ambience

Active managed Buildings with
Energy performaNce Contracting

Deliverable 3.4 (D3.4)

Preparation of operational AEPC in pilots

The AmBIENCe Consortium

July | 2022

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 874054.

DOCUMENT CONTROL PAGE

PROJECT ACRONYM	AmBIENCe
DOCUMENT	D3.4 Preparation of an operational AEPC in pilots
TYPE (DISTRIBUTION LEVEL)	☒ Public ☐ Confidential ☐ Restricted
DUE DELIVERY DATE	31/03/2022
DATE OF DELIVERY	07/07/2022
STATUS AND VERSION	V2
DELIVERABLE RESPONSIBLE	EDP CNET
AUTHOR (S)	Tiago Soares (INESC-TEC) Sarnavi Mahesh (VITO) Claire Harvey (EDP CNET) Raquel Castanho (Smart Energy Lab) Raquel Figueireido (Smart Energy Lab) Lieven Vanstraelen (ENERGINVEST)
OFFICIAL REVIEWER/s	Chris Caerts (VITO) Martina Caliano (ENEA) Ainhoa Galarza (CEIT)

EXECUTIVE SUMMARY

Deliverable 3.4 “Preparation of an operational AEPC in pilots” describes how the AEPC concept can be made operational by focusing on two diverse pilot buildings – 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 Portuguese pilot” and Deliverable 3.3 – “Performance contract for Belgian pilot”).

The deliverable describes the steps required to make a AEPC operational, highlighting the various process phases required up until after contract signing for the project to reach performance phase. This includes the engagement and management activities, the monitoring and control requirements and the actuation of the flexibility. Section 2 details key information based on the AmBIENce methodology and suite of tools, which were used to demonstrate the AEPC concept in the pilot buildings.

Section 3 and 4 are dedicated specifically to the Portuguese and Belgian pilot buildings respectively, where the AEPC measures are briefly described, and the engagement activities, monitoring requirements and actuation of flexibility for the AEPC to become operational in each pilot case are detailed.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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 AEPC contracts, calculating the performance baseline, project Key Performance Indicators (KPIs) and guarantees, as well as the flexibility options and added revenue streams resulting from DR activities. A variety of business models are introduced to support engaging the stakeholders in the AEPC contract.

To verify the effectiveness of the proposed concept, tools and business models, the AEPC concept, methodology, and business model 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 and methodology.

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 of results, further implementation steps are required after contract signature.

1.2 PURPOSE AND SCOPE OF THE DOCUMENT

This deliverable describes the context of each pilot and the AEPC measures proposed, highlighting key results from the Active Building Energy Performance Modelling (ABEPeM) simulations, and details the key activities and requirements to make the Ambience concept operational, based on the learnings from WP3 (including a description of engagement and management activities, monitoring requirements and the actuation of flexibility). A general description is provided in Chapter 2 – making an AEPC operational, and more detailed sections focus on each pilot (Chapter 3 – Portuguese pilot and Chapter 4 – Belgian pilot).

2. MAKING AN AEPC OPERATIONAL

As has been described in Deliverable D2.1 – The Active Building Energy Performance Contract concept and methodology [1], the main steps required for the implementation of an AEPC are divided into three main phases: the pre-contracting, contracting and performance phases. Making and AEPC operational requires full completion of the first two phases, as described below.

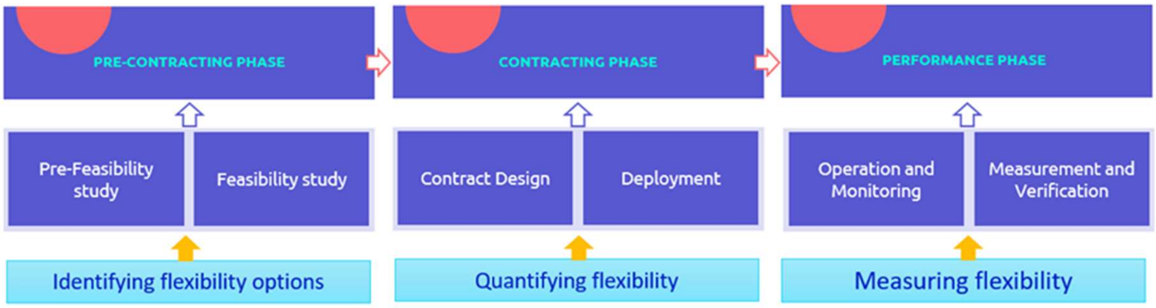

FIGURE 1: AEPC project general procedure.

The *pre-contracting phase* consists in identifying the potential of a project, defining the main objective of the project and a first evaluation of the potential case. This phase has two main steps: (i) the pre-feasibility study and the (ii) the feasibility study. The pre-feasibility involves the collection and analysis of data related to energy users, the benchmarking of all significant consumption in the evaluated facility, and the development of a simple energy audit analysing equipment, estimating consumption based on energy bills, etc. The potential of flexibility available is verified by evidencing the flexible appliances available in the building, as well as a preliminary analysis of possible new equipment to be installed. The feasibility study aims to objectively and rationally uncover the strengths and weaknesses of the existing business or proposed opportunities and threats, determining whether the solution should be implemented. This phase consists of a technical feasibility study to check the condition for the energy savings, an economic and financial analysis to develop a preliminary cost estimation and a social and environmental analysis that considers the environmental and social costs and benefits of the proposal. In an AEPC, the feasibility study would also determine if the case should be considered for an AEPC or is better suited for a classic EPC.

The *contracting phase* is the pivotal phase for the development and implementation of the project. In this phase, the main measures and features of the contract are calculated. The accuracy and adequacy of terms defined in this phase contribute to lowering the risks for the ESCO, as well as better performance gain for the customer. This phase is divided into two main steps: (i) the contract design and (ii) the deployment. The contract design consists of the main calculations and quantifications on the terms of the contract and shaping the features of the AEPC, which are performed by the Active Building Energy Performance Modelling (ABEPeM) tool. It includes the expected costs savings including flexibility usage. Then, in the second step, there is the deployment step where the selected design options of the project are installed and performed. More precisely, all the equipment needed to provide, control and measure the energy efficiency and flexibility measures are installed in the facility. A detailed description of each of the phases of an AEPC can be found in deliverable D2.1 – The Active Building Energy Performance Contract concept and methodology [1].

After the installation of the equipment and the signing of the contract, there is the *performance phase.* This phase refers to the period that the operational activities under the scope of the contract start until the end of the project. It is divided into two main steps: (i) the operation and monitoring and (ii) the measurement and verification. The operation and monitoring activities consist of the training of the end-users and supervising the operation of the energy management plan, which is carried out by the ESCO. However, in an AEPC, the proper data metering and records are crucial for meeting the requirements of optimizing the equipment operation as well as complying with the DR schedules. Therefore, during this step, it is necessary to check that the information sent by the new sensors and smart meters is well recorded and does not cause any delays in the operation of the DR activities. Then, in the last step, the measurement and verification activities consist of a regular measurement and verification procedure to determine the energy and cost savings that result from the implemented energy efficiency and flexibility measures. This procedure is performed along with general operations and maintenance activities, until the end of the contract term when all financial and other obligations are fulfilled. The calculation of the savings is performed through the International Performance Measurement and Verification Protocol (IPMVP) used in standard EPCs implemented in the ABEPeM platform, which is based on determining the savings by comparing the measured consumption before and after the implementation of a program, making suitable adjustments for changes in the pre-set conditions.

After contract development, several further activities will need to be performed to make the AEPC operational and to ensure contractual clauses can be met in a performance phase. As a general overview, the preparation for an operational phase is described in the following sections:

- Engagement and management activities
- Monitoring equipment requirements
- Actuation of flexibility

2.1 ENGAGEMENT AND MANAGEMENT ACTIVITIES

The engagement and management activities for each customer depends on the local stakeholders and type of business model. The business model definition allows to map partners' and stakeholders' organisation activities and the identification of financial flows between parties. The selection of the most adequate business model for an AEPC should always take into consideration the stakeholders involved, their interactions and service/payment flows that apply. All business model variations follow the structure of this generic business model (Figure 2) suitable for implicit

DR. In this generic business model, an ESCO delivers an AEPC service, consisting of guaranteed energy cost savings, based on energy efficiency and renewable energy supply measures and active control of flexibility. This business model can be applied to commercial, public and residential buildings, considering individual occupation and implicit DR. The beneficiary is typically the owner-occupier of the building, who will reimburse the ESCO for the energy efficiency investment through an annual payment, including interests and periodically calculated payments based on the cost savings that are being generated via the flexibility.

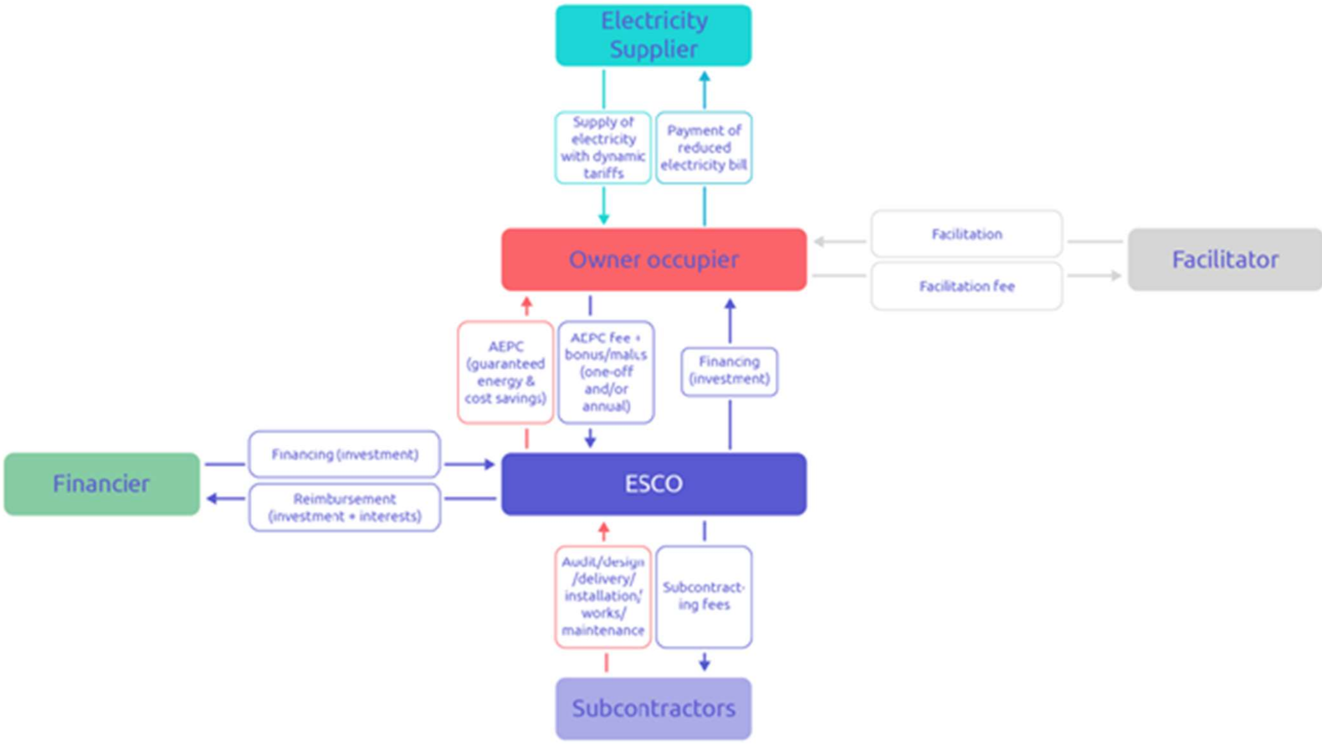

FIGURE 2: Generic AEPC business model considering implicit DR and ESCO financing

In the case of using explicit DR, the business model structure varies significantly, as the role of an aggregator must be introduced. In that case, several options emerge for the aggregator: (i) Aggregator directly interacts with the owner of the building and the flexibility requester, (ii) Aggregator interacts with the ESCO and the flexibility requester, (iii) Only behave as a market aggregator, in which the ESCO is the technical aggregator, or (iv) the ESCO acts as a full aggregator.

Even though a generic Business Model can be defined, depending on the sector in which the business model is applied there can be smaller or larger variations in the type of involved stakeholders, how they interact, and which flows of services and payments occur. Five main characteristics of AEPC beneficiaries lead the business model choice: type of building, occupation model, type of DR, owner/tenant relation and the financing requirements. These are the drivers to deciding on responsibilities among all stakeholders. Besides those intrinsic building owner characteristics, there are other stakeholders' specifications that should be taken into account when designing a business model, such as their motivation/availability, resources and stakeholder relations. The full options and description can be found in the deliverable D2.3 – Business Models for Active building EPC Concept [2].

2.2 MONITORING REQUIREMENTS

For both pilots, to develop the AEPC contract, the ABEPeM suite of tools, developed as part of project (more information in Deliverable 2.2 [3]) were tested for the two demonstration cases. The baseline models and performance guarantees were generated with the ABEPeM Energy Cost Cash Flow Estimation sub-tool, considering various conditions, which, in case of any change of information in an operational phase, would need to be updated as part of the M&V plan, as a routine or non-routine adjustment. Figure 3 illustrates how the routine and non-routine adjustments (pink box) would generate a new baseline and reference operating costs to update the performance guarantees throughout the contract. For effective M&V in an operational phase of an AEPC, automation of the monitoring tasks, integrated in a BEMs would be preferential.

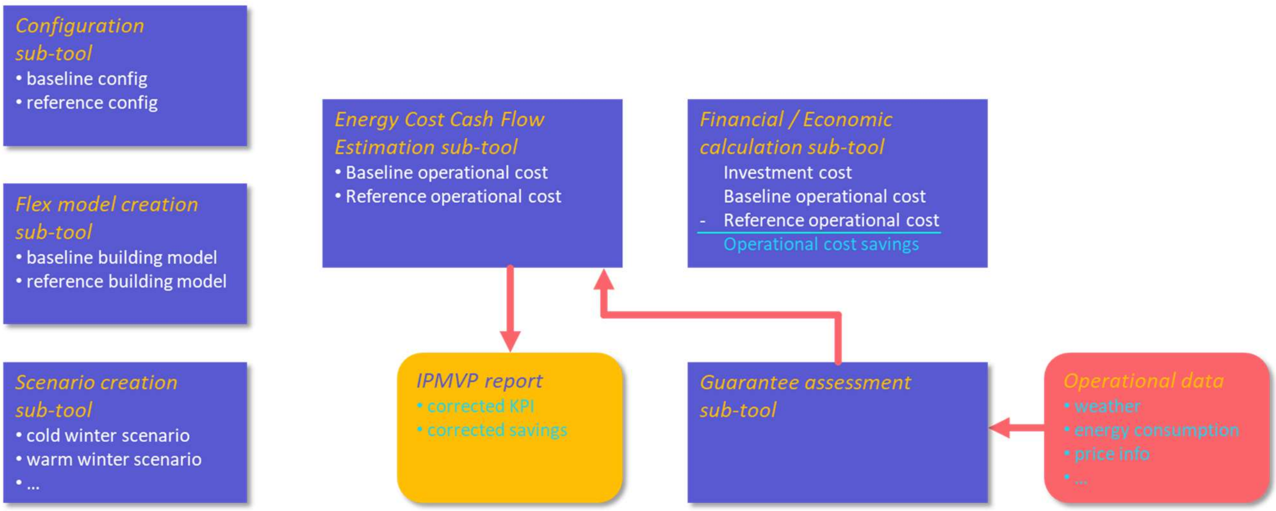

FIGURE 3: MODEL RE-USE OF ABEPEM FOR AN OPERATIONAL PHASE

The operational data during a performance phase is needed to update the models of an AEPC. The M&V plan for each pilot identifies the routine and non-routine adjustments, following the standards for EVO described methodology: IPMVP application guide on routine and non-routine events & adjustments (EVO 10400 1:2020) [4]. Routine adjustments will not necessarily differ from EPC to AEPC, the key differentiating factor between classic EPCs and an AEPC would be to include dynamic pricing changes.

Dynamic price information with the applicable granularity (probably hourly) will be used to determine the optimal consumption profile that results in the minimal cost. In fact, the optimisation can be done for more complex tariff structures than just dynamic or ToU prices. The optimisation may as well account for peak prices or a capacity tariff scheme where prices not ony depend on the amount of energy that is consued, but as well on the amount of power. Tariff and price information is a trigger for the activation of flexibility via Active control. This – occasionally – might result in a small increase of consumed energy, though at a lower cost. Therefore, the applicable price and tariff information and the impact on the active control decisions must be transparently shared between the customer and the ESCO.

In the end, the ESCO will still need to guarantee monetary cost and/or carbon emissions savings. The risk of dynamic price changes, within the agreed electricity supply contract, thus lays with the ESCO, unlike most other routine adjustments (like degree days, opening hours, occupation, etc.) for which the risk lays with the customer.

If price tariffs would change in the course of the AEPC contract, these changes can be integrated easily changing the pricing matrix like described above when calculating the monetary savings. An automated approach for creating baselines and rebaselining will be essential for a cost-effective application of AEPC.

2.3 ACTUATION OF THE FLEXIBILITY

Alongside re-using the ABEPeM related models for the M&V in the performance phase, the ABEPeM platform can be developed into a Building Energy Management System (BEMS). Similar to ABEPeM in the pre contracting phase, the BEMS calculates the optimal consumption plans, which are used by local controllers – like PLCs or BACS – to determine and send control signals or setpoints the various energy systems (e.g., heat pump). The BEMS needs access to relevant state information through various relevant measurements such as indoor temperature and energy consumption, as well as forecasts like outdoor temperature and solar radiation.

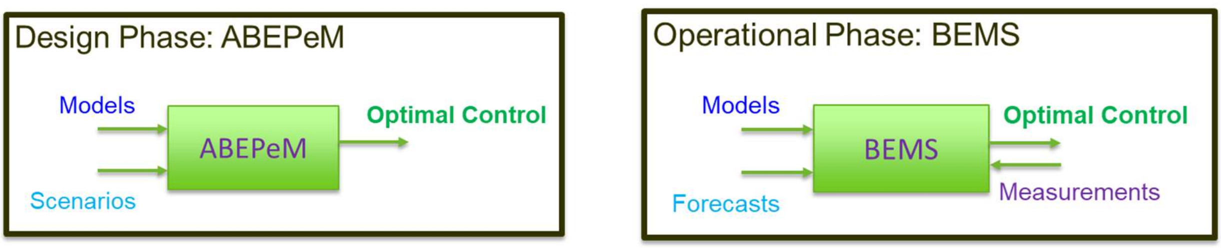

FIGURE 4: Schematics of ABEPeM in design and operational phase

Multiple sensors measure relevant properties of energy systems and buildings. The properties or measurements are used by the BEMS for determining an optimal plan and by any intermediatory

PLCs for system control. The PLCs collect measurements and can act as data loggers as well. Relevant measurements related to the system's state are communicated to the BEMS.

The sensors to be used measure properties such as temperature, pressure, flow rate, power, and solar radiation. The measured property along with their sensor, accuracy, and purpose is listed in the table below.

TABLE 1: Proposed sensors for measurements for ABEPeM in the selected pilot buildings

Property	Sensor	Accuracy	Purpose
Water Temperature	Pt 100, 3 wire with JUMO transducer (4-20 mA)	<0.1 K	Temperature of water (hot water tank) - used for space heating and hot water
Indoor Temperature	Pt100, 3-wire	<0.4 K	Indoor temperature for control operations and for building model
Outdoor Temperature	Pt100, 3-wire, with radiation shield	<0.4 K	Outdoor temperature for building model and/or for air-source operation of heat pump
Total Solar irradiation	Pyranometer with Modbus	< 5 W/m^2	Total solar radiation on PV surface
Flow rate	Electromagnetic flow rate meter with Modbus	< 0.5 % of measured value	Flow rate of water – used for space heating and hot water
Electricity	Power meter	< 0.2 % of measured value	Electricity consumption of heat pump, chillers, and auxiliary devices
Pressure	Pressure transmitter	NA	Pressure sensor at solar circuit

			for hot water tank safety reasons
PV inverter	Micro-inverter	0.5 % MPPT efficiency	DC to AC conversion of electricity produced by PV

The above sensors will be able to measure all the information required to run a BEMS system in coordination with PLC controllers for the operational phase.

Devices installed in the pre-contracting/contracting phase by pilot building owners to gather data from the buildings can also be re-utilized in the operational phase to ensure measurement and verification. Different sensors or other measurement devices can also be used by pilot owners if the relevant properties can be measured with similar accuracy thereby satisfying the purposes.

As mentioned in the preceding section, ABEPeM with additional monitoring systems turns into a Building Energy Management System (BEMS) for the operational phase. To that end, models of energy systems and buildings can be reused for calculating control outputs even in operational phase. Usually, the local BEMS hardware is connected to a cloud-based controller where optimal consumption profiles (plans) are computed and sent to the on-site BEMS hardware. The cloud-based platform should be adapted to handle different types of control variables and system models as required by different pilots. The BEMS on-site hardware controller can be built using the following off the shelf components:

- Single board computers (Raspberry Pi4/Arduino Mega/Asus Tinker)
- Wi-Fi antenna
- Modbus communication board
- AC componentry for electricity.

The major control related to the pilots in Ambience is temperature control of the building based on temperature set-points. This also in turn leads to control of hot/cold water circulation. An additional control is in the solar circuitry to avoid overheating hot water that is required for space heating. All the different controls are tabulated below.

TABLE 2: Proposed control of system components via BEMS and/or PLCs

Component/Part	Sensor Required	Purpose
Condenser outlet valve for heat pump/chillers	Water temperature sensor	Condenser outlet water flow control for hot/cold water tank

Evaporator inlet valve for heat pump/chillers	Water temperature sensor	Evaporator inlet water flow control for hot/cold water tank
Fan and/or water pump from water tanks/buffer to building	Water temperature sensor, Indoor temperature sensor, Flow rate sensor	Control heating and/or cooling of the building according to the temperature set-points
Solar circuit componentry	Solar irradiation sensor, water temperature sensor, pressure sensor	Check the heating of hot water under control. Reject additional heat in case of over-heating.

Additional components might be controlled based on specific requirements of pilot/building. The heating/cooling proposed controls above will be briefly explained next.

Control of heating/cooling:
The heating and cooling control would require a mix of temperature sensors in different zones/rooms, adjustable valves for water flow, air blower/fans, and water pumps. There are two sets of temperature set-points, one for the daytime usually between 8am – 7pm and another one for the evening/nighttime usually between 7pm – 8am. Individual pilots can have their own hours for their temperature setpoints different than the ones mentioned but essentially there are two sets of setpoints in a day, one for the day and the other for the night. The setpoints are provided to the controller via a scheduling system before the start of the operational phase.

The indoor temperature is constantly monitored in each zone/room. Once temperature difference is detected between the actual temperature and the setpoint, a command is given to the water pumps to circulate cold/hot water from the water tank/buffer. If there are fan components in the heating/cooling system, the water is pumped to the fan units. Otherwise, the water is pumped to the pipes that run inside the radiator or under the floor. Once all the rooms/zones have reached their desired temperature setpoint, the hot/cold water supply is stopped. There can be an option to bypass the controller and manually adjust the setpoints, to ensure thermal comfort of the occupants.

Controller Calibration:
The different control functions will be implemented in the BEMS and/or the device PLC, but they need calibration of numerical discrepancies, response times, and fine-tuning temperature differences. The calibration process would have been conducted during the operational phase.

3. THE PORTUGUESE PILOT

3.1 CONTEXT

The Portuguese demonstration site is a services building located in the center of Oporto at an altitude of 86 meters and less than 5 kilometers from the maritime coast. The building complex, composed of two buildings, designated by building A and building B, was inaugurated in 2011 and is one of the two EDP national headquarters, as depicted in Figure 5. Ambience project focused its attention on building A due to the availability of monitoring equipment. Moreover, the COVID-19 pandemic situation significantly reduced the occupancy of building B, resulting in reduced energy needs. Building A has a useful floor area of 18 655 m^2 and normal utilization of around 600 people. In what concerns the property's energy performance class, it is rated B-. The construction solutions provide the building with medium-grade thermal inertia.

FIGURE 5: THE PORTUGUESE PILOT BUILDING IN OPORTO

The building is composed of ten floors of which three are underground floors dedicated to parking and technical areas, with 7 electric vehicles (EV) chargers already installed and 8 more planned. In the ground floors, there is a laboratory, a printing room, an auditorium, the EDP store, medical rooms, reception, meeting rooms and a cafeteria. The upper floors are mainly constituted by open space office rooms. Each office floor has a contained "data centre" room, where varying dimensions of server racks are housed.

Building A has 10 820 m^2 of climatised area. The climatisation system consists of three chillers for cooling and one heat pump for heating. The data centres are climatised by a separate cooling system due to the criticality of the components. Additionally, the building features a Photovoltaic (PV) solar system on the roof comprised by 192 PV panels and 54 PV panels on the southern facade for self-consumption. The lighting system consists mainly of fluorescent bulbs, although there are already some LED technology. The building's major energy consumption systems and estimated demand for 2017 is depicted in Figure 6, where the building is fully electric.

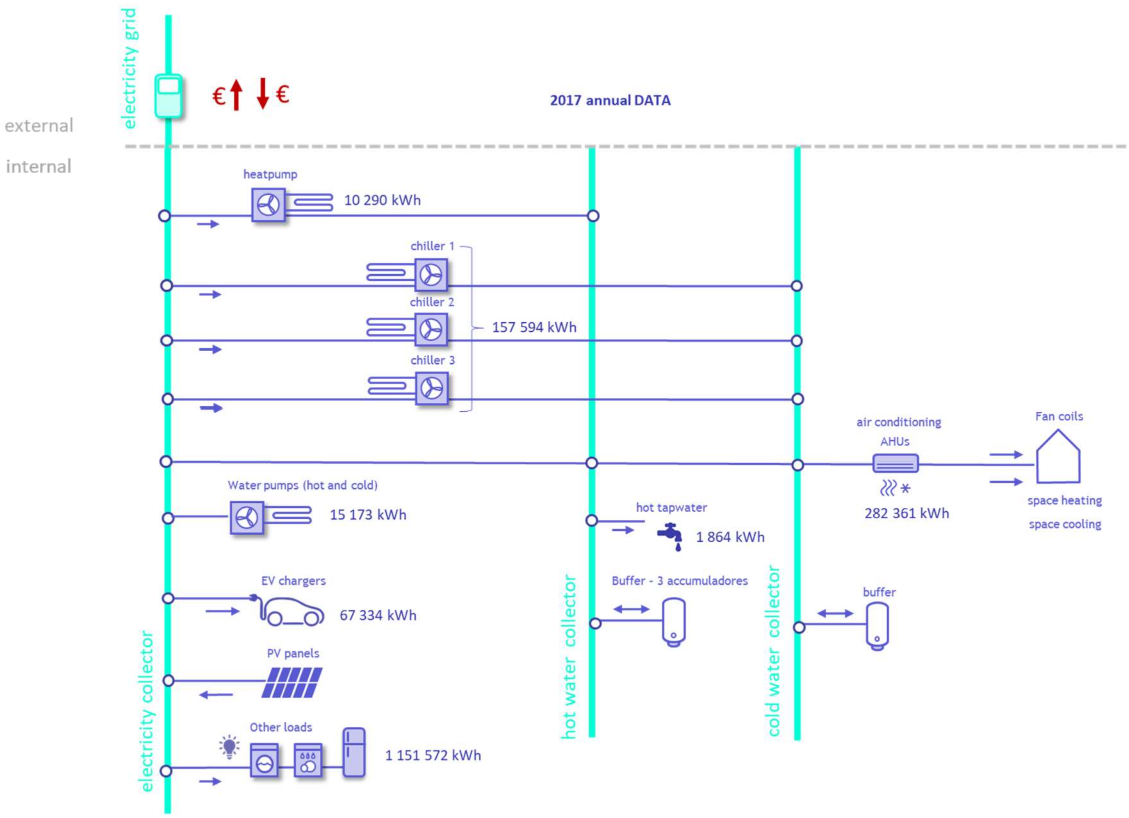

FIGURE 6: SCHEMATIC OF BUILDING A'S ENERGY SYSTEMS

3.2 AEPC MEASURES

As part of the AEPC contract, the agreed measures with the client involved classic energy efficiency improvements: increasing PV capacity, full LED lighting replacement, installation of variable speed drives in the electrical motors of pumps. As well as this, 2 additional measures regarding building operation were proposed: standby optimization of the ventilation units (reducing operation for 2 hours per day), and smart heating and cooling, by shifting consumption to periods of the day with a lower electricity cost, while maintaining indoor comfort values. Dynamic thermal models of the building were developed and used in optimization frameworks to generate the simulated yearly cost and energy savings from each EEM and DR measure, shown in Table 3. Analysis on the results can be found in Deliverable D3.5 - Pilot Evaluation and lessons learned report of the proposed Active Building Energy Performance Contract concept and business model [5].

TABLE 3: YEARLY COST AND ENERGY SAVING FOR EACH EEM + DR MEASURE FOR PORTUGESE PILOT

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

3.3 ENGAGEMENT ACTIVITIES

3.3.1 STAKEHOLDERS

In the Portuguese pilot, the building owner, the building manager, the tenants and the Energy Service Company are part of EDP group. However, all those companies work independently from each other. Oporto building is managed by an asset management company (AMC) whose role is to ensure functionality, comfort, safety and efficiency of the built environment on the behalf of the owner. Although this company has several departments, the most relevant for the AEPC awarding process are the project management department and the infrastructure management department (IMD).

The project management department includes a specific area for engineering consulting (EC). Any projects and assets investment required for the building is included in their budget, thus they are responsible for the payment of any CAPEX that might be required for the implementation of an AEPC. The Infrastructure management department main role is to act as a building manager, being responsible for all operational and maintenance tasks required. Any costs related to additional operational costs due to an AEPC should be charged to them.

These two departments work together to achieve the best possible performance of the building, which means that they want to provide the best work conditions for their tenants while keeping their operational and investment costs under budget.

3.3.2 AEPC PILOT IMPLEMENTATION PROCESS

Hereafter, we provide a view on the process that needs to be taken within the EDP business unit ecosystem to approve an AEPC, which is summarized in Figure 7. The same holds true for pilot implementation. Below, a short description of each implementation phase is provided.

1) Preliminary market consultation: The IMD and the EC together conduct a preliminary market consultation to understand the possible energy efficiency and demand response measures that could be implemented in the building and the correspondent investment/fees required. In practise, this would imply consulting with one or more ESCOs. In the pilot context, the Portuguese ESCO in Ambience project, supported by APEBeM results, presents a set of cost saving measures that could be applied to Oporto building, including those resulting from active control.

2) Internal decision: Afterwards, an internal discussion between the EC and the IMD takes place about the potential or feasibility of implementing the suggested measures. Further studies may be requested by the IMD to be carried out by the EC or even suggested by the EC area itself, in the case there is lack of evidence that the measures to be installed represent good value overall.

3) Presentation of internal decision: Then, the EC and the IMD must present the proposal to improve the building's energy performance to the board of directors of the AMC.

4) Official decision: Given the arguments presented by internal departments, the board of directors decides on approval or disapproval of the ESCO's proposal.

5) Contract signature: With the approval of the board of directors, the IMD can sign the contract with the ESCO for the implementation of the measures envisaged.

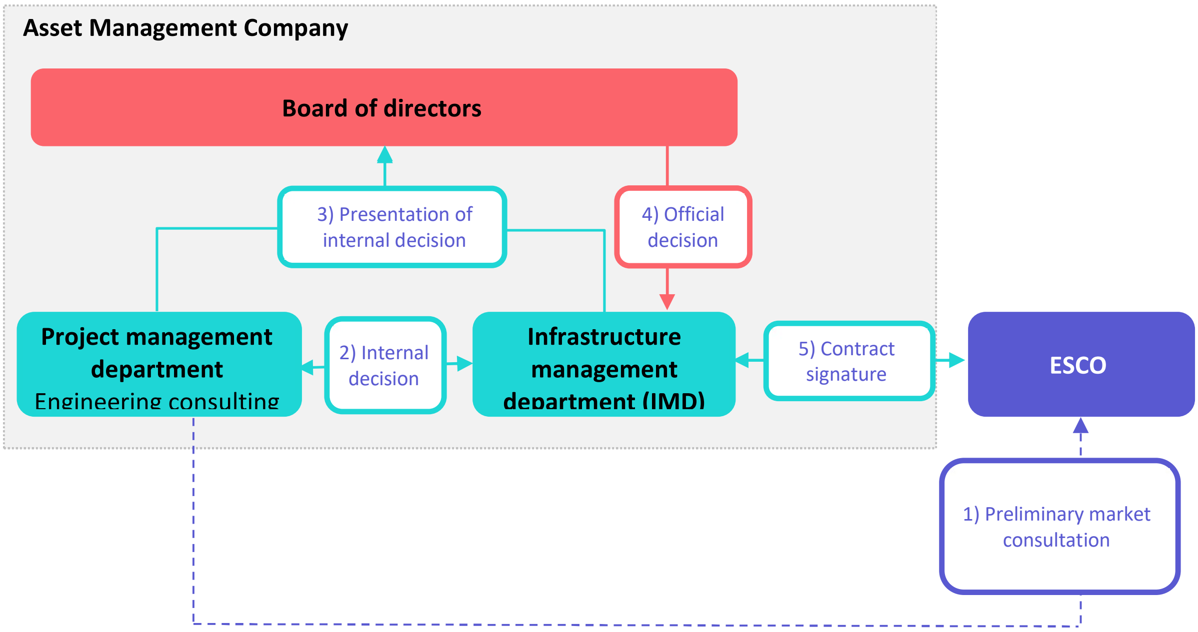

FIGURE 7: SCHEMATIC OF PROCESS TO APPROVE AND IMPLEMENT AN AEPC

3.3.3 MAIN CONTRACTUAL RESPONSIBILITIES

For the sake of a successful contractual relation, the establishment of clear roles in what concerns each stakeholder responsibility is crucial. For AEPC contracts, four main contractual responsibilities were found: Financing, Maintenance, Warranties and Measurement and Verification (M&V). Hereafter, we provide a small description of those responsibilities in the context of the Portuguese pilot.

Financing

As the AMC as a whole has financial capabilities to improve the building's energy performance, a business model with no external financial institution was chosen for the Portuguese pilot. Moreover, the AMC is responsible for the expenditures arising from the AEPC contract under a guaranteed savings mechanism (in opposition to shared savings mechanism).

Maintenance

The AMC will also be responsible for the maintenance of the equipment installed under the AEPC in the Portuguese pilot. Presently, the technical maintenance of Oporto building is carried out by an external company based on specific contracts with fixed Service Level Agreements (SLAs). Hence, the existing contracts between the AMC and the maintenance company shall be amended to cover the new equipment installed under the AEPC contract. However, the AMC must ensure that this is executed according to the maintenance plan prepared by the ESCO. In addition, the building manager must share, with the ESCO, the O&M reports of the facility, notify and even give evidence in case of equipment malfunction or force majeure events not only for savings calculation purposes but also activation of warranties/insurances if applicable.

Warranties

The rights and remedies under the warranties shall be exercised by the ESCO. The ESCO covenants that all equipment purchased as part of the AEPC contract is new, in good and proper working condition, and protected by appropriate written warranties covering all parts and equipment performance.

Measurement and Verification (M&V)

The M&V of the savings would be performed by the ESCO.

3.3.4 AEPC PILOT IMPLEMENTATION CHALLENGES AND TIMINGS

Unfortunately, it was not possible to setup a pilot in the Ambience project duration. The results obtained come from simulations carried out by ABEPeM tool and these still needed to be validated in an operational environment. There were several obstacles to enter into an operational phase of the project.

One of the most relevant was the Covid-19 outbreak. Although Building A has been less affected than Building B of the complex, this resulted in less occupants and, as a consequence, some of the most relevant energy systems (such as HVAC, that corresponds to approximately 50% of the total electricity consumption) were operated differently which decreased their consumption (14% drop in 2020 compared to previous years' average). The following table (Table 4) shows the electricity consumed by the whole building and its HVAC system in 2017-2021 period.

TABLE 4: YEARLY ELECTRICITY CONSUMED BY THE WHOLE BUILDING AND THE HVAC SYSTEM IN 2017-2021 PERIOD

Consumption [MWh]	2017	2018	2019	2020	2021
HVAC (% total)	900 (45.9%)	962 (47.6%)	940 (47.4%)	823 (48.2%)	826 (49%)
TOTAL	1960	2023	1985	1707	1686

Covid-19 effect was a constrain for pilot implementation as it would not allow to fully exploit the benefits of AEPC in the Portuguese pilot. Besides, the complexity of the building for modelling purposes, the number of stakeholders that needed to be reached to obtain information on the current status of the buildings (even if they belong to the same utility group) made the pilot execution harder in due time. In hindsight, the delays during the project allowed the consortium to develop more realistic performance guarantees for an AEPC post-covid. The occupation and therefore consumption of the Oporto building will not go back to pre-Covid levels, due to the new rules on hybrid and flexible working procedures taken up by EDP. Adjustments to the baseline and reference calculations will need to be closely monitored, but the current results give more accurate performance guarantees than what would have been developed had the simulations been performed in 2019, with historical (pre-remote working) conditions.

Based upon its experience with the classic EPC, the Portuguese ESCO would normally take up to 12 months from approaching the client to the contract signature, with all operational teams dedicated to the process. To implement an EPC contract, resources from several areas of expertise are necessary; we name some of them, which can be found in-house or be outsourced: marketing and communication, sales, procurement, engineering, auditing, legal, construction and installation, security and inspection. This would also be true for the AEPC. In addition, the contracting timeframe can vary significantly from one Customer to another since contracts for classic EPC in Portugal are tailor-made and depend on the number of negotiation rounds/interactions between the ESCO and the Customer to agree upon a final version of the contract. Thus, this sets a comprehensive basis of the expect time for pilot launch.

At this point, with the results of ABEPeM suite of tools simulations, the project meets the conditions to move on to the second phase of the implementation process: the Internal decision (please refer to subsection 3.3.2). After showcasing the potential of the implicit flexibility through active control of the HVAC system, a set of cost saving measures can be proposed to AMC for their appreciation. To agilize the process, an AEPC contract template applicable to the Portuguese pilot has been developed as part of WP3 (D3.2).

3.4 MONITORING REQUIREMENTS

In the *pre contracting* and *contracting* phases, to develop the AEPC contract, data was collected to create baseline and performance guarantees. Some data was available from pre-existing equipment in the building, some data had to be collected by installing new equipment during the pilot, and some data required for modelling purposes had to be calculated considering the building information and data available. In an operational implementation of the AEPC concept, the data collection process would need to be streamlined to ensure calculations of performance guarantees could be made in a quicker timeframe than during the pilot. During the pilot the following data was utilised to calculate performance guarantees:

Measured data from existing metering equipment in building:
- Electrical consumption of the overall building (every 15 minutes, kWh)
- Electrical consumption of the HVAC (including heating, cooling, pumping and ventilation loads. Every 15 minutes, kWh)
- Energy generated from PV system (every 15 minutes, kWh)

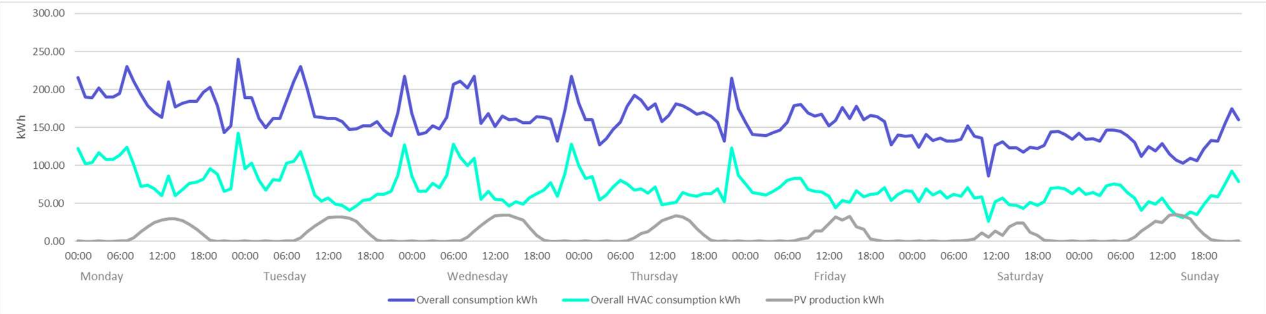

FIGURE 8: EXISTING DATA AVAILABLE FROM THE BUILDING. EXAMPLE FROM WEEK IN APRIL 2021

Measured from equipment installed during the pilot:
- Indoor temperature data across the climatized office floors (every minute, deg. C)
- Electrical consumption of the heat pump (every 15 minutes, kWh)
- Electrical consumption of the 3 chillers (every 15 minutes, kWh)

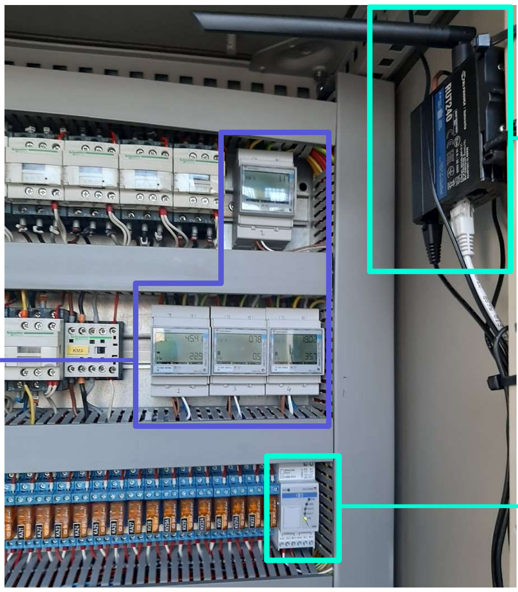

FIGURE 9: MONITORING EQUIPMENT FOR ELECTRICAL CONSUMPTION OF CHILLERS AND HEAT PUMP

Data from other sources:

- Weather data (external temperature and solar radiation at the location) accessed from 3rd party source
- Building information from energy certificate and site visits: composition of building envelope, type of glazing, interior walls, volume of the indoors, estimated occupancy for a regular working day, inflow rate per floor (Q/m3) from each air handling unit (AHU), Coefficient of Performance (COP) of the heat pump, Energy Efficiency Ratios (EER) of the chillers.

In preparation for an *operational phase*, the ESCO and client would need to agree on what data would be required for the ongoing measurement and verification (M&V) of the performance of the building and assets. In the Portuguese pilot case, it's important that the data collected could be automatically sent to the same platform, and no manual extraction of data from separate platforms and significant effort is needed from the ESCO side to monitor the building performance. Throughout the reporting period, as a minimum, the electricity consumption meters should be reporting the consumption of the building and assets to ensure performance guarantees are met and that appropriate routine and non-routine correction factors (depending on weather, occupancy etc) can be applied to the models and ensure fair compensation.

The baseline and reference case, obtained from the ABEPeM platform, which were used to create the template contract for the Ambience project, would need to be fully described and well documented for an operational phase. All baseline data used and assumptions and calculations for the models should be fully transparent for the client and ESCO to understand accuracy and risk. This is addressed in Deliverable 3.2 – Performance contract for the Portuguese pilot, however should the contract go to signature level, more details would need to be defined.

Second phase monitoring requirements for an operational phase may be considered depending on the client and ESCO preferences, where any change from the baseline values should be considered for correction factors. These could be collected through communication from the client to the ESCO, spot measurements, or identified by short or long-term metering installed as part of the M&V plan. Parameters identified as potential important monitoring factors to be reported for an operational phase of the Portuguese pilot building are:

- Dependent variables: Billing data. This is the most differential correction factor for an AEPC in comparison to an EPC. As the performance guarantees are based on optimizing time of use tariffs for the demand response measures, the ESCO needs access to updated time of use tariffs and consumption considered from the energy retailer, to ensure energy savings and cost performance guarantees are met. The M&V plan specifies utility prices and tariffs, so any change to utility prices should be reported during the project, to reflect any inflation/escalation rates. This can be updated on a routine (e.g. yearly) and non-routine (e.g. whenever the customer is notified by retailer of price change) basis.
- Routine correction factors (same as for standard EPC, with higher granularity of data) Independent variables: Real consumption data, production data, outdoor environmental conditions, ambient temperature, seasonal coefficient of performance (SCOP), seasonal energy efficiency ratio (SEER), thermal monitoring data (real thermal load), equipment speeds, pressure, which all may affect the dependent variable described above.
- Non routine correction factors (same as for standard EPC) Operating conditions: Any change in occupancy type, density and schedules. Change in set points for equipment, lighting and ventilation levels, comfort set point levels, for each period and including seasonal changes. Change in building envelope or floor space. Significant equipment problems or outages, or any change in operating sequence that could affect energy use should be monitored.

For all the above variables, monitoring responsibilities should be clearly stipulated before an operational phase. The responsibilities for collecting, analysing, archiving and reporting the data should be assigned to the party that is qualified to efficiently and effectively provide it (a certified M&V specialist). Any non-utility monitoring equipment should be specified in the plan: including the equipment type, make, model and characteristics including accuracy and precision, meter reading protocol, calibration procedure/process and methods of dealing with lost data and data transfer.

3.5 ACTUATION OF FLEXIBILITY

Like many buildings of similar characteristics, the Oporto building has in place a Building Management System (BMS, or in Portuguese: GTC – Gestão Técnica Centralizada) which monitors and manages mechanical and electrical equipment in the building. The current system is Siemens Desigo Insight, where sensors, actuators and meters throughout the building are integrated and data displayed into a user interface (UI), where the building operator has a limited level on control of the operation of the equipment. Most of the systems in the building are self-managing since the configuration of the BMS, with limited control functionality for the operator, for example:

- Illuminance sensors, as well as weather sensors measuring power of the wind are used to control the actuation of the window shutters automatically
- Movement sensors in some corridors and bathrooms automatically turn on the lighting when occupancy is detected
- For the lighting of the office spaces, a schedule is set on the BMS, to turn on all lighting spaces between 08:30 and 21:00 during weekdays.
- The BMS has predefined reference temperatures for the cold collector (8.4°C) and hot water collector (43°C), and the BMS controls the setpoints for the cold production and hot production to start automatically when those set points are reached (10°C/40°C). The chillers and heat pump then self-manage by turning on/off as needed (to reach the set points of each collector) and can be controlled by the BMS (on/off), although this functionality is only used in extreme cases. As the chillers and heat pump do not have variable speed drives and cannot reduce the compressor speed and smooth the required load, they automatically turn on/off frequently, especially when the heating/cooling requirements are low and set points are rapidly reached.
- The heating and cooling is provided to the climatized spaces by air handling units (AHUs) and fan coils (around 40 per floor, depending on spaces to be climatized). The temperature setpoint for each AHU can be set on the BMS (22°C) as well as a comfort band for each fan coil (comfort/pre comfort/economy), of which the set points can be adjusted and also programmed in different time windows. E.g. economy (set points 15 - 28°C) for rooms which are not in use, pre comfort (set points 19-25°C) for a period before the occupants arrive to ensure comfort (22-24°C) is reached in time for rooms in the predefined schedule.

The maintenance company makes use of the BMS to perform their duties in the Oporto building, and has contact with the BMS suppliers (Siemens) should there be bugs with the software's functionalities. None of the realtime data used for the operation of the building (as described above) is collected or stored further than the local machines in which the BMS is installed. The Desigo Insight software system has limited functions and is outdated, with supplier Siemens no longer issuing new licences, it has been replaced by Siemens Desigo CC [6] building automation and control system portfolio of solutions. For an *operational phase,* additional functionality may be required from the BMS, to allow for active control as stipulated by the AEPC contract. An optimal arrangement between the ESCO, Building Owners, Asset Management Company, Tenants (in this pilot case, all companies of the EDP group), and Maintenance company would need to be agreed to ensure the BMS has the required control functionalities for the AEPC to be operational.

For the AEPC concept to become *operational*, the basic control of the current BMS would need to be upgraded to be able to communicate with middleware/controllers to allow for active control and the implementation of results from ABEPeM. There are 2 scenarios that would allow for the application of active control in an operational phase for the pilot case:

1) Upgrade of the BMS to the newest version, to become a more advanced Building Energy Management System (BEMS) or Building Automation and Control (BACs) system: This would entail development in collaboration with the BEMS suppliers – in this case Siemens, to ensure control functionalities related to the active control of flexibility can be integrated.
2) Development of a middleware to allow communication to the current BMS where flexibility operation automation can be programmed in a separate application/platform: The middleware layer would propose changes to the fan coils set points based on the optimal power plan proposed by the ABEPeM platform.

The above options have various advantages and disadvantages associated. In large buildings such as the Portuguese pilot, there are many metering points, many sensors and monitoring and control devices that are used by different parties in the building for different purposes (e.g. maintenance, energy, comfort). Synchronizing this information, ensuring efficient data collection and control functionalities with the right granularity for the correct stakeholders who manage the systems is an essential step for active buildings to become a reality.

4. THE BELGIAN PILOT

4.1 CONTEXT

The Belgian pilot building is a privately owned residential house located in the town of Seneffe, about 50 km south of Brussels. It is occupied by the couple who bought the house in October 2012. The house was built in 1912 and is a typical example of a “Maison de maître” (urban mansion). This means that there are some major constraints on insulation from the outside for aesthetic reasons, e.g. on the historical front facade. Urban regulations are also quite strict as the street is located in the town centre. The 3-story house has many different spaces that are climatised for different uses, and some, such as an artist’s space, which are not regularly heated - only a few days a year when used or at low temperature to avoid damage from freezing in the winter.

FIGURE 10: BELGIAN PILOT BUILDING

Most roofs are traditionally sloped and not insulated, except for a flat roof above the bathroom and bedroom in the back volume. That flat roof has been renovated and insulated in 2020. The flat roof (under the terrace) of the home office space has also been insulated from the outside. The walls are in bricks and are not insulated. Most windows are in PVC with double glazing (from the first generation). The doors and windows of the office space and kitchen (main heated volume), have been replaced in 2013 with double highly insulated glazing in the existing wooden frames. There are 2 wooden frames left with single glazing in the storage room of the artistic workshop on the 1st floor.

The current owner did some heat system renovations since 2012:

- the replacement of the fuel-fired boiler by a condensing gas boiler
- the installation of a wood pellet stove

One of the building's particularities is the fact that it is being used in a very modular way. In winter time, only the private office space/TV space, the kitchen, the bathroom and the bedroom next to it, are continuously heated. All other spaces are only heated occasionally (e.g. living and dining room at the front), for a few hours a week (e.g. artistic workshop) or not at all (e.g. storage and guest bedroom on the ground floor and the entire attic on the 2nd floor). The office space and kitchen are being used all year long because of the owners' professional teleworking profile.

The current consumption is about 8,184 kWh/year of electricity and 36,057 kWh/year for heating (modelled to include gas and wood pellets), for a total energy bill of 3,706 €/year.

4.2 AEPC MEASURES

The following AEPC measures are foreseen in the Belgian pilot:

- Thermal insulation of roofs and walls and replacement of windows
- An electrical heat pump (air/water)
- PV solar panels
- Electrical Vehicle (EV) charging
- Smart Charging and Smart Heating (demand response using flexibility)

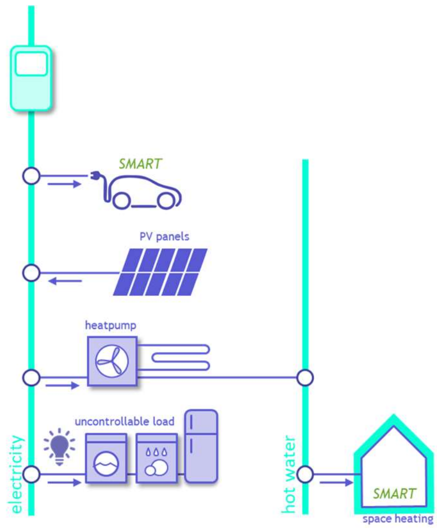

FIGURE 11: SCHEMATIC OF BELGIAN PILOT BUILDING ENERGY SYSTEMS

The investments are show in the following table.

TABLE 5: INVESTMENT COSTS FOR 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**

The following table provides an overview of the savings and pay back times 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 pay back time (PBT).

TABLE 6: INVESTMENT COSTS AND PAY BACK TIMES FOR MEASURES IN BELGIAN PILOT

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				
EV Charging	2,000.00	-5,048 (consumption)			
Smart heating		455			
Smart charging		1,454			

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.

With the ABEPeM platform, 8 different simulation cases (including the baseline) were created to understand the significance of the AEPC measures, with results detailed in Deliverable 3.5 – Pilots Evaluation and lessons learned [5].

4.3 ENGAGEMENT ACTIVITIES

4.3.1 STAKEHOLDERS

In the Belgian pilot, the main stakeholders are the building owner, who owns and occupies the home, the ESCO, and the bank/financier. Other secondary stakeholders are the Architect (advising the home owner), the energy auditor and scanner, and the public authorities that validate the building permit.

4.3.2 AEPC PILOT IMPLEMENTATION PROCESS

Hereafter, we provide a view on the process that needs to be taken for this type of residential building, summarized in Figure 12. The same holds true for pilot implementation. Below, a short description of each implementation phase is provided.

1) Preliminary market consultation – At the outset, one assumes the building owner (the Client) desires to contract a service designed to save energy and associated energy costs at the Seneffe building and needs energy saving equipment and insulation works. Therefore, the first step would be to conduct a market consultation to understand the possible energy efficiency and demand response measures that could be implemented in the building and the correspondent investment/fees required.

2) Preliminary offer – Given basic requirements, determined by the building owners, based on the Energy Audit and the owners' ambition level, the ESCO will provide a preliminary offer. This has to be sufficient to allow the home owner to make the overall investment decision and initiate the building permit request.

3) Technical and architectural validation – Based on the preliminary offer, the Architect will validate some of the key technical choices proposed by the ESCO and define or validate any architectural implications of internal or external insulation measures (e.g. window types, openings and material, outside insulation material, risks for thermal (cold) bridges).

4) Financing agreement – Based on the preliminary offer, the building owner will have a good idea of the investment and savings. This is sufficient to obtain a financing agreement with the bank or, alternatively, the ESCO. Key parameters will be the financing duration and interest rate.

5) Building permit – Once the preliminary offer received and an agreement reached on the financing, the building permit request can be initiated. It is required for any works with a strong visual impact towards public space or in case of works that could jeopardize the stability of the building (e.g. large openings in supporting walls). Depending on the level of works and local regulations, this can be relatively easy or more complex. In case of important deviations from standard regulations, the permit could be refused at the local level, requiring an appeal procedure at the regional level.

6) Final offer – In order to come to an agreement, once the building permit is obtained, the ESCO will provide a final offer, based on exact measures of doors and window dimensions and types, as well as exact wall and roof surfaces and insulation materials and coverings. Any heat pump dimensions and regulation will also be finetuned for the final offer, ready for signature after any final negotiations.

7) Contract signature – With the final offer approved by the building owners, the AEPC contract is being signed, allowing the ESCO to start the detailed engineering and implementation of the measures. If the contract includes commissioning and maintenance provisionings, which it typically does, they will also be put in place after contract signature.

8) Financing contract signature – The AEPC contract signature automatically triggers the signature of the financing contract between the building owners and the financier, typically their or another bank, possibly the ESCO if they are providing financing.

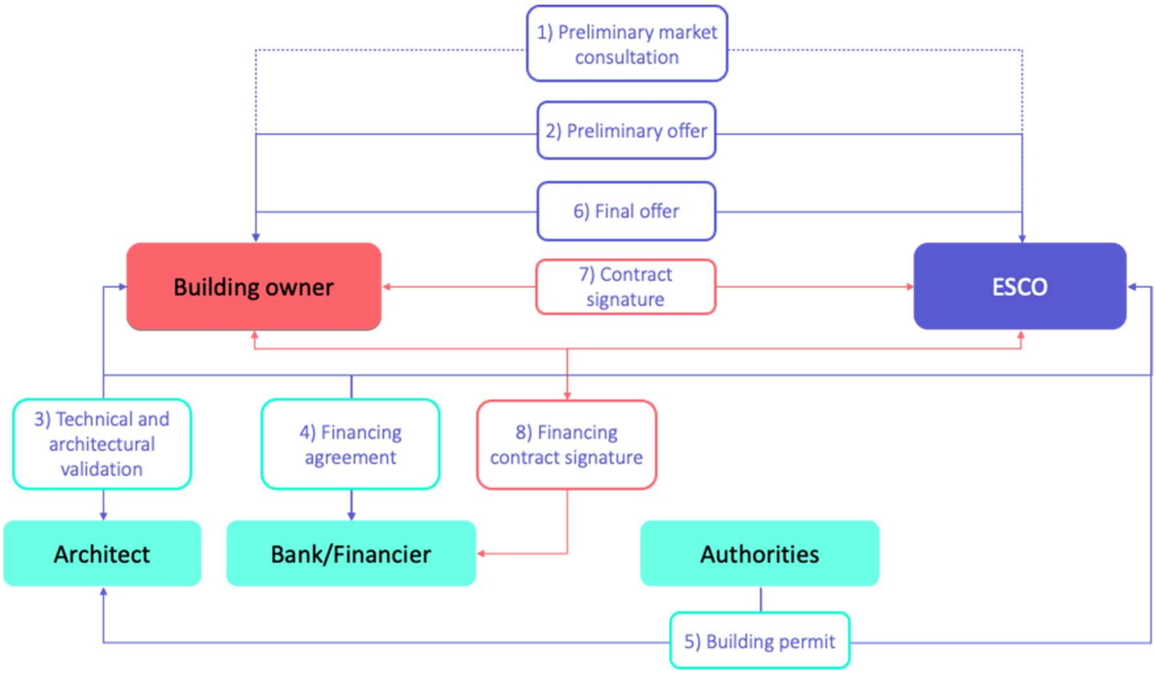

FIGURE 12: SCHEMATIC OF PROCESS TO IMPLEMENT AN AEPC IN THE BELGIAN PILOT

4.3.3 MAIN CONTRACTUAL RESPONSIBILITIES

The following main contractual responsibilities were identified for the AEPC contract: Design and Implementation of the EE Measures, Financing, Maintenance, Warranties and Measurement and Verification (M&V). Hereafter, we provide a small description of those responsibilities in the context of the Belgian pilot.

Design and Implementation of the EE Measures

The full design and implementation of the EE Measures is in the hands of the ESCO which is delivering the AEPC contract. Even though the homeowner will have some input on the ambition level and on functional and esthetic or comfort requirements, the technological choices are essentially made by the ESCO.

Financing

As the home owner does not want to pay for the investment, but prefers to use the financial savings as a source of reimbursement, ESCO or bank financing are foreseen. A contribution of around 20% of the home owner's own funds allows the financing rate to be reduced. The guaranteed savings under the AEPC agreement improve the financing rate by the bank.

Maintenance

The ESCO will also be responsible for the maintenance of the equipment installed under the AEPC in the Belgian pilot. Presently, there is no technical maintenance contract, but only 3-yearly legal maintenance is contracted on a regular basis from a local maintenance technician. Maintenance in the AEPC could be performance-based, using the NEN2767 standard as is explained in the Deliverable D3.3 [7].

Warranties

The rights and remedies under the warranties shall be exercised by the ESCO. In Belgium there is a standard legal 2-year warranty on equipment, which can be extended. There is also a 10-year legal warranty for any construction or large renovation works.

Measurement and Verification (M&V)

The M&V of the savings would be performed by the ESCO, to support the energy cost savings guarantees but validated by the home owner. This involves agreeing on the baseline, guaranteed energy and cost savings levels and routine and non-routine corrections. Energy savings have been defined as absolute kWh and €, but a fixed target in terms of kWh/m^2 consumption or an energy level (e.g. label A) could be a more pragmatic approach that is easier to measure when based on basic parameters like family composition.

4.3.4 AEPC PILOT IMPLEMENTATION CHALLENGES AND TIMINGS

Despite efforts to reach the implementation and operational phase of a Belgian pilot, it was impossible to get to that stage in the Ambience project duration. The results were therefore based on static simulations, followed by dynamic simulations carried out using the ABEPeM tool, that simulates the smart active control. Several barriers existed to reach the operational phase of the project, as was the case with the Portuguese pilot project.

The first main reason for the delay was the difficulty finding pilot buildings as explained in the following paragraph:

A) The original attempt, backed-up by a letter of support, involved educational buildings of the PXL University of Hasselt. Through internal changes of strategy, that initial pilot project had to be abandoned.
B) A second attempt involved an agreement with Siemens to do a pilot project for AEPC with one of their commercial customer’s buildings. Due to COVID early 2020, they decided to disinvest from the building sector in favor of the industrial sector.
C) A third pilot project attempt was set-up with Engie Cofely (recently changed into Equans), that proposed one of its existing customers for maintenance: The Clara Fey site of the “Broeders of Liefde” a large educational and day care center for people suffering from mental problems. Despite quite advanced talks with the customer on renovation scenarios, involving flexibility, the customer needed more time to come to a decision. Eventually this third pilot site also had to be abandoned.
D) The Seneffe pilot building therefore was the 4th option and successful one. But more than a year was lost in the process, time that could not be recovered and leading to the delay that was mentioned. Also, no ESCOs are active in the individual housing sector, which meant that it was

anyway virtually impossible to get a project through the full life cycle, including the AEPC contract signature, implementation and operations.

The Covid-19 outbreak led to delays in decision making from the home owner and an overall delay in project management by the home owner.
Covid-19 represented a barrier for pilot implementation as it would not allow to fully explore the AEPC conditions in the Belgian pilot. In addition, the modular use, the complexity of the building for modelling purposes and the interaction with stakeholders (Bank, ESCO, Architect) that needed to be reached to obtain information on the current status of the building, made the pilot a bit slower to set-up. The occupation and therefore consumption of the Seneffe building will probably not return to pre-Covid levels due to increased home working. Adjustments to the baseline and reference calculations would need to be closely monitored, but the current results give more accurate performance guarantees than what would have been developed had the simulations been performed in 2019.
Based upon the experience with the classic EPC, any Belgian ESCO would normally take up to 18 months from approaching the client to the contract signature.
At this point, with the results of ABEPeM suite of tools simulations, the project meets the conditions to move on to search for an ESCO willing to make an offer. There is likely still a reluctance to enter into a contract with guaranteed cost savings. Given the potential of the implicit flexibility through active control of the HVAC system and EV charging, a set of cost saving measures can be proposed to the home owner for their appreciation. To make the process more agile, an AEPC contract template applicable to the Belgian pilot, almost identical to the one for the Portugues pilot, has been jointly developed by both pilot projects part of WP3 [8].

4.4 MONITORING REQUIREMENTS

In the *pre contracting* and *contracting* phases, to develop the AEPC contract, data was collected to create baseline and performance guarantees. Data was available from the existing heating system (condensing gas boiler and wood pellet stove) in the building, some higher frequency data had to be collected by installing temporary heat consumption measurement probes, during the pilot. 4 temperature probes in relevant rooms were also installed for a few weeks to collect real time temperature data to be correlated with the heat consumption data. During the pilot, the following data was utilized to calculate performance guarantees:

Measured from equipment installed during the pilot:
- Indoor temperature data across 4 different rooms: living room, kitchen, bathroom and artist work space (every minute, deg. C)
- Electrical consumption of the gas boiler, with the wood pellet stove turned off (every 15 minutes, kWh)

After the measurement campaign a smart meter was installed to perform the post-implementation consumption measurement with a 15-minute frequency and establish a reliable baseline.

FIGURE 13: SMART METER FOR ELECTRICAL CONSUMPTION OF OVERAL INSTALLATIONS IN BELGIAN PILOT

Data from other sources:

- Weather data (external temperature and solar radiation at the location) accessed from 3rd party source,
- Building information from energy certificate and site visits: composition of building envelope, type of glazing, interior walls,
- Proposed capacity of the PV panels, Coefficient of Performance (COP) of the proposed heat pump, estimated EV charging profile.

In preparation for an *operational phase*, the ESCO and client would need to agree on what data would be required for the ongoing measurement and verification (M&V) of the performance of the building and assets. Ensuring M&V data is efficiently stored, sent and updated is important for a residential AEPC, where the routine and non routine correction factors should be stimulated clearly in the AEPC contract M&V plan [7].

An energy monitoring solution was studied and the choice was made to install a system from SMAPPEE (Infinity), including capabilities for smart electrical control and measurement of all electrical load equipment consumption data. Smappee Infinity offers a single solution for voltage monitoring and dynamic load balancing between solar, EV, and other appliances in the home and buildings through a cloud-based application interface. New phase measurement capabilities allow the Infinity modules and gateway to aggregate more data, reducing costs for (multi) family and enterprise systems.

FIGURE 14: SMAPPEE HOME ENERGY MANAGEMENT SYSTEM (HEMS) ENERGY MONITORING

FIGURE 15: SMAPPEE HOME ENERGY MANAGEMENT SYSTEM (HEMS) DASHBOARD

Parameters identified as potential important monitoring factors to be reported for an operational phase of the Belgian pilot building are very similar to those of the Portuguese pilot, as described in Section 3.4, where monitoring responsibilities should be clearly stipulated between home owner and ESCO before an operational phase.

4.5 ACTUATION OF FLEXIBILITY

The flexibility potential comes from heating control and smart EV charging control. It is the optimization of the PV solar production, heat control and EV charging when the car is parked at the building that allow for the overall active control potential.

Separate smart control devices and software for heat pumps or EV charging exist. But the real challenge for the Belgian pilot is to combine both based on ToU tariffs and the PV panels' production profile. The goal is to maximize auto-consumption of renewable energy.

Unlike commercial buildings, the Seneffe building has no Building Management System (BMS) which monitors and manages mechanical, gas- or wood pellet-fired and electrical equipment in the building. The only system capable of measuring data is the smart meter. The current gas boiler has some basic data that can be made available through a smart phone app, but it is insufficient for the required purpose.

Therefore, in the AEPC contract, the placement of a HEMs (Home Energy Management system) capable of actuation and control would be required. It would ideally integrate the ABEPeM algorithms.

The ESCO should make use of a HEMs to perform its duties in the Seneffe building, and should implement a solution with the HEMs supplier for integrating the algorithms. For an *operational phase,* active control of the heat pump and EV charging is required, as stipulated by the AEPC contract. An optimal arrangement between the ESCO and building owner would need to be agreed, in order to ensure the HEMS has the required control functionalities for the AEPC to be operational.

The HEMs would be used by the ESCO and the home owner in the building for different purposes (e.g. maintenance, energy management, comfort control). Synchronizing this information, ensuring efficient data collection and control functionalities for the ESCO and home owner is an essential step for active buildings to become a reality. But the bigger barrier is probably the underlaying business case for ESCO to renovate individual homes. Aggregating them at street or neighborhood level is probably a requirement. The same is true for more standardized and scalable ways of renovating building envelopes, for example via prefabricated wall panels, as is the case in a growing number of social housing or apartment building renovations.

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” [7], and developed the quantitative performance guarantees and template AEPC contracts in Deliverable 3.2 – “Performance contract for the Portuguese Pilot” [8] and Deliverable 3.3 – “Performance contract for the Belgian pilot” [9], this describes the requirements to take those results and prepare the pilots to be operational for phase (iii) – performance phase.

Key requirements for the implementation of the AmBIENce methodology and data requirements and developments suite of tools, which were used to demonstrate the AEPC concept in the pilot buildings, highlighted the need for data collection at an early stage, and further development of the concept in real-world scenarios.

The AEPC measures for each pilot, engagement activities, monitoring requirements and actuation of flexibility for the AEPC to become operational in each pilot case were detailed, and by developing the requirements for each pilot to become operational, the assumptions and steps of the AEPC methodology have been tested and highlight that, as a proof of concept, there is potential for advantageous results for different stakeholders. There is still some development required to the steps of the process and the tools that support them, for the AEPC to reach commercial readiness and be implemented in an operational phase.

6. REFERENCES

[1] "AmBIENce Deliverable D2.1 – The Active Building Energy Performance Contract concept and methodology," [Online]. Available: https://ambience-project.eu/wp-content/uploads/2020/12/D2.1-The-Active-Building-Energy-Performance-Contract-concept-and-methodology.pdf.

[2] "AmBIENce Deliverable 2.3 - Business Models for the Active Building EPC Concept," 2021. [Online]. Available: https://ambience-project.eu/wp-content/uploads/2021/05/AmBIENCe_D2.3_Business-Models-for-the-Active-Building-EPC-Concept.pdf.

[3] "AmBIENce Deliverable D2.2 - Proof-of-Concept of an Active Building Energy Performance Modelling framework," 2020. [Online]. Available: https://ambience-project.eu/wp-content/uploads/2020/12/AmBIENCe_D2.2_Proof-of-Concept-of-an-Active-Building-Energy-Performance-Modelling-framework-for-publication.pdf.

[4] E. -. IPMVP, "IPMVP APPLICATION GUIDE ON NON-ROUTINE EVENTS & ADJUSTMENTS," 2020. [Online]. Available: https://evo-world.org/images/denisdocuments/NRE_TOC.pdf.

[5] "AmBIENce Deliverable 3.5 - Pilot Evaluations and lessons learned report of the proposed AEPC concept and business model," 2022.

[6] "Desigo CC," Siemens, [Online]. Available: https://new.siemens.com/global/en/products/buildings/automation/desigo/building-management/desigo-cc.html. [Accessed March 2022].

[7] "AmBIENce Deliverable 3.1 - Pilot building specific models and performance calculation components".

[8] "AmBIENce Deliverable 3.2 – "Performance contract for the Portuguese Pilot"".

[9] "AmBIENce Deliverable 3.3 – "Performance contract for the Belgian piliot"".

ABBREVIATIONS AND ACCRONYMS

ABEPeM	Active Building Energy Performance Modelling
AEPC	Active Building EPC
AHU	Air Handling Units
BACS	Building Automation and Control System
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
HEMS	Home Energy Management System
HVAC	Heating Ventilation and Air-Conditioning
KPI	Key Performance Indicator
M&V	Measurement and Verification
NPV	Net Present Value
PLC	Programmable Logic Controller
PV	Photovoltaic panels