Lessons Learned from Use Case DE#2
Version 1.0

Deliverable D5.8

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EXECUTIVE SUMMARY

Deliverable 5.8 describes the results and lessons learned from Use Case 2 of the German Demonstrator of InterFlex, focussing on ancillary services. Initially designed as a combination of Use Case 1 (DER feed in management) and Use Case 3 (demand side management), Use Case 2 was facing much higher barriers than expected. Essentially the regulatory framework in its current form does not enable the envisioned Use Case.

To address this issue InterFlex has taken the opportunity to exhibit the flexibility concept in the context of the German demonstrator and highlight the motivation behind this Use Case. Building on the successful demonstration of Use Case 1 and 3 this document also imagines a potential way forward to implement Use Case 2 in the future.

The focus however is on highlighting the barriers that impede the activation of flexibility in this context. For example, the combination of rooftop PV and battery storage systems is subject to a rather complicated set of rules to ensure proper accounting of virtual renewable power flows. These rules, once designed to address issues in the context of grid charge allocation, present a significant disincentive for customers to invest into storage systems that can apply their flexibility to behind- and in-front-of-the meter Use Cases alike.

The second promising source of flexibility, EV chargers in the distribution grid, is out of scope of today's flexibility activations because there simply exists no rule about the how and when of activation. While the energy industry act states that EV chargers could fall under a certain classification of interruptible loads, it does not state to which extent DSO could influence charging and neither under which circumstances. This unclear and uncertain situation poses high risks for the investment of resources and material into the implementation of Use Cases that might be obsolete the next year, not to mention an unwillingness of customers to participate in a flexibility scheme that has no legal basis.

The document closes with a set of recommendations that could improve the situation and help to make a greater share of existing flexibility accessible for the DSO. For example, InterFlex encourages the German government to speed up the design of the statutory law governing the activation of interruptible loads, including EV chargers (the so called "§14a-Verordnung"). To effectively use flexibility, DSO also require a certain and stable regulatory framework that encourages the use of flexibility and enables DSO to take advantage of flexibility-based solutions without hurting their bottom line. Regarding the activation of domestic batteries InterFlex suggests to simplify the rules concerning how power flows are metered and accounted for, to make it easier to apply in-front-of and behind-the-meter Use Cases at all devices.

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1. INTRODUCTION

1.1. Scope of the document

Deliverable 5.8 – Lessons Learned from Use Case 2 covers the results and experience gained from the field tests in InterFlex work package 5 and the demonstration project in Germany. It includes the reasoning behind the success and failure of Use Case execution and highlights barriers to the successful practical implementation of the Use Case. It further provides data analyses and showcases practical results obtained in the field testing with pilot customers in the Lüneburg area. The document concludes with a set of recommendations to remove barriers to the application of the envisioned Use Cases.

1.2. Notations, abbreviations and acronyms

The table below provides an overview of the notations, abbreviations and acronyms used in the document.

Table 1 - List of Acronyms

ADMS	Advanced Distribution Management System
CLS	Controllable Load System
DER	Distributed Energy Resources
DSO	Distribution System Operator
EC	European Commission
HV	High Voltage
KPI	Key Performance Indicator
LTE	Long-Term Evolution (broadband standard 4G)
LV	Low Voltage
MV	Medium Voltage
OT	Operational Technology
PLC	Powerline Communication
SCADA	System Control and Data Acquisition
SGH	Smart Grid Hub
SMFW	Smart Meter Framework
SMGW	Smart Meter Gateway
UC	Use Case
UI	User Interface
UTC	Coordinated Universal Time
VHV	Very High Voltage
WPL	Work Package Leader

2. DESCRIPTION OF USE CASE

Use Case DE#2 is described in the Grant Agreement as follows:

“Ancillary services (for instance balancing energy) may come from the aggregation of generation, consumption and storage devices. The signals sent out for ancillary services have to be coordinated with other signals such as the ones for curtailment or demand response. The security and speed of data transmission as well as the speed of command execution and the respective confirmation signals are crucial.”

The paragraph above comes down to three key goals for the execution of Use Case 2 demonstrations:

a. Demonstration of aggregation of generation, consumption and storage devices
b. Coordination of ancillary service requests with higher-ranking control signals
c. Evaluation of communication system’s performance

Since the Grant Agreement was written and negotiated a lot has changed, particularly the key assumptions regarding the availability of the smart meter framework in Germany. Contrary to the initial expectations at the time of conceiving the project proposal, the smart meter framework was not readily available when InterFlex kicked off. As a result, WP5 had to direct a lot of resources towards making the smart meter framework work and making flexibility of different types available in the first place. This has shifted the focus of WP5 from evaluating the performance of specific Use Cases more towards developing and demonstrating the general feasibility of said Use Cases.

In the case of Use Case 2 the main condition is the availability and controllability of generation, consumption and storage devices. While these capabilities have been successfully demonstrated in previous Use Case demonstrations (see also Deliverables 5.7 and 5.9) the question of storage devices remains open. Today, batteries are not controllable in the context of WP5 and chapter 4.1.1 describes in detail why this is the case.

As for the performance of the communication link, aforementioned Use Cases have evaluated the performance and given a clear picture on how the Use Cases performed in terms of reliability and speed of data transmission, a detailed description can be found in InterFlex deliverable 5.6.

This leaves for Use Case DE2 to imagine a concept to aggregate flexibility of a higher grade from what has been made available in Use Case DE1 and DE3. And of course, to develop ideas how the coordination of ancillary service requests with other, potentially higher ranking requests of flexibility could be implemented in practice.

In this sense, Use Case DE2 has been carried out with the following questions in mind:

a. What flexibility is available for aggregation?
b. What are the barriers to increase the available flexibility?
c. What are potential implementations?

3. AVAILABLE FLEXIBILITY

WP5 of InterFlex has relied on flexibility that can be made available today without the need for the DSO or flexibility provider to invest in additional assets or devices. It makes more sense to activate existing, but maybe yet inaccessible flexibility, before committing resources to the construction of additional elements. It was a main concern of Avacon to design Use Cases as close as possible to today's operation and in line with current legislation and regulation, with a strong focus on tapping into dormant flexibility rather than introducing new sources of flexibility.

This approach limited the possibilities of field test and Use Case design. Instead it put emphasis on developing technologies and processes of practical relevance with a mature technical readiness. Another consequence of this philosophy was also that the German demonstrator was relying completely on what flexible devices customer owned and were willing to offer.

Of relevance for the DSO is not some theoretical potential of flexibility, but how much of it can be made readily available. Availability depends on a number of factors.

3.1. Overview and classification of connected flexibility

Flexibility in the distribution grid is both poorly defined and from a regulatory perspective spread across several legal acts, at least in Germany. This requires for us to define flexibility in the context of this Use Case as

"The ability of a device to modify its interaction with the network in response to an external signal."

This definition covers a very broad spectrum of different types and kinds of flexibility. Within this range however we find flexibilities with different qualities and varying grades of usefulness.

Flexibility could be classified along the dimension "direction" and the mode of DSO-interference. Flexibility could increase or reduce momentary production or consumption. The mode of interference by the DSO depends on the technical nature of the device and its typical mode of operation. It can also be influenced by the rules set out by the legal and regulatory framework. As an example, in Germany we find rules that allow the DSO to interrupt consumption or generation as well as a mechanism to shift load for a limited amount of time. Today, there are no mechanisms for the DSO to increase load or consumption.

Table 2 shows the classification of flexibility in the German Demo of InterFlex:

Table 2 - Classification of Flexibility in InterFlex WP5[1]

	Generation	Consumption
Activate	Storage Vehicle2Grid	Electric Vehicles **(Storage Heater)** **(Heatpump)**
Shift	Storage Vehicle2Grid	Storage **Storage Heater** Electric Vehicles
Interrupt	**PV** Wind CHP	Electric Vehicles **Heatpump** Commercial & industrial Customers

- PV: Momentary generation can be interrupted via the curtailment mechanism. Has been successfully demonstrated as part of previous InterFlex field trials.
- Wind & CHP: Momentary generation can be interrupted. Used in daily operations in high-voltage levels, not in the scope of InterFlex.
- Electric vehicles & Verhicle2Grid: Could be shifted, interrupted or activated. Technically feasible, but today there exists no regulatory basis to execute control by the DSO.
- Storage heater: Can be shifted temporarily within limits. Has been successfully demonstrated as part of InterFlex field trials. Targeted activation could be possible, but such a Use Case would require additional forecasting and data processing capabilities.
- Heatpumps: Can be interrupted within limits. Has been successfully demonstrated as part of InterFlex field trials. Targeted activation could be possible, but such a Use Case would require additional forecasting and data processing capabilities.

Beyond the classification of flexibility along those dimensions we can also assign a grade of quality to any given flexibility. The factors to determine the grade of a particular source of flexibility are

- Direction (increase/decrease/both of consumption/generation/both)
- Duration (time until reversion to uncontrolled/autonomous state)
- Ramp rate
- Availability (Seasonality, metrological factors)
- Price of activation
- Accessibility (Mandatory provision, competition among requests, deliberate offers)

The goal of Use Case DE2 could also be interpreted as the attempt to improve the grade of the flexibility at the DSO's disposal by combining the sources of flexibility in Use Case 1 and 3.

In practice flexibility can also be ranked according to the level of importance granted by the regulatory framework. In Germany the Association of Power and Gas Suppliers has established the traffic-light concept for the activation of flexibility. It approaches the topic on a state-of-the-grid basis and ranks flexibility Use Cases as follows:

[1] Devices that have been successfully activated in the InterFlex field trial in **bold**

- Green Phase, during which the grid experiences no limitations and the forces of the market reign free. During these times the grid operator does not intervene, does not activate flexibility or interrupt consumption. The wholesale, retail and commercial flexibility markets steer flexibility according to their transactions
- Amber phase, during which the grid predicts congestion or any other critical situation. The amber phase is not yet critical but indicates a congestion period later in time. DSOs starts planning measures for the activation of flexibility to avoid potential predicted congestions. If DSO's flexibility demand can not be met by the available supply, the traffic-light will switch into the red phase.
- Red phase, during which the grid is in a critical state which requires intervention by the DSO. The critical situation might be caused by fault-induced reconfiguration, excess local generation or excess peak load.

The red phase forces the DSO to take a heavy handed approach to regain system stability and usually relies on DER curtailments or load shedding. In the context of these traffic light phases, Use Case DE1 (feed in management) can be located firmly in the red phase while Use Case 3 (DSM) would be considered part of the green and amber phase. Use Case 2 would be located somewhere between the amber and red phase. The main question of Use Case 2 was, whether or not, and if so to what extent, a flexibility platform like the Smart Grid Hub could create bi-directional flexibility from a multitude of small uni-directional devices. Aggregated into bi-directional flexibility, even devices that are considered less useful in terms of flexibility provision, could be elevated to significant contributors to system stability and grid balancing.

3.2. Analysis of available flexibility

Among the many potential sources of flexibility, we can differentiate between what is readily available today, provided by existing flexibility mechanisms, and what could only be activated once changes in the regulatory framework have been implemented. While the Use Case demonstration UC DE1 and UC DE3 have shed some light on the behaviour of uni-directional flexibility, we are now looking into the possibility of creating bi-directional flexibility from subsets of uni-directional flexibility. Chapter 3.2.1 demonstrates the results obtained with readily available flexibility while chapter 4 will describe in detail the barriers to the utilization of additional sources of flexibility.

3.2.1. Results from Use Case 1 and 3

Use Case 1 and Use Case 3 have demonstrated the technical capabilities of the Smart Grid Hub in combination with the smart metering communication devices to control flexibilities operated by residential real-life customers in the field test area of Lüneburg. Whereas the technical focus of Use Case 1 was the steering of generators such as PV, Use Case 3 focused on switching and shifting the consumption of the loads which are in use as domestic heater in private households.

During Use Case 1 the Smart Grid Hub, its IT- architecture as well as peripheral systems and interfaces were tested and generally performed as planned. The Smart Grid Hub has been proven to be a useful tool to integrate DSO operation with the public smart meter framework and which makes privately owned PV accessible with a high degree of automation. Operation engineers have successfully tested the user interface, algorithms for generating practical switching schedules and fundamental functionalities for the determination of the availability of flexibility, reliability of control, data transmission and the speed of command execution and data transmission in first on-line tests with customers. For steering PV systems in the field, many devices needed to be equipped with an additional electrical switch to make the device controllable. During the tests it has been proven that switching actions can be carried out in less than 60 seconds, including command confirmation and post-switching measurement. Notable improvements in steering PV were made by measurement – switching – measurement cycles, which required on average less than two minutes for the system in the field test trials. Use Case 1 did also shed light on shortcomings in performance and reliability such as the time required to establish and close secure communication channels for measuring purposes and the exchange for steering commands. A major technical roadblock for the onboarding of pilot customers and integration of their flexibilities into the infrastructure was the lack of LTE-coverage (mobile 4G network) in rural areas, which was far lower than expected. A sufficient LTE-signal at customers metering location emerged to be the most critical criterion for the installation of the digital meter and control box and integration into the network.

The focus of Use Case 3 was on controlling flexible loads in the residential segment with the goal of improving DSO operations, increasing hosting capacity for DER and improving the quality of supply in low and medium voltage networks. Residential customers participating in existing flexibility schemes with a controllable or interruptible heating device, e.g. a heatpump or storage heater, were the targeted segment. A major learning was that in all testing scenarios of UC3, not all control signals could be transmitted successfully. In some cases the control signal was transmitted successfully but the customers device did not respond as expected, e.g. reducing power to a setpoint different to that requested by the SGH. The success rate of measurement- and control requests overall was 50% for storage heaters and 61% for heatpumps. Successful requests have shown a surprising diversity of behaviour of devices and sometimes inconsistent responses. One key learning toward storage heaters was that these devices come in a wide variety of thermal capacity and charging strategy. Whereas reverse charging heaters offer little to no flexibility due to their relatively high complexity, standard-loading devices were behaving exactly as expected and showed potential for useful flexibility to the DSO. Heatpumps however, showed different characteristics. Because of their relatively low base load and spikes or pulses in load when generating heat, the conclusion was that erratic behaviour makes it difficult include heatpumps in control strategies, which go beyond emergency response actions. At any given moment heatpumps can turn off, ramp up the next minute and vice versa. Therefore, these devices were classified as “interruptible load” with little to no potential for a more active use of their flexibility. Consequently, efforts for the integration of such devices into the network should be weighed in advance. Further testing is required to determine the appropriate level of aggregation at which a set of multiple heatpumps could be treated as one continuous load.

Use Case 1 and 3 have proven the technical feasibility to replace old control technologies with the new digital meter and control box and carry out existing Use Cases on a digital infrastructure. The availability of flexibility for different groups of devices differs strongly due to different technological characteristics and usage profiles. The limitation to LTE mobile data and the resulting poor signal coverage in rural areas has emerged as a major burden on the Use Cases.

For the purpose of highlighting the results and learnings during Use Case 2 we have picked a group of customers that reflects the most common types of flexibility that are at the DSOs disposal today in Germany. To demonstrate key insights, we are looking at the data set generated by 2 heatpumps, 2 PV generators and 1 storage heater. Data sets range from February 2019 to May 2019.

Table 3 - Sources of flexibility in UC2 field test

Customer #	Type of device	Rated power [kW]
…3616	Storage heater	36
…1105	Heatpump	6
…6812	Heatpump	3
…9095	PV	6
…3319	PV	2

Table 3 shows the rated power and type of the customers.

To evaluate the available flexibility, we assume for now that all devices could be switched off at the DSO's request for at least 15 minutes at a time[2]. As it has been demonstrated in previous field tests in WP5, these general switching capabilities have been developed successfully and the regulatory framework described in chapter 2 enables control of these devices by the DSO. Under these conditions we can define the available bi-directional flexibility at any point in time, as the amount of generation and demand that's online simultaneously.

$$P_{Flex,bi-directional,t} = Min\left(\sum P_{Load,t}\, , \sum P_{Generation,t}\right) \qquad (1)$$

Where $P_{Flex,bi-directional,t} = Momentary\ amount\ of\ available\ bi-directional\ flexibility$

$$P_{Load,t} = Momentary\ electric\ load\ of\ all\ connected\ devices$$

$$P_{Generation,t} = Momentary\ electric\ feed-in\ of\ connected\ DER$$

In other words, bi-directional flexibility from uni-directional sources always amounts to the power that is being generated and consumed simultaneously by these subsets of devices.

Figure 1 shows the entire data set of heatpumps, storage heaters and PV. The profile is dominated by the 30 kW storage heater installation, which dwarfs the consumption by heatpumps and to a lesser extent also the feed-in from PV installations. However, at first glance it also appears that during the transitional phase in the European meteorological spring there can be a fair overlap between PV generation and load in the heating segment. We can identify a period of very low solar production in March but see solar production slowly ramping up as the year goes on. Consumption data shows, at least in terms of peak demand a surprisingly constant behaviour until the first period of warm weather with ambient temperatures during the day of 25°C and above in late April.

Figure 2 exhibits the practically available flexibility if the DSO combined interruptible loads and decentral generation to a source of bi-directional flexibility. As expected the controllable flexibility is much less than the production and load that's online at any given point in time. It also shows that aggregating flexibility requires a delicate balance between

[2] This assumption simplifies the way storage heaters can be controlled.

weather fair enough, so that solar production is online, and cool enough temperatures so that domestic heating still shows significant demand.

In the considered period the 1st of April stands out as day with a high flexibility offer. Figure 3 visualizes that this day was relatively cold (-0,5°C) and had a relatively high solar radiation (2540 J/cm²) compared to others in the respective period.

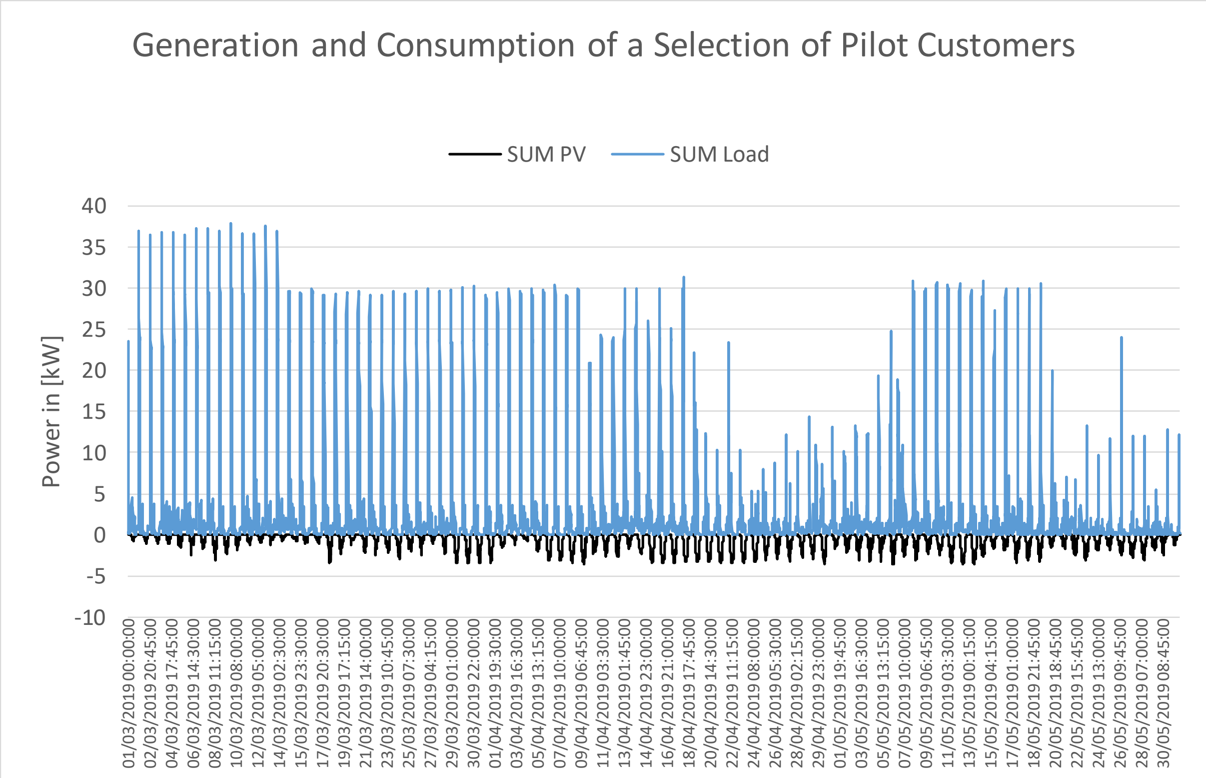

Figure 1 - Generation and consumption data of field test customers

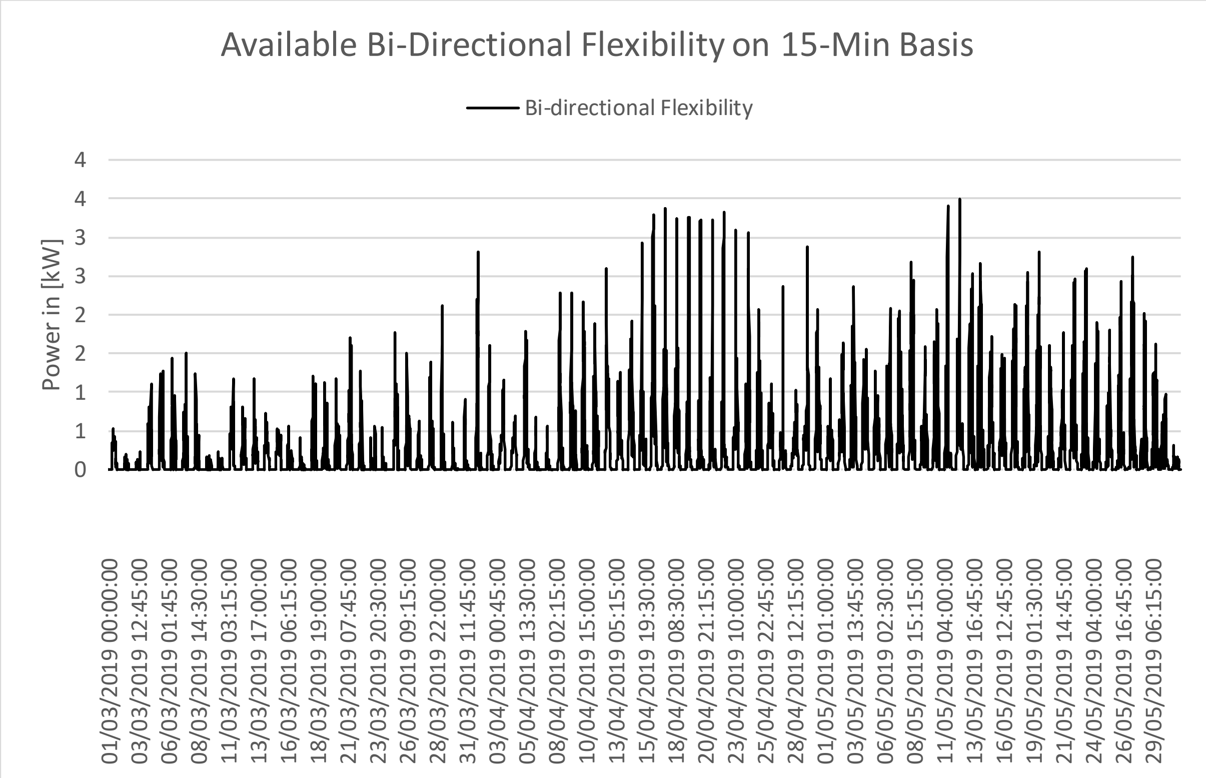

Figure 2 - Available bi-directional flexibility on 15-min basis

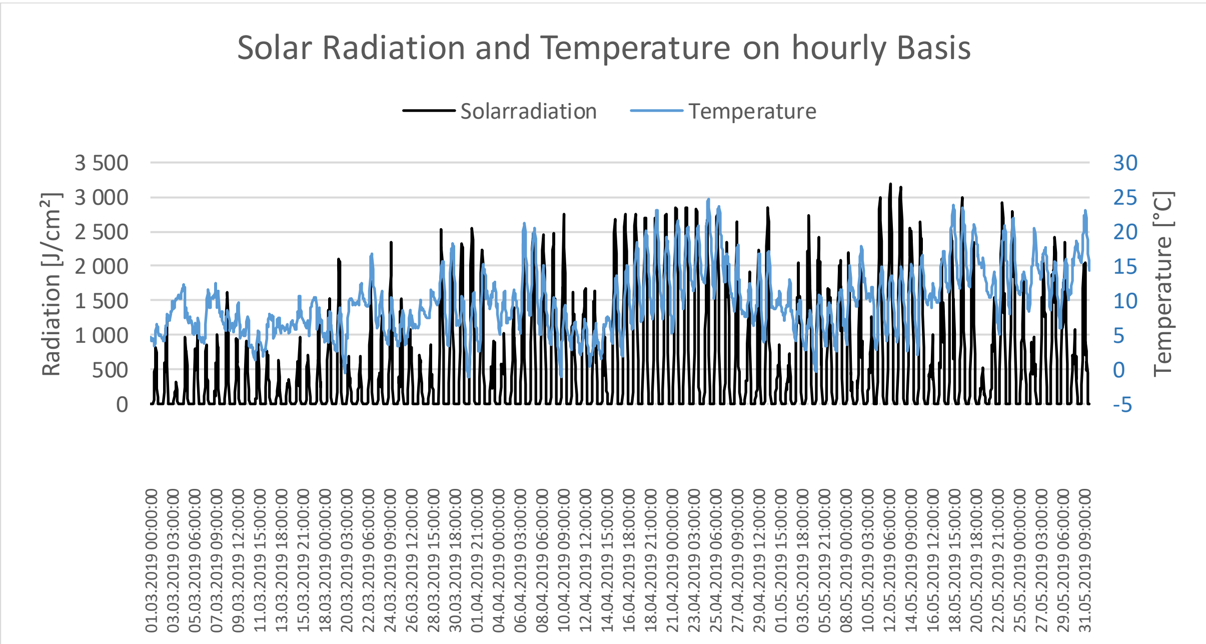

Figure 3 - Solar Radiation and Temperature on hourly Basis

Another interesting metric would be, what share of online generation and demand can be diverted to a flexibility mechanism at any point in time. One way to quantify this amount would be to calculate the ratio of available flexibility to the available generation and demand at that point in time. Looked at it this way, 57% of the time (4558/8743) the available flexibility equals 5% or less of online production and demand. In only 2% of the observed data points did the available flexibility amount to more than 95% of online generation and demand. For further illustration Figure 4 displays the entire data set sorted by the amount of available flexibility. Even keeping in mind that this is a fairly small sample in a small geographic area it is still clear that the flexibility aggregated from uni-directional sources must be expected to be much less than the individual power rating and production of the aggregated elements.

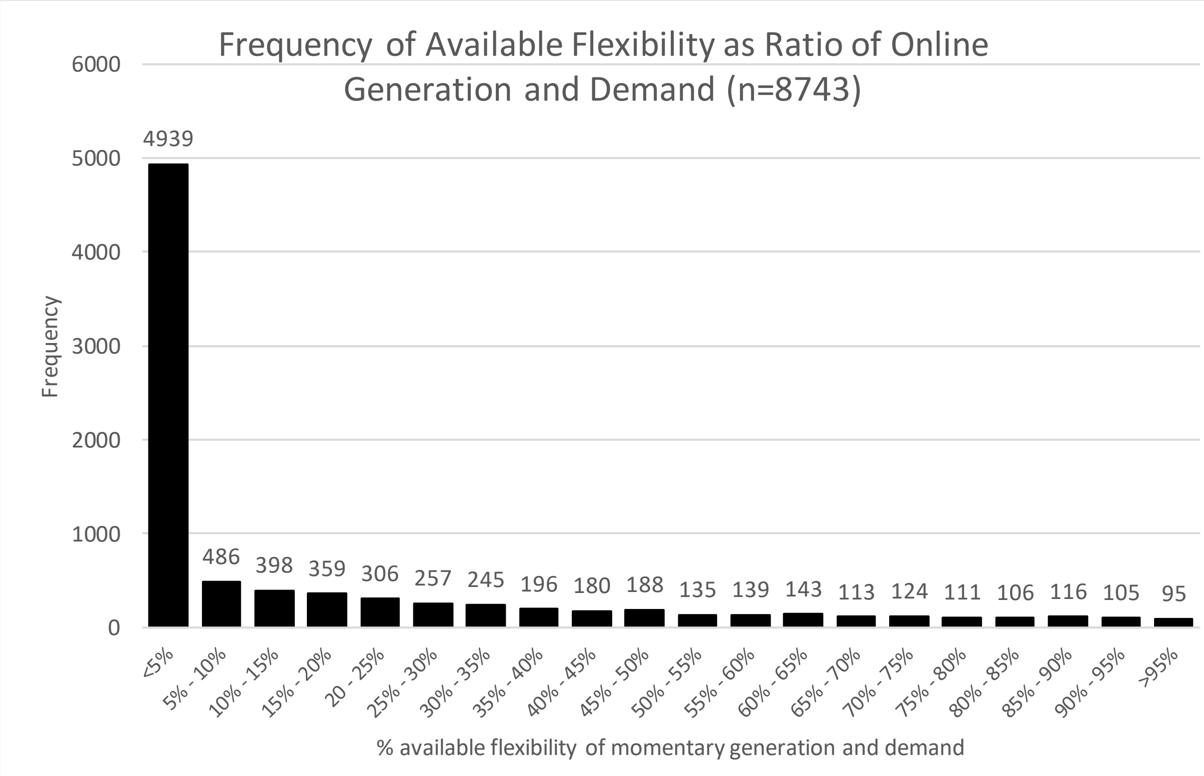

Figure 4 - Available bi-directional flexibility as % of momentary generation and demand

In general, we would expect the available flexibility to increase during the transitional months in spring and autumn, while summer would favour generation heavily and winter not allowing for enough solar generation to balance the high demand in domestic heating. The observed time period of the months March, April and May are therefore ideal to better quantify the potential of flexibility from uni-directional sources.

As we have seen, the share of flexibility from the overall generation and demand is fairly low. During the testing period PV generators produced a total of 5,131.51 kWh, the demand in domestic heating during the same period amounted to 25,216.5 kWh[3]. The total available flexibility during that period was 2,174.3 kWh, 8.6% of the total demand and 41% of the total generation[4].

Taking a closer look at relevant scenarios show further how the different technologies interact and overlap. For example, in early March we saw a period of bad weather with low temperatures and little solar radiation. During these times, uni-directional flexibility increases due to high demand in domestic heating, bi-directional flexibility however is reduced significantly due to the lack of solar radiation. Figure 5 displays the data for the

[3] The storage heater was vastly overdimensioned, serving a larger living facility for the elderly.

[4] This also means, that in this scenario theoretically 41% of local generation has already been consumed locally.

days in early March. We see the demand in domestic heating, particularly the big storage heating installation, dwarfing solar production. In addition to this we can also see that the peak in load and generation are almost perfectly set apart.

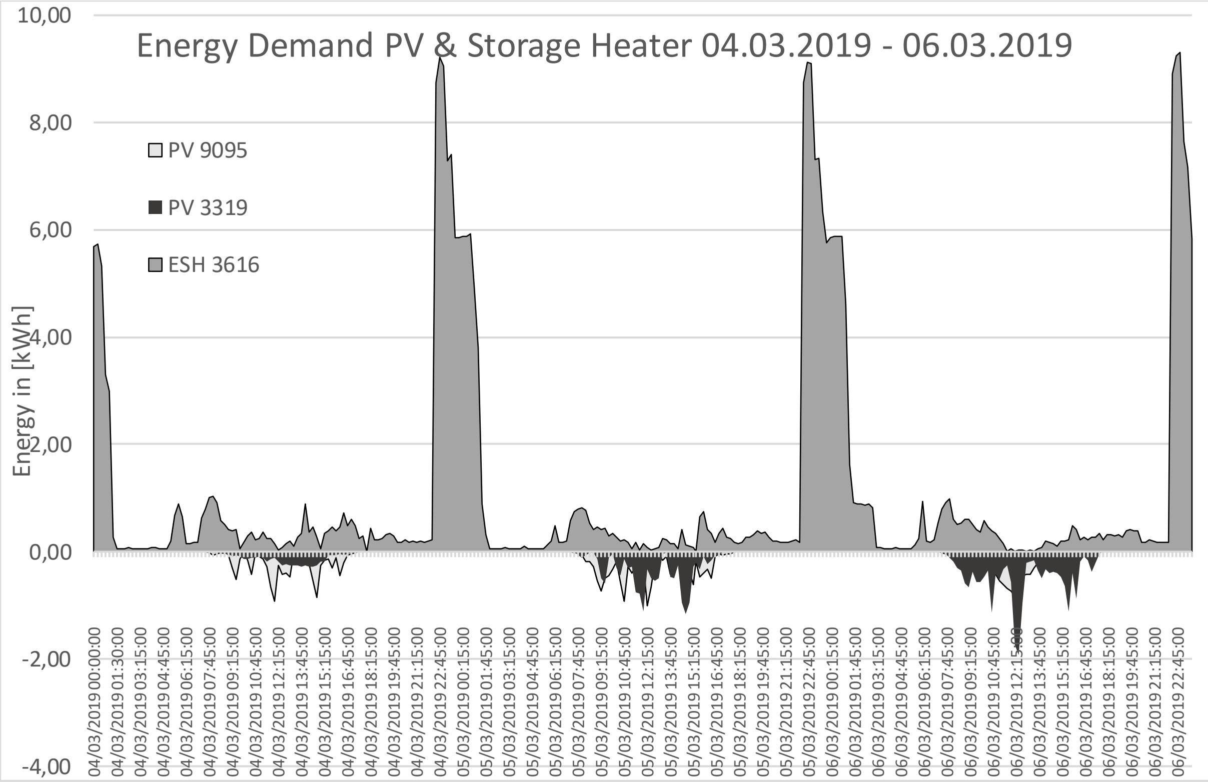

Figure 5 - Comparison of heating demand and PV production 04.03. - 06.03.2019

If we take a look at the opposite scenario, times of high solar production and comparably lower domestic heating demand, we see a different situation. Here the demand in domestic heat does not outweigh solar generation as much. The time shift between the two however remains. A large amount of potentially useful bi-directional flexibility is being wasted when storage heaters remain limited to charging at night.

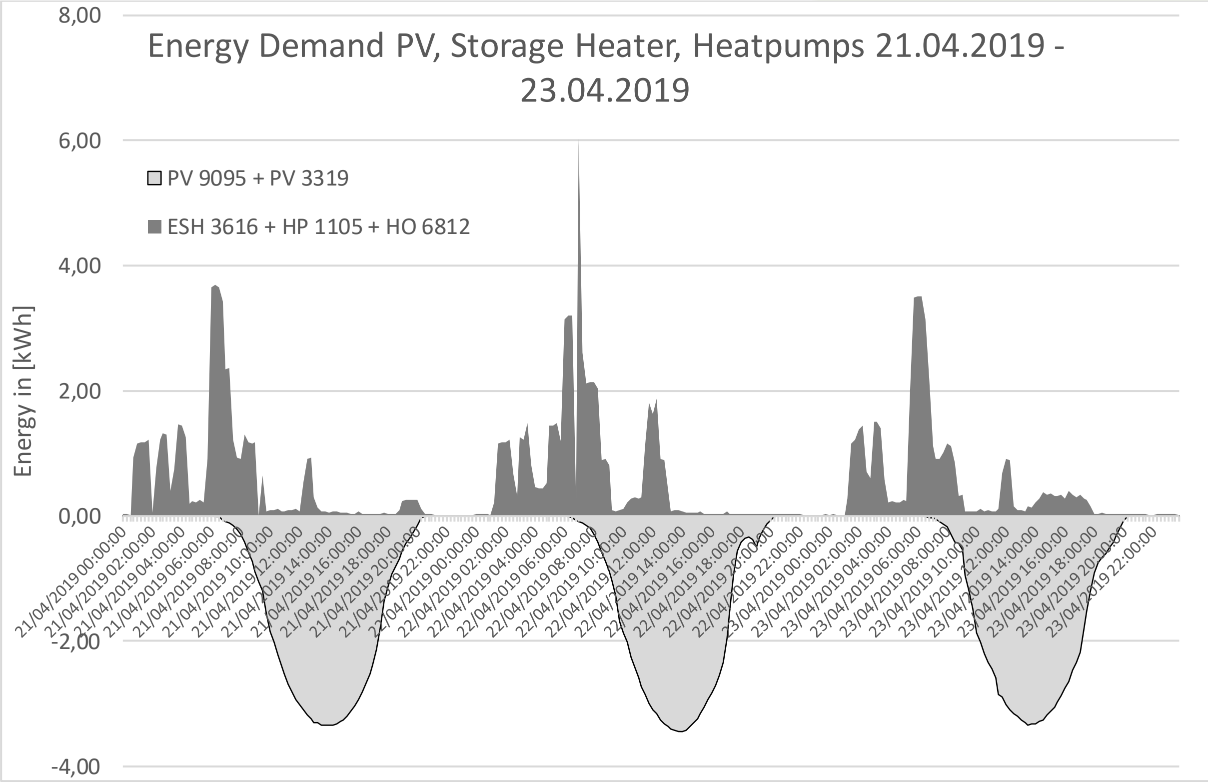

Figure 6 - Comparison of heating demand and PV production 21.04. - 23.04.2019

4. BARRIERS TO INCREASING FLEXIBILITY

InterFlex has been able to demonstrate at least 3 Use Cases that represent some kind of flexibility activation by the DSO that are covered under the current national regulatory framework in Germany. The temporary curtailment of DER, the temporary interruption of heatpumps and the control of storage heater installation that fall under the double-tariff mechanism. And even though these mechanisms were not devised as parts of a DSO-based flexibility concept, they can be interpreted in such a way. With these tools in place Germany has taken the first step towards an understanding of flexibility in power networks that is required to fulfil the ambitious goals for our energy transition. Still, we find that there is room for improvement, as described in the following chapter.

4.1. Barriers in national regulation concerning flex activation

4.1.1. Barriers to utilize flexibility provided by storage

For system operators a battery presents an ideal source of flexibility. Batteries can deliver bi-directional flexibility and do so independently of daytime, weather or season. This makes batteries particularly useful and sources of flexibility of the second highest grade. The only real downside is their limitation in duration when providing flexibility. Depending on the technology, a battery runs out of flexibility within a few hours at best.

Germany has seen a tremendous growth in domestic battery systems, almost exclusively in combination with a rooftop PV installation. By late 2018 the number of domestic battery installations exceeded 100,000 units. The majority of these systems range from 5 to 10 kWh in useable storage capacity and charging / discharging power between 2 and 6 kW. Assuming a fair mix of available systems an average customer might offer ±4 kW and 7.5 kWh of capacity. Across the entirety of all installations the theoretical flexibility potential adds up to 400 MW and 750,000 MWh.

Unfortunately, this flexibility potential remains very difficult to capture in practice as InterFlex has shown. The feed in by rooftop PV has posed a significant challenge for DSOs in Germany. Nowadays the cumulative feed in power of PV in a given low voltage network often exceeds the peak load for which network and distribution station were designed. DSOs operating in rural and suburban areas are highly affected by the growth of rooftop PV and have therefore no other choice, but to replace and uprate existing transformers. The peak feed in power also causes voltage to rise along the feeder. This PV-induced voltage rise frequently pushes the local voltage to or beyond limits, requiring the DSO to add more feeders and reinforce existing networks. In some areas these effects can be countered to some degree with the deployment of voltage regulating distribution transformers and advanced reactive power management. But the cumulative feed in power of PV in rural networks remains a big challenge for DSOs.

From an economic point of view the situation isn't ideal either. DSOs in Germany are subject to a regime of incentive regulation. The regulator grants an annual total revenue for the DSO, which is then recovered via grid charges that apply on energy consumption. For household customers, grid charges apply per kWh of demand. Customers that decrease their demand from the public grid consequently contribute less to the financing of the network, which is in and by itself considered a fair effect. Taken to the extreme however we find a situation, where the wealthy areas withdraw from refinancing the public grid by substituting grid-demand with self-generated PV power, leaving urban areas and less wealthy neighbourhoods to cover the cost of the network.

All these effects led the government and regulator to encourage battery systems in combination with a PV generator as means to increase self-consumption and reduce feedback to the public network. The rationale was that by increasing self-consumption and reducing grid interaction, the overall costs of integrating DER into low voltage networks could be kept in check. While it can be argued that this aim has been achieved to some extent, the regulations applying to batteries have created tall barriers to use domestic batteries for anything but the increase of self-consumption.

In Germany, renewable tax applies to self-consumption. That means if a customer is producing his or her own electricity, a renewable tax of currently 6,405 cent/kWh applies. Installations with a rated power of less than 10 kWp are exempt from this rule. This exemption does extend to batteries, if they are considered “EE-Stromspeicher” or “Renewable Power Storage”. To qualify as such the owner must ensure that the battery can only be charged directly from the PV and under no circumstance from the public grid.

Figure 7 depicts the different power flows in an exemplary household with PV and a battery. A widely accepted solution to ensure the status of renewable storage is to install a power flow indicator at the customer's point of connection and feed the information to the battery inverter. The inverter then monitors the household's net exchange with the grid and stops charging whenever the house is drawing energy from the outside.

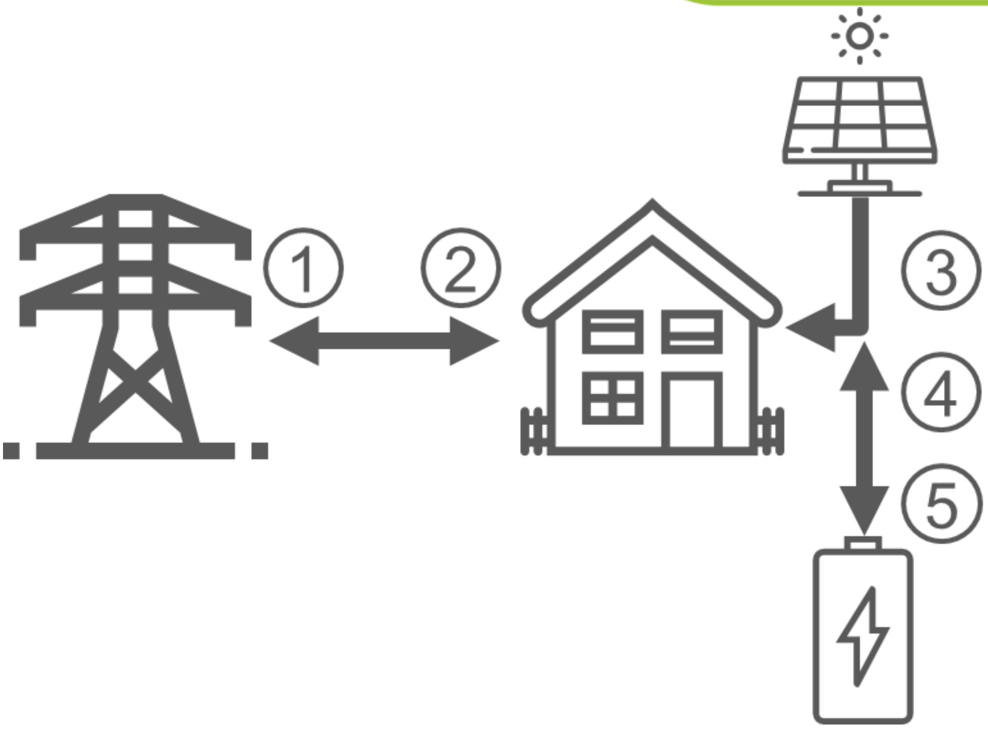

Figure 7 - Depiction of power flows in households with PV + battery installation

Installations like these are commonplace in Germany and represent all storage offers among the acquired InterFlex field test pilot customers in Germany. Because of this, these customers could not be integrated in the InterFlex field trial, even though they were willing and open to participating in the project. Including these customers in the field trials would have required disabling of the power flow indicator and an alteration of the mode of operation of the battery system. While this could have been technically possible, it defeated the purpose of InterFlex Germany, namely to activate dormant flexibility without interfering with local installations. In addition to this, the customer would also suffer the application of renewable tax on the share of self-consumption that was stored in the battery prior to consumption. A simple example of a customer with 5 kWp installed capacity would produce about 5,000 kWh of solar power in Germany. A typical battery system might increase the self-consumption by about 1,500 kWh per year on which renewable tax would apply. At 6.5 cent/kWh that would be 97.5 € per year of additional cost for the household. Keeping in mind that under the current market design there is little to no chance to counter these effects with market-generated income for the flexibility, altering the battery installation did not appear to be a reasonable choice.

The way how renewable tax is applied under these circumstances has created a situation where customers are clearly discouraged from designing a storage-PV-installation that could also offer flexibility to the DSO.

In 2017 an updated renewable energy act introduced additional rules that should, in theory, alleviate this issue. Now, storage systems could be used for multiple Use Cases. A requirement for this is that customers install several metering points to ensure that power flows could be clearly discriminated on a 15-minute basis. In order to qualify for the renewable tax exemption but still be able to participate in other flexibility markets customer would have to have their main point of connection, their PV-production and their battery all metered in 15-minute intervals. They would also be required to discriminate between battery-stored self-consumption and exchange between battery and grid on a 15-minute basis and report this data to the DSO for the handling of renewable tax.

While this rule poses an improvement over the previous situation by introducing the possibility of multiple-use batteries in households, it is still too complicated. For one, it requires setting up the system for this purpose from the start as the space for additional metering equipment is oftentimes difficult to find later after installation. The lack of space for metering equipment is oftentimes also the reason why retrofitting older systems according to the new regulation doesn't make much sense. Secondly it also introduces additional costs.

In InterFlex Germany, all potential participants were set up according to the old rule and did not have the metering equipment required to participate as mixed-use storage systems.

A lack of commercial offers and Use Cases for flexibility in-front-of-the-meter has led customers to put emphasis solely on maximizing individual self-consumption. This shows in the way regulation deals with residential batteries but also in the dimensioning of storage systems for private use.

4.1.2. Barriers to utilize flexibility by interruptible loads and electric vehicles in particular

The control of flexible elements in low voltage networks by the DSO is governed in §14a Energy Industry Act and states that "DSO must offer a discount on grid charges to those customers and suppliers, that are offering some form of controllability in return". It explicitly states that electric vehicles fall under this definition. It does not comment on the exact meaning of "controllability" or the design of the contractual agreement between DSO and owners of interruptible loads, neither does it make comments on how the discount has to be determined. Instead it empowers the government, in this case the federal ministry of economics, to define these details in a statutory law that defines what control actions shall be owned by the DSO and which belong to the supplier. It shall also take care of adjusting the laws governing the meter service provision to enable these Use Cases.

This mandate has been introduced in 2016 and since then no progress has been made. Rather discouragingly, the German government has just announced that the first draft of the statutory law in question will be delayed at least for another year until 2020. Taking into account that the draft will require political discussions and go through the legislation process we cannot expect results before 2021.

This situation is dissatisfying for many stakeholders in the field of local flexibility. DSO, customers, aggregators, suppliers and operators of DER alike share the opinion that this situation hinders the energy transition in Germany. The lack of a clear regulatory framework and a lack of vision makes it increasingly difficult to justify the efforts towards developing much needed technologies and strategies for the management of flexibilities in low voltage networks. InterFlex has demonstrated a few Use Cases that could be implemented under certain interpretations of the current regulatory framework. These Use Cases, as many others, are at risk if the expected law overturns today's expectations.

A further roadblock in this regard is the complete lack of a framework on how domestic energy storage systems (ESS), electric vehicles (EV) and chargers (EVC) fit into the picture. The established technologies in domestic heating and small scale generation can provide some flexibility under existing guidelines. For ESS, EV and EVC however there are no rules in place and accordingly no way to begin testing and developing flexibility mechanisms. As far as InterFlex is concerned this situation made it impossible to include ESS and EV(C) in the real life field tests.

5. CONCLUSIONS

5.1. Results from Use Case 2 demonstrations in Germany

Over the course of Use Case 2 demonstrations and the subsequent analysis of data we could see that there is potential for additional bi-directional flexibility in today’s distribution networks. This is an important finding, as it can encourage DSO to start activating and using these flexibilities for the benefit of the network. All it takes is a control- and metering infrastructure such as the one Avacon has developed and demonstrated in the German demo.

The available bi-directional flexibility that can be aggregated from uni-directional sources is less than the total amount of generation and momentary load. How much flexibility can be made available at any given point in time is depending on the type of devices offered by customers, the time of the year and time of day as well as meteorological factors like ambient temperature and solar radiation. Especially in the transitional months during spring and autumn when solar generation is producing and coincides with demand from domestic heating we can find significant contributions to the available flexibility in low voltage networks. This flexibility could be directed for example to prevent grid congestion or to increase the local consumption of renewable energy. Not taking into account the regulatory barriers for a second, the DSO could also aggregate flexibility from small scale devices and private customers via existing infrastructures and offer it to the TSO for balancing purposes.

There are ways to increase the amount of available flexibility. For example, adding ESS, EV an EVC to the concept would bring more flexibility. This additional flexibility would also reduce the dependency on the local weather. Roadblocks for the integration of these technologies have been described in chapter 4.

5.2. Recommendations to enable flexibility in low voltage networks in Germany

Based on the outcomes of the final Use Case demonstrations and the technical and regulatory analysis of previous chapter we recommend a set of actions to enable more flexibility in low voltage networks for the access of the DSO.

5.2.1. Simplify the rules for domestic energy storage to encourage participation in flexibility mechanisms

In chapter 4.1.1 we gave a detailed description of why the current regulatory framework in Germany is hindering the participation of domestic ESS in flex mechanisms. We recommend simplifying the rules in such a way, that it becomes easy for any owner of an ESS to offer flexibility to third parties. We acknowledge the reasoning behind the existing rules to be well-intentioned. However, we also advocate that useful flexibility offered by domestic ESS can provide additional value and increase the cost-effectiveness of the batteries.

5.2.2. Expanding on the control of heatpumps

Aggregated at scale, heatpumps could potentially become a big potential source of flexibility in low voltage networks. The activation is nowadays limited by contractual agreements between DSO and the customer. It should be possible to expand on these limitation whenever more flexibility could be offered without impeding the customers comfort. If, for example, the customer’s installation contains more thermal inertia, it should be possible to interrupt operation for longer than 2 hours at a time.

5.2.3. Explicit acknowledgement that double-tariff grid charges can be used for the benefit of the DSO

As shown in Use Case 3 and beyond, there is tremendous flexibility in the legacy double-tariff mechanisms in Germany. While technically possible it must be acknowledged by the regulators that these mechanisms can be used as part of an active flexibility management for the benefit of the grid.

5.2.4. Encouragement for DSO to implement advanced flexibility concepts

The concepts and technologies demonstrated in InterFlex must find their way into daily operation. The numerous benefits have been confirmed during field testing and technical feasibility has been proven during the demonstrations. What lacks is the acknowledgement of the regulator that investments and costs incurred to develop and maintain an active flexibility management are part of the DSO’s regulated cost base and that these can be recovered via grid charges.

5.2.5. Allow DSO to add control boxes to smart meters at rollout and allow for the cost to be recovered via grid charges

The demonstrated technology and Use Case rely on the grid-wide deployment of smart meters in combination with a control box. The control box is crucial in this context because it enables all existing Use Cases to be migrated onto the new technology and control these via the Smart Grid Hub. As of today, the control box is not mandatory part of the smart meter roll-out in Germany and the allocation of costs is not clear.

5.2.6. Finalize the Statutory Law governing the utilization of small-scale flexibility by the DSO

It has been mentioned in previous chapters how the lack of clear rules and regulations on the activation of small scale flexibility by the DSO is slowing down the development of flexibility management strategies and technologies. We encourage the German government to speed up the development and consultation regarding the statutory law concerning §14a Energy Industry Act. It should set out clear rules on how and under which circumstances DSO can activate flexibility, how to reimburse customers for the provision of flexibility and where the grid-centered activation ends and market-based flexibility mechanisms begin. It should acknowledge that there are economic benefits to allow DSO to leverage this kind of flexibility to improve and optimize operations.