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Guidelines for implementing Scalability and Replicability Assessment (SRA) methodology

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Guidelines for implementing the prescribed technology

Additional subroutines and requirements

Scientific background and state of the art

Scalability & Replicability Task Force

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1. Introduction

1.1 Background of the Task Force

In its present state (version 3), this report presents the Scalability and Replicability Assessment (SRA) highlighting the scientific background of the methodology and illustrate in the most attractive and comprehensive way the SRA application in ongoing and ending/ended BRIDGE projects. By illustrating the methodological guidelines, the Scalability and Replicability Task Force needs to make sure that the information is useful and usable by any R&I project.

To do so, it has been agreed during the BRIDGE General Assembly (February 2020), that this Task Force will work on the definition/specification of a common repository with useful information for helping projects in implementing the guidelines. As a basis, the repository could help to collect:

- Use cases / scenarios from existing projects with relevant KPI details;
- Tools from existing projects;
- Best practices and lessons learned from previous SRAs;

The common repository along with the SRA per se have been agreed to be included in the EIRIE platform of the commission. (https://ses.jrc.ec.europa.eu/eirie/en)

1.2 Collection of information about projects

To collect this information and to draft the specification of the SRA common repository, a questionnaire has been circulated from 28 May 2020 to 10 July 2020.

12 out of 27 projects replied to this survey and among them 3 mentioned that they were not mature enough to provide their KERs and KPIs. The analysis of the answers received led to the following conclusions:

- There is a confusion between the qualitative and the quantitative approach to evaluate project results. More quantitative responses were expected.
- For projects at an early stage, the questionnaire might be too complex: they either do not have results to provide regarding scalability and replicability, or they are not always familiar with SGAM and not done enough for their scalability / replicability trajectory.

1.3 Breaking down the proposed SRA process

Based on the above findings and the feedback from consortia of projects, the following corrective actions were decided by the Task Force:

- Update/Rebuild the questionnaire and target only the quantitative aspect
- Include a section on project's key objectives in order to involve early-stage projects.
- Include examples to validate the process which is broken down to help consortia in building the SGAM path.
- A four-step approach has been decided and it is detailed in the next chapters.
- The scientific background of each step has been highlighted
- The steps taken towards the built up of case repository will be presented

2. SRA process

2.1 The need of an SRA process for the BRIDGE projects

It is of crucial importance that the projects outcomes and efforts would be replicated and escalated in order to secure the seamless advancement of technologies and solutions within the R&I community. Within this section, a review on the approaches proposed in previous projects and lessons learned are presented.

In the past few years several EU funded smart grid research and demonstration projects have addressed scalability and replicability from different perspectives. In [1] a comprehensive analysis of those projects is presented. Here below we summarised the main findings and tools developed for assessing the SRA of smart grid related projects.

- **Grid +** [1] aimed to contribute to the development of the European Electricity Grids Initiative (EEGI), thus Grid+ developed a EEGI labelling to identify projects aligned with the EEGI Roadmap [2]. Mainly focused on the technology features of the developed solution, the methodology approach adopted in Grid+ is reported in [3, 4].

- **Grid4EU**[2] cases. GRID4EU has developed a methodology for SRA based on a first stage of technical analysis using simulation (load-flow analysis, reliability analysis and dynamic analysis) and representative networks, and a second stage to include regulatory and stakeholder-related drivers and barriers to upscaling and replication [5,6]. SRA was performed for the different use cases, producing a set of scalability and replicability rules [7]

- **SuSTAINABLE**[3] SRA was focused on the identification of barriers to scaling-up and replication of the SuSTAINABLE functionalities. Technical, economic and regulatory barriers were mapped against the functionalities, and their impact was characterised, to determine whether functionalities can still be deployed, and whether the deployment would be delayed, the cost increased or the effectiveness reduced. SRA of the tested smart grid pilots in four target regions (UK, Germany, Greece and Portugal) was performed [8].

- **IGREENGrid**[4] The project includes the assessment of the scalability and replicability at an EU level of the solutions identified as most promising to generalise the results obtained by 6 individual projects located in Spain, Italy, Austria, Germany, France and Greece [9]. For this purpose, simulation was carried out to assess the performance of the solutions in terms of achievable hosting capacity increase, impact on network losses and impact on reactive power balance.

- **SiNGULAR**[5] investigated the effects of large-scale integration of RES and DSM on the planning and operation of insular (non-interconnected) electricity grids. Based on the study of different insular systems across Europe (S. Miguel of the Azores Islands in Portugal, Crete Island in Greece, Pantelleria Island in Italy, La Graciosa of the Canary Islands in Spain, and Great Island of Braila in Romania) the project addressed upscaling and replication, to allow the development of generalised guides for smart grid implementation in insular system.

- InterFLEX6 assesses within its SRA the effects of the boundary conditions for the implementation of the use cases by the implementation of several methodologies adopted. The SRA is applied to 5 demos and their use cases. The developed methodology for performing the technical (Functional-system logic) SRA is based upon a modularity design concept (demo based and Smart Grid Architecture Model - SGAM representation) and its adaptability. This methodology is structured in three separate phases: a pre-

[1] http://www.gridplus.eu
[2] http://www.grid4eu.eu
[3] http://www.sustainableproject.eu
[4] http://www.igreengrid-fp7.eu
[5] http://www.SiNGULAR-fp7.eu
[6] https://interflex-h2020.com

evaluation phase, an execution phase and a conclusion of the analysis performed for each of the demos [10]

- **IELECTRIX**[7] SRA will cover up to seven countries, comprising both the demo countries (Austria, Hungary, Germany, and India) and the replication countries (France, Greece, and Sweden). The SGAM layers that will be considered in the SRA are the business layer, the function layer and the communication layers. A specific methodological approach for each of the aforementioned dimensions is described [11]:

  - Functional: this part of the analysis aims to assess how changes in some of the technical and economic boundary conditions may affect the impact of the project High Level Use Cases, measured through a set of KPIs computed through network modelling and simulations.

  - Interoperability and ICT SRA: the IElectrix SRA will include a high-level qualitative assessment of the ICT architecture implemented in the demonstrators to identify the critical bottlenecks for the scaling-up and replication of the solution from an ICT perspective.

  - Regulatory analysis: this part of the SRA aims to identify barriers or drivers for replication or upscaling of the use cases posed by power system regulation. In order to achieve this, a qualitative framework has been defined, according to the following steps: i) identify key regulatory topics, ii) map regulatory topics to use cases and assess their relevance, iii) characterise regulation in the countries considered, and iv) identify regulatory barriers and drivers for the deployment of use cases.

  - Stakeholder analysis: the goal for this dimension is to assess the perspective of all relevant stakeholders to understand how their behaviour can affect the deployment and performance of LECs. A survey-based approach to characterise the related boundary conditions is proposed to identify and later assess the effect of stakeholder-related drivers and barriers.

- **INTEGRID**[8] also matches the main scopes of the project with the 5 SGAM's layers.

  - SGAM Business layer: InteGrid Economic and Regulatory domains.

  - SGAM Functional layer: InteGrid Functional domain.

  - SGAM Information and Communication layers: InteGrid ICT domain.

The general SRA has been approached with three consecutive steps [12]:

1) Pre-Evaluation of High-Level Use Cases (HLUCs) to select the most promising ones for the SRA with respect to each domain (functional, ICT, economic and regulatory). Dependencies among HLUC and HLUCs' most relevant tools are identified in this phase, as well as the main input factors to be considered for the SRA (at a qualitative level) and the outputs in terms of KPI. The impact of each factor in terms of scalability or replicability, and the main domains (Functional, ICT, Economic and Regulatory) affected, are also identified.
2) Definition of scenarios for the Smart Grid functions and for the HLUCs.

   The scenarios are defined according to the main factors identified in the pre-evaluation phase, by quantifying these factors with a reduced set of significant alternatives, and by indicating precisely which KPIs should be considered. Common scenarios are developed for both economic and technical domains since the outputs from the technical SRA will be used as inputs for the economic analysis. The regulatory SRA will also be fed from both the technical and economical SRA.
3) Execution of the SRA for each domain, following the scenarios developed

[7] https://ielectrix-h2020.eu/
[8] https://integrid-h2020.eu/

a) Functionality-oriented SRA (technical) is based on simulations
b) ICT-oriented SRA: the ICT-SRA performed on the HLUCs will be mostly qualitative-based

2.1.1 Discussion on project approaches

Projects above are examples of EU projects including SRA. Of course, many other projects with their respective approaches to SRA can be found. Some of them already completed or still ongoing (SMILE, PENTAGON, WiseGRID, GOFLEX, CREATORS, HESTIA, Lightness…) Nevertheless, several similar findings can be appointed:

- Some of the projects aligned the SRA methodology to the five layers of the SGAM (i.e. Business, Functional, Information, Communication and Component layers) to make the analysis more comprehensive to the researchers
- SRA for most projects relies mainly on technical analyses using simulation and sensitivity analysis.
- Simulation models are validated with the results observed in real-life testing (pilots) while sensitivity analyses reflect the variability of boundary conditions in the regions of interest.
- Regulation and stakeholder- related aspects are mostly included by analysing the context of the regions of interest to identify how this context can facilitate or hinder the development of the studied solutions.
- Collaborative approaches among projects can be found (eg. GRID+ addressed the SRA of the solutions from the point of view of technologies involved, while GRID4EU focuses on the impact of the enabled functionalities.

So, the mission of this BRIDGE TF is to share with all projects a universal and standardised process that will assess the Replicability and Scalability of each project and at the same time offer the potential to all researchers to check upon the use cases replicate, escalate and advance them.

2.2 State of the art and literature review

The following section is a review of the relevant literature that has been the baseline of the proposed SRA methodology.

2.2.1 Identification of quantifiable KPIs (related to KERs)

Various scientific studies focus on the identification of key performance indicators for evaluating smart grids, smart cities or positive energy neighborhoods and districts with an underlying common objective the scalability and replicability of technological solutions. Mia Ala-Juusela et al. [1] proposes key performance indicators for energy positive neighbourhoods and presents a decision support tool for measuring the energy positivity level of an area. Thanos et al. [2] defines a number of different performance indicators for peak reduction, demand variation, and reshaping, as well as economic benefits for evaluating Demand Response (DR) programs. Door Hans van Nes [3] introduces the idea of Key Exception Indicators to understand exceptions to expectations of key performance indicators measurements and diagnose their root causes as additional monitoring for performance. Other studies propose KPIs for defining specific standards for measuring the supply and power quality in different EU countries [4–7], while Sigrist et al [8] propose factors that influence and condition the potential for scalability and replicability for innovations on smart grid projects.

The European Electricity Grid Initiative (EEGI), one of the European Industrial Initiatives under the Strategic Energy Technology Plan (SET Plan) focuses on energy system innovations promoting the involvement of research and market players. EEGI [9] proposes a set of indicators for the assessment of grid-based technologies towards establishing an adequate European grid (both at transmission and distribution level), and achieve the European energy policy strategic objectives. In Pramangioulis et al. [10] a method for defining key performance indicators for Smart Grids in isolated energy systems i.e. islandic conditions is proposed. The method emphasises on the role of the various stakeholders involved who may undertake a different perspective on the technological solutions applied.

Other initiatives, like CITYKeys [11] and SCIS [12], although they focus more on the evaluation of smart cities and positive energy districts, they offer comprehensive lists of key performance indicators, in the fields of energy efficiency in buildings, energy system integration, sustainable energy solutions on district level, smart cities and communities, diffusion of solutions, and strategic sustainable urban planning. A comprehensive review of EU funded projects [13–22] and scientific studies [23–30] that introduce assessment frameworks i.e. KPI repositories for evaluating smart city performance is offered by Angelakoglou et al. [31,32]. Angelakoglou et al. proposes a methodological framework for determining a repository of KPIs that can evaluate different technologies and services applicable to smart cities solutions and energy system integration, using a citizen-centric approach.

In this context, the BRIDGE Scalability and Replicability Task Force builds upon the body of knowledge around the different evaluation frameworks for smart grids but is also informed by frameworks related to the evaluation of smart cities, and positive neighborhoods and districts and concentrates on developing and proposing an easy-to-use and versatile evaluation framework for assessing the potential of scalability and replicability of demonstrated innovative technological solutions.

2.2.2 Defining the KPI attributes

The development of a KPI repository requires the identification of key dimensions- attributes, which should be considered for assessing and monitoring energy efficient technological solutions. Various KPI frameworks propose different lists of attributes i.e. indicators assessing the performance of environmental, economic, technical, social, mobility, governance, propagation, ICT legal, LCA, and urban planning attributes [32]. The most prevalent of those attributes appearing in most of the frameworks are indicators dealing with environmental, economic, ICT, and social aspects. Although legal aspects are not appearing so often in other KPI frameworks, both [10,31] introduce KPIs related to legal aspects, since those can act as barriers or enablers for the implementation of state-of-the-art solutions, and can catalyse the scalability and replicability of solutions in the energy transition process. In [8] the technical, economic, regulatory, and stakeholder acceptance aspects are analysed, being regarded as shaping the potential for scalability and replicability of smart grids technological solutions. The BRIDGE Scalability and Replicability Task Force builds upon the KPI attributes identified in the literature and classifies them in: technical, economic, environmental, social and legal KPIs covering all possible categories.

2.2.3 Other Evaluation frameworks proposing composite indicators

Beyond studies focusing on the methods for defining a comprehensive list of KPIs and KPI attributes for monitoring the energy transition of smart grids and smart cities, other studies focused on building evaluation frameworks with composite indexes for assessing the impact, the performance and the sustainability potential of smart city projects. Those evaluation frameworks can be used for comparing multiple projects within a city as well as project performance in different cities, and also evaluate technological interventions with respect to a city's sustainability vision [33], Kourtzanidis et al.(in press]. Such evaluation frameworks also serve as decision support tools for policy makers and financiers to evaluate smart city interventions and compare how impactful each intervention is for a city or assess what types of interventions create a greater impact in different cities with varying contextual characteristics. Those frameworks offer a comprehensive review of methods for constructing composite indicators illustrated in the sections below.

1.1.1.1 Review on aggregation methods

The section below provides a review of aggregation methods for constructing composite indexes. The most commonly used aggregation methods for summing-up normalised values of sub-indicators in the literature of forming Sustainability indexes is the weighted arithmetic mean [34]. When using additive aggregation methods, it is assumed that there is no synergy or conflict between indicators. This means that the normalised score of indicators can be added together to provide an overall value [35]. Weights used in additive aggregation methods imply a compensatory logic and represent substitution rates. As such, synergy between sub indicators should not apply in using additive aggregation methods [36].

Less common methods used in forming sustainability indexes are the geometric aggregation methods. They use multiplicative instead of additive functions, with the weighted geometric mean being the most popular method used [34]. Geometric mean methods allow compensability but with certain limitations i.e., indicators with very low scores cannot be fully compensated by indicators with high scores. Some trade-offs though are allowed, while geometric aggregation methods are considered preferentially dependent [37]. A disadvantage of geometric additive methods is that sensitivity analysis and quantifying uncertainty is not possible to be analysed using measurement errors of indicators [38].

In cases, where compensation between sub-indicators for the construction of sustainability indexes are not permitted i.e., in strong sustainability indexes, non-compensatory methods i.e. conjunctive and disjunctive functions are used [39]. These methods are of limited use for decision makers though, because when values of sub indicators are not extreme, their information is greatly undermined [35]. Another non-compensatory method used is the Multicriteria Decision Making Method (MCDM), which is a decision maker preference approach [40]. Although MCDM methods have limited restrictions on the type of variables (i.e., both quantitative and qualitative data can be used), they have computation limitations when the number of indicators is increasing and lose information on the intensity of sustainability [41].

In the proposed framework, the geometric aggregation methods are selected for constructing the Scalability and Replicability Indexes as will be presented thoroughly below. The reasoning behind is that the different Replicability and Scalability attributes are intertwined with each other and this should be captured. This means that a low scalability attribute may have a significant impact to the whole scalability of a certain use case and the geometric aggregation method can capture this.

2.1.1.1 Review on Weighting methods

In studies, which examine the development of sustainability indicators, the validity of the methods used to assign scores to indicators depends on the weighting methods used [34]. One of the most common methods used is equal weighting offering a simple and replicable method. However, this method has been questioned by scholars in terms of validity and transparency of indexes results [42,43]. Equal weighting implies an implicit judgement on the weights being equal, which may ignore potential causal relationships into a subset of indicators related to a dimension [35]. Other statistical methods used, include the principal component analysis (PCA) and Factor Analysis (FA). The original scope of those methods however is to examine relationships and not to weight variables. Therefore, weights determined with these methods may result in important variables being assigned a lower weight due to statistically low correlations with other dimensions, instead of real-world correlations among assessed indicators [44]. In addition, the use of these methods, require a sufficient number of indicators and a degree of correlation [37]. Data envelopment analysis has also been used, but also criticised for incomparability and low transparency of results as it weighs indicators based on the relative performance of a set of indicators [34]. Regression analysis assumes that there is no multi-collinearity (e.g., investments is often positively associated with energy efficiency and CO2 reductions, but all three are independently relevant for measuring sustainability).

Unobserved component models have been used in literature for constructing aggregate governance indicators [45]. However, this method requires the collection of enough data and indicators that are not highly correlated, while it is quite sensitive to outliers of an indicator leading to low weighting [35] of this indicator. Another method used is the analytic hierarchy process (AHP), which is used for multiple-criteria decision-making and for weighting indicators. The AHP requires a high number of pairwise comparisons and a relatively short number of indicators in each dimension [35]. The budget allocation method (BAL) applies weighting on indicators based on expert opinion by assigning to them “n” points, which are then distributed over a number of indicators [35,37]. In the BAL method weights are based on the perceptions of experts in a specific region, who make consider current needs at policy level. This raises question as to whether those weightings are transferable to other regions [35]. Public opinion polling is a method where stakeholders express their “concern” regarding a public agenda and weighting is based mainly on the respondents concern rather than importance, raising also questions on transferability to different local conditions. Finally conjoint analysis (CA) assigns weights to indicators based on individual preferences, ranking a set of alternative scenarios. This method focuses on the preferences of respondents and requires a large sample and large preference data set rendering the weighting processes complicated [46].

According to Kourtzanides et al, the Budget Allocation method can offer a transparent weighting system if the expert pool includes experts from various disciplines covering a wide spectrum of knowledge, experience and concerns e.g., experts in energy efficiency, climate change, mobility, ICT, technology providers, business support organisations and financiers. Kourtazanidis et al. proposes that experts should be selected to cover a wider geographical area to ensure that weightings assigned are not based on the political agenda of a specific region, and therefore weights can be transferred to other regions. The BRIDGE Scalability and Replicability Task Force will utilise the equal weighting for determining indicator's weights due to its transparency, simplicity, explicitness, and short time of execution.

3.1.1.1 Normalising Indicators' Units

Before applying any weighting or aggregation methods it is important to normalise data for transforming the indicators to a dimensionless set of variables. In Kourtza et al. normalisation is elaborated with the use of functional units (FU) inspired by ISO 14040 series on Life Cycle Assessment. A FU is "a unit that supports fair comparability and benchmarking between two or more systems". All indicators to be included in the S&R index should be initially transformed into FUs. This can be achieved by transforming the indicators absolute values to be expressed as relative values i.e. per m2, per population, per total energy needs, as a % of increase/decrease, etc. depending on the type of every indicator. This process would enable comparisons of indicators between different projects or different technological solutions.

4.1.1.1 Normalising Indicators' Value

One of the challenges encountered in constructing composite indexes is to develop a uniform evaluation scale, as it is often the case that most of the adopted indicators are expressed in different units, making data aggregation not feasible. Several normalisation methods can be applied to resolve this problem and are available in literature including min-max, z- score, percentage of annual variations over consecutive years, distance to a reference and categorical scales [37]. Zhou et al. [47] have analysed commonly applied normalisation methods by variance-based sensitivity analysis, arguing that the distance to a reference method seems to be the optimum choice for sustainability performance evaluations. Kourtzanidis et al. suggest a hybrid normalisation method for addressing the fact that both quantitative and semi-quantitative (e.g., through Likert-Scale) indicators are often applied in the evaluation of energy transition projects. This hybrid method includes the integration of the distance to a reference with the categorical scale method. With the distance to a reference, it is possible to compare the value of a given indicator to one or more reference points and with the categorical scale it is possible to assign a score to every indicator using either a numerical or qualitative scale. Adopting the approach of Kourtza et al. we adopt a 5-point (ranging from 1 to 5) semi-qualitative evaluation scale with the following conventions and margins adopted:

1. Non-Scalable and non-Replicable: X12 (1 point is assigned to the examined indicator)

2. Little Scalable and little Replicable >X12 and X23 (2 points are assigned to the examined indicator)

3. Moderately Scalable and Moderately Replicable >X23 and X34 (3 points are assigned to the examined indicator)

4. Very Scalable and Very Replicable >X34 and X45 (4 points are assigned to the examined indicator)

5. Highly Scalable and Replicable >X45 (5 points are assigned to the examined indicator)

where XN(N+1), N=1,4 is the boundary value for each of the 4 margins embedding neighbouring scale points. Fig. 1, depicts these points on the uniform scale. The adoption of such scale provides flexibility and adaptability for the evaluation procedure to each indicator and consequently the S&R index.

Non-Scalable and Non-Replicable	Little Scalable and Little Replicable	Achieves Scalability and Replicability	Very Scalable and Very Replicable	Highly Scalable and Highly Replicable
1	2	3	4	5

X_{12} X_{23} X_{34} X_{45}

Figure 1. The uniform evaluation scale used in this study

Scaling is performed based on one or more reference points that can serve as the boundary values i.e. an indicator gets a value of three if the solutions achieves the baseline value set by the project. Those reference point can be derived either from baseline values (i.e., a technology is modular and uses standard communication protocols enabling its interaction with other systems) or a threshold value (i.e., something causing irreversibility of the system) [48]. Alternatively, reference points can be extracted from best available techniques (BAT), national regulations, commonly accepted standards and/or goals-success target values and expert judgements. The selection of a reference point depends on the attributes and aim of the KPI. The reference point can be used to indicate both a positive (>X23, X34, X45) or negative (X12, X23) “performance”. For instance, if the examined indicator is “investment payback period”, a reference point for the payback period of an investment less than ten years (a target that is considered acceptable for a range of energy transition projects) could be assigned to X45. On the other hand, a reference point of >10 years, could be assigned to X12. In many cases the reference point could also be applied as the starting point for assigning the rest of the boundary values. This is largely applicable to the case where a target value is known (or set) such as when assessing an indicator set by a project to have a specific value (it is evident that these target values are then project specific). In this case, the target value is the midpoint of the boundary reference points X23 and X34 and an index scoring of 3 denotes achieved performance. Combined reference points could additionally be applied if necessary (one indicating non-scalable and replicable and the other highly scalable and replicable). In this way, the evaluation scale is built upon a distance to commonly accepted boundaries thus increasing objectivity of the results. It should be clarified that the distance between the boundary values does not need to be necessarily equal.

Significant advantages derive from the adoption of the proposed normalisation and evaluation procedure. In many cases, it may be necessary for the assessment of replicability and scalability analysis to include qualitative indicators in the analysis (especially in case of e.g., social indicators). Common normalisation methods such as z-score and min-max require an adequate set of data to be efficiently applied. This may serve as a deterrent of application on newly operating solutions for smart grids that did not have an organised indicator tracking system until recently. Most methods would give the “best in class” smart gird solution the highest score, which seems fair at a first glance, it does not however ensure that the specific smart grid solution is developed in a sustainable way but rather exhibits better performance compared to other relevant initiatives (or the baseline scenarios). In this case, the “best in class” smart grid solution will still receive a better score in comparison with the benchmarked system; however, it will have to try more to reach the highest score, if the pre-determined performance thresholds are not met. This is more in accordance with the notion of sustainable development, according to which fundamental changes may be needed in various levels (institutional, legal, administrative etc.).

2.3 Proposed SRA methodology

Based on the previous findings, the SRA methodology that was put together by R&S BRIDGE TF is based on the scientific background and the experts’ opinion. Four subroutines/steps have been identified in the following logical process, considering the project’s maturity (i.e. early stage / on-going / ending project).

The subroutines are described in the chapters that follow, to support their implementation.

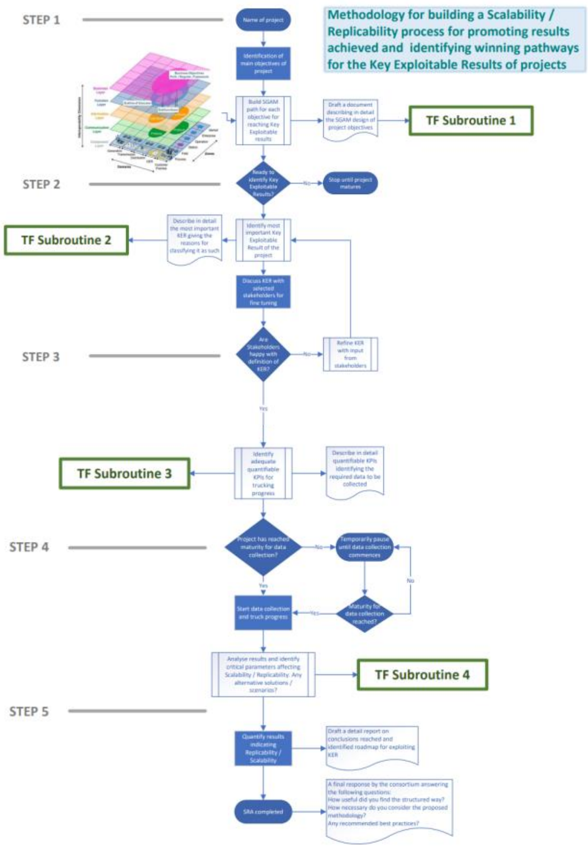

Figure 2. The SRA methodology review

At the validation stage, 7 projects have followed SRA process and the findings are presented in the attached Annex 2. It has to be mentioned, that what is presented within Annex 2 is not an indication of how these certain projects are replicable and scalable as they are still ongoing. So, the results included shall be treated as a part of the validation process of the proposed SRA and by all means not as a part of evaluating the participating projects.

2.4 Subroutine 1: Mappin of project objectives into the SGAM architecture

Example: GOFLEX project

Develop and demonstrate mature and commercially viable, scalable and easy-to-deploy solutions for distributed flexibilities through an automated dynamic pricing flexibility market for distributed resources and Demand Response as a flexibility service to the integrated grid.

2.4.1 Introduction

In this revised process of the guidelines, the starting point is the key objective of the project.

Through a detailed analysis of the project objective and sub-objectives the following steps and subroutines should be addressed, depending on the project maturity. This is done **once** for every project and the targeted SGAM plot should contain all envisaged actions / steps addressing the targeted objectives of the project under investigation, as one single process irrespective of how many branches it may have.

The different objectives of the project should be ranked, aiming to identify the main key objective of the project to be mapped once. This will be a critical input for the second Team working on Subroutine 2.

Example used: GOFLEX project	
Key objective of the project: Develop and demonstrate mature and commercially viable, scalable and easy-to-deploy solutions for distributed flexibilities through an automated dynamic pricing flexibility market for distributed resources and Demand Response as a flexibility service to the integrated grid.	
Objective 1	Develop and demonstrate a platform for peer-to-peer flexibility trading
Objective 2	Develop and demonstrate a device for aggregating flexibility at the level of consumers
Objective 3	Develop new business models for trading flexibility

Table 1. Setting the objectives of the project

To do this and to be in line with the universal classification of projects within BRIDGE, it is required to align with the adapted classification of technologies and systems (see Appendix 1).

Mapping starts with the component layer: the physical system is detailed including physical system components serving the various operational zones, the market and appropriate roles.

Based on the component layer the communication and data layers are generated.

The physical linking of the various layers is developed with all connectivity details.

Building on the underlying concepts of the project the required roles and responsibilities of involved actors is sketched that will form the basis for serving the envisioned functions and business objectives to be developed in layers 4 and 5 of the SGAM architecture / process.

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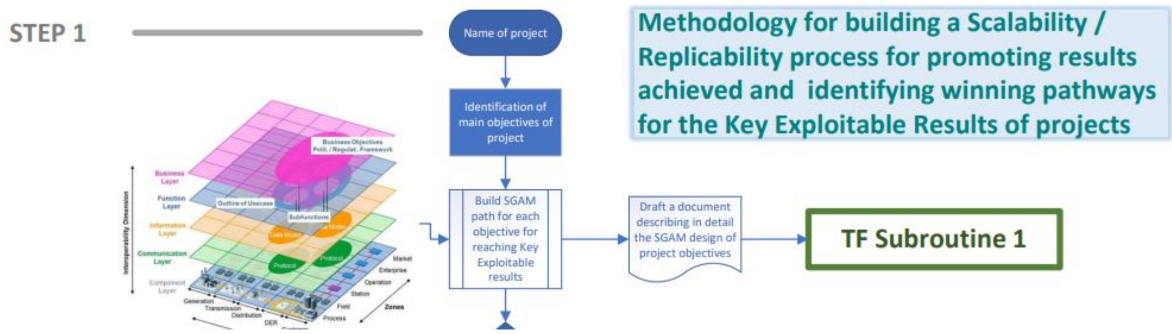

Figure 3. Step 1 in the SRA Methodology Overview

An example of the application of the methodology for the GOFLEX project is described in next sub-section.

5.1.1.1 Application of subroutine 1 to the GOFLEX project

The GOFLEX project aims to accelerate the GOFLEX technology solution in Europe by developing and demonstrating mature and commercially viable, scalable and easy-to-deploy solutions for distributed flexibilities. Automated dynamic pricing is utilised to enable the establishment of a flexibility market for distributed resources and Demand Response in order to improve the secure energy supply at local level and increase the economic efficiency of the overall energy system.

To meet these strategic goals, the main objective of GOFLEX is to make a set of technology solutions for distributed flexibilities and automated dynamic pricing market ready which enables regional actors like Generators, Prosumers, Flexible Consumers and Demand Side Operators, Energy Suppliers, Microgrid Operators and Energy Communities to aggregate and trade flexibilities.

What is the key objective of the GOFLEX project?

> Develop and demonstrate mature and commercially viable, scalable and easy-to-deploy solutions for distributed flexibilities through an automated dynamic pricing flexibility market for distributed resources and Demand Response as a flexibility service to the integrated grid.

What are the branches of this key objective?

Example used: GOFLEX project	
Key objective of the project: Develop and demonstrate mature and commercially viable, scalable and easy-to-deploy solutions for distributed flexibilities through an automated dynamic pricing flexibility market for distributed resources and Demand Response as a flexibility service to the integrated grid.	
Objective 1	Develop and demonstrate a platform for peer-to-peer flexibility trading
Objective 2	Develop and demonstrate a device for aggregating flexibility at the level of consumers
Objective 3	Develop new business models for trading flexibility

Step 1: Map the key objective in the Smart Grid Architecture Model

How can this be mapped in the SGAM model? Analysing the requirements for addressing the needs of the GOFLEX project it is identified that all interoperability layers are required:

- Business Layer

- Function layer
- Information layer
- Communication layer
- Component layer

To detail the required mapping, it is important to note the reference designs of the SGAM related to the following and shown in figures below:

SGAM: Mapping of harmonised role model

SGAM: Mapping of communication networks

SGAM: Data modelling and harmonisation work mapping

Moreover, the SGAM layers listed and described in Table 1, should be well understood prior to any attempt to map projects. It is for this reason that consortia of projects should be well conversant with the SGAM architecture and the manual "**SGAM User Manual - Applying, testing & refining the Smart Grid Architecture Model (SGAM)"9** must be well studied to learn how to implement for best results.

In this process, it is important to note that interoperability is fundamental in the technology evolution progressing the interconnected grid and associated markets towards the envisioned smart options capable of facilitating the seamless operation of the emerging technologies in support of energy transition to the low carbon economy of 2050.

Hence, mapping objectives of projects in the SGAM model provide consortia with the readymade solutions for developing the interoperability layers using approved standards with broader scope and enrich the scalability and replicability capabilities of the project and its targeted objectives.

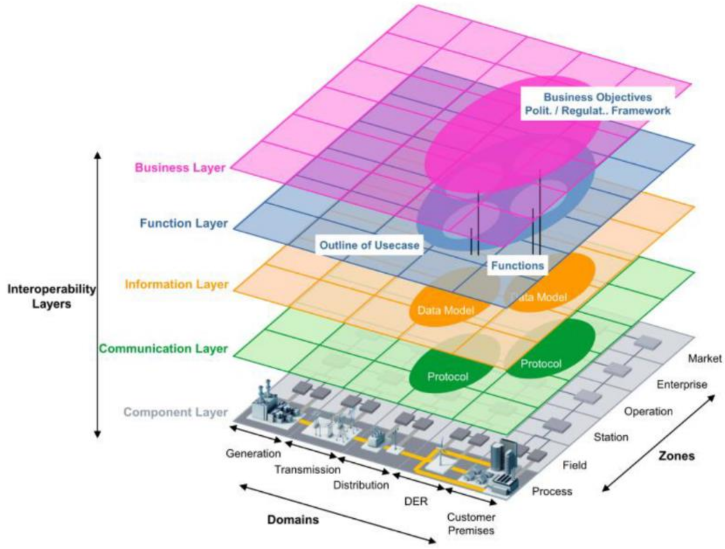

Figure 4 SGAM model

9 https://manualzilla.com/doc/6919852/sg-cg-m490-k_-sgam-usage-and-examples-sgam-user-manual

Layer	Description
Business	The business layer represents the business view on the information exchange related to smart grids. SGAM can be used to map regulatory and economic (market) structures (using harmonised roles and responsibilities) and policies, business models and use cases, business portfolios (products & services) of market parties involved. Also business capabilities, use cases and business processes can be represented in this layer.
Function	The function layer describes system use cases, functions and services including their relationships from an architectural viewpoint. The functions are represented independent from actors and physical implementations in applications, systems and components. The functions are derived by extracting the use case functionality that is independent from actors.
Information	The information layer describes the information that is being used and exchanged between functions, services and components. It contains information objects and the underlying canonical data models. These information objects and canonical data models represent the common semantics for functions and services in order to allow an interoperable information exchange via communication means.
Communication	The emphasis of the communication layer is to describe protocols and mechanisms for the interoperable exchange of information between components in the context of the underlying use case, function or service and related information objects or data models.
Component	The emphasis of the communication layer is to describe protocols and mechanisms for the interoperable exchange of information between components in the context of the underlying use case, function or service and related information objects or data models.

Table 2. SGAM layers

The mapping process starts with the component layer shown in Fig 4, on which the physical system is detailed with the components to be deployed up to and including the market with appropriate roles.

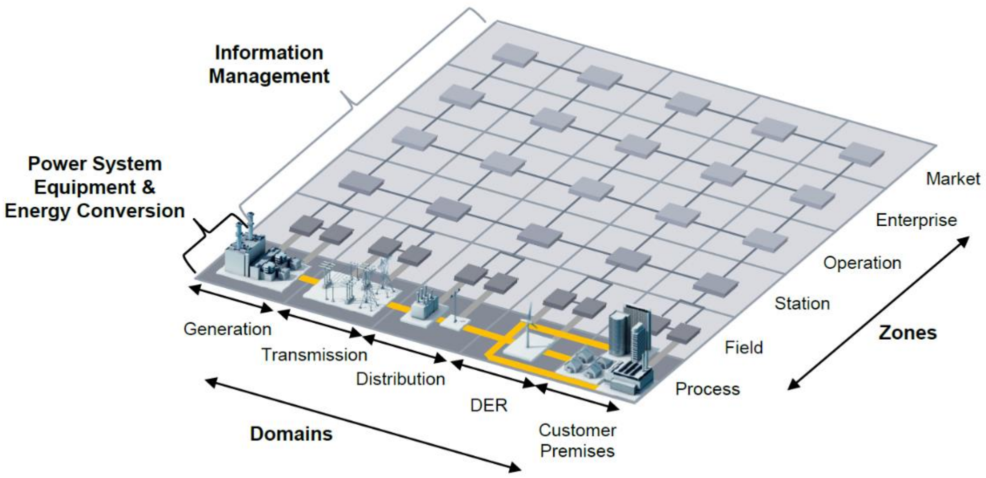

Figure 5. SGAM – Smart Grid Plane – domains & zones

In building this architecture, it is important to note that power system management distinguishes between electrical process and information management. These viewpoints can be partitioned into the physical domains of the electrical energy conversion chain and the hierarchical zones for management of the electrical process.

The *Smart Grid Plane* spans in one dimension the complete electrical energy conversion chain, partitioned into five domains: (Bulk) Generation, Transmission, Distribution, DER and Customer Premises.

In the other dimension the hierarchical levels of power system management are partitioned into six zones: Process, Field, Station, Operation, Enterprise and Market.

This smart grid plane enables the representation of the zones in which power system management interactions take place between domains or within a single domain.

Domain	Description
(Bulk) Generation	Representing generation of electrical energy in bulk quantities typically connected to the transmission system, such as by fossil, nuclear and hydro power plants, off-shore wind farms, large scale solar power plant (i.e. PV, CSP).
Transmission	Representing the infrastructure which transports electricity over long distances.
Distribution	Representing the infrastructure which distributes electricity to customers.
DER	Representing distributed electrical resources directly connected to the public distribution grid, applying small-scale power generation and consumption technologies (typically in the range of 3 kW to 10,000 kW). These distributed electrical resources may be directly controlled by e.g. a TSO, DSO, an aggregator or Balance Responsible Party (BRP).
Customer Premises	Hosting both end users of electricity and also local producers of electricity. The premises include industrial, commercial and home facilities (e.g. chemical plants, airports, harbours, shopping centres, homes). Also generation in form of e.g. photovoltaic generation, electric vehicles storage, batteries, micro turbines.

Table 3. SGAM domains

Zone	Description
Process	Including the physical, chemical or spatial transformations of energy (electricity, solar, heat, water, wind …) and the physical equipment directly involved (e.g. generators, transformers, circuit breakers, overhead lines, cables, electrical loads, any kind of sensors and actuators which are part or directly connected to the process,…).
Field	Including equipment to protect, control and monitor the process of the power system, e.g. protection relays, bay controller, any kind of intelligent electronic devices which acquire and use process data from the power system
Station	Representing the areal aggregation level for field level, e.g. for data concentration, functional aggregation, substation automation, local SCADA systems, plant supervision…
Operation	Hosting power system control operation in the respective domain, e.g. distribution management systems (DMS), energy management systems (EMS) in generation and transmission systems, microgrid management systems, virtual power plant management systems (aggregating several DER), electric vehicle (EV) fleet charging management systems.
Enterprise	Including commercial and organisational processes, services and infrastructures for enterprises (utilities, service providers, energy traders), e.g. asset management, logistics, work force management, staff training, customer relation management, billing and procurement.

Market	Reflecting the market operations possible along the energy conversion chain, e.g. energy trading, retail market.

Table 4. SGAM zones

Following the above definitions, the identified key objective of the GOFLEX project is first mapped on the component layer, making sure that all processes are included starting from the physical processes and field components to the systems that will serve the market through appropriate communication channels that will generate the required data that is managed in line with the detailed European standards.

This is presented in Fig 3 below. Based on this detailed component layer, the communication and data layers are generated as depicted in Figs 4 and 5 respectively.

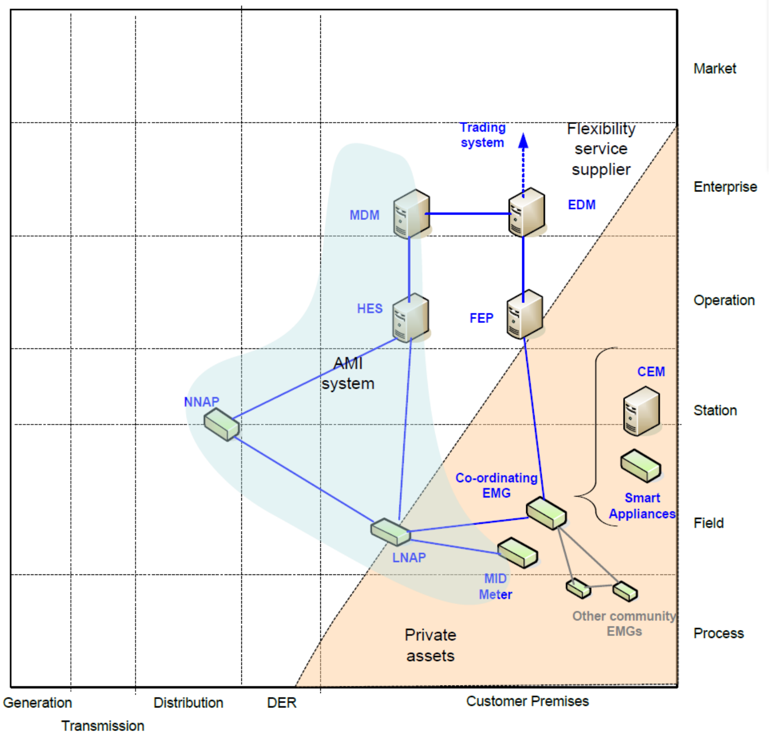

Figure 6. SGAM – GOFLEX mapping a component layer for flexibility trading

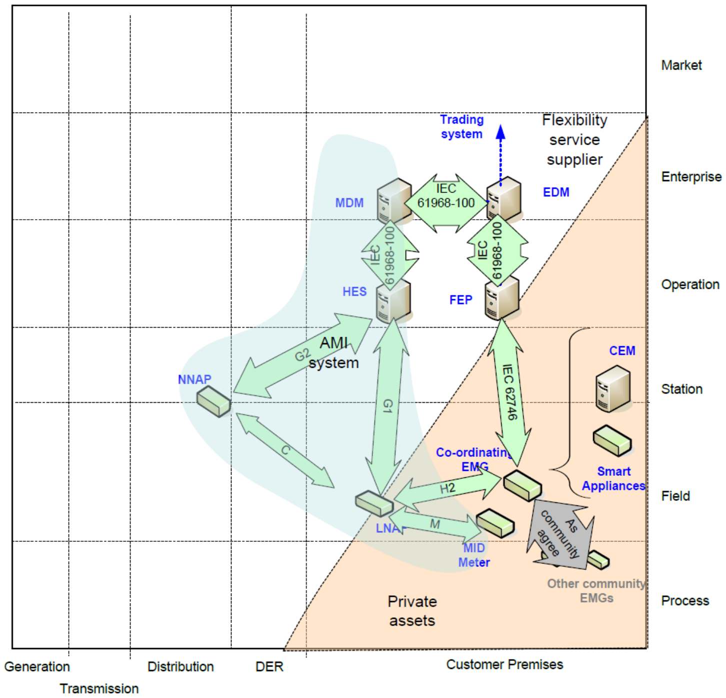

Figure 7. SGAM -GOFLEX mapping of the communication layer for trading flexibility

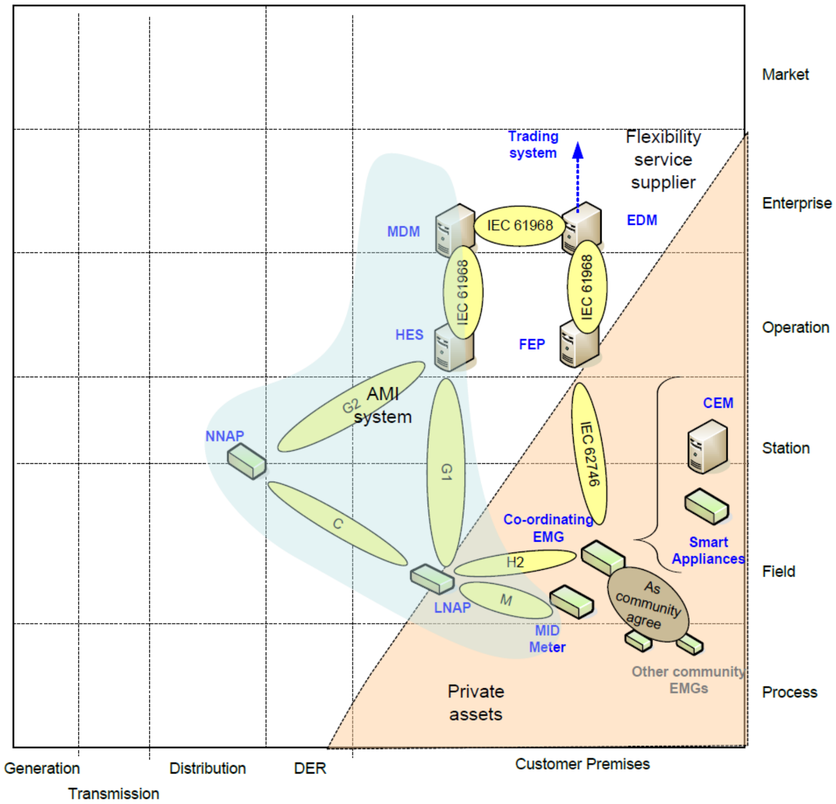

Figure 8. SGAM – GOFLEX mapping of the information layer

The above mappings form the basis for transforming the key objective of the project into at least one detailed use case within the SGAM framework. This use case has physical linking between the various layers as depicted in Fig. 6. In general, projects are targeting more than one use case that can be developed using the same procedure and detailing connectivity in all layers as required.

For each identified use case, roles are identified and market participants defined using the role model mapping of Fig 7.

Use cases are a well-proven approach in systems engineering and used worldwide to derive a common understanding for the objectives of the project. Despite (or because of) the large set of use cases available in different databases, the level of granularity differs widely in these use case descriptions. A simple classification for the design and scope of the selected use case is preferred and this should be adopted as a general rule. In this process, differentiation should be made between use case concepts (or high level use cases), business use cases and device/system use cases.

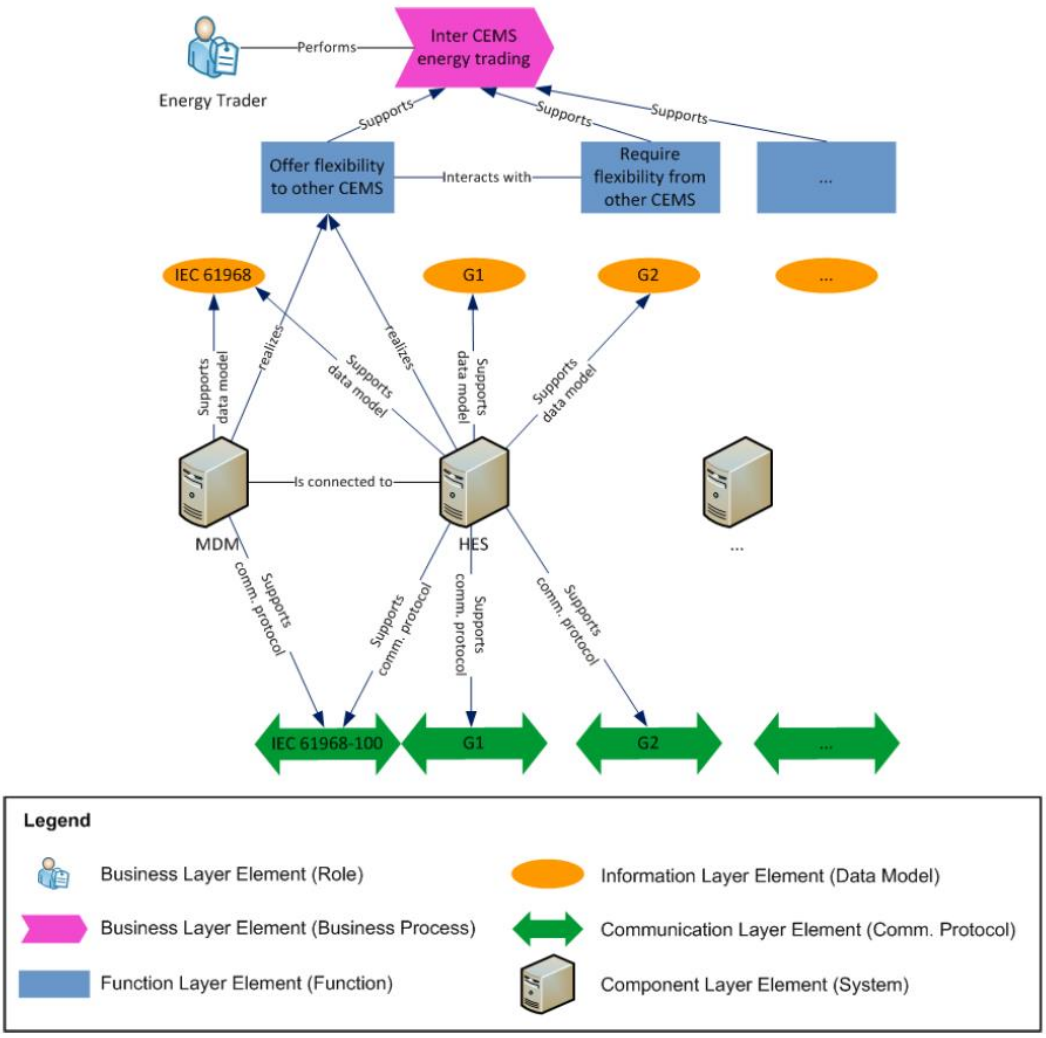

Figure 9. Interrelationship between concepts on different levels in the SGAM model (CEMS: Customer Energy Management System, MDM: Meter Data Management, HES: Hypertext Editing System)

Following, this procedure the underlying concepts of the project are described by defining the roles involved and sketching their responsibilities with details on the underlying business models or processes thus distinguishing use cases between them with the required granularity for unique mapping in the SGAM.

For the purpose of this exercise, we will limit further steps to **only one use case and one objective to** prove the process but consortia of projects will need to complete all use cases of their project to the required detail that will facilitate all next steps that will lead to the evaluation of Scalability and Replicability indices of the project.

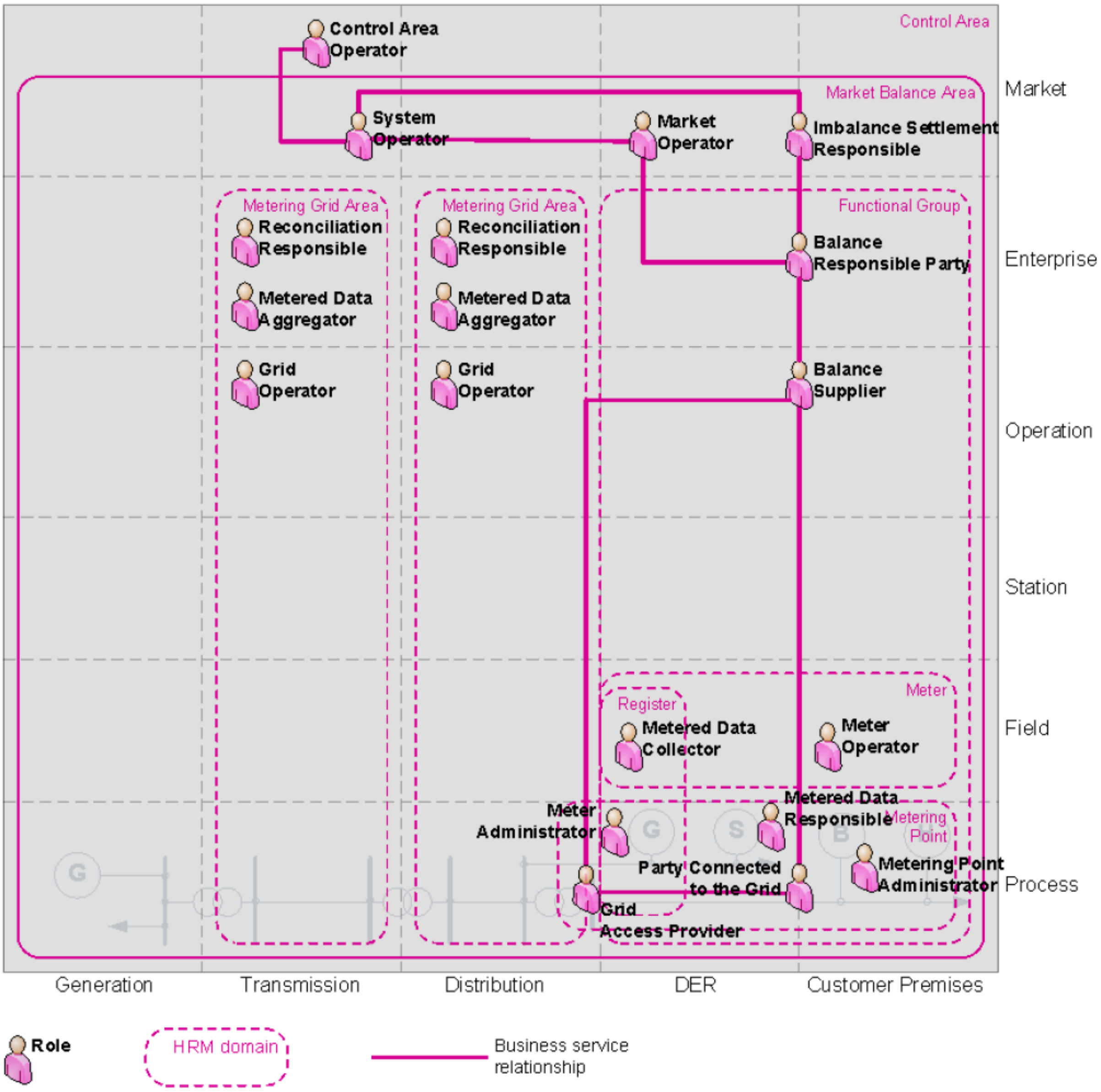

Figure 10. SGAM – Mapping of harmonised role model

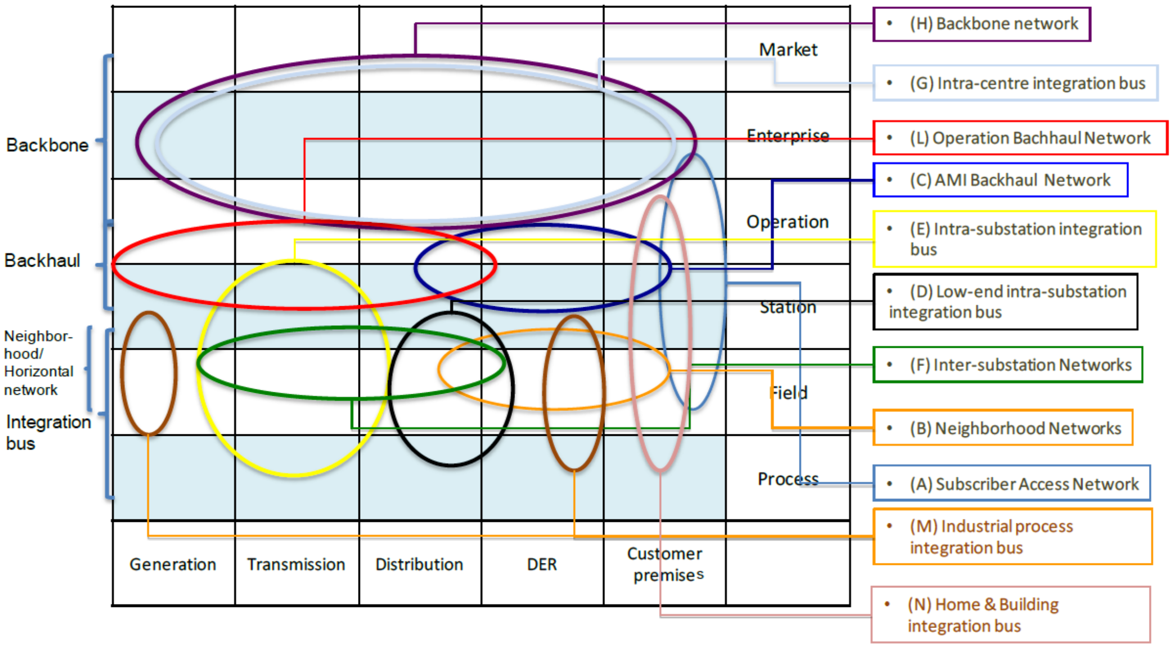

Figure 11. SGAM – Mapping of communication networks

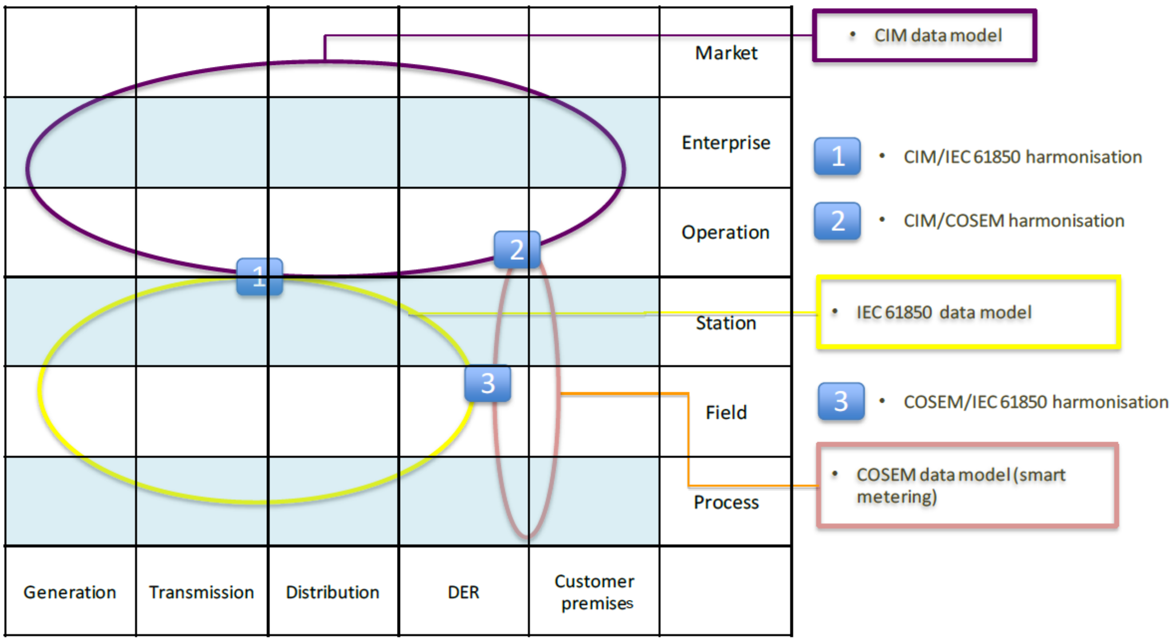

Figure 12. SGAM – Data modelling and harmonisation work mapping

2.5 Subroutine 2: KERs Identification

Within this section, the main advancements that the project aims to deliver in technologies / systems / solutions in response to the set-out objectives of the project will be identified. These advancements will be distinctly separated into complete entities within separate layers of the SGAM. Each such entity related to a separate layer will be described as a Key Exploitable Result (KER) [10] of the project meeting the attributes of the definition in the following paragraph serving the different objectives of the project as identified in the previous subroutine. To do this and to be in line with the universal classification of projects within BRIDGE, it is required to align KERs with the adapted classification of technologies and systems (see Appendix 1).

Exploitation definition: The utilisation of results in further research activities other than those covered by the action concerned, or in developing, creating and marketing a product or process, or in creating and providing a service, or in standardisation activities.

Key Exploitable Result (KER) is an identified main interesting result (as defined above) which has been selected and prioritised due to its high potential to be 'exploited' downstream the value chain of a product, process or solution, or act as an important input to policy, further research or education.

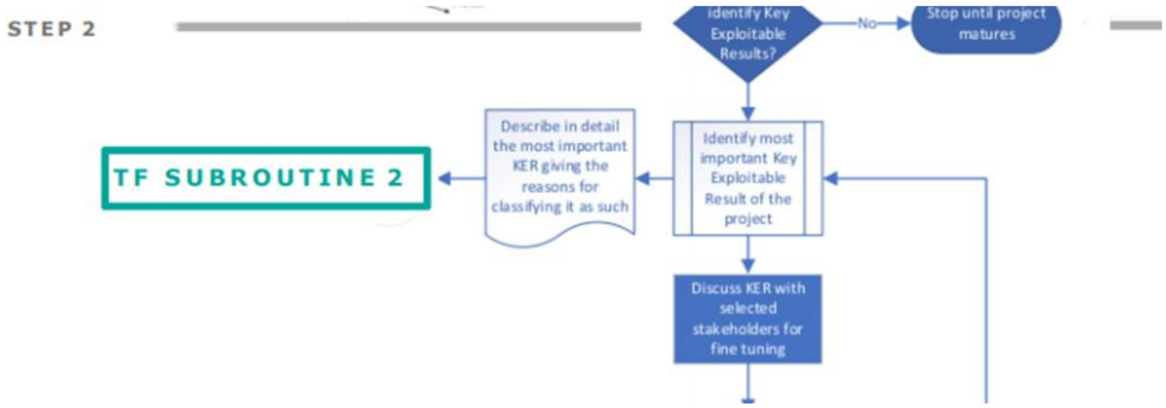

Figure 13. Step 2 in the SRA Methodology Overview

In order to distinctly identify the KER advancements and link them to the objectives as they were identified in Table 1 of SR1 section and the technologies/systems/solutions classification (Appendix 1), the following table is highly helpful to be completed in the identified structured way.

Layers	Objective 1	Objective 2	Objectrive3	Objective 4	Objective 5	Objective 6	KER
Component layer			x	x			KER1
Communication layer	x				x		KER2
Information layer	x						KER3
Function layer	x	x					KER4
Business layer			x		x		KER5

Table 5. KERs mapping into the SGAM plane

Hence, the projects need to identify through this exercise how the KERs are linked to the objectives as set in SR1 and with which layer they are linked. All KERs can serve more than one project objectives but can be linked to only one SGAM layer i.e technology. So, projects need to split or merge identified advancements in technology/systems/solutions to form distinct KERs related to specific layers of the SGAM layout. As this process

10 https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/support/glossary

is performed, it is critical not to lose any important details of the targeted development work within the project, that is related to technologies / systems / solutions.

In this process, the following table needs to be filled by the projects for every identified KER having the following main objectives:

- Define in detail the innovation areas of the project and build through them the KERs of the project
- Identify role of innovation areas in building and operating wider systems following the SGAM approach
- Identify missing links from the state of the art of systems that the project targets to solve and deliver, and
- Through detailed analysis qualify starting TRL and finishing TRL for each KER and note it in TABLE6.

The KER table below is required to be filled in for every identified KER of the project.

KER1 short description	Provide a short description of this KER and its objective
Main advancements of KER1	Provide a short description of this KER and its objective
Qualification of KER1 based on R&S characteristics	For each KER you need to complete Table below "R&S characteristics". This actually will be a quantification of how replicable and how scalable this innovation of KER is.
TRL of KER1 at the end of the project	Qualify the starting TRL and finishing TRL for this KER

Table 6. KER description table

First the Replicability characteristics column is to be filled in. Each characteristic should be scaled between 0 and 1 depending on technologies / systems used that are non-proprietary with 0 being non-replicable and 1 being fully replicable. The evaluation should be done with the following rationale:

Should the KER uses for example 4 standards but only 2 of them are open, then the valuation for replicability characteristic 1 is 0.5. In case that all of them are open then replicability index should be 1.

Then the scalability characteristics column should be filled in for additional resources (if applicable) with the same rationale.

The main R&S characteristics that the KER will be quantified against are listed in the Table 7 below. This table is accompanying each KER. So, it should be replicated for each KER as well. Each characteristic should be scaled between 0 and 1 depending on technologies / systems / solutions used that are non-proprietary. The overall Replicability / Scalability index for the specific KER will be the product of the individual indices.

Please note that for each KER, there are two overall indexes. The first one is the Replicability related index and the second is the Scalability related index.

	Replicability characteristics	Scalability characteristics
1	Data addresses using open standards (a no between 0 and 1) For this exercise the projects mention the standards that the KER uses and the valuation index	In addition to what is specified for R, does scaling up require additional resources that are based on open standards? In case that no further resources are needed, the scalability index is the same as for the replicability.

2	Data addresses using open standards (a no between 0 and 1) For this exercise the projects mention the standards that the KER uses and the valuation index	In addition to what is specified for R, does scaling up require additional resources that are based on open standards?
3	Interoperable systems (0 or 1) For this exercise please mention the interoperable systems that the KER employs and the evaluation index	In addition to what is specified for R, does scaling up require additional resources that are based on open standards?

Table 7 R&S characteristics

This is of critical importance for identifying how scalable and replicable are the KERs of the projects and give solid feedback for the analysis in the next SR4. A project having all characteristics met for both indexes is considered to be fully replicable and scalable. Of course, this is linked to the technologies and systems that each of the project advances. Hence, fundamental in shaping the maturity indexes of systems and functionalities forming the integrated smart grid of 2030 and beyond.

To sum up, the main outputs of this subroutine are the following:

- Populate the list of KERs of the project and provide it as input to SR3 by quantifying the Replicability & Scalability that is expected to be achieved through the identified KERs and the related technologies / systems/solutions.
- Develop an exhaustive description of the most valued KERs (in terms of replicability and scalability) and the anticipated advancement of the related technology/system/solution
- Identify the most valued KER of the project from the qualified list.
- Provide the TRL level that will be reached by each KER at the end of the project.

2.6 Subroutine 3: Quantifiable KPIs identification (related to KERs)

This subroutine aims at establishing generic and quantifiable KPIs (Key Performance Indicators) based on the KERs described above, that can track the results of these KERs as the project progresses. The challenge faced in this subroutine was to start from KERs which are project specific and develop generic KPIs, which are universal and not project specific.

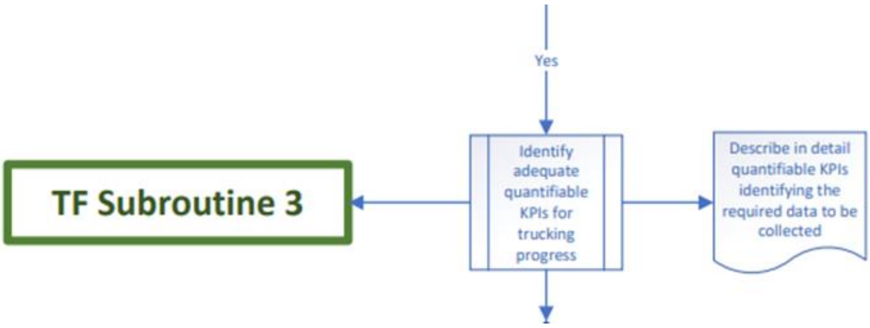

Figure 14. Step 3 in the SRA Methodology Overview

The main goal of this subroutine is to answer the question: To what degree is it possible to generate KPIs to measure the evolution of KERs as they progress through the project?

Key Performance Indicator: Metric which evaluates and monitors the progress of a project, task, objective, etc.

2.6.1 Step 1: Creating a preliminary KPI repository

Among the current 64 projects that are part of the BRIDGE initiative, 35 had already published their KPIs (or had a list of KPIs ready to be published). The remaining 29 projects either did not make them available or they were too recent to have a list prepared. The following Table presents the outcome of the first step of this subroutine. In the cases that KPIs could not be directly linked to the project KERs, the KERs were considered as not available.

Reviewed BRIDGE projects		KERs available?	Total number of KPIs	Methodology for KPI definition
1	AnyPLACE	Yes	23	Other
2	Compile	Yes	70	Other
3	CoordiNET	No	39	EEGI Roadmap
4	CROSSBOW	Yes	46	EEGI Roadmap
5	ELSA	No	4	EEGI Roadmap
6	EU-SysFlex	No	52	EEGI Roadmap
7	FEVER	No	61	N/A
8	FLEXICIENCY	Yes	30	Other
9	FLEXIGRID (864579)	Yes	44	Other
10	FLEXITRANSTORE	Yes	6?	Other
11	FLEXMETER	Yes	10	N/A
12	FutureFlow	No	20	EEGI Roadmap
13	GOFLEX	Yes	44	Other
14	GRIDSOL	Yes	5	N/A
15	IElectrix	No	20	Other
16	INSULAE	No	19	N/A
17	InteGrid	No	88?	N/A

18	InteGRIDy	No	59	EEGI Roadmap
19	InterFlex	No	6	Other
20	INVADE	No	31	General/Specific
21	MERLON	Yes	N/A	N/A
22	MIGRATE	No	4	N/A
23	MUSE GRIDS	No	65	Other
24	NOBEL GRID	Yes	67	EEGI Roadmap
25	OSMOSE	Yes (partially)	31	N/A
26	P2P-SmarTest	Yes	29	EEGI Roadmap
27	Platone	No	31	Other
28	SENSIBLE	No	9	EEGI Roadmap
29	SmarterEMC2	Yes	24	N/A
30	SMILE	Yes	45	Bottom-up
31	STORE&GO	Yes	29?	N/A
32	STORY	No	36	N/A
33	UPGRID	No	25	EEGI Roadmap
34	WiseGRID	Yes	58	Other
35	X-FLEX	Yes	41	EEGI Roadmap

Table 8. Review of KPIs in BRIDGE projects

By checking the methodology followed in these projects, it appears that 11 of them explicitly follow the EEGI 2013-2022 Roadmap or the ETIP SNET R&I Roadmap. These two guidelines recommend a 'top-down' approach of KPI definition with proposed KPIs related to objectives in the distribution network (new services, devices, algorithms, and regulatory frameworks). This top-down approach starts with defining overarching KPIs, which assess the contribution to national or international targets. Then, general KPIs are defined, which address common objectives in similar demonstration projects. Finally, project specific KPIs are defined.

The goal of this subroutine is thus to follow the route of general KPIs from project specific KERs in order to establish a common list of KPIs from which project stakeholders could pick what serves best their own identified KERs.

It is interesting to note that some of the reviewed projects, proposed a different methodology which is more 'bottom-up', i.e. KPIs are firstly defined by projects' stakeholders and demonstration sites' interests and own objectives.

2.6.2 Step 2: Defining KPIs attributes

Usually, KPIs are defined under different attributes. The most common attributes are:

1. Technical
2. Economic
3. Environmental
4. Social
5. Legal.

We choose here to follow this attribute classification, but many projects adapt these attributes to their own needs (e.g. communication aspects, grid technical objectives, end-user engagement, replication objectives, sustainability, etc.).

2.6.3 Step 3: Application to a few projects

To draft a preliminary list of generic KPIs and to answer the main question of the subroutine, a focus was done on the projects detailed in subroutine 2. From the information provided, the analysis performed for the validation projects are included in Annex2.

In case the initial list of KPIs does not fall under the 5 attributes indicated above, they were reclassified in order to belong to these categories. Similarly, in case the KPIs were not explicitly connected to some KERs, they were rearranged, to the best of the taskforce's knowledge, in order to have KPIs that can sufficiently track the progress of the specified KERs.

From this first iteration, the following conclusions were reached:

1. Environmental, social, legal, and – to some extent – economic KPIs are relatively general in most of the projects and a common list could be easily achievable. A first selection can already be made from the four projects.
2. Technical KPIs are much more specific to the KERs and extremely diverse, so one common list is not possible. Sub-categories are necessary to create a KPI repository. The first selection of technical KPIs is defined by the systems in place in the grid and the services developed in the projects.
3. Most of the projects link their KPIs to their objectives and use cases, rather than directly to their KERs Thus, following the SRA process, i.e. creating a KPI repository based on KERs is not common and can create difficulties in the initial definition of KPIs.
4. The taskforce identified as the most beneficial approach to define the KER as either a service, a device (hardware), or a software and to define who are the actors involved in the KER (e.g. consumer, DSO, TSO, supplier, etc.). As described in bullet 2., assets which are integrated to the grid could also define subcategories of KPIs.

Following the above approach, the identified generic KPIs listed under the initial list of attributes environmental, social, legal, economic and technical are:

Environmental KPIs	Specific application

EROI (Energy Return on Investment)	
Change in GHG emissions // Change in CO2 or NOx emissions	
Fossil fuels consumption	In the case of EV
Carbon Footprint of Heating House	In the case of heating

Social KPIs	Specific application
User satisfaction	
Demand side participation	In the case of DR schemes
Thermal comfort	In the case of heating
End user involvement	Particularly for energy communities

Legal KPIs	Specific application
Data and cyber security	
GDPR risk	
Privacy	
Local grid balancing legal framework development	In the case of balancing market
Suitable Energy Storage Regulation	In the case of energy storage

Economic KPIs	Specific application
Internal Rate of Return (IRR)	If there is initial investment: relates more to hardware KERs
Rate of Interest (ROI)	
Investment Payback Period	
Total Annual Costs	

Asset OPEX	
Average Cost of Energy Consumption	
Average Production Cost/MWh // Life-cycle cost of energy generation	
Heating Prices	In case of heating

Technical KPIs	Specific application
General technical KPIs	
Data Quality (%)	
Share of RES in final electricity consumption	
Improved Interoperability (n/a)	
Total energy use reduction (if applicable)	
Technical KPIs related to Energy storage system	
Peak shaving (kW or %)	
Storage energy loss (kWh)	
Battery degradation rate (%)	
Reduced Energy Curtailment of DER (kWh)	
Degree of self-supply (%)	
Technical KPIs related to EV system	
Peak shaving (kW or %)	
Reduced Fossil Fuel Consumption	can also be defined as environmental KPI
EV demand flexibility availability (kWh or %)	
Technical KPIs related to RES generation system	
Degree of self-supply (%)	

Generation Forecasting Accuracy (%)	
Technical KPIs related to Grid stability services / software and services for DSO	
System Average Interruption Frequency Index (SAIFI)	
System Average Interruption Duration Index (SAIDI)	
Degree of self-supply (%)	
Harmonic distortion (%)	
Voltage quality compliance / Voltage deviation (%)	
Frequency quality compliance / Frequency deviation (%)	
Generation forecast accuracy (%)	
Consumption forecast accuracy (%)	
Reduced frequency or intensity of congestion (%)	
Reduced Energy Curtailment of DER (kWh)	
Increase in DER hosting capacity (kW)	
Technical energy losses (kWh)	
Peak shaving / Peak-to-average ration improvement (kW or %)	
Percentage of consumer load capacity participating in DSM (%)	
Technical KPIs related to software and services for aggregator	
Degree of self-supply (%)	
Peak shaving (kW or %)	
Generation forecast accuracy (%)	

Consumption forecast accuracy (%)	
Flexibility availability forecasting accuracy (%)	

This is of course a drafted version of a generic KPI list for projects related to smart grids, energy storage, islands, and digitalisation.

Further work is needed in the KPI evaluation process. A list of areas to investigate for the drafting of the guidelines are:

- Expand the list of generic technical KPIs using the remaining projects under BRIDGE
- Build up subcategories of technical KPIs which encompass the span of objectives of BRIDGE projects

Each project consortia needs to identify the following for tracking progress work of their KERs:

- For the chosen KPIs, build the missing data resource and develop the automated process for collecting the identified data that will feed the KPI evaluation process.
- For each chosen KPI, identify the base case scenario that will be compared to for validating the performance of the primary KER.
- For each base case scenario, establish the sourcing of the required data to be automated in the evaluation process.

2.7 Subroutine 4: Results Analysis, identification of limitation factors and alternative solutions

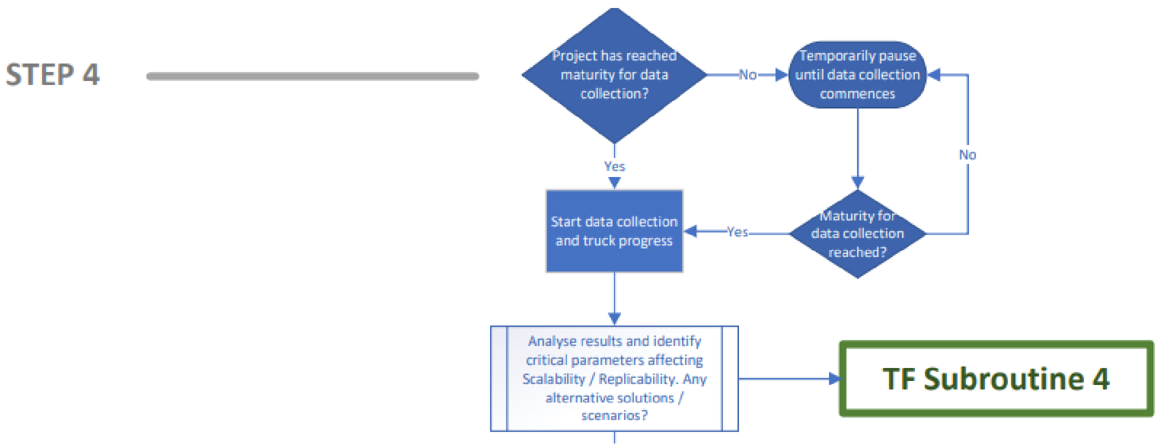

Figure 15. Step 4 in the SRA Methodology Overview

Projects as indicated in the paragraphs above will identify,

- KERs with a good description of the advancements that are envisioned through the project,
- Generic KPIs through which progress made through the project in the targeted developments of the project i.e. KERs
- Base case scenarios that result will be judged on using valuable data generated through the project feeding appropriately the identified KPIs for tracking progress and results achieved.

It is of vital importance that projects should set a process through which results are monitored continuously feeding the KPI processes that lead to quantitative analysis that will judge performance compared to base case scenarios and degree that technology developments are delivering.

Consortia should set a quality cycle, so that through the conducted analysis, they quantify the identified in subroutine 2 critical parameters affecting scalability / replicability. The critical parameters can be:

- Proprietary solutions that require the development of open standards in linking them to the various SGAM layers.
- Missing communication standard
- Missing data standard
- Missing system code
- Missing market rule or mechanism
- Any other

Thus, this project quality loop will operate as the process for developing the solutions that will minimise the identified limiting factors for achieving seamless scalable and replicable solutions or improve to the maximum degree possible. Alternative solutions will be sought and if identified, they will be fed in back in the project set up process to influence appropriately the active contributors to improve and restrict to the highest degree possible the effect of identified limitations. This will be pursued to the degree that the identified solutions can allow. This process will be repeated as long as the conducted analysis of results identify areas for improvement. Final solutions will be noted and systems developed should be described in detail to form the revised deliverables of the projects including revised replicability and scalability indices.

Moreover, this quality loop will Identify future work that will surpass any remaining limitation factors indicating where possible solutions and possibilities.

3. Methodology: Best practice approach (use case collection – link with Data Management WG)

In support of the above identified guiding methodology for building the scalability / replicability process of projects, there is an identified need for developing the following supporting libraries:

- **Targeted use cases: The technology solutions for developing the smart system of 2030 / 2050 mapped in the SGAM architecture.** Consortia are vested with the responsibility of mapping the objectives of their projects in the SGAM environment and follow the methodology described in the earlier sections in order to build the scalability and replicability capabilities of their projects. This is the first and important step of every project consortium and it will be very helpful if they see examples of previous mappings to help them to do it correctly and not start from scratch each time. This library of use cases should continuously grow to facilitate the solution adaption of project consortia in mapping their planned project objectives and maximising the benefits of the SGAM process. This repository will contain the adapted mapping together with a detailed description of the use case and what makes it different from other related use cases that have been archived in the repository. An attempt will be made to adapt a coding system that will help to manage the repository with an effective query application based on an effective taxonomy. The taxonomy will divide the use cases that are built in the repository, in brought category depending the on the technologies they serve so as to help the project consortia to choose a use case which is the most relevant to their project.
- The family of solutions provided through the adapted use cases will be exhaustively linked to approved standards and codes provided by the appropriate EU bodies: CEN, CENELEC, ETSI, ENTSO-E etc

The above identified work is under development within the EIRIE platform and is expected to be a tool hosted under the platform (www.eirie.eu).

4. Annex 1

4.1 The classification of technologies

No.	Group of technologies	Systems of Technologies/Nesting	Technologies Description
1	Integrated Grid	Flexible ac transmission systems (FACTS)	Controllable power electronic equipment that will support the Transmission smart grid operations
2		Models, Tools, Systems for the operation analysis, control and the development of the integrated grid including cost elements	Advanced models, tools, systems for the operation analysis, control, state estimation and the development of the integrated grid (TYNDP etc) including cost elements
3		HVDC	High Voltage Direct Current overhead and underground grid.
4		Forecasting (RES)	Advanced forecasting tools (RES) that will allow a low estimation error and provide a accurate feedback for the actors that need this type of services. E.g. aggregators, operators, RES owners, ESP, the market operator etc.
5		Asset management	The methodology, procedures, the devices and software that allow the efficient management of assets of the integrated grid.
6		Outage management, fault finding and associated equipment (including protection)	The methodology, procedures, the devices and software that allow the efficient management of outages including fault finding of the integrated grid.
7		Equipment and apparatus of the integrated grid	All the primary equipment (rated at the rated voltage of the system) and apparatus constituting the integrated grid including Power guards and limiters.
8		Equipment, sensing, monitoring, measuring for analysis, solutions and control	Equipment, sensing, monitoring, measuring for analysis, solutions and control including procedures and software that make observable the integrated grid. These include the devices and the procedures that allow PMUs, PDCs and GPS to be efficient tools of the smart grid paradigm
9		Advance distributed load control	Software or hardware devices or procedures that allow advanced

			distributed control of distributed assets of the grids including different type of DERs and load
10		Feeder auto-restoration / self-healing	Advanced procedures and systems that facilitate the feeder auto-restoration thus implementing the self- healing of the interconnected system
11		Smart metering infrastructure	All the procedures and systems that are related to smart meters as devices and complete bi-directional communication link between metering data management systems and end users.
12	Customers and market	Distributed flexibility, load management & control and demand response including end devices, communication infrastructure and systems	All procedures, controls and devices that facilitate distributed flexibility, load management including explicit demand response and system
13		Smart appliances	Smart appliances that allow customer market participation and smart load control.
14		Building control, automation and energy management systems	All procedures, controls and devices that secure smart building automation including home energy management, active control, monitoring and market participation
15		Electric vehicles	Electric vehicles are vehicles based on battery or fuel cell resource for transport needs.
16		Energy communities	
17		Lighting	Any apparatus emitting light and related systems.
18		Electricity market	All elements of the electricity market including platforms that enable wholesale, retail, real time pricing / spot, flexibility, aggregated and peer to peer trading including ancillary services, etc.
19	Storage	Storage Electric	In the electricity system, apparatus capable of deferring the final use of electricity to a moment later than when it was generated, or the conversion of electrical energy into a form of energy which can be stored, the storing of such energy, and the subsequent reconversion of such energy into electrical energy.;

20		Thermal Storage	The main parts and all auxiliary components that form a ready to integrate device capable of storing thermal energy for use at a later stage.
21		Power to gas	The main parts and all auxiliary components that form a ready to integrate device from technologies that uses electrical power to produce a gaseous fuel for storing or use otherwise.
22		Pumped storage	The main parts and all auxiliary components that form a ready to integrate system to operate as a Pumped storage system which is the process of storing energy by using two vertically separated water reservoirs. Water is pumped from the lower reservoir up into a holding reservoir. Pumped storage facilities store excess energy as gravitational potential energy of water.
23		Other Storage	The main parts and all auxiliary components that form a ready to integrate device capable of storing energy other than the above systems.
24	Generation	Flexible generation	The main parts and all auxiliary components that form a ready to integrate device
25		Solar including PV & CSP	The main parts and all auxiliary components that form a ready to integrate systems capable of generating electricity from PV or CSP technologies.
26		Wind	The main parts and all auxiliary components that form a ready to integrate systems capable of generating electricity from wind technologies.
27		Hydropower	The main parts and all auxiliary components that form a ready to integrate system, capable of generating electricity from flowing hydro.
28		Hydrogen & sustainable gases	The main parts and all auxiliary components that form a ready to integrate systems capable of generating electricity from hydrogen and other sustainable gases.
29		Other generation	The main parts and all auxiliary components that form a ready to

			integrate systems capable of generating electrical energy other than the above.
30	Digitalisation, Communication and Data	Communication networks including devices and systems for signals and data connectivity and solutions	Any combination of equipment and systems forming a communications network as a group of nodes interconnected by links that are used to exchange messages between the nodes. The links may use a variety of technologies based on the methodologies of circuit switching, message switching, or packet switching, to pass messages and signals including Local Area Networks, Home Area Networks and web-based solutions and cloud services for smart gird operations
31		Digital Twins	Any combination of equipment and systems forming Digital twins that are virtual replicas of physical devices that can used to run simulations before actual devices are built and deployed.
32		Artificial intelligence	Any combination of equipment and systems forming Artificial intelligence that simulates human intelligence in machines that are programmed to think like humans and mimic their actions.
33		Data and cyber security including repositories	Any combination of equipment and systems offering Cyber security for defending computers, servers, mobile devices, electronic systems, networks, and data from malicious attacks, including generated data from the interconnected system with related repositories other than that related to the MDMS (Meter and Data Management System).

5. Annex 2

Within this Annex, the validation process of the methodology described in the main text is provided. All the projects listed has validated all SRs and their results are summarised below. Of course, this is seen as a rolling procedure and it is expected that as the projects mature more data and updated information shall be given.

5.1 eBalancePlus

Step 1:

Define the project's objectives

eBalancePlus project	
Key objective of the project: The e-balance Project aims at integrating the energy customers into the future smart-grids in order to address future environmental problems with holistic technical solutions based on ICT, new business models and citizens' behaviour under real world conditions.	
Objective 1	Develop and deploy a replicable and scalable energy balancing platform
Objective 2	Quantify and manage the available energy flexibility at building and LV grid level in real time
Objective 3	Identify and describe barriers to innovation
Objective 4	Demonstrate a rich variety of flexibility solutions such as smart-storage, electric charging points for vehicles (V2G), demand response based on IoT, and power-to-X technologies to increase the energy flexibility in low voltage grids

Step2:

Define in detail the innovation areas of the project and build through them the KERs of the project

KER1 | Smart-storage solution to unlock and manage building flexibility

- KER1a. INNOVATION: three-phase model high power storage at building level (component layer)
- KER1b. INNOVATION: handling large amounts of information, more than before (information layer)
- KER1c. INNOVATION: interact with ebalance-plus platform (function layer)

KER2 | Prediction models and balancing algorithms which enable new possibilities for the electric market INNOVATION: delivering high quality forecast data on very fine-granular level (function layer)

- KER3 | User-oriented IoT solutions to engage building users into the electric market
- KER3a. INNOVATION: IoT hub to integrate multiple building technical systems and devices (component layer)
- KER3b. INNOVATION: multiprotocol hub (communication layer)
- KER3c. INNOVATION: mobile app based on user engagement techniques

KER4 | Control and automation LV and MV solutions to increase the electric grid observability, make the system safer and secure and use the available flexibility for it
INNOVATION: Modular architecture (common elements between components) with processing power for edge computing (component layer)

KER5 |Comprehensive energy balancing platform to manage hidden flexibility of buildings and distribution grids

- KER5a. INNOVATION: bi-directional communication between units, hierarchical and fractal-like architecture (communication layer)
- KER 5b. INNOVATION: Data model / ontology / middleware deals with different communication protocols, different info from different units, user preference, tariffs, etc. (information layer)
- KER 5c. INNOVATION: flexibility mechanisms & energy efficiency services (function layer)

KER6 | Integrated Smart Hubs - solar carparking, battery energy storage and V2G electric vehicle charge management

- KER6a. INNOVATION: SiC-based DC-DC V2G chargers (component layer)
- KER 6b. INNOVATION: flexibility mechanisms and services (function layer

KER7 | Cloud-based microgrid optimisation platform
INNOVATION: Advance energy optimisation algorithms based on AI.

Identify role of innovation areas in building and operating wider systems following the SGAM approach.

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