Horizon 2020 – LCE-2017 - SGS

FLEXCoop

Democratizing energy markets through the introduction of innovative flexibility-based demand response tools and novel business and market models for energy cooperatives

WP2 - STAKEHOLDERS REQUIREMENTS,

BUSINESS MODELS AND ARCHITECTURE DESIGN

D2.8 – FLEXCoop PMV Methodology Specifications – Final Version

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FLEXCOOP CONSORTIUM PARTNERS

Fraunhofer	Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.
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HYPERTECH	HYPERTECH (CHAIPERTEK) ANONYMOS VIOMICHANIKI
DTU	DANMARKS TEKNISKE UNIVERSITET
GRINDROP	GRINDROP LIMITED
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SUITE5	SUITE5 DATA INTELLIGENCE SOLUTIONS Limited
S5	SUITE5 DATA INTELLIGENCE SOLUTIONS Limited
CIMNE	CENTRE INTERNACIONAL DE METODES NUMERICS EN ENGINYERIA
RESCOOP.EU	RESCOOP EU ASBL
SomEnergia	SOM ENERGIA SCCL
ODE	ORGANISATIE VOOR HERNIEUWBARE ENERGIE DECENTRAAL
Escozon	ESCOZON COOPERATIE UA - affiliated or linked to ODE
MERIT	MERIT CONSULTING HOUSE SPRL

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EXECUTIVE SUMMARY

This document is an outcome of the second part of Task 2.4, Definition of Monitoring & Verification Methodology for DR settlement and remuneration and Key Performance Indicators. In the first part of the task, a preliminary version of the FLEXCoop Performance Measurement and Verification (PMV) methodology has been specified. This methodology has been described in D2.5, FLEXCoop PMV Methodology Specifications - Preliminary Version, that is an outcome of the first part of Task 2.4. Based on the project progress realised so far, in this second part of the task the methodology has been reviewed. The review performed consists in analysing how the methodology has been implemented trough the FLEXCoop modules and tools in the FLEXCoop system deployment and the pilot roll-out. Therefore, the aim of this document is to verify that the PMV methodology already defined in D2.5 can be applied successfully in the pilot cases and include the necessary modifications. In parallel, a revision of the KPIs defined in the D2.5 has been carried out in the last section before conclusions.

The review highlights that the PMV methodology has been successfully applied throughout modules that compose the FLEXCoop system, according to the recommendation defined in the D2.5. In order to give an overview on how each step of the PMV methodology is applied, this document goes through the whole methodology and explains how the FLEXCoop modules and the works carried out during the project development are aligned to implement the methodology.

As result of this overview, it can be stated that the methodology does not need modifications because of its application has proved to be possible thanks to the FLEXCoop modules and tools. Further validation of this methodology (out of the scope of FLEXCoop) can be performed once pilots' testing will be completed and the results are expected in Tasks 7.4 ,Pilot Roll Out and Demonstration, and Task 7.5 ,Socio-Economic, Environmental and Technological Impact Assessment, and reported in D7.5, FLEXCoop Holistic Performance Evaluation, Impact Assessment and Cost-Benefit Analysis - Preliminary Version, and D7.7, FLEXCoop Holistic Performance Evaluation, Impact Assessment and Cost-Benefit Analysis - Final Version.

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ABBREVIATIONS

ACER	AGENCY FOR THE COOPERATION OF ENERGY REGULATORS
ACM	Authority for Consumers and Markets (Spain)
AESG	Agreement on Energy for Sustainable Growth
aFRR	Automatic Frequency Restoration Reserve
AMI	Advanced Metering Infrastructure
API	Application programming interface
APX	Amsterdam Power Exchange
BIM	Business Integration Manager
BRP	Balance Responsible Party
BSP	Balance Service Provider
CAGR	Compound Annual Growth Rate
CEER	Council of European Energy Regulators
CNMC	National Commission for Markets and Competition (Netherlands)
CO	Confidential, only for members of the Consortium (including the Commission Services)
CRM	Capacity Remuneration Mechanism
D	Deliverable
DA	Day-Ahead Market
DER	Distributed Energy Resources
DHW	Domestic Hot Water
DR	Demand-Response
DRMS	Demand - Response Management System
DRS	Demand-Response settlement
DRSR	DRS and remuneration
DSM	Demand Side Management
DSO	Distribution System Operator
DSR	Demand Side Resources
DSS	Dispatch Service System
DSU	Demand Side Unit
DoW	Description of Work
EC	European Commission
EE	Energy Efficiency

EED	Energy Efficiency Directive
EMO	Energy Market Operator
EMS	Energy Management System
ENDEX	European Energy Derivatives Exchange
ENTSO-E	European Network of Transmission System Operators for Electricity
ESDN	European Sustainable Development Network
ETS/non-ETS	Emission Trading System / non- Emission Trading System
EP	European Parliament
ESB	Message Oriented Middleware
EU	European Union
EV	Electric Vehicle
FCR	Frequency Containment Reserve
FLOSS	Free/Libre Open Source Software
FRR	Frequency Restoration Reserve
G2V	Grid to vehicle
GDEM	Global Demand Manager for Aggregators
GDPR	General Data Protection Regulation
GHG	Greenhouse Gas
GUI	Graphical User Interface
H2020	Horizon 2020 Programme
ICT	Information and communication technology
ISP	Imbalance Settlement Period
ID	Intraday Market
IEQ	Indoor Environmental Quality
IPR	Intellectual Property Rights
IPS	Integrated Power System
L	Law
LDEM	Local demand energy manager
mFRR	Manual Frequency Restoration Reserve
MGT	Management
MIBEL	Iberian Electricity Market
MS	Milestone
NEEAP	National Energy Efficiency Action Plan

NRA	National Regulatory Authority
nZEB	Nearly Zero-Energy Buildings
O	Other
OMIE	Operador del Mercado Ibérico-Polo Español
OMIP	Operador del Mercado Ibérico-Polo Portugués
OS	Open Source
OSB	Open Smart Box
OSB	Open Smart Box
OTC	Over the counter
P	Prototype
P2H	Power-to-Heat
PCM	phase change materials
PM	Person Month
PMV	Performance measurement and verification
PRP	Programme Responsible Party
PU	Public
PV	Photovoltaic
PVPC	Precio Venta a Pequeño Consumidor (regulated tariff in Spain)
R	Report
RD	Royal Decree
REE	Red Eléctrica Española
RES	Renewable Energy System
RR	Replacement Reserve or Regulating reserve
RTD	Research Technology development
RTD	Research and Development
SEAC	Security Access Control
SEM	Single Electricity Market
SG	Smart Grid
SLA	Service Level Agreements
SM	System Manager
SME	Small- and Medium-size Enterprises
TEN-E	Trans-European Networks for Energy
TFEU	Treaty on the Functioning of the European Union

TM	Task Manager
ToU	Time of Use
TSO	Transport System Operator
VAT	Value-Added Tax
V2G	Vehicle to Grid
VOC	Volatile Organic Compounds
VPP	Virtual Power Plant
VRES	Variable RES
VTES	Virtual Thermal Energy Storage
VTESM	Virtual thermal energy storage module
WP	Work Package
WSN	Wireless Sensor Network
Y1, Y2, Y3	Year 1, Year 2, Year 3

1. INTRODUCTION

This deliverable is based on the work undertaken during the second period of Task 2.4, Definition of Monitoring & Verification Methodology for DR settlement and remuneration and Key Performance Indicators. It is an additional document that completes Deliverable 2.5 ,FLEXCoop PMV Methodology Specifications - Preliminary Version, with the main aim of evaluating the eventual need of changes in the Performance Measurement and Verification (PMV) methodology already defined based on pilot roll out findings and following the system component development and deployment in the pilot sites. In order to be certain that the main objective of this deliverable is achieved, those modules whose development has taken in consideration recommendations of the PMV methodology and that allow the PMV implementation have been evaluated with the collaboration of each module responsible partner. Firstly, the modules and results achieved in other tasks of the FLEXCoop in relation with the PMV have been identified for each step of the PMV methodology reviewed. Then, it has been analysed how those modules or results are useful for the application of the PMV methodology. This work is enclosed in Section 2 which is organized according to the steps of the methodology. For each step it is first shown in *italics* its definition made according to the D2.5 and then it is explained how it can be applied through the use of modules or other results of FLEXCoop. Finally, all deliverables that contain additional information regarding the modules or the other results considered have been referenced. Following the overview of the PMV methodology, the Section 3 explains the progresses made since the end of the first part of Task 2.4, related to the definition of the set of KPIs and that will be used for the evaluation of pilot sites. The results of the whole revision are finally summarised in the conclusions of this document where, it is also highlighted that the PMV methodology do not need further modifications.

2. REVISION OF PMV

This section is organised according to the steps of PMV methodology. For each step it will be commented how it has been implemented through the FLEXCoop specific modules and results obtained so far in the project. At the beginning of each step, the step description, as written in D2.5, is reported in italics. Then, it is explained how it has been implemented through the FLEXCoop's modules and tools. Finally, references to documents that contain additional information are reported.

1) Ex ante analysis

a) *Definition of Demand Respond (DR) events and criteria for remuneration.*

The aggregator has to define at which types of DR event the customer will potentially participate (e.g. Automatic Frequency Restoration Reserve (aFRR), Replacement Reserve or Regulating reserve (RR), etc.), including also information about their frequency or foreseen schedule along a year or along the duration of the contract between customer and aggregator. At the same time, also the remuneration information (i.e. if it will be done monthly, yearly and the unit price) and the time of event notification (e.g. 2 hours before the event, day before the event, etc.) has to be agreed. For the latter, despite FLEXCoop solution provide automated response to DR events (without requirements of users' interaction), sending a notification to the users before the beginning of the event to inform them that a DR event will start is not needed, but it is recommended in order to address potential issues about user confidence and friendliness in FLEXCoop models (as analysed in Deliverable 2.1).

The decision regarding which DR events are the most appropriate and available for the FLEXCoop pilots has been taken according to both legal and technical framework. This study has been carried out in Task 2.3, New Business Models for Demand Response, and it is explained in Deliverable 2.7, Emerging Business Models, Associated DR Strategies and Standard Contracts Templates – Final Version. According to the latter, on one hand the Dutch pilot (led by ODE) has been designed for participating on the ancillary services market, more concretely on the aFFR market (once a day). On the other hand, the scope of the Spanish pilot (led by SomEnergía) is the optimization of the energy to be purchased on the day ahead market and the optimization of the PV self-consumption. More details of both business scenarios have been depicted on D7.2, Evaluation Framework and Respective Validation Scenarios.

In order to define all the aspects required by this first step of the PMV methodology, a questionnaire that will be proposed to the final users and a template of the contract for each type of DR event have been defined in the Annex 2,3 and 4 of D2.7 ,Emerging Business Models, Associated DR Strategies and Standard Contract Templates - Final Version. The questionnaire requires users to show their preferences about contractual notification periods, rates and payments and the terms and conditions specified for market participation of their aggregated flexibility.

These contracts will be the bases for depicting the relationship between the aggregator and their clients. Also, those contracts will be the base for the remuneration process that takes place at the end of every day, affecting to all the users that have participated in a DR event (and also the ones who were supposed to participate but did not).

The remuneration process in the FLEXCoop framework will be carried on by the DR settlement and remuneration module. The final remuneration per user will take into account the energy savings (Rem_{save}) and the penalties due to the deviation for excess or defect in energy consumption (Pen).[1]

$$Rem = \sum_{all\ periods} (Rem_{save} - Pen)_i$$

The PMV methodology is applied in the calculation of the energy up and down variations (Rem_{save}) as a result of the DR event. Besides all this remuneration process, this module is in charge of defining the baseline that every aggregated load should follow for the entire duration of a DR event, which is needed for the calculation of the remuneration at the end of every day. More details about this module will be depicted at D5.8, FLEXCoop DR Settlement and Remuneration Module – Final Version.

b) *Definition of DR systems and minimum comfort conditions*

In this step, according to the type of DR events and of pilot's users, the electrical systems that will be used for participation in DR events should be defined. All selected electrical systems have to be audited in order to collect their most relevant information (e.g. nominal power, efficiency, type of technology, etc.). Furthermore, for each type of use that will be affected by DR events, an agreement on minimum comfort conditions that must be always maintained, should be taken between the aggregator and customers in order to avoid any future

[1] This process is still ongoing and further details will be depicted on D5.8 "FLEXCoop DR Settlement and Remuneration Module – Final Version".

dissatisfaction. Since end-users cannot always explicitly specify their comfort boundaries (often driven by intrinsic behavioural factors) this will be realized through more intuitive service level agreements, also allowing the users to by-pass system automated control actions. The minimum comfort conditions defined by the users and/or inferred by the FLEXCoop comfort profiling engine will fed the FLEXCoop model to optimize the consumptions as well as the demand variations during DR events. In addition, since comfort conditions can vary along a year, FLEXCoop models will update the initial parameters set by the users without affecting their comfort. This will be possible thanks to the users' reaction to automated actions undertaken by FLEXCoop solution on dwelling's systems. This information will be collected by FLEXCoop models that will automatically learn which are the optimal comfort conditions at any time.

In this step, the equipment that will be used for participating in DR events and the minimum comfort conditions that users accept to have in their home are defined. Regarding the first point, two types of devices are used for covering the DR requests: Domestic Hot Water (DHW) and Heating Ventilation and Air Conditioning (HVAC).

Regarding the second point, in the case of FLEXCoop solution, instead of manually defining the comfort conditions that must be always maintained by each device, the FLEXCoop behavioural profiling mechanism will be in charge of calculating those boundaries for each comfort parameter and user of the portfolio, taking into account some historical data and the behaviour of the user. One of the main parts of the FLEXCoop behavioural profiling mechanism is the prosumer energy behaviour and comfort module (part of the Demand Flexibility Profiling Module), which revolves around the automated learning of personalized comfort boundaries for the occupants. It is responsible for addressing the visual/thermal preferences and non-preferences of occupants under different temperature and illuminance conditions.

The input measurements required for the estimation of the thermal and visual comfort profiles are the following:

- Environmental conditions, pertaining temperature and illuminance measurements.
- Control actions (Heating/Cooling and light dimming), notifying any changes in the operating status of devices, triggered by the occupant.
- Occupancy status.

Therefore, sensors for measuring temperature/illuminance as well as occupancy need to be installed in appropriate locations at each relevant end user's dwelling to enable such an analysis. End-users' control actions and device status, together with the sensing data referring to the corresponding physical feature (e.g. indoor temperature) compose the inputs for this "comfort profile" engine. At a first stage, comfort and discomfort events are identified based on data processing of IoT data streams from building's control and monitoring system. Then, the comfort profile training and prediction starts. The outcome of this module is the comfort profile and comfort boundaries of the relevant feature. For more details regarding the algorithmic framework used and how these calculations happen, check the deliverables of the WP3, Demand Flexibility Modelling and Forecasting, and in particular D3.2, FLEXCoop Context-Aware Demand Flexibility Profiling Models, can be examined.

c) *Identification of static and dynamic variables that affect the demand and that need to be measured.*

According to the type of DR events and systems that will be used to give response, all the variables that have to be monitored to make possible the assessment of demand variations should be defined in this step. These variable will be also used for the creation and auto-calibration of FLEXCoop forecast models' and are typically related to indoor and outdoor climate conditions (e.g. temperature, humidity, etc.) and to user behaviour (e.g. occupancy, schedule of electrical equipment, etc.). As results of this step, the specification of a set of variables and of their dependency with energy uses affected by DR events is expected.

In the previous steps the type of events available for the pilot's users, the devices that will be used for participating in these events and the market restrictions have been defined. In this step the variables that will be monitored and then exploited to create the forecast baseline should be defined. In the case of the Dutch pilot site and the aFRR market, not all the Distributed Energy Resources (DERs) can be considered for covering demand request; that market has some restrictions that have to be taken into account (all the details about this issue can be found at D7.2). For measuring the evolution of every DR event at dwelling level in the Dutch pilot, only consumption data is needed (the actual one vs the forecasted on the baseline calculation at the beginning of the event). On the other hand, for the Spanish pilot, the Photovoltaic (PV) production forecast is also needed. In order to create and train the forecast models other variables are needed. Regarding the independent variables weather historical data for models training and weather forecast data are needed for baseline forecast. In addition, in order to define the individual device's baseline, the following dependent variables have been selected at both pilots:

- Individual load consumption based on sub-metering equipment installed in the houses
- Indoor environmental conditions (e.g. temperature, illuminance) measured by off-the-shelf sensors installed
- Control actions made by the occupants in the concerned devices captured by the installed devices (e.g. IntesisBox)
- Occupancy status based on sensorial equipment installed in the pilot users' dwellings

Once the variables needed are defined in this step of PMV methodology, the appropriate monitoring systems to collect them will be studied in the next step.

2) Implementation

a) *<u>Analysis of existing monitoring system and specification of metering points' and sensors' characteristics.</u>*

In this step an evaluation of the monitoring system (if any) already installed in the dwelling will be performed. The evaluation foreseen the collection of information such as communication infrastructure, mode of transmission, communication protocols, measured parameters and installed devices. Furthermore, in case of smart appliance or systems, also their characteristics have to be audited. Once collected this information, the variables identified in the previous step as those that need to be monitored as well as the electrical systems that will participate to DR events, will provide the basis for the specification of the new monitoring system's characteristics (e.g. performances, accuracy, communication protocol, etc.). In this phase, also which location is the most appropriate for each sensor should be defined.

During the FLEXCoop solution implementation this step has been carried out by means of detailed questionnaires used to collect information from the devices installed in the pilots. The survey template is included as an annex in D7.1, FLEXCoop System Deployment Plan in Pilot Sites. Those questionnaires were filled-in by the pilot users with the guidance of the pilot representatives (ODE and SomEnergia) and in continuous and constant communication with Hypertech for technical details. The information needed to extract the users comfort profiles was defined according to the analysis of the technical requirements of the existing end users' equipment (sensors and actuators), reported by these questionnaires. Survey results cannot be shared since they are protected by General Data Protection Regulation (GDPR) rules. The list of equipment and metering points that have to be installed at the users' dwellings can be found on D7.1, FLEXCoop System Deployment Plan in Pilot Sites, along with a detailed installation plan. The list of the installed equipment and metering points in the Spanish pilot site is described in D7.3, Report on FLEXCoop Framework deployment at Pilot Sites -Preliminary Version. Besides sensors and generic meters, an Open Smart Box (OSB) has been placed at every dwelling. This piece of hardware has two main functionalities: 1) to control the configured devices, 2) to act as a monitoring system gathering measurements coming from the different installed sensors. All this information is published on the Middleware component by following the SEAC framework detailed on D4.5, FLEXCoop (SEAC) Framework – Preliminary Version. The description of the installed equipment related to the OSB was described in D4.1, FLEXCoop OSB Prototype Design, and D4.2, OSB Prototype – Preliminary Version. The updates of the last installed equipment will be detailed in D4.6, Open Smart Box (OSB) Prototype – Final Version. The bills of materials of the installed equipment at the Spanish pilot site and the users' dwellings during the FLEXCoop project are reported in D7.1 ,FLEXCoop System Deployment Plan in Pilot Sites, and D7.3 ,Report on FLEXCoop Framework deployment at Pilot Sites - Preliminary Version. The bills of materials of the installed equipment at the dwellings of the Dutch pilot site will be reported in D7.6, Report on FLEXCoop Framework deployment at Pilot Sites -Final Version. This bill of materials contains information of the specific devices to buy and install, their location at the dwelling and their price.

All the information contained in these documents can be considered as the output of the implementation of this step of the PMV methodology.

b) *Analysis of the technical and economic reliability of individual loads measurements.*

In this step, the economic and technical reliability of the FLEXCoop monitoring and control system installation should be assessed. This analysis has to be performed considering the audit realised in the previous steps as well as the definition of the monitoring system specifications (e.g. location of the sensors, communication protocol, etc.). Considering that the FLEXCoop PMV foresees the measurements of loads as individuals (following in this sense a similar approach to Option B of IPMVP protocol), this step will provide relevant information to verify that PMV methodology can be implemented successfully. Thus, pre-identifying and addressing potential barriers that can arise during the FLEXCoop solution implementation is the main objective of this step.

This step follows after defining the characteristics of pilot users' dwellings (e.g. the devices already installed) and the components and devices (e.g. price, number, type, location at the dwelling, etc.) that need to be supplied and then appropriately installed in the pilot users' dwellings to implement the FLEXCoop solution.

First, the technical barriers and the associated solutions should be identified. In the case of the FLEXCoop solution implementation, potential barriers that can arise deal with the malfunctioning of the equipment and the maintenance and replacement, when needed. Depending of the issue, this could compromise the data availability of some users at some periods of time, which would mean the whole solution to work only partially, unqualifying that user for a time. In addition to this, communication issues between the FLEXCoop framework and the equipment that intervenes during a DR event can emerge. For instance, it the case of the Spanish pilot site we found that some users switch off the Wi-Fi during night hours which may lead to data loses.

As an example, in the specific case of Dutch pilot (and one user in the Spanish pilot site) the type of heat pump (air to water) led to a significant delay in the solution implementation. The key issue related to this type of heat pumps is that during the auditing it was identified that users are not interacting with these systems in most cases. Hence, no control actions are performed in normal operation by the users, but the systems function in an automated efficient way with configurations that are made by the installer during the installation of the heat pump. To solve this issue and after a research in manuals and heat pump manufacturers' data sheets some interfaces allowing to control these devices have been found. However, the available control functionality varies among the different heat pump brands (even in different models of the same brands). In some cases, the available control depends on some auxiliary equipment that has (or has not) been installed in the heat pump during the initial installation. In other words, there are no standardised interfaces that can be used towards communicating with these heat pumps in a "global" common way. One solution under investigation is the communication through a Smart Grid-ready (SG-ready) interface. However, in the FLEXCoop pilot users this interface is not established yet and there are specific requirements by the heat pump manufacturers in order for this interface to be enabled (e.g. ask the permission from the manufacturer, pre-requirement: existence of SG ready standard in the concerned country, etc.). After an in-depth research, a possible way to "emulate" the SG Ready communication may consist on performing actions identical to those that would be performed through the SG Ready interface (if it were established). This may partially solve this communication issue, although the interaction of the users with their heat pumps is still missing. The latter significantly affects the FLEXCoop solution performance as one of the identified dependent variables (see above) is the users' control actions. The importance of the implementation of this step of the PMV methodology is exactly for the identification of issues like this, that could compromise not only the effective implementation of the FLEXCoop (or any similar) solution, but also the future correctness of measurements and flexibility estimations.

Regarding the economic reliability a Cost-Benefit analysis related to the application of explicit DR framework to Dutch and Spanish business cases has been performed from the perspective of both prosumers and aggregators in Task 7.1 ,Detailed Pilot Evaluation, Impact Assessment and Cost-Benefit Analysis Framework. This analysis has considered for each involved player the estimated annual incomes and the necessary operational costs. For the prosumers, the cost needed to participate in a DR programme (e.g. purchasing and installation of equipment, maintenance costs, etc.) has been compared with the reduction in foreseen electricity bills and other possible incentives paid by aggregators. In this analysis also the impact on users' comfort (either positive or negative) should be taken into account. Regarding the aggregators, the development costs are financed within the FLEXCoop project frame, but there are annual licencing and maintenance fees, still under discussion in D7.5, FLEXCoop Holistic Performance Evaluation, Impact Assessment and Cost-Benefit Analysis – Preliminary Version.

Revenues depend on the business models selected by each cooperative. In the case of ODE revenues would come from the active participation in the Dutch Ancillary Service Market. In the case of SomEnergia , revenues are twofold: on one side, the savings made by the increase in PV self-consumption for prosumers (shifting loads to high PV-generation hours), and on the other side, savings made in the wholesale day-ahead electricity market (shifting loads from peak price periods to lower price periods). In both cases, these revenues are split for the two beneficiaries, the end user and the cooperative. A complete list of cost and benefits that should be considered for both prosumers and aggregators referred to Dutch and Spanish pilots can be found in Section 5.2, 5.3 and 5.4 of D7.2, FLEXCoop Evaluation Framework and Respective Validation Scenarios. Once identified all accountable costs and benefits, the indicators (e.g. Net Present Value, Internal Rate of Return) used to assess financial feasibility of a project are explained in Section 5.5 of D7.2, FLEXCoop Evaluation Framework and Respective Validation Scenarios. A full cost-benefit analysis of the two business cases is finally available in D7.5,FLEXCoop Holistic Performance Evaluation, Impact Assessment and Cost-Benefit Analysis – Preliminary Version, and D7.7, ,FLEXCoop Holistic Performance Evaluation, Impact Assessment and Cost-Benefit Analysis - Final Version.

c) *Conduct post-installation verification activities for algorithm calibration.*

After the installation of monitoring and control equipment is required a control of the system's operation status to check that all its components operate as expected and to correct any deviation. Following this activity, a period for the calibration of the FLEXCoop model is needed before starting the participation in DR events. Since this period depends on the accuracy achieved by the model, it is variable. In fact, the model is self-calibrated with measured data that monitor not only energy consumptions or interior conditions, but also users' behaviour. Depending on how much will vary the users' behaviours (and in general the variables that define the model) the period for calibration can last from few days to few weeks. Concerning demands loads that are sensitive to environmental conditions (outdoor/indoor temperature/humidity and sunlight), it is of course expected that the models will be considered fully calibrated when they have been exposed to data reflecting all environmental variations. However, FLEXCoop will complete fast calibrations that very early will allow the system to perform sufficiently well, while fine-tuning its performance in a continuous manner throughout time. Until an adequate accuracy of the model is reached, customers will not be allowed to participate in DR events.

According to the Performance, Measurement and Verification (PMV) methodology defined in FLEXCoop D2.5 ,FLEXCoop PMV Methodology Specifications - Preliminary Version, the FLEXCoop models will provide a continuously self-calibrated baseline that uses data from the minimum number of recent days needed to obtain a high accuracy. There will be automated DR flexibility events performed during this period. Although the DR events will be automatically controlled, participants will have options to opt out temperature or other comfort categories' preferences. Feedback from participants will be gathered via questionnaire or participation in workshops/living labs.

The integration of FLEXCoop components (T6.4) is performed following the sprint approach. That means that the functionalities are being integrated step by step (each of those steps is called "sprint"), and as a result of that, at the end of each sprint there is a prototype of the system including new complete functionalities (in addition to the already integrated ones).

Regarding the flexibility model training, the plan was to finish on April 2020 (assuming a problem-free functioning and interfacing between the various components described below). To be able to start with the training process all the OSBs should be sending the collected data from home devices to the Middleware component and the Middleware sending the relevant data to the demand flexibility profiling engine. After that, the initial training period of the Demand Flexibility Profiling has a duration of approximate 2 weeks (depending of course on the actual data gathered and the interaction of the users with their devices), that will give as a result the first batch of real and usable comfort profiles, which will be constantly updated all the time. In cases, where there are no adequate control actions performed by the users, further tests (duration ~3-4 days) are scheduled and communicated to the end-users. Automated control signals would be sent to the respective devices. In these cases, special attention would be paid to follow any guidelines by the users and to ensure that the testing approach would not violate their comfort preferences.

The post-installation verification activities are reported in T7.4, Pilot Roll Out and Demonstration. In T7.1, Detailed Pilot Evaluation, Impact Assessment and Cost-Benefit Analysis Framework, there are reported algorithms for BS2 and BS3. The PV-optimization algorithm equation from D7.2 ,FLEXCoop Evaluation Framework and Respective Validation Scenarios, is being modified for the implementation of the Local Demand Manager (T5.3 ,Dynamic demand-based VPP module and Global Demand Manager,) and the Demand Flexibility Profiling (T5.1 ,Demand Flexibility Profiling Mechanism Configuration,).

3) Ex Post analysis

a) <u>*Testing of the system in a DR event to validate model accuracy and reliability.*</u>

Once the model is calibrated (Step 2.c), the accuracy achieved by the model auto-calibration needs to be verified in one or more DR test events. At least one test should be carried out for each type of electrical system participating to the DR programme (i.e. those defined in step 1.b). During the test, the demand will be reduced by a predetermined value that then will be compared with the amount of demand flexibility estimated by the FLEXCoop model. As result, the gap (representing the accuracy) between estimated demand flexibility and the actual/measured consumption is obtained (usually it should be less than 10%). Once the test phase is completed, the customer must be informed about the level of model's accuracy and have to accept it to participate in the DR programme.

Several tests were designed and are being performed in both Spanish and Dutch pilots with the aim of analysing and validating the performance of the installed FLEXCoop system. At prosumer level, tests are used to assess the flexibility and the base load forecast. Regarding forecast assessment, a set of tests can be carried out depending on the evaluation methodology and the type of installation (i.e. type of heat pump's setup and type of thermostat). In any case, the two important signals that must be described are the electrical load and the internal temperature. All tests for the flexibility assessment were designed observing the following conditions to obtain a sufficient signal to noise ratio:

- Systems where heating is the main use of the heat pump, the diurnal average temperatures must be below 10 ºC.
- Systems where cooling is the main use of the heat pump, the diurnal average temperatures must be above 22 ºC.

In addition, the following principles have been taken in consideration:

- During the test, the full activation (i.e. full shut down and full power) must be kept through appropriately long periods (if not, it will not be possible to assess the full flexibility potential)
- Tests can exceed comfort bounds; however, it is preferable that the test keeps the conditions within comfort bounds.
- For example, the best tests will be adaptive, such that the limits of the comfort bounds can be reached, but not violated. In this way information can be maximized while keeping comfort.

Together with tests for the flexibility assessment, other tests for the base load forecasting are needed for each single prosumer in the FLEXCoop system, such that the base load can be aggregated and the aggregator can establish the baseline when delivering up or down regulating power. For each prosumer, the following data must be recorded with a time resolution of 1 hour or less during the test:

- Averaged electrical load for the prosumer in the intervals (kW)
- Forecast of the electrical load in each interval
- As a minimum the ambient air temperature should be available, but also solar radiation and wind will be useful

In this case, test period depends on the test conditions, but preferably a wide range of weather and building usage should be covered. When such long period cannot be tested, the same conditions used for flexibility tests should be observed and test period cannot be shorter than 14 days in total.

At aggregators level tests are also needed. At the beginning of each test, once the DR campaign signal has been generated, firstly that signal is split into the individual DR events that will be communicated to each user participating on that campaign, and after that the Demand Response Settlement and Remuneration module calculates the baseline for each one of them; this baseline defines his/her behaviour during the entire campaign. Once it has finished, during the remuneration process that takes place at the end of every day that baseline is compared with the real behaviour of the customer, and according with his/her energy savings and penalties the remuneration is calculated and also the accuracy of that user, detecting if it has been less than a 10%. This information is useful for the Global Demand Manager module in order to know how reliable that user is for future DR events.

The different validation tests are being carried out in T7.4,Pilot Roll Out and Demonstration, and more details about their application and results can be found in D7.6,Report on FLEXCoop Framework deployment at Pilot Sites - Final Version and D7.7 FLEXCoop Holistic Performance Evaluation, Impact Assessment and Cost-Benefit Analysis - Final Version.

b) <u>Demand flexibility assessment</u>

FLEXCoop forecasting models will be used for the assessment of demand flexibility. Based on recent historical data, they provide an estimation of the baseline that is continuously auto calibrated and self-adjusted to guarantee high accuracy. As commented before, this way of estimating the baseline follows the same philosophy of the High/Mid X of Y approaches. The main difference with this method is that the selection of the number of days' prior the DR event for baseline estimation is not needed, since it is performed automatically. In fact, the FLEXCoop models does not use a fixed or limited number of days because it uses the minimum *number of days needed to achieve a reduced gap between actual and estimated consumption. Also, setting exclusion rules within the PMV process is not needed since the FLEXCoop models automatically exclude outliers. This exclusion process is performed not only to avoid considering values representative of extraordinary users' behaviour but also to exclude from baseline estimation, values of demand affected by the DR event. The exclusion of values from ramp period (i.e. between notification and beginning of the DR event) can be carried out automatically thanks to FLEXCoop solution. In fact, when it is installed, no actions are required from the users for demand reduction since both the preparation (e.g. for pre/post-heating/cooling) and the participation to the event are performed automatically. In this way FLEXCoop models are able to understand when measurements should not be considered for baseline construction because are not representative. Thus, the assessment of demand flexibility can be made simply analysing the baseline estimated by the FLEXCoop models without concerns about which period before the DR event should be selected for estimation (i.e. baseline windows) since it is optimised automatically by the model. Being this approach based on calibrated forecasting models, it is similar to the Option D of the IPMVP protocol, with the main difference, that in FLEXCoop PMV, the energy loads are analysed individually and not at building/dwelling level.*

At the time of drafting this document, pilots' tests have not been completed yet, therefore any results regarding demand flexibility assessment can be shown. Nevertheless, this step will be carried out through the demand flexibility profiling module that is aligned with the PMV baselining recommendations presented above. In fact, the forecasted baseline of each individual load is provided by this module upon request by the Local demand energy manager (LDEM). The baseline is continuously self-calibrated and self-adjusted based on actual real-time measurement data. The baseline forecast depends on the prediction horizon of the forecasting and its accuracy is increased for short-term prediction. Furthermore, this module does not use a fixed or a high number of days (e.g. year) for baselining because it uses the minimum number of days needed for the models to be calibrated as recommended by the PMV. The results of the impact assessment will be reported in D7.5, FLEXCoop Holistic Performance Evaluation, Impact Assessment and Cost-Benefit Analysis -Preliminary Version, and D7.7, FLEXCoop Holistic Performance Evaluation, Impact Assessment and Cost-Benefit Analysis - Final Version.

c) <u>Definition of the PMV report</u>

A PMV report will be issued for each customer after their participation in DR events. It will include the explanation of the demand reduction assessment made through the FLEXCoop PMV. The detailed information that the report will provide to the customer should be defined at this step of the methodology. Usually it will include information about the event, such as type (e.g. aFRR, RR, etc.), schedule and duration, amount of reduced demand (kW or kWh), unitary price (€/kW or €/kWh), comfort conditions during the event (temperature, humidity, etc.), remuneration information, increased amount of self-consumption rate, etc. The report will be issued to the customer with a periodicity according to its preferences. For instance, it could be at the end of each DR event or on a weekly/monthly/yearly basis. In most cases, sending remuneration information with high frequency should guarantee a higher transparency to the programme.

In the case of FLEXCoop users, the "PMV report" will be generated from the settlement and remuneration application and will delivered to the customers through the Prosumer application as part of the remuneration process for participation in DR events. The app consists of different dashboards for the analysis of monitoring data and control of devices. Among these, the one called "Contracts monitoring and management" allows the user to visualize information about participation in DR campaigns, DR rewards/penalties and DR level of compliance, among others. Therefore, at a periodical basis and considering participation on a DR event this report will be elaborated including the real behaviour of the customer during the DR event and the aforementioned remuneration. A final version of the app that could include some updated features according to the end users' feedback at the end of the demonstration period will be delivered together with the D6.7, FLEXCoop Prosumer Application – Final.

3. Revision of KPIs

As part of the Task 2.4, in D2.5 a set of KPIs for the assessment of the pilots were defined. In Task 7.1 this set has been revised and enhanced in order to perform a system performance evaluation and Cost Benefit Analysis in the context of the evaluation framework and validation scenario of the pilot sites. In addition to those included in D2.5, additional KPIs have been defined for the evaluation of forecast measures, load flexibility and deviations from promised flexibility at individual and aggregated levels and how they can be used for remuneration applications between the aggregator and the prosumers. Different examples of their application are provided, while their calculation for the Spanish and Dutch pilot sites will occur when the FLEXCoop system will be completely deployed. At following a resumed list of these additional KPIs can be found:

- Mean Absolut Error (MAE) to measure the bias of the forecast performance
- Root Mean Square Error (RMSE) to measure the accuracy or variance of the forecast performance
- Continuous Ranked Probability Score (CRPS) for measuring probabilistic forecast performance
- Requested Activation Power (P) for the calculation of up-regulation or down-regulation flexibility required at individual and aggregated level

Regarding the KPIs already defined in the D2.5 Appendix A, those selected for the evaluation of the performance of the FLEXCoop system are:

- Self-Consumption (ENE1) for evaluation of individual prosumers self-consumption ratio
- Building Final Energy Consumption (ENE3) for calculation of total amount of building energy consumption in a time period.
- Renewable total energy consumption (ENE4) to calculate the total amount of renewable energy (electricity) consumed in a building
- Demand response and flexibility KPIs such as "DR participation analysis" (DRF1), offered aggregated flexibility ("flexibility on offer", DR2) or "Peak load reduction" (DRF3)
- Environmental Impact Indicator (E) to calculate CO_2 emissions
- Comfort KPIs such as Predicted Percentage of Dissatisfied (COM1), System Average Interruption Duration Index (COM2) or Thermal Discomfort Factor (COM3)

A detailed description of all KPIs here presented can be found in Section 2 of D7.2, FLEXCoop Evaluation Framework and Respective Validation Scenarios.

4. Conclusion

The PMV methodology defined in the first part of Task 2.4 has been here reviewed step by step in order to verify how it can be implemented through the FLEXCoop system and to evaluate any need of further modifications or fine tuning. It has been found that the different FLEXCoop modules developed so far together with some other results achieved so far in the project are useful for the methodology application:

- The contract templates defined in the Annex 2.3 and 2.4 of deliverable D2.7,Emerging Business Models, Associated DR Strategies and Standard Contracts Templates – Final Version, provide the basis for the definition of which types of DR event customers will potentially participate in and their preferences (Step 1.a of FLEXCoop's PMV methodology);
- DR Settlement and Remuneration module establishes a common remuneration process for all users (Step 1.a);
- Prosumer Energy Behaviour and Comfort module defines comfort conditions automatically, based on users' interaction with their home systems, complying this way with the Step 1.b of the PMV methodology;
- FLEXCoop System Deployment Plan in Pilot Sites defines variables to be monitored and the characteristics and location of sensors that need to be installed to monitor them (Steps 1.c and 2.a of the PMV methodology);
- Cost-Benefit analysis related to the application of explicit DR framework to Dutch and Spanish business cases can be used for the economic reliability analysis foreseen in Step 2.b of the PMV methodology;
- The approach used for post-installation verification activities carried out in Task 7.4 complies with Step 2.c of the PMV methodology;
- The methodology defined for the deployment of tests for the flexibility assessment and for the base load forecasting allows the fulfilment of Step 3.a of the PMV methodology;
- Demand Flexibility Profiling and the Local Demand Energy Management modules will be used for the demand variation assessment foreseen in Step 3.b of the PMV methodology;
- FLEXCoop Prosumer Application allows to deliver the report and notifications to the prosumers as required in Step 3.c of the PMV methodology;

The step by step overview shown in this document highlights that all steps of the PMV can be implemented thanks to the use of the FLEXCoop modules. Therefore, no further modifications have been brought to the methodology. Another significant outcome of this task is related to the review of the KPIs that were already defined in the first part of the Task 2.4. As result of the revision, it has been identified that additional KPIs have been defined during the Task 7.1 for the evaluation of forecast measures, load flexibility and deviations from promised flexibility at individual and aggregated levels. A further analysis, that is not under the scope of this deliverable but can be useful for confirming the validity of the PMV methodology and KPIs will be feasible once the FLEXCoop system full deployment in the pilot sites will be completed and the results from the impact assessment will be available.