RESilient

Resilience for Cyber-Physical
Energy Systems

Deliverable D3.1

Resilient Planning and Operation Requirements

Version 1.0

Deliverable

Jawad Kazmi (AIT)
Paul Smith, Francesca Soro, David Allison, Catalin Gavriluta, Filip Pröstl Andrén (AIT),
Henrik Sandberg, Daniel Selvaratnam (KTH),
Victor Bagge, Fredrik Akke (DLAB),
Arlena Wellssow (OFFIS),
Marco Mittelsdorf (ISE),
Malte Puhan (SOL)

2023-04-24

This project has received funding in the framework of the joint programming initiative ERA-Net Smart Energy Systems' focus initiative Digital Transformation for the Energy Transition, with support from the European Union's Horizon 2020 research and innovation programme under grant agreement No 883973.

Smart Energy Systems ERA-Net

DOCUMENT INFORMATION

- **Deliverable No.:** D3.1
- **Deliverable Name:** Resilient Planning and Operation Requirements
- **Work Package:** WP3 Concept and Architecture for Resilient Planning and Operation
- **Lead Partner:** AIT
- **Submission Date:** 2023-04-24
- **Status:** ☐ draft, ☐ final, ☒ submitted

DISSEMINATION LEVEL

☒	**Public**	Publicly available
☐	**Programme Participants**	Restricted to other programme participants (including ERA-Net and national funding organizations)
☐	**Restricted**	Restricted to a group specified by the Consortium (including ERA-Net and national funding organizations)
☐	**Confidential**	Confidential, only for members of the Consortium (including ERA-Net and national funding organizations)

CHANGE LOG

Date	Version	Author/Editor	Summary of Changes Made
2022-12-15	v0.1	J. Kazmi (AIT)	Initial document structure
2022-01-16	v0.2	J. Kazmi (AIT)	Added contents for methodology
2022-02-20	v0.3	J. Kazmi (AIT)	Added main contents for analysis chapter
2022-03-10	v0.4	J. Kazmi (AIT)	Added appendices
2022-03-10	v0.5	E. Widl (AIT)	Review
2022-03-13	v0.6	F. Pröstl Andrén (AIT)	Small editorial changes
2022-03-21	v0.7	J. Kazmi (AIT)	Addressed reviewer comments and updated the appendix
2022-04-24	v1.0	F. Pröstl Andrén (AIT)	Deliverable submitted

TABLE OF CONTENTS

1 Executive Summary

Over-provisioning, as is done today, cannot be used to create resilience for future energy systems. On the one hand, it cannot handle the complexity and difficulties of the digital transition that energy systems are going through, and, on the other hand, is not socially sustainable. It is necessary to reconsider resilience theory and practice for energy systems.

This is accomplished by *RESili8*'s innovative resilience solution package for Cyber-Physical Energy System (CPES), which consists of new approaches for the resilient operation of energy systems as well as optimal and sustainable planning, AI-based analysis of resilient architectures, and continuous implementation and validation of resilient applications.

By ensuring supply security and supporting the continued integration of green energy technologies, this creative solution package will speed up the switch to renewable energy sources.

This deliverable documents the requirements for developing *RESili8* solutions for a resilient Smart Grid (SG). Developing such solutions correctly is a complex task and would be hard without a well defined methodology. Therefore, one such methodology is defined in this document, comprising three phases that are dedicated to eliciting the requirements, identifying gaps and defining a transformation roadmap.

The methodology is based on the rationale that for improving a system it is important to understand the existing (baseline) system. Once the baseline system is know, a transformation to the target system can be defined guided by the objectives of the project. It would then be possible with a *gap analysis* to identify the needed improvements for the transformation. In *RESili8*, the baseline system is a non-resilient SG system that needs to be transformed into a resilient SG. In this deliverable only the analysis and input collected in phase 1 is documented.

As a result of applying the methodology, a set of 50+ functional, non-functional and business requirements are extracted. In addition to 20+ primary use case and 15+ actors. The modeling is conducted with Sparx Enterprise Architect 16. The analysis in the reaming phases will be conducted in the other tasks of WP3 and will be reported subsequently in respective deliverables.

2 Introduction

Future energy systems will be characterized by a much higher degree of digitalization than today's systems. Digital solutions in the energy system are cornerstones for enabling increased penetration of renewable energies. Digitalization also allows new energy solutions that challenge current structures and policy frameworks, such as microgrids, regional energy communities, and sector coupling. They all fundamentally change how the energy system needs to be operated and they would not be possible without new digital solutions.

For energy system operators, system resilience and security will always be of the highest importance. They are now faced with the challenge to improve their system resilience in order to handle the future digital transformation. Furthermore, an improvement in resilience should not come at the cost of sustainability. Resilience is the ability of a system to detect and predict disruptive events, respond by securely transitioning to a stable (sub-optimal) operation point, and take appropriate measures for fast recovery to a desired normal operation mode. When energy systems are digitalized to a high degree on all levels, resilient and secure future energy systems can only be promised if a cyber-physical view is taken on all aspects.

The *RESili8* project solves these challenges with a novel solution package that ensures resilience on three fronts:

- Today system operators are faced with challenges to choose the right architectures that can provide resilience for future scenarios. Together with participating need-owners in the project and external stakeholders, *RESili8* will develop a toolkit that supports system operators with planning and evaluation of resilient future energy systems.
- To be resilient, all parts of the system must be implemented accordingly, including applications such as control and monitoring functions. *RESili8* will provide new and rapid implementation and validation solutions to ensure resilient applications.
- Today, resilience is mostly assured by planning for worst-case scenarios – usually achieved through over-provisioning – which is expensive and not sustainable. *RESili8* will develop solutions for the resilient operation of cyber-physical energy systems, considering both physical and cyber ways to handle disruptive events.

For the purpose of baseline system requirements gathering, the *RESili8* consortium is divided into three groups:

- Group 1: partners who are bringing in the baseline components that will be improved during the project;
- Group 2: partners who are bringing in the improvement and extension proposals;
- Group 3: partner(s) who are providing the field validation infrastructure for testing and validating the *RESili8* resilience package or parts of it.

This deliverable provides the results from discussions on the description of the baseline systems and different use cases and their resulting requirements mainly for Group 1 (dLab, ISE, SOLANDEO, OFFIS). The goal of these use cases is to provide a clear overview of what is being targeted in the project. The use cases are analysed in detail and requirements are derived. These use cases and requirements will serve as inputs for the rest of the project in order to align developments and validations and field tests at the end of the project. Group 2's proposal and requirements will be addressed in D3.2 after gap analysis on top of the baseline system analysis, while Group 3 will be addressed in D3.3.

The rest of the deliverable is structured as follows: Section 3 gives a detailed overview of the methodology that was used for the use case and requirements analysis. In Section 4, a summary of the results from the use case analysis are presented together with details for selected partners. The deliverable is concluded in Section 5.

3 Methodology

Smart Grid (SG) is a complex system-of-systems that requires the integration of a large number of cyber systems and physical systems. Developing a SG, therefore, requires a well-developed methodology that would enable eliciting the requirements to provide insight into the required functionality as well as to help in developing and testing the solution.

For developing *RESili8* solutions, one such methodology has been derived and used to elicit the requirements. This section first provides an overview of this methodology in Section 3.1 along with a brief explanation of the three main phases. Later, Section 3.2 provides some explanation of the two input templates that are used for collecting the information about the baseline system.

3.1 Overview

An overview of the employed methodology is presented in Figure 1. As can be seen in the figure, it is divided into three phases, labeled with numbers 1, 2 & 3. These three phases are to 1) collect knowledge about the *baseline system* and define the *target system*, 2)identify the needed improvements, 3) and devise a plan for implementing the improvements. The methodology tries to answer the question *"Where are we now and where do we want to go?"*. The rationale behind it is that to improve a system, it is important to understand the existing (baseline) system. Once the baseline system is known, a transformation to the target system can be defined and guided by the objectives of the project. It would then be possible with a *gap analysis* to identify the needed improvements for the transformation. In *RESili8*, the baseline system is a non-resilient SG system which needs to be transformed into a resilient SG.

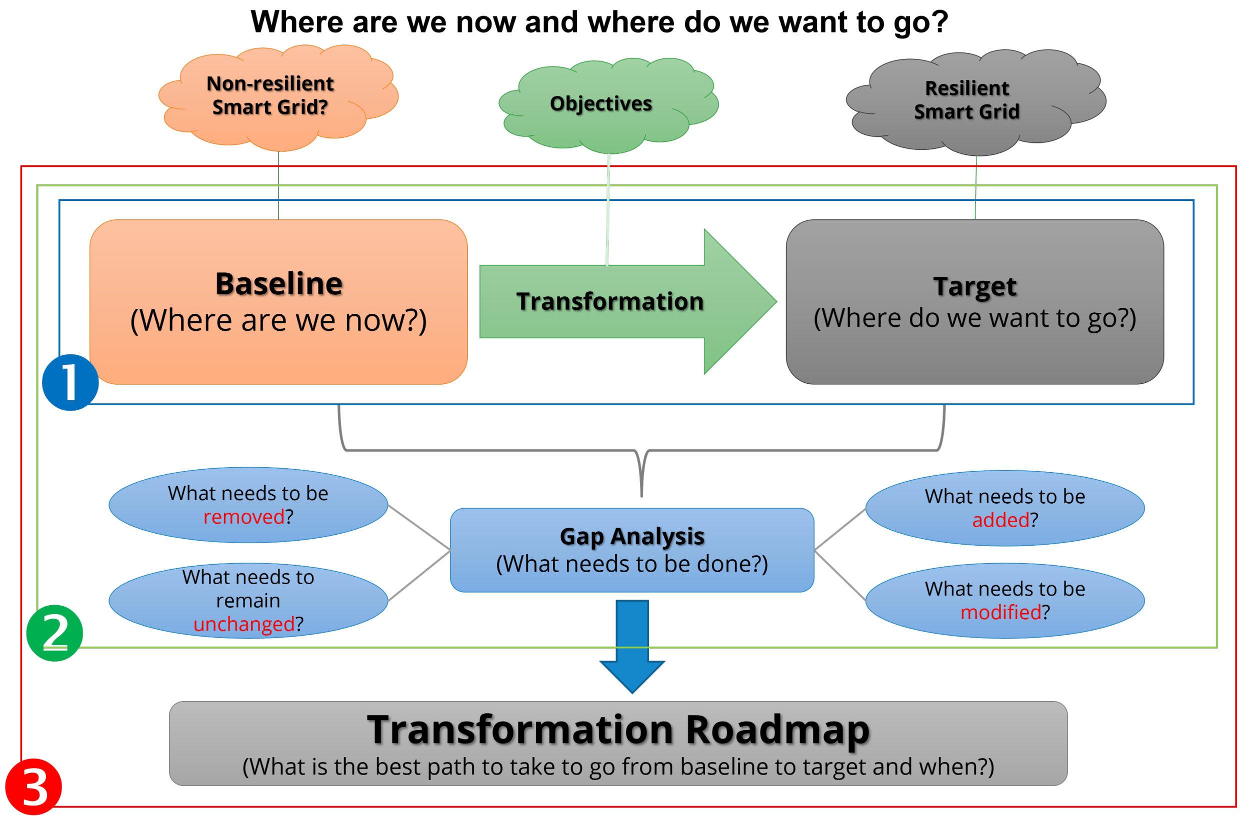

Figure 1: Overview of the proposed methodology with three phases marked with numbered boxes.

Based on the gap analysis, a transformation roadmap can be developed that would detail on the actions on a timeline linked with the project life cycle.

Below, each of the three phases is defined in some more detail, also specifying the inputs and outputs and the analysis to be performed.

3.2 Phase 1 – The baseline requirements phase

This phase is dedicated to gathering first an understanding of the baseline (existing) system for the reasons mentioned before in Section 3.1. Once the baseline system is well understood, this knowledge can be used to define the target system that needs to be built as the solution promised in the project for fulfilling the defined objectives.

To understand the baseline system it is important to know it from the *inside* and from the *outside*. The inside view provides information about how the various services are organized in different roles and then performed by different actors. Similarly, the outside view of the system provides information about how various actors, roles, stakeholders, and any other external systems that are interacting with the system. For capturing both these *views* of the system, two Microsoft Excel-based templates (*Internal* and *External* View templates) have been created. These templates are explained below.

3.2.1 Internal View Template

The first view of the system is the internal view that captures various actors, services, and roles performed by the system. Figure 2 shows the major concepts being collected in the *Internal View template* and how they are related to each other. In summary, each system has some *Business Process* primarily to serve its *Stakeholder*. For the interactions, various *Roles* like monitoring, administration, controlling, etc. can be assumed. In each of these roles, different *Services* are offered, which are then used by specific *Actors*.

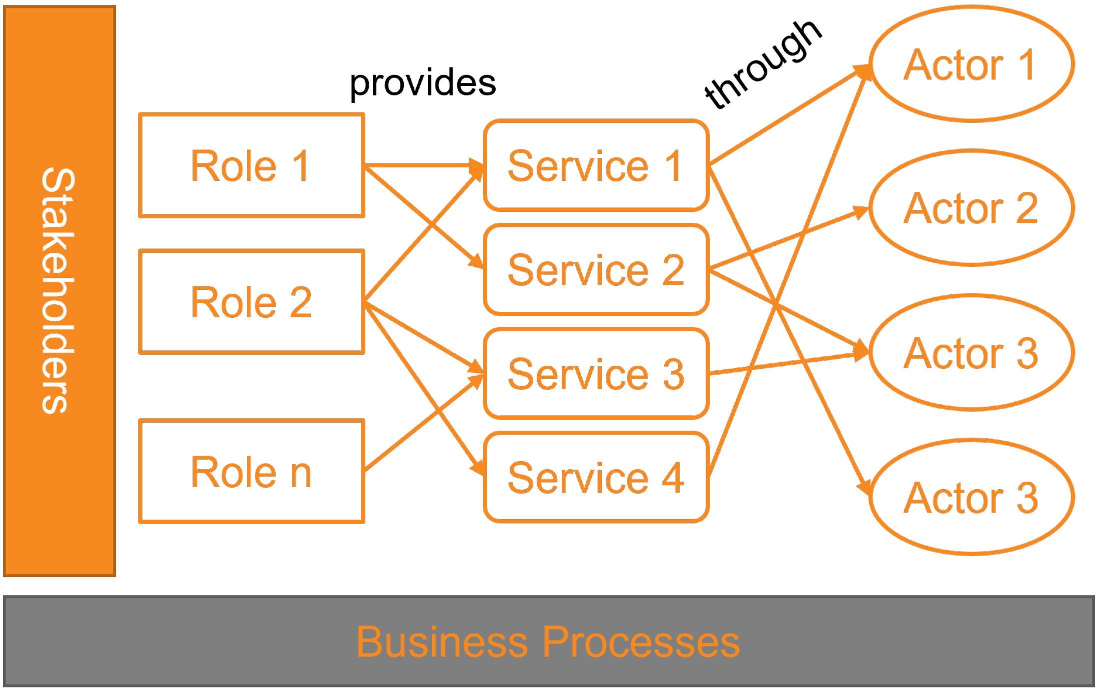

Figure 2: Conceptual overview of the Internal View template, showing stakeholders, roles, services, and actors as well as their relation to each other.

To capture these concepts, the template defines three *tables* that are shown in Figure 3. These tables can be filled either in a bottom-up or a top-down fashion. However, the bottom-up approach (highlighted with arrows in the figure) typically turns out to be easier, as it considers going from the more visible parts of the system to the more abstract concepts. These three tables collect information about the system based on the rationale shown in Figure 2, implementing the hierarchy and relationships.

Figure 3: Overview of the proposed methodology.

3.2.2 External View Template

For capturing the external view of the system, a second template is defined based on the rationale shown in Figure 5. It is intended to identify *external systems* that are interacting with the system and to establish the linkages with the *stakeholders*.

For collecting information on the system, several concepts are used for capturing various aspects of the system. Some of these concepts are:

- *User profiles* is a group of stakeholders/roles that are similar in needs and interactions,
- *external systems* are the systems that interact with the baseline system,
- *delivery channels* are the communication channels that are used by external systems for communicating with the system,
- *information exchange* is the data being exchanged between the system and other external systems

A Microsoft Excel template is defined for collecting this information as well. The template is shown in Figure 4. Again, there are three tables that collect information about the users and user profiles, external systems, and the information exchange.

USERS				
S.#	User Profile	Description and Context	Interations	
			Required Information	Frequency and Volume
1	PROSUMER	Is one of the key member of the energy community. Its has the ability to both generate and consume the energy.	1. View energy flow, 2. view billing information and compensations for the shared energy, 3. etc.	Up to X requests per second/minute (on average

External System and Delivery Channels (Proxy for Business Users)												
S.#	Name	Description/purpose	Possible Interaction scheme	Supported Network(s) & Protocols				Bandwidth		Quality attribute requirements, capabilities and limitations	User Profiles that use this channel	Remarks
				Network(s)	Protocol(s)	Response Delay	Communication Type	Download	Upload			
1	Mobile (Display) Device	An autonomous display device that is installed in participants' homes with some own operating system and networking capabilities.	Provides an API that can be used to publish data to the device	WIFI 802.11 a/b/g	HTTP/HTTPS	20ms	One-way (write only) from our system to this system	Upto 100Mbps	Upto 10Mbps	**Security**: the data passed should be encrypted. **Availability**: this system is available 99.0% of the time. **Performance**: only support data updates in not faster than the second range.	PROSUMER	

Information Flow							
S.#	Functional Need	Description	Type	Frequency	Size	Soruce	Sink
1	Display price and demand information	A PROSUMER would need to know what are the current price and demand information so that it can plan accordingly.	Near Realtime	5 requests per second	1k per request	System-to-be-built	Mobile (Display) Device

Figure 4: The three main parts of the external view template.

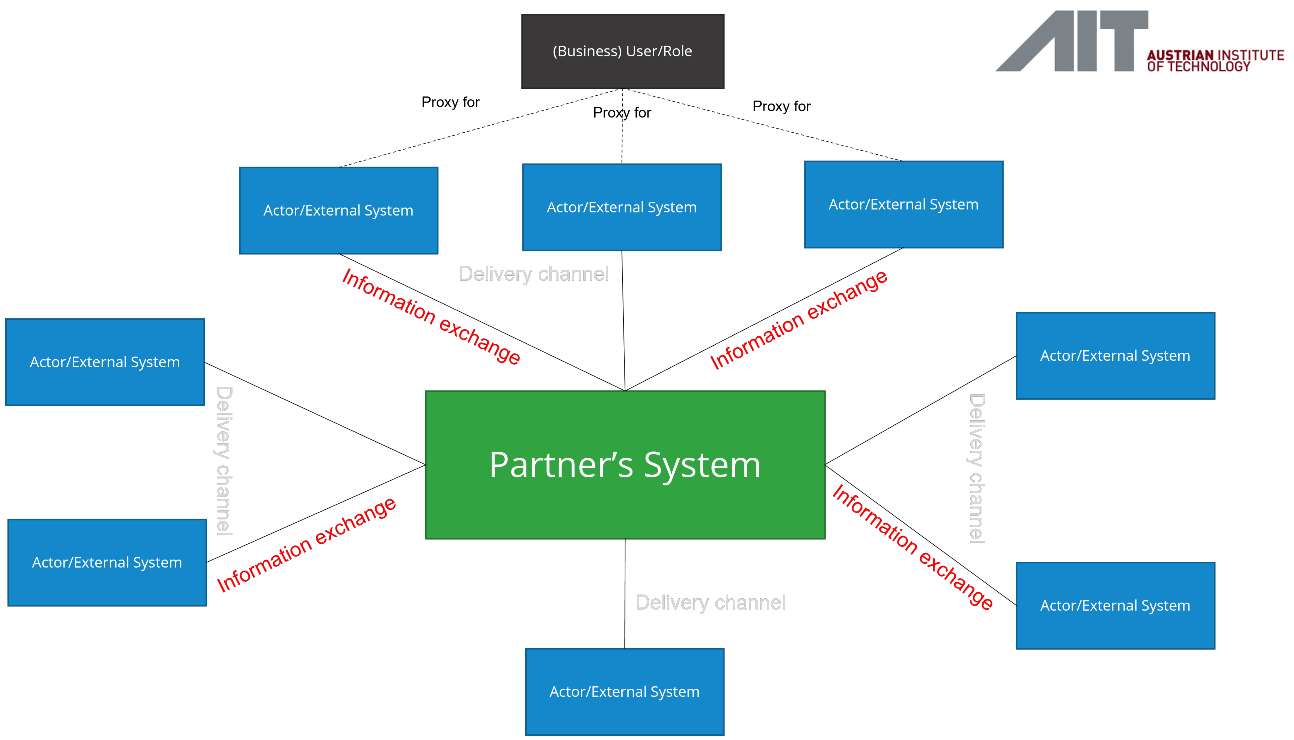

Figure 5: Overview of the rationale for the information collected with the external view template.

The collected knowledge about the baseline system is then analyzed to develop requirements and use cases as described in Section 4

3.3 Phase 2 – The gap analysis phase

This phase is about finding the *gaps* between the baseline system and the defined target system. The analysis in this phase depends on the availability of knowledge about the baseline and target system. This knowledge is then used to identify the gaps.

This way, it is possible to identify what needs to be done on top of the baseline system so that the target system can be achieved. At a high level, it could be as simple as answering the following four questions about the baseline system:

1 What needs to be added to the baseline system so that it would fit as a target system?

2 What needs to be updated in the baseline system so that it would fit as a target system?

3 What needs to remain unchanged in the baseline system so that it would fit as a target system?

4 What needs to be removed from the baseline system so that it would fit as a target system?

3.4 Phase 3 – The transformation roadmap definition phase

At the beginning of this phase, the baseline system is known and the target system has already been defined in the baseline requirements phase (see Section 3.2). Furthermore, the gaps have also been identified in the gap analysis phase (see Section 3.3). It is now possible to organize, prioritize and plan the actions and map them on a timeline. In some cases, it might not be possible to implement all the identified enhancements due to, for example, available resources, missing regulations and/or regulations, etc. In this case, prioritization can be carried out based on the project objectives, available resources, technology, regulations, etc.

4 Analysis

The methodology presented in Section 3 provides the basis for the analysis of the baseline system. This section presents the analysis and its outcome in the form of high-level functional and non-functional requirements, identification of the actors, and the use cases as well as the mappings on various partners' systems.

4.1 Summary of the analysis

This sub-section provides a summary of the analysis based on the input received from the *RESili8* consortium partners. The provided input is collected using the two sets of input templates (see Section 3.2). Appendix A provides a sample of the processed input.

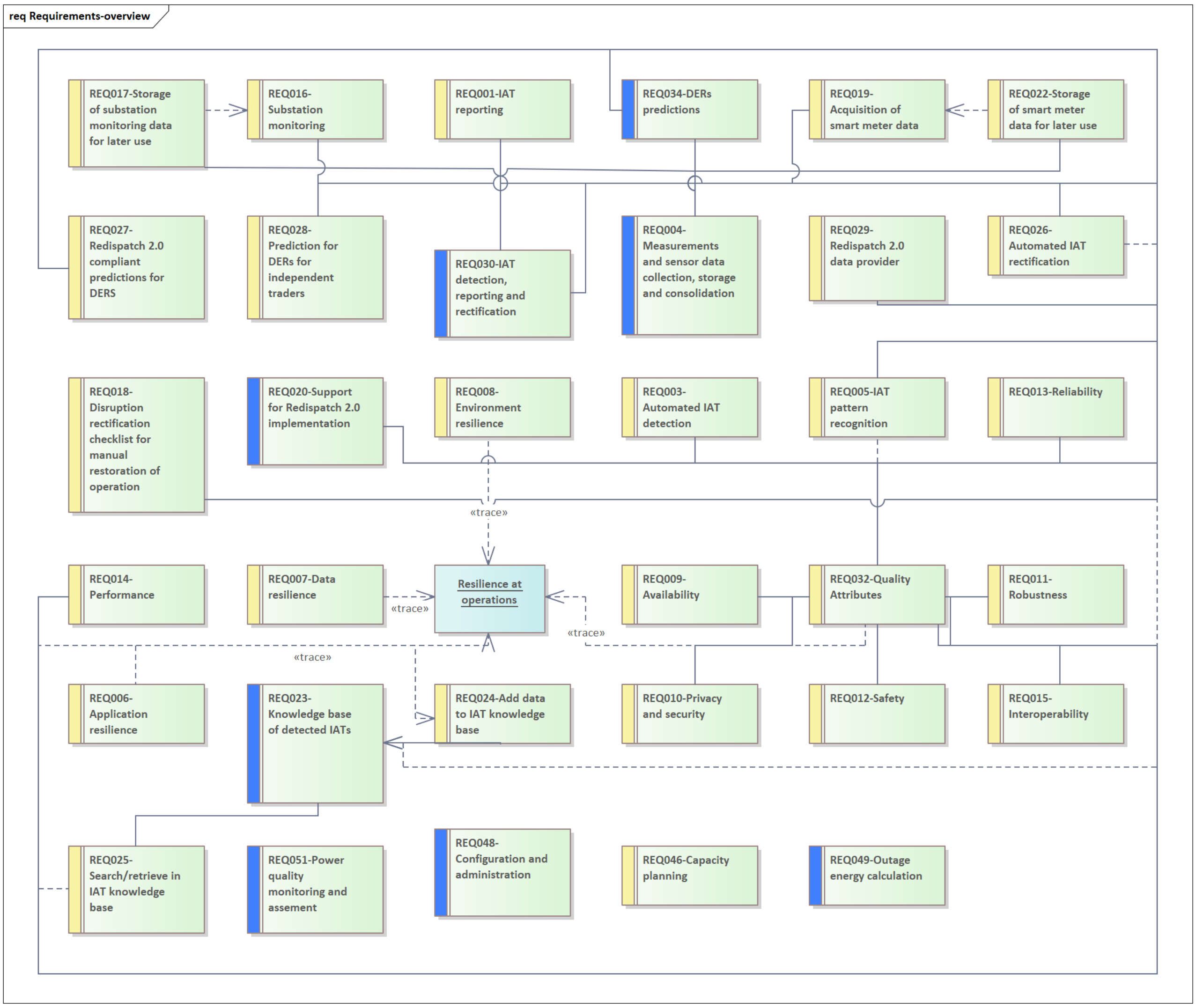

Figure 6: Summary model of the high-level functional and non-functional requirements.

Based on the input provided in the baseline requirements phase (phase 1) of the methodology (see Section 3.2), Figure 6 shows an overview of the elicited functional and non-functional requirements. In the figure, the requirements with a blue ribbon are a group while the requirements with a yellow ribbon are related to one or more of the groups.

Similarly, Figure 7 presents a partial view of the high-level use cases, actors, and some of the requirements that are related to each other in some form of the relationships.

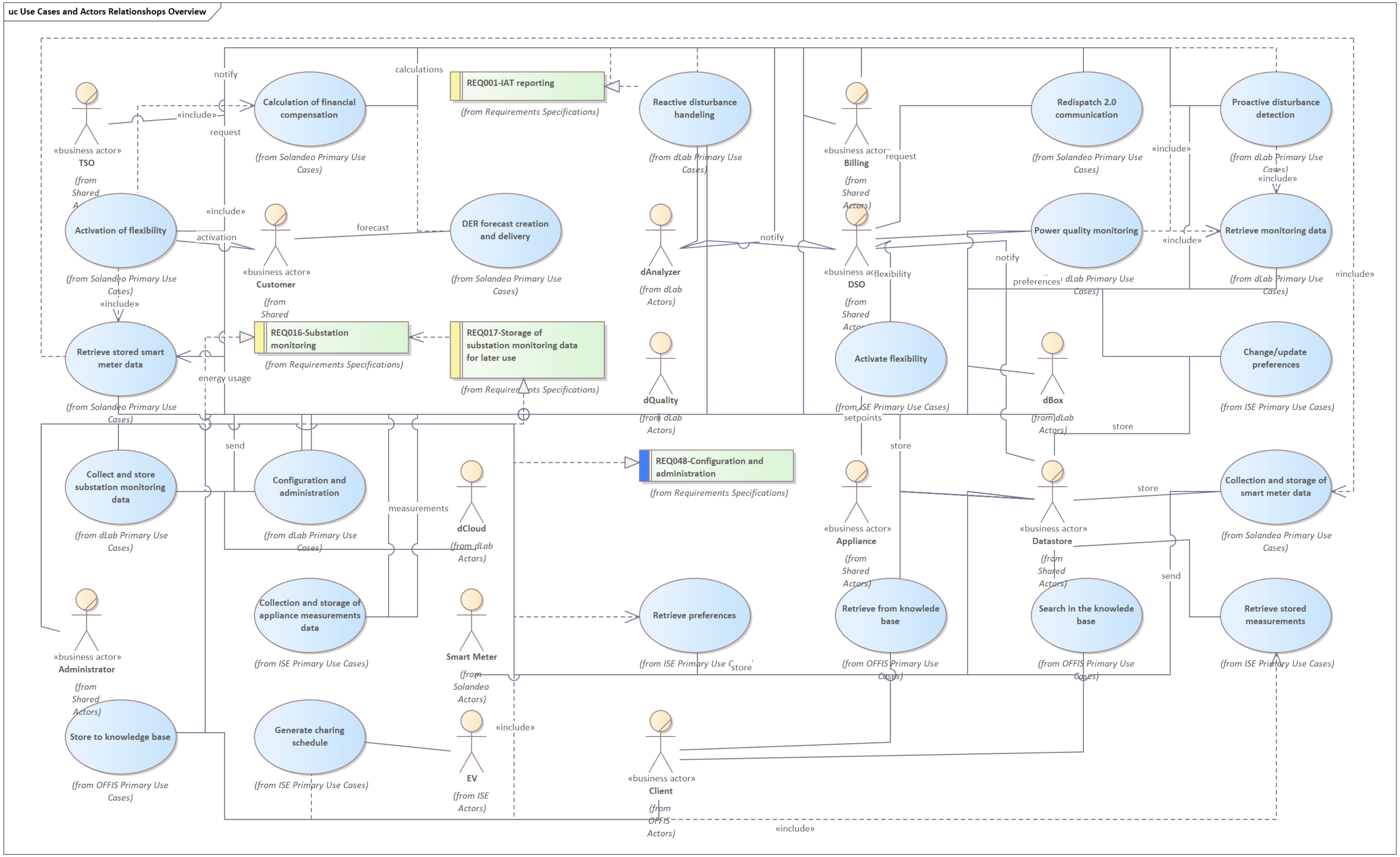

Figure 7: Partial view of the developed use case along with the identified actors and linked requirements.

The elicited requirements and mappings are further explained in Section 4.2 while Section 4.3 talks in more detail about the identified use cases and actors and their mappings.

During the analysis, the *RESili8* objectives as extracted and summarized from the grand agreement are considered in line with the defined methodology. Some of these objectives are listed below:

1 Develop an optimal scheduling tool for planning resilient architectures that consider a trade-off between system quality attributes and (social) sustainability

2 Develop an AI-based analysis tool for the evaluation of attacker/defender strategies

3 Develop a prototypical toolkit for resilient integration of applications

4 Develop a rapid validation framework for resilient applications based on digital twins

5 Develop an incident and anomaly detection system with root cause analysis to detect and predict disruptive events

6 Develop new methods for consolidation of sensor data

7 Develop resilient operation strategies based on AI analysis to counter existing as well as new threats

4.2 Elicited business, functional and non-functional requirements

During the requirements analysis, a set of business, functional, and non-functional requirements have been elicited based on input from the involved stakeholders. An overview of them is provided in Figure 6. A further classification of these requirements is shown in Figure 8 where the requirements have been assigned to the stakeholders of the project *RESili8* as well as some baseline functions.

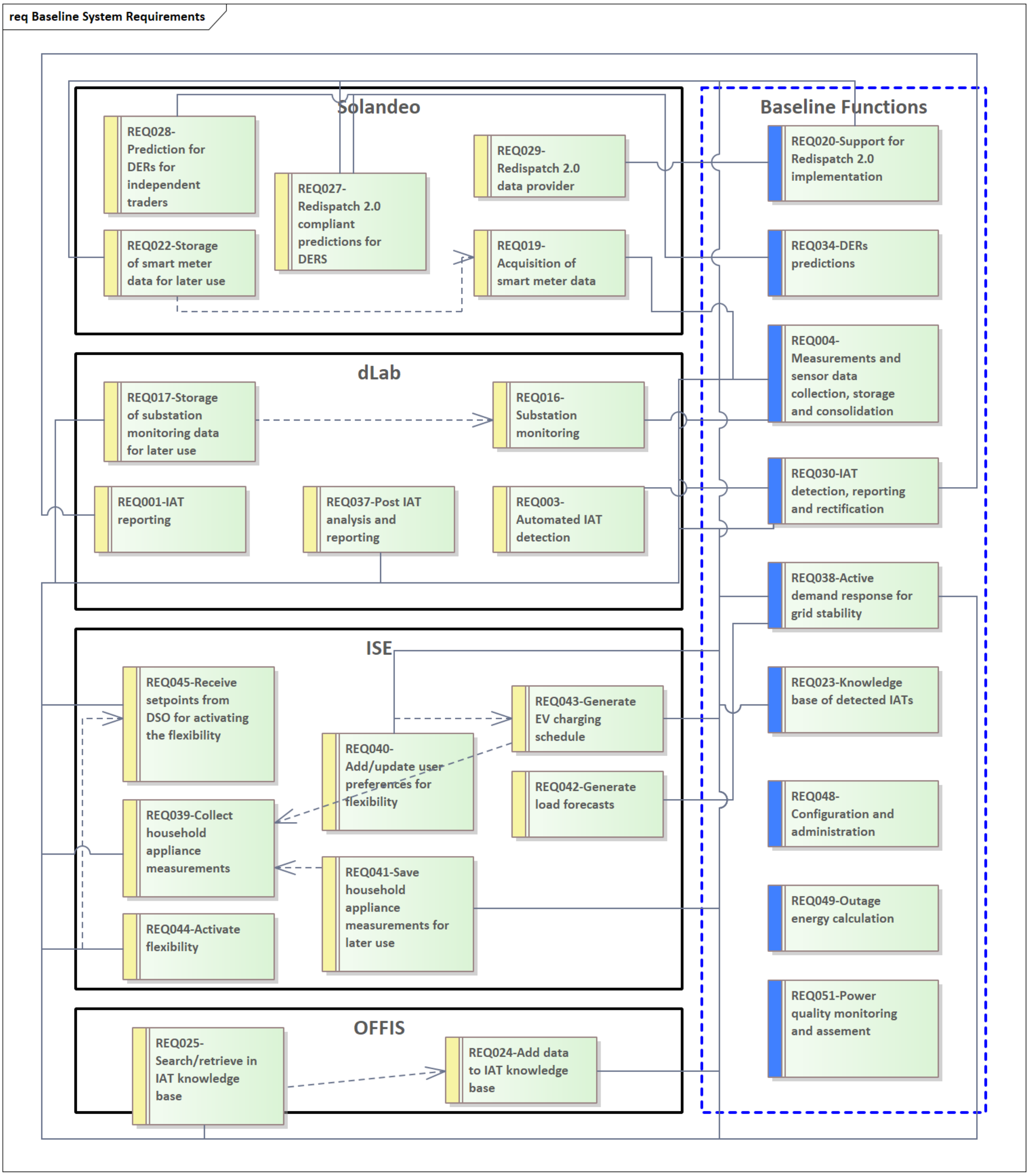

Figure 8: Summary of requirements allocated to each partner's system.

Below is the list of identified baseline functions. These functions are then described in the individual subsections.

- Resilience in system operation
- Measurements and sensor data collection, storage, and consolidation
- Support for Redispatch 2.0 implementation
- A knowledge base of detected Incident, Anomaly, and Threat (IAT)

- IAT detection, reporting, and rectification
- Quality Attributes (non-functional) requirements
- Distributed Energy Resource (DER) predictions
- Active demand response for grid stability
- Capacity planning
- Configuration and administration
- Outage energy calculation
- Power quality monitoring and assessment

4.2.1 Resilience in system operation

This group of non-functional requirements defines that the developed solution should be capable of providing data, application, and environmental resilience.

1 **REQ007 – Data resilience:** The *RESili8* solution shall address both physical and local data resilience

2 **REQ006 – Application resilience:** The *RESili8* solution shall provide a high level (>2) of application resilience

3 **REQ008 – Environment resilience:** The *RESili8* solution shall address both physical and logical environment resilience.

4.2.2 Measurements and sensor data collection, storage, and consolidation

This group of **functional requirements** defines that the *RESili8* solution shall provide new methods for data collected (substation, smart meter, sensor).

1 **REQ016–Substation monitoring:** The *RESili8* solution shall provide capabilities to monitor various devices in a substation.

2 **REQ017–Storage of substation monitoring data for later use:** The *RESili8* solution shall provide the capabilities to store substation monitoring data in a data store for later use.

3 **REQ019–Acquisition of smart meter data:** The *RESili8* solution shall provide the capabilities to acquire data from a smart meter.

4 **REQ022–Storage of smart meter data for later use:** The *RESili8* solution shall provide the capabilities to store collected smart meter data in a data store for later use.

5 **REQ035–Sensor data collection and storage:** The *RESili8* solution shall provide the capabilities to acquire data from various sensors and provide services to store this data in a data store for later use. The stored data must be retrievable from the *data store* whenever requested.

6 **REQ036–Data consolidation:** The *RESili8* solution shall include the capabilities for consolidating data, for example from smart meters, sensors, controllers, etc.

7 **REQ039–Collect household appliance measurements:** The *RESili8* solution shall include acquiring data from various smart appliances installed in a household.

8 **REQ041–Save household appliance measurements for later use:** The *RESili8* solution shall provide the capabilities to store data collected from the household appliances and smart meter for later use.

4.2.3 Support for Redispatch 2.0 implementation

This group of functional requirements defines the capabilities of the *RESili8* solution that will enable it to implement Redispath 2.0.

1 **REQ029-Redispatch 2.0 data provider:** The *RESili8* solution shall provide the capabilities to help connect a Distribution System Operator (DSO) system to the Redispatch 2.0 data provider system.

4.2.4 A Knowledge base of detected IATs

The *RESili8* solution shall provide an IAT knowledge base that, for example, can be used to learn about the IAT patterns.

1 **REQ024–Add data to the IAT knowledge base:** The *RESili8* solution shall provide the capabilities that new data about the detected IAT can be added to the IAT knowledge base.

2 **REQ025–Search in/retrieve data from IAT knowledge base:** The *RESili8* solution shall provide the capabilities to search within the IAT knowledge base.

4.2.5 IAT detection, reporting, and rectification

This group of functional requirements defines the capabilities needed in the *RESili8* solution that will help in detection, reporting, rectification, and analysis of the IAT.

1 **REQ003–Automated IAT detection:** The *RESili8* solution shall provide the capabilities for detecting various Threats, Incidents, and Anomalies based on the collected data. These capabilities shall work fully automated and in (near) real-time.

2 **REQ005–IAT pattern recognition:** The *RESili8* solution shall provide the capabilities for recognizing various patterns that can lead to some form of Anomaly, Threat, and Incident in the grid. The basis of such an analysis shall be the collected data and history of previously detected Incidents and Anomalies.

3 **REQ001–IAT reporting:** The *RESili8* solution shall provide appropriate capabilities to report any detected Incident, Anomaly, or Threat.

4 **REQ018–Disruption rectification checklist for manual restoration of operation:** When an IAT shall be detected, the *RESili8* solution shall provide a checklist suggesting various possible rectification measures that can help in manually removing IAT.

5 **REQ026–Automated IAT rectification:** The *RESili8* solution shall provide the capabilities to rectify some detected IAT automatically.

6 **REQ037–Post IAT analysis and reporting:** The *RESili8* solution shall provide the capabilities to perform a post IAT analysis and reporting capabilities so that the processes and policies can be improved by incorporating the mitigation steps to avoid them happening again.

4.2.6 Quality Attributes

Required functionality in the system-to-be-built is the primary focus while designing and developing it. However, there are many qualities of it that are closely related to functionality but go beyond it. These quality attributes are so important that missing them could result in a system re-design even when the system-to-be-built is not missing any promised functionality. This group of requirements defines some of these quality attribute requirements for the *RESili8* solution. These quality attributes are a measure for evaluating the level and existence of such qualities in the developed solution. The quality attributes that shall be considered are:

1 **REQ009–Availability:** The *RESili8* solutions shall have the ability to be accessible and functional whenever it is needed with minimal downtime or interruptions. Availability is closely linked to some other quality attributes like reliability, security, etc.

2 **REQ015–Interoperability:** Interoperability is an important and desired quality attribute for *RESili8* solutions. This will enable the sub-systems, assemblies, and components to communicate and exchange information with each other in a meaningful way.

3 **REQ014–Performance:** The *RESili8* solutions shall have the ability to obey and meet the specific timing and resource usage constraints for performing various operations during the interaction with internal and external systems.

4 **REQ013–Reliability:** The *RESili8* solutions shall have the appropriate level of reliability that will ensure that the system, services, and components are able to perform required operations for the specified period of time in an acceptable fashion.

5 **REQ011–Robustness:** The *RESili8* solutions shall have the ability to handle various perturbations at a tolerable level. This quality attribute is positively dependent on some other attributes such as reliability, privacy and security, availability, performance, etc.

6 **REQ012–Safety:** The *RESili8* solutions shall ensure that all the provided services, implemented sub-systems, components, and assemblies are not harmful to use for its environment, including users, operators, etc. as well as the infrastructure.

7 **REQ010–Privacy and security:** The *RESili8* solutions shall have the ability to provide their services and data only to authorized users and systems. This means that appropriate authentication and authorization together with integrity and confidentiality of the data and services shall be implemented. Mitigation actions would be incorporated into the developed solutions to address any efforts to access service and/or data in an unauthorized manner. All such events will be monitored, prevented, and logged.

4.2.7 DER predictions

This group of functional requirements defines the capabilities in the *RESili8* solution that will enable it to support in DER predictions.

1 **REQ027–Redispatch 2.0 compliant predictions for DERs:** The *RESili8* solution shall provide predictions within the Redispatch 2.0 processes.

2 **REQ028–Prediction for DERs for independent traders:** The *RESili8* solution shall provide DER predictions to energy market participants (direct traders)

3 **REQ050–Prediction delivery:** The *RESili8* solution shall provide capabilities that enable the predictions to be delivered to customer-specific interfaces.

4.2.8 Active demand response for grid stability

This group of functional requirements defines the *RESili8* solution capabilities that enable the use of customer assets to activate flexibility for grid stability.

1 **REQ040–Add/update user preferences for flexibility:** The *RESili8* solutions shall provide the ability for the user to choose the way they like to participate in the system using appropriate opt-in and/or opt-out options.

2 **REQ042–Generate load forecasts:** The *RESili8* solution shall implement a load forecasting algorithm that would be able to predict the load for any individual household as well as for a specific part of the distribution grid. The algorithm developed for predicting household load forecasts can be used inside an energy management system in the household for local optimization while the distribution grid load forecasts would be used by a distribution system operator for global optimization, for example.

3 **REQ043–Generate Electric Vehicle (EV) charging schedule:** The *RESili8* solution shall implement algorithm(s) for optimizing the charging schedule for an EV.

4 **REQ044–Activate flexibility:** The *RESili8* solution shall implement service(s) that enable activation of flexibilities that could be in the form of controllable loads owned by a prosumer and located at a household or could be owned/managed by an aggregator or a DSO. This activation would be based on the setpoints sent by, for example, a DSO.

5 **REQ045–Receive setpoints from DSO for activating the flexibility:** The *RESili8* solution shall implement the functionality that enables a DSO to send setpoints to be used for activating the flexibility. The actual activation would happen by the functionality covered by REQ044.

4.2.9 Capacity planning

The requirement regarding grid capacity planning is summarized here. Although this requirement can be more granularly defined, here it is considered at a higher level as this is not one of the focuses of the project *RESili8*.

1 **REQ046–Capacity planning:** The *RESili8* solution shall provide the services that will implement algorithms for the calculations needed for capacity planning.

4.2.10 Configuration and administration

The ability to configure and perform administrative actions for adapting to the needs is an important functional requirement and should be present in any reasonable solution. Although it would be possible to break down this general requirement into more specific sub-requirements, it is still presented as one big requirement here due to not being the main focus of the *RESili8* solutions.

1 **REQ048–Configuration and administration:** The *RESili8* solution shall provide an appropriate set of user interfaces that enable the administrators to configure, monitor and do the usual system administration activities like user and roles creations, authentication, and authorization configuration and administration, monitoring system by using, for example, a dashboard.

4.2.11 Outage energy calculation

The general requirement mentioned here is about defining a need in the *RESili8* solution for providing the provisions for calculating the outage energy. Like some of the previous requirements, this requirement can also be defined with sub-requirements for a more detailed specification, however, this is avoided to keep the focus on a more relevant set of requirements.

1 **REQ049–Outage energy calculation:** The *RESili8* solution shall provide an appropriate set of services that enable the calculation of outage energy.

4.2.12 Power quality monitoring and assessment

This general requirement specifies that the developed solution should have the capabilities to enable monitoring of the distribution grid to identify any deviation from the power quality threshold. Again, it would be possible to define a set of sub-requirements defining these capabilities in more detail, however, for the reasons mentioned earlier, only a generalized view of this requirement is specified.

1 **REQ051–Power quality monitoring and assessment:** The *RESili8* solution shall provide an appropriate set of services that would enable monitoring the power quality threshold violations.

4.3 Actors and Use Cases

After presenting a summary of the main business, functional and non-functional requirements in the previous section, this sub-section presents the actors and the use cases that are identified by analyzing the requirements and the input.

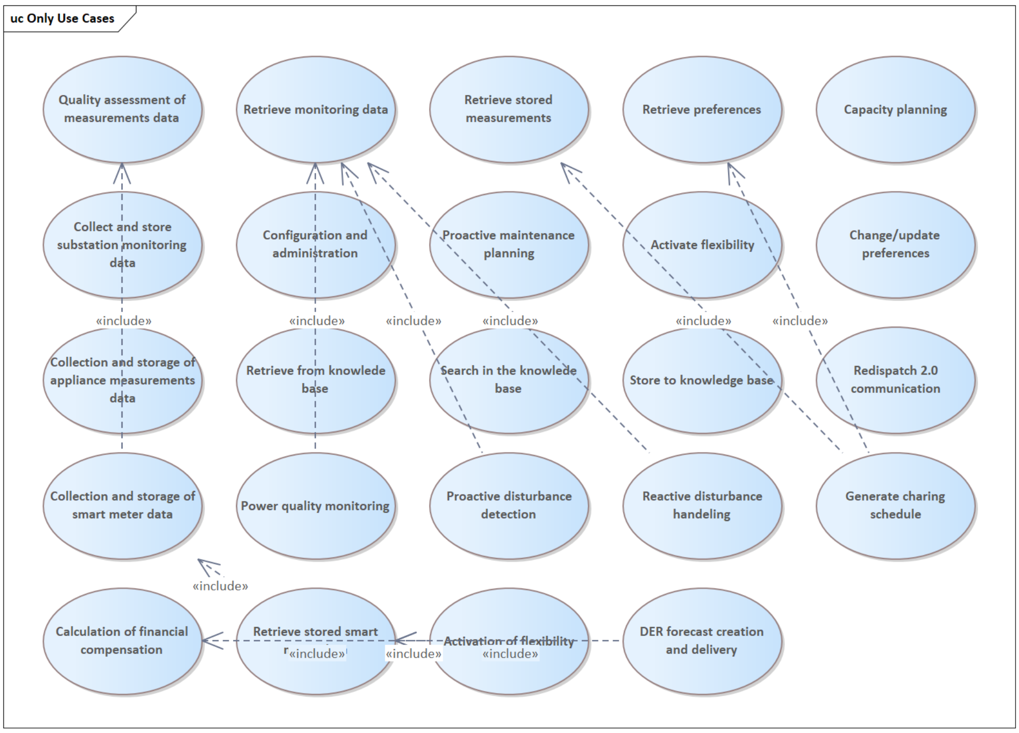

Figure 9: Overview of the identified high-level use cases.

The model presented in Figure 9 shows an overview of the primary use cases identified during the analysis in the requirements phase. The model shows around 24 use cases along with some relationships (mostly such as <include>). The model is using the Unified Modeling Language (UML 2.0) notation.

These use cases are only the high-level primary use cases and most have the potential to be developed into a use case model of their own. However, at this stage of the analysis, only the primary use cases are considered, while the detailed system use cases will be considered later in the development of the project.

For the requirements modeling, use cases alone are not sufficient. An important element is the identification of the actors that would interact and support the *RESili8* solution. For this, the analysis also identified a set of actors. A list of the most relevant actors is shown in Figure 10 below. Again, the model is using the UML 2.0 notation where stereotypes are used to distinguish between different types of actors.

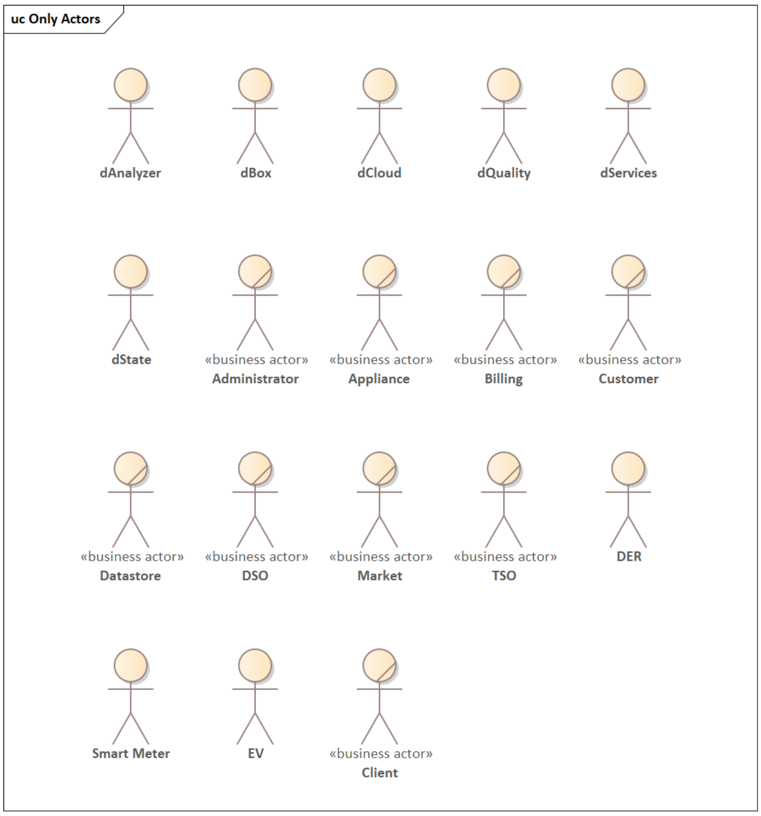

Figure 10: List of the most relevant actors identified during the analysis.

After showing the primary use cases and the actors, Figure 11 assigns the use cases and actors to different partners' baseline systems. The figure shows the mapping with the name of the partner in a package diagram from UML 2.0.

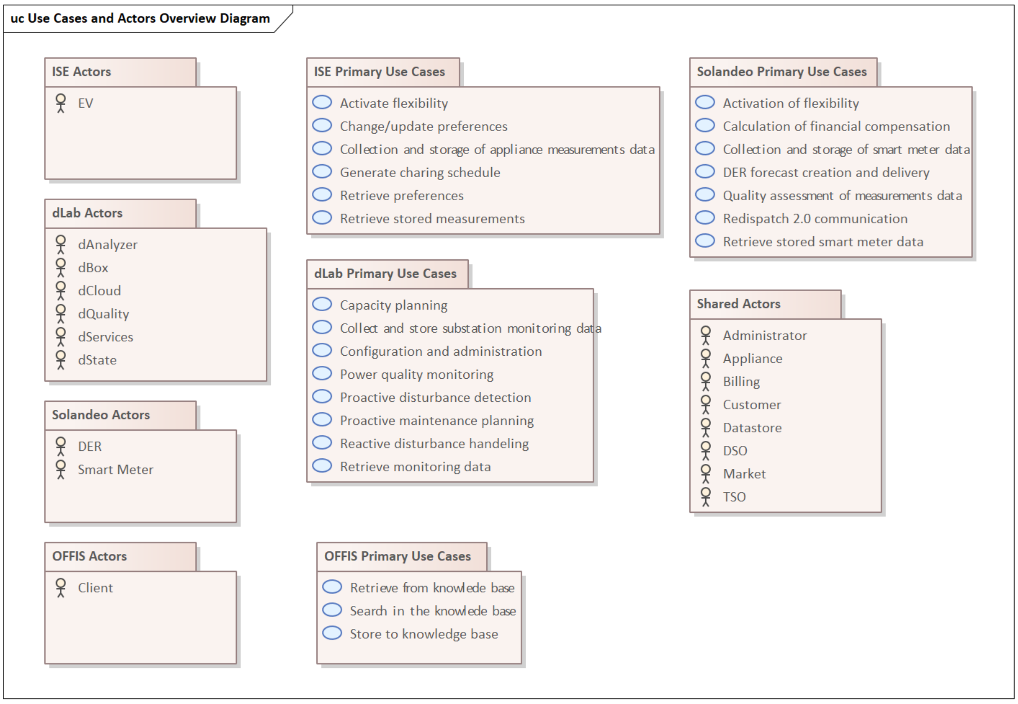

Figure 11: Mapping of the primary use cases and actors to the baseline systems of the partners in *RESili8*.

More detailed mapping and use case modeling for individual partners' baseline systems are presented next.

4.4 Partner specific requirements and use cases

This part of the analysis describes in more detail the use case modeling for the individual partners' baseline system. As mentioned previously, the modeling is based on the input provided by the partners when describing their system in the form of internal and external view templates (see Section 3.2).

In each case, at first, a high-level requirements model is presented that is then proceeded by the use case model that captures the baseline system's functionality. For each of the presented high-level requirements models, the requirements are grouped into two categories. The *Baseline Functions* categories are created to collect the groups of more relevant requirements whereas sub-requirements from the baseline system, grouped in the other category, are then linked to these baseline functions. An aggregate model for the whole baseline system is shown in Figure 8 above.

4.4.1 dLab

A description of dLab's baseline system is presented with high-level requirements modeling first and then with the use case model. Figure 12 shows the high-level requirements. As can be seen in the model, the system is described with three baseline functions that are then linked to five sub-requirements.

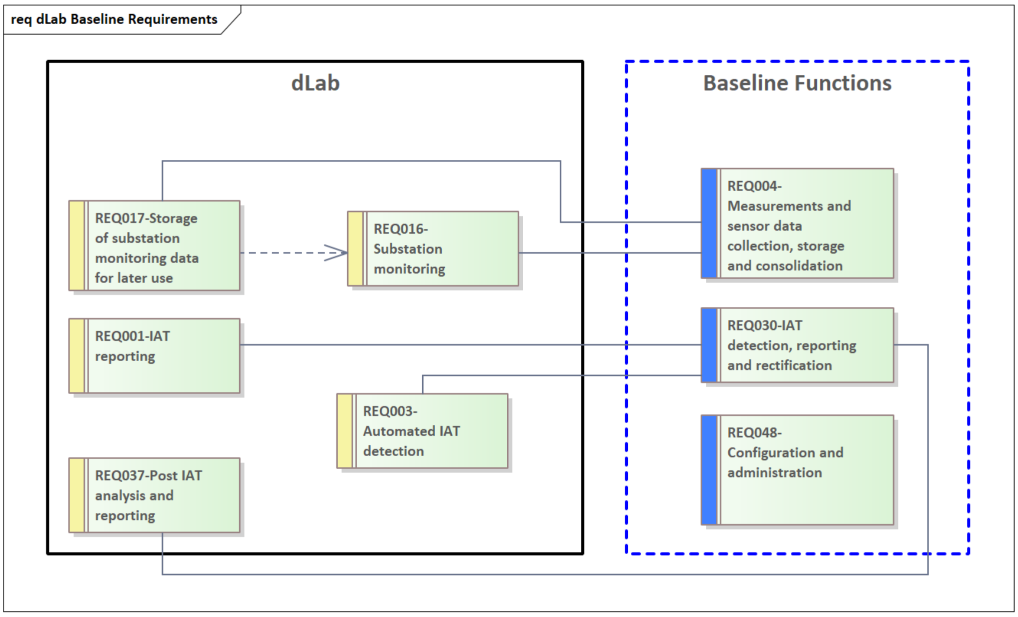

Figure 12: The modeled high-level requirements for the dLab's baseline system.

The use case model in Figure 13 show the use cases and actors and how the interaction is taking place in the baseline system.

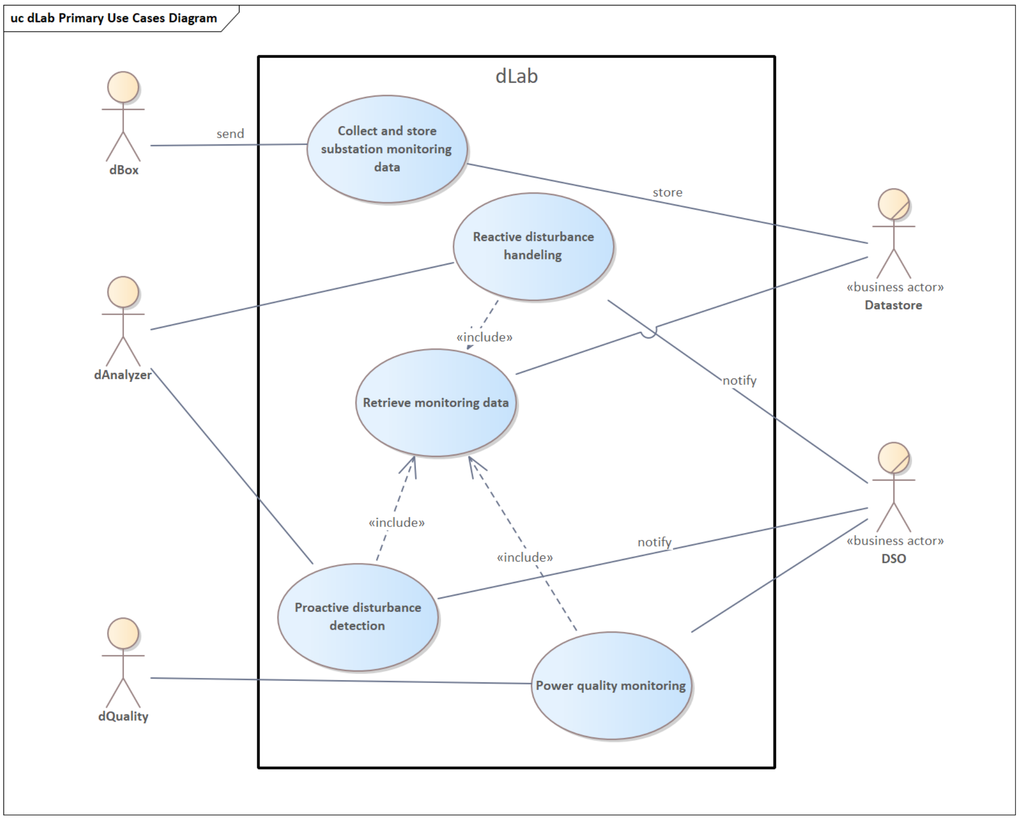

Figure 13: Overview of the developed use cases along with the identified actors for dLab's baseline system.

In the model there are five different actors.

1 **dAnalyzer:** This is a software service that runs at dCloud. Its main function is to analyze data collected from the dBox to detect any disturbances.

2 **dBox:** This device is installed in a substation and is responsible for collecting monitoring data that can then be used to detect and analyze various disturbances and effects in the grid.

3 **dCloud:** This is the infrastructure that hosts many software services including dAnalyzer, dQuality, dState, and dService.

4 **dState:** This is a software service that runs at dCloud. Its primary function is to analyze (state) data collected from dBox to keep track of the state of the devices installed in the substation.

5 **dQuality:** This is a software service that runs at dCloud. Its primary function is to analyze data collected from dBox to detect and suggest rectification for power quality issues.

6 **<businessactor>Datastore:** This is a business actor that represents a data store. This actor could exist in many different forms and variations including a relational database, a file-based storage, a NoSQL database, etc.

In the model, there are five use cases that constitute the behavior of the baseline system. The model shows what the various functions are provided in the system are how different actors are interacting with them. The model also shows relationships among the use cases. The type of relationship is mostly `<include>`. The five primary use cases are:

1 **Collect and store substation monitoring data** deals with collecting measurements and monitoring data from the substations. The collected data is then stored in a *Datastore* for later retrieval, use, analysis, etc.

2 **Reactive disturbance handling** deals with disturbances once they are detected.

3 **Proactive disturbance detection** is about preempting and predicting disturbances before they happen.

4 **Retrieve monitoring data** is about the functionality for retrieving data (mainly the monitoring data) from the data store.

5 **Power quality monitoring** is about collecting monitoring data about the power quality.

4.4.2 ISE

The high-level requirements model presented in Figure 14 shows the requirements and their relationships to the identified high-level baseline functions for the ISE baseline system. As can be seen, the system is implementing two functions which are fulfilled by seven sub-requirements.

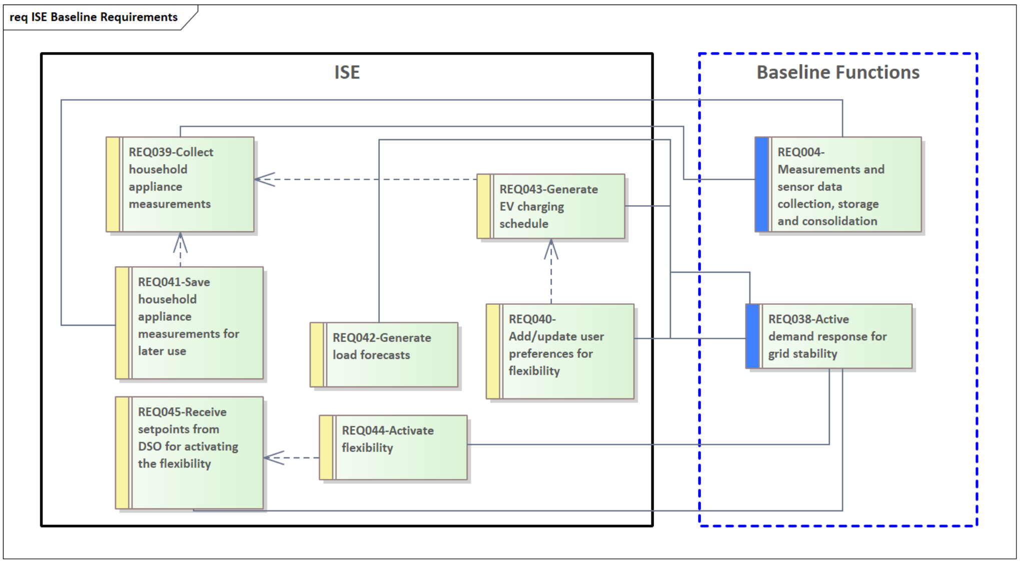

Figure 14: The modeled high-level requirements for ISE's baseline system.

The use case model for the baseline system for ISE is depicted in Figure 15. The model depicts which of the system's various functions are provided and how different actors interact with them. The model also depicts the relationships between the use cases. The majority of the relationships are `<include>`. The model has five actors, which are briefly explained below:

1 **<businessactor>Appliance** is a business actor that refers to a controllable household appliance.

2 **<businessactor>Datastore** is a business actor representing a data store. This actor could exist in many different forms and variations including a relational database, a file-based storage, a NoSQL database, etc.

3 **<businessactor>Customer** is a business actor that represents a customer of an energy provider (DSO usually).

4 **<businessactor>DSO** is a business actor representing a distribution system operator.

5 **EV** is an actor that represents an electric vehicle owned and stored at the household that can then be used for flexibility and/or for charging with an optimized charging schedule.

There are five use cases in the model. A brief summary of each is presented below:

1 **Activate flexibility** deals with activating flexibility that has previously been identified and made available for the purpose.

2 **Change/update preferences** deals with providing the users to make changes to the system so that it would match their preferences.

3 **Collection and storage of appliance measurement data** deals with collecting various types of monitoring and measurement data from household appliances and storing it in a data store for later use.

4 **Retrieve stored measurement** deals with reading data back from the data store.

5 **Generate charging schedule** deals with providing the EV with an optimized charging schedule.

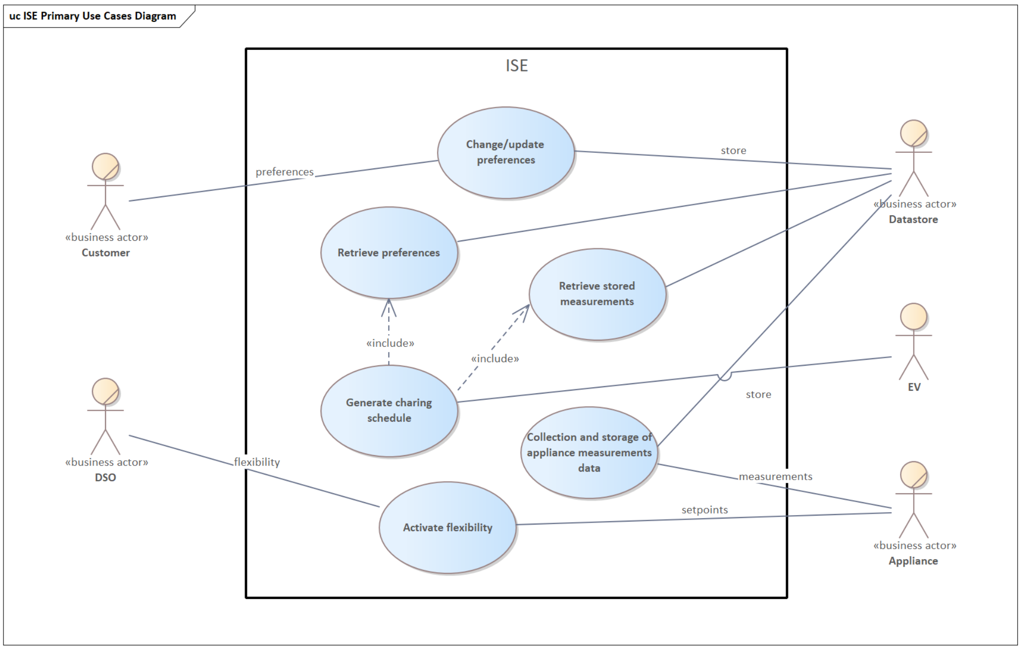

Figure 15: Overview of the developed use case along with the identified actors for ISE's baseline system.

4.4.3 OFFIS

The high-level requirements model for the baseline system of OFFIS is presented in Figure 16. The model shows the requirements addressed in the baseline system and their linkage to the baseline functions. As can be seen, there is only one high-level baseline function defined with two sub-requirements.

Figure 17 shows the use case model for the OFFIS baseline system. The use case model shows which of the various system functions (use cases) are being offered as well as how various actors interact with them. The relationships between the use cases are also shown in the model. Most of the relationships are `<include>` relationships. The two actors in the model are briefly described here.

This model shows three high-level use cases and two actors. The two actors are:

1 **<businessactor>Client** is a business actor representing a client for the system. As this is a generic actor, the client can be any system or human that is interested in retrieving or providing information/data.

2 **<businessactor>Datastore** is a business actor representing a data store. This actor could exist in many different forms and variations including a relational database, a file-based storage, a NoSQL database, etc.

The three use cases shown in the model are:

1 **Store to knowledge base** deals with storing the information provided by a client to the knowledge base.

2 **Retrieve from the knowledge base** deals with accessing the data store and retrieving stored data.

3 **Search in the knowledge base** deals with searching the data store for a specific piece of information.

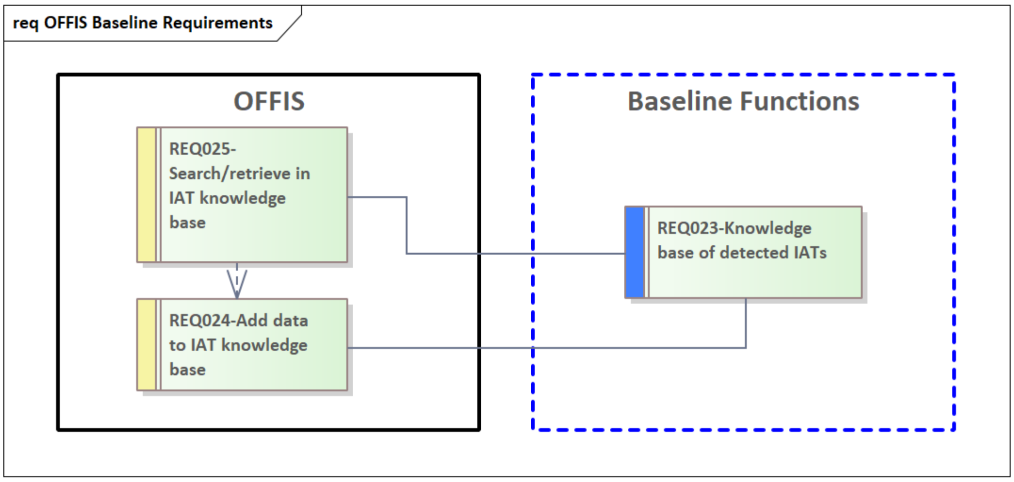

Figure 16: The modeled high-level requirements for OFFIS's baseline system.

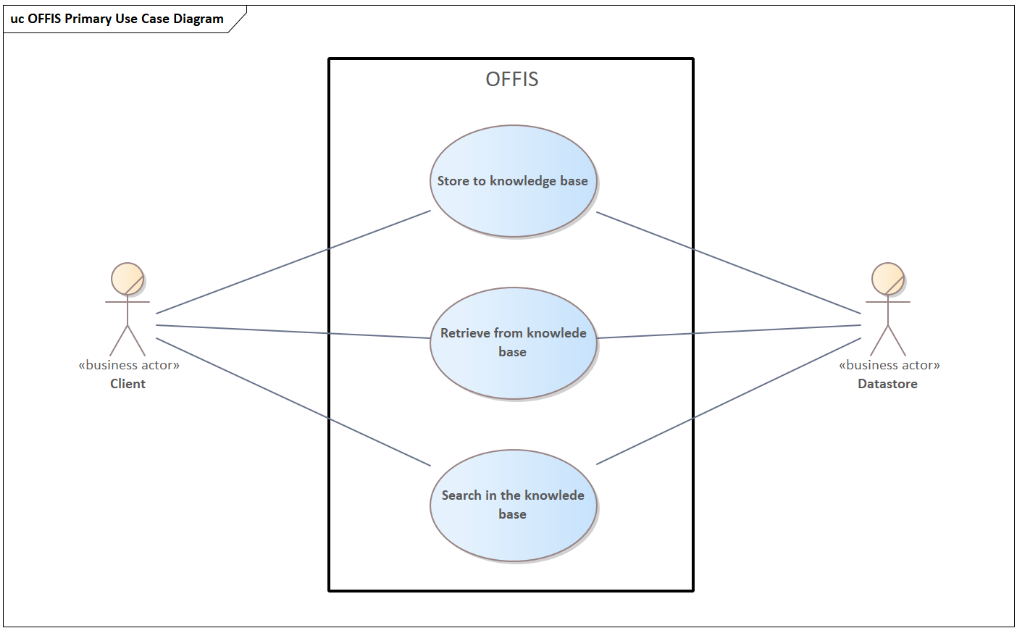

Figure 17: Overview of the developed use case along with the identified actors for OFFIS's baseline system.

4.4.4 Solandeo

Figure 18 shows the high-level requirements model for Solandeo's baseline system. As can be seen in the model, the system is represented with three baseline functions and they are then linked to five high-level requirements.

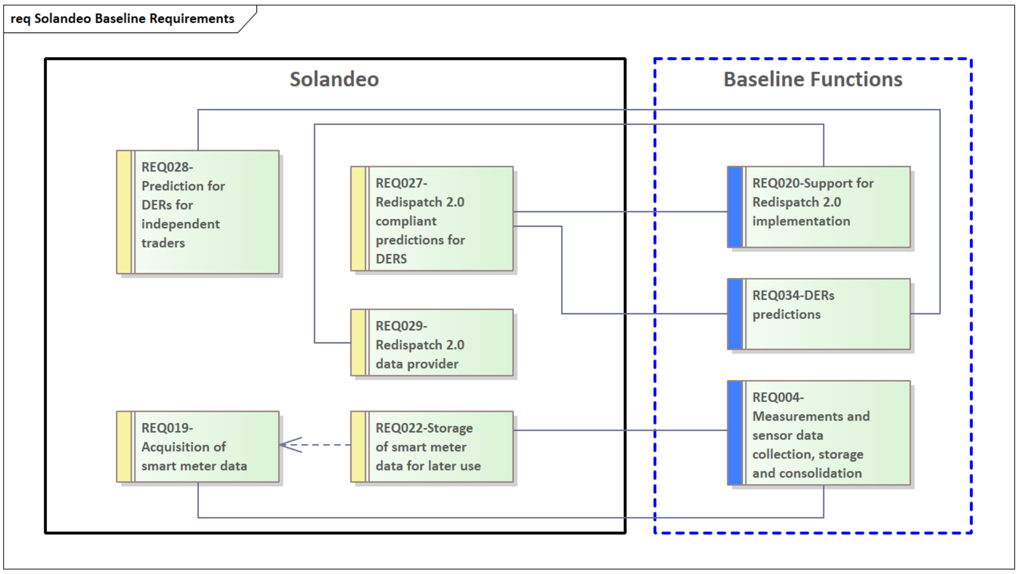

Figure 18: The modeled high-level requirements for Solandeo's baseline system.

The Solandeo baseline system's use case model may be seen in Figure 19. The use case model displays the different system functionalities (use cases) that are being provided as well as how different actors interact with them. The model also displays the connections between the use cases. The majority of the connections are `<include>` connections. Below is a quick description of the actors who are mentioned in the model.

This model shows seven high-level use case and six actors. The six actors are:

1 **<businessactor>Datastore** is a business actor representing a data store. This actor could exist in many different forms and variations including a relational database, a file-based storage, a NoSQL database, etc.

2 **<businessactor>Customer** is a business actor that represents a customer of an energy provider (DSO usually).

3 **<businessactor>DSO** is a business actor representing a distribution system operator.

4 **<businessactor>TSO** is a business actor representing the transmission system operator.

5 **<businessactor>Billing** is a business actor representing the entity responsible for billing.

6 **Smart Meter** represent the smart electrical meter.

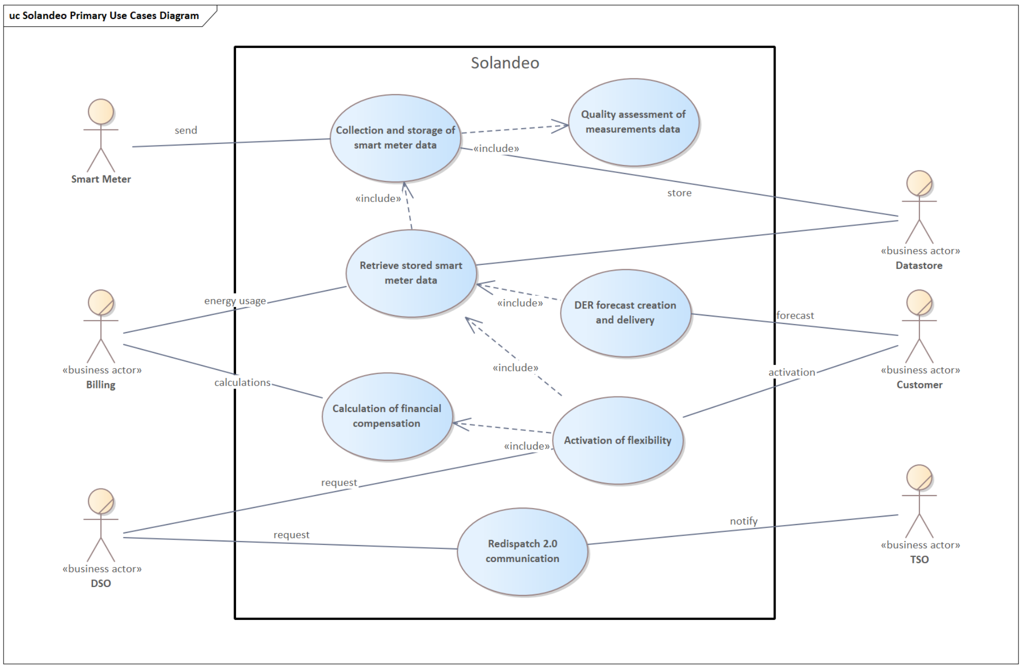

Figure 19: Overview of the developed use cases along with the identified actors for Solandeo's baseline system.

5 Conclusions and Future Work

This deliverable provides an introduction to the proposed methodology for eliciting requirements as the basis for developing the *RESili8* solutions. The proposed methodology is divided into three phases. The first phase provides the baseline where at first the knowledge about the existing system is gathered and used to define the target system. The methodology is foreseen to be used in all the tasks of *RESili8* WP3 and beyond. However, in this deliverable only the analysis and input collected in phase 1 is documented. As a result of applying the methodology, a set of 50+ functional, non-functional and business requirements have been extracted. In addition, 20+ primary use case and 15+ actors have been identified. The analysis in the reaming phases will be conducted in the other tasks of WP3 and will be reported subsequently in respective deliverables.

Appendix A Filled Requirements Input Templates

This appendix lists the input received from the *RESili8* partners in the form of Internal View and External View templates (see Section 3.2).

A.1 dLab Requirements Input Templates

Extracted requirements and use cases based on this input can be seen in Section 4.4.1.

Figure 20, Figure 21, and Figure 22 show the bottom-up view of the system.

Actors			
S.#	**Actor**	**Domain**	**Description & Goal**
1	DER	DER	Distributed energy resources and their behavior
2	Substation	Distribution	Primary substations and their components and their behavior
3	Distribution network	Distribution	Lines, secondary substations and their components, line disconnectors etc. and their behavior
4	External physical actors	Distribution	Trees falling on lines, salt, excavator damaging a cable, customer equipment contributing to bad PQ etc.
5	External IT actor	Distribution, DER	Cyber attacks on substation automation systems, SCADA etc., DDOS-attacks on the grid by using smart appliances
6	dLab Cloud Service	Distribution	Server running analysis for evaluating measured data
7	**dLab hardware (dBox)**	Distribution	Hardware for data acquisition

Figure 20: Actors from dLab Internal View template.

Services			
S.#	**Service**	**Description**	**Involved Actors**
1	dAnalyzer	Incident detection and analysis	Substation, distribution network, external physical actors, external IT actors, dBox, dLab Cloud Service
2	dQuality	Power quality and load evaluation	Substation, distribution network, DER, external physical actors, external IT actors, dBox, dLab Cloud Service
3	dState	Condition based maintenance	Substation, distribution network, dBox, dLab Cloud Service
4	dServices	Investigation of complex disturbances	Substation, distribution network, external physical actors, external IT actors, dBox, dLab Cloud Service

Figure 21: Services from dLab Internal View template.

Roles					
S.#	Role	Description	Process Description	Services Used	Stakeholders
1	Reactive disturbance handling	High quality recording and automatic analysis of all disturbances in the grid to be able to investigate the cause and to take appropriate action to minimize the probability of the same disturbance to happen again	In the case of a disturbance, dAnalyzer utilizes the dLab Cloud Service to automatically analyze the data gathered by the dBox hardware platform in the actual substation during the disturbance. The result is available a few minutes later for the user, which might be operations personell or a power system engineer. Either the analysis result can be used to get more detailed information about the actual disturbance to ease the troubleshooting in order to solve the outage faster, or for investigation afterwards to be able to take actions to minimize the risk of the same disturbance happening again in the future. The analysis results can be reached through a UI or as an email notification. The post-disturbance investigation can be carried out on consultant basis by dServices.	dAnalyzer, dServices	Operations, network customers
2	Proactive disturbance detection	Detection of small deviations in grid behavior that might lead to a disturbance to be able to take action beforehand and avoid outages	Even very small events in the grid are recorded by dBox. The analysis can then sort out natural deviations from short transient ground faults, high ohmic earth faults and other early signs of a potential disturbance. By keeping track of which feeders and phases that show early warnings, proactive measures can be carried out, for example inspecting secondary substations for abnormal wear, overhead lines in locations prone to have disturbances caused by treebranches close to the line etc. Resectionalizing of part of a feeder line to another bay to see if the early warnings also move to that bay is one method for narrowing down the amount of network that might need inspection.	dAnalyzer	Maintenance, operations, network customers
3	Proactive maintenance planning	Recording of key data for components in the substation to be able to determine their condition and plan maintenance based on that data	The dBox hardware can also monitor signals related to the switchgear components within the substation. Another service, dState, running in parallell with dAnalyzer and dQuality on the dLab Cloud Service, gathers the relevant signals and events to be able to keep track of the state of the devices (for example circuit breakers and on-load tap changers). This information can be used in a maintenance system to be able to do proactive maintenance planning.	dAnalyzer, dState	Maintenance, operations, network customers
4	Capacity planning/monitoring	Monitoring of currents and active and reactive power flow to handle DERs, varying power flow directions, voltage control, planning future capacity needs etc.	Statistics over line/feeder load and power flow can be difficult to obtain from various systems such as the SCADA system, since the data is gathered for another purpose and stored in a way that limits access. Furthermore, all signals needed might not be available (for example active and reactive power flow of all feeders in MV networks). The dBox data acquisition makes the data readily available. Maximum/minimum load flow, reactive power generation from cable networks and capacity utilization can all be monitored either in the user interface, or via notifications when exceeding chosen threshold levels.	dQuality	Grid planning, network customers
5	Power quality evaluation	Monitoring power quality to handle increasing number of DERs, non-linear loads and a more varying production and load pattern	All non- linear loads and productions sources adds harmonics to the grid. With increasing number of DERs (PV, wind etc) the need to monitor power quality parameters are also increasing. It is important to start measuring at an early stage to get the full picture of the power quality status also before adding DERs to get a reference state.	dQuality	Maintenance, DER owners, network customers

Figure 22: Roles from dLab Internal View template.

Figure 20, Figure 21, and Figure 22 show the bottom-up view of the system.

USERS				
S.#	User Profile	Description and Context	Interations	
			Required Information	Frequency and Volume
1	OPERATIONS	Operates the grid in real time, at disturbance events working to restore power to the customers as quick as possible	Short and clear information in near real-time about the disturbance event to help take proper measure to maintain and/or restore the supply to the customers, complimentary to the information found in other systems (SCADA etc.)	Depends on type of grid, anywhere from a few times per year to a few times per month on average, data amount a few MBs per recording on average
2	DISTURBANCE ANALYSIS	Post-disturbance analysis to determine if the protection system has worked as intended and that all regulations have been complied with	1. Real-time recordings of currents and voltages, several kHzs sample rate on the time of the disturbance 2. Results and key values from automatic analysis to make the workflow more efficient and save time	Depends on type of grid, anywhere from a few times per year to a few times per month on average, data amount a few MBs per recording on average
3	PROACTIVE FAULT CLEARANCE	Pre-disturbance analysis to be able to find small upcoming faults at an early stage, avoiding customer outage or shorten the outage time	1. Real-time recordings, several kHzs sample rate on the time of the event 2. Results and key values from automatic analysis of the recordings to point out details about the fault condition	Depends on type of grid, anywhere from a few times per year to a few times per month on average, data amount a few MBs per recording on average
3	POWER QUALITY EVALUATION	Continous monitoring of the power quality in the grid to ensure compliance with regulations	1. Measurements of power quality parameters according to standards and evaluation against regulatory limits 2. Reporting of power quality status	1. 10-minute values of all power quality parameters according to standard 2. Weekly reports
4	GRID PLANNING	Using information about loads and power flow to plan the operation of the grid, future expansion and renewal, determine marigin to capacity limits, determine losses	1. Statistics over current and power flow, extreme values are important to catch to be able to make forecasts 2. Information about transferred energy to compare with customer meter data	1. At least hourly values need to be available to be able to compare with connection agreements to TSOs etc, 10 minute values to be able to catch extreme values, requested for evaluation on weekly to monthly basis. 2. Losses can be evaluated on monthly basis but demands might change to day or even hour in the near future
5	OPERATIONAL IT	Responsible for the IT infrastructure regarding control of the distribution grid (RTUs, substation communication, SCADA etc.)	Measurement data values originating from the same source but collected and communicated by separate systems to be compared	1. Notifications when the difference between data values obtained from the diffents systems is too big to be considered OK and therefore one of the systems might be compromised, 2. Reports on a regular basis even if there are no major deviations detected
6	MAINTENANCE	Planning, order and follow-up on the maintenance of substations, lines and other equipment	Events connected to substation components (breaker operations etc.), calculated health status of substation components based on measured values	1. Reports on a regular basis (monthly) 2. notifications on more urgent situations

Figure 23: User Profiles from dLab External View template.

External System and Delivery Channels (Proxy for Users)												
S.#	**Name**	**Description/purpose**	**Possible Interaction scheme**	**Supported Network(s) & Protocols**				**Bandwidth**		**Quality attribute requirements, capabilities and limitations**	**User Profiles that use this channel**	**Remarks**
				Network(s)	**Protocol(s)**	**Response Delay**	**Communication Type**	**Download**	**Upload**			
0	Mobile (Display) Device	An autonomous display device that is installed in participants' homes with some own operating system and networking capabilities.	Provides an API that can be used to publish data to the device	WIFI 802.11 a/b/g	HTTP/HTTPS	20ms	One-way (write only) from our system to this system	Upto 100Mbps	Upto 10Mbps	**Security**: the data passed should be encrypted. **Availability**: this system is available 99.0% of the time. **Performance**: only support data updates in not faster than the second range.	PROSUMER	
1	User portal	A user interface to access the measurement data and analysis results from the applications utilizing the dLab platform	Provides a web-based portal with versatile and customizable interfaces		HTTPS	20 ms	Two-way communication between user and service	At least 10 Mbps	-		OPERATIONS, DISTURBANCE ANALYSIS, PROACTIVE FAULT CLEARANCE, POWER QUALITY EVALUATION, GRID PLANNING, MAINTENANCE	
2	Data export functionality, disturbance events	Automatic export of disturbance data to other systems	Provides an API that can be used to retrieve information about disturbance events for use in other systems (e g NIS for fault location calculations)		MQTT		One-way from the dLab server to the other system(s)		-		OPERATIONS, DISTURBANCE ANALYSIS	
3	Data export functionality, data integrity analysis	Export of measurement data to compare with data from the same origin but collected with another system (e g RTU and SCADA) to ensure data integrity	Provides an API that can be used to retrieve measurement data		MQTT?		One-way from the dLab server to the other system(s)		-		OPERATIONAL IT	
4	Email notification	Notifications on events	Provides an auto-generated email to notify about a disturbance event		SMTP		One-way from the dLab server to the user		-		OPERATIONS, DISTURBANCE ANALYSIS, PROACTIVE FAULT CLEARANCE	

Figure 24: External Systems from dLab External View template.

Information Flow

S.#	Functional Need	Description	Type	Frequency	Size	Source	Sink
1	Display price and demand information	A PROSUMER would need to know what are the current price and demand information so that it can plan accordingly.	Near Realtime	5 requests per second	1k per request	System-to-be-built	Mobile (Display) Device
1	Alert about a disturbance that just occurred	OPERATIONS need more information about the actual disturbance to be able to work more efficient with the troubleshooting process	Near Realtime (1-5 minutes)	1-5 events per week	10 kB per email, 5-30 MB per analysis report in the portal (including sampled recordings)	dAnalyzer	Email notification linking to the user portal
2	Power Quality report	POWER QUALITY EVALUATION need a weekly report stating wether the power quality regulations have been met or not	Non-critical, within a few hours	Weekly	1 MB per report	dQuality	User portal, email notification in the future
3	Disturbance information	DISTURBANCE ANALYSIS need extensive information about a disturbance to do a deeper analysis	Within hours	1-5 events per month	10 kB per email, 5-30 MB per analysis report in the portal (including sampled recordings)	dAnalyzer	Email notification linking to the user portal, user portal
4	Automatic fault location calculation	OPERATIONS need information about the approximate fault location of the actual disturbance	Near Realtime (1-5 minutes)	1-5 events per week	10 kB	dAnalyzer	dXport API to NIS
5	Data integrity alert	PROCESS IT need information about potentially compromised measurement values	Within hours?		10 kB	dQuality and system-to-be-built	API to-be-built to existing or new system
6	Asset status	MAINTENANCE need information about the condition of equipment in the substation	Non-critical, within a few hours	Weekly or monthly reports	1 MB per report	dState	User portal
7	Power flow information	GRID PLANNING need information about active and reactive power flow in the grid, both over time and alerts on more critical levels	Within hours	1-5 events per month	10 kB (notification)	dQuality	Email notification linking to the user portal on urgent occasions, user portal
8	Early warnings for upcoming faults	PROACTIVE FAULT CLEARANCE need information about smaller events that might lead to a disturbance to be able to take out proactive actions	Near Realtime (1-5 minutes)	10-15 events per month	5-30 MB per analysis report in the portal (including sampled recordings)	dAnalyzer	Email notification linking to the user portal, user portal

Figure 25: Information Flow from dLab External View template.

A.2 SOLANDEO Input Templates

Extracted requirements and use cases based on this input can be seen in Section 4.4.4. Figure 20, Figure 21, and Figure 22 show the bottom-up view of the system.

Actors			
S.#	Actor	Domain	Description & Goal
1	Electrician contractor management	DER	Optimize the installation process of meters in all german grids using third party installation contractors
2	Meterdata management	DER	Measure and save energy data from all meters for later usage in realtime
3	Market communication channels & formats	DER, Distribution	Distribute the energy data over official channels and formats to all relevant participants the customers works with
4	RZÜ based message interaction	Distribution	Share grid planning and operation messages securely between grid operators
5	Webservices & push messages	DER	Provide interfaces and processes to provide data and predictions to customer specific software interfaces like trading systems, enerydata management etc.
6	Machine learning	DER	Use machine learning to train plant specific models for prediction
7	Vizualisation & Reporting	DER	Use vizualisation software and custom reporting to measure prediction quality and identify potentials for optimization

Figure 26: Actors from SOLANDEO Internal View template.

Services			
S.#	Service	Descrption	Involved Actors
1	Meter installation	Metering hardware has to be installed at the customers plant according to the official process guidelines (WIM)	1
2	Meter operation	Metering hardware needs to measure the energy flow at the plant side	2
3	Meter data distribution	Metering data needs to be provided to several endpoints for accounting and trading	3
4	RD2.0 Dataprovider connection	Grid operator systems need to be connected to the redispatch2.0 dataprovider system	4
5	Outage energy calculation	When plants are used to control grid stability, the amount of energy needs to be calculated for financial compensation	5
6	Prediction creation	Predictions are created for individual plants as well as for portfolios for intraday and day ahead predictions	6
7	Prediction delivery	Predictions need to be delivered to customer specific interfaces	5
8	Quality measurement	Prediction and input data quality needs to be measures and reported	7

Figure 27: Services from SOLANDEO Internal View template.

Roles

S.#	Role	Description	Process Description	Services Used	Stakeholders
1	Meter operator	Solandeo is a registered independent meter operator in Germany	All services that ensures the secure and contiuous operation of smart meters for renewable plants	1,2,3	Plant owner, Grid operator
2	Redispatch2.0 service provider	Solandeo is a registered provider of redispatch2.0 solutions for grid operators	Connect grid operators to the new redispatch2.0 dataproviders (connect+ and RAIDA)	3,4,7	Grid operators, Grid distributors, Plant owner, Plant operator, Accounting grid operator, EDM software provider
3	Prediction provider	Solandeo provides predictions for renewable energy production and usage	Provide predictions within the redispatch2.0 processes and as standalone products to energy market participants (direct trader)	6,7,8	Grid operators, Direct traders

Figure 28: Roles from SOLANDEO Internal View template.

Figure 26, Figure 27, and Figure 28 show the bottom-up view of the system.

USERS				
S.#	User Profile	Description and Context	Interations	
			Required Information	Frequency and Volume
1	TRADER	key member of the energy market. Trades energy for plant owners at the energy market. Uses energy predictions as input for trading strategy	1. Current energy production/usage 2. energy production/usage forecast	1./2. one request every 15min
2	GRID OPERATOR	Key member of the energy infrastructure. Ensures the stability of the energy grid. Has the capability to control plants directy or indirectly	1. predicted energy production/usage 2. plant control requests and commands 3. Prediction quality reports 4. Energy outage information	1. one request every 15min. 2. up to multiple requests every 15min. (theoretically) practically 1-5 requests per day 3. once per month 4. once per month

Figure 29: User Profiles from SOLANDEO External View template.

External System and Delivery Channels (Proxy for Users)												
S.#	Name	Description/purpose	Possible Interaction scheme	Supported Network(s) & Protocols				Bandwidth		Quality attribute requirements, capabilities and limitations	User Profiles that uses this channel	Remarks
				Network(s)	Protocol(s)	Response Delay	Communication Type	Download	Upload			
1	Trading platform	A software platform, used by energy traders to support their trading strategy and trading decisions. Including meterdata und prediction vizualization	API, SFTP	Internet	HTTP/HTTPS	100ms	One-way (write only) from our system to this system	Upto 100Mbps	Upto 10Mbps	**Security**: RSA2048 / RSA3072 Key pairs. **Availability**: this system is available 99.0% of the time. **Performance**:	TRADER	
2	Virtual powerplant platform	A software platform that integrates information regarding an energy plant portfolio. May include energy datamanagement, trading access, prediction, weatherdata, market data as well as controlling capabilities	Market communication (MAKO)	GSM, Internet	SMTP		Two-way. We deliver meter data, the VK software may send control signals (e.g. plant shutdown)	Upto 100Mbps	Upto 10Mbps		TRADER	Metering Abt. fragen
3	Energy datamanagement software	Used by grid operators to monitor their grid	API, SFTP, depends on system provider	Internet	HTTP/SFTP	approx. 100Ms	One-way (write only) from our system to this system	Upto 100Mbps	Upto 10Mbps	Security: depends on Grid operator size and Ecosystem. Min: unencrypted sending of data with user/pw access Avg: encrypted sending of data, user/pw credentials exchanged encrypted or unencrypted Max: RSA Keypair + signed cerficicate	GRID OPERATOR	
4	Grid control center (Leitwarte)	Used by grid operators to monitor and control their grid and specific plants	Mail, Rest, SFTP, depends on system provider	Internet	HTTPS/SFTP	approx. 100Ms	Two-way. We deliver redispatch control commands from the general redispatch2.0 data provider platform. The control center ackknowledges the commands and send a ‚fulfilled' message when execution is done	Upto 100Mbps	Upto 10Mbps	KRITIS infrastructure. RZÜ conform messaging (RSA Keypair + signed certificate)	GRID OPERATOR	Peter nochmal nach RZÜ fragen
5	PDF viewer	Used by grid operators to read the prediction quality reports	Mail	Internet	SMTP	??	One-way (write only) from our system to this system	Upto 100Mbps	Upto 10Mbps	Unencrypted / encrypted mail to registered mail addresses	GRID OPERATOR	
6	Billing system	Used by GRID OPERATOR to fulfill monetary comensation of PLANT OWNERs after induced plant shutdowns	API	Internet	HTTPS	approx. 100Ms	One-way (write only) from our system to this system	Upto 100Mbps	Upto 10Mbps	depends on system provider	GRID OPERATOR	

Figure 30: External Systems from SOLANDEO External View template.

Information Flow							
S.#	Functional Need	Description	Type	Frequency	Size	Source	Sync
1	Display energy production/usage	An energy TRADER need to know the current energy production/usage to plan his trading strategy and fulfill market based control commands (e.g. plant shutdown)	Near Realtime	Once every 15 minute	1 double value per request	smart meter	Trading platform; Virtual powerplant software
2	Display predicted energy production/usage	A GRID OPERATOR need to know the predicted energy production/usage in the grid to maintain grid stability and plan redispatch (e.g. plant temporary shutdown)	Near Realtime	Once every 15 minute	192 values per request (2 days a 95 15min intervals)	prediction system	Trading platform; Virtual powerplant software, Energydata management software, grid control center
3	Deliver redispatch2.0 control commands	A GRID OPERATOR need to exchange control requests from neighbour GRID OPERATOR to ensure grid stability and coordinate actions	Near Realtime	Once every 15 minute	192 values per request (2 days a 95 15min intervals)	Redispatch2.0 system	Grid control center
4	Deliver prediction quality reports	A GRID OPERATOR need to monitor the quality metrics of plant predictions on a monthly base	Ex post	monthly	10MB per request	Redispatch2.0 system (reporting module)	pdf viewer
5	Deliver Energy outage calculation	A GRID OPERATOR need to know the amount of energy outage after a plant shutdown command to calculate the monetary compensation of the PLANT OWNER	Ex post	monthly	96 values per request	Redispatch2.0 system (energy outage module)	billing system

Figure 31: Information Flow from SOLANDEO External View template.

A.3 ISE Input Templates

Extracted requirements and use cases based on this input can be seen in Section 4.4.1. Figure 38, Figure 39, and Figure 40 show the bottom-up view of the system.

Actors			
S.#	**Actor**	**Domain**	**Description & Goal**
1	User Interface	customer/private	Enables Residents to enter their charging parameters
2	Meter Operator	market	Collects meter data for billing, provides measurements for DSO and customers
3	DSO	distribution	Wants to have a stable grid. Creates load predictions, creates control signals for buildings at grid connection point
4	GWA (Gateway Administrator)	customer/distribution/market	configures smart meter gateways (SMGWs), grants access to external market participants (EMT)
5	Charging Station	customer	receives power setpoints according to charging schedules
6	Smart Meter	customer	provides measurements

Figure 32: Actors from ISE Internal View template.

Services			
S.#	**Service**	**Description**	**Involved Actors**
1	Load forecast	Creates load predictions based on historical data	Meter Operator, GWA, Smart Meter
2	Scheduler	Optimisation that creates charging schedules based on DSO signal, technical restrictions, meter data, user input	User Interface, Meter Operator, DSO, Charging Station

Figure 33: Services from ISE Internal View template.

Roles

S.#	Role	Description	Process Description	Services Used	Stakeholders
1	grid stabilisation	the system (EMS) helps to stabilise the grid by utilising the flexibility of electric vehicles	the system (EMS) collects all necessary data (user input, meter measurements, control signals) and generates an optimal charging schedule respecting grid and user constraints	Load forecast, Scheduler	DSO, Residents

Figure 34: Roles from ISE Internal View template.

Figure 38, Figure 39, and Figure 40 show the bottom-up view of the system.

USERS				
S.#	User Profile	Description and Context	Interations	
			Required Information	Frequency and Volume
1	DSO	Ensures grid stability by distributing dynamic power consumption limits per grid connection point (building). Provides power setpoints to the system (EMS)	measurements of smart meter at grid connection point (voltage, power, …)	15 min to seconds
2	RESIDENT	Resident living in the building and driving an electric vehicle. Want to charge their EV at low costs. Enters user needs into the system (EMS) e.g. departure time and needed energy	Feedback from the EMS related to provided user input. E.g. predicted charging schedule, predicted end time, notification on schedule changes	for each charging process (1-x times per day)

Figure 35: User Profiles from ISE External View template.

External System and Delivery Channels (Proxy for Users)												
S.#	Name	Description/purpose	Possible Interaction scheme	Supported Network(s) & Protocols				Bandwidth		Quality attribute requirements, capabilities and limitations	User Profiles that use this channel	Remarks
				Network(s)	Protocol(s)	Response Delay	Communication Type	Download	Upload			
1	Web App	Web Application for user input	enters user input which is processed by EMS	GSM/LTE/Wifi	HTTPS (REST)	1 second	one way form App to EMS	?	?	user name/password for access	RESIDENT	
2	SCADA system / control room of DSO	create control signals in form of dynamic power set points to stabilise the gird	send control signal to EMS	DSL	IEC 60870-05-104	few seconds? depending on protocol timeouts	one-way (write only) from DSO to EMS	?	?	uses an encrypted TLS channel from DSO to EMS via Smart Meter Gateway	DSO	

Figure 36: External Systems from ISE External View template.

Information Flow

S.#	Functional Need	Description	Type	Frequency	Size	Soruce	Sink
1	deliver control command (power limit schedules)	A DSO needs to send out control signals to stabilise the grid. Signal could be a power limit schedule containing 15 minute values covering 24 hour. Could be updated every 4 hours.		1 schedule / every 4 hours	1 MB / request	SCADA	EMS
2	deliver user preferences	A RESIDENT needs to enter his/her desired charging parameters		1-3 request per day	100 kB / request	Web App	EMS

Figure 37: Information Flow from ISE External View template.

A.4 OFFIS Input Templates

Extracted requirements and use cases based on this input can be seen in Section 4.4.1. Figure 38, Figure 39, and Figure 40 show the bottom-up view of the system.

Actors			
S.#	**Actor**	**Domain**	**Description & Goal**
O_A1	Defender Agent	LV + Energy Market	Detection of upmade bottlenecks, resolve of the situation, this might be done by affecting market pricing or forciblly reducing power consumption at the detected attackers grid connection point
O_A2	Rational Market Participants	LV + Energy Market	Maximizes own profit, will theoreticially deterministically lead to gaming the market
O_A3	Self Optimizing Market Participant	LV + Energy Market	Optimize tariff, follow energy use preferences
O_A4	Grid Operator	Grid (LV + MV) + Energy Market	Stable grid operation, be profitable, optimize asset usage
O_A5	Crook	LV	Tries to bring the grid down and force blackouts, mostly via voltage band violations induced from controlled assets
O_A6	Market Operator	Energy Market	Provide a functioning, accessible local real power energy market

Figure 38: Actors from OFFIS Internal View template.

Services			
S.#	**Service**	**Description**	**Involved Actors**
O_S1	Timed artificial increase in power consumption	Create artificial bottleneck	Rational Market Participants
O_S2	Consumption behavior change	Create monetary incentive on EM to reduce power consumption	Grid Operator
O_S3	Market Operation	Provide market clearing house	Market Operator
O_S4	Change power consumption	Modify own energy consumption to fulfill incentivized modified load schedul	Rational Market Participants, Self Optimizing Market Participant
O_S5	Pay market participants on modified power schedule	Pay those agents who have changed their power consumption in order to resolve the bottleneck	Market Operator, Grid Operator, Self Optimizing Market Participant, Rational Market Participants
O_S6	Detect market gaming	Detect coalitions of gaming rational agents	Defender Agent
O_S7	Foil market exploitation	Change either pricing or act directly in grid in order to make market exploitation nearly impossible	Defender Agent, Grid Operator
O_S8	Grid Attacks!	Use controlled assets to inflict physical damage in the grid (or a branch)	Crook
O_S9	Grid defense	Use grid operator's assets to keep voltage band stable	Defender Agent, Grid Operator

Figure 39: Services from OFFIS Internal View template.

Roles

S.#	Role	Description	Process Description	Services Used	Stakeholders
O_R1	Market based grid manager	Proviedes a optimized grid operation through local energy markets	Operate a local energy market	O_S3,O_S4,O_S5,O_S6,O_S7	VPP Provider,O_A4,O_A6
O_R2	Exploitation provider	Exploits a local energy market to generate profit.	Exploit a local market	O_S1,O_S4,O_S5	
O_R3	Grid Attacker	Attacks a grid	Grid Attack	O_S8	
O_R4	Grid Defender	Defends a grid	Grid Defense	O_S9	

Figure 40: Roles from OFFIS Internal View template.

Figure 38, Figure 39, and Figure 40 show the bottom-up view of the system.

USERS				
S.#	**User Profile**	**Description and Context**	**Interations**	
			Required Information	**Frequency and Volume**
1	Server User	Is the most common user of the TAXII server. It can get data and therefore information from the server.	1. TAXII Server information	If information is needed
2	Push Authorized Server User	Information generating user, can push data to the server. This user might also be a Server User but doesn't have to.	1. TAXII Server information, 2. Data to p	If information is generated and ready to share

Figure 41: User Profiles from dLab External View template.

External System and Delivery Channels (Proxy for Users)												
S.#	Name	Description/purpose	Possible Interaction scheme	Supported Network(s) & Protocols				Bandwidth		Quality attribute requirements, capabilities and limitations	User Profiles that use this channel	Remarks
				Network(s)	Protocol(s)	Response Delay	Communication Type	Download	Upload			
1	TAXII Client	An external system/sub-system that requires that is interested in using the services provided by the TAXII (Server).	REST API/SDK	Wired/Wireless	HTTP/HTTPS	< 1 sec	Non-realtime	100 Mbps	10 Mbps	**Availability**: 99.0%, **Security**: In most cases, an SSL connection would be the preferred choice.	Server user, Push Authorized Server User	

Figure 42: External Systems from OFFIS External View template.

Information Flow						
S.#	Functional Need	Description	Type	Frequency	Size	Soruce	Sync
1	Return information	A Server User needs to get its desired information.	non-realtime	1-2 requests per minute	Differs (KB to maximal MB)	TAXII Server	TAXII Client
2	Insert information to the server	The Server needs to recieved data sent by a push authorized server user	non-realtime	1-2 request per hour	Differs (KB to maximal MB)	Push Authorized Server User	TAXII Client

Figure 43: Information Flow from OFFIS External View template.

Abbreviations

CPES . . . . Cyber-Physical Energy System

DER . . . . Distributed Energy Resource

DSO . . . . Distribution System Operator

EV . . . . Electric Vehicle

IAT . . . . Incident, Anomaly, and Threat

SG . . . . Smart Grid

UML 2.0 . . . . Unified Modeling Language

Glossary

Anomaly . . . . A situation that deviates from the standard, norm, or expectation.

Incident . . . . An unwanted event.

Redispatch 2.0 . . . . Redispatch 2.0 is a set of measures designed to prevent grid congestion in the German power grid.

Threat . . . . A hostile intention to bring harm and/or to disrupt the normal operations of a power grid.

CONSORTIUM

DISCLAIMER

All information provided reflects the status of the RESili8 project at the time of writing and may be subject to change.

Neither the RESili8 Consortium as a whole, nor any single party within the RESili8 Consortium warrant that the information contained in this document is capable of use, nor that the use of such information is free from risk. Neither the RESili8 Consortium as a whole, nor any single party within the RESili8 Consortium accepts any liability for loss or damage suffered by any person using the information.

The content and views expressed in this material are those of the authors and do not necessarily reflect the views or opinion of the ERA-Net SES initiative. Any reference given does not necessarily imply the endorsement by ERA-Net SES.

COPYRIGHT

© 2023 by the authors, the RESili8 consortium. This work is licensed under a "CC BY 4.0" license.

This project has received funding in the framework of the joint programming initiative ERA-Net Smart Energy Systems' focus initiative Digital Transformation for the Energy Transition, with support from the European Union's Horizon 2020 research and innovation programme under grant agreement No 883973.