



## Building Energy Efficiency for Massive market Uptake

Beem-Up assessment of energy  
efficient performance and indoor  
environment in all 3 sites



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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.3.9

Assessment of energy efficient performance and indoor environment in all 3 sites

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CO	Confidential, only for members of the consortium (including the Commission Services)	

## Deliverable description

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This document provides a general assessment of energy efficient performance and indoor environment in all 3 sites.

In order to present such an assessment that not only repeats the work already presented in other deliverables (D3.8 especially), but that provides added value, we selected to perform a generic evaluation focused on the following aspect: technical results obtained regarding the implemented retrofitting solutions. The objective is to share conclusions on the measured data analysis, and conclude on the success of the retrofitting projects as compared to predicted performance. The measurements results are also compared to the post-occupancy evaluation performed in Task 5.5. This evaluation is grounded on several initial criteria based on the objectives of the project (energy savings, involvement of the tenants, indoor quality demonstration...).

In that way, D3.9 focuses on a more general evaluation of the monitoring results regarding the initial objectives and the solutions identified and implemented within the retrofitting projects.

For that purpose we start from the overall objectives of the project and we remind the monitoring results in a factual way. Deviations from the original objectives of the project are thus identified and an analysis is conducted to identify where these deviations come from. Several potential sources of deviations are analyzed (interventions level, tenants' behavior level and monitoring level).

The aim of this analysis is to get to a valuable evaluation about the interest of perpetuating the initiative conducted within BEEM-UP project and the used methodology for the buildings' owners (from the tools to the approach...). In that sense, this report provides the main recommendations and perspectives related to the BEEM-UP lessons learned from the 3 demonstration sites.

## Table of content

<b>DELIVERABLE DESCRIPTION.....</b>	<b>III</b>
<b>CHAPTER 1 INTRODUCTION OF TASK 3.4 (EVALUATION OF MONITORING RESULTS)</b> .....	<b>5</b>
1.1 BRIEF DESCRIPTION OF THE DEMONSTRATION SITES .....	6
1.2 REMINDER ON THE OBJECTIVES .....	13
1.3 REMINDER ON THE MONITORING METHODOLOGY USED AND DEPLOYED .....	13
<b>CHAPTER 2 TECHNICAL RESULTS OBTAINED REGARDING THE IMPLEMENTED RETROFITTING SOLUTIONS.....</b>	<b>15</b>
2.1 MONITORING RESULTS OBTAINED IN THE THREE PILOTS.....	15
2.2 COMPARISON BETWEEN THE MEASUREMENTS AND THE PREDICTED PERFORMANCES .....	23
2.3 BUILDING OWNERS' FEEDBACKS .....	32
2.4 CORRELATION WITH THE POST-OCCUPANCY EVALUATION OF TENANT INTERACTION WITH ENERGY SAVING SOLUTIONS .....	35
2.5 INDOOR QUALITY DEMONSTRATION .....	38
2.6 IDENTIFICATION OF POSSIBLE ADAPTATIONS TO THE DESIGN AS WELL AS TO THE MONITORING PROGRAM .....	39
<b>CHAPTER 3 ASSESSMENT OF THE MONITORING METHODOLOGY AND PROCESS</b> .....	<b>41</b>
<b>CHAPTER 4 FROM THE TOOLS TOWARDS THE APPROACH...</b> .....	<b>42</b>
<b>REFERENCES .....</b>	<b>44</b>

## Chapter 1 Introduction of task 3.4 (evaluation of monitoring results)

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Task 3.4 of BEEM-UP project was dedicated to the **general assessment of energy efficient performance and indoor environment in all 3 sites**. This task focuses on the evaluation of the monitoring results regarding the initial objectives and the solutions identified and implemented within the retrofitting projects.

In order to present such an assessment that not only repeats the work already presented in other deliverables (D3.8 especially), but that provides added value, we selected to perform a generic evaluation focused on the following aspect: technical results obtained regarding the implemented retrofitting solutions. The objective is to share conclusions on the measured data analysis, and conclude on the success of the retrofitting projects as compared to predicted performance. The measurements results are also compared to the post-occupancy evaluation performed in Task 5.5. This evaluation is grounded on several initial criteria based on the objectives of the project (energy savings, involvement of the tenants, indoor quality demonstration...).

Finally the document proposes an analysis of the interest of perpetuating the initiative conducted within BEEM-UP project and the used methodology for the buildings' owners (from the tools to the approach...).

In that sense, this report provides the main recommendations and perspectives related to the BEEM-UP lessons learned from the 3 demonstration sites.

The three following sections provide:

- A brief description of the demonstration sites (key parameters, interventions conducted during the renovation process...),
- A reminder on the overall objectives of the BEEM-UP project in terms of energy savings target,
- A reminder on the monitoring methodology used and implemented within the project.

## 1.1 Brief description of the demonstration sites

### 1.1.1 Swedish site

The BEEM-UP demonstration in Alingsås, Sweden, is a complete refurbishment of 144 dwellings distributed over 8 houses. The houses, built in the 1970s, have been stripped down to the concrete skeleton and been refurbished using passive house techniques. The houses are extremely well insulated and need next to no additional heating.

Key indicators of the pilot site	Value for the Swedish pilot site
Location	Alingsås (Sweden), arranged around large car free courts in a green environment on walking distance from the town.
Year of construction	1971-1973
Surface retrofitted	14,860 m <sup>2</sup> gross living area for the 8 blocks involved in the BEEM-UP project (1613m <sup>2</sup> for the Building H which was monitored during the BEEM-UP project)
Number of dwellings	144
Owner/partner	Alingsåshem AB
Level of intervention	Deep renovation (tenants evacuated during retrofitting)
Total investment	€ 22,25 millions

Table 1: Key indicators related to the Swedish pilot site

Within the BEEM-UP project, one house has been selected for monitoring. The house holds 18 apartments on 3 floors and has a south facing façade. The size of the apartments varies from 1 to 4 rooms + kitchen per dwelling. The house is called “building H” within the BEEM-UP project. The monitoring of the building is done both on building level as well as more in detail for four of the apartments (see deliverable D 3.3, [ 1 ]). This building has also a shared laundry room. The following pictures show the renovated buildings as well as the House H during the renovation process in Alingsås.

a)



b)







c)

**Figure 1: Pilot site in Alingsås**

a) A renovated building in front of the photo, building that has not yet been renovated in the back.

b) House H during renovation.

c) Facades and roofs of buildings B, C, F, G and H as seen clockwise

The improvement measures for the site of Alingsås through the implementation of Passive House standards are summarized in the table below.

<b>Envelope</b>	Walls: Previous wall is replaced by new wall with several layers of insulation and slotted steel studs. In total 440 mm insulation. Basement: 100 mm expanded polystyrene extends 1 meter below ground level. 100 mm drainage panel downwards to ground floor. Roof: 400 mm new mineral wool insulation.
<b>Windows</b>	New triple-glazed cryptone filled low-emitting windows ( $U_{\text{window}} 0.85 \text{ W/m}^2/\text{K}$ )
<b>Heating (source and distribution)</b>	District heating (bio fuelled), heat recovery from outlet air Airborne distribution with waterborne heat supply to air heaters, controlled per flat.
<b>Domestic hot water</b>	Central system, district heating as before. Reducing taps.
<b>Ventilation system</b>	Central system, mechanical supply and exhaust system with heat recovery Single unit serves entire building.
<b>ICT – energy management (incl. smart meters)</b>	Electricity is measured individually; hot water is monitored remotely for each flat; heating is measured for each building. Individual billing and feedback is introduced.
<b>Lighting</b>	Low energy fittings. Low energy or halogen lighting and LED lighting in staircases.
<b>Renewable Energy Source</b>	District heating is renewable to 98%.
<b>Other energy saving</b>	The tenants receive energy-saving tips

**Table 2: Improvement measures conducted in the site of Alingsås**



### 1.1.2 Dutch site

The BEEM-UP demonstration in Delft, The Netherlands, is a refurbishment of 108 dwellings distributed over 3 types in 8 blocks. These dwellings have had similar improvements in their envelope. Some 50 dwellings have received a new installation with a solar boiler. Some 34 dwellings received a feedback system which gives occupants a real time insight into their electricity and gas consumption, as well as weekly and monthly statistics (see Deliverable D3.3 for more information about the feedback system installed in DELFT and named TOON). It also enables the user to control the heating in the house through an application on their smart phone.

Key indicators of the pilot site	Value for the Dutch pilot site
Location	Delft (the Netherlands), situated along five more quiet streets outside central Delft.
Year of construction	1958
Surface retrofitted	9128 m <sup>2</sup>
Number of dwellings	108 (28 rowhouses and 80 flats)
Owner/.partner	Woonbron
Level of intervention	Exterior measures and installations (tenants not evacuated during retrofitting)
Total investment	€ 3.544.000 excl. VAT

Figure 2: Key indicators related to the Dutch pilot site

The Figure 3 shows the Delft project and the different types of dwellings.





Figure 3: The Delft project has 3 types of houses in 8 blocks.

The improvement measures conducted in the site of Delft are summarized in Table 3:

<b>Envelope</b>	Walls: 1,7 m <sup>2</sup> K/W Basement/floor: 1,7 m <sup>2</sup> K/W Roof: 4,0 m <sup>2</sup> K/W Floor uninsulated
<b>Windows</b>	HR++ argon filled windows with a reflective layer. 1.6 times better insulation than double-glazing. ( $U_{\text{window}} \leq 1.2 \text{ W/m}^2/\text{K}$ )
<b>Heating (source and distribution)</b>	Fossil gas. Option of new condensing boilers and solar collectors per flat (about 50%). HR 107 boiler with use of solar panels on the houses. Insulated distribution. Waterborne system with radiators offered, individually controlled per radiator.
<b>Domestic hot water</b>	Decentralized systems, heated by fossil gas. Water saving showers.
<b>Ventilation system</b>	Natural ventilation. New windows equipped with ventilation openings
<b>ICT – energy management (incl. smart meters)</b>	Feedback system (TOON system) mounted to the wall and including both functions to set temperature and weekly schedule as well as feedback on actual usage of electricity and gas.
<b>Renewable Energy Source</b>	Solar energy on roof for warm water and heating.
<b>Other energy saving</b>	Focus on tenant behaviour and awareness-raising during and after retrofit is expected to lead to further reductions in energy consumption

Table 3: Improvement measures conducted in the site of Delft

### 1.1.3 French site

The BEEM-UP demonstration in Paris, France is a complete refurbishment of a building located in the center of Paris, 800 m from Montparnasse train station, at the corner of Rue Cotentin and Rue Falguière (2 addresses for one building). It is composed of 87 dwellings distributed over 8 levels in one building, and it was built around 1950. In 1993, the building was renovated (outer insulation, double glazed windows, boilers), but it needs a major upgrade to become a pilot for bringing their housing park to the low energy standard for renovated buildings.

Key indicators of the pilot site	Value for the French pilot site
Location	Paris (France), in an urban city area close to the Gare Montparnasse railway station
Year of construction	1958
Surface retrofitted	4352 m <sup>2</sup> living area
Number of dwellings	87
Owner/partner	ICF Habitat Novedis
Level of intervention	Deep renovation (tenants not evacuated during retrofitting)
Total investment	4.251.000€ excl. VAT (about 2 M€ for energy measures)

Figure 4: Key indicators related to the French pilot site



a)



b)

Figure 5: Pilot site in Paris

- a) Façade view of the building in Paris before refurbishment
- b) Façade view of the building in Paris after the refurbishment

The improvement measures for the site of Paris are summarized in the table below:

<b>Envelope</b>	Thermal insulation of facades, roof, basement ceilings and balconies Walls street side: + 20cm ETICS EPS $\lambda$ 032 / Walls back side : New 20cm EPS ETICS $\lambda$ 032 / Basement: + 10 cm insulation EPS $\lambda$ 032 below ceiling / Roof: New 10cm insulation PUR $\lambda$ 024 on ceiling
<b>Windows</b>	Replacement of windows and apartment doors New PVC double glazing, $U= 1,5 \text{ W/m}^2.K$
<b>Heating (source and distribution)</b>	New condensing boilers for heating and warm water (fossil gas) Replacement of floor heating by radiator. Radiators with individual thermostat to adjust the central heating setpoint.
<b>Domestic hot water</b>	Central system, with a heat pump in combination with sewage heat recovery
<b>Ventilation system</b>	Central system, humidity controlled mechanical exhaust system
<b>Electricity</b>	Electrical renovation of common spaces and non-renovated homes
<b>ICT – energy management (incl. smart meters)</b>	Synco living system displays in flats; an 11% saving expected. Individual billing of DHW and heating is introduced.
<b>Lighting</b>	All public spaces fitted with low-energy light systems. All tenants encouraged to switch to low-energy lighting.
<b>Renewable Energy Source</b>	Implementation in the basement of a system for grey water heat recovery, Heat recuperation from waste water
<b>Sanitary hot water</b>	Focus on tenant behavior and awareness-raising during and after retrofit is expected to lead to further reductions in energy consumption.

Table 4: Improvement measures conducted in the site of Paris

#### 1.1.4 Comments

Although the three demonstration sites are very different with respect to heating systems, energy sources, dimensions and even building structure, the improvement measures that are implemented in all three sites are very similar (envelop improvement; windows replacement, renewable energy source introduction,...). They all aim at first reducing the heating consumption that is the most predominant end-use of energy in dwellings. Then the domestic hot water that represents also a large share of energy is targeted by the refurbishment measures by implementing enhancements of installation or introduction of renewables sources of energy aiming at lowering this energy use also. The indoor climate conditions are at the same time targeted through the improvement of building envelop and ventilation systems, replacement of windows and implementation of acoustic measures. Electricity consumptions are not directly related to the refurbishment measures implemented during the renovation process but could be considerably reduced by awareness actions. In that frame, both Dutch and French sites have introduced feedback systems based on the display of energy consumptions. Both Swedish (tenants evacuated during retrofitting) and French (tenants not evacuated during retrofitting) sites are heavy refurbishments and this point may have a large impact on the tenants' satisfaction as well as on the savings results achieved for the whole building.

## 1.2 Reminder on the objectives

The initial objectives of the BEEM-UP project established in the DoW regarding energy performances after refurbishment are given in the following table, “target column”, as well as the predictions results related to the simulations carried out in WP1 during the project execution.

	Target from DoW	Predictions from WP1		
%	Project objectives	Swedish site	Dutch site	French site
Heating savings	75	89	36-77	82
DHW savings	45	13	6-52	41
Lighting savings	42 (lighting)	37	28	62

Table 5: Objectives in terms of energy savings within BEEM-UP project

Therefore the simulations conducted within WP1 show that it is “theoretically” feasible to reach most of the original objectives of the project. However, the goals for DHW and lighting seem the most difficult goals to reach even if a great improvement can be achieved thanks to the identified renovation options. Another main objective of the BEEM-UP project is to ensure a comfortable and healthy living environment while producing an important reduction of energy consumption. This item is specifically investigated through the analysis of indoor temperature of the dwellings as well as, when possible, some interviews that provide objective assessment from the tenants.

## 1.3 Reminder on the monitoring methodology used and deployed

General monitoring guidelines have been delivered for the BEEM-UP project in Deliverable 3.1 [ 2 ]. This document proposes a procedure for the definition and design of a monitoring program gives tools for its implementation and delivers a full IPMVP framework for measurement and verification program (M&VP) aiming at the evaluation of energy savings as it is the case in the project.

As stated in D3.2 [ 3 ], those guidelines are general and may apply to different building refurbishment projects similar to BEEM-UP.

The information to be delivered from such monitoring is the general performances of the implemented refurbishment solutions, but also the detailed performances of each action undertaken in the project in each pilot.

### 1.3.1 IPMVP framework

The IPMVP (International Performance Measurement and Verification Protocol) which the ICT PSP methodology is based is used as the framework for the monitoring programme content. It theoretically insures both quality of the assessment to be done and homogeneity between each pilot site.

IPMVP allows integrating a global analysis for the monitoring program, from requirements to reporting. It brings coherence to the measurements realized and insures the quality of the results.

### 1.3.2 M&VP

As suggested by Vol. 1 of IPMVP (Concepts and Options for Determining Energy and Water Savings), the protocol can be implemented through a Measurements and Verification Plan (M&VP) for the project and for each of the pilots. An M&VP is based on 13 points to be fulfilled in order to set up a clear and

coherent measurement and verification plan. These steps have been implemented within the BEEM-UP project. This has led to the definition of an M&V plan for each demonstration site required to evaluate the improvement brought by the refurbishment measures in terms of energy performances and indoor environment conditions.

In addition to the methodology approach, the local building managers have been involved and always present and supportive of the tenants within the whole refurbishment and monitoring processes.

The tenants' involvement has been also studied within BEEM-UP through the WP5 which aimed at developing a common methodology of tenant involvement to ensure that retrofitting projects are successful also from a social point of view.

### **1.3.3 Analysis of the applicability of the monitoring methodology**

The methodology described in the previous sections has served as a basis for monitoring implementation as well as for the monitoring data analysis. However some specificities of each site have required a customised approach allowing complying with the schedule as well as with the overall objectives of the project.

This was the case for instance for the French pilot site for which the retrofitting works were delayed. In that case, a backup solution of monitoring for the post refurbishment period has been implemented.

For the Swedish site for instance, additional measurements focusing on the systems functioning have allowed to perform a deep analysis and to make also some adjustments when required in the same way that it could be done in a commissioning approach.

Regarding the overall methodology, when the monitoring is based on data collection for a sample of dwellings, special precaution should be taken when interpreting the data. Indeed, the results may be inhomogeneous between the different dwellings monitored and it is sometimes difficult to generalize the results to a whole site or a whole building. This can be avoided by taking measurements at a higher level as a complementary measurement in order to cross correlate the monitoring results and then be able to extrapolate from the dwellings sample to the whole building (see Paris site for the DHW use for instance).

The deliverable D3.7 [ 4 ] provides some guidelines and recommendations for the monitoring of future energy retrofitting projects. These guidelines and recommendations are based on the evaluation of the monitoring process conducted during the BEEM-UP project for each site and relatively to technical, social and economic aspects. The main lessons learned from the BEEM-UP monitoring implementation have also contributed to the definition of these guidelines and recommendations.



## Chapter 2 Technical results obtained regarding the implemented retrofitting solutions

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### 2.1 Monitoring results obtained in the three pilots

This section provides a summary of the main factual results obtained related to the monitoring measurements performed in all three sites in the framework of the Work Package 3 of the BEEM-UP Project (see the detailed results in D3.8 [ 5 ]). It also highlights the main improvements that can be observed in energy consumptions and comfort conditions.

#### 2.1.1 Alingsås

For the Alingsås site, Table 6 provides the main results obtained in terms of energy savings measured after refurbishment. For comparison, the figures relative to the overall objectives of the project are also given.

This table clearly highlights that very positive results have been obtained for the Alingsås site. Brogården is a passive house renovation with extreme heat demand reduction through insulation, sealing and heat recovery ventilation. The monitoring results are in very good agreement with the initial objectives underlying this ambitious refurbishment.

The use of domestic hot water, electricity and heating has decreased after refurbishment. The savings achieved for the heating demand comply with the objectives of the project (80% for the reporting #2 that is to say after the adjustment conducted on the setup of the ventilation and heating systems in November 2013 i.e. for a nominal functioning of the heating system). The savings achieved for the DHW (mean value 12%) is lower than the objectives of the BEEM-UP project. However the 45% savings in energy for domestic hot water that were specified at the very beginning of the project seemed to be too ambitious especially, as the consumption is very much dependent on tenants' behavior. The electricity use (sum of domestic and common consumptions) that includes lighting consumption shows a decrease of 35%. The discrepancy between this result and the objective of the project on lighting (42%) could be explained by tenants' habits and also because electricity consumptions are not directly linked with the refurbishment measures implemented within the project.

In terms of comfort, the comfort conditions completely fulfil the objectives of the building owner as well as comply with the Swedish regulation. Both during winter 2012/2013 and 2013/2014 the temperatures remain well above 21 °C. In that sense, the indoor quality demonstration which is also one of the objectives of the BEEM-UP project has been completed for this site.

Moreover, for Alingsås, a peculiar improvement has to be highlighted. A detailed analysis of monitoring data collected after the refurbishment has emphasised some issues with abnormal/unnecessary use of heating. Some changes in the control strategy for the heating and ventilation have been operated and led to improvements and decrease in energy consumption (see D3.8 for more details, [ 5 ]). After this



adjustment, the use of heating was reduced and the efficiency of heat recovery was optimized leading to 80% of energy savings.

Brogården site	TARGET from DoW	METERED in WP3		
	Objectives of the project in terms of energy savings (see DoW Part B, p.6)	Baseline period measurements	Reporting period measurements	Savings achieved (%)
	%	kWh/m <sup>2</sup> -year	Period 1 [dec2012–nov2013] Period 2 [dec2013–nov2014] kWh/m <sup>2</sup> -year	%
Heating (heating degree day adjusted values)	75	141.8	37.9/28.7	73/80
Domestic hot water	45	27.7	23.3/25.5	16/8
Sum electricity	42 (only for lighting)	48*	30.5/31.3*	36/35
Indoor climate	NA	--	22-23 °C	NA

\* All electricity in the building. Sum of common and domestic electricity

Table 6: Summary of monitoring results and comparison with the general objectives of the project for the Swedish site

### 2.1.2 Delft

For the Delft site, Table 7 provides the main results obtained in terms of energy savings measured after refurbishment. For comparison, the figures related to the overall objectives of the project are also given.

In the case of Delft, the results obtained are moderately disappointing in the sense that the energy savings achieved are not at the level expected at the beginning of the project. The energy focus of the renovation has not met its theoretical promises. On average half of the ambitions have been reached. Looking at the final result, we can conclude that taking the rebound effects into account, the renovation package in Delft leads to 50% energy savings, compared to 75% in theory. However, because not all tenants took the maximum package, the overall savings are one third of the energy use compared to the reference before the renovation. These savings effects have been realized with relatively minor measures, which is a positive result.

A focus has been made on the advantages brought by the different refurbishment options offered to the tenants regarding the energy savings reached for each of them.

**TOON's influence:** the feedback system has not proved itself as being efficient in reduction gas and electricity consumption (see D3.8 [ 5 ] for further details). Nevertheless, people having chosen this option seem very enthusiastic. Interviews with users indicate that the "real-time" information on energy consumption gives new insights and effects behaviour. Quite many households use the four pre-set set points of TOON (away/at home/sleeping/comfort) similar to the manual thermostat: lower by selecting "away", higher with "comfort". This feedback is pretty similar to the manual thermostat and is effective as energy saving measure.

**Heating installation influence:** the effect of high efficient heaters is positive, especially when replacing traditional central heating. But the impact of the "efficiency factor" is not what counts, rather the side effects of the closed combustion system, the missing pilot flame. The temperature control is less efficient, while in the future new tenants may change the function of rooms, because the central heating systems support other functions than sleeping.

**Insulation influence:** The contribution of insulation measures is rather disappointing in practice, which is caused by the relatively low improvement in insulation value of the facades including windows, while the roof has low impact on heat losses, because it covers bedrooms that are not heated or atticks that already function as an important temperature buffer. The improvement of the insulation value of the envelope is quite modest and does not change the heating habits. For the envelope to have effect, a much higher thermal resistance and sealing is needed, with side effects such as the need for balanced flow ventilation. In the Delft project, renovation led to up-to date performance of the envelope, but the improvement of the heating zone, which is the living room and kitchen, is minimal.

**Solar domestic hot water systems and heaters with high efficiency:** the effect of solar domestic hot water systems and heaters with high efficiency is positive. The number of showers is 14 per week on average and the solar thermal system can save 50% of the energy use for hot water. When changing from small geysers with 2,5 dm<sup>3</sup>/minute hot water flow to 6 dm<sup>3</sup>/min with the new installations, the solar system compensates for this higher comfort level or even more, meaning that the solar system covers the rebound effect and does not save energy in practice, however improves the comfort level.

These findings do not come from the data analysis alone. Learning to know the tenants in how they use the dwellings and how they perceive the comfort is very important in such an analysis.

It should be emphasized that the improvements of the technical installations have side effects. The heat production efficiency is higher, but the comfort level as well, which reduces the effect in practice. The solar hot water system is an example: savings are reached, but just a little more than the rebound effect of providing higher water flows.

Nevertheless, the tenants' feedbacks are very good regarding the comfort conditions reached after the refurbishment works. The qualitative and very positive results obtained in term of tenants' satisfaction related to comfort should therefore be emphasized and put forward regarding the benefits from the refurbishment process in that demonstration site.

The main conclusion is that dwellings with sober installations before the renovation will not save much energy with modern installations that provide much more comfort.

Positive considerations from the Delft project are the involvement of the service provider for the technical installations including TOON. Also the involvement of the tenants has had a positive impact on the quality of the community and the acceptance of the renovation turmoil.

Delft site	TARGET form DoW	METERED in WP3		
	Objectives of the project in terms of energy savings	Baseline period measurements	Reporting period measurements	Savings achieved (%)
	%	kWh/m <sup>2</sup> ·year	kWh/m <sup>2</sup> ·year	%
Heating (heating degree day adjusted values)	75	137	75	45
Domestic hot water savings	45	21.5	33	-53
with solar system after renovation		21.5	16.2	24.6
Electricity	42 (only for lighting)	32.4	30.2	0

Table 7: Summary of monitoring results and comparison with the general objectives of the project for the Dutch site

### 2.1.3 Paris

For the Paris site, Table 8 provides the main results obtained in terms of energy savings measured after refurbishment. For comparison, the figures related to the overall objectives of the project are also given.

The multi-storey apartment block in Paris shows a great improvement in installations for heating and domestic hot water and includes a home energy management system integrated in the videophone-door answering service. The measurements reveal positive results relative to the two first items.

The use of general electricity and heating has decreased after refurbishment (between 60 and 65% savings for heating, 58% for general electricity). More mitigated results are obtained for the DHW consumption. In fact, there is almost no saving observed for the DHW consumptions in the Paris site even if the BIOFLUIDES system is providing free energy for the hot water production.

Concerning the DHW, two kinds of energy are used for the production of DHW:

-first, the BIOFLUIDES system pre-heats the water at a temperature around 47°C (BIOFLUIDES is based on electricity energy)

-and then the gas boilers raise the water temperature up to 60°C (legionella elimination) and maintain the hot water loop at the same temperature.

By analyzing in details the amounts of energy involved in the whole installation, large heat losses have been highlighted in the DHW distribution circuit. Moreover the distribution loop requires an additional amount of energy to be maintained at the same temperature. This energy is constantly provided by the gas boilers. These losses and the hot water loop have a large impact on the gas consumptions and literally mask all the energy savings that could have been achieved thanks to the new installation.

The ERS BIOFLUIDES system really contributes to decrease the energy consumption related to hot water production in the building. This renewable system constitutes an almost free source of energy that largely contributes to the decrease in energy consumptions for the Paris site (it provides about 14.2 kWh/m<sup>2</sup>/year according to the data analysis conducted from the end of August to the end of November).

In terms of qualitative analysis of refurbishment works, the punctual measurements performed in the dwellings have revealed some improvements relative to the acoustic insulation of the dwellings and the air leakage performance in comparison to the characteristics evaluated before renovation.

The acoustic insulation could have been even more improved by installing double wall in the whole room. In a quantitative way, the measured value does not reflect the improvement perceived by the tenants who were interviewed about their feeling regarding the acoustic improvement of the apartments. The tenants have really observed an improvement in the bedrooms where a double wall has been installed.

Regarding the comfort conditions, the percentage of hours located out of the comfort zone (<19°C or >28°C) has decreased compared to the period before refurbishment. During the autumn months, the indoor temperatures are on average lower than those observed during the baseline period highlighting a better managed heating system in the dwellings (technical management as well as awareness of the tenants regarding the energy management considerations). This also shows the improvements brought by the renovation process and the positive effect of radiators.

Paris site	TARGET from DoW	METERED in WP3		
	Objectives of the project in terms of energy savings	Baseline period measurements	Reporting period (2014) measurements	Savings achieved (%)
	%	kWh/m <sup>2</sup> ·year	kWh/m <sup>2</sup> ·year	%
Heating (heating degree day adjusted values to HDD used for the calculations)	75	263.8	105.5	60-65*
Domestic hot water*	45	29.1 (measured) 28.5 (thermal study)	33.3 (real conditions) 14 (considering reduced heat losses in the DHW distribution circuit)	0/52**
Domestic electricity	--	100	41.7	58.3
Electricity for lighting	42	2.33 (measured) 2.3 (thermal study) 3.33 (IST study)	4.6	-100
Indoor climate	NA	22.5	21.6	NA

\* Depending on the period considered for the comparison (6months data and extrapolation to one full year or ten months taken into account)

\*\* Considering reduced heat losses (30%) in the DHW distribution circuit

Table 8: Summary of monitoring results and comparison with the general objectives of the project for the French site



## 2.2 Comparison between the measurements and the predicted performances

In WP1 calculations were done to determine the theoretical energy performance of the building before and after refurbishment. First the buildings were analysed, all stakeholders gave input about goals, legal requirements, technical possibilities, cost, and energy saving potential. Then the targets were defined (based on ecological, economical, and social aspects), single measures were developed as well as combinations. And finally, this led to a methodology to choose very good performing variant in all three dimensions of sustainability [ 6 ].

This section gives the main results dealing with comparison of monitoring results with the predictions according to the variants that have really been implemented within the three pilot sites.

### 2.2.1 Alingsås

Table 9 provides a comparison between the monitoring results and the predictions for the Swedish site. The heating, DHW and indoor temperature results are the most important results to focus on.

As shown in Table 9, all the energy consumptions measured (heating and DHW) are higher than the predicted one and this is more pronounced for the reporting period data.

Despite this, the savings achieved for the heating demand comply with the objectives of the project but are still a little bit lower than the predicted one.

The savings achieved for the DHW is compliant with the predictions but it is lower than the objectives of the BEEM-UP project.

Some of the discrepancies observed between the predictions and the measurements could be explained by the fact that the calculations are made with the assumption that the heating and ventilation systems are functioning perfectly. The heating example shows that some important differences can be observed when the system has not been adjusted nor optimized. This optimisation can lead to several percent of additional energy savings

Another explanation for the difference between measurements and predictions is the temperature set point used in the dwellings. The temperature set point that was used for the predictions calculation was 21°C for Brogården. The monitored indoor temperatures have been well above this at all times. An average for the year has been 22-23 °C. Therefore this should be the most important difference, every degree in indoor temperature having a massive influence on consumption<sup>1</sup>.

Lastly, the simulations are done based on hypotheses that do not take into account the gap that could exist between a theoretical performance of a system or a material and the real performance reached after a real implementation of the system or material.

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<sup>1</sup> 1 °C more in the temperature set-point in residential sector corresponds to an additional energy consumption of 5 to 8% [<http://fsd.monash.edu.au/environmental-sustainability/environmental-issues/set-points-faqs>].

Brogården site	SIMULATED in WP1			METERED in WP3		
	Predicted performance before refurbishment (WP1)	Predicted performance after refurbishment (WP1)	Savings according to predicted performances	Baseline period measurements	Reporting period measurements	Savings achieved (%)
	kWh/m <sup>2</sup> -year	kWh/m <sup>2</sup> -year	%	kWh/m <sup>2</sup> -year	kWh/m <sup>2</sup> -year	%
Heating (heating degree day adjusted values)	134.6	15.1	89	141.8	28.7	80
Domestic hot water	23.3	20.4	12.5	27.7	23.3/25.5	12
Domestic electricity	No prediction	No prediction	37 (calculated from a previous project)	Not measured separately	22.2	--
Sum electricity	No prediction (11.8 for lighting)	No prediction (7.2 for lighting)	39	48*	31.3**	35
Indoor climate	--	21°C		--	22-23°C	

\* Measured value

\*\* Sum of domestic and common electricity

Table 9: Summary of monitoring results and comparison with the predictions (WP1) for the Swedish site

### 2.2.2 Delft

Table 10 provides a comparison between the monitoring results and the predictions for the Dutch site. The contribution of different measures to energy savings is different from theoretical models. Besides, the measured heating values are lower than the simulated one. And when the energy use is lower than calculated, the savings are lower as well. As for the percentage: it is harder to save on energy when the consumption is low already, even expressed as a percentage of the reference situation.

The reasons for the discrepancy between predictions and measurements in the Delft site can be based on both the limits of calculation methods and also based on user behavior.

The calculations were made considering that the whole building was heated, not only one room. Nevertheless before refurbishment, the tenants were only able to heat single room. Therefore the consumption was not very high before refurbishment. In any case it was much lower than for a dwelling where all rooms could be heated. Therefore before refurbishment this point explains the smaller values measured for heating consumptions compared to the predictions. However, this level of comfort should not be assumed for healthy living/ future living where adequate comfort conditions need to be provided. And these conditions have been apparently reached thanks to the refurbishment according to the very positive comments from the tenants collected during the interviews about the comfort conditions.

Moreover, in the case of Delft site, there have been many different refurbishment combinations (tenants had the choice between different options) and the predictions cannot fully correspond to what has been really implemented on site in terms of refurbishment. Main differences are in the wall insulation quality and missing floor insulation.

Therefore the simulations hypotheses are slightly different from the real parameters to be considered for the Dutch site. And this could be identified at several levels:

- air exchange rates through window ventilation can be very different from figures used in the calculations,
- the efficiency of old boilers (before renovation) used for the simulations was based on estimated figures therefore calculation of data relative to the baseline period can be distorted.

Another explanation for the discrepancy between measurements and predictions could concern the temperature set-point used by the tenants and that could be different than the one used for the simulation (the temperature set point used for the predictions calculation was 20°C for Delft). This could lead to a very different result. It is commonly admitted that decreasing heating temperature by 1°C could lead to 7% energy savings in return. Unfortunately, indoor temperature has not been monitored in the dwellings but it has probably risen. Indeed, the average temperature of living/bedrooms and circulation spaces before the renovation is more likely in the range of 12-13°C than 20°C. It is quite obvious that this temperature level improved after refurbishment. And this may explain the mixed results obtained for heating savings.

Lastly, in the calculations there had to be made assumptions for the saving potential of the feedback system and the influence of such a system could have been over estimated within the predictions calculations. This has to be considered as an additional explanation for the discrepancies between the predictions and the measured results.

Dutch site	Simulated in WP1			Metered in WP3		
	Predicted performance before refurbishment (WP1)	Predicted performance after refurbishment (WP1)	Savings according to predicted performances	Baseline period measurements	Reporting period measurements	Savings achieved (%)
	kWh/m <sup>2</sup> -year	kWh/m <sup>2</sup> -year		kWh/m <sup>2</sup> -year	kWh/m <sup>2</sup> -year	%
Heating only (degree day adjusted)	314.2	91.9	71	137	75	45
Domestic hot water	19.9	9.6	52	21.5	33	-53
with solar system after renovation				21.5	16.2	24.6
Electricity	11.8 (for lighting only)	8.5 (for lighting only)	28 (for lighting only)	32.4	30.2	0

Table 10: Summary of monitoring results and comparison with the predictions (WP1) for the Dutch site

### 2.2.3 Paris

Table 12 provides a comparison between the monitoring results and the predictions for the French site.

In general, some discrepancies can be observed between the calculated predictions and the real measurements.

The heating values measured before renovation are in really good correlation with the predictions (gap <1%) whereas the one measured after refurbishment are about 50% greater than the simulated one.

The operative temperature used for the calculations (20°C) is a little bit lower than the average indoor temperature observed in the dwellings (around 21-22°C). This can explain a part of the discrepancy observed between the measured values and the predictions for heating consumption.

Concerning the DHW, as described previously, a large amount of heat losses has been identified and additional gas consumption has been measured for the heat losses compensation by the gas boilers (hot water loop). This last action can explain the high gas consumptions measured in 2014 for DHW production. Therefore the gas consumptions can be highly affected by the distribution circuit that in the case of the Paris site is not as performant as intended. In fact, the heat losses in the distribution circuit have not been taken into account within the prediction calculations and therefore the simulated values are underestimated regarding the gas consumptions.

Moreover many other parameters related to the technical set-up of the Biofluides system may explain the observed discrepancies between predictions and measurements. For instance the temperature set-up for the water pre-heating could be mentioned as an influencing factor that could really affect the consumptions predictions (take 55°C instead of 47°C for instance).

Furthermore it should be emphasized that the measured values are well above the predictions including for the baseline period. The predictions largely underestimate the DHW consumption and this is mainly due to the hypothesis taken for the calculations. Indeed, Table 11 gives the mean values of DHW consumption in the residential sector in France according to the size of the dwelling (40l/day minimum) whereas the calculations hypothesis consider 25l/person/day which seems very low for the Paris site. This can explain the large discrepancy observed between the measured DHW consumptions and the predictions for the baseline period as well as for the reporting period.

Number of rooms of the dwelling	1	2	3	4	5
DHW consumption (l/day) 60°C	40	55	75	95	125

Source <http://www.tecsol.fr/Lettres/articles/Documents/ECsolaire1.pdf>

**Table 11: Mean values of DHW use in France according to the size of the dwelling**

Concerning the lighting use, the measurements provide very low values of consumptions compared to the predicted one. Despite that, the energy savings are not in agreement with the predictions. It should be emphasized that the measurements of lighting consumptions are very dependent on the way the lighting system is used in the dwelling (lighting distribution or lamps directly plugged on the general electricity distribution of the housing). This last configuration prevents a reliable measurement of this electricity usage and unfortunately can't be anticipated within the monitoring process.

Lastly, in the calculations there had to be made assumptions for the saving potential of the feedback system and the influence of such a system could have been over estimated within the predictions

calculations. For the Paris site, the feedback system has just been installed in the dwellings (after summer 2014) and one can assume that the system has not reached yet its full impact for the time being.



French site	Simulated in WP1			Metered in WP3		
	Predicted performance before refurbishment (WP1)	Predicted performance after refurbishment (WP1)	Savings according to predicted performances	Baseline period measurements	Reporting period (2014) measurements	Savings achieved (%)
	kWh/m <sup>2</sup> -year	kWh/m <sup>2</sup> -year	%	kWh/m <sup>2</sup> -year	kWh/m <sup>2</sup> -year	%
Heating (heating degree day adjusted values)	264.26	48.41	82	263.8	105.5	60
Domestic hot water*	16.7	9.8	41.3	29.1 (measured) 28.5 (thermal study)	33.3 (real conditions) 14 (considering reduced heat losses in the DHW circuit)	0/52
Domestic electricity	No prediction	No prediction	62 [cf brochure]	100	41.7	58.3
Electricity for lighting	11.78	7.28	38	2.33 (measured) 2.3 (thermal study) 3.33 (IST study)	4.6	-100
Indoor climate		20°C		22.5	21.6	NA

Table 12: Summary of monitoring results and comparison with the predictions (WP1) for the French site

## 2.2.4 General assessment

As a general rule, the discrepancy between simulated and real building energy use is an important issue essentially determined by the three following items which correspond to the three main phases of a building life:

- (1) Limitations of the simulation tools themselves and hypotheses taken for the calculations, involved within the design phase of a project (construction or refurbishment);
- (2) Workmanship and quality of building elements, involved during the construction or refurbishment phase of a building;
- (3) Building usage patterns/occupants behaviour, involved during the exploitation phase of the building.

A fourth parameter can contribute as well to the discrepancy between predictions and measurements and it is related to the monitoring issues that can be inevitably encountered in real conditions of operation.

The second item that is related to the impact of quality of building elements is supposed to have been avoided or at least reduced thanks to the Quality Assurance system that has been defined and implemented within the BEEM-UP project in order to achieve the intended performance results.

However, the two other parameters (hypotheses used for the calculations and tenants' behaviour) have been highlighted within the three demonstration sites.

As a general rule (all the following explanation is applicable for all three sites), the reasons for the differences between measurements and predictions can be the following:

- The temperature set point used in the dwellings can be really different from the one used within the simulations. In most cases, the monitored indoor temperature is above this. Therefore this should be the most important difference, every degree in indoor temperature having a massive influence on consumption.
- The air exchange rates before refurbishment were not measured (could be higher or lower than assumed) and this parameter can have a large influence on the calculated results in terms of heating consumptions particularly.
- The ICT savings were based only on assumptions (one can assume they are of the order of 5-10%).
- The room temperatures before refurbishment could have been lower than calculated (in the case of Delft, for instance, only one room was really heated before refurbishment).
- The efficiency of old building services could not be calculated exactly, only assumptions can be made (no information was available about efficiency of old components: boiler, air change rates unsure, distribution losses).
- The consumption of warm water may differ from calculations considerably (before and after) especially, as the consumptions are very much dependent on tenants' behaviour.
- The rebound effect could also be a very impacting parameter that cannot be anticipated or measured and therefore that is difficult to quantify or estimate (higher temperature after refurbishment, lower temperature than calculated before refurbishment (pre-bound effect)...).

## 2.3 Building owners' feedbacks

This section provides the own feedbacks of each building owner for each pilot site regarding the technical results obtained regarding the refurbishment solutions implemented in each pilot.

### 2.3.1 Alingsås

The monitoring results for Alingsås have been compared with the data of the Swedish Building regulation as well as with the building company objectives.

The predicted performance of the building company has been done before the calculations in WP1 within the BEEM-UP project and is totally independent of these.

The use of domestic hot water has decreased with 8-16% from 27 kWh/m<sup>2</sup>/year to 23-25 kWh/m<sup>2</sup>/year. The use of domestic hot water is even lower than the predicted performance of the building company.

The use of common electricity has decreased with 35% which is exactly the same as predicted performance. It is however difficult to compare the common electricity before and after renovation since the common electricity was measured together with the domestic electricity for the baseline period.

In Sweden the building regulations regarding energy performance focuses on the term specific use of energy. This includes the heating, domestic hot water and the common electricity. The specific energy is always reported as used energy per square meter temperated area (kWh/m<sup>2</sup>/year).

The measured data have been compared to the figures available for a newly built house located in the region where Brogården is situated<sup>2</sup>. The specific use of energy for this kind of house is 90 kWh/m<sup>2</sup>.year. Table 13 shows this comparison. The results of the measurements show that even if the used energy does not match the predicted performance this renovated house uses 27% less energy than what is required for a newly built house in Sweden in terms of energy consumptions.

It is also interesting to see that the building situated in the coldest climate within this project is the building that has the lowest need for energy for heating. This indicates that the potential for reducing the energy demand in Europe is even larger than what has been showed in this project.

House H	Reporting period	Predicted performance according to Skanska	Building regulations
	kWh/m <sup>2</sup> .year	kWh/m <sup>2</sup> .year	kWh/m <sup>2</sup> .year
Specific use of energy	66	47	90

Table 13: Specific use of energy -Comparison between measurements and Swedish building regulation

<sup>2</sup> National Board of Housing, Building and Planning. (2014). Boverkets författningsamling BBR 21. Boverket.

Therefore the results obtained in the Alingsås site are very satisfactory and the implemented improvement measures have allowed reaching most of the goals initially targeted.

### 2.3.2 Delft

A comprehensive analysis of the solutions implemented in the Delft site is provided in [ 7 ]. The main conclusions are given below.

In Delft the focus is on a basic “free” package for insulation of the envelope (except floor insulation) and relies much on free selective measures that tenants can choose to further increase the energy performance: floor insulation, central heating with highly efficient heating/hot water source, solar domestic hot water system and an intelligent home energy management system.

#### **Local versus central heating**

Before the renovation of the Delft site, many apartments had either one chimney tied gas heater or the mother-fireplace in the living room with radiators in all other rooms. The tenants that still use a single chimney tied heater are satisfied with the improved comfort after insulation of the envelope, while showing lower energy consumption than in dwellings with central heating. These findings raise the question of priorities in renovation. Better insulation of the envelope would increase the overall temperature without heating due to solar and indoor gains and lower heat losses to a degree that meets the needs of tenants who prefer unheated bedrooms. The combined heating/hot water appliance has developed into a high performance and cheap appliance, meaning that radiators are just needed in the living room and kitchen.

#### **ICT technology as feedback system raising awareness of people**

In Delft, the HEMS (Home Energy Management System) in Delft is called TOON and it includes a programmable thermostat that the users can activate through their smart phone to manage the indoor temperature. The system is also able to give information on:

- Real time power use (electricity) and heat consumption;
- Comparison of electricity and natural gas or heat with the previous day, week, month or year;
- Expected energy consumption both in energy units (kWh and m<sup>3</sup> natural gas) and in Euro's;
- Comparison of energy use with the average in the neighbourhood;
- Actual temperature and manual adjustment of the set-point for the actual period;
- Pre-set period with four set-points: away, home, sleeping and comfort;
- The weather (expected rain showers).

Interviews conducted with the users indicate that the real-time information gives new insights and does have effect on behaviour. The learning curve is fast and will last a few weeks, but energy or cost minded people stay interested the energy consumption. When being faced with replacement decisions, they are more likely to take an A++ type refrigerator or a LED television, while taking long showers may be discouraged on the basis of the energy effect.

The TOON is a free service for two years, after that period the tenants have to pay a monthly fee of € 4,0 to € 5,0. If we consider that the energy saving effect over period of months is around 7%, this represents about 50-60% of the cost for using it. Almost all interviewed people choose to continue using the HEMS.

### **Improvement in terms of comfort conditions**

The large satisfaction of users in the Delft site concerning the comfort conditions of their dwellings are strongly influenced by the technology selected for the glazing technology.

As said in [ 7 ], the extreme insulation value, high transmittance, low weight and small thickness due to a cavity of only 4-5 mm makes this innovation welcome and may push triple glazing aside as a detour in the transition towards better energy performance of building products.

### **Use of monitoring results for future refurbishments**

The information collected during the monitoring phase will be very useful for new refurbishments. This enables to know what percentage of the theoretical savings are actually recovered. And therefore it is possible to make better estimations of costs of living after refurbishment. This analysis could therefore provide a sort of refurbishment guide providing a savings level attached to each kind of renovation measure.

### **2.3.3 Paris**

In the Paris site, the results are preliminary for now because of the short period of monitoring and therefore the small amount of data available for the savings analysis (the refurbishment works have been really ended in October 2014).

Despite that, the preliminary data indicate already pretty good results and promising energy savings values. The gas consumptions have been considerably reduced leading to validate the improvement measures implemented relatively to envelop, windows and boilers.

Nevertheless, the results obtained regarding the DHW are highlighting a mitigated observation about the way the new installation is functioning. As presented above in this document and in details in the D3.8 [ 5 ], the positive impact of the new installation on the overall DHW consumptions (renewable energy introduced through the installation of the BIOFLUIDES system) is masked by the large amount of heat losses observed in the DHW distribution circuit.

Regarding this issue some improvements measures can be identified to enhance the hot water circulation. Among them, one can mention:

- Improve the pipes insulation,
- Use a programming system to control the pump related to the circulation circuit (circulation stopped during the nights),
- Use a thermostat which can stop the pump when the water reaches the needed temperature to be able to stop the circulation (this is particularly useful during the period when this network is always in circulation),
- Use a pipe with a small diameter in order to minimize the energy losses,
- Minimize as much as possible the distance between the circulation network and the tap in order to reduce the waiting time to obtain warm water,
- Place the return as high as possible in the tank,
- Create the circulation so that the pump pulls the hot water from the tank and therefore pushes the chilled water into the tank.

Regarding the feedback system installed in the dwellings, half of the interviewed people don't use it for now. Some technical problems are still present regarding the reliability of the measurements (some individual meters are still not connected). Therefore for the next billing

(2014-2015), ICF will use the old way for the billing because the measurements are not reliable enough for now.

Moreover, ICF considers that the building is still in a phase related to adjustments or settings of the systems and in that frame, the measurements can bring useful information enabling to detect defects or abnormal behavior.

## 2.4 Correlation with the post-occupancy evaluation of tenant interaction with energy saving solutions

Post occupancy evaluation studies provide information that enable designers to make more informed decisions about the performance and operation of a building.

Buildings are active systems with users and owners in constant interaction. Occupants utilise the buildings features to suit their needs, which may not equate with original design intent. This can often be due to lack of education on building systems and operation. All claims that buildings are energy efficient and environmentally friendly need to be substantiated by an independent assessment. Post occupancy evaluation has demonstrated that the expectation of a building tend to be favourable in comparison with the results. Post occupancy evaluation can also help explain why there are differences in the operation of a building.

The following section provides the main information collected during the post-occupancy evaluation conducted within BEEM-UP within the task 5.5 [ 8 ]. It intends to evaluate if the tenants experience coincides with the technical data obtained in WP3 and how the tenants' behaviour can have influenced the final performance of the building.

### 2.4.1 Alingsås

Brogården is a passive house renovation with extreme heat demand reduction through insulation, sealing and heat recovery ventilation, but with little interest in user behaviour or individual heat metering, because the consumption is considered too low for that.

Alingsåshem executed a post-occupancy evaluation in October 2014. The study has been performed in House H at Brogården (the same house that has been monitored within the project). Out of 18 households, 10 participated in the post-occupancy study.

As far as it is possible to tell from the answers in the survey, tenants of House H do not generally think about energy efficiency when going about their normal lives. They try to keep their water consumption down and they seem modest consumers, making it hard for some of them to be more efficient. Before the retrofit both hot water and electricity was included in the rent for the tenants at Brogården. After the refurbishment the hot water is billed on the rent invoice, and the household electricity is billed separately from Alingsås Energy. The survey shows that the tenants do not study their bills even if they are concerned or interested in energy savings.

Overall the tenants seem pleased with the indoor climate after the renovation but there are still issues that affect the level of satisfaction. Individual needs and preferences make it hard to provide a temperature that is optimal to all – more so in a passive house. The bedroom temperature during the night is too high for some respondents while it is not enough for others. It is, however, quite clear that the house has withstood both winters and an extremely hot summer and managed to keep most of the tenants content or very content with the indoor

climate. Overall that must be considered a success. The interviews also show that the tenants in the survey follows the Swedish average for preferred temperatures (between 20 and 23°C, never be lower than 18°C, and never higher than 26°C for a longer period of time). The temperature measurements collected in the dwellings confirm this point.

Regarding the heating use, the tenants found the thermostat that has been implemented in the living room after the retrofit easy to use, and appreciated the possibility of regulating the temperature individually. But due to the slow process of temperature regulation in a passive house (due to regulation by the incoming air), all respondents stated that during the winter, they always kept the thermostat at 5 (maximum value) and never changed it. Despite that, the heating consumption complies with the general objectives of the project and the predictions as well.

Therefore for Alingsås, tenants' behavior seems to have a low impact on energy use and this is also correlated with the relatively low discrepancy between measurements and predictions. This emphasizes the robustness of the improvements measures implemented.

#### 2.4.2 Delft

Some interviews during house visits with 31 households have been conducted in Delft in May 2014.

General information about tenants' satisfaction has been collected during these interviews. As a general rule, the users are very satisfied about:

- Higher indoor temperatures that leads to a better comfort,
- More bedrooms heated (not more overheating in the summer),
- Better windows, vents and less draught,
- The energy awareness effect of TOON,
- The process of the renovation.

But there are still some items which are source of dissatisfaction:

- Poor acoustic insulation (neighbours upstairs),
- Poor maintenance of technical installations after breakdown.

A general complaint is heard about the noise from neighbors and from outside.

Draught problems are still heard from the ground floor-maisonettes, not any more from the other housing types. Everybody is happy with the hot water service, even the people who still use the geyser (with only 2.5 instead of 6 dm<sup>3</sup>/min of hot water).

Before the renovation of the Delft site, many apartments had either one chimney tied gas heater or the mother-fireplace in the living room with radiators in all other rooms. The tenants that still use a single chimney tied heater are satisfied with the improved comfort after insulation of the envelope, while showing lower energy consumption than in dwellings with central heating [ 7 ].

Many households are aware of their energy costs and therefore they have few electrical appliances and use the heating and hot water service as sparsely as possible. For this people, the renovation brings a "plus" because the same energy can be consumed but with better comfort conditions.

The improvements of the technical installations have side effects. The heat production efficiency is higher, but the comfort level as well, which reduces the effect in practice. The solar hot water system is an example: savings are reached, but just a little more than the rebound effect of providing higher water flows.

### 2.4.3 Paris

A household survey has been conducted by Couleur d’Avenir [ 9 ]. This survey (47 interviews) enables the analysis of tenants’ satisfaction regarding the refurbishment as well as the collection of the energy consumptions habits of the tenants. It is important to emphasize that 1/3 of the tenants have moved in the dwellings during the refurbishment works in 2014.

The tenants’ dissatisfaction points are mainly due to the nuisances related to the renovation works. The tenants are mostly satisfied regarding the equipment’s installed in the dwellings except some small points of dissatisfaction related to noise produced by the ventilation systems, and delay in the implementation of the videophones (energy feedback system).

The windows quality and new radiators are really appreciated by most of interviewed tenants (acoustic and thermal improvements for the windows). The removal of individual DHW production systems in the dwellings has been really appreciated by the tenants who are very happy to have their individual electricity bills reduced thanks to this measure.

In Paris, the energy feedback system is multifunctional including the door opener function (integrated in a videophone service) as well as the display of energy consumptions ( Figure 6). Data on daily consumption as well as on accumulated consumption is available on the display. The system also enables the building owner NOVEDIS to communicate with the tenants. During the interviews, the feedbacks related to the feedback system are mitigated. Some of the tenants report that the functioning is not easy to handle. The thermostat seems not to be used by the tenants mainly because of the difficulty to use it in a simple way (lack of operating instructions). Whereas the individual thermostats attached to the radiators seem to be intensively used by the tenants, and that seems in good correlation with the indoor temperature management observed in the monitoring process [ 5 ].







Figure 6: Examples of displays used in the feedback system installed in Paris site

Regarding the DHW consumption, the rebound effect is clearly highlighted through the interviews. People say that before renovation, they take care of their hot water consumptions because of the limited volume available in their hot water tank. Now the DHW production is centralized (boilers and BIOFLUIDES system) and almost unlimited, they are afraid not to still take care of their hot water consumptions. This observation is not confirmed by the collected measurements at least for the time being (the DHW meters located in the dwellings show that the consumption has decreased by 30%).

Concerning the comfort evaluation, the main parameters that are emphasized by the tenants are the acoustic improvements (mainly during the summer months) and the removal of warm feeling during winter. The acoustic improvement has also been noticed during the measurement but the figures obtained are not reflecting a huge enhancement. Regarding the warm feeling during winter, the measurements have clearly highlighted lower indoor temperature and a better heating management in the whole building. The replacement of floor heating by radiators has also surely contributed to the improvements of comfort conditions. Some of the tenants indicate that a programmable thermostat would have been more useful in order to manage the heating of their dwelling according to the time of the day.

Most of the interviewed people use low energy light bulbs, switchable plugboards, low energy home appliances that is in good correlation with the electricity use measured after the refurbishment. But again the interviews were done very early after the refurbishment works and the tenants don't seem to have largely changed their habits regarding energy consumptions yet.

## 2.5 Indoor quality demonstration

As a general rule, the indoor quality has been improved for all the three sites.

For Alingsås, the indoor temperature is well above the temperature guaranteed by Alingsåshem (20°C) during the whole year and even during the winter periods. The relative humidity level remains below 60% whatever the season. These measured parameters highlight the improvements led by the improvement measures selected (mechanical ventilation system with a rotating heat exchanger, passive house techniques). One of the major improvements in the

indoor climate is that thanks to the well-insulated walls and windows the cold draft is no longer a problem.

In Delft, no measurements have been implemented during the monitoring process. However, occupants are very enthusiastic about the better indoor thermal climate, mainly higher temperature and for some less draught. The display thermostat helps users awareness of high electricity consumption and some have energy savings through TOON, but not all, because use as a clock thermostat leads to more heating energy (and more comfort). Even if there is satisfaction about energy savings and average data shows a good result, there is still dissatisfaction about poor acoustic insulation (neighbours upstairs).

For Paris, as said in §2.4.3, some improvements have been reported by the tenants regarding the acoustic conditions as well as the suppression of warm feeling during winter. This has also been measured within the monitoring process. The radiators associated with local thermostats have largely contributed to the improvement of comfort conditions in the dwellings.

## 2.6 Identification of possible adaptations to the design as well as to the monitoring program

There are multiple parameters influencing the actual energy use of the buildings monitored within the BEEM-UP project as well as parameters dependant on one another. Therefore it is hard to determine the impact of each separate novel solution on the energy efficiency at aggregate level.

However, the results presented in the previous sections highlight some general improvements and several energy savings complying with the initial goal of the refurbishment process.

Nevertheless, some of the renovation practices as they were applied in the three pilot sites are out-dated now. For the DELFT site for instance, for higher effects the insulation value must be far better improved. The cool bedrooms can be welcomed, but need a separate thermal zone. The layout of the central heating must allow two zones of heating. The natural ventilation can be energy efficient, considering avoiding electricity use for fans and the embedded energy of installation and maintenance, but for real low-energy dwellings heat recovery ventilation does not have good alternatives, considering the few winter months. A solar thermal system is included in the package as well as a large grid-connected PV area.

For the Paris site, one can also envisage to link the BIOFLUIDES system to the heating process of the building. Indeed, the BIOFLUIDES system is also able to provide preheated water for the heating circuit. This can bring additional savings (renewable energy introduced both for heating and DHW production) and leads to far higher global energy savings for the whole operation.

In most cases, people are satisfied with the process of renovation. In the case of Delft, the quality of installation is sometimes criticized because of giving up a closet for boiler/heater in apartments with solar system and also in apartments where many heating pipes are visible and ugly. But the tenants' satisfaction related to indoor thermal comfort may sometimes obscure these issues. Therefore, additional efforts are needed to take these items into consideration in a more concrete and efficient manner.

In Delft, many users have still a complaint about something that is not done well or out of order and there is major dissatisfaction about the follow-up maintenance, especially by the contractor who has to maintain the performance of TOON and of the heating/hot water system including the solar system.

Further improvement can also be identified regarding the monitoring process implementation. This has been largely detailed and described in the document [ 4 ].

## Chapter 3 Assessment of the monitoring methodology and process

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This section focuses on the monitoring process itself relatively to its implementation in the three pilot sites (process, homogeneity/heterogeneity, time and plans of the retrofitting projects which are different from one site to another). The aim is to share experience on the monitoring process and compare the three cases with regards to the similarity or discrepancies between the three pilot sites. Another goal is to identify within the monitoring process the parameters that can have influenced the discrepancies between the measurements and the predictions and objectives of the project.

The level and detail of the measurements conducted within a monitoring process can have a large impact on the accuracy of the conclusions to rise from a monitoring process.

For instance to cover the impact of all the improvement measures requires the use of a very detailed instrumentation enabling the measurement of very detailed functioning of the systems. This was the case for Alingsås for instance for which sensors located on the ventilation or heating distribution system allow the validation of the optimised functioning of the energy systems. In the case of Paris, the various sensors and energy meters located both at system level and dwellings level enables the evaluation of heat losses and therefore the breakdown of the energy use.

Moreover the sample of dwellings that is used for the evaluation needs to be large enough to be the most representative as possible of the refurbishment measures implemented. This proved to be difficult in the case of Delft for which the refurbishment options are selected by the tenants and therefore makes the savings evaluation more difficult as a whole.

A major influencing parameter is related to the occupation of the dwellings which is the most difficult parameter to handle and that nevertheless has the largest impact on the energy use.

In the case of the French site, the fact that the refurbishment works were delayed regarding the BEEM-UP project has introduced additional difficulties. Indeed, some instrumentation has been installed during the renovation works. Some problems with disconnection of the system or damage to the sensors were noticed. Moreover, it was not possible to use the remote control of the system because of internet access not being available before the end of the refurbishment works.

Difficulty in monitoring data analysis (comparison between baseline/reporting period) when the refurbishment process introduces a radically different way of delivering the energy (BIOFLUIDES introduction for instance). In that case, comparison could be challenging and this leads to difficulties in energy savings evaluation.

Despite the use of IPMVP framework for the monitoring implementation and analysis, some assumptions need to be taken in several cases to get a tangible savings value. These hypotheses necessarily introduce uncertainties in the general assessment.

## Chapter 4 From the tools towards the approach...

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This section is devoted to analyse the interest of perpetuating the initiative conducted within BEEM-UP and the used methodology for the buildings' owners (from the tools towards the approach...).

The methodology related to the monitoring process which has been developed within the BEEM-UP project provided the basis for a tool largely replicable and transferable to other refurbishment project [ 4 ].

Moreover the figures demonstrated within BEEM-UP are bringing useful evidence and proofs of concept for future renovation plans. For instance, the results obtained regarding the heating consumption decrease as well as the indoor environment conditions improvements highlight the fact that a high insulation and a good sealing are the very first prerequisites in renovation plans.

The feedback system had proved to have a real impact on the occupants regarding the way of using the energy. But this impact still remains limited and need to be proved over a long period of time. The most important item is to teach the users and explain what would happen if they use their systems or dwellings in an inadequate manner.

But this feedback system should be necessarily associated with a real management flexible for the occupants. People need to get information in direct relation with their actions in the houses. The most efficient way to make them aware is to show them the consequences of their actions instead of providing them tips based on theoretical approaches. This passes through the development and the dissemination of operating manual allowing the users to be engaged in the understanding and management of their house.

The benefits illustrated within the BEEM-UP project can be beneficial at different levels:

### **From the building owner point of view:**

-Replication of the refurbishment process based on validated technologies. This makes easier the technological choices and gives a strong framework for replications. Even if the objectives were high 4 years ago, most of them have been reached. Therefore the solutions that have been implemented can be considered as effective solutions in terms of energy savings.

-Replication of the refurbishment process easily acceptable by the tenants because it is based on tangible results of energy savings. The monitoring process allows a real feedback about the technical solutions implemented. This gives tangible results that can be extrapolated as well as passed on the rent of the tenants.

-The different strategies used within BEEM-UP (feedback system and introduction of individual metering and billing) addressing households' energy awareness and usage bring useful examples and tools to the building owners for replication in other refurbishment projects. But some improvements may be identified and serve as a way of progress for the building owners. For instance, the long term attractiveness of the tool needs to be studied and increased. The design of the feedback system is also an important aspect that should be carefully analysed and developed because it is a sine qua none condition for positive impact of the tool.

**From the tenants' point of view:**

The long term involvement of the tenants in energy management still remains an issue. Some new initiatives are emerging including feedback process based on competition or gamification approaches that aim to keep the users involved in the long term. The approach developed in the Delft site (comparison of energy use with the average in the neighbourhood integrated in TOON) is a good approach in providing reference target to the user so that he can be stimulated and engaged over the long term.

**From the energy savings point of view:**

-To increase the visibility of households' energy usage is one energy efficiency measure a housing owner can implement [ 10]. Individual metering and billing constitutes a beneficial way of making people more economic responsible. They are measured and pay their own consumption which is also fairer.

-The smart metering will become an obligation in the coming years all over Europe. Many benefits can be identified from this technology and not only on the cost side.

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