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BEEM-UP

Building Energy Efficiency for Massive market UPtake

Integrated Project

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Demonstration of Energy Efficiency through Retrofitting of Buildings

Deliverable D.3.7

Evaluation, guidelines, and recommendations for the monitoring of future energy retrofitting

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Deliverable description

Performance monitoring is a key point for an energy efficient refurbishment program and it´s fully integrated in the BEEM-UP project. Monitoring the buildings before and after the retrofitting interventions aims at verifying the predicted energy efficiency increase on the sites. This monitoring process also provides useful information and feedback about the advantages brought by the refurbishment process itself well beyond the energy savings assessment.

To perform the monitoring of the three pilot sites within the BEEM-UP project, an overall methodology has been defined and implemented in order to get a common performance evaluation process for all three sites. Some measurements equipment have been selected and installed according to the level of ambition of the Project objectives. The selection of the equipment is based on the specific site and objectives of the monitoring process in the three locations.

The methodology used as well as the experience of implementation of the monitoring process in the pilot sites gives the opportunity to learn various lessons on this topic.

This report includes all the lessons learned from the BEEM-UP monitoring process in relation to the technical, social, economic and constructive aspects. It aims at identifying the items that may help to support BEEM-UP replication initiatives by providing general guidelines and recommendations for the monitoring of future energy retrofitting.

This report is organized within three main chapters:

- In chapter 1, some guidelines and recommandations are reported for the monitoring of future energy retroffiting projects.
- In chapter 2, an evaluation of the monitoring process conducted during the BEEM-UP project is reported for each site with respect to technical, social and economic aspects.
- In chapter 3, the main lessons learned from the BEEM-UP monitoring implementation are collected. The details about the methodology evolution, from an initial concept to a pragmatic implementation experience in pilot sites, help in highlighting these lessons learned based on a collective approach.

Executive summary

The BEEM-UP project has allowed us to identify common problems associated to the monitoring system designed and its deployment and verification in the three pilot sites. Some of these common problems are the adequate selection of sensors and meters, the communication protocols and limitations due to the building configuration, and the availability of historic energy consumption from bills. BEEM-UP has also highlighted some specific problems related to each site that brings useful information that can be fruitfully used for preventing or anticipating such common problems. The involved partners have learnt how to do things better in the future and to avoid repeating the same mistakes.

The methodology developed within BEEM-UP provides guidelines for replication in other countries by capitalising on the main lessons learned and make the difficulties encountered profitable through the solutions implemented within the BEEM-UP project to overcome these difficulties. The methodology also highlights the main key points that should be taken into account for other implementations and for a successful process. Moreover, the methodology is based on the IPMVP that assures both quality of the assessment to be done and homogeneity between each pilot site.

The BEEM-UP methodology is based on the comparison of a baseline period to a reporting period, which seems to be the most suitable method for a refurbishment evaluation (in comparison to a ‘”control group” approach that proved to be less reliable). In that frame, a strong baseline of energy consumptions patterns is absolutely required to be able to perform the comparative analysis and evaluate the energy savings achieved after the interventions are performed in the demonstration buildings This baseline can be built based on measurements, and bills collections, and should cover in a detailed way, the specific energy uses and all the influencing factors required for the adjustment calculations and comparison.

The monitoring system definition and implementation should be conducted in a close relation with the refurbishments plans. That means that when defining the solutions to be implemented during the refurbishment works, the requirements related to the monitoring process should be taken into account. This is required in order to be able to define a reliable and affordable monitoring solution that could be possibly merged with the solution of feedback that could be implemented in the dwellings. For instance this choice was made for the Paris site (to use the Synco Living system as a monitoring system collecting all the data required for the monitoring purpose). Unfortunately, it was not possible to completely implement this approach due to delays in the refurbishment works.

The maintenance of the monitoring system is of primary importance to get a periodic analysis of the data collected. First, this can avoid losing data that can be difficult to handle at the end of the monitoring phase when the data analysis needs to be conducted. And second, it also allows feedback process on the functioning of the building after renovation and therefore enables an optimization of this functioning (commissioning approach).

The use of actual data next to calculations is crucial for transparent communication about the renovation plans with the users. The real measurements of what are the actual energy consumptions after a refurbishment process can be very helpful for a building owner in order to justify this refurbishment and also perhaps to adjust the rents of the refurbished dwellings. These measurements can also be used as a dissemination item towards the tenants and raise tenants’ awareness and makes them more concerned in the way they handle their housing. The monitoring

results could also be capitalized by the building owners providing them some tangible results to be applied for future refurbishment programs planned within their buildings stock (identify possible ways of improvement or corrective actions and quantify the potential energy savings in order to reduce tenants' burden).

Finally, the actual performance after renovation includes several qualities: comfort and health, affordability, social and ecological sustainable quality. An active role for the tenants in the discussion about the monitoring strategy is part of the renovation process.

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Chapter 1 Guidelines and recommendations for the monitoring of future retrofitting projects

The global methodology developed by BEEM-UP aims to promote replication beyond the pilot buildings and countries considered in the project, encouraging other stakeholders in other countries to adopt the defined strategy or, alternatively, to adapt and integrate it into their own methodologies.

To have an overview of the demonstration sites studied within the BEEM-UP project, the reader can refer to the deliverable D3.8 [1] that provides a brief description of each demo site (key indicators related to each pilot site, improvement measures conducted in each pilot site, …) and to the deliverable D3.3 [2] that synthetizes the monitoring systems that have been finally installed in all three sites.

The evaluation of the monitoring process conducted during the BEEM-UP project is provided site by site in Chapter 2. It starts from the global methodology used for the implementation of the monitoring development and gives an exhaustive report and analysis of the experience.

The lessons learned are described in details in Chapter 3 of this document and helps to feed and enrich the feedback of such a process. The lessons learned during the real implementation of the methodology developed within BEEM-UP gives the Consortium important hints on how to customize it on different environments and how to make it more flexible and adaptive to different contexts.

The whole methodology includes three items of special interest that need to be highlighted and taken into consideration in the whole process:

-The methodology begins and ends with the client (building owners/managers and tenants), from the analysis of requirements to the assessment of energy savings. This is a very important point that will further condition the design and implementation phases of the monitoring process. In particular, the interventions conducted in each pilot site (from a refurbishment point of view) are key parameters to consider when selecting the monitoring strategy.

-IPMVP[1] appears in two different places, the development of a measurement and verification plan, and then the calculations and assessment of energy savings. The use of IPMVP for the design of the monitoring plan gives a guarantee for the monitoring process implementation. It assures that data needs and planned measurements match correctly, for the benefit of a full and detailed enough energy efficiency evaluation. Therefore this key factor has a global impact on the development of the methodology but also gives a certain freedom to customise the approach according to pilot sites specificities. The deliverables D3.1 [3] and D3.2 [4] provide the common guideline for the monitoring program as well as the specific monitoring program defined for each pilot site.

[1] International Performance, Measurement and Verification Protocol. It has been used as a framework for the BEEM-UP program.

-**Engaging stakeholders and tenants** is needed to keep the tenants involved in the whole process. This is a crucial point that may contribute a lot to the success of the monitoring process. Please refer to D5.5 and D5.6 of the BEEM-UP Work Package 5.

The methodology includes three main steps that should be implemented in a chronological way. These three steps are described in detail in the following sections and take into account the evaluation of the monitoring process conducted during the BEEM-UP project as well as all the lessons learned during the real implementation.

1.1 Definition and design of the monitoring system

The first step of the methodology is the definition and design of the overall monitoring system, taking into consideration specific requirements of users and building, technical and non-technical constraints, and available resources. The methodology for design encompasses the following aspects:

- **Building's requirements**
  - ✓ Building typology analysis: This step consists in identifying the typology of the building and specifies the requirements and constraints that may have an impact on the design of the monitoring system (region, climate, typology of dwellings, living surface, etc.). The typology of tenants also needs to be identified in this frame.
  - ✓ Energy audit: In the specific framework of this methodology, a Level 1 audit – Simple Audit - is recommended based on a remote investigation of the dwellings using historic energy bills, tenants' information, equipment inventories, and usual occupation of the dwellings.
  - ✓ Technical visit to the site: The aim of the technical visit is to get a clear picture of the environment where the monitoring system will be implemented and, in particular, to get evidence of possible installation, structural or architectural limitations that have not been identified before (presence of smart and communicating meters …). Specific issues such as comfort problem, or miss functioning can also be identified during these visits.
- **Overall strategy:** The monitoring strategy, mostly derived from the IPMVP protocol and based on the project objectives, is grounded on the following approaches:
  - ✓ Size of the sample: address an intermediate number of dwellings,
  - ✓ Multi-level analysis: year-to-year comparisons, but also seasonal analysis, typical week, typical day, etc...
  - ✓ Multi-source data: combination of measurements and energy bills or meter readings,

- ✓ Two approaches for evaluation: comparison of reference period – baseline period, or use of control group, the most suitable for retrofitting evaluation being the comparison of baseline and reporting periods[2],

- ✓ Definition of indicators for different aims: raw data, first level indicators, opportunity indicators,

- ✓ Definition of influencing factors and adjustments (e.g. Heating Degree Days, HDD, for heating consumption, occupancy).

- **Specification on measurement, metering and monitoring**: monitoring in the field of retrofitting for energy efficiency in buildings defines the whole process of evaluation of performance, and of the assessment of the refurbishment measures implemented in the pilot site. Measurements refer to the process of collecting raw data using hardware tools, mainly meters and sensors, or through energy bills collection. Metering refers to the process of counting the consumption of energy and fluids in the buildings, and it is complementary to the information gathered from other types of sensors (e.g. temperature and humidity).

- **Monitoring system design**
  - ✓ Development of a Measurement & Verification Plan: The International Performance Measurement & Verification Protocol (IPMVP) defines standard terms and suggests best practices for quantifying the results of energy efficiency investments. IPMVP Volume 1 suggests a 13 steps planning process, as a way to organise the completion of the M&V plan in general for any energy efficiency project. All the 13 topics have been described in detail in D3.1 [3] and they all should be discussed during this first phase of the methodology in order to agree on a global framework and address all the questions that are decisive for a correct monitoring implementation.
  - ✓ Monitoring solution analysis: The next step of the methodology is to analyse the collected requirements of the pilot buildings and the report after the technical visit, to identify the installation constraints that have an impact on the design of the monitoring infrastructure. The main outcome of this step is a diagram block, linked to a tentative and cost-effective monitoring system.

    Within this step, four points need to be analysed:
    - Available monitoring technologies,
    - Equipment (best savings/cost solution),
    - Data management and analysis system,
    - Budget.

[2] The control group strategy considers two different groups (group 1 and group2, group 1 receiving a treatment and group 2 which receives no treatment) and compares them for the same period. It is used when no baseline energy consumption data are available (for instance in case of new construction). Other options can be applied according to the nature of intervention (for instance calculated reference method that determines the baseline energy use by using engineering calculations calibrated to actual energy use patterns and subtracts metered energy usage (or similarly calculated post-retrofit energy) to estimate renewable energy delivery).

1.2 Implementation of the monitoring system

The second step of the methodology (methodology for implementation) consists of the following steps:

- Step 1 consists of the implementation of the monitoring solution for the baseline period in the pilots. The actions included in this step are:
    - Preliminary contacts with tenants and gathering of necessary authorizations; if required, a preliminary phase of dwelling selection can be conducted using an external support.
    - Deployment of the monitoring devices;
    - Data collection before the refurbishment starts (preferably for 12 months at least) through measurements or bills or manual reading of the meters, and monitoring data analysis.

- The second step deals with the monitoring solution dedicated to the reporting period. In some cases, the tools used for the baseline period can be reused. Complementary and additional sensors or meters may be necessary in order to cover the whole monitoring plan. In other cases, a completely different solution should be implemented. This solution could be a unique set of measuring equipment for both monitoring purposes and feeding with data the ICT system implemented in the dwellings.

For both periods, it is important to choose a local responsible of each site for the implementation of the monitoring system. This could avoid practical difficulties and ensure a quick intervention on site in case of problems.

1.3 Operation of the monitoring and analysis process

The last step is the monitoring phase itself, in which the results obtained during the reporting period (i.e. period after the refurbishment of the pilot, at least for 12 months) in terms of energy savings will be assessed. The following aspects shall be considered:

-Operate and maintain the monitoring system

Periodic inspections on site, maintenance of the system, and periodic checks of the data collected are required.

It is highly recommended to perform data analysis as the project is progressing in order to get intermediate results but also to detect potential issues in the adjustment/optimization of the new systems installed. Ideally, the monitoring phase conducted after the refurbishment works constitutes a commissioning approach[3] that goes well beyond the savings assessment and may provide useful information on the energy systems functioning and their optimization.

- Indicators: most important indicators to be considered are:

* *Energy related indicators:* Energy consumption per type of energy: gas, electricity; and energy consumption per usages: heating, DHW, lighting, electrical appliances,

[3] Commissioning definition: Process by which a building, and its systems and equipment are designed, installed, and tested to verify if they function according to their design objectives or specifications and according to meet the Owner's Project Requirements in terms of performance.

* *Comfort indicators:* Indoor temperature (i.e. number of hours above 28°C in the dwellings, for summer period),

**Progress indicators:* Global energy consumption (and savings) indicators to assess the gains achieved thanks to the refurbishment process.

-Analysis procedure and results calculation: Indicators shall be evaluated relatively to their context (exterior temperature, dwellings areas, occupation rate) by performing suitable adjustment (HDD adjustment for instance) and relatively to specific periods (warm and cold season, typical week, etc.). Lastly the relative evolution between the baseline period and the reporting period shall be calculated (in % relative to the baseline period).

For the sake of simplicity, the following figure shows a general diagram illustrating the whole monitoring process, including the key factors to be taken into account for the implementation and for a successful process.

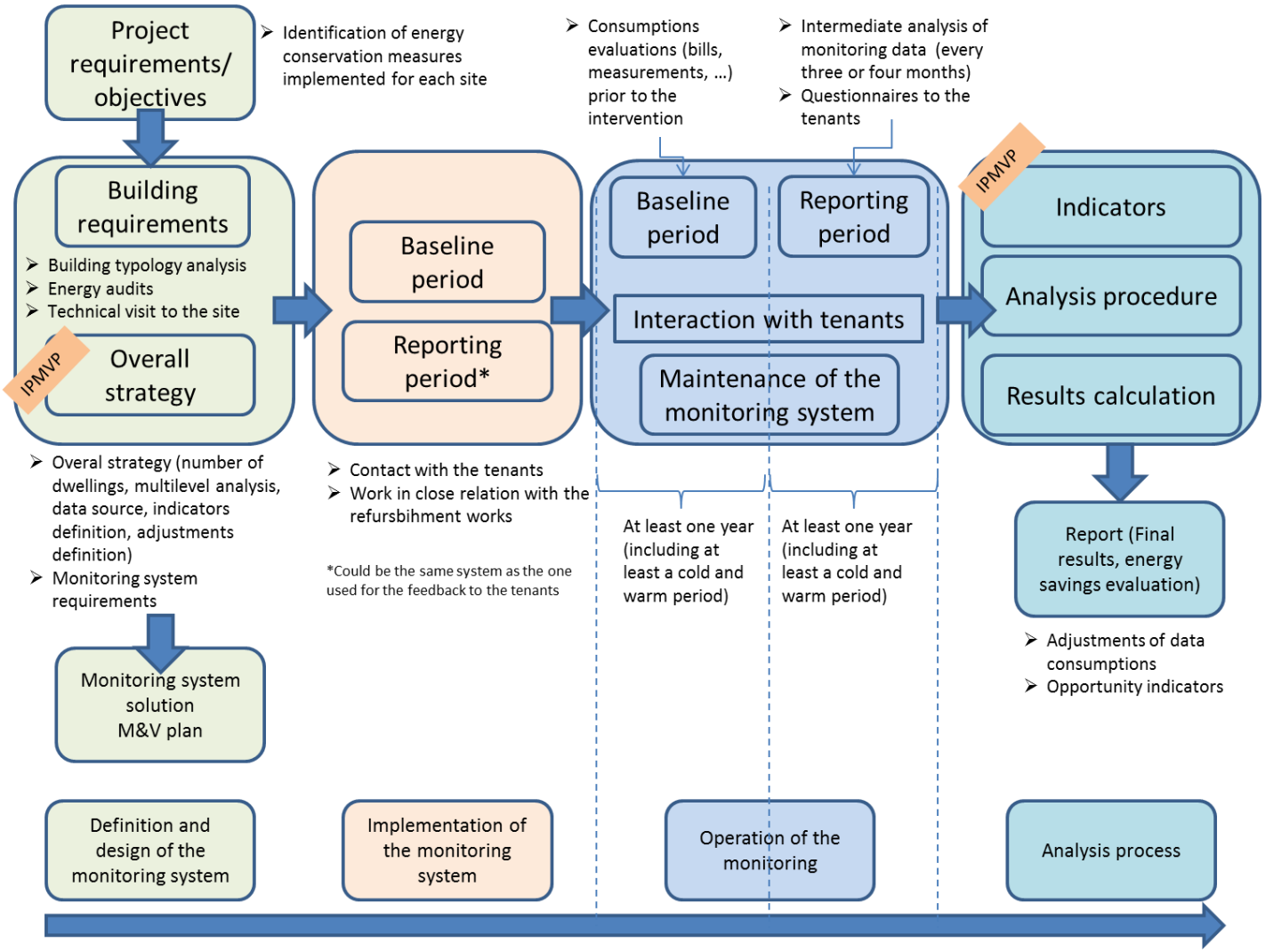

Figure 1: Diagram illustrating the global methodology (and the different steps) relative to the monitoring process

Chapter 2 Evaluation of the monitoring process during the BEEM-UP project

2.1 Reminder on the methodological aspects

An overall methodology has been defined and implemented within BEEM-UP project in order to get a common performance evaluation process for all three sites.
Hereafter the initial methodology applied for the monitoring is briefly presented. And the evaluations of this monitoring process in relation to the technical, social and economic aspects are detailed.

2.1.1 Overall strategy

Energy savings were assessed through a specific monitoring methodology, which was defined early in the project and presented in the reports dedicated to the detailed technical design of monitoring (D3.1 [3] and D3.2 [4]). The monitoring strategy was defined according to the specificities of the projects (measure the effects of refurbishment process in residential buildings, three different pilot sites, and coordination with other European projects) and following the most recent international standards and methodologies for energy savings measurements, mostly derived from the IPMVP[4] protocol.

This strategy is mainly based on the following approaches:

- A sample of dwellings representative of the refurbishment measures implemented.
- Multiple levels of analysis: one year to one year comparison or season to season comparison, but also typical days and weeks analysis.
- Multi source of data: use of measurements data, manual counter reading (Delft case) and use of bills, when available.
- Savings evaluation based on a single method: comparison of the reporting period to a baseline period for all three sites.
- Flexible monitoring requirements integrating compulsory and optional data (because of the previous point).
- Initial definition of adjustment methods: for heating, domestic hot water, and electricity consumption.

This global monitoring methodology was implemented as planned and led in some cases to adjustments. In the case of the Paris site for instance, a temporary monitoring solution was required because of the calendar constrains imposed by this retrofitting case. In the case of Alingsås, some adjustments on energy systems settings (heating and ventilation) were conducted following the first monitoring results collected during the first year post-refurbishment.

[4] International Performance Measurement and Verification Protocol

How to implement this customized strategy is part of the lessons learned. These lessons learned also integrate multiple theoretical and practical observations realized during the design, implementation and data collection phases. All these observations give the opportunity for much better practices for future retrofitting projects.

2.1.2 Choices relative to the baseline and reporting data

Energy savings objectives are common in the BEEM-UP project but there is no common basis for the technological means to be used to generate those savings. The refurbishment program and the exact definition of energy efficient solutions to be implemented are specific for each demo site. This point leads to specificities to take into account for each site and also to customize monitoring to enable the comparison between the baseline and the reporting period in each demonstrator.
For instance, the energy performance of a building has to be presented as energy per square meter and the surface to be taken into account for this evaluation could have changed between the two periods of investigation (this is the case for the Brogården site, where the surface before and after are not exactly the same).
Other example related to the Dutch pilot site which includes some refurbishment items that are chosen by the tenants and that led to many different configurations to be considered (including the fact that not all the dwelling spaces were initially heated before renovation and the whole dwelling surface is conditioned after BEEM-UP).

2.1.3 Indicators, influencing factors and adjustments calculation

In the case of the Swedish site, and since Brogården is a low energy building (Passive house) after renovation, ordinary adjustment with HDD (Heating Degree Days) cannot be used for the analysis of data collected after refurbishment as it is done for the baseline data (before refurbishment). Within the BEEM-UP project, the adjustments are made for a full year (see D3.8 [1] for a more detailed description of the adjustment methods used)[5].

In the case of innovative systems implemented in the Paris demonstrator building (for instance the BIOFLUIDES system which consists in a heat recovery from waste water to preheat the domestic hot water), it is always difficult to perform the assessment of energy savings through a simple comparison between data collected before the refurbishment and data collected after the refurbishment phase. In the case of Paris for example, the domestic hot water (DHW) was initially (before refurbishment) produced with individual electric boilers (production at dwelling level). After refurbishment, the DHW is produced by a collective new condensing boiler associated with the BIOFLUIDES system. In that case, the energy system used for the production of DHW is radically different between the two periods and may require a specific calculation process to assess the efficiency of the renovation process.

[5] Adjustments on monthly basis are possible for the reporting period. But the information has to be bought from the metrological institute of Sweden. The cost for this was too large to be included in the project. For the full year the equations were derived by SP and are used for the analysis.

Some considerations of the previous section (§**Error! Reference source not found.**) must be considered as influencing factors (surface for instance) and must be included also as adjustments parameters in the calculations.

2.2 Technical aspects evaluation

2.2.1 Alingsås

Originally, the building owner in Sweden, Alingsåshem, had plans to provide the tenants with individual energy monitoring displays. The display would show the warm water and household electricity consumption. These two parameters are going through two different meters though, and it proved to be difficult to get a monitoring system that collected the data to one display – especially as the meters would have to use radio transmitters that have difficulties reaching through thick passive house walls.

All water meters are located in one local, and all the electricity meters are located in another locale. In both cases, all the meters are placed within centimetres from each other. Extra monitoring equipment installed was in danger of disturbing each other since they would "pollute" each other's readings.

Thanks to the monitoring, it was discovered quite quickly that too much energy was used without knowing why (see D3.8 for more details, [1]). This lead to a short investigation that enabled to make adjustments that would have been missed for sure if the monitoring had not been done.

2.2.2 Delft

The range of monitoring activities in the Delft project aims at studying both the energy performance, the dwelling type and location and the household characteristics in relation to energy consumption for natural gas (heating and domestic hot water and cooking) and electricity use. Partnership with the energy provider ENECO (BEEM-UP Partner) allowed for a detailed data set.

a. four dwellings with smart meters that allow 15 minutes –interval energy reading, but was used for day-to-day analysis;
b. meter readings per address for about 80% of the (108) apartments and over a period of four years that allow comparison of applications such as high efficiency heater, solar hot water system and home energy management system,
c. meter readings for all apartments and dwelling over a period of five years and up to June 2014,
d. interviews with 31 households, of which 14 cases allow accurate confrontation between dwelling characteristics, installations applied, household type and user patterns and the energy consumption;

Despite this range of activities, the analysis has been complicated, due to flaws in the dataset, for instance caused by substitution of non-returned actual meter readings by prognoses. Also,

the tenants are free to choose their individual energy provider and a number took energy from other providers.
The rebound effect is an issue, because the comfort level of heating and hot water service increased. Also, the impression is that low income households pay attention to their strict budget use rather than savings: extra comfort is good as long as it does not result in higher monthly total cost of living.

Moreover, for the Dutch site the original plan was to use the feedback systems that were supplied to the tenants for monitoring use but this seemed impossible due to some unexpected circumstances. Due to privacy constraints it was not possible to obtain the data from the Toon. It was an issue that BEEM-UP Partner Eneco could see all the information of the tenants and that's why Eneco could not use the Toon for active monitoring. Eneco called the tenants to obtain the data, but this was very hard. The tenants didn't pick up the telephone, didn't want to provide the data etc. That's why Eneco then supplied smart meters to four typical homes were actual usage data could be supplied on a minute by minute basis, to get a true grip on the energy use. Besides that, a call centre was used to call for the different meter standings every six months. Also WOONBRON bought the usage information for 2010, 2011, 2012 and 2013 from company Stedin, who is the legal grid owner and can supply this data on a minimum level of 5 dwellings per group, because of privacy issues. Finally, Partners OTB and Woonbron interviewed some 50% of the tenants about their attitude towards energy efficient behaviour. During these interviews some tenants supplied their usage bills and these data were also considered as monitoring data participating in the analysis of refurbishment benefits.
Therefore the data collection used in Delft site is quite original because it involves many different ways of getting the information (measurements, bills collection, interviews) and also includes certain proximity with the tenants that could be very useful for the data understanding and analysis.

Another technical issue has to be highlighted for Delft site. The solar-boilers were all repaired in the spring of 2013 so the monitoring in 2014 will only show the full effect of the BEEM-UP project. This specific point has also been observed for Alingsås site. This shows that a sufficiently long period of measurement is required after refurbishment to allow some adjustments, corrections or fine tuning of the energy systems implemented in order to have the full retrofitted site working properly.

The indoor temperature was not measured in the dwellings after the refurbishment phase. However it would have been very instructive because from the interviews this has greatly improved.

Lastly in the Delft project, the energy meter readings are available over a four-year period including at least one year before and after the renovation. The winter seasons have been extremely warm and correction of data for degree days are not reliable. Therefore the results should be adjusted by considering the practical experience that in cold winters the tenants accept lower indoor temperatures, while systems tend to perform with better efficiency during cold periods than in intermediate seasons.

2.2.3 Paris

For the site of Paris, a radio transmission system was used for the monitoring of the baseline period and also for a temporary phase related to some delays encountered in the renovation works. Some radio transmission issues related to this wireless technology were encountered during the different phases. Even if some repeaters were used and a suitable meshing of the building was implemented, many data were lost with no way to correct the problem. The reliability of this kind of monitoring solutions can be put into question especially if the refurbishment is not finished. This problem was noticed by Partner NOBATEK in the French site where the temporary system was installed to get intermediate measurements (waiting for the installation of the definite monitoring system SYNCO LIVING from BEEM-UP Partner SIEMENS). As the refurbishment works were not completed when this temporary system was installed, some problems with disconnection of the system or damage to the sensors were noticed. Moreover, the remote control of the system was not possible to use because of internet access not being available before the end of the refurbishment works. We also noticed that when the refurbishment is conducted while the tenants still remain in their dwellings, the furniture can be moved many times within the dwellings and the radio transmission can be really affected by such modifications.

Some technical problems were also noticed in relation to specific refurbishment measures implemented on the French site and relative to specific adjustments that should be done to assess the impact of refurbishment in a detailed way. This is the case when the energy efficiency measure introduces a radically different way of delivering the energy (for instance common boiler transformed into a more distributed/individual energy delivery, or see also the example detailed in §**Error! Reference source not found.**). These specific cases may require a very detailed instrumentation to enable a very precise analysis of gains achieved and energy savings reached that might not be compatible with the timing or financial aspects of a project.

2.3 Social aspects evaluation

The communication of data can lead to privacy issues related to disclosing personal consumption profiles of the energy consumers. In the case of BEEM-UP, the problem has been treated differently according to the pilot site. In some cases, the individual data are made anonymous upstream.

The role of the building owners is crucial in the monitoring process as it has been observed in all three sites during the project. On one hand, the building owners ensure a direct contact with the tenants, which is mandatory for data collection whatever the way these data are collected. On the other hand, a strong interaction needs to be maintained during the whole refurbishment process. The comparison between baseline and reporting period implies a long period to be covered and this requires the users to keep being involved over the whole period. This can only be done through the building owners' active participation.

The following sections explain in a more detailed way which have been the problems or solutions implemented within the social domain for each site to keep the monitoring process going on.

2.3.1 Alingsås

In Alingsås the tenants did not have to actively participate in the monitoring. BEEM-UP Partners Alingsåshem and SP asked all tenants for permission to install the monitoring equipment and permission to access information from the energy company. All tenants signed an agreement to avoid any future misunderstanding. When signing the agreements, the tenants were informed that all information would be anonymised so that no data could be connected to a specific individual.
No specific difficulty or problem was encountered with the tenants during the monitoring implementation and the monitoring phase itself. The tenants accepted that the equipment would be installed without any protests at all. Some of them thought it was exciting to be part of the evaluation.

The equipment installed in their flats is more or less invisible and requires no active handling from the tenants. The temperature and humidity meters are visible and Alingsåshem and SP have been listening if the tenants have any complaints about the installation. This happened only once, and the problem was easily solved by moving the meter.

It is a strong possibility that some of the tenants have forgotten the monitoring devices that were installed in the flat when they moved into two years earlier.

2.3.2 Delft

Home energy management system
A home energy management system (TOON) was offered by Partner ENECO as a free selective tool for the households in Delft. Almost half of the households chose to have the tool in their houses. TOON is a programmable thermostat and shows day-to-day energy consumption, compares it with set targets and with historical data and also allows reading the weather forecast. From a health point of view, indoor monitoring being available on smart apps could help people keep their climate in optimum conditions.

Communication of data and privacy issues
In the Netherlands, the energy data are protected by privacy laws. The metering company is allowed to provide data on a neighbourhood base only, to avoid any connection to individual households. However, in the Delft project many households buy energy from the BEEM-UP Partner ENECO, who has supported specific analysis of energy data. Of course, nowhere in reports it is possible to connect results with individual households.
During the post occupancy evaluation, the interviewed persons were asked to supply energy meter readings. When easy at hand, these were discussed, but many could not show them.
The TOON feedback system supplied by ENECO was supposed to supply monitoring data for the BEEM-UP project but this was not possible. Although there is an internet connection, and although the users can access their usage data both on the feedback system and online, there was no possibility to connect these systems to a BEEM-UP database. This was because of privacy constraints. People were scared that Eneco could follow their whole life. That's why Eneco had to change the privacy rules of the Toon and had stop monitoring with Toon. The role-out of the TOON all over The Netherlands that started shortly after their introduction in the BEEM-UP

project saw to very strict privacy protocols being used by ENECO, which were then countered by installing 4 smart meters in the project.

Non-intrusive measurements
It is not practical to visit the tenants every week to read their meters or collect measurements data. Energy usage is only a small part of the tenants' life so it is not possible to really hassle them with an intrusive monitoring all the time. So remote and non-intrusive systems are really required to get the information over long periods of time.

2.3.3 Paris

For the French pilot site, in order to get monitoring data in time for the project objectives, a temporary monitoring system has been implemented in February 2014. Except the fact that some technical issues have been encountered with this temporary system (see §**Error! Reference source not found.**), it has been needed to select dwellings to participate in this monitoring phase. At the request of ICF, and to minimize the impacts on the tenants, this action has required the help of an external company (Couleur d'Avenir) who has been in charge of identifying volunteer tenants for the monitoring of their dwellings.
Regarding the project, this constitutes a mitigate point because it implies an additional step that could be time consuming. On the contrary, this process allows getting more involved tenants who are well aware of the objectives and the constraints to the monitoring implementation.

2.4 Economic aspects evaluation

2.4.1 Alingsås

Within in the BEEM-UP project, several different systems have been used to monitor the building and to gather information about the building. Data from all systems have been used in the BEEM-UP project to analyse the performance of the building. The BEEM-UP project has financed the monitoring equipment that measures the indoor and outdoor climate (temperature, relative humidity, carbon dioxide) and also additional monitoring equipment in the district heating subsystem. Without the support of the BEEM-UP project, the building owner would not have had the financial possibility to perform such a detailed monitoring.

The monitoring that would exist also without the BEEM-UP project is the monitoring of the heating and the common electricity which are used for charging the energy costs. This energy use is regularly followed up by the building owner.

In the heating and ventilation unit there is a built in monitoring system that is standard for all ventilation units from this supplier. The building owner has therefore no cost for this monitoring equipment. However, before BEEM-UP project no one had done a deep analysis of the monitoring and connecting it to the monitoring of the heat done by another system. This analysis gave the insight that a change in the regulation of the heating and ventilation could decrease the use of energy even further.

This specific case pinpoints an important issue, a fact that it is of great importance not only to finance the installation of equipment, but also to give time and financial means to evaluate the monitoring data.
Originally, there was a plan to provide all the households (269 flats, only 144 are considered in the BEEM-UP project) in Brogården with individual energy display-systems. However, this proved to be unreasonably expensive and the display systems were never ordered. A second plan was to provide display systems only to the tenants in one house (House H) that was being monitored by SP, but this also failed since it proved to be too difficult to decide who would be economically responsible for the equipment.
Since the tenants themselves pay for the domestic hot water and the domestic electricity, it is hard to find a financial model for the building owner regarding this kind of equipment since the payback of the installations is non-existent. Before finding a good financial solution to this problem, the building owner cannot make any investments in that frame.

2.4.2 Delft

ENECO supplied the TOON systems in the BEEM-UP project free of charge for WOONBRON and crucially also free of charge for the tenants. After the termination of BEEM-UP, the tenants will have to pay a market-related fee for the service, which is expected to be about € 3,50 per month. In interviews conducted spring 2014, most tenants said they would keep the system even though the monthly cost would start in January 2015. If the tenant does not want the monthly costs, they can still use the TOON as a Thermostat. On its website, ENECO states that average savings are about € 15 a month.
As explained in the previous sections, it was initially planned to use a unique set of measuring equipment for both monitoring purpose and feeding with data the feedback system implemented in the dwellings. When this solution is technically and sociologically (privacy issue) feasible, it can bring significant economic advantages especially for a large refurbishment program.
Note that the smart meters are supplied to the tenants as a free extra service at no cost.

2.4.3 Paris

In the case of the Paris pilot site, it was initially planned to use the ICT solution implemented for the tenants' awareness (SYNCO LIVING system by SIEMENS) as a monitoring system for the BEEM-UP project. This way of proceeding implies anticipating the monitoring needs and requirements while designing the refurbishment. In such a case, more reliable and cheap monitoring solutions could be implemented. The objective is thus to use a unique set of measuring equipment for both monitoring purpose and feeding with data the ICT system implemented in the dwellings. This could be a solution selected for practical and economic reasons provided that the system is available within the time frame of the reporting period. This has not been the case for the French pilot site. This is why a temporary monitoring system has been implemented.

2.5 Constructive aspects evaluation

From a general point of view regarding a general retrofitting project, it would be better to install smart meters wherever possible before a refurbishment, since these smart meters will be mandatory soon anyway. This would give better access to data for a monitoring process to be implemented. And this could also bring economic advantages if this installation is taken in charge by the refurbishments works. But this needs to be anticipated and to be clearly defined in advance according to what should be demonstrated and in which timeframe. The IPMVP is a strong approach which allows having a common set of criteria to be followed and providing the frame for the monitoring process to be deployed.

Chapter 3 Lessons learned from the BEEM-UP methodology: installation, operating and monitoring experience

An overall methodology has been defined and implemented within BEEM-UP project in order to get a common performance evaluation process for all three sites. However the implementations of this monitoring strategy lead to adaptations in the methodology and in its application, giving the opportunity during the project to learn various lessons on this topic.
The lessons learned and the details about methodology evolution in the project, from an initial concept to a pragmatic implementation experience, are presented in this section. Conclusions and lessons learned have been derived by all the members of the consortium directly involved in the monitoring process. This has been collected through collective work on this deliverable.

From the observation realized between initial methodology and pragmatic implementation on site, the main lessons learned about monitoring practices are presented hereafter. It is difficult, and in some cases almost impossible, to apply the whole items of the IPMVP methodology. This is why IPMVP is used as a basis and not as a protocol strictly followed point by point.

The development of a global methodology for design, implementation and monitoring, including guidelines for replication is a key factor. We have identified common problems in the different pilot sites associated to monitoring solution design, deployment and verification like communication, and have learned about how to do it better in the future and avoid repeating the same mistakes.

The implementation of radio transmission sensors (electrical sub metering through smart plugs and comfort conditions sensors) should be carefully assessed, as the experience of the project shows that the collected data may be difficult to analyse due to communication problems and data missing over long periods of time. The capacity of the monitoring system to automatically detect errors and to evaluate the accurateness of the treated data (i.e. missing data or data indicating a wrong value) should be reinforced in order to improve the reliability of the data collected through the monitoring solution. This is an important issue as it affects uses of the data collected for the project monitoring purpose.

-**Size and representativeness of the sample of dwellings**: sample size in BEEM-UP was defined as a compromise between the need to have representative number of dwellings and the affordability of the project. For instance, for the site of Paris, the selection has been made according to the tenants' agreement and involvement in the project.
For comparative approach, it is necessary to control additional parameters of the dwellings such as occupation and number of people in the dwellings at certain periods of time. These parameters are often difficult to assess and to follow over a long period of time. In the case of Alingsås, new tenants have moved in the dwellings after refurbishment and this point can have a great impact on the consumptions trends.

-Monitoring strategy:
Some parameters collected after the refurbishments were not monitored before the refurbishment (this can be due to the timeframe of the project). In that case, and for comparison purpose, other kinds of data may be used for comparison and evaluation of the gain brought by the renovation.
For Paris, BEEM-UP has used a single monitoring strategy: monitoring on similar group of dwellings, before and after the implementation of the refurbishment process. With regard to the reference period, data treatment showed the importance of having a consolidated baseline very soon and at this moment to identify the issues that might occur during the reporting period, in terms of quality of data and exploitation process, in order to be able to anticipate such difficulties.
In Delft, a good comparison between before-after the renovation can be made, as nearly all tenants stayed in their house during the renovation. Also, the energy data are available. The period around the renovation is unreliable, as measures taken vary over a period of several months.

-Monitoring plan: The selection of sensors is critical in order to achieve the right balance of usefulness, cost and tenant inconvenience. A lesson therefore is to devise beforehand what are the required sensors and make sure their data are reliable. Additional measurements which are not directly related to energy consumptions, may bring useful information about the right functioning of the new systems installed and about the optimisation of the buildings' functioning after refurbishment (commissioning process). This is the case for the Paris site with the punctual measurements (acoustic and leakage tests) and also for Alingsås with the complementary measurement conducted in the building (ventilation measurement for instance).

-Mix use of bills, manual reading of meter and measurements: the use of both bills and manual reading of meter for long term assessment and measurements for analysing the details week per week and day per day into the dwelling give a good balance of information and allowed to ensure the data quality through cross comparison. However, it is often difficult to collect the bills from tenants (this is the case for the Delft and Paris site) or not metered individually (Alingsås before refurbishment) or from building owners if they are not directly involved in the project. In Alingsås the involvement of the energy company has been crucial for gathering information about the use of energy. With the signed agreement from all tenants, it has been possible to collect data from the energy company instead of asking for energy bills from all tenants.

-Data assessment and interpretation: refurbishment impacts are scattered on many different parameters (on temperature demand, on electricity and heating consumption, and also in some way on comfort management). Therefore the interpretation of the data can become complex when trying to make direct link between a particular renovation measure and an energy parameter.

-Practical implementation issues: radio communication and batteries are among the main issues with the wireless technologies used for the monitoring process.

Nevertheless, being involved within the refurbishment process could help to install integrated monitoring systems but in that case, the implementation is closely dependant on the refurbishment works that could be delayed in some cases.

-Communication between the stakeholders (building owners and tenants): regular communication process between stakeholders is needed for such project. Within the BEEM-UP project, the communication with tenants has been ensured by buildings owners who were partners responsible of each local site.
Local partners around the pilots (for instance tenants´ association) are also fundamental to support the tenants' involvement.
The case of refurbishment in an occupied site is the most complex situation to handle because tenants are constantly solicited and an additional solicitation can frighten them. Therefore a continuous dialogue is recommended between the building owners and the tenants.

-Building owners' role: the active participation of the building owners as partners is absolutely necessary for the mobilization of tenants, the impact analysis and further replication. They also play a key role in keeping the dialog going with the tenants (see previous point).

-Detailed audit of the pilot sites at the very beginning of the project: a technical audit (supplemented by an energy efficiency audit) before the refurbishment starts is convenient for a global view of sites and metering possibility and an initial check of the energy savings potential of the building. The monitoring plan which is defined in the early stages of such a project also strongly depends on this first detailed "photo" of the pilot sites.

-Link with the refurbishment process: it is recommended to maintain a link with people or companies intervening during the refurbishment phase in order to interact and if possible orientate the choice of metering of the housing (help to reduce the need to install additional equipment). This point is closely linked to the previous one related to the practical implementation issues.

-Refurbishment delays: a larger duration of the project (especially when it is related to refurbishment process) is recommended because some delays can occur in the retrofitting works (especially when they are heavy as it was for the Paris site for instance). According to the IPMVP at least 12 months of monitoring are required to get information for different seasonal conditions. Moreover in case of refurbishment, a preliminary phase of proper regulation of systems' settings could be required to get the nominal operational functioning of a refurbished building (commissioning phase). Therefore in some cases, the timeframe of a project such as BEEM-UP can be not compatible with the real refurbishment works.

-Local technical representation: For further projects and for further replication of the method in other refurbishment projects in foreign countries, local technical representation is an important positive point to ensure implementation quality and quick reaction to technical incidences. This local representation could also contribute to the tenants' trust in the whole process implementation.

-Homogeneity/heterogeneity: large discrepancies observed in consumptions profiles of similar dwellings (in terms of surface, occupants and from indoor temperature levels) can lead to inhomogeneous patterns that are difficult to take into account for a general application of the results. The users of the dwellings have a great impact on the consumptions profiles (appliances, lifestyle, and number of occupants) and this parameter is difficult to handle from a monitoring point of view and regarding the data analysis and interpretation.

-**Can the monitoring data help to convince the tenants that they get better energy conditions with the refurbishment**? Will the monitoring data be used and presented to the tenants for a positive feedback?
In Delft, the energy management tool TOON does help the tenants' awareness of energy use and even has an energy saving impact, however quite different per household. Moreover the monitoring data and its analysis by OTB to scientific standard will be used in the communication to tenants in new refurbishments. This is of particular importance when a rent increase is proposed of –typical– 65% of the expected savings.

Chapter 4 Conclusions

The BEEM-UP project has allowed us to identify common problems associated to the monitoring system designed and its deployment and verification in the three pilot sites. Some of these common problems are the adequate selection of sensors and meters, the communication protocols and limitations due to the building configuration, and the availability of historic energy consumption from bills. BEEM-UP has also highlighted some specific problems related to each site that brings useful information that can be fruitfully used for preventing or anticipating such common problems. The involved partners have learnt how to do things better in the future and to avoid repeating the same mistakes.

The methodology developed within BEEM-UP provides guidelines for replication in other countries by capitalising on the main lessons learned and make the difficulties encountered profitable through the solutions implemented within the BEEM-UP project to overcome these difficulties. The methodology also highlights the main key points that should be taken into account for other implementations and for a successful process. Moreover, the methodology is based on the IPMVP that assures both quality of the assessment to be done and homogeneity between each pilot site.

The BEEM-UP methodology is based on the comparison of a baseline period to a reporting period, which seems to be the most suitable method for a refurbishment evaluation (in comparison to a '"control group" approach that proved to be less reliable). In that frame, a strong baseline of energy consumptions patterns is absolutely required to be able to perform the comparative analysis and evaluate the energy savings achieved after the interventions are performed in the demonstration buildings This baseline can be built based on measurements, and bills collections, and should cover in a detailed way, the specific energy uses and all the influencing factors required for the adjustment calculations and comparison.

The monitoring system definition and implementation should be conducted in a close relation with the refurbishments plans. That means that when defining the solutions to be implemented during the refurbishment works, the requirements related to the monitoring process should be taken into account. This is required in order to be able to define a reliable and affordable monitoring solution that could be possibly merged with the solution of feedback that could be implemented in the dwellings. For instance this choice was made for the Paris site (to use the Synco Living system as a monitoring system collecting all the data required for the monitoring purpose). Unfortunately, it was not possible to completely implement this approach due to delays in the refurbishment works.

The maintenance of the monitoring system is of primary importance to get a periodic analysis of the data collected. First, this can avoid losing data that can be difficult to handle at the end of the monitoring phase when the data analysis needs to be conducted. And second, it also allows feedback process on the functioning of the building after renovation and therefore enables an optimization of this functioning (commissioning approach).

The use of actual data next to calculations is crucial for transparent communication about the renovation plans with the users. The real measurements of what are the actual energy consumptions after a refurbishment process can be very helpful for a building owner in order to justify this refurbishment and also perhaps to adjust the rents of the refurbished dwellings. These measurements can also be used as a dissemination item towards the tenants and raise tenants' awareness and makes them more concerned in the way they handle their housing. The monitoring results could also be capitalized by the building owners providing them some tangible results to be applied for future refurbishment programs planned within their buildings stock (identify possible ways of improvement or corrective actions and quantify the potential energy savings in order to reduce tenants' burden).

Finally, the actual performance after renovation includes several qualities: comfort and health, affordability, social and ecological sustainable quality. An active role for the tenants in the discussion about the monitoring strategy is part of the renovation process.

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