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D1.4
Performance Measurement & Verification methodology report

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Executive Summary

This document describes the Performance Measurement and Verification Methodology to be followed in DELTA project. This methodology indicates how the outcomes of the project will be evaluated. Such outcomes cover various aspects of the project, such as technical issues, in terms of the technologies and services delivered, as well as qualitative issues, such as user satisfaction.

For this reason, in this document we define the Key Performance Indicators that serve to evaluate the outputs of the project. These indicators are categorised in three groups:

- KPIs that are defined in a quantitative way, meaning that formulas are provided to evaluate each KPI.
- KPIs that are defined in a qualitative way and which give information about user satisfaction, stakeholders satisfaction, effectiveness of business models, etc. Such KPIs are evaluated through feedback from the end-users or the involved stakeholders.
- KPIs that are met through the conclusion of the project's tasks and deliverables, like for example through the successful implementation of the pilot sites.

Each of the KPIs is analytically described. The formulas for the quantitative KPIs are given, where all parameters are explained. Possible means of getting feedback for the qualitative KPIs are also presented, which focus on potential questions directed to the end-users and relevant stakeholders. In addition, the KPIs that depend on the successful implementation of other tasks/ deliverables are described. The targets for all KPIs are presented.

For evaluating KPIs that deal with the successful implementation of demand response, it is important to define the baseline, which defines the energy consumption when demand response doesn't take place. The baseline serves as comparison criteria and is fundamental to evaluate the results the project brings to pilot sites. For this purpose, we give a methodology for defining the baseline.

Finally, we give a short description of the pilot sites and their energy schematics diagrams, which depict the types of energy carriers available per site. In such a way, it becomes clearer how the measurement and verification methodology can be applied on the actual pilot sites.

To sup up, this document presents the methodology for evaluating the baseline that can be applied to the project's pilot sites and gives a detailed description of the KPIs, which serve to assess the outputs of the project.

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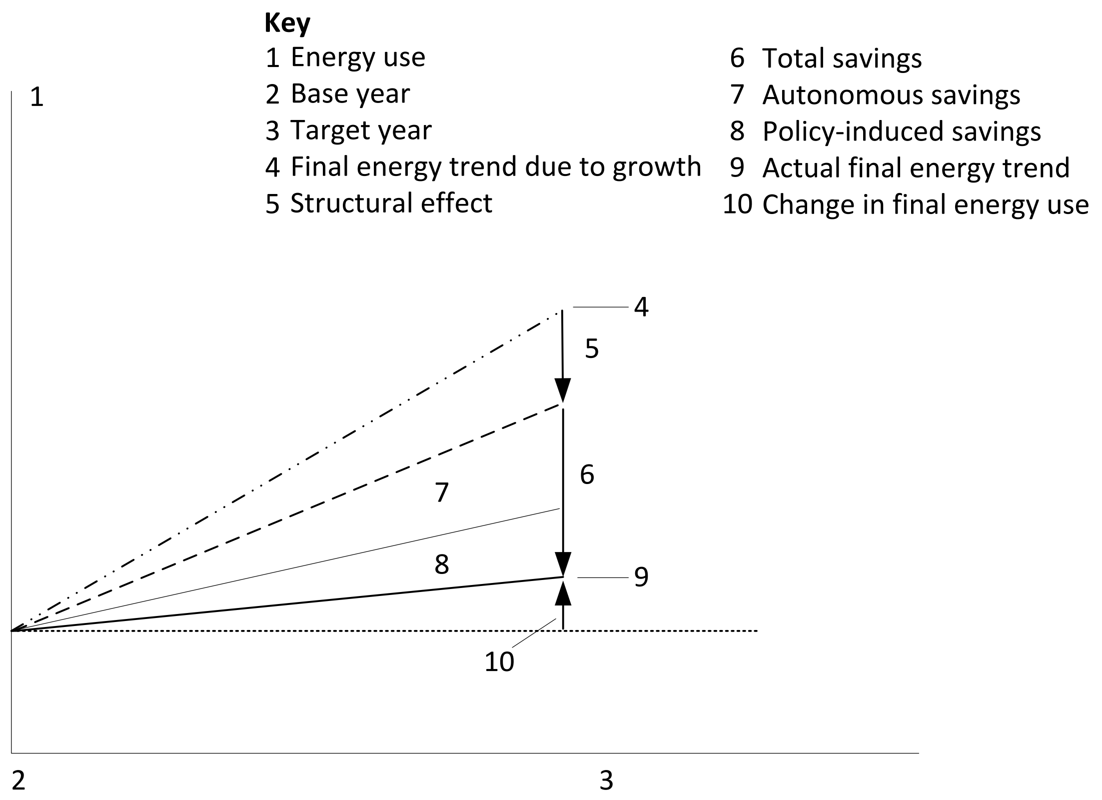

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List of Acronyms and Abbreviations

Term	Description
AMI	Advanced Metering Infrastructure
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BEMS	Building Energy Management System
CEN	European Committee for Standardization
DR	Demand Response
ECM	Energy Conservation Measures
EEC	Energy Efficiency Certificate
EnB	Energy Baselines
EnMS	Energy Management Systems
EPIAs	Energy Performance Improvement Actions
EVO	Efficiency Valuation Organization
FEMP	Federal Energy Management Program
ICT	Information and Communication Technologies
IPMVP	International Performance Measurement and Verification Protocol
ISO	International Organization for Standardization
KPI	Key Performance Indicators
M&V	Measurement and Verification
NAESB	North American Energy Standard Board
NAPDR	National Action Plan on Demand Response
PMV	Performance Measurement and Verification Methodology
PV	Photovoltaics
RES	Renewable Energy Sources
SE	Standard Error
SEU	Significant Energy Use
VPP	Virtual Power Plant

1. Introduction

Demand Response (DR) plays a key role in the Inclusive Energy Transition and has therefore gained great scientific interest. In general, it defines the ability to adjust loads according to peak hours so as to achieve smoother load consumption. DR is a promising method for balancing supply and demand in power systems with a high share of variable renewable energy generation, offering flexibility to the market. Nowadays the smart grid implies that DR can be done in a more sophisticated way aiming at minimizing drastic decisions and at reducing the discomfort caused to end-users. Usually automation functions on the customer side are also described. For DR programs, it is considered that both industrial and residential consumers can contribute in the realization of the fully operating smart grid.

The importance of Demand Response and the interest it gets is depicted by the recent investments on the topic and the high number of research projects focusing on the topic. According to the Smart Grid Projects Outlook 2017 [1], which depicts the smart grid projects with at least one European partner, 346 projects deal directly or indirectly with demand response. Out of these, 67 have initiated from 2014 and onwards, showing the upcoming interest in the topic. It should also be mentioned that this number is greater, since many projects have initiated after the conclusion of the Smart Grid Projects Outlook report[1] .

There are numerous projects where research on DR is carried out. The majority of these projects entail pilot sites, where the DR programs and their supporting technologies are being tested. The pilot sites are fundamental for evaluating and testing the novel solutions proposed before they can be applied in real systems. They reveal the advantages and the problems to be solved that such new technologies can bring up.

Key Performance Indicators (KPIs) are used for this scope to assess the targets that have been set and verify the validity of the project. The KPIs can refer to quantitative values, like emission reductions or peak load shaving, whereas they can also refer to qualitative values, like user satisfaction and successful business models provided.

For this purpose, a specific measurement and verification procedure is of vital importance, which gives the guidelines for evaluating the KPIs, thus assessing the novel techniques proposed and contributing in obtaining results in a structured way. The measurement and verification methodology explains the necessary steps for calculating the KPIs, either these are quantitative or qualitative. It shows the results obtained in a clear and straightforward way, which leaves no doubt with respect to the achieved outcome.

In addition, there are KPIs that can be successfully met through the successful implementation of the pilot sites or through other deliverables. For reasons of completeness, we describe these KPIs and we give the guidelines through which they will be assessed.

1.1 Scope and objectives of the deliverable

This deliverable is the fourth and last one comprising Work Package 1 (WP1) on DELTA Requirements and System Architecture Definition. The work package aims, among others at: defining the business cases that will be realized through the DELTA project; specifying the DELTA architecture; defining the dependencies between components and specifying the inputs and outputs for/ from each component. This deliverable aims at defining the procedure to assess the pilots' outcomes and overall project's achievements.

One of the objectives of this deliverable is to describe, present and give the guidelines for evaluation of the Key Performance Indicators. Based on the description of the project's technical annex, we use 26 KPIs to measure the expected impact set out in the EU Work Programme. These KPIs are either quantitative or qualitative. The former ones are related to a value that usually needs to be calculated through mathematical formulas. The parameters that determine the mathematical formulas are explained and the steps to be undertaken are defined. Such KPIs may be cost or energy related (may refer to emission savings, peak load reduction, energy efficiency, cost reduction etc.). On the other hand, the qualitative KPIs are usually not evaluated through formulas. They can be related to

[1] An updated version of the exercise "Smart Grid Projects Outlook" is expected later this year or early 2020.

user satisfaction, the successful delivered business models, etc. Such KPIs can be evaluated through feedback collected by end-users and stakeholders. This deliverable gives the means through which such parameters are evaluated and the justification for following such a process.

For both types of KPIs, data collection is necessary. This deliverable defines the data collection process both from the pilot sites as well as from end users or stakeholders through a survey. The data collection and evaluation process is strongly related to pilots. In this report, the strategies for evaluating and validating the pilot sites are defined.

The critical parameters to determine the evaluation of the KPIs are defined along with the methodology to calculate these KPIs.

1.2 Other Demand Response Projects at International level

This deliverable takes into account similar work that has been done in relevant projects around DR. In fact, there are several projects that have already developed their measurement and verification methodology. In this report, we take into account the work already been done and we build upon it in order to describe the DELTA project's objectives and evaluate the pilot sites of this project.

At this point, we briefly mention other relevant projects on demand response. For instance, in the Scalable Energy Management Infrastructure for Aggregation of Households (SEMIAH) project, a system for DR services was implemented based on aggregation and scheduling of electricity loads in households. A front-end platform for smart grid services for households was developed, as well as a back-end system, which could manage aggregation, forecasting, and loads scheduling for at least 200,000 homes [2]. In the Peer-to-Peer Smart Test (P2P SmartTest) project, special focus is given to market issues and the market models/competition relations between different actors. It suggests how to define the baseline methodology, how to design DR products, the measurement and validation activities, the bidding process for implementing DR, and how to remove potential barriers in the system [3]. In the AnyPLACE project, one of the targets has been to create a platform for managing and controlling the network, through which bidirectional information exchange will take place among actors like end users, market representatives, electricity network operators [4]. The DREAM-GO project describes the situation with respect to business cases in Europe and the US. Information is given about the enablers and the promotion of demand response in these territories. In addition, it creates a framework with the required methods and solutions to facilitate adoption of results in final applications [5]. In the EMPOWER project, an ICT framework has been developed to support several services on the grid, including integration of renewables and providing with incentives to participate in DR programs. They proposed the use of a platform which facilitated the energy trading and management of electricity. The proposed solution has been planned to be used at local markets for balancing between supply and demand [6]. In the FLEXICIENCY project, new services are offered, like flexibility, monitoring and energy control to the electricity market players. The project supports standardised interactions among all players through an open market [7]. The NOBEL-GRID project dealt mainly with the promotion of DR and the involvement of active consumers in such programs. For this purpose, advanced telecommunication and information technologies (ICT) have been used in order to facilitate renewable energy sources integration and demand response actions. Services have been offered to various actors, like Distribution System Operators (DSOs), aggregators, end-consumers. Business models have been proposed in order to validate the proposed solutions, which have been tested on pilots [8]. The P2P-SmarTest project focused on improving the adaptation of demand side flexibility actions and achieving a better integration of distributed energy sources. Advanced ICT technologies have been used in order to accomplish real-time network control, effective energy trading and network optimization [3]. The main goal of the SEMIAH project has been to promote demand response and provide smart grid services for residential consumers. For this reason, a system for demand response has been created in which aggregation, forecasting and planning of electricity consumption takes place. Business models are also proposed with emphasis on residential consumers [2].

Another project, DR BoB [9] aims at demonstrating the economic and environmental benefits of DR focusing on buildings as a manageable unit in pilots across different countries. DRIvE [10] also ambitions to deliver a fully-integrated, interoperable and secure DR Management Platform for Aggregators offering advanced hybrid forecasting, optimization, fast-response capabilities and enhanced user interaction in compliance with Open ADR following the market model for the trading and commoditization of energy flexibility. The RESPOND [11] project aims to deploy an interoperable energy automation, monitoring and control solution that is capable of delivering demand response at a building unit and district level. Using smart energy monitoring infrastructure, RESPOND aims at detecting energy conservation opportunities, adapt to indoor and outdoor conditions, and comfort levels in real time. The FLEXCoop [12] introduces a complete DR framework providing a tool suite for aggregators and residential electricity consumers, in order to enable aggregators to exploit the flexibility of end-users in an effective way and give the possibility to consumers to participate actively in the energy management. The project presents models for load and generation forecast and present a visual and thermal comfort adaptive model to inform about flexibility criteria. In addition to this, also the eDREAM [13] project makes use of distributed ledger technologies and aims to contribute to the transformation of traditional energy market concepts considering smart grid capabilities and novel decentralized and community-driven energy systems. The main goal is the exploration of local capacities, constraints and Virtual Power Plants (VPP).

The analytical State-of-the-art in DR Programs related to DELTA project are listed in Deliverable D2.2 along with their expected outcomes [14].

1.3 Structure of the deliverable

The structure of this deliverable is as follows:

- Chapter 2 describes the pilot sites, the facilities available and the issues that are critical for the project's success. It also gives the measurement and verification approach followed.
- Chapter 3 describes the KPIs and the methodology followed to assess them. There are two subchapters describing the quantitative and qualitative KPIs respectively. The formulas for calculating the quantitative KPIs are given along with the parameter description, whereas the means for evaluating the qualitative KPIs are presented and described in depth.
- Finally, Chapter 4 concludes the deliverable.

1.4 Relation to Other Tasks and Deliverables

The relation of this Deliverable to other tasks and deliverables is described as follows:

- Relation to the Deliverables of Work Package 1:

Deliverables D1.2 and D1.3 define the high level specification of each component, the hardware requirements, sequence diagrams and the ontology specifications, inputs/ outputs of components respectively. Such information is useful in order to identify which component is responsible for providing the data necessary for the KPIs evaluation. In addition, the outcome of D1.1, where the business cases are described, could give feedback in order to define better the way of evaluating the qualitative KPIs. For instance, when surveys are used as means of such KPIs evaluation, they should be linked to the respective business cases described in D1.1.

- Relation to other Deliverables and Tasks:

This report is related to D2.2, where the state-of-the-art in DR Programs related to DELTA project is listed. As being aforementioned, the measurement and verification methodology presented here takes into account and builds upon already existing methods. Therefore, D2.2 gives us a good feedback.

This deliverable is highly related to Work Package 7, which describes the pilot implementation and DELTA business model validation.

Tasks T7.2 and T7.4, related to end users engagement and experience evaluation respectively, can be connected to the evaluation of the qualitative KPIs assessment. Surveys to evaluate user satisfaction and their trust level towards DELTA solutions can be part of tasks T7.2, T7.4 and can give valuable feedback to the respective deliverables.

On the other hand, tasks 7.3 and 7.6, which deal with the pilot realisation and the life cycle cost analysis respectively, are strongly related to this deliverable, since the final evaluation of the quantitative KPIs depends on data obtained from the pilots. The application of the measurement and verification methodology on the data obtained by the pilot sites will determine the extent of success of the pilot sites.

2. Description of Pilot Sites and Guidelines for baseline determination

2.1 Pilot 1 – UK

The pilot site in the UK entails two buildings/ complex of buildings, the Moore House, which is an office building and the Ernest Dence, a residential complex in Greenwich Council. In the UK, there are already different DR programs that are valid. Therefore, before describing the pilot sites, we briefly list the DR programs that exist in the country. Table 1 shows the various programs that exist in the UK, their response time, the duration of the event as well as their availability window.

Table 1: Different Demand Response programs in UK

Type of Programs	DFFR (Dynamic Firm Frequency Response)	SFFR (Static Firm Frequency Response)	Constraint Management (DNO programme)	STOR (Short Term Operating Reserve)	Capacity Market
Response Time	1 second	1-30 seconds	15 Minutes	15 Minutes	4 hours
Duration of the event	Continuous	30 Minutes Fixed	2-4 hours	Max 2 hours	4 hours
Payments	Availability	Availability	Availability and utilization	Availability Utilization	Availability
Types	Dynamic – Any variance from 50 Hz	Static – 50.3 Hz – 49.7 Hz	Demand Turn up Demand Turn down	Static	1. Existing generation 2. DSR A. Proven B. Unproven
Availability window	24/7	24/7	Summer/ Winter	06:00 to 14:00 16:30 to 22:00	24/7

2.1.1 Moor House

Moore House is an office building located in Central London hosting 4,100 employees and covering a total area of 43,300 sqm. Energy consumption is split between electricity (total annual consumption of 9,636 MWh) and gas (total annual consumption of 3,883 MWh).

The building is equipped with 2 Perkins 2.5MVA standby generators, providing energy to the building during power cut-offs or in peak demand events happening in the electricity grid. Each floor has a North and South zone of fan coils with individual temperature set points. Moor House is participating via KiWi to Static Frequency Response (SFR) and provide resilience to the grid frequency. Figure 1 shows the schematic diagram for the London Moor house to participate in the DR activities. Figure 2 shows a screenshot of the asset responding to a Static Frequency event.

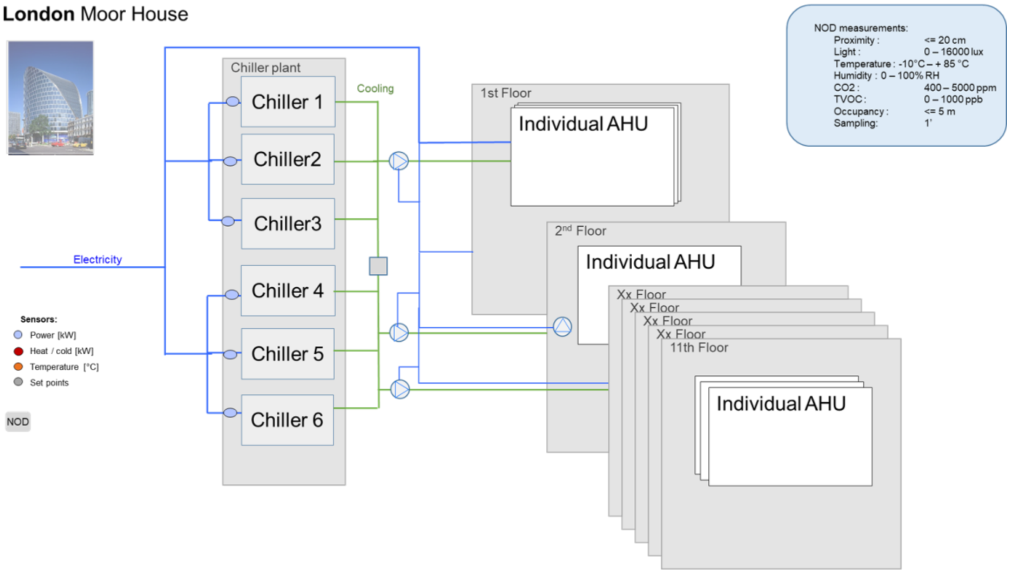

Figure 1: Line Schematic for London Moor House

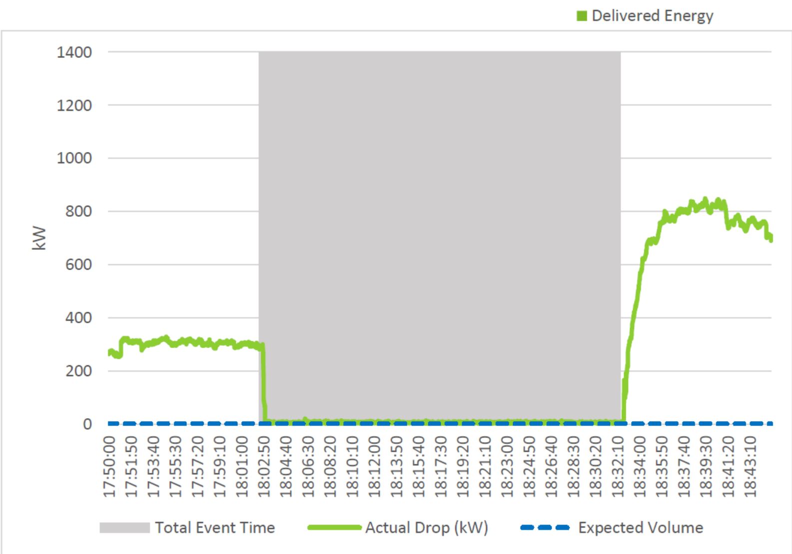

Figure 2: Screenshot of asset responding to a Static Frequency event

Static Frequency Response is requested on a monthly Tender by UK National Grid, so every month KiWi has to make a market analysis and see what are the requirements from National Grid for the ancillary services. Moor House, via the chiller, is turning down 365kW and it's part of a 1MW portfolio, as the minimum requirement for frequency participation is 1 MW. So, the load capacity is 365 kW.

KiWi is providing the data through their own proprietary technology (Fruit) and the asset responses automatically to the frequency drop within 30 seconds. The time step of information Kiwi can acquire from Moor House is near real-time, second by second, minute by minute, half-hourly etc. Having this time step(s) in mind, for the definition of our regression model, the frequency with which data can be obtained is sufficient to run the model.

2.1.2 Ernest Dence-Greenwich council

Ernest Dence is a residential complex in Greenwich Council, London consisting of 3 buildings. These buildings are as follows:

- Aylmer House (64 flats);

- Jennings House (20 flats);
- Gifford House (20 flats).
- Currently installed equipment: energy consumption

The status of the project is under development (installing monitoring equipment) so we will be able to receive readings by end of October. DELTA project will test implicit DR signals that will suggest to the residents who have signed up for the DELTA project to reduce the energy consumption to avoid high electrical tariffs. Figure 3 shows the philosophy of the project and how the residents will receive the DR signals for the purpose of the DELTA pilot. A mobile application will be created during the DELTA project.

Since modern smart meters are to be applied, the time step with which the variables for the regression model can be obtained is considered sufficient to run the model.

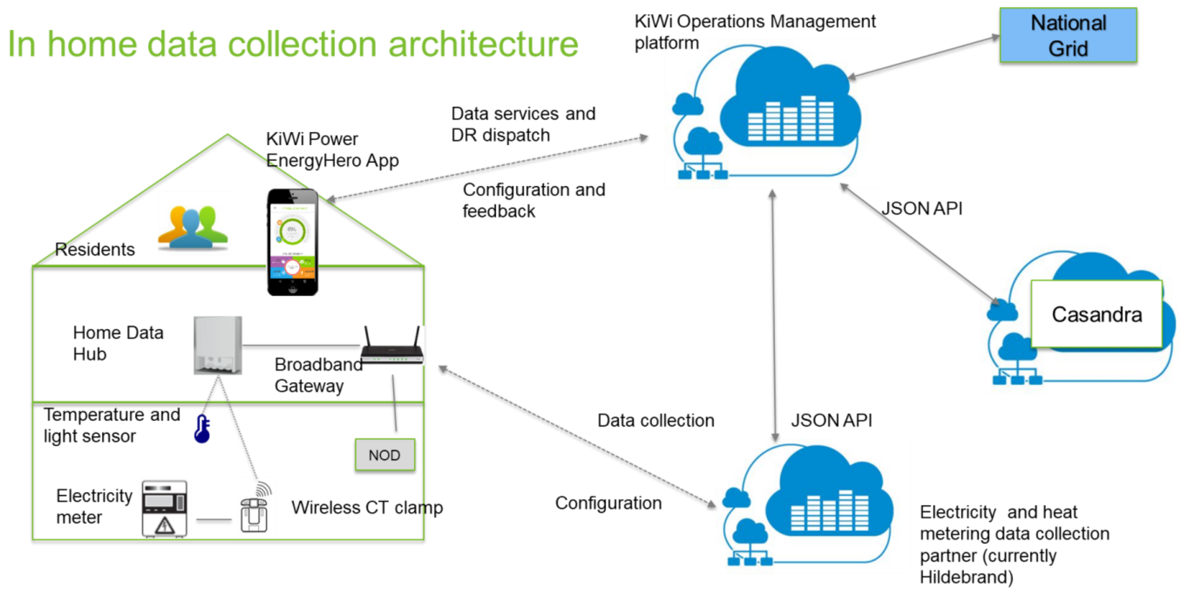

Figure 3: Project's concept and how the residents receive the DR signals

2.2 Pilot 2 - Cyprus

In Cyprus, the pilot site is actually a university campus, where various buildings are included (tertiary and residential). A connection of 11 kV to the network is used; the campus is considered a medium voltage commercial entity and thus it is offered either single or two-season two-rate tariffs. The following tables show the tariff situation:

Table 2: Medium Voltage Commercial Single Tariff in Cyprus

Item	Charge
Energy Charge per kWh	c€ 9.72
Network Charge per kWh	c€ 3.00
Ancillary Services Charge per kWh	c€ 0.64
Bi-monthly Meter Reading Charge	c€ 0.98
Bi-monthly Supply Charge	c€ 4.76

Table 3: Two-rate Commercial & Industrial Tariff for Medium Voltage Commercial and Industrial Entities in Cyprus

Charge per Unit cent / kWh						Monthly Charge €
Tariff charges	Periods	October - May		June – September		-
		Weekdays	Weekends and holidays	Weekdays	Weekends and holidays	-
Energy Charge	Peak	9.02 cent	8.68 cent	13.97 cent	8.73 cent	-

	Off-Peak	7.71 cent	7.36 cent	8.61 cent	8.43 cent	-
Network Charge	Peak	1.89 cent	1.89 cent	1.89 cent	1.89 cent	-
	Off-Peak	1.89 cent	1.89 cent	1.89 cent	1.89 cent	-
Ancillary Services Charge	Peak	0.62 cent	0.62 cent	0.62 cent	0.62 cent	-
	Off-Peak	0.62 cent	0.62 cent	0.62 cent	0.62 cent	-
Meter Reading Charge	-					0.49
Supply Charge	-					2.38

Table 4: Peak and Off-peak Times in Cyprus Tariff System

Tariffs Structure				
Periods	Description			
	October - May		June – September	
	Weekdays	Weekends and Holidays	Weekdays	Weekends and Holidays
Peak	16:00 – 23:00	16:00 – 23:00	09:00 - 23:00	09:00 – 23:00
Off-Peak	23:00 – 16:00	23:00 – 16:00	23:00 – 09:00	23:00 – 09:00

A broad range of buildings are included in the pilot site, like office buildings, sports and health centres and restaurants. Newly constructed and energy efficient buildings are present in the pilot site, covering an area of 80,000 m^2. The annual consumption of the whole University campus is around 12 GWh for a cost of more than 2 million euros. Heating/ cooling consumption is a significant proportion of the consumption. A district heating grid for the heating / cooling needs is available in the site.

There are three major PV installations on campus, namely one of 70 kWp and one of 150 kWp (rooftop systems) along with a small 175 kWp PV farm. The pilot site is equipped with Building Management systems from various vendors, like Siemens, Johnson Controls and Honeywell. Building operations are also monitored by supervisory and control equipment. The energy schematic that describes the pilot site is described by Figure 4. Regarding the characteristics of the loads participating in the pilot site, these are described in Table 5.

Finally, with respect to the time step with which data is acquired, this can be set as low as every minute. Schneider Electric PowerLogic ION power quality meters, which communicate over Modbus TCP will be used for data collection. Source of data requests will be the FEIDs. Each entry will be recorded minutely using average values determined from one second spot value measurements. It is considered that the frequency for data collection is sufficient to define the baseline for DR events and thus evaluation of KPIs can be done successfully.

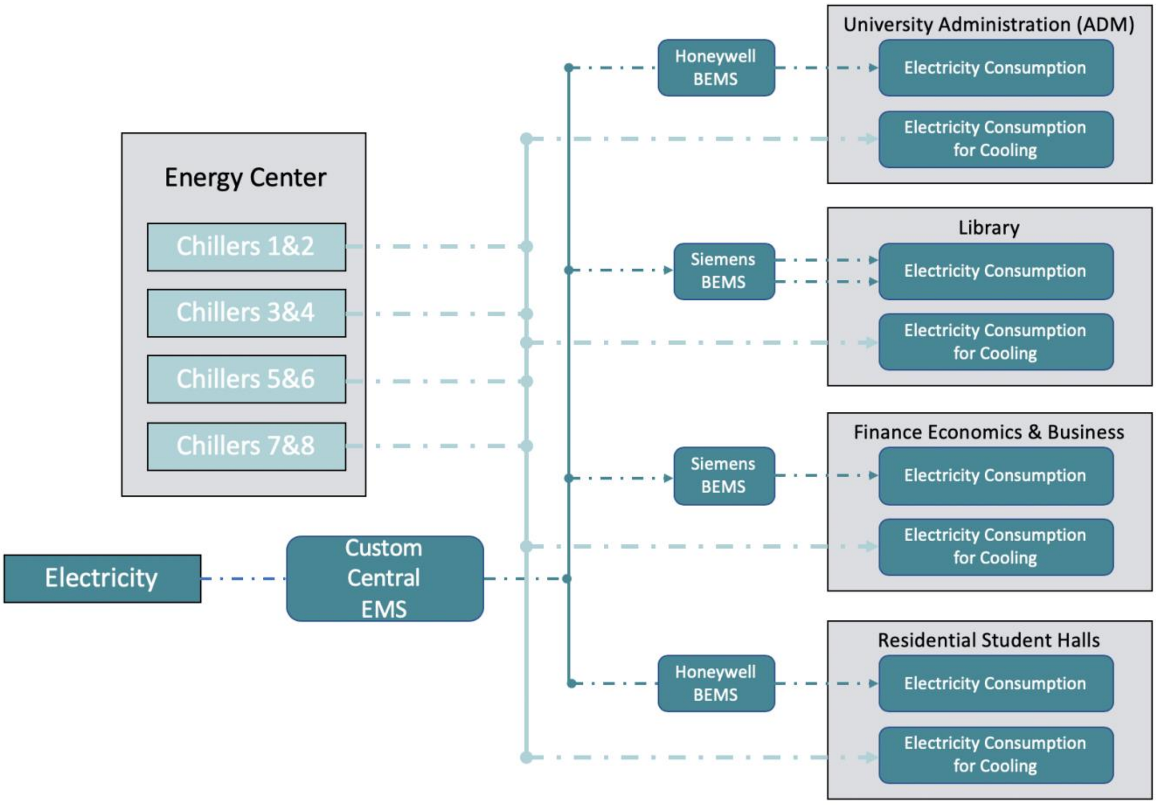

Figure 4: Line Schematic for University of Cyprus Campus Connections

Table 5. Overview of characteristics of loads participating in the pilot site

No	Building	Type	Annual Consumption [kWh/year]	Annual Peak Consumption [kWh/year]	Annual Off-Peak Consumption [kWh/year]	Annual Peak Consumption on Weekends [kWh/year]	Annual Off-Peak Consumption on Weekends [kWh/year]	Annual Electricity cost [€/year]
1	University Administration (ADM)	Commercial - Offices	1,352,034.95	474,733.99	545,345.74	146,245.45	185,709.77	254,592.88
2	Athletic Centre Sport	Commercial - Sports Facilities	26,079.72	9,157.26	10,519.30	2,820.96	3,582.20	4,910.90
3	Athletic Hall	Commercial - Sports Facilities	317,482.14	111,476.08	128,056.99	34,341.06	43,608.00	59,782.99
4	Energy Centre – Chillers 1&2	Commercial – Heating / Cooling	997,303.07	350,178.57	402,264.00	107,875.20	136,985.31	187,795.64
5	Energy Centre – Chillers_3&4	Commercial – Heating / Cooling	1,227,904.08	431,148.47	495,277.33	132,818.59	168,659.69	231,218.61
6	Energy Centre – Chillers 5&6	Commercial – Heating / Cooling	816,722.27	286,772.04	329,426.40	88,342.33	112,181.50	153,791.64
7	Energy Centre – Chillers 7&8	Commercial – Heating / Cooling	304,947.75	107,074.94	123,001.22	32,985.26	41,886.33	57,422.72
8	Energy Centre	Commercial - Offices	1,581,973.59	555,471.32	638,091.90	171,117.20	217,293.17	297,891.13
9	Faculty of Finance Economics & Business (FEB)	Commercial - Offices	1,054,308.01	370,194.46	425,257.04	114,041.24	144,815.27	198,529.86
10	Faculty of Pure	Commercial -	2,664,764.83	935,666.97	1,074,837.71	288,239.39	366,020.77	501,784.48

	and Applied Sciences (FST 01)	Offices/ classrooms						
11	Faculty of Pure and Applied Sciences (FST 02)	Commercial - Offices	1,044,136.88	366,623.12	421,154.49	112,941.06	143,418.20	196,614.60
12	Library – Incomer 1	Commercial - Library	377,085.34	132,404.29	152,098.05	40,788.16	51,794.84	71,006.48
13	Library – Incomer 2	Commercial - Library	483,643.88	169,819.71	195,078.63	52,314.27	66,431.27	91,071.82
14	PV Lab: Chillers-Climatic	Commercial – Heating / Cooling / Offices	6,916.20	2,428.45	2,789.66	748.10	949.98	1,302.34
15	PV Lab	Commercial - Offices	26,122.34	9,172.22	10,536.49	2,825.57	3,588.05	4,918.93
16	Social Facilities Building	Commercial – Facilities	1,352,034.95	474,733.99	545,345.74	146,245.45	185,709.77	254,592.88
17	Residential Student Halls	Residential – Facilities	223,550.00	78,494.11	90,169.30	24,180.71	30,705.88	42,095.24
	Total		13,857,010.00	4,865,550.00	5,589,250.00	1,498,870.00	1,903,340.00	2,609,323.17

2.3 DELTA PMV Framework – Guidelines for baseline determination

In this section, the framework provides guidelines regarding the approach for the determination of the baseline energy/power demand in DELTA pilot sites. The framework describes three baselining approaches, i.e. "regression model(s)", "meter before/meter after", and "day match" baselining. The detailed analysis of the standards used as literature review is shown in the Annex I.

2.3.1 Regression model for energy consumption

In pilot sites where historical data are available, regression models associating the dependent variable (energy/power demand) with the independent ones can be developed. A regression model is the proper option when metering data are available at the building level.

We qualify the use of a regression model for the DELTA PMV methodology in order to capture the relationship between the dependent variable, i.e. energy/power demand and the independent variables such as outdoors humidity (H_{out}), outdoors temperature (T_{out}), outdoors illumination (O_{ill}), normal weekdays (WD_N), holiday weekdays (WD_H), weekend days (WE). Other independent variables can include timestamp of demand (T_{stamp}), heating degree-days (HDD), cooling degree-days (CDD), a weighted temperature humidity index (W_{THI}) – can be used instead of individual temperature and humidity variables.

A multi-variate regression model of the following form is formed for the purposes of the framework:

$$E_D = a + b_1 * H_{out} + b_2 * T_{out} + b_3 * WD_N + b_4 * WD_H + b_5 * WE + b_6 * T_{stamp} + b_7 * O_{ill} + b_8 * HDD + b_9 * CDD + e \quad (4)$$

Where e is the error associated with the regression model.

Other independent variables that could be used as predictors of load/power demand are the socio-economic group of considered users, floor area (m^2) of considered buildings (or sub-parts), location (longitude, latitude) of the buildings, energy efficiency certificate (EEC) grade of the buildings.

A preliminary statistical analysis of the available data will determine which of the considered independent variables have a significant impact on energy/power[2] demand. The final model will only considered those variables.

2.3.2 Day Match

Day match baselining technique is used when there is lack of historical data for power demand in association with other variables for a given site. When this is the case, load demand during a number of (X) similar days prior to the day of the DR event is used in order to produce a baseline. This baseline is then used for calculating potential savings during the deployment of DR events. The number of similar days can span between 5 and 45 [15] [16]. Average, median and maximum values for load demand during the X similar days can be used as baseline load demand.

2.3.3 Meter Before / Meter After

When data are available at the asset level then the "*meter before/meter after"* technique before and after the deployment of a DR event should be used for estimating the baseline demand and potential savings. This method implies the presence of a meter for each of the assets that could

[2] A regression model for power demand can extracted from the regression model developed for the energy demand, since these two quantities are proportional. The proportionality factor is related to the time-step of the data used for creating the regression model for energy demand.

potentially participate in a DR event. Real time monitoring in a business as usual (BAU) mode for load demand (no DR event) has to be compared with load demand during the deployment of DR events; thus leading to the determination of potential energy savings etc.

3. Key Performance Indicators

3.1 List of KPIs

The DELTA project has numerous KPIs in order to address its expected impact in the Work Programme. These KPIs are categorised according to the value they assess. The KPIs are categorised according to the objectives they aim to. Therefore, KPIs are divided into 7 categories:

1) KPIs that are relevant, compatible with the broad EU energy policy context such as Climate-Energy packages and Energy Union
2) KPIs that address ongoing policy developments in the field of the design of the internal electricity market, of the retail market and discussions on self-consumption
3) KPIs that address interconnections between Member States and/or between energy networks
4) KPIs related to the EU power network being capable of integrating large share of renewables in a stable and secure way
5) KPIs showing that EU based companies are able to deliver adequate competitive product and services on the market in 5-10 years after the end of the project
6) KPIs that enable and/or enhance DR schemes bringing proven and quantified benefits for the grid and the consumers/ prosumers; validation of business models
    - Quantified benefits for aggregators/ retailers
    - Quantified benefits for prosumers
    - Quantified benefits for the grid
7) KPIs showing quantified benefits for the Ad-hoc DELTA indicators

In total, we have 26 KPIs to assess which characterise in a complete way the output of the project. As it has been mentioned in the Introduction, the KPIs can be assessed in a quantitative or qualitative way. The former ones refer to KPIs that are related to a value that usually needs to be calculated through mathematical formulas. The latter ones are usually not evaluated through formulas. They can refer to user satisfaction or the successful delivered business models. Such KPIs can be evaluated through feedback collected by end-users and stakeholders. In addition, there are KPIs that can be met only through the completion of other deliverables or after the implementation of the pilot sites.

The rest of the chapter is divided into three parts, one describing the KPIs that require a quantitative evaluation, one describing KPIs that require a qualitative evaluation and one describing KPIs that become evident through other deliverables or after the implementation of the pilot sites. Table 6 presents a list with the total number of KPIs, their title and the group to which they belong according to their evaluation procedure (QT for quantitative, QL for qualitative, DD for other DELTA deliverables or tasks). It should be noted that KPIs named 1.x refer to the KPIs of the first category, meaning the KPIs that are relevant, compatible with the broad EU energy policy context such as Climate-Energy packages add Energy Union. Accordingly, KPIs named 2.x refer to the KPIs that address ongoing policy developments in the field of the design of the internal electricity market, of the retail market and discussions on self-consumption, KPIs named 3.x refer to KPIs that address interconnections between Member States and/or between energy networks, etc.

Table 6: List of KPIs and their grouping

KPI	Title / **Target**	Group
1.1	Emission savings / **At least 20% lower carbon emissions in the Customers of the pilot activities**	QT
1.2	Increase in trust and security / **At least 75% of the Customers in the sites will acknowledge DELTA integrity**	QL
1.3	Peak load reduction / **At least 44% peak load reduction is expected during the demonstration activities**	QT
1.4	Energy efficiency / **At least 20% energy savings expected for the pilots' participants**	QT
2.1	Guidelines regarding current policies for including the DELTA solution / **Consolidating relevant outputs of workshops in at least 2 white papers**	DD

2.2	Recommendations for policy makers for developing appropriate regulations to accelerate market adoption of the project solutions / **A number of recommendations would be included from the various Stakeholders and organizations**	DD
3.1	Workshops organization and participation / **4 workshops will be organized throughout the project lifetime**	DD
3.2	Number of people participating in workshops / **At least 100 people/workshop are expected to participate**	DD
3.3	Utilities willingness to validate the solution / **At least 4 Utilities will be interested in validating the solution, during the project**	DD
4.1	Inclusion of distribution grid-connected RES and energy storage in VPP / **A 10 MW of installed capacity PV park and 1MWh Storage will be included and participate in the VPP-based DELTA solution, along with residential prosumers, during the demonstration activities**	DD
4.2	Reduced imbalance penalties-related costs due to RES supply volatility / **Aggregators and Retailers will validate a minimum reduction of imbalance-related costs of 15-20%**	QT
4.3	Increase of distribution grid capacity to support RES / **At least 30% more grid capacity will be evaluated by the Cyprus pilot DSO**	QT
5.1	Validation of DELTA solution from key Energy Stakeholders / **At least 1 Aggregator, 1 DSO and 1 Retailer will validate the solution during pilot activities**	DD
5.2	Number of software products delivered / **At least 5 (collaboration, award, visualization, segmentation and forecasting)**	DD
5.3	Customers, Retailers, SMEs acceptance for future use / **At least 70% of participants would express their interest for future use of the DELTA solution**	QL
6.1.1	Number of successfully delivered and validated business models / **At least three complete business models will be conceived and two will be validated during the pilot activities**	DD
6.1.2	Delivery of DR-enabling tools and devices for utilization from Retailers/Aggregators **Delivery Decision Support System for Aggregators, Virtual-Node-Platform, Fog-Enabled Devices and deployment in the pilots' phase**	DD
6.1.3	Increase of revenues / **Revenues for Aggregators are expected to exceed 20%, compared with current best DR practices in single buildings**	QT
6.1.4	Customers' Responsiveness / **Customers' responsiveness that use a FEID combined with BMS will go beyond 95% (fully-automated solution)**	DD
6.2.1	Discount in Customers' costs / **At least 25% discount in Customers' costs during the demonstration activities**	QT
6.2.2	Number of Customers successfully engaged / **At least 100 end-users will participate in the two real-life demonstrators of DELTA technologies (residential and non-residential blocks of buildings)**	DD
6.2.3	Customers' satisfaction and user friendliness of the UIs / **More that 70% of the involved customers in the demonstration sites express positive opinion on the ease of use solution**	QL
6.3.1	Full-scale provision of grid balancing and ancillary services / **At least 70% of the services delivered/tested during the demonstration activities**	QT
6.3.2	Smart load shedding, instead of Low Voltage/Frequency Demand Disconnection (LVDD&LFDD) / **100% achieved/tested during the demonstration activities**	QT
6.3.3	Distribution Grid congestion losses reduced / **At least 15% losses reduction during the demonstration activities**	QT

7.1	Timely and full (at the designated percentage) provision of defined indicators at the end of each year / **Respective KPIs should have reached their target at the end of each year**	DD

3.2 Quantitative KPIs

In this section, we describe the KPIs that can be evaluated in a quantitative way, meaning that one or more mathematical formulas are used to describe the KPI. For the quantitative KPIs we need many times the baseline. This is defined according to the procedure described in Chapter 3.

3.2.1 Emission savings (KPI 1.1)

This indicator shows the reduction in CO_2 emissions after the application of the demand response event provided by the DELTA solutions. The target to be achieved at the pilot sites by the customers that participate in the DELTA project is set to at **least 20% lower** carbon emissions.
The indicator can be calculated in $kgCO_2$ and according to [9] it is:

$$I_{CO_2,reduction}(\Delta t) = \sum_{t\in\Delta t} \Delta I_{CO_2}(t) \quad (5)$$

where:

$$\Delta I_{CO_2} = \sum_{source\in\{sources\}} \left(D_{DR,elec}(t) - D_{baseline,elec}(t)\right) \cdot MIX_{source}(t) EF_{source} + \sum_{fuel\epsilon\{sources\}} \left(C_{DR,fuel}(t) - C_{baseline,fuel}(t)\right) EF_{fuel} + \left(D_{DR,distrheating}(t) - D_{baseline,distrheating}(t)\right) EF_{distrheating} \quad (6)$$

If no different sources of energy are present other than electricity, then the equivalent terms are set to zero.

In the above equation, we have the following variables that are considered the input for the calculations.
$D_{DR}(t)$: energy demand during DR event in kW
$D_{baseline}(t)$: energy demand without DR event in kW
$C_{DR,fuel}(t)$: fuel consumption during DR event in kg/h
$C_{baseline,fuel}(t)$: fuel consumption without DR event in kg/h
$MIX_{source}(t)$: national electricity mix; production sources of electricity that can be extracted from ENTSO-E database [17]
EF_{source}: emission factors of national production sources and district heating supplier in $kgCO_2$/kWh
EF_{fuel}: emission factors of fuel consumed in $kgCO_2$/kg

The national production sources of electricity are depicted through the index “source” and their proportions are time varying MIX_i. The ENTSO-E database [17] gives the electricity MIX for all countries. The electricity sources have different emission factors, EF, which are given us shown in Table 7, [18].

Table 7: National CO_2 emission factors

Country	National emission factor in tCO_2/ MWh (EF_{source})
Cyprus	0.707
UK	0.515

The national mix and the fuel emission factors for electricity (in $kgCO_2$/ KWh) and stationary combustion are presented in subsection 4.2.10. The emission factors are presented for various fuels, thus covering all the options of fuels that can be involved in DR

3.2.2 Peak Load Reduction (KPI 1.3)

This KPI shows the reduction in the maximum electricity demand. The target set for the DELTA demonstration activities is **at least 44%** peak load reduction. The KPI is actually the difference between the two peaks, the electricity peak with respect to the baseline and the electricity peak with respect to the Demand Response event.

$$D_{elec,peak\_reduction}(\Delta t) = max_{t\in\Delta t}\left(D_{elec,baseline}\right) - max_{t\in\Delta t}\left(D_{elec,DR}\right) \quad (7)$$

$$D_{elec,peak\_reduction}[\%] = \frac{D_{elec,peak\_reduction}[kW]}{max_{t\in\Delta t}(D_{elec,baseline}[kW])} \quad (8)$$

The required inputs are the real electricity demand during the DR event ($D_{elec,DR}(t)$) and the baseline electricity demand if no DR event occurred ($D_{elec,baseline}(t)$). All the measures are in kW.

3.2.3 Energy Efficiency (KPI 1.4)

With this KPI, the energy savings should be calculated that correspond to the reduction or not of the consumed energy during a DR event. The target for DELTA is set to **at least 20%** energy savings expected for the pilots' participants.

For this calculation, the baseline energy consumptions are needed (consumption under no DR). It is also required, the time moments where DR takes place. Information in [9] has been taken into account.

Savings for electricity:

$$E_{savings,elec}(\Delta t) = \int_{t\in\Delta t}\left(P_{baseline,elec}(t) - P_{DR,elec}(t)\right)\cdot \delta_{DRactive}(t).dt \quad (9)$$

When there are discrete values instead of continuous, the following formula is used:

$$E_{savings,elec}(\Delta t) \approx \sum_{t\epsilon\Delta t}\left(\overline{P}_{baseline,elec}(t) - \overline{P}_{DR,elec}(t)\right)\cdot \delta_{DRactive}(t) \quad (10)$$

In the above equations, the following variables are defined as:

$\delta_{shed+shift}$: DR event trigger (δ = 1 when a demand response occurs, δ = 0 if no demand response occurs)

$P_{DR}(t)$: real energy consumption during a DR event (kW)

$P_{baseline}(t)$: baseline energy consumptions when no DR event occurs

Energy savings for other sources of energy will be calculated respectively.

The savings in percentage can be expressed as:

$$E_{savings}[\%] = \frac{E_{savings}[kWh_p]}{E_{cons,baseline}[kWh_p]}\cdot 100 \quad (11)$$

$$E_{cons,baseline}(\Delta t) = \sum_{\forall ev}\left(\int_{\Delta t} P_{baseline,ev}(t).dt\right) \approx \sum_{\forall ev}\sum_{t\in\Delta t}\overline{P}_{baseline,ev}(t) \quad (12)$$

which stands for the energy consumption, whereas the variable ev stands for the various energy sources.

If no different sources of energy are present other than electricity, then the equivalent terms are set to zero.

3.2.4 Reduced imbalance penalties-related costs due to RES supply volatility (KPI 4.2)

This KPI has to do with the penalties due to imbalance in the network with and without the inclusion of RES. The reduction should be calculated as follows: first the penalties for imbalance when having RES but no DR are calculated, and afterwards with the same RES but with DR. The penalty, in general, equals the difference between the imbalance price and the day-ahead price.

The necessary data to calculate the KPI will come from KiWi Power in the case of the UK pilot, based on their trading activities. The penalties as imposed from the TSO (National Grid) will be included in the Virtual DELTA Node (VDN) level. There will be no calculation for the KPI regarding the Cyprus site, since for the moment there are no such imbalance penalties, as there is no respective market.

The target for this KPI is set to a **minimum reduction** of imbalance-related costs of **15-20%**. The target KPI refers to the whole pilot site, to the DELTA Aggregator level.

3.2.5 Increase of distribution grid capacity to support RES (KPI 4.3)

This KPI depends highly on how the DSO measures it. There are many different limits that can determine the grid hosting capacity for RES, but typically it refers to the voltage limits (over/under-voltage). Thermal constraints of the cables and coordination of the protection equipment are also considered in calculating the distribution grid hosting capacity. There are many methodologies to calculate the hosting capacity [19], [20], [21], but typically it involves the modelling of the distribution grid and simulations using a power-flow software under different RES penetration scenarios, either deterministic or probabilistic. By increasing the penetration rate the level where one of the limits is violated is defined as the hosting capacity, see figure below:

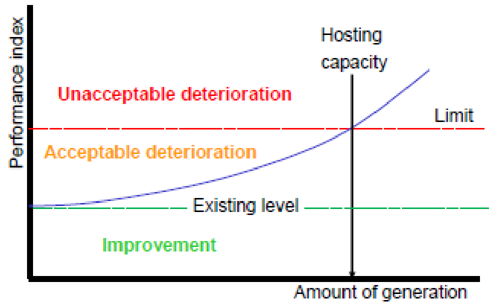

Figure 5: Definition of grid hosting capacity [19]

DR can have an impact on the distribution grid capacity. If there is a mechanism by which variable load/supply can be called upon to normalise outputs then this can be considered as an increase in capacity for RES. For example, if loads can be shifted to PV generation peaks then you can put more PV.

For the DELTA scope, the Cyprus pilot will be used to assess this KPI. In specific, EAC (Cyprus DSO) has a network model of the pilot site (University of Cyprus) with real data of the Medium Voltage distribution grid and the line and transformer equipment, prepared in DIgSILENT PowerFactory, as seen in the figure below.

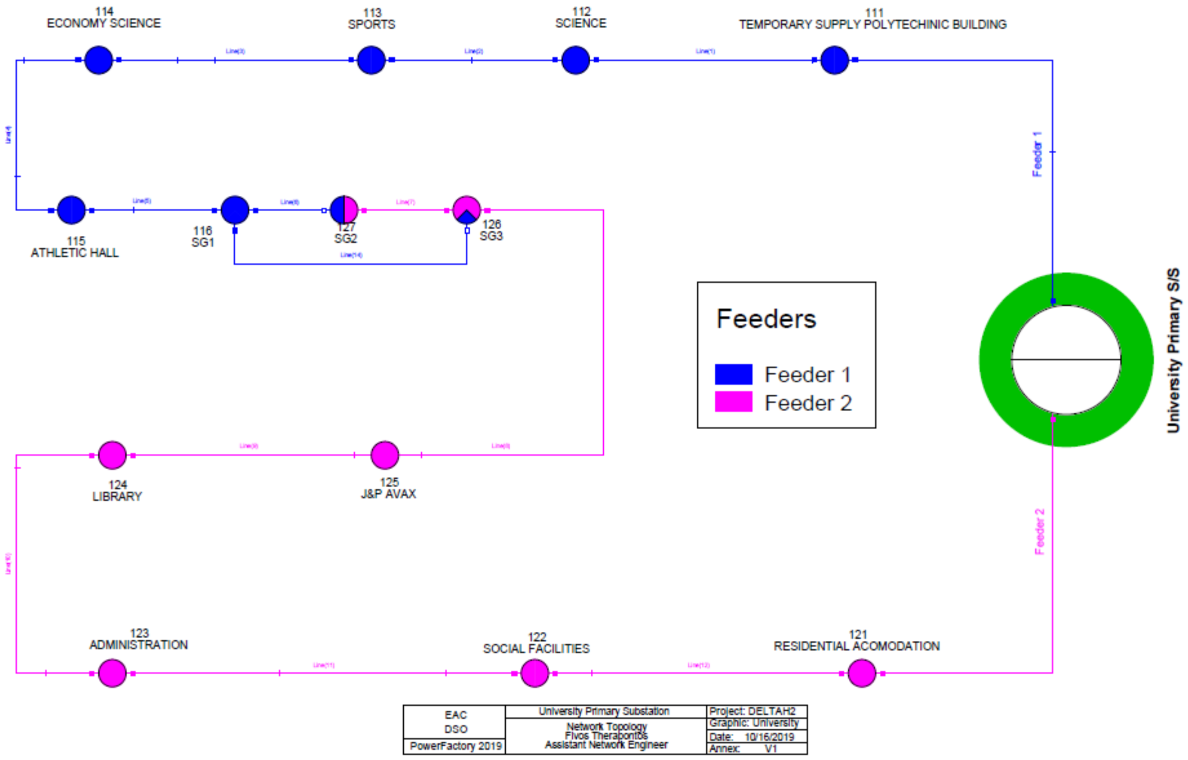

Figure 6: University of Cyprus (plot site) – Network Topology as modelled in DIgSILENT PowerFactory by EAC.

A special module of this software suite is used, i.e. "Distribution tools – Hosting Capacity", in order to calculate the hosting capacity. Based on the Cyprus Grid Codes the voltage in the distribution grid (11kV level) should always be between 0.9 and 1.1 pu., the equipment loading must always be lower than 100% of the nominal capacity of the equipment, and for PV (RES in general) connections the voltage difference at the point of common coupling (PCC) before and after the PV connection must be always lower than 2%. These values are used as limits, following the definition given in Figure 5. It has to be noted that based on the Cyprus Grid Code for Connecting RES, the power factor of the PV must be 1 until the PVs reach 40% of their nominal (max) output power and decreases linearly to 0.9 (Capacitive) from 40% to 100% of nominal output power.

As an example, three loading conditions were examined, i.e. 20% (low load), 50% (medium load) and 90% (high load) of nominal capacity of each distribution substation. The analysis was repeated two times, one for 0.9 leading pf and one with 1 pf of the PV. The results are shown below:

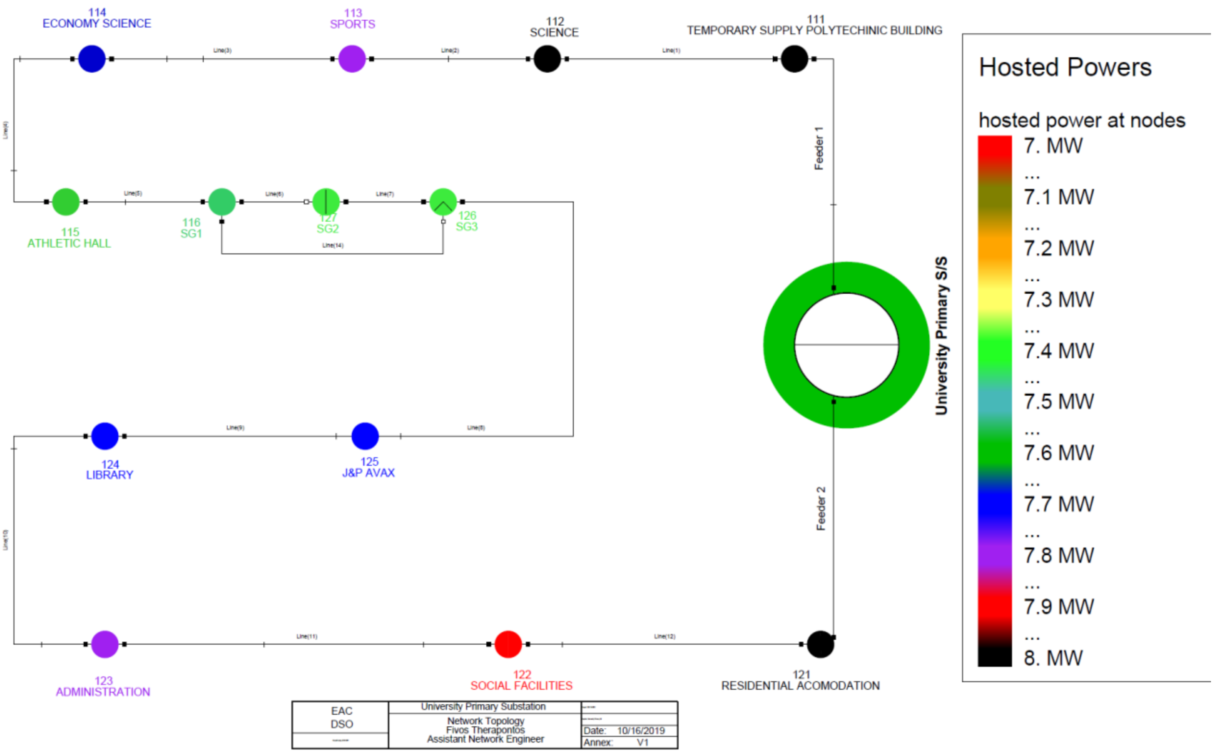

Figure 7: Example of Hosting capacity calculation for the Cyprus pilot site, with low loading conditions (20% of the nominal capacity of each transformer)

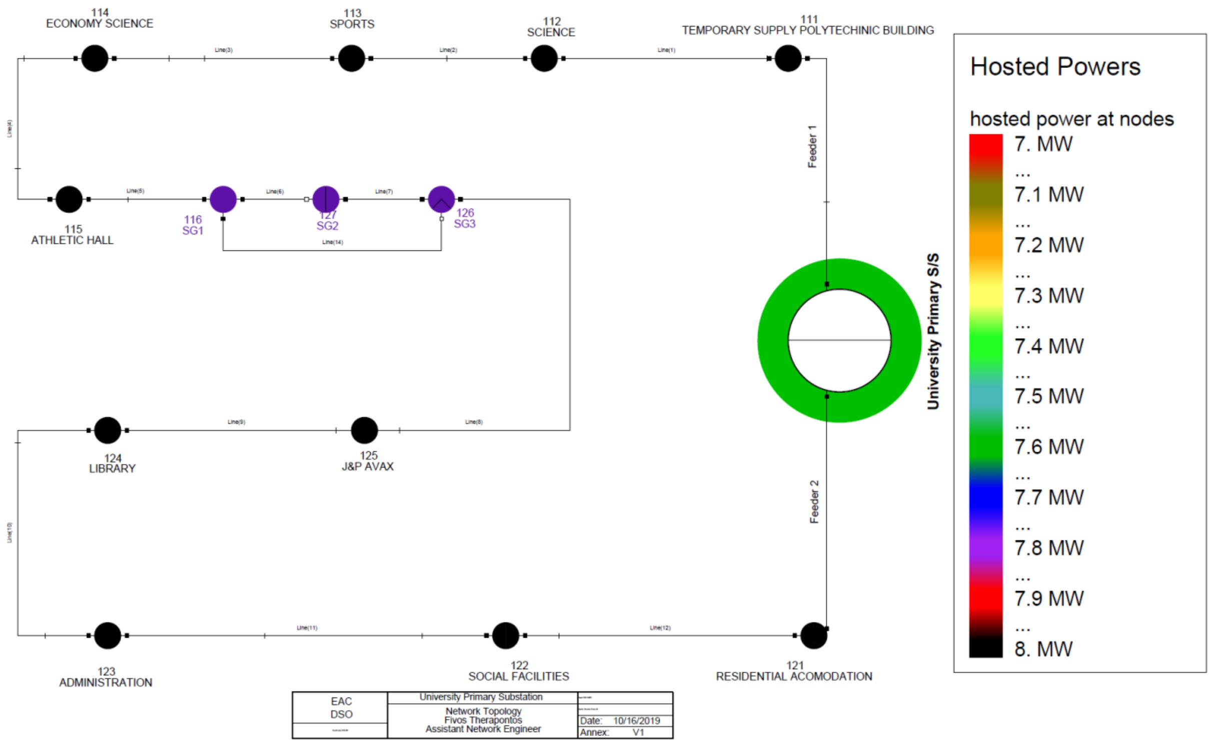

Figure 8: Example of Hosting capacity calculation for the Cyprus pilot site, with medium loading conditions (50% of the nominal capacity of each transformer)

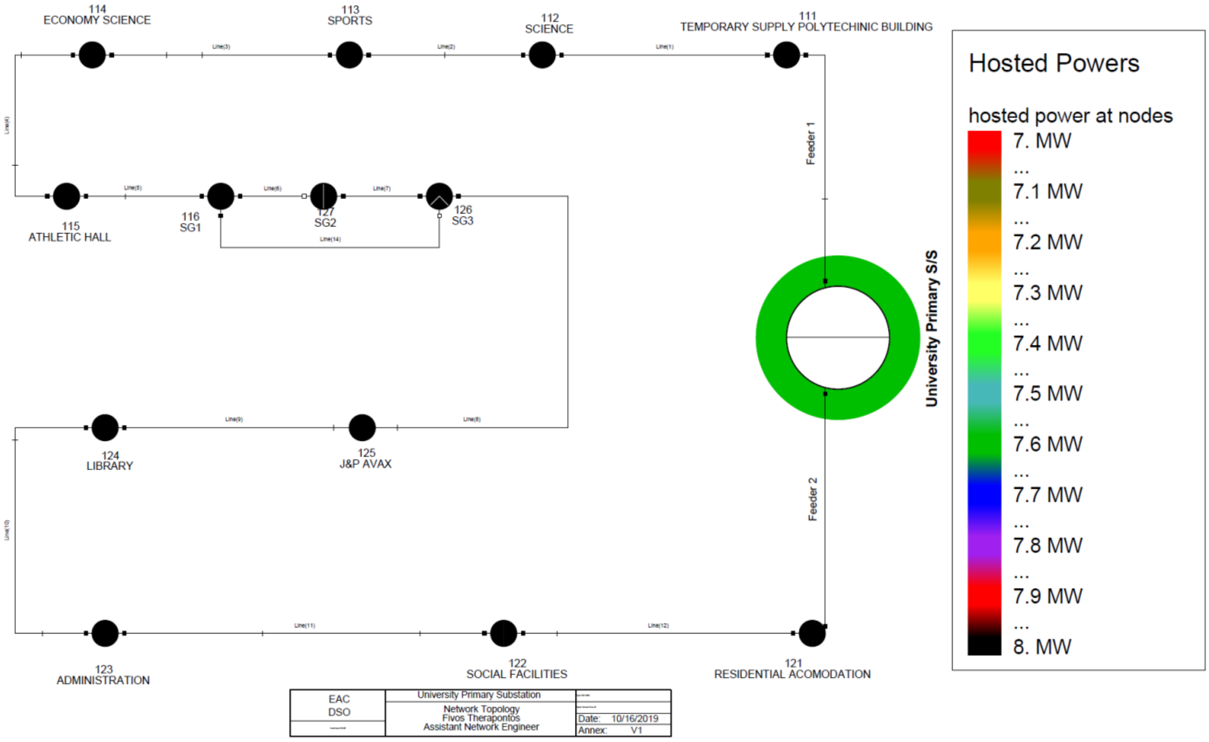

Figure 9: Example of Hosting capacity calculation for the Cyprus pilot site, with high loading conditions (90% of the nominal capacity of each transformer)

After the implementation of the DELTA solution to the Cyprus pilot site, the baseline and the actual loading condition will be applied to a similar analysis using the Hosting Capacity function of the software and the achieved increase in the hosting capacity, i.e. the KPI in question, will be calculated.

According to the targets set for this KPI, there should be an increase of 30% of the grid capacity. This target will be re-evaluated and if necessary reset in the second version of this report (Deliverable 1.8).

3.2.6 Increase of revenues (KPI 6.1.3)

This KPI is related to the aggregators' revenues and it is set as its target that the revenues will be **increased by more than 20%** with respect to the revenues that would have been achieved if current DR solutions were to be applied in buildings.

For the evaluation of this KPI the current DR solutions will be used as input. However, since in general there is no fixed formula to calculate the revenues of the aggregator for an asset, it is difficult to assign an increase to a specific DR solution. Aggregators tend to focus on optimizing the utilization of their assets as much as possible for a specific DR programme that this asset is committed. Therefore, this KPI will be calculated by the aggregator (KiWi Power), ex post. In specific, KiWi Power already calculates the revenues per "bucket" (portfolio of assets), but they can also calculate them per asset (in a manual way) and provide the results for the KPI. The target value for the KPI will refer to the whole portfolio, not a single asset.

3.2.7 Discount in Customers' costs (KPI 6.2.1)

This KPI has to do with economic gains for customers. It can be evaluated through the procedure defined in [9]:

$$EG(\Delta t) = \Delta FR(\Delta t) + \sum_{t \epsilon \Delta t} \Delta Ex(t) \quad (13)$$

where ΔEx stands for the energy expenses variations (electricity, fuels and district heating) and ΔFR stands for financial rewards. The output is calculated in national currency. The target for this KPI is a minimum discount of 25% in customers' costs during the pilot sites activities.

$$\Delta Ex(t) = \left(D_{baseline,distr\_heating}(t) - D_{DR,distr\_heating}(t)\right) Pr_{distr\_heating} + \left(D_{baseli\ \square,elec}(t) - D_{DR,elec}(t)\right) Pr_{elec}(t) + \sum_{fuel\in\{fuels\}} \left(C_{baseline,fuel}(t) - C_{DR,fuel}(t)\right) Pr_{fuel} \quad (14)$$

$$\Delta FR(t) = FR_{Dr,util} + FR_{DR,avail} + \sum_{t\in\Delta t} \left(S_{DR,elec}(t) - S_{baseline,elec}(t)\right) Pr_{elec,feedin} \quad (15)$$

In the above equation, the following variables are defined as:
$D_{DR}(t)$: real energy demand during DR event (kW)
$D_{baseline}(t)$: energy demand without DR event (kW)
$S_{DR,elec}(t)$: Electricity selling during DR event (kW)
$S_{baseline,\ elec}(t)$: Electricity selling without DR (kW)
$C_{DR,fuel}(t)$: real fuel consumption during DR event in m^3/h.
$C_{baseline,fuel}(t)$: baseline fuel consumption (without DR event, in m^3/h)
$Pr_{elec}(t)$: electricity sales tariff in national currency per kWh
$Pr_{elec,feedin}(t)$: electricity feed-in tariff (sold to the grid)
Pr_{fuel}: fuel tariff in national currency per m^3
$Pr_{distr\_heating}$: district heating tariff, in national currency per kWh
$FR_{DR,util}$: Utilization payment of related DR program in national currency or national currency per kW per hour
$FR_{DR,avail}$: Availability payment of related DR program

If no different sources of energy are present other than electricity, then the equivalent terms are set to zero. .

3.2.8 Smart load shedding, instead of Low Voltage/ Frequency Demand Disconnection (LVDD&LFDD) (KPI 6.3.2)

This KPI has to do with the events of smart load shedding. The target for this KPI is set to **100%** achieved during the demonstration sites. For evaluating this KPI, it would have been necessary to report the total number of smart load shedding events and the number of the events during which Low Voltage/ Frequency Demand Disconnection occurs. The latter number needs to be equal to 0, whereas the scheduled smart load shedding events should be equal to the ones actually realized.
The formula for this KPI is given as:

$$LSER = 100\% \cdot \sum_{i=1}^{B} [\sum_{t=1}^{t=N} Ev_S]/Ev_T \quad (5)$$

Where:
B: total number of houses/apartments/buildings where assets are needed to be disconnected for DR purposes
N: the amount of time for which the calculation is done (hours, days, etc.)
Ev_T: the total number of events when a smart load is disconnected
Ev_{LS}: the number of events when smart load shedding occurs, meaning when the assets are requested to be engaged for the deployment of shedding due to demand response for $t\epsilon[t-1, t]$

S_a: the event or not when the supplier asks for smart load shedding to be activated
Asset(i): the i-th asset asked to be disconnected by the supplier during a DR smart load shedding event
N_a: the total number of assets asked to be activated by the supplier during a DR event for a specific house/apartment/building

$$Ev_T = \sum_{t=0}^{t=N} (S_a = 1) \quad (6)$$

Where

$$S_a = \begin{cases} 1, when\ the\ supplier\ asks\ for\ N_a total\ assets\ to\ be\ disconnected\ from\ a\ building \\ 0, when\ the\ supplier\ asks\ for\ no\ assets\ to\ be\ disconnected\ from\ that\ building \end{cases}$$

$$Ev_S = \begin{cases} 1, for\ \sum_{i=1}^{N_a}(Asset(i) = 1) = N_a\ for\ every\ S_a = 1 \\ 0, elsewhise \end{cases} \quad (7)$$

For the purpose of DELTA, this KPI will be calculated via simulations. In specific, for the Cyprus pilot site, the already available grid model will be run twice, once with the actual load profiles including the DR offered by the DELTA solution, and once using the baseline load profile (made from historical data). By comparing the results, it will be demonstrated that in cases where we would otherwise have disconnections of loads due to low voltage, these disconnections are avoided thanks to the applied DR, i.e. Business As Usual vs. DELTA.

3.2.9 Distribution Grid congestion losses reduced (6.3.3)

This KPI is related to the congestion losses on the distribution grid, as its title implies. The target for this KPI is set to **at least 15% losses reduction** during the pilot sites activities. This target will be re-evaluated and if necessary reset in the second version of this report (Deliverable 1.8).For the evaluation of this KPI we need to calculate the congestion losses without the application of any demand response event and the equivalent losses after the application of the demand response event.

This is also related to the hosting capacity of the feeders in the distribution network, since as a feeder gets overloaded it's becoming less efficient carrier. To measure the losses we need to have the grid data to model a representative feeder and run power flow analyses for a high RES penetration or a high load request scenario (e.g. the simultaneous need for EV charging in a feeder). Afterwards, the same scenarios will be simulated but with a different load profile, due to the application of DR. The difference in the calculated losses will give the KPI. The same network model of the Cyprus pilot site (provided be EAC, see §4.2.5) will be used to run the necessary simulations. The input data will come after the implementation of the DELTA solution.

3.2.10 Electricity mix and emission factors

In this subsection we present the electricity mix for UK and Cyprus, since the pilot sites are in these countries, as given in the ENTSO-E database 2018 [17].

Table 8: Electricity mix, as extracted from [17]

2018	CY		GB	
	Value in MW	Coverage ratio in %	Value in MW	Coverage ratio in %
Non-Renewable	**1,478.00**		**51,078.00**	
Nuclear	Not Expected		9,160.00	100
Non-renewable hydro				
Of which hydro pure pumped storage	Not Expected		Not Expected	
Of which Hydro mixed pumped storage (non-renewable part)	Not Expected		Not Expected	
Fossil fuels	**1,478.00**		**41,918.00**	

Of which Fossil Brown coal/Lignite	Not Expected		Not Expected	
Of which Fossil Coal-derived gas	Not Expected		Not Expected	
Of which Fossil Gas	Not Expected		30,176.00	100
Of which Fossil Hard coal	Not Expected		10,860.00	100
Of which Fossil Oil	1,478.00	100	882	100
Of which Fossil Oil shale	Not Expected		Not Expected	
Of which Fossil Peat	Not Expected		Not Expected	
Of which Mixed fuels	Not Expected		Not Expected	
Of which Other fossil fuels	Not Expected		Not Expected	
Non-renewable Waste	Not Expected		Not Expected	
Other non-renewable	Not Expected		Not Expected	
Renewable	**289.8**		**19,829.00**	
Wind	**155**		**14,014.00**	
Of which Wind offshore	Not Expected		6,610.00	100
Of which Wind onshore	155	100	7,404.00	100
Solar				
Of which Solar PV	Not Expected			100
Of which Solar Thermal	Not Expected		Not Expected	
Bio			**2,017.00**	
Of which Biomass	Not Expected		2,016.00	100
Of which Biogas	Not Expected		1	100
Geothermal	**Not Expected**		**Not Expected**	
Renewable Waste	**Not Expected**		**5**	**100**

Renewable Hydro			**3,793.00**	
Of which Hydro Pure storage	Not Expected		2,830.00	100
Of which Hydro Run-of-river and pondage	Not Expected		963	100
Of which Hydro mixed pumped storage (renewable part)	Not Expected			100
Of which Hydro Marine (tidal/wave)	Not Expected		Not Expected	
Other renewable (not listed)	**134.8**	**100**	**Not Expected**	
Non identified (other not listed)	**Not Expected**		**Not Expected**	
Total Hydro			**3,793.00**	
Total Waste			**5**	
Total NGC	**1,767.80**		**70,907.00**	

In addition, we also present the Fuel CO_2 emission factors for electricity, in $kgCO_2/\ kWh_{th}$ (Table 8) and the emission factors for stationary combustion (Table 9).

Table 9: Fuel CO2 emission factors in kgCO2/ KWh, [22]

Fuel	CO2 Emissions Factor (kgCO2/kWhth)
Biodiesel, bioethanol etc.	0.00
Biomass (such as woodchips, chicken litter etc.)	0.00
Blast furnace gas	1.01
Coal and lignite	0.32
Coke oven gas	0.14
Domestic refuse (raw)	0.12
Ethane	0.18
Fuel oil	0.27
Gas oil	0.25
Methane	0.18
Mixed refinery gases	0.25
Natural gas	0.18
Other Biogas (e.g. gasified woodchips)	0.00
Other gaseous waste	0.18
Other liquid waste (non-renewable)	0.19
Other liquid waste (renewable)	0.00
Other solid waste	0.23
Sewage gas	0.00
Waste exhaust heat from high temperature processes	0.00
Waste heat from exothermic chemical reactions	0.00
Other waste heat	0.00

Wood Fuels (woodchips, logs, wood pellets etc.)	0.00
Fuel cells	0.18
Syngas / Other Biogas (e.g. gasified woodchips)	0.00
Other Industrial By-Product gases	0.18
Hospital waste	0.23

Table 10: Emission Factors for stationary combustion [23]

Fuel type	CO2 factor
	kg CO2 per short ton
Coal and Coke	
Anthracite Coal	2,602
Bituminous Coal	2,325
Sub-bituminous Coal	1,676
Lignite Coal	1,389
Mixed (commercial sector)	2,016
Mixed (electric power sector)	1,885
Mixed (industrial coking)	2,468
Mixed (Industrial sector)	2,116
Coal Coke	2,819
Other fuels – solid	
Municipal Solid Waste	902
Petroleum Coke (solid)	3,072
Plastics	2,850
Tires	2,407
Biomass Fuels – Solid	
Agricultural Byproducts	975
Peat	895
Solid Byproducts	1,096
Wood and Wood Residuals	1,640
	kg CO2 per scf
Natural gas	
Natural gas	0.05444
Other fuels – gaseous	
Blast Fumace Gas	0.02524
Coke Oven gas	0.02806
Fuel gas	0.08189
Propane gas	0.15463
Biomass Fuels - Gaseous	
Landfill gas	0.025254
Other Biomass Gases	0.034106
	kg CO2 per gallon
Petroleum products	
Asphalt and Road Oil	11.91
Aviation Gasoline	8.31
Butane	6.67
Butylene	7.22
Crude Oil	10.29
Distillate Fuel Oil No. 1	10.18
Distillate Fuel Oil No. 2	10.21
Distillate Fuel Oil No. 4	10.96

Ethane	4.05
Ethylene	3.83
Heavy Gas Oil	11.09
Isobutane	6.43
Isobutylene	7.09
Kerosene	10.15
Kerosene – Type Jet Fuel	9.75
Liquefied Petroleum Gases (LPG)	5.68
Lubrificants	10.69
Motor Gasoline	8.78
Naphtha (< 401 deg F)	8.50
Natural Gasoline	7.36
Other Oil (> 401 deg F)	10.59
Pentanes Plus	7.70
Petrochemical Feedstocks	8.88
Petroleum Coke	14.64
Propane	5.72
Propylene	6.17
Residual Fuel Oil No. 5	10.21
Residual Fuel Oil No. 6	11.27
Special Naphtha	9.04
Unfinished Oils	10.36
Used Oil	10.21
Biomass Fuels - Liquid	
Biodiesel (100%)	9.45
Ethanol (100%)	5.75
Rendered Animal Fat	8.88
Vegetable Oil	9.79

3.3 Qualitative KPIS

The KPIs described in this section are the ones that cannot be defined through mathematical formulas. In this section we present them and we give a method for their evaluation.

3.3.1 Increase in security and trust (KPI 1.2)

This KPI has to do with the acknowledgement of the participants towards the integrity of the DELTA technologies and their trust towards the system. The target set for this KPI is that **at least 75%** of the customers participating in the demonstration sites will acknowledge DELTA integrity.

This KPI could be evaluated through a questionnaire during the pilot sites functionality. For this reason, we need to the questions to be addressed to the participants of the survey. The questionnaire addressed to these user groups will be unique and will entail all questions to be assessed by various KPIs. In this case, the questions that are of interest can be as follows:

Table 11: Questions for KPI: Increase in trust and integrity

Increase in Trust and Integrity
Do you feel your data is secured through the DELTA system?
Do you think the DELTA architecture is a robust system that guarantees the functionality agreed?
Would you recommend DELTA solution to other users?

Annex I shows a prototype questionnaire that can be used for DELTA evaluation through user feedback. The answers can have the option of giving a score from 0 to 10 according to how much satisfied the user is with the relevant service or how much the user agrees with the statement given.

3.3.2 Customers, retailers, SMEs acceptance for future use (KPI 5.3)

This KPI is related to user acceptance and it can be evaluated through customers' feedback. Such an evaluation can be done through the questionnaire, which will be used also for the assessment of the KPI related to security and trust, described in the previous subsection. In this case, the questions that are of interest can be as follows:

Table 12: Questions for KPI: customer acceptance for future use

Customer acceptance for future use
Are you satisfied by the DELTA solutions overall?
Do you think that you obtained benefits through the use of DELTA solutions?
Is it likely that you use the DELTA solution also in the future?

The questions are shown in Annex 1.

Apart from customers' acceptance, the KPI evaluates also acceptance for future use by other actors, such as retailers. Therefore, feedback from such actors should also be addressed. A questionnaire can be a sufficient solution for this scope, which will be tailored-made for their role and will differ from the one directed to end-users. Annex 2 shows a prototype of a questionnaire addressed to actors like a retailer. The questions that can be of interest can be as follows:

Table 13: Questions for KPI: retailers acceptance for future use

Retailers acceptance for future use
Do you think that DELTA products offer a complete and integer solution in the field of DR?
Do you think that you obtained benefits through the use of DELTA solutions?
Is it likely that you use the DELTA solution also in the future?

The target for this KPI is set to **at least 70% expressing their interest** for future use of the DELTA solution and it will be verified through the questionnaires feedback.

3.3.3 Customers' satisfaction and user friendliness of the UIs (KPI 6.2.3)

This KPI can be evaluated through a questionnaire addressing the extent at which the end-users are satisfied with the user interfaces provided to them. Such interfaces should be user-friendly and easy to use, so as people will be able to handle them without difficulty. The target set for this KPI is set to **more than 70%** of the involved customers expressing **a positive opinion** with respect to the **ease-of-use**. The questions that can be of interest can be as follows:

Table 14: Questions for KPI: customers' satisfaction and user friendliness of the UIs

Customers' satisfaction and user friendliness of the UIs
Do you find the user interfaces easy to use?
Do you find the instructions given for handling the user interface explanatory enough?

The questions are shown in Annex 1.

3.4 KPIS to be evaluated through other deliverables or tasks

The KPIs described in this section are the ones that are proved through the successful implementation of the pilot sites or through other deliverables.

3.4.1 Guidelines regarding current policies for including the DELTA solution (KPI 2.1)

The target for this KPI is set to consolidating relevant outputs of workshops in at least 2 white papers. The evaluation of his KPI will take place after the completion of the project, when the total number of publications, workshops and outcomes will be reported. The consortium is highly oriented towards the publication of papers and the participation in workshops/ conferences.

3.4.2 Recommendations for policy makers for developing appropriate regulations to accelerate market adoption of he project solutions (KPI 2.2)

In Deliverable D2.1, an analysis of the current regulatory framework is done, where the situation in several countries is depicted. Opportunities of the existing regulatory framework for the application of DELTA services are assessed and incentives and barriers for the participation of small/medium consumers/prosumers are presented. Deliverable D2.3 aims at defining energy business models for enhancing and introducing new business roles in the energy markets. In addition, another target is to provide innovative services to DELTA actors.

On the other hand, deliverable D8.2 aims at the development of the DELTA business model, marketing and pricing strategy, start-up and marketing activities, cost-benefit analysis and risk analysis and management. In addition, preparation of individual exploitation plans defining roles and responsibilities will be done, and the process of marketing new products will be described. Deliverable D8.3 focuses on developing market opportunities to identify segments of interest for individual DELTA components. The Business Model Canvas methodology will be used for this scope, which is a tool for developing new business models.

Based on these deliverables, it is expected that a number of recommendations will be included for the policy makers by the stakeholders, which is the target for this KPI.

3.4.3 KPIs for enhanced interconnections between Member States and / or between energy networks (KPIs 3.x)

There are three KPIs with respect to this category, namely the:

1. Workshops organization and participation (KPI 3.1)
2. Number of people participating in workshops (KPI 3.2)
3. Utilities willingness to validate the solution (KPI 3.3)

The targets for these KPIs are set as follows:

1. to organize 4 workshops throughout the project lifetime
2. to have a participation of at least 100 people per workshop
3. to have at least 4 utilities expressing their interest to validate the solution

These KPIs will be evaluated at the completion of the project, when the total number of workshops, number of participants and the utilities expressing their interest for DELTA solutions will be reported.

3.4.4 Inclusion of distribution grid-connected RES and energy storage in VPP (KPI 4.1)

This KPI is related to the infrastructure that is installed in the pilot site(s). The target for this indicator is to include a 10 MW capacity PV park and a 1 MWh storage unit for participating in the VPP-based DELTA solution. In addition, residential prosumers will be present in the demonstration activities. This KPI will be verified after the implementation of the pilot sites when the infrastructure will be installed and ready to function. The capacity of the PV park and the storage unit to be used will prove the validity of this KPI.

3.4.5 Validation of DELTA solution from key Energy Stakeholders (KPI 5.1)

The target for this KPI is that **at least 1 aggregator, 1 DSO and 1 retailer will validate the solution** during the pilot activities. This KPI can be easily verified after the implementation of the pilot sites, when the number of actors (aggregators, retailers, DSOs, etc.) to validate the DELTA solution will be reported.

3.4.6 Number of software products delivered (KPI 5.2)

The goal for this KPI is to have **at least 5 software products** (collaboration, award, visualization, segmentation and forecasting). Similarly to the other KPIs described in this Section, this KPI will be evaluated at the completion of the project, when the total number of software products will be reported.

3.4.7 Number of successfully delivered and validated business models (KPI 6.1.1)

This KPI is related to the business models that are developed during the project's lifetime and their successful implementation at the pilot sites. Deliverable D1.1 describes the business scenarios and business use cases that are considered during the DELTA project. The business user requirements are also defined. On the other hand, deliverable D2.3 will define the DELTA energy business models that will enhance and introduce new business roles in the energy markets. The goal is that these models will be tested and verified in the pilot sites. The implementation of the models will be analysed during the pilots phase and verified through them.

As a result, this KPI will be verified after the completion of the pilot sites, where the business models will be tested and assessed as to which extent they have been successful. The target for this KPI is set to **minimum 3 business models being developed** and **at least two** being **validated during the pilot activities**.

3.4.8 Delivery of DR-enabling tools and devices for utilization from Retailers/ Aggregators (KPI 6.1.2)

This KPI is related to the DR tools (software and hardware) that will be developed during the project lifetime. These tools will be applied during the pilot sites and will be verified by the functionality of the pilot sites.

The target for this KPI is to deliver the Decision Support System for Aggregators, the Virtual-Node-Platform and the Fog-Enabled Devices. These tools are foreseen to be developed through the project's duration. Their functionality will be verified through the pilot sites.

3.4.9 Customers' responsiveness (KPI 6.1.4)

This KPI is related to the degree of automatization for customers that use a FEID combined with a Building Management System (BMS). The target for this KPI is set **to 95% for customers' responsiveness**, meaning that a close to fully automated solution is targeted at.

This KPI will be verified through the pilot sites implementation, where the DELTA solution will be tested. The FEID should be able to contribute to consumers' automatization and the level of their responsiveness will be evaluated. The end-users should be reached to a degree of 95% in an automatic way, which can be easily verified after the DR program implementation.

3.4.10 Number of customers successfully engaged (KPI 6.2.2)

This KPI has to do with the total number of end-users participating in DELTA solutions. The target is set to **at least 100 end-users** in the pilot sites of the UK and Cyprus for residential and non-residential buildings.

This KPI will be evaluated through the implementation of the pilots, when the total number of participants will be reported.

3.4.11 Number of customers successfully engaged (KPI 6.2.2)

This KPI has to do with the demand response events realized through the pilot sites. The target for this KPI is set to: **at least 70% of the services delivered**/ tested during the demonstration activities.

For this KPI to be met, we need to ensure that 70% of the services developed are indeed delivered/ tested. For example, if the project was planned to provide 5 services: load shedding, load shifting, etc., then the 70% target means to provide at least 4 out of these 5 into the pilot sites. Depending on the type and with the agreement of the consortium, a service could be considered provided, even if it will be ready for provision, but eventually only be studied off-line (e.g. in simulation scenarios). This KPI can be evaluated after the successful implementation of the pilot sites.

3.4.12 Timely and full (at the designated percentage) provision of defined indicators at the end of each year (KPI 7.1)

This KPI is related to the successful achievement of the other KPIs defined in this chapter, meaning that the KPIs should have reached their target at the end of each year.
This KPI is evaluated easily when assessing the achievement or not of the rest of the KPIs and it is expected to be evaluated at the end of the project's lifetime.

4. Conclusions

In this deliverable, the Performance Measurement & Verification methodology is described. The definition of the baseline is important, since it gives us values such as electricity consumption, peak load demand when no demand response event takes place. Such information is crucial to determine the advantages obtained from the application of demand response solutions provided from DELTA project.

The pilot sites are described, where the energy schematics diagram is depicted showing the loads connections and the metering points. In addition, tariff information is given as well as information about the time step with which the variables for the regression model to evaluate the baseline.

This deliverable lists all Key Performance Indicators of the project and defines a way of their evaluation. These KPIs are divided in three categories, namely quantitative KPIs, qualitative KPIs and KPIs to be evaluated through other deliverables or tasks. The former category entails KPIs that can be evaluated through mathematical formulas. The baseline is used for this category in order to compare the results with and without the presence of a demand response event. The second category includes KPIs that are evaluated through users' or other stakeholders' feedback, i.e. user satisfaction, retailers acceptance. Such KPIs can be evaluated through questionnaires directed to the correct stakeholders.

The latter category refers to KPIs that can be evaluated through the successful delivery of other tasks or milestones, i.e. number of software products delivered, number of successfully delivered and validated business models. Many of the KPIs that belong to this category are successfully met after the successful implementation of the pilot sites. This latter category does not include mathematical calculations or processing of users feedback in order to define if the KPIs are successfully met; however, the KPIs are listed here to give an overall description of the project's objectives and how they are evaluated.

In this report, all KPIs included in the technical annex are listed and a method for their evaluation is presented along with their set target. This report will be useful to define the overall objectives of the project.

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ANNEX 1: DELTA Measurement and Verification Framework

Introduction

In this Annex, we present the measurement and verification (M&V) framework used for assessing the effectiveness of DR programs across the pilot sites under the DELTA framework. A plethora of European and international standards and protocols on M&V techniques related to energy efficiency and energy savings are available in the literature. For the needs of this chapter, we present some of the available standards on M&V of energy savings in projects as well as the M&V protocol chosen to act as a reference work in this project, i.e. the international performance measurement and verification protocol (IPMVP) [24].

European as well as international standardization bodies are active in drafting and publishing standards on M&V of energy savings in projects. The European Committee for Standardization (CEN) has published the EN 16212:2012 "Energy Efficiency and Savings Calculation – Top-down and Bottom-up Methods" [25] that provides a general approach for energy efficiency and energy savings calculations with top-down and bottom-up methods applicable in buildings, cars, appliances, industrial processes, etc. Similarly, the International Organization for Standardization (ISO) has published, among others, the ISO 50015:2014 "Energy management systems – Measurement and verification of energy performance in organizations – General principles and guidance" [26] and the ISO 17741:2016 "General technical rules for measurement, calculation and verification of energy savings of projects" [27]. General principles and guidelines for the process of M&V of energy performance of an organization or its components and the general technical rules for measurement, calculation and verification of energy savings in retrofits projects or new projects, are presented respectively. In 2015, the "M&V Guidelines: Measurement and Verification for Performance-Based Contracts Version 4.0" [28] document was prepared for the U.S. Department of Energy (DoE) - Federal Energy Management Program (FEMP). ISO 50006 "Energy management systems – measuring energy performance using energy baselines (EnB) and energy performance indicators (EnPI) – General principles and guidance" [29] is briefly described due to the value added to a project from depicting a given site in a fence diagram where energy carriers, energy flows and associated assets (electrical loads) are depicted. The "Measurement and Verification for Demand Response" [30] document prepared under the National Action Plan for Demand Response for the USA DOE & FERC is also described. Key concepts such as the chain of events taking place before, during and after the deployment of a DR event are adapted to the needs of the DELTA M&V framework. Different baselining techniques are presented along with performance evaluation methodologies. Regression models are proposed for depicting the relationship between the dependent and independent variables for a given site.

Finally, we present the key elements of the International Performance Measurement and Verification Protocol (IPMVP) used as a reference work for the needs of the DELTA M&V framework. Key characteristics of the IPMVP protocol as well as its suitability and applicability within the DELTA framework are given. Most of the relevant (or similar) H2020 projects on DR, mentioned in previous chapters, make use of the IPMVP protocol as the means used for M&V of energy savings calculations.

Other, European and international standards, relevant to M&V for energy efficiency and savings at different scales (project, organization, country), not considered in this report are the following:

- EN 15900:2010 "Energy efficiency services – Definitions and requirements" [31]
- EN 16231:2012 "Energy efficiency benchmarking methodology" [32]
- EN ISO/IEC 13273-1:2016 "Energy efficiency and renewable energy sources - Common international terminology - Part 1: Energy efficiency" [33]
- EN ISO/IEC13273-2:2016 "Energy efficiency and renewable energy sources - Common international terminology - Part 2: Renewable energy sources" [34]
- ISO 50046:2019 "General methods for predicting energy savings" [35]
- ISO 17742:2015 "Energy efficiency and savings calculation for countries, regions and cities" [36]

- ISO 17743:2016 “Energy Savings – Definition of a methodological framework applicable to calculation and reporting on energy savings” [37]
- ISO 50006:2014 “Energy management systems – Measuring energy performance using energy baselines (EnB) and energy performance indicators (EnPI) – General principles and guidance” [38]
- ISO 50021:2019 “Energy management and energy savings – General guidelines for selecting energy savings evaluators” [39]
- ISO 50046:2019 “General quantification methods for predicted energy savings” [40]
- ISO 50047:2016 “Energy savings – Determination of energy savings in organizations” [41]
- ASHRAE “Guideline 14-2014 – Measurement of energy, demand and water savings” [42]

Below, we provide a brief description of the above-mentioned standards and protocols. The International Performance Measurement and Verification Protocol (IPMVP) is described extensively since it constitutes the document on which the ICT PSP Methodology is based.

EN 16212:2012 “Energy Efficiency and Savings Calculation, Top-down and Bottom-up Methods”

The EN 16212:2012 “Energy Efficiency and Savings Calculation, Top-down and Bottom-up Methods”, published in 2012 provides a general approach for energy efficiency and energy savings calculations with top-down and bottom-up methods. It is applicable for energy savings in buildings, cars, appliances, industrial processes etc. The standard covers all of the end use sectors. Both ex ante and ex post evaluations for expected and realized energy savings for any chosen period can take place.

Initially, the characteristics of top-down and bottom-up methods are presented. The key importance of the application of energy efficiency improvement measures is highlighted, since energy efficiency improvement could act as facilitator for the overall decrease of demand (e.g. peak values, decrease of annual energy demand etc.) as well as smooth and effective delivery of DR programs. The types of energy savings under this specific standard are presented (total, autonomous and policy induced savings and baseline and additional savings).

Next, both top-down and bottom-up savings calculations are described. Specific indicator types and formulas for calculating values are given. Calculation of energy saving per indicator as well as energy consumption units are provided too.

Figure 10 presents the energy trend before and after the application of actions aiming to increase energy savings in a given building, process etc. Autonomous savings, according to this standard occur without any deliberate effort to save energy, either from the users themselves or by other actors (e.g. technological progress).

Figure 10 is relevant both for top-down and bottom-up methods used for calculating energy savings. In [25] it is stated: “Top-down methods calculate the savings of end-user actions, whether they are the result of facilitating measures (e.g. policy) or due to autonomous developments (e.g. higher energy costs or technological progress)”, whereas: “Bottom-up methods focus on savings of specific end-user actions, whether connected to facilitating measures or not. Bottom-up methods can be used to evaluate policy-induced energy savings and total savings.”.

Regarding the type of the data used, top-down methods generally rely on statistical figures at the aggregated level e.g. energy consumption at the sub-sector level whereas bottom-up methods require detailed at the appliance level.

System boundaries have are taken into consideration since they define where the end-user actions take place and whether they have a larger impact on the energy conversion chain. System boundaries are defined according to the method used for calculating energy savings. Finally, in Table 15 an overview of the characteristics of top-down and bottom-up calculation methods is provided.

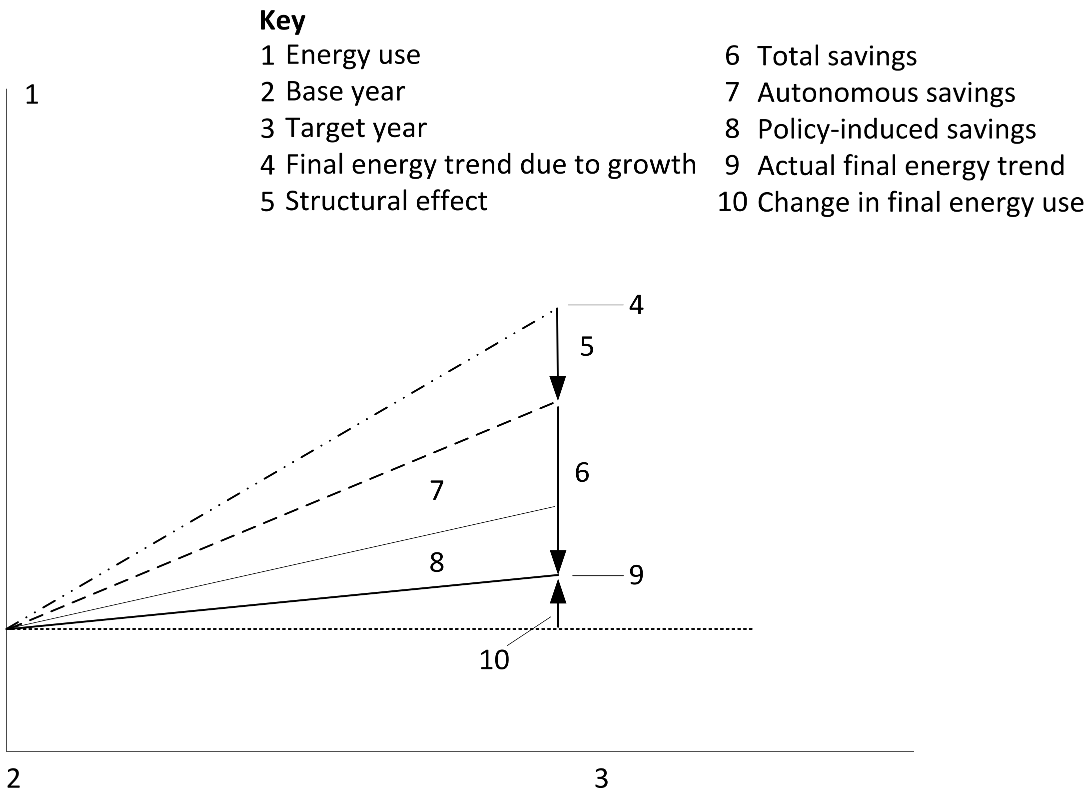

Figure 10. Autonomous, policy induced and total energy savings, [25]

Table 15. Overview of characteristics of top-down and bottom-up calculation methods, [25]

	Top-down	Bottom-up
Scope per method	Sector, final energy end-use, equipment	Targeted energy use, facilitating measure
EEI measure	End-user actions (aggregated)	End-user actions with/without facilitating measures
Resulting energy savings	Total	Additional (policy) – Total
Data used	Representative statistics at the level of analysis	Monitoring, surveys, test results on equipment, etc.
System boundary	Statistically defined	Dependent on measure

The rest of the standard deals with the description of energy savings with respect to the methods used as well as the definition of the indicator types available, indicator calculation formulas and example cases.

ISO 50015:2014 "Energy management systems – Measurement and verification of energy performance of organizations – General principles and guidance"

The ISO 50015:2014 "Energy management systems – Measurement and verification of energy performance of organization – general principles and guidance" provides information on M&V principles, the preparation of M&V plan as well as its implementation. Additionally, it provides information on how to manage uncertainty and prepare the M&V documentation.

Next, the standard presents the general M&V principles along with the definition of an appropriate accuracy and management of uncertainty for the considered variables, transparency and reproducibility of M&V process itself. The data management and measurement planning, the description of the competencies of the M&V practitioner, as well as impartiality and confidentiality principles that should permeate the M&V plan are presented as well. Subsequently, the M&V plan specifies the six fundamental steps in the M&V process. These are:

- Establish and document an M&V plan: the M&V plan is the document that describes how each phase of the M&V should be performed
- Data-gathering
- Verify the implementation of EPIA(s), if any
- Conduct M&V analysis
- Report M&V results and issue documentation
- Review the need to repeat the process, as necessary

Figure 11 presents graphically these steps.

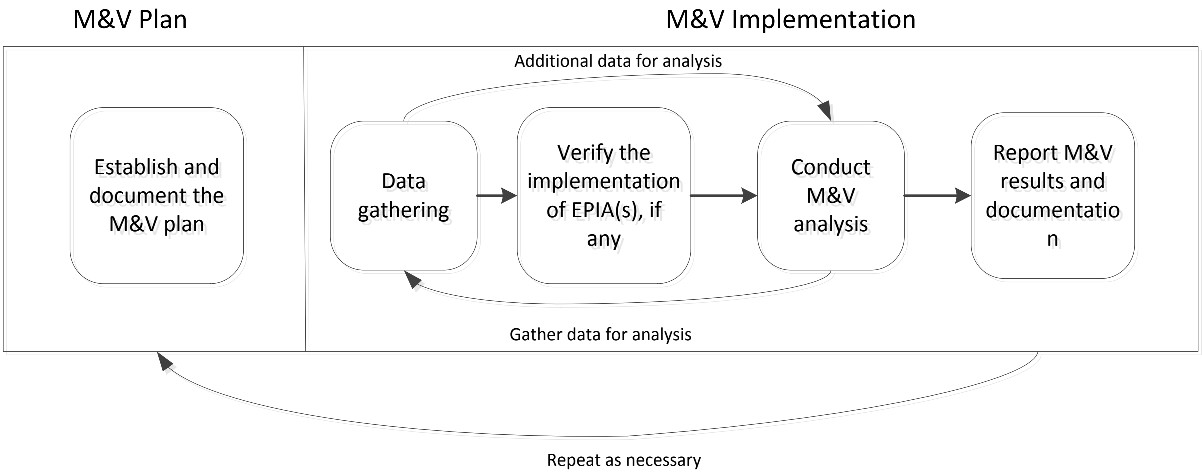

Figure 11. Fundamental steps in the M&V process, [26]

Next, the standard describes how to draft the M&V plan. General guidelines, the scope and the purpose of the standard are outlined. Energy performance improvement actions (EPIAs), if any, should be described and documented. The boundaries of the M&V process should be clarified and a preliminary M&V plan assessment should take place. Energy performance metrics, relevant variables and factors should be characterized and selected properly. A proper data gathering plan should be in place since they are the prerequisite for establishing the baseline and making relevant adjustments (if needed). Resources required, roles and responsibilities in place and the process the documentation process of the M&V plan should also be clear.

Once the M&V plan is in place it should be verified with real data and information relevant to EPIAs. The monitoring of the performance of the system leads to M&V analysis and reporting. Figure 12 presents an overview of the M&V flow used in the standard.

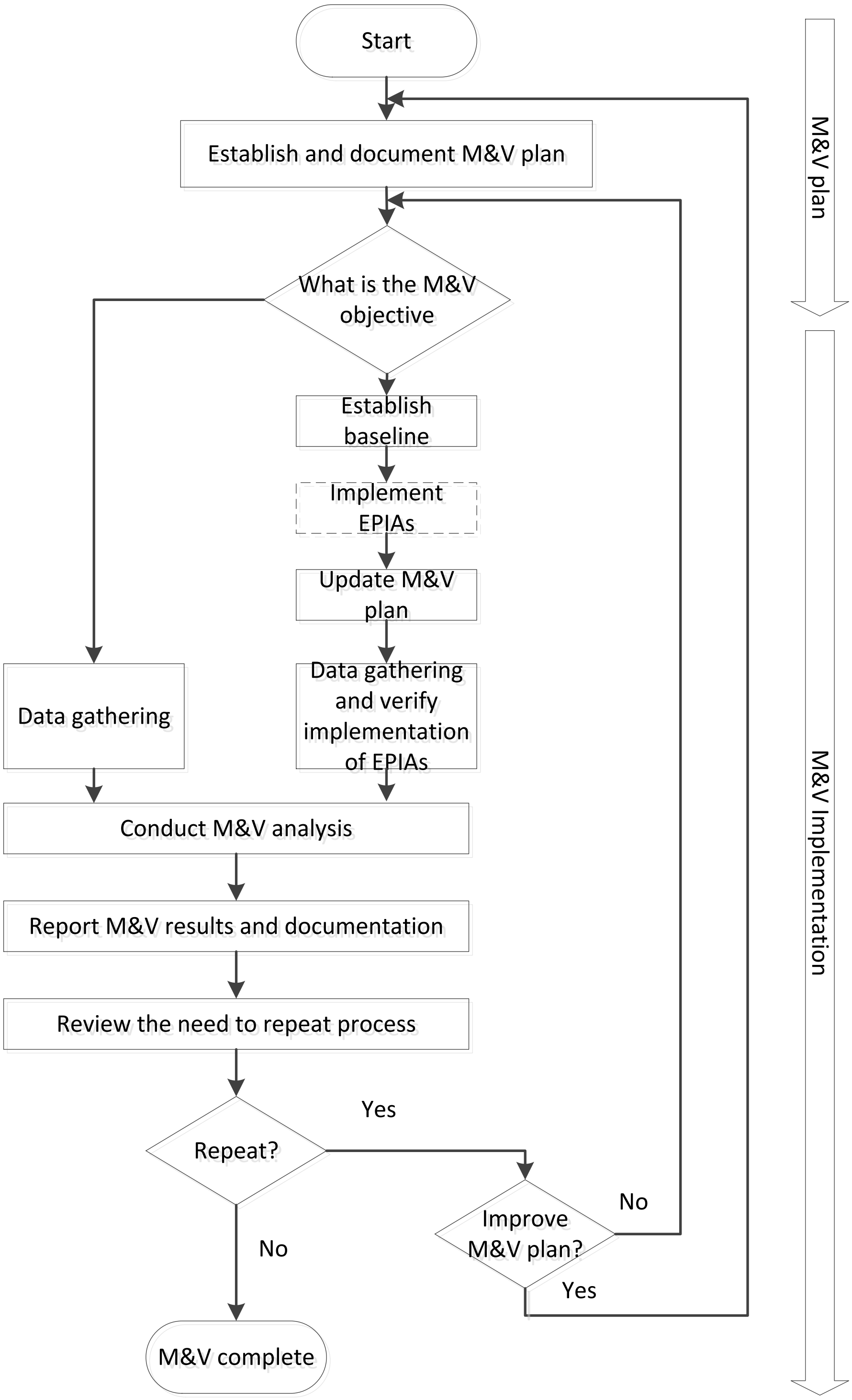

Figure 12. Overview of the measurement and verification flow, [26]

ISO 17741:2016 "General technical rules for measurement, calculation and verification of energy savings of projects"

The ISO 17741:2016 "General technical rules for measurement, calculation and verification of energy savings of projects" has the purpose of establishing a set of general rules for measurement, calculation and verification of energy savings of projects irrespective of M&V methodology used. Energy savings are determined through a comparison between measured, calculated, or simulated energy consumption before and after with or without implementation of interventions.

Energy savings are defined as the difference between the energy consumption during the baseline period adjusted properly and the energy consumption during the reporting period. Figure 13 shows the energy savings achieved during the reporting period compared to the baseline period.

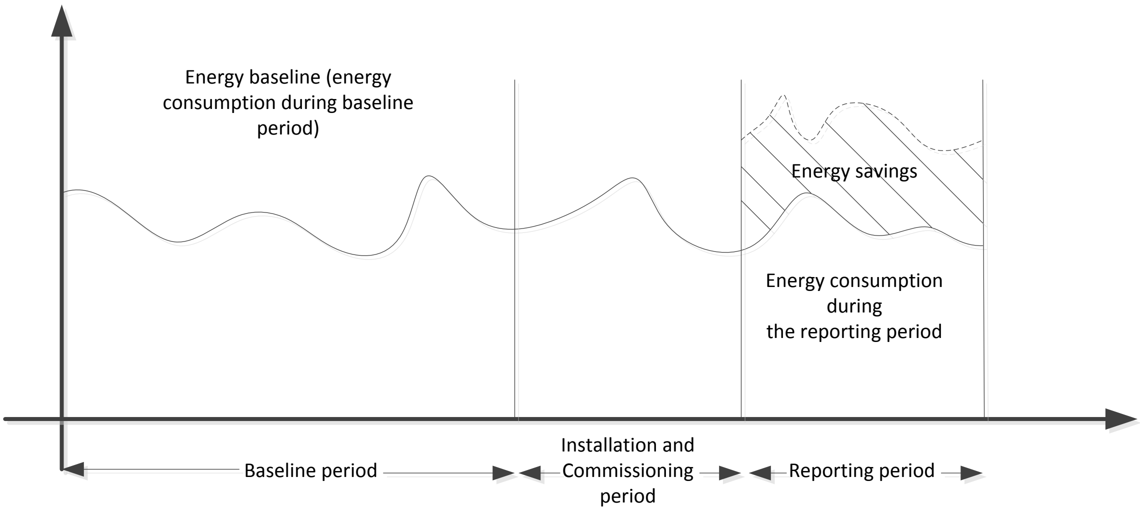

Figure 13. Demonstration of energy savings of projects, [27]

Figure 14 shows the procedure for M&V of energy savings of a project according to the standard. The preparation of the M&V plan relies on the boundary identification, the determination of baseline and reporting periods, the selection of the calculation method and the determination of specification of data collection & uncertainty of the result. Three calculation methods of energy savings are described. These are:

I. Direct comparison
   - Energy savings can be determined by turning on and off the energy performance improvement action (EPIA) without affecting the energy using systems or equipment. This method is used in retrofit projects.

II. Adjusted calculation
   - Statistical analysis is used to establish the model between the baseline period energy consumption and its relevant variables. This method is used in retrofit projects.

III. Calibrated simulation
   - Applicable when baseline energy data and reporting period energy data is unavailable. This method is used in both new projects and retrofit projects.

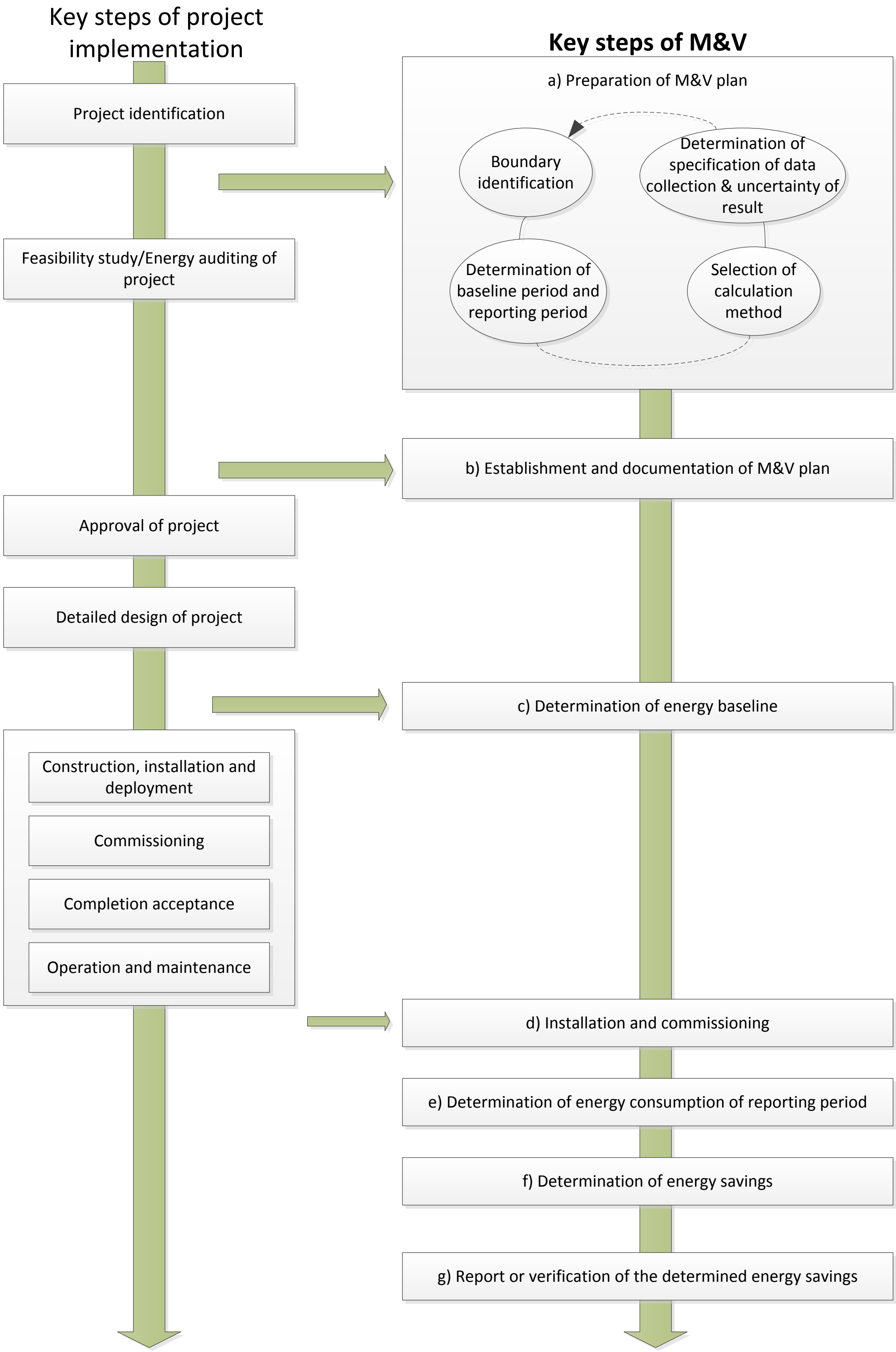

Figure 14. Demonstration of the logical relationship between the M&V and the project implementation, [27]

FEMP M&V Guidelines: Measurement and Verification for Performance-Based Contracts Version 4.0

The "M&V Guidelines: Measurement and Verification for Performance-Based Contracts Version 4.0" was prepared for the Federal Energy Management Program (FEMP) of the U.S. Department of Energy with the purpose of "quantifying the savings resulting from energy efficient equipment water conservation, improved operation and maintenance, renewable energy, and cogeneration projects installed under performance-based contracts" [19].

The FEMP M&V Guideline represents a specific application of the IPMVP protocol where procedures for determining M&V approaches and evaluation plans and reports for M&V tasks are outlined. The procedures outlined as well as the document in its whole is fully compatible with the IPMVP protocol.

The Guideline provides the general approach to M&V adopted in the document. This method is used because it fits the DELTA needs; this method will enable us to define the baseline needed to evaluate the KPIs. Energy savings are determined based on both performance and use factors for the considered facilities. Figure 15 presents the energy savings as a function of performance and use. The baseline and post-retrofit efficiency as well as baseline and post-retrofit operating hours are used into account for calculating energy savings.

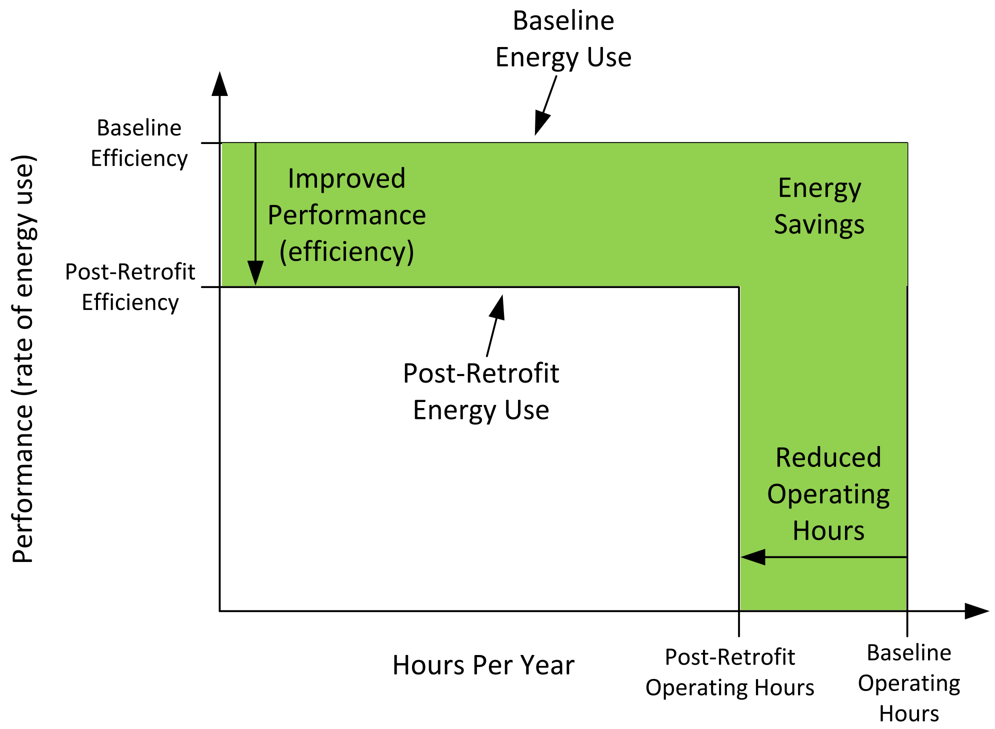

Figure 15. Energy Savings Depend on Performance and Use, Source: [28]

Next, the Guideline provides the steps for determining and verifying savings. These are follows:

- Step 1: Allocate Project risks and Responsibilities
- Step 2: Develop a Project-Specific M&V Plan
- Step 3: Define the Baseline
- Step 4: Install and Commission Equipment and Systems
- Step 5: Conduct Post-Installation Verification Activities
- Step 6: Perform Regular-Interval M&V Activities

The Guideline describes in detail how to use M&V for managing risks and developing an energy savings performance matrix, where a variety of variables are considered. The four M&V options available in the Guideline are thoroughly described and examples are presented. Since these options are adopted from the IPMVP protocol, they will be described extensively in the following section. Figure 16 presents the two methods and corresponding options available in the standard. Loads considered and metering point(s) are depicted.

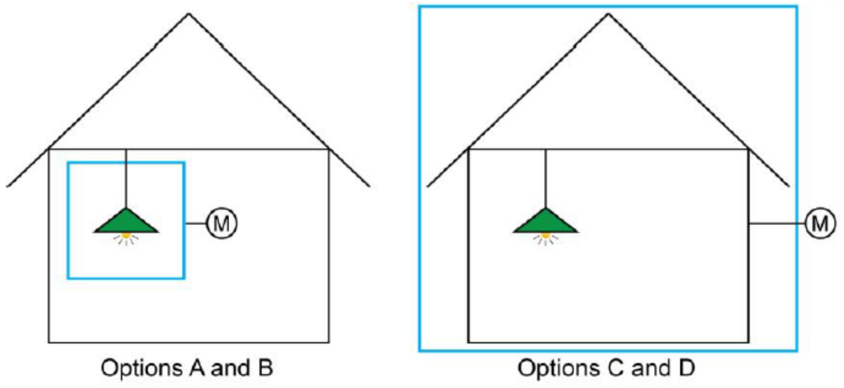

Figure 16. Retrofit-isolation M&V methods (Option A and B) Vs. Whole-facility methods (Option C and Option D), Source: [28]

Next, the guideline presents a guide for selecting the M&V approach that will be implemented along with estimated savings, uncertainties, savings risks (with no M&V program), calculation formulas for uncertainties, measurement accuracies, sampling techniques, estimation of relevant variables and modelling etc. Finally, specific Energy Conservation Measures (ECMs) are presented along with relevant M&V plan, M&V Option Selection Rationale and M&V Performance Assurance Activities.

ISO 50006:2014 "Energy management systems – Measuring energy performance using energy baselines (EnB) and energy performance indicators (EnPI) – General principles and guidance"

This standard provides guidance on the establishment, use and maintenance of energy performance indicators (EnPIs) and energy baselines (EnBs) in measuring energy performance and energy performance changes in projects. "Energy performance is a broad concept which is related to energy consumption, energy use and energy efficiency" [31]. Figure 17 shows the relationship between energy performance, EnPIs, EnBs, and energy targets when energy performance improvement actions are implemented in projects, organizations, etc. This figure summarizes the energy planning process that organizations include in the energy management systems (EnMS). Specific targets need to be in place and the means for achieving them should be clearly defined.

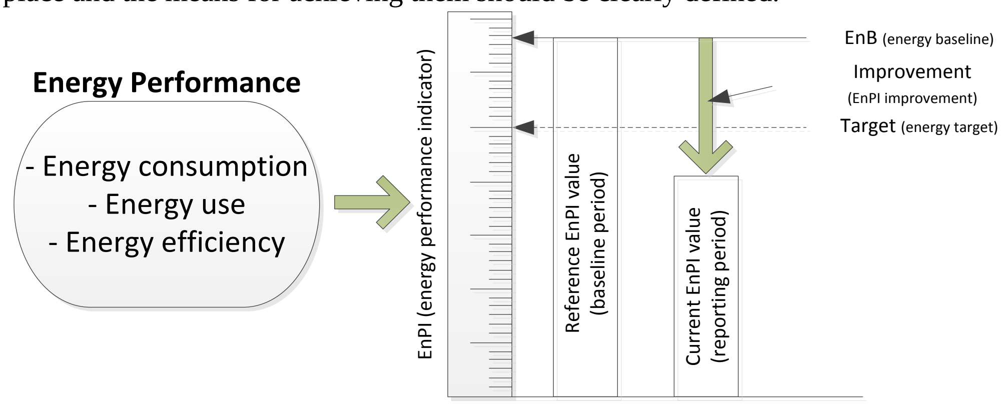

Figure 17. Relationship between energy performance, EnPIs, EnBs and energy targets, Source: [29]

EnPIs and EnBs are established in order to help organizations to measure and quantify their energy performance. EnBs quantify the energy performance of organizations during a period of time and before the introduction of Energy Performance Improvement Actions (EPIAs). Energy performance can be expressed in units of consumption (e.g. kWh), specific energy consumption (e.g. kWh/unit), peak power (e.g. kW), percent change in efficiency or dimensionless ratios, etc. The big picture regarding all the energy carriers (electricity, gas, etc.) used should be clear while maintaining a common unit of measure of energy consumption. The identification of energy uses in different systems (steam, chilled water, etc.), processes and equipment helps categorizing energy consumption. Energy efficiency is often used as a metric for measuring energy performance (EnPI). Different ways for expressing energy efficiency are available, i.e. energy output/energy input (conversion efficiency), production output/energy input, etc. Figure 18 presents the overview of energy performance measurement as provided in the standard.

EnPIs should be chosen properly in order to provide proper information to various users within an organization aiming at helping them to improve its energy performance. They can be applied at facility, system, and process or equipment level. The standard elaborates on the need of definition of suitable measurement boundaries for each EnPI. The standard defines the following three primary EnPI boundary levels that an organization may want to control:

- Individual facility/equipment/process (physical perimeter of a facility/equipment/process)
- System (physical perimeter of a group of facilities/processes/equipment)
- Organizational (physical perimeter of facilities/processes/equipment taking into account energy management of individuals, groups or business unit designated by the organization)

Next, the standard elaborates the need of defining and quantifying energy flows within the chosen EnPI boundaries. Figure 19 presents an energy map with energy flows, metering points and product flows for a given site. The definition and quantification of the relevant variables affecting the pattern of the EnPI is also discussed. Seasonality trends need to be captured along with the significance (R^2) of the variables considered to contribute to the overall performance of the EnPI. Finally, the standard suggests the identification of the static factors that may affect the EnPIs. They need to be maintained when relevant changes occur e.g. changes in building occupancy, shifts per day in industrial facilities, changes in the floor area of a building etc.

Next, the standard discusses the data gathering process including the data collection points for each considered EnPI. Direct measurements of energy consumption and indirect calculations of energy consumption based on e.g. flows of fuel or any other relevant raw materials have to be considered. Data collection frequency is also relevant and a sufficient number of data points for the needs of performing analyses should be available. The quality of the data points used should be assured towards quality requirements.

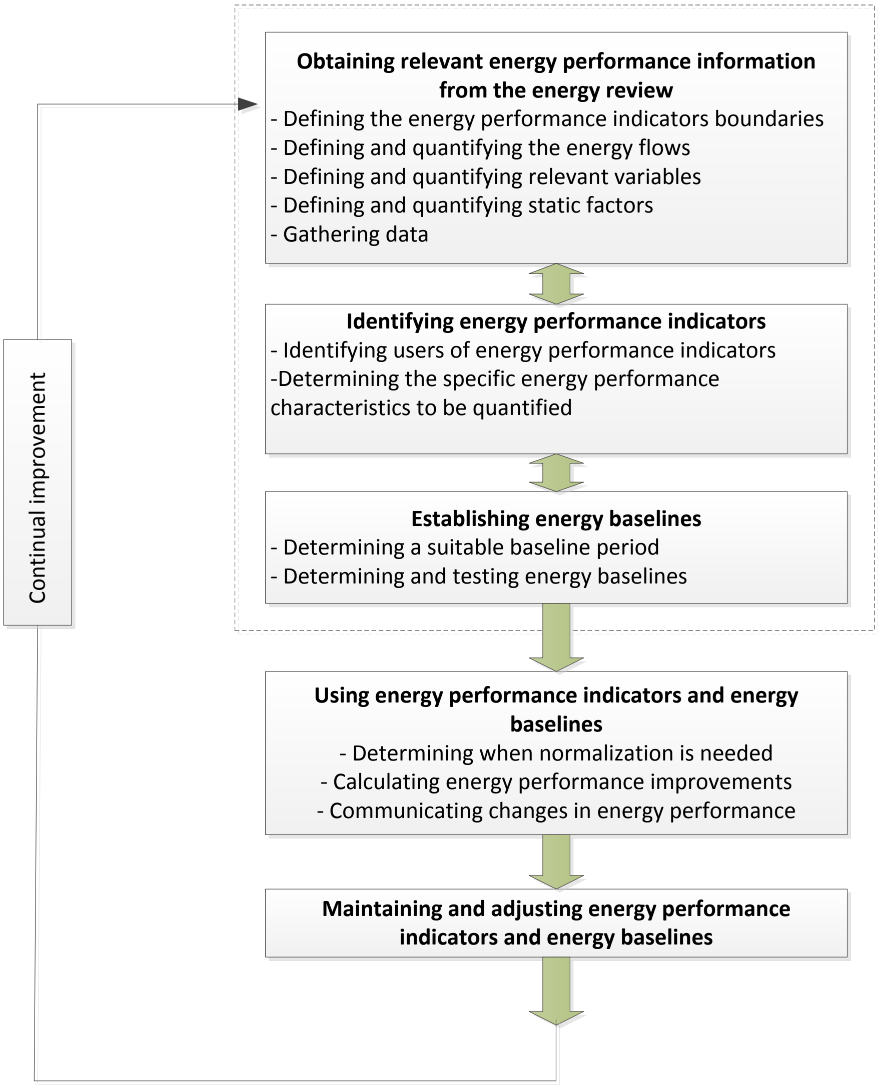

Figure 18. Overview of energy performance measurement, [29]

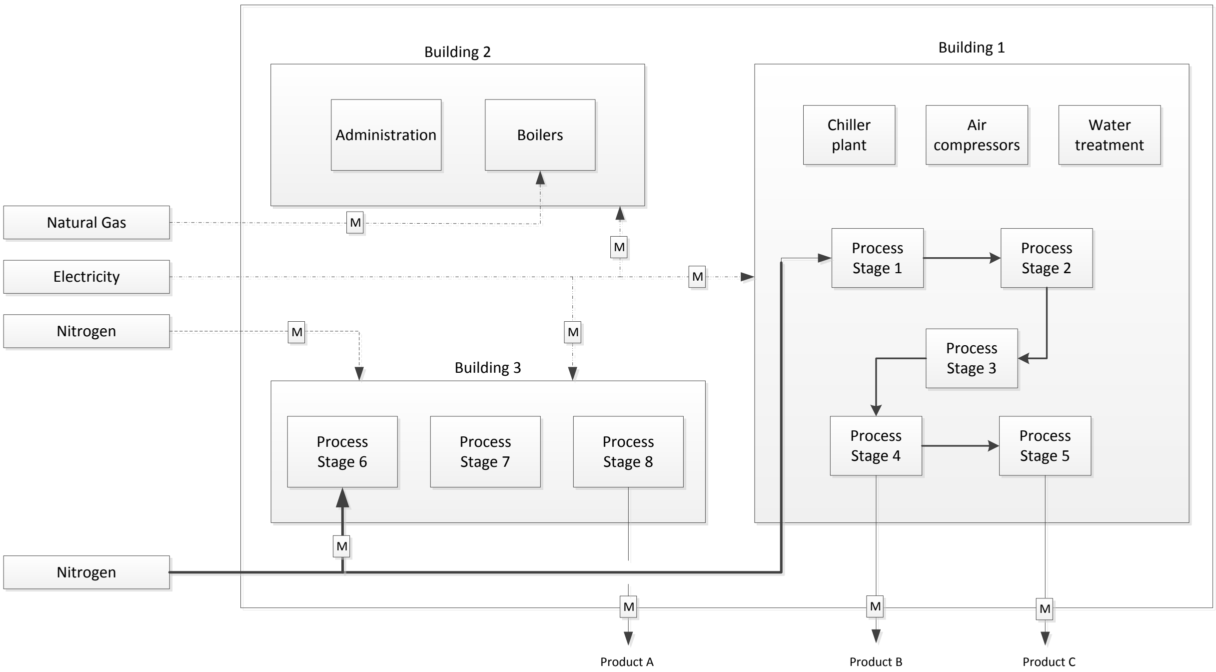

Figure 19. Energy map of a given site, [29]

Next, the standard discusses the approach that organizations need to pursue when identifying EnPIs. Organizational targets with respect to EnPIs should be defined as part of the energy planning process that are maintained in EnMS. Main types of EnPIs are identified as follows:

- Measured energy value (consumption at the site level or at different part of the site)
- Ratio of measured values (energy efficiency)
- Statistical model (linear or non-linear regressions for relationships between energy consumption and relevant independent variables)
- Engineering based model (engineering simulations for relationships between energy consumption and relevant independent variables)

The standard provides a table where the application areas of the EnPIs types, introduced above, are described extensively. EnPI values are used in order to define the EnB during the baseline period. The standard suggests taking into account a set of steps for establishing EnB. These are:

- Determine the specific purpose for which the EnB will be used
- Determine a suitable data period
- Data collection
- Determine and test EnB

Typically, the data collection for determining the baseline performance should last for a minimum of 12 months in order to account seasonality in energy consumption and relevant variables. Less than a year's period can also be considered when there is no seasonality in energy consumption or when shorter periods capture a reasonable range of operating patterns. When models are used, the use of statistical tests such as P-value, F-test, etc. can be used to determine how well the model fits the data considered.

The standard also addresses any normalization needs in order to compare energy performance between two periods under equivalent conditions. Formulas for calculating energy performance improvements are provided as well. Finally, guidelines for maintaining and adjusting energy performance indicators and energy baselines.

Four informative annexes are present in the standard in order to help practitioners clarify concepts mentioned in the core part of the text. Annex A deals with the "information generated through the energy review to identify EnPIs and establish EnBs". Annex B deals with the identification of EnPI boundaries in an example production system. Significant Energy Use (SEU) facility and equipment(s) are identified as shown in Figure 20.

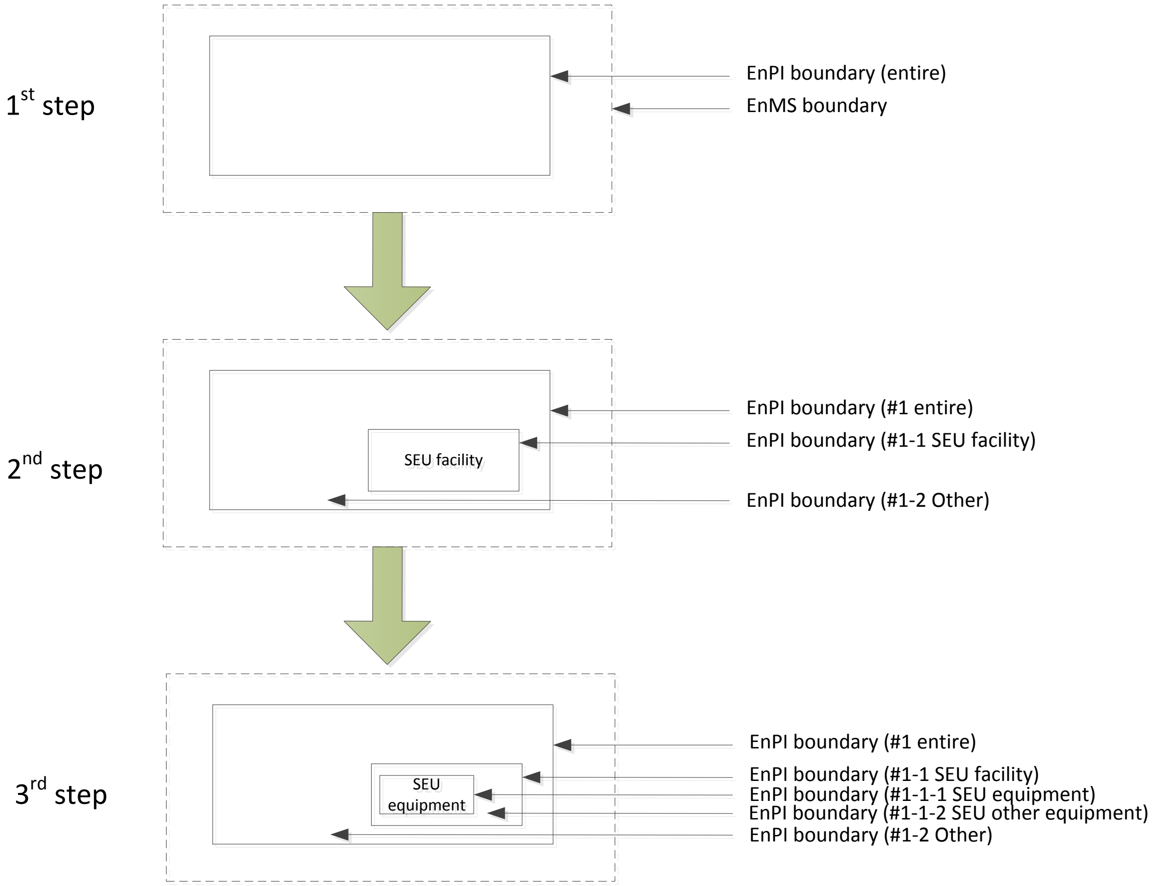

Figure 20. EnPI boundaries division process, [29]

Annex C deals with further guidance on energy performance indicators and energy baselines. A practical guide on measured energy values, statistical models and examples of EnPI types and application along with a case study on how to address EnPIs at different levels are provided. Annex D deals with the concept of normalization by providing an example where energy performance is calculated using normalization. A multiple linear regression model is used for estimating energy consumption and calculating consumption changes. Annex E deals with monitoring and reporting on energy performance. Energy performance is decomposed to its constituent parts, i.e. energy use, energy consumption, energy efficiency, energy intensity, etc. and different chart types for visualizing relevant quantities are provided.

NAPDR – Measurement and Verification for Demand Response (USA DOE & FERC)

The document was prepared in order to fulfil part of the Implementation Proposal for the National Action plan on Demand Response (NAPDR) of the USA DOE and FERC. The document describes the role of M&V for DR as a Resource, it adopts the North American Energy Standard Board's (NAESB's) M&V terminology and common DR program concepts and provides guidance on M&V methods for settlement and impact estimation.

The purpose of the document is to provide guidance on methods for M&V of DR in wholesale and retail markets. The document means to support designer and operators of DR programs as well as regulators, and potential participants in wholesale and retail DR program offerings. Two broad contexts within which demand reduction quantities are assessed under M&V programs are discussed, i.e. Settlement (demand reductions achieved by individual program or market participants and corresponding financial payments or penalties) and Impact Estimation (program level demand reduction achieved or projected to be achieved).

The role of M&V for DR as a resource is elaborated. The use of M&V for multiple purposes in the context of DR involves establishing the eligibility or capability of resources, the retail and wholesale settlement, future projections on the performance of individual assets taking into account their past performance, impact estimation of a product or program as a whole and forecasting and planning activities. Baselining methods for wholesale and retail settlement are particularly emphasized. Retail program or service structure (e.g. mechanisms through which the customer or the DR aggregator is compensated), common applications (e.g. demand bidding, peak time rebate, direct load control, dynamic or fixed time varying rates, firm load demand response, curtailable rates, etc.), M&V needed for participant settlement with program retail or wholesale operator (e.g. measured demand reduction, verification of event participation, metered usage by time interval, metered demand reduction etc.) and M&V needed for program level impact estimation are discussed. Guidelines on managing the DR M&V errors are provided (assessment of magnitude of systematic and random errors, adjustments for reduction of M&V errors and effect mitigation etc.).

NAESB's DR M&V terminology and common DR program concepts are outlined. Common DR mechanisms accompanied by NAESB DR M&V methods are described. This includes program mechanisms (firm load, reduction from baseline, behind the meter generation, direct load control), market/service types (retail or wholesale energy/capacity/reserves with respect to the mechanism), resource/customer type *(*individual or aggregate loads, individually interval metered, aggregate loads not individually interval metered, customer-sited generation, individual end users, aggregate of retail participants), and applicable NAESB DR M&V method (maximum base load evaluation, baseline type 1 (interval meter), baseline type 2(not interval meter), meter before/meter after, metering generator output etc.).

A plethora of aspects of program planning, design and operations affect the DR M&V methods, results and accuracy. Program rules, participant characteristics, M&V method used, cost effectiveness of the program chosen, planning and forecasting activities, etc. have their specific impact.

The document provides recommendations for M&V methods related to the characteristics of the participating loads. When implementing DR programs and according to type of the customers considered key qualities such as load sensitivity to load variations, load seasonality unrelated to weather and load variability unrelated to season or weather should be considered. The choice of the M&V method used and its accuracy are affected by the program design features. Recommendations regarding the reduction of the baseline error for weather sensitive loads, limiting gaming opportunities and static baseline opportunities are provided. The settlement M&V accuracy is assessed through a recommendation to include a baseline method assessment based on load simulation. Other aspects related with DR resources providing load reductions every day, highly variable loads, baseline methods for residential customers, peak time rebate are discussed.

The document provides guidance on impact estimation of DR programs. The determination of program effects takes place taking into account particular set of events, decrease (or increase) in energy consumption, monetary effects etc. A summary of impact estimation applications with respect to purpose (annual or seasonal program measurement, settlement with individual end users of DR aggregator, day-ahead or shorter operational planning, daily bidding and operations, annual planning), perspective (ex post or ex ante – if applicable), user (program operator, regulator, program participant – individual or aggregator), level of customer aggregation (program or specified aggregated load, individual account, all DR resources or targeted subset, own resources), event aggregation (individual event, summary of events, ranges of potential events under various scenarios), timing (end of season, day(s) after event or monthly, day or hour(s) ahead, season ahead, season ahead up to long term planning horizon) is outlined. The typical usefulness of DR impact estimation methods by end-use participant type and perspective is also presented. These impact estimation methods include *individual regression*, *pooled regression, match day, experimental design simple difference, experimental design with modelling, end use metering with duty cycle analysis, custom engineering and site analysis, composite analysis*. The evaluations take place either in ex-post or ex-ante manner and the impact categories are as follows *not useful, not generally useful, possibly useful, potentially useful, useful with additional work, useful if match on customer condition, useful, useful with additional work, very useful*.

As already mentioned, the purpose of the M&V methodology for DR is threefold. First, the baseline load should be determined (regression, day match, etc.), meaning the load that would have occurred in absence of any DR event. Second, the reduction of demand can be calculated as the difference between the baseline load and the observed load during a DR event. Third, the financial settlement amounts can be determined either as payments or as penalties based on the calculated reduction (or increase).

The document adopts the terminology used in NAESB's DR M&V standards since key terminology and assessment mechanisms are available there. Figure 21 presents the chain of actions taking place before, during the realization and after the delivery of a DR event.

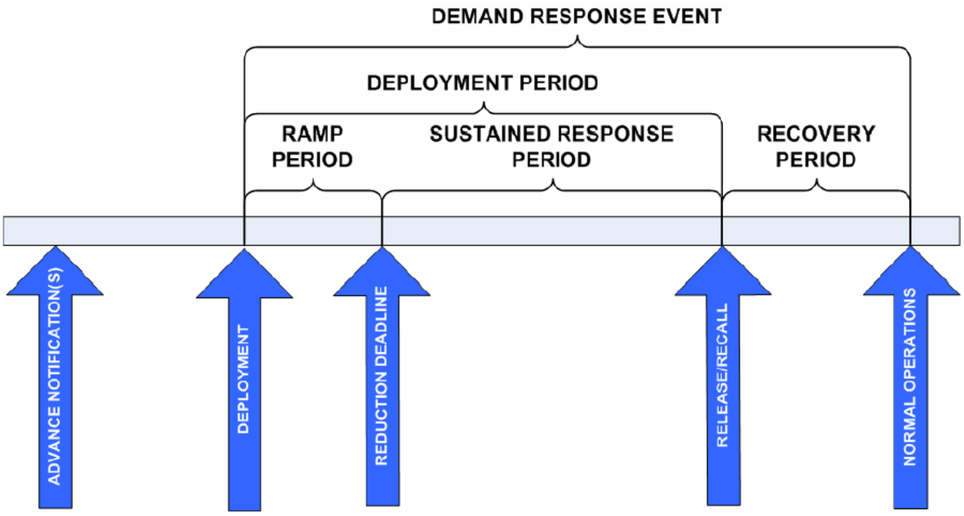

Figure 21. NAESB DR event terms, *Source: Adapted from NAESB (WEQ ratified March 21st, 2011)*

Table 16 and Table 17 present the performance measurement methodologies and criteria that are used in the US context for DR programs. The document provides three different options for creating a baseline with the use of a regression model. These are: individual hourly load regression model (Eq. 1); individual hourly regression model with event-day terms (Eq. 2); and pooled load regression model with event-day terms (Eq.3). The mathematical equations that accompany the models are:

$$L_{idh} = a_{jh} + b_{jh} * C_d + e_{jdh} \quad (1)$$
$$L_{idh} = a_{jh} + b_{jh} * C_d + d_{jh} * E_{dh} + e_{jdh} \quad (2)$$
$$L_{idh} = m_j + t_{dh} + a_h + \beta_h * C_d + \delta_h * E_d + e_{jdh} \quad (3)$$

Table 16. NAESB service types and applicable performance evaluation methodologies, Source: NAESB (WEQ ratified March 21st, 2011)

Performance Evaluation Methodology	Valid for Service Type			
	Energy	Capacity	Reserves	Regulation
a. Maximum Base Load (ability of a DR resource to maintain its demand below a specified level)	✓	✓	✓	
b. Meter Before/Meter After (demand over a prescribed period of time prior to deployment is compared to similar readings during the sustained period)	✓	✓	✓	✓
c. Baseline Type-I Interval Metering (based on historical interval meter data which may include other variables such as weather or calendar data)	✓	✓	✓	
d. Baseline Type-II Non-interval	✓	✓	✓	

metering (statistical sampling of electricity usage of an aggregated demand resource where interval metering is not available)				
e. Metering generator output (demand reduction value based on the output of a generator located behind the demand resource's revenue meter)	✓	✓	✓	✓

Table 17. NAESB criteria for performance evaluation methodologies, Source: NAESB (WEQ ratified March 21st, 2011)

Baseline information	Baseline window (range of data used e.g. the previous year, 10 weekdays prior to event, the last 45 calendar days, etc.)
	Calculation type (average value, rolling average value, maximum value, regression)
	Sampling precision and accuracy (sampling and accuracy requirement e.g. Baseline Type-II)
	Exclusion rules (exclusion of historical data from Baseline Window, e.g. days with DR events, days with outages, day with extreme weather etc.)
	Baseline adjustments (calculation based on a variety of conditions such as temperature humidity, event day etc.)
	Adjustment window (time period for which the adjustment data can be evaluated)
Event information	Use of real time telemetry (specifies if real time two-way communication with the program administrator for performance evaluation is needed)
	Use of after the fact metering (specifies if after the fact metering can be used for performance evaluation)
	Performance window (time period during the event that is used to evaluate the performance of a DR resource)
	Measurement type (arithmetic method used to compute demand reduction)
Special processing	Highly-variable load logic (additional data requirements or calculations for treating highly variable loads providing demand reduction)
	On-site generation requirements (additional requirements for reporting the performance on on-site generation during a DR event)

Where L_{idh} is the load for customer j at hour h of day d, C_d is cooling degree-days for the day, a_{jh}, b_{jh} are base and cooling coefficients for each hour of the day, specific to customer j, E_{dh} is a dummy 0,1 variable indicating the occurrence of an DR event for hour h, and e_{jdh}. In the model described in Eq. (3) the parameters a_h, β_h and δ_h are not customer specific but are estimated across all customers. The terms m_j and t_{dh} are fixed used for handling residual correlation effects for repeated observations at the same day and hour.

Other baselining techniques for DR impact estimation include: match days, experimental design and end-use metering. In match days method, days similar to the day of the DR event are taken into account for the estimation of the load demand (averaging). In principle, match day models perform worse than regression models. They could perform better in case of extreme weather conditions. In experimental design method the customers are randomly assigned to two groups, namely the "treated" and "control" group. The impact is calculated as the difference between the dispatched group's modelled and observed load, minus the respective difference for the control group. When AMI metering data is available at the customer premises then the large-scale impact for residential and commercial direct load control can be determined. Finally, end-use metering at the asset level creates the capacity for creating much more accurate models. Operating characteristics for the participating assets such as duty cycle can be identified and load curtailment can be observed if end-use metering data are collected at 1-minute intervals.

Finally, the document provides examples of customer baseline methodologies used in the North American Wholesale Electricity Demand Response Program where product and service definitions, performance evaluation methods, acronyms, definitions and timing examples are provided. A similar depiction at the EU level would be of value for European institutions to have a clear overview of the wholesale and DR programs.

IPMVP Protocol

The IPMVP is an international measurement and verification protocol that is maintained by the Efficiency Valuation Organization (EVO) aiming to provide a set of tools and options that can be used in different contexts, in order to assist measurement and verification activities in energy efficiency projects.

The latest version of the following set of documents is used as reference work for supporting the DELTA approach:

- IPMVP Core Concepts, October 2016, EVO 10000-1:2016 [43]
- IPMVP Measurement & Verification – Issues and Examples, February 2019, EVO 10300-1:2019 [44]
- Uncertainty Assessment for IPMVP, July 2019, EVO 10100-1:2019 [45]
- IPMVP Renewables Application Guide, March 2017, EVO 10200-1:2017 [46]

IMPVP Core concepts, October 2016, EVO 10000-1:2016

This document introduces the core concepts of the IPMVP protocol. Normative references are provided and terms and definitions used in the protocol are outlined. Key principles providing the basis for assessing the adherence to the M&V process of the protocol are described. M&V reports should be *accurate, complete, conservative, consistent, relevant, and transparent.*

The IPMVP protocol establishes the process that should be followed for calculating energy savings resulting after the implementation of an energy conservation measure (ECM). Figure 22 presents savings after the installation of an ECM. A transformation of this graph could be used in order to resemble the situation for savings (or increase in consumption) in the context of DR programs. Such a graph will be provided in the next subsection. At this point, it should be stated that the reliability of DR programs is higher when the sites at which these programs are applied are already energy efficiency optimized. By energy efficiency optimized sites it is meant that the equipment used for the provision of services (e.g. HVAC systems, lighting, etc.) are performing in an optimal way with respect to the technological developments for each equipment. Old and outdated equipment tend to consume more energy and the instantaneous power demand is high too.

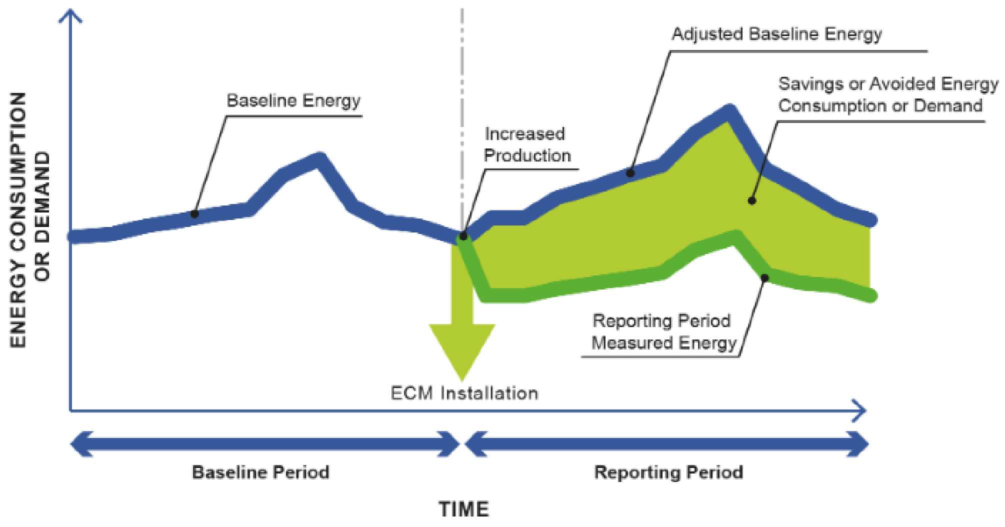

Figure 22. Savings or Avoided Energy Consumption or Demand, [43]

Relevant measurement boundaries should be defined since they define which parts of a facility (or the facility as a whole) are monitored for the determination of relevant savings. The document suggests the use of one of the four options available (Option A, Option B – retrofit isolation, Option C – whole facility, Option D – calibrated simulation) that best fits each project in order to calculate energy savings. Relevant calculation formulas for each option are provided.

Measurement periods for baselining and reporting purposes should be properly selected. Two types of adjustments are possible, namely routine (load demand variation correlated with a set of independent variables) and non-routine (accounting static factors that do not change usually, e.g. size of a facility, weekly production shifts, type and number of occupants etc.) adjustments. These adjustments are used in order to guarantee the same set of conditions both for baseline and reporting periods. Different energy savings accounting approaches are described and savings normalization needs (if any) are clarified. A set of operational verification approaches that includes: visual inspection, sample spot measurements, short-term performance testing, data trending and control-logic review. Operational verification aims to serve as a low cost initial step for assessing energy saving potential or verifying performance over time. Table 18 presents the options, provides calculation approach and illustrate typical application in which each option can be used.

Table 18. Overview of IPMVP Options, [40], [43]

IPMVP Option	Definition	How savings are calculated	Typical applications
A. Retrofit isolation: Key Parameter Measurement	• Saving are determined by field measurement of the key parameter(s), which define the energy consumption and demand of ECM's affected system(s) or the success of the project • Measurement frequency ranges from short-term to continuous, depending on the expected variations in the measured parameter and the length of the	• Engineering calculation of the baseline period energy and reporting period energy from: short-term or continuous measurements of key parameter(s) and estimated values • Routine and non-routine	• A lighting retrofit where the power draw is the key parameter measured and secondly, lighting operating hours are estimated based on facility schedules and occupant behaviour.

	reporting period. Parameters not selected for field measurements are estimated values. Estimates can be based on historical data, manufacturer specifications or engineering judgement. • Documentation of the source or justification of the estimated value is required. The plausible saving error arising from estimation rather than measurement is evaluated.	adjustments as required. Key parameter(s) measured during both baseline and reporting period.	
B. Retrofit isolation: All Parameter Measurement	• Savings are determined by field measurement of the energy consumption and demand and/or related independent or proxy variables of the CEM affected system. • Measurement frequency ranges from short-term to continuous, depending on the expected variations in savings and length of the reporting period.	• Short term or continuous measurements of baseline and reporting period energy, or engineering computations using measurements of proxies of energy consumption and demand • Routine and non-routine adjustments as required	• Application of variable speed drive and controls to a motor to adjust pump flow. Measure electric power with a kW meter installed on the electrical supply to the motor, which reads the power every minute. In the baseline period this meter is in place for a week to verify constant loading. The meter is in place throughout the reporting period to measure power consumption and demand.
C. Whole facility	• Savings are determined by measuring energy consumption and demand at the whole facility utility meter level. • Continuous measurements of the entire facility's energy consumption and demand are taken throughout the reporting period.	• Analysis of the whole facility baseline and reporting period (i.e., utility) meter data. • Routine adjustments as required, using techniques such as simple comparison or regression analysis.	• Multifaceted energy management programs affecting many systems in a facility. Measure energy consumption and demand with the gas and electric utility meters for a twelve-month baseline period

		• Non-routine adjustments as required.	and throughout the reporting period.
D. Calibrated Simulation	• Savings are determined through simulation of the energy consumption and demand of the whole facility, or of a sub-facility. • Simulation routines are demonstrated to adequately model actual energy performance in the facility. • This option requires considerable skills in calibrated simulation.	• Energy consumption and demand simulation, calibrated with hourly or monthly utility billing data. Energy end-use metering and metered performance data may be used in model refinement.	• Multifaceted energy management programs affecting many systems in a facility but where no meter existed in the baseline period. • Energy consumption and demand measurement, after installation of gas and electric meters, is used to calibrate a simulation. • Baseline period energy, determined using the calibrated simulation, is compared to a simulation of reporting period energy consumption and demand.

Next, the document describes all the relevant aspect of each one option by providing general guidelines, savings calculation formulas, any relevant incurred costs, issues regarding the availability of energy consumption data and its granularity and best application areas for each one of the standards. Finally, the document concludes with describing the requirements for developing and implementing an IPMVP adherent M&V plan and report. All relevant aspects such as: facility and project overview, ECM intent, selected IPMVP option and measurement boundary, baseline: period-usage-and conditions, reporting period, basis for adjustment, calculation methodology and analysis procedure, energy prices, meter specifications, monitoring responsibilities, expected accuracy, budget, report format, and quality assurance are elaborated.

IMPVP Measurement & Verification – Issues and Examples, February 2019, EVO 10300-1:2019

This document provides an overview of the M&V purpose and process followed. M&V is defined as the "process of using measurement to reliably determine savings created within an individual facility by an energy management program". M&V activities normally include the following activities: meter installation, calibration and maintenance, data gathering and screening, development of a computation method and acceptable estimates, computations with measured data and reporting, quality assurance and third-party verification of reports.

Facility owners and energy efficiency project investors use M&V techniques in order to: increase energy savings, document financial savings, enhance financing for efficiency projects, improve engineering design and facility operation and maintenance, manage energy budgets, enhance the value of emission-reduction credits, support evaluation of regional efficiency programs, and increase public understanding of energy management as a public policy tool.

A number of steps are prerequisite for supporting the M&V Design and Reporting process. They include: consideration of the needs of the user of the M&V report (step 1), selection of the IPMVP option that best suits the ECM(s), the needs for accuracy and the budget for M&V (step 2), gathering of relevant energy and operating data from the baseline period (step 3), preparation of M&V plan (step 4), design, install and calibrate any special measurement equipment needed under the M&V plan (step 5), ensure potential to perform and achieve savings by conducting operational verification (step 6), gather energy and operating data from reporting period (step 7), compute savings in energy and monetary units (step 8), report savings in accordance with the M&V plan (step 9).

The document provides a selection guide for selecting the M&V Option that fits best a given site/project according to its characteristics. This process is followed for the pilot sites of the Delta project in order to select the approach through which the baseline will be determined.

Next, the document addresses common issues that may arise regardless the M&V Option chosen. These include: the application of energy prices (price schedules, marginal prices, fuel switching and price schedule changes), non-routine adjustments (e.g. when change occurs in equipment or operations within the measurement boundary), advanced M&V methods (coupling of interval energy use data with advanced analytics in order to achieve increased savings resolution e.g. automated creation of multi-variant regression models from data acquired by AMI infrastructure), the role of uncertainty (accounting for instrumentation, modelling, sampling, interactive effects, estimation of parameters rather than measurement e.g. in Option A), issues with costs (e.g. effect of M&V Option chosen to overall costs, number of energy flows across the measurement boundary, sample sizes, duration of reporting period, accuracy requirements, etc.), techniques for balancing uncertainty and cost, assessment of the need for a review from an independent verifier, data for emission trading (IPMVP provides confidence in energy report savings and subsequently confidence in reports of emission-reduction commodities), minimum operating conditions, weather data, minimum energy standards, measurement issues, data collection errors and lost data, use of control systems for Data Collection, and the choice of significant digits.

Finally, the document provides M&V application examples. Table 19 summarizes the examples provided per each Option. This kind of categorization is useful for practitioners of the IPMVP protocol to correctly choose the option that fits best a project and utilize the tools needed for calculating savings.

Table 19. Examples of twelve different scenarios and categorization per Option of the IPMVP protocol, [44]

Option	Description
Option A	• Pump/motor efficiency improvement • Boiler efficiency improvement • Lighting efficiency • Lighting operational control • Compressed air leakage management
Option B	• Street lighting efficiency and dimming • Turbine-generator set improvement Pump/motor demand shifting
Option C	• Multiple ECMs with metered baseline data • Whole facility energy accounting relative to budget
Option D	• Multiple ECMs in a building without energy meters in the baseline period • New building designed better than building code

Uncertainty Assessment for IPMVP, July 2019, EVO 10100-1:2019

This document provides the tools for uncertainty assessment for the IPMVP protocol. An introduction to the statistical tools used for modelling purposes is provided. Statistical model estimates for performing statistical analysis of the data series available at pilot sites are provided too. They include central tendency statistics (mean, median, and mode), dispersion statistics (variance, standard deviation, and standard error), association (correlation, regression).

Sources of uncertainty are identified and systematic (data measurement errors, data collection errors, data modelling errors) and random errors are assessed. Uncertainty assessment in M&V plans and reports takes place taking into account: metering equipment (e.g. accuracy of meters used), modelling approach (e.g. type of model used, dependent and independent variables and their significance, any plans for sensitivity analysis), sampling design (sample design, number of end-use metering and length of metering, expected level of confidence and precision).

Next, the document defines commonly used statistical terms (sample mean, sample variance, sample standard deviation, standard error (SE) of the mean of a sample, coefficient of variation (CV), and standard error of the regression estimate. Confidence and precision of the results are outlined and the use of t-statistic is justified. Formulas for relative and absolute precision are provided too. Formulas for sample size determination are also provided along with the steps to be followed in order to have an effective sampling process. These steps are as follows: a. Select homogeneous populations, technologies, or end uses b. determine the desired precision and confidence levels for the estimate c. decide on the level of disaggregation d. calculate the initial sample size e. adjust the initial sample size for small populations. Next the metering period should be determined along with the dependent and independent variables that are being monitored. The acquired data should be processed aiming at the development of a multi-variant regression model. The effectiveness of the model should be studied through the assessment of the coefficient of determination (R^2 and its adjusted version) and the significance of the variables chosen to act as independent should be evaluated. Modelling errors including: omission of relevant variables, inclusion of irrelevant variables, functional form used, (potential) data shortage, autocorrelation, prediction errors, and overfitting should be thoroughly studied in order to guarantee that the model perform well under any circumstance.

Finally, the document provides an example for each one of the options (A, B, C, D) where relevant statistical analysis takes place. Remedies for dealing with issues are discussed as well.

IMPVP Renewables Application Guide, March 2017, EVO 10200-1:2017

This document describes special M&V considerations for renewable energy systems. Examples and recommendations for specific applications are provided. A guidance on operational and savings verification for renewable energy systems is provided.

The operational verification of a system includes controlling whether the system specifications match design and expectations, evaluates if the system is installed according to manufacturer requirements, codes and standards, and verifies if the system is operating as expected. Key information regarding the manufacturer of equipment installed should be collected. Location of the installation, ratings of equipment and compliance with standards and codes should be collected as well.

Savings verification involves the direct measurement of the contribution of a renewable energy system with a point of connection to the associated infrastructure (e.g. the electricity system in a building, etc.). Direct or indirect measurements (e.g. measure reduction or change in the behaviour of the associated system) and different types of utility rates structures (energy - €/kWh, power demand €/kW/month, time of day usage, seasonal rates, block rates, various tiers and thresholds, charges for ancillary services such as power factor, demand ratchet, fixed customer charges & other riders, etc.) should be taken into account. Guidelines for metering and data collection are provided as well. Guidelines on accounting resource variability (e.g. solar irradiation, wind, etc.) of the renewable energy technology considered are also provided. They include on-site data-logging of the solar or wind resource, measurements from nearby source, satellite data. An application guide of IPMVP options for renewable energy projects is provided as well. Finally, the document provides guidelines for M&V Applications using statistical sampling for renewable energy fleets as well as costs and benefits when M&V plans are used.

This document was briefly described here due to the fact that in some of the pilot sites there are PV installations in place. The verification of the performance of such systems is considered as a requirement for the DELTA methodology.

ANNEX 2: Questionnaire for the evaluation of DELTA architecture through end-user feedback

As it has been aforementioned, it is necessary to receive feedback from the end-users of the DELTA services in order to evaluate these services offered. For this purpose, a questionnaire will be given to participants. The answers can have the option of giving a score from 0 to 10 according to how much satisfied the user is with the relevant service or how much the user agrees with the statement given. An example of such a questionnaire is given here.

Section: Trust and Security User feedback

Do you feel your data is secured through the DELTA system?										
Completely disagree					Neither agree nor disagree					Completely agree
0	1	2	3	4	5	6	7	8	9	10
Do you think the DELTA architecture is a robust system that guarantees the functionality agreed?										
Completely disagree					Neither agree nor disagree					Completely agree
0	1	2	3	4	5	6	7	8	9	10
Would you recommend DELTA solution to other users?										
Completely disagree					Neither agree nor disagree					Completely agree
0	1	2	3	4	5	6	7	8	9	10

Section: Acceptance for future use

Are you satisfied by the DELTA solutions overall?										
Completely disagree					Neither agree nor disagree					Completely agree
0	1	2	3	4	5	6	7	8	9	10
Do you think that you obtained benefits through the use of DELTA solutions?										
Completely disagree					Neither agree nor disagree					Completely agree
0	1	2	3	4	5	6	7	8	9	10
Is it likely that you use the DELTA solution also in the future?										
Completely disagree					Neither agree nor disagree					Completely agree
0	1	2	3	4	5	6	7	8	9	10

Section: User friendliness of the UIs

Do you find the user interfaces easy to use?										
Completely disagree					Neither agree nor disagree					Completely agree
0	1	2	3	4	5	6	7	8	9	10
Do you find the instructions given for handling the user interface explanatory enough?										
Completely disagree					Neither agree nor disagree					Completely agree
0	1	2	3	4	5	6	7	8	9	10

ANNEX 3: Questionnaire for the evaluation of DELTA architecture through retailers' feedback

Apart from end-users it is necessary to receive feedback also from actors like retailers, who will give information about the validity and integrity of DELTA products from a business perspective. For this purpose, a questionnaire will be used. The answers can have the option of giving a score from 0 to 10 according to how much satisfied they are with the relevant service or how much they agree with the statement given. An example of such a questionnaire is given here.

Section: Acceptance for future use

Do you think that DELTA products offer a complete and integer solution in the field of DR?										
Completely disagree					Neither agree nor disagree					Completely agree
0	1	2	3	4	5	6	7	8	9	10
Do you think that you obtained benefits through the use of DELTA solutions?										
Completely disagree					Neither agree nor disagree					Completely agree
0	1	2	3	4	5	6	7	8	9	10
Is it likely that you use the DELTA solution also in the future?										
Completely disagree					Neither agree nor disagree					Completely agree
0	1	2	3	4	5	6	7	8	9	10