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STORY

added value of STORage in distribution sYstems

Deliverable 6.2
Demonstration protocol book

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EXECUTIVE SUMMARY

This report comprises the results of several tasks developed in the framework of the WP6 regarding monitoring activities around the demo plants with the objective of defining a common methodology to evaluate the performance of those plants and others in the future through KPIs.

Monitoring the performance of the systems is essential to ensure their proper and safe operation but also to evaluate how efficient is this operation in terms of technical reliability and efficiency, economics and environmentally. However, we cannot measure everything, and a selection of the fundamental parameters needed for the right operation and evaluation of the systems must be done. Also, the accuracy and frequency of the measurements should be determined and finally, the monitoring devices able to provide the suitable data should be selected.

Since monitoring is essential for adequate operation but is only a supporting component in energy systems, it is necessary to reach a balance between the real measurement needs and the capabilities of the devices so that the costs of the monitoring system are as low as possible without jeopardizing their function. Also, the interests of the data users are different as well as their requirements in terms of accuracy, reliability, frequency, etc.

In summary, this report includes the analysis of all those aspects to provide future microgrids and energy systems developers with some guidelines for monitoring systems sizing, design and configuration.

The aim of STORY project is to demonstrate and quantify the added value of energy storage solutions in the distribution level and to evaluate the success of the solution implementation. Therefore, we have developed an analysis framework that establishes the relationship between the diverse activities carried out in the project. This framework is described in the second Section of the document and defines the links and information exchange between the WPs in a systematic way through a common methodology.

In the first step we have defined diverse Key Grid Challenges that energy storage could solve in some extension by means of a proper operation or control strategy. Therefore, different demonstrators with different goals have been installed and large-scale models have been developed for extrapolation purposes by simulation. To evaluate whether the goals have been achieved and how well, numerical results are needed and for that, we have defined different KPIs.

KPIs allow the comparison of a base case (BC) or the initial situation and a case study (CS) that corresponds to the new situation with the solution implemented. This way, the advantages (or disadvantages) of applying the evaluated solution can be quantified. In STORY project diverse KPIs have been defined, the ones related to the grid and the Key Grid Challenges, and others related to the technology, economic, and environmental KPIs. All have been defined with the same structure: the purpose, the object of evaluation, the calculation method, the parameters needed for calculation and the evaluation period.

The general KPIs that apply to most of the demos are described also in Section 2. Additional KPIs that apply only to some demonstrators are not included in the common monitoring methodology but are analysed in the performance evaluation Sections per demo (Deliverable 6.1).

It is crucial to define properly the aspect (goal) to evaluate, how the KPI represents this aspect and to identify the information necessary for the KPI assessment. Moreover, the performance

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evaluation of the systems should not focus on the momentary values of KPIs separately but look at the system as a whole and the evolution of the KPIs in longer periods. One KPI value *per se* could be meaningless but in a larger context taking into consideration also other KPIs, the process can show a behaviour or a tendency.

In Section 3 the common monitoring methodology is described. During the KPIs definition, the necessary parameters to be measured to assess the KPIs are identified. According to them, the monitoring devices are selected taking also into account the technical requirements. The procedure includes data gathering, transfer and processing in a common database installed and managed by STORY partner BASN.

KPIs calculation and reporting have been automatized; however, the differences among the demonstrators and monitoring systems have made necessary a customization of KPIs and more precise establishment of the baseline which is different depending on the demo plant and the initial conditions.

The main lesson learned from this task is the importance of defining the most representative KPIs at the beginning of the process in order to be able to develop later all the monitoring activities in a structured and systematic manner. Although differences of the demos (or future projects) will make necessary adaptations, such approach will reduce risks and the required time in putting up the monitoring systems in service since the main aspects can be harmonised in earlier steps.

When we talk about monitoring, engineers always think about numerical data and technical KPIs. However, the deployment of a new technology such as energy storage systems requires the interest of the “end users”, different stakeholders that will use or invest in these technologies. Understanding their interests and reasons for being involved in new deployments and markets is crucial for new technologies development. Therefore, we include in Section 4 a stakeholder engagement methodology that describes the steps to approach and engage potential “users” of these new technologies by “measuring” their interests not only from the economic but also from the social, environmental, public image, and other points of view.

Monitoring is essential for ensuring safe operation of the plants, but costs must be minimised as much as possible since this system is only a part of the supporting infrastructure of the plant. A detailed analysis of the monitoring-related costs’ impact in the profitability of a plant and other economic issues to take into account during monitoring system design are described in Section 5. The analysis is done over three demos and shows that the share of the monitoring infrastructure in the overall costs depends on the size and objectives of the plants. And more important, in a Cost-Benefit Analysis (CBA) it is very difficult to valorise the benefits that the monitoring provides since it doesn’t contribute directly to the revenues; however, a wrong decision in the definition of the monitoring system can make a project unprofitable.

Finally, in the last Section we focus on the interests of the stakeholders regarding the data. Depending on the stakeholder viewpoint, the needs and interests regarding data are different; for instance, a DSO needs different information and data accuracy than a residential end user since the use and objective of the measured parameters are different. In this Section an analysis of their interests has been developed by means of a customised questionnaire as well as a review of the current regulation about Data Protection. Data reliability and accuracy are also aspects to take into account since they impact the decision-making process related to the control of the plants. An example based on the OHL demo is also included in this Section.

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1 INTRODUCTION

The objective of this project is to demonstrate and quantify the added value of energy storage systems in applications or services of the distribution network. Storage technologies per se are not capable of providing any service or benefits; that depends on the way in which these technologies are operated or controlled.

To evaluate the success of the solution’s implementation and operation, we have defined overall analysis framework that connects activities on multiple sector throughout the project. This framework is described in the first Section of the document and defines the links and information exchange between the WPs in a systematic way through a common methodology.

The monitoring of the systems, in the STORY project the demonstrators that include energy storage systems, has two fundamental objectives: the observability of the plants to ensure their correct operation and the evaluation or analysis of their performance to determine if the planned objectives are met or what is the same, identify and quantify the benefits.

Trying to quantify the added value requires a methodology that allows to compare the "before" and "after" of the system with objective and numerical criteria, if possible. To this end, the STORY project has defined a protocol that allows this analysis to be carried out in a harmonized and systematic way based on the use of KPIs and that is fed by data measured in the demonstration plants.

The protocol includes a guideline to design the monitoring systems ensuring the availability of all the necessary information to achieve its two main objectives mentioned above but minimizing the associated cost.

Second Section of the document describes the methodology for evaluating the operation of the demonstration plants and the quantification of benefits based on KPIs. This methodology also establishes the relationship between the different activities and their contribution to achieve the main objective of the project. The STORY Monitoring and Engagement strategies are presented. In Section 3, it shows the procedure that demonstration leaders should follow, in terms of variable measurement, to be able to obtain its Key Performance Indicators (KPIs) in a reliable, accurate and cost-efficient way. This document moreover shows the procedure followed to define the measurement activities at each demo, once its specific performance indicators are set.

In Section 4, this document contains a stakeholder engagement methodology, i.e. a guide for STORY demonstration leaders to identify their stakeholders, identify their key criteria for evaluating the storage technologies, and how to subsequently monitor these criteria with them. Co-developing these 'Stakeholder Evaluation Criteria’ (SEC), based on which key stakeholders assess the success of the demonstration’s technologies, can result in both quantitative and qualitative criteria to be monitored.

The KPIs, as well as the implementation of the stakeholder engagement methodology, will allow STORY to monitor and evaluate the success of its demonstrations, ensuring future roll-out of these storage technologies.

Additionally, an analysis of the costs associated to the monitoring issues has been developed and included in the report, in Section 5, with the objective of determining the impact of this activity in the cost-effectiveness of this kind of solution.

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Another focus was also on nature of measurement data, presented in Section 6. Since the measurements itself can contain personal information about the measured user. Several Stakeholders are involved in data sharing process and their treatment of the collected data and awareness of measured data were investigated. With the General Data Protection Regulation law, new requirements must be met, and we can deploy several techniques to achieve protection of personal information in regard to measurement data of the users. Generally, end users are positively inclined to sharing their data if this results in better economic outcome, such as energy savings and cheaper service. They, however, are concerned about how their data is being treated, thus other stakeholders involved, such as Suppliers, DSOs, Aggregators, who define their business model and services offered on the data, which is being measured, need to treat data properly. Data is being processed with several algorithms which are developed by each company. They have some challenges with meeting the GDPR requirements but other Stakeholder groups such as the Regulators are monitoring their operation and prevent misuse of the data.

On the example of neighbourhood control, which is innovative control and aggregation of household users, data analysis was performed. The data, which is needed to enable this control is described and data quality as well. In event of alarms going off, which signals missing data, malfunction of the communication equipment and other events the impact on data quality and mitigation measures are described.

Table 1.1: Partner Contributions

CEN	Design of overall analysis framework, Monitoring approach definition, Coordination as a WPL
UL	Design of overall analysis framework, Definition of technical KPIs and USE cases, Data privacy chapter and questionnaire on users of measured data analysis
JR	Design of overall analysis framework, Definition of environmental KPIs, official review of the deliverable
THNK	Review and feedback of the Living lab demo KPIs
VITO	Beneens demo KPI and Use case review, measurement costs for the Beneens demo
VLER	Costs of measurement chapter, Economic KPIs and baseline definition for monitoring purposes.
BASN	Data storage description, online calculation of the KPIs, review of the deliverable
EG	Review and feedback on EG demo selected KPIs and use cases
B9	Definition of B9 demo use cases and KPIs
ACT	OHL demo KPIs review, data quality analysis for OHL demo
PROS	Description of stakeholder engagement methodology and questionnaire on users of measured data design
UCL	Cost of measurement chapter and example of costs for 3 demos

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2 Added value analysis framework

2.1 Overview

There are many benefits that arise by large scale integration of Small-Scale Storage Solution (S4) technologies in the distribution system. In Figure 2.1, the STORY Value Analysis Framework is shown schematically. Various building blocks of the framework are defined in respective Work Packages (WPs), and coloured accordingly.

The STORY Value Analysis Framework rests on the following concepts:

- The benefits are realized as **value** to the **actors**, when **services** are exchanged among them.
- Services are provided by actors controlling S4 technologies, network resources, Distributed Renewable Energy Sources (DRES) and Demand Response (DR) units.
- The principal aim of the services is to influence and respond to **Key Grid Challenges**.
- The **control strategies** for the S4 and other resources are defined in **WP3** and are structured in 3 control layers: device layer, network layer and service layer.
- **The actors** are connected through **Business Models** developed in **WP8** that describe the nature of exchange of **services**. Each actor has a different portfolio of benefits, and they are captured in the Business Models.
- **Value** is realized also beyond the Key Grid Challenges, with broader societal **benefits** (e.g. increased RES consumption and reduced losses in the system)

In STORY, we aim to demonstrate these benefits through the **demonstration cases (DEMOs)** in **WP5** and through **simulations** in **WP7**. Each of them presents one or more **Test Cases**, in which a set of services is provided among the actors under a specified **framework condition**. They are defined in a **Framework Matrix**, that describes the technical, economic, market and regulatory aspects of the business models.

To comprehensively capture the value of the services provided by the actors, a set of **Business Requirements (Aims)** has been defined. Business Requirements are the functional aims of STORY, describing the business needs and the required features of the S4 solution and the associated control strategies.

The typical ways each S4 is used are described in Use Cases, defined in **WP3**. The **Use Cases** describe the procedures of how the control strategies are implemented with the S4 to achieve the goals stated in the Business Requirements. To determine whether the goals have been achieved or not, a set of quantitative **Acceptance Criteria** is defined for each Business Requirement.

The **Acceptance Criteria** are expressed in terms of the **Key Performance Indicators (KPIs)**, defined in **WP6.** As the KPIs, quantities are defined that are either directly measurable or that are calculated from the measured data. The KPIs have the following parameters defined:

- Input variables;
- Control parameters;
- Calculation methodology, expressed in mathematical formulae;

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· Output variables (the KPI values): baseline and the boundaries of the result space.

The Acceptance Criteria are defined as the acceptable level of the KPIs.

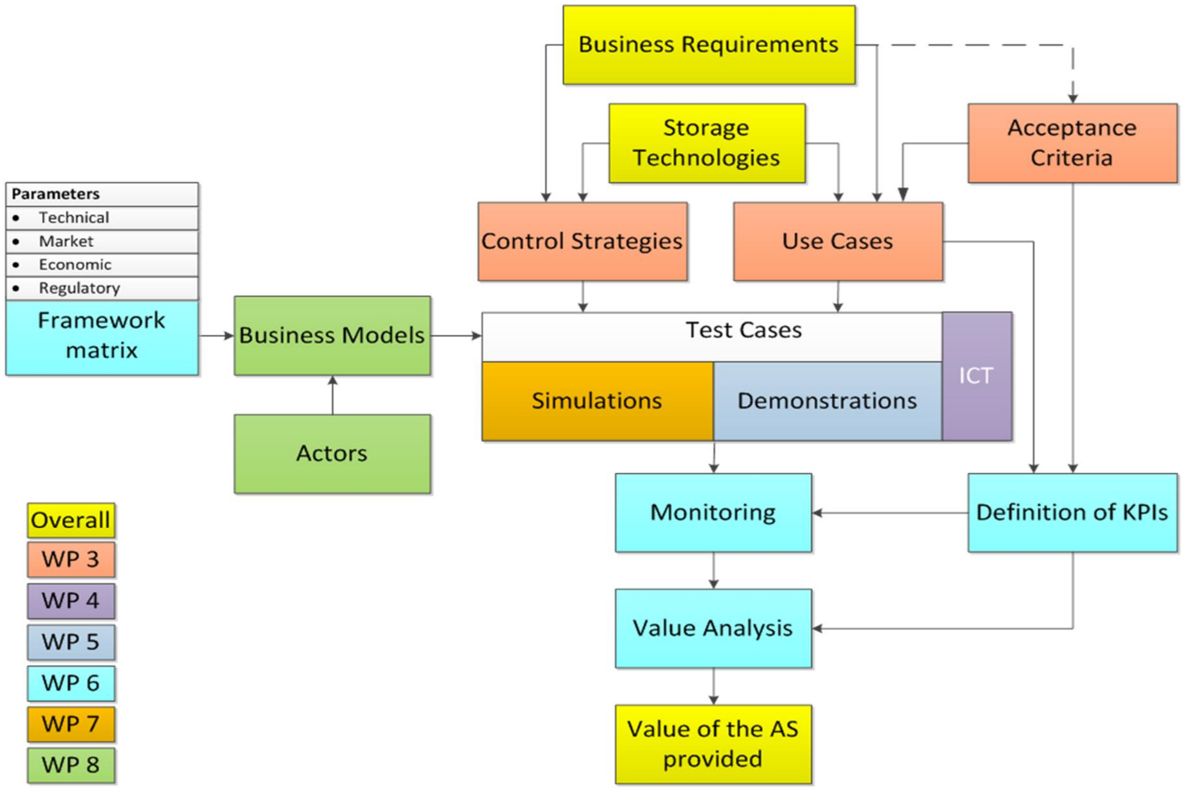

Figure 2.1: The schema of the STORY Value Analysis Framework

For evaluation, several **Test Cases** can be defined for each Use Case. The Test Cases are either carried out in the field (DEMOs), in the laboratory, or per simulation. Test Cases are defined as scenarios, covering various parameters that influence the operation of S4, and are defined in WP7. The results of the demonstrations and simulations are monitored in WP6.

- **Demonstration**: in WP5, several DEMOs have been defined. Each of the DEMOs is running several Test Cases, covering several Use Cases, and conforming to several Business Requirements.
- **Simulation:** in WP7, simulation approach is being designed to carry out the simulation of the Test Cases.
- **Value Analysis**: the value provided by the services is the result of the monitoring in WP6.

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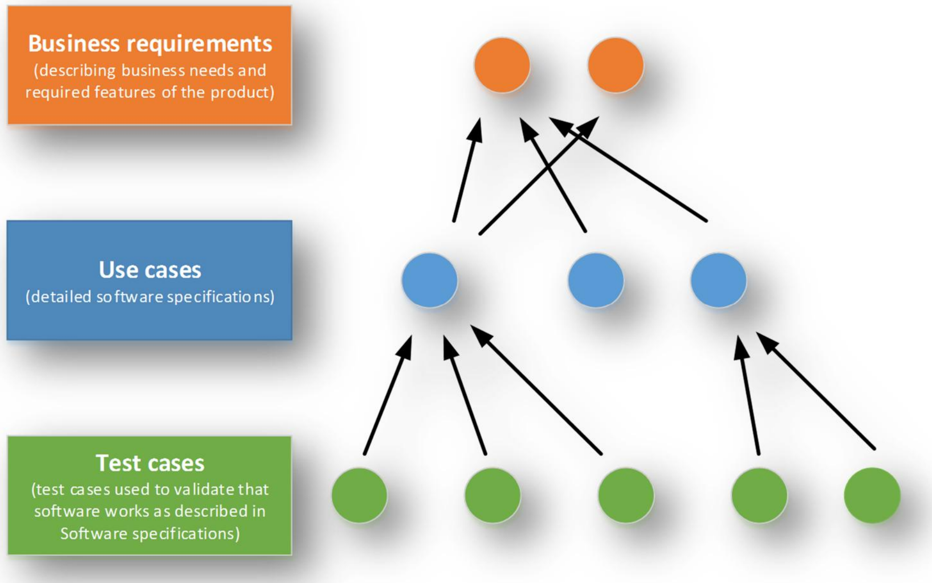

Figure 2.2: The relationship among BR, UC and TC

2.2 Terminology

For better understanding, a short description of terminology is provided.

Term	Meaning
Control strategy	A series of decision-making steps involving algorithms and input/outputs that are needed to implement a use case
Functionality	A property of a device or of a system. It is a combination of technical properties and control algorithm. The functionalities are described in the control strategies Section.
Use case	Description of the services and the required implementation of the control strategies to achieve the stated goals
Key performance indicator (KPI)	Quantity used to monitor the progress, either directly measurable or calculated from the measured data.

2.3 Performance Indicators (KPIs) Overview

The simulation and demonstration activities performed in the STORY project aim to achieve the use cases of the project. The use cases are related to the general aims that we want to achieve in demonstrations, aligned with the STORY's main goals. To evaluate the quality of our performance and to assess the efficiency of the control strategies taken, an evaluation methodology based on KPIs was designed, where for each KPI a baseline and its range (upper, lower limit and optimal level) is defined.

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Each of the use cases can be achieved by different control strategies, which differ in costs and side effects. To assess all the control strategies' different impacts, we apply three main types of KPIs:

- Technical KPIs, including grid-related and device-level KPIs
- Environmental KPIs, and
- Economic KPIs.

To assess the success of the control strategies through the results of the KPIs, the control strategies need to be compared to baseline criteria, specific to each KPI. The determination of the baseline criteria will be presented in the separate demos' Sections in separate report describing the performance of the demos. The KPI assessment methodology flowchart is presented in Figure 2.3.

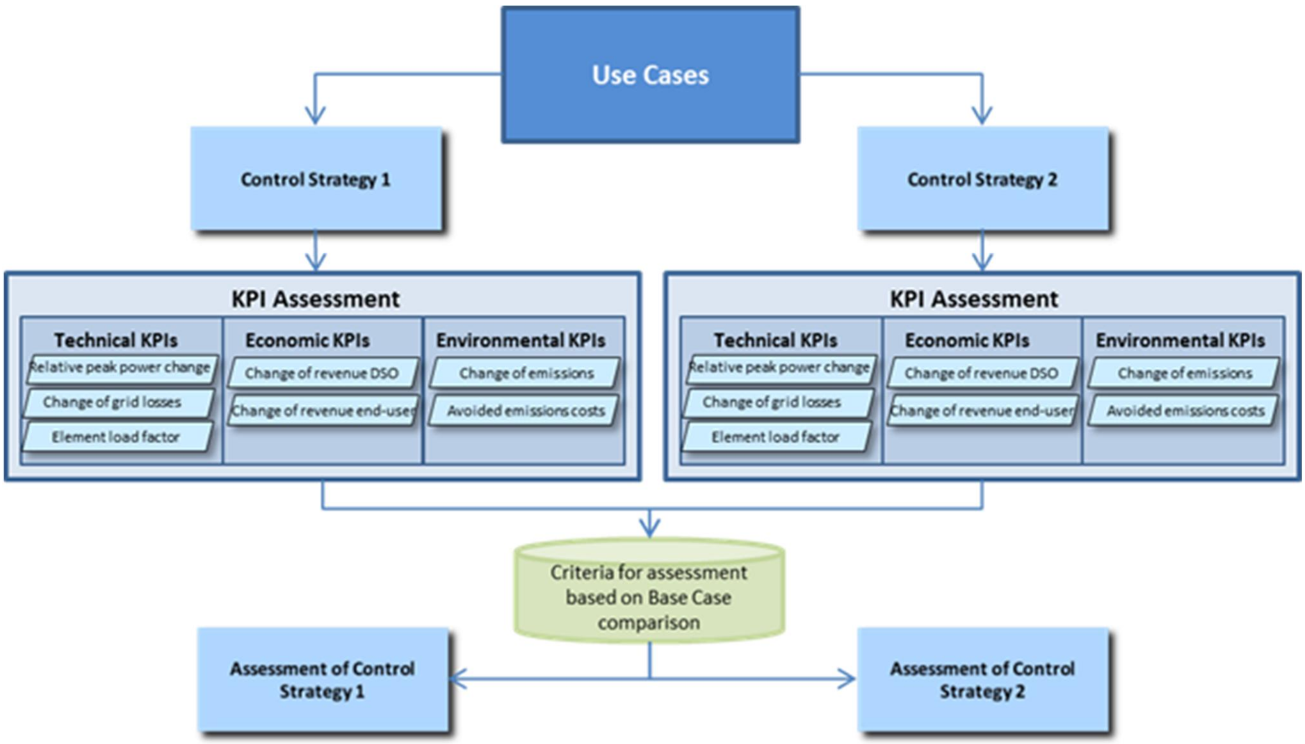

Figure 2.3: The methodology of comparing efficiency of control strategies

In STORY the use cases will be demo-tested and simulated, but not all use cases can be both, demo tested and simulated as some of them are limited only to simulations, e.g. Zero load provision (islanding mode) due to demo site limitations. Testing of some others is possible only in real demo cases (e.g. reserve provision), as shown in Table 2.1. In this report, a mark D for demonstration, S for simulation or both are written next to each use case.

The use cases can be met using different control strategies. In STORY we focus only on the control strategies involving energy storage implementation and control, except for flexible demand

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control in some of the demos. The control strategies can involve either electricity, heat or a combination of both.

Table 2.1: **The level of testing of the KPIs in STORY**

Use case	Simulation	Demonstration
Increased RES use		
Increased self-consumption		
Electrical peak shifting / Peak shaving		
Peak power reduction of heat demand		
Reserve provision		
Zero load provision		
Voltage control		
Reactive power compensation		
Local optimization of households and neighbourhoods		
Service optimization (system level value)		
Heat loss reduction of district heating network by multi-temperature network		
Load and generation on demand for the CAES		

The control strategies used to achieve the goals or use cases have different effects on the network operation, environment, and economics of the system. Thus, each measure needs to be evaluated with all three types of KPIs. We can highlight the primary effect intended with the proposed control strategy and the specific KPI to assess the performance of the control strategy. However, to see the overall picture and the possible effects on some other fields, each of the control strategies must be evaluated with the whole set of general KPIs. As the demos differ in use cases and in the technology implemented, not all KPIs can be calculated in each of them due to the missing measured quantities or due to other technical reasons. Therefore, in each demo, we only assess the KPIs that can be calculated with the available data without additional cost or workload for the demo leaders.

In addition to the general KPIs, applicable to all demos, specific KPIs are used to evaluate technology-specific characteristics and performance of the demos. They need to be modified specifically for each technology in those demos and adapted to their functionalities. The table below gives an overview of the KPI categories.

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Table 2.2: An overview of the KPI categories in STORY

	KPI Category	Description
@	Technical KPIs	Grid-related KPIs Device-level KPIs
‘	Economic KPIs	Change of revenue for the main actors
P	Environmental KPIs	Change of emissions Avoided emissions costs

2.4 Description of the STORY use cases

The use cases are the goals of a demo that are aligned with the goals of the project. They are reflected in the use cases that describe the real-world application of the goals that we want to achieve by implementing new solutions. The use cases listed below are aligned with the goals of the STORY project in general and demo cases as well as simulations that need to be carried out in STORY. The first two use cases relate to all demos as they are based on the overarching aims of the project.

2.4.1 Increased self-consumption (D + S)

Increased self-consumption involves increasing the contribution of local generation to the total load supply, reducing thereby the energy supply from the grid. This service can be provided by avoiding the curtailment or export of surplus onsite energy generation, either by locally storing energy for a later use or following a demand-response strategy. This use case is analysed in all demo cases which have on-site generation.

2.4.2 Increased RES use (D+S)

An increased RES use refers to the maximisation of the load supplied by the present renewable energy sources, either instantaneously by means of a demand response strategy or shifting energy by the means of an energy storage device. The goal of increased RES use cases is to maximise the consumed RES production avoiding reductions/curtailment.

2.4.3 Electrical peak shifting / Peak shaving (D+S)

Traditionally, electrical peak shifting/peak shaving is a demand response strategy of controlling the maximum consumption of the local grid. In STORY, electricity storage is added in addition to the responsive demand. The goal of peak shaving is to change the energy pattern in the local grid in order to reduce peak consumption. This allows the DSO to avoid /postpone grid capacity expansion and other investors to avoid generation capacity installation to supply the peaks of a highly variable load.

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- Peak shaving involves reducing the load supplied from the central grid in peak hours by local energy supply thus reducing the peak demand on the grid.
- Peak shifting involves shifting of energy consumption in time by reducing the amount of energy consumed during the peak demand hours and increasing it in off-peak times.

In STORY this use case is also analysed from the generation side. Due to the emerging PV generation capacity in the LV distribution network, the peaks in production are causing increasingly more problems with overvoltage during the day and undervoltage in the evening and at night. The goal is to reduce the PV generation peaks with activating energy storage (batteries) or with controlling flexible load.

This use case is addressed in the OH building and neighbourhood level, the Spanish factory and the Slovenian (Suha and Kranj) demos.

2.4.4 Peak power reduction of heat demand (D)

Peak power reduction of the heat demand refers to the reduction of the thermal demand peak. It can be achieved by the integration of thermal energy storage and load shifting. During periods with low heat demand or high local generation the thermal energy storage system can be charged. During periods with high heat demand, heat can be supplied by heating installation and the thermal energy storage. Integration of thermal energy storage can reduce the cost of the heating installation as the latter can be dimensioned at base load instead of peak power. To control the heating installation, an accurate State of Charge (SoC) determination of the thermal energy storage system is important.

This use case is being analysed in OH 1&2 and the Beneens demo cases.

2.4.5 Reserve provision (D)

Reserve provision is the act of a power generation or consumption capacity made available to the system operator to increase or decrease electricity injection within a short interval of time to meet the demand in case of an outage event in its network. Different types of reserve can vary in scope, activation time and duration.

Due to the specific nature of the reserve provision, which is activated upon request by DSO or TSO, it will be tested through two STORY demonstrations:

- EG demo: to prove the viability of reserve provision by the battery in the LV network and
- Lecale demo: to test the compressed air energy storage (CAES) capabilities to provide various types of reserve.

2.4.6 Zero load provision (S)

Zero load provision consists of obtaining a minimal power flow (ideally zero) through the transformer station or the Point of Common Coupling (PCC) by instantaneously supplying or absorbing energy as required.

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This goal is being analysed in the EG demo cases (Suha and Kranj) to demonstrate the capability of storage to balance the power flows to minimise or avoid the energy exchange with the grid.

2.4.7 Voltage control (D+S)

Voltage control service refers to continuously maintaining the voltage profile within its network operation limits. The goal of voltage control is, on the one hand, to mitigate voltage problems created mostly by RES local energy injection and on the other hand to keep the voltage level in the prescribed network operation limits.

This use case is analysed in the Suha and Oud-Heverlee demo case.

2.4.8 Reactive power compensation (S)

Reactive power compensation refers to compensating the reactive power consumed by electrical motors, transformers etc. and involves supplying or absorbing reactive power within a consumer network to avoid an undesirable reactive power exchange with the grid.

The main benefits identified are:

- Improvement of the system power factor
- Reduction of network losses
- Avoiding penalty charges from utilities for excessive consumption of reactive power
- Reduction of costs and increased revenues for the customer
- Increased system capacity and saving cost on new installations
- Improved voltage regulation in the network
- Increased power availability

This use case will be analysed in the EG demo case.

2.4.9 Local optimization of households and neighbourhoods (D+S)

Household level optimisation

The main goal of local optimization, or better said household level optimization, is focused solely on local information of a single household with control algorithms for DR that take into account only household conditions and limitations. This is performed in demo OHL1 in the peak shaving case.

Neighbourhood-level optimisation

The neighbourhood level optimisation also looks at very local consideration such as peak load or increased self-consumption but does not take household consideration into account. It tries to optimize those objectives by looking at the neighbourhood as a single entity, using only locally available information.

This is tested in the peak-shaving business case, performed at neighbourhood level in OHL 2.

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2.4.10 Service optimization (system level value) (D+S)

Service optimization is based on the pooling of flexible assets into a virtual power plant. The resources are coordinated to answer specific system level needs (electricity prices, reserve, etc.). This means local constraints (at neighbourhood level) will no longer be the priority of the control algorithm. It is therefore very important to assess the local impact of the system level optimisation. The impact can be positive (positive correlation between system needs and local needs) as well as locally detrimental (when this correlation is negative).

This is performed in the dynamic pricing business case, performed at household level in OHL1 and at neighbourhood level in OHL2. In the household level optimisation, a system level value such as a high price will tend to indirectly coordinate household consumption. The local level optimisation will thereby lead to positive/negative local, neighbourhood and system-level impact.

2.4.11 Use cases for the CAES (D)

There are several use cases related to the CAES as reflected also in the demo specific KPIs.

Demand reduction

When CAES is compressing and therefore acting as a load on the system we become eligible for demand side reduction services that would be described in a service contract with a Demand Side Unit (DSU). In the event of a system requirement the trip signal to shut down the compressor comes from DSU and payment in respect of contract is triggered.

Standby generation

When CAES is compressing or idle we become eligible for standby generation through the capacity market. This arrangement would be described in a contract with System Operator Northern Ireland (SONI) and/or the DSU. In the event of a system requirement the start signal for the expander would be received and payment in respect of contract is triggered.

Peak shaving

Maximising the quantity of air stored on a daily basis at commencement of the peak shaving episode (4pm - 8pm). Generation during this period will be on a load following profile. This will maximise generation export at the highest market prices. Minimise the quantity of compressed air remaining at the end of the peak shaving episode so that the system is ready for night-time (off-peak) compression duty. This arrangement will be described in a Power Purchase Agreement with a public electricity supply company. The fossil fuel combustion savings and the emission savings will be calculated and recorded.

Generation on demand

In parallel with Peak Shaving above, the “generation on demand” service will be sold to the DNO so that thermal loading on the substation will be kept within design limits. This will allow the DNO to defer or avoid costly upgrading of the substation and 33kV circuits.

This arrangement will be described in a Generation on Demand contract. The KPI will be measured by technical performance of the CAES control system to commence generation when

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called to do so by the DNO and by fulfilment of all of the commercial agreements in the Generation on Demand contract.

Load on demand

Load on demand to avoid reverse power flow at the substation and thereby reduce constrained wind and solar on the 11kV circuits. Load on demand also avoids curtailment of distant windfarms. Three revenue streams identified are:

- Constrained wind (local)
- Constrained solar (local)
- Curtailed wind (distant)

These arrangements will be described in a Load on Demand contract. The KPI will be measured by technical performance of the CAES control system to commence compression when called to do so by the DNO and by fulfilment of all the commercial agreements in the Load on Demand contract with local and distant renewable generators (payments would be made on a per MWh basis).

2.5 General-purpose KPIs

While the economic and environmental KPIs are applied in all demos the application of the technical KPIs depend on the specific demo. Yet, there are several general technical KPIs which are applied in more than one demo. In addition to these general KPI'S, demo-specific ones were designed.

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2.5.1 General technical KPIs-Overview

Table 2.3: Application of the technical KPIs

KPIs	OHL 1		OHL 2		Exkal	Beneens	Lecale	Suha	Kranj
	LL	others	LEC	FlexNH					
Increase RES use	ü	ü	ü	ü	ü	ü	ü	ü	ü
Increased Self consumption use	ü	ü	ü	ü	ü	ü	ü	ü	ü
Peak-to-average demand ratio		ü			ü			ü	ü
Relative peak power change					ü	ü		ü	ü
Grid losses change								ü	ü
Grid energy consumption change			ü	ü	ü			ü	ü
Current and voltage total harmonic distortion change			ü	ü				ü	ü
Voltage deviation change			ü	ü				ü	ü
Full Cycle Equivalents of Storage					ü			ü	ü
Storage capacity factor					ü			ü	ü
Storage efficiency	ü	ü			ü		ü	ü	ü
Device availability		ü			ü			ü	ü

2.5.1.1 *Increased RES use (K1)*

Definition:

Increased RES use is the difference in energy production of the RES unit which is increased with activation of the storage assets, DR units or other measures.

Calculation:

$$\Delta E_{RES}[\%] = \frac{E_{CS} - E_{BC}}{E_{BC}} \cdot 100\%$$

$\Delta E_{RES}[\%]$	Increased RES use
$E_{BC}[kWh]$	RES unit production in kWh in base case in the defined interval (24h)
$E_{CS}\ [kWh]$	RES unit production in kWh in demo case in the defined interval (24h)

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2.5.1.2 Increased self-consumption (K2)

Definition:

Associated with the previously defined use case Increased RES use, this KPI measures the self-consumption of locally produced energy by the loads in the network and self-sufficiency level of local assets. This applies to electricity and heat.

Self-consumption level SCL is defined as a ratio between self-consumed (or local consumption) of locally produced energy and the total amount of locally produced energy, of which the surplus is injected into the main grid. Self-sufficiency level SSL is defined as a ratio between the consumption, covered by local production and the total consumption over a certain monitored interval.

Calculation:

$$SCL(\%) = \frac{E_{Local,Consumed}(T)}{E_{Local,Produced}(T)} \cdot 100\%$$

$SCL(\%)$	Self-consumption level
$E_{Local,Consumed}(T)$	Locally generated energy, which is used for consumption within the monitored sector in the defined time interval T in [kWh].
$E_{Local,Produced}(T)$	Total amount of locally produced energy [kWh] in defined interval T.

Calculation:

$$SSL(\%) = \frac{C_{Locally\ covered}(T)}{C_{Total}(T)} \cdot 100\%$$

$SSL(\%)$	Self-sufficiency level
$C_{Locally\ covered}(T)$	Consumption in the network [kWh] in the defined interval (24 hours), which is covered by local sources and
$C_{Total}(T)$	Total consumption [kWh] in interval T (24 hours) in the network.

Proposed time interval: 24 hours

2.5.2 Grid-related KPIs

The grid-related KPIs are calculated based on the same input parameters for each demo case and simulation and are therefore core KPIs for the technical performance assessment. There are some established KPIs (e.g. CAIDI, CAIFI, SAIDI, SAIFI) designed for assessing the security of grid operation, which deal with the number of service interruptions. However, they are mostly not suitable for assessing the impact of new technologies on the power quality on the distribution level. Therefore, a set of new KPIs for the STORY use cases and the associated control strategies has been designed.

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2.5.2.1 Change of peak-to-average demand ratio (K3)

Definition:

Change of peak to average demand ratio is defined as the ratio between the peak value of the demand profile and the average value of demand. Ratios before and after the implementation of storage are compared in order to provide the relative change of peak to average ratio.

This KPI has been selected to evaluate the techno-economic benefits linked to an improvement of the grid capacity. Generally, grids and reinforcement plans are sized according to the peak power demand in the nodes. Therefore, most of the time the networks are underused since the energy demand is on average 2/3 of the peak power. An increased capacity factor leads to a rise in the use of the grid and a reduction of the energy cost.

Calculation:

$$\Delta PAR_{Demand}(\%) = \frac{\left[(\frac{|P_p|}{\underline{P}})_{BC} - (\frac{|P_p|}{\underline{P}})_{CS} \right]}{(\frac{|P_p|}{\underline{P}})_{BC}} \cdot 100\%$$

$\Delta PAR_{Demand}(\%)$	Change of the peak-to-average demand ratio relating to the case study and the base case [%],
$\left(\frac{\lvert P_p \rvert}{\lvert \underline{P} \rvert}\right)_{BC}$	Ratio of peak power (P) over base case average demand, where $\lvert P_p \rvert$ represents peak power and $\lvert \underline{P} \rvert$ represents average demand in selected time interval [unitless]
$\left(\frac{\lvert P_p \rvert}{\lvert \underline{P} \rvert}\right)_{CS}$	Case study average demand and peak power (P) ratio, where $\lvert P_p \rvert$ represents peak power and $\lvert \underline{P} \rvert$ represents average demand in selected time interval [unitless].

Proposed time intervals: 24hours

7 days

1 month

2.5.2.2 Relative peak power change (K4)

Definition:

Relative peak power change is defined as the change of peak power flows in the network, before and after storage implementation, compared to peak power levels before the storage technology implementation. In addition to the relative peak power, we also measure the relative average peak power. This KPI is suited to be calculated for a feeder on the transformer level, or PCC with the rest of the network, if applicable.

Calculation:

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$$\Delta RPP(\%) = \frac{P_{BC} - P_{CS}}{P_{BC}} \cdot 100\%$$

$\Delta RPP(\%)$ Relative peak power change

P_{CS} Grid peak power [kW] in the demo case and

P_{BC} Grid peak power [kW] in the base case.

Proposed time interval: *24 hours*

7 days

30 days

2.5.2.3 Grid losses change (K5)

Definition:

Change of grid losses is defined as the deviation of losses in the network before the storage implementation and after the implementation of storage. This KPI is suited to be calculated for a feeder on transformer level, with the rest of the network, if applicable. Due to a reduced power flow through the transformer, the electricity losses will be lower on the complete distribution power infeed line (the MV line and MV/LV transformer).

Calculation:

$$\Delta E_{loss}(\%) = \frac{E_{loss,BC} - E_{loss,CS}}{E_{loss,BC}} \cdot 100\%$$

$\Delta E(\%)$ Relative change of grid losses [%]

$E_{loss,BC}$ [kWh] Losses through transformer prior to implementation of storage and control

$E_{loss,CS}$ Losses in case study [kWh]

The transformer losses are calculated based on the transformer's current measurements and the distribution transformer specification (copper losses data).

$$E_{loss} = E_{pri} - E_{sec}$$

Proposed time interval: *24 hours*

7 days

30 days

The KPI for the proposed time intervals calculated for equal/comparable sun radiation conditions.

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2.5.2.4 Grid energy consumption change (K6)

Definition:

The grid energy consumption change KPI compares the grid-injected energy before and after storage implementation. With this KPI, we monitor the energy exchanged between the monitored region/section and the rest of the distribution grid and the increase of renewables share in local energy supply.

Calculation:

$$\Delta E_{Grid}(\%) = \frac{\Delta E_{Grid,Use\ Case} - \Delta E_{Grid,Base\ Case}}{\Delta E_{Grid,Base\ Case}} * 100\%$$

Where

$\Delta E_{Grid}(\%)$ Relative change of grid-supplied energy [%],

$\Delta E_{Grid,Use\ Case}$ Energy supplied from the main grid after the implementation of storage [kWh]

$\Delta E_{Grid,Base\ Case}$ Energy supplied from the grid before implementation [kWh].

Proposed time interval: 24 hours

7 days

30 days

The KPI for the proposed time intervals should be calculated for equal/comparable sun radiation conditions.

2.5.2.5 Current and voltage total harmonic distortion change (K7)

Definition:

Current harmonic compensation represents one of the most salient storage features. The operation of PV inverters highly influences the current total harmonic distortion (THD) of transformers, mostly on power on and power off periods. By monitoring transformer loads, storage operation should compensate highly distorted currents during the most critical periods.

Local voltage harmonic distortion normally represents the sum of offset THD level influenced by the operation of middle voltage level and the influence of the local current on specific low voltage network impedance. Voltage THD improvement, therefore, depends only on the influence of local current THD improvement on the existing network impedance.

Calculation:

$$\Delta I\ THD\ (\%) = \frac{I\ THD_{Grid,Use\ Case} - I\ THD_{Grid,Base\ Case}}{I\ THD_{Grid,Base\ Case}} * 100\%$$

$\Delta I\ THD\ (\%)$ I THD grid change

$I\ THD_{Grid,Use\ Case}$ I THD grid use case

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$I\,THD_{Grid,Base\ Case}$	I THD grid base case

$$\Delta U\,THD\ (\%) = \frac{U\,THD_{Grid,Use\ Case} - U\,THD_{Grid,Base\ Case}}{U\,THD_{Grid,Base\ Case}} * 100\%$$

$\Delta U\,THD\ (\%)$	U THD grid change
$U\,THD_{Grid,Use\ Case}$	U THD grid use case
$U\,THD_{Grid,Base\ Case}$	U THD grid base case

Proposed time interval: 24 hours

7 days

30 days

The KPI for the proposed time intervals should be calculated for equal/comparable sun radiation conditions.

2.5.2.6 Voltage deviation change (K8)

Definition:

The voltage level in the electricity network can deviate from its nominal value due to several reasons:

· A voltage drop is expected along the MV and LV feeder in the direction of the power flow, from the injection location towards the consumption location.
· In intervals with high demand, the voltage profile decrease is significant and in times of low demand, the voltage profile rises.
· Additional voltage profile rise occurs due to distributed RES generation units, connected and injecting power to the distribution grid.
As a result, the voltage profile is variable in different locations of the grid and in different times of the day.

The nominal value of the voltage for a grid Section is the voltage level, which is set on the transformer secondary taps. Expressed in per unit system, it is nominally 1.p.u. In high demand grids it can be set to a higher value (e.g. 1.05 p.u.) or is regulated with OLTC transformer where the voltage level is set by controlling the transformer taps.

Voltage deviation is defined as a relative change of the measured voltage level compared to the nominal voltage value.

Calculation:

$$VD[\%] = \frac{V_{Measured} - V_n}{V_n} \cdot 100\%$$

$V_{Measured}$	Measured voltage level [p.u.]
V_n	Nominal voltage level [p.u.]

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VD Voltage deviation factor [%]

Voltage deviation change due to storage unit implementation is defined as a relative change of the voltage deviation factor between the base case and the study case:

$$\Delta VD = VD_{Base\ Case} - VD_{Study\ Case}$$

When expressed in [%], it is expressed as:

$$\Delta VD[\%] = \frac{VD_{Base\ Case} - VD_{Study\ Case}}{VD_{Base\ Case}} \cdot 100\%$$

Proposed time interval: 24 hours

2.5.3 Device level KPIs for performance monitoring

2.5.3.1 Full cycle equivalents of storage (K9)

Definition:

Full cycle equivalents of storage are the number of the full discharge cycles a storage unit could perform if every cycle of operation includes a full discharge.

Calculation:

$$FCE = \frac{E_{Out}[kWh]}{E_{Cap,nom}[kWh]}$$

$E_{Cap,nom}[kWh]$ The nominal storage capacity of the asset [kWh],

$E_{Out}[kWh]$ Total amount of energy that was extracted from the storage asset during the test period [kWh].

The energy E_{Out} is the integral of the power output $P_{Out}(t)$ [kW] at each time instance t, or directly measured at the device as $E_{Out}[kWh]$. Storage capacity $E_{Cap,nom}[kWh]$ is provided by the manufacturer and is given in the documentation.

$$E_{Out}[kWh] = \int P_{Out}(t)dt$$

Alternatively, the discharging energy is measured:

$$E_{Out}[kWh] = \sum_{k=1}^{n} E_{Out}(\sum_{k=1}^{n} E_{Out}(k)$$

Proposed time interval: 24 hours, 7 days, 30 days

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2.5.3.2 Storage Capacity Factor (K10)

Definition:

Storage capacity factor SCF is defined as the ratio of maximum available capacity compared to the nominal storage capacity.

Calculation:

$$SCF(\%) = \frac{E_{Cap,measured}[kWh]}{E_{Cap,nom}[kWh]} \cdot 100\%$$

$E_{cap,measured}[kWh]$ This refers to the measured value of maximum storage capacity and degradation over time. It is measured once in a specified time interval (e.g. 6 months), by initiating a full charging and discharging cycle if control allows it, under operating conditions (e.g. temperature, power for charging and for discharging). If the storage operation within this interval reaches a state of full charge, the measurement should be saved for that instance as well, since it will help define the degradation curve more accurately.

$E_{Cap,nom}[kWh]$ Storage nominal capacity is provided by the manufacturer and is given in documentation [kWh].

Proposed time interval: 90 days

180 days

2.5.3.3 Storage efficiency (K11)

Definition:

Storage efficiency is defined as the overall system efficiency, comparing the amount of stored energy and energy injected from the device at the PCC back to the network.

Calculation:

$$\varepsilon_{Storage} = \frac{W_{in}}{W_{out}} * 100\%$$

$\varepsilon_{Storage}[\%]$ Storage efficiency [%]

W_{in} Energy stored in the device [kWh]

W_{out} Energy extracted from the device [kWh]

Proposed time interval: *7 days*

30 days

<u>In the case of CAES</u> the storage efficiency o can best be described as the 'Return Trip Electrical Efficiency'. This is the ratio of the electrical energy exported during expansion compared to the electricity imported during compression. Commercial CAES systems need to achieve a RTEE of between 60% and 75% in order to be considered viable. Most of the system energy losses

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are through heat loss to atmosphere. The design aim of an isothermal CAES system is to limit process air temperature rise through high performance internal heat exchange which in turn reduces the heat transfer temperature gradient to ambient. A project specific KPI in respect of heat exchanger thermodynamic performance can therefore be described as the 'process air temperature rise at full power condition'. Note, This KPI value can be measured in compression mode and assumed to be the same value for temperature drop in expansion mode.

2.5.3.4 Device availability (storage or other technical solution) (K12)

Definition:

The reliability of the operating devices needs to be monitored. Device availability is defined as a comparison of the time, or the number of availability checks, when the device is available for operation and the duration of the monitored interval. The fallout duration is determined by measuring the time between the availability checks.

Calculation:

$$DA = \left(1 - \frac{\sum_{t=1}^{N} D_{NA}}{\sum_{t=1}^{N} D_{A}}\right) * 100\%$$

$$DA = \left(1 - \frac{\sum_{t=1}^{N} D_{NA}}{N}\right) * 100\%$$

DA	Device availability (%)
D_{NA}	Device not available check (integer/counter)
N	Number of time instances / number of availability checks (integer/counter)

Proposed time interval: 1 year, 1 month

In case of the CAES availability is determined with application of same formula both for generators, storage units or any other device, or overall performance of a facility, if needed. Availability is the proportion of time that a device or system is in a functioning condition. It is calculated using the following formula:

$$Availability(\%) = \left(\frac{MTTF(h)}{MTTF(h) + MTTR(h)}\right) \cdot 100$$

MTTF = Mean time to failure in hours

MTTR = Mean time to repair in hours

2.5.4 Economic KPIs

2.5.4.1 Change of revenue for the main actors (K13)

Definition:

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Change of revenue for the main actors (end consumer, PV owner, DSO, Storage owner) are defined as the difference between existing revenues and revenues after upgrading the system (storage implementation, PV installation or smart inverter upgrade, etc.). For the end consumer, for example, the energy costs may be lower (costs savings) or new market revenues may be included. For other actors, additional revenues are generated by selling new services, provided by storage (Market operation, balancing services). In aspect of investment the DSOs and other system operators are presented with storage as alternative grid reinforcement measure and savings in comparison to classical grid investments can be made.

By generalizing the $R_{current}$ and R_{new} on monthly or yearly expenses/revenue changes, the problems of missing data and unnecessary details regarding different electricity prices, network costs and missing measurements are avoided. For each demo case, the basic economic differences are calculated, and by their comparison, broad explanations can be given of the differences that occur due to the different business models, electricity price, etc.

Calculation:

$$\Delta P_{Revenue} = R_{Current} - R_{New}$$

$\Delta P_{Revenue}$	Change of revenue [€]
$R_{Current}$	Current, existing revenue (Base Case)[€]
R_{New}	New revenues (Demo) [€]

Proposed time interval: 30 days

1 Year

2.5.4.2 Average cost of energy consumption (K14)

Definition:

This KPI evaluates the cost decrease that can be achieved through demand response. The average cost of energy consumption is calculated before and after the storage implementation with the following formula.

Calculation:

$$\emptyset E, cost = \frac{E, cost}{E, consumption}$$

$\emptyset E, cost$	Average cost of energy consumption [€/kWh]
$E, cost$	Cost of energy consumption [€]
$E, consumption$	Total energy consumption [kWh]

Proposed time interval: 1 month, 1 year

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2.5.5 Environmental KPIs

2.5.5.1 Change of emissions (K15)

Definition:

This KPI has been selected to evaluate the benefits associated with environmental sustainability. The greenhouse gas (GHG) emissions reduction per year and per kWh in % due to the increase of the renewable's contribution to the energy supply in the network is calculated. The Base Case (BC) corresponds to an emissions rate before implementation of the storage, which is compared to the emissions rate of the specific case study (CS).

Calculation:

$$\Delta CO_2 eq(\%) = \frac{CO_{2eq,BC} - CO_{2eq,CS}}{CO_{2eq,BC}} \cdot 100$$

CO_{2eq} describes the global warming potential on a 100-year basis (GWP 100). For its calculation the GHG emissions CO_2, CH_4, and N_2O are included with a life-cycle assessment. In demonstrations using heat pumps FKW, FCKW, HFCKW or CKW emissions are also considered. Besides GHG emissions the reduction of air pollutants (e.g. SO_2, NO_x, NH_3, CO, NMVOC, fine particles) are calculated with the same method.

$CO_{2,CS}$ is calculated with the following formula:

Calculations:

$$CO_{2,CS} = \frac{CO_2[g / kWh, grid] \cdot E_{grid}[kWh]}{E_{Loads}[kWh]}$$

$$\begin{aligned} CO2eq, CS = {} & [g\ CO2eq\ /\ kWh\ grid\ electricity]\ x\ kWh\ grid\ electricity \\ & + [g\ CO2eq\ /\ kWh\ PV\ electricity]\ x\ kWh\ PV\ electricity \\ & + [g\ CO2eq\ /\ kWh\ battery]\ x\ kWh\ electricity\ out\ of\ battery \end{aligned}$$

Proposed time interval: Seasonal

2.5.5.2 Avoided emission cost (K16)

Definition:

Based on the reduced emissions due to a higher share of renewables, the KPI avoided emission cost (CO_2, CH_4 and N_2O) is calculated in €.

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Calculation:

$$CA = \sum_{i=1}^{N} EQ_i * EC_i$$

CA avoided cost [€]

N number of GHG emissions

EQ_i *i*-th emission quantity [t]

EC_i *i*-the emission cost [€/t]

No primary data are needed, all data results from the LCA.

Proposed time interval: *Annual*

Seasonal

2.6 Conclusions

During the definition and implementation of the KPIs we have faced several challenges. First at all, it was necessary to identify the relationship of the aspect we wanted to evaluate and how his impact was expressed in the performance of the demo plants. To detect and evaluate performance modifications we need to compare the current situation once the solution is implemented with the previous situation; that is, we need to define properly the baseline. In a general manner, all the KPIs are defined as a change of the aspect in the Case Study compared to the Base Case. However, the implementation of the KPIs requires a customisation of the KPIs in terms of baseline definition, calculation methods and periods, or data processing.

The level of difficulty to define the base case depends on the demonstration plant and is of special importance in the case of demand response services. It is not the purpose of this report to describe the different methodologies applied to the definition of the base case of each demonstrator, but it is important to highlight that it is a critical aspect in the analysis and evaluation of the performance of the plants.

In the general definition of KPIs, different periods of evaluation (daily, monthly, annual) have been proposed, taking into account when the impact of the parameter analysed would be significant. This aspect also influences the evaluation of the behaviour of the systems. Once the KPIs were implemented, it was observed in some demos that the calculated values were meaningless when measured and calculated during short period and a detailed review revealed the need to analyse the trend of the KPIs over long periods instead of focusing on momentary and unrepresentative values. Deciding what is the threshold from which a KPI is "good" or "bad" is difficult since on the one hand, many KPIs are not completely independent of other KPIs and influence their values and on the other hand, the goodness or not of a KPI depends on the plant since the evaluation must be done globally.

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In addition, for the calculation of the KPIs in numerous occasions, specific aspects of the plant such as the way of calculating the electric bill depending on the country, the treatment of the raw monitoring data to eliminate noise or simplify calculations, etc., must be taken into account. This means that despite defining a common methodology for the demos, the automation of the evaluation through KPIs requires customization based on the specificities of the plant.

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3 MONITORING METHODOLOGY

3.1 Approach

Measurement is the part of engineering that converts a physical magnitude into data, nowadays in a specified digital format. Although a detailed description of monitoring techniques is out of the scope of this document as plenty of literature is available about this topic, a brief review of the main aspects of monitoring to be taken into account is given. This data will later be processed to obtain results or indicators that will give the operator inputs that help to make decisions or have information on the performance of the facilities:

1. **Magnitudes to be measured:** First thing that needs to be clear for the operator are the magnitudes to be measured. As KPI need to be calculated, certain inputs are required. The list should be similar to the one shown later in table 2.6. These are usually magnitudes measured at specific points of the facility. Once the complete list is compiled, for each magnitude, the following specification should be defined:

   i. **Measurement requirements:** Each measurement needs to be defined. There is plenty of literature on this but as a fast review, the following should be taken into account for the definition of measurement:

      a) Range of measurement: The magnitude to be measured has a range of values in which the magnitude is expected to be.

      b) Output signal format: The sensor used to convert the physical signal into a variety of engineering signal formats. A compatible one with acquisition or control system should be chosen. Depending on the field of measurement there are more standardized formats; some of the most widely used ones are 4 - 20mA, 0- 10VDC. If digital meter is used, the device directly provides digital data.

      c) Sampling frequency: Physical magnitudes are continuous signals, but acquisition is performed in a discrete mode. This means that measurements are taken each certain period, called sampling frequency. As one of the basic rules of measuring states, the sampling frequency should be at least twice faster than the dynamic of the physical signal under study. This way, the original signal will be represented without significant distortions and no significant points will be missing in the data log because they happened between the logged ones. Typically for the applications this project focuses on 1Hz should be a reasonable sampling frequency for magnitudes such as temperature, pressure,… electrical magnitudes such as current or voltage if measured RMS and all kinds of power (active, reactive, etc) could rise to 5Hz but as they are linked to inertia of the systems linked as well to temperatures. 1Hz can also be considered sufficient from control point of view. Another important aspect regarding the sampling frequency is the personal information gained from monitoring. With frequent monitoring (1s, 1min, <1h) a lot of information is gathered about the persons, involved in the residential demos. So, compliance with the GDPR [1] must also be taken into consideration.

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d) Accuracy, precision, error: These values indicate different characteristics of the quality of the measurement. ISO 5725 standard specifies them in detail in the magnitude could be considered acceptable for the kind of measurement involved.

ii. **Equipment requirement.** Equipment selected to measure should fulfil the above requirements and besides that the environmental conditions, for instance ambient ranges (temperature, humidity, Ex, IP …), safety regulations (CE), power supply (AC/DC), installation (DIN rail...) and connection requirements. It should be placed where the relevant physical magnitude is taken place. The engineering signal often needs to be sent to a distant point to be collected, so the mean of communication should be previewed (cable, optical fibre, wireless…).

Nowadays, measurement equipment usually provides digital data as a result of the measuring process. These devices include all stages described in the measurement requirements, being transparent for the final user. Digital data is provided to the control and acquisition system through any communication protocol such as Modbus, CAN, etc.

The aim of this Section is to define monitoring requirements at a plant managing level, not at primary equipment control level, the recommendation is to select measurement equipment that includes minimum computation features of the measured variables. For example, physical electric signals to be measured would be the current and the voltage. However, there are a lot of derived variables to compute, such as RMS values, Active Power, Reactive Power, Power Factor, Harmonics, etc. It is not in the scope of this document to supply methods to compute these variables. The same would be applicable for other variables such as mechanical variables. It is supposed and highly advisable that the selected measuring equipment include minimum calculation capabilities to accomplish this task.

Once it has been identified the needed monitoring variables and their origin, it would be necessary to elaborate a table that allows to the database developer to integrate those variables at the database.

For STORY monitoring issues, the common database will store the variables submitted by the different demos. The complete list of the required variables is defined by the KPI list. The database remains available for any other studies on the performance of the demos at the end of the STORY project. Measurements will be stored in raw format (no aggregation), but physical signals (mV) will be converted to actual measurements variables.

SCADA or alternative management systems get data from sensor or measurement devices distributed in the facility. The specification of these devices allows measurement to fulfil minimum quality requirements, so the results are representative.

A table of monitoring variables has been developed aimed at easing the database integration. Furthermore, with the aim of giving a better insight of the monitoring variables origin, a layout has been attached in which it is possible to identify the measurement hardware/equipment used. The table and image below are shown as an example for the demo 3.

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Table 3.1: Example of Variables Details Table

Hardware	Variable Name	Typical Range	Normal Values	Units	Data Type	Error/Tolerance	Read/Write	Comments
Grid Power Meter (#2)	Pgrid	0-500	-	kW	double	-	R	
	Egrid	?	-	kWh	double	-	R	
Loads Power Meter (#1)	Ploads	0-500	-	kW	double	-	R	
	Eloads	?	-	kWh	double	-	R	
Photovoltaics Inverter (#4)	PpvAC	0-200	-	kW	double	-	R	
	PpvDC	0-200	-	kW	double	-	R	
Li-ion Battery Inverter (#3)	PbatAC	0-100	-	kW	double	-	R	
	PbatDC	0-100	-	kW	double	-	R	
	IbatDC	-200-+200	-	A	double	-	R	
	VbatDC	0-800	-	V	double	-	R	
	IrbatAC	-150+150	-	A	double	-	R	
	IsbatAC	-150+150	-	A	double	-	R	
	ItbatAC	-150+150	-	A	double	-	R	
	PrbatAC	-50-+50	-	kW	double	-	R	
	PsbatAC	-50-+50	-	kW	double	-	R	
	PtbatAC	-50-+50	-	kW	double	-	R	
	VrbatAC	0-250	-	V	double	-	R	
	VsbatAC	0-250	-	V	double	-	R	
	VtbatAC	0-250	-	V	double	-	R	
	ItotbatAC	-500+500	-	A	double	-	R	
	Error Trigger	0-1	-	-	boolean	-	R	
	Warning Trigger	0-1	-	-	boolean	-	R	
Li-ion Battery BMS (#5)	SOC	0-100	-	%	double	-	R	
	SOH	0-100	-	%	double	-	R	
	Warning Codes	To define	-	To define	To define	-	R	
General Controller (#6)	General Alarm Trigger	0-1	-	-	boolean	-	R	
	National Generation Mix	To define	-	To define	To define	-	R	

Each field of the table is described below:

- Hardware: this field contains the name of the measuring equipment and the layout identifier of this hardware.
- Variable Name: this field contains the name of the measured variables so as to be stored in the SEP database and to compute KPI values.
- Typical Range: this field contains the typical numeric values of the variable’s values.
- Normal Values: this field contains the normal operation values of the variable’s values. In case the database provides alarm trigger to the demo, this field must be filled.
- Units: this field contains the units of the variables.
- Data Type: this field contains the data type of the variables data. It should suit to the database formats: 64bit integers, IEEE 64bit doubles, UTF-8 strings and binary (8bit octet array).
- Error/Tolerance: this field contains the error of the measure chain of the variables.
- Read/Write: sets whether the shared variable writes or reads data, in other words, the access type.
- Comments: this field is reserved to any other interesting comment about the variable, for instance a short description or any other consideration.

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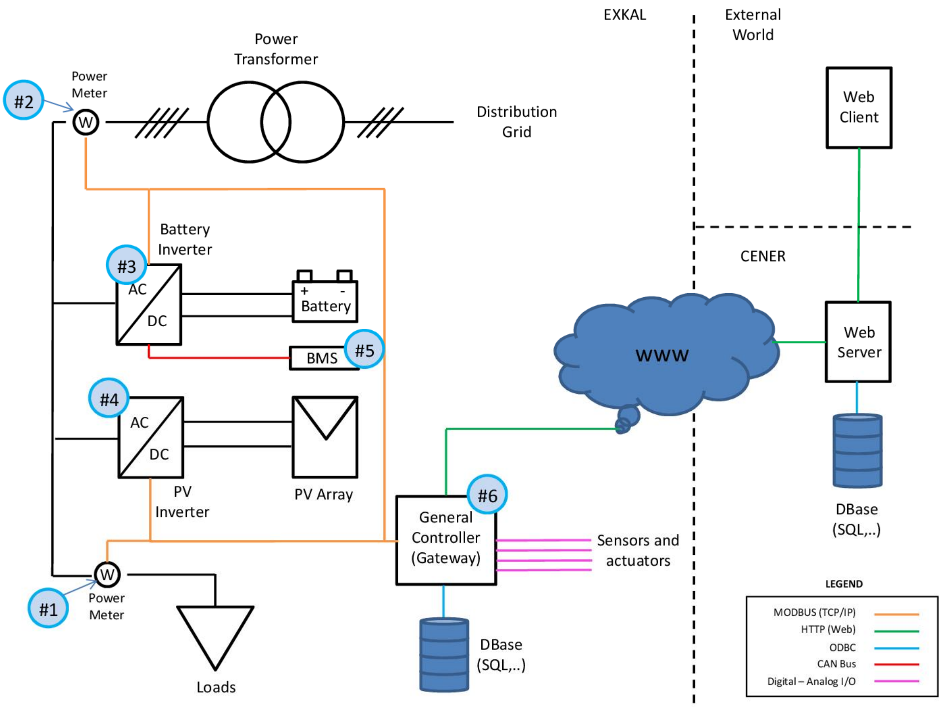

Figure 3.1: **Example of monitoring hardware/equipment layout**

The identifier number must also appear in the hardware list, enabling to identify unequivocally each measuring element.

The list of KPIs and the variables used define the data that needs to be collected from the demos and the method used to perform the data process. Data process will be performed by the Smart energy platform (SEP) with data coming from its data repository. SEP is described in the next Section.

3.2 Data storage

As already mentioned, within the STORY project, a common database has been defined in order to have a centralised repository of demo activities and the possibility of performing performance analysis following the earlier indications. Each demo will have a specific communication procedure with the data base. A description of the technical specifications of the database can be found in the following paragraphs.

3.2.1 Main ideas and areas of application

Base^n platform is a private high availability cloud-based system meant for time series collecting and analysis. System originally started from the needs of industrial and telco network monitoring, where the availability requirements for systems are very high, and is nowadays used in data collection and analysis in various fields, from telco and internet service providers, to smart living and e-health. In the STORY project, platform is used as a shared 3rd layer service, which is

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available to all parties. It can both collect measurement data for KPIs, but also offers a feedback connection for control purposes.

The system is distributed with services announcing their availability and requesting services based on needs. This also makes the system highly scalable as new services can be added on the fly, if there is an increased demand.

The system is redundant with all services being available from several servers (and in commercial installations, from different data centres with redundant internet connections). Similarly, all data is mirrored to multiple physical and logical storages.

All the measured data is stored lossless, data aggregation is done only on demand, so new algorithms can also be tested with historical data. Data is stored with a Unix epoch millisecond stamp (UTC, milliseconds from 1.1.1970) in a format, where all measurements from same source share a common path and then each series has a unique identifier within that path (data identifier that also contains information about data hierarchy, can be thought as a tree, with leaves being separate series). Supported data formats are 64bit integers, 64bit floats, UTF-8 Strings and binary.

In STORY case this means that a separate schema for data is not needed, we just need to know the presentation of devices (what measurements they provide, what are the semantics of measurements and how they are measured). This information is used to create visualization, analysis and reporting templates. Several layers of templates are used, so different templates might be used for each site to create correct data for KPI calculation and then a shared template for KPI long term analysis.

A small dedicated installation of the Base^n platform is used in STORY, it can handle 10k+ measurements per second and several thousand measurement streams analysed for near real time triggers, and more processing capability can be added, if necessary.

3.2.2 Architecture

Agents in the Base^n system are either a small Raspberry Pi like Linux computers collecting data from local bus devices, or proper Linux rack servers either located in customer premises or within Base^n data centers. Agents act as a protocol abstraction layer, reading external protocols (SNMP, SMTP, HTTP, various udp/tcp/ip protocols, modbus, knx, etc, remote scripts over ssh) and transforming them to an internal presentation. Agents also provide a non-volatile cache for cases where internet connection is down. Agents also provide the return route to devices; in case a control signal is needed.

In the STORY case, 3 sites use JSON over HTTPS, one site uses OPC-UA, one ETSI m2m and one monthly excel batch runs for data transport. Both OPC-UA and ETSI require somewhat complex backend to operate, whereas when things are built from scratch JSON/HTTPS is usually the easiest to implement and interface with. All sites are also offered a JSON/HTTPS feedback connection for potential control.

Data receiver layer collects data from all agents and forwards it to both permanent storage and real time analysis. Data is kept in agent's storage, until data receival signals that it has been written to permanent storage.

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The data storage system provides a redundant storing system, where all measurement data is stored raw (it can also be stored sampled/aggregated if so required, but sampling is handled in agent layer) and compressed lossless, so historical data over several years can be used. Data is stored with a millisecond time stamp and optimized for few seconds-few minutes granularity data.

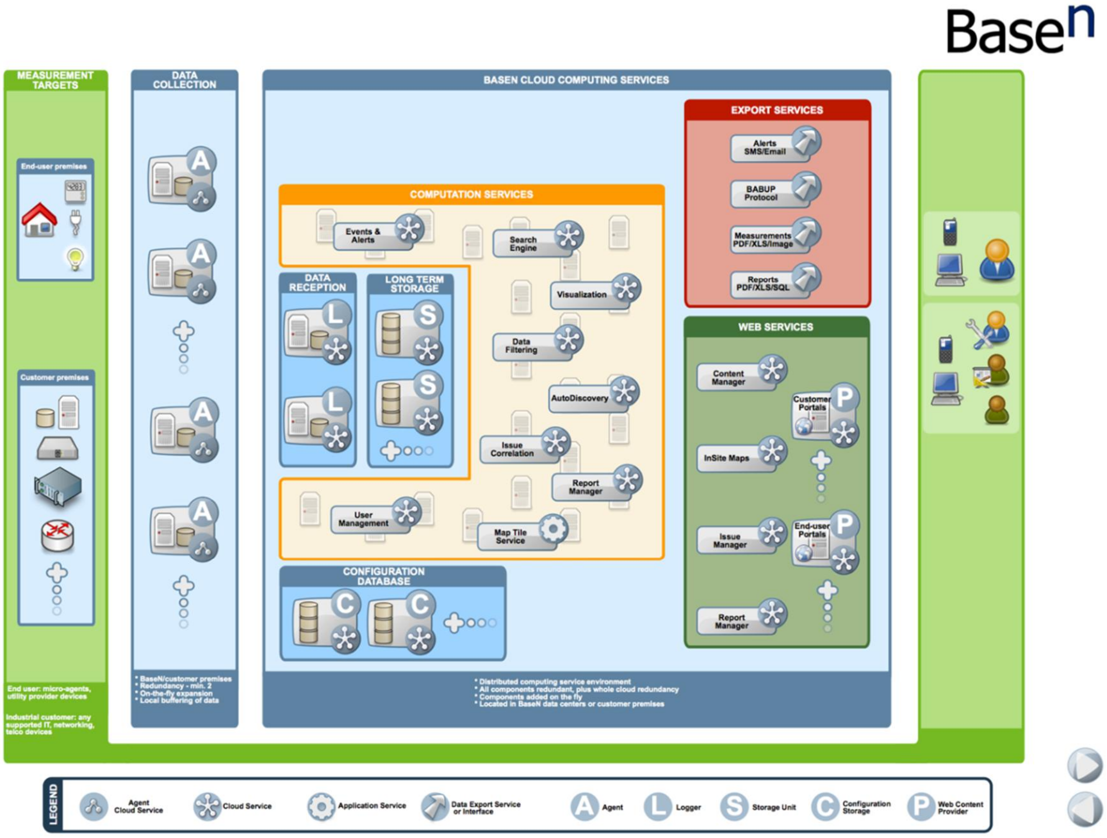

Figure 3.2: Data Base Architecture of the STORY Smart Energy Platform

Both real time and batch analysis capabilities are provided in form of mathematical filters which can be chained together. These include fetching and joining several data channels (streams of measurements from single source), performing sampling, mathematics and visualization. Data can be exported either in xml/JSON over M2M interfaces, or as pdf/excel reports.

Real time analysis (alerting) takes a copy of incoming data stream, checks which streams are tagged to real time analysis and feeds each of the tagged stream to configured filter chains. These chains can then aggregate streams, perform further mathematical analysis and then compare the results to preconfigured trigger conditions. If a condition is matched, a reaction can include a call to m2m interface, SNMP trap, email, SMS or a script being run. In STORY, the real time analysis is also used to monitor the data connection to each site. If site data feed drops, an automated email is generated and after platform side error logs are checked, site admins can be alerted. This both minimizes downtimes and gives site admins more visibility to potential problems.

UI and reporting layers handle how data is shown to the end user. Different users can have different views and restrictions for the data. (So, authentication and authorization are separated.)

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Both the agent and the platform have also capability for control logic. If there are cases where immediate reaction is needed, the script doing data collection can send a command in reply channel of the reaction. And for longer term control, platform has ability to monitor incoming data for specified time and if requested conditions are met, send a command to an actuator. (This second scenario of course needs the actuator to be visible to the outside world, whereas in the first case reply channel of the initial request origination from measured device is used.)

The data submitted from the demo to the SEP for KPI process is usually recorded during the Demo standard operation and simultaneously sent following an established protocol. Data sent to common data base is generally submitted by the communications gateway developed at ICT level 2 of each demo.

Additionally, data is often stored at this level at each demo. Local data bases are usually placed at the demo SCADA system. This SCADA system gets an overall overview of the facility and performs intelligent control on it. Roughly, the system receives data from the different sensors in the facility as inputs, processes the data continuously with internal algorithms and finally as outputs sends command signals and parameters to the different devices installed. Data bases store all input, output, command and state signals, as well as warnings and alarms of the system.

Data bases allow operators to perform tasks related to O&M activities such as predictive or preventive maintenance, updating base cases, investment estimation an offline reconstruction of the performance of the facility. Backup strategies are widely applied to avoid loss of data.

3.3 Reporting

Once data has been collected at the database as explained in the previous points, it is available to be used. Reporting is one of the main tasks usually related to operation and maintenance in facilities. The objective is to have a real idea of how a facility is performing in its different aspects in the fastest and most accurate way possible. In STORY case, beside the information needed to operate the demo, some reports should be free to public access. This access will be done from Base^n database located in the SEP.

With the aim of evaluating the performance of Small-Scale Storage Solution (S4) Technologies, reports must collect the KPI values for the different demos, including graphs and histograms that give a fast overview about the current values and the evolution of the KPIs.

Reports should verify if KPIs fit into the acceptance criteria for each business requirement. Furthermore, a value about the compliance of the business requirements should be given.

In regard to the Demo-Specific KPIs, a differentiated report should be available for each demo, grouping the KPI values and giving a good insight about the system.

In case that some variables had enough specific weight on KPIs values, it would be interesting to provide some information about the values of these variables, for both General KPIs and Demo-Specific KPIs.

The scope of the reports could be framed in two differentiated levels:

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a) **Single Demo Report**

The aim of this report is to give information about the performance of the facilities and provide a mechanism to be able to make corrections in the control and management system.

For the current defined period and for both General and Specific KPIs the report per demo should include an analysis about all KPIs. For each KPI the following information is recommended:

- The result of the computation of the KPI in the defined period. The comparison with the minimum and maximum expected values and with the baseline conditions before implementation.
- Values of main variables involved in the computation of the KPI and that could have a meaningful impact in the KPI values. It could include some trend graphs, maximum, minimum, average and the typical deviation values.
- A graph showing the evolution of the KPI values along the time.

One report of these characteristics must be generated per demo.

In Figure 3.3 the schema associated to specific demo reports is shown.

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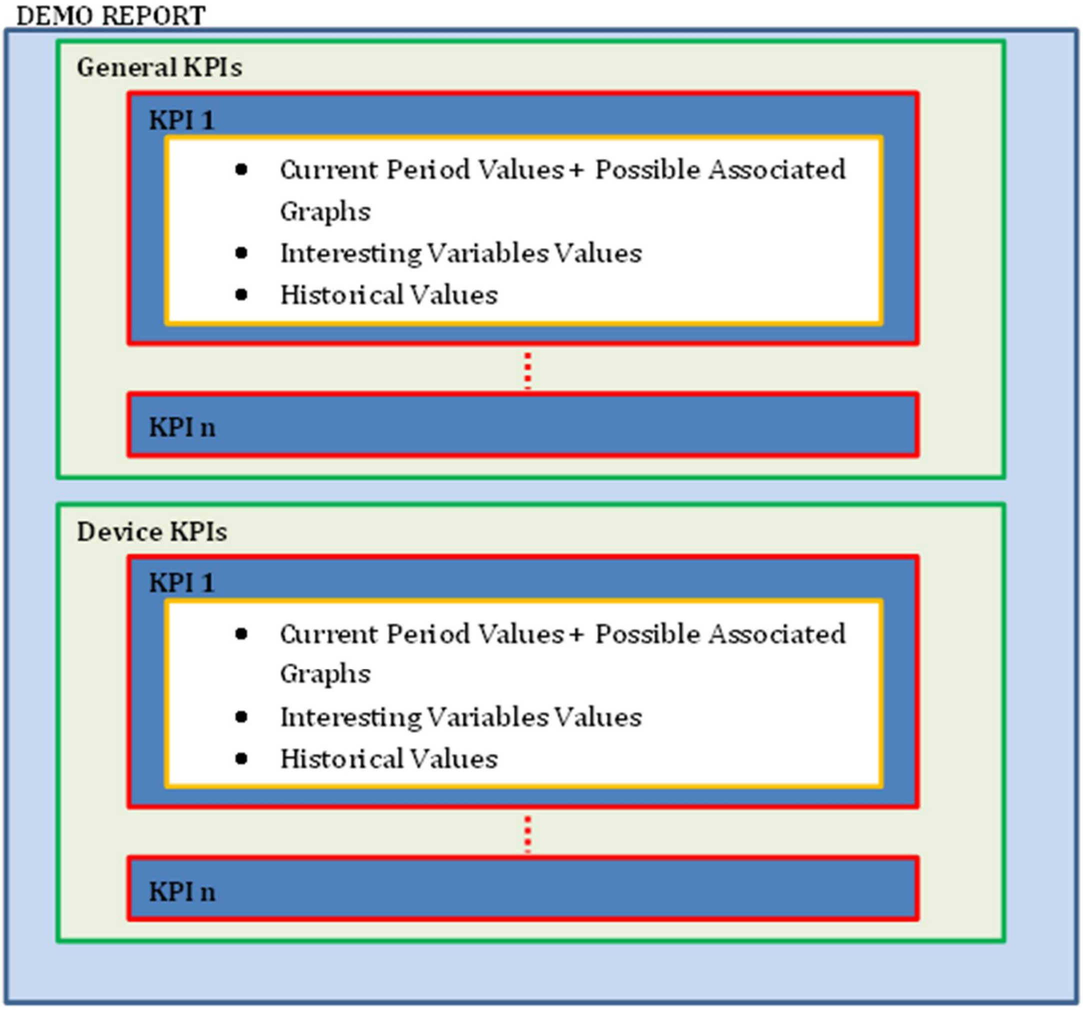

Figure 3.3: Specific Demo Report Schema

b) Overall STORY project Report

The aim of this report is to provide the method to assess general performance and give information about the general performance of all the project demos. With this report it is possible to compare the performances of each demo and to improve those demos in which the results are below the expected values.

For the current defined period for each General KPI the following information is recommended:

- A table with the values of the General KPIs per demo. The information could be organized in a unique table or in a table per KPI.
- A graph that makes possible to compare the results among demos.

For the current defined period for each Business Requirement and related Use Case, the following information is recommended:

- A table with the level of fulfilment of the Business Requirements. The computation of this degree of compliance could be obtained from a computation that involves the KPIs

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with different weights related to the Business Requirement. The information could be organized in a unique table or in a table per Business Requirement.

- A graph enabling the comparison of the results among demos.
- A graph with the evolution of the business requirements per demo.

In Figure 3.4 the content associated to specific demo reports is shown.

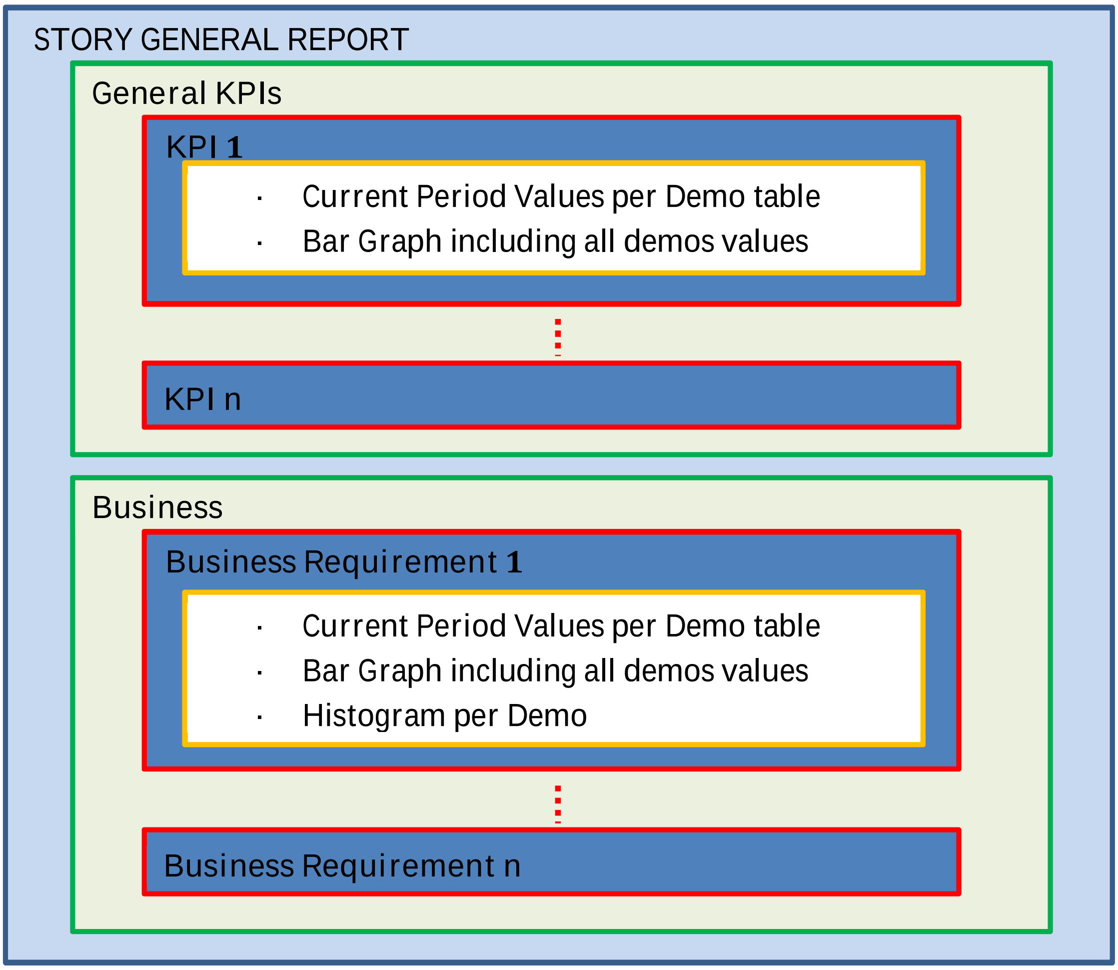

Figure 3.4: Overall Project Report Schema

The following example shows an automatic KPI generation in a case where site has PV generation and goal is to have at least 10% of the monthly power usage from PV generation. The underlying system collects power consumption data from multiple meters and sums them into single measurement called Grid Power. Another measurement channel called PV Power shows the average power from PV. First graph shows average values for these per day for the month and next shows the KPI (PV/Grid ratio) for the current month. The final graph shows the KPI for the current year. These values can also be imported into excel, csv etc. KPI reporting will happen monthly, but the values and graphs are available always, both for current and historic data.

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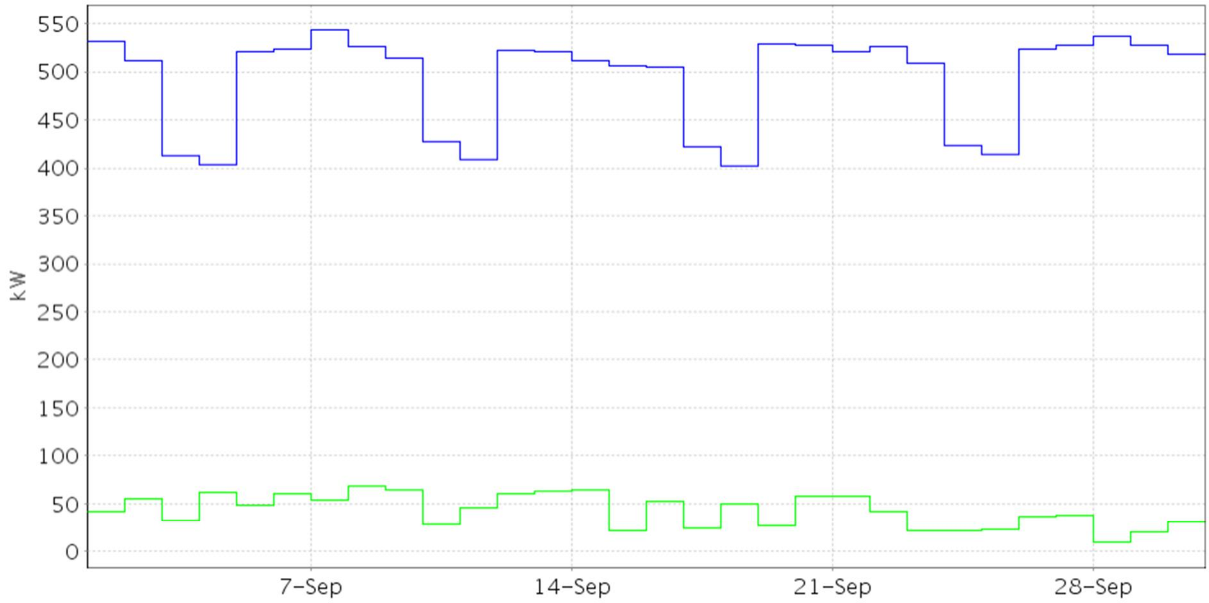
Power generation and consumption (01/09/16 00:00 - 30/09/16 23:59 EEST (UTC+0300))



Month | Year | Calendar | < | > | + | - | Apply to all | Reset | Popup | More...

	Name	minimum	average	maximum	last value
	Grid power	401.82	493.1	543	518.21
	PV Power	9.4227	42.818	69	30.809

Figure 3.5: Example of monitoring report: PV energy and consumption

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Figure 3.6: Example of monitoring report. PV energy/Load ratio daily and yearly

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3.4 Conclusions

In this Section we have established a common methodology to define and design the monitoring infrastructures for microgrids and distributed systems including energy storage technologies.

Monitoring systems are needed for two main purposes: safe operation or control of the plants and supervision and performance evaluation (KPIs). Generally, the operation of the plant is most demanding in terms of monitoring requirements. Nevertheless, many measurement devices (sensors, actuators, PLCs, etc.) depending on the control level, are implemented in the equipment (e.g. thermocouples or voltmeters in batteries) or take part of the hardware for controlling. Supervision takes advantage of those monitoring devices by gathering signals and alarms for later analysis and usually additional measurements are not necessary.

The monitoring methodology developed in the STORY aims to define the monitoring systems of the demonstration plants, minimizing costs without jeopardizing the operability and observability of the plants. The methodology is also extrapolated and can be applied in large-scale deployments.

The approach is based on the identification of the data to measure and the technical requirements in terms of collecting time, frequency, accuracy, etc. that data should meet depending on the aim: KPIs assessment or demo operation (control). The equipment used for monitoring and collecting data is also identified per demo plant in order to later select the most suitable monitoring devices for these purposes and to avoid duplicities. Moreover, data are collected and stored in the STORY database where KPIs calculation is automatized and the performance evaluation of the demos through KPIs assessment is developed.

In summary, the common methodology comprises the common aims and KPIs of the diverse demo plants and their corresponding monitoring methods including data measurements, data requirements, equipment and other issues to be used as guideline for future pilot plants setting up.

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4 THE STORY STAKEHOLDER ENGAGEMENT METHODOLOGY

4.1 Overview

The methodology below is designed to support demonstration leaders in engaging their relevant stakeholders. An engagement activity implies a *"two-way, relational, give-and-take between organisations and stakeholders/publics with the intended goal of* (…) *making decisions that benefit all parties involved"*[1].

The methodology therefore envisages an engagement process between demonstration leaders and their stakeholders, leading to the co-development of Stakeholder Evaluation Criteria (SEC), on the basis of which stakeholders assess the success of the demonstration's technologies. Specifically, the methodology sets out a process of mapping stakeholders and selecting key decision-makers, understanding and co-developing their criteria, through which they evaluate the technologies, and a system to monitor these.

4.2 STORY demonstrations and stakeholder monitoring methodology

"The main objective of STORY is to show the added value storage can bring for a flexible, secure and sustainable energy system."[2]

Each demonstration sites entails a wide range of stakeholders, from engineers installing equipment to private customers that consume the energy. Within the context of WP6 ('Monitoring and Evaluation') however, the interest is in those stakeholders that will take decisions on whether to adopt storage technology after the demonstration ends. The objective is to roll out storage technologies, and therefore engagement activities are to be focused on those stakeholders that make decisions on what type of energy system to use ('decision-makers').

As outlined in this document, the six STORY demonstration cases reflect different scales and types of energy use, ranging from residential households to industrial factories. The people making decisions on storage technology will therefore vary from one demonstration site to another. In the residential context this may be the owner of the house, and at the factory level it may be the finance director or CEO. It is also likely that the people making the decisions will want to first discuss the pros and cons of energy storage with others. The owner of the house will talk to other people living there e.g. spouse / partner, children, parents, neighbours etc. Likewise, at the factory level there will be discussions with colleagues, shareholders, board members and even customers etc.

Following these discussions, the stakeholders will normally have a clear idea of what their interests / concerns in storage technologies are. These factors may be objective and relate to the costs involved, the reliability of energy supply etc., but may be influenced by other factors such

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[1] Taylor & Kent (2014), 'Dialogic Engagement: Clarifying Foundational Concepts', in *Journal of Public Relations Research,* vol. 24, p. 391

[2] Project Summary p.3 of the STORY Grant Agreement Amendment AMD: 646426-3

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as a concern for the environment or interest in new technologies. Whatever the motivation, these criteria will be used to decide on whether to adopt storage technologies or not.

These aforementioned factors stakeholders developed form the basis of the key stakeholder evaluation criteria (SEC) needed in WP6. If the demonstration sites are able to meet the criteria, then there is a high likelihood that the stakeholders will continue to be interested in and use storage technologies after a project's end.

What follows below is a step-by-step guide outlining the above approach, and an additional tool to arrive to these SEC to be identified, monitored and evaluated.

4.3 Stakeholder engagement methodology: identifying stakeholders, co-developing Stakeholder Evaluation Criteria (SEC) and monitoring

Step 1. Identifying Stakeholders and Decision-Makers

Each demonstration site works with a broad range of internal and external stakeholders. For the purposes of WP6, we are further specifying stakeholders as decision-makers: i.e. within a broad stakeholder group, we need to further identify the individuals that take decisions on energy systems. In all likelihood, demonstration leaders already know the decision-makers as they may have been involved in giving permission for the demonstration. However, to make sure you have identified the right person(s), ask the stakeholders in your demonstration:

Q. "After the demonstration project ends, will you invest financial resources in buying this storage technology and using it for your energy supply?"

If the stakeholder replies that this is not a decision they can make, then find out who can take the decision. It is likely that several stakeholders will be involved in taking decisions rather than just one individual. Map the different stakeholders and try to set up a meeting with them all together.

Step 2: Identifying Criteria Used by Decision-Makers.

The objective of the meeting is to understand why the stakeholders are interested in storage technology and the criteria they will use to measure whether this is a success or not. Find out what motivated them to get involved in the demonstration site and if they have any ambitions for using storage technology in the future. The specific question they should answer is:

Q. What results (outputs) from the demonstration site would persuade you to adopt this storage technology?

When collecting answers from stakeholders, you may get a mixture of objective and subjective criteria. Objective criteria can be based on a cost-benefit analysis, or new business model etc. Subjective criteria may relate to larger strategic goals such as improving the environment or moving away from fossil-fuel dependency.

From the list of criteria, ask the stakeholders to select the "make or break" issues that are central to the decision-making process. For example, a stakeholder may say that they are committed

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to finding an alternative energy supply but if the cost is higher than €xxx,xx then they will not make the switch. In this case the price is the "make or break" criteria.
Step 3: Co-Developing Stakeholder Evaluation Criteria (SEC) Ask the stakeholders to limit the number of "make or break" criteria to around 3 or less. For each criterion they select, we need to find a SEC that is relevant to your demonstration site and that is relatively easy to monitor and evaluate. The idea here is not to create more work but rather to find a SEC in your demonstration site that the stakeholders find convincing. To help this process, ask the stakeholders: *Q. "How can we monitor your 'make or break' criteria in the demonstration site so that it provides the data you need to make decisions on storage technology?"* Once you have identified the relevant SEC, agree with the stakeholders how often this should be monitored and how they would evaluate its success / failure. Since SEC is not technical parameter, it is not included in measurement database. It is more connected to the social aspect and it needs to be evaluated differently.

4.4 Stakeholder Engagement Tool

With the above guide implemented and in place, a demonstration leader will have a set of very robust SECs that are of interest to their stakeholders and can help them make a commitment to investing in storage technology.

The Table 4.1 below details further guiding questions for implementation of the methodology, serving as additional background.

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Table 4.1: Guiding questions examples

Level	Aspect investigated
Demonstration Site	Q. Location + context of demonstration site.
Organisation / House	Q. Which entity is hosting the demonstration site?
Decision-Makers	Q: Who will make a decision on energy system when the demonstration site ends?
Decision-making criteria	Q. What results (outputs) will persuade stakeholders to adopt storage technology?
Make or Break Criteria	Q. What are the dealmakers / breakers?
SEC No1	Q. How can we monitor and evaluate the dealmaker?
SEC No2	Q. How can we monitor and evaluate the dealmaker?
SEC No3	Q. How can we monitor and evaluate the dealmaker?

4.5 Stakeholder Interest in Storage Technology

From the interviews with all the demo leaders, which represent main stakeholders and research conducted at each STORY demonstration site, we can categorise the principle interests of stakeholders towards storage technology under five broad headings.

a) Sustainable Economic Development.

In all demonstration sites, stakeholders have a general interest in finding sustainability economic activities that reduce impacts on the environment. Generating and storing electricity from non-fossil fuels or nuclear sources is therefore an attractive option if it is reliable and affordable.

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However, the interest in STORY storage technology is not limited to access to energy, but also covers additional aspects of sustainable economic development. In one demonstration site the main aim was how to handle waste generated by economic activity. STORY storage technology therefore contributed to sustainable waste disposal through incineration that generated heat and electricity. For many stakeholders, the technological innovations are seen as a benefit in themselves. Stakeholders are keen to try new technologies that can help make the transition to more sustainable economic activity. This is related to the issue that resources will become scarce and more expensive and we therefore need more efficient technology that does not rely on traditional fossil-based resources. It is also anticipated that the price of electricity will increase as fossil fuels become more expensive. The new storage technology should therefore provide a hedge against these costs.

b) Positive Image.

All stakeholders, ranging from residents in the Oud Heverlee demonstration to entrepreneurs in the B9 Energy Group, believe that involvement with the new storage technology has a positive impact on their public image. Private residents said that through participating in the local energy community they generate a positive impact in their street, with neighbours talking to each other and becoming a closer, more caring neighbourhood. They are not only building an energy community but also a social community. From a corporate perspective, stakeholders perceive a range of advantages for their business. Their corporate profile is enhanced as they are invited to give talks on the new technology, get media enquiries and are invited to join different business platforms. The companies become associated with innovation and cutting-edge technology, which gives them more of a dynamic feel compared to their competitors. This has in turn been positive in setting up new business ventures with clients and business partners who are attracted to the innovation mind-set. The companies are seen to be part of the solution in the big picture on climate change and new economic models, rather than as part of the problem. Finally, engaging with new technology has helped with staff recruitment and retention. Workers find it more attractive and interesting to work for companies that innovate and find creative solutions, than those focused only on profits.

c) Regulation.

Both private residents and companies anticipate that STORY storage technology will help them meet new regulations on energy, pollution and climate change. Compliance with environmental targets, low emissions, pollution and waste is likely to increase and STORY storage technology can help companies and private citizens meet these regulations. The regulations may also create new business opportunities for companies such as B9 who hope to disrupt traditional energy markets with the compressed air energy storage technology they are developing. In all demonstration sites, regulations are a challenge but also an opportunity to disrupt markets and sell services derived from the new storage technology. Companies also see an opportunity to use regulatory compliance to position themselves as ‘official’ service providers and use compliance ‘labels or certificates’ to compete with companies that do not fulfil these standards. This also means that should the regulations change or be interpreted differently the advantages of STORY storage technology could be diminished or disappear completely. For example, if regulations on the disposal of waste wood change then the Beneens demonstration technology could become economically redundant. Finally, in some demonstration sites the national and European

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regulations are the barriers that prevents the roll out of STORY storage technology, as we have seen in the Spanish demonstration.

d) Business Case.

None of the stakeholders are engaging with the STORY project for purely altruistic reasons; the business case must make sense. This means that having a reasonable expectation on reducing energy costs is an important consideration. However, the cost savings do not need to be immediate; indeed, most of the business stakeholders calculate the cost-benefit over the medium to long-term. The calculation is also heavily influenced by the funds being supplied by the STORY project to purchase and install the storage technology. If the stakeholders had to buy and install the storage technology themselves with no subsidy or reduction on costs, the cost-benefit analysis becomes largely negative.

Most stakeholders also see the cost-benefit linked to whether the storage technology can contribute to the overall economic health and growth of the company. The calculation is not strictly limited to the price of energy but more holistically to the additional advantages of public image, sustainability, regulations etc.

Finally, for the business demonstrations in Spain, Slovenia and Northern Ireland, the expectation is that STORY storage technology helps grow their market share and increase profits through the sale of energy and related services. This might be through using the technology in new markets in Africa (Exkal), flexible supply to villages and communities (Electro Gorenjska) or major electricity market penetration (B9).

e) Technology.

The storage technology generates considerable interest amongst most stakeholders, there is a natural curiosity to see what options and possibilities are being created to store and use energy. However, this curiosity can quickly evaporate if the technology proves to be overly complex and not reliable. Most stakeholders need the technical solutions being proposed to be (i) reliable in the delivery of energy / electricity to the same level as conventional supply, (ii) be available on the market to buy and install with minimum complications or waiting times and (iii) be compatible with other technology for using and regulating energy / electricity. The interest and excitement that engineers and researchers have in experimenting with new storage systems to see what works and does not work, is not shared by stakeholders.

A second important consideration for some stakeholders is whether the technology itself can become an attractive product to sell and generate profit? This is most clearly seen with B9 and the compressed air technology but is also relevant to the other demonstrations.

Finally, some stakeholders want to know if the storage technology is going to deliver sustainable and environmentally-friendly energy? Burning waste wood and using batteries is not obviously good for the environment; particularly the manufacture and disposal (recycling) of batteries can be problematic and harmful. Stakeholders understand the need to find ways of storing electricity generated by renewables, but if the storage technology is polluting and unsustainable then it loses its attractiveness when compared to traditional electricity generation, that is more reliable and price competitive.

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5 COST OF MEASUREMENT

5.1 Introduction

An important aspect that needs to be taking into account when evaluating the business case of the roll out of smart grid solutions, is the actual cost of gathering the data to operate a service. This Section contains and discusses detailed cost calculations for 3 demonstration sites, which differ significantly concerning measurement equipment and its integration in the overall system. Next, a discussion of the cost of measurement in general is included. It provides strategic insight concerning the cost of measurement in smart energy installations. Finally, the integration of the cost of measurement in the CBA of the overall installation/demonstration is discussed.

5.2 Cost of Measurements in 3 demonstration sites

For a selection of 3 demonstration sites, the cost of measurement on site is calculated. This Section discusses the demonstrations sites overall. Detailed cost information for each of these sites is provided in annexes I, II and III. The selected sites are located in Oud-Heverlee, Belgium (a residential building), in Navarra, Spain (a factory in an industrial zone), and in Olen, Belgium (multi-energy grid in an industrial area).

Looking at the simplest – from a cost of measurement viewpoint – site, the ***Navarra demo site*** did not require any specific monitoring equipment solely intended for measuring. All measurement equipment is part of a larger system and it is necessary for this system to function properly. From annex I – providing detailed information – most costs are included within the overall cost of not-only-measurement equipment (i.e. the cost of the measurement part is not available separately).

From a site CBA perspective, these larger systems are an “all-or-nothing” decision, which avoids the requirement to know the cost of embedded measurement equipment for the site CBA. In the demo case, for the measurement equipment for which the cost can be identified, the total amount is small relative to the overall investment (e.g. 695,- euro for a power analyser and 262,50 euro for 3 current sensors versus 55 000,- euro for the MM60 micro-grid manager and 199 000,- euro for the batteries). Moreover, the separately acquired measurement equipment is needed for the proper operation of the overall system; it does not serve its own “benefit”. Thus, the cost of measurement within the Navarra demo site has no distinct own CBA in which a benefit from a measurement is identified against the cost of measurement.

At the ***Olen demo site***, the cost of measurement equipment can be identified (see Annex II for detailed information). In total, digital measurement devices and the connected computer amount to 17 080,- euro. Relative to the overall cost of the installation, this is small, which implies that equipment to enhance system integrity (e.g. system health monitoring) is likely to have a positive CBA result on its own.

The main purpose of the measurement devices is to render the overall system smart. Accordingly, an Olen site CBA needs to include also the cost of actuation, structural elements (i.e. steel and concrete), etc. and compare the benefits of the smart system, enabled by the sensors and actuators, with a dumb baseline system and/or other smart alternative. Overall, the cost of measurement is unlikely to determine the viability of a smart energy installation.

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Finally, the ***Oud-Heverlee demo site*** is *de facto* a laboratory, which allows to experiment with a large number of possible smart energy systems. Accordingly, the system is well-equipped regarding measurements devices and actuation devices. This high degree of instrumentation allows to assess a number of configurations, each of which requires a subset of the installed measurement devices.

Cost of Measurement – Oud-Heverlee demo site	
Thermal Lab - Energy Monitoring Cost	18.449,43 euro
Battery - Energy Monitoring Cost	798,53 euro
2 seasonal storage tanks & DHW tank	9.758,46 euro
Mains - Energy Monitoring Cost	290,31 euro
IT Equipment & Data Storage	4.688,95 euro

The cost of measurement is more significant compared to the above demo cases for two reasons. First, it is not a single-purpose candidate end-user installation, which the two demo sites above are, but an installation to perform experiments. Each experiment corresponds to a possible end-user installation. Each experiment requires a subset of the measurement devices and will have its own CBA to assess its performance and/or characterize its behaviour.

Second, the capital investment of the envisaged end-user installations is much lower than in the above industrial installations. As it is likely to be a larger part of the overall costs, the cost of measurement in this domain needs to be considered in an overall CBA; it is likely to have an impact on the viability of the candidate end-user installations. On the other hand, the CBA for the demo site itself needs to determine the benefit to society and the EU of this laboratory rather (and not as an end-user installation). This CBA is out of scope for reported activities of this task in the STORY project.

Overall, the demo sites exhibit significant difference concerning the cost of measurement. As concerns CBA, a stand-alone CBA looking at the benefits of a measurement versus its cost revealed to be largely irrelevant. The measurement equipment is present to allow the installation to be smart, and thus measurement contributes to the benefits brought about by the smartness of the entire installation. In conclusion, a CBA for the cost of measurement weighs the presence/absence of a measurement device against the performance of the overall installation. Ordinarily, the absence of a measurement device prevents the installation from operating (smartly) as a whole.

5.3 Cost of Measurements in general for smart energy

While calculating the cost of measurement for the selected sites, the complexity of real-world situations became obvious. Keeping in mind the ultimate objective of WP6 – to support business cases in determining whether a case is worthwhile pursuing and/or which business case shall be preferred among a number of candidates – this Section presents insights on how to address measurements and the associated costs on a strategic level.

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The purpose is to provide a context in which the KPI's – i.e. 1-dimensional scalars derived from a multidimensional reality – are to be understood properly and correctly. Indeed, all too often a community consensus on the calculation of numbers (performance indicators) will be a best-effort and compromise. Failure to account for such imperfection is likely to maximise the impact of the approximation errors (e.g. maximize turnover instead of net added value).

After introducing the challenges related to "establishing what the cost of measurements is", this Section presents key notions of cost accounting. This will help the uninitiated reader. Moreover, it provides a vocabulary, equally establishing the level of depth and detail, for the discussion. Finally, the factors, structures and elements that impact and/or determine the cost of measurements are discussed.

5.3.1 Challenges

Defining the cost of measurement in smart energy installations, applications and operations is challenging. In particular, many costs – i.e. capital investments and operational expenses related to equipment, services, etc. that are needed by the measurement activities – cannot be assigned to the measurement functionality in their entirety. And, it is hard to assign a percentage. Unless considered in a specific situation and instant in time, such an assignment would be mostly arbitrary, which is not acceptable. This 'discussion in general' targets precisely on this arbitrariness and how to manage it.

Furthermore, STORY aims at knowhow, knowledge and information that is usable beyond its own innovation action (i.e. maximise impact and replication potential). Looking into the (not so distant) future, disruptive technology can be expected to change aspects of the cost of measurement drastically (especially when accompanied by suitable regulation). Such changes may reduce certain costs by orders of magnitude, not only in financial terms but also in technical ways (e.g. reduce the delay between measurement and data availability). This 'discussion in general' intends to illustrate what is likely to happen, how this is beneficial to society, and how this may 'change some games' entirely.

However, the next Section first sets the scene by discussing cost calculation principles in view of these challenges. In particular, the arbitrariness of assigning costs is addressed (i.e. how the avoid it).

Example of full costing causes poor decisions.
Profit center A needs an expensive crane for three weeks. It has an offer from profit center B (same owner) that includes the estimated wear (€1500) and depreciation costs (€10 000). Profit center A also received offers on the open market. At the time, excess capacity characterizes the market and some crane rental companies offer really sharp reduction in prices (€5000). Profit center A goes for the €5000 offer. The owner (of both A and B) spends €3500 (€5000 -€1500) plus the expenses related to the idling crane (in profit center B), i.e. financial costs (cost of loans, missed return on investment in financial products) and technical obsolesce (e.g. when crane models with lower operating costs enter the market).

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5.3.2 Cost Accounting 101

The purpose of cost measurement in smart energy in general and STORY in particular is decision support (and e.g., not calculating taxes due). In cost accounting, there exist various systems, and there are significant differences as regards their suitability and/or correctness when used to make decisions.

Full costing – the old-fashioned one – is utterly unsuited as a basis for decision making. Among others, it considers sunk costs as subjected to the decisions that are to be made (and, by definition, sunk costs cannot be avoided whatever is decided). Second, it assigns all kinds of overhead costs in manners that do not reflect the decisions and their impact.

A classic example of how this leads to poor decisions is a profit centre deciding whether to outsource or utilise heavy/expensive equipment from another profit centre (with the same owner). When deciding to use the in-house equipment, depreciation costs are assigned to the profit centre that uses it. When deciding to outsource, the equipment will be idle, but the depreciation costs are either assigned to the 'depot profit centre' (when based on time) or put on hold (when based on running hours logged on the controller of the equipment). Here, full costing may result in outsourcing when the best choice overall is to use in-house equipment. Overall, decisions based on full costing are only useful to (ab)use power (by pretending not to understand the mistake).

Direct costing – the theoretically correct one – avoids the issues with full costing completely. It calculates the inflows and outflows (i.e. the estimated net present values) for the complete system and for the duration under consideration (i.e. to compare candidate scenarios). Sunk costs are – by definition – the same for all candidates (each corresponding to a possible set of decisions) and, thus, sunk costs do not affect the selection of a final outcome. Overheads, e.g., covering shared services, do not have to be assigned to specific decisions, activities or equipment. E.g., when the combination of Measurements, Controls and User Interfacing exceeds a bandwidth threshold and the cost of communication rises (i.e. bandwidth exceeds the basic package and a premium package is needed), direct costs can be calculated without assigning the extra expense of the premium package across its users.

As there is no such thing as a free lunch, direct costing often is a difficult, expensive and time-consuming exercise. In particular, it fails to offer a way to divide the work, the costs, … along the lines of the organisations concerned (departments, profit centres, households, or control, measurements, billing, access control, etc.). Consequently, it often is not applied in practice.

However, direct costing is the model that should be in everybody's' mind when participating in a collective decision-making activity. And, failing to understand the concept of direct costing (to assess the approximations and deviations made by using other costing methods) shall be considered a case of "politician's dementia", especially when the inaccurate costing leads to a selfish-advantageous conclusion from the perspective of the person (faking to) not understanding the direct costing conclusion/correction.

Marginal costing, activity-based costing, etc. all attempt to avoid the issue with direct costing without incurring the flaws of full costing entirely. Cost of measurement seems to favour activity-based costing. While intending to render cost accounting more doable, the reintroduction of arbitrariness all too often comes with a very significant price tag. It leads to poor decisions, it demotivates the more intelligent persons, it leads to long discussions and undecidedness, it leads

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to artificial compromises and working conventions that are not open for questioning, also when they should be questioned. In fact, the more arbitrary a convention or reference model is, the more painful the negotiations are, and the more closed-for-discussion the model or convention will be. Indeed, fully justified models or conventions do not (need to) fear discussions.

Overall, the challenges facing the cost of measurement analysis clearly include this arbitrariness of assigning costs, where these hard-to-assign costs cannot be ignored in many situations in the foreseeable future for smart energy (i.e. they can be a major part of the costs). Thus, it is relevant to know facts and figures from an activity-based costing perspective or a marginal costing perspective. But it is crucial to understand the possibilities, alternatives and candidate solutions from a direct costing perspective. Importantly, this direct costing understanding will cover decision making that looks into futures where disruptive technologies or regulations create opportunities.

5.3.3 Cost of measurement in smart energy

5.3.3.1 Measurement equipment

In the energy domain, measurement devices (sensors) constitute a cost factor. These devices have to purchased and installed (in most cases by professionals), and the corresponding invoices need to be paid. At first, this appears to be a straightforward direct cost for cost of measurement. As is to be expected, reality is more complicated.

Installation costs vary greatly. When installing a device within a perfectly planned and perfectly executed green field project, typical installation costs will be minor. On the other extreme, adding a low-cost sensor to an existing installation, either to upgrade or repair, can be costly when e.g. isolation material needs to be removed and replaced, when workers have to sit in traffic jams to perform a one-hour task.

With complex installations, mistakes are bound to happen. Flow meters may be exposed to high temperature (and need replacement) or turbulent flows when a pump is installed too closely (and perform badly). Undoing those mistakes represents another cost element (e.g. quantified in an insurance fee), again possibly costing more than the measuring device.

Learning curves and critical mass will cause these costs to drop over time. Qualified personnel and experienced planners – adopting and adapting a familiar design – will make significantly less mistakes and waste less time due to poor coordination. Of course, when technology keeps changing too rapidly, we may never get to enjoy this.

Larger installations usually are one-of-a-kind. They are designed by engineering firms where the learning curve results in a body of knowledge and knowhow. The installation is built from well-known and reliable components. As a result, there are less mistakes, more effective and efficient organisation is provided in this manner. But such knowhow and expertise will be billed/assigned to the customer/installation. In other words, even intangible costs are relevant.

Likewise, when smartness gets into a next stage, a measuring device itself may address these issues and induce more cost-effectiveness. Also, smart devices may provide leverage to qualified personnel ("the proverbial guy/girl who know how it should be done") to manage a large number of installations and less-qualified personnel (i.e. supported by these highly-paid experts).

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Overall, the cost of measurement will be impacted by conditions and circumstances where a suitable strategy is likely to make a difference. E.g. smart devices that know how they need to be installed and used to avoid costly mistakes. E.g. redundant installation of low-cost devices to avoid expensive repairs/replacement when some of them malfunction.

5.3.3.2 Embedded measurement devices in other equipment

In many installations, there are sub-installations that contain both actuators and sensors (e.g. a heat pump or CHP). And, their vendor only provides a purchasing cost for the sub-installation as a whole. What is the cost of measurement here, if this data is accessible for third parties? More relevant, what cost information remains useful and relevant for impact creation, i.e. for assessing which smart energy solutions to adopt? Again, a strategy or approach to look at a broader picture is indicated.

Moreover, embedded measurement devices can contribute in two manners. Always, they serve the sub-installation in which they are embedded. Trickier is access to the embedded sensor data from systems and applications that are external to this sub-installation. From a practical stance, that's decided by the designer/vendor of the sub-installation.

From a societal perspective, poor access to embedded sensors results in underutilisation of scarce resources. Worse, often it is technically impossible to add a sensor (duplicating the embedded sensor) to get the data without the cooperation of the sub-installation. This adds costs through the suboptimal operation of the overall installation and/or increases efforts when a work-around needs to be developed and maintained. As an example, the battery management within e-vehicles and their charging station can be closed to third parties. Even if technically possible (to access it on the CAN-bus), it may violate legally binding agreements, render warrantees to be void and, technically, may require checking and adapt the own software after every update from the 'hacked system'. This is true in case of large customers, they can state that API need to be public/opened, or they will change supplier for example.

Again, the cost of measurement reveals to elude naïve views. Embedded measurement devices do not have a separate price tag. And, when monopolising access to relevant parts of the energy equipment, they rarely are truly available beyond their sub-installation. How to address this last issue goes beyond the discussion in this document (Note: T3.6 and T3.7 address this kind of issue). Note that access to embedded sensors and, most certainly, actuators can be subject to certification and/or authorization. But first, the systems need to be designed such that certification and authorization does not require software maintenance/redesign.

5.3.3.3 Operational costs

Although mostly very small, digital measuring devices constantly consume electric power while in operation. And, some devices use measurement mechanisms that dissipate energy (e.g. by friction when a liquid is pumped through a circuit). Most of the time, this can be ignored in CBA. But if a large number of sensors is present in an installation, the combined electricity consumption has to be considered.

Moreover, the own energy consumption and/or the need for physical access for maintenance (cleaning, replacing parts, restarting) may have a – at first sight – negligible impact on a CBA. But indirectly, the impact can be significant when e.g. it prevents battery-operated solutions that would

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have avoided cabling costs or allowed for solutions with expensive maintenance access (e.g. requiring a helicopter or alpinist skills).

5.3.3.4 Data communication, storage, access

Measurement data needs to be transferred to where it is used. It may need to be stored until it is used. Different measurement devices may use a variety of communication protocols, leading to the introduction of additional conversion units with specific investment costs. Various data access services for software (API, cloud server) and humans (GUI, Web server) may be required.

The cost of (measurement) data communication, storage and access is not determined in full by the measurements. If the measurement devices utilize mainstream protocols, media, formats that are supported anyway (e.g. IP networking, Wi-Fi, JSON or XML, ASCII, Unicode), the cost will be low whereas more exotic devices will require significant effort, which translates in costs due to the measurements.

Overall, it is not possible to assign a cost to a device without a specific context, in which it will be installed and used. Nonetheless, not all devices are created equal. On the one hand, there are outdated technologies and protocols, which are to be deprecated regardless how commonplace. They imply a cost reflecting that they are not future-proof (and may need a ‘wrapper/conversion unit’ to protect the remainder of the installation). On the other extreme, there are advanced technologies, which may suffer from teething problem, poor support and uncertain future availability. In between, there are mainstream, future-proof technologies.

In the energy domain, outdated technologies are prevalent. Among them, there are modest ones, which are easily wrapped/converted, and there are overassertive ones, which require disproportional efforts to convert/wrap. In addition, proper wrapping/converting often requires knowhow about the ‘ugly facts of life’ if mistakes or degraded performance is to be avoided. And, such knowhow does not come for free (i.e. requires expertise).

Again, the bigger picture is (all) what counts. It makes little sense to spend effort and time on arbitrariness; efforts targeting the overall requirements, impacting the bottom line is anyway what will count in the end. Here, direct costing of alternative courses of action will reveal which options are to be preferred.

5.3.3.5 Data cleaning, certification, anonymization

Certain usages of data require more than access to the raw data. E.g. when it is to be used for matters that may be disputed in a court of law, cleaning (identifying measurement errors) and certifications is likely to be required. For making data publicly available, state-of-the-art anonymization of suitably aggregated data is required. And, the efforts needed for cleaning may depend on the type and/or number of measurement devices that are used.

Does this belong to the cost of measurement? No, the measurements are done before this processing starts. Yes, this processing is essential to deliver measurement data that can be used. Anyhow, without a specific context, the cost cannot be assigned (without being arbitrary). With a specific context, direct costing becomes possible/doable/… and the need for arbitrary assignment will disappear. Here, measurements can be annotated with relevant information, but that information needs to be incorporated in a broader setting (e.g. for direct costing purposes).

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5.3.3.6 Disruptive technologies and/or legislation

Some parts of the cost of measurements are likely to become outdated soon. For instance, block chain technology radically changes the certification of data. Compared to bitcoins, which needs Fort Knox security, smart energy needs a jewellery box investment to provide a trace of evidence equivalent to present-day certification. Indeed, customers may even be more convinced that their rights will be respected and will have more trust in cryptography than in large organisations. In other words, cost of measurement in the medium- and long-term needs technology watch to highlight where significant changes may and/or will occur.

5.3.3.7 Cost of missed opportunities

When designing installations or sub-installations, the (im)possibility of measurements is established. Denying, by the overall design, the opportunity to measure something, or denying the opportunity to measure at low cost, or denying the opportunity to have a small delay, low jitter, high data rates, etc. has an indirect cost. It may prevent to optimize an installation. In addition, it may prevent niche markets from emerging when a smart application cannot serve a sufficient number of installations with a low recurring cost (per installation).

Similar to denying the measurement itself, denying or delaying access to measurement data may prevent valuable applications from happening. E.g. when data cleaning and/or certification introduces significant delay (e.g. several weeks), access to the raw data could be granted with much less delay (e.g. seconds). Proper legislation and model agreements (ensuring raw data cannot be used in a court of law in manners reserved for certified and cleaned data) may represent added value to society. Failing to do so is a cost of how we measure (badly).

Summarizing, the cost of measurement is anything but straightforward. When looking at specific cases, as in the analysis below, it is possible provide data on the direct cost of measurement equipment and what their environment is. It illustrates the diversity and heterogeneity therein. However, when looking at the cost of measurement from a decision-making perspective (e.g. to decide whether or not to measure, which device to use, what the degree of redundancy should be, etc.), a broader picture is to be combined with a sound strategy and approach. Moreover, when the decision-making horizon goes beyond the immediate future, imminent developments in technology and legislation may need to be accounted for.

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6 DATA SHARING CONCERNS AND USERS OF MEASURED DATA

Installation of measurement equipment in the electricity grid serves several purposes. Historically, system or grid operator installed measurement equipment in important sectors of the grid, for example transformer stations, hubs, and critical locations in the network. This allowed him to maintain stable network conditions and indicated critical locations, intervals and users. Furthermore, monitoring allows close and accurate forecasting of electricity demand and effective matching of production and consumption in the network. With liberalisation of the energy markets, new actors emerge to the energy supply sector, which results in lowering the DSOs and existing suppliers overview of the grid. Since the end users of the grid may now belong to different balancing groups, suppliers, aggregators and the system operators have increased need for closely monitoring the system and its users. DSO need more detailed information in the grid to maintain security of supply and network stability, while market actors need to accurately forecast their balancing group profile to achieve best economic outcome. Aggregators, who includes flexible units in the portfolio need monitoring and control equipment installed at end user's location in order to has access and overview on the system.

Installation of measurement equipment at point of common coupling (PCC) is problematic in comparison with previously mentioned measurement location. Measuring at transformer station or feeder level provides network parameter info, influenced by group of electricity users. With measuring at PCC, the data, which is gathered provides insight on the consumer behaviour. In order to prevent exploitation of personal data, which is collected from this measurement location, the involved parties must ensure that end users' privacy is ensured, and no exploitation or abuse of the data is possible by the involved parties. This concern is specially highlighted in last few years with all new laws concerning personal data and use of personal data by third parties.

6.1 GDPR

The Regulation 2016/679 [1]also known as General Data Protection Regulation (GDPR) defines the rules of the protection, processing and free movement of personal data. It also protects the rights and freedoms of natural persons and their right to the protection of their data.

'Personal Data' is any information, relating to natural person ('data subject'), which can be identified, directly or indirectly, in particular by reference to an identifier such as a name, location an identification number, an online identifier or to one or more factors specific to the physical, physiological, genetic, mental, economic, cultural or social identity of that natural person[1].

The GDPR describes the 'processing of the data' as any operation, which is performed on personal data. Processing includes also automated means, such as collection, recording, organisation, structuring, storage etc.

'Pseudonymisation of the data' is processing of data, where as a result, personal data cannot be attributed to a specific data subject without the use of additional information. Additional information is kept separately and needs to be protected with technical and organisational measures to ensure that the personal data are not attributed to an identified or identifiable natural person [1].

Data controller is natural or legal person, public authority, agency or other organisation, which determines the purposes and means for processing of personal data. The purposes and means

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of such processing are determined by Union or Member State law, the controller or the specific criteria for its nomination may be provided for by Union or Member State law [1].

The principles of protection apply to any data or information related to identified or identifiable person. To determine whether an individual is identifiable, record should be taken of all the measures, which could potentially be used either by the controller or by any other person to identify the person. The principles of protection shall not apply to data rendered anonymous in such a way that the data subject is no longer identifiable.

Anonymisation and pseudonymisation are vital for privacy of the participants, securing their personal data, restriction policies and lowering the security risks.

For example: the process of anonymisation usually occurs at the point of collection. The participants are informed about the signed consent. Consent of the subjects is stored separately from the data in order to ensure anonymity.

6.2 Data protection techniques

6.2.1 Anonymization

Data anonymisation is information processing technique used for protection of the privacy. It is the process of encryption and/or removal of identifiable information from data. As a result, the people whom the data describe remain anonymous [2].

Anonymisation technique converts clear text data into a nonhuman readable and irreversible form, including encryption techniques in which the decryption key has been removed. It enables the transfer of data across a system border, from one entity to another, while reducing the risk of unintended disclosure and at the same time enables evaluation and analytics. For medical example: the anonymised data prevents patient's identification by the recipient of the information. The person's details: full name, address, post code or any other data, that could potentially identify the patient, must be removed. The process of anonymisation includes actions that make a single piece of the set unidentifiable. It also involves specific details to make the data non-relatable to the identity of a single person. After the anonymisation process, the identification of a person or a data subject must be impossible in a reasonable way, whether by adding or reverse engineering specific information. Notion of cost and time is also considered when talking about a 'reasonable way'.

In the 26th paragraph of the Regulation 2016/679 [1] a conceptual definition of anonymisation is presented. To anonymise the data, it must be stripped of enough elements that the data subject can no longer be identified. The data must be irreversibly processed and is no longer used to identify a natural person by using "all the means likely reasonably to be used" by either the controller or another party.

There is no universal or prescriptive standard to use or follow that will ensure the anonymity of the collected and processed data. There are several anonymisation techniques and the controller must choose the best option for the given data.

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Lawfulness of the anonymisation process:

- Anonymisation achieves irreversible deidentification. It must be first collected and processed in compliance with the applicable legislation on the retaining of the data in an identifiable format.
- Anonymisation of the personal data is an instance of further processing. Thus, this processing must comply with the test of compatibility in accordance with the guidelines provided by the Working Party in its Opinion O3/2013 on purpose limitation.

Anonymisation techniques offer several levels of robustness, depending on the techniques and practices. With the available technology and techniques, currently there are three risks that are essential to anonymisation. These risks are:

- **Linkability** is ability to connect, at least, two data sets concerning data subject or a group of data subjects, either in the same database or in separate databases. If an attacker manages to figure out that two records are assigned to a same group of individuals but cannot single out individuals in this group, the technique provides resistance against Singling out, but not against Linkability.
- **Singling out** is the possibility to isolate some or all the records which identify an individual in the dataset.
- **Inference:** The possibility to deduce the value of an attribute from the values of a set of other attributes with significant probability.

6.2.2 Pseudonymisation

Pseudonymisation is a data management and de-identification procedure by which personally identifiable information fields within a data record are replaced by one or more artificial identifiers of pseudonyms. A single pseudonym for each replaced field or collection of replaced fields makes the data record less identifiable while remaining suitable for data analysis and data processing [2].

The process of pseudonymisation replaces one attribute, typically a unique attribute in a record. In this case, the data subject could still be identified indirectly. Pseudonymisation, when used alone will not result in an anonymous dataset. It will reduce the linkability of a dataset with the original identity of a data subject. It is a security measure but not a method of data anonymisation.

Much like the random number generated by the controller or the last name chosen by the data subject, the output of the pseudonymisation is not related to the initial or input value of the data. It can either be delivered by the original values via various hashing or encryption procedures or it can be randomly assigned by the controller or the data subject itself.

There are many ways to pseudonymise the data, which depends on the privacy impact assessment. From Scrambling, which involves a mixing or obfuscation of letters, to masking which partially hides the data subject ID or name, for example: ‘John Doe’ becomes ‘J*****e*’. Some of the pseudonymisation approaches can sometimes be reversible and just not efficient from the processing perspective.

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Some of the most used pseudonymization techniques:

- **secret key encryption,** where the owner of the key can re-identify each person by applying the process of decryption on the dataset. This is possible due to the identities still contained in the dataset in the encrypted form. The decryption is only possible with the key.
- A **hash function** is function that can be used to map data of arbitrary size to data of a fixed size. The values returned by a hash function are called hash values, hash codes or simply hashes [3]. A cryptographic hash function makes it easy to verify that some input data maps to a given hash value but makes it deliberately difficult to reconstruct the input data if it is not known. This means that the risk of connecting the pseudo name and the real name of the data subject no longer exists.
- **Tokenisation** technique typically applied in the financial sector to replace card ID numbers with values that have reduced usefulness for an attacker. The output values are derived from the previous numbers (input values) that are typically based on the application with the one-way encryption mechanisms of the assignment, through an index function, a sequence number or a randomly generated number that is not mathematically derived from the original data.

6.3 Stakeholders view on data privacy

For five group of stakeholders, we created the questionnaire to define their interest, awareness and privacy concerns. The stakeholders were:

- **End Consumers**: users of electricity grid, whose data is being measured and data used. The data is usually monitored by other actors in the electricity grid.
- **The DSO**: Distribution system operators were the first party to monitor the users in the power sector. They installed measurement equipment in order to have grid under control. Based on the collected data, they performed regulations in the grid and planned grid investments.
- **The Supplier**: Supplier is traditional entity in the electricity grids, which supplies energy to the users in his balancing group. He uses energy data to perform billing on his business, which also involves database with user's data.
- **The aggregator**: the aggregator is similar to the supplier functionality. He has aggregated several users in his business portfolio. He supplies energy to his balancing group and additionally he utilizes the flexible demand, generation and storage capacities of his users. He collects info on the user's equipment, devices and stores personal business-related data from his portfolio.
- **The Regulator**: acts like an electricity market supervisor. He performs monitoring on the market where market participants are purchasing and selling the energy and prevents market abuse and unfair market operations. He collects and operates with market data of the market participants such as: suppliers, industrial users, generation groups, power plants, etc.

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6.3.1 Questionnaire analysis and findings

End consumer awareness/opinion on privacy aspect and willingness to participates in data sharing schemes

The end consumers were asked about their awareness on data, which is being measured, what their suppliers and the DSOs have collected and their interest in sharing the data in business schemes. A group of 40 end consumers was reached in the survey, they participated via online form and premade questionnaire in word document.

Do you think your supplier and DSO have records on your:	Percentage [%]
Age	47
Gender	60
Location	100
Occupation	40

100% of the end consumers agreed that Energy consumption is collected as a technical parameter and 93% also think installed power is recorded in their database.

When asked about participation in new data sharing schemes the results were following.

Would you be interested in new data sharing schemes	Percentage [%]
Strongly agree	20
Agree	40
Neutral	20
Disagree	7
Strongly disagree	13

Other concerns raised were:

- improving the communication between the end users and stakeholders, which collect data about them and
- profiling regarding security issues information when users are at home and consuming and being away and consuming less

DSO's collection of personal data and privacy aspect

DSO's questionnaire was more oriented in their approach and data which is being collected. The DSOs have information about end users regarding their location, name of the owner, installed power and consumption. Their main measuring activities are connected to network elements in their ownership, such as transformers and specific network locations. Frequency is additionally measured as an indicator of network conditions. All their collected data is being used for practical use in their business of maintaining secure and stable network. DSO's expressed concerns about

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implementing GDPR conditions which they must oblige. They use special electronic system for anonymisation of the data in the database. Usually they do not share network specific data with third parties, unless its connected strictly to their business of maintaining the grid stability. Their users are generally being informed about use of their data, they organise meetings and events to keep them updated on the changes and updates. The suppliers and aggregators inform their customers about updates.

Aggregator's and supplier's collection of personal data and ensuring privacy techniques

Aggregator's and suppliers' main interests in end user's data is electricity consumption, the device information which end consumers own, frequency of the usage and geographic location of the user. Both Stakeholder groups store data in internal database, where data is used for business intention and research and analysis. Both sectors are actively working and meeting the data privacy requirements and laws connected to them, since they share the collected data with third parties. Regarding the data protection systems, they use specific algorithms, developed within the company, manual systems and for pilot site implementations, some of the data is not protected. That specific data is used within company, for research purposes and the end users are informed about the use of their data.

In regular business portfolio, the collected data is treated according to GDPR and other laws which apply. They inform their customers about their data intentions and their consents are collected, if the data is shared to third parties or for reporting purposes. They use meetings for that purposes, emails, newsletters and other various social events.

Both stakeholder groups pointed out the importance of having access to end user's data. The GDPR is bringing new challenges in approach and collection of the personal data. The end users should be properly informed about the use of data and their consent for use of their data collected. Their data then should be provided to other stakeholders in order to develop new accurate services to the end users.

The market regulator's protection of the privacy

The Regulator has the overview of the market activities and the trading results of the involved actors. Their main data which is processed are energy market transactions related data. The results are stored in internal and external database for the analysis, studies and reporting purposes. They use electronic system for automatic anonymisation, using the specific algorithms, developed within the company. They prevent misuse and exploitation of the personal data, involved in the business with all relevant data protection measures and several IT security rules and procedures.

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6.4 Users of measured data

This Section aims to show the required data stream of measurements, collected in OHL demo, where new proposed business model for the aggregator's business is being tested. The households in the neighbourhood are aggregated and controlled by the aggregator. He is controlling the smart grid devices with available flexibility, the heat pumps and boilers. In exchange for using their flexibility on the energy markets, he offers them reduced grid energy consumption and lower cost of electricity. The aggregator installed measurement equipment and control devices in houses in the neighbourhood. In addition to existing household level of control, he offers services to the entire community involved in the demo. In that aspect, overall grid exchange on neighbourhood level is decreased. With flexible devices he mitigates grid injection and offtake as much as system allows it. He collected information which devices are installed in each house and it measures their data to accurately forecast their daily profiles.

In this Section we present the devices needed for such control and data streams of the measurement equipment. The data quality as well as the data availability in the demo is analysed. The data is stored in the project Database by BASEn, described in Section 3.2. Parameters, which are being measured vary from thermal measurements, energy readings and activation and status of the devices.

To ease the description of the data analysis, each communication protocol will be documented one by one. Hereunder, each LoRa gateway is represented by a star, and each house from T5.2 is circled as well as T5.3 houses. Following subsections contain information for LoRa devices, WAGO, Thermostat data, external services acquired through API and boundary conditions for the alarm in the system.

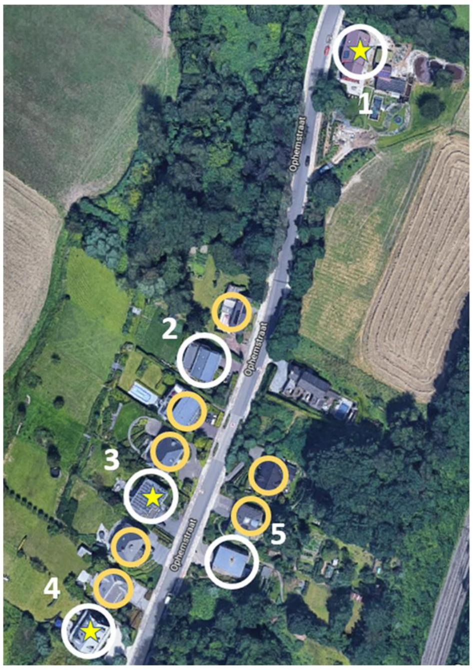

Figure 6.1: OHL T5.2 Houses in white and T5.3 Houses in yellow

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6.4.1 LoRa Devices data

Five Lora device groups are described in the table below. They are all LoRa class A communication except LoRa smart plug, which is type C [3]. Their locations and connected measurement devices with measurement info and data flows are described here.

Table 6.1: LoRa Device info

Hardware	Number	Situation	Device	Data	Units	Reporting Frequency	Data/packet	Data/day	Stakeholders
LoRa Temp Sensor (#3)	26	5 Houses	NKE Temperature sensor	Temperature	°C	1 packet/hour	57 bytes	1368 bytes	ACT, Residents, BaseN
				Humidity	%	1 packet/hour	57 bytes	1368 bytes	ACT, Residents, BaseN
LoRa Smart Plug (#4)	3	1 House & Hybrid car	NKE Smart plug	Instantaneous Demand	W	1 packet/6 hours	20 bytes	80 bytes	ACT, Residents, BaseN
				Current Summation Delivered	Wh				ACT, BaseN
				On/Off state	boolean	Each time the device state is switched (Class C)	8 bytes	Depends on the number of switches during the day	ACT, Residents, BaseN
LoRa Pulse Sensor & Kamstrup Energy meter (#5)	8	3 Houses	NKE Pulse sensor	Pulse Counter	/	1 packet/hour	59 bytes	1416 bytes	ACT, BaseN
Smartlog Sensor/controller (#6)	1	1 House	Smartlog Monitor and Control sensor	tophotwater1	State	1 packet/5 minutes	80 bytes	23040 bytes	ACT, BaseN
				lowerhotwater1	State				ACT, BaseN
				gearhotwater1	/				ACT, BaseN
				gearsheating1	/				ACT, BaseN
				demandstatus1	State				ACT, BaseN
				operationalmode1	State				ACT, BaseN
				starttemphotwater1	°C				ACT, BaseN
				stopttemphotwater1	°C				ACT, BaseN
Smartlog temperature sensor (#7)	1	1 House	Smartlog temperature sensor	Temperature (Bottom)	°C	1 packet/5 minutes	37 bytes	10656 bytes	ACT, Residents, BaseN
				Temperature (Center)	°C				ACT, Residents, BaseN
				Temperature (Top)	°C				ACT, Residents, BaseN

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6.4.2 WAGO

Three phase and one phase electric meter's info is described here. They all communicate via FTP (Through IP) and are in all houses in the demos. Every 5 minutes, the CSV file is sent through FTP with measured data, which is 1800 bytes in size, which accumulates to 520 kilobytes in one day.

Table 6.2: WAGO data

Data	Units	Expected range min-max	Stakeholders
Total Active Power	W	[100 – 10 000] (peak power can reach exceptionally power above 15 kW) -> With behind-the-meter generation: [-Nominal Power - 10.000]	ACT, Residents, BaseN
Total Reactive Power	VAr	[-2000 - 2000] (peak value is unlikely)	ACT, Residents, BaseN
Total Apparent Power	VA	[100 – 12 000] (should be close to Active power at peak time)	ACT, Residents, BaseN
Total Power Factor	-	(not needed)	ACT, BaseN
Total Active Energy	Wh	[5 kWh per day - 100 kWh per day] (>20kWh per day is due to heating)	ACT, BaseN
Total Reactive Energy	VArh	up to 50 % of Active energy	ACT, BaseN
Total Apparent Energy	VAh	up to 125% of Active Energy	ACT, BaseN
Current Phase 1	A	a) Consumption: 0 to Fuse Value or lower when more information in house (usually 10-20 Amps) b) Generation & inverter : 0 to [Inverter Power / 230 V]*1.1	ACT, BaseN
Current Phase 2			ACT, BaseN
Current Phase 3			ACT, BaseN
Voltage Phase 1	V	207-253 (RMS)	ACT, BaseN
Voltage Phase 2			ACT, BaseN
Voltage Phase 3			ACT, BaseN
Cos Phi Phase 1	-	a) Consumption: [0.7 - 1] for Current between 0.5 A to 1 A b) Generation & inverter : 1 or -1 at high current depending on desired direction	ACT, BaseN
Cos Phi Phase 2			ACT, BaseN
Cos Phi Phase 3			ACT, BaseN
Maximum Voltage Measured	V	253 (RMS) (it can be transiently around 260)	ACT, BaseN
Frequency Phase 1	Hz	Normal range 49.8-50.2 Hz	ACT, BaseN
Frequency Phase 2			ACT, BaseN
Frequency Phase 3			ACT, BaseN
Harmonic Phase 1	%	Voltage : [0 - 5]	ACT, BaseN
Harmonic Phase 2			ACT, BaseN
Harmonic Phase 3			ACT, BaseN
Active energy Phase 1	W	[5 kWh per day - 100 kWh per day] (>20kWh per day is due to heating)	ACT, BaseN
Active energy Phase 2			ACT, BaseN
Active energy Phase 3			ACT, BaseN
Reactive energy Phase 1	VAr	up to 50 % of Active energy	ACT, BaseN
Reactive energy Phase 2			ACT, BaseN
Reactive energy Phase 3			ACT, BaseN
Apparent energy Phase 1	VA	up to 125% of Active Energy	ACT, BaseN
Apparent energy Phase 2			ACT, BaseN
Apparent energy Phase 3			ACT, BaseN
Active power Phase 1	Wh	[100 - 10000] (peak power can reach exceptionally power above 15 kW) -> With behind-the-meter generation : [-Nominal Power - 10.000]	ACT, BaseN
Active power Phase 2			ACT, BaseN
Active power Phase 3			ACT, BaseN
Reactive power Phase 1	VArh	[-2000 - 2000] (peak value is unlikely)	ACT, BaseN
Reactive power Phase 2			ACT, BaseN
Reactive power Phase 3			ACT, BaseN
Apparent power Phase 1	VAh	[100 - 12000] (should be close to Active power at peak time)	ACT, BaseN
Apparent power Phase 2			ACT, BaseN

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Apparent power Phase 3			ACT, BaseN
Phase angle Phase 1	°	0-360°	ACT, BaseN
Phase angle Phase 2			ACT, BaseN
Phase angle Phase 3			ACT, BaseN
THD Current Phase 1	%	Current : [0 - 100] at high current, up to 400 at very low current (electronics)	ACT, BaseN
THD Current Phase 2			ACT, BaseN
THD Current Phase 3			ACT, BaseN

6.4.3 Honeywell Thermostat data

Hardware: Honeywell Sensors are in 2 houses in the demo. They communicate though Honeywell API with the database, sent data is describe in the table below.

Table 6.3: Honeywell data

Device	Data	Units	Reporting Frequency	Data/packet	Data/day	Stakeholders
Honeywell Thermostat	indoor Temperature	°C	1 packet every 5 minutes	851 bytes	245088 bytes	ACT, Residents, BaseN
	heat Temperature	°C				ACT, Residents, BaseN
	Minimal heat set point	°C				ACT, Residents, BaseN
	Maximal heat set point	°C				ACT, Residents, BaseN
	Heat set point	°C				ACT, Residents, BaseN

6.4.4 External data received through API

For the requirements of the demos, two external services are included in the control scheme. First of the services is weather forecast, which provides inputs on outside temperature needed for the control of heating devices. The second service is market prices from the Belgium spot market which are inputs for the economic operation of the flexible devices and other assets.

Table 6.4:API information for weather and price forecast

Communication		Situation	Data	Units	Reporting Frequency	Data update	Prediction	Data/packet	Data/day	Stakeholders
API		All houses	Solargis outside temperature prediction	°C	1 packet every hour	Refreshed every hour	2 hours	7291 bytes	175 000 bytes	ACT, Residents, BaseN
			Belpex price	€	1 packet every hour	Refreshed every day at 11:59 PM	24 hours	7291 bytes	175 000 bytes	ACT, Residents, BaseN

6.4.5 Boundary conditions – Nagios alarms

Each of the devices has predefined boundary conditions, which defines the expected normal operation range. If the measured data is not received or the values exceeds defined range for normal operation, the alarms are activated, and event logged. For each of the hardware, the measured data is given and the expected range. If the values are not received or exceeds for the time limit given, the warning and critical indicators are activated. The method of comparison of

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the values is described together with reporting frequency. Last row provides data availability information for each group.

Table 6.5: Nagios alarms info

Hardware	Data	Expected range min – max	CRITICAL Limit	WARNING Limit	Comparative Limit	Check Interval	Reporting Frequency	Data availability
Electric meter - 3 phases (#1)	Total Active Energy	[5 kWh per day - 100 kWh per day] (>20kWh per day is due to heating)	20 min	10 min	Delta between actual time and J-1 values different than 0	10 min	Every 5 min	90.403%
Electric meter - 1 phase (#2)	Total Active Energy	[5 kWh per day - 100 kWh per day] (>20kWh per day is due to heating)	20 min	10 min	Delta between actual time and J-1 values different than 0	10 min	Every 5 min	90.073%
LoRa Temp Sensor (#3)	Temperature	13 to 27 °C	3 hours	2 hours	No	10 min	Every hour	96.097%
LoRa Smart Plug (#4)	Current Summation Delivered		12 hours	9 hours	No	10 min	Every 6 hours	88.434%
LoRa Pulse Sensor & Kamstrup Energy meter (#5)	Pulse Counter	Range [20 to >100 kWh/day]	3 hours	2 hours	No	10 min	Every hour	98.401%
Smartlog Sensor/controller (#6)	Demandstatus1		3 hours	2 hours	No	10 min	Every 5 min	96.761%
Smartlog temperature sensor (#7)	Temperature (Top)		3 hours	2 hours	if <40° or if >60°	10 min	Every 5 min	96.685%
Honeywell Sensor (#8)	indoorTemperature		3 hours	2 hours	if <20° or if >23°	10 min	Every 5 min	86.912%

As seen in the table, data availability varies from 88% to 98%, which is result of unstable communication connection and some reliability issues of the devices. In order to have established business, data availability must meet sufficient levels in order to not have negative impact on the business operation. In the appendix 11, the Nagios Alarm activation logs are included. For each activation, there is the list of included houses, cause and duration of the event that caused alarm and impact on data quality and availability.

6.5 Conclusions on Data Privacy Aspect

The legislation demands regarding use of personal data are becoming stricter and end consumers are becoming more aware and concerned of what data is being collected and their consent must be acquired before using their data. This is bringing additional effort, challenges and obstacles in the core business of supplier and aggregator. Their aim is to present new services on the market,

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which are customizable from user to user and adjustable to their personal preferences. With new service they aim to attract new potential customers and keep existing portfolio as well. Each of the consumers must decide where his favourable setting is. In exchange for personal data, the service providers can provide cheaper services with better quality of the delivered solution and very personalized approach to the customer. The customer is in this example very exposed and all his data is available to the service provider and his related parties. Security concern and proper data treatment are crucial in proper data management. All involved stakeholders are working extensively in meeting the regulations on this topic, and constant/periodic database upgrades are made to meet the requirements, which are monitored by correspondent authorities. The existing business models are updated specially in security and privacy aspects, while the overall business schemes remain similar to the existing ones. Each of the end consumer decides what is most valuable and what services he would like to have regarding his energy needs. With allowing the close monitoring, insight on consumer behaviour is unavoidably acquired. The aggregator must review in his monitoring scheme, how high frequency of the measuring is required to properly react to market conditions. Frequency of the trading is gradually coming down from hour products to 15 min resolution and 1 min products are to be expected in the future energy markets. So, in this aspect, the need for close monitoring is ever present. However, inertia of the system, for example temperature and other slow gradients would be sufficiently monitored at lower frequencies, hourly intervals. In addition to properly set monitoring intervals, to get sufficient information and avoid excess data and other costs, the overall high data availability is crucial for successful business.

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7 CONCLUSIONS

In this report, demo related activities are presented as a process of establishing a demo and operating and exploitation of it. It describes all the involved and required steps. The report includes findings of several demo-related activities which all describe the process of the demo setting up, monitoring, related expenses and data collected.

After the decision to create the demonstration or a pilot location, we must know for what purpose or the use case we will use the tested device, which control strategies will be deployed and what goals will be chased. Initially, the overall design and definition of demo related activities, topology and relations are presented. An overview for the STORY demos is presented, what use cases are present in each demo and how the impact of technology will be measured.

Key performance indicators were defined, which enable monitoring and determine the effectiveness and performance of the storage technologies. A set of general KPIs was designed for use in multiple demo locations. KPIs are collected in 5 different groups from technical, grid and device related KPIs to economic and environmental ones.

The next part of report describes what infrastructure is needed for successful monitoring, how the data is stored and how reporting is performed.

An important segment, connected to end consumer related demonstrations is also engagement of potential demo participants, who would be interested in participating in the demo. The defined methodology is applicable to broader spectre of demo owners, who would like to engage and connect additional other stakeholders. Once the stakeholders are connected and involved in the demo, the selected monitoring devices must be installed and there is cost, related to the measuring activities. How the costs are structured is presented in Cost of measurement Section. Afterwards the treatment of the measured data, issues with compliance with laws protecting the personal data and involved stakeholder awareness and measures are described. With the latest laws on this topic, the measured subjects are getting protected better, while other stakeholder groups, who are using the measured data are facing additional challenges and activities in order to meet the defined criteria. A neighbourhood demonstration's data traffic is presented in final Section. An aggregator established a business case with households in the neighbourhood. A complete overview of gathered data is included. The information about installed sensors, measured parameters and reporting frequency is given. To have effective method of monitoring the data quality must be on sufficiency level. The analysis of available data is included, together with the conditions for alarm activations, which notify the users about unexpected events in the systems. Important information on that matter is included also in the appendix, where actual alarm logs are presented, together with cause for the event, mitigation measure and impact on the data quality.

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8 LIST OF STORY DEMOS

Demo 1: Oud Heverlee, Belgium a) Living Lab and b) four other buildings with flexible devices
Demo 2: Oud Heverlee, Belgium a) Local Energy Community and b) flexible neighbourhood that interacts with the grid/with the market
Demo 3: Storage in the EXKAL factory in Spain
Demo 4: ORC at the Beneens factory site, Belgium
Demo 5: CAES in Lecale, Northern Ireland
Demo 6: Community battery a) in the village of Suha and b) the headquarters of Elektro Gorenjska

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9 LIST OF ABBREVIATIONS

API	Application programming interface
BC	Base case
CAES	compressed air energy storage
CS	Case study
DRES	Distributed Renewable Energy Source
DSO	Distribution System Operator
GHG	Greenhouse Gas
FTP	file transfer protocol
IP	Internet Protocol
HV	High voltage
KPI	Key Performance Indicator
LV	Low voltage
MV	Medium voltage
OHL	Oud Heverlee (location)
OLTC	On Line Tap Changer
PCC	Point of Common Coupling
SCL	Self-consumption level
SSL	Self-sufficiency level
SOC	State of charge

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10 REFERENCES

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[3] Konheim, Alan (2010). "7. HASHING FOR STORAGE: DATA MANAGEMENT". *Hashing in Computer Science: Fifty Years of Slicing and Dicing*. Wiley-Interscience. LoRa Device type data https://www.loraserver.io/loraserver/features/device-classes/

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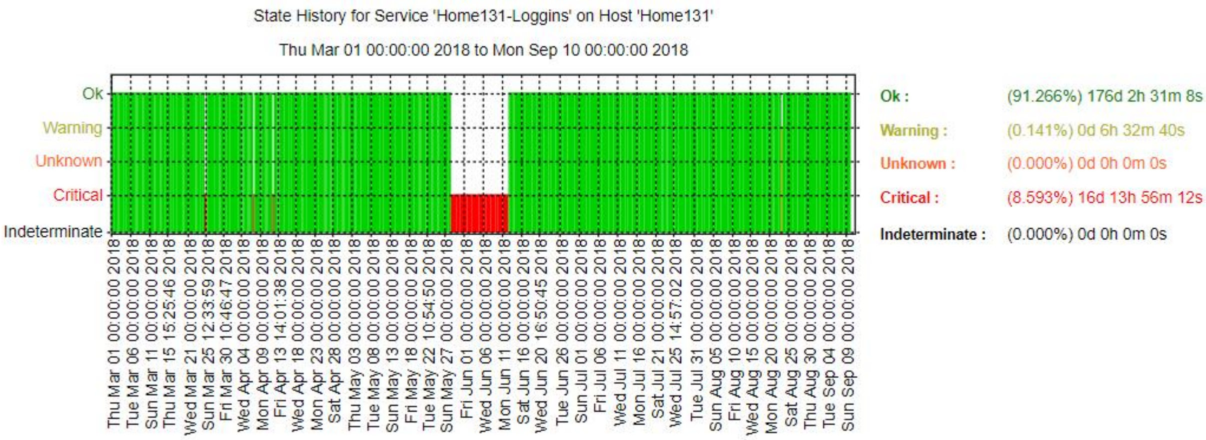
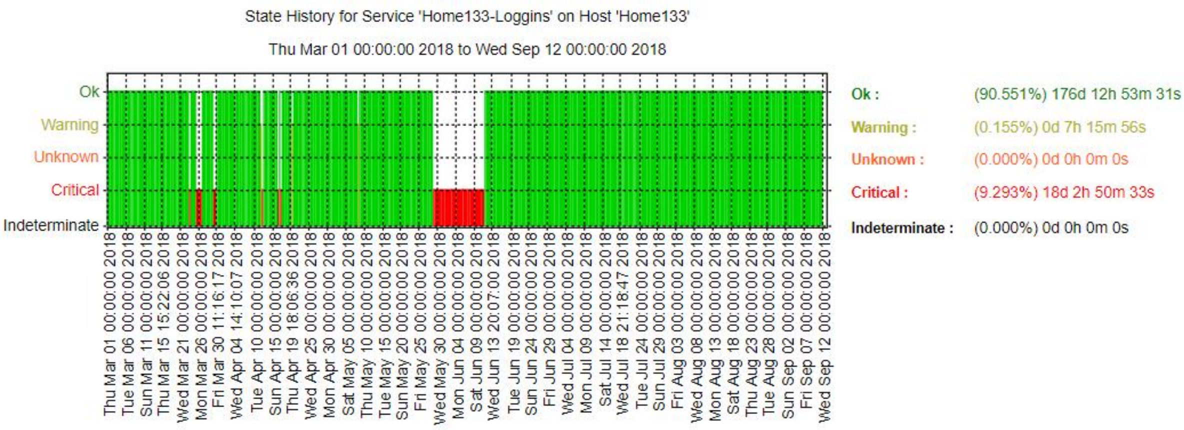
11 APPENDIX: NAGIOS ALARM LOG (T5.2 HOUSES)

Hardware	Location	Number	Data availability
Electric meter - 3 phases (#1)	House 131	1	91.266%
	House 133	1	90.551%
	House 137	1	90.126%
	House 143	1	89.668%



Event	Major change in ACT database
Impact of unavailability / stakeholders	Data for ACT in different database No data for BaseN No data for house owners, no impact on their comfort
Solution	Corrective patch applicated in order for BaseN to fetch correctly the data

From May/28th to June/12th (15 days), this CRITICAL period represents (15 days / 190 days) * 100 = 7.89% of the total period.



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Event	Major change in ACT database
Impact of unavailability / stakeholders	Data for ACT in different database No data for BaseN No data for house owners, no impact on their comfort
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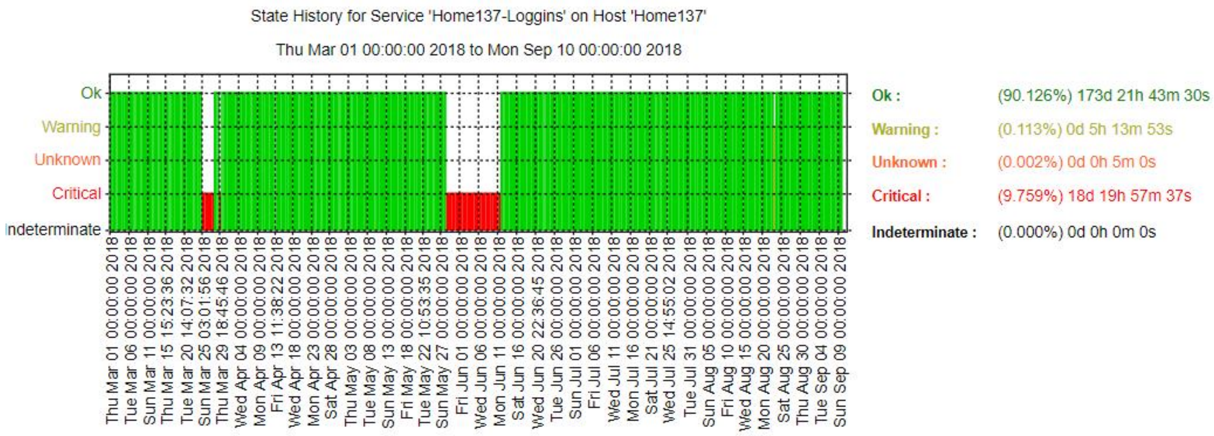

Event	Major change in ACT database
Impact of unavailability / stakeholders	Data for ACT in different database No data for BaseN No data for house owners, no impact on their comfort
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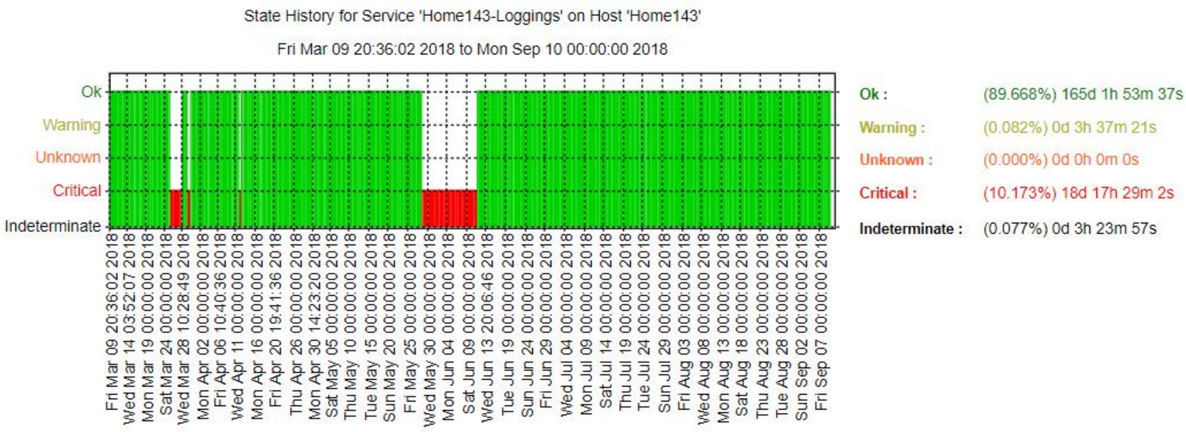
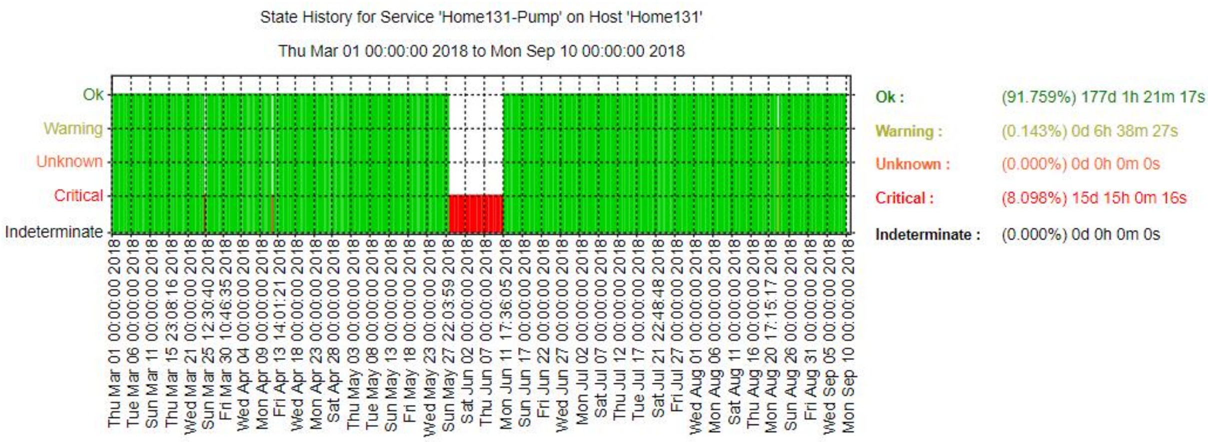


Event	Major change in ACT database
Impact of unavailability / stakeholders	Data for ACT in different database No data for BaseN No data for house owners, no impact on their comfort
Solution	Corrective patch applicated in order for BaseN to fetch correctly the data

From May/28th to June/12th (15 days), this CRITICAL period represents (15 days / 190 days) * 100 = 7.89% of the total period.

Hardware	Location	Number	Metering type	Data availability
Electric meter - 1 phase (#2)	House 131	1	Pump	91.759%
	House 137	1	PV	90.567%
	House 137	1	Pump	90.267%
	House 143	1	Pump	87.697%



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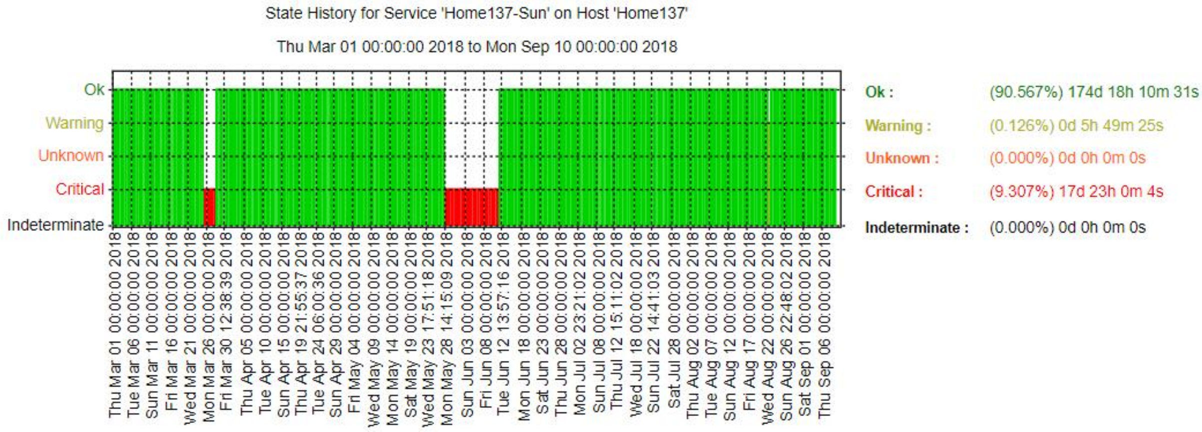
Event	Major change in ACT database
Impact of unavailability / stakeholders	Data for ACT in different database No data for BaseN No data for house owners, no impact on their comfort
Solution	Corrective patch applicated in order for BaseN to fetch correctly the data

From May/28th to June/12th (15 days), this CRITICAL period represents (15 days / 190 days) * 100 = 7.89% of the total period.



Event	Major change in ACT database
Impact of unavailability / stakeholders	Data for ACT in different database No data for BaseN No data for house owners, no impact on their comfort
Solution	Corrective patch applicated in order for BaseN to fetch correctly the data

From May/28th to June/12th (15 days), this CRITICAL period represents (15 days / 190 days) * 100 = 7.89% of the total period.

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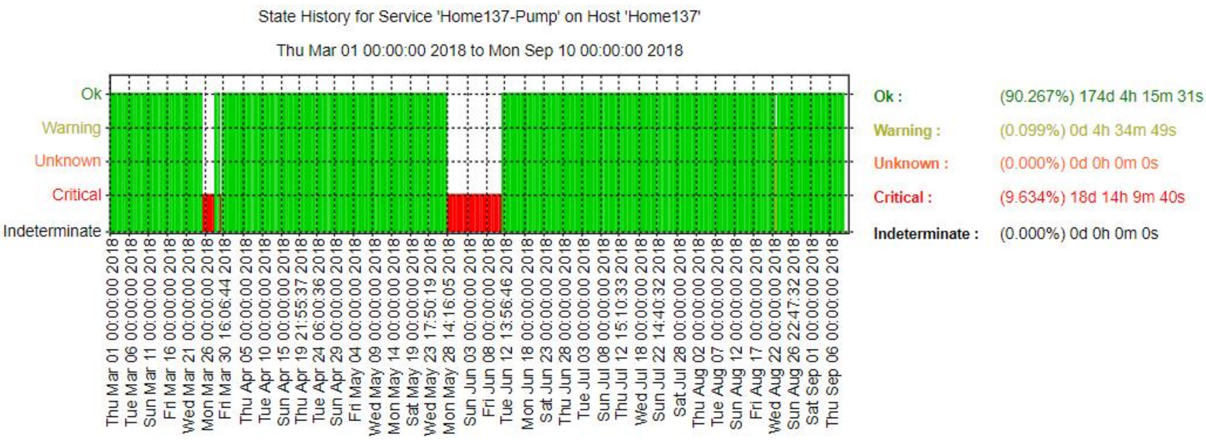
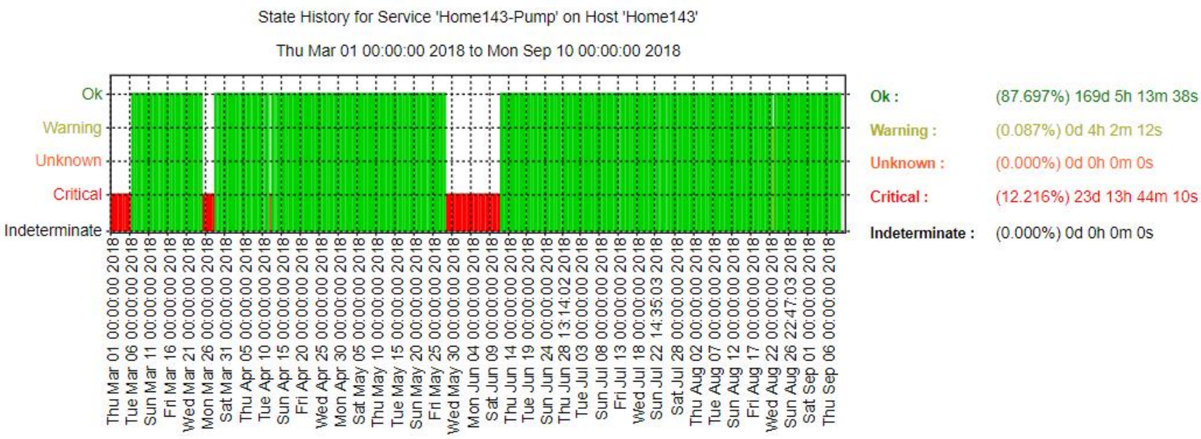


Event	Major change in ACT database
Impact of unavailability / stakeholders	Data for ACT in different database No data for BaseN No data for house owners, no impact on their comfort
Solution	Corrective patch applicated in order for BaseN to fetch correctly the data

From May/28th to June/12th (15 days), this CRITICAL period represents (15 days / 190 days) * 100 = 7.89% of the total period.



Event	Major change in ACT database
Impact of unavailability / stakeholders	Data for ACT in different database No data for BaseN No data for house owners, no impact on their comfort
Solution	Corrective patch applicated in order for BaseN to fetch correctly the data

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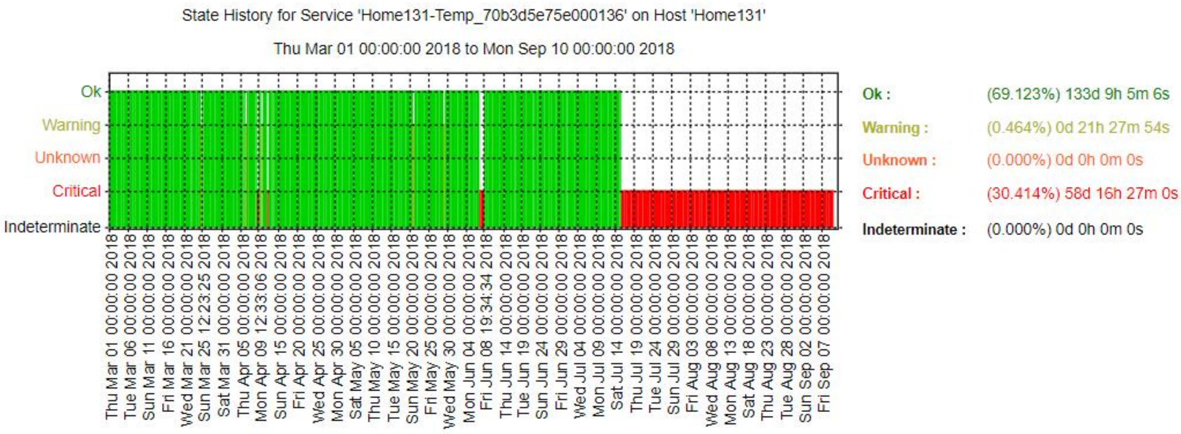
From May/28th to June/12th (15 days), this CRITICAL period represents (15 days / 190 days) * 100 = 7.89% of the total period.

Hardware	Location	Number	Data availability
LoRa Temp Sensor (#3)	House 131	5	95.392%
	House 133	5	95.675%
	House 137	5	98.493%
	House 143	1	94.827%

House 131



Event	No more battery since July 14th
Impact of unavailability / stakeholders	No data for ACT No data for BaseN No data for house owners, no impact on their comfort
Solution	Battery to be replaced

Not taken into account for the data availability calculation (not relevant)

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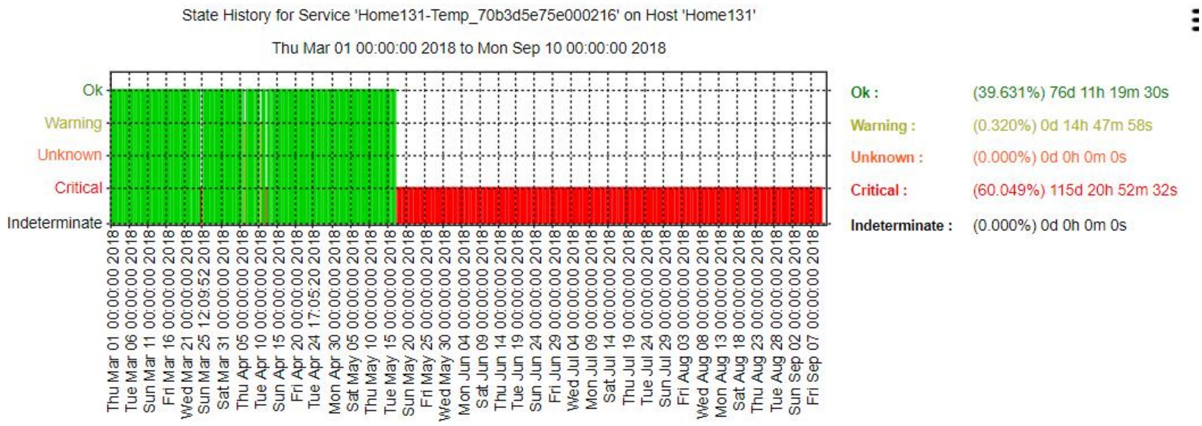
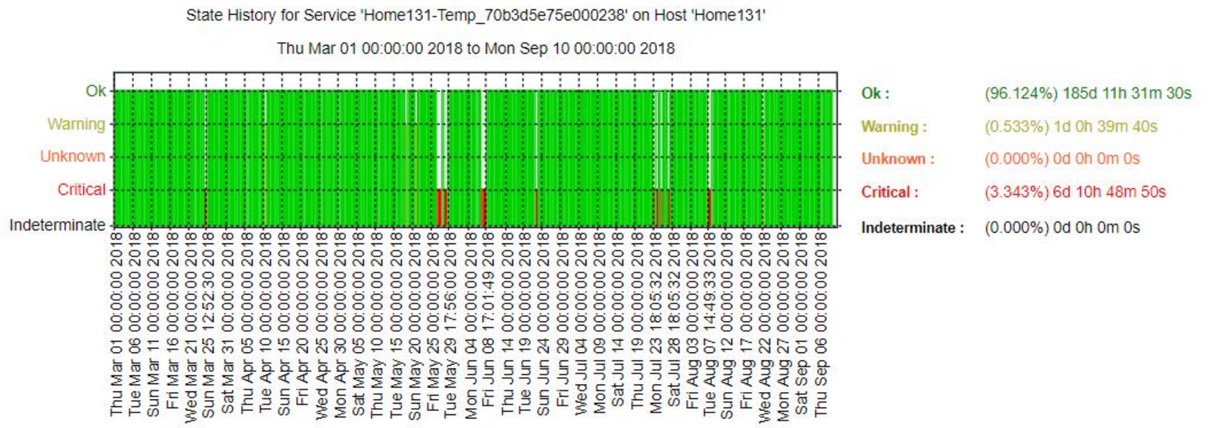


Event	No more battery since May 15th
Impact of unavailability / stakeholders	No data for ACT No data for BaseN No data for house owners, no impact on their comfort
Solution	Battery to be replaced

Not taken into account for the data availability calculation (not relevant)



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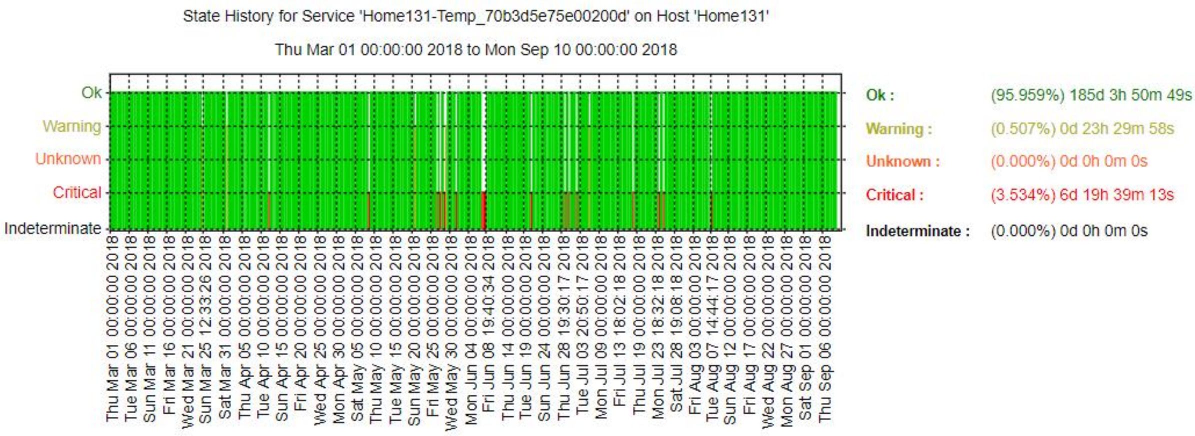
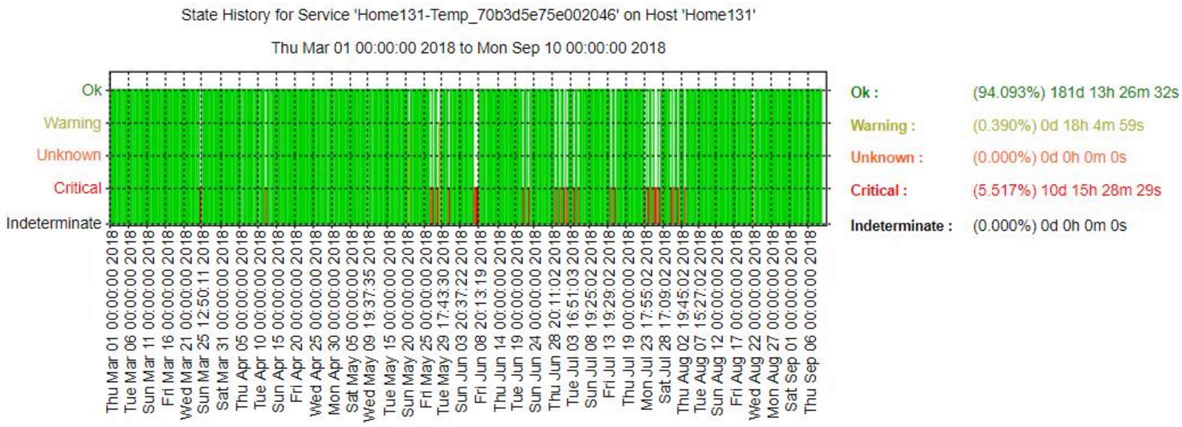
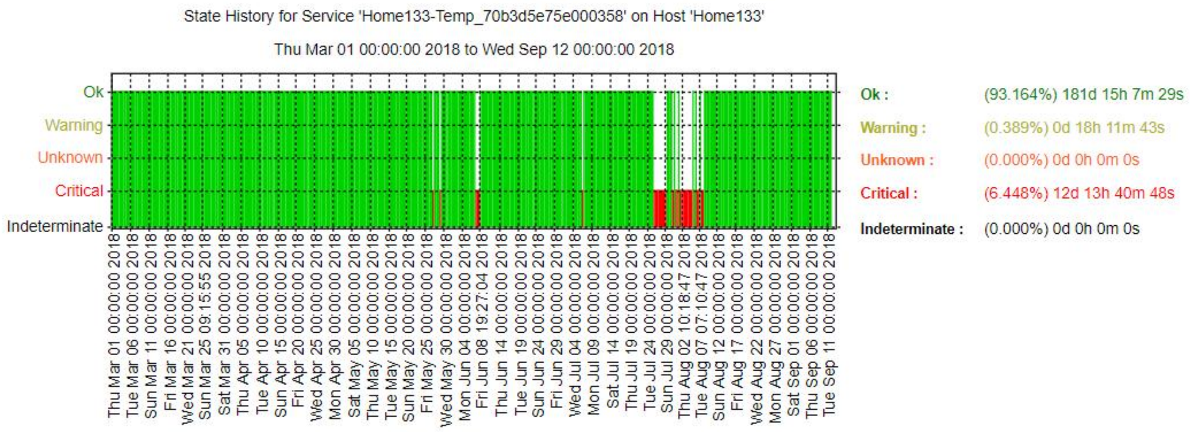




House 133



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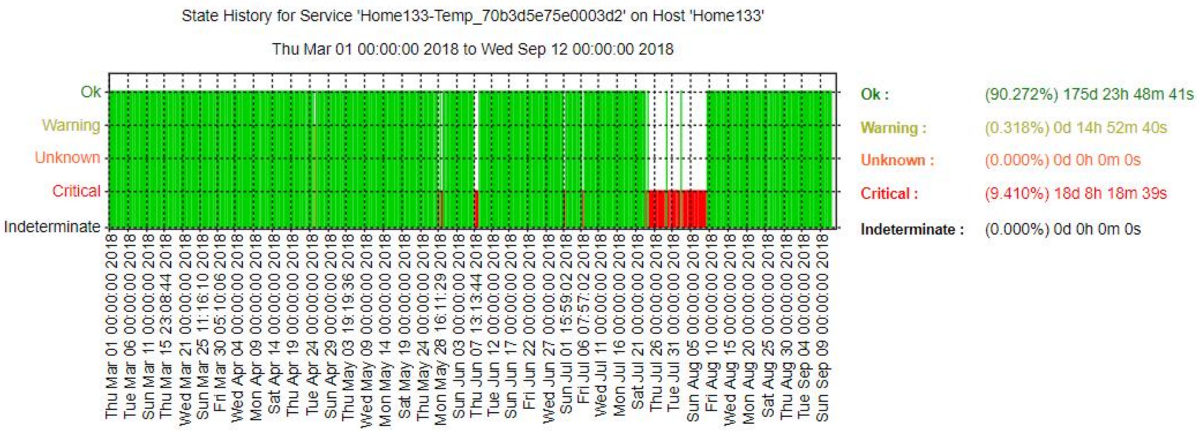
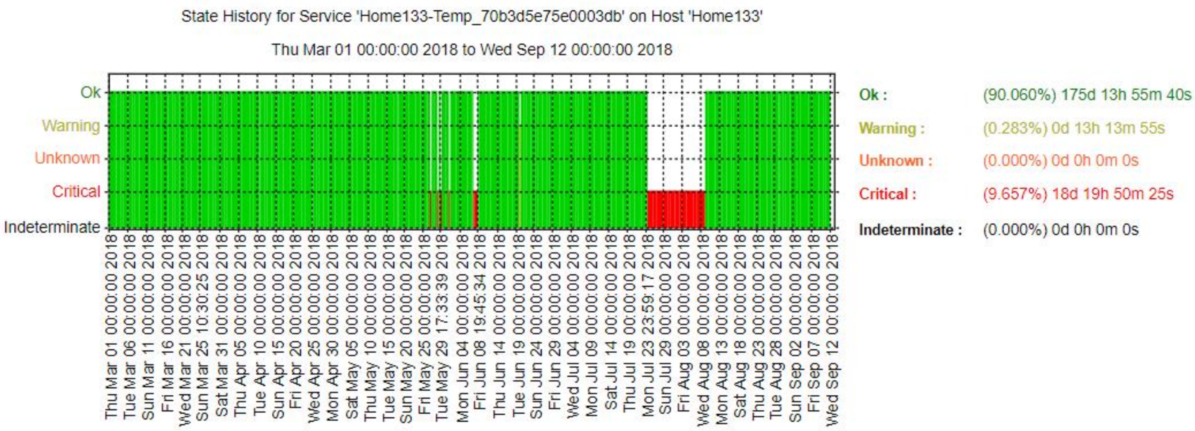
Event	Value out of range (13-27°C)
Impact of unavailability / stakeholders	No impact for ACT No impact for BaseN No impact on house owners' comfort
Solution	Wait for summer period to end

Not taken into account for the data availability calculation (not relevant)



Event	Value out of range (13-27°C)
Impact of unavailability / stakeholders	No impact for ACT No impact for BaseN No impact on house owners' comfort
Solution	Wait for summer period to end

Not taken into account for the data availability calculation (not relevant)



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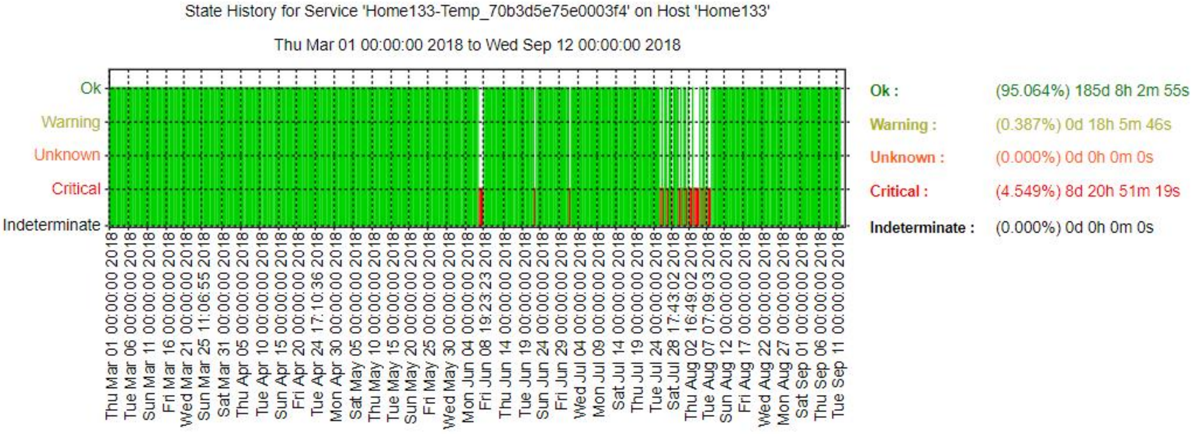
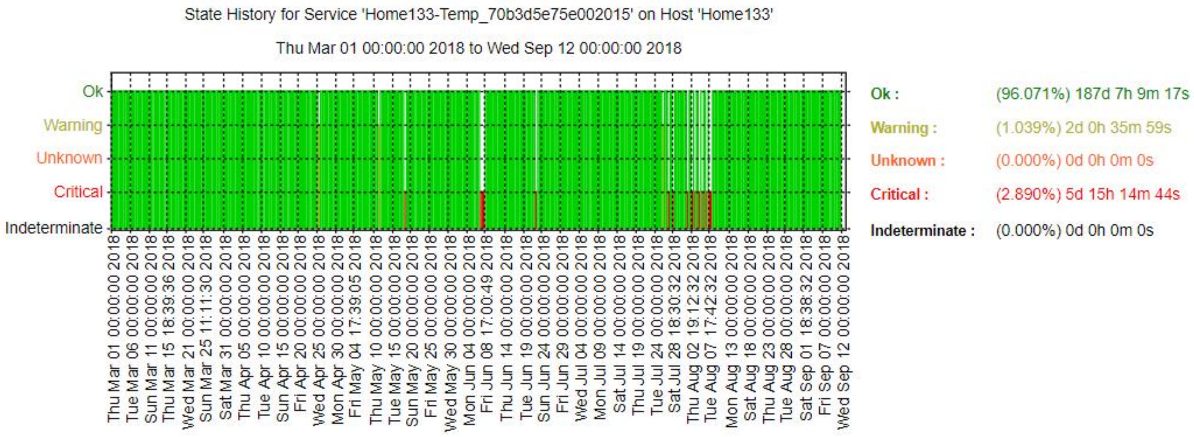
Event	Value out of range (13-27°C)
Impact of unavailability / stakeholders	No impact for ACT No impact for BaseN No impact on house owners' comfort
Solution	Wait for summer period to end

Not taken into account for the data availability calculation (not relevant)



Event	Value out of range (13-27°C)
Impact of unavailability / stakeholders	No impact for ACT No impact for BaseN No impact on house owners' comfort
Solution	Wait for summer period to end

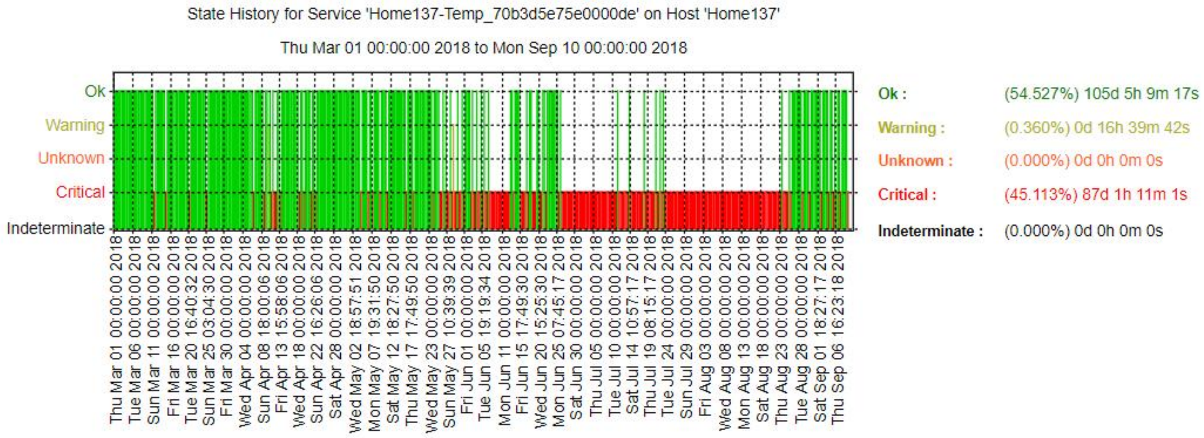


This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3

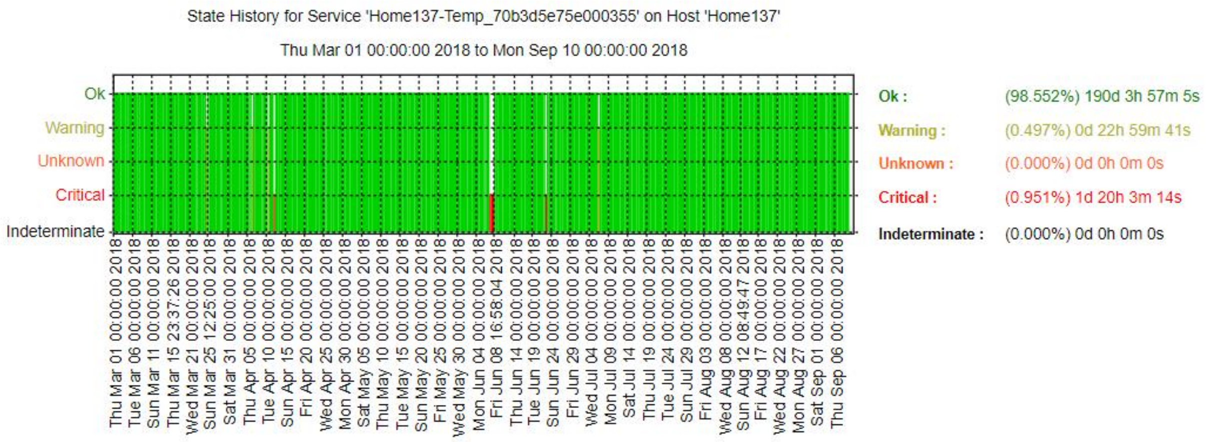
Event	Value out of range (13-27°C)
Impact of unavailability / stakeholders	No impact for ACT No impact for BaseN No impact on house owners' comfort
Solution	Wait for summer period to end

House 137



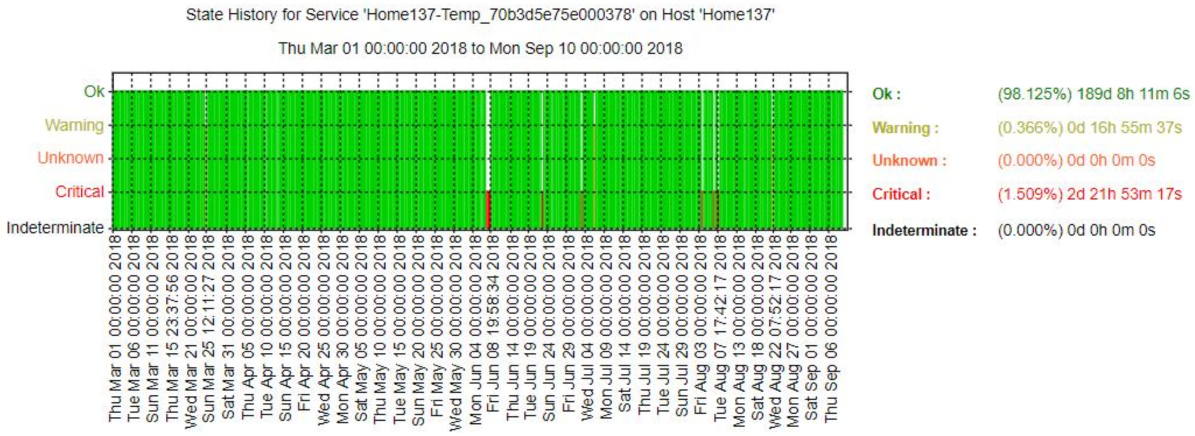
Event	Value out of range (20-23°C)
Impact of unavailability / stakeholders	No impact for ACT No impact for BaseN No impact felt by house owners (not relevant in summer period)
Solution	Smartlog device controlled the heat pump in order to get back to house owner temperature comfort

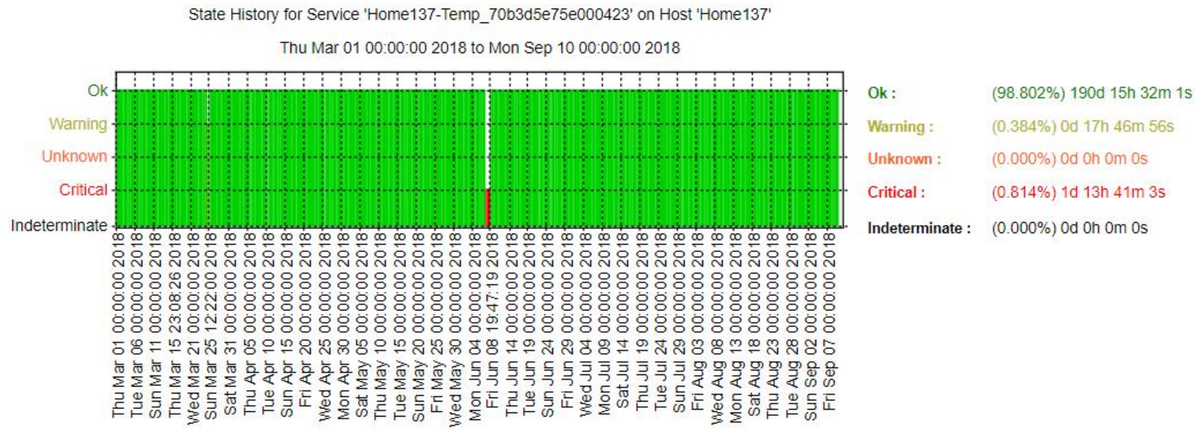
Not taken into account for the data availability calculation (not relevant)

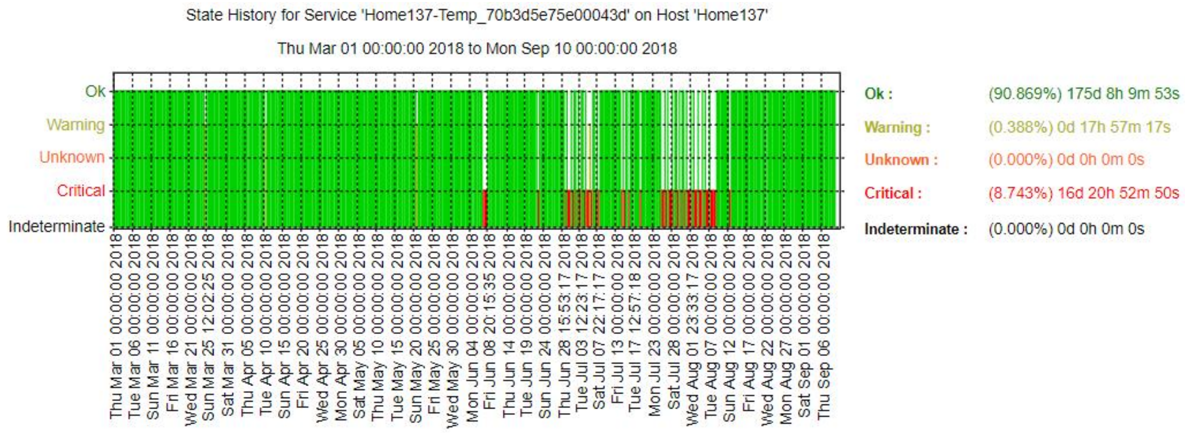


This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3





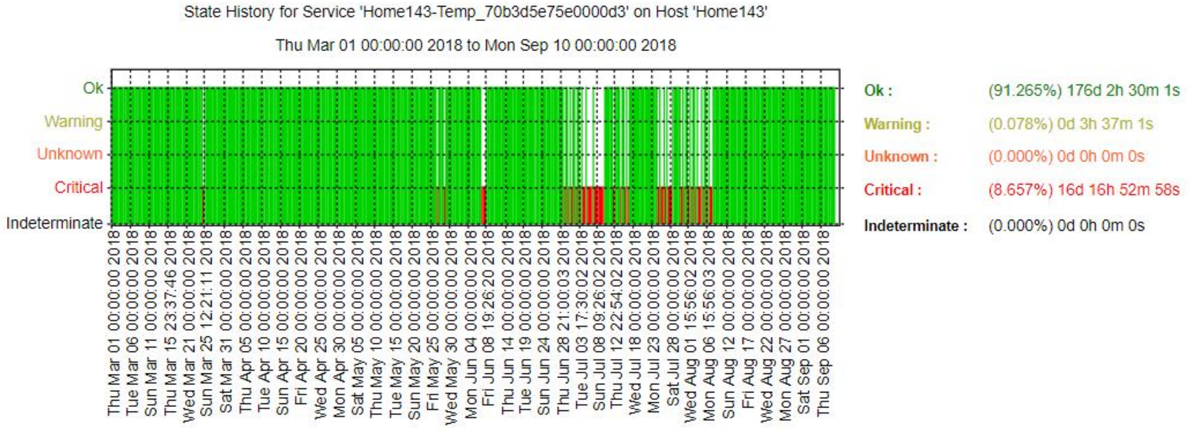


Event	Value out of range (13-27°C)
Impact of unavailability / stakeholders	No impact for ACT No impact for BaseN No impact on house owners' comfort
Solution	Wait for summer period to end

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

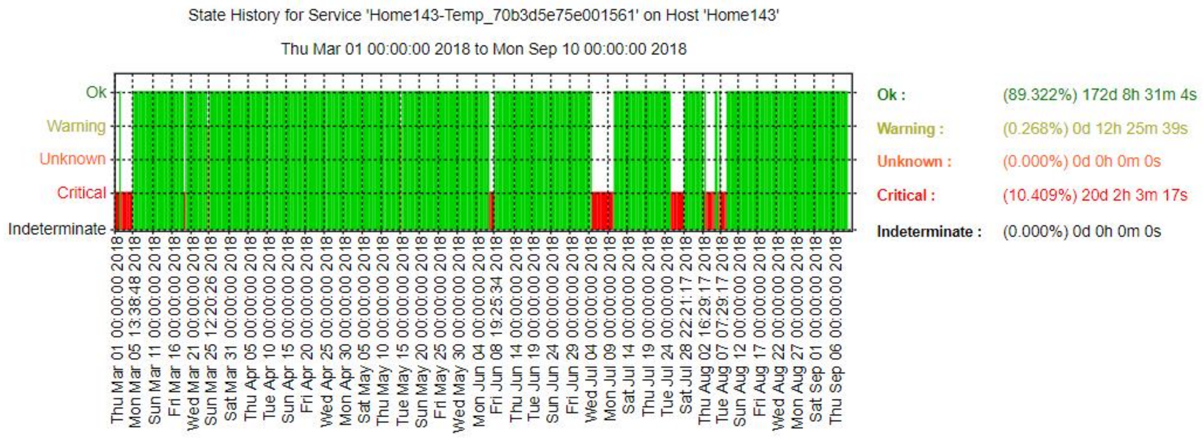
Not taken into account for the data availability calculation (not relevant)

House 143



Event	Value out of range (13-27°C)
Impact of unavailability / stakeholders	No impact for ACT No impact for BaseN No impact on house owners' comfort
Solution	Wait for summer period to end

Not taken into account for the data availability calculation (not relevant)



Event	Value out of range (13-27°C)
Impact of unavailability / stakeholders	No impact for ACT No impact for BaseN No impact on house owners' comfort
Solution	Wait for summer period to end

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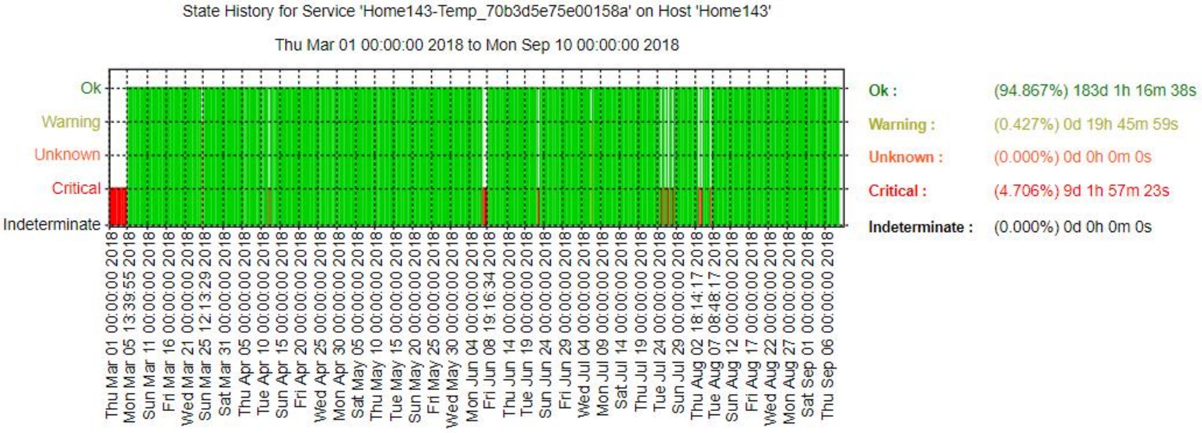
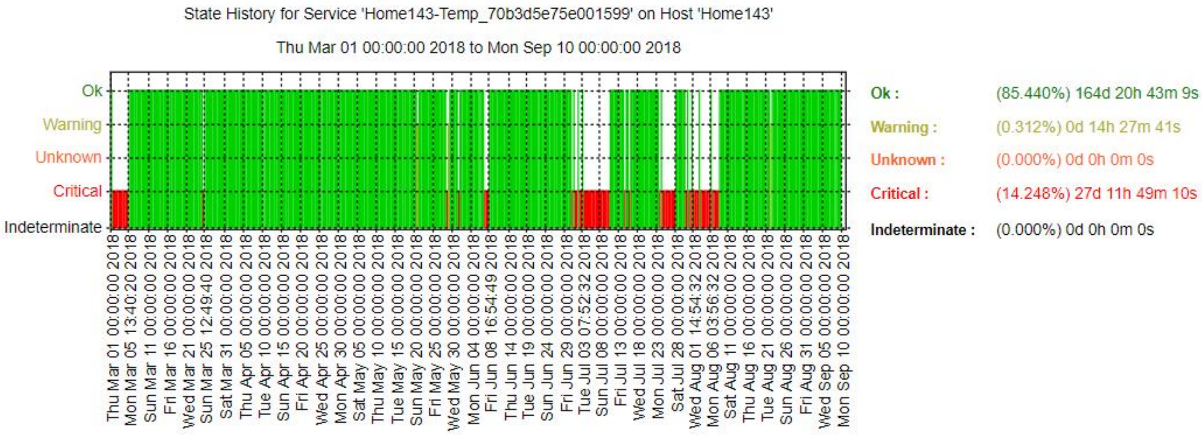
Project STORY - H2020-LCE-2014-3

Not taken into account for the data availability calculation (not relevant)



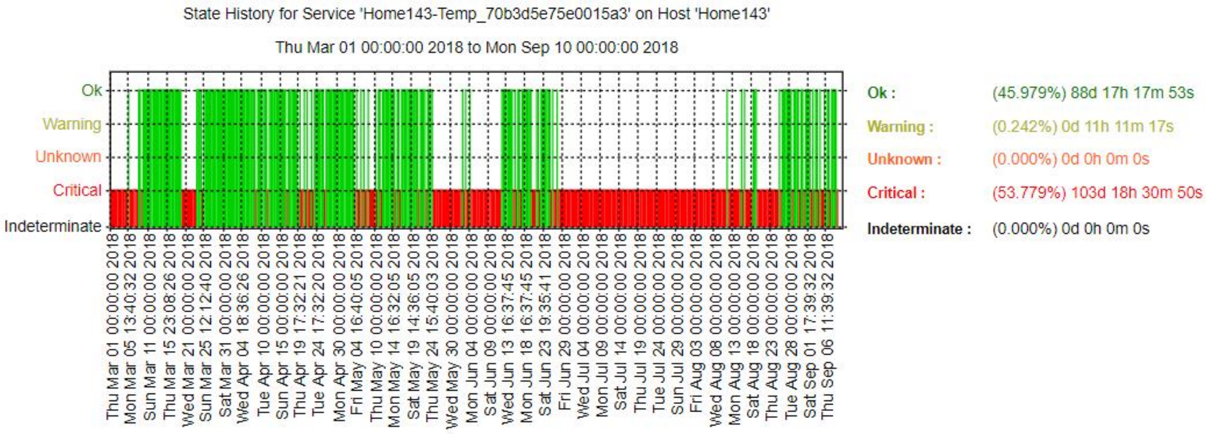
Event	Value out of range (13-27°C)
Impact of unavailability / stakeholders	No impact for ACT No impact for BaseN No impact on house owners' comfort
Solution	Wait for summer period to end



Event	Value out of range (13-27°C)
Impact of unavailability / stakeholders	No impact for ACT No impact for BaseN No impact on house owners' comfort
Solution	Wait for summer period to end

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

Not taken into account for the data availability calculation (not relevant)

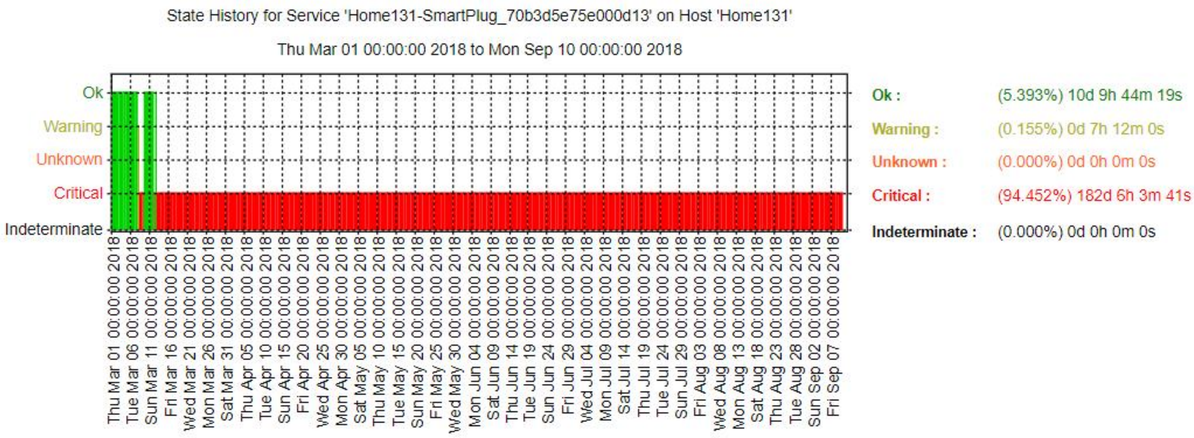


Event	Value out of range (19-23°C)
Impact of unavailability / stakeholders	No impact for ACT No impact for BaseN Impact on their comfort (not in summer period)
Solution	Analysis on the issue: linked to the indirect control of the Heat Pump by the Honeywell thermostat, not due to ACT model.

Not taken into account for the data availability calculation (not relevant)

Hardware	Location	Number	Data availability
LoRa Smart Plug (#4)	House 131	2	Not relevant
	House 133	1	88.434%
	House 137	0	
	House 143	0	

House 131



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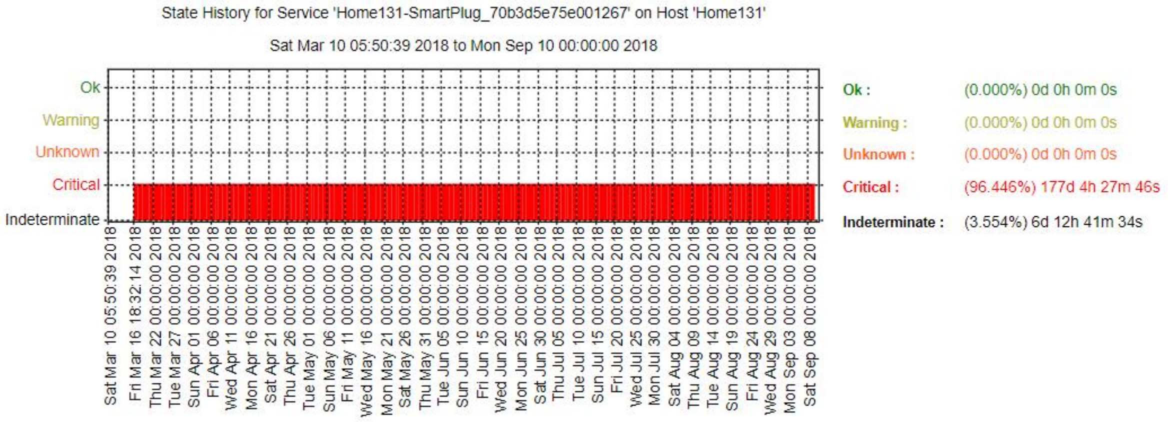
Event	Device unplugged by house owners
Impact of unavailability / stakeholders	No data for ACT and no possible Boiler control No data for BaseN No impact on their comfort (Boiler is heated again with no ACT control)
Solution	Analysis on the issue: presentation to house owners to show them that control has been operational more than 80% of the case. Start control again in T5.3 context.

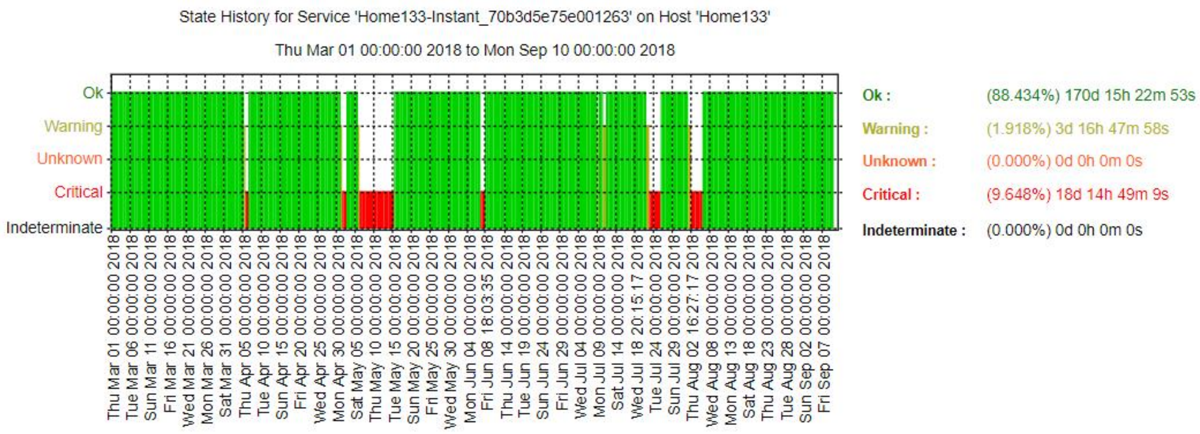
Not taken into account for the data availability calculation (not relevant)



Event	Device unplugged by house owners
Impact of unavailability / stakeholders	No data for ACT and no possible Boiler control No data for BaseN No impact on their comfort (Boiler is heated again with no ACT control)
Solution	Analysis on the issue: presentation to house owners to show them that control has been operational more than 80% of the case. Start control again in T5.3 context.

Not taken into account for the data availability calculation (not relevant)

House 133



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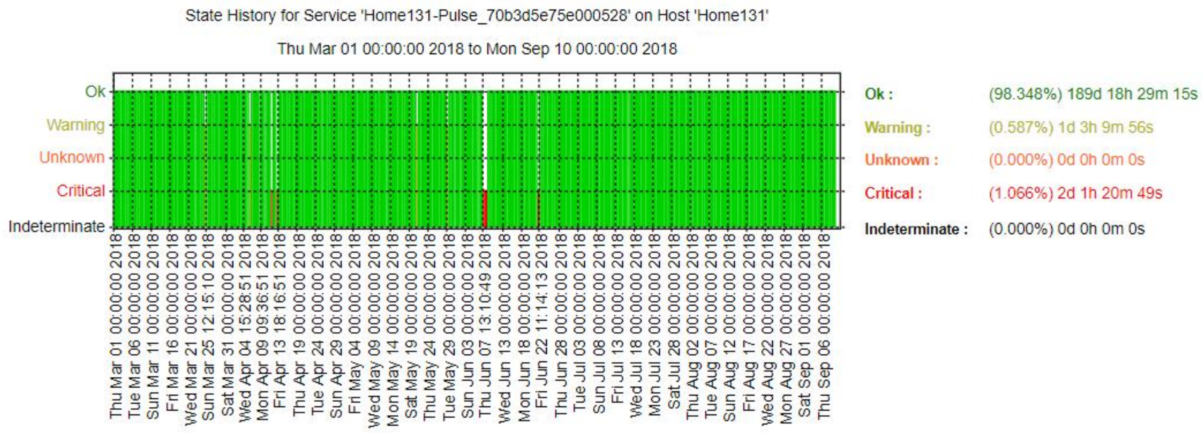
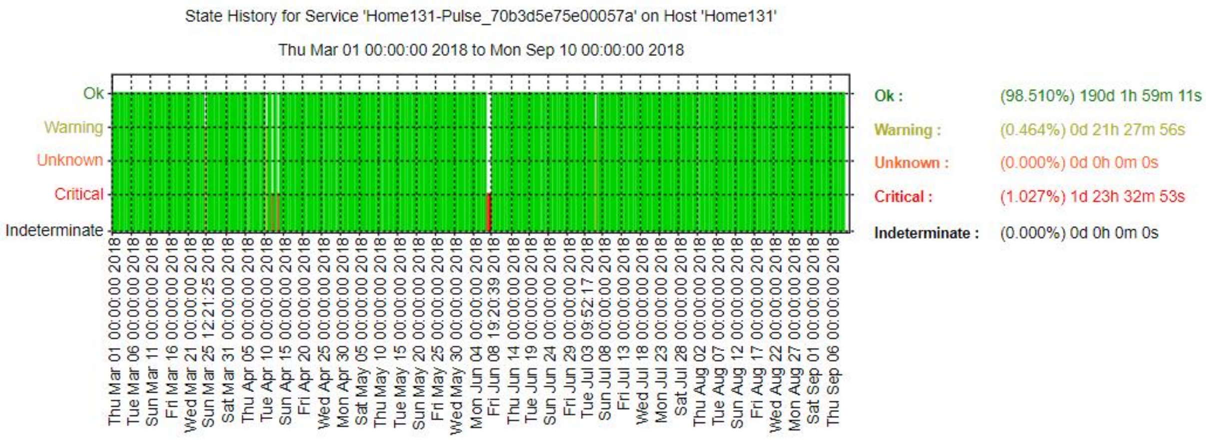
Event	No data sent for 9 hours
Impact of unavailability / stakeholders	No data for ACT No data for BaseN No impact on their comfort
Solution	Analysis on the issue: presentation to house owners to show them that control has been operational more than 80% of the case. Start control again in T5.3 context.

Hardware	Location	Number	Data availability
LoRa Pulse Sensor & Kamstrup Energy meter (#5)	House 131	4	98.401%
	House 133	2	Not relevant
	House 137	0	
	House 143	0	

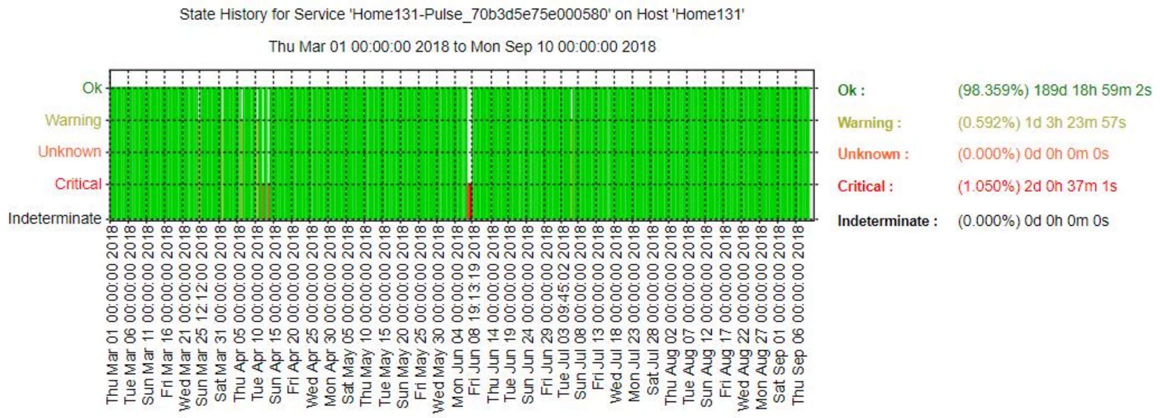
House 131

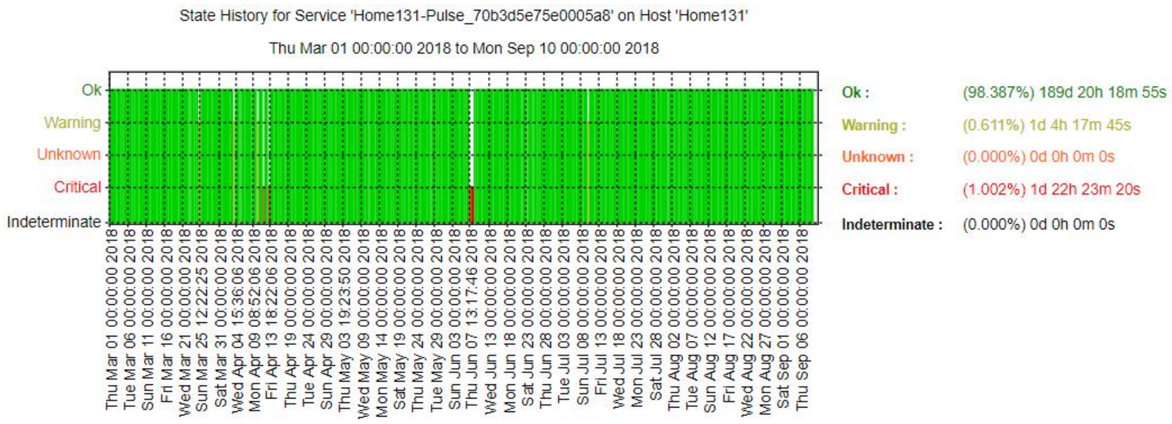




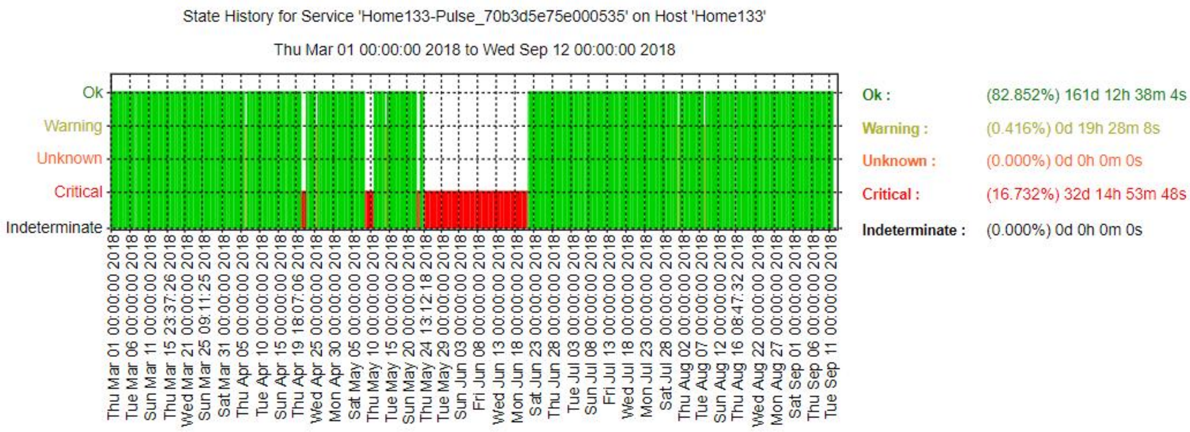
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3





House 133



Event	(Current value) = (Day-1 value)
Impact of unavailability / stakeholders	No impact for ACT No impact for BaseN No device consumption on house owners' side
Solution	Wait for device to consume energy

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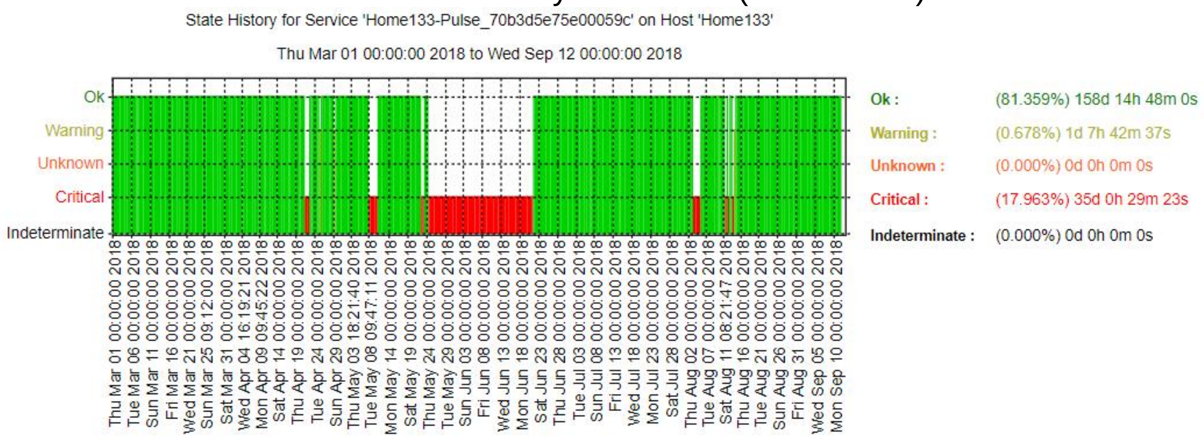
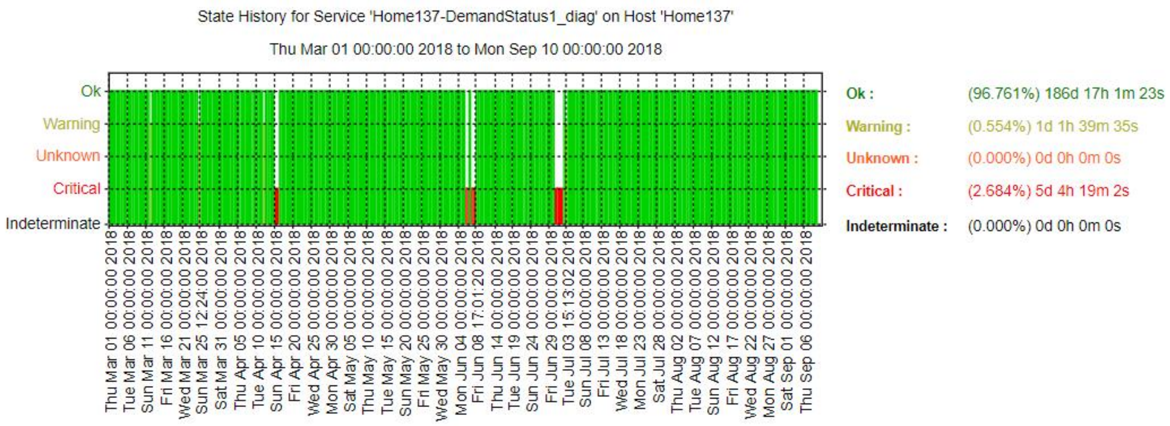
Not taken into account for the data availability calculation (not relevant)



Event	(Current value) = (Day-1 value)
Impact of unavailability / stakeholders	No impact for ACT No impact for BaseN No device consumption on house owners' side
Solution	Wait for device to consume energy

Not taken into account for the data availability calculation (not relevant)

Hardware	Location	Number	Data availability
Smartlog Sensor/controller (#6)	House 131	0	
	House 133	0	
	House 137	1	96.761%
	House 143	0	



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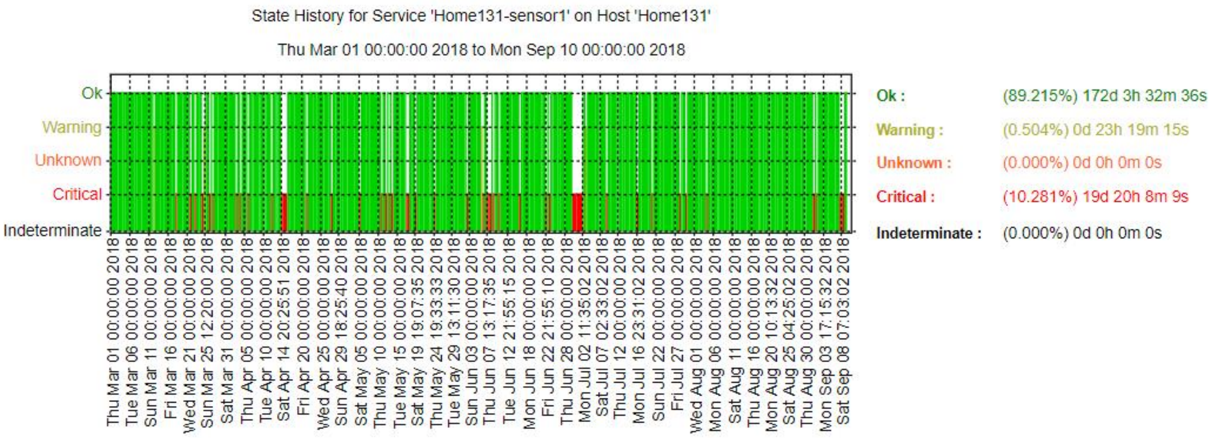
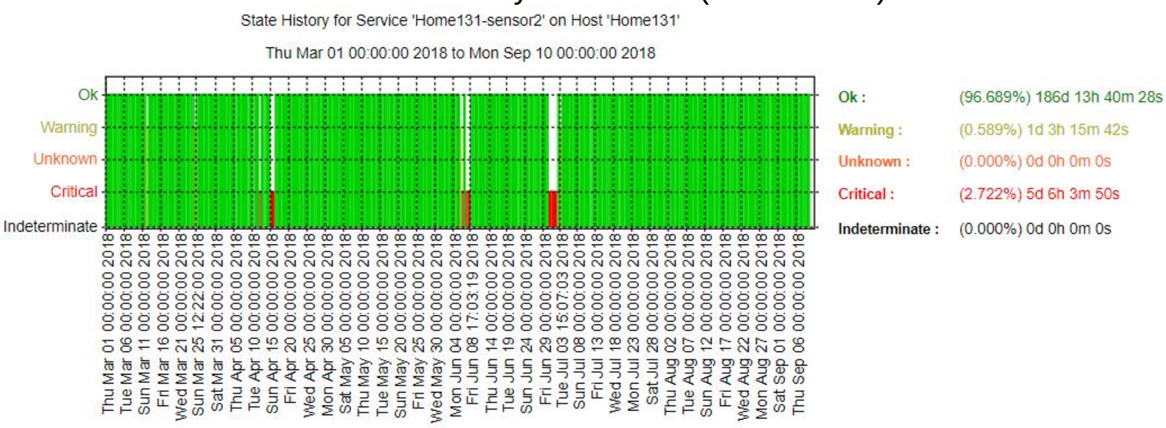
Hardware	Location	Number	Data availability
Smartlog temperature sensor (#7)	House 131	1	96.685%
	House 133	0	
	House 137	0	
	House 143	0	

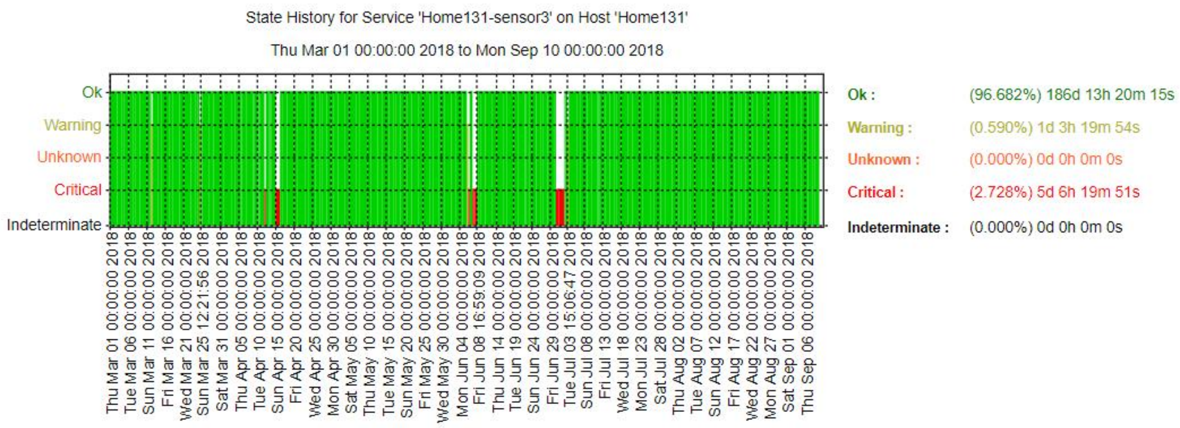


Event	Value out of range (40-60°C)
Impact of unavailability / stakeholders	Impact for ACT in case of control (reference temperature to control the Boiler), no impact when ACT is not controlling No impact for BaseN Impact on house owners' comfort (cold temperatures)
Solution	Activate the Smart Plug in order to heat the boiler temperature

Not taken into account for the data availability calculation (not relevant)

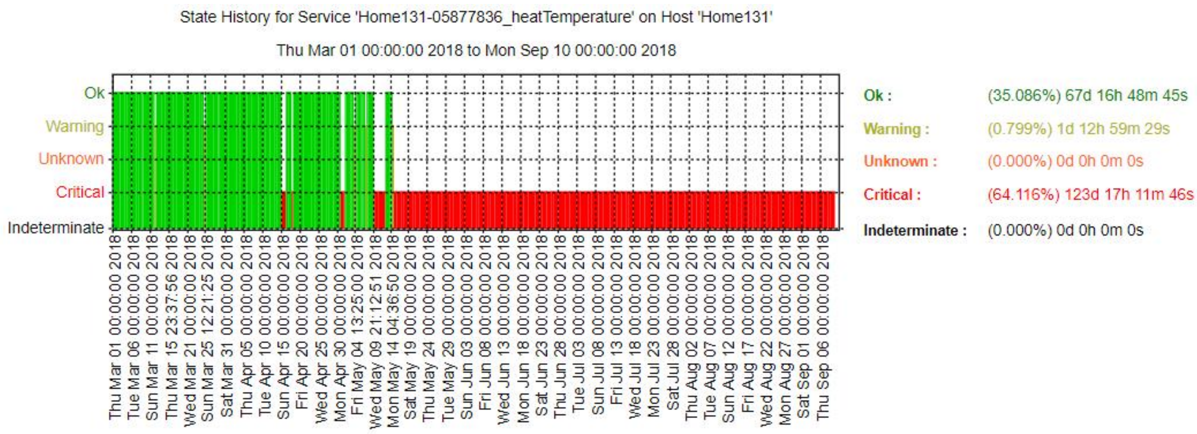


This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426



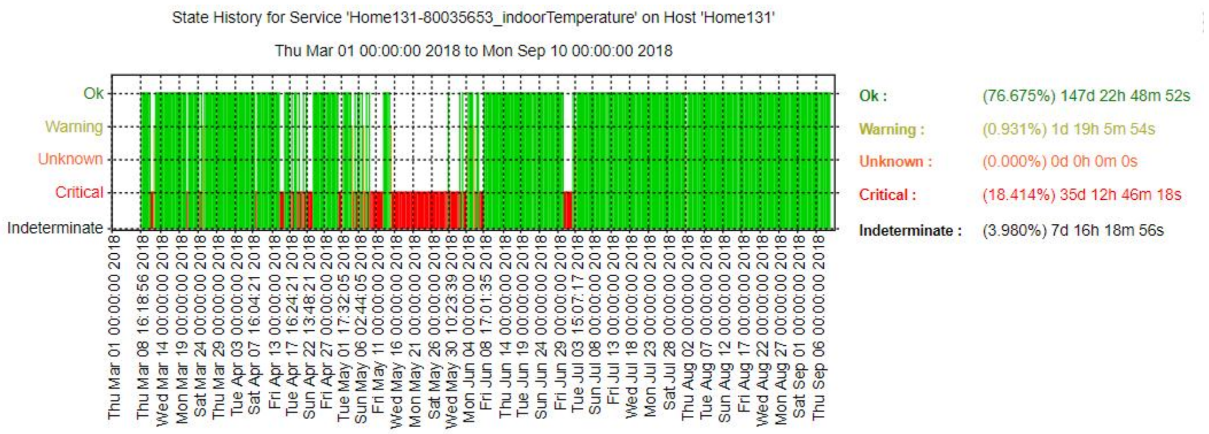
Hardware	Location	Number	Data availability
Honeywell Sensor (#8)	House 131	3	86.805%
	House 133	0	
	House 137	0	
	House 143	2	87.019%

House 131



Critical alarm due to Honeywell API bug from May/14th. Intervention needed in the house to fix this Honeywell situation.
Not taken into account for the data availability calculation (not relevant).

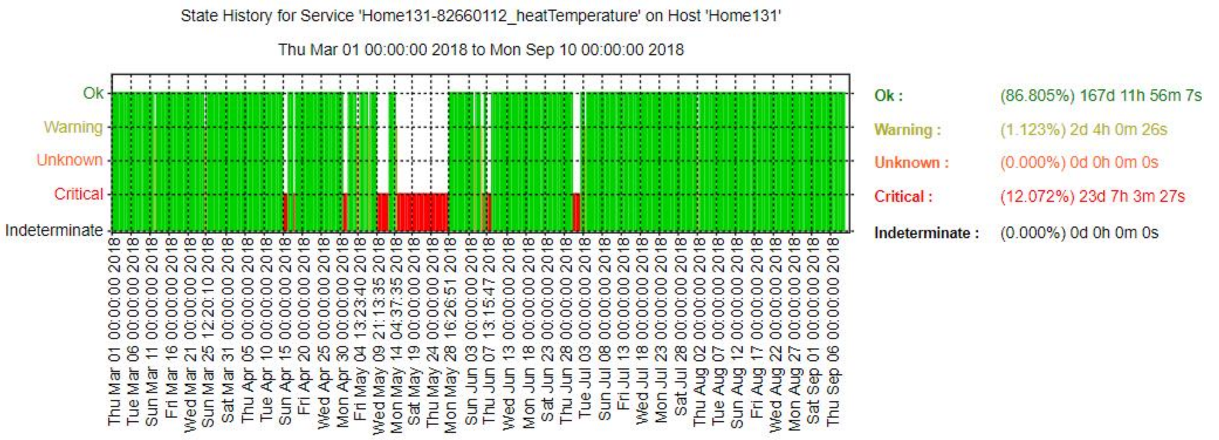
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426



Event	Value out of range (20-23°C)
Impact of unavailability / stakeholders	No impact for ACT No impact for BaseN Impact on house owners' comfort (not in summer period)
Solution	Analysis on the issue: linked to the indirect control of the Heat Pump by the Honeywell thermostat, not due to ACT model.

Event	Honeywell API bug from May/14th to May/28th
Impact of unavailability / stakeholders	No data for ACT No data for BaseN No impact on house owners' comfort
Solution	Corrective patch applicated in order for BaseN & ACT to fetch correctly the data

This CRITICAL period represents (15 days / 190 days) * 100 = 7.89% of the total period. Not taken into account for the data availability calculation (not relevant)

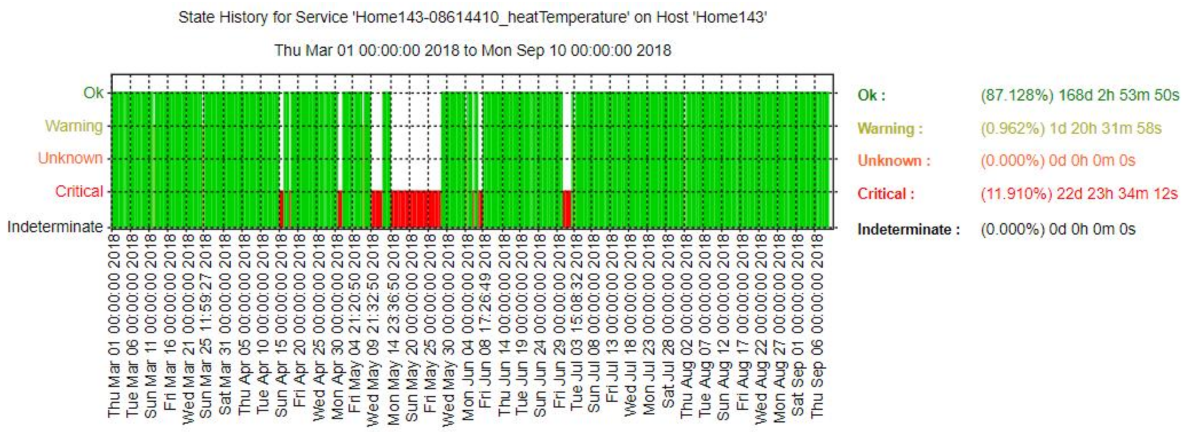


This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

Event	Honeywell API bug from May/14th to May/28th
Impact of unavailability / stakeholders	No data for ACT No data for BaseN No impact on house owners' comfort
Solution	Corrective patch applicated in order for BaseN & ACT to fetch correctly the data

This CRITICAL period represents (15 days / 190 days) * 100 = 7.89% of the total period.
Not taken into account for the data availability calculation (not relevant)

House 143

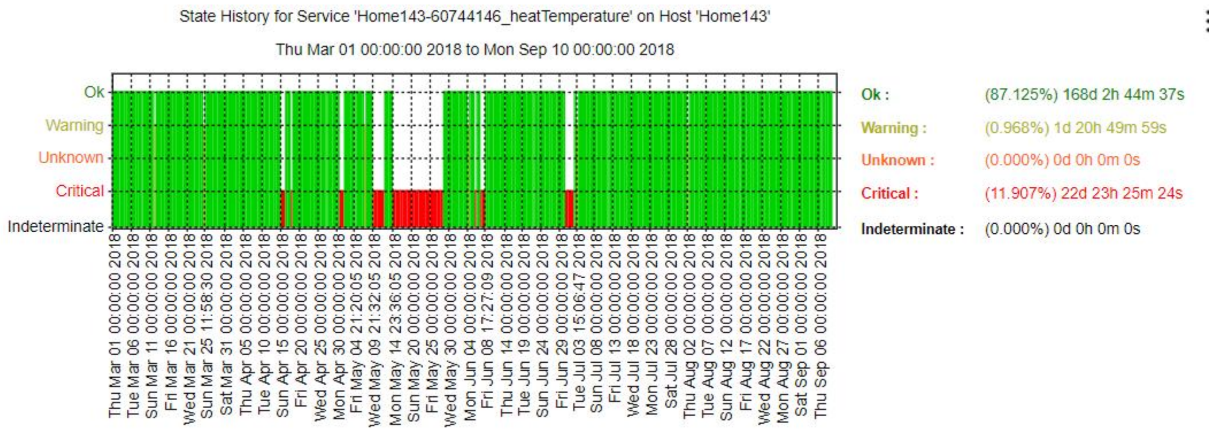


Event	Honeywell API bug from May/14th to May/28th
Impact of unavailability / stakeholders	No data for ACT No data for BaseN No impact on house owners' comfort
Solution	Corrective patch applicated in order for BaseN & ACT to fetch correctly the data

This CRITICAL period represents (15 days / 190 days) * 100 = 7.89% of the total period.
Not taken into account for the data availability calculation (not relevant)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 646426

Project STORY - H2020-LCE-2014-3



Event	Honeywell API bug from May/14th to May/28th
Impact of unavailability / stakeholders	No data for ACT No data for BaseN No impact on house owners' comfort
Solution	Corrective patch applicated in order for BaseN & ACT to fetch correctly the data

This CRITICAL period represents (15 days / 190 days) * 100 = 7.89% of the total period.
Not taken into account for the data availability calculation (not relevant)

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12 APPENDIX : T6.4 PRIVACY DATA QUESTIONNAIRE

12.1 QUESTIONNAIRE: Stakeholder Awareness about Data Privacy

12.1.1 End-Consumer

1) Can you list the data you think are being collected by your energy provider?

   Personal data
   - Age
   - Gender
   - Location
   - Occupation

   Data concerning your consumption
   - Installed power
   - Energy consumption

   - Other: ______________________________

2) Would you be ready to share more personal data with your energy provider in order to receive a more tailored service (lower prices, more stable service)?

   - Strongly agree
   - Agree
   - Neutral
   - Disagree
   - Strongly disagree

3) Do you have any other comments or concerns?

   ____

   ____

12.1.2 DSO

1) What kind of data do you collect?
   - Use of electricity (washing-machine, dishwasher, laptop, telephone, smartphone, TV, etc)
   - Frequency (high, medium, low)
   - Timing (hour, week, month, year)
   - Geographic (city, area, neighbourhood)
   - Other: ____________________________________

2) For which purpose are you using these data?
   - Practical use (Maintaining a stable and reliable network)

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- Internal Database and Research (analysis, studies and report)
- External Database Research (analysis, studies and report)
- Conference, Meeting, Event
- Other___________________________________

3) Is your organization facing difficulties implementing specific laws to protect end-consumer data?
   - Yes
   - No
   - I don't know

   What are the most difficult aspects of the legislations to comply with?

   ____

   ____

4) How do you anonymize the data?
   - Manual system
   - Electronic system
   - Specific algorithm invented by the company
   - Specific system invented by the company
   - Other___________________________________

5) How do you balance between the privacy of the end-consumer and the need for collecting data to ensure a stable and reliable distribution network?

   ____

   ____

6) Do you or your company share the data with third parties?
   - Yes
   - No
   - I don't know

And if yes, which data do you share?

- Personal data of consumers (age, telephone number, gender, occupation
- Data concerning the consumption
- Both
- Other: _____________________________

7) Do you keep your users informed about the treatment of their data?
   - Yes
   - No
   - I don't know

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If yes, how do you inform your users about the treatment of their data?
- Email / Newsletter / Social Media
- Call / SMS
- Meeting / Event
- Bill

8) Do you have any other comments or concerns?

____
____

12.1.3 Aggregator

1) What kind of data do you collect?
   - Use of electricity (washing-machine, dishwasher, laptop, telephone, smartphone, TV, etc)
   - Frequency (high, medium, low)
   - Timing (hours, weeks, months, years)
   - Geographic (cities, area, neighbourhood)
   - Other: ____________________

2) How are you using this data and for which purposes?
   - Internal Database and Research (analysis, studies and report)
   - External Database Research (analysis, studies and report)
   - Other______________________

3) Is your company implementing specific laws to protect the privacy of the end-consumer data?
   - Yes
   - No
   - I don't know

4) How do you anonymize the data?
   - Manual system
   - Electronic system
   - Specific algorithm invented by the company
   - Specific system invented by the company
   - Other______________________

5) How do you balance between the privacy of the end-consumer and the need for collecting data to accurately forecast demand and generation amount?

   ____
   ____

6) Do your company share the data with third parties?
   - Yes

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- No
- I don't know

And if yes, which data do you share?

- Personal data of consumers (age, telephone number, gender, occupation
- Data concerning the consumption
- Both
- Other________________________________

7) Do you keep your users informed about the treatment of their data?
   - Yes
   - No
   - I don't know

If yes, how do you inform your users about the treatment of their data?

- Email / Newsletter / Social Media
- Call / SMS
- Meeting / Event
- Bill

8) Do you have any other comments or concerns?

____

____

12.1.4 Supplier

1) What kind of data do you collect?
   - Use of electricity (washing-machine, dishwasher, laptop, telephone, smartphone, TV, etc)
   - Frequency (high, medium, low)
   - Timing (hours, weeks, months, years)
   - Geographic (cities, area, neighbourhood)
   - Other: ____________________________________
2) How are you using this data and for which purposes?
   - Internal Database and Research (analysis, studies and report)
   - External Database Research (analysis, studies and report)
   - Conference, Meeting, Event
   - Other_____________________________________
3) Is your company implementing specific laws to protect end-consumer data?
   - Yes

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- No
- I don't know

4) How do you anonymize the data?
   - Manual system
   - Electronic system
   - Specific algorithm invented by the company
   - Specific system invented by the company
   - Other___________________________________

5) How do you balance between the privacy of the end-consumer and the need for collecting data to establish and provide competitive market conditions?
   ____
   ____

6) Do you or your company share the data with third parties?
   - Yes
   - No
   - I don't know

   And if yes, which ones?
   - Personal data of consumers (age, telephone number, gender, occupation)
   - Data concerning the consumption
   - Both
   - Other ___________________________

7) Do you keep your users informed about the treatment of their data?
   - Yes
   - No
   - I don't know

   If yes, how do you inform your users about the treatment of their data?
   - Email/Newsletter/Social Media
   - Call/SMS
   - Meeting/Event
   - Bill

8) Do you have any other comments or concerns?

____
____
___

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12.1.5 Regulator

1) What kind of data do you collect?
   - Use of electricity (washing-machine, dishwasher, laptop, telephone, smartphone, TV, etc)
   - Frequency (high, medium, low)
   - Timing (hours, weeks, months, years)
   - Geographic (cities, area, neighbourhood)
   - Other: ______________________________

2) How are you using this data and for which purposes?
   - Internal Database and Research (analysis, studies and report)
   - External Database Research (analysis, studies and report)
   - Conference, Meeting, Event
   - Other______________________________

3) Is your organization implementing specific laws to protect end-consumer data?
   - Yes
   - No
   - I don't know

4) How do you anonymize the data?
   - Manual system
   - Electronic system
   - Specific algorithm invented by the company
   - Specific system invented by the company
   - Other______________________________

5) How can you prevent the abuse of personal data by organisations you are regulation?

____
____
___

6) Do you have any other comments or concerns?

____
____
___

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