GUIDELINE: KPIS FOR ENERGY CONSUMPTION EFFECTS

Abstract

This guideline describes how key performance indicators (KPIs) can be used for determining the effect of the smart grid environment on the energy consumption of the users. The goal of this guideline is to give an overview about applying KPIs in your project for the purposes of providing consumer feedback and project evaluation. The guideline is intended for the smart grid project leaders, utilities and other smart grid service providers dealing with the consumers.

What is it?

Smart energy products and services are introduced to have a certain effect on the energy consumption behaviour of the consumer, e.g. to decrease overall consumption or to shift consumption to off-peak periods. Measuring to what extent such effects take or have taken place is thus vital for determining the success of (a set of) smart grid products and services. The first step in doing this is monitoring the energy consumption of the consumer, which is further elaborated in the guideline Monitoring demand response performance.

Key performance indicators (KPIs) help express the effects of the (set of) smart grid products and services. Depending on your project objectives you should determine a set of KPIs that will allow you to see what the energy consumption effects are. How well the smart grid environment or its individual consumers perform in light of the overall project aim can be determined by calculating how well they score on the KPIs. This calculation is based on the monitoring data that you have collected.

Where this guideline focusses on the effects of the smart energy environment in terms of changes in energy consumption, it is also possible to see how the consumers have experienced the smart grid. More on this is explained in the guideline User-centred KPIs for the evaluation of smart grids, where KPIs for measuring the successfulness of a project from the consumer point of view are discussed.

When to use?

Based on the project aims the KPIs with respect to energy consumption effects should be determined early in the project. They are used for two different purposes, one the one hand such KPIs can be used for evaluating the project result, so the cumulative effect of the individual participants, which is usually done at the end of the project or at predetermined intervals during the execution phase.
Next to this such KPIs can also be used for individual consumers to provide them with feedback on their energy consumption behaviour. Notifying the consumers

about their progress helps keeping a high level of consumer engagement. The presentation of the performance indicator value to the consumer as feedback can encourage them to adjust energy consumption behaviour in the desired way. This can be provided by comparison of the indicator with a similar population average or define some target values the consumer should follow. That enables self-evaluation and triggers the competition instincts resulting in consumer behavior change, see the S3C guideline How to make energy visible through feedback.

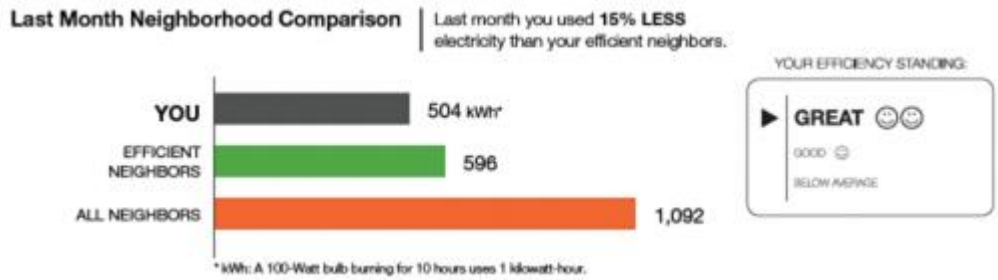

Figure 1: Sample of user information with performance indicators [Ideas42 and Opower, http://www.ideas42.org/social-norms-and-energy-conservation/]

Examples of performance indicators

The key performance indicators evaluating the effects of the smart grid activities may be basically separated into a) evaluation of consumption efficiency and b) evaluation of energy shift. The samples presented in this chapter are sourced from common practices in Family of Projects (FoP) in S3C. Their description below also points out the object of interest which may be consumers (for consumer feedback) or service provider (evaluation of project goals).

Consumption efficiency

At introduction of smart meters usually brings the interests for measurement of the consumption efficiency and energy savings. The following list provides some technical and economic indicator examples, which may be used for utility as well as for consumers. The indicators, where utility is involved, are usually used for the project evaluation. The indicators purposed for households are intended for consumer behavior change.

KPI	User	Definition
Absolute energy savings [kWh]	Households, SME	Difference between measured and reference data.
Relative energy savings (expressed in share of the total consumption)	Utility	Difference between measured and reference data divided by total.
Consumption per entity - household	Utility	Averaged total consumption per household.
Consumption per entity size (number of inhabitants, size of flat)	Utility, households, SME	Individual total consumption divided by entity parameter.
Consumption per product	SME, industry	Individual total divided by production result.
Cost savings	Household, SME	Difference between measured and reference data multiplied by price.
Consumption per employee	SME, industry	Individual total divided by presence of employees.
Operating hours (Energy consumed divided by peak consumption)	SME, industry	Individual total divided by individual peak consumption.

Table 1 Examples of KPIs for energy efficiency

The KPIs for monitoring the consumption efficiency requires specific form to evaluate the realization of the goal on the consumer level. A common option in this case is the definition of consumption per entity/household. The advantage of this definition lies in its simplicity, but it also has some disadvantages, since the consumption depends also on the size and population of the measured entity.

When applying the performance indicators to the SME, one should take into account that its primary interest is production intensity. The performance indicator describing this is “operating hours” which tells share of time the production is in operation and is calculated as a ration between energy consumed and peak consumption in the examined period (day, week, year). When one measures the energy efficiency at SME, he must also take into account the “operating hours” indicator.

Energy efficiency performance indicators may be further elaborated into the benchmarking – evaluation by comparison with similar users. ODYSEE-MURE project offers more information about it (see further reading).

Energy shift and demand response

The targets of demand response functionality are peak consumption and energy shifting. The peak consumption should be expressed in a dimensionless form of peak consumption to average consumption power ratio, which enables common comparison of the indicator and its main measured effect – peak reduction.

The flexible energy is the amount of energy that may be shifted during consumption. The performance indicator is expressed in dimensionless form of flexible energy to the average daily consumption ratio. Such definition still does not enable an adequate comparison, since it does not take into the account the flexibility time, which is very important for the service provider. For example the flexible energy of 1kWh for up to 10 hours of time shift may be much more valuable than 10kWh for 1 hour. An additional complication of the indicator definition is that flexible energy is much more valuable during daylight when the consumption is large than during the night.

The practice recommends that the flexibilities are expressed in the form of a project goal. If the target is introduction of new time of use (ToU) tariff or dynamic pricing, the energy shift is measured as a difference of the consumption patterns with and without dynamic pricing. Another option is using the capability to reduce the peak consumption. On average the daily peak consumption usually lasts two hours in the evening. The performance indicator is calculated as total capacity of loads which are in operation during the peak and are capable to shift the energy out from that peak.

KPI	User	Definition
Peak to average ratio	SME, Utility	Peak power consumption divided by average power.
Energy shift ratio	households, SME, Utility	Shifted energy divided by total daily consumption.
Consumption per tariff	Household, Utility	Amount during the tariff divided by total.
Peak reduction capacity	Utility	Peak load capacity divided by total daily consumption.
Demand response reliability	Utility (automated demand response)	Requested energy shift divided by realized energy shift.

Table 2: Examples of KPIs for demand response

Automated demand response solution enables the utility to be informed about the consumer's real time adaptation capacity. The indicator "demand response reliability" is the ratio between realized adaptation and reported adaptation capacity after triggering the adaptation. This information is important for the utility to foresee the effect of the adaptation requests and also to provide higher incentives for more reliable consumers.

More details about evaluation KPIs for utilities are available in ADVANCED project (see Deliverable D1.2).

What do you need to do?

Definition of the performance indicator

The definition of the performance indicator consists of the two components: a) the choice of the variables involved and b) the definition of the monitoring interval. The variables involved into the indicator must be dependent. It is recommended that the dependence is linear. The monitoring interval must be long enough to eliminate the value oscillations.

The following example shows the definition of performance indicator "Measuring the consumption efficiency" in a commercial building. Figure 2 shows the time history of the one week electricity consumption. Beside the background (“fixed part”) there is obvious dependence from the employee presence (“variable part”). This hints the introduction of indicator which divides total consumption with hours of employee presence for measuring the consumption efficiency and savings. The proper monitoring interval is one week since its value has large day/night and workday/weekend oscillations. The alternative may be splitting the indicator to measure “background” and “variable” consumption efficiency separately what requires advanced mathematical operations.

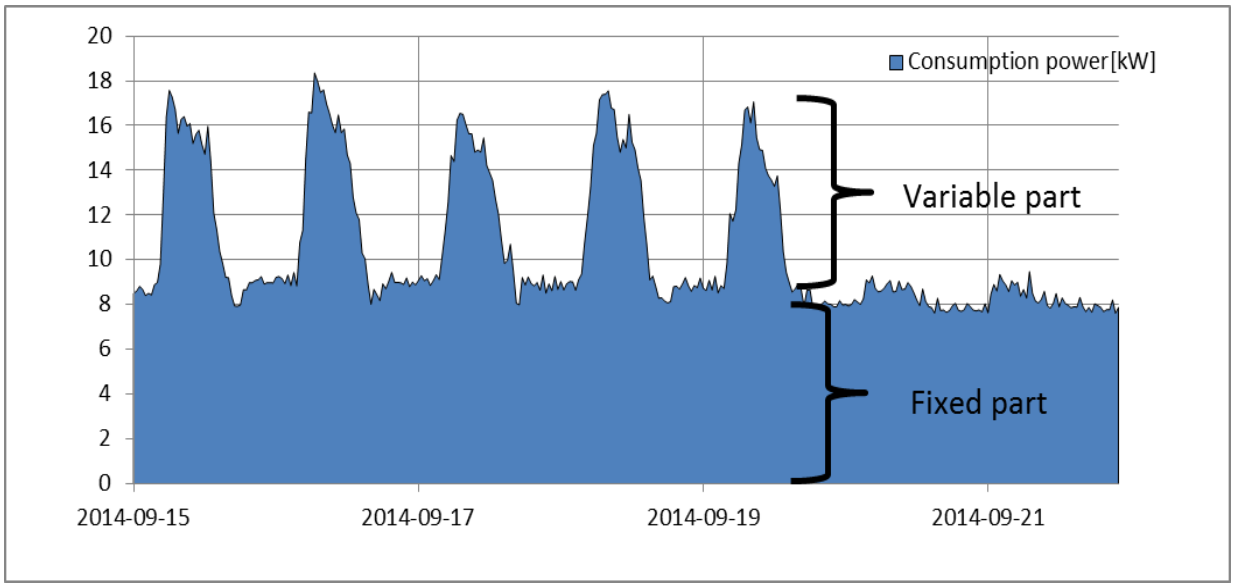

Figure 2: Example of electricity consumption in a commercial building: consumption history for 1 week [measurements from the commercial building, project SPEU]

When appealing to the consumers to behave smarter and more energy efficient, they usually manage to affect the variable part. Addressing the changes in the fixed part usually requires advanced approach and analyses or structural differences in the

operation or building (e.g. better insulation). While this is usually manageable in a single household, it may become very complex in multi flat buildings or SMEs.

The target level for the KPI

Introduction of performance indicators should be accompanied with energy targeting, when one wants to make proper consumer feedback with the change of behaviour. The project targets should be reflected in the target levels for the KPIs, which need to be translated into user targets in order for the consumers to have goals to work towards and to compare their progress to.

The corresponding performance indicators need to address the proper consumer segment with the exclusion of the external influences, such as the weather. For example, if the project aims to achieve a specific amount of consumption savings, then this goal should be transferred to the consumers according to their characteristics and seasonal effects, as for larger consumers it might be easier to save energy and it might be easier to reduce consumption during winter.

It is necessary to remain realistic when comparing the current energy consumption behaviour with the target for the KPI. For example, at SMEs if the number of employees decreases (e.g. during the summer period) the performance indicator “energy consumption per employee” may increase even if the employees behave more energy preserving when the fixed part of energy consumption is large. Therefore the target must be adapted to a more realistic level to prevent that consumers are discouraged beforehand.

For more information on setting the right goal, see our guideline How personal goals can motivate behavioural change. Calculating the energy consumption effect of the smart energy environment is further explained in the guidelines on How to create a consumption baseline and Smart meter monitoring and controlling functionalities.

Data-related privacy issues

There are cases where it could be more informative to use indicators that are relative, e.g. a specific measure per entity size (consumption per square meter) or population (consumption per household member), both in terms of feedback for the consumer as well as for the overall project evaluation. Although this may improve the quality of the indicator, due to confidentiality of the data one also needs to consider the related privacy issues, for more information see also guideline Privacy and data protection.

One option to avoid security issues and strengthen the consumer confidence is implementation of the data processing on the location of consumers. Instead of sending the sensitive private data (e.g. the energy consumption as well as the

number of people in the household) to the service provider, the performance indicator is calculated locally and sent out from the personal environment instead. This allows for more anonymized data to be shared with the service provider, such that they cannot access the sensitive information.

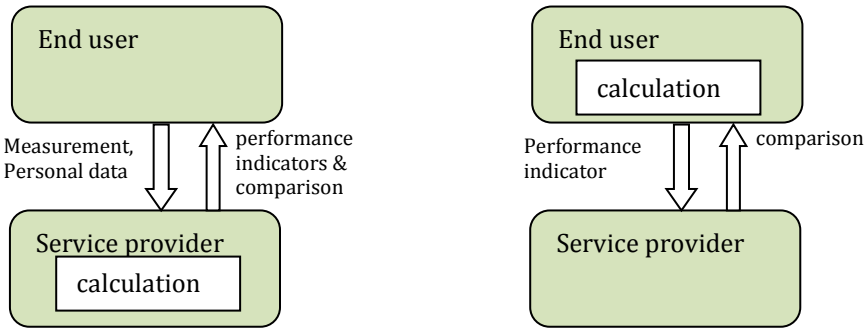

Figure 3: Privacy in KPI processing: personal data is sent to the service provider (left), service provider does not directly operate with personal data

Measurement of energy efficiency on segmentation groups (Ecogrid,DK)

The Ecogrid (DK) project introduced real time pricing. The evaluation of the project followed the peak consumption as well as a change in consumer consumption efficiency performance indicators. To analyse the technology effect the users were segmented according to different smart equipment installation types (different levels of automatic and manual control). The evaluation provided the effects on the total peak and portion of energy savings for each segmentation group. Additionally to trigger the consumer's behaviour change they have received regular information on consumption efficiency in the form of comparison between their past and current structure ToU energy usage (consumption portion per tariff).

More information on http://www.eu-ecogrid.net/.

Do's and don'ts

- **Choose the optimal calculation period.** The important issue is the collection and evaluation of the data within the proper time period. Commonly performance indicators should not be monitored on the daily or even hourly level to give the proper information of the consumer, since even the workday/weekend variations have a significant impact. The performance indicator like "energy consumption per household" should not be monitored on the lower than weekly period level to get the proper results.
- **Define proper segmentation for KPI comparison.** When dealing with a diverse consumer portfolio, calculation and comparison of the KPI should be separated. For example, the consumption efficiency in low cost multi-flat

building has different characteristic than individual house and the indicators cannot be compared adequately despite the common definition.

- **Include external influences.** The inclusion of the external influences like weather conditions into the KPI is important and should be taken into account, see the S3C guideline How to create a consumption baseline.
- **Present only the relevant information.** It is not recommended to present the savings and behavior efficiency in the form of costs (euros) if the savings are so small that they do not draw the interest of the consumer. Also feedback in the form of kWh saved might not be most effective, due to the kWh being a very abstract concept to most consumers.

Introduction of "price elasticity" performance indicator (MOMA, DE)

In the MOMA (DE) project also the performance indicators were used for both – for providing feedback to the users as well as to evaluate results of accomplished changes of users' behaviour. The project introduced the dynamic multi-tariff system for the group of consumers with smart meters. To improve the engagement the performance indicator measuring the savings were delivered them through the user interface. The project evaluation has used another indicator called "price elasticity" which has measured a portion of shifted daily energy at a double change of the price.

More information on www.modellstadt-mannheim.de.

Further reading

- ODYSSEE-MURE, project at http://www.odyssee-mure.eu/
- Maggiore, S. (RSE), Laes E., Kessel K., Valkering P (VITO), Hegermann K., Reiss P. (BAUM), Straver K., Uyterlinde M. (ECN), Černe G., Vindišar J. (INEA), Brolin M., Thomten M.(SP), Ramalho D., Castanheira C. (EDP) (2013). *Description of candidates to from the 'Family of Projects'* (S3C D2.1). http://www.s3c-project.eu/Deliverables.html
- Dromacque C.(VaasaEtt), Benintendi D.(FEEM) , Idstein D. (Entelios), Schmidt T.(Entelios) , Barron M. (Enel Distr.), Xu S.(2014). *Report on the validated KPIs (ADVANCED D1.2)*, http://www.advancedfp7.eu/getattachment/44451b5a-8543-44d6-841b-7fa66c0a8fd2/ADVANCED-1-2-Report-on-the-validated-KPIs.aspx

This guideline was developed in the S3C project, and is freely available from www.smartgrid-engagement-toolkit.eu.

S3C paves the way for successful long-term consumer engagement, by acknowledging that the "one" smart consumer does not exist and uniform solutions are not applicable when human nature is involved. Beyond acting as a passive consumer of energy, consumers can take on different positions with respective responsibilities and opportunities. In order to promote cooperation between consumers and the energy utility of the future, S3C addresses the consumer on three roles. The *smart consumer* is mostly interested in lowering his/her energy bill, having stable or predictable energy bills over time and keeping comfort levels of energy services on an equal level. The *smart customer* takes up a more active role in future smart grid functioning, e.g. by becoming a producer of energy or a provider of energy services. The *smart citizen* values the development of smart grids as an opportunity to realise "we-centred" needs or motivations, e.g. affiliation, self-acceptance or community.

S3C performed an extensive literature review and in-depth case study research in Smart Grid trials, resulting in the identification of best practices, success factors and pitfalls for consumer engagement in smart energy ventures. The analysis of collected data and experiences led to the development of a new, optimised set of tools and guidelines to be used for the successful engagement of either Smart Consumers, Smart Customers or Smart Citizens. The S3C guidelines and tools aim to provide support to utilities in the design of an engagement strategy for both household consumers and SMEs. The collection of guidelines and tools describe the various aspects that should be taken into account when engaging with consumers, customers and citizens. More information about S3C, as well as all project deliverables, can be found at www.s3c-project.eu.