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WP8 – System Qualification, Demonstration and Impact Assessment

D8.3 – MERLON Evaluation Framework and Respective Validation Scenarios – First Version

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V0.3	07/01/20	First full draft version for review
V1	10/01/20	Final version for submission

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EXECUTIVE SUMMARY

This document defines the MERLON global evaluation framework and the respective validation activities. Concerning the evaluation of energy related project aspects, the validation framework has been based upon the PMV methodology specified in T3.3 “Measurement & verification methodology and key performance indicators” and instantiate specific validation scenarios, associating them to Key Performance indicators (KPIs) defined in the same task to properly address specificities of each pilot case, but also retain a uniform evaluation of the project results.

The evaluation framework presented in this document details the already defined KPIs in the D3.3 “MERLON PMV Methodology Specifications” and provides additional quantitative and qualitative KPIs, as these were identified so far. The final list of MERLON KPIs has been divided into four (4) major categories, namely:

- Technical
- Economic
- Environmental
- Social

to enable the holistic assessment of the project impact. All KPIs have been detailed using the template introduced in the D3.3, which includes all the information required in order for the KPIs to be quantified and assessed.

Furthermore, the deliverable presents the appropriate instruments that will be used for the uniform collection of evaluation data during pilot executions (e.g. online questionnaires, data collection forms, impact check-lists and data forms, etc.).

Finally, the document presents a high-level description of the MERLON Cost-Benefit-Analysis methodology that will be used towards assessing MERLON overall monetary and non-monetary impact in the concerned stakeholders.

List of Abbreviations

Term	Description
aFRR	automatic Frequency Restoration Reserve
AMI	Advanced Metering Infrastructure
ASAI	Average Service Availability Index
BESS	Battery Energy Storage System
BFM	Building Flexibility Manager
BMM	Battery Management Module
C&I	Commercial and Industrial
CBA	Cost-Benefit-Analysis
CAIDI	Customer Average Interruption Duration Index
CTAIDI	Customer Total Average Interruption Duration Index
CEC	Citizen Energy Community
CHP	Combined Heat and Power
DER	Distributed Energy Resource
DHW	Domestic Hot Water
DoA	Description of Action
DoE	Department of Energy
DR	Demand Response
DSM	Demand Side Management
DSO	Distribution System Operation
EC	European Commission
ECM	Energy Conservation Measures
EE	Energy Efficiency
EEM	Energy Efficiency Measure
ESCO	Energy Service Companies
ESI	Energy Saving Intervention
ESPC	Energy Savings Performance Contracts
ESS	Energy Storage System
EV	Electric Vehicle
EVFM	Electric Vehicle Flexibility Manager
EVO	Efficiency Valuation Organization
FEMP	Federal Energy Management Programme
FERC	Federal Energy Regulatory Commission
FFSA	Flexibility Forecasting, Segmentation, Aggregation Module
FR	Frequency Regulation
GDPR	General Data Protection Regulation
GFM	Global Flexibility Manager
GHG	Greenhouse Gas
HVAC	Heating Ventilation and Air-Conditioning

ILES	Integrated Local Energy System
ILESEM	Integrated Local Energy System Energy Management
ISO	International Organization for Standardization
KPI	Key Performance Indicator
LFM	Local Flexibility Manager
M&V	Measurement and Verification
NPV	Net Present Value
PCC	Point of Common Coupling
PMV	Performance Measurement and Verification Methodology
RTE	Round-Trip Efficiency
PV	Photovoltaic
QA	Quality Assurance
RES	Renewable Energy Sources
RR	Replacement Reserve
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SoC	State of Charge
SoH	State-of-Health
TSO	Transmission System Operation
UC	Use Case
UI	User Interface
USEF	Universal Smart Energy Framework
V2G	Vehicle to Grid
VoLL	Value of Lost Load
VER	Variable Energy Resource
VPP	Virtual Power Plant
VRES	Variable Renewable Energy Sources
WP	Work Package

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1 Introduction

1.1 Description of activities

The activities performed and described in this document provide the necessary methodological pathway to enable the holistic evaluation and impact assessment of the MERLON project, following the pilot roll-out phase.

The current document is the outcome of the T8.3 "Detailed pilot evaluation, impact assessment and cost-benefit analysis framework" and in particular it is the first version of the "MERLON Evaluation Framework and Respective Validation Scenarios" while a second and final version will be delivered later during the project implementation (D8.6 "MERLON Evaluation Framework and Respective Validation Scenarios - Final Version" – M24) that will include updates based on findings identified during the deployment phase in the pilot sites.

1.2 Structure of the deliverable

The current deliverable is structured as follows:

- Section 1 includes a brief description of the activities performed and the relevance to other tasks and WPs of the project
- Section 2 describes the MERLON validation scenarios and respective validation activities. More specifically, this section includes:
    - An introduction summarising the outcome of the D3.3 "MERLON PMV Methodology Specifications" and conducting the appropriate link with the MERLON use cases
    - A description of MERLON value chain identified in the ILES based on USEF
    - A description of the methodology and the basic principles considered for the definition of the basic demonstration scenario and respective validation activities in the pilot sites
    - A step-by-step description of the basic scenario to be demonstrated in the MERLON pilot sites
    - A description of the MERLON validation framework and the specificities considered for the Austrian pilot site
- Section 3 includes the whole list of MERLON KPI detailed based on the template introduced in the D3.3. In particular, this section describes in detail the updated list of all KPIs considered in the different KPI categories, namely:
    - Technical
    - Social
    - Economic
    - Environmental
- Section 4 describes the MERLON methodology for the collection of the evaluation data
- Section 5 introduces the MERLON Cost-Benefit-Analysis (CBA) methodology that will be performed in later stages of the project. The methodology adopted and described herein should include:
    - An economic analysis
    - A qualitative non-monetary analysis
    - An overall assessment part combining the economic with the qualitative analysis
- Section 7 concludes the document summarising key findings.

1.3 Relationship with other deliverables and tasks

The T8.3 “Detailed pilot evaluation, impact assessment and cost-benefit analysis framework” is closely related to various WPs and tasks. In particular, the current deliverable has been based on:

- T3.1 “Elicitation of user & business and grid-relevant requirements for local flexibility markets, ancillary services and islanding requirements” where the MERLON use cases and relevant requirements were detailed
- T3.2 “Analysis of socio-economic and regulatory obstacles to innovation” where a socio-economic analysis was performed along with an analysis of the regulatory framework with special focus on MERLON pilot sites
- T3.3 “Measurement & verification methodology and key performance indicators”, where the initial list of KPIs were defined and the MERLON PMV methodology was described
- T3.4 “Ex-Ante Pilot Sites Surveys and Deployment Planning” and the respective deliverable D3.4 “Ex-Ante Pilot Audits and Pilot Deployment Plan in Austria”, where the specificities of the Austrian pilot site were described

The work performed in the T8.3 has also taken feedback from the parallel work performed on:

- T3.5 “Detailed architecture design, protocols and interfaces specifications for ILES DER” towards understanding the overall scope and establishing the most appropriate methodology for the assessment of MERLON impact.
- T10.1 “New business models for ILES and flexibility markets” were the MERLON business models are clearly defined.

Furthermore, T8.3 and its first outcome, meaning the current deliverable D8.3, will be the base for the activities to be performed in the other tasks of WP8 and more specifically:

- T8.4 “Community recruitment and integration into local flexibility market” for keeping track of the relevant social KPIs and ensuring actively end-user engagement
- T8.5 “Pilot roll-out and demonstration” that will validate MERLON technical applicability and robustness and evaluating its impact, cost-efficiency and performance under real-life conditions, based on the validation scenarios resulting from T8.3 (that as mentioned above will be primarily based on the activities performed in T3.3)
- T8.6 “Socio-economic, environmental and technological impact assessment” that will perform an overall analysis and evaluation of the pilot operation phase across the pilot sites of MERLON at individual, aggregated and comparative level.

Finally, T8.3 activities were in full alignment of all the horizontal WPs of the project. In particular, T8.3 was in a continuous feedback process with WP9 “Dissemination, Communication and Stakeholder Engagement” and WP10 “Exploitation and Business Innovation”.

2 MERLON VALIDATION SCENARIOS AND ACTIVITIES

2.1 Validation Scenario Creation

MERLON validation strategy comprises several scenarios that will be demonstrated in the pilot sites capturing their specificities. Upon these scenarios and the quantified KPIs, a holistic validation of MERLON ILES framework will be conducted. The aforementioned validation scenarios will be created upon MERLON Use Cases defined at a conceptual level in deliverable D3.3 [1] and will incorporate the MERLON Performance Measurement and Verification (PMV) methodology as defined in D3.3 [2].

A brief reference to MERLON PMV principles is presented herein as an introductory comment to the validation framework. In general, the focus of MERLON measurement and verification will be on each of the ILES flexibility assets individually in the frame of a bottom-up assessment strategy. On top of this, a holistic evaluation of performance of the MERLON ILES will take place in terms of ILES grid quality and reliability assessment, as well as quality of ancillary services delivered to the overlay distribution or the transmission grid.

In terms of intra-ILES assets' performance measurement and verification, the primary classification concerns [2]:

- M&V of BESS in the distribution network of the pilot sites
- M&V of DR programmes and products using the aggregated demand flexibility.

The inherent difficulties that are encountered in baselining procedure, which is the cornerstone of PMV in DR programs, are minimised through the MERLON modelling approach. Namely, intentional and/or unintentional manipulation in baseline definition are induced by factors such as representativeness of monitored consumption, time windows, forecast adjustments, inclusion of ramp periods in estimation, etc. In MERLON, these are addressed through recursive baseline automated calibration with exclusion of pre-heating/cooling time intervals, effective data pre-processing and user profiling in terms of occupancy and visual/ thermal comfort.

The MERLON PMV main consecutive stages are the ex-ante analysis, the implementation and the ex-post assessment. The **ex-ante analysis** includes the definition of DR programs and any preparatory activities required for the set-up of smart-contract mechanism in terms of templates required to support the automated blockchain-enabled flexibility marketplace. This initial stage also includes the training process of the comfort and flexibility profiling mechanisms that infer comfort boundary conditions to be respected in explicit DR schedules. Apart from the ex-ante preparatory stage, the automated learning of profiling algorithms is a continuous procedure that enables profiling while taking into account weather variability and seasonal patterns. Last, during the ex-ante phase the parameters and conditions that will be monitored are defined, e.g. charge/ discharge rates, ambient conditions, schedules of operation, etc.

Following the ex-ante analysis and during the stage of **implementation**, the sensing and monitoring equipment is assessed in terms of equipment specification, optimal infrastructure placement, communication set-up, etc. For the Demand Side Response case, after the installation of the monitoring and control equipment, an overall system operation status assessment takes placed followed by the model calibration period prior to the participation in DR events. In fact, until an adequate accuracy of the model is reached, costumers will not be allowed to participate in the corresponding programmes.

Finally, the **ex-post analysis** focuses on model validation after equipment commissioning for verification of the estimation reliability and accuracy, the effective assessment of baseline windows and other parameters affecting the demand modification assessment. Reporting of actual measured conditions in DR events and corresponding conclusions are also included in this stage.

2.1.1 Requirements

MERLON validation activities will be based on respective scenarios that will be demonstrated in each pilot site capturing their particularities and the extend of MERLON research framework as defined through the use cases of [1].

More specifically, the validation scenarios shall fulfil the following set of requirements:

i. Cohesiveness with MERLON use cases, system requirements and corresponding business cases.
ii. Validation based on quantified KPIs.
iii. Relevance with PMV principles.
iv. Assessment of the capabilities of all MERLON components, optimisation techniques and deriving tool suites.
v. Applicability of scenarios to both pilot sites.
vi. Compliance with existing standards that define interaction between energy community stakeholders, e.g. USEF provisions.

2.1.2 Use Case Validation

In an attempt to fulfil the requirements i-iv presented above and as an initial step to form MERLON validation scenarios, a set of use-cases has been further elaborated and combined with specific services that can be offered by Demand Side Response and Distributed Energy Storage, which are the main optimisation platforms utilised in MERLON. Figure 1 shows which aspects of distributed energy storage services are incorporated in use cases scenarios of UC2, UC5, UC8, UC9, UC11.

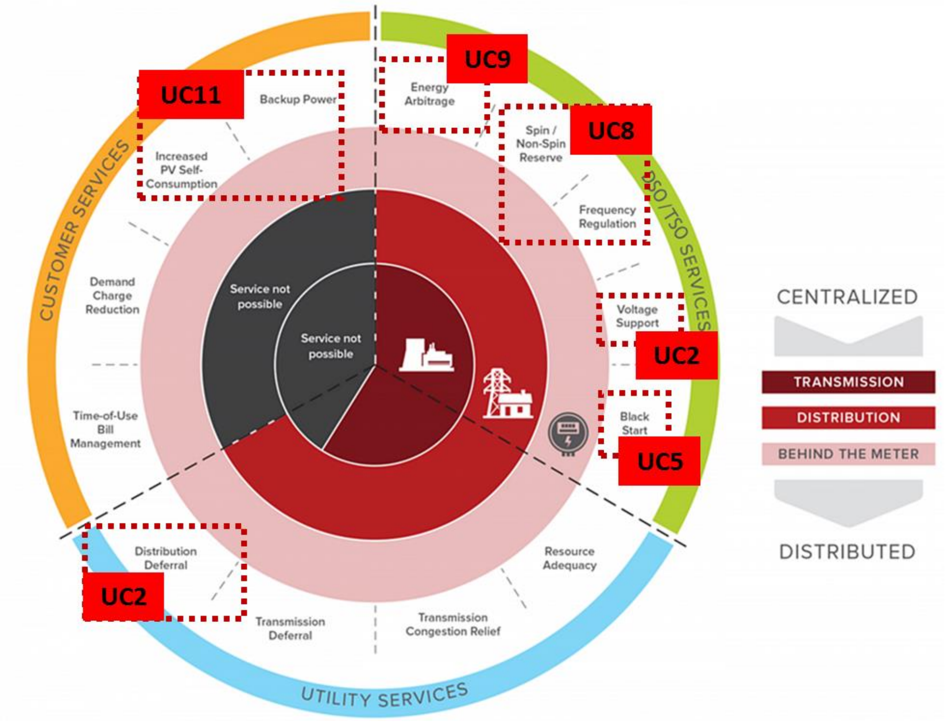


Figure 1 Clusters of services offered by Battery Energy Storage System (BESS). Source: [3] further edited.

The same approach for demand side response is shown in Figure 2. Three different segments of services are identified based on the “product“ delivered: energy, capacity and balancing power.

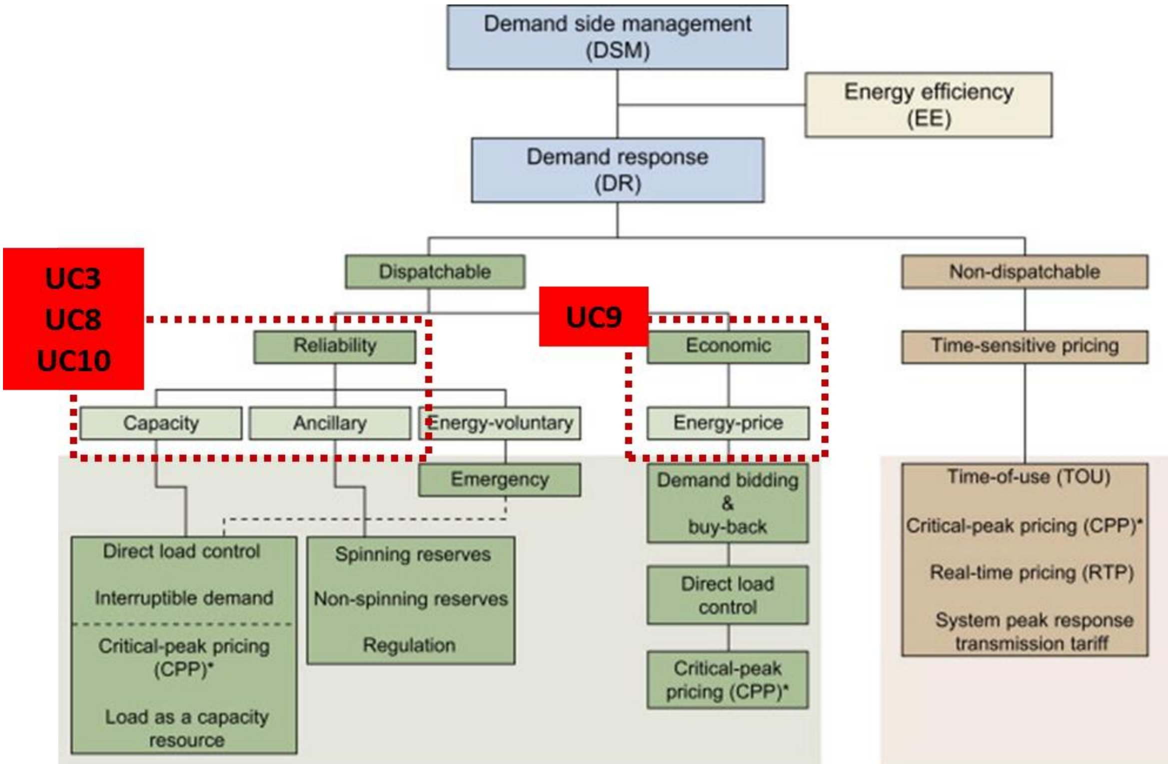


Figure 2: Services of Demand Side Response (DSR). Source: [4] further edited.

Technical use cases, such as UC1 and UC4 have been excluded since they focus on the description of procedures rather than scenarios of system interactions, e.g. interoperability platform set-up, BESS installation, etc. UC12 is also excluded due to limited applicability to pilot sites, given that the CHP unit will not be part of MERLON pilot site physical assets.

Further to the matching of use cases with key performance indicators performed in [2], Table 1 presents the validation aspects per use case and further short-lists the corresponding KPIs.

Table 1 Validation aspects per use case scenario and KPI correlation

Use Case	Narrative	Aspects for Validation	KPIs
UC-2 Local distribution network management with battery storage solutions	The Battery Energy Storage System performs real-time constraints management and reactive power support contributing to: network voltage control and losses minimization	1. Grid Constraints Management improvement per year (interruptions, voltage within limits, thermal limits, congestion – line loading, etc.) 2. BESS participation in network management (cycles/year, performance degradation rate, etc.) 3. Ability to host more RES in local distribution grid due to constraints management of BESS 4. Cost-Benefit aspects, Avoided investments from the part of the distribution grid due to the presence of BESS	**TEC-11** Battery degradation rate **TEC-15** Increased system flexibility **TEC-27** Voltage quality performance **TEC-5** Curtailment Avoidance **EC-5** Investment Deferral **EC-6** Cost Benefit Ratio
UC-3 Explicit Demand Response through context-aware flexibility profiles	Personalized, human-centric and contract-safeguarding participation in explicit demand response programmes on the basis of context-aware flexibility profiles	1. Non-intrusiveness achieved through context-aware and comfort-centric approach in explicit demand response 2. Comfort modelling accuracy 3. Baseline definition accuracy 4. "Responsiveness" of prosumers in terms of actual flexibility delivery 5. Effective exploitation of Demand Side Response within the ILES based on aggregated demand flexibility in order to optimise operation 6. Cost-Benefit aspects for the prosumer	**SOC-3** Thermal discomfort factor **SOC-4** Visual discomfort Factor **TEC-18** Energy shift ratio **TEC-13** Delivered Flexibility **TEC-14** Baseline consumption **TEC-16** Peak Load reduction **EC-6** Cost Benefit Ratio
UC-5 Grid-forming/ islanding capabilities in ILES to increase security of supply	Demonstrate the transition from grid connected to island operation mode of the ILES, which will reduce supply interruptions	1. Capability of the energy system to switch to/from islanding uninterruptedly 2. Reduction of total time of black-out 3. Reduction of number of interruptions 4. Power quality and reliability during off-grid operation 5. Capability of existing smart converter technologies to support uninterruptible on/off-grid transition 6. Cost-Benefit aspects for the DSO	**TEC-22** Islanding **TEC-23** Average number of electrical interruptions/ years **TEC-26** Power Quality and Quality of Supply **TEC-20** Technical Compatibility **EC-6** Cost Benefit Ratio

Use Case	Narrative	Aspects for Validation	KPIs
UC-8 Services provision from local flexibility systems to the transmission system	Participation of ILES distributed energy resources (DER) specifically in ancillary services markets, and demonstrating how their flexibility can be optimally coordinated to generate additional revenues through ancillary service provision, e.g. frequency response, capacity reserve, etc.	1. Compliance with System Operator's requirements in terms of time and active/reactive power. 2. Availability of service provision by the ILES (Reliability of instance aggregation module) 3. Quality of ILES Forecast 4. Additional quantified revenue for the ILES flexibility providers and impact on ILES energy consumption 5. Assessment of current regulatory framework in terms of fostering MERLON approach in ancillary service provision 6. Cost-Benefit aspects for the prosumer / aggregator	**TEC-25** Reliability (Grid) **TEC-9** Annual electricity consumption per appliance **TEC-13** Delivered Flexibility **EC-6** Cost Benefit Ratio **SOC-6** Advantages for end-users
UC-9 Participation of local flexibility sources in electricity energy markets	Development of suitable mechanisms for the participation of local distributed energy resources (DER) specifically in the electricity energy market, and demonstrating how their flexibility can be optimally coordinated to reduce their individual energy costs and the energy costs of the whole ILES	1. Possibility of participation of ILES in electricity energy markets (contracts with electricity suppliers, direct participation in wholesale market, local community trading, etc.) 2. Investigate the potential for local community trading among the DER of the ILES through peer-to-peer designs and blockchain technologies. 3. Optimise overall ILES participation in energy markets accounting for different trading options. 4. Quantify the energy cost savings triggered by optimal coordination of DER flexibility. 5. Analyse the regulatory framework around energy markets and suggest relevant changes 6. Cost-Benefit aspects for the prosumer / aggregator	**TEC-2** Relative energy savings **TEC-6** Energy demand & consumption **TEC-19** Reduction of Energy Cost **TEC-18** Energy shift ratio **EC-6** Cost Benefit Ratio **SOC-6** Advantages for end-users
UC-10 Flexibility marketplace establishment	Specify a local flexibility marketplace to enable flexibility trading among prosumers and aggregators and allow them to	1. Facilitation of prosumers to make their flexibility available. 2. Facilitation of aggregators to access and contract with prosumers in order to exploit their available flexibility. 3. Transparency and effectiveness in the overall contractual and	**TEC-20** Technical Compatibility **TEC-15** Increased system flexibility for prosumers and Aggregators

Use Case	Narrative	Aspects for Validation	KPIs
	select the best deal. The scope of this use case is to facilitate peer to peer flexibility exchange among prosumers and aggregators.	remuneration procedure. 4. Technical innovation in marketplace set-up (enabled by blockchain-based technologies).	**TEC-30** Data Safety **TEC-31** GDPR risk **SOC-5** Ease of use for end users of the solution **EC-4** Total Annual Costs
UC-11: Optimal operation of an ILES	Optimal operation of the grid so that it can operate as much as possible in islanded mode while maximizing the interests of all actors.	1. Impact on security of supply in terms of how much the imports of upstream energy are reduced due to combined operation of local RES – BESS. 2. Percentage of flexibility from each resource that is exploited within the ILES 3. Green House Gas emission reduction due to reduction of load coverage by conventional sources 4. Perceived benefit for local stakeholders 5. Cost-benefit aspects of stand-alone ILES operation	**TEC-4** Total RES consumption **TEC-3** Self-consumption on ILES level **TEC-15** Increased system flexibility for ILES energy players **ENV-1** Carbon dioxide Emission Reduction **ENV-2** Decreased emission of oxides (NOx) **SOC-6** Advantages for end-users **EC-6** Cost Benefit Ratio

2.1.3 Value chain identification in the ILES

MERLON project's validation activities will be correlated with business cases that unlock values created within the ILES framework. The value chain identification and the market scenarios to be validated have been outlined herein based on the Description of Action [5], the elaboration on business models that have been conducted by the MERLON consortium so far (that will be documented in D10.1 "Definition of MERLON Business Models for ILES and flexibility markets") as well as USEF framework elaborations [6] [7], given the defined requirement vi in Section 2.1.1.

The structure of ILES comprises a part of the electrical distribution grid and a flexibility optimisation platform involving local DER assets and stakeholders. As a consequence, the establishment of a MERLON ILES forms an energy community framework and/or constitutes an important tool suite for existing local energy communities.

Value chains that are emerging on community basis are classified in two categories:

a. Energy-related services that are offered inside the ILES
b. Energy-related services that the ILES offers to markets "outside the ILES".

The explicit Demand Side Response is the strategy followed within MERLON for the exploitation of demand flexibility that obtains value either for the prosumers or as a product in different energy markets.

Within the MERLON framework, the ILES flexibility, deriving either from BESS or from explicit demand response upon remuneration and based on contracts, is utilised by the ILES operator. The role of aggregators is central within the ILES as they intervene between the prosumers and the flexibility requesting parties (e.g. the DSO) [8].

According to USEF white paper on flexibility value-stacking [8] "The aggregator is responsible for acquiring flexibility from prosumers, aggregating it into a portfolio, creating services that draw on the accumulated flexibility and offering these to different markets, serving different market players".

Four (4) main types of services are identified in the same study [6] as the main routes of value creation of the aggregated flexibility:

- **Constraints management services**
  They are offered to system operators (e.g. ILES DSO, overlay DSO, TSO) and are utilised for system control and power flow optimisation in terms of alleviation of voltage violations, minimisation of thermal losses, grid congestion, reverse power, etc.

- **Wholesale services**

  They are offered in day-ahead and intra-day markets BRPs to decrease sourcing costs of electricity.

- **Balancing services**

  They are offered to the TSO and are utilised for frequency regulation[1] (e.g. Frequency Containment Reserve (FCR), Automatic/ Manual Frequency Restoration Reserve (mFRR/ aFRR), Replacement Reserve (RR), etc.).

- **Adequacy services**

  They are offered in capacity markets to the business parties that are responsible for security of supply based on the market design (e.g. TSO). In this type of service, the aggregated flexibility is utilised for security of supply increase via arrangement of long-term peak and non-peak generation capacity.

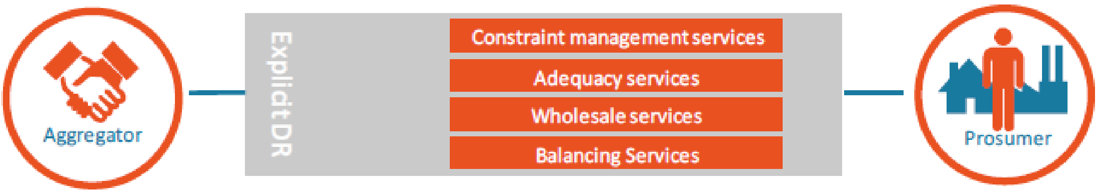


Figure 3 Types of services based on aggregated flexibility. Source: USEF [8]

Based on the energy service segmentation of Figure 3, the additional flexibility optimization services that can be offered by an ILES will be evaluated. A further segmentation per service category combined with an allocation per MERLON UC is presented in Figure 4.

[1] According to [6], ancillary services comprise balancing services and constraints management services.

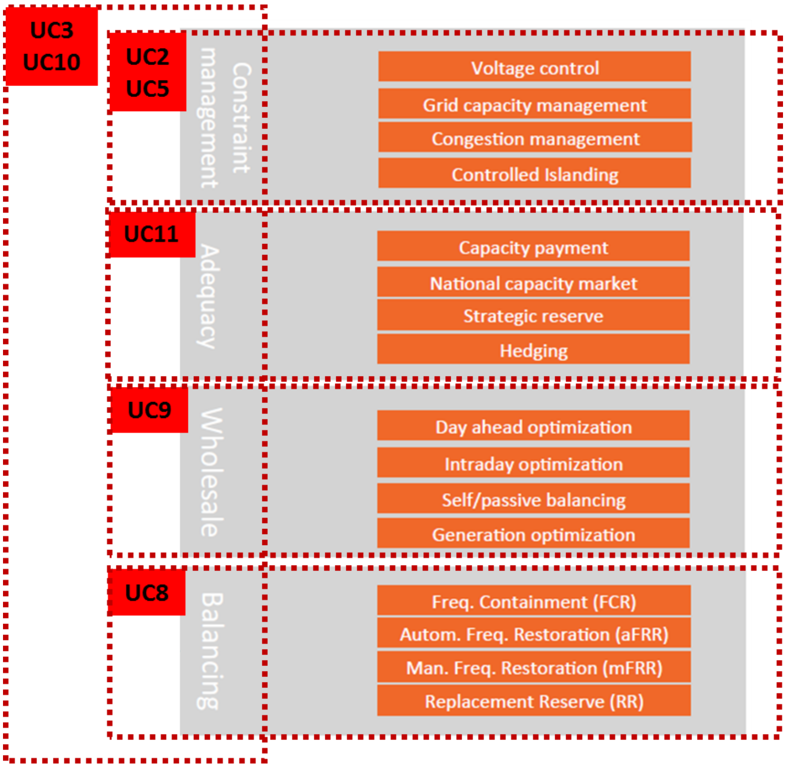


Figure 4 Energy-related service analysis. Source: USEF [6]

With reference to MERLON UC3 and based on DoA guidelines, ILES prosumers engage their collective flexibility through **explicit demand-response** techniques to provide services within the ILES and optimise their energy profiles. To this end, the role of aggregation inside the ILES is crucial in order to valorise the demand flexibility. In parallel and apart from the **intra-ILES aggregators**, the entire ILES community can assume the role of Aggregator (“**Aggregator of Aggregators**“) negotiating with other flexibility requesting parties (e.g. overlay DSO, TSO, etc.) the surplus ILES flexibility available.

With reference to **MERLON UC5** and based on USEF elaborations on flexibility service from Citizen Energy Communities (CEC), the concept of **aggregated Value of Lost Load** (VoLL) during electrical gird outages could be explored in combination with the Battery Energy Storage System (BESS) that will be installed in MERLON pilot sites. The BESS will enable the uninterruptible power supply during emergency islanding combining VoLL with **constraints management services** in a value stacking perspective. The concept could be also combined with **joint purchase, maintenance and profit sharing of shared assets** such as BESS [8].

With reference to **MERLON UC11** and given the structure of the Austrian pilot site in Strem, the concept of “**community self-balancing**” can be considered. More specifically, an energy community that operates as an Integrated Local Energy System (ILES), including part of a distribution grid and a single connection to the upstream distribution network, could investigate the cost-benefit ratio of local self-consumption in combination with an alternative approach regarding network charges allocation. For example, if the community is considered as a single connection to the grid through a substation or a virtual interconnection point, network charges could be adapted to the rated usage of network and cost of interaction with the upstream system. Upon the ILES structure, as defined in MERLON, **community peak load management** and **KWmax control of the locally aggregated load** could be also investigated in the frame of optimal system operation.

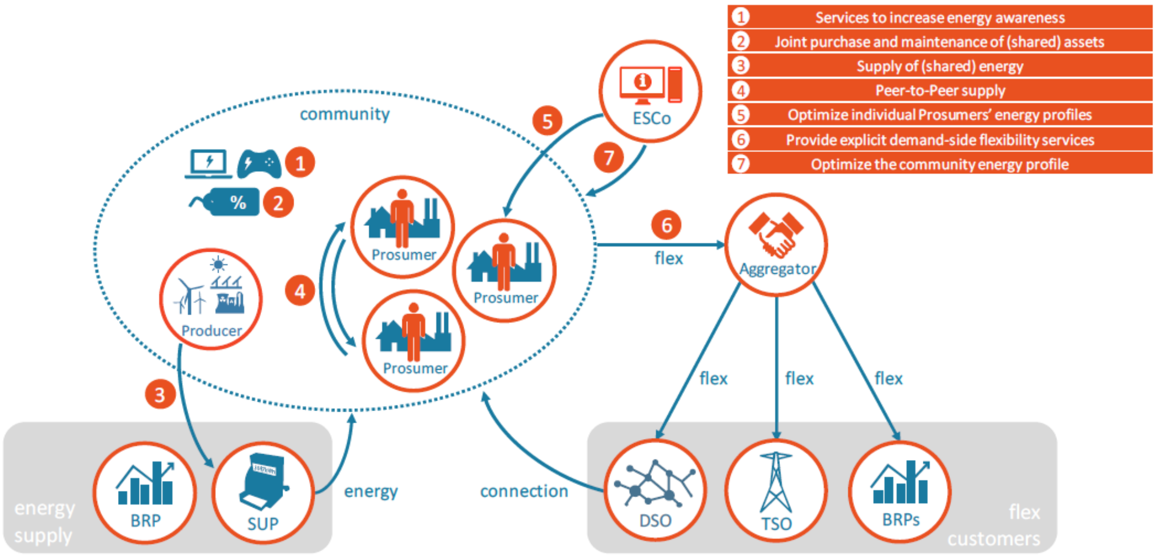


Figure 5 Energy and flexibility services offered within a Citizen Energy Community context. Source: USEF [8]

Figure 5 presents the energy and flexibility service-related interactions with the CEC context. Some of them are relevant to MERLON framework and will be validated accordingly on site through the project demos.

Given a scheme of joint generation and storage assets (RES and BESS), the local community can assume the role of supplier as described in USEF schematic of Figure 6. This enables the community to bypass utilities that are profit-driven. However, this role will not be extensively analysed herein as it will not be primarily investigated within MERLON with possible exception of UC8 which will be further elaborated at a later stage.

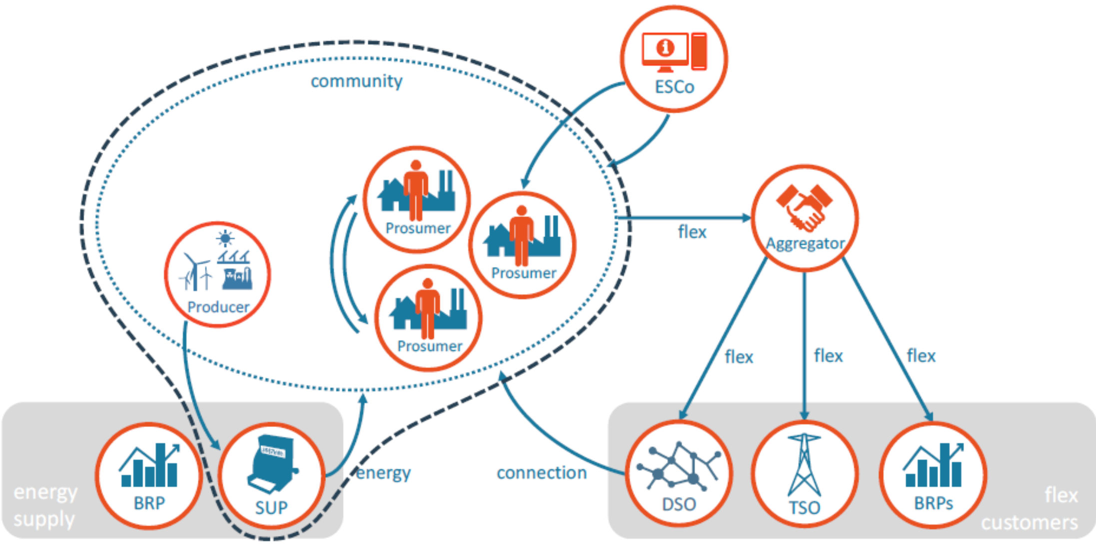


Figure 6 Citizens Energy Community assuming the role of Energy Producer and Supplier.

Aggregation of demand-side flexibility and optimisation is offered by aggregators in the frame of explicit demand-response. According to USEF role models, an energy community can assume both the role of an ESCO and/or an Aggregator. However, the cases of ESCo performing optimisation will not be analysed given that they refer to implicit demand-side flexibility services [8] which are not part of MERLON framework. The role model presented in Figure 7 is relevant to MERLON framework and will be investigated in terms of flexibility-related services that an ILES can offer to the upstream energy system (e.g. overlay DSO, TSO, etc.), utilising its internal optimisation platform and explicit demand response techniques.

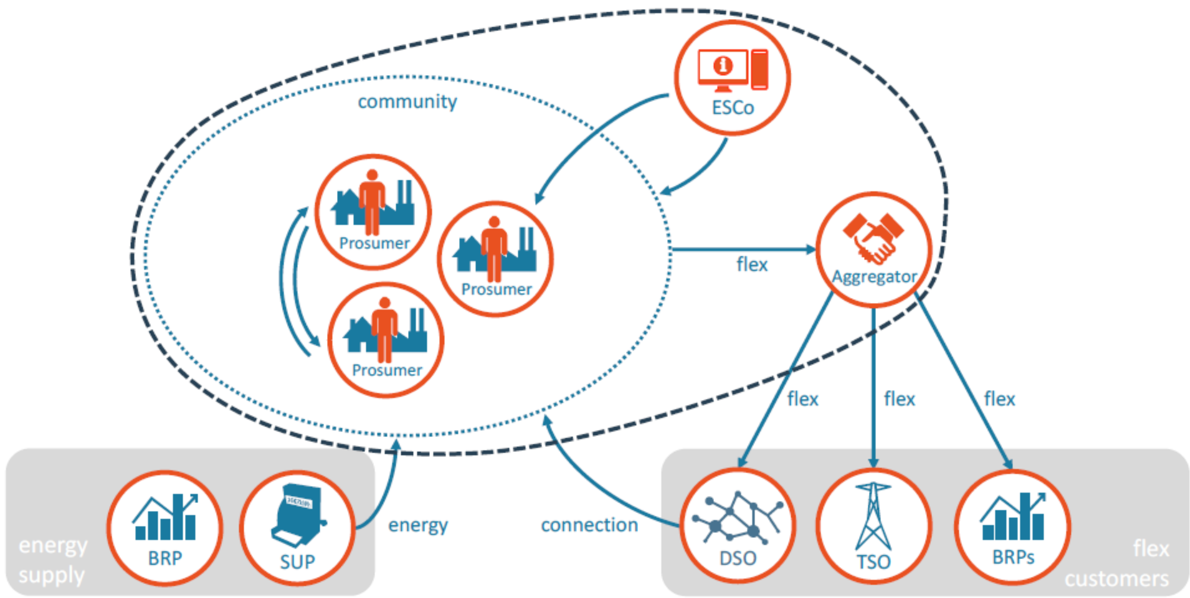


Figure 7 Illustration of the Energy Community that takes on the role of both ESCo and Aggregator, thereby having the possibility to offer optimization

In the MERLON framework, the operation on the local grid has a central role in the ILES. In fact, the entire optimization platform revolves around the optimal operation of the electrical system on local level combined with development of "Microgrid-as-a-Service" models. To this end, market models in which the local energy community is responsible for its local grid, taking the role of a DSO, fall within MERLON scope. Such a role model is presented in Figure 8, where the community assumes the DSO role for the local grid and constraints management is combined with energy and grid cost reduction objectives [8]. The possibility of operation of the local grid by the CEC is not yet widely permitted without the participation of the local DSO, although it is encouraged by the "Clean energy for all Europeans" package.

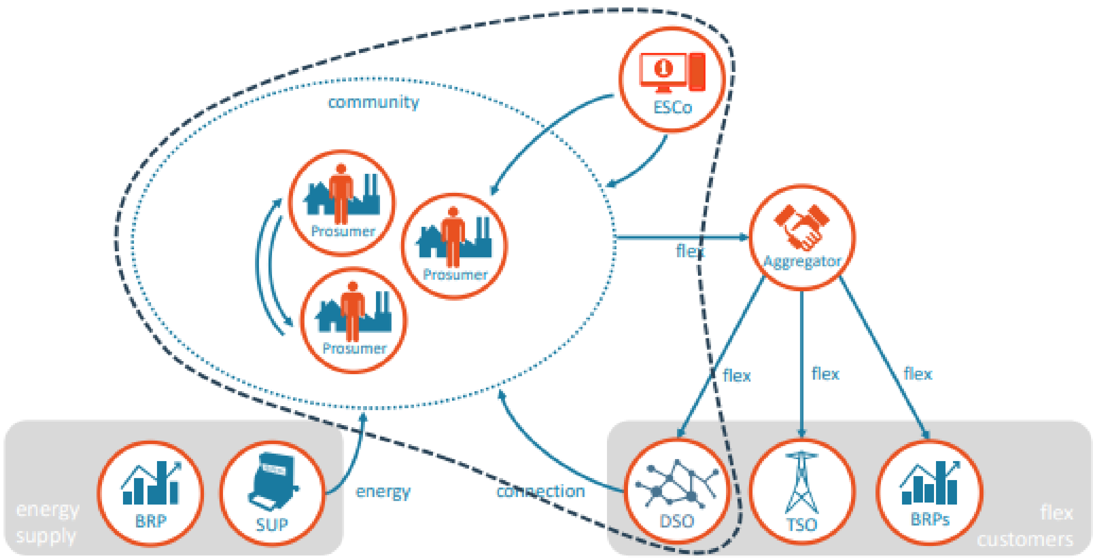


Figure 8 Schematic of Energy Community assuming the role of local DSO. Source: USEF [8]

2.1.4 Methodology

As a starting point for the definition of MERLON validation scenarios and in parallel with the elaboration on MERLON business models of task T10.1 “New business models for ILES and flexibility markets”, a basic demonstration scenario has been constructed according to the following characteristics:

- Clear and concrete scenario that includes the most important interactions within MERLON flexibility optimisation platform.
- Generic enough to be applicable to both MERLON pilot sites setting the basis for further customisation of the validation activities per case.
- Fulfilling the requirements of paragraph 2.1.1.

Based on the market model background defined in USEF and presented in paragraph 2.1.3, MERLON optimisation frameworks **first priority** will be to provide **constraints management services** for the local grid, namely for the ILES, enabling USEF role model of **energy community as local DSO**. In other words, the services described in MERLON UC2 and UC5, concerning local distribution network management and emergency islanding, are considered as first priority for the ILES. **Given that the local constraints are respected and the ILES grid operates optimally**, **the available surplus flexibility** can be utilised for **balancing, adequacy and wholesale services**, as described in use cases 8, 9 and 11. The local community taking multiple roles in a certain priority within MERLON framework is presented in Figure 9 and Figure 10.

In terms of component development and implementation, the requests for constraints management should be inserted through the DSO Web Interface of ILESEM and directed to its forecasting and scheduling modules. The requests for balancing services and energy markets participation should be inserted through the Aggregator Web Interface of ILESEM and directed to its instance aggregation module.

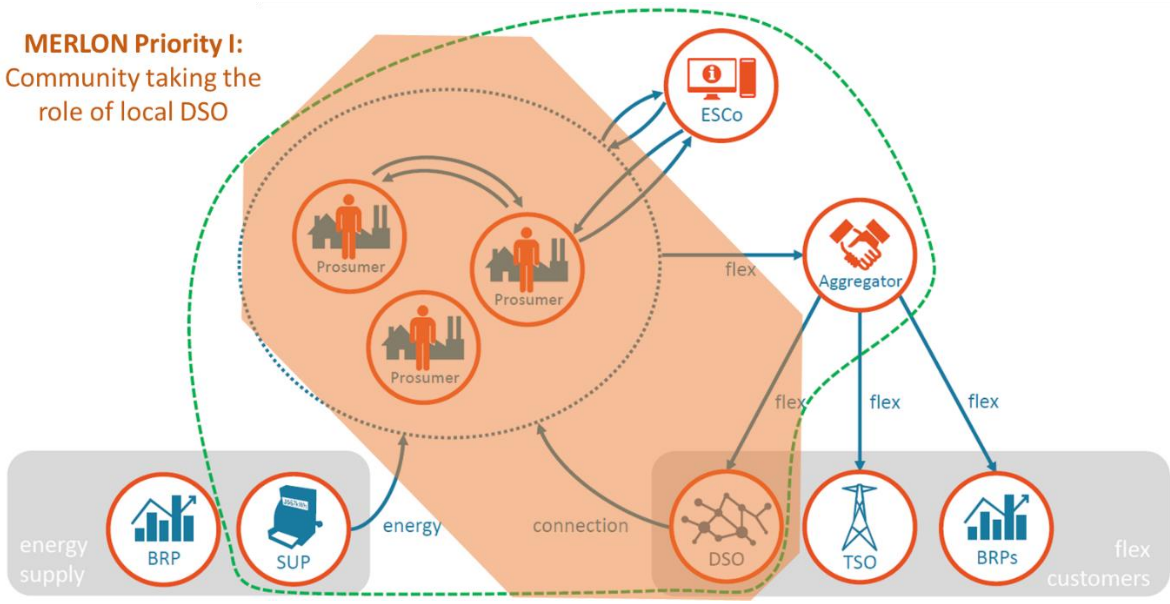


Figure 9 MERLON priority I: Constraints management Services. Source: USEF [7] further edited.

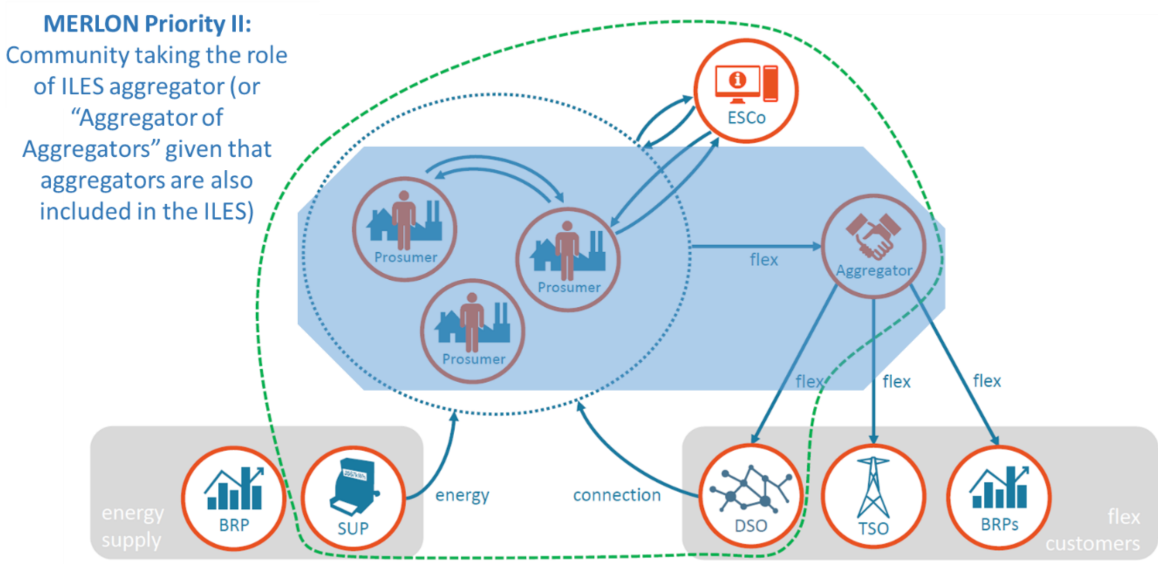


Figure 10 MERLON priority II: Provision of Balancing, Adequacy and Wholesale Services. Source: USEF [7] further edited.

In the following paragraph, a more specific step by step description of the information flow and interaction of the scenario is specified. It includes source and destination components as well as information exchange specification. The basic demonstration scenario is presented as a sum of instances followed by the required explanations on interactions.

2.2 Basic Demonstration Scenario

The basic demonstration scenario comprises 9 instances where the main interactions, that show component functionalities and capabilities, are outlined. The operation of the flexibility pooling and sharing marketplace is presented in a separate figure given that some of its functions run in parallel with the main operation optimisation and not as a step of it.

Starting the scenario flow description as presented in Figure 11, the DSO triggers the ILESEM platform in order to check network constraints, forecast potential violations and schedule the flexibility units in order to optimally manage to resolve them. Therefore, the DSO sets the time horizon to perform either day-ahead or even intra-day forecasts and schedules. For the requested time horizon, the forecasting module of ILESEM retrieves the weather forecast for the geographical area of the ILES and with the predefined time parameters, such as timestep and horizon. Based on this input and the "nominal" specifications of the PV plants of the ILES (e.g. inclination, azimuth, peak power, plant-specific parameters, etc.), the module creates the ILES renewable generation flexibility forecast. The module also retrieves data from smart meters installed in the ILES grid through the middleware and creates the forecast of loading conditions at critical points. With the assumption that the VRES production shall be fully integrated in the ILES grid and no curtailment shall be applied, the flexibility required from optimal grid operation is estimated together with the baseline loading conditions at the Point of Common Coupling (PCC). The estimation varies in terms of horizon according to the DSO input starting from 30-minute ahead forecast [5].

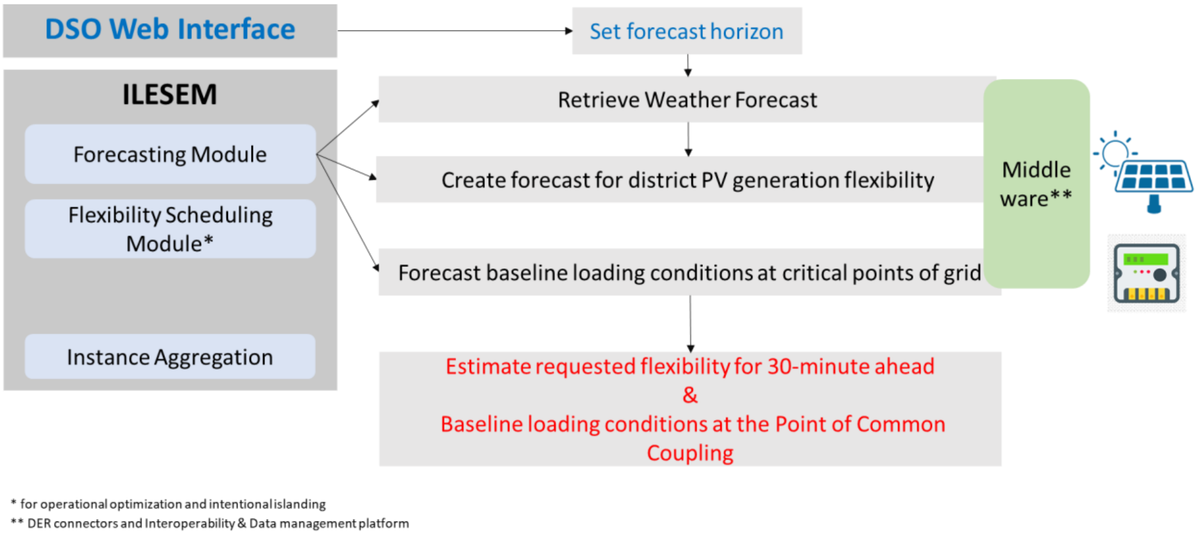


Figure 11 Basic demonstration scenario: Instance I

When concluded, the forecast estimations are fed as input to the scheduling module of ILESEM together with the ILES grid constraints and the available flexibilities from each of the ILES assets for the same time horizon. The "Flexibility Scheduling Module for Operational Optimisation and Intentional Islanding" requests flexibility forecasts of the BESS from the Battery Management Module (BMM) and of the aggregated ILES demand (incl. prosumers and EVs) from the Global Flexibility Manager (GFM). Upon receipt of the forecasted flexibilities, the module defines the operational schedule for the requested time period ahead in terms of demand modification (to GFMs) and control modes and setpoints (to the BMM), as shown in Figure 16.

Figure 12 presents the second instance of the demonstration scenario showing that upon receipt of the grid and VRES forecast, ILESEM firstly requests the BESS flexibility. Upon the receipt of feedback from the BMM, ILESEM request for the aggregated demand flexibility forecast.

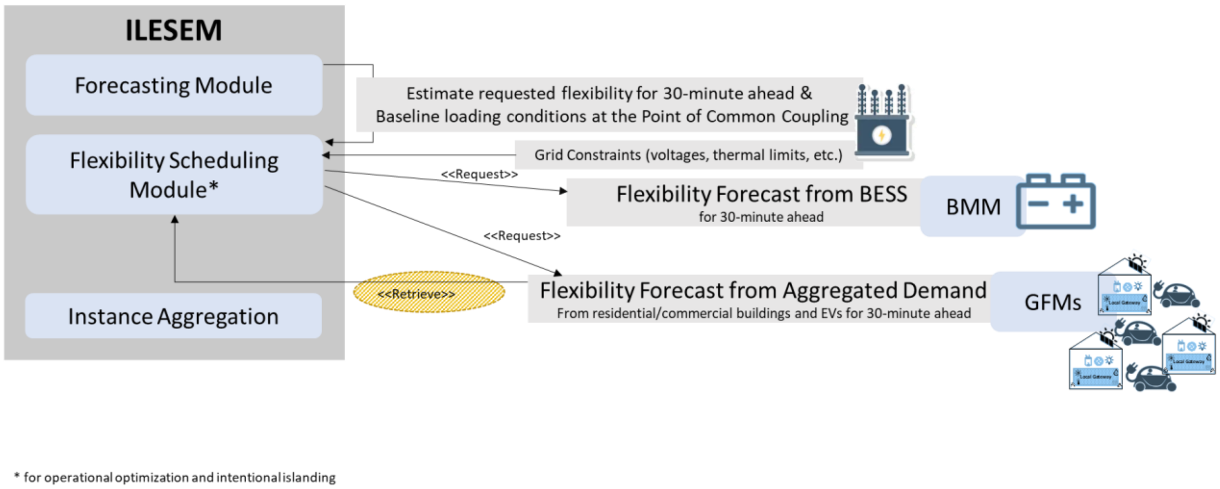


Figure 12 Basic demonstration scenario: Instance II

Figure 13, Figure 14 and Figure 15 outline the interactions that are triggered by the Global Flexibility Manager for the creation of the aggregated demand flexibility forecast estimation (the information retrieved by the scheduling module of ILESEM in the yellow shadowed area of Figure 12). Initially, upon the request of the ILESEM, the "Flexibility Forecasting, Segmentation, Aggregation Module" (FFSA) retrieves information from the marketplace upon the contacted DERs that are accessible and available to provide flexibility, given physical constraints and/or contractual terms. The FFSA module performs pattern analysis over specific metrics (e.g. device characteristics, flexibility details and reliability, spatio-temporal similarity) and return groups or clusters of DERs that fulfil particular requirements (e.g. can provide flexibility specific hours within a day). Afterwards, a request for flexibility forecast is dispatched to the "Local Flexibility Manager" (LFM) that represents each contacted DER (e.g. building/zone and/or EV) belonging to the clusters identified in the previous step. This interaction is displayed in Figure 13.

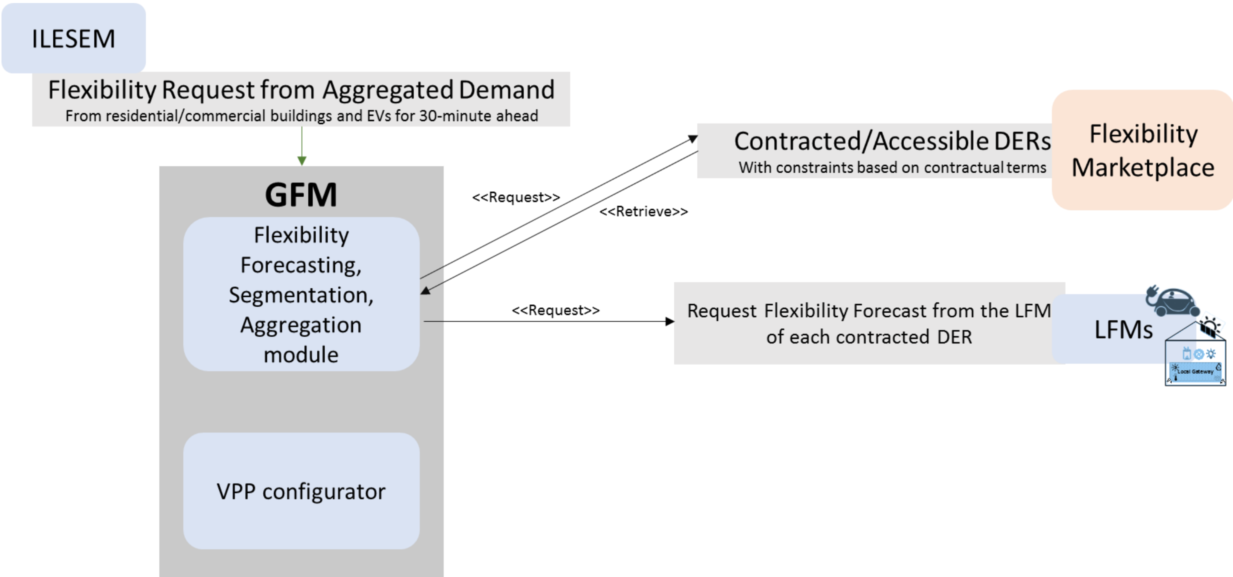


Figure 13 Basic demonstration scenario: Instance III

The above-described interaction from the perspective of the LFM is depicted in Figure 14. As indicated in the schematic, there is a continuous feed-in of information from the building and EV connectors to the flexibility profiling engines of the "Building Flexibility Manager" (BFM) and the "Electric Vehicle Flexibility Manager" (EVFM). Thus, when the request is sent from the GFM to the LFM for a specific time horizon, the latter responds back with the demand flexibility forecast.

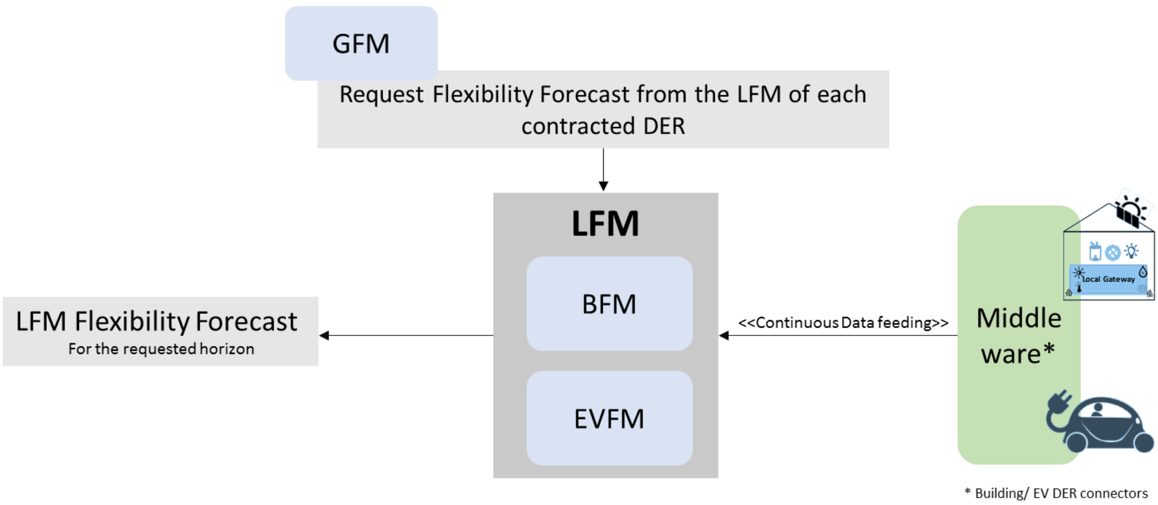


Figure 14 Basic demonstration scenario: Instance IV

Upon receipt of the flexibility forecast per LFM, aggregation is conducted in the GFM as well as further elaboration on the aggregated portfolio based on internal GFM optimisation algorithms. Finally, the aggregated demand flexibility forecast is provided to the scheduling module as shown in Figure 15.

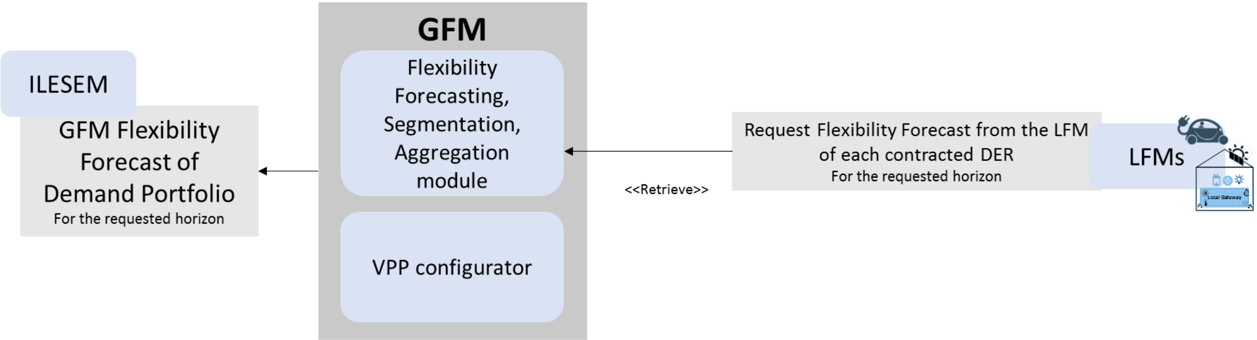


Figure 15 Basic demonstration scenario: Instance V

With reference to Figure 16 and as mentioned above, ILESEM upon receipt of:

- the flexibility request by the ILES
- available flexibility by the ILES assets and
- certain parameters of interest in the ILES grid

defines the operational schedule of the BMM and the GFMs.

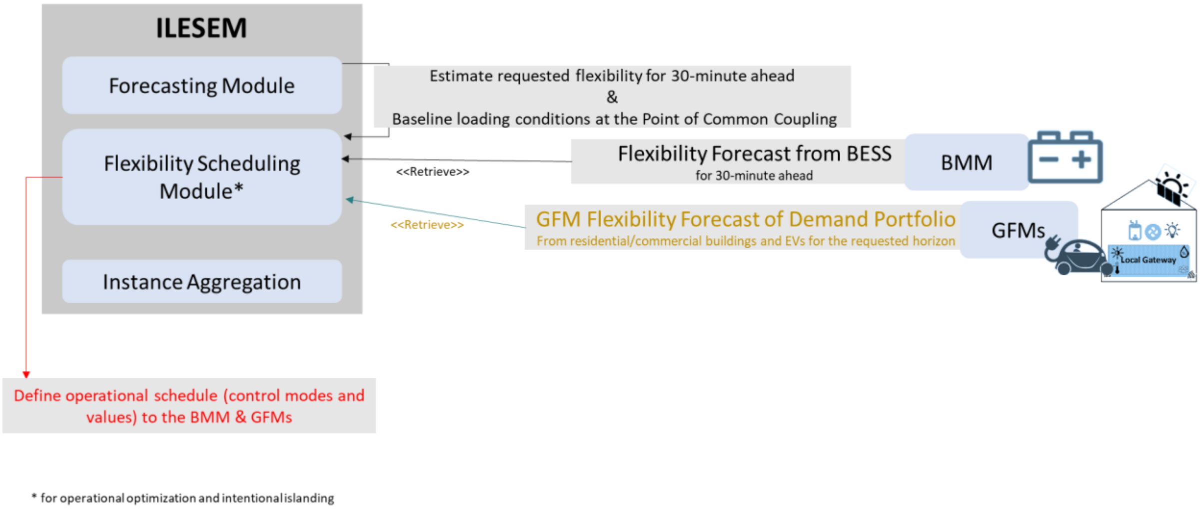


Figure 16 Basic demonstration scenario: Instance VI

To this end, the flexibility that shall be utilised for the specific time period ahead is defined and the respective control signals are dispatched towards the BMM and the GFM. The control signals may take the form of demand modification request, specific operational setpoint and/or control mode, as shown in Figure 17. In parallel, the “result” of the operational schedule for the user-defined horizon ahead as well as the remaining ILES flexibility (if any) is reported to the “Instance Aggregation Module” of the ILESEM. This is the module that will provide feedback to the “ILES Aggregator Web Interface” of the ILESEM. Through this UI, the “Aggregator of Aggregators” can assess the aggregated flexibility portfolio of the ILES community for participation in balancing/ adequacy service markets. The aforementioned “aggregated flexibility portfolio” refers to the time of the forecast horizon and represents the available and not-utilised flexibility for constraints management purposes for this time-period.

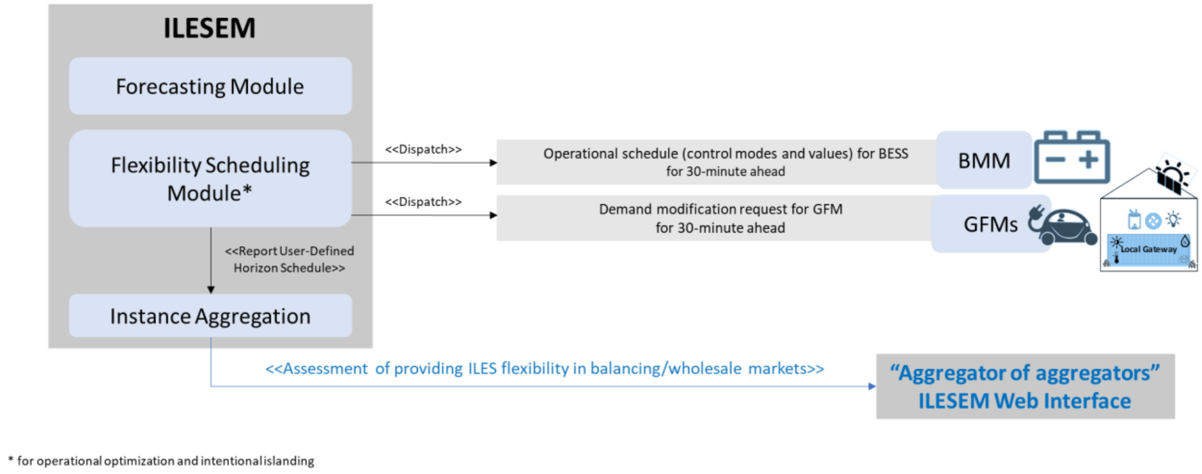


Figure 17 Basic demonstration scenario: Instance VII

As final instances of the demonstration scenario, Figure 18 and Figure 19 show the control signal flow from the ILESEM to the GFM and more specifically the dispatch of the aggregated demand response signal to the VPP configurator and the respective segmented control dispatch to the LFMs. Upon receipt of the demand modification request, the LFM separates the request for flexibility per asset manager (BFM/ EVFM) and specifies further down to control setpoints per device (Figure 19).

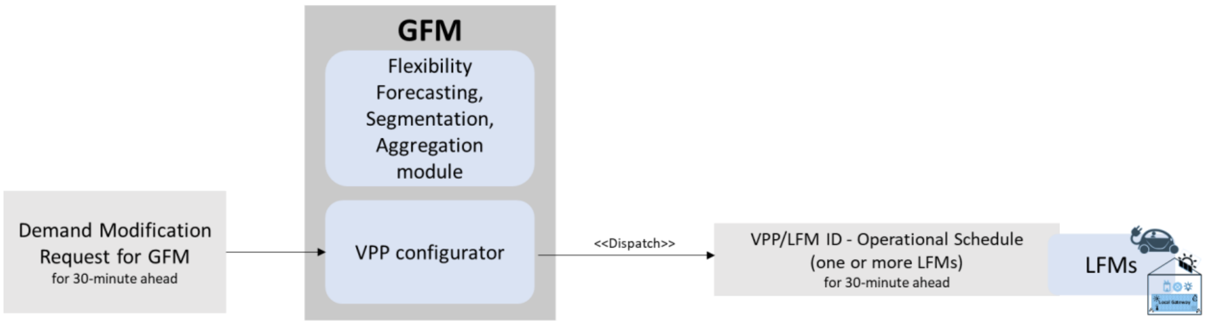


Figure 18 Basic demonstration scenario: Instance VIII

The control setpoints are communicated to the actual device controllers through the middleware and, more specifically, through the building and EV DER connectors.

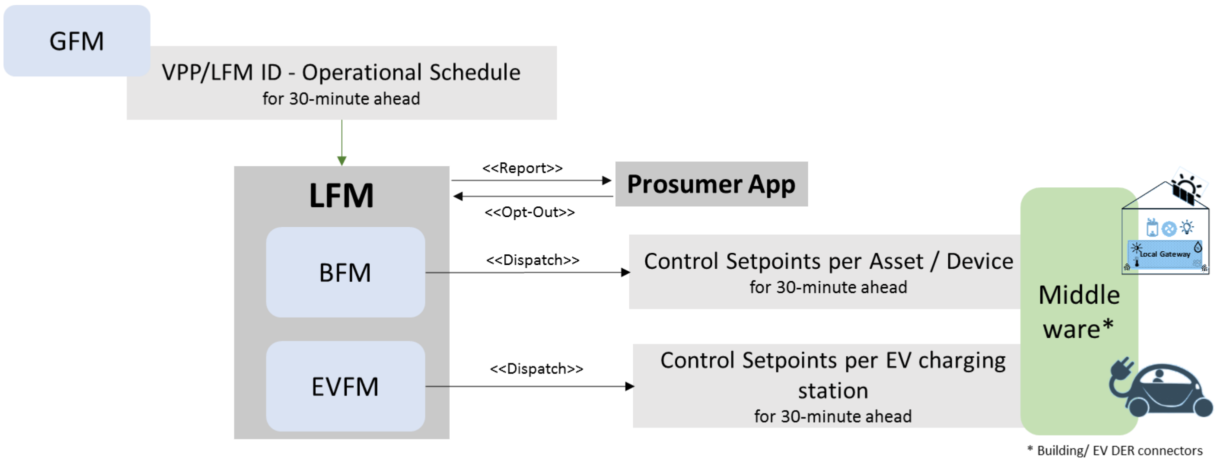


Figure 19 Basic demonstration scenario: Instance IX

The basic demonstration scenario shall also include the "Flexibility Pooling and Sharing Marketplace" beyond its role in providing information to the GFM upon a forecast request from the ILESEM (ref. to Figure 13). The schematic of Figure 20 presents the processes of offer publishing, contract development, settlement and remuneration as they are crucial MERLON functionalities to be demonstrated. In the presented procedure, the interacting components with the flexibility marketplace are the interfaces of MERLON stakeholders, namely the DSO's UI, the intra-ILES Aggregators' UIs and the prosumer app. More specifically:

- Through the DSO web interface, any requirements set by the DSO in order to valorise aggregator's portfolio flexibility and / or relevant contractual agreements in place should be communicated to the intra-ILES aggregators and being visible through the aggregator web interface
- Aggregator web interface should enable intra-ILES aggregators to publish their offers to prosumers, through the prosumer app, based on their DER devices and the respective flexibility potential
- Marketplace should allow for a negotiation of contractual terms among intra-ILES aggregators and prosumers until an agreement is reached and a contract is signed
- Having a contractual agreement signed all aforementioned ILES actors, namely, DSO, intra-ILES aggregators and prosumers should be able to get informed about the settlement and remuneration for the offered flexibility. This should be provided by the settlement and remuneration component of the flexibility marketplace and visualised for the concerned actors in the relevant user interfaces.

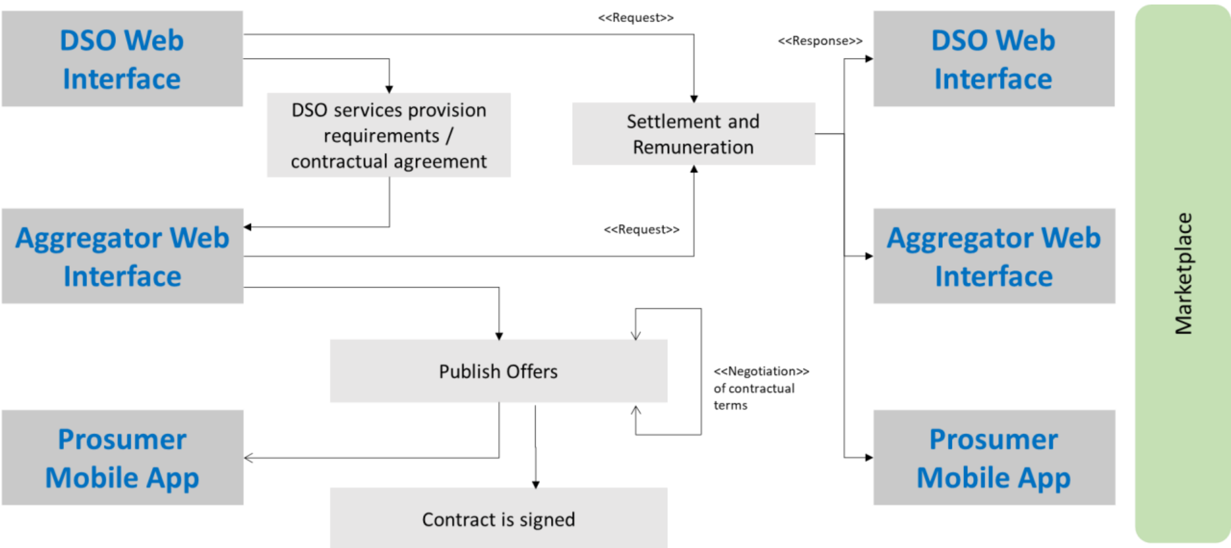


Figure 20 Flexibility Pooling and Sharing Marketplace

2.3 Validation activities

Upon the basic demonstration scenario of Section 2.2 and the specified KPIs, validation of several aspects and holistic impact assessment will be enabled in MERLON demo sites. The validation activities will range from **a single service assessment provided by a single ILES asset** at a specific stage of the demonstration scenario to the **holistic assessment of MERLON ILES optimisation platform**. In particular:

- **Service assessment provided by a single ILES asset at a specific stage of the demonstration scenario**

  For example, in "revenue stacking" models, a single asset such as the BESS can provide simultaneous services, such as [2]:

  a. Control reserve such as droop control, frequency regulation, etc.
  b. Voltage stabilization, namely active and reactive power control.
  c. As balancing unit in times of supply/demand mismatch.

  The BESS capability on providing each of these services should be validated separately but also a holistic evaluation of the BESS integration needs to be performed horizontally and combine the multi-level impact.

- **Holistic assessment of MERLON ILES optimisation platform under a specific validation activity**. In particular, after performing:
  a. All the validation activities relevant to a single service of a specific ILES asset.
  b. All the validation activities relevant to the holistic evaluation of all services that can be provided by the ILES asset of the previous point.
  c. All the validation activities (following the two previous points) of all the ILES assets.

  The holistic assessment of the MERLON integrated ILES optimisation framework should be validated.

The whole framework as described above is depicted in the Figure 21 below.

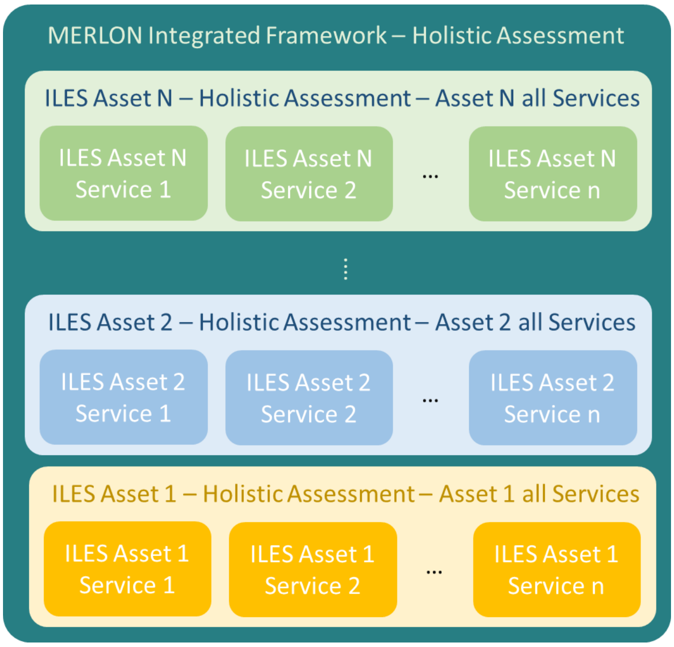


Figure 21: MERLON Validation Framework

2.3.1 Austrian Pilot Site

The configuration of the electrical grid in Austrian area of interest and its interconnection to the upstream network is presented through the schematic of Figure 22. More specifically, the 110 kV power grid in the province of Burgenland is connected to the transmission grid of the Austrian TSO APG (Austrian Power Grid) at two 380 kV substations, one in the north and one in the south of Burgenland, and at one 220 kV substation in the north. The two DSOs operating the distribution grid in Burgenland are “Netz Burgenland” and “Energie Güssing”. While “Netz Burgenland” operates on the 110 kV, 20 kV, and 0.4 kV level, Energie Güssing operates the 20 kV and 0.4 kV levels connected to one of the 110 kV substations (UW Güssing).

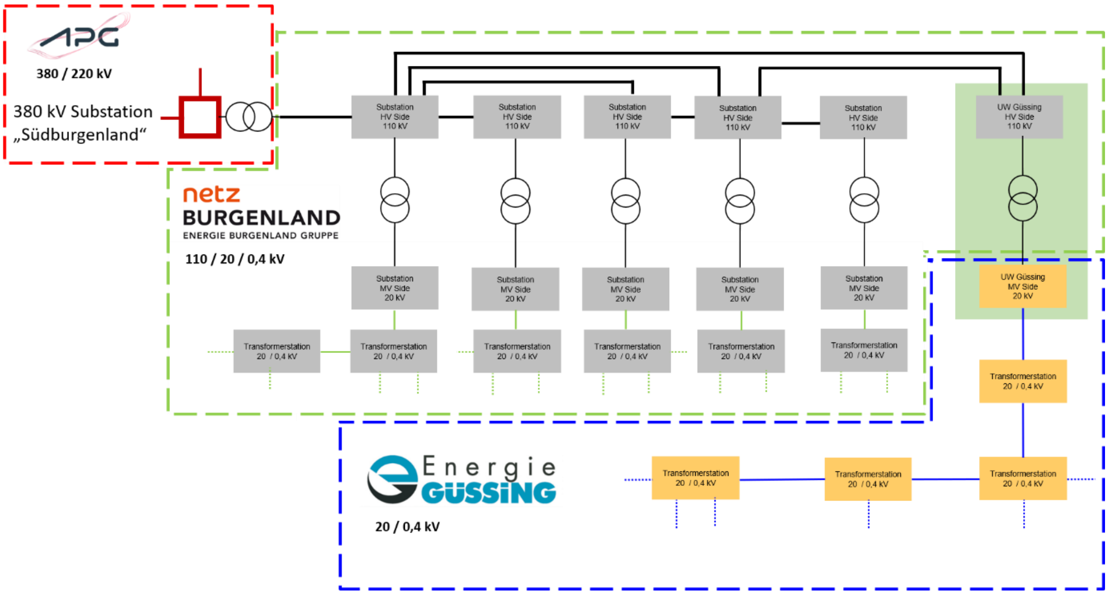


Figure 22 ILES and upstream electrical grid schematic of MERLON demo site in Austria

MERLON ILES demo site is situated in one of the 20/0.4kV substations of Energie Gussing electrical distribution network as shown in Figure 23. Therefore, Energie Gussing constitutes the MERLON ILES DSO that will have access and make use of the DSO web interface.

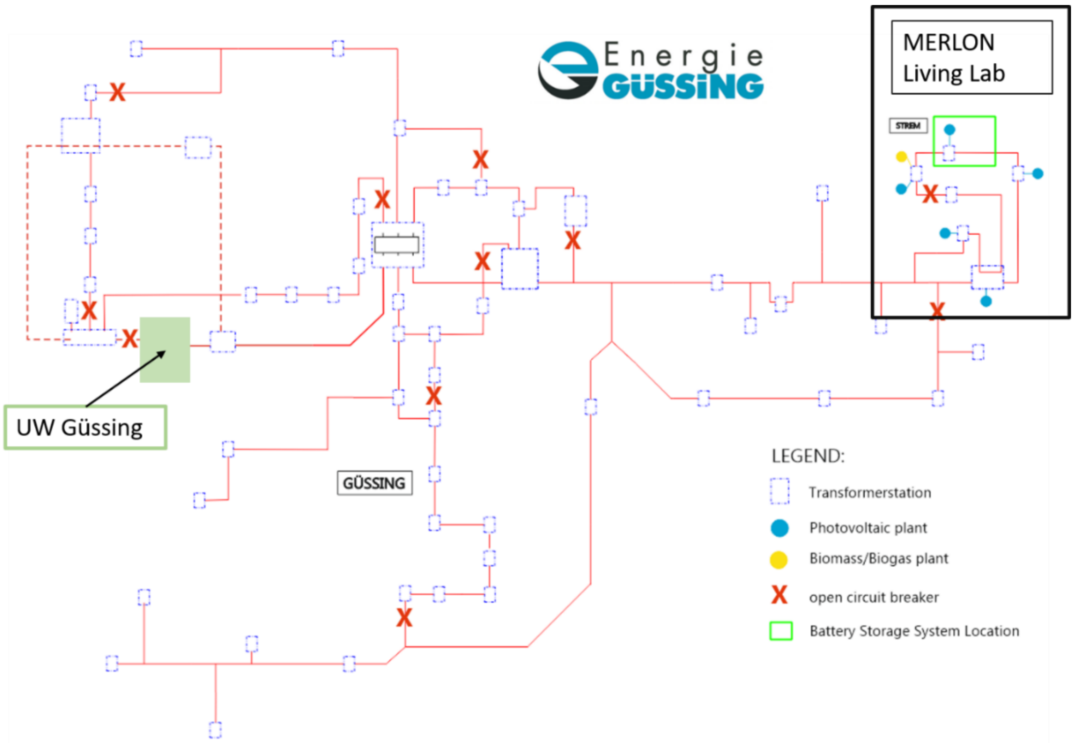


Figure 23 MERLON ILES grid boundaries in the distribution network of Energie Gussing

In theory, “Netz Burgenland” represents the overlay distribution system operator and APG the TSO that would accept balancing services in case of real-life operation.

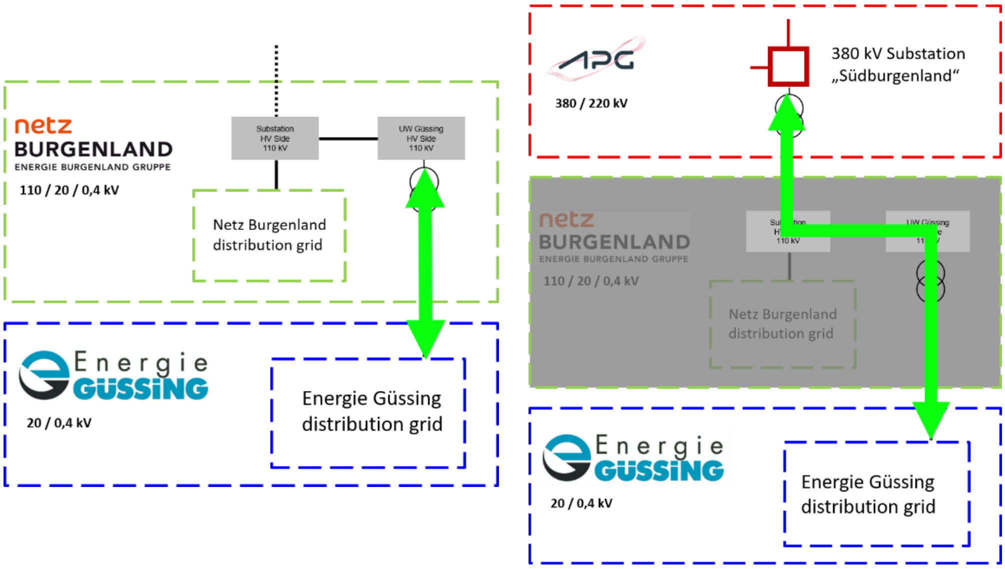


Figure 24 Service provision to (a) the overlay DSO (Netz Burgenland) operating the 110 kV level and (b) the TSO (APG) via the 110 kV grid

Upon this structure and with the information flow adapted from the basic demonstration scenario, validation activities of several business scenarios shall be conducted. An initial pool of business scenarios for holistic ILES validation is outlined as follows:

- Local distribution network management – aligned with UC 2
    - Resolve a thermal / voltage constraint through ILES flexibility and get remunerated based on contract with DSO.
    - Reduce use-of-network charges by suitable management of ILES flexibility.

  One of the initial motivations of Energie Gussing is to resolve issues in the distribution grid and to be able to have a more detailed overview of the power grid in order to be able to manage and operate it to the best of the DSOs abilities. Thus, this scenario will be implemented and validated in the Austrian Pilot site.

- Provision of security of supply during islanding conditions – Aligned with UC 5

  Under emergency conditions the ILES may be disconnected from the main grid and operate as an island. This scenario explores the management of ILES flexibility to minimize the required load shedding during such conditions and therefore enhance the security of supply for the local consumers.

  This islanding scenario shall be implemented and validated in order to test the ability of islanding the part of the grid used within the MERLON Living Lab. The ILES will remain physically connected to the main grid, but the operation mode will be adapted, as it would be, if it is actually disconnected. A positive result of the operation can lead to further implementation of the physical possibilities of islanding the part of the grid.

- Provision of balancing services to the TSO – aligned with UC 8

  In this scenario the ILES provides various types of reserve and frequency response to the TSO. This lies in the ability of the ILES flexible resources to either increase or decrease their produced / consumed power with respect to the levels prescribed by their energy trading activities, in case an imbalance occurs between the total generation and total demand in the system.

- Contracting balancing services with the TSO (availability payment)
- Actual provision of balancing power upon TSO request (utilisation payment)

Service provision from the local flexibility systems within this scenario can be established by a stepwise approach. Since the Energie Güssing distribution grid is not directly connected to the Austrian transmission grid, the first step would be the provision of services to the overlaying 110 kV distribution grid. In a further step, and as a future scenario with higher available flexible amounts of energy and power, service provision to the transmission system (380 kV) can be simulated.

Both the 110 kV DSO as well as the Austrian TSO are no members of the MERLON consortium. Therefore, these actors have to be simulated. This means, that requests, that could be made by these actors, have to be generated and sent.

- Participation in energy markets – aligned with UC 9
  - Contract with supplier: respond to time-varying tariffs offered by supplier through optimal use of the available flexibility.
  - Participation in wholesale market: ILES participates directly to the wholesale market and manages available flexibility to minimise energy costs.
  - Local community trading: Local DER within the ILES perform energy trading among them to limit their dependency on electricity suppliers and the wholesale market.

  Since neither Energie Güssing nor EEE are working as retailers or are directly involved in the energy market, no in-depth experience is locally available at the Austrian Pilot site.

3 MERLON KPI ANALYSIS

In this section, the KPIs initially presented in the D3.3 are detailed based on the template that was introduced in the same document.

The following KPIs categories have been defined:

- **Technical** assessing mainly technical compatibility and interoperability issues, including KPIs for energy efficiency, DR, Security and quality of supply, ICT-related performance like ICT security, data privacy, etc.
- **Social** assessing the impact of a technology to social factors like comfort and user preferences
- **Environmental** for understanding and evaluating the environmental impact of MERLON solution deployment
- **Economic** that evaluates the business efficiency of an application and usage scenario from the market stakeholder perspective

In the MERLON project there are different levels of aggregation - from a single building to the whole ILES. Thus, the different levels of aggregation that can be evaluated using the MERLON KPIs are:

- **Asset** that concerns individual DER loads in the buildings e.g. DHW, HVAC, lights
- **Building** that concerns the energy performance of the building that may include:
    - The energy required to meet building's energy needs
    - The exported energy from the building
    - Or the energy balance of the demand and production at building level
- **Group of buildings** (e.g. buildings of an aggregator's portfolio or sub-portfolio). In this case, the indicators can be calculated by summing up the respective buildings as a group
- **Renewable Energy Sources** including district-wide assets or building assets (e.g. rooftop PVs)
- **Group of Renewable Energy Sources**. In this case, the indicators can be calculated by summing up the respective RES as a group
- **ILES** that is composed by a number of different entities e.g. buildings, RES (district-wide and local small units), storage units, EVs.

3.1 MERLON Technical KPIs

In the following table we provide the KPIs falling under the "technical" category. Each of these KPIs is further detailed in the following sub-sections.

Table 2: Final List of MERLON Technical KPIs

KPI	Name	Definition
TEC 1	Absolute Energy savings	Difference between measured and reference consumption data within a predefined period
TEC 2	Relative energy savings	Difference between measured and reference data divided by total
TEC 3	Self-consumption	Efficiency of load shifting mechanisms and energy storage by quantifying the amount of electricity produced and consumed locally relative to the total local production available from the respective generation units
TEC 4	Total RES consumption	Total amount of renewable energy consumed within a predefined period
TEC 5	Curtailment Avoidance	Reduction of RES curtailment. The integration of MERLON solution will have an impact on RES curtailment, as the time for curtailment will be reduced
TEC 6	Energy demand & consumption	The energy demand/consumption corresponds to the energy entering the system to keep operation parameters (e.g. comfort levels).
TEC 7	Space Heating Energy consumption / floor area	Energy consumption of households for space heating per floor area adjusted for climatic conditions

TEC 8	Energy consumption for water heating	Energy consumption of households for water (and cooking) heating per inhabitant
TEC 9	Annual electricity consumption per appliance	Electricity consumption per appliance type in kWh/year
TEC 10	State-of-Charge (SoC)	At any moment, the state-of-charge of a battery represents the percentage at which the battery is charged compared to its maximum stored capacity.
TEC 11	State of Health	State-of-Health (SoH) represents the measure of battery degradation where the numerator is the measured actual battery capacity and the denominator the nominal/rated capacity at the beginning of the battery life (during a discharge cycle).
TEC 12	Storage Energy Losses	This KPI illustrates the energy losses because of battery storage. The conclusions of this KPI concern the effectiveness of this technology.
TEC 13	Delivered Flexibility	Difference between promised and requested flexibility
TEC 14	Baseline consumption	Difference between the baseline demand / consumption forecast for a predefined period and the actual measured values
TEC 15	Increased system flexibility for energy players	This KPI is an indication of the ability of a system to respond to – as well as stabilize and balance – supply and demand in real time, as a measure of the demand side participation in energy markets Stability refers to the maintaining of voltage and frequency of a given power system within acceptable levels.
TEC 16	Peak Load Reduction	Compare the peak demand before the DR implementation (baseline) with the peak demand after the DR implementation.
TEC 17	Peak to average ratio	Peak power consumption divided by average power
TEC 18	Efficiency of a load-shifting DR event	This KPI represents the efficiency of a load-shifting DR event.
TEC 19	Reduction of Energy Cost	This KPI is intended to assess the economic benefits of a scheduling strategy for prosumers coordinated by an aggregator. The KPI will measure the cost of the energy traded by an aggregator e.g. the effect of shifting the demand to consume from the grid when the electricity price is lower
TEC 20	Technical Compatibility	This indicator aims to provide an indication of the technical compatibility of the MERLON solution, meaning the extent to which the solution fits with current practices and existing technological standards/ infrastructures / framework / etc.
TEC 21	Improved Interoperability	Interoperability is the ability of a system (or product) to work with other systems (or products) by providing services to and accepting services from other systems and to use the services so exchanged to enable them to operate effectively together (ISO/TS 37151). The indicator assesses the improvement in interoperability in a qualitative manner without going into details.
TEC 22	Data Quality	This KPI aims to assess the quality of data exchanged within the MERLON integrated optimisation framework as well as the output data to be delivered to the external world.
TEC 23	Islanding	Capacity of the energy system to switch to islanding whilst keeping the power quality requirement.

TEC 24	Customer Total Average Interruption Duration Index (CTAIDI)	CTAIDI is the average total duration of interruption for customers who had at least one interruption during the period of analysis.
TEC 25	System Average Interruption Frequency Index (SAIFI)	SAIFI represents the yearly average interruption times for all customers in the system. This is just the total number of customer interruptions that occurred in the year divided by the total number of customers in the system.
TEC 26	Power Quality and Quality of Supply	Average time needed for awareness, localization and isolation of grid fault.
TEC 27	Voltage quality performance	This KPI is used to evaluate the fulfilment of regulatory voltage limits in the distribution network
TEC 28	System Average Interruption Duration Index (SAIDI)	SAIDI represents the average interruption duration for each customer served
TEC 29	Average Service Availability Index (ASAI)	Ratio of electricity supply hours to electricity demand hours
TEC 30	Data Safety	Number of blocked malicious hacking attempts. The nature of the web environment is hostile. There are a lot of agents trying to exploit vulnerabilities in any software system. This KPI is intended to give a statement about the safety of data in the MERLON applications
TEC 31	GDPR risk	Assessing the data privacy risk level due to MERLON solution usage
TEC 32	Response Time	Time that the BESS requires to increase or decrease its rated power during charge or discharge upon a signal trigger
TEC 33	Ramp Rate	Through the ramp rate KPI, it can be evaluated if a battery is properly sized for a certain service
TEC 34	Round-Trip Efficiency (RTE)	It is a measurement of energy efficiency that covers both charge and discharge modes, namely the overall battery operation.

3.1.1 TEC 1 - Absolute Energy savings

<table>
<tr><td colspan="5">Technical</td></tr>
<tr><td colspan="5">TEC 1 – Absolute Energy Savings</td></tr>
<tr><td>Asset</td><td>√</td><td></td><td>RES</td><td></td></tr>
<tr><td>Building</td><td>√</td><td></td><td>Group of RES</td><td></td></tr>
<tr><td>Group of Buildings</td><td>√</td><td></td><td>ILES</td><td>√</td></tr>
<tr><td>KPI Definition</td><td colspan="4">We consider that absolute is referred to all assets in the ILES.
Difference between absolute measured and absolute reference consumption data within a predefined period.
There should be a substantial difference between absolute and measured when requests of Energy Island or network constrains occurs.

- The absolute reference consumption is the total baseline load of the ILES and it is based on statistical consumption data
- The absolute measured consumption data is the total real consumption of the ILES.

Therefore, this indicator shows the difference between expected consumption and real consumption.</td></tr>
<tr><td>Input Parameters and Calculation</td><td colspan="4">Input Parameters:
$BC_{zk} = Baseline\ Consumption\ \ of\ asset\ z\ during\ k\ interval$
$L_{zk} = power\ of\ load\ z\ during\ k\ interval$
$Z = total\ number\ of\ assets$
$K = set\ of\ time\ intervals$
Calculation:
$Absolute\ baseline\ consumtion\ (ABC) = \sum_{1}^{K}\sum_{1}^{Z} BC_{zk}$
$Absolute\ measured\ consumption\ (AMC) = \sum_{1}^{K}\sum_{1}^{Z} L_{zk}$
$Absolute\ energy\ savings\ (AES) = \ ABC - \ AMC$</td></tr>
<tr><td>Measurement Process</td><td colspan="4">For calculating this KPI we need:
• Measurement of individual asset consumption (kWh)</td></tr>
<tr><td>Unit</td><td colspan="4">kWh</td></tr>
<tr><td>References</td><td colspan="4">[4][5]</td></tr>
<tr><td>Comments</td><td colspan="4"></td></tr>
</table>

3.1.2 TEC 2 – Relative energy savings

Technical					
TEC 2 – Relative energy savings					
Asset	√			***RES***	
Building				***Group of RES***	
Group of Buildings				***ILES***	
KPI Definition	Difference between absolute measured and absolute reference consumption data divided by total. This value is computed per asset and divided by Absolute Energy Savings (see previous KPI)				
Input Parameters and Calculation	Input Parameters: $BC_K = Baseline\ Consumption\ of\ an\ specific\ asset\ during\ k\ interval$ $L_k = power\ of\ z\ load\ during\ k\ interval$ $AES = Absolute\ energy\ savings\ (from\ previous\ KPI)$ $Z = total\ number\ of\ assets$ $K = set\ of\ time\ intervals$ Calculation: $Baseline\ consumption = \sum_{1}^{K} BC_k = \boldsymbol{BC}$ $Measured\ consumption = \sum_{1}^{K} L_k A = \boldsymbol{MC}$ $Relative\ energy\ savings = \frac{BC - MC}{AES}$				
Measurement Process	For calculating this KPI we need: • Absolute Energy Savings • Measurement of individual asset consumption (kWh)				
Unit	kWh				
References	[4][5]				
Comments					

3.1.3 TEC 3 – Self-Consumption

Technical				
TEC 3 – Self-consumption				
Asset			***RES***	
Building			***Group of RES***	√
Group of Buildings			***ILES***	√
KPI Definition	Efficiency of load shifting mechanisms and energy storage by quantifying the amount of electricity produced and consumed locally relative to the total local production available from the respective generation units.			
Input Parameters and Calculation	Input Parameters: $T = predefined\ period$ $t = instant\ t$ $EP_t = Energy\ produced\ by\ one\ connection\ point$ *(from RES or obtained from Battery) in an instant t (kWh)* $ED_t = Energy\ demanded\ by\ one\ connection\ point\ in\ an\ instant\ t\ (kWh)$ $ILES.EP_t = Energy\ produced\ by\ the\ whole\ ILES\ in\ an\ instan\ t\ (kWh)$ Calculation: $Self\ Consumption = \frac{\sum_1^T \min(EP_t, ED_t)}{\sum_1^T ILES.EP_t}$			
Measurement Process	For calculating this KPI we need: • Energy produced by one place (kWh) • Energy produced by the whole ILES (kWh)			
Unit	kWh			
References	[4][5]			
Comments				

3.1.4 TEC 4 - Total RES consumption

Technical				
TEC 4 – Total RES consumption				
Asset			**RES**	
Building			**Group of RES**	
Group of Buildings	√		**ILES**	√
KPI Definition	Total amount of renewable energy consumed locally by the ILES loads within a predefined period			
Input Parameters and Calculation	Input Parameters: $T = predefined\ period$ $t = instant\ t$ $ILES.ED_t = Energy\ demanded\ by\ the\ whole\ ILES\ in\ an\ instan\ t\ (kWh)$ $ILES.EP_t = Energy\ produced\ by\ the\ whole\ ILES\ in\ an\ instan\ t\ (kWh)$ Calculation: $Total\ RES\ consumption = \sum_{1}^{T} \min(ILES.EP_t, ILES.ED_t)$			
Measurement Process	For calculating this KPI we need: • Energy produced by the whole ILES (kWh) • Energy demanded by the whole ILES (kWh)			
Unit	kWh			
References	[4][5]			
Comments				

3.1.5 TEC 5 - Curtailment Avoidance

Technical				
TEC5 – Curtailment Avoidance				
Asset			***RES***	
Building			***Group of RES***	√
Group of Buildings			***ILES***	√
KPI Definition	Reduction of RES curtailment. The integration of MERLON solution will have an impact on RES curtailment, as the time for curtailment will be reduced. The RES curtailment is referred to the Energy not injected from each RES unit within the ILES grid.			
Input Parameters and Calculation	Input Parameters: $T = predefined\ period$ $t = interval$ $K = total\ number\ of\ RES\ in\ the\ ILES$ $k = specific\ RES$ $ENIBL_{tk} = Energy\ Not\ Injected\ Base\ Line\ per\ RES\ in\ an\ interval\ t$ $ENIM_{tk} = Energy\ Not\ Injected\ Measured\ per\ RES\ in\ an\ interval\ t$ Calculation: $Reduction\ of\ RES\ curtailment = \sum_{1}^{K}\sum_{1}^{T}(ENIBL_{tk} - ENIM_{tk})$			
Measurement Process	For calculating this KPI we need: • Energy not injected by RES (kWh) • Energy injected by RES (kWh)			
Unit	kWh			
References	[4][5]			
Comments				

3.1.6 TEC 6 - Energy demand & consumption

Technical				
TEC6 – Energy demand & consumption				
Asset			***RES***	
Building	√		***Group of RES***	
Group of Buildings	√		***ILES***	
KPI Definition	The energy demand and consumption correspond to the energy entering the system to keep operation parameters (e.g. comfort levels). The energy demand is referred to forecasted value based on ambient parameters. The energy consumption is referred to the real energy measured.			
Input Parameters and Calculation	Input Parameters: $T = predefined\ period$ $t = interval$ $K = total\ number\ of\ buildings$ $k = specific\ building$ $EDF_{tk} = Energy\ demand\ forecasted\ per\ building\ in\ an\ interval\ t$ $ECM_{tk} = Energy\ consumption\ measured\ per\ building\ in\ an\ interval\ t$ Calculation: $Energy\ demand\ forecasted = \sum_1^K \sum_1^T EDF_{tk}$ $Energy\ cosumption\ measured = \sum_1^K \sum_1^T ECM_{tk}$			
Measurement Process	For calculating this KPI we need: • Energy demand simulated for comfort parameters for all buildings (kWh) • Energy consumption measured for all buildings (kWh)			
Unit	kWh			
References	[4][5]			
Comments				

3.1.7 TEC 7 – Space Heating Energy consumption / floor area

<table>
<tr><td colspan="5">Technical</td></tr>
<tr><td colspan="5">TEC7 – Energy consumption / floor area</td></tr>
<tr><td>Asset</td><td></td><td rowspan="3"></td><td>RES</td><td></td></tr>
<tr><td>Building</td><td>√</td><td>Group of RES</td><td></td></tr>
<tr><td>Group of Buildings</td><td></td><td>ILES</td><td></td></tr>
<tr><td>KPI Definition</td><td colspan="4">Energy consumption of households for space heating per floor area adjusted for climatic conditions in a period.</td></tr>
<tr><td>Input Parameters and Calculation</td><td colspan="4">Input Parameters:
$T = predefined\ period$
$t = interval$
$K = total\ number\ buildings$
$k = specific\ Building$
$ECH_{tk} = Energy\ consumption\ /\ household\ for\ space\ heating\ in\ an\ interval\ t$
$A = Area\ of\ a\ specific\ household$

Calculation:
$Energy\ consumption\ of\ household\ for\ space\ heating\ per\ m^2 in\ a\ period\ T = \sum_1^K \sum_1^T \left(\frac{ECH_{tk}}{A_k}\right)$</td></tr>
<tr><td>Measurement Process</td><td colspan="4">For calculating this KPI we need:
• Energy consumption for space heating per building (kWh)
• Area per building (m^2)</td></tr>
<tr><td>Unit</td><td colspan="4">kWh per m^2</td></tr>
<tr><td>References</td><td colspan="4">[4][5]</td></tr>
<tr><td>Comments</td><td colspan="4"></td></tr>
</table>

3.1.8 TEC 8 - Energy consumption for water heating

Technical					
TEC8 – Energy consumption for water heating					
Asset				**RES**	
Building	√			**Group of RES**	
Group of Buildings	√			**ILES**	
KPI Definition	Energy consumption of households for water heating per habitant.				
Input Parameters and Calculation	Input Parameters: $T = predefined\ period$ $t = interval$ $K = total\ number\ of\ buildings$ $k = specific\ building$ $ECHWH_{tk} = Energy\ consumption\ per\ household\ for\ water\ heating\ in\ an\ interval\ t$ $H = total\ number\ of\ habitants$ Calculation: $Energy\ consumption\ of\ household\ for\ water\ heating\ per\ habitant\ in\ a\ period\ T = \sum_1^K \sum_1^T \left(\frac{ECHWH_{tk}}{H \cdot K}\right)$				
Measurement Process	For calculating this KPI we need: • Energy consumption water heating and cooking per building (kWh) • Number of habitants per building				
Unit	kWh per habitant				
References	[4][5]				
Comments					

3.1.9 TEC 9 - Electricity consumption per appliance type

Technical				
TEC9 – Electricity consumption per appliance type in kWh/year				
Asset	√		***RES***	
Building			***Group of RES***	
Group of Buildings			***ILES***	
KPI Definition	Electricity consumption per appliance type in kWh/year. This KPI calculates the consumption per load type like HVAC, DHW, lights			
Input Parameters and Calculation	Input Parameters: $T = 365$ $t = interval$ $K = total\ number\ of\ appliances\ for\ a\ specific\ type$ $k = specific\ appliance\ belonging\ to\ a\ type$ $ECA_{tk} = Energy\ consumption\ for\ a\ specific\ appliance\ for\ an\ interval\ t$ Calculation: $Energy\ consumption\ per\ appliance\ type\ for\ one\ year = \sum_1^K \sum_1^T \left(\frac{ECA_{tk}}{K}\right)$ For example: K = 50 HVAC devices			
Measurement Process	For calculating this KPI we need: • Energy consumption for all assets (kWh)			
Unit	kWh per appliance type			
References				
Comments				

3.1.10 TEC 10 - State-of-Charge (SoC)

Technical				
TEC 10 - State-of-Charge (SoC)				
Asset	√		**RES**	
Building			**Group of RES**	
Group of Buildings			**ILES**	√
KPI Definition	Battery applications are either power intensive, including high power and short-term discharges, or energy intensive with deep discharges in time. An operation cycle comprises a charge and a discharge with possible intermediate rest periods. At any moment, the state-of-charge of a battery represents the percentage at which the battery is charged compared to its maximum stored capacity. $$\text{SoC} = \frac{Battery\_Ah_{remaining}}{Battery\_Ah_{nominal}}$$ When the battery is "fully charged", its SoC equals 100%.			
Input Parameters and Calculation	$Battery\_Ah_{remaining}$ Battery Capacity (rated measurement from BMS) $Battery\_Ah_{nominal}$ Nominal Battery capacity (from BESS data sheet)			
Measurement Process				
Unit	%			
References	[9]			
Comments	Depth-of-Discharge (DoD) is an alternative expression of the same metric indicating "how much a battery is discharged". $$\text{DoD} = 1 - \text{SoC}$$			

3.1.11 TEC 11 - State of Health (SoH)

Technical				
TEC 11 – State of Health (SoH)				
Asset	√		**RES**	
Building			**Group of RES**	
Group of Buildings			**ILES**	√

KPI Definition	As a limiting condition in BESS cost-benefit analysis, the battery cycle/calendar life degradation over time under specific conditions/ operation modes shall be calculated. State-of-Health (SoH) represents the measure of battery degradation where the numerator is the measured actual battery capacity and the denominator the nominal/rated capacity at the beginning of the battery life (during a discharge cycle). $$\mathrm{SoH} = \frac{Battery\_Ah_{measured}}{Battery\_Ah_{nominal}}$$ Depending on technology and market, a battery is considered to be at the end-of-life when SoH equals either 80% or even 60%.
Input Parameters and Calculation	$Battery\_Ah_{measured}$ Actual Battery capacity at the moment of measurement $Battery\_Ah_{nominal}$ Nominal Battery capacity (from BESS data sheet)
Measurement Process	
Unit	%
References	[9]
Comments	Cycle life and calendar life are two different metric and usually refer to distinct ageing mechanisms of a battery. Cycle life refers to the number of charge / discharge cycles the battery can perform measured by energy throughput (total AH-throughput). The calendar life may be much longer and may be a limiting factor mostly in stand-by operations. SOH quantifies the degree of battery degradation. The KPI illustrates the capacity losses of the batteries used in the project.

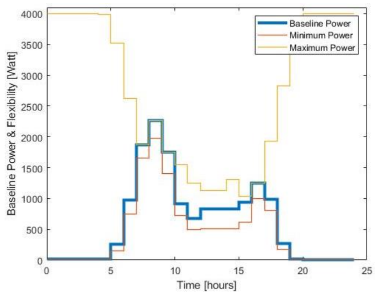
3.1.12 TEC 12 – Storage Energy Losses

Technical				
TEC12 – Storage Energy Losses				
Asset	√		***RES***	
Building			***Group of RES***	
Group of Buildings			***ILES***	

KPI Definition	This KPI quantifies the battery energy losses arising from converting electrical energy to chemical potential energy and back again as well as the sum of the auxiliary consumptions and the internal Joule losses of the battery. The conclusions of this KPI concern the effectiveness of this technology and thus, gives useful data concerning the financial feasibility of its integration.
Input Parameters and Calculation	Assuming that $\mathrm{E_{input}}$ is the energy absorbed by the BESS and $\mathrm{E_{out}}$ is the energy supplied by the BESS, then, storage energy losses can be quantified by the following equation: $$TEC\ 12 = \frac{E_{input} - E_{out}}{E_{out}} \cdot 100\%$$
Measurement Process	
Unit	%
References	[10] [11]
Comments	In general, the contribution of heaters and Joule losses depends on the operating conditions. Thus, this should be taken into account when this KPI is calculated

3.1.13 TEC 13 – Delivered Flexibility

Technical				
TEC13 – Delivered Flexibility				
Asset	√		***RES***	
Building	√		***Group of RES***	
Group of Buildings	√		***ILES***	√

KPI Definition	This KPI quantifies the difference between promised flexibility and requested flexibility
Input Parameters and Calculation	In MERLON, the following three time series are available for the decision making: - $\hat{P}_t$: The forecasted baseline power (blue line), which is the forecast of the load given no activation is requested. - $\hat{P}_t^{min}$: The forecasted minimum power (orange line) that can be applied for providing downwards flexibility (reduced load) - $\hat{P}_t^{max}$: The forecasted maximum power (yellow line) that can be applied for providing upwards flexibility (reduced load) These timeseries will be available per asset / building / group of buildings (e.g. portfolio of an aggregator) as required. They represent the flexibility which was "promised" for a specific time period and afterwards in the evaluation period they are the reference power which the actual measured power must be compared to, in order to measure how much flexibility was actually delivered. The requested flexibility should be between the limits of the promised flexibility. None, all or part of it should be available for delivery (when requested). Let's consider $a_t = [0.1]$, the signal that represents the requested flexibility (ranging from 0 indicating no activation to 1 indicating full activation). In what follows, we consider the case that the signal refers to decreased consumption (i.e. provide downwards flexibility). Similar approach should be followed, if we assume increase of consumption. The ***requested load reduction*** (downwards flexibility) is: $$P_t^{down,req} = a_t \cdot (\hat{P}_t - \hat{P}_t^{min})$$ While the ***delivered downwards flexibility*** at time t is: $$P_t^{down,del} = a_t \cdot (\hat{P}_t - \max(P_t, \hat{P}_t^{min}))$$ From the above equations, it is evident that: - If $P_t > \hat{P}_t^{min}$, the promised but not delivered flexibility at time t is equal to $a_t \cdot (P_t - \hat{P}_t^{min})$ - If $P_t = \hat{P}_t^{min}$, the flexibility requested is equal to the one delivered at time t - If $P_t < \hat{P}_t^{min}$, the flexibility delivered is greater than the one requested at time t. The additional flexibility delivered is equal to $a_t \cdot (\hat{P}_t^{min} - P_t)$
Measurement Process	All the above values (forecasts and actual measurements) should be available for validation. The KPI can be measured at different MERLON levels as mentioned above
Unit	Watts (W)
References	[12]
Comments	We assume that one activation can be requested only to one side at any time t. Furthermore, we assume that the following timeseries will be available (see the figure): - $\hat{P}_t$: The forecasted baseline power (blue line) - $\hat{P}_t^{min}$: The forecasted minimum power (orange line) - $\hat{P}_t^{max}$: The forecasted maximum power (yellow line) 

3.1.14 TEC 14 – Baseline Consumption

Technical				
TEC 14 – Baseline Consumption				
Asset	√		***RES***	
Building	√		***Group of RES***	
Group of Buildings	√		***ILES***	√

KPI Definition	This indicator will quantify the difference between the baseline demand / consumption forecast for a predefined period and the actual measured values. The indicator will measure the Mean Absolute Error (MAE) between the forecasted and the observed (measured) demand / consumption. The evolution of this KPI will be monitored through a moving window, observing how the MAE value evolves, verifying that the solution reduces its forecasting errors as time evolves. Another KPI that can be used towards this direction is the Root Mean Square Error (RMSE) which is the standard deviation of the residuals (prediction errors). Root mean square error is commonly used in forecasting and regression analysis to verify experimental results.
Input Parameters and Calculation	The first KPI for assessing the closeness of the forecast $\hat{P}_t$ to the eventual outcome P_t is the MAE defined as: $$MAE_k = \frac{1}{n}\sum_{t=1}^{n} \hat{P}_t - P_t$$ Where n is the number of observations. The second KPI is the RMSE that represents the sample standard deviation of the differences between predicted values ($\hat{P}_t$) and observed values (P_t) and is defined as: $$RMSE = \sqrt{\frac{1}{n}\sum_{1}^{n}(\hat{P}_t - P_t)^2}$$ where n is the number of observations.
Measurement Process	For calculating these KPIs, we need as inputs: - The predicted values of the baseline demand / consumption - The observed / measured values for demand / consumption These KPIs can be calculated at different MERLON levels including: - Asset Level - Building Level - Group of Buildings (portfolio of an aggregator) Level - ILES Level
Unit	The units of the KPIs when assessing demand and consumption are as follows: - Baseline Demand (kW) - Baseline Consumption (KWh)
References	[12]
Comments	

3.1.15 TEC 15 – Increased system flexibility for energy players

Technical				
TEC15 – Increased system flexibility for energy players				
Asset			***RES***	
Building			***Group of RES***	
Group of Buildings			***ILES***	√
KPI Definition	This KPI assesses the additional flexibility capacity gained for energy players. It measures the progress brought by MERLON (and possibly other R&I activities), assessing the additional electrical power that can be modulated in the selected framework, such as the connection of new RES generation, to enhance an interconnection, to solve congestion, or even all the transmission capacity of a TSO. This KPI is an indication of the ability of a system to respond to – as well as stabilize and balance – supply and demand in real time, as a measure of the demand side participation in energy markets.			
Input Parameters and Calculation	This KPI quantifies the increase in the amount of load capacity participating in demand side management and is calculated as follows: $$TEC\ 15 = \frac{SF_{MERLON} - SF_{BAU}}{P_{peak}} \cdot 100\%$$ Where SF_{MERLON} is the amount of load capacity participating in demand side management (W) due to MERLON project, SF_{BAU} is the amount of load capacity participating in demand side management without taking into account MERLON (business as usual) and P_{peak} is the peak demand (W).			
Measurement Process				
Unit	%			
References	[13]			
Comments				

3.1.16 TEC 16 – Peak Load Reduction

Technical				
TEC 16 – Peak Load Reduction				
Asset	√		***RES***	
Building	√		***Group of RES***	
Group of Buildings	√		***ILES***	√
KPI Definition	This KPI compares the peak demand before the DR implementation (baseline) with the peak demand after the DR implementation			
Input Parameters and Calculation	This KPI quantifies the difference between the peak demand before the aggregator implementation (baseline) with the peak demand after the aggregator implementation (per final consumer, per feeder, per network). Peak load is the maximum power required by a building or a group of buildings to provide certain comfort levels. With the correct application of ICT systems like MERLON, the peak load can be reduced on a high extent and therefore the dimension of the supply system. In MERLON, the indicator will be used to analyse the maximum power demand reduction in multiple levels (i.e. asset, building, group of buildings and ILES). The formula to be used for this calculation is: $$TEC\ 16 = \left(1 - \frac{P_{peak,MERLON}}{P_{peak,BAU}}\right) \cdot 100\%$$ Where $P_{peak,MERLON}$ (W) is the peak demand of an asset / building / group of buildings / ILES when the MERLON solution has been applied and $P_{peak,BAU}$ is the peak demand at this specific level prior to MERLON implementation (business as usual).			
Measurement Process	For calculating this KPI, the following inputs are needed (at each level that the KPI is considered): - Peak demand prior to MERLON implementation - Peak demand after MERLON solution deployment and demonstration			
Unit	%			
References	[13]			
Comments				

3.1.17 TEC 17 – Peak to average ratio

Technical				
TEC 17 – Peak to average ratio				
Asset			**RES**	
Building	√		**Group of RES**	
Group of Buildings	√		**ILES**	√

KPI Definition	Peak power consumption divided by average power. In a smart grid network, demand-side management plays a significant role in allowing consumers to manage their energy consumption providing various incentives. This can be done through shifting consumption to off-peak hours and thus reducing the peak-to-average ratio (PAR) of the electricity system.
Input Parameters and Calculation	Among the targets of demand response are peak consumption and energy shifting. The peak consumption should be expressed in a dimensionless form of peak consumption to average consumption power ratio, which enables common comparison of the indicator and its main measured effect – peak reduction. This KPI can be calculated using the following mathematical formula: $$TEC\ 17 = \frac{P_{peak}}{P_{average}}$$ Where • P_{peak} is the peak load (W), which can be calculated as follows: $$P_{peak} = \max_{t \in T} P_t$$ where t is a unit time interval and $t \in T$, where T is the total number of all unit time intervals considered • $P_{average}$ is the average load (W), which can be calculated as follows: $$P_{average} = \frac{1}{T}\sum_{t \in T} P_t$$ where t is a unit time interval and $t \in T$, where T is the total number of all unit time intervals considered
Measurement Process	For calculating this KPI, the following inputs are needed (at each level that the KPI is considered): • Peak load (W) • Average load (W) This KPI can be calculated at different MERLON levels including: • Building Level • Group of Buildings (portfolio of an aggregator) Level • ILES Level
Unit	Dimensionless
References	[14] [15]
Comments	

3.1.18 TEC 18 – Efficiency of a load-shifting DR event

Technical					
TEC18 – Efficiency of a load-shifting DR event					
Asset	√			**RES**	
Building	√			**Group of RES**	
Group of Buildings	√			**ILES**	√
KPI Definition	Many thermal-electrical loads share key characteristics that make them ideally suited to providing load-shifting DR. The flexibility to operate within an acceptable temperature range and the dynamic interaction between electrical input and heat output mean that power consumption can be shifted in time while maintaining acceptable operating conditions. Such thermal loads include heating, cooling, and refrigeration. This KPI represents the efficiency of a load-shifting DR event.				
Input Parameters and Calculation	A DR event consists of a response followed by a recovery. A DR event can commence with either a supply of power to the system or a draw of power from the power system. At the device level, this translates to a DR event commencing with either a shed of load or pre-cooling/pre-heating. The efficiency of a load-shifting DR event can be calculated as the ratio of the energy supplied to the power system (ΔP^{+}) and the energy drawn (ΔP^{-}) from the power system during a DR event. $$TEC\ 18 = \frac{\sum_{t=1}^{T} \Delta P^{+}}{\sum_{t=1}^{T} \Delta P^{-}} \cdot 100\%$$ where t is a unit time interval and $t \in T$, where T is the total number of all unit time intervals of the considered DR event				
Measurement Process	For calculating this KPI, the following inputs are needed (at each level that the KPI is considered): - Energy supplied to the power system (W) - Energy drawn from the power system (W) This KPI can be calculated at different MERLON levels including: - Asset Level - Building Level - Group of Buildings (portfolio of an aggregator) Level - ILES Level				
Unit	%				
References	[16]				
Comments	A higher efficiency (>100%) is most desirable, as this indicates that the amount of energy drawn from the power system is less than the energy supplied to the system. Events in which the power supplied to the power system are small but sustained for a long time, and the power drawn is large but over a short time, exhibit the highest efficiencies. Symmetric events (where response and recovery have the same magnitudes) tend to exhibit an efficiency of just below 100%.				

3.1.19 TEC 19 – Reduction of Energy Cost

Technical				
TEC 19 – Reduction of Energy Cost				
Asset	√		**RES**	
Building	√		**Group of RES**	
Group of Buildings	√		**ILES**	√
KPI Definition	This KPI is intended to assess the economic benefits of a scheduling strategy for prosumers coordinated by an aggregator. The KPI will measure the cost of the energy traded by an aggregator e.g. the effect of shifting the demand to consume from the grid when the electricity price is lower.			
Input Parameters and Calculation	The KPI can be calculated using the following formula: $$TEC\ 19 = \frac{COST_{MERLON} - COST_{BAU}}{COST_{BAU}} \cdot 100\%$$ Where $COST_{MERLON}$ (€) is the cost of power consumed during a period of time when the MERLON solution is used, and, in particular, when a scenario on energy cost reduction is considered. $COST_{BAU}$ (€) is the cost of power consumed during a period of time T when the MERLON solution is not considered.			
Measurement Process	For calculating this KPI, the following inputs are needed (at each level that the KPI is considered): - Electricity prices (€/kWh) at each time interval t - Electric power consumption (kWh) at time t when MERLON is used - Electric power consumption (kWh) at time t when MERLON is not considered This KPI can be calculated at different MERLON levels including: - Asset Level - Building Level - Group of Buildings (portfolio of an aggregator) Level - ILES Level			
Unit	%			
References	[13]			
Comments				

3.1.20 TEC 20 – Technical Compatibility

<table>
<tr><td colspan="5">Technical</td></tr>
<tr><td colspan="5">TEC 20 – Technical Compatibility</td></tr>
<tr><td>Asset</td><td>√</td><td rowspan="3"></td><td>RES</td><td>√</td></tr>
<tr><td>Building</td><td>√</td><td>Group of RES</td><td>√</td></tr>
<tr><td>Group of Buildings</td><td>√</td><td>ILES</td><td>√</td></tr>
<tr><td>KPI Definition</td><td colspan="4">This indicator aims to provide an indication of the technical compatibility of the MERLON solution, meaning the extent to which the solution fits with current practices and existing technological standards/ infrastructures / framework / etc.</td></tr>
<tr><td>Input Parameters and Calculation</td><td colspan="4">The indicator provides a qualitative measure and is rated on a five-point Likert scale as follows:
1. No technical compatibility: the solution needs many and major adjustments to current (infra)structures and/or practices for its implementation
2. Low compatibility: the solution requires some major adjustments to current (infra)structures and/or practices for its implementation.
3. Moderate: some adjustments to current (infra)structures and/or practices are necessary to implement the solution.
4. High: only minor adjustments (think of a different type of plug, a specific internet connection, etc.) are needed to implement the solution.
5. Very high: no adjustments to current (infra)structures and/or practices are needed, the solution can immediately be implemented.</td></tr>
<tr><td>Measurement Process</td><td colspan="4">Qualitative process assessing the compatibility with existing equipment and infrastructure as well as the compliance to well-established standards in the relevant domain.</td></tr>
<tr><td>Unit</td><td colspan="4">N/A</td></tr>
<tr><td>References</td><td colspan="4">[10]</td></tr>
<tr><td>Comments</td><td colspan="4"></td></tr>
</table>

3.1.21 TEC 21 – Improved Interoperability

Technical				
TEC 21 – Improved Interoperability				
Asset	√		***RES***	
Building			***Group of RES***	
Group of Buildings			***ILES***	
KPI Definition	Interoperability is the ability of a system (or product) to work with other systems (or products) by providing services to and accepting services from other systems and to use the services so exchanged to enable them to operate effectively together (ISO/TS 37151). While the term was initially defined for information technology or systems engineering services to allow for information exchange, a broader definition takes into account social, political, and organizational factors that impact system to system performance. Different levels of interoperability can be distinguished. - When two or more systems are able to communicate with each other, this is called **syntactic interoperability**. - **Semantic interoperability** is when the systems are also capable of interpreting the information exchanged in order to produce useful results. - **Cross-domain interoperability** exists when organizations or systems from different domains interact in information exchange, services, and/or goods to achieve their own or common goals. The indicator assesses the improvement in interoperability in a qualitative manner without going into details.			
Input Parameters and Calculation	The indicator provides a **qualitative measure** and is rated on a five-point Likert scale as follows: 1. Not at all: the project does not increase interoperability. 2. Poor: the project does little to increase interoperability. 3. Somewhat: the project somewhat increases interoperability. 4. Good: the project increases interoperability sufficiently. 5. Excellent: the project increases interoperability extensively.			
Measurement Process	Qualitative process assessing MERLON Information Model based on CIM standards/ MERLON interoperability and data management platform based on standards analysed in T4.1/ the portion of existing DER assets in two pilot sites that have been integrated in MERLON ICT platform through DER connectors through the course of the project.			
Unit	N/A			
References	[10]			
Comments				

3.1.22 TEC 22 – Data Quality

Technical				
TEC 22 – Data quality				
Asset			***RES***	
Building			***Group of RES***	
Group of Buildings			***ILES***	

KPI Definition	The most important dimensions whose data quality can be assessed are: • **Correctness**: factual agreement of the data with the properties of the real-world object that it represents. • **Consistency**: agreement of several versions of the data related to the same real objects, which are stored in various information systems. • **Completeness**: complete existence of all values or attributes of a record that are necessary. • **Actuality**: agreement of the data at all times with the current status of the real object and adjustment of the data in a timely manner as soon as the real object has been changed. • **Availability**: the ability of the data user to access the data at the desired point in time. This KPI aims to assess the quality of data (based on the above-mentioned dimensions) exchanged within the MERLON integrated optimisation framework as well as the output data to be delivered to the external world.
Input Parameters and Calculation	This metric can be defined as a percentage of non-conformity and can be applied for any data exchanged among the different MERLON components and / or data that are outputs of the MERLON integrated system to the external world. The metric can be calculated using the following formula: $TEC\ 22 = \frac{Number\ of\ non-conformed\ values\ identified\ within\ a\ sample}{Total\ number\ of\ values\ within\ the\ same\ sample} \cdot 100\%$
Measurement Process	• Select one or more data quality dimensions that will be assessed • Determine the proper location within the information chain to attach the measurement probe • Choose a centre line and control limits for the assessment • Choose the sample • Plot the chart and calculate the centre line and control limits based on history
Unit	%
References	[17]
Comments	The measurement process should be carefully followed. Critical data for system's operation should be assessed in terms of quality

3.1.23 TEC 23 – Islanding

Technical				
TEC 23 – Islanding				
Asset			***RES***	
Building			***Group of RES***	
Group of Buildings			***ILES***	√
KPI Definition	Capability of the energy system to switch to island operation whilst maintaining compliance with power quality requirements. Both frequency and voltage compliance will be quantified during island operation. Both will be measured as a % of the time for which the quantity remains in prescribed limits.			
Input Parameters and Calculation	This KPI will measure the capacity of an islanding to last as long as required. It can be calculated using the following formula: $$TEC\ 23 = \frac{D_{islanding}}{D_{required}} \cdot 100\%$$ Where $D_{islanding}$, is the duration of a single islanding maintaining compliance with power quality requirements $D_{required}$ is the required duration of an islanding, after an intentional or unintentional disconnection from the grid			
Measurement Process	Both frequency and voltage compliance will be quantified during island operation.			
Unit	%			
References	[18]			
Comments				

3.1.24 TEC 24 – Customer Total Average Interruption Duration Index

<table>
<tr><th colspan="5">Technical</th></tr>
<tr><th colspan="5">TEC 24 – Customer Total Average Interruption Duration Index (CTAIDI)</th></tr>
<tr><td>Asset</td><td></td><td rowspan="3"></td><td>RES</td><td></td></tr>
<tr><td>Building</td><td></td><td>Group of RES</td><td></td></tr>
<tr><td>Group of Buildings</td><td></td><td>ILES</td><td>√</td></tr>
<tr><td>KPI Definition</td><td colspan="4">CTAIDI is a reliability indicator associated with electric power distribution. CTAIDI is the average total duration of interruption for customers who had at least one interruption during the period of analysis.

This should be measured relative to the number of outages on the network, since this will give a better indication of how much MERLON is improving reliability. The KPI should compare the CTAIDI before $(CTAIDI_{BaU})$ and after $(CTAIDI_{MERLON})$ MERLON implementation.</td></tr>
<tr><td>Input Parameters and Calculation</td><td colspan="4">The KPI can be calculated using the following formula for a one-year period:

$$TEC\ 24 = \frac{CTAIDI_{BaU} - CTAIDI_{MERLON}}{CTAIDI_{BaU}} \cdot 100\%$$
Where CTAIDI is defined as follows:

$$CTAIDI = \frac{\sum U_i N_i}{N_{io}} \left(\frac{Sum\ of\ durations\ of\ customer\ interruptions}{Number\ of\ distinct\ customers\ interrupted}\right)$$
Where

N_i is the number of customers

U_i is the annual outage time for location *i*

N_{io} is the number of customers at location *i* that were interrupted</td></tr>
<tr><td>Measurement Process</td><td colspan="4"></td></tr>
<tr><td>Unit</td><td colspan="4">%</td></tr>
<tr><td>References</td><td colspan="4">[19] [20]</td></tr>
<tr><td>Comments</td><td colspan="4">CTAIDI is measured in units of time, such as minutes or hours.</td></tr>
</table>

3.1.25 TEC 25 – System Average Interruption Frequency Index

Technical				
TEC 25 – System Average Interruption Frequency Index (SAIFI)				
Asset			**RES**	
Building			**Group of RES**	
Group of Buildings			**ILES**	√

KPI Definition	SAIFI represents the yearly average interruption times for all customers in the system. This is just the total number of customer interruptions that occurred in the year divided by the total number of customers in the system. The KPI should compare the SAIFI before ($SAIFI_{BaU}$) and after ($SAIFI_{MERLON}$) MERLON implementation.
Input Parameters and Calculation	The KPI can be calculated using the following formula for a one-year period $$TEC\ 25 = \frac{SAIFI_{BaU} - SAIFI_{MERLON}}{SAIFI_{BaU}} \cdot 100\%$$ Where SAIFI is a system index of average frequency of interruptions in power supply and can be calculated as follows: $$SAIFI = \frac{\sum \lambda_i N_i}{\sum N_i} \left(\frac{Total\ number\ of\ custmer\ interruptions}{Total\ number\ of\ customers\ served} \right)$$ Where λ_i is the failure rate and N_i is the number of customers for location i
Measurement Process	
Unit	%
References	[19] [20]
Comments	SAIFI is measured in units of interruptions per customer. It is usually measured over the course of a year, and according to IEEE Standard 1366-1998 the median value for North American utilities is approximately 1.10 interruptions per customer.

3.1.26 TEC 26 – Power Quality and Quality of Supply

Technical				
TEC 26 – Power Quality and Quality of Supply				
Asset			***RES***	
Building			***Group of RES***	
Group of Buildings			***ILES***	√
KPI Definition	This KPI represents the average time (T_{fault}) needed for awareness, localization and isolation of grid fault prior to $(T_{fault,BaU})$ and after $(T_{fault,MERLON})$ MERLON implementation.			
Input Parameters and Calculation	The KPI can be calculated as follows: $$TEC\ 26 = \frac{T_{fault,BaU} - T_{fault,MERLON}}{T_{fault,BaU}} \cdot 100\%$$			
Measurement Process				
Unit	%			
References	[13]			
Comments				

3.1.27 TEC 27 – Voltage quality performance

Technical				
TEC 27 – Voltage quality performance				
Asset			**RES**	
Building			**Group of RES**	
Group of Buildings			**ILES**	√

KPI Definition	This KPI is used to evaluate the fulfilment of regulatory voltage limits in the distribution network during interconnected operation. The impact of MERLON on voltage quality performance can be assessed keeping track of short interruptions, voltage dips, flicker, supply voltage variation and harmonic distortions. It is useful to group the different voltage disturbances mentioned above into continuous phenomena and voltage events. • Continuous phenomena are voltage variations that occur continuously over time. Continuous phenomena are mainly due to load pattern, changes of load or nonlinear loads. They occur continuously over time and can often be satisfactorily monitored during measurement over a limited period of time, e.g. 1 week. • Voltage events are sudden and significant deviations from desired wave shape or RMS value. Voltage events are typically due to unpredictable events (e.g. faults) or to external causes. Normally voltage events occur only once in a while. To be able to measure voltage events, continuous monitoring and predefined trigger values are needed.
Input Parameters and Calculation	In order to assess the MERLON impact over voltage quality performance, we calculate the variation in the MERLON and Business-as-Usual (BaU) scenarios of: • Voltage limit violations (over a predefined period of time, e.g. yearly), defined in accordance with the EN 50160 standard. The resulting KPI could be expressed in terms of number of voltage line violations over a predefined period of time as follows: $$TEC\ 27_a = \frac{V_{violations,BaU} - V_{violations,MERLON}}{V_{violations,BaU}} \cdot 100\%$$ • Total harmonic distortion factor (THD). The THD can be measured as defined in EN 50160. The KPI could be expressed as follows: $$TEC\ 27_b = \frac{THD_{BaU} - THD_{MERLON}}{THD_{BaU}} \cdot 100\%$$
Measurement Process	
Unit	%
References	[20]
Comments	Violations are calculated with reference to the following requirements: • Variations in the stationary voltage RMS value are within an interval of +/-10% of the nominal voltage (in steady state) • Number of micro-interruptions, sages and surges, assessing the number of events (MV-LV violations) recorded over a given time period (one year for example). Dips and surges are recorded when the voltage exceeds the threshold of +/-10% of its nominal value (in transient state).

3.1.28 TEC 28 – System Average Interruption Duration Index

Technical				
TEC 28 – System Average Interruption Duration Index (SAIDI)				
Asset	√		***RES***	
Building			***Group of RES***	
Group of Buildings			***ILES***	
KPI Definition	SAIDI represents the average interruption duration for each customer served. The KPI should compare the SAIDI before ($SAIDI_{BaU}$) and after ($SAIDI_{MERLON}$) MERLON implementation.			
Input Parameters and Calculation	The KPI can be calculated using the following formula for a one-year period $TEC\ 28 = \frac{SAIDI_{BaU} - SAIDI_{MERLON}}{SAIDI_{BaU}} \cdot 100\%$ Where SAIDI is the average outage duration for each customer served, and is calculated as follows: $SAIDI = \frac{\sum U_i N_i}{N_T} \left(\frac{Sum\ of\ durations\ of\ customer\ interruptions}{Number\ of\ distinct\ customers\ interrupted}\right)$ Where N_i is the number of customers U_i is the annual outage time for location *i* N_T is the total number of customers served			
Measurement Process				
Unit	%			
References	[21], [20]			
Comments	SAIDI is measured in units of time, often minutes or hours. It is usually measured over the course of a year, and according to IEEE Standard 1366-1998 the median value for North American utilities is approximately 1.50 hours.			

3.1.29 TEC 29 – Average Service Availability Index

Technical				
TEC 29 – Average Service Availability Index (ASAI)				
Asset			***RES***	
Building			***Group of RES***	
Group of Buildings			***ILES***	√

KPI Definition	ASAI is the ratio of electricity supply hours to electricity demand hours. The KPI should compare the ASAI before ($ASAI_{BaU}$) and after ($ASAI_{MERLON}$) MERLON implementation.
Input Parameters and Calculation	The KPI can be calculated using the following formula for a one-year period $$TEC\ 29 = \frac{ASAI_{BaU} - ASAI_{MERLON}}{ASAI_{BaU}} \cdot 100\%$$ Where ASAI is calculated as follows: $$ASAI = \frac{\sum 8760 \cdot N_i - \sum U_i \cdot N_i}{\sum 8760 \cdot N_i} \left(\frac{Sum\ of\ durations\ of\ service\ availability}{Total\ customer\ hours\ demanded}\right)$$ Where N_i is the number of customers U_i is the annual outage time for location *i*
Measurement Process	
Unit	%
References	[22]
Comments	ASAI can be represented in relation to SAIDI (when the annual SAIDI is given in hours): $$ASAI = 1 - \frac{SAIDI}{8760}$$

3.1.30 TEC 30 – Data Safety

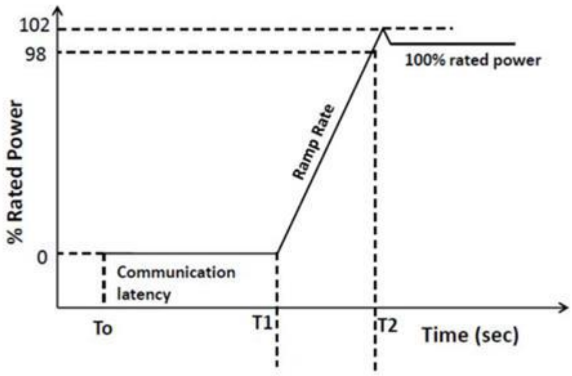
Technical				
TEC 30 – Data Safety				
Asset			***RES***	
Building			***Group of RES***	
Group of Buildings			***ILES***	

KPI Definition	The nature of the web environment is hostile. There are a lot of agents trying to exploit vulnerabilities in any software system. This KPI is intended to give a statement about the safety of data in the MERLON applications.
Input Parameters and Calculation	Number of blocked malicious hacking attempts.
Measurement Process	Detailed usage analytics will be used throughout the MERLON demonstration phase.
Unit	Number of issues found per application in a predefined period of time.
References	[23]
Comments	

3.1.31 TEC 31 – GDPR risk

Technical				
TEC 31 – GDPR risk				
Asset			***RES***	
Building			***Group of RES***	
Group of Buildings			***ILES***	
KPI Definition	This KPI is used to assess the data privacy risk level due to MERLON solution usage. It falls under security and privacy category. The KPI assesses the level of data privacy collected in the MERLON project that meet GDPR requirements (2016/679/EC). Failing to meet the standards of the regulations will increase the risks related to the GDPR, including protection, costs, access, and other data challenges. Reducing the risks through GDPR policies will improve the MERLON performance for data security.			
Input Parameters and Calculation	The indicator provides a **qualitative measure** and is rated on a five-point Likert scale as follows: 1. Very low risk 2. Low risk 3. Medium risk 4. High risk 5. Very high risk			
Measurement Process	Compliance of MERLON with GDPR is assessed throughout the project lifecycle. This is a continuous feedback process that aims to ensure with GDPR and the national and international regulations concerning data privacy and security.			
Unit	N/A			
References	[24]			
Comments				

3.1.32 TEC 32 – Response Time

Technical				
TEC 32 – Response Time				
Asset	√		**RES**	
Building			**Group of RES**	
Group of Buildings			**ILES**	√
KPI Definition	Time that the BESS requires to increase or decrease its rated power during charge or discharge upon a signal trigger. According to US DoE, the response time is specifically defined as follows: The time required by a BESS to attain 100% of rated power during charge or discharge starting from an initial "rest" status [9]. $$T_{response} = T_2 - T_0$$			
Input Parameters and Calculation	T_0 : Timestamp when signal is dispatched to BESS T_2 : Timestamp when BESS ramps up/down to 100 ± 2% of its rated power capacity during charge or discharge			
Measurement Process	Retrieve timestamps from EMS and/or middleware			
Unit	sec			
References	[9]			
Comments	The response time comprises two (2) time intervals: the communication latency & actual ramp up/down. The communication latency depends on the EMS technology and configuration. 			

3.1.33 TEC 33 – Ramp Rate

Technical				
TEC 33 - Ramp Rate				
Asset	√		RES	
Building			Group of RES	
Group of Buildings			ILES	√

KPI Definition	Ramp rate excludes communication latency and actually evaluates the battery technology in terms of response velocity. Through the ramp rate KPI, it can be evaluated if a battery is properly sized for a certain service. $$PP = \frac{P_{rated}}{T_2 - T_0}$$
Input Parameters and Calculation	P_{rated}: Rated BESS power capacity T_1 : Timestamp when the BESS starts the ramping T_2 : Timestamp when BESS ramps up/down to 100 ± 2% of its rated power capacity during charge or discharge
Measurement Process	Retrieve timestamps from EMS and/or middleware, retrieve BESS rated power
Unit	sec
References	[9]
Comments	A BESS is configured and sized properly in order to meet balancing service requirements when the parameters of power, energy and response time are taken into consideration [9].

3.1.34 TEC 34 – Round-Trip Efficiency (RTE)

Technical				
TEC 34 - Round-Trip Efficiency (RTE)				
Asset	√		**RES**	
Building			**Group of RES**	
Group of Buildings			**ILES**	√
KPI Definition	It is a measurement of energy efficiency that covers both charge and discharge modes, namely the overall battery operation. It is actually the ratio of the discharged energy from the battery towards a load/grid to the required energy for the full battery charge. $$\mathrm{n}_{RTE} = \frac{E_{discharge}}{\mathrm{E}_{charge}} = \frac{\int_{T_{initial,d}}^{T_{final,d}} P_{AC,d}\, \partial t}{\int_{T_{initial,c}}^{T_{final,c}} P_{AC,c}\, \partial t}$$			
Input Parameters and Calculation	$P_{AC,d}(t)$: The power discharge timeseries of the BESS AC output $P_{AC,c}(t)$: The power charge timeseries of the BESS AC output The RTE calculation has to be performed during one duty cycle of the battery under normal operating conditions (comprising charge and discharge).			
Measurement Process	Retrieve power timeseries over 1 duty cycle from BESS converter (AC electrical endpoint)			
Unit	%			
References	[9]			
Comments	Given that a BESS installation may include several auxiliary loads directly connected to the battery (e.g. container lighting, UPS, air-conditioning, etc.), their consumption must be subtracted as it is not part of the useful energy and also increases the charging energy required. Thus, another parameter is added to the calculation formula, which is the auxiliary equipment consumption, E_{aux}, that is present in all battery modes of operation (charge, discharge and rest): $$\mathrm{n}_{RTE} = \frac{E_{discharge} - E_{aux,discharge}}{\mathrm{E}_{charge} + E_{aux,charge} + E_{aux,rest}}$$			

3.2 MERLON Social KPIs

In the following table we provide the KPIs falling under the “social” category. Each of these KPIs is further detailed in the following sub-sections.

Table 3: Final list of MERLON Social KPIs

KPI	Name	Definition
SOC 1	System average interruption duration	Average outage duration that any given customer would experience (average restoration time)
SOC 2	Thermal discomfort factor	Assessing the people’s satisfaction with the thermal environment
SOC 3	Visual discomfort factor	Capturing the feeling of visual discomfort from sensing and actuation data
SOC 4	End user satisfaction	The extent to which the solution is perceived that satisfies the end users. It is presumed that a solution that is easy to use and understand will be more likely adopted than a difficult one.
SOC 5	Advantages for end-users	The extent to which the project offers clear advantages for end users. The advantage can take many forms, for instance cost savings, improved quality and increased comfort. It is presumed that solutions which have a higher level of advantages to end users will be more likely to be adopted than solutions which have negative or no advantages.
SOC 6	Local community involvement in the implementation phase	The extent to which potential users have been involved in the implementation process.

3.2.1 SOC 1 - System average interruption duration

Social				
SOC1 - System average interruption duration				
Asset	√		**RES**	
Building	√		**Group of RES**	
Group of Buildings	√		**ILES**	
KPI Definition	Average outage duration that any given customer would experience (average restoration time)			
Input Parameters and Calculation	Each customer experiences an outage or restoration time t_i (hours) of the system throughout a period of time (normally a year). If N denotes the total number of customers and M the total number of interruptions, the average outage or restoration duration that a customer would experience (SOC1) is: $$\text{SOC 1} = \frac{\sum_{i=1}^{N} t_i}{M}$$			
Measurement Process	For calculating this KPI we need measurements/data for the total number of times that each of the N customers experiences outage (hour) during the testing period and its extrapolation over a year. Similarly, measurements/data are needed for the restoration time (hours) for each of the N customers during the testing period and its extrapolation over a year.			
Unit	Hours			
References				
Comments	If measurements/data is available for a long period of time (a year) then no extrapolation is required.			

3.2.2 SOC 2 - Thermal discomfort factor

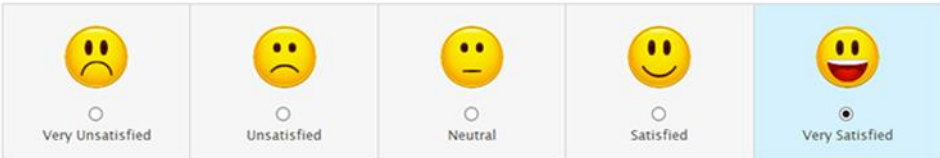
Social				
SOC 2 - Thermal discomfort factor				
Asset	√		**RES**	
Building	√		**Group of RES**	
Group of Buildings	√		**ILES**	
KPI Definition	Assessing the people's satisfaction with the thermal environment			
Input Parameters and Calculation	The most commonly adopted thermal model indicators are the predicted mean vote (PMV) and the predicted percentage dissatisfied (PPD). PPD index predicts the percentage of thermally dissatisfied persons among a large group of people and is derived from the PMV as follows: $$\mathrm{PPD} = 100 - 95\exp\left(-(0.3353\mathrm{PMV}^4 + 0.2179\mathrm{PMV}^2)\right)$$ Typically, a 10% dissatisfaction criterion for thermal comfort is used for the determination of acceptable thermal conditions which corresponds to a PMV in the range -0.5 to +0.5. Also, a Likert Scale can be used: Very uncomfortable 1-2-3-4-5 Very comfortable, following the definition of each level of the scale.			
Measurement Process	Different types of sensors can be installed in order to gather data related to thermal comfort. PMV can be measured from the responses of the end-users who rate the thermal sensation in a range from 3 (hot) to -3 (cold). Simulation results, as well as customer responses, can be used for the evaluation of PPD & PMV parameters, in which case parameters such as air temperature, radiant temperature and relative humidity are measured.			
Unit	%			
References	[25] [26] [27]			
Comments				

3.2.3 SOC 3 - Visual Discomfort Factor

Social				
SOC3 - Visual discomfort factor				
Asset	√		**RES**	
Building	√		**Group of RES**	
Group of Buildings	√		**ILES**	
KPI Definition	Capturing the feeling of visual discomfort from sensing and actuation data			
Input Parameters and Calculation	The main requirement in terms of visual comfort is sufficient illuminance for the specific visual tasks carried out in the area under investigation. Regarding lighting quality illuminance is used as the main indicator, i.e. the luminous flux per unit area. In a typical office the European standard requires a maintained illuminance level of 500 lux on the working plane for activities such as writing, reading and typing. In the surroundings of the desk, up to 0.5 meter around it, the lighting level should be at least 300 lux. In the remaining area of the workspace an illuminance level of 200 lux is recommended. The inputs for this KPI can also be the replies of the customers to appropriate questionnaires with respect to the visual comfort experiences in the framework of the demonstration phase. Such a questionnaire could be: - I think that there is a clear improvement in visual comfort - I experienced noticeable variations of the visual quality (Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree)			
Measurement Process	Different types of sensors will be installed in order to gather data related to visual comfort. And/or questionnaires will be answered by the users after the solution implementation and will be processed to elicit the user response.			
Unit	%			
References	[28] [29] [30]			
Comments	Different sensor installation topologies can further enable the calculation of illuminance level, Contrast Rendering Factor and Luminance ratio.			

3.2.4 SOC 4 - End user satisfaction

Social					
SOC 4 – End user satisfaction					
Asset				**RES**	
Building				**Group of RES**	
Group of Buildings				**ILES**	

KPI Definition	This is a UX KPI that expresses end user satisfaction in a convenient metric. Some solutions or innovations are perceived as relatively difficult to understand and use while others are clear and easy to the adopters. It is presumed that a smart solution that is easy to use and understand will more likely satisfy users and will be easier adopted than a difficult solution. Users should be asked: How satisfied are you with MERLON? The result is a percentage from 0 to 100, where 100 stands for maximum satisfaction. The scale usually includes five rating options, ranging from very unsatisfied to very satisfied. 
Input Parameters and Calculation	To calculate this KPI, only the answers of the satisfied users are counted, i.e. the users who gave 'satisfied' $(EU_{satisfied})$ or 'very satisfied' $(EU_{very\ satisfied})$ as an answer. Then the KPI is calculated as follows: $$SOC\ 4 = \frac{\sum(EU_{satisfied} + EU_{very\ satisfied})}{EU_{total}} \cdot 100\%$$ Where EU_{total} is the total number of users participated in the survey.
Measurement Process	For calculating this KPI a survey should be performed and the answers should be collected and analysed.
Unit	%
References	[31]
Comments	This method of calculation is called the "top-2-box" measure of customer satisfaction because it only takes into account the two highest possible response ratings: "satisfied" and "very satisfied." Studies have shown that the two highest values on customer feedback surveys are the most accurate at predicting customer retention.

3.2.5 SOC 5 - Advantages for end-users

Social				
SOC 5 - Advantages for end-users				
Asset	√		**RES**	
Building	√		**Group of RES**	
Group of Buildings	√		**ILES**	
KPI Definition	The extent to which the project offers clear advantages for end users. The advantage can take many forms, for instance cost savings, improved quality and increased comfort. It is presumed that solutions which have a higher level of advantages to end users will be more likely to be adopted than solutions which have negative or no advantages.			
Input Parameters and Calculation	The inputs for this KPI will be the replies of the customers to questionnaires about the advantages they believe they have with the new solution. The questions will expand in a variety of issues like cost savings, comfort, improved air quality etc, e.g.: • I think that there is clearly an added value offered by the system • I think that there is a clear improvement in cost savings • I think that there is a clear improvement in comfort level • I think that there is a clear improvement in air quality Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree (Equivalently Likert Scale: No advantage 1-2-3-4-5 Very high advantage, following the definition of each level of the scale)			
Measurement Process	The questionnaires/surveys will be answered by the end-users and be processed to elicit the user reception of the advantages offered by the new solution.			
Unit	%			
References	[32] [33] [34]			
Comments				

3.2.6 SOC 6 - Local community involvement in the implementation phase

Social				
SOC 6 - Local community involvement in the implementation phase				
Asset	√		**RES**	
Building	√		**Group of RES**	
Group of Buildings	√		**ILES**	

KPI Definition	The extent to which potential users have been involved in the implementation process.
Input Parameters and Calculation	The user involvement can be implemented in several ways ranging from the installation of metering systems for giving feedback, to the involvement in the management of their energy consumption. The total number of customers N_i of user category i (households, services, industry, transport etc) to the total number of potential users M_i in each of the above categories in the local community: $\text{SOC 6} = \frac{\sum_i N_i}{\sum_i M_i}$
Measurement Process	For calculating this KPI we need the total number of customers with involvement in the implementation process N_i of user category i, as well as the total number of potential users M_i in the local community.
Unit	%
References	
Comments	

3.3 MERLON Economic KPIs

In the following table we provide the KPIs falling under the “economic” category. Each of these KPIs is further detailed in the following sub-sections.

Table 4 Final List of MERLON Economic KPIs

KPI	Name	Definition
EC 1	Total Investments	An investment is defined as an asset or item that is purchased or implement with the aim to generate payments or savings over time. Total investments apply to the energy aspects of the system (e.g. BESS purchase) and exclude investments non-energy related
EC 2	Payback	The payback period is the time it takes to cover investment costs. Payback period is usually considered as an additional criterion to assess the investment, especially to assess the risks. Investments with a short payback period are considered safer than those with a longer payback period.
EC 3	Internal Rate of Return (IRR)	The IRR determines the discount rate for an investment where the sum of the present values of the expected future cash flows and the initial investment outlay equals zero
EC 4	Total Annual Costs	The total annual costs are defined as the sum of capital-related annual costs, operation-related costs and other costs. The total annual costs are related to the considered interval of time (year).
EC 5	Investment Deferral	Assessment of avoidance of demand growth- and system security-related investment e.g. due to the installation of the BESS system in the distribution network
EC 6	Cost Benefit Ratio	This is an indicator that attempts to summarize the overall value for money of a project or proposal
EC 7	Net Present Value (NPV)	NPV is the difference between the present value of cash inflows and the present value of cash outflows over a period of time

3.3.1 EC 1 - Total Investments

Economic				
EC 1 – Total Investments				
Asset			**RES**	
Building			**Group of RES**	
Group of Buildings			**ILES**	√

KPI Definition	An investment is defined as an asset or item that is purchased or implement with the aim to generate payments or savings over time. The investment in a newly constructed system (e.g. BESS in MERLON) is defined as cumulated payments until the initial operation of the system. The investment in the “smartness” of an existing system (e.g. IoT ecosystem in a residential building) is defined as cumulated payments until the initial operation of the system after the purchase and installation of the relevant equipment. Total investments apply to the energy aspects of the system (e.g. BESS purchase, intra-building IoT equipment) and exclude investments non-energy related.
Input Parameters and Calculation	This KPI will be very useful for the cost-benefit-analysis that will be performed later in the project. It should consider all the investment costs relevant to MERLON that otherwise would have not been considered including: • all BESS related costs until its initial operation in each of the two MERLON pilot sites ($COST_{BESS}$) • intra-building smart equipment required for the establishment of an IoT ecosystem ($COST_{IoT}$) e.g. sensors, actuators, gateway, etc. • other investment costs that may be required for the initial operation of the MERLON integrated system ($COST_{other}$) Thus, the KPI can be calculated as follows: $EC\ 1 = COST_{BESS} + COST_{IoT} + COST_{other}$
Measurement Process	For calculating this KPI we need to quantify: • the BESS related costs ($COST_{BESS}$) in € • the IoT related costs ($COST_{IoT}$) in € • any other investment costs ($COST_{other}$) in €
Unit	€
References	
Comments	

3.3.2 EC 2 - Payback

Economic				
EC 2 – Payback				
Asset			**RES**	
Building			**Group of RES**	
Group of Buildings			**ILES**	√

KPI Definition	The payback period is the time it takes to cover investment costs. Payback period is usually considered as an additional criterion to assess the investment, especially to assess the risks. Investments with a short payback period are considered safer than those with a longer payback period.
Input Parameters and Calculation	The payback period refers to the amount of time it takes to recover the cost of an investment, which is calculated as follows: $$EC\ 2 = \frac{EC\ 1}{\left(\frac{TB}{Lifetime}\right)}$$ Where EC 1 is the purchased and installation cost (i.e. the total investments defined before), TB is total benefit and $Lifetime$ is the total time to be considered in the analysis.
Measurement Process	For calculating this KPI we need to: • Quantify the EC 1 in € • Specify the $Lifetime$ to be considered in years • Quantify the total benefit in €
Unit	Time Period (e.g. years)
References	[35]
Comments	This KPI is crucial in the Cost-Benefit-Analysis that will be performed later on in the project.

3.3.3 EC 3 - Internal Rate of Return (IRR)

Economic				
EC 3 – Internal Rate of Return (IRR)				
Asset			**RES**	
Building			**Group of RES**	
Group of Buildings			**ILES**	√
KPI Definition	The IRR determines the discount rate for an investment where the sum of the present values of the expected future cash flows and the initial investment outlay equals zero. It basically means that the IRR is the discount rate that equates an investment project's Net Present Value (see the EC 7 in Section 3.3.7) to zero.			
Input Parameters and Calculation	The IRR determines the discount rate for an investment where the sum of the present values of the expected future cash flows and the initial investment outlay equals zero. It basically means that the IRR is the discount rate that equates an investment project's NPV to zero. The equation used for the estimation of this KPI (IRR) is: $$\sum_{t=1}^{Lifetime} \frac{NC_t}{(1 + \mathrm{EC\ 3})^t} = \mathrm{EC\ 1}$$ Where NC_t is the net cash inflow the period t, EC 3 (IRR) is the internal rate of return, EC 1 is the total initial investment costs (defined above), t is the time of the cash flow, $Lifetime$ is the total time considered for the analysis.			
Measurement Process	For calculating this KPI we need to: • Quantify the EC 1 in € • Specify the $Lifetime$ to be considered in years • Quantify the net cash inflow for each time period t in €			
Unit	%			
References	[36]			
Comments	In general, the higher a project's internal rate of return, the more desirable it is to undertake.			

3.3.4 EC 4 - Total Annual Costs

Economic				
EC 4 – Total Annual Costs				
Asset			**RES**	
Building			**Group of RES**	
Group of Buildings			**ILES**	√

KPI Definition	The total annual costs are defined as the sum of capital-related annual costs and operation-related costs. The total annual costs are related to the considered interval of time (one year).
Input Parameters and Calculation	The input parameters are divided into 2 categories: • capital costs incurred for the investment in RES (C^{RES}), energy storage (C^{ES}), demand response (C^{DR}) as well as the enabling ICT equipment, including metering, communication and control equipment in the ILES (C^{ICT}) • b) operating costs associated with supply interruptions for local consumers (O^{INT}), curtailment of local RES (O^{CUR}) and the operation and maintenance costs of all RES, energy storage, demand response and enabling equipment (O^{OM}) Calculation at ILES level $EC\ 4 = (C^{RES} + C^{ES} + C^{DR} + C^{ICT}) + (O^{INT} + O^{CUR} + O^{OM})$
Measurement Process	For calculating this KPI we need: • Measurement of capital costs for all involved assets (€) • Measurement of energy not supplied (kWh) • Measurement of curtailed RES output (kWh) • Measurement of operation / maintenance costs of all involved assets (€)
Unit	€
References	
Comments	All cost components should be expressed in discounted present values

3.3.5 EC 5 - Investment Deferral

Economic				
EC5 – Investment Deferral				
Asset			**RES**	
Building			**Group of RES**	
Group of Buildings			**ILES**	√

KPI Definition	Assessment of deferral or avoidance of investment (reinforcement) in distribution network assets (associated with demand growth and / or RES growth) due to the installation of RES, energy storage and demand response in the ILES. This lies in the ability of ILES flexibility to manage network flows and reduce network losses (by reducing net demand peaks) as well as provide voltage support (through both active and reactive power control).
Input Parameters and Calculation	For practical reasons, the calculation will be performed for a set of key distribution network assets which will be indicated by the local DSO e.g. assets that currently operate or are expected to operate very close to the nominal technical (thermal or voltage) limits in the near future. The input parameters include the expected year of reinforcing the asset in the benchmark case without operation of the ILES (Y^{BEN}) and the expected year of reinforcing the asset in the examined case with operation of the ILES (Y^{ILES}). Calculation at network level (by definition) $$EC\,5 = Y^{ILES} - Y^{BEN}$$
Measurement Process	For calculating this KPI we need: - Measurement of power flows on the set of key assets (MW) - Measurement of voltages on a set of key network nodes (V)
Unit	Years
References	
Comments	Suitable optimal power flow (OPF) models are required for obtaining the measurements outlined above.

3.3.6 EC 6 - Cost Benefit Ratio

Economic					
EC 6 – Cost Benefit Ratio					
Asset				**RES**	
Building				**Group of RES**	
Group of Buildings				**ILES**	√
KPI Definition	This is an indicator that attempts to summarize the overall value for money of a project or proposal (in our case the whole ILES)				
Input Parameters and Calculation	The input parameters are divided into 2 categories: • the total annual costs of the ILES (which are quantified by the previously defined KPI $\mathrm{EC\ 4}$) • b) the total annual economic benefits of the ILES, which generally include benefits associated with savings in energy costs ($\mathrm{B^{EN}}$), revenues from the provision of services to the TSO ($\mathrm{B^{TSO}}$) and revenues from the provision of services to the DSO ($\mathrm{B^{DSO}}$) Calculation at ILES level: $$\mathrm{EC\ 6} = \frac{\mathrm{B^{EN}} + \mathrm{B^{TSO}} + \mathrm{B^{DSO}}}{\mathrm{EC\ 4}}$$				
Measurement Process	For calculating this KPI we need: • The same measurements required for calculating the previously defined KPI $\mathrm{EC\ 4}$ • Measurements of the savings in energy costs and revenues from the provision of services to the TSO and the DSO (Euros)				
Unit	No physical unit (ratio can be expressed in %)				
References					
Comments	Both costs and benefits should be expressed in discounted present values.				

3.3.7 EC 7 - Net Present Value

Economic				
EC 7 – Net Present Value				
Asset			**RES**	
Building			**Group of RES**	
Group of Buildings			**ILES**	√
KPI Definition	Net Present Value (NPV) is the difference between the present value of cash inflows and the present value of cash outflows over a period of time for a project or proposal (in our case the whole ILES)			
Input Parameters and Calculation	The input parameters are divided into 2 categories: • the total annual costs of the ILES (which are quantified by the previously defined KPI EC 4) for each year of the ILES lifetime • the total annual economic benefits of the ILES (which are quantified as part of the calculation of the previously defined KPI EC 6) for each year of the ILES lifetime Calculation at ILES level $\mathrm{EC}\ 7 = (\mathrm{B}^{\mathrm{EN}} + \mathrm{B}^{\mathrm{TSO}} + \mathrm{B}^{\mathrm{DSO}}) - \mathrm{EC}\ 4$			
Measurement Process	For calculating this KPI we need: • The same measurements required for calculating the previously defined KPI EC 6			
Unit	Euros			
References				
Comments	Both costs and benefits should be expressed in discounted present values.			

3.4 MERLON Environmental KPIs

In the following table we provide the KPIs falling under the “environmental” category. Each of these KPIs is further detailed in the following sub-sections.

Table 5 Final List of MERLON Environmental KPIs

KPI	Name	Definition
ENV 1	Carbon dioxide Emission Reduction	CO_2 accounts for a major share of Green House Gas emissions in urban areas. The main sources for CO_2 emissions are combustion processes related to energy generation and transport. CO_2 emissions can therefore be considered a useful indicator to assess the contribution of urban development on climate change.
ENV 2	Reduced VRES Energy Curtailment	The difference between the VRES energy curtailment before and after the integration of MERLON solution
ENV 3	Reduced NOx Emissions	This KPI will assess the difference between the NOx emissions before and after the integration of MERLON solution based on electricity consumption.

3.4.1 ENV 1 - Carbon dioxide Emission Reduction

Environmental				
ENV 1 - Carbon dioxide Emission				
Asset	√		**RES**	
Building	√		**Group of RES**	
Group of Buildings	√		**ILES**	√

KPI Definition	Greenhouse gases (GHGs) are gases in the atmosphere that absorb infrared radiation that would otherwise escape to space; thereby contributing to rising surface temperatures. There are six major GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF6) (ISI/DIS 37120, 2013). The warming potential for these gases varies from several years to decades to centuries. CO_2 accounts for a major share of Green House Gas emissions in urban areas. The main sources for CO_2 emissions are combustion processes related to energy generation and transport. CO_2 emissions can therefore be considered a useful indicator to assess the contribution of ILES on climate change.
Input Parameters and Calculation	The difference between the CO_2 emissions before ($E_{co2,BaU}$) and after ($E_{co2,MERLON}$) the integration of MERLON solution is quantified as follows: $$ENV\ 1 = \frac{E_{co2,BaU} - E_{co2,MERLON}}{E_{co2,BaU}} \cdot 100\%$$ The national average carbon dioxide output rate for electricity generated in 2017 was 998.4 lbs CO_2 per megawatt-hour (EPA 2018), which translates to about 1,074.7 lbs CO_2 per megawatt-hour for delivered electricity, assuming transmission and distribution losses of 7.1% (EIA 2018b; EPA 2018) [6] **Asset level calculation** $$E_{co2} = \frac{asset\ consumption\ (kWh) * 998\ (lbs/kWh) * 0.453592(kg/lbs)}{(1-0.071) * 1000}$$ **Building level calculation** $$E_{co2} = \frac{building\ consumption\ (kWh) * 998\ (lbs/kWh) * 0.453592(kg/lbs)}{(1-0.071) * 1000}$$ **Group of buildings** $$E_{co2} = \frac{\sum buildings\ consumption\ (kWh) * 998\ (lbs/kWh) * 0.453592(kg/lbs)}{(1-0.071) * 1000}$$
Measurement Process	For calculating this KPI we need: - Measurement of individual asset consumption (kWh) - Measurement of individual building consumption (kWh)
Unit	%
References	[5][6]
Comments	Perhaps Carbon dioxide Emission reduction can also be calculated by measuring this prior to MERLON intervention and afterwards

3.4.2 ENV 2 – Reduced VRES Energy Curtailment

Environmental				
ENV 2 - Reduced VRES Energy Curtailment				
Asset			***RES***	
Building			***Group of RES***	
Group of Buildings			***ILES***	√

KPI Definition	The difference between the VRES energy curtailments before ($P_{curtailed,BaU}$) and after ($P_{curtailed,MERLON}$) the integration of MERLON solution.
Input Parameters and Calculation	The KPI can be calculated using the following formula for a defined period $$ENV\ 2 = \frac{P_{curtailed,BaU} - P_{curtailed,MERLON}}{P_{curtailed,BaU}} \cdot 100\%$$
Measurement Process	
Unit	%
References	[37]
Comments	

3.4.3 ENV 3 – Reduced NOx Emissions

Environmental				
ENV 2 - Reduced VRES Energy Curtailment				
Asset			***RES***	
Building			***Group of RES***	
Group of Buildings			***ILES***	√

KPI Definition	In atmospheric chemistry, NOx is a generic term for the nitrogen oxides that are most relevant for air pollution, namely nitric oxide (NO) and nitrogen dioxide (NO2). These gases contribute to the formation of smog and acid rain, as well as affecting tropospheric ozone. The total daily NOx emissions from all electric generating units is highly dependent on electric demand and the resultant combination of which units operate, the fuel utilization at these units, and the emission control performance on the given day. Thus, this KPI will assess the difference between the NOx emissions before ($E_{NOx,BaU}$) and after ($E_{NOx,MERLON}$) the integration of MERLON solution based on electricity consumption.
Input Parameters and Calculation	The difference between the NOx emissions before ($E_{NOx,BaU}$) and after ($E_{NOx,MERLON}$) the integration of MERLON solution is quantified as follows: $ENV\ 1 = \frac{E_{NOX,BaU} - E_{NOx,MERLON}}{E_{NOX,BaU}} \cdot 100\%$ Where based on JRC and ENEL elaborations, 2018 the correlation of NOx with the electricity consumption is: $E_{NOX} = P\ (Mwh) \cdot 0.00124\ ({}^{tonne}/_{MWh})$
Measurement Process	The KPI will be quantified at ILES level
Unit	%
References	[38] [39]
Comments	

4 MERLON METHODOLOGY FOR COLLECTION OF EVALUATION DATA

MERLON framework attempts a holistic optimisation on an Integrated Local Energy System level and thus requires a multi-level validation approach as indicated by the demonstration scenario and the KPIs detailed herein. An important requirement for the validation activities to be conducted properly and the KPIs to be calculated accurately is the consistent and unbiased data collection from the pilot sites where MERLON solution is applied.

The exact data to be collected derive from the input requirements of the KPI calculation formulas and the assessment framework itself. In general, there are two types of evaluation data: the **quantitative** and the **qualitative**. The first type of data that represent the „measures of values or counts that are expressed as numbers “. On the other hand, the quantitative are data about strictly numeric variables, responding to questions such as „how many; how much; or how often“ [40].

The quantitative data required for the calculation of technical and economic KPIs can be automatically retrieved in majority from the energy management systems of ILES assets and from the smart meters installed in the electrical substations. Beyond the data that will be retrieved through “MERLON interoperability and Data Management Platform” for validation purposes, surveys and tests are common ways of obtaining numerical data.

The qualitative data are related to narrative information and therefore they are often subject to context-dependent interpretation. This type of evaluation data will be collected within MERLON living labs in the demo sites. The structure of living labs has been designed to include workshops, focus group discussions, interviews as instruments of data collection for impact assessment. MERLON Living Labs are established on demo site level within the pilot ILES and construct a concrete communication channel with the local community in order to capture and evaluate all aspects of MERLON solution impact. As defined in MERLON deliverable D9.1 [41] and shown in **Figure 25**, the living lab activities are segmented in three (3) stages according to the project evolution. The first stage is focused on requirements extraction, the second on familiarisation of the local community with MERLON solution and the third entirely on project evaluation.

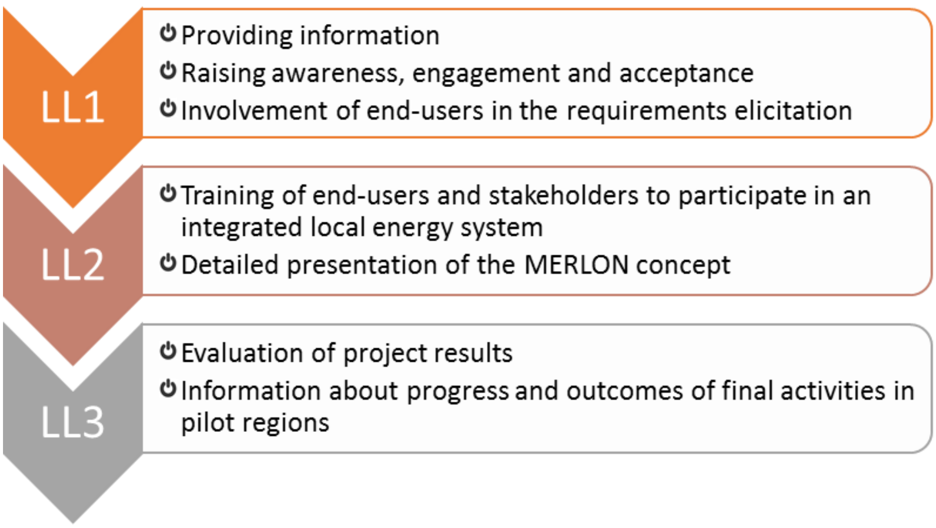


Figure 25 MERLON Living Lab phases

More specifically for the Austrian pilot site, the specified instruments for evaluation data collection are listed below:

- **Questionnaires (Offline)**

Considered the best suited tool for data collection in the 10 DR-households with respect to necessary information coming directly from the end-users.

- **Questionnaires (Online)**

Considered as a good tool for data collection from MERLON stakeholders that are involved in site inspections and/or visits with check-lists and data collection forms.

- **Interviews**

Considered complementary instrument to offline questionnaires which can be necessary in order to evaluate aspects related to user experience in the DR-households.

- **Compilation of available digital data**

The digital data (from the demonstrations, from the households, from DER, etc.) in the pilot site needs to be compiled prior use for MERLON research purposes. In the case of the households the data also needs to be anonymised.

- **Measurements**

Technical data collected via measurements (automatically in most cases).

- **Feedback sessions of Living Lab Workshops**

After the execution of each Living Lab workshop, a feedback session takes place in order to gather evaluation data from participants and finalise workshop conclusions. From the first MERLON Living Lab workshop conducted in Austrian pilot site, it was proved that the feedback sessions provided valuable information coming directly from the focus group of the DR-households.

- **Focus group discussions**

Focus group discussions within or outside living lab workshops (e.g. project partner discussions with stakeholders, technology providers, end users, etc.) contributes to information gathering for impact evaluation. From the first MERLON Living Lab workshop conducted in Austrian pilot site, it was proved that structured discussions based on open questions that tackle specific points are useful for gathering meaningful qualitative information.

5 MERLON CBA METHODOLOGY

In this Section, we describe the Cost-Benefit-Analysis (CBA) methodological framework that will be used for conducting the actual MERLON CBA in the context of the T8.6 “Socio-economic, environmental and technological impact assessment“.

In MERLON, a micro-level analysis will be followed, where several main steps are needed in order for assessing at the end whether the examined business scenarios are economically attractive for all actors. In MERLON framework, the concerned actors (as these have been defined so far) are local DSOs, local energy communities, aggregators and prosumers. The main steps to perform a CBA are to:

- identify the relationships among involved parties
- define the principles for the CBA analysis.

Every single entity involved in a business scenario must be able to make a profit. This should be clear for anyone building a new business idea, since no stakeholder is interested in a new product or service, if its benefit is not evident.

Any business scenario/case can be represented by a value model. A value model represents several players exchanging objects of economic value among them, that all of them benefit. As already mentioned, there are different concerned stakeholders in MERLON. The benefits can be different for each one of them. Especially, for prosumers and energy communities, the benefits can be of various types and not necessarily expressed in monetary terms (e.g. increase comfort, contribute to a more “eco-friendly” use of electricity, etc)

The specific value chains for all the business scenarios to be examined in MERLON project will be defined in the frame of T10.1 “New business models for ILES and flexibility markets“ and will be detailed in the respective deliverable D10.1 “Definition of MERLON Business Models for ILES and flexibility markets - First Version“.

The MERLON CBA will be performed for all major actor following the guidelines for conducting CBA of smart grids projects proposed by JRC [42]. Based on this methodology, MERLON CBA has as a general target an economic-oriented CBA, which goes beyond the costs and benefits incurred by the actor(s) carrying out MERLON. The CBA aims to take a societal perspective as well, considering the project’s impact on the entire value chain and on society at large.

Furthermore, the adopted methodology goes beyond what can be captured in monetary terms. Therefore, MERLON CBA aims to integrate an economic analysis with a qualitative impact analysis, as proposed by JRC.

5.1 Economic analysis

The goal of the economic analysis is to extract the range of parameter values enabling a positive outcome of the CBA and define actions to keep these variables in that range. Possible output indicators representing the CBA outcome have already been described before in the KPI description and include:

- EC 7: Net Present Value (NPV)
- EC 3: Internal Return of investment (IRR)
- EC 6: Cost / Benefit Ratio

The methodology adopted comprises three main parts (see Figure 26):

- ***Part 1: definition of boundary conditions and of implementation choices including (non-exhaustive list):***
    - Discount rate taking into account the time value of money and the risk or uncertainty of anticipated future cash flows
    - Time horizon of the CBA - over how many years the benefits and costs will be analysed along with relevant justification
    - Impact of the European and national regulatory framework in the pilot sites
    - Macroeconomic factors like inflation rate or carbon costs
    - Technology Maturity needs to be taken into account as well, in order to make estimates as accurate as possible.

- ***Part 2: identification of costs and benefits following seven (7) defined steps:***
    - Step 1: Review and describe technologies, elements and goals of the project including scale of the project, technologies to be adopted, local characteristics of the grid of the pilot sites, relevant stakeholders, regulatory relevant context, etc.
    - Step 2: Map assets onto functionalities. The assets of the project should be clearly defined and mapped to functionalities. A non-exhaustive list of functionalities as proposed in JRC methodology include:
        - Facilitate connections at all voltage/locations for any kind of device
        - Facilitate the use of the grid for the users at all voltages/locations
        - Update network performance data on continuity of supply and voltage quality
        - Automated fault identification/grid reconfiguration, reducing outage times
        - Identification of technical and non-technical losses by power flow analysis
        - Frequent information exchange on actual active/reactive generation/consumption
        - Intermittent sources of generation to contribute to system security
        - Improve energy usage information
    - Step 3: Map the identified functionalities of the previous step onto benefits. These benefits are divided into ten sub-categories, namely: economic, reliability, environmental and security. A non-exhaustive list of such benefits as proposed in JRC methodology include:
        - Optimised Generator Operation
        - Deferred Generation Capacity Investments
        - Reduced CO2 Emissions
        - Deferred Distribution Capacity Investments
        - Reduced Electricity Losses
        - Reduced Momentary Outages
        - Reduced Electricity Cost
    - Step 4: Establish the baseline by defining the ‘control state’ that reflects the system condition which would have occurred, if the project would not have taken place.
    - Step 5: Monetise benefits and identify beneficiaries. Once the baseline and project scenarios have been defined, we need to identify, collect

and report the data required for the quantification and monetisation of the benefits. We also need to allocate benefits to different beneficiaries e.g. consumers, DSOs, retailers/aggregators and society at large.
  - Step 6: Quantify costs incurred in implementing the project, relative to the baseline.
  - Step 7: Compare costs and benefits using economic indicators like NPV, IRR, cost to benefit ratio, etc.

- ***Part 3: sensitivity analysis of the CBA outcome to variations in key variables / parameters***

  The goal of the sensitivity analysis is to find the range of variables leading to a positive outcome of a CBA. This requires identifying the switching value of critical variables, i.e. the value that would have to occur in order for the NPV of the project to become zero, or more generally, for the outcome of the project to fall below the minimum level of acceptability.

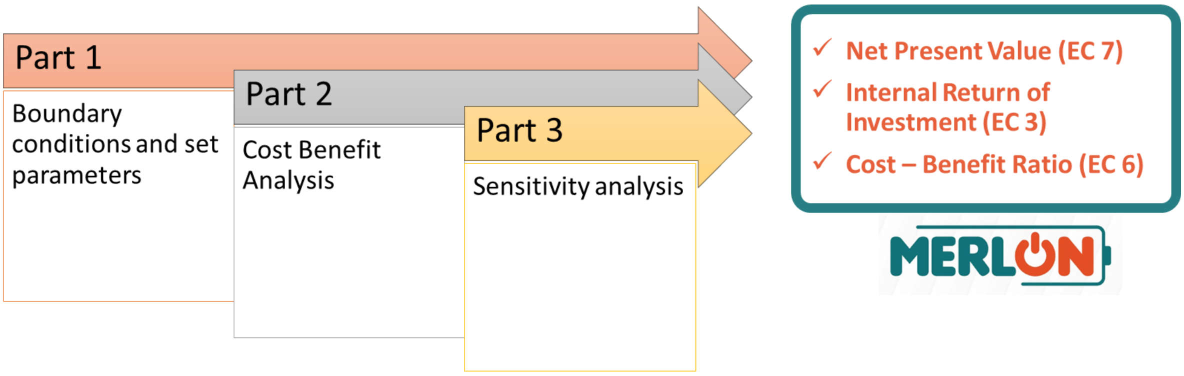


Figure 26: MERLON CBA methodology parts (economic analysis)

5.2 Qualitative impact analysis

The MERLON analysis will also consider externalities that are not quantifiable in monetary terms. This includes, for example, the costs and benefits derived from broader social impacts like security of supply, consumer awareness and participation, etc.

To this end, it is necessary to identify project impacts and externalities and assess them in physical terms or through a qualitative description, in order to give the whole range of elements for the non-monetary.

For example, social impacts represent a significant portion of the possible externalities of the project and include (non-exhaustive list):

- Jobs creation
- Environmental impact
- Increased privacy and security
- Enabling new services and applications and market entry for third parties

5.3 Combining economic with qualitative impact analysis

Once the outcomes of the economic analysis and of the qualitative impact analysis have been assessed, it is necessary to specify weights to combine the different impacts of the qualitative impact analysis. These weights should reflect the relative importance of the different criteria.

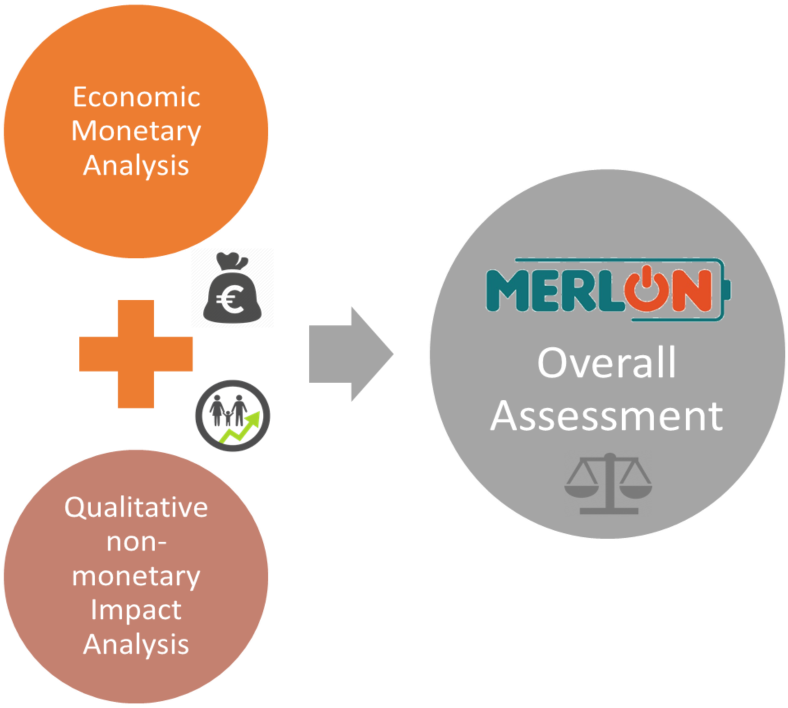


Figure 27: MERLON Overall Assessment

6 CONCLUSION

The current document is the first outcome of the T8.3 “Detailed pilot evaluation, impact assessment and cost-benefit analysis framework”. It is the first version of the “MERLON Evaluation Framework and Respective Validation Scenarios” while a second and final version will be delivered later during the project implementation (M24) and will include updates based on findings identified during the deployment phase in the pilot sites.

The document defines the MERLON global evaluation framework and the respective validation activities. It presents the basic demonstration scenario linked with MERLON use cases and components of the architecture describing a step-by-step process that should be followed for the MERLON solution to be validated in the pilot sites.

The whole validation framework has been based on the MERLON PMV methodology and details the final list of MERLON (Technical, Economic, Environmental, Social) to enable the holistic assessment of the project impact. All KPIs have been detailed using the template introduced in the D3.3, which includes all the information required in order for the KPIs to be quantified and assessed.

Furthermore, the deliverable describes the means that will be used for the collection of evaluation data. Finally, it introduces the MERLON Cost-Benefit-Analysis methodology and its principles that should be followed for the MERLON overall impact assessment.

7 CITATIONS

[1] ICL, "D3.1 Elicitation of user & business and grid-relevant requirements for local flexibility markets, ancillary services and islanding requirements," MERLON Consortium - H2020, 2019.

[2] XTN, "D3.3 Measurement & verification methodology and key performance indicators," MERLON Consortium - H2020, 2019.

[3] Navigant Consulting, "Energy Storage Trends and Opportunities in Emerging Markets," 2017 .

[4] Association of Edison Illuminating Companies, "Demand Response Measurement Verification," March, 2009.

[5] MERLON, "Description of Action," No. 824386, 2019.

[6] Universal Smart Energy Framework, "Flexibility Value Chain - update 2018," USEF, 2018.

[7] Universal Smart Energy Framework, "Value creation for energy communities".

[8] Universal Smart Energy Framework, "Energy and Flexibility Services for Citizens Energy Communities," USEF, Feb-2019.

[9] "Protocol for Uniformly Measuring and Expressing the Performance of Energy Storage Systems," Pacific Northwest National Laboratory and US DoE, Washington DC, 2016.

[10] "IRIS - Integrated and Replicable Solutions for Co-Creation in Sustainable Cities, Deliverbale 1.1 - Report on the list of selected KPIs for each Transition Track," 2018.

[11] F. M. Gatta, A. Geri, S. Lauria, M. Maccioni, and F. Palone, "Battery energy storage efficiency calculation including auxiliary losses: Technology comparison and operating strategies," *IEEE Eindhoven PowerTech 2015,* 2015.

[12] H2020 FLEXCoop Project, "D7.2 – FLEXCoop Evaluation Framework and Respective Validation Scenarios," 2019.

[13] "SMART CITIES INFORMATION SYSTEM KEY PERFORMANCE INDICATOR GUIDE VERSION: 2.0," 2017.

[14] S3C, "Guideline: KPIs for Energy Consumption Effects," p. 1–9.

[15] Y. Liu, C. Yuen, S. Huang, N. Ul Hassan, X. Wang, and S. Xie, "Peak-to-average ratio constrained demand-side management with consumer's preference in residential smart grid," *IEEE J. Sel. Top. Signal Process,* vol. 8, no. 6, p. 1084–1097, 2014..

[16] N. O. Connell, E. Hale, I. Doebber, and J. Jorgenson, "On the Inclusion of Energy- Shifting Demand Response in Production Cost Models: Methodology and a Case Study," *NREL Natl. Renew. Energy Lab. Off. Energy Effic. Renew. Energy,* p. 1–42, 2015.

[17] D. Loshin, “Metrics and Performance Improvement, in The Practitioner’s Guide to Data Quality Improvement,” Elsevier, 2011.

[18] H2020 InterFLEX Project, “D2.2 Minimal set of use case KPIs and measurement methods to perform the technical and economic analysis of the resulting definitions,” 2017.

[19] H. L. Willis, Power Distribution Planning Reference Book, Second Edition. CRC Press, 2004.

[20] JRC, “Definition of an Assessment framework for Projects of Common Interest in the fields of Smart Grids,” 2014.

[21] “SAIDI - Wikipedia,” [Online]. Available: https://en.wikipedia.org/wiki/SAIDI. [Accessed 02 01 2020].

[22] “Average Service Availability Index - Wikipedia,” [Online]. Available: https://en.wikipedia.org/wiki/Average_Service_Availability_Index. [Accessed 02 01 2020].

[23] IRIS Project, “Deliverable 1.1 Report on the list of selected KPIs for each Transition Track,” 2018.

[24] HORIZON 2020 - FLEXCoop, , “D2.5 – FLEXCoop PMV Methodology Specifications – Preliminary Version,” 2018.

[25] “ANSI/ASHRAE Addendum d to ANSI/ASHRAE Standard 55-2013,” 2015.

[26] ISO - ISO 7730:2005, “Ergonomics of the thermal environment — Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria,” ” [Online]. Available: https://www.iso.org/st.

[27] ISO - ISO 7726:1998, “Ergonomics of the thermal environment — Instruments for measuring physical quantities,” https://www.iso.org/standard/14562.html, 21-Oct-2019.

[28] Efficiency Valuation Organization, “IPMVP - Concepts and Options for Determining Energy and Water Savings vol. 1,” 2012 . [Online]. Available: www.evo-world.org.

[29] BS EN 12464-1:2003 , “Light and lighting — Lighting of work places —,” 2003.

[30] MOEEBIUS, “D2.3 MOEEBIUS Energy Performance Assessment Methodology,” HORIZON 2020 , 2016.

[31] “Customer Satisfaction Score (CSAT): The Happy Customer KPI,” [Online]. Available: https://blog.emolytics.com/customer-experience/customer-satisfaction-score-csat-kpi/. [Accessed 02 01 2020].

[32] H. C. Kim, “Acceptability engineering: The study of user acceptance of innovative technologies,” *J. Appl. Res. Technol.,* vol. 13, no. 2, p. 230–237, 2015.

[33] ISO - ISO 9241-210:2010, “Ergonomics of human-system interaction — Part 210: Human-centred design for interactive systems,” 2010. [Online]. Available: https://www.iso.org/standard/52075.html. [Accessed 21 10 2019].

[34] F. D. Davis, “Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology,” *MIS Q. ,* vol. 13, no. 3, p. 319–340, 1989.

[35] F. Eldali, T. Hardy, C. Corbin, D. Pinney, and M. Javid, “Cost-benefit analysis of Demand Response programs incorporated in Open Modeling Framework,” *IEEE Power and Energy Society General Meeting (PESGM),* 2016.

[36] “Internal rate of return - Wikipedia,” [Online]. Available: https://en.wikipedia.org/wiki/Internal_rate_of_return. [Accessed 03 01 2020].

[37] D. Pramangioulis, K. Atsonios, N. Nikolopoulos, D. Rakopoulos, P. Grammelis, and E. Kakaras,, “A methodology for determination and definition of key performance indicators for smart grids development in island energy systems,” *Energies,* vol. 12, no. 2.

[38] G. Flego, S. Fulli, Marretta L, and Stromsather J, “Cost-benefit analysis of Smart Grid projects: Isernia Costs and benefits of Smart Grid pilot installations and scalability options,” 2018.

[39] D. L. Mackintosh, “Evaluating Northeast Electric Generating Unit NOx Emissions Based on Electric Demand”.

[40] Australian Bureau of Statistics, “Statistical Language - Quantitative and Qualitative Data,” [Online]. Available: https://www.abs.gov.au/websitedbs. [Accessed 10 12 2019].

[41] MERLON Consortium, “D9.1 MERLON Living Lab Activities Planning and Evaluation Report – First Version,” 2019.

[42] “Reference Report by the Joint Research Centre of the European Commission, "Guidelines for conducting a cost-benefit analysis of smart grid projects",” 2012.