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Abstract
This document is defining a set of Key Performance Indicators (KPIs) associated with the European Electricity Grid Initiative (EEGI) Research and Innovation Roadmap 2013-2022. It is a methodological guide which facilitates the usage of the KPIs in the framework of EEGI and/or R&I projects related to the EEGI Roadmap.

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EXECUTIVE SUMMARY

The objective of this update to the European Electricity Grid Initiative (EEGI) Key Performance Indicators (KPIs) defined in D3.4 [1] is to provide further support and practical insight into the practical application of the indicators to address areas of common interest and to make improvements based on the feedback that has been received. The feedback has provided us confirmation that the EEGI KPIs are relevant to ongoing projects and EEGI related activities. Using suggestions from other projects we have provided further recommendation on the application of the KPIs and additional examples of possible calculation methodologies. These include recommendations on where the KPIs could be applied within a Research and Innovation (R&I) programme and what type of calculation methods could be expected. We also consider the risks to large scale deployment and representation of uncertainties using a sensitivity analysis. Not only does this provide an approach for numerically representing uncertainty, it will also provide a mechanism for quantifying the impacts of the various uncertainties which could be shared with the relevant stakeholder to assist any decision making process. A more practical calculation approach based on network planning is also suggested for the Improved Hosting Capacity indicator.

There are projects already using similar indicators to those that have been defined by the EEGI. The indicators are currently being used by the FP7 funded IGREENGrid for evaluating the KPIs at programme level and addressing the scalability and replicability of R&I solutions related to EEGI Roadmap objectives. The expectations beyond GRID+ are that new projects will adopt the EEGI KPIs when defining their own project KPIs. This is expected to be achieved after the completion of the GRID+ project by the continued use of the tools such as the Knowledge Sharing Platform that have been developed and promoted by GRID+.

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1. INTRODUCTION

In April 2013 a set of KPIs were defined for the EEGI programme and are these are described in the GRID+ public deliverable D3.4. These indicators are related to the coherent set of R&I activities that are defined in the EEGI Research and Innovation (R&I) Roadmap 2013-2022 (EEGI Roadmap) [2]. The KPIs were tailored to capture the enabling role of network operators to reach the ambitious European energy goals and to make the targeted low carbon economy a reality at affordable costs by 2050.

Within deliverable D3.4 a proposed framework is described based on two categories of KPIs: Implementation Effectiveness KPI, which measures the completion of the EEGI Roadmap; Expected Impact KPIs, these will measure the benefits achieved by European R&I projects and are split into three levels, Overarching, Specific and Project KPIs. The monitoring of these KPIs will help prepare the deployment of promising network innovations as demonstrated by the EEGI activities together with national regulatory bodies, that are supported by proper scalability and replicability studies.

A definition and a general methodological guide for each KPI is also presented in D3.4. The detailed calculation methodologies are assumed to be done within projects or possibly defined in dedicated TSO and DSO documents.

The methodological guide helps to determine and estimate as accurately as possible the benefits that different innovations might bring. It is not intended to halt any of the innovations at the R&I stage, but to frame in what circumstances they can be useful in order to widen the portfolio of solutions available for decision-makers. It should be noted that not only are the numerical results of the KPIs important, but also the frame and the interpretation of the results according to the circumstances.

Since the publication of the definition of the EEGI KPIs in deliverable D3.4 members of the GRID+ team have been actively promoting the use of the KPIs by EEGI related projects and activities and also asking for feedback and suggestions how the indicators could be further improved. This included participating in dissemination events, published a technical paper for CIRED [3] that was presented at in the CIRED 2014 event in Rome. Workshops and web conferences have also been organised as a means of promoting the application of EEGI KPIs and obtaining feedback from EEGI related projects.



This document provides an update to the EEGI KPIs based on the feedback received from European projects and other EEGI related activities. Further guidance is provided to projects and other stake holders on the practical application and calculation of the KPIs.

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2. FEEDBACK RECIEVED ON EXPECTED IMPACT KPIS

Feedback on the definition and calculation of the EEGI Expected Impact KPIs has been received from other European projects and EEGI related activities. Most of this feedback has been obtained from interaction and dissemination events throughout the course of the last year.

Feedback has also been provided by the FP7 funded project IGREENGrid. A description of the feedback from IGREENGrid will be published in the IGREENGrid public deliverable D4.1 (Report listing selected KPIs and precise recommendations to EEGI Team for improvement) [4].

Some reoccurring themes were identified where there was common interest or the identification of common problems that could be associated with evaluation of the Expected Impact KPIs. A summary of these challenges is provided here and possible solutions are provided in Section 3 of this document.

More clarity is needed for the definition and calculation method of the B.1. Increase RES and DER Hosting Capacity KPI

There were numerous comments and questions regarding the RES/DER hosting capacity KPI. It does appear that this indicator is relevant to many ongoing EEGI related activities and particularly large scale demonstration projects where novel technologies are being applied to achieve cost effective solutions that can be implemented in relatively small time scales to address potential problems on the network associated with increasing the amount of renewable energy generation capacity that the network can host. It became apparent that a more practical definition and calculation methodology would be needed for the application of this indicator to evaluate the deployment potential of solutions that are currently being tested in large scale demonstration projects. In practice it is understood that network operators will deploy a technology based on its ability to provide a safe, reliable, sustainable and cost effective solution for a given problem, or expected problem on the network. The KPI could be improved by including a cost element in its definition. As an addition to the previously proposed calculation formula and methodology in D3.4 some further options, including a cost element based on a two possible approaches: 1) based on network planning and 2) the potential to defer network reinforcement costs, are proposed in Section 3.

Uncertainty associated with parameters that will impact the successful deployment of R&I solution

Again, mostly relating to solutions that are currently being tested across Europe in large scale demonstration projects, there is some uncertainty over the future conditions related to some of the following areas:

- **Regulatory conditions** – we are witnessing a paradigm shift in the electrical power systems across Europe. This is principally as a result of the increasing amounts of renewable generation that is key to achieving the European targets for reducing green house gasses and tackling climate change. The current model that is based on generation follows demand and power is distributed downstream by static distribution networks with unidirectional flows is no longer valid. It is expected that as a result we will see a paradigm shift in the regulatory conditions in which these systems operate. This is a fundamental requirement to facilitate the changes that are now needed to meet these European objectives. Since we are currently in the middle of this transition, where we have new technologies that are already being deployed in large scale demonstration projects, but we are still operating under regulatory conditions that are representative of the old mind set, there could be some difficulties in evaluating how the regulation will change and how this will impact the effectiveness and successful deployment of the solutions that are currently being developed as part of a strategy to meet the European energy goals
- **Market design** – this is one of the clusters defined within the EEGI Roadmap, although the objectives may be defined within separate clusters in the EEGI Roadmap they cannot be considered in isolation. Market design is seen as a dependency for evaluating the success of many of the other objectives define in the EEGI Roadmap. For example, solutions developed for the integration of smart customers (Cluster C1) will be strongly dependant on market designs. Difficulties may be experienced where solutions are being developed, maybe within a large scale demonstration project, where market design will play a key role in its successful deployment, but market design and market rules are yet to be defined either nationally or across the wider European systems
- **Customer participation** – this is another area which could have a substantial impact on the successful deployment of new technologies. An obvious example would be active demand. Human behaviour is not always easy to predict and there is likely to be differences between

different countries, or even within the same country where different cultures or a different way of life exists.

- **Network planning rules** – it is evident that there are cases where technologies are being tested in large scale demonstration projects but it is not yet clear how the application of these solutions can be considered at the network planning stage. In many cases these are new technologies that are not currently included in existing network planning rules. The implications of the network planning rules that are used at the market uptake phase could have dramatic effects on the benefits that can be realised and the successful deployment of these technologies
- **Cost of technology** – during the development stage of a technology and while there is a relatively small market demand for the new technology, the manufacturing costs are expected to be higher compared to what they would be at a large scale deployment or market uptake phase. The uncertainty of what these costs will be at the market update phase can present problems when evaluating the deployment potential of the solutions that are currently being tested in large scale demonstration projects.

These could all have a potential impact on the successful deployment of the R&I solutions. A suggested approach, based on a sensitivity analysis, to address these uncertainties when calculating a KPI to evaluate the deployment potential of a solution is given in Section 3.4.

More clarity needed over application of EEGI KPIs

Some questions were raised over where the EEGI KPIs would be applied. The purpose of the KPIs is to provide a platform for EEGI related activities and to communicate the objectives of the EEGI. The EEGI KPIs or an adaptation of the EEGI KPIs can be used at any stage of the R&I programme. These are specific to the EEGI and the objectives defined in the EEGI Roadmap, but could also be applied to other initiatives or R&I programmes, one example would be the SET Plan Integrated Roadmap and Horizon 2020.

A further explanation and some examples of what type of calculation methodology could be used at different stages within the R&I programme are given in Section 3.3.1.

Additional indicators could be introduced to cover benefits that might not be covered by existing EEGI KPIs



It is recognised that not all aspects of power transmission and distribution systems are captured in the seven Expected Impact KPIs defined in D3.4. The idea was to focus on the core objectives of the EEGI Roadmap and to provide a tool for monitoring the main aspects that will contribute towards the overarching goals of the EEGI. This does not mean that other aspects should not be considered and other projects or other EEGI activities should have flexibility to focus on their specific needs and interests while trying to encapsulate as much as possible the themes defined by the EEGI KPIs.

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3. FURTHER RECOMMENDATIONS ON EXPECTED IMPACT KPIS

Based on the feedback described in the Section 2 of this document some recommendations are provided here to address any ambiguities, common concerns or areas of interest for the EEGI Expected Impact KPIS. This includes an update to the approach for evaluating the indicator *B1. Increased RES and DER hosting capacity*, some further guidance for how the Expected Impact indicators may be calculated, in addition to what has been previously provided in D3.4, and some possible approaches for calculating the indicators (ex-ante) given some of the current uncertainties concerning the future evolution of electrical power systems throughout Europe and hence how to address uncertainty of how this will impact the R&I solutions that are being developed.

3.1 Updated calculation methodology for B.1 Increased RES and DER hosting capacity KPI

In Annex B of D3.4 a calculation methodology is given for the Expected Impact KPI *B.1. Increase RES and DER hosting capacity*. Based on feedback received and further consideration of how to best measure the achievement of the goals linked to this indicator it was decided to make some modifications to the calculation methodology and to provide more detail and examples of how this indicator could be calculated. A complete description of the updated methodology is provided in ANNEX A. A summary of the changes and justification for these updates are described here.

An opportunity to improve the previous calculation methodology that was provided in D3.4 for *B.1. Increase RES and DER hosting capacity* KPI was identified. Ultimately most problems on the network could be solved using the business as usual approach, i.e. reinforcements to the network such as upgrading substations, new overhead lines, etc. The real limitations to the success of these solutions would be investment costs and the practicality of implementation. The practicality aspect would include the time scales involved to build new or upgrade existing infrastructure and also limitations on what can be done at all. It is becoming increasingly difficult to build new overhead lines or carry out intrusive construction works. Without these limitations it could be feasible to provide unrealistic expectations for the increase in hosting capacity that can be expected. A similar argument could also be made for the R&I solution. It is also not expected that the objective of network operators will be to maximise the hosting capacity on the network, but instead to find the

best solution given the expected demands on the network. Since these indicators will be applied to evaluate the deployment potential of the R&I solutions, a more practical and realistic approach is needed and this was consistently the message that was received in the feedback.

Network planning approach

The first approach for evaluating the Increased RES and DER hosting capacity KPI could be based on a conceptual method based on network planning. A more detailed description is given in ANNEX A. This approach will measure the unit cost of increasing the networks hosting capacity (k€/MW or k€/MVA). The advantage of using a cost element is that the cost could include a risk factor that can be applied to the investment and operational costs. The risk element would represent practicality or elements of uncertainty associated with any given solution that is considered. It is expected that the indicator will be calculated using computer based modelling and simulation studies, where the results of ongoing or completed large scale demonstration projects could be used to validate the models that are developed.

Deferring reinforcement approach

Another approach that could be used would consider how much additional capacity can be realised, beyond that which already exists, by the deployment of the R&I solution on the existing network before reinforcements would be needed. This could be calculated as the amount of power (MW or MVA) or as a unit cost of increasing the hosting capacity (k€/MW or k€/MVA). More details and an example of using this approach is provided in ANNEX A. Using this approach the indicator could be calculated either ex-ante or ex-post.

3.2 Calculation of Expected Impact KPIs

It is expected that the EEGI KPIs will be used as a starting point or as a point of common reference and the precise details of how KPIs are calculated could be customised within a specific project or cluster or projects addressing a common objective. This common objective could be a Functional objective or Cluster from the EEGI Roadmap. The diversity of potential solutions addressing the objectives defined within the EEGI Roadmap and the range scenarios in which they will be applied was recognized when defining the EEGI KPIs and efforts were made to maintain a balance between providing an appropriate level of flexibility while avoiding ambiguity. An example of where the EEGI KPIs have been used as a starting point and further elaboration has taken place in both the

definition of the KPIs and the calculation methods can be seen in the FP7 funded IGREENGrid project. Feedback has also been provided to the EEGI from the IGREENGrid project (public deliverable D4.1). This feedback is summarized in Section 2 of this document and includes recommendations for both the definition and the method of calculation of the KPIs.

The following guide for calculating EEGI KPIs was developed based on the recommendations provided from the IGREENGrid project and other feedback received from GRID+ dissemination and interaction activities (these are described in Section 2 of this document). This guide will include examples of how ex-ante and ex-post calculation methods could be used. The guide is intended to enhance the understanding of the intended application and purpose of the EEGI KPIs. Given the wide scope associated with the application of the EEGI KPIs, the actual method used for calculation is to be determined within the project in which the KPIs will be evaluated. Ultimately this will be done as a study that could be a research project into a particular technology, linked to a large scale demonstration project or a project or academic study that considers the results of several large scale demonstration projects. A guide for the calculation of EEGI KPIs is described in the next section of this document.

3.3 Further Guidelines for the Calculation of EEGI Expected Impact KPIs

While using the definition EEGI KPI definitions as a foundation, the precise definition and calculation methodology should be determined within the specific project or academic study and will be based on several factors

1. Within which phase of the research and innovation programme the KPIs are applied
2. The type of solution that is being evaluated

The next sections will provide a more detailed description of what these factors are and will provide some examples and different calculation approaches that may be used. This is addition to the guidelines that are provided in Section 5 of D3.4.

3.3.1 Consideration to which phase of the EEGI R&I programme in which the KPIs will be applied

First of all we will start by describing the different development phases that are associated with the EEGI R&I programme and the more recent SET Plan Integrated Roadmap and where within this the

EEGI KPIs could be applied. Whether we consider the EEGI R&I programme or the SET Plan Integrated Roadmap, the research and innovation programmes can be broken down into the following three distinct phases:

1. Advanced research
2. Large scale demonstration
3. Market uptake

The approach for calculating the values of each indicator would be expected to vary depending on which phase of the R&I programme the EEGI KPIs are to be applied.

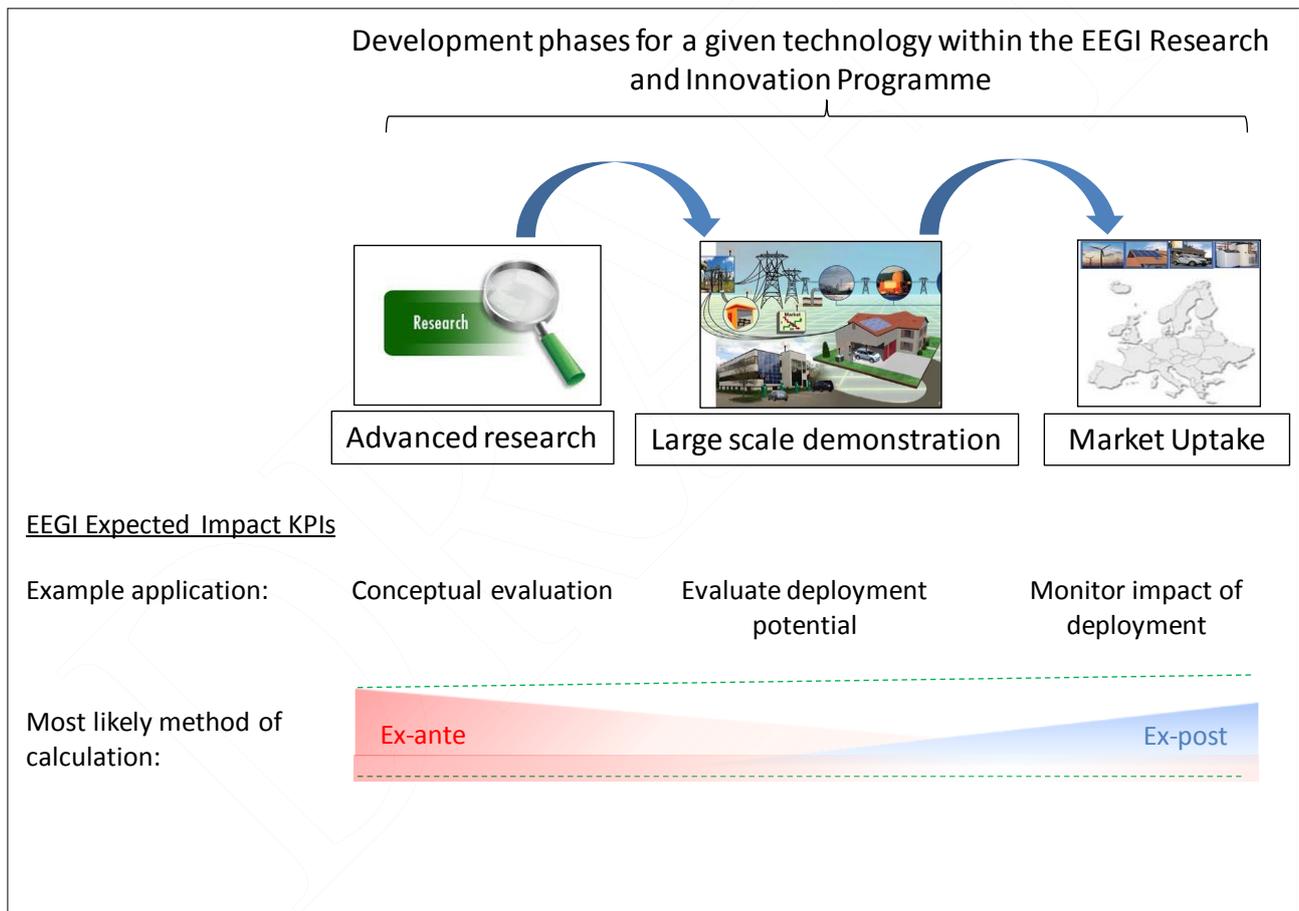


Figure 1 Application of EEGI Expected Impact KPIs to R&I programme

Here are some example of the application and calculation methods that could be used at each of the R&I programme phases.

Advanced research

The EEGI Expected Impact KPIs could be used to evaluate a specific technology using high level assumptions and simplifications to provide a representative model of the European electrical transmission or distribution system where the technology will be applied. For example the CIGRE 10 node transmission and 12 node distribution network models described in the GRID+ deliverable D3.4b [5] or similar could be used. Other assumptions could be made based on regulatory conditions, network planning rules, load and generation scenarios, market conditions and consumer behaviour, etc. If the EEGI KPIs are used at the advanced research stage it is highly likely that the calculation of these indicators will be done using computer based modelling and simulation studies (ex-ante) at a conceptual level and based on the assumptions described. The results from pilot projects or academic studies may be used to provide or validate the models that are developed but the evaluation of the KPIs would be done ex-ante.

Large scale demonstration

At the large scale demonstration stage the EEGI Expected Impact KPIs could be used as a tool to evaluate the deployment potential of a given solution that is being tested in a large scale demonstration project. An example application of these indicators would be to both monitor the effectiveness of the solution(s) that are being tested in the demonstration project using actual results obtained from 'field data' (Ex-post) and to evaluate the potential for large scale deployment, or market uptake, of these solutions outside the demonstration project and under different boundary conditions. As described in Section 5.1 of D3.4, an initial evaluation of the KPIs could be based on the expected benefits of the project at the proposal stage, although the application of the indicators here would be strictly limited to the demo project itself and would not necessarily consider the large scale deployment potential of the solutions. Evaluating the deployment potential of the solutions that are being tested in the demonstration project is effectively a study of the scalability and replicability and this could be done using computer based modelling and simulation studies (Ex-ante). The model that could include planning rules, costs, etc. could be based an evaluation of standardization, regulatory conditions, etc.

This is currently one of the main challenges for projects that are currently applying the EEGI KPIs at this stage to evaluate the deployment potential of solutions that are being tested in large scale

demonstration projects. A further description of this challenge and possible solutions are given in Section 3.4.

Market Uptake

At the market uptake phase the application of the EEGI Expected Impact KPIs could be used to monitor the progress towards achieving the expected benefits from the deployment of novel solutions on the network. At this phase, although simulation studies would still be used for example in network planning or evaluating a CBA, it is expected that the evaluation of the indicators would be more focused on measured results from 'field data' (Ex.post).

3.3.1 Consideration of which type of solutions are being deployed

The EEGI Expected Impact KPIs were first defined in the GRID+ deliverable D3.4 and a guidelines on the application and evaluation of each indicator are provided in Section 5. Further details are also provided along with an example calculation methodology in Annex B for both TSO and DSO projects. In addition to the information provided in D3.4, consideration should also be given to the following:

The calculation methodology that is used will inevitably depend upon the type of solution or solutions that are being applied

The calculation technique and method will ultimately be determined by the type of solution that is being evaluated. For example, the level of detail of the models that are used for ex-ante calculations will be should be determined by the functionality of the R&I solution and different approaches may be used where several different types of R&I solutions may contribute to a given indicator.

Within a given project several different solutions may contribute the value of an indicator

It is also expected that within a large scale demonstration or a deployment project, there may be several solutions that could simultaneously contribute to the results of one indicator. This could create difficulties for evaluating the indicator ex-post, using field measurements. In this case it is expected that the expected impact indicators will be evaluated using simulation studies and the results from the demonstration projects could be used to validate the models used and the results for the simulation studies.

3.4 Proposed solutions to address uncertainties

Through various interaction and dissemination events that have been carried out over the last year the GRID+ team has received valuable feedback from other projects throughout Europe. Some of the feedback received is summarized in Section 2. Through this feedback we also received a consistent picture of some of the main challenges that are expected when evaluating the EEGI Expected Impact KPIs. These can vary depending on which stage of the R&I programme the indicators are being used. At the time of writing, most of the interest in the application of EEGI KPIs seems to be focused towards evaluating the results of large scale demonstration projects and evaluating the deployment potential of the solutions being tested.

As described in the previous section the EEGI Expected Impact KPIs may be used as one of the tools for evaluating deployment potential of the solutions using ex-ante calculations. This will involve computer based modelling and simulation studies to assess the replicability and scalability of the solutions.

In order to evaluate the impact of these solutions ex-ante either detailed information or assumptions are needed to define operational aspects of the system that will directly impact the performance of the solutions under evaluation. Some degree of uncertainty could be associated with the future status of the following:

1. Regulatory framework
2. Market rules / conditions
3. Network planning rules
4. Cost of new technology at market deployment

Where uncertainty exists, assumptions need to be made. An approach that could be adopted would be to assume a realistic set of conditions that would allow the maximum potential and optimise the performance and benefits achieved by the R&I solution. A sensitivity analysis could then be completed imposing increasing operational restrictions on the R&I solution. The sensitivity analysis could then be used to evaluate the risk of deployment or the risk on investment of the R&I solutions.

Here is an example where a sensitivity analysis could be used to address uncertainty associated with future regulatory conditions when evaluating the deployment potential of a voltage control solution to enable the integration of DER on the network.

Example: Uncertainty over regulatory conditions for the deployment a voltage control solution to enable the integration of DER on the network

Relevant indicators: The indicators that would be relevant to the voltage control solution described here would be **B.1. Increased RES and DER hosting capacity** and **B.2. Reduced energy curtailment of RES and DER.**

Description of challenge

From some of the ongoing large scale demonstration projects we have seen that one of the first limitations for increasing the amount of renewable generation (DER) that can be connected to a distribution network is imposed by maintaining a voltage profile within the defined operational limits. It is perhaps no coincidence that we see this as a focal point of ongoing activities to increase the hosting capacity for DER on distribution networks.

Some of the solutions that are being demonstrated use a controllable component on the network to regulate the power that is injected using various control solutions. One of the components that could be used is a “smart” inverter. Here the amount of active or reactive power that is injected into the network at the point of common coupling can be regulated by some kind of control system. One of the main challenges for evaluating the deployment potential of these solutions is how to address the lack of details available on the regulatory constraints that will be in place at the deployment (or market uptake) phase of the R&I programme. Since, for many distribution networks, existing regulation does not permit the control of power injected by the DER customers, in some of the demonstration projects bilateral, non-regulated contracts between the DSO and DER customers have been used.

Possible solution

Ex-ante studies using computer based modelling and simulations could be used to evaluate the deployment potential of these solutions. For the purpose of developing these models it is accepted that certain assumptions would have to be made about the regulatory conditions under which the DSOs would operate. The assumption would be based on the most optimum but realistic conditions that could be foreseen to maximize the potential of the solution that is to be evaluated. A sensitivity analysis could then be performed using more a more restrictive criteria for the regulatory conditions

applied. This is illustrated in Figure 2. The outcome of these studies could then provide an optimum outcome with a risk element that could be factored in to cover the uncertainty relating to regulatory conditions. An advantage of using this approach could be that the conclusions from such a study could potentially be used to present a case to the regulatory authority to justify new arrangements that would support the deployment potential of the R&I solutions and hence the benefits that could be realised by the end user.

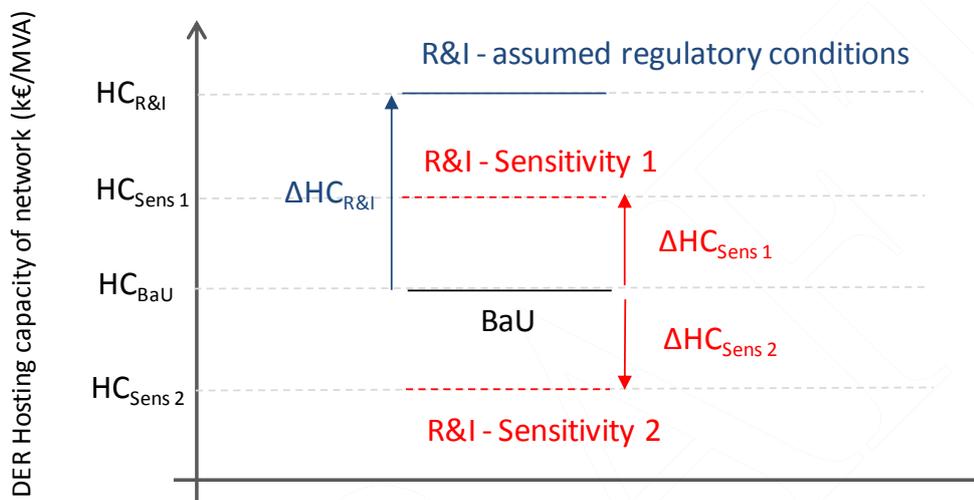


Figure 2 Evaluation of *B.1. Increased RES and DER hosting capacity KPI* for a modelled using assumed regulatory conditions with sensitivity analysis

The evaluation of the *B.1. Increased RED and DER hosting capacity KPI* is illustrated in Figure 2sopra. Here the indicator is evaluated using ex-ante studies with the application of assumed regulatory conditions which are both realistic and the most optimal to realise the full potential of the R&I solution being deployed. For example, for the voltage control solution using “smart” invertors, the regulatory conditions will allow the DSO to control, within sensible limits, the amount of power that is injected into the network at the point of common coupling at any given time. Economical aspects of this scheme such as compensation to the customers would be factored in to the evaluation of the KPI using the cost of increasing hosting capacity by unit of power formula (k€/MVA) as proposed in Section 3.1. This formula could include both capital and operational costs. The model could then be modified to represent more stringent regulatory conditions, perhaps allowing less control of the injected power from the DER or imposing a higher operational cost associated with



the regulation of the injected power. One of these sensitivity scenarios could also include a range of existing regulatory conditions currently in place throughout Europe. The impact of these different regulatory schemes would then be captured by the evaluation of the indicator to provide a sensitivity analysis. This sensitivity analysis could then be used to evaluate the risk of investment and potentially to provide vital conclusions from these results to the regulating authorities.

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4. CONCLUSIONS

The feedback received from various interaction events and European projects and related EEGI activities provides us with the conclusion that the indicators defined are relevant and could be applied to evaluate the progress towards achieving the goals of the EEGI at programme level using the results from research and demonstration projects.

Further studies are needed to study the scalability and replicability potential of the solutions that are being developed. These studies could potentially use the evaluated KPI results from projects that are already using similar indicators. It is expected that these results will also come from new projects that have intentionally aligned their KPIs to those defined by the EEGI as a result of the promotional activities that have taken place within GRID+ and with the continued availability of the EEGI tools such as the Knowledge Sharing platform. The FP7 funded project IGREENGrid is starting to address this with a focus on the integration of Distributed Renewable Energy Sources (DRES) on distribution networks which is directly related to Cluster C2 of the EEGI Roadmap.

Based on the feedback received, some further guidelines have been developed to explain where and how the EEGI indicators are expected to be applied, how to address uncertainties and also some further guidelines and alternative approaches for calculating the Increased RES/DER Hosting capacity KPI. These include:

- A suggestion of where the KPIs could be applied in the EEGI programme and what sort of calculation method would be expected (ex-ante or ex-post)
- An approach for addressing uncertainties when calculating the KPIs. These uncertainties might be related to the large scale deployment of the solutions that are being tested in demonstration projects. Uncertainties could include regulatory conditions, cost uncertainty, uncertainty on level of standardisation, social acceptance, etc. The approach describes a method of assuming “best case” conditions and then applying a sensitivity analysis by introducing limitations that could be imposed by these uncertainties. Not only does this provide an approach for numerically representing uncertainty, it will also provide a mechanism for quantifying the impacts of the various uncertainties and this could be shared with the relevant stakeholder to assist any decision making process.

- An alternative approach for calculating the Increased RED/DER Hosting capacity indicator is provided. On the basis of feedback received it was decided to provide a comparison to the Business as Usual approach using network reinforcements by considering the economical aspects of the R&I solution. Two approaches are provided, first using a network planning approach and the second is based on the economical benefits realised by deferring network reinforcements.

The purpose of the EEGI KPIs is to provide a basis for evaluating the progress achieved in projects and other EEGI related activities towards achieving the objectives defined in the EEGI Roadmap. It is expected that the indicators will continue to be used especially in projects or studies that are evaluating the scalability and replicability potential of R&I solutions related to the EEGI. Further promotion must continue beyond the GRID+ project and this will be achieved within such projects that have adopted the EEGI KPIs. Through tools that have been developed by the GRID+ project, such as the Knowledge Sharing Platform, projects will become increasingly aware of the EEGI KPIs and their potential. Through these tools, new start up projects will be encouraged to consider the EEGI KPIs when defining their own project KPIs.



ANNEX A UPDATED CALCULATION METHODOLOGY

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A.1 B.1. INCREASED RES AND DER HOSTING CAPACITY

A.1.1 OVERVIEW

Described here is an update to the calculation methodology for the *B.1 Increased RES and DER Hosting Capacity* indicator presented in Annex B of D3.4. The updates are based on feedback that has been received from other European projects and these updates are expected to maximise the added value and practicality of using this indicator, in particular to evaluate the deployment potential of solutions that prove to be successful in large scale demonstration projects.

Please see Annex B.1 of D3.4 for a complete description of the indicator, including the objectives and motivation. The update presented here is not necessary intended to supersede or replace the calculation methodologies that were previously provided, the intention is to provide more options, scope and practicality for how this indicator could be applied.

A.1.2 NETWORK PLANNING APPROACH

This improvement to the calculation methodology will help to capture the practicality and expected benefits of deploying R&I solutions to increase the hosting capacity of renewable generation on the network at the market uptake phase of the R&I programme. It is based on the expectation that, in reality network operators will make investment decisions based on first of all, an expected problem on the network. This problem could be that operational constraints for certain parameters, as defined in the grid code or national or European standards, would be exceeded. This could be as a direct result of increasing the amount of renewable generation (RES/DER) connected to the network. For example, thermal limits (security of supply) or voltage limits (power quality). Once the investment need is identified, the network operator will then make a strategic decision based on the most economical and sustainable solution for a given time horizon. This could be the planning period (e.g. seven or ten years) or beyond. The ex-ante evaluation of the KPI could use a standard network or a set of standard networks as a platform for testing any given R&I solution. An example of such a standard network was given in D3.4b although, at the market uptake phase, more detailed models could be used to provide a more accurate representation of European networks. Further consideration would have to be given to planning rules, network codes and other regulatory aspects and assumptions would have to be made where there is uncertainty. A real or hypothetical load / generation profile could be used and a range of studies performed to calculate average values of the

unit cost for increasing the RES/DER hosting capacity. The cost could include investment and operational costs along with a risk factor that would represent uncertainties associated with either the implementation or in realising the expected benefits of the R&I solution.

The following procedure could be used to calculate the RES/DER KPI using computer based modelling and simulation studies. The results from large scale demonstration projects could be used to evaluate the models that are used to represent the R&I solution.

Proposed calculation process

1. Identify investment needs using simulation studies with models developed from representative networks, forecast RES/DER penetration, provisional load/generation profiles, expected or assumed planning rules and regulatory conditions. The required investment will be based on meeting the expected load/demand profile over that period for a given RES/DER penetration that could be based on real expectations or a hypothetical scenario. A hypothetical increase in RES/DER on the network could be based on the growth in RES/DER that would be required and could be reasonable expected on a given network to achieve the ambitious European energy goals and to make the targeted low carbon economy a reality at affordable costs by 2050.
2. Plan network using BaU approach:
 - a. Plan network reinforcements to find the most economical and sustainable solution to meet the demands on the network of given time horizon (e.g. 10 years) and calculate investment and operational costs, including a risk factor.

For example,

$$BaU \text{ Investment Cost}, C_{BaU} = (CAPEX_{BaU} + OPEX_{BaU}) \times RISK \text{ FACTOR}_{BaU}$$

- b. Once the most economical BaU solution has been identified, the maximum RES/DER hosting capacity on the network after the reinforcements have been made will be calculated. This is because reinforcements made to the network will be designed to meet the identified requirements (increasing RES/DER hosting capacity) at the minimum cost. However, it is not possible to design the network such that the actual capacity provided is exactly that which is required. It is therefore expected

that the most economical solution to meet the requirements will be considered but to calculate the KPI, the actual hosting capacity that is available on the network must be considered. This will be equal to or greater than the increase in hosting capacity that is required. The maximum hosting capacity could be determined by incrementally simulating increased RES/DER penetration until one of the parameters exceeds its predefined operational limits (as defined in the actual or assumed grid code / European or national standards). This will provide the hosting capacity, HC_{BaU} in terms of apparent power (MVA) or active power (MW) of the network using the BaU approach.

3. Plan network using R&I approach:

- a. Plan the network using the option of deploying R&I solution with the objective of providing the most economical and sustainable solution. It should be emphasised that it is not necessarily expected that the R&I solution alone will be sufficient to meet all the demands on the system for the given time horizon and this approach may also include BaU network reinforcements (new / upgrading substations / over head lines etc.). The purpose is to compare a realistic network planning approach with the availability and option of deploying R&I solutions and then to compare the economical advantages of the R&I approach.

For example,

$$R\&I \text{ Investment Cost, } C_{R\&I} = (CAPEX_{R\&I} + OPEX_{R\&I}) \times RISK \text{ FACTOR}_{R\&I}$$

- b. In the same way as described for the BaU approach, the maximum hosting capacity available on the network after the investments have been applied using R&I solutions to support traditional network reinforcements to find the most economical and sustainable solution to meet the system demands, will be calculated. The maximum hosting capacity could be determined by incrementally simulating increased RES/DER penetration until one of the parameters exceeds its predefined operational limits (as defined in the actual or assumed grid code / European or national standards). This will provide the hosting capacity, $HC_{R\&I}$ in terms of apparent power (MVA) or active power (MW) of the network using the R&I approach.

4. Evaluate indicator using the formula to calculate the EHC (Enhanced Hosting Capacity) of RES / DER on network,

$$EHC = \frac{C_{R\&I}}{HC_{R\&I}} - \frac{C_{BaU}}{HC_{BaU}}$$

The EHC could be expressed in either k€/MVA or k€/MW.

The process for calculating the RES/DER hosting capacity KPI using the network planning approach is illustrated in Figure 3 below.

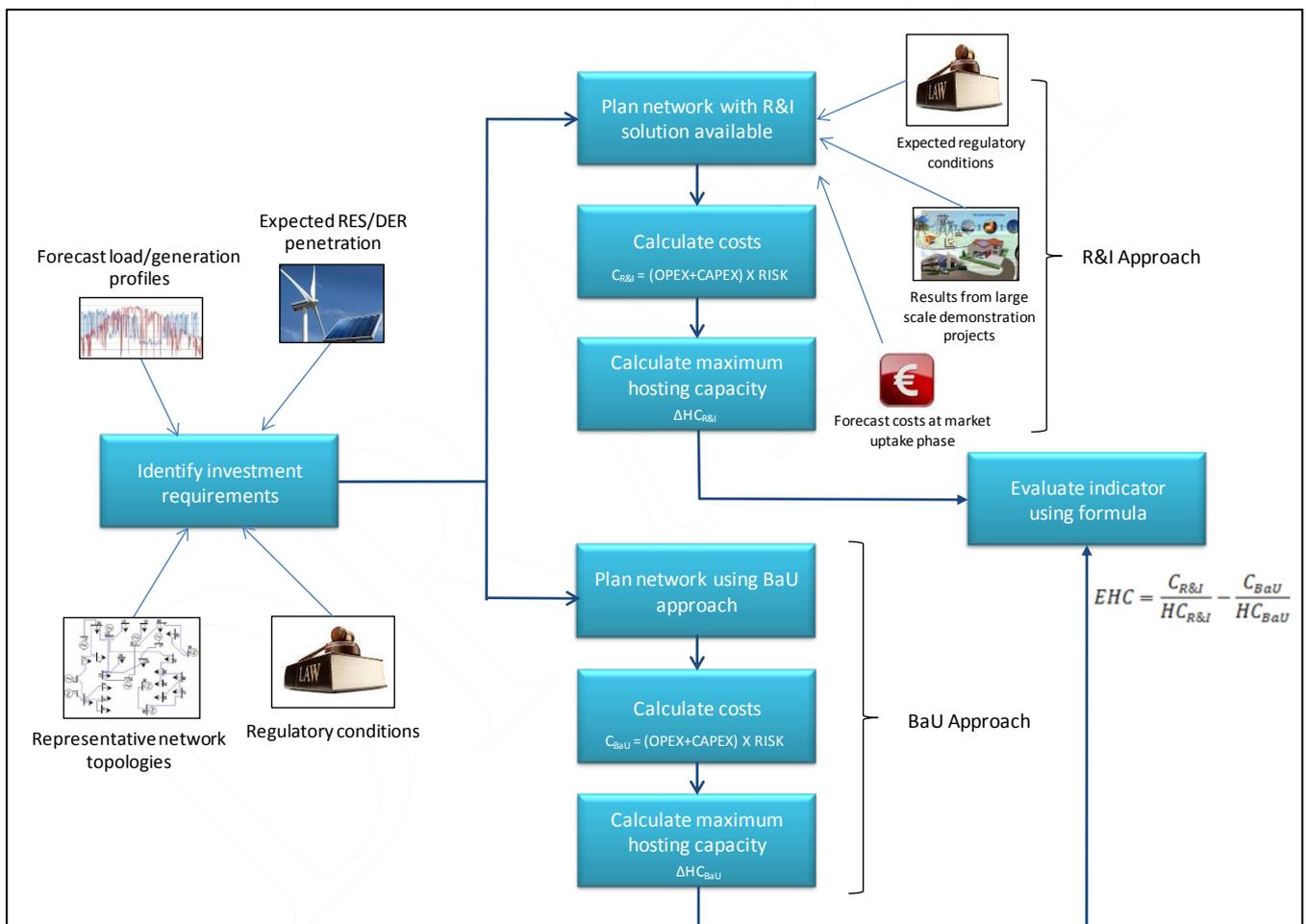


Figure 3 Example process for calculating the RES/DER hosting capacity KPI using the Network Planning approach

Sensitivity analysis

It is accepted that for R&I solutions with a relatively low maturity, meaning that the technology has not yet been deployed on a large scale, there may be uncertainties that could have a direct impact on the performance and the benefits that can be expected from the deployment of these solutions. This is also addressed in Section 3.4 of this document, some of these uncertainties might include:

- Regulatory conditions – this could be limitations imposed by the regulator on how much the network operator can control the generated power from DER. This will have a direct impact on the success of R&I solutions where their function is dependent on controlling the power generated by DER to optimise network performance
- Planning rules – To what extent can the benefits of the R&I solutions be considered when planning the network. For example, to what extent can demand side management be considered to contribute to the flexibility of the load when performing load flow calculations to evaluate the security of supply requirements on the network.
- Costs – One of the main difficulties in the evaluation of the deployment potential of a solution that is being developed using innovation and the development of novel technologies is cost uncertainty. It would be expected that while the maturity of a given technology is in an early, pre-deployment phase, due to the low demand for that technology, the manufacturing costs would be high. Once this technology reaches what is described as the market uptake phase, where it is deployed on a large scale throughout Europe, then the costs are expected to reduce. The current difficulty to evaluate the deployment potential of these new technologies is the lack of information available to accurately estimate these costs.

Where uncertainties exist assumptions could be made that will provide the optimal, yet realistic, conditions for the success of the solution to be deployed. A sensitivity analysis could then be completed using other, less optimal scenarios. This is illustrated in Figure 2 in Section 3.4 of this document. The sensitivity analysis could be used to evaluate the risk factor parameter in the equation that is proposed for the calculation of R&I cost.

A.1.3 DEFERRING NETWORK REINFORCEMENTS APPROACH

An alternative approach could be to consider how much the hosting capacity of RES/DER on the network can be increased, beyond that which is already available, by the deployment of the R&I solution. Hence the indicator will measure how much additional RES/DER generation can be hosted by the network, as a result of the deployment of the R&I solution, before network reinforcements are needed. The following process could be followed:

Proposed calculation process

1. Determine the maximum RES/DER penetration that can be facilitated on the existing network before reinforcements would be needed. This could be done by incrementally increasing the amount of RES/DER generating capacity on the network, using appropriate consideration of unit size, generation profiles and positioning on the network. This could be determined by information provided from the results of large scale demonstration projects testing the R&I solution. This will provide the maximum existing hosting capacity of the network, $HC_{Existing}$ (MVA or MW)
2. Simulate the deployment of the R&I solution and then using the same technique as described in Step 1, incrementally increase the amount of RES/DER connected to the network until it is no longer possible to increase the hosting capacity for RES/DER on the network using the deployment using the R&I solution. This could be an iterative process in cases where the scale of deployment of the R&I solution can be varied (For example, in the case of a voltage control solution this could be the number of storage units, number of smart invertors, centralised vs. decentralised control systems, etc.) The resulting increase in hosting capacity of the network would be the increase of hosting capacity using the R&I solution, $HC_{R\&I}$ with respect to the existing hosting capacity, $HC_{Existing}$.

$$EHC = HC_{R\&I} - HC_{Existing}$$

The EHC (Enhanced Hosting Capacity) could be measured by apparent power (MVA) or real power (MW). The cost of the R&I investment could also be used to provide a unit cost for increase in RES/DER hosting capacity on the network. (k€/MVA or k€/MW).

The process for calculating the RES/DER hosting capacity KPI using the network planning approach is illustrated in Figure 4 below.

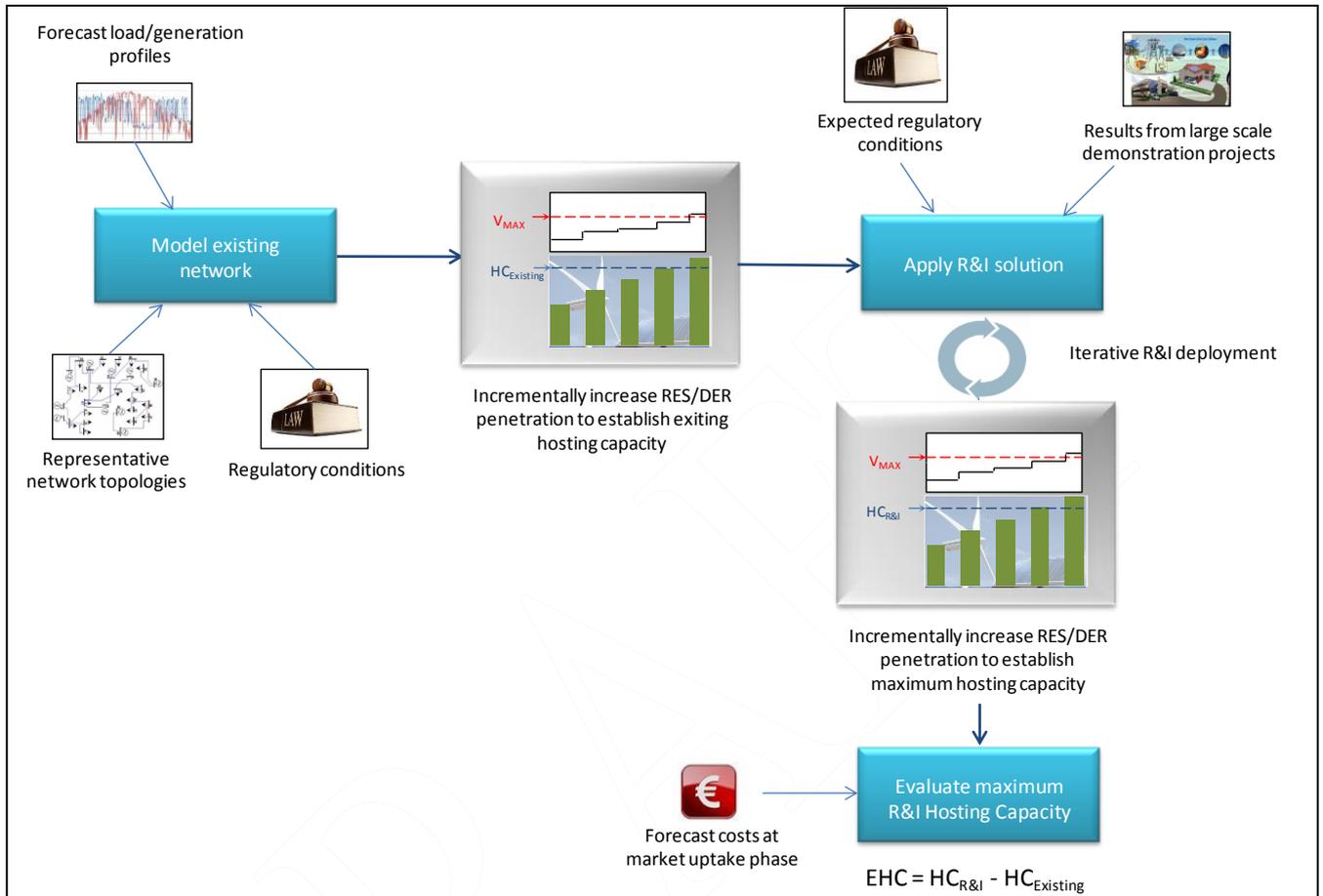


Figure 4 Example process for calculating the RES/DER hosting capacity KPI using the Deferring Reinforcements approach

A sensitivity analysis, similar to that previously described for the Network planning approach could also be completed to address uncertainties that may impact the successful deployment of the R&I solution.

REFERENCES

- [1] Define EEGI Project and Programme KPIs, GRID+ public deliverable D3.4
- [2] EEGI Research and Innovation Roadmap 2013-2022
- [3] CIRED Paper 0058 Definition and practical application of Key Performance Indicators to support European grid operators to enable the energy policy goals
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- [5] Example of Simulation Studies Methodology for Ex-ante Evaluation of EEGI KPIs, GRID+ public deliverable D 3.4b (support material)