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Active managed Buildings with
Energy performaNce Contracting

Deliverable 3.5 (D3.5)

Pilot evaluation report of the proposed AEPC concept and business model

The AmBIENCe Consortium

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EXECUTIVE SUMMARY

Deliverable 3.5 - "Pilot evaluation and lessons learned report of the proposed AEPC concept and business model" describes the key results and findings from the two pilot buildings in AmBIENCe project - a residential house in Belgium and a commercial office building in Portugal. Energy efficiency and flexibility measures were developed and quantified in each case, with simulation results used to build template contracts (detailed in Deliverable 3.2 – “Performance contract for the Portuguese pilot” and Deliverable 3.3 – “Performance contract for the Belgian pilot”).

This deliverable evaluates the Active building Energy Performance Contract (AEPC) concept from the pilots experience, with a brief general chapter in Section 2 highlighting the key phases the pilots were able to pass through, and a description of the tools used to develop the demonstration cases highlighting the maturity of the Active Building Energy Performance Modelling (ABEPeM) platform developed in the project.

Section 3 presents an evaluation of each pilot case individually, describing highlights from the AEPC contract development and pilot process - the AEPC measures and performance guarantees, the interest and motivation for an AEPC from local stakeholders, and the lessons learned in each context.

Section 4 highlights the regulatory influences (status/barriers/drivers) in each pilot countries national context, and presents the overall lessons learned from the pilots implementation, divided into three main findings: the importance of client and stakeholder engagement activities; simplifying complex design options into clear benefits; and that there is potential for significant cost savings from optimising flexible building assets.

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1. INTRODUCTION AND BACKGROUND

1.1 THE CONTEXT

In the AmBIENCe project, the classic Energy Performance Contracting (EPC) concept is extended to introduce flexibility measures and the value of Demand Response (DR) to performance guarantees. A proof-of-concept platform was developed to support the Energy Service Companies (ESCOs) in the design of an Active building Energy Performance Contract (AEPC), calculating the performance baseline, project Key Performance Indicators (KPIs) and guarantees [1], as well as the flexibility options and added revenue streams resulting from DR activities [2]. A variety of business models are introduced to support engaging the stakeholders in the AEPC contract [3].

To verify the effectiveness of the proposed concept, tools and business models, the AEPC concept, methodology, and business models were tested with two demonstration cases. The pilot cases cover a range of uses and climatic areas, obtaining valuable information on the feasibility, barriers and impact of AEPC. An office building and a residential building were considered to check the applicability of the AEPC concept, methodology and business model.

Through the demonstration in the two pilots, the AmBIENCe concept and methodology has been tested and developed further by the challenges that arise in trying to implement innovative concepts in real world scenarios. The demos were able to pass through key stages of the *pre contracting phase* and some steps of the *contracting phase,* however, for a *performance phase* - real implementation and monitoring of an AEPC and measurement and verification (M&V) of results, further implementation steps are required which were not possible within the timeframe of the project.

1.2 PURPOSE AND SCOPE OF THE DOCUMENT

This deliverable highlights the results of the pilots, the interest and motivation for an AEPC by stakeholders in each context, and overall lessons learned from the pilot implementation process. A general description and evaluation are provided in Section 2 - Evaluation of AmBIENCe concept from pilots experience, and more detailed sections focus on each pilot (Section 3.1 – Portuguese pilot and Section 3.2 – Belgian pilot), with overall lessons learned described in Section 4, alongside a recap of the regulatory enablers and barriers in each country, which contributed to the AEPC development process.

2. EVALUATION OF AMBIENCE CONCEPT FROM PILOTS EXPERIENCE

The general procedure for an AEPC project is divided into three main phases: the pre-contracting, contracting and performance phases, fully described in Deliverable D2.1 – The Active Building Energy Performance Contract concept and methodology [2] and highlighted in Figure 1 and [4]. The duration of these phases is highly dependent on each specific case (including the country, building type, stakeholders and teams involved), ranging from months to years, with continual client engagement to get to contract signature, then recurring interactions, when it comes to the performance phase – operation and monitoring and M&V. The pilots, in AmBIENCe project, were able to pass through key stages of the *precontracting phase* and some steps of the *contracting phase*. However, for the pilot contracts to be signed by the client and ESCO, and for implementation of the measures in a *performance phase*, further steps are required which were not possible during the timeframe of the project.

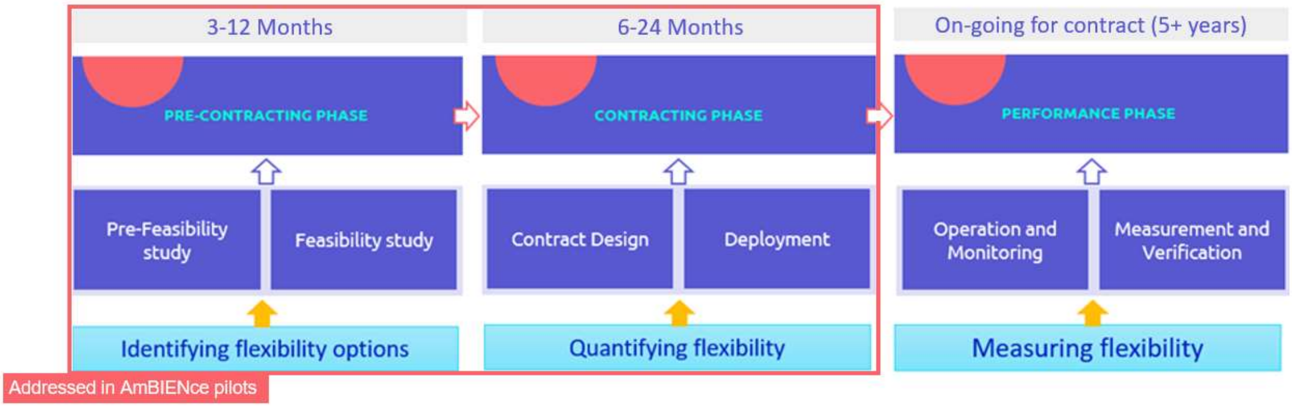

FIGURE 1: AEPC PROCESS AND TYPICAL TIMELINES

To design the performance guarantees required for an AEPC, the Active Building Energy Performance Modelling (ABEPeM) proof of concept platform was developed and tested with both pilot buildings. The suite of tools with different modules allowed the pilot owners and related stakeholders to quantify the impact of energy efficiency measures (EEM) and DR. A schematic of the modules included are shown in Figure 2, with detailed information in Deliverable 2.2 - Proof-of-Concept of an Active Building Energy Performance Modelling framework [1].

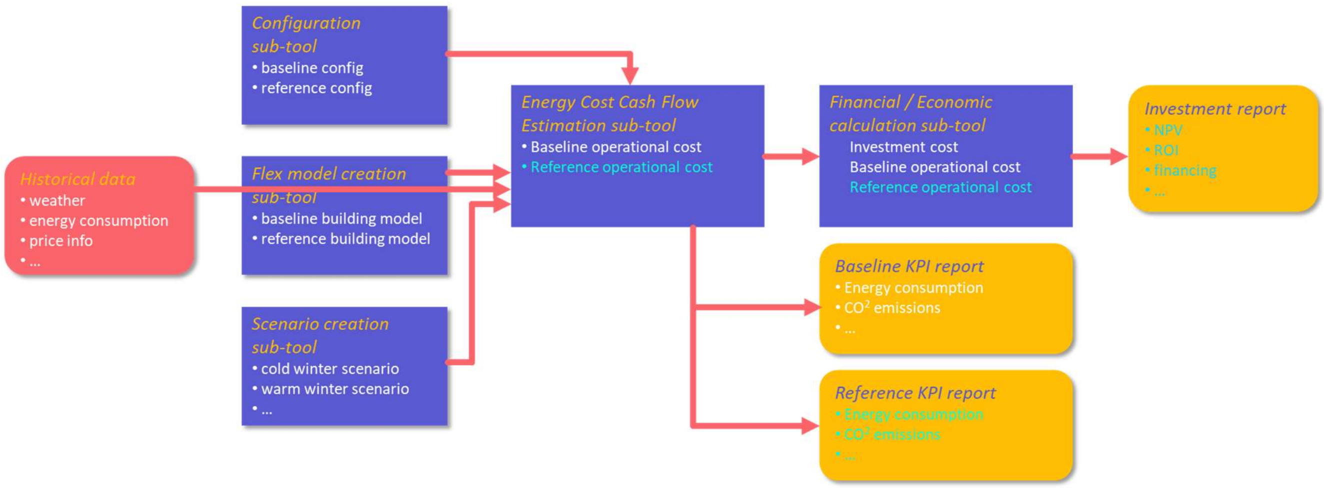

FIGURE 2: ABEPEM INTEGRATED MODULES

With collected data and information from the pilot buildings, the *flex model creation sub-tool* built dynamic thermal models of each pilot building, taking into account various inputs (such as outdoor environmental conditions, historic energy usage of uncontrollable and controllable loads, current operation schedules of assets, storage of heat/cold, comfort limits of the building) to develop a **baseline and reference building model** for before and after implemented EEM and flexibility measures.

This then feeds into the *energy cost cash flow estimation sub tool*, which calculates the **yearly baseline and reference operational cost** before and after measures.

Then, the *financial and economic calculation tool* calculated **overall operational cost savings for different scenarios**, taking into account investment costs and type of business model or financing, with resulting KPIs such as return on investment, Net present Value (NPV) etc for ESCOs to develop the most suitable AEPC contract.

The ABEPeM suite of tools highlights the benefit of the AEPC as a proof of concept, and for both pilot buildings, shows promising results for the value of DR alongside EEMs. The tools would need further refinement to be exploited commercially by ESCOs in the design and implementation of AEPC contracts in an operational phase, especially for large complex buildings such as the Portuguese pilot or for the aggregation of clients in the residential building sector such as the Belgian pilot.

3. EVALUATION OF PILOTS

This section highlights the results from the pilot buildings, including a short description of the pilot context, the results from the dynamic simulations which in turn generated the AEPC performance guarantees and the stakeholders' interests and motivation for the AEPC concept from the pilots' experience. The section is divided in two, for each pilot, where the first one (section 3.1) focusses on the commercial office building case AEPC in Portugal, and the following one (section 3.2) on the residential building case AEPC in Belgium.

3.1 PORTUGUESE PILOT

The AmBIENCe report Deliverable 3.4 – Preparation of an operational AEPC in pilots [5], provided a description of the context of the Portuguese pilot in detail, including the characteristics of the building and AEPC measures, the monitoring requirements and methods for the actuation of flexibility in the building to perform DR measures. Figure 3 shows the pilot building alongside some key characteristics, highlighting that the building already has a level of energy efficiency by design, and is fully electric, making it good candidate to optimise flexible electrical loads. Important to note is that the building's energy contract includes 4 tariff periods (Peak, Shoulder, Normal Off Peak and Super Off Peak [6]), with additional charges for the energy used during Peak periods, meaning its cost of operation can be optimised using implicit DR measures. As there are no market mechanisms in place in Portugal for the aggregation of flexibility, explicit DR could not be considered at this stage for pilot implementation.

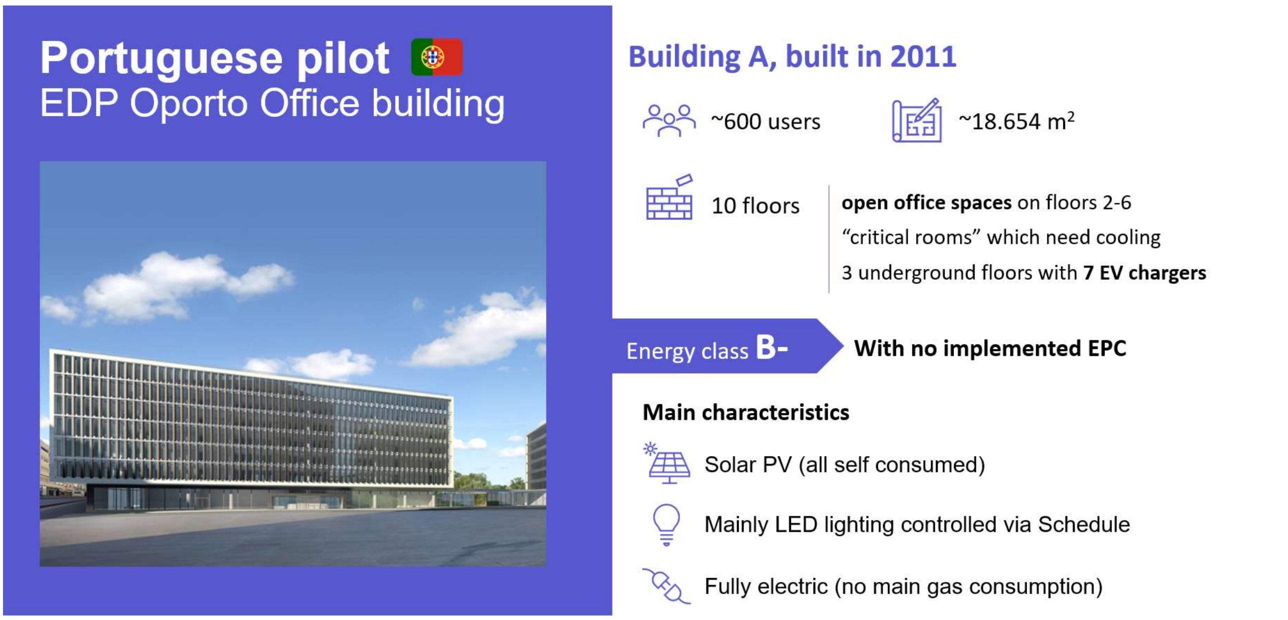

FIGURE 3: OVERVIEW OF PORTUGUESE PILOT BUILDING

3.1.1 AEPC MEASURES AND PERFORMANCE GUARANTEES

As described in Section 2, the ABEPeM suite of tools was used to simulate the current operational performance and cost of the building, and the energy and cost saving potential of the different AEPC measures proposed (fully described in Deliverable 3.2 and 3.4 [7] [5]). The simulated cases are described below and the resulting energy and cost savings are shown in Table 3.

Case #0 (Baseline): A simplified dynamic thermal model of the building was generated with data collected from the building and ABEPeM. It proved difficult to be able to make a realistic thermal model of the building with the data available and additional metering had to be installed during the pilot, as described in D3.4 [5]. This was used alongside simplified models for the loads and generation assets of the building, to simulate a reference year's operational energy use and cost. The results for the baseline simulation outcome in electricity consumption of 1,721 MWh per year, with the current photovoltaic panels (PV) system generation providing 69 MWh, of which already the majority (~99%) is self-consumed, resulting in electricity offtake of 1,652 MWh from the grid. For the baseline case, the simulation results in a yearly operating cost of 162,242 €, as shown in Figure 4.

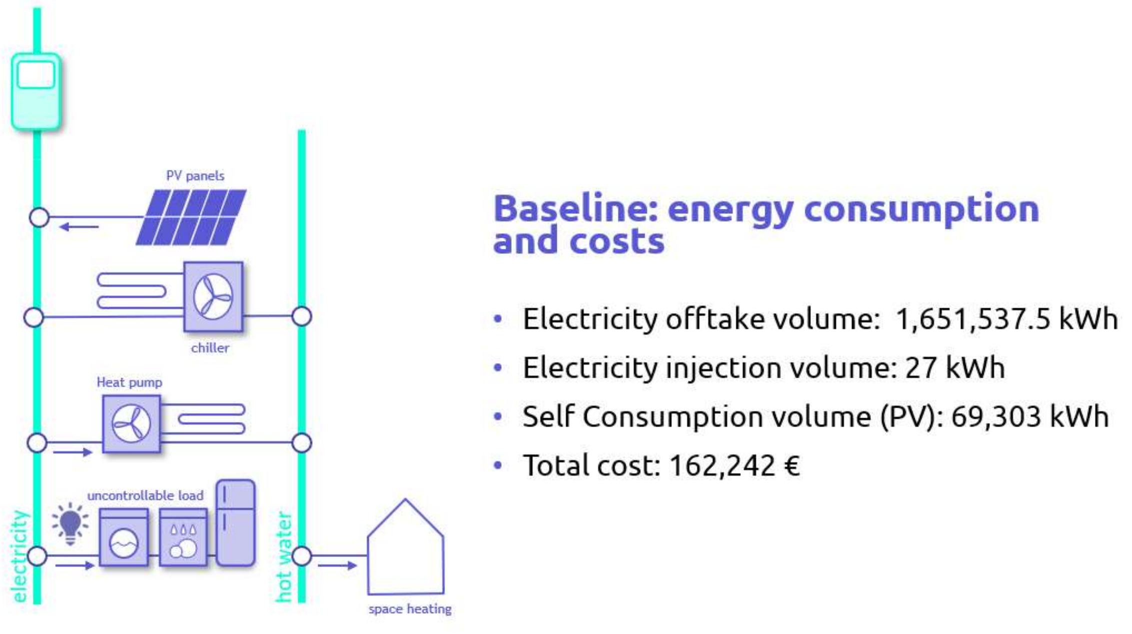

FIGURE 4: SIMPLIFIED BUILDING MODEL COMPONENTS AND ABEPEM BASELINE SIMULATION RESULTS

The ABEPeM suite of tools uses a variety of historical data and simulation methods to come up with the baseline electricity use scenarios, fully described in D3.2 [7]. When comparing the energy certificate (EC) simulation values for annual consumption, and average of values of real annual consumption from the past 4 years, we can see that the ABEPeM baseline is a feasible representation of consumption patterns in the building across the different tariff periods (see Table 1). All assumptions used to create the baseline should be stipulated on the AEPC contract, as the baseline model will need to be updated should there be any change in regard to routine or non-routine correction factors (e.g., weather conditions, electricity prices, or occupancy).

TABLE 1: ANNUAL BASELINE CONSUMPTION FROM ENERGY CERTIFICATE SIMULATION, REAL MEASURES, AND ABEPEM SIMULATION

Electricity Use (Baseline)	2017 (simulated from EC)	2017 - 2021 (real consumption)	ABEPeM simulation
Peak hours	na	~13% of total	12% of total
Shoulder hours	na	~45 % of total	46% of total
Normal Off-peak hours	na	~27% of total	26% of total
Super Off-Peak hours	na	~15% of total	16% of total
Total (MWh)	1,604	1,686 – 1,985	1,651

Case #1, PV increase: To make use of available roof space, the installation of a further 8 kWp solar PV system on the roof is foreseen as the first AEPC measure. Based on the area of PV planned to be installed (65m^2), efficiency and solar radiation, a production profile is generated in ABEPeM, resulting in a yearly production of 14.8 MWh of which the majority is still able to be self-consumed by the building loads.

Case #2, Switch to Light Emitting Diodes (LEDs): Of the 5,902 existing lamps, 2,101 are not yet replaced with LED technology. Implementing this measure results in an estimated annual electricity reduction of 71 MWh from energy certificate (EC) simulations.

Case #3, Variable speed drives installation: The installation of variable speed drives in the cold and hot water pumps and ventilation units with power >750 W would result in an estimated annual reduction of 67 MWh from the EC.

Case #4, Stand by Optimisation of Air Handling Units (AHU): With such high loads used for the ventilation in the building, it's an important asset to optimise. A two-hour reduction in the operation of the two main AHUs would result in energy savings of 75 MWh annually according to the EC.

Case #5, Smart heating & cooling: The measure of smart heating and cooling (DR) is modelled in ABEPeM, optimizing the heating and cooling throughout the year taking into account the dynamic thermal model of the building and energy prices. Figure 5 shows an example daily operation of the input power for heating considering no smart control (Case #0 – Baseline), and Figure 6 shows the heating operation optimised to be operated out with peak tariff periods when possible, maintaining the comfort level of the building.

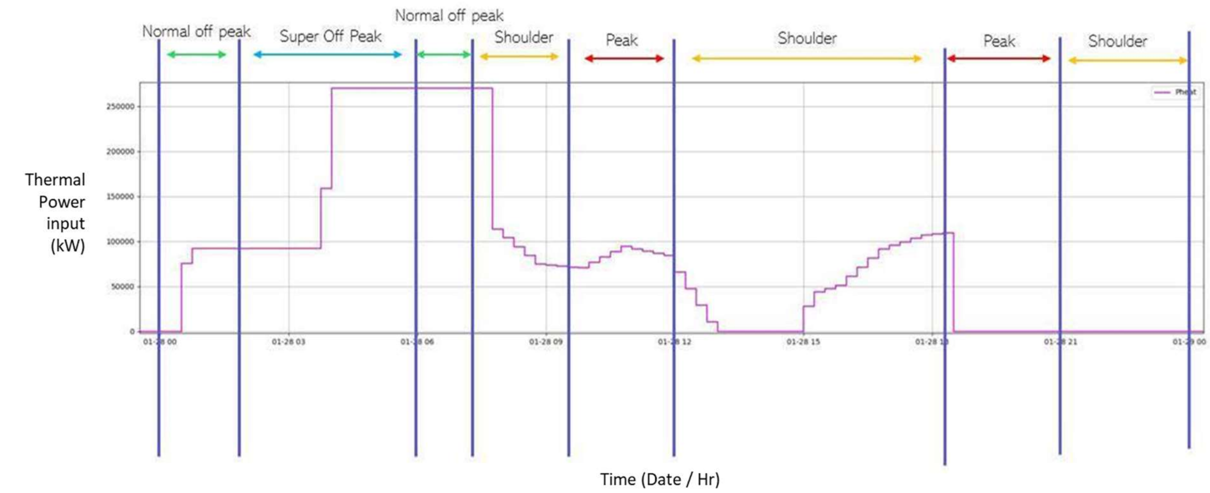

FIGURE 5: HEATING LOAD WITHOUT SMART CONTROL

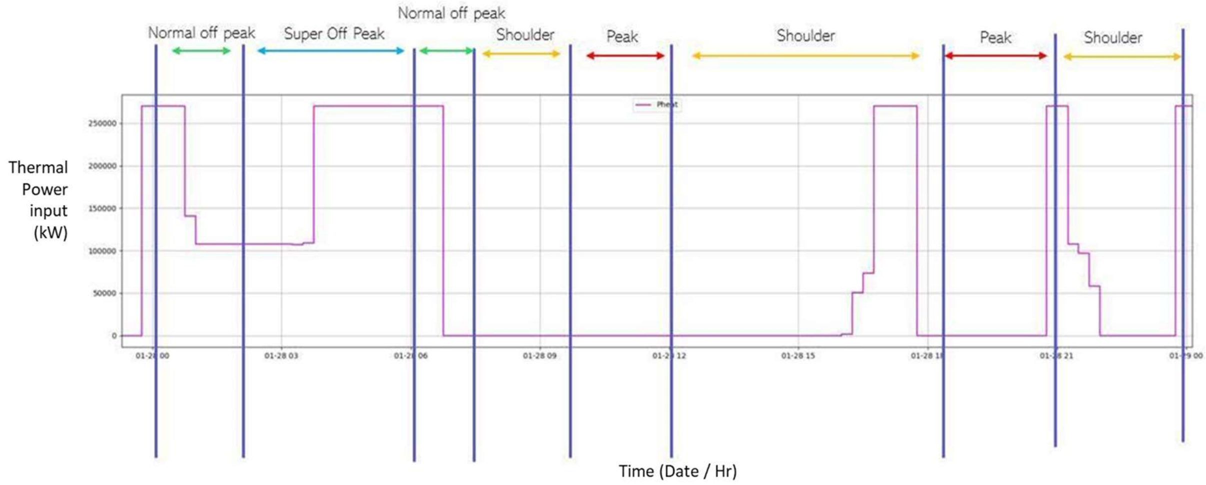

FIGURE 6: HEATING LOAD WITH SMART CONTROL

The reference case aggregates all the EEM and DR measures (Cases #1 - #5 highlighted above) to make the optimal (reference) case with the highest cost savings, and is used for the AEPC contract.

Table 2 shows the annual baseline case and reference case consumption from ABEPeM. Apart from an overall reduction in energy use (highlighted in Table 3), the consumption during peak hours is reduced by 1% due to the smart heating and cooling, representing significant cost savings in a building with such scale, as the Oporto pilot, and the associated tariffs and extra charges for using energy during peak hours.

TABLE 2: ANNUAL BASELINE AND REFERENCE CONSUMPTION IN DIFFERENT TARIFF PERIODS FROM ABEPEM SIMULATION

Electricity Use calculated with ABEPeM	Baseline (from ABEPeM)	Reference (from ABEPeM)
Peak hours MWh	203.1 (12%)	159.1 (11%)
Shoulder hours MWh	765.5 (46%)	648.6 (46%)
Normal Off-peak hours MWh	425.7 (26%)	376.4 (27%)
Super Off Peak hours MWh	257.3 (16%)	226.1 (16%)
Total (MWh)	1,651	1,410
Total cost (€)	162,242	139,974.2

TABLE 3: ANNUAL COST AND ENERGY SAVING FOR EACH EEM + DR MEASURE

Measure	Yearly € saving	Yearly MWh saving
1: PV addition	1,515	15
2: Switch to LEDs	6,070	71
3: Variable Speed drives	5,791	68
4: Reduced AHU operation	6,365	75
5: Smart Heating & Cooling	2,528	13
All measures	22,268	241

As can be seen from Table 3, significant costs and energy savings can be achieved with classic EEM such as replacing lights with LEDs and installation of variable speed drives; however, these usually have a higher upfront investment cost (defined in Deliverable D3.2 – Performance contract for the Portuguese Pilot [7]), which means a longer payback period and a potential length of AEPC. In comparison, the smart operation of equipment (e.g., reduction of air handling units and smart heating/cooling) has little investment cost to implement, but still results in notable savings. The reduction in energy use due to decreased use of air handling units (a conservative reduction of 2hrs was used) is the largest energy saving, highlighting the potential for ventilation systems to be optimised in large buildings.

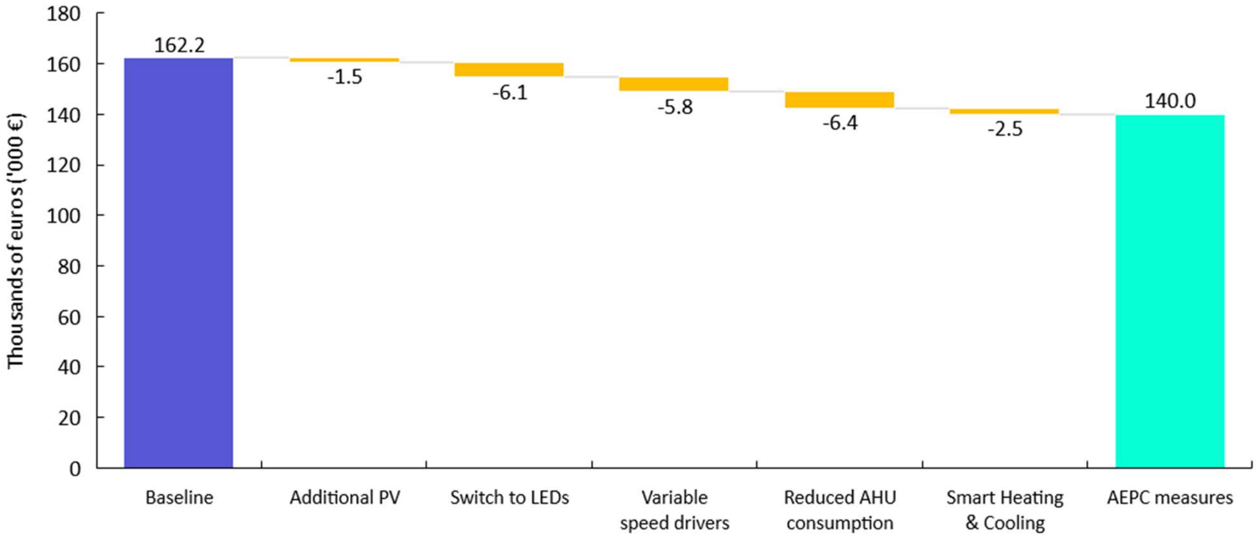

FIGURE 7: AEPC MEASURES ANNUAL COST REDUCTION

From the simulation results, insights with the local stakeholders and further analysis with other ABEPeM tools, the AEPC contract was developed, with detailed sections on contract conditions [7]. Cost guarantees are defined, where savings in an AEPC are in monetary terms instead of energy, as the optimisation aims to shift energy use rather than always reduce it. Using the ABEPeM results, yearly cost savings with all measures combined result in an annual cost saving of **~14%** (see Figure 7). For the cost guarantees, a range of +/- 1 – 2% of the estimated yearly savings is foreseen. If savings are out with this interval, a reward-penalty mechanism applies. The contract term is for 10 years, coinciding with the payback period of all the measures.

3.1.2 INTEREST AND MOTIVATION FOR AEPC

The local stakeholders and decision-making processes are described in Deliverable 3.4 – Preparation of an operational AEPC in pilots [5], where the implementation phases of AEPC measures are described, and the main contractual responsibilities established. The challenges to reach an operational phase of an AEPC in the Portuguese pilot case in the timeframe of the project is documented, highlighting that the Portuguese ESCO in normal EPC procedures take up to 12 months to get to contract signature for tailor made proposal (required for buildings of the scale of the building in Oporto). The key stakeholders involved in the AEPC process include the ESCO, Building owner, Building manager, Tenants and Maintenance company, where the Building Manager (part of the Asset Management Company) is considered the beneficiary of the AEPC, considering it is the entity responsible for approving implementation of any EEM and DR measures, paying energy bills, paying maintenance and investing on building infrastructure investments.

With the results of ABEPeM suite of tools simulations, the project meets the conditions to be considered for implementation by the Asset Management Company (the client), After showcasing the potential of the implicit flexibility through active control of the HVAC system, a set of cost saving measures can be proposed. As can be seen by Figure 8, which shows schematics of the internal decision-making process of the local stakeholders, internal bureaucratic processes can take some time when approving initiatives, so the clarity of results and benefits to each party is essential to streamline decision making processes.

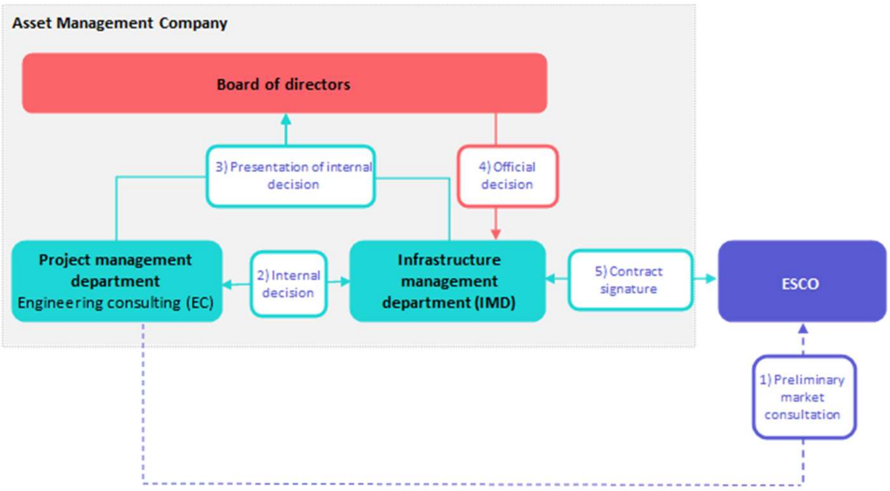

FIGURE 8: SCHEMATIC OF PROCESS TO APPROVE AND IMPLEMENT AEPC MEASURES

From interviews and interactions conducted which presented the AmBIENCe concept, the Portuguese ESCO (EDP Comercial) showed interest in the pilot results, highlighting that the flexibility potential (with cost saving significance and smaller upfront investment costs), is a prospective addition to their portfolio of solutions in the business to business sector. For service buildings such as the office used for the pilot, the complex stakeholder engagement process is a limiting factor for the development of many AEPCs, where the operator taking care of facility management (a sector where EDP Comercial is not directly involved) has better knowledge of the client premises and may be better placed to develop the performance guarantees. Due to the high transactional cost in developing the measures pre contract (communication with client, feasibility studies, measures definition etc.), the ESCO will usually aim at higher value contracts (<2M€) to balance the cost benefit ratio. Nonetheless, to facilitate and make more agile the process for the ESCO, an AEPC contract template applicable to the Portuguese pilot has been developed as part of WP3 (Deliverable D3.2 – Performance contract for the Portuguese Pilot [7]), which has been validated and provided to EDP Comercial for future use in this sector.

3.1.3 LESSONS LEARNED

The key lessons learned from the Portuguese pilot can be divided into three categories, as described below. More specific and technical lessons learned about improvements to the AEPC methodology and tools can be found in Annex 1.

1) Client and Stakeholder engagement activities:
   i. Responsibilities between stakeholders (e.g., ESCO, building managers and maintenance teams) need to be clearly stipulated in any AEPC contract;
   ii. Decision making processes can be streamlined, if potential value and benefits to all stakeholders is clear from offset.

2) Simplifying complex design options into clear benefits:
   i. Developing a thermal model of a large office complex such as the Portuguese pilot is difficult, with deep technical understanding required on the ESCO side, especially to define baselines and performance guarantees. All assumptions must be clearly stated and sufficient sensitivity analysis performed to mitigate risks;
   ii. Simultaneously, the results must be clearly understandable by all involved stakeholders

3) There is potential for significant cost savings from optimising flexible building assets:
   i. With little investment cost, an extra ~6% of annual cost savings can be achieved in the Portuguese pilot building with control of assets and activating implicit DR: stand-by optimization of the AHU and smart operation of the heating and cooling.

3.2 BELGIAN PILOT

In Deliverable 3.4 – Preparation of an operational AEPC in pilots [5], the Belgian AEPC pilot was described in more detail. This covered not only the current situation in terms of building envelopes and technical systems but also the measures that were foreseen in the pilot. Also, the monitoring requirements and how to actuate flexibility were covered. Figure 9 provides a snapshot of the pilot building's front façade, as well as some characteristics. Although some energy saving measures were taken, like the installation of a condensing gas boiler, some flat roof insulation and a small amount of double glazing to replace simple glazing, there is still a large potential, in particular in the building envelope. This is the first key EEM in the pilot. Other measures in the pilot include an electrical Heat Pump, PV panels and Electrical vehicle (EV) charging as the owner plans to get a new electrical company car end of 2022. The building's energy contract includes 2 tariff periods (Peak and Off Peak), meaning its cost of operation can be optimised using implicit DR measures. Explicit DR was not looked at, at this stage.

FIGURE 9: OVERVIEW OF BELGIAN PILOT BUILDING

3.2.1 AEPC MEASURES AND PERFORMANCE GUARANTEES

The following measures were included in the Belgian pilot as can be seen in Figure 10:

- Thermal insulation of roofs and walls and replacement of windows;
- An electrical heat pump (air/water);
- PV solar panels;

- EV charging;
- Smart Charging and Smart Heating (DR using flexibility).

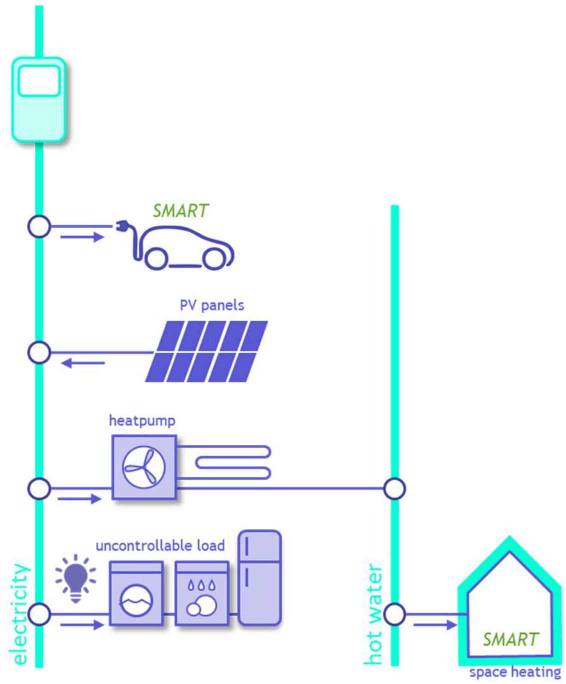

FIGURE 10: OVERVIEW OF BELGIAN PILOT BUILDING

The investments are shown in Table 4.

TABLE 4: INVESTMENT COSTS BELGIAN PILOT

Investments overview (excl. VAT)	
Investment measures	**Investment (€)**
Building insulation	84,884.30
PV system	20,668.71
Heat Pump	10,763.00
EV charging	2,000.00
Total	**118,316.01**

Table 5 provides an overview of the savings and pay back times (PBT) for each measure, except the active control for which it is difficult to estimate the investment at this stage. EV charging increases energy consumption and thus does not have a PBT.

TABLE 5: INVESTMENT COSTS AND PAY BACK TIMES FOR BELGIAN PILOT MEASURES

Investments overview

(excl. VAT)					
Investment measures	**Investment cost, incl. VAT (€)**	**Electricity savings (kWh/yr)**	**Gas Savings (kWh/yr)**	**Simple PBT (years)**	**PBT, incl. Indexation (years)**
Floor insulation	2,460.79		643	47	34
Wall insulation	26,542.82		4,313	110	61
Roof insulation	39,286.14		5,104	115	62
Windows insulation	21,687.60		1,683	230	90
PV system	21,908.83	6,725		14	13
Heat Pump	10,763.00	-4 667 (consumption)			
EV Charging	2,000.00	-5,048 (consumption)			
Smart heating		455			
Smart charging		1 ,454			

The heat pump allows to cut the remaining gas consumption, but replaces it by an increase in electricity consumption. The EV charging does not represent a saving in kWh, but an extra consumption. However as this additional consumption is sold to the employer, it represents a financial income for the home owner (employee). As there can be some margin between the cost (either from electricity produced from the PV panels or from electricity bought from the grid) and this income, it can represent a financial saving.

8 different cases (including the baseline) were created to understand the effect of each EEM and DR measure.

<u>Case #1 (Baseline or reference case):</u> The results for the baseline simulation outcome in electricity consumption of 8,183 kWh per year, all taken from the grid. The annual gas consumption is 36,057 kWh/year. For the baseline case, the simulation results in a yearly operating cost of 3,706€.

The AEPC measures as described in Section 3.2.1 are input to the simulations on ABEPeM, to give new reference cases for operational energy and cost savings, to be applied in an AEPC contract. The measures are input in the ABEPeM optimisation, as described below, and the results from the simulations are shown in Table 6, where Cases 2 – 8 show the results of the simulations by cumulatively adding the measures as they are foreseen.

<u>Case #2, renovated building:</u> This includes all the building envelope insulation measures (roofs, floors, doors & windows), resulting in a reduced yearly consumption of 15,053.93 kWh/year and a reduction of the energy cost tot 2,550 €/year.

<u>Case #3, introduction of heat pump</u>: Replacing the current condensing gas boiler by an electrical heat pump allows to exit gas consumption, leaving 12,850.75 kWh/year electrical consumption. This also strengthens the case for PV panels. It generates a significant CO_2 emission reduction, but the cost increases slightly to 2,678.9 €/year, when compared to case #2.

<u>Case #4, introduction of PV panels:</u> This includes the installation of solar PV panels on to the roofs and one outside wall, allowing for local renewable electricity production to feed the heat pump or other electrical equipment. The cheaper local PV production allows to further reduce the annual energy cost to 1,897 €, which represents a reduction of 48.8%, when compared to case #3

<u>Case #5, introduction of EV charging:</u> This case refers to the add-on of a home charging point. As the homeowner is planning for an EV, the charging costs (assumed at 0.30 €/kWh) related to the electricity produced by the PV panels or taken from the grid, would be invoiced to the employer and thus reduce the costs. In practice, the EV charging price would be part of the negotiation between employee and employer, but as public charging tariffs are significantly higher (0.36 to 0.70 €/kWh), this should not be a problem. Basically, this would probably be settled at the level of the EV business case and global lease and consumption budget. The EV Charging charge back to the employee is 1,552.75 €/year. The rest of the electricity for the car charging comes from the grid (Electricity Off-take increase), i.e., 5,114 kWh. The effective cost (compared to Case #4) for the homeowner/employee is only reduced by 340 €/year, the rest of the cost increase is paid by the employer, but at a rate that is comparable or even competitive with public charging tariffs. This thus represents a win-win for employer and employer. Other parameters of the EV like tax implications are out of the scope of the business.

<u>Case #6, Smart heating:</u> From this case onwards, the active control managing and exploiting flexibility are introduced. In this case, smart heating control only is added, as compared to Case #5. The measure of smart heating and cooling (DR) is modelled in ABEPeM, optimizing the heating throughout the year taking into account the dynamic thermal model of the building and energy prices. This smart heating control of the heat pump, in conjunction with the PV panels, allows for another effective cost reduction of 102 €, which is relatively modest.

<u>Case #7, Smart charging:</u> This case introduces smart EV charging control, in conjunction with the PV panels and heat pump (without smart control) and needs also to be compared to Case #5, where there is no smart control. The potential of smart charging control is higher as it allows to gain another 376 € compared to Case #5, which is more than 3.5 times the amount gained by smart heating control.

<u>Case #8, Smart heating and charging</u>: Finally, this case includes the full implementation of the AEPC measures, i.e., smart heating and smart charging, on top of the building insulation, heat pump, PV panels and EV charging. The gain in effective cost (I.e. as bared buy the employee, after the charge back of the electricity cost for the EV charging by the employer) reached in Case #8 (full smart control) as compared to Case #5 (no smart control) is 457 €/year or 29%. The gain reached in Case

#8 as compared to the reference Case #5 is however only 14.5% in total cost. The gain in effective cost for the homeowner, thanks to the EEM, the EV charging and the smart control in Case #8, compared to the reference Case #1 is 2,605 €/year or 70.3%.

The following table provides an overview of the different scenarios (cases) and the corresponding energy and cost savings against the reference scenario (case #1). Cases #5 corresponds to the situation after the implementation of the EEM. Case #6 and #7 correspond to addition of smart heating and smart EV charging control. Case #8 of both together.

TABLE 6: RESULTS OF THE DYNAMIC SIMULATION: CONSUMPTION COSTS FOR THE VARIOUS SIMULATION CASES

Simulation Configuration	Total Cost	EV Charging Charge Back	Effective Cost	Uncontrollable Load + EV Charging + Heat Pump (kWh)	Electricity Offtake (kWh)	PV Production (kWh)	Electricity Injection (kWh)	Gas (kWh)
Case #1 reference case	3705.6 €	0 €	3705.6 €	8183.54	8183.54	0	0	36056.70
Case #2 renovated building	2550.4 €	0 €	2550.4 €	8183.54	8183.54	0	0	15053.93
Case #3 introduction of heat pump	2678.9 €	0 €	2678.9 €	12850.75	12850.75	0	0	0
Case #4 introduction of PV panels	1897.04 €	0 €	1897.04 €	12850.75	10276.79	6729.57	4155.60	0
Case #5 introduction of EV charging	3108.77 €	1551.76 €	1557.01 €	18040.77	15390.68	6729.57	4079.47	0
Case #6 smart heating	3011.99 €	1557.21 €	1454.78 €	18109.45	15147.76	6729.57	3767.88	0
Case #7 smart charging	2727.77 €	1546.96 €	1180.80 €	18007.29	14368.87	6729.57	3091.142	0
Case #8 smart heating and charging	2647.47 € ~14.5% (case #5) ↓	1546.96 €	1100.51 € ~29% (case #5) ↓	18071.50	14244.46	6729.57	2902.53	0

3.2.2 INTEREST AND MOTIVATION FOR AEPC

The stakeholders involved and the way the decision-making processes work are described in Deliverable 3.4 – Preparation of an operational AEPC in pilots [5]. It includes the steps to get an AEPC signed and who signs which agreements (AEPC, financing). The process of reaching the operational phase is quite cumbersome, although some barriers are related to implementing energy efficiency measures in general and not to using the AEPC model specifically. As a matter of fact, AEPC is supposed to lift some of the barriers of the classical approach to energy efficiency, as the performance risk or financing needs. Getting an AEPC in place can take as much as 12 to 18 months in the current context, as Energinvest's experience in Belgium in the public sector shows. They facilitated no classic EPC project that was implemented under 14 months. All others took at least 16 to 18 months. The first EPC project, which of course was real pioneering work in Belgium and involved a lot of original development took as much as 48 months in a difficult multi-stakeholder context. It is expected that a residential project, in what is considered a relatively new sector, would take at least that amount of time. The main stakeholders are the Building owner, the ESCO and the Bank/financier. Other important stakeholders are the Architect, advising the home owner, and the Authorities that need to handle and validate the building permit. Secondary stakeholders are the energy scanner and auditor, whose role is limited to providing initial information on the savings potential. The Building owner is the investor and thus the overall decision maker, although key technological choices are made by the ESCO, who is also managing the smart control to exploit the flexibility potential.

Figure 11 illustrates this commercial, administrative and decision-making process of the main and and other important stakeholders. The secondary ones are not shown as they add little value to the process.

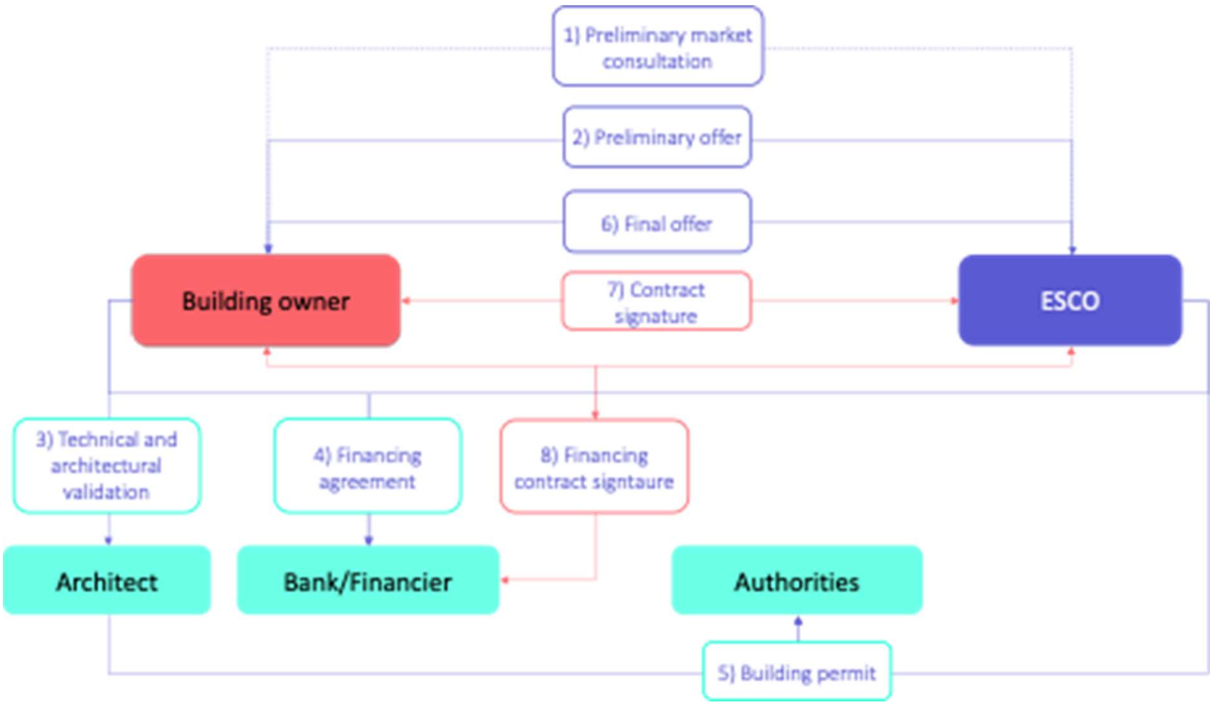

FIGURE 11: SCHEMATIC PRESENTATION OF THE PROCESS TO APPROVE AND IMPLEMENT AN AEPC IN THE BELGIAN PILOT

Although no extensive market study or survey was undertaken in the framework of the Belgian pilot, some ESCOs who were asked to review the AEPC contract template, showed interest in the results and further work. Several agreed to participate in the WP5 survey on replication efforts, described in Deliverable D5.1 Replication plan, section 4.2 [8].
Within the framework of a tender from the Federal Government to set-up a dedicated entity and financing vehicle to renovate federal public buildings, the concept of AEPC also received positive feedback in terms of both the concept and the additional savings potential. Although the residential Belgian pilot building does not correspond to the topology of public buildings, some conclusions are still of interest. Also, the learnings from the Portuguese pilot could be useful as that commercial

building topology is closer to that of public buildings. On the other hand, the more deep energy renovation scenario was not studied.
The main barriers for ESCOs to enter the residential building renovation market are the diversity of buildings and existing technologies, the small size of projects and the high relative transaction costs, the risks related to behavior and the risk related to changing occupation. Uncertain or changing subsidy schemes and uncertain building permit procedures are also key barriers.
Within BELESCO, the Belgian ESCO Association, a SWOT analysis of the case for residential EPC and AEPC is being envisaged. Also, in Flanders, following a recent study "Pre-financing mechanisms for climate renovations accessible to all Flemish homeowners" from Climact & Energinvest for BBLV (Bond Beter Leefmilieu Vlaanderen) , the topic may gain some interest in Flanders [9]. This could be strengthened by a SEIF[1] (Sustainable Energy Investment Forums) national and regional round table planned in the second half of 2022.
In the end, ESCOs will determine if and under which conditions they will try to enter the residential market and how. It is likely that they will either prefer to start with multi-apartment buildings in co-ownership as there is a single entity to engage with, i.e., the association of co-owners, or seek aggregation through collective home renovations at neighborhood or street level, organized and managed by some local aggregator, e.g., a neighborhood council, municipality or local cooperative.

3.2.3 LESSONS LEARNED

There are several lessons that can be learned from the Belgium pilot. As for the Portuguese pilot we can divide them into three categories, as seen below.

1) <u>Client and Stakeholder engagement activities:</u>
    i. Residential home owners are difficult to engage with, without local **facilitators or one-stop-shop** support.
    ii. There is currently no ESCO-market for the residential sector. Local models like cooperative ESCOs could provide an alternative or they could combine their cooperative offer with those of larger market players.
    iii. Growing interest from stakeholders as shown in the previous paragraph.
2) <u>Simplifying complex design options into clear benefits:</u>
    i. Need to improve current process involving the folloing steps: 1) energy scan 2) energy audit 3) static simulation 4) dynamic simulation.
    ii. "Theoretical" consumptions used in energy audits don't facilitate investment decisions.
    iii. The current subsidies scheme in Wallonia is not well adapted to a progressive deep renovation logic, as all the steps have to be predefined and followed as indicated in the audit. As the audit, that creates the conditions to obtain the

[1] https://energy.ec.europa.eu/topics/energy-efficiency/financing/capacity-building-and-technical-assistance/sustainable-energy-investment-forums_en

subsidies, does not contain the final EEMs, it has to be updated after the dynamic simulation. Later on there is little or no flexibility. In addition subsidies are uncertain as they have a closed enveloppe (first come first serve) which is a major hurdle given the business case that is not good. Subsidies can improve it, but uncertainty on obtaining them will complicate decision making by the home owner.

iv. Numerous practical, aesthetical and architectural constraints exist on such older buildings with an architectural value.

3) <u>There is potential for significant cost savings from optimising flexible building assets:</u>

i. With little investment cost, an extra **~14,5% of annual cost savings** can be achieved in the Belgian pilot building with active control: smart heating control and smart EV charging control.

ii. The potential of smart EV charging, in the case of a leased employee company car is 3 times that of smart heating control.

Other lessons learned are documented in the Annex.

4. LESSONS LEARNED

4.1 REGULATORY INFLUENCES

The regulatory context in each pilot building country potentially influenced the interest of local stakeholders as the experience of the actors involved in an (A)EPC process varies, and the national policies stimulate the market at different rates. Table 7 summarises the study of AmBIENCe Deliverable 1.1 [8] for the specific pilot countries, complemented by additional lessons learned throughout the AmBIENCe pilots and related national workshops.

TABLE 7: PILOT COUNTRY HIGHLIGHTS FROM AMBIENCE D1.1 - ANALYSIS OF DIRECTIVES, POLICIES, MEASURES AND REGULATION RELEVANT FOR THE ACTIVE BUILDING EPC CONCEPT AND BUSINESS MODELS [9]

	Belgium	Portugal
Status of EPC implementation	• The energy service market is **stable and moderately sized**, although young; • The real market development started in **2006;** • The EPC **market size** is estimated at **50 million euro;** • The growth of turnover of EPC contracts can be estimated from a **few million in 2014 to roughly 50 million euro in 2018;**	• The ESCO sector is still **underdeveloped** and **small;** • The ESCO market started to gain traction in **2010;** • The ESCO **market size** is estimated to be close to euro **75 million in 2018** with an **annual growth rate** of about **20%** starting from 2014; • The **EPC market turnover** was about **30 million euros in 2018** • EPCs are mostly used in the public sector;

	• EPCs are implemented in **many building sectors**, and the **public one** is the most developed.	• The number of companies registered as EPC facilitators or EPC providers is no more than 10; • Companies tend to target larger clients for energy efficiency measures, where the transaction costs in developing the contract are met with quicker returns. •
Status of DR implementation	• The status of DR services offered by buildings is well-developed / commercially active; • A framework to enable participation of new energy sources, such as demand flexibility, with new types of market players, such as aggregators, is presented.	• The status of DR services offered by buildings is in preliminary development; • Different tariff structures allow for Implicit demand response but it is not widely implemented.
Status of other factors enabling the active EPC	• Independent **aggregation of Distributed Energy Resources (DER)** is facilitated; • With reference to the exploitation of **demand-side flexibility on building level,** in theory, the framework to engage individuals more actively is present; • The integration of **Energy and Non-Energy services** is only regulated through Energy Performance for Buildings (EPB) regulations	• **DER flexibility** is not exploited for participation to the market in the aggregated form; • Regarding the exploitation of **demand-side flexibility on building level**, some pilot projects exist which have started to aggregate energy at demand side; • With reference to the integration of **Energy and Non-Energy services**, the relevant regulatory framework is totally absent.
Barriers for EPC/ESCO	• Complexity of the political system; • Fundamental and culturally driven conservatism; • Subsidy conditions not well adopted to EPC.	• Administrative barriers; • Lack of knowledge and trust; • Lack of standard and enforced M&V protocols and lack of a neutral third-party institution that certifies the accountability of a particular ESCO • Duration of contracts; • Financial barriers; • Absence of a regulatory framework related to the integration of Energy and Non-Energy services.
Drivers for EPC/ESCO	• Existence of a national ESCO association (BELESCO);	• New legislation relating to energy

	• Creation of several so-called public One-stop-shops or facilitators; • Growing of the know-how about and availability of Eurostat-compatible ESCO financing solutions; • EPCs include Non-Energy Services; • Strong legislative background and standards established for energy efficiency in buildings.	communities being able to trade excess energy/flexibility through an aggregator.
Barriers for DR services offered by (cluster of) buildings	• Integration of Energy Services and Non-Energy Services is limited to EPB.	• Legal barriers; • Market barriers; • Technical barriers; • Social barriers; • Absence of a regulatory framework related to the integration of Energy and Non-Energy services.
Drivers for DR services offered by (cluster of) buildings	• Ongoing revision of the regulatory framework according to the concept of "technology-neutrality"; • Well-established (or under revision) regulatory framework for accepting independent aggregators; • Ongoing revision of minimum performance requirements; • Standardized and clear M&V procedures for all market players.	• Energy Performance of Buildings Directive, especially the Smart Readiness Indicator initiatives; • New legislation relating to energy communities being able to trade excess energy/flexibility through an aggregator.

4.2 OVERALL LESSONS LEARNED

By following the AmBIENCe and AEPC methodology in the two pilot cases, lessons learned and best practices for future developments of the concept are developed. Summarising the shared lessons learned for both pilot buildings, these mainly relate to early interventions in understanding building context and feasibility for AEPC, technical improvements for building the simulation models that provide the key results to generate the performance guarantees in the AEPC contract, and stakeholder engagement activities. Similar to the individual pilots lessons learned mentioned in 3.1.3 and 3.2.3, they can be divided into three main categories:

1) <u>Client and Stakeholder engagement activities:</u>
   i. Before the pre-contracting phase and throughout the AEPC process,

client/stakeholder buy-in is key. Trust between the client and the ESCO should be established, to ensure swift communication for steps in the process and the transfer of data and information

ii. Responsibilities between the ESCO, client, building manager and maintenance teams need to be clearly stipulated in the AEPC contract

iii. Decision making processes can be streamlined if the potential value and benefits to all stakeholders of an AEPC is clear from the offset.

2) Simplifying complex design options into clear benefits:

   i. Developing a thermal model of a building is complex, with deep technical understanding of concepts required on the ESCO side. This is essential as they will be defining baselines and performance guarantees, and must understand all assumptions used and associated risks to their contractual guarantees. Calculations must therefore be transparent and trustable, will be all assumptions clearly recorded in an AEPC contract.

   ii. Simultaneously, the results and potential value of the proposed measures must be communicated in simplified terms, and be straightforward enough for the client and associated stakeholders to understand, to streamline the contract development and signing process.

3) There is potential for significant cost savings from optimising flexible building assets:

   i. Implicit demand response using flexibility from smart heating and cooling and stand by optimisation of the ventilation system requires little investment cost in terms of hardware in the pilot building, but can account for significant annual cost savings.

   ii. Compared to traditional EPCs with classic energy efficiency measures which require higher upfront investment costs, AEPCs can be more competitive, reaching new markets and decreasing payback period.

5. CONCLUSIONS

The AEPC methodology consists of three main phases, namely, the (i) pre-contracting phase, (ii) contracting phase, and (iii) performance phase. Having identified the potential of the pilot project, collected extensive data, defined the main objectives and a first evaluation of their potential in the previous Deliverable 3.1 – "Pilot building specific models and performance calculation components" [10], and developed the quantitative performance guarantees and template AEPC contracts in Deliverable 3.2 – "Performance contract for the Portuguese Pilot" [7] and Deliverable 3.3 – "Performance contract for the Belgian pilot" [11], as well as describe the requirements to prepare the pilots to be operational in Deliverable 3.4 – "Preparational of an operational AEPC in pilots" [5], this deliverable highlighted the key results from all phases and the lessons learned for both pilots.

Through the demonstration in the two pilots, in Belgium and Portugal, the AmBIENCe concept and methodology has been tested and developed further by the challenges that arise in trying to implement innovative concepts in real world scenarios. The importance of client and stakeholder engagement activities, data collection, simplifying complex design options into clear benefits will be important in the development of AEPCs. The pilot results show there is potential for significant cost savings from optimising flexible assets in different building types, which highlights opportunities for the AEPC business models for ESCOs and other stakeholders.

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ANNEX 1

Portuguese Pilot other lessons learned:

Data collection pre-contract:

- Important to note that for the pilot, extra equipment was installed pre-contract / pre agreement. How would we get this installation in real case? It could be owned by ESCO and put there temporarily but still incurs a cost.
- Improvement: easier way to estimate flexibility in pre-contract phase based on readily available data, such as the D4.1 database. Then in the contracting/operational phase, a more accurate thermal model and use of ABEPeM could be employed. Then in the contracting/operational phase, a more accurate thermal model and use of ABEPeM could be employed.
- Improvement: all data (e.g. temperature, radiation) integrated into same platform as energy consumption data collection.
- Have detailed building plans, have 3D model of building at the beginning of process to understand systems.

Building Model:

- Type of thermal model too simple for a large office building. Although the results showed general trends similar to the building, a multizone model would need to be created for higher accuracy and certainty in performance guarantees.
- Building floor plans, 3D model of building, walls, windows etc. would help accuracy

Boundary conditions for baseline:

- Thermal comfort limits were simplified. In practice they may be not uniform across all rooms in building and across weekday/weekend.

Modelling:

- Use a dynamic Coefficient of Performance (COP) to model the performance of the chillers and the heat pump. Enhance accuracy with Seasonal Coefficient of Performance (SCOP) or Seasonal Energy Efficiency Ratio (SEER)
- Model every component in the building (each chiller and heat pump separately), water tanks etc.
- Ventilation and pumping shown to be very high loads will great potential for optimisation, include these in modelled components.
- Information on accurate schedules (e.g. lighting schedules, set points) important for AEPC because we are building the contract based cost reduction also due to time of use, more than

just an overall decrease in consumption, it matters for there to be decrease in consumption in the right periods for cost guarantees
- Different possibilities of the type of optimization would be useful for the ESCO to fully understand risks.

Scenarios:
- Bringing some randomized error in the optimisations to see the impact of non-deterministic control (what would be the case in operational phase)
- Important to simulate many different measures with different levels of sensitivity on certain parameters, for CLIENT and ESCO to agree on best option in each case
- Finding the balance in simplifying extremely complex building information in models that can be used quickly by ESCOs and clients to understand potential of DR.

Active control
- The missing link is to translate the input power for heating and cooling into set points for equipment, which is a complex and bespoke task depending on the equipment in the building, especially for large equipment which sometimes have various set points (e.g. temperature of water, output temperature, target air temperature) and from this regulate their own power output. Potential solutions for the actuation of flexibility is described in D3.4 [5].

Stakeholders:
- Service buildings like offices often have a complex mix of stakeholders (i.e. facility management is not the same as owner, or the tenant is not the person who pays the bills) so other types of buildings may be more appropriate – logistics, industry, hospitals, public buildings etc.

For an operational pilot:
- Need to Validate ABEPeM results in a real environment and the concept itself.
- Recommendation: Select a pilot site that is representative of a target clients segment, particularly those that could potentially be early adopters, yet simple;
- Map ABEPeM data requirements a priori (and not along the way) as a preparatory pilot activity to easily spot if additional monitoring equipment is necessary and where this must be installed. Although Building A had measurements for the HVAC system as a whole, it was necessary to install extra monitoring equipment to separate cooling and heating loads for proper modelling and flexibility estimation in ABEPeM tool. EDP had some of this equipment in stock but other needed to be ordered. There were significant delays in shipping which affected the data collection of the historical/baseline data. If this mapping was carried out in an early stage of the project, the impact of such uncontrollable variables could be mitigated;
- Build an interdisciplinary team to prepare and deploy the pilot as a broad range of capabilities shall be involved in developing an AEPC;
- Define a realistic plan (following a widely-use framework) and timeline for pilot implementation

Belgian Pilot other lessons learned:

- The business case for a deep renovation (even with electrification) is still a large barrier for this type of building
  - The key numbers are: INVESTMENT = 140 k€ (probably underestimated)/ NPV = -90 k€ / PBT = 54 years / Subsidies (< 30k€) uncertain
  - The insulation challenge is the main one, with a simple PBT of over 65 years
  - The practical, architectural, regulatory and esthetical issues are not solved and can represent a major barrier to insulation measures.
- Without aggregation on the demand side, ESCOs will not be interested as projects are too small to handle individually, both commercially and technically.
- The potential from flexibility/active control is interesting, but seems to be more of a nice to have, on top of this renovation challenge. This is particularly the case for smart heating in specific pilot conditions where the insulation level is already quite high before the implementation of the smart heat control.
- This project is in competition with other functional renovation opportunities, that may however create an occasion and leverage for some energy measures
  - E.g. floor insulation with change of floor, thermodynamic SWW boiler with move of electrical one
- There is probably a need for a full accompaniment program, beyond the simple energy scan and audit offered now.
- Local ESCOOP models, like studied in the REHDCOOP[2] project have potential but are still far from coming to the market
- We should interrogate ESCOs about their views on the residential AEPC market, knowing that today there is not EPC market
- Focusing first on social housing neighborhoods or multi-apartment buildings could be a step-up strategy, as they have a single owner (social housing company or SHC) or mandated entity (association of co-owners or ACO) and represent a much higher investment volume.

ABBREVIATIONS AND ACCRONYMS

ABEPeM	Active Building Energy Performance Modelling
AEPC	Active Building EPC
AHU	Air Handling Units
BEMS	Building Energy Management System
BMS	Building Management System
DER	Distributed Energy Resources
DR	Demand Response
EC	Energy Certificate
EEM	Energy Efficiency Measures
EPB	Energy Performance of Buildings
EPC	Energy Performance Contract
ESCO	Energy Services Company
EV	Electric Vehicle
HVAC	Heating Ventilation and Air-Conditioning
KPI	Key Performance Indicator
M&V	Measurement and Verification
LED	Light Emitting Diode
NPV	Net Present Value
PBT	Pay Back Time
PLC	Programmable Logic Controller
PV	Photovoltaic panels