allows the energy flexibility of a device to be determined by the capabilities of the devices. This makes it easier for an EMS developer to incorporate support for a multitude of devices (based on the generic capabilities instead of devices-specific options). In the table below examples are given of different types of smart energy devices that can be linked to these categories.

THE FOLLOWING CATEGORIES ARE IDENTIFIED

Inflexible smart energy devices, in principal, do not provide any option to control their flexibility. Every smart energy device has inflexible load for covering device integrity and user comfort.

Shiftable smart energy devices perform a task that has a corresponding power profile that is known or predicted beforehand. Their flexibility mainly comes from the ability to change the start time of that power profile, or choose between alternatives.

Adjustable smart energy devices have the possibility to control the amount of power they produce or consume, without significant effects on the energy flexibility in the future.

Storage smart energy devices can store or buffer energy. How energy is stored or buffered does not matter, as long as there is a means to measure how full the storage or buffer is (State of Charge).

Hybrid Energy Type devices are devices that can use different types of energy. This is only applies to “hybrid” devices, such as hybrid heat pumps, that can use electricity and / or gas as energy source.

The smart energy devices listed in the following table can be linked to one or more of the flexibility categories mentioned above:

	Limit production or consumption (adjustable) ⊖	Shift production or consumption in time / Pause a task / Alternative energy profiles	Power modulation	Buffer energy / Story energy	Switch energy type (hybrid energy type)
Photovoltaic panel	(●)		●		
Small windmill	(●)		●		
Washing machine, dryer, dishwasher	(●)	●			
Charge point (with connected EV)	(●)	●	●	(●‡)	
Heat pump	(●)	●	●		(●)•
Freezer, Refrigerator	(●)	●			
Stationary battery	(●)			●	

Please note that the extent to which devices are flexible differs per device. For example, a heat pump with a minimum temperature is less flexible than an EV that is connected to a charger during the entire night.

⊖ In some cases inflexible smart energy devices are curtailable, for instance photovoltaic panels can be temporarily switched off when the voltage of the connection is too high. In that case, these can be considered as adjustable, however, since this does not take into account “user comfort”/user integrity, this is not considered as “real” flexibility.

‡ Vehicle to X requires technology / protocols that is relatively new and expensive.

• Hybrid heat pumps only.

3

Models of unlocking flexibility

There are two fundamentally different approaches for unlocking energy flexibility within a building. It is important to identify these two approaches as this provides the framework for the protocols to be applied.

The first approach is the direct connection between EMS and each of the flexible devices. The second approach involves an indirect link between the EMS and the flexible devices. In the first approach, a single protocol is applied to solve the interoperability challenge with each device.

Handling all functions of an EMS/device (flexibility, remote maintenance etc) via a direct link can lead to device specific, proprietary protocols, making it difficult to connect to 3rd party equipment.

In the second approach multiple protocols are needed on the interface to bridge the gap between EMS and flexible device. This indirectness opens the door to using different protocols for different functions. When this is done, specific interfaces for specific functions can be standardized and the different interfaces can be used more easily by different 3rd party equipment (see also paragraph 3.3). This latter approach is more focused on interoperability between protocols than on pursuing a single protocol.

The first approach is often encountered as the basis for various protocol developments. The second approach is the starting point within the European standardization initiative: EN 50491-12-1 created by CEN[ʘ] and CENELEC[§].

> **Note**: within both approaches it is recognized that there are other reasons to connect with the flexible devices. The devices without this energy flexibility, such as lights, automatic shutters and TV, can be controlled by a Home Automation System that uses other functions and as such protocols for communication, such as Zigbee, Z-Wave, etc. Many devices will become 'connected' in the near future, and energy management will not be the only or primary reason for this. The flexible devices are often also connected for maintenance reasons. Those devices will have an interface that is about more than just energy management, and will therefore not be primarily linked to an EMS.
>
> In this study and the approaches discussed in the next paragraphs, energy flexibility functions and energy flexibility connectivity (protocols) are separated from these other functions such as maintenance for which connectivity is needed.

ʘ CEN is the European Committee for Standardization. An association that brings together the National Standardization Bodies of 34 European countries. CEN is one of three European Standardization Organizations (together with CENELEC and ETSI) that have been officially recognized by the European as being responsible for developing and defining voluntary standards at European level

§ CENELEC is the European Committee for Electrotechnical Standardization and is responsible for standardization in the electrotechnical engineering field. CENELEC is a Non Profit International Association and prepares voluntary standards.

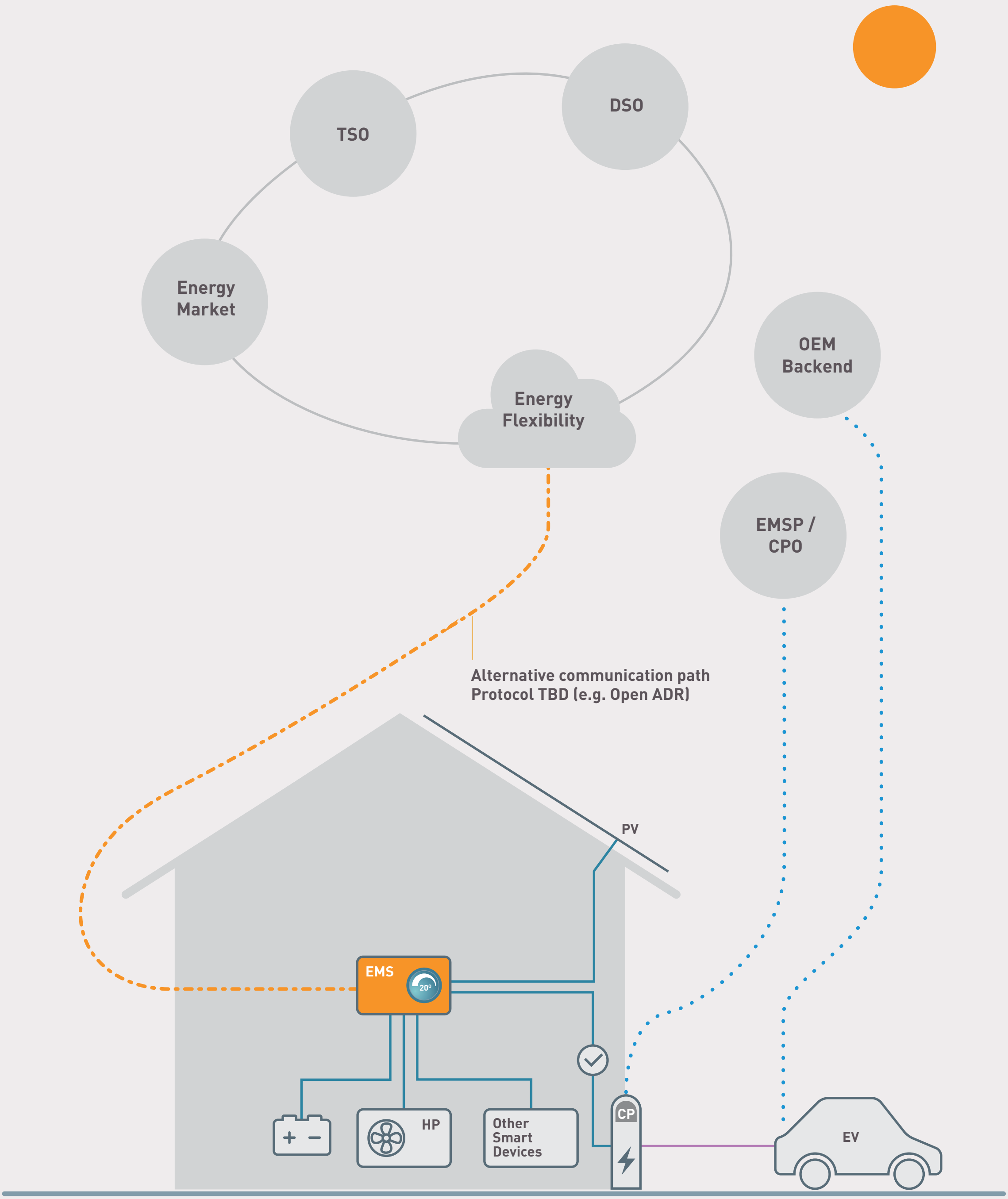


Figure 4: Direct approach

3.1. Direct approach

In this approach the EMS plays a central role in the direct communication between external parties and the flexible devices in-home. The key point in this approach is that the EMS can communicate directly with the flexible devices through a single protocol which is directly connected between EMS and the flexible device. In practice this means that when different devices all use their own proprietary protocol, either an EMS can support only devices that use the same protocol, or the EMS has to implement many different protocols ("polyglot"), some of which might be proprietary. These different approaches are visualized in **Figure 5**.

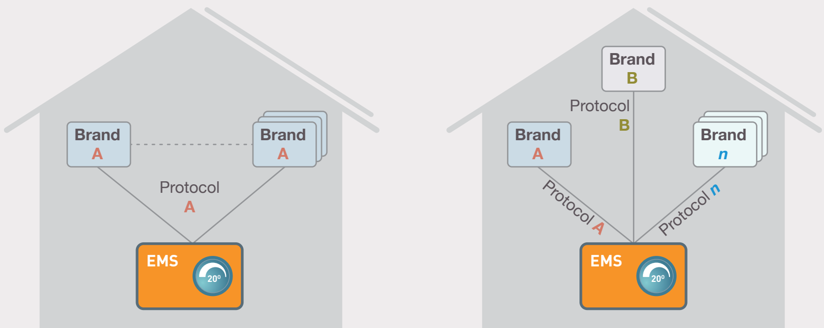


Figure 5: one protocol EMS (left) vs. "polyglot" EMS (right)

Following this approach it is possible to send detailed information to the flexible device itself. For example, an EMS can use energy prices to optimize the charging plan of an EV, by sending maximum power limit signals to the charging station. When using multiple devices such as solar panels, heat pumps, charging stations, the EMS takes care of optimization and sending signals to each of the devices.

← This diagram shows the 'in-home' direct approach.

3.2. Indirect approach

The core of the indirect model's approach is based on an approach as currently followed by CEN and CENELEC in the joint effort EN 50491-12-1. The idea is that a software representative of a flexible device (comparable with a driver of a printer) is introduced. The EMS does not communicate directly to a flexible device, but to this representative, the Resource Manager (RM), which is the 'connection point' of the device from/to the EMS and determines for example the integrity of the device and user comfort.

In this approach, the Energy Management System is the entity providing the logical connection between the energy flexibility stakeholders and the flexible devices in the home/building. The basic function of the EMS is to multiplex/de-multiplex communication between the energy flexibility stakeholders and the different flexible devices in-home.

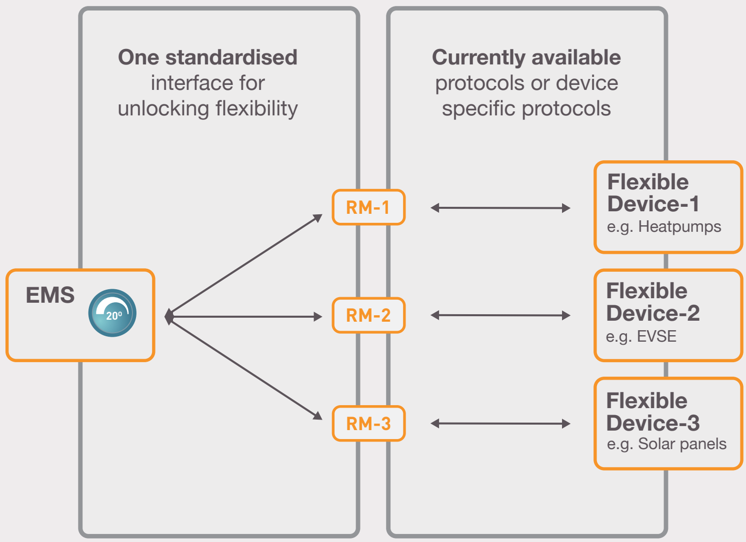


Figure 6: schematic overview of EMS to device communication via a Resource Manager

Since there are many different types and brands of flexible devices which can be used, it is very likely that those devices use different communication protocols and/or different data/function models. In order to use the energy flexibility of all the flexible devices present in a home it is necessary that the EMS can communicate with all these flexible devices. Therefore, it is important to define a common data/function model, message structures and message sequencing rules which can be used between the actors to control the energy flexibility of the flexible devices.

Currently no such standardized interface is available in the market, the interface named "**S2**" as defined in the CEN CENELEC approach is foreseen as a standard to fill this gap. S2 allows for generic, interoperable communication concerning flexibility between the flexible devices and the EMS. The interface S2 is positioned on the interface that is the core of the scope of this study, but as mentioned, this is not a direct protocol between the EMS and the flexible devices: the concept of Resource Manager (RM) is introduced and positioned between the EMS and the flexible device:

This seems to simplify the exchange; on the device side, the RM and the flexible device continue to "speak" through the native flexible device interface (can be a high -or low level protocol like modbus). On the EMS side, the RM and the EMS will communicate with each other through a standardized protocol, in which energy flexibility functions are laid down. The RM can then use the information obtained through the native flexible device interface to estimate the amount of energy flexibility and adjust capacity of the flexible devices according to device integrity, user comfort and energy flexibility needs.

The RM is a software module and can be situated as part of the flexible device, the EMS or 'as a service' in a cloud environment. This kind of flexibility in implementing and adapting to changes is an advantage of this architecture by facilitating a shorter time to marked in the energy transition.

When the RM is part of the EMS, it simplifies the development of the EMS (no external dependency), but decentralised maintenance can be more complex. If the RM is run from the cloud, maintenance can be more simple, but introducing a cloud connection to the in-home device introduces an additional security challenge. The RM could also be part of the device it belongs to, however, this would impose additional effort on the device manufacturers, while the main (direct) benefit is on the EMS side. These options are visualized in the following figure:

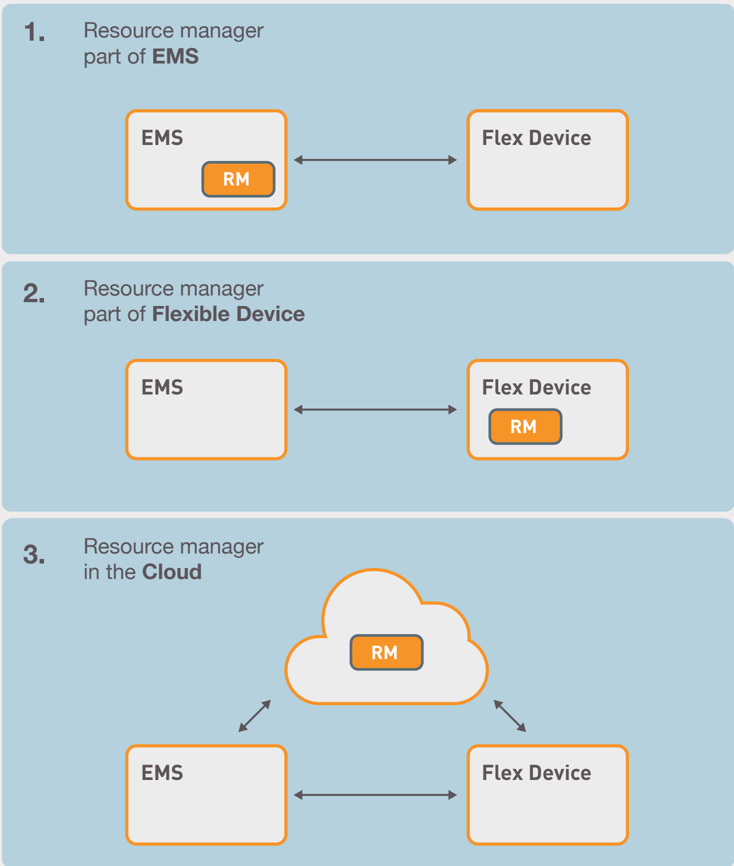


Figure 7: options for positioning Resource Manager

Since more and more flexible devices are ‘connected’, it is also conceivable that the RM could be positioned between the device management system of the supplier to which the flexible device connects for both flexibility related as well as non-flexibility related functionalities and the EMS, which in most cases is ‘connected’ anyway. The device management system could then provide a communication channel to the EMS for the flexibility related functionalities that are communicated to the flexible device via the RM.

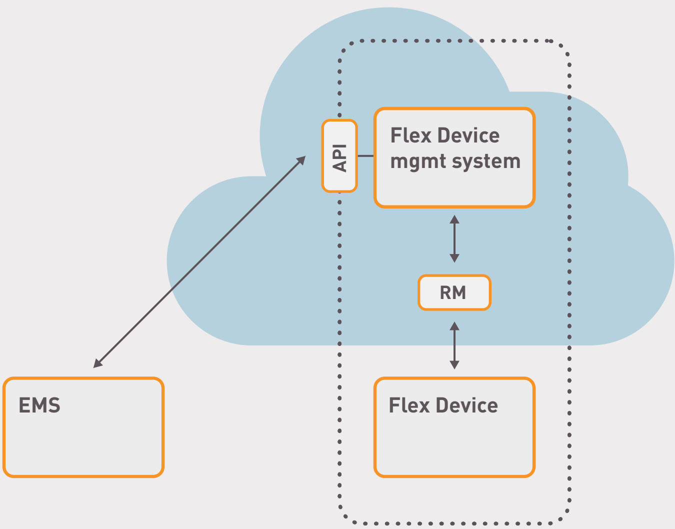


Figure 8: Resource manager “behind” manufacturer system

In this setup, the flexible device will then no longer have to be connected via a direct (often specific wired) connection to the EMS but instead via an internet connection. Advantages of this approach are a relatively simple/high level interface for easy access to devices, better control for manufacturers over their devices (device integrity) and possible new business models that can emerge (e.g. predictive maintenance). However, security challenges will then play a greater role. Such an external connection does put pressure on the ability of the system to function autonomously (and in island mode). Ideally, such a system should be able to function without “outside” influence.

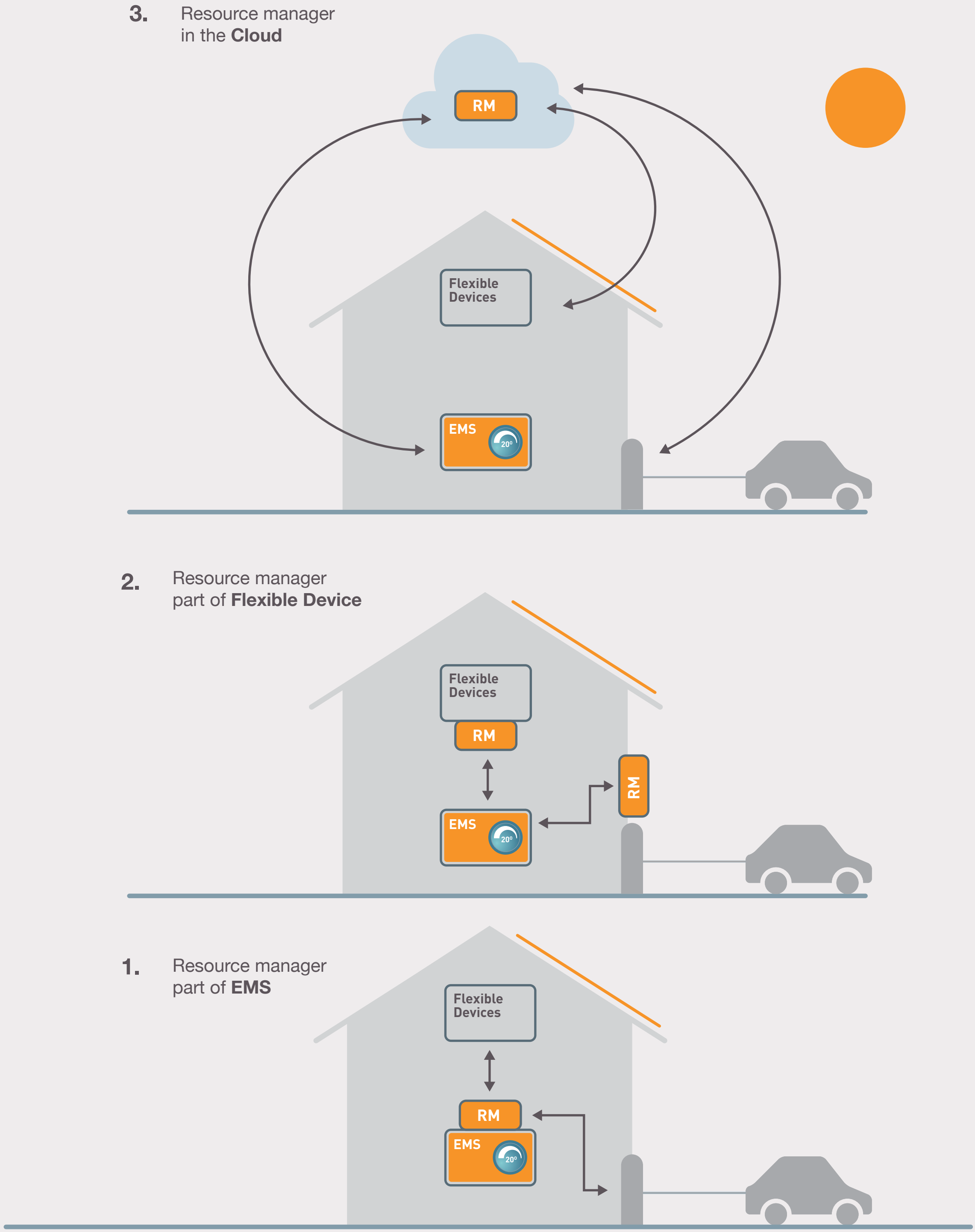


Figure 9: indirect approach

When applying this architecture the consumer can still control and influence the operation of ‘in-home’ flexible devices and determine the amount of energy flexibility. The consumer probably has its own set of preferences for the behavior of their flexible device that must be taken into account by the EMS. These preferences shall take precedence over those of the energy stakeholders unless otherwise specified.

The figure on the left page illustrates this indirect approach.

The work within **CEN CENELEC** (specification document, EN 50491-12-2) is developing during the time frame of this study and is expected to finish beginning of 2021. This could lead to one standard for EMSs (from CEN CENELEC) for in-home interoperability

3.3. Comparison direct and indirect approach

The following table shows the advantages and disadvantages of both approaches.

	Advantages	Disadvantages
Direct approach	Simpler: less "moving parts" in technical setup No additional layer/RM component necessary. Easier to have a high performance/response time	Can lead to proprietary protocols EMS has to support either 1 protocol that can do everything" or many different (sometimes proprietary) protocols in order to integrate different devices
Indirect approach	Specific functions such as "flexibility handling" can be standardized separately. Separation of concerns Reuse of existing ("direct") protocols Different options for RM	Additional layer in technical setup RM component needed More difficult to have a high performance/response time with additional layer(s) Unknown whether this approach will work in practice.

One of the last points in the table above is a crucial aspect. The indirect approach, the S2 interface is a well thought out solution, but the feasibility, the manufacturability has not been tested in practice so far. In anticipation of the recommendations, it is very important to test the feasibility through a practical implementation. The 'Direct approach' and 'Indirect approach' should not be read as a kind of contradiction, as this chapter is not intended; one does not exclude the other, it can even reinforce each other.

Note-I: it may occur in theory and practice that a flexible device can be connected via two sides. for example a charging station can be connected to an EMS and a CSO back-end. This could result in different information for charging optimization, from different angles which could result in conflicts. Therefore it is important to make business rules on which information has priority in which situation.

Note-II: when making use of an external communication channel it is important that those interfaces are secure by design, which means that those interfaces make use of communication security. This will assure message integrity, availability and confidentiality. See recommendations for more information about cyber security.

4 Protocol exploration

As part of the theoretical research of this study multiple existing protocols were examined. The scope, which protocols were examined, has been defined together with experts and the 'supervisory committee'. In the following paragraphs we will give an overview of the protocols in scope and how they can be assessed in terms of openness, interoperability, maturity and how they incorporate the functions.

4.1. Protocols in scope

This study focuses on protocols that are classified as fit for purpose for unlocking in-home energy flexibility. The protocols were selected based on interviews with experts in this field. The scope of this study did not allow us to perform a complete meta-study for all existing protocols. In consultation with the supervisory committee, it was decided to focus on the following protocols.

Protocol	Version	Author	Year of publication
ECHONET Lite	1.13	ECHONET	2018
EEBus SPINE	1.1.1	EEBus Initiative e.V.	2016
EFI	2.0	Flexiblepower Alliance Network (FAN)	2017
KNX	2.1	KNX	2013
OCF	2.0.2	Open Connectivity Foundation	2019
OCPP	2.0.1	Open Charge Alliance	2018
SEP – IEEE 2030.5	2.0	Zigbee Alliance	2013
OpenADR 2.0	1.1	OpenADR Alliance	2015
Modbus Δ	1.1b3	The Modbus Organization	2012

Please note: the EFI protocol is the predecessor of the previously mentioned S2 standard.

Δ Compared to the protocols in scope modbus can be indicated as a low-level protocol. Please refer to 4.1.2 for the differences between low-level and high-level protocols in this study.

4.1.1 Importance of open standards

Open standards in IT communication between different devices like heat pumps, charging stations, solar panels or back-office systems need to be transparent, user-friendly, and offer consumers freedom of choice. Open standards lead to better solutions because many parties work together on an equal basis, leading to cheaper solutions. These better, cheaper and widely available solutions will accelerate the roll-out of a “flexibility infrastructure” and will ensure that unlocking and using flexibility is a success.

When unlocking flexibility from multiple devices, communication is required for transmitting control signals. So it is essential that a universal ‘language’ is used to enable control of each device via any Energy Management System, regardless of brand: there must be no lock-ins tying users to a specific brand.

> Open standards lead to better solutions ”

MORE BENEFITS ARE

- **Innovation and competition is encouraged.** This translates into better services, lower prices and more new services such for end users, e.g. smart charging using your own solar panels.
- Parties that invest in the flexibility infrastructure (companies, grid operators, government) have the **freedom of provider-choice**. They can choose the best price/quality ratio, add new providers to their existing infrastructure, and develop new services.
- There is a large number of stakeholders: the consumer, device manufacturers, energy companies, government etc. By developing a shared protocol, **each stakeholder’s interests are assured**, and joint solutions can be introduced faster.

- Knowledge-sharing between a range of parties and countries leads to incremental gain: through open cooperation, new ideas and best practices spread faster.

- Open protocols within the flexibility infrastructure can be reused, enabling interaction with multiple devices such as charging stations, heat pumps and solar panel inverters.

4.1.2 Low level vs. high level protocols

When considering protocols, a distinction can be made between a ‘low-level’ and a ‘high-level’ protocol.

When discussing communication functions or protocols, the (classic) OSI model is often used as a conceptual model to characterize standards/protocols. The communication protocols discussed in this document often cover standardization on more than one level of the OSI model. For example, when using OCPP, this implies using JSON (OSI layer 6 - Presentation) over websockets (OSI layer 5/7 - Session/Application), thus using TCP/IP (Layer 4 - Transport and Layer 3 - Network).

In this study we will primarily look at the functionalities supported by the protocols, which we consider as part of the Application (or an even higher) layer. The protocols discussed in this study are however not all at the same “level” within this Application layer. Whereas Modbus allows writing values in numbered registers that are to be defined for each implementation, EFI for example has predefined data structures with names such as Flexibility Registration or Measurement. These data structures have predefined fields with predefined fieldnames with a predefined meaning. The latter category of protocols does not only focus on syntax of the protocol, they also provide meaning to the data sent (semantics). In this study this category of protocols will be referred to as “high-level protocols”. Protocols focusing primarily on syntax will be referred to as “low-level protocols”.

In general high-level protocols are more helpful for providing interoperability, but have to be developed specifically for each application. Low-level protocols can in general not be used for plug and play solutions, since these do not provide interoperability, without first making it application specific. On the other hand, low-level protocols can often be used in many more applications without any altering of the protocol itself.

In this definition, when looking at the protocols in scope for this study, Modbus can be considered as a more 'low-level protocol' with respect to the other protocols under consideration.

4.1.3 Different types of interoperability

When considering protocols, a distinction can also be made between protocols that were (originally) specifically designed for one type of device and protocols that were designed for multiple types of devices. Within this latter category of protocols, some protocols have messages that are independent of devices or only make a distinction between categories of devices (e.g. storage or production only) whereas other protocols specify for each type of device (e.g. heat pump, electric vehicle charger) how the protocol has to be applied.

Although all these types of protocols can still provide interoperability, especially for protocols that were (originally) specifically designed for one type of device, the interoperability will vary between types of devices. If a protocol was originally designed for heat pumps, it can be expected that for heat pumps interoperability will be higher than for solar panels.

In this protocol study, OCPP is also explored, which is originally and primarily used for communication with Electric Vehicle charging stations.

OPENNESS

The criterion 'Openness' is based on a combination of several factors. It is assessed if the standard has been developed by an accredited standards organization, whether it is subject to intellectual property[α] (IP) licensing and/or royalties or other implementation/usage restrictions and whether the specification is publicly accessible at no (or minimal) cost.

INTEROPERABILITY

In this study the interoperability is assessed by looking at the 'interchangeability' and 'Integrateability' of the protocol.

INTEGRATEABILITY

In this study interchangeability is defined as to which extent different devices can easily be integrated/functionally connected, simply referred to as "plug and play". This criterion is assessed by looking at the following questions: what is the chance that we get a working system if 2 parties/devices use the protocol without other communication? Can the protocol be interpreted in different ways? Is it clear which messages should be used (syntax) and what those message mean (semantics)? Are there organized Plugfest[¥] available?

INTERCHANGEABILITY

In this study Interchangeability is defined as: 'the ability to exchange types and/or brands of devices'. This criterion is assessed by looking at the following questions: Can the protocol be used by e.g. EMS from different brands? Can the protocol be used for e.g. communication with a heat pump as well as an EV?

MATURITY

The maturity of a protocol is hard to determine in detail. In this study it will be based on: number of releases, time in use, market adoption[ϴ], certification possibility (at an official test laboratory), availability of a testing tool (dedicated/specific), availability/detail of the (test) specification and the possibility to implement only basic/relevant parts. The aspect of reaction time (lag, frequency, refresh rate, etc.) is not assessed.

FUNCTIONS

As given in paragraph 2.4, there are four basic functions for energy flexibility, to know:

- Registration
- Energy flow reservation
- Adjust capacity
- Metering

α To the knowledge of the authors and reviewers.

¥ An event based on a certain technical standard where the designers of electronic equipment or software test the interoperability of their products or designs with those of other manufacturers.

ϴ Based on experience and estimation of the authors and reviewers.

In this chapter we will assess if these specific functions are supported by the different protocols. The question on how exactly the functions are supported is not addressed in this study.

4.2. Overview

An in-depth description of the protocols in scope will be given in the following paragraphs.

Although a 100% fair comparison is not possible of the protocols because of the above mentions aspects of high level vs. low level and the different types of interoperability, the following overview tries to capture the study results in a summary table. Below is given an overview of **openness**, **interoperability** and **maturity** when using these standards in-home connectivity (for unlocking flexibility):

	Version	Openness	Interoperability	Maturity	Registration	Energy flow reservation	Metering	Adjust capacity
ECHONET Lite	1.13	High	High	Medium/ High	●	○	○	○
EEBus SPINE	1.1.1	Medium/ High	High	Medium	●	●	●	●
EFI	2.0	Medium/ High	Medium/ High	Low	●	●	●	●
KNX	2.1	Medium	High✱	High‡	●	○	●	○
OCF	2.1.0	Medium/ High	High✱	Medium/ High	●	○	●	○
OCPP‡	2.0.1	Medium/ High	Medium✱	Medium	●	○	●	○
SEP – IEEE 2030.5	2.0	High	Medium/ High	Medium/ High	●	●	●	●
OpenADR 2.0	1.1	High	Medium/ High✱	High	●	○	●	●
Modbus Ξ		High	Low	High	○	○	○	○

○ → function is partially supported or only supported under conditions. Please refer to the protocol specific chapter for more explanation.

✱ Some functions must be realized using extensions (for some devices), having impact on the interoperability.

‡ The high maturity has brought a high complexity which has an impact in the ease of use/implementation for vendors.

Ξ Please note that this protocol is heavily used by EMS / device manufacturers, although it is a more ‘low level’ protocol than the other protocols investigated. Please also refer to 1.4.

	Version	Registration	Energy flow reservation	Metering	Adjust capacity
ECHONET Lite	1.13	●	○	○	○
EEBus SPINE	1.1.1	●	●	●	●
EFI	2.0	●	●	●	●
KNX	2.1	●	○	●	○
OCF	2.0.2	●	○	●	○
OCPP	2.0.1	●	○	●	○
SEP – IEEE 2030.5	2.0	●	●	●	●
OpenADR 2.0	1.1	●	○	●	●
Modbus		○	○	○	○

This table gives an overview of the supported ***functions.***

4.3. ECHONET Lite

INTRODUCTION

The ECHONET Lite protocol is developed by the ECHONET Consortium, which was established in Japan in 1997. It currently has over 170 members. Based on the member list, it seems primarily used in Japan. The communication protocol has been developed for the “smart houses of the future”. It was developed because of a growing demand for controlling in-home equipment and for monitoring, for example, electricity usage. It started out as a voluntary organization, but was made a general incorporated association in 2014.

The protocol is built up of several documents, containing the architecture, specifications for message format, protocol processing, startup sequence etc, hardware specifications and detailed specifications of ECHONET device objects.

OPENNESS

The ECHONET Lite protocol specification is publicly available at no cost from the ECHONET website. ECHONET is not considered an accredited standardization organization but part of the ECHONET lite protocol is standardized in IEC 62394 (which is currently under maintenance for consistency with the latest ECHONET Specification). The specification indicates that it is established without regard to industrial property rights (e.g., patent and utility model rights).

INTEROPERABILITY

The specification aims to provide interoperability by introducing a middleware adapter concept. The description of the protocol is quite detailed, properties of each device type are listed in a separate “device objects“ specification, including data types, size, unit, access rule etc. This is expected to lead to a high integrateability and high interchangeability. Although the consortium cannot guarantee that implementations are interoperable, it organizes PlugFests and other events to improve certainty of interoperability.

A certification program consisting of 2 systems is available, where either conformance tests can be executed by product developers and submitted to an authorization institute or recognized test institutes can carry out tests to verify conformity.

MATURITY

The ECHONET Consortium is founded in 1997, the ECHONET lite specification is at version 1.13. It has seen multiple releases and part of the protocol is standardized at the IEC. Furthermore, a list of commercial products of different types and of multiple vendors is available from the website, including a list of over 400 certified products. Combined with the market adoption that is primarily focused in Japan, the maturity of the specification is estimated as medium/high.

FUNCTIONS

Function	Supported
Registration	●
Energy flow reservation	○ → Depends on the device under consideration. Each device has its own specification.
Metering	● → ECHONET lite supports reading out a meter. When the meter is part of a device, it depends on the device under consideration. Each device has its own specification.
Adjust Capacity	● → Depends on the device under consideration. Each device has its own specification.

4.4. EEBus SPINE

INTRODUCTION

The EEBus SPINE (Smart Premises Interoperable Neutral-message Exchange) protocol is developed by the EEbus Initiative e.V; which is a non-profit organisation with manufacturers from the sectors of networked building technology, electromobility and energy. The protocol makes it able to exchange information to coordinate and shift the energy between an intelligent power grid and the individual components in the households and buildings, e.g. photovoltaic system, battery storage, heating and electric vehicle.

OPENNESS

The EEBus SPINE protocol is publicly available at no cost from the EEbus website. The standard does not have any IP associated with it. The EEbus Initiative is not considered an accredited standard organization but EEBus SPINE harmonised the data model for White Goods and along with CENELEC introduced it into the European Smart Appliance Standard prEN50631. Furthermore, EEBus has collaborated in the EU Framework SAREF (Smart Appliances REFerence) to add an extension for EEBus (and Energy@Home).

MATURITY

The current version of the EEBUS SPINE protocol is 1.1.1, which was published on 2018-12-17. The EEBus Initiative e.V. was founded in 2012 as a result of a project funded by Germany's Federal Ministry of Economics. In 2016 the first version of EEBus SPINE was released. In 2018, an introduction of Use Case specifications was published which is a document that describes potential use cases that can be fulfilled with the EEBus SPINE protocol. In 2019 the E-Mobility Use Case Specifications were published which is a "manual" on how to use the modular and universal SPINE toolbox to implement EV use cases. In the future also other categories of Use Case Specifications will be published.

According to the EEbus.org website, the Initiative has 60 member companies and they are active in the following standardization bodies: CENELEC, ETSI, DKE and IEC. They are also connected with leading alliances and consortia around the globe. One of the companies building an EEBus stack offers “validation and test soft equipment for EEBUS implementations”.

INTEROPERABILITY

Interchangeability

The protocol is quite generic and can be used in a wide range of areas. To limit the variability of the implementation scenarios EEBus has published use case specifications that can be used as a manuals on how to use the ‘SPINE toolbox’ for a certain use case. In this way EEBus tries to be interoperable and expandable. It is possible to do an interoperability test at the VDE testing and certification institute.

Integrateability

To make sure that the EEBus SPINE protocol can be used by different EMS and smart devices the protocol is developed in working groups. Here, experts of participating companies develop the corresponding data models and specifications. The working groups ensure that the protocol is standardized and that the specifications are consistent. They also organize joint plugfests and independent testings before publication of new use cases.

FUNCTIONS

Function	Supported
Registration	●
Energy flow reservation	●
Metering	●
Adjust Capacity	●

4.5. EFI

INTRODUCTION

The EFI (Energy Flexibility Interface) protocol is developed by TNO and governed and promoted by the Flexible power Alliance Network (FAN), which brings together approximately fifteen participants with specific knowledge and different market connections. With EFI it is possible to control multiple smart appliances (heating, airco, solar panels and EVs).

OPENNESS

The EFI protocol is publicly available at no cost from the FAN GitHub and does not have any IP associated with it. The FAN is not an accredited standardization organization. However, the EFI protocol is used as input for the European CENELEC EN50491-12-1 specification, which is still work in progress.

INTEROPERABILITY

Interchangeability

The EFI protocol is dedicated to energy flexibility and can only be used to communicate about this flexibility. In EFI there are four different categories for energy flexibility; uncontrolled, timeshiftable, storage and unconstrained. These categories ensure that it is clear which messages should be used and what these messages means. EFI does not have any organized plugfests and a certification program is not available.

Integrateability

Nowadays most EMS's are coupled to a particular Demand Side Management (DSM) approach. This results in a vendor lock-in for consumers, because a switch to another DSM approach will require the installation of another EMS in most cases.

The objective of EFI is to create a bridge between all the smart grid control systems and all the smart devices by creating an interoperable interface that is able to connect to a variety of smart appliances and support a host of DSM approaches. In this way the EMS hardware does not need to be changed when a consumer wants to switch to another DSM approach.

MATURITY

The current version of the EFI protocol is 2.0 which is published in 2017. However, this version is still under construction, because of the mentioned CENELEC formalization process. The Flexible Alliance Network currently has ~15 members with different area-of-expertise. The EFI protocol is used for several pilot projects and some commercial project. Currently no devices are marketed with an EFI-interface.

FUNCTIONS

Function	Supported
Registration	●
Energy flow reservation	●
Metering	●
Adjust Capacity	●

4.6. KNX

INTRODUCTION

KNX is a worldwide standard for home and building control. It provides energy efficiency by controlling heating/cooling, lighting. KNX is an OSI layer based communication standard for building automation. The KNX standard is administrated, developed and promoted by the KNX Association that was founded in 1999. Development of KNX done under responsibility of a technical board that has a number of working groups per topic (extensions to the standard, certification etc.). KNX used to be largely for the commercial sector but nowadays it is implemented into many residential properties as well.

KNX provides energy management to control for example when to start charging the EV. Within a KNX system each device can be programmed, for example to read information from solar panels or other renewables to know how much energy those devices are generating.

In contrast to a standard electric installation, there is no hard wired connection between the control units and the power supply, for example a light switch is not directly connected with the respective light. Instead, devices and electric assets are connected via the KNX BUS. Both star -and tree network topologies are supported. This enables setting it up as a completely decentralized system, but also supports a setup with an EMS (closest to the direct approach).

The KNX system has, besides the KNX power supply, no single point of failure. Because of its autonomous and decentralized characteristics it does not have to have a central processor (no central brain) and therefore every KNX component is responsible for the communication to other components it is related to.

KNX is quite complex/has a steep learning curve, requiring courses to use it.

OPENNESS

The KNX association (knx.org) sells engineering software (the ETS tooling) that is needed to create a non proprietary, autonomous and decentralized system. The KNX standard offers a way for a device to auto configure itself or have the manufacturer equip the device with a preprogrammed configuration. In some cases it is not possible to change the device configuration yourself (using the ETS tool) unless you use the manufacturers (proprietary) tools. This might create a vendor lock-in.

In essence devices (both EMS's as well as in-home devices) using the KNX standard are not proprietary, which means there's no lock-in of any supplier or manufacturer. You can choose the KNX manufacturer yourself or switch from one manufacturer to another.

Companies that are involved in manufacturing KNX products are registered with the KNX association and can certify their product at one of the KNX accredited test labs. Essentially what they are doing is putting software in their devices and letting KNX verify their products as KNX capable, or in line with the standard. After this they are allowed to sell their products as 'KNX devices' (with the KNX trademark).

INTEROPERABILITY

Using a KNX gateway it is possible to interface with non KNX devices over IP, Modbus, M-bus, RS485, etc. There's various ways of connecting the KNX system to the internet, though when implemented incorrectly the system is susceptible to attacks from outside the house.

> **Interchangeability**
>
> KNX communication is peer-to-peer and usually only for control -or measurement data. The behaviour of a KNX device is configured using the ETS tool. Sensors can send events and actuators can listen/react to events. KNX facilitates the interaction between the devices. The KNX standard does not prescribe the information that is exchanged making devices not interchangeable without re-configuring/re-programming them with the KNX software.

Some manufactures have additional pieces of software. This means that if you use all of their kit together than you get more functionality than just the default that you might receive.

Integrateability

KNX devices are all inter-operable. Choose any KNX product from any manufacturer and they should work together. Though every device has its own wiring and configuration. and every event and/or action is ‘device specific’. Using the ETS tool the configuration and an electrical wiring plan can be made. Beside determining if the device has the right features (events and/or actions) you will have to reconfigure this part of the system using the ETS tool.

Examples

Automatically charging your EV is a use case in the KNX energy management system. The system can decide to use energy from either the Utility or, in case available, use the energy generated by the solar panels. It is possible to connect a non-native KNX smart meter using M-bus or the S0 Interface (pulse counting). In the future this will enable the end user to choose between demand based tariffs.

But also the smart meter will then be able to communicate with devices in-home. The smart meter (the KNX smart energy platform) will then for instance be able pause charging of the car when tariffs are high and resume when the tariff drops.

There are multiple solutions for connecting a charge point via Modbus to KNX. Although this solution is very flexible every charge point manufacturer needs to develop such a device itself which makes this a non-scalable solution.

When providing ‘charge control’ on KNX a solution might be to implement an OCPP adapter. Such a device will than couple KNX charge control telegrams and OCPP messages. There’s no such thing as a ‘generic charging control interface’ (yet).

MATURITY

According to the knx.org website, the initiative has 470 manufacturers developing products, solutions and software for more than 8000 products. This figure increases on a daily basis.

KNX is the successor of three previous standards: the European Home Systems Protocol (EHS), BatiBUS, and the European Installation Bus (EIB or Instabus). KNX is approved as a European (CENELEC EN 50090 and CEN EN 13321-1) and an international standard (ISO/IEC 14543-3).

Companies like ABB, Gira, Philips and Siemens are involved in the KNX environment. It can be stated that KNX is a reliable, credible and robust system.

When it comes to connecting the KNX system to the internet there are some security challenges that should be taken in consideration. Checklists as well as a security scan are available at the website knxscan.com.

FUNCTIONS

Function	Supported
Registration	●
Energy flow reservation	○
Metering	●
Adjust Capacity	○

○ → depending whether a standard device specification is available for a device and whether this is included.

4.7. OCF

INTRODUCTION

The OCF specification is developed by the Open Connectivity Foundation (OCF). The OCF is an industry group whose mission is to develop IoT standards that promote interoperability. The OCF was formerly known as the Open Interconnected Consortium (OIC) which was founded in 2014. The OCF protocol can be used in different types of industry, namely: Smart home, Automotive, Healthcare, Security and Industry. In this study we will focus on the Smart home aspect which aims to a system where devices can communicate with each other – without direct customer interaction – to increase the efficiency which leads to a better use experience.

OPENNESS

The OCF protocol is free and publicly available at the OCF website. The foundation actively submit their specifications for publication as International Standards by the International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC). The 1.0 specifications where ratified and accepted in November 2018. The 2.02 specifications were submitted in July 2019 and wait for approval.

INTEROPERABILITY

The OCF protocol is very generic and can be used in several industries. The messages for smart home are dedicated for each defined device type. A device type is a classification of a device. Each device type defined will include a list of minimum resource types that a device shall implement for that device type. A device may expose additional standard and vendor defined resource types beyond the minimum list. Within an OCF implementation a device is 'self-describing' and can therefore be automatically discovered.

OCF has a set of pre-defined (ISO/IEC 30118-5:2018) device types including for example a 'electricvehiclecharger' device that could match an EVSE or charging station and an 'electricmeter' device is available which represents an energy meter.

The protocol is flexible enough so that any device type, with the corresponding resource types, can custom defined as well. The device and resource specifications are defined separately and the OCF setup is suitable for using these extensions in an interoperable way. Of course, this means that only extensions that are publicly available/shared will be interoperable. The Interchangeablility and integrateability are both depending on the extent to which pre-defined device types and publicly available extensions are used. The mechanism in the OCF specification provide high interoperability when used.

MATURITY

The current version of the OCF protocol is 2.1.0 and was published in November 2019. The OIC was created in 2014 and published their first specifications in September 2015. In February 2016 the OIC changed their name to OCF and in 2018 the specifications were ratified by the ISO as ISO/IEC 30118-1:2018. The foundation has over 300 member partners and also have their own Certification Program which includes conformance testing to ensure a robust and secure connectivity. Currently, the OCF website reports about 140 certified products (excluding an unknown number of products that companies want to keep private).

FUNCTIONS

Devices and resources are specified separately in OCF. The function "Energy Flow Reservation" and "Adjust Capacity" below are thus not supported by default for every device, this depends on the specification for the device. As indicated above, these specifications are extensible, but this has effects on the interoperability.

Function	Supported
Registration	●
Energy flow reservation	○
Metering	●
Adjust Capacity	○

○ → See KNX

4.8. OCPP

INTRODUCTION

The Open Charge Point Protocol (OCPP) has been designed and developed to standardize the communications between an Electric Vehicle Charging Station and a Charging Station Management System, which is used for operating and managing charging stations. The communication protocol is open and freely available ensuring the possibility of switching from charging network without necessarily replacing all the charging stations or need significant programming, including their interoperability and access for electric grid services. The protocol is intended to exchange information related to transaction management, metering data, maintenance and smart charging. OCPP started out as an initiative of ElaadNL, a collaborative foundation created by a number of Dutch grid operators and the first version was published in 2009. In the beginning of 2014 development and maintenance of the protocol has been transferred to the Open Charge Alliance (OCA). The OCA has an international board of directors, and widespread global membership of over 150 members, including grid companies, research institutes, charge point manufacturers and commercial software and hardware companies. The OCPP has become the defacto open standard for charger to network communications in many countries.

With the introduction of the “device model” in OCPP 2.0, the protocol is more extensible and parts of it can be applied to devices other than charging stations (for which it is originally intended).

OPENNESS

The OCPP protocol is publicly available at no cost from the website of the Open Charge Alliance, without licensing/royalty obligations or usage restriction. It is made available under the Creative Commons Attribution-NoDerivatives 4.0 International Public License (with no other intellectual property assertions). The Open Charge Alliance is not considered an accredited standards organization.

INTEROPERABILITY

Integrateability

The OCPP standard is a strict protocol: it does not only describe messages, but also the related behaviour of the CSMS (Charge Station Management System) and charging station is included in the protocol in the form of use cases. The protocol defines use cases, such as booting a charge point, and the exact sequence of messages that is to be used. This “strictness” makes integrateability high.

With the introduction of the “device model” in OCPP 2.0, the protocol is more extensible. When a manufacturer uses an implementation with an extension to the protocol, it is only interoperable if other manufacturers also implement the same extension. Thus when using extensions, the integrateability can be low(er).

Interchangeability

Due to the strictness of the protocol (without extensions), the interchangeability when used for charging stations is high as well. Charging Station Management Systems can manage different devices from different manufacturers and when the OCPP standard is followed, this leads to no/little issues. Again, when using extensions for other types of devices, these might not be interchangeable anymore.

MATURITY

In recent years, many parties extensively used OCPP to interact with public and private charging stations. Version 2.0.1 is the fourth “real” release of the protocol - the previous releases of OCPP were 1.2, 1.5 and 1.6. The protocol has been further developed while it was also being used in practice and has been enhanced both technically as well as functionally over the years. The 2.0.1 version of OCPP is developed within the Open Charge Alliance. The specification is divided in “functional blocks”.

These functional blocks include functionalities such as firmware management, smart charging and reservation. A testing tool and certification program for OCPP

1.6 is offered by the OCA. For OCPP 2.0.1 these are currently under development. The technical level of detail of the OCPP specification for charging stations is high, a separate test specification is not yet available. For use with other devices than charging stations, no specifications are available.

FUNCTIONS

As mentioned in the introduction, the "device model" in OCPP 2.0.1 has made the protocol extensible enabling it to apply parts of OCPP to devices other than charging stations. Based on this, OCPP could be used as an in home protocol not only for charging stations, but also for other devices.

Function	Supported
Registration	● → Registering a charging station at a CSMS and providing information via the device model can also be used to register a device at an EMS. Of course the terminology in the messages currently refers to EV chargers.
Energy flow reservation	○ → OCPP contains a message to express the charging needs of an EV. This could be reused for other devices. This does not include bidirectional power transfer (i.e. discharging is not supported) Another option would be to use the device model or a message extension to communicate an energy flow reservation.
Metering	● → Sending metering data from charging station to a CSMS can also be used to send metering data from any device to an EMS.
Adjust Capacity	○ → OCPP contains a message to set the charging profile of a charging station/EV. This could be reused for other devices. This does not include bidirectional power transfer (i.e. discharging is not supported yet). Another option would be to use the device model or a message extension to communicate an adjustment in the capacity.

4.9. SEP – IEEE 2030.5

INTRODUCTION

The SEP 2.0 protocol or IEEE 2030.5 standard formalizes the requirements for many aspects of the smart energy ecosystem including device communication, connectivity and information sharing requirements. It provides the guidelines in which the internet enabled devices should communicate with one another. The protocol is based on the IEC 61968 common information model and the IEC 61850 information model for DER. It follows a RESTful architecture utilizing widely adopted protocols such as TCP/IP and HTTP.

SEP 2.0 originates from the ZigBee Alliance and is a successor to the Zigbee Smart Energy Protocol v1. In 2012, the Consortium for SEP 2 Interoperability (CSEP) was formed by the WiFi, ZigBee, HomePlug and Bluetooth Alliances to specify certifications requirements. The Consortium was disbanded in early 2016.

OPENNESS

The protocol is publicly available at the website of IEEE. It can be bought at limited costs and contains no intellectual property. IEEE is considered an accredited standards organization.

INTEROPERABILITY

The protocol defines various device properties that can be manipulated. These properties (also known as “resources”) work together in logical groups to implement SEP 2.0 functionalities (called the “function sets”). A metering system, or pricing system, is an example of an application-specific function set. Devices like smart meters implement one or more function sets to provide value-added services such as usage statistics and trends. These pricing statistics and trends can then be used by either the energy provider or the consumer to further manage services or usage, respectively.

The IEC 61968 data model is used for most of the semantics. The protocol adopts the IEC 61850-7-420 logical node classes for DER components and anticipated extensions are intended to be made consistent with IEC 61850 extensions for DER. It consists of an XML schema and a description how messages are to be sent, including message examples. CSEP conducted dozens of industry interop events for SEP 2 devices as a follow-on to multiple events conducted by the Zigbee Alliance. The protocol is quite broad and the function sets are defined in a generic way (client can be a thermostat, but also an EV) which means that it can be used in a wide range of areas. This genericity makes it impossible to describe exact behavior.

MATURITY

In 2013 the protocol has become a standard within the IEEE. In 2016 the protocol was selected as the "default protocol" for the state of California as part of the rule 21 activities. The specification not only describes the messages, but it also has an extensive description of registration, discovery, the transport protocol and security. Furthermore, the specification contains sequence diagrams including message examples for a number of use cases. The specification itself does not mention which parts of the standard are to be implemented for certification. The CSEP consortium qualified a set of test tools to implement certification of devices to the "CSEP Version 1.0 Test Specification" (in December 2013). As already mentioned, the consortium was disbanded in early 2016, further development is done in an IEEE working group. The test tools are available and used in an IEEE 2030.5 Conformance Test Program by two Nationally Recognized Testing Laboratories in the US and Korea.

FUNCTIONS

Function	Supported
Registration	●
Energy flow reservation	●
Metering	●
Adjust Capacity	●

4.10. OpenADR 2.0

INTRODUCTION

The Open Automated Demand Response standard is a (dynamic) Demand Response protocol, developed by the United States (U.S.) Department of Energy's Lawrence Berkeley National Laboratory (LBNL) since 2002, formally published, as a standard by the international standards development organization OASIS and maintained by the OpenADR Alliance. The OpenADR Alliance (US-based) has members from all over the world, including grid companies, research institutes and commercial component and infrastructure companies.

As the name implies, the protocol is aimed at automating demand response communication, it supports a system and/or device to change power consumption or production of demand-side resources. This standard can be used, for example, by grid companies to send DR signals based on grid needs (e.g. via tariff or emergency signals).

Besides certified systems, many certified OpenADR products exist, such as thermostats or lighting related products. The standard is setup in a generic way, making it suitable for any 2 components that want to exchange DR signals. Instead of sending signals from grid companies to devices, it is also possible to send these signals from an Energy Management System to individual devices.

OPENNESS

The OpenADR protocol specification profiles A and B are publicly available at no cost from the website of the OpenADR Alliance. The standard does not have any IP associated with it. The alliance is not considered an accredited standards organization but the OpenADR 2.0 A and B profiles are based on a standard called Energy Interoperation that has been formally adopted as an international standard by the OASIS standards organization. In addition, the IEC has approved the OpenADR 2.0b Profile Specification as a full IEC standard, to be known as IEC 62746-10-1 ED1 in 2019.

INTEROPERABILITY

Interchangeability

The protocol is quite generic (due to the nature of DR programs), which means that it can be used in a wide range of areas ranging from utility to EMS communication to EMS to device communication. Since the DR program message content is an outcome of a specific implementation, this genericity makes it impossible to describe the exact signal content and behavior for interoperability with every program. To limit the variability of the implementation scenarios, the OpenADR Alliance has published a number of DR Program Guides that sets out to harmonize the programs.

Integrateability

The OpenADR alliance organizes interoperability test events, provides a testing tool and certification. Testing and certification includes a number of mandatory cases that are tested and certified to ensure that any client can communicate when installed and enrolled. This means that the technical interoperability is high.

MATURITY

The current version of the OpenADR 2.0b standard is 1.1 (with minor updates to the version 1.0 published in 2013). The OpenADR standard is divided into several "profiles" (A and B, where the A profile is a sub-set of B profile, hence "2.0a" and "2.0b") and does not only describe the messages in the protocol, but also provides registration, the transport protocol and security. The specification defines which parts of the standard are to be implemented to be OpenADR compliant. There are (members only) on-site interop tests in an authorized OpenADR Alliance test lab or other suitable facility. Furthermore members can purchase an Alliance testing tool that is identical to the test harness used by the authorized certification test labs to complete the certification testing.

According to the website, the alliance has 130 member companies and the database of OpenADR certified products contains over 100 products. The standard has been adopted for use in the US, South Korea, Japan, and Canada and is under consideration in Europe and elsewhere in the world.

FUNCTIONS

Function	Supported
Registration	● → à the default OpenADR registration service supports extensions which can be used to communicate exchange additional information.
Energy flow reservation	○ → à the generic OpenADR reporting functionality can be used for this.
Metering	●
Adjust Capacity	●

4.11. Modbus

INTRODUCTION

The Modbus protocol is a messaging structure developed by Modicon (Schneider Electric) in 1979. It is used to establish master-slave/client-server communication between various devices connected to the same network. It is a request/reply protocol. A device exposes services via Modbus registers and function codes. Function codes are predefined (for instance read 2 bytes from register 10000). Registers are free to be filled in by the manufacturer.

Each device communicating (transferring data) on a Modbus network is given a unique address.

There's many variants of the Modbus protocol available. Most common are:

- **Modbus RTU:** this variant is used in serial communication and makes use of a compact, binary representation of the data. Binary is machine readable.

- **Modbus ASCII:** this variant is used in serial communication and makes use of an ASCII representation of the data. ASCII is human readable and less efficient (in communication between devices) than binary/machine readable.

- **Modbus TCP**: this variant is used for communication over IP (Internet Protocol). TCP/IP provides a reliable data transport mechanism (better than the above) between devices.

Data model and function calls are identical for all these three variants. However the variants are not interoperable, nor are the messages.

OPENNESS

Modbus is openly published and royalty-free. All specification needed to develop a Modbus device are available from the website modbus.org. The specification is available free of charge for download, and there are no subsequent licensing fees. Additional sample code, implementation examples, and diagnostics are available for free to Modbus Organization members and available for purchase by non-members.

INTEROPERABILITY

The protocol was developed for industrial applications, is relatively easy to deploy and maintain compared to other low-level protocols, and places few restrictions other than size on the format of the data to be transmitted. The Modbus organization offers a Conformance Testing Program which provides independent verification to verify whether implementations work in compliance with Modbus specifications. Conformance testing can be done under a controlled self-test program for member companies of by approved third-party test laboratories.

Modbus is the de facto standard in multi-vendor integration in the industry.

Interchangeability

Every device has its own way of expressing functionality via Modbus registers and function codes. There's not a common way to express for instance a 'set limit' or 'read power measurement' command. Every manufacturer can choose which services are made available (which registers and functions should be used) and what those registers mean. Besides the fact that all Modbus devices 'speak' the same language it is still to be determined which 'messages' should be used and what their meaning is. As mentioned earlier note that there's various (not interoperable) variants of the protocol available.

Integrateability

Because every device has its own way of expressing its functionalities, interaction between Modbus devices always requires a device specific coupling. This implementation consists of a piece of software inside the calling/using device (e.g. the EMS) that couples functionalities to registers and function codes.

MATURITY

The development and update the protocol variants has been managed by the Modbus Organization since April 2004. The Modbus Organization is an association of users and suppliers of Modbus-compliant devices that advocates for the continued use of the technology.

It is the de facto standard and a widely used network protocol in the industrial manufacturing environment. It has been implemented by hundreds of vendors on thousands of different devices to transfer discrete/analog I/O and register data between devices. It's a lingua franca (common language) or common denominator between different manufacturers.

FUNCTIONS

Function	Supported
Registration	○
Energy flow reservation	○
Metering	○
Adjust Capacity	○

Practical experiences

In this chapter the practical experiences with energy flexibility by the market are described. An overview of the consulted parties can be found in the last part of this section. Their practical experiences were collected in addition to the theoretical study from the previous chapter. After a workshop with different companies who relate to this topic and multiple follow-up interviews the following insights were gained.

Workshop 'practical experiences'

Date: September 10th 2019
Location: Utrecht, The Netherlands

Allego
EEbus
Smappee
FAN
Vito
ABB
Axians
IWell
Jules Energy
EnergieAgenthur.NRW
Itho Daaldrop
Spectral
ABB
Recoy
Jedlix
Senfal
Alfen
Vandebron
Enervalis
NVDE
Technolution
Cohere

Known information from the EV domain

Regarding EV the ‘in-home domain’ holds the same level of interoperability for EV charging stations as the public terrain, but the connectivity with other in-home devices differs.

Charging stations have a higher degree of connectivity and manageability than other flexible devices such as heat pumps. Charging stations are already connected and “flex ready”.

Charging stations form a good base for unlocking energy flexibility. They are usually connected to a back-office system of the Charging Station Operator (CSO) and can be combined with an Energy Management System. The large majority of charging stations are connected through OCPP, the standardized and open protocol for connecting charging stations•.

Learnings can be drawn from the EV domain for OEMs of other flexible devices to increase interoperability.

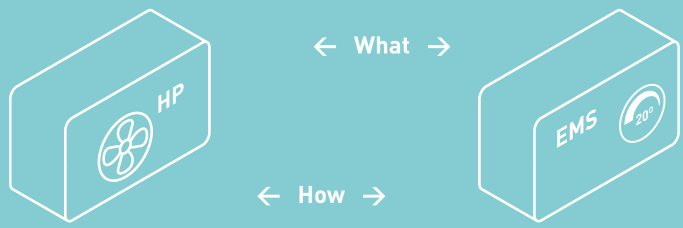
• Please note that OCPP was specifically created for EV charging stations. So in this chapter it is used as a reference for a device specific, high level protocol, In the previous chapter it was considered as one of the possibilities for using as an in home protocol for any in home device.

Practical experiences

The companies consulted share the following observations and opinions:

Regarding the level of interoperability a distinction must be made between communication and information levels. Interoperability at the information level concerns the “what” and interoperability at the communication level the “how”.

DISTINCTION BETWEEN COMMUNICATION & INFORMATION LEVELS IS NECESSARY



OEMS PREFER TO INCREASE INTEROPERABILITY AT INFORMATION LEVEL FIRST

Device manufacturers want to increase interoperability at the information level (first). This level concerns the standardization of attributes/registers/data fields of the different devices and not necessarily a ‘high level-protocol’ like OCPP (when used for EV Chargers).

FLEXIBLE ENERGY DEVICES CAN BE CONNECTED VIA MODBUS

The consulted companies state that the different devices that can provide energy flexibility can often be connected via Modbus. Modbus is a so-called "low-level protocol" (see 4.1.2) that facilitates the transport of data/information, but does not prescribe what the content of the messages looks like and what should be done with this data/information. Using Modbus means that for every installation customization is needed. One device manufacturer may use **2** registers to adjust capacity, the other may use **6**. In this way for each type of device, a different Modbus interface is required.

2

6

OR THE DEVICES CAN BE CONNECTED THROUGH AN API

Another possibility given by the consulted companies is connecting through an external communication channel to the manufacturers backend for specific functions (API). An increasing amount of flexible devices like heatpumps are connected with a backend and also offer such APIs.

In practice establishing the connection lies largely with 'the integrators', which could be considered as the EMS operators. Currently there are mainly implementations within larger companies, mostly production locations. These companies state that using Modbus works well enough for them now, but the question is if this customization is still acceptable when these systems are going to be installed in-homes.

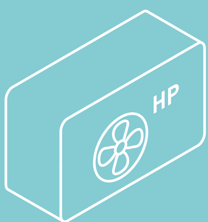
MODBUS CAN WORK
BUT THE QUESTION IS IF THE
CUSTOMIZATION IS ACCEPTABLE
WHEN INSTALLED AT HOME

HOME AUTOMATION SYSTEMS
ARE CURRENTLY NOT SUITABLE
FOR MANAGING FLEXIBILITY

Device manufacturers need access to the device for algorithms and maintenance/configuration management. The device is (mostly) accessible via the same access for home automation applications. According to the consulted parties, these home automation systems are currently not suitable for managing energy flexibility, since these need higher hardware requirements (e.g. more memory and computing power). Their general perception is that it is not possible to run 'energy flexibility services' on 'normal' home automation systems. The opposite is however possible, they state; to run home automation services on the EMS systems. An EMS needs and contains more computing power than a home automation system.

Computing power

Not yet suitable for flexibility



Finally, it is worth mentioning that several EMS manufacturers are trying to make a connection through OCPP to other devices than charging stations.

OCPP IS GAINING GROUND IN OTHER SYSTEMS BESIDES CHARGING STATIONS

The pursuit of increased interoperability is supported by all consulted companies. The translation of this need towards a market wide accepted solution (whether direct or indirect, one or multiple protocols) is more nuanced. Not only because of the complexity due to different existing standards, but also due to different interests of companies, different points of view on a technical and functional level and the simple fact that this topic is currently not yet on the top of the priority lists of some of the involved companies. The question is what is the best approach would be to reach the desired level of interoperability.

Impressions

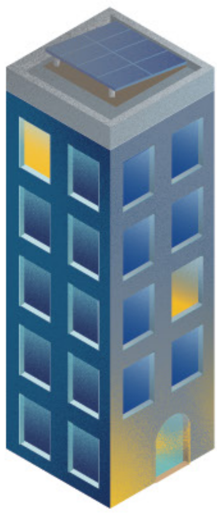
The diversity of flexible devices, such as PV, electric vehicles (EV), heat pumps, potentially energy storage and different energy flexibility (demand response) possibilities, provides new opportunities and bring new complexities at the same time. While these technologies can be used to improve the energy transition and grid reliability and resiliency, uncoordinated and siloed deployments of these technologies and communication standards can potentially lead to less flexibility, higher system integration costs and longer timelines.

The research on in-home interoperability has started with the perspective of pursuing one standard, whereas from practical experiences the alignment of attributes already seems a good first step. Furthermore, an EU standardisation process is about to provide a standard specifically for energy flexibility in 2020. It is a complex situation with the involvement of several different stakeholders.

Manufacturers of flexible devices are mainly working on improving their products and are not primarily focused on the connectivity of their devices for reasons of energy flexibility. Manufacturers of charging stations are an exception in this. Parties that develop Energy Management Systems are focusing on this connectivity and exploring and preparing market propositions in this area. This while the real flexibility comes from the devices.

There are no guidelines for interoperable communications and information exchange between flexible devices.

The current status of in-home connectivity is that so far little experience has been gained with it. What is available is used (Modbus), but this does not provide a basis for in-home interoperability and therefore the unlocking of flexibility.



5
Conclusions & Recommendations

The system changes, flexibility is needed

This study focused on the status of in-home connectivity and the exploration of possibilities for improvement. During this exploration insight was gained in various areas, the result of which is shown in this document:

- Insight into the various functionalities of energy flexibility
- Insight into various architecture options
- Insight into various protocols
- Insight into the current practical situation and opinions of the various parties

This study is focusing on how to increase the connectivity between the flexible devices in the home and the EMS, in order to unlock energy flexibility from these devices. With the current status of connectivity the interoperability is becoming an increasingly important area of research. The developments with regard to interoperability differ per type of device.

The study shows that the practice is more unruly and complex. In this chapter the conclusions, recommendations and a number of considerations are given.

5.1. Conclusions

main conclusion

The **main conclusion** from this study is that several open, in-home protocols already exist that are mostly suitable for unlocking energy flexibility. Most protocols discussed in the study use a direct approach, communicating from an Energy Management System directly to devices. **In practice**, unlocking flexibility is currently not the main concern for manufacturers that are focusing primarily on a stable, working product.

Several open, in home protocols already exist that are mostly suitable for unlocking energy flexibility.

Having different protocols implemented in different devices leads to interoperability issues and incompatibilities between EMS's and devices when trying to use devices and more specifically, when trying to unlock flexibility. To address this issue, different options exist:

- Choosing one worldwide protocol to implement in every EMS
- Each EMS chooses one of the protocols to support
- Implementing several protocols in parallel in EMS's ("polyglot" approach)
- Choosing an indirect approach, adding an additional layer to the architecture to allow for standardization on the EMS side while keeping different standards/protocols on the device side.

Unlocking flexibility is currently not the main focus for manufacturers.

As shown in this study, several protocols are suitable for unlocking flexibility and are already applied in practice, basically ruling out the first option on the short term. This leaves the choice to implementers of Energy Management Systems to choose out of the remaining approaches, where currently only the second and third option are possible. The indirect approach is being developed, but no (final) standard is available for this approach yet.

A formal European standardization process has been started in this domain that follows the indirect approach. This development takes place within the joint initiative of CEN and CENELEC. Both CEN and CENELEC provide a platform for the development of European Standards. EN 50491-12-1 (requirements document) is a joint effort of CEN and CENELEC and under the name EN 50491-12-2 a standard for in-home interoperability is in development. The work contains the specification of General Requirements and Architecture of an application layer interface between the Customer Energy Management System and Smart Devices operating within the smart grid premises-side system (i.e. home or building but not industrial premises). This work includes the “Resource Manager” as described in 3.2 - Indirect approach.

Note →

This development means that it is expected that the interface specification to the RM will be provided, however, this does not yet prove the technical feasibility. Moreover , all though the CEN CENELEC standard provides a formal, ‘de jure’ standard, manufacturers decide themselves what protocol they use; they form their own ‘interoperability-policy’.

It is expected that the interface specification to the RM will be provided. However, this does not yet prove the feasibility from both a political and technical point of view.

OTHER SUB-CONCLUSIONS THAT CAN BE DRAWN:

1) The prioritisation of efforts to unlock energy flexibility differs per stakeholder. The (potential) manufacturers of EMS systems give priority to unlocking energy flexibility and working on applying and improving connectivity. They are engaged in technical development and are preparing their market propositions. The manufacturers of most flexible devices do not have their priority here. They are primarily concerned with improving existing products (in terms of efficiency) and are not primarily concerned with connectivity to unlock energy flexibility. They offer a basic connection (Modbus) but are not actively engaged in the further development or “high level connectivity” in this.

2) There are several protocols that are suitable for unlocking energy flexibility, according to the functions as shown in this document. In addition to existing protocols, a protocol is also being developed within the European standardization work as mentioned above. That protocol is being specifically developed for unlocking energy flexibility and fits within the indirect approach. There seems no need for the development of an additional, similar protocol, but rather the incorporation of the functionalities for energy flexibility into an existing protocol and/or adoption of an existing protocol.

3) There are developments and protocols aimed at connectivity with flexible devices for multiple purposes other than just energy flexibility (such as KNX EEBUS). In addition, there are protocols that only focus on unlocking energy flexibility (e.g. EFI as discusses in 4.5).

4) The connectivity of the flexible devices differs per device type. For example, a charging station is almost automatically suitable for in-home connectivity, while other devices lack this connectivity to unlock energy flexibility. With other types of devices, Modbus is currently mainly used to achieve connectivity.

5) Even with the same type of devices, such as heat pumps, it is not certain that these devices communicate in the same way, are programmed in the same way. This means that one heat pump can be controlled differently than the other.

6) There is no single in-home standard that stands out for all types of devices. With regard to EV, OCPP stands out, but there is no broad experience with the application of OCPP with other types of devices.

7) In the absence of the availability of a single high level standard for unlocking flexibility from different devices, what people know is applied in practice; unlocking flexibility through Modbus.

Flexibility access and developments that support this are approaching a tipping point. There is more attention for it, more demand arises and there are more and more devices that can actually deliver a relevant amount of flexibility. More and more parties are also working on unlocking flexibility both on the side of the devices themselves and on the side of energy management systems. By this tipping point, we also mean that the various applications that are used to unlock energy flexibility can be coordinated more closely in the coming period, among other things through standardization work in this area.

This study is also intended to retrieve the network of all developments that play a role in this area and to make recommendations for follow-up, for more alignment in this regard.

5.2. Recommendations

Based on the conducted research we provide the following recommendations.

1. **Need for coordination**

   The goal is the development and harmonization of in-home flexibility.

2. **Investigate feasibility of indirect approach**

   We recommend to develop different pilots in which this indirect approach is going to be implemented to test the technical feasibility in practice.

3. **Short term: attributes alignment & API development**

   Set up pilots with the purpose to investigate and realize harmonization.

4. **Assess suitability for unlocking flexibility**

   Investigate the claim by the consulted companies that home automation systems in their current state are not suitable for unlocking flexibility.

5. **Cyber security**

   Implement the correct cyber security measures. Conduct stakeholder analysis (NEN)

1 Need for coordination

The long term goal is the development and harmonization of in-home connectivity. Currently there is no or a siloed approach for connectivity per device type which could lead to no or a unique development and adoption cycle for each device type. This brings the risk of lack of interoperability, when different protocols are developed independently of each other. Furthermore, generally, the manufacturers of particular flexible devices do not prioritize connectivity for the purpose of energy flexibility.

> The goal is development and harmonization of in-home connectivity

There is a strong need for coordination and broader involvement of different stakeholders (whether or not represented by sector organizations). Improvement on connectivity and interoperability will not arise automatically. It is recommended to perform a stakeholder and analysis.

2 Investigate feasibility of indirect approach

Given the different priorities of the various parties involved, and the given (dis) advantages of the different approaches, in theory the indirect approach of CEN CENELEC (and the implementation of S2) looks like a good solution for unlocking flexibility in-home. However, the feasibility, both on a policy / market level, but also from a technical point of view, must first be investigated. We recommend to develop different pilots in which this indirect approach is going to be implemented to test the technical feasibility in practice.

The indirect approach makes it possible to communicate with different types of devices from an EMS, without the EMS having to know all the protocols, and the possible business rules when using these protocols, of all different devices. There is a great complexity within the domain of energy flexibility. In chapter 2 basic energy flexibility functions and categories are described. Our recommendation is to make use of these basic functions and categories. To achieve interoperability, the starting point should be a common terminology that focuses on energy flexibility only.

We believe that the indirect approach leads to the least effort on the part of the manufacturers of flexible devices. Unlocking energy flexibility in the current phase

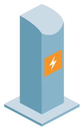
We recommend to develop different pilots in which this indirect approach is going to be implemented to test the technical feasibility in practice.

is not their priority, this approach therefore suits, since it asks the least effort from their side. The EMS manufacturer, who has the priority of energy flexibility, could then take care of part of the implementation of the in-home standard. This implies that EMS manufacturers will also have a task in developing the required Resource Manager components. As discussed in 3.2 Indirect approach, the RM concept can be used in multiple ways. Whether the EMS manufacturers will indeed be willing to cooperate on implementing these Resource Manager components and whether they will agree on how to implement these components in the architecture, is yet to be seen.

We propose a short-term and long-term solution, as shown in figure 10. These solutions are further discussed below.

PROTOCOL SELECTION AND RM DEVELOPMENT

With regard to protocol selection and RM development, we recommend a nuanced device-specific approach within the CEN CENELEC architecture) for the main reason that the status of connectivity differs per type of device. The core of this recommendation is that dominant device specific protocols are connected with S2 as the generic in-home protocol. The development of the RM, which must make the connection' with these protocols, differs per device type. As stated in chapter 3 the 'Direct approach' and 'Indirect approach' should not be read as a kind of contradiction, as this chapter is not intended; one does not exclude the other, it can even reinforce each other. If flexible devices do not support S2 themselves, external Resource Managers will be required. The more of the 'direct protocols' can be standardized, the more often Resource Manager implementations can be reused. So in addition to using an 'indirect protocol', it is good to standardize as much of (device specific) 'direct protocols' as possible.



CHARGING STATIONS

OCPP can be applied well within the CEN CENELEC approach. OCPP is already a "high level standard" that organizes connectivity and interoperability for charging stations. Almost all charging stations communicate via OCPP. Although Modbus is now also used for the connection between an EMS and charging

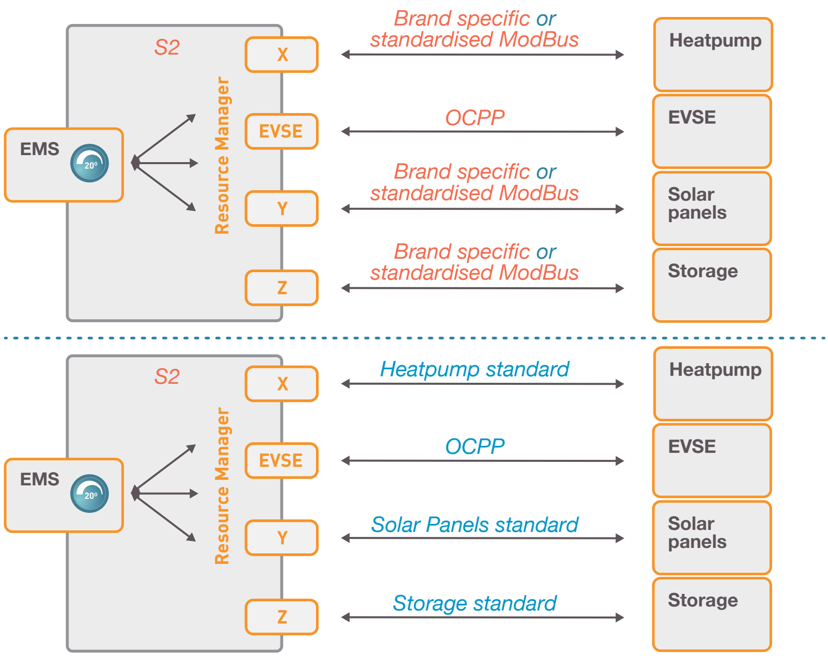


Figure 10: Proposed solution for short term (top) and long term (bottom)

stations, we recommend the combination of S2 and OCPP because it offers the advantages of a 'high level protocol'. Modbus has the major disadvantage that it does not offer "plug-and-play" interoperability, each device is controlled differently.

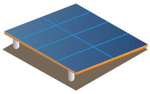
This means that on the side of the charging stations, there is no need for major adjustments/improvement, other than the further promotion for the use of OCPP in-home and perhaps minor changes for integrating a RM. A "charging station-specific RM" could then communicate with charging stations through OCPP and can receive flexibility signals "from the other side" via S2. (according to the functions of Chapter 2). This is illustrated in Figure 9.

Because (almost) all charging stations communicate via OCPP, the RM can be part of the EMS, this is more complex with for example heat pumps. A further recommendation is to involve the OCPP development organization (www.openchargealliance.com) in the development of a charging station specific RM.

HEAT PUMPS

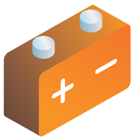
The approach of CEN CENELEC prefers placing the RM at the flexible devices. One of the main reasons for this is that it is quite possible that each type of device must be controlled differently to do the same. One may use 2 Modbus registers to adjust power, the other may use 6. For each type of device, a different (Modbus) interface is than required. Because the manufacturer of these devices knows their own devices best, it makes sense to place the development of the RM with the device builders. This means the development of different RMs for heat pumps; one per manufacturer (or type).

SOLAR PANELS INVERTER[α]



Solar panels are in this context simpler devices from which ‘just measuring’ is expected. For in-home situations these devices are not categorized as flexible loads (although currently inverters exist that switch off based on local voltage measurements). Measurement data is often offered through an API, so no extra wired connections are required. Curtailment is perhaps interesting for very large installations, but less interesting for the in-home situation.

LOCAL STORAGE



This study has not gained specific connectivity insights for local storage solutions . Based on the insights of the study "Smart Grid Ready Energy Storage" by DNV GL and Technolution for TKI Urban Energy we suggest that the battery manufacturers develop the RM, to secure the safe operation of the battery[β].

Conduct pilots to harmonize attributes in data models

The indirect approach as such (of S2) has been demonstrated in multiple pilots. The feasibility study must be focused on maturing this approach, to unlock flexibility on a large scale. Based on S2 and the suggested connection with ‘direct protocols’ as given here. This entails amongst others: Ensure that manufacturers, aggregators and ESCos get started. Develop guidelines. Develop test facilities. Make (open source) implementations of Resource Managers for common devices / protocols.

α To be correct, the subject of unlocking flexibility relates in fact directly to the inverter of the solar panels, and actually not to the panels themselves

β https://www.topsectorenergie.nl/sites/default/files/uploads/Urban%20energy/publicaties/Rapport%20SmartGridReadyEnergyStorage.pdf

3 Solution for short term: attributes alignment and API development

Earlier we recommended to investigate the CEN CENELEC architecture for unlocking energy flexibility. 'At the other side', the device type specific protocol (see Figure 5), the protocol between flexible device and RM, is not addressed by CEN CENELEC. We however believe that this interface can also be improved. Starting small, we believe that aligning the Modbus attributes used especially with heat pumps is a first improvement on the side of flexible devices regarding interoperability. Resulting in alignment in attributes used for the management of heat pumps.

This standardization can also be connected to the S2 development as sketched before.

Another possibility is connecting to the manufacturers backend via an API. More and more devices are connected with a backend and also offer connectivity through APIs. In the backend of the device manufacturer there can be a RM which can make energy flexibility available through an API through generalized messages (e.g. S2). (The RM could also run on a different backend which in turn is connected to the manufacturers backend). In our opinion, this is a better approach than a (wired) Modbus connection. Modbus is not in all cases intended for energy flexibility, but often for maintenance. As stated in Chapter 2, device integrity is important and should not be undermined by messages for energy flexibility. The EMS and device manufacturer will have to make agreements about this, otherwise device integrity may be compromised.

However, feedback from parties involved in daily practice with connecting heat pumps implies that Modbus can be applied quite well.

We recommend to align heat pump attributes and develop pilots in which aligned heat pump attributes are used. This can be connected as a combined project with the development of S2, but could also be developed as a separated pilot.

← Note

4 Assess flexible device and system suitability for unlocking flexibility

We recommend to assess the suitability of the different types of flexible devices for unlocking flexibility. A final recommendation is to investigate the claim by the consulted companies that currently home automation systems are not suitable for unlocking flexibility. An assessment of the hardware, software and security requirements of these systems and flexible devices to become suitable for unlocking flexibility could be the topic of a separate study.

We recommend the following 'planning':

Note →

- Functions per device type
- Aligning attributes of heatpumps
- Feasibility study on S2
- Select a device specific (high level-) protocol to connect to S2

5 Cyber security

It's of utmost importance to take cyber security into account. For more information on this topic, please refer to the references "ElaadNL, Cybersecurity" and "Handreiking Cyber Security". When devices start communication with each other and rely on the information shared, it's important that communication can be trusted and that the information is end-to-end secured between devices. Especially when actions are taken upon the information shared, like using more or less energy from the grid. Depending on the architecture, different security measurements should be taken. At least a secure communication channel should be setup between the devices, with mutual authentication so every device can be sure it actually talks to the device it thinks it talks to. Having a security standard for these kinds of devices would be a very wise thing to do. This would mean that agnostic of the chosen protocol all the system should be compliant with the security standard. We recommend to follow the way of working according to the German DIN specification . They presented a cyber security specification for IoT devices. Finally, privacy is also an aspect to take into account for designing an overall flexibility ecosystem. However, privacy considerations primarily apply to systems and less to the communication protocols between them.

Δ https://www.din.de/de/mitwirken/normenausschuesse/nia/din-spec/wdc-beuth:-din21:303463577

1 Coordination
2 Basic set of functions per device type
3 Attribute alignment
4 Feasibility study on S2
5 Device specific protocol selection and RM development to connect to S2
6 Take into account the right cyber security measures
7 Context switch
8 Quantify energy flexibility and its value per device type
9 Investigate customer preferences and entering customer settings
10 Investigate suitability of "home platforms" and home automation systems to unlock flexibility
11 Research external connectivity towards the in-home domain
Milestone planning
TKI URBAN ENERGY
Topsector Energie

5.3. Considerations for further research

Below we give a number of considerations that are not directly related to the improvement of interoperability, but which we believe can nevertheless contribute to the understanding of this issue or indirectly to the development of interoperability in-home.

5.3.1 Context switch

The logical characteristic of an electric vehicle is that it is not always in the same place. Another feature is that this EV, wherever it is, can deliver energy flexibility. At a public charging station it is logical that flexibility is unlocked by the charging station itself, in fact by the charging station operator (CSO).

However, when the EV "comes home", the EV undergoes a "context switch" from public to in-home. The vast majority of home charging stations in the Netherlands are also managed by a CSO. The situation may arise that the EMS wants to unlock energy flexibility via the home charging station, but that the CSO also wants to unlock energy flexibility from the same station. This situation requires harmonization of protocols to promote interoperability, but also further technical and organizational agreements and coordination. It must be prevented that conflicts arise in the management model. The Emobility Communication & Information System Structure (ECISS) project from TKI Urban Energy describes how that context switch works and in more detail how conflicts can arise in this context. There is still much to be investigated. ECISS is working on an architecture to prevent these conflicts.

5.3.2 Quantify energy flexibility per device type

We give the following consideration as input for a possible roadmap for the connectivity improvement for in-home devices. Under recommendations, coordination is put forward as the first point. Developing a roadmap for each type of device would be a good development.

It is worth considering starting a study on quantifying ‘flexibility space’ of the different devices and the “value” of this flexibility. This way, insight is provided for which types of devices improving interoperability will have the biggest impact. Perhaps more insight can be provided through the following criteria into the energy flexibility to be offered:

- The “power requirement” of the various devices
- The separation (in time) between the power demand and the use of the device
- The current status of connectivity per device type
- The current status of interoperability per device type

Based on manufacturers input, we have stated that there is currently no priority given by manufacturers of flexible devices to unlock energy flexibility. In our opinion, more extensive research has to be conducted into using this “value” of flexibility, which might change the manufacturers priorities. We want to consider developing a general business scan to create more clarity about the value proposition or energy flexibility for the various parties.

5.3.3 Investigate customer preferences and entering customer settings

Another consideration is related to the need and if so, the simplicity of entering the preferences of the consumer. Chapter 2 indicates that the amount of energy flexibility is determined by "device integrity" and "consumer preferences". It must be possible to make these preferences known. A study into the end customer preferences for “full automation” vs. “being in control” and into the possibilities to provide settings by the customer can provide more insight into this. Research questions could then focus on how complex or simple input for customer settings can be provided and what the willingness of the customers is to provide these settings and the extent to which the customer wants to be in control.

5.3.4 Investigate home “platforms”

The investigation of home “platforms”, such as Google Home and Apple HomeKit should be considered. These platforms cover more than energy management and other in-home devices, but also a total comfort solution for users, ranging from payments to storing photos to have a remote thermostat.

5.3.5 External connectivity towards the in-home domain

A further consideration is to perform in-depth research of the connection of “a house” with “the grid and energy and ancillary markets”. What connectivity is possible for the unlocked in-home flexibility and what protocols are available/being developed in this area? And what work is done in terms of alignment within this area as well as harmonizing this area and the in-home domain to have an efficient flexibility chain. The topic of cybersecurity is very important here as well.


HOTEL

APPENDICES

Definitions/abbreviations

API	Application Programming Interface. An external communication channel to a backend (for specific functions)
BRP	Balance Response Parties
CEM	Customer Energy Management. (used in CEN / CENELEC. In this study we use the term Energy Management System)
CS	Charging Station
CSO	Charging Station Operator
DR	Demand Response
EMS	Energy Management System
EMSP	Electric Mobility Service Provider
EV	Electric Vehicle
DER	Distributed Energy Resources
DSM	Demand Side Management
DSO	Distribution System Operator
HBES	Home and Building Electronic System
HES	Head End System
HEMS	Home Energy Management System
IoT	Internet of Things
ISO	International Standards Organization
LNAP	Local Network Access Point
NNAP	Neighbourhood Network Access Point
MDM	Meter Data Management
OEM	Original Equipment Manufacturer
RM	Resource Manager
RP	Roaming Platform
S2	Interface between EMS and Resource Manager
SASS	Singe Application Smart System
SMG	Smart Meter Gateway
TSO	Transmission System Operator
V2X	Vehicle-to-X

Protocols out of scope

Many in-home protocols exist. For the sake of time, we were forced to make a selection. The following protocols were not selected, although some could be added in future comparisons, to assess these for in-home purposes.

Protocol	Reason
BACnet	Home automation communication protocol, not primarily aimed at energy flexibility
Clipsal C-Bus	Home automation communication protocol, not primarily aimed at energy flexibility
EnOcean	Involves “low level” (low battery) communication
MESA	This standard provides a framework for utility-scale energy storage system (ESS) data exchanges and addresses how components in ESS’s communicate with each other and other operational components (source: http://mesastandards.org/). Since this is not aimed at in-home use, this is not part of the scope of this document.
oBIX	Home automation communication protocol
Opentherm	Only used for HVAC, aimed at temperature, not at energy flexibility.
SUNSPEC	Main focus is large DERs (PV), not primarily aimed at in-home communication for unlocking flexibility.
Z-Wave	Wireless communication protocol for home automation (alternative to bluetooth and WiFi). Not on the “higher” level of unlocking energy flebility.

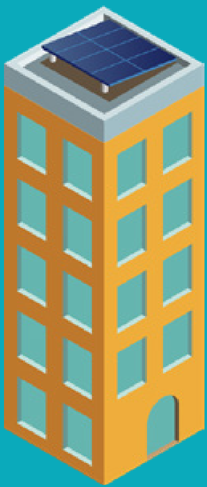
References

Protocol	Website	Specifications
ECHONET Lite	echonet.jp/english/	https://echonet.jp/spec-en/#standard-01
EEBus SPINE	eebus.org	https://www.eebus.org/en/media-downloads/#SPECIFICATIONS
EFI	flexible-energy.eu	https://github.com/flexiblepower/efi
KNX	knx.org	https://my.knx.org/en/shop/knx-specifications
OCF	openconnectivity.org	https://openconnectivity.org/developer/specifications/
OCPP	openchargealliance.org	https://www.openchargealliance.org/downloads/
SEP – IEEE 2030.5	ieee.org	https://standards.ieee.org/standard/2030_5-2018.html
OpenADR 2.0	openadr.org	https://www.openadr.org/specification
Modbus	modbus.org	http://modbus.org/specs.php

Notable projects: https://projecten.topsectorenergie.nl/

Slim laden met dynamische nettarieven	Slim laden dynamische nettarieven
OROSL	Onbalansreductie
JEDaFRR	JEDaFRR
Smart Charging	Smart Charging TSE Urban Energy
SlimFlex	Slim en Flex Laden
B-DER	Blockchain Based Plaform
BlauFlex	BlauFlex
Slim met Trafo	Pilot Smart-Charing Trafo
DC Laadplein	DC Laadpleinen
ECISS	E-mobility Communication

Eurelectric	Flexibility and Aggregation Requirements for their inter-action in the market, 2014	https://www.usef.energy/app/uploads/2016/12/EURELEC-TRIC-Flexibility-and-Ag-gregation-jan-2014.pdf
CENELEC	General requirements for Home and Building Electronic Systems (HBES) and Building Automation and Control Systems (BACS) – Smart grid – Application specification – Interface and framework for customer – Part 12-1: Interface between the CEM and Home/Building Resource Manager – General Require-ments and Architecture, 2018.	https://www.nen.nl/NENShop/Norm/NENEN-504911212018-en.htm
TNO	Unlocking residential Energy Flexibility on a large scale through a newly standardized interface	https://ieeexplore.ieee.org/document/9087658/authors#-authors
Vito		https://smartreadinessindica-tor.eu/
ElaadNL	EV Related protocol study, 2016.	https://www.elaad.nl/research/ev-relat-ed-protocol-study/
	Exploring the Public Key Infra-structure for ISO 15118 in the EV charging ecosystem, 2018	https://www.elaad.nl/uploads/files/Exploring_the_PKI_for_ISO_15118_in_the_EV_charging_ecoys-tem_V1.0s2.pdf
	Using OCPP with an EMS, 2020	ElaadNL
	Cybersecurity	https://www.elaad.nl/projects/cybersecurity/
TKI	Handreiking Cyber Security,	https://www.topsectorenergie.nl/sites/default/files/uploads/Urban%20energy/kennisdos-sier/HandreikingCyberSe-curityVoorSmartEnergy.pdf



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