Active managed Buildings with
Energy performaNce Contracting

## Deliverable Number (D2.3)

# Business Models for the Active Building EPC concept

The AmBIENCe Consortium

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| AUTHOR (S) | Lieven Vanstraelen (Energinvest),<br>Miguel Casas (Energinvest),<br>Ricardo Ramos (EDP CNET),<br>Chris Caerts (VITO). |
| OFFICIAL REVIEWER/s | Nilufar Neyestani (INESC TEC),<br>Marialaura Di Somma (ENEA),<br>Chris Caerts (VITO),<br>Miguel Casas (Energinvest). |

# EXECUTIVE SUMMARY

The purpose of this document is to present the Business model for Active building Energy Performance Contracting (AEPC), building on the existing business model for Energy Performance Contracting (EPC). This new business model is focused on the integration of flexibility in buildings into the AEPC model. Defining the Business model for a new type of EPC required a structured approach.

The **first Chapter** of the work consists of summarising the AEPC concept, developed in Deliverables D1.2 “Overview of actors, roles and business models related to Enhanced EPC and Building Demand Response services”, D2.1 “The Active Building Energy Performance Contract concept and methodology” and D2.2 “Proof-of-Concept of an Active Building Energy Performance Modelling framework”.

Subsequently, in **Chapter two** the eco-system of the stakeholders that are directly or indirectly involved in the AEPC model is defined and analysed. This allowed identifying 14 main stakeholders, like end-customers, aggregators, Energy Services Companies (ESCOs), technology providers, etc., that play a role or are directly or indirectly involved in the AEPC model. Risk management being an important aspect of any EPC, the risks associated with the AEPC model were analysed, allowing to identify not only the general risks of EPC, but also the ones, such as price risk, that are particular to AEPC. The interactions between stakeholders in the eco-system are also established as part of the value chain for delivery of AEPC service. This allowed developing the level of integrated service that is delivered by the ESCO, first at the level of the key components, next as a holistic service to deliver energy efficiency and flexibility at the physical and potentially at the virtual level.

Some of the stakeholders are more directly involved in delivering, receiving, financing or contributing to the energy efficiency measures and flexibility services. These are ESCOs, building owners and tenants, financiers, electricity suppliers, aggregators and Distribution System Operators (DSO)/Transport System Operators (TSOs). Keeping these key stakeholders in mind, the work has allowed defining the generic scheme for the AEPC Business model, describing which stakeholders interact with which other ones. Interactions involve service delivery and reception (between ESCO and building owner, and sometimes tenant). The service includes guaranteeing energy and cost savings, through the implementation of both energy efficiency measures and flexibility services. But they also involve various financial flows, related either to paying for the services or to pre-financing investments by financiers on one hand or reimbursing those investments to the financiers on the other hand.

Based on this generic Business model, several variations of the Business model (13 in total) are defined and presented in **Chapter Three**, reflecting various parameters listed below:

- The diversity in types of buildings (Public, Commercial, Residential vs. Social Housing);
- The occupation model (Individual vs. Collective);
- The owner/tenant relation (Owner occupier vs. Owner lessor);
- The type of Demand Response (Implicit vs. Explicit);
- the type of Financing (by Financial Institutions (banks), the ESCO or a particular type of Umbrella Organisation in case of Social Housing).

Not only do they reflect the variety of cases that ESCOs encounter, but their analysis has allowed highlighting key challenges associated to different variations. They share however all the same common AEPC model.

In each of the variations, electricity suppliers play a key role, in particular in implicit Demand Response (DR), providing dynamic tariffs that allow to valorise the flexibility. In the case of explicit DR, which has been considered for some other variations, the aggregators and DSOs/TSOs (or Balance Responsible Parties (BRPs)) also play a key role. For explicit DR, the evolving role of ESCOs - as parties that work closely together with Aggregators up to becoming themselves Aggregators - has been described.

Although both explicit and implicit DR are part of the same AEPC Business Model, we can conclude they are sufficiently different in terms of business logic and actors involved to consider them as two main submodels of the generic one.

For residential collective housing (i.e. multi-dwelling apartment buildings) and individual and collective social housing, the more complex owner/tenant relations and financing options have led to describing several variations that reflect the more complex delivery of AEPC services. In these cases, the services partially benefit tenants and involve them in the conditions (e.g. flexibility in comfort delivery) to provide all of the benefits of the service.

The 13 variations are not necessarily a comprehensive description of all cases, as some other combinations can exist. But they have allowed understanding the key features of the Business model and provided insight that allowed describing the main characteristics of the AEPC business model, within a varying eco-system.

The Business model described emphasizes how both energy savings (from energy efficiency (EE) and renewable energy measures, which also lead to cost savings and $CO_2$ emission reductions) and cost savings (from flexibility, which again in some cases allow for additional $CO_2$ emission reductions) are combined to maximize the potential. This is enhanced by the electrification of heat demand that increases the flexibility potential beyond the one that is already present in the building. Depending on the aggregation potential of the ESCO, this provides the opportunity to use mainly implicit DR or rather engage with network related stakeholders to valorise explicit demand response. The key to delivering the service is the active control that is added to the traditional Building Energy Management Systems to activate flexibility.

The purpose eventually was to have a Business Model that integrates building envelope measures that allow for profitable business cases when combined with the EE/ER measures, based on a lower level of insulation but a higher level of renewable energy, used in a flexible way.

Once the Business model being defined, the need to have a business modelling tool to calculate specific business cases is emphasized, which lead to the development of an Economic and Financial Calculations Module (E&CFM) presented in **Chapter Four**, that will be integrated into the global Active Building Energy Performance Modelling (ABEPeM) tool that calculates the energy, cost and $CO_2$ savings. For purpose of clarity, a User Manual is also developed and included in **Annex A**. The E&CFM tool allows calculating key financial indicators to evaluate the business case of an AEPC projects, based on input parameters, like investment, the energy and cost savings, maintenance costs and financial variables like discount rate, energy price evolution or inflation. The underlying calculations are done in the ABEPeM Tool.

A business case is then evaluated and presented in **Chapter Five** based on the example of a single-family poorly insulated residential home, using a static simulation to determine heat system and insulation scenarios. The required levels of insulation to reach the minimum comfort levels are determined, as well as heat demand after insulation. The main cases that are compared, are the replacement of the existing gas boiler by a new condensing gas boiler versus the replacement by an electrical heat pump (HP) in addition to

Photovoltaic (PV) panels and a buffer storage vessel. This allowed to determine the needed installed heat system power for each case. These were fed into the dynamic solution tool of ABEPeM to determine energy and cost savings. For the HP scenario, the distinction was made between with or without DR.

This analysis showed that the business case for the HP and PV is slightly better than for the condensing gas boiler, with an improved Net Present Value (NPV) of about 10%. Adding DR led to an improved NPV of roughly 20% compared to the condensing gas boiler scenario. The NPV-to-investment ratio only improved slightly, with 1.1%. This is likely caused by the fact that the initial insulation level of the simulated home was very low, requiring a significant level of insulation to reach the minimum comfort and the fact that the HP is more expensive than the boiler.

Different financing options for 35 to 40 years periods were compared showing how the variations in financing cash flows give slight variations in NPV. This residential case study is provided in more detail in **Annex B**, together with a similar simulation for a school building. Further simulations, as well as feedback from the pilot projects, should allow to increase the understanding of the parameters contributing to positive business cases and validate the application potential of the AECP Business model.

Finally, **Chapter Six** contains a short evaluation of the results of the previous chapters and the conclusion.

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# INTRODUCTION

The AmBIENCe project aims to extend the Energy Performance Contracting (EPC) model for energy renovations of buildings, to include the valorisation of the flexibility potential that is present in buildings. This Active building EPC (AEPC) model will impact the way energy renovation strategies are conceived, including the possibilities for an increased electrification of heat production, in combination with on-site renewable energy production and an optimal level of insulation given the local building characteristics and constraints.

Assessing whether the AEPC concept is applicable to buildings and in which cases, requires studying and defining the Business Model and possible variations. The Business Model is a description of how an organisation's activity is set-up with partners and/or stakeholders to create value by delivering (and sourcing) service or product offerings to customers, while identifying financial flows between parties.
This process of Business model definition involves several steps:

- An analysis of the stakeholders that are involved in the AEPC Business Model, which will include all of the existing stakeholders of the EPC model, but also some new ones that are currently involved in flexibility;
- An analysis of the eco-system in which these stakeholders are active and how they interact which each other;
- The determination of the business relations between them and how value is created. This is the core of the Business model;
- How variations of this Business model allow us to adapt to specific requirements in certain building segments or configurations;
- How the Business model can vary according to the type of Demand Response that is included or the type of financing that is implemented.

The Business model is the basis for developing a tool that offers the possibility of analysing Business cases. These will grow understanding of which building topology, for which investment scenario and for which boundary conditions, can allow ESCOs to build a positive Business case. It also allows to compare an AEPC Business case to an EPC Business case or to a classical Separate Contractor Based case. It can compare an electrification scenario with heat pumps and active control to a traditional renovation scenario based on fossil fuel heat production.

The first chapter is dedicated to summarizing the key elements of the AEPC concept. It is a high-level description of key features and building blocks.
Chapter two is dedicated to describing the AEPC Eco-system. This provides more insight into the larger set of actors that have a direct or indirect interest in the areas covered by AEPC and how they interact. This

not only covers actors that get actively involved in the value creation, but that may benefit from or provide input to the core stakeholders.

Chapter three provides the description and details of those core stakeholders and defines the way they work together in the AEPC Business Model. Different variations of the Business Model are given to cater for the diversity of building sectors, building configurations and financing schemes.

Chapter four provides a description of the Economic and Financial Modelling Tool that was developed to perform a number of business case simulations.

Chapter five provides insight into one of those business cases and the results of the technical and financial simulations that were done as inputs to the business case, for a case of a residential stand-alone single-family home. This chapter also contains an analysis of several financing options, applied to the business case.

Chapter six contains a short evaluation of the results of the work done in the previous chapters and the conclusion.

# 1. AEPC CONCEPT

The Active building Energy Performance Contracting (AEPC) is a new concept and contracting model developed in the AmBIENCe project and presented in Deliverable D2.1 "The Active Building Energy Performance Contract concept and methodology". Based on the definition provided for AEPC, it is an enhanced modular and performance-based delivery mechanism, using the financing mechanism for the energetic renovation and optimization of existing and new buildings, tapping into all passive and active energy and cost saving measures. AEPC leverages from a comprehensive set of technical, operational, usage, behavioural and dynamic energy or $CO_2$ pricing parameters. It is an enhancement of the basic EPC concept, through a strong focus on the electrification (also of the local heat supply and including mobility) and the addition of active control measures.

In the AEPC contract, newly added features are the inclusion of flexibility and demand response (DR) in the contract; hence, providing the energy cost saving guarantees along with the energy savings, which is the common guarantee in EPCs. The cost saving is a result of implementing implicit and explicit DR services. Based on the definition, explicit DR is the dispatchable flexibility that can be traded on the different energy markets and is usually facilitated and managed by an aggregator that can be an independent service provider or a supplier. On the other hand, implicit DR is the consumer's reaction to price signals where the users can adapt their behaviour (through automation or personal choices) reflecting variability on the market and the network. These concepts are explained in more detail in Deliverable D1.2 "Overview of actors, roles and business models related to Enhanced EPC and Building Demand Response services".

Adding these features to energy performance contracts enlarges the stakeholder's involvement in the contract and adds new business values, consequently affecting the business models in which an AEPC can perform. In the AmBIENCe project, the value chain of energy service contracts is extended and flexibility trading is added to the business model options of ESCOs. With an extended value proposition and stakeholder group, new variations of business models are envisaged for AEPC. Moreover, AEPC broadens its applicability to a wider range of building types, adding complexity to the business models and requiring specific considerations for new building types.

To support the implementation of AEPC projects, the Active Building Energy Performance Modelling (ABEPeM) platform is developed and presented in Deliverable D2.2 "Proof-of-Concept of an Active Building Energy Performance Modelling framework". The ABEPeM platform has several modules that provide the computational requirements of AEPC projects. One of the main modules is the Economic and Financial Calculation Module (E&FCM), that performs an economic analysis and calculates the costs and benefits with the new revenue models, helping ESCOs to decide on the viability of a project, as well as defining the contract Key Performance Indicators (KPIs). With the variation of business models, this module plays a critical role in the decision-making process of an AEPC project and the selection of the suitable financial model for each case.

# 2. AEPC ECO-SYSTEM

In this chapter, we will analyse the actors' involvement in the new AEPC as an integrated service. An integrated service is a customer focused service that consists of one solution including the implementation and monitoring of the building performance, value streams from flexibility, energy savings, comfort, quality control and maintenance of the building(s). This way, the customer does not have to sign different contracts to solve different needs. The integrated service is a turn-key solution that is simpler for the customer as it is an all-in-one solution that is more economic to the client. Getting a solid vision of the integrated service requires a consistent build-up of the different components that comprise it. As a matter of fact, the service as an offer is only an image of all the backend work that has been developed. So, after we define who are the different actors on the system, the next step is to explain the connections between them and how they establish the different individual priorities within this backend system. Finally, after having explained how the backend will work, it is time to provide the holistic view over the offer.
This analysis will allow an improved understanding and clear identification of the actors with the most relevance for the new EPC concept, and how these can cooperate for offering an integrated service and a profitable business case.

The approach will consist on building the relations and interactions between the different actors of the system and, then, progress to define the integrated service and its main offers.
The goal of this analysis is to explain how the integrated service will work and provide support to the business plans to be developed, while explaining the relations and interactions between the different actors.

## 2.1. INTERACTIONS BETWEEN THE DIFFERENT ACTORS

### 2.1.1. ACTOR CHARACTERISATION

In Table 1, the different actors of the AEPC system are being characterised. For each one, a description is provided and their role explained.

**TABLE 1 AEPC ACTORS (IN ALPHABETICAL ORDER)**

| Actor | Description | Role |
|---|---|---|
| **Aggregator** | Service provider which can increase or moderate the electricity consumption of a group of consumers according to demand on the grid | • Bundles flexibility to engage as a single entity in power or services markets,<br>• Tracks customers' consumption and DSO requirements in real time,<br>• Compensates customers for the offered flexibility. |

| | | |
|---|---|---|
| **Energy Auditor** | Ensures the fulfilment of the contract obligations | • Audits existing buildings and installations,<br>• Determines investment scenarios and estimates investment and maintenance costs,<br>• Estimates and calculates energy savings and flexibility cost savings,<br>• Provides audit reports, incl. calculated KPI's, like payback times, IRR and NPV |
| **Contractor** | Companies responsible for establishing delivery, installation of maintenance contracts with ESCOs | • Provide delivery, installation and maintenance contracts |
| **Distribution System Operator (DSO)** | Operates the distribution system of electricity/gas | • Operates the distribution system in a certain area,<br>• Ensures maintenance and development of the distribution system in a certain area,<br>• Ensures interconnections with other systems to meet demand and supply for the distribution of electricity/gas,<br>• Requests flexibility in case of need for Explicit DR. |
| **Energy supplier** | Company responsible for providing energy (e.g. Electricity, gas, fuel...) | • Provide energy,<br>• Define tariffs that can be dynamic or time-of-use tariffs. |
| **End-customer** | The end-customers can be building occupants, building owners, associations of co-owners (ACO) of apartment buildings and building managers | • Exploits the functionality of the building,<br>• Owns energy efficiency technology,<br>• Invests in energy and cost savings,<br>• Possibly accepts comfort and flexibility constraints according to contract definition,<br>• Pays AEPC fees |
| **Engineering Company** | Designs and engineers energy efficiency and renewable energy measures | • Designs technological solutions for energy efficiency and renewable energy,<br>• Dimensions installations and provides detailed engineering and as-built documents,<br>• Coordinates installation of equipment |
| **ESCO** | Provides energy services | • Provides the AEPC,<br>• Subcontracts audit/design/installation/ maintenance if necessary |

| | | |
|---|---|---|
| **EPC Facilitator** | Facilitates the relationship between the different actors of the eco-system | • Links costumer to the ESCO or other relevant stakeholders,<br>• Follows and advises the customer,<br>• Prepares and coordinates tendering and intermediates |
| **Financier** | Player that finances the investment, typically a Financial Institution (FI) or bank. Can also be an investment fund. | • Provides the credit for the investment |
| **Policy makers** | Responsible for developing legislation | • Policy makers influence the path towards a cleaner, less centralised and more intelligent energy system by developing favourable legislation,<br>• Drive green investment with financial schemes and incentives |
| **Maintenance Company** | Responsible for the operational processes of delivery, installation and maintenance of equipment | • Deliver, install and maintain ESCO's and Customer's assets |
| **Regulator** | Responsible for the regulation of electricity/gas sectors | • Protects the rights of energy consumers,<br>• Balances the interests of the main groups in the energy system, mainly electricity system stakeholders and consumers |
| **Technology Provider** | Develops and provides technological solutions, used in the building | • Analyses technological needs,<br>• Designs and tests technology solutions,<br>• Sells and potentially replaces (in case of default) and improves the technology solutions |
| **Transmission System Operator (TSO)** | Controls and Operates the Transmission system of the electricity network (typically 220kV and 380 kV) | • Monitoring and control of the grid topology and the voltage in all parts of the transmission grid,<br>• Managing security of supply and balancing the network,<br>• Contracting of ancillary service providers by determining the required control reserve capacity,<br>• Calling the reserves when needed |

### 2.1.2. ACTORS RELATIONS

In the scope of the model being proposed for an AEPC contract, the correspondent process for an AEPC contract will follow closely the same model of a traditional EPC. Revisiting this process is important to understand how each actor relates to others in terms of risks and responsibilities and how can these relations guarantee efficient contract economies.

The ESCO should be responsible for performing an analysis on the customers' site, by quantifying saving opportunities, as well as prices and economy exposure, with the objective of defining the business model of mutual benefit in which the contract will be settled. Based on this quantification, the ESCO defines a baseline through which future savings will be calculated. Then, the ESCO should perform an analysis on the risks to be included within the contract.
In parallel, all the necessary subcontracting for creating a plan for installation and Operations and Maintenance should be included as well as all the Service Level Agreements to be offered, including the guarantee on energy and cost savings. Finally, the contract should be executed which implicates, not only the installation and maintenance, but also all the measurement and verification necessary for reporting and for guaranteeing that savings' performance is being delivered. By integrating DR in the contract, the ESCO will assume a more active role in what the contract management is concerned. For this matter, the ESCO will have to be responsible of providing the means for the customer to trade flexibility on the market based on the existing technical possibilities and on what the customer is willing to accommodate. This means that the ESCO should be responsible of providing the algorithm and the automation that could govern the DR and then the customer acts on the market via an aggregator, having the responsibility of sharing the profits obtained. Also, the ESCO can take the role of the aggregator, as an energy supplier, this way assuming a greater responsibility in the process. In conclusion, the ESCO could mainly act either as an actuator or as an aggregator in what DR is concerned, depending on how this service is offered. The way in which this service is offered is further detailed in the following section.

Figure 1 describes the eco-system of the different stakeholders of the AEPC service, referred above, from a business point of view. The first ellipse shows the core stakeholders that are directly involved in the AEPC services delivery. The second ellipse shows those stakeholders that are more generally involved in the ESCO business and in delivering EPC or other Energy Contracting services. The final outer ellipse shows a third range of stakeholders that are only indirectly involved or influence the activity of the first two categories of stakeholders.

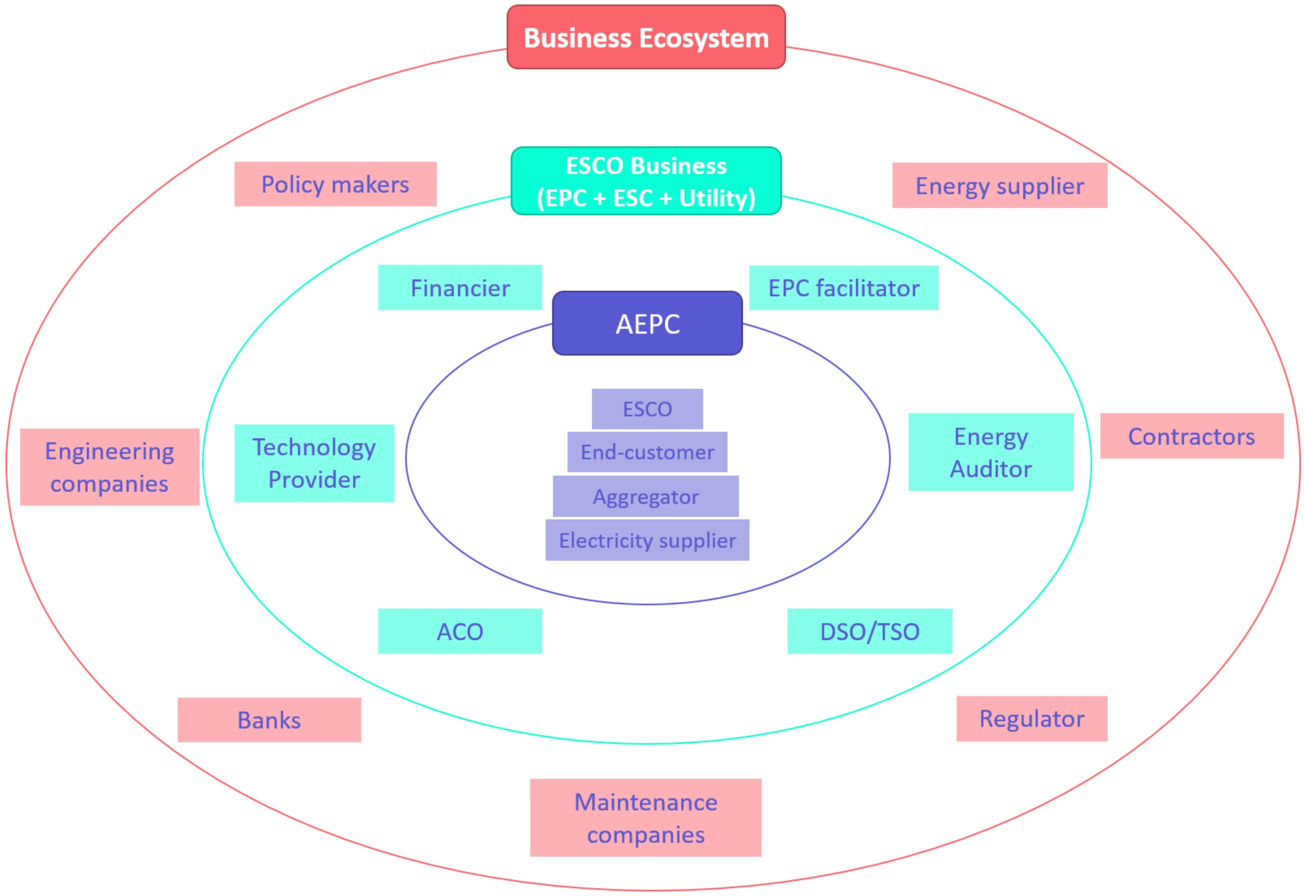


**FIGURE 1 AEPC MOST RELEVANT STAKEHOLDERS' BUSINESS ECO-SYSTEM**

Apart from the stakeholder involvement in the eco-system described above, all the responsibilities and important risks must be taken into account and be well detailed in the contract. For a summary of those, please refer to Table 2.

Typically, the customer should answer for non-predicted changes to the baseline and improper use of equipment. To mitigate the later, the users must understand the importance of each measure and rule established for the AEPC. For that, users should be included in the AEPC process since its beginning, and also awareness and training sessions should be provided to them. The risk of energy prices cannot be controlled by any of the involved parties, and the contract should set how energy prices are predicted to evolve during the contract duration. However, usually this risk stays with the customer.

As for ESCO's risk responsibilities, it absorbs all the technical risks related to the equipment and poor quantification of objectives (seeTable 2). The ESCO should be responsible for ensuring the best possible alignment between customer and subcontractors in order to partially mitigate the risks described in Table 2

In addition, there are other force majeure risks that are not the responsibility of any of the parties in particular.

TABLE 2 RISKS OF AN AEPC AND THE AGENTS RESPONSIBLE FOR THEM

| Risk category | Risks |
|---|---|
| Client | Risk of changes to the baseline,<br>Improper use,<br>Market risk (incl. Price risk) |
| ESCO | Equipment,<br>Malfunctions,<br>Engineering defects,<br>Defects of reference calculation,<br>Poor quantification of objectives,<br>Poor maintenance,<br>Poor performance or deficient time to correct anomaly,<br>Poor sizing |
| Force majeure risks | For example, COVID-19 |

## 2.2. INTEGRATED SERVICE

We will describe the main options that can be applied for services, monitoring and contracts. After a simple overview of the options, it will be pointed which ones are best suited to an integrated AEPC.

The offer may be divided in three relevant types of services in which the entity responsible for the AEPC may act as: (i) a consultant, when it provides relevant information to a third party that actuates the customers' assets and receives the added value of the shared knowledge; (ii) an actuator, when it actuates directly with the customer according to certain assumptions or collected data; (iii) an aggregator, when it goes to the market with the customers' flexibility assets. These services bring different levels of risk, which should be taken into account when choosing the type of contract to be performed.

An AEPC contract may follow similar structures as the traditional EPC, which can be described as one of the following: (i) third-party financing, here, the financing entity shares guarantees back-to-back with ESCO; (ii) fast-out contract, an economic target is established and the contract typically ends when its goal is achieved; (iii) utility sales, it applies when an entity sells a service at a certain price ensuring its quality and its contracted characteristics (e.g. an electricity contract with a defined contracted power and at a given price per kWh), in this case the market risk is absorbed by the seller.
Based on the contract models that have been described, measure and verification should follow the International performance measurement and verification protocol (IPMVP)[1], that defines the standard terms and practices for energy efficiency and, also, demand side management. Within the options provided in the protocol, option C, or even option D for the cases of unreliability of the baseline definition, are the more appropriate options for Measurement and Verification (M&V) under the execution of a contract of

[1] https://evo-world.org/en/products-services-mainmenu-en/protocols/ipmvp

this type. Options A and B would be more appropriate for M&V under equipment retrofitting related to energy efficiency programs, whereas options C and D are specifically designed to whole facility performance monitoring. Option C requires the use of utility meters, whole-facility meters, or sub-meters to assess the energy performance of a total facility. This option calculates the total savings of the measures applied to the part of the facility monitored by the energy meter. Routine adjustments are made, as required, using techniques such as simple comparison or regression analysis. Option D could also be considered as it still applies to whole facility monitoring but differs from option C because it involves energy consumption and demand simulation, calibrated with utility billing data. Also, energy end-use metering data may be used in the model adjustment.

Even though monitoring is critical for an AEPC to control and manage the contract and its revenues, it can also be one of its biggest handicaps. The complexity of measures and variables to monitor can easily escalate the transactional costs to a level that it may offset the savings and benefits obtained.
In the case of an AEPC, which considers complex and hardly predicted transactions, the benefits collected are strongly dependent on the fluctuations of the energy market. Given this unpredictability, the most suitable type of contract to apply when integrating flexibility is the fast-out model. It is one of the most flexible contracts that may predict mechanisms to exit the contract when achieving the defined target or mechanisms to extend the contract duration until the target is met. In a fast-out contract, there are two main variables that may be adjusted according to the benefits that are being gained: time duration and share of savings. For the time duration, there are two scenarios that can change the pre-established contract duration: (i) the target benefit is achieved earlier than expected and the contract ends or the parties agree to share the extra benefits until the end of the contract; or (ii) the benefits are lower than expected and the contract may be extended to a maximum cap defined in the contract, which should be indexed to the useful lifetime of involved equipment. As for the share of savings, it may also be adjusted according to the real savings and its maximum cap should be 100%.

Finally, after having explained how the backend will work and how the different options for the contracts and services are, it is time to provide the holistic view over the offer.

Compared to the traditional EPC, the AEPC integrates flexibility valorisation. In the case of explicit demand response, customers adjust their consumption to market fluctuating prices, instead of paying a fixed price per kWh. This requires the use of an Energy Management System (EMS) to control equipment. Therefore, the integrated offer would have to include an EMS. The EMS would automatically take the best decisions in terms of energy flows and periods for consumption for a certain customer. From the customer side, this one must have a certain percentage of load that is controllable and that can be adjusted according to signals from the DSO. This percentage can be one of the requirements that can be used to check if a client has the right profile for an AEPC. A battery system can also be part of the controllable load and can enhance greatly the flexibility offered by a client by choosing to buy from the grid at a certain moment and consume later when prices are higher. Or decide which option is better at a certain moment for the PV production: consume, sell or store? Therefore, a battery system has a great potential to be included in the integrated offer of the AEPC.

Furthermore, the AEPC intends to capitalise on advancements on fields like Internet of Things, Artificial Intelligence and Distributed Energy Resources to create new integrated services (comfort, energy, health, mobility) for building managers and tenants, improving efficiency and enhancing flexibility.

AEPC contract structure will be sold through a customer visible structure, which might be virtual or physical. To support it, it should exist a complex operation behind, that propels the delivery of the contracts. Therefore, the integrated service is when the system functions are based on these coordinated structures.

To build the physical side of the AEPC sales operation, a dedicated team on the ESCO's structure should work as the product promoters to the client. This team will be the main ambassador of the AEPC, since they already have the relationship with the client and the individual energy services knowledge that now are presented in a holistic package that may bring cost benefits, due to the horizontal integration of operations. For B2B (business to business) customers, the sales operation will rely mainly on the relationship the client managers hold with their customers and the cost or environmental benefit that they perceive from AEPC. For B2C (business to consumer) customers, the sales operation will rely more heavily on marketing, advertising or door to door sales.

On the virtual side, the ESCO may decide to do the technological operations and externalize the delivery or part of it. This decision will be based on the company strategy in terms of long-term technological development. Nonetheless, whatever the approach, this platform would be a game changer in terms of sales, since it might reduce physical sales costs and effort. Moreover, it could boost the virality of the product, since each satisfied customer could be an indirect point of sales to a potential one.

Finally, the sales process could only be successful with a seamless integration to the already described AEPC structure. The different actors should already be defined and with frictionless relationships between them, so that the delivery capacity could scale with the product interest. Regarding core services to be part of the AEPC contract, the following will be considered:

- Cost Saving (Optimise consumption through metering, Efficient Lightning, etc.);
- $CO_2$ savings;
- Demand Side Management.

# 3. AEPC BUSINESS MODELS

## 3.1. INTRODUCTION TO THE BUSINESS MODEL

The Business Model is a description of how an organisation's activity is set-up with partners and/or stakeholders to create value by delivering (and sourcing) service or product offerings to customers, while identifying financial flows between parties.

In the case of AmBIENCe, the AEPC Business Model includes two elements

- That of a traditional EPC Business Model (i.e. delivering guaranteed energy savings, often combined with maintenance and other services, against a fee consisting of one-off or periodical payments that cover the investments and operational costs made by the ESCO. This includes various financing options. Typical measures that are implemented under EPC contracts are replacement of boilers, roof insulation or LED lights, but basically all energy saving measures and/or renewable energy production installations (e.g. PV solar or biofuel fired Combined Heat and Power) can be included.
- That of the Demand Response service, generating a guaranteed cost saving in return for accepting a certain flexibility of building and equipment use and/or comfort levels. Focus lays on energy cost savings made possible by the introduction of more complex tariff structures featuring dynamic prices, injection fees (i.e. no net-metering) and capacity tariffs. With these, the time period, i.e. "WHEN", building users are consuming energy becomes increasingly more important and can have a large impact on their energy cost. An example of the use of flexibility is a Heat Pump that is used to heat domestic hot water at the time when the cost and/or carbon intensity of the electricity is lowest, combined with maximizing the auto-consumption by the Heat Pump of the green electricity produced by PV-panels. The business model has some small variations depending on whether it integrates explicit or implicit demand response.

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.
In the section below, we propose a taxonomy of AEPC business models based on configurations per building/type of beneficiary and based on implicit versus explicit DR.

## 3.2. AEPC BUSINESS MODEL DRIVERS

Before defining the business model, it is important to understand the underlying drivers that define why and how the AEPC model adds value to the traditional EPC model, but may also introduce some more drawbacks.

A first element that changes when adding flexibility to energy efficiency is the uncertainty related to Demand Response incentives and opportunities. With traditional EPC, the kWh savings are relatively predictable and either related to technological improvements (e.g. a condensing boiler with a better efficiency than an old atmospheric boiler or an LED lamp with a lower power for an equivalent lighting level), to regulation and recommissioning for which experience allow to estimate more or less accurately the energy savings potential up to actions to influence behaviour that also will allow for some predictable savings based on previous experience, but with much less accuracy. Measurement and Verification methodologies (e.g. the ones based on the IPMVP protocol) allow to measure relatively accurately the real savings against the guaranteed savings, using the appropriate method of defining a boundary around the measurements and taking into account the amount and type of parameters that are measured or rather calculated or assumed. M&V in traditional EPC will take into account routine correction factors (like changing weather conditions or building occupation) and non-routine correction factors (like change in building use or unexpected works outside of the contract).

However, adding demand response to the equation introduces new levels of uncertainty related to the level of available flexibility that can be captured. This effect operates at 2 levels: 1) the number of occasions where flexibility is being requested and 2) the amount of cost savings that these demand response events allow to generate, in particular when prices are highly dynamic. Managing demand response based on the carbon intensity of the energy vector, in a dynamic market, will only make things more complicated as renewable energy prices may vary significantly over the measurement period of the contract. In any case, in most EPC projects, a measurement period of one year is being used, whereas the measurement period for AEPC may need to be shorter in order to take into account short term demand response events. Overall, the flexibility valorization potential is more difficult to capture and to measure.

The behaviour-related aspects in classical EPC, are determined by fixed boundary conditions (e.g. comfort set points) and “standard” behaviour patterns (e.g. hot water consumption, not opening windows in the winter, etc.). Although this occupant behaviour may deviate somewhat from what is expected, many elements can be fixed in the contract to eliminate risks for the ESCO. The ESCO will be allowed to fix the comfort levels manually or automatically as agreed in the contract or intervene when users go outside of the comfort set points. Similarly, the ESCO can intervene manually to close windows that are left open or even install special locks that do not allow for users to open windows inadvertently.

The way demand response is handled in AEPC differs whether this demand response is explicit or implicit. If it is explicit, it will be based on explicit requests either directly to a customer or (more often) via an aggregator who valorises the flexibility by offering it to a DSO or TSO. The latter will pay for the flexibility that is offered to him during this demand response event. So, the aggregator and the DSO play a key role in the explicit AEPC business model. As a matter of fact, the ESCO may very well play this role of a (technical) aggregator of explicit DR.

If demand response is implicit, there is no direct link between the customer and the DSO/TSO, nor an indirect link via an aggregator. The flexibility is handled between the ESCO and the customer and is driven by the dynamic pricing structure that is delivered by the electricity supplier. The ESCO may itself deliver the electricity or manage local electricity production facilities on-site. Thus, also the optimization of auto-consumption (e.g. from solar panels) or local storage (via fixed batteries or batteries in electric vehicles) is intrinsically part of the flexibility valorization in the building of the customer.

The level of uncertainty that is being introduced by the flexibility will be higher in case of a manual control of the equipment than in case of the use of automated control, e.g. via a Building Management System (BMS). This may influence the capacity of the ESCO to deliver performance guarantees on the flexibility part of the service. Effectively, the higher the risk for the ESCO, the more difficult to offer performance guarantees. At best, these performance guarantees may come with a risk premium and thus lower somewhat the financial return for the customer.

In all cases, the ESCO will deliver the BMS and will have control of the management of the flexibility. Contractually agreed parameters and boundary conditions will be able to be automated by the ESCO, improving the capacity to provide guarantees. The BMS and energy monitoring tools will also allow to provide data for Measurement and Verification. Linking the BMS algorithms to those used in a performance simulation tool like the one developed in the scope of the AmBIENCe project will likely increase the level of predictability.

Therefore, as performance guarantees are a key feature of EPCs, also in case of AEPC, the capacity to provide guaranteed costs savings on top of guaranteed energy savings will be key in the business model. Having the appropriate M&V methodologies to determine these cost savings will be essential. Most likely this will require particular attention to the price structures and levels that are agreed upon in the AEPC contract. As a matter of fact, in classical EPC prices are often fixed in the contract, based on historical prices. Thus, the risk of price evolution remains with the customer. As dynamic prices are part of the AEPC business model, this will likely not be the case anymore in AEPC.

In case of explicit DR applied to the AEPC Business Model, the contract needs to include the conditions under which the ESCO can request flexibility. These can be limited by deviations from standard comfort conditions or agreed impact on usage of the equipment on-site. Likewise, in the AEPC contract both parties need to make clear and transparent arrangements about the rules that apply to Demand Response triggered events. The contract may probably require penalty clauses in case of non-respect of the agreed rules.

## 3.3. AEPC BUSINESS MODEL DESCRIPTIONS

This section presents the AEPC Business Model and a number of variations, based on the Building sector or type, the occupation model, the type of Demand Response (DR) applied and the Owner/Tenant relation, as described in Table 3.

The table should be read from left to right, where each column entry corresponds to one or more possible options for each variation parameter in the column headings. If a given cell spans different entries on the left or the right side, this means that the combination is feasible. E.g. both commercial and public buildings can be occupied by “individual” (single or multiple) tenants only, without there being a “collective” occupation model that influences the Business Model. So, from a business model point of view, it does not matter whether there is only one or multiple occupants. They all have a 1-to-1 relation with the owner. Whereas for residential buildings (private or social housing) there are two options: individual occupation (typically a single-family house) or collective occupation (an apartment building with multiple apartment units). These can be occupied by owner occupants or tenant lessees. This is a collective occupation model with a many-to-many relationship. Also, in the case of social housing there are individual occupation models and collective ones. The individual ones will typically involve multiple houses in a social neighbourhood.

Distinction is made between implicit and explicit Demand Response and - in particular for explicit DR - different variations of how the ESCO acts as an aggregator or alternatively interacts with other aggregators or directly with the requesters of flexibility.

Some Business Model variations will apply to different types of buildings. This will be indicated in the summary table at the beginning of each BM variation description.

In all the Business Model variations there can also be different financing options. The first financing option for the end customer is to use own funds. A second option is ESCO financing. A third option is financing by a bank or financial institution, also called FI financing. Where relevant, options 2 and 3 will be distinguished. Option 1 will not be depicted since it is very basic and does not involve any external stakeholder, even though it is a rather common option today. A mix of 2 or 3 of these financing options is also possible. However, this particular case will equally not be described for reasons of simplicity.

**TABLE 3 BUSINESS MODEL VARIATION PARAMETERS**

| Building type | Occupation model | Type of DR | Owner/Tenant relation | Financing |
|---|---|---|---|---|
| Commercial building | Individual | Implicit<br>Explicit | Owner occupier<br>Owner lessor & tenant (lessee) | ESCO financing<br>FI Financing |
| Public building | | | | |
| Residential building | Individual<br>Collective (ACO) | | | |
| Social housing | Individual<br>Collective | Implicit | Owner lessor & Social Tenant | ESCO financing<br>Umbrella Organization Financing |

The details for each of the AEPC Business Model variations are described in the following sub-sections, highlighting the parameters from Table 3 that apply to each model, via a table at the start of each section. The tables will not be referred to specifically each time. The first model is the most generic and simple one, the following ones are more specific as they take into consideration different building types, occupation models, owner/tenant relations or financing options. We can however always find back the structure of the generic one in these more specific models.

### 3.3.1. AEPC BUSINESS MODEL – VARIATION A.1 (GENERIC MODEL – IMPLICIT DR)

TABLE 4 CONFIGURATION FOR VARIATION A.1 (GENERIC MODEL – IMPLICIT DR)

| Variation | Building type | Occupation model | Type of DR | Owner/Tenant relation | Financing |
|---|---|---|---|---|---|
| A.1 | Commercial building | Individual | Implicit | Owner occupier | ESCO financing |
| | Public building | | | | |
| | Residential building | | | | |

In this generic AEPC 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 – to an end customer. This is the main difference between EPC and AEPC. In case of EPC, it is energy savings (kWh) that are being guaranteed and they are typically multiplied by a contractually agreed (average) energy price. This is done for each energy vector (electricity, gas, fuel, etc.). In the case of EPC, because of the more dynamic pricing, the business model is about providing cost savings. These cost savings will come partially from energy efficiency, partially from flexibility, but in particular the flexibility contribution will aim at delivering cost savings, not necessarily energy savings. The way to measure these cost savings will thus also differ from the pure energy consumption savings. Underlying $CO_2$ savings will in both cases be a secondary or even primary driver. Active control of the flexibility is a key factor of AEPC. Without it, we cannot consider it as an AEPC model.

The beneficiary is typically the owner-occupier of a commercial, public or individual residential building, who will reimburse the ESCO for the energy efficiency investment through an annual payment, including interests and a periodically calculated payment based on the cost savings that are being generated via the flexibility.

The ESCO also provides maintenance and other services (e.g. energy management, energy monitoring) against a periodical operational fee.

A key aspect of any EPC is the guarantee mechanism that applies to the savings. There are two mechanisms: Guaranteed Savings and Shared Savings. Guaranteed Savings imply that the ESCO provides an absolute guarantee on the energy savings as compared to a baseline consumption, e.g. 30%, including a bonus/penalty scheme in case of under or overperformance. Shared Savings imply that the ESCO and the customer agree on a fixed (and thus guaranteed) share (e.g. 60% for the ESCO/40% for the customer) of retribution of the savings amount, however without establishing upfront how many savings will be achieved. The risk/reward balance is thus different between both mechanisms. In Europe, the Guaranteed Savings model is more common, whereas in North America for example Shared Savings contracts are quite common. Variations of performance contracting that are based on aaS (as-a- Service- models, like Comfort-as-a-Services (CaaS) or Light-as-a-Service (LaaS) use other but similar guarantee mechanisms, that are more related to Energy Supply Contracts for heat, cold or some other form of useful energy.

As Guaranteed Savings is by far the dominant model for EPC in Europe, we will focus our Business Model and the descriptions of guarantees within them, on this model. In any case, the fundamental business model does not change with the risk sharing model, even though the way risks are managed and rewarded will have some impact on the cashflows that will be generated. In other words, it may affect the specific business case.

The guarantee mechanism offered through an EPC contract, and the same holds for an AEPC contract, will typically include a penalty in case of underperformance (often 100% of the non-achieved savings) and a bonus in case of overperformance (typically 50%, sometimes up to 80%) of the additional savings.

The ESCO may use a wide array of subcontractors for part or all of the technical elements of the project, including audits (by auditors), design and engineering (by engineering companies), delivery and installation (by contractors) or insulation works (by other contractors). Some focus on audits, others on the design, others on implementation and still others on maintenance. The impact of using subcontractors will only be on the margin for the ESCO and on risk allocation and management between parties in the ESCO consortium, if these subcontractors agree to carry some of the performance risk.

Demand Response in this generic case is implicit, involving only the electricity supplier who supplies electricity based on dynamic tariffs. These tariffs may contain costs that are determined by the DSOs or TSOs network cost components, but the contract conditions and the prices will be part of the Energy supplier's contract. The performance guarantee extends to the cost savings that are delivered through this flexibility within the usage and comfort boundaries defined in the contract. The flexibility potential can be improved by the electrification of the heat demand, typically via the replacement of the existing gas or fuel fired boiler by an electrical heat pump. The investment will typically also include the installation of PV panels, to provide green electricity to the building, thus reducing the off-take from the grid and the overall $CO_2$ emissions.

In this generic Business Model, the ESCO also provides pre-financing of the Energy Efficiency and DR investments, which are being reimbursed by the owner over the duration of the contract, sometimes over a shorter or longer period. The ESCO would typically refinance itself for the investment through a financier, that is typically also a financial institution or an investment fund.

This AEPC Business model is an improvement of the classical EPC or Maintenance and Energy Performance Contract (M-EPC) business model with the flexibility potential being added, allowing – in combination with the electrification potential – to potentially improve the overall ecological and economical value. This would allow for climate-neutral or deep energy renovations, by increasing the renewable electricity share and benefiting from the flexibility-induced cost reductions, while lowering the need for a higher degree of insulation.

The customer may hire the services of a facilitator to accompany him/her throughout the project with expert advice, against the payment of a facilitation fee. Some customers will consider this facilitation fee as a sunken cost (I.e. that will anyway need to be paid). Others will integrate this fee in their business case, meaning that they will ideally also want to recover them via the savings. Facilitation fees could be spread over the contract period or pre-financed by the Facilitator, although this is not at all common today.

The following Figure 2 shows an overview of the Generic AEPC Business Model. For ease of representation and since this does not change for this and all other variations, the facilitator of the client nor the subcontractors of the ESCO will be shown anymore in the schemes of the rest of the variations.

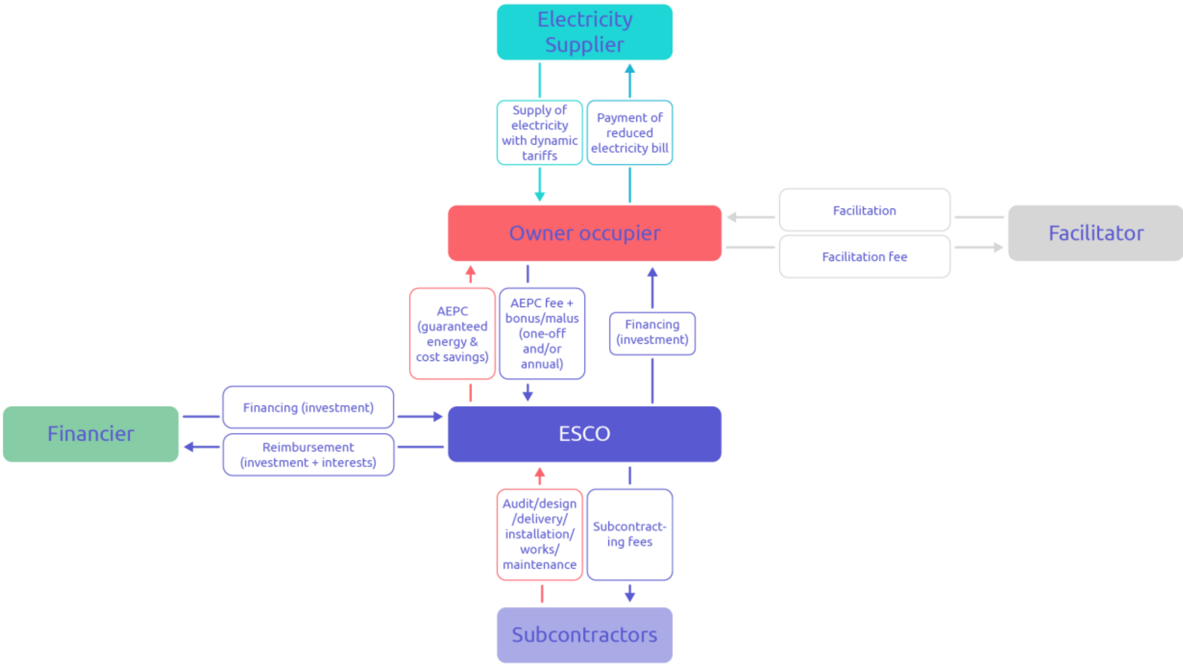


**FIGURE 2 GENERIC AEPC BUSINESS MODEL WITH IMPLICIT DR AND ESCO FINANCING**

In addition to the implicit DR that is described here, there is also the possibility to use explicit DR, in various ways. The variations are described in the following paragraphs.

### 3.3.2. AEPC BUSINESS MODEL – VARIATION B.1 (EXPLICIT DR – VIA AGGREGATOR TO CUSTOMER)

**TABLE 5 CONFIGURATION FOR VARIATION B.1 (EXPLICIT DR – VIA AGGREGATOR TO CUSTOMER)**

| Variation | Building type | Occupation model | Type of DR | Owner/Tenant relation | Financing |
|---|---|---|---|---|---|
| B.1 | Commercial building | Individual | Explicit (Aggregator to Customer) | Owner occupier | ESCO Financing |
| | Public building | | | | |
| | Residential building | | | | |

In this variation, the ESCO implements EE measures, including equipment that allows for flexibility, but the DR service is delivered directly by an external aggregator that aggregates flexibility from different customers towards the flex requestors (typically DSO/TSO's or possibly a BRP). This is what is called "explicit" DR, in which each DR event is the object of a specific "explicit" (manual or automatic) request and a corresponding payment. This can happen when an ESCO wants to add DR services to his current (classical) EPC contract or when starting to offer a basic AEPC, while partnering with an existing aggregator who is active in the industrial market. The case where there is already an existing building DR aggregator is possible, but less likely.

In this case, the role of the ESCO is just to provide the technology and manage the availability of the equipment and active control software, but the explicit DR contract (incl. the service level agreement) is typically signed between the Owner occupier and the Aggregator. Therefor the AEPC service depends on the collaboration between the ESCO and the Aggregator in the design and operational phase. This collaboration can be the basis for a number of more advanced business model variations, in which the ESCO takes on an increasingly important role in valorising the flexibility at the customer premises, as described in the following paragraphs.

The aggregator provides this flexibility to a DSO/BRP/TSO who is willing to pay certain fees for the use of flexibility. The goal of the DSO/BRP/TSO is either to balance the network, deal with network congestion and or avoid or optimize infrastructure investments. Balancing can be either portfolio balance (role of the BRP) or real time balancing (role of the DSO/TSO). Thus, the DR services will need to be more predictable or available at request and more event driven. Providing a guarantee on the flexibility-based savings may therefore turn out to be more complicated or at least “conditional”. The condition to trigger the DR services will require specific clauses and price arrangements in the contract, and agreements on consumption baseline practices for DR activation settlements.

As the DR events are triggered by requests from the DSO/TSO and managed by the Aggregator, they may impact the energy and/or cost savings that have to be guaranteed by the ESCO as part of the EPC. Thus, clear boundaries need to be established between savings measures coming from all parties and clear agreements need to be established between the ESCO and the customer and/or Aggregator about how to account for both types of savings (EE versus flexibility).

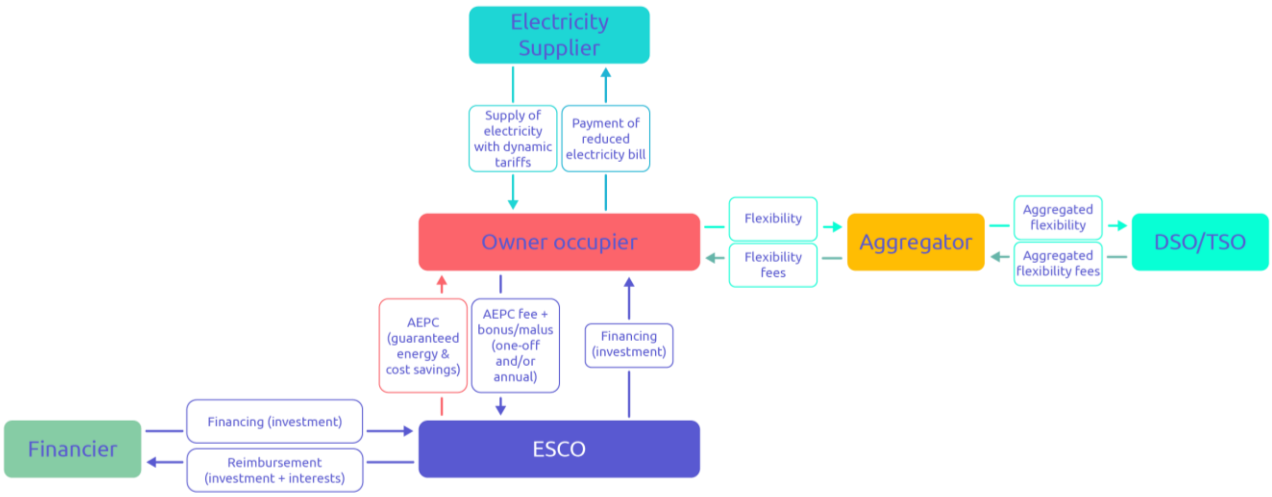


**FIGURE 3 AEPC BUSINESS MODEL WITH EXPLICIT DR DELIVERED VIA AN AGGREGATOR TO THE CUSTOMER**

### 3.3.3. AEPC BUSINESS MODEL – VARIATION B.2 (EXPLICIT DR – VIA AGGREGATOR TO ESCO)

**TABLE 6 CONFIGURATION FOR VARIATION B.2 (EXPLICIT DR – VIA AGGREGATOR TO ESCO)**

| Variation | Building type | Occupation model | Type of DR | Owner/Tenant relation | Financing |
|---|---|---|---|---|---|
| B.2 | Commercial building | Individual | Explicit (Aggregator to ESCO) | Owner occupier | ESCO Financing |
| | Public building | | | | |
| | Residential building | | | | |

A first obvious evolution of the previous business model is the one where the ESCO substitutes the customer as the contact and contractual party for the aggregator of the (explicit) DR. This not only allows the ESCO to create an integrated service and a single AEPC contract, but it also allows the aggregator to benefit from the potential of ESCO to start pooling flexibility across different buildings and different customers. This will improve the aggregator's aggregating capacity and allow him to reduce the number of contractual partners. On the other hand, he will lose some control over the end customer which could represent a barrier to implement this model from a commercial and strategic point of view. This may be compensated by the opportunity of more strategic cooperation with ESCOs, access to a large existing ESCO market and economies of scale.

Figure 4 provides the graph that describes this variation of the Explicit DR model.

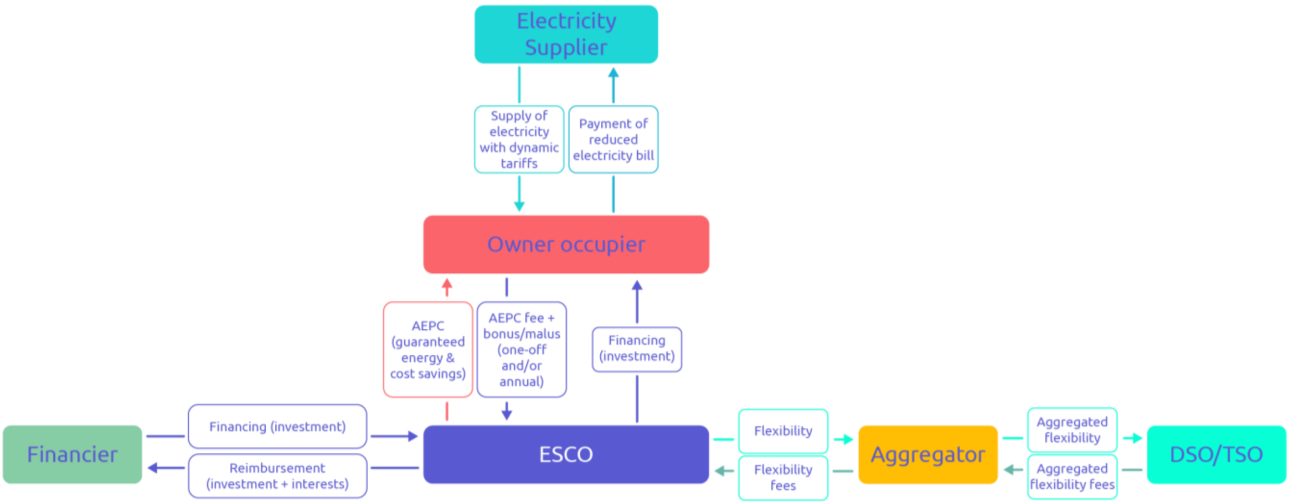


**FIGURE 4 AEPC BUSINESS MODEL WITH EXPLICIT DR DELIVERED VIA AN AGGREGATOR TO THE ESCO**

### 3.3.4. AEPC BUSINESS MODEL – VARIATION B.3 (EXPLICIT DR – VIA MARKET AGGREGATOR TO ESCO ACTING AS TECHNICAL AGGREGATOR)

**TABLE 7 CONFIGURATION FOR VARIATION B.3 (EXPLICIT DR – VIA MARKET AGGREGATOR TO ESCO ACTING AS TECHNICAL AGGREGATOR)**

| Variation | Building type | Occupation model | Type of DR | Owner/Tenant relation | Financing |
|---|---|---|---|---|---|
| B.3 | Commercial building | Individual | Explicit (ESCO as Technical aggregator) | Owner occupier | ESCO Financing |
| | Public building | | | | |
| | Residential building | | | | |

The ESCO integrating the DR into what becomes a true AEPC service, adds value to all stakeholders. However, the simple pooling or bundling of flexibility does not allow for the optimization of the flexibility across the ESCO's portfolio of multiple customers and multiple buildings. By developing and offering solutions that (technically) aggregate the flexibility and align the full capacity, he can optimise the Demand Response towards the flex requesters (DSO/TSO and potentially BRP). This role of Technical aggregator is an interesting add-on to the Business Model.

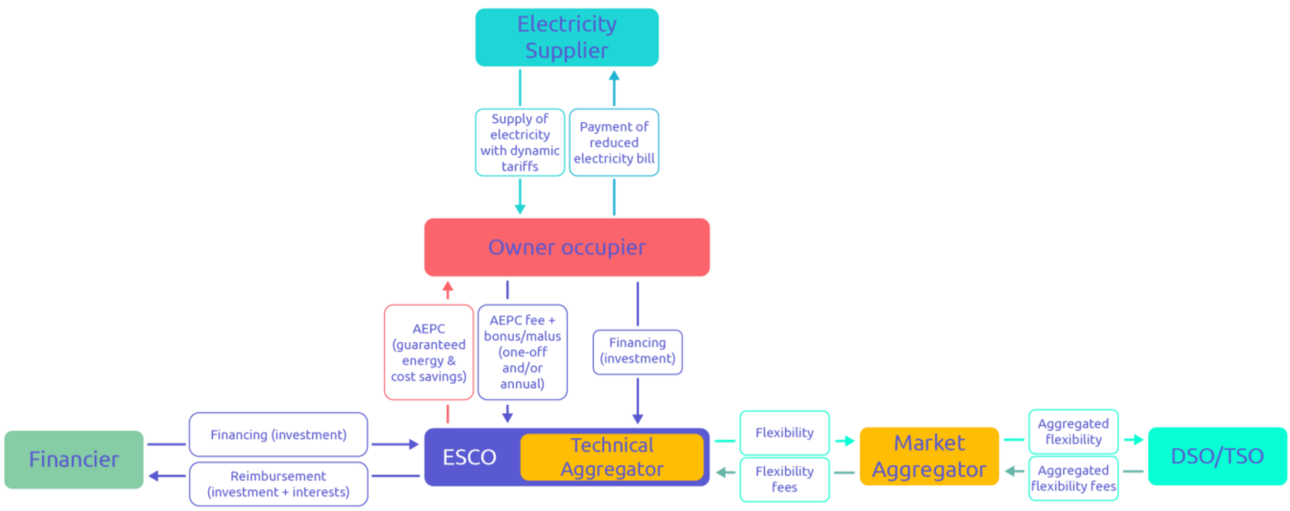


**FIGURE 5 AEPC BUSINESS MODEL WITH EXPLICIT DR DELIVERED VIA A MARKET AGGREGATOR TO THE ESCO ACTING AS TECHNICAL AGGREGATOR**

In Figure 5, this variation is described showing the role of the ESCO as technical aggregator and the role of what is now more of a market aggregator to sell this flexibility to the DSO/TSO. Technically, the ESCO has the control of the Building Energy Management System (BEMS) and the software to do the active control at the request of the flex requesters, via the Market aggregator. This variation of the model is likely to increase collaboration in the market between existing aggregators and ESCOs in a common approach to AEPC. This increased attractiveness of the flexibility to those who request it, may also improve the interest for the customer as the flex requester is likely to pay a better price for it. It also increases the likelihood to reach a minimum critical level to get the DSO/TSO's interested in the first place.

### 3.3.5. AEPC BUSINESS MODEL – VARIATION B.4 (EXPLICIT DR - ESCO ACTING AS AGGREGATOR)

**TABLE 8 CONFIGURATION FOR VARIATION B.4 (EXPLICIT DR - ESCO ACTING AS AGGREGATOR)**

| Variation | Building type | Occupation model | Type of DR | Owner/Tenant relation | Financing |
|---|---|---|---|---|---|
| B.4 | Commercial building | Individual | Explicit (ESCO as Aggregator) | Owner occupier | ESCO Financing |
| | Public building | | | | |
| | Residential building | | | | |

In this variation, the ESCO implements explicit DR and sells it to the flex requesters. This means that the ESCO plays itself the role of the aggregator and explores and manages the flexibility potential at the customer's building site(s). The ESCO provides this flexibility directly to a DSO/BRP/TSO who is willing to pay certain fees for the use of flexibility. The goal of the DSO/BRP/TSO is either to balance the network, deal with network congestion and or avoid or optimize infrastructure investments. Balancing can be either portfolio balance (role of the BRP) or real time balancing (role of the DSO/TSO). As the ESCO is the aggregator, the DR service will need to be even more predictable or available at request. Providing a guarantee on the flexibility-based savings may therefore turn out to be more complicated or at least "conditional". The condition to trigger the DR services will require specific clauses and price arrangements in the contract, and agreements on consumption baseline practices for DR activation settlements.
The ESCO will need to be able to deliver the flexibility and manage the explicit DR service, meaning he will need to master the full technical implementation, incl. Software and active control systems across multiple buildings. He will also need to negotiate and signs direct contracts with DSO/TSO's. Having an existing portfolio of buildings that are often already managed via a BEMS, makes him however a potentially attractive party for the flex requesters.

This variation of the explicit DR-driven AEPC business model does not require the ESCO to interact anymore with another (market) aggregator, which opens his business fully to this new market of DR in buildings. This may lead to evolutions in the market were aggregators and ESCO end up merging or aggregators being acquired by ESCOs, fuelling further growth. On the other hand, the ESCO acting as a full autonomous aggregator may lead to them being considered as direct competitors to certain aggregators, which could also hinder the market development. This clearly shows how these emerging business models have an impact on the market evolution itself, not only on the service being delivered.

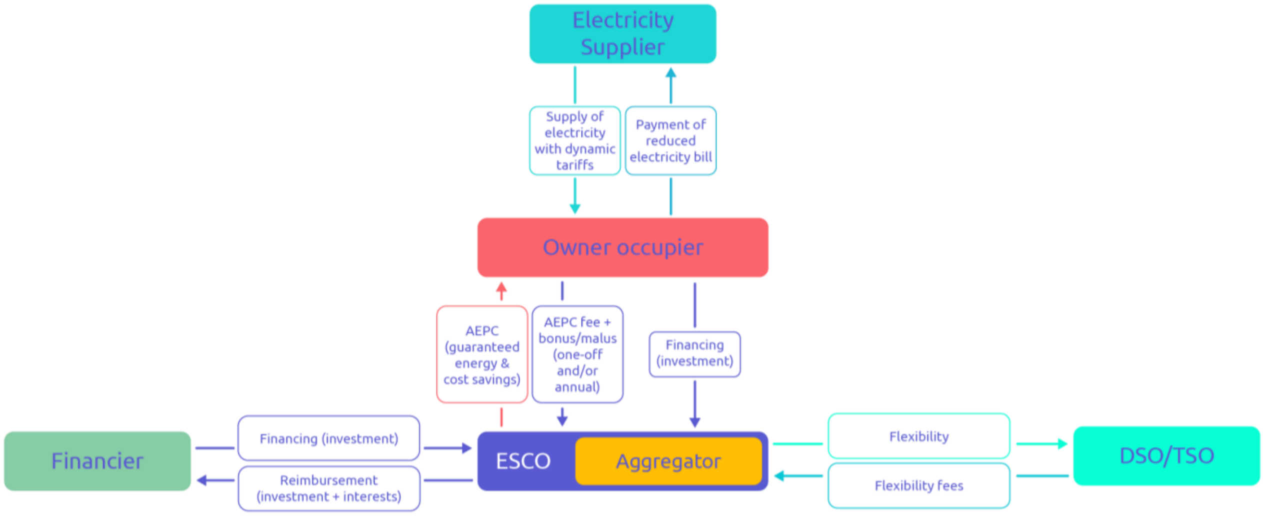


**FIGURE 6 AEPC BUSINESS MODEL WITH EXPLICIT DR AND ESCO AS AGGREGATOR**

### 3.3.6. AEPC BUSINESS MODEL – VARIATION B.5 (EXPLICIT DR – ESCO AS AGGREGATOR & AS ELECTRICITY SUPPLY INTEGRATOR)

**TABLE 9 CONFIGURATION FOR VARIATION B.5 (EXPLICIT DR – ESCO AS AGGREGATOR & AS ELECTRICITY SUPPLY INTEGRATOR)**

| Variation | Building type | Occupation model | Type of DR | Owner/Tenant relation | Financing |
|---|---|---|---|---|---|
| B.5 | Commercial building | Individual | Explicit (ESCO as Aggregator & as Electricity supply integrator) | Owner occupier | ESCO Financing |
| | Public building | | | | |
| | Residential building | | | | |

In this final variation, shown in Figure 7 and ultimate AEPC model including Explicit DR, the ESCO goes one step further and also integrates the delivery of the energy, or at least the electricity needed to power he building and the electrical installations that provide key functions to provide the comfort and other functionalities. In that case the ESCO not only manages the energy efficiency measures and flexibility but also has more leverage to negotiate prices or volume discounts. He may negotiate and provide more dynamic prices that allow to combine implicit DR with explicit DR.
Ultimately the ESCO can become electricity supplier or an electricity supplier could develop an ESCO activity for AEPC's, which is already the case for classical EPC.

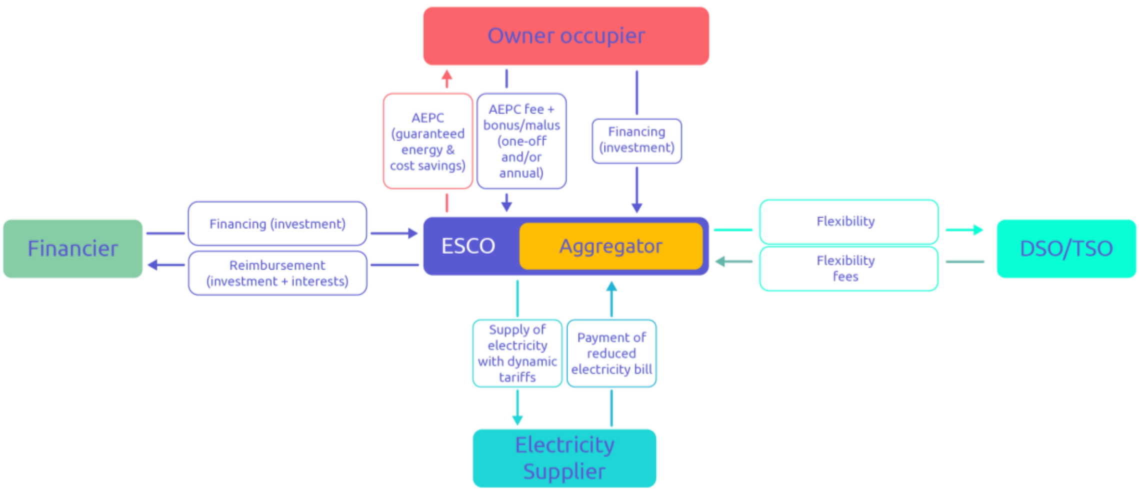


**FIGURE 7 AEPC BUSINESS MODEL WITH EXPLICIT DR AND ESCO AS AGGREGATOR & AS ELECTRICITY SUPPLY INTEGRATOR**

### 3.3.7. AEPC BUSINESS MODEL – VARIATION A.2 (FI FINANCING)

**TABLE 10 CONFIGURATION FOR VARIATION A.2 (FI FINANCING)**

| Variation | Building type | Occupation model | Type of DR | Owner/Tenant relation | Financing |
|---|---|---|---|---|---|
| A.2 | Commercial building<br>Public building<br>Residential building | Individual (individual measures only) | Implicit | Owner occupier | FI Financing |

In this variation, which in all other aspects corresponds to variation A.1 (generic model) the financing of the investment is done not by the ESCO but by a third-party bank of financial institution. Such financing is based on either a credit financing or a classical project financing. Accountancy wise, such financing is always "on balance" for the customers. This means that the underlying assets are on the active side of the customer's balance sheet and the corresponding credit or loan on the passive side. In other words, the customer is the economic owner of the assets, but he has a corresponding debt that may influence the way external financiers look at his capability to take on more loans. Thus, such accounting considerations are often an important driver for the type of financing solution that the customer is looking for. The financing solution and the accounting treatment will thus be intrinsically defined elements of the Business Model. Customer may decide to go with another ESCO if it offers a more adequate answer to his accounting requirements. The ESCO will rarely want to add any margin to the cost of financing of the investment, if it wants to stay competitive, but needs to make its margin entirely on the periodical AEPC fees.

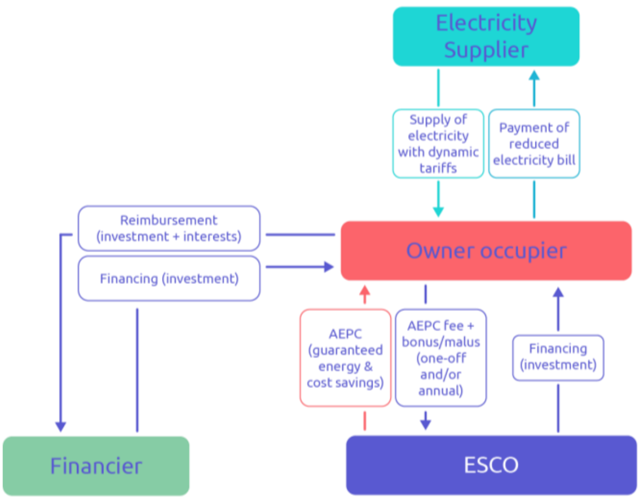


**FIGURE 8 AEPC BUSINESS MODEL WITH FI FINANCING**

### 3.3.8. AEPC BUSINESS MODEL – VARIATION C.1 (COLLECTIVE RESIDENTIAL HOUSING)

TABLE 11 CONFIGURATION FOR VARIATION C.1 (COLLECTIVE RESIDENTIAL HOUSING)

| Variation | Building type | Occupation model | Type of DR | Owner/Tenant relation | Financing |
|---|---|---|---|---|---|
| C.1 | Residential building | Collective (ACO) (individual measures only) | Implicit | Owner occupier | ESCO Financing |

The business model in case of collective residential housing, i.e. apartment buildings with multiple apartment units is another variation of the more generic business model, applicable to this specific segment of residential housing. In this case, the building owners are collectively organized into what is known as an ACO. Investment decisions typically are taken for the whole co-ownership or apartment building, not only for common parts of the building (like hallways, basements, elevators collective boilers or PV panels on the roof, outside wall insulation, etc.) but even for some individual parts (like windows, inside wall insulation (which is rare) or even individual Heating Ventilation and Air-conditioning equipment to insure a common infrastructure across the apartments).

In this particular model it is assumed that all building co-owners are occupants of their apartments, which influences the business model, as this automatically implies that there is no split incentive between the apartment owner and the tenant. All energy and cost savings go the apartment owner who can use them to reimburse all or part of the investment. This is different in the next variation of the Business Model where there is a split incentive between owner lessors and tenant lessees.

The Association of Co-owner acts more as an intermediary entity and decision-making body (during General Assembly meetings of the ACO), but the energy and cost savings services of the AEPC ultimately benefit the individual co-owners. They are also the ones that pay for the investments, although a part can come from historical reserves that were built up by co-owners through the rules that were decided by the ACO. The ACO will typically have a number of representatives from the co-owners in the so-called Council of Co-Owners. This Council will typically work closely with a Syndicate that is taking care of the daily management of the apartment affairs. In small apartment buildings the Syndicate may be one of the co-owners, but in larger apartment buildings this is typically a dedicated professional third-party Syndicate. They are typically mandated to engage with suppliers and service providers, close electricity contracts, do small repair works, manage accounting, etc. In the AEPC case, the Syndicate in collaboration with the Council will typically engage with the Facilitator and eventually with the ESCO for the AEPC-contract.

The ACO can legally engage all the co-owners, once a decision is made at a General Assembly or General Meeting, respecting the necessary quorum. This quorum can differ from country to country.

An important element in this Business Model variation is the financing, which is more complex than with a single building owner.

In case of FI or ESCO financing (represented here), there needs to be both a global financing plan and individual financial plans per co-owner. FI or ESCO financing will typically consist of a collective loan or pre-financing contracted by the ACO. This engages all of the co-owners who participate in this financing to reimburse the part corresponding to their investment, determined either by individual costs (e.g. for their

windows or boiler) or by the contractually agreed shares they own in the co-ownership (e.g. a common share of 120/1.000th or 500/10.000th).
Another key question for the ESCO is whether it needs to deliver only a global guarantee at the level of the building or also at the level of the individual apartment. The first option is more common, although in some cases, individual co-owners may want to demand also some individual guarantees. In case of a common heating installation (e.g. heat pump after installation), this is often easier as energy costs are divided according to the mechanism of shares in the co-ownership. In that case, savings are also divided according to these same shares in the co-ownership. This would not be true in case of individual heat pumps with individual electricity meters. These aspects need to be taken into consideration during the pre-contractual phase.
The flexibility service within the AEPC would also need to be designed and implemented on an individual or collective basis depending on whether the equipment (e.g. heat pump, ventilation, air-conditioning) is individual or collective. The fact that there are multiple apartment units could offer more potential for flexibility, e.g. through the use of a collective battery - possibly in combination with PV panels – managing the different occupation or usage patterns of the different co-owners.
In terms of electricity contracts that need to deliver dynamic pricing, they are mainly between electricity suppliers and the individual owner occupiers, but there may also be a collective contract between the ACO and another electricity supplier for the common parts of the building. Each may allow for different levels of flexibility corresponding to the equipment, the usage and the available tariffs.
Figure 9 shows the more generic model for residential collective housing, i.e. an apartment building with owner occupants and ESCO financing.

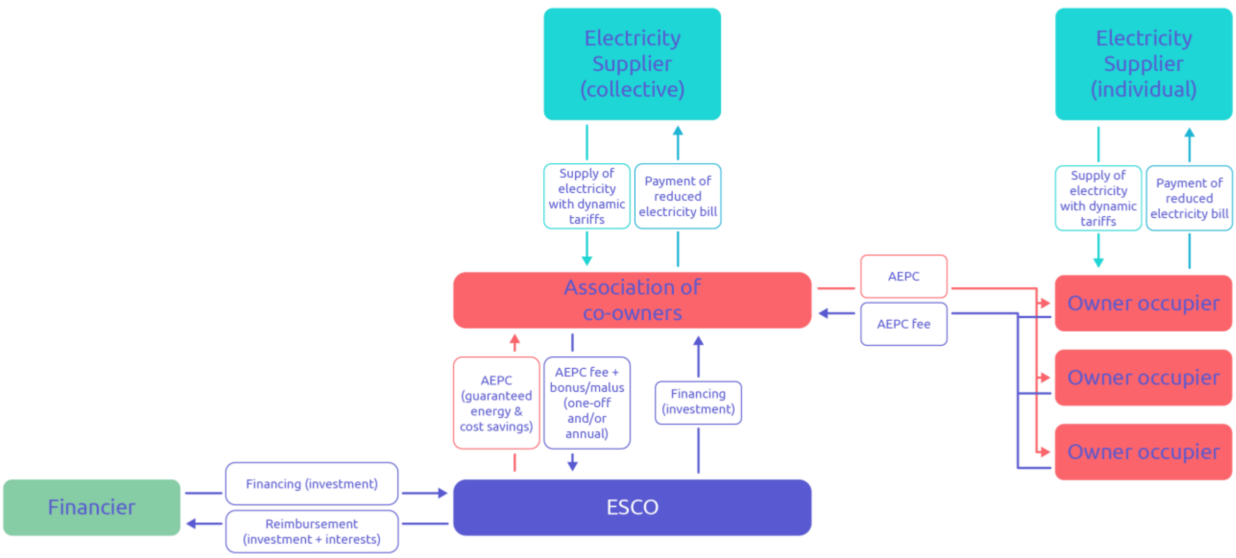


**FIGURE 9 AEPC BUSINESS MODEL FOR COLLECTIVE RESIDENTIAL HOUSING WITH OWNER OCCUPIERS**

### 3.3.9. AEPC BUSINESS MODEL – VARIATION C.2 (COLLECTIVE RESIDENTIAL HOUSING WITH TENANTS)

**TABLE 12 CONFIGURATION FOR VARIATION C.2 (COLLECTIVE RESIDENTIAL HOUSING WITH TENANTS)**

| Variation | Building type | Occupation model | Type of DR | Owner/Tenant relation | Financing |
|---|---|---|---|---|---|
| C.2 | Residential building | Collective (ACO) (individual measures only) | Implicit | Owner lessor & tenants | ESCO Financing |

In this variation of the Business Model for collective apartment buildings, the main difference is situated in the apartment occupation. Some or a large number of apartments are not occupied by the building co-owners, but rather by other tenants who rent or lease the apartment from the co-owners.
The AEPC is still signed between the ESCO and ACO, but in this Business Model variation, any energy savings from energy efficiency measures or building renovation, and cost savings from flexibility, will benefit the tenant or lessee, not the building owner. The co-owner will either have to pay for the investment from own funds or external financing (typically through the FI or ESCO) without any return on investment from the energy or cost savings. In this case, the decision to invest would mainly be driven by maintaining or improving the asset value of the apartment or the need to renovate the building that has maybe deteriorated beyond a point that rental prices become too low to represent a sound investment. In some cases, it may be the consequence of a large majority of co-owners having decided for the building renovation at the General Meeting of the Co-owners.
In some cases, the co-owner may negotiate a financial contribution by the tenant to the investment he is paying for. In this case he/she trades off an improvement in comfort against the return of part of the savings to his/her landlord who owns the apartment. This can be a one-off payment (e.g. a percentage of the investment cost paid by the owner) or an increase in monthly rent, agreed between both parties. If this is not possible, the apartment owner may need to wait until the end of the lease to increase the rent for the next tenant. The co-owner would take this into account when taking the decision of investing or when voting in favour of the project at the General Meeting.
Any cost savings coming from the flexibility are likely to benefit the tenant anyway as he/she is accepting the corresponding flexibility in comfort or usage and as the electricity contracts are with the tenant not with the co-owner.
From the Facilitator or the ESCO point of view, this presence of tenants - rather than only co-owners - represents an additional risk in the pre-contractual and contractual phase as some co-owners may decide not to go ahead with the project after all.
For the financier, there is not necessarily a large difference in comparison with the previous model, except the fact that some co-owners represent an increased credit risk, as they are not directly benefiting from the savings, but only from the increased building value. This may favour mortgage-based financing solutions.
Figure 10 represents this Business Model variation of a collective apartment building with tenants.

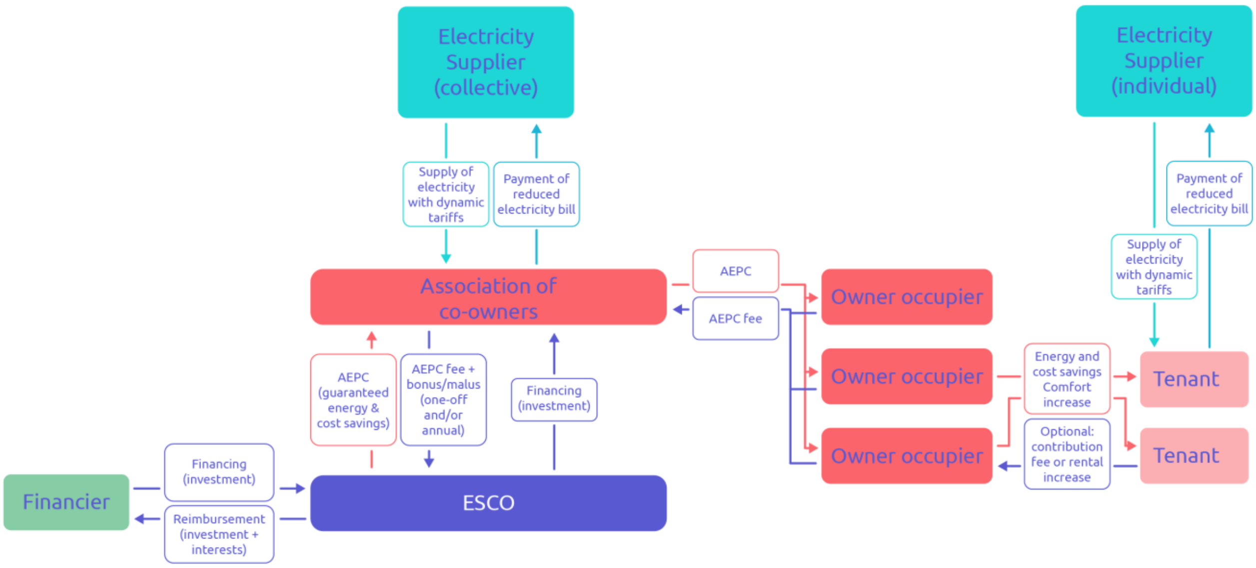


FIGURE 10 AEPC BUSINESS MODEL FOR COLLECTIVE RESIDENTIAL HOUSING WITH TENANTS

### 3.3.10. AEPC BUSINESS MODEL – VARIATION C.3 (COLLECTIVE RESIDENTIAL HOUSING – FI FINANCING)

TABLE 13 CONFIGURATION FOR VARIATION C.3 (COLLECTIVE RESIDENTIAL HOUSING – FI FINANCING)

| Variation | Building type | Occupation model | Type of DR | Owner/Tenant relation | Financing |
|---|---|---|---|---|---|
| C.3 | Residential building | Collective (ACO) (individual measures only) | Implicit | Owner occupier | FI Financing |

In this variation, the only difference is the fact that the financier directly finances the ACO, rather than the ESCO. As in the generic case, this shifts the credit risk from the ESCO to the FI which may be a more suitable solution, as a FI is probably better equipped to assess and manage risks at the level of an individual co-owner. Mortgage-based solutions are another familiar option for banks. They would already have a license for providing loans, which is much less likely to be the case for ESCOs unless the ESCO is specialized in this sector and obtains the necessary licenses to provide customer loans to residential apartment owners.
A mix of FI and ESCO financing is also possible as mentioned earlier for the generic model.
This FI financing variation could also apply to the case where there are a number of tenant lessees. In that case the increased credit risk of the owner lessor may again be more easily managed by a FI than by the ESCO. This case is he credit risk of the co-owner not being able to reimburse the loan directly shifts to the

FI, away from the ESCO. This financing option may be preferred by the ESCO or can be implemented in case the ACO cannot obtain a collective loan. not depicted as it is just a combination of both previous models. Figure 11 represents this Business Model variation of a collective apartment building with direct financing to the ACO.

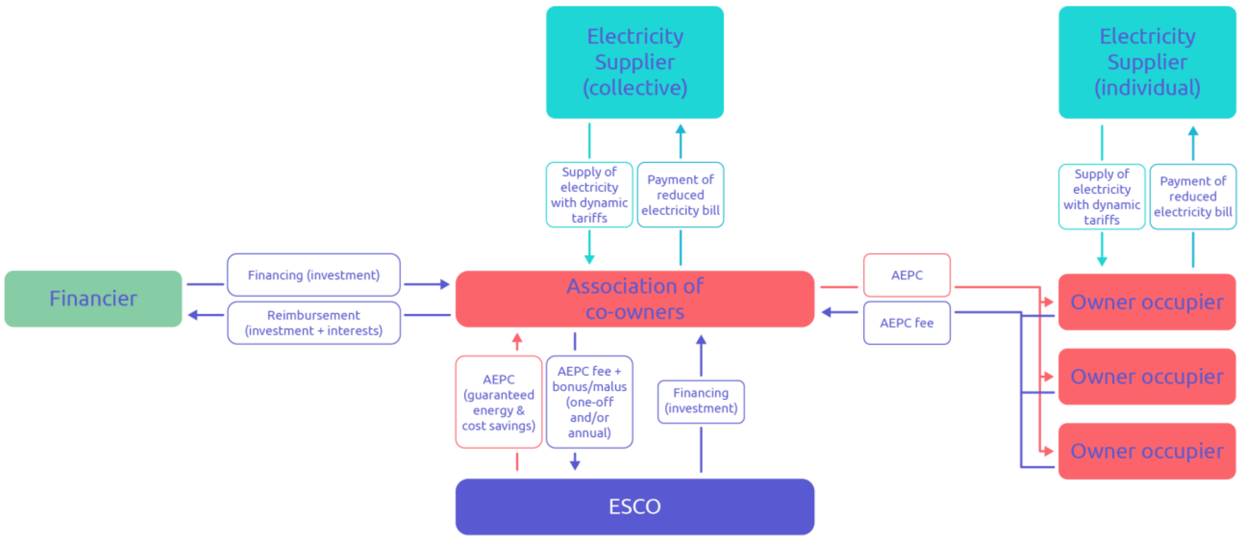


**FIGURE 11 AEPC BUSINESS MODEL FOR COLLECTIVE RESIDENTIAL HOUSING WITH FINANCING TO THE ACO**

### 3.3.11. AEPC BUSINESS MODEL – VARIATION C.4 (COLLECTIVE RESIDENTIAL HOUSING – FI FINANCING TO CO-OWNERS)

**TABLE 14 CONFIGURATION FOR VARIATION C.4 (COLLECTIVE RESIDENTAIL HOUSING – FI FINANCING TO CO-OWNERS)**

| Variation | Building type | Occupation model | Type of DR | Owner/Tenant relation | Financing |
|---|---|---|---|---|---|
| C.4 | Residential building | Collective (ACO) (individual measures only) | Implicit | Owner occupier | FI Financing to Co-owners |

This case is again a variation of the previous Business Models for apartment buildings with co-owners, in which the financing is done directly by the financier, typically a bank or financial institution, to some or all of the co-owners, as is shown in Figure 12.

The model may be used for all co-owners if that is the preferred solution. It can also be the case of a smaller number of co-owners if they prefer to be financed through their own bank, rather than participating in a collective loan or other types of financing (e.g. ESCO financing).
Here the credit risk of the co-owner not being able to reimburse the loan directly shifts to the FI, away from the ESCO. This financing option may be preferred by the ESCO or can be implemented in case the ACO cannot obtain a collective loan.
For the rest, there is little difference with the case of a collective loan as the ESCO would still need to deliver the AEPC services to the ACO with whom the AEPC contract is signed. Going a step further and signing individual AEPC contracts with all co-owners would probably not be feasible and represent a high commercial and operational risk for the ESCO. At best, there would be a back-to-back engagement from the ACO to the co-owners as is the case in the generic case of AEPC for the co-owners.

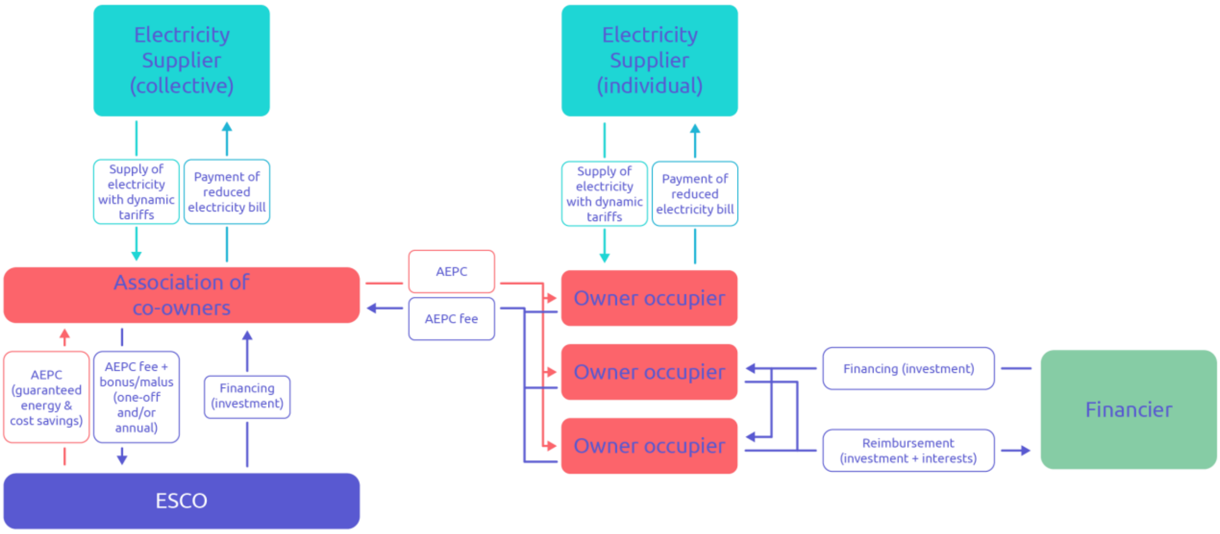


**FIGURE 12 AEPC BUSINESS MODEL FOR COLLECTIVE RESIDENTIAL HOUSING WITH FINANCING TO THE CO-OWNERS**

### 3.3.12. AEPC BUSINESS MODEL – VARIATION D.1 (SOCIAL HOUSING)

**TABLE 15 CONFIGURATION FOR VARIATION D.1 (SOCIAL HOUSING)**

| Variation | Building type | Occupation model | Type of DR | Owner/Tenant relation | Financing |
|---|---|---|---|---|---|
| D.1 | Social Housing | Individual Collective | Implicit | Owner lessor & Social tenant | ESCO Financing |

This variation of the Business Model is particular in the sense that the ESCO contracts the AEPC with a single building owner, i.e. the Social Housing Company (SHC), who has several social tenants who benefit from the energy and cost savings. This often relates to large numbers of individually occupied homes in a social neighbourhood or development. But it could also apply to a single apartment building with multiple social tenants. This latter case bears some resemblance to the previous case of a privately co-owned apartment building but is much simpler because of the unique owner, i.e. the SHC, and the fact that all occupants are social tenants. There is no mix of occupant types.

Sometimes, in the case of multiple houses, some houses may have been sold to some tenants, which complicates any common renovation strategy but it does not affect the Business Model as such.
The Business Model variation is similar to the general model of one (public) building owner from the point of view of the ESCO, but it is much more complicated for the SHC to build a profitable business case. As the energy savings from energy renovation and renewable energy or cost savings from flexibility benefit entirely the social tenant (similarly as with tenants in case of privately co-owned apartments), there is no real return on investment for the SHC.

This means that for this Business Model to be successful, there needs to be either some level of funding from the government or public authority in charge of the social housing sector financing or some level of retribution from the social tenants. This retribution can take the form of an AEPC fee (as has been demonstrated for classical EPC-like models in projects like “Stroomversnelling”, “Energiesprong” or “REnnovates” in the Netherlands and other countries) or of an increase in the monthly social rental based on the overall energy performance of the building after renovation (as is being envisaged in the “Sociale Energiesprong” project in Belgium). Such retributions generally need to be agreed by law or decree, as to create equal conditions to all social tenants.

Another element of the Business Model of this type of configuration is the capacity of the ESCO to industrialize the design, build and installation of the building renovation in case of multiple identical or very similar social houses. This can be the case for 2, 3 or 4 façade houses, sometimes grouped together by 2, 4 or 6 units. This industrialization can include on-site laser-based measurement of the dimensions and Computer Aided Design/Computer Aided Manufacturing (CAD/CAM)-based design or even prefabricated exterior insulated building envelope modules that are entirely built in the factory and installed by a crane on site. The contain both windows and doors as well as solar PV panels on the roof modules. The projects mentioned in the previous paragraph are built upon this methodology.

If they include a significant level of exterior insulation, they always allow for an energy shift from gas or fuel-based boilers to electrical heat pumps. These in return can deliver flexibility, increasing the potential for flexibility services. Whether this is a feasible scenario and under which conditions will depend on the business case of the project. So, if the funding problem is solved, this sector of buildings theoretically represents an interesting case for AEPC.

Figure 13 represents the Business Model variation for these types of buildings, showing the case of individual occupation of separate houses or collective occupation of an apartment building.

The financing option depicted here is ESCO financing, but this scheme can also apply to FI financing (not shown here). All will depend on the financing possibilities that the SHC has. Often, they are restricted to financing from some internal government managed “umbrella organisation”. This specific case is explained in the next variation.

ESCO financing may however be an option if the purpose is to keep the financing outside of the public debt (or off-balance). EPC in general and AEPC in particular may offer some opportunities in this area that neither FI nor financing by this umbrella organisation would allow. An alternative could be a Public Private Partnership that has its own off-balance capabilities. These public accounting issues will not be considered.

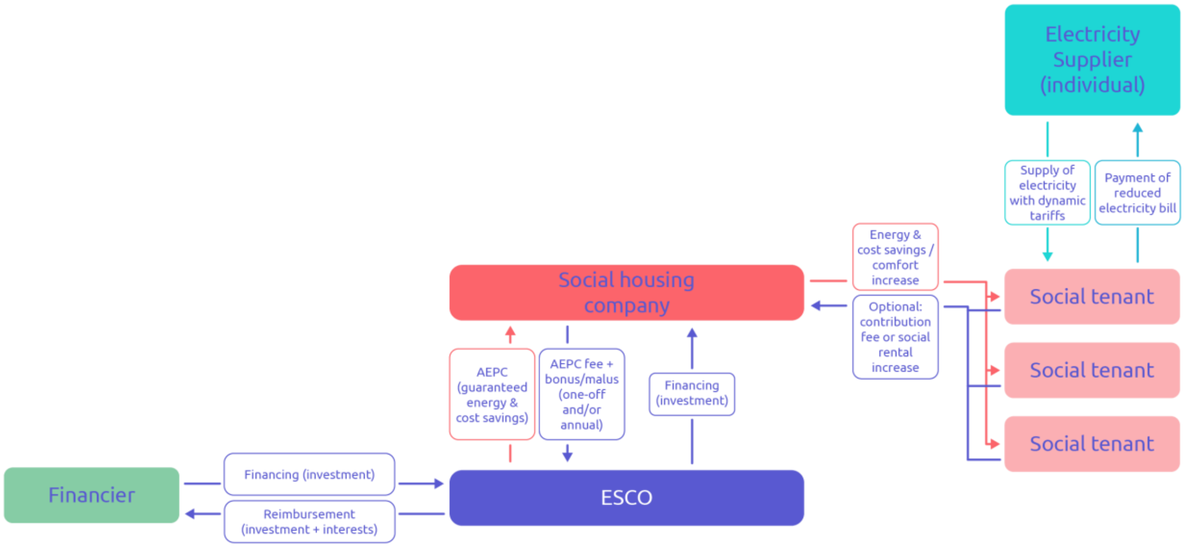


**FIGURE 13 AEPC BUSINESS MODEL FOR SOCIAL HOUSING WITH ESCO FINANCING**

### 3.3.13. AEPC BUSINESS MODEL – VARIATION D.2 (SOCIAL HOUSING – FINANCING BY UMBRELLA ORGANISATION)

**TABLE 16 CONFIGURATION FOR VARIATION D.2 (SOCIAL HOUSING – FINANCING BY UMBRELLA ORGANISATION)**

| Variation | Building type | Occupation model | Type of DR | Owner/Tenant relation | Financing |
|---|---|---|---|---|---|
| D.2 | Social Housing | Individual Collective | Implicit | Owner lessor & Social tenant | Financing by Social Housing Umbrella Organisation |

This variation of the Business Model involves financing by a Social Housing Umbrella Organisation that is very common in many countries. It finances the investment programs of the Social Housing Companies within the general budget of the national or regional government. Often, they provide either subsidies or low interest loans. As this type of financing is often mandatory for the SHCs, this limits the possibility to contract alternative financing (e.g. ESCO financing). Also, this type of financing often comes with imposed savings targets (e.g. renovation to label B), with a restricted budget per social housing unit. This will then limit the insulation capacity and still require a gas fired boiler for heating. In other words, such financing schemes may limit the capability of the SHC to do more deep energy renovations in combination with electrification of the heat supply. The deep energy renovation with prefabricated wall modules may not be feasible either. As this creates a potential strong limit on the flexibility, the Business Model is this case may be more complicated to implement and the business case may turn out not to be positive for an AEPC in comparison to a standard EPC or even a Separate Contractor Based approach.

In general, the issue, with today's imposed savings targets, is also that they are often targeted at energy savings and not on CO2 savings. AEPC models could help change this perspective by creating an additional focus on the use of energy when the carbon intensity is lowest, in addition to maximizing the auto consumption of locally produced renewable energy by controlling demand side flexibility.

Figure 14 depicts this variation of the AEPC model for a Social Housing Company that can only use financing from an umbrella organisation that is often itself financed by the public authorities.

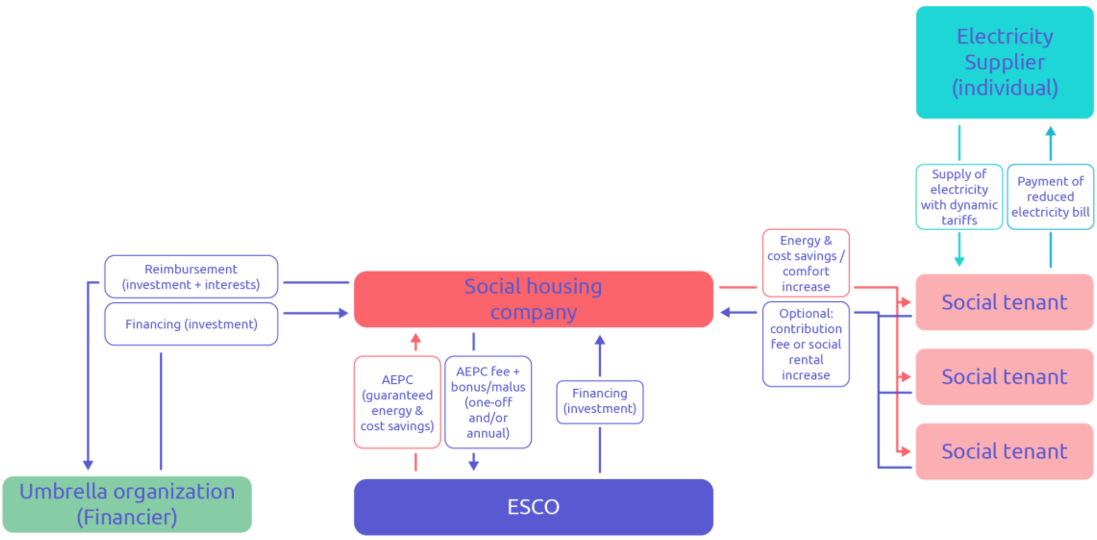


**FIGURE 14 AEPC BUSINESS MODEL FOR SOCIAL HOUSING WITH UMBRELLA ORGANISATION FINANCING**

## 3.4. SUMMARY OF THE AEPC BUSINESS MODEL VARIATIONS

All of the previous models are variations of the same AEPC business model, but they differ in the type and number of stakeholders that are involved, in who takes on the investment, in who finances it, in the way services are delivered, in who benefits for them or in who pays for them.

The Table 17 provides the summary of the Business Model variations that were defined.

**TABLE 17 SUMMARY OF BUSINESS MODEL VARIATIONS**

<table>
<tr><th>Building type</th><th>Occupation model</th><th>Type of DR</th><th>Owner/Tenant relation</th><th>Financing</th><th>Business Model Variations</th></tr>
<tr><td rowspan="7">Commercial building<br>Public building<br>Residential building</td><td rowspan="7">Individual</td><td>Implicit</td><td rowspan="8">Owner occupier</td><td rowspan="6">ESCO Financing</td><td>A.1</td></tr>
<tr><td rowspan="5">Explicit (variations 1 to 5)</td><td>B.1</td></tr>
<tr><td>B.2</td></tr>
<tr><td>B.3</td></tr>
<tr><td>B.4</td></tr>
<tr><td>B.5</td></tr>
<tr><td rowspan="7">Implicit</td><td>FI Financing</td><td>A.2</td></tr>
<tr><td rowspan="4">Residential building</td><td rowspan="4">Collective (ACO)</td><td rowspan="2">ESCO financing</td><td>C.1</td></tr>
<tr><td rowspan="3">Owner lessor & Tenant</td><td>C.2</td></tr>
<tr><td>FI Financing</td><td>C.3</td></tr>
<tr><td>FI Financing to co-owners</td><td>C.4</td></tr>
<tr><td rowspan="2">Social housing</td><td rowspan="2">Individual<br>Collective</td><td rowspan="2">Owner lessor & Social Tenant</td><td>ESCO Financing</td><td>D.1</td></tr>
<tr><td>Umbrella Organisation Financing</td><td>D.2</td></tr>
</table>

# 4. ECONOMIC AND FINANCIAL CALCULATIONS MODULE

## 4.1. INTRODUCTION

The Economic and Financial Calculations Module (E&FCM)[1] is an integral part of the ABEPeM, presented in deliverable D2.2 Proof-of-concept of an Active Building Energy Performance Modelling framework, and actually builds the financial business case for an energy performance project based on AmBIENCe Active building Energy Performance Contracting (AEPC) concept. Its core functionality is the calculation of relevant economic and financial Key Performance Indicators (KPIs) based on the cash flows resulting from investments, from changed operational expenses and changed income (savings or additional income) resulting from quantification/estimation of energy cost cash flows.

The purpose of this E&FCM is to support the ESCO and other AEPC beneficiaries (Owner-Occupiers, Owner-Lessors and Lessees) in the process of deciding whether a proposed investment in selected energy efficiency measures combined with DR flexibility makes sense from a financial and economic point of view.

This module has a key role in the process of AEPC development because it determines the savings and/or revenues of the project by providing the relevant cash flows and the financial KPIs.

The E&FCM includes the relevant cash flows, discounted to reflect the time value of money, resulting from the investment in selected energy efficiency measures and the application of active control (DR flexibility) over the analysed or observed period (usually the lifetime of the asset). It shows both the cash flows related to benefits and cost reductions such as energy savings, savings from active control, maintenance savings, additional income (when applicable) and residual building value and cash flows related to relevant expenses such as initial capital expenditures, maintenance, repairs, operating expenses, capital replacements and energy service fees.

In order to provide the additional value of DR Flexibility the E&FCM builds on two different cash flow tables:

- the first one showing the relevant project cash flows after implementation of the Energy Efficiency Measures (EEM) only and
- the second one showing the cash flows after the implementation of DR Flexibility (active control measures), thus in addition to the first EEM only case.

The results from these two cash flow worksheets are included in a KPI worksheet providing all financially important Key Performance Indicators of the energy efficiency project to be included in the business case

[1] The authors refer to the "AmBIENCe User Guide Economic & Financial Calculation Module" in Annex of this report for a detailed description and use of the E&FCM.

## 4.2. ARCHITECTURE

The E&FCM is implemented as an Excel workbook consisting of 12 worksheets or tabs structured in the following four groups:

- Input worksheets
- Auxiliary worksheets
- Cash flow worksheets
- KPI worksheet

Data can only be entered in the E&FCM in the different **Input Worksheets**. There are three input worksheets:

- General Input table
- Price evolutions
- Input Table DR_FLEXIBILITY

The Input tabs will be fed manually by the user of the E&FCM or by other ABEPeM modules such as the "Energy Cost Cash Flow Quantification Module" and/or the "Configuration Form". These input tabs include all necessary and required data to run the cash flow analysis in the Cash Flow worksheets and perform the calculations in the Auxiliary worksheets when the latter are applicable.

The core of the E&FCM are the two **Cash flow worksheets**: one showing the relevant project cash flows after implementation of the Energy Efficiency Measures (EEM) only, and another showing the cash flows after the implementation of DR Flexibility (active control measures), thus in addition to the first EEM only scenario.
These two cash flow tabs feature all relevant information, on a year-on-year basis, grouped in the following cash flow groups:

- Operating income (e.g. rent income, rent charges income),
- Operating expenses (e.g. rent expense, rent charges, energy expenses and energy/DR Flexibility savings, maintenance expenses and other relevant expenses),
- Initial Outlay (e.g. capital expenditures and other initial outlays), and
- One-off Income (e.g. subsidies or grants and sales or residual value of the asset).

Both cash flow tabs also include separate financing cash flows to show the effect of the financing cash flows from ESCO (Shared Savings Agreements, First-In or First-Out agreements, …) or third-party financing when applicable.
The data in the cash flow tabs is being obtained from the different Input tabs and Auxiliary tabs (for the financing cash flows) within the E&FCM tool.

The **Auxiliary worksheets** calculate the financing cash flows depending on the financing option chosen in the General Input table (No third-party financing, third party financing based on lending or ESCO financing) and ESCO payment models (Shared Savings, First In, First Out).

Project owners and other specific stakeholders look at KPIs and other relevant financial information when making investment decisions. E&FCM provides this relevant information in the **KPI worksheet**. The KPI are grouped in Investment, Energy, Financial and Other KPI.

Figure 15 shows the high-level architecture and building blocks of the E&FCM

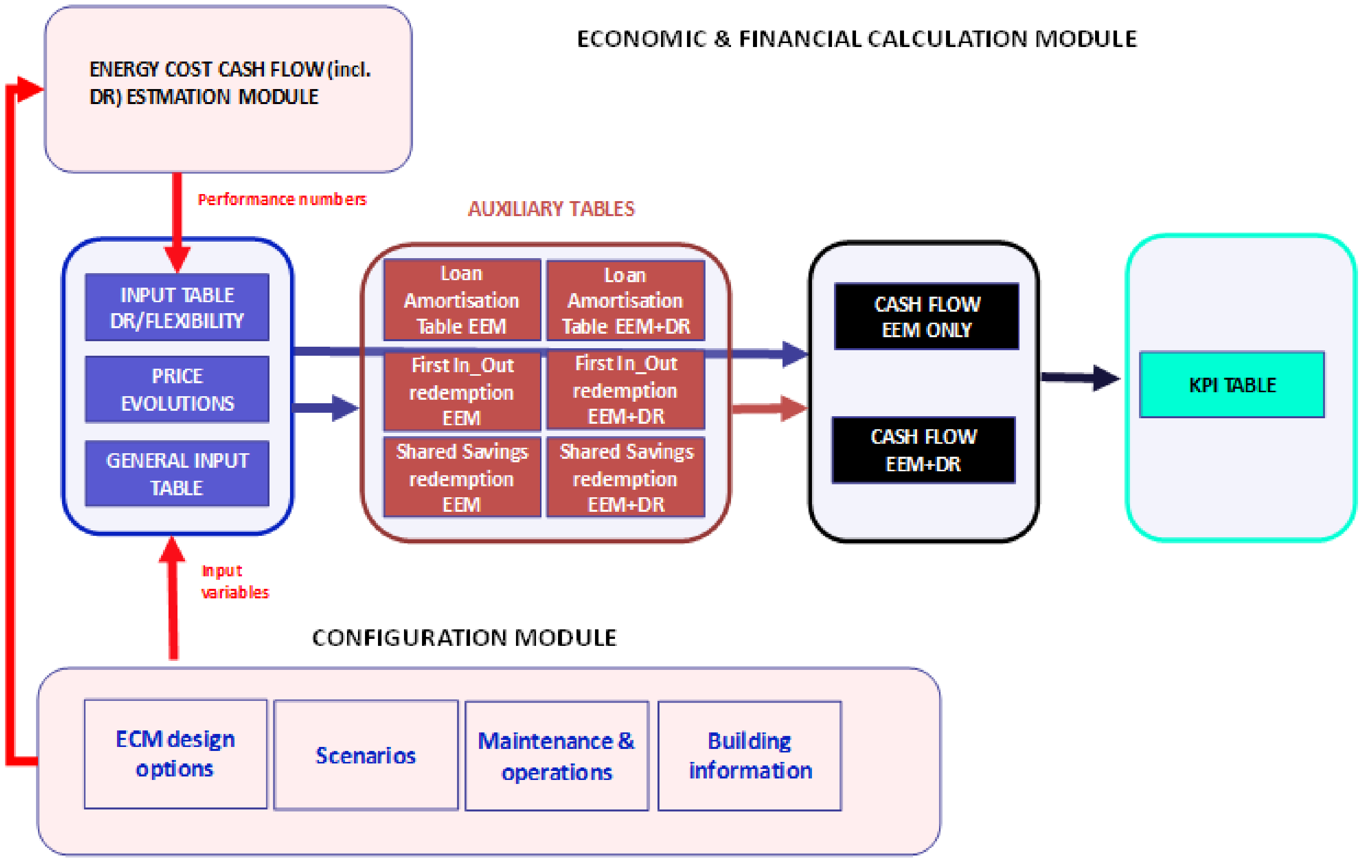


FIGURE 15 HIGH LEVEL ARCHITECTURE & BUILDING BLOCKS OF THE E&FCM AS SHOWN IN D2.2.

# 5. BUSINESS CASE: RESIDENTIAL BUILDING

In this section, the combined use of the ABEPeM tool and the E&FCM tool is illustrated for a business case quantification of a very poorly insulated Single Family Residential Building, from the Owner-Occupier's

**Reference Building parameters:**

2-storey building with saddle-roof
Volume: 412 $m^3$
Ground floor surface: 84,35 $m^2$
First floor surface: 78,35 $m^2$
Roof surface: 104,83 $m^2$
Façade surface: 175,78 $m^2$
Window surface: 44,87 $m^2$ (3,12 $m^2$ + 7,04 $m^2$ + 1,95 $m^2$ + 3,84 $m^2$ + 0,24 $m^2$ + 1,2 $m^2$ + 1,68 $m^2$ + 1,44 $m^2$ + 2,88 $m^2$ + 2,7 $m^2$ + 16,8 $m^2$ + 1,98 m2)
Façade parameters: cavity walls without insulation; 10 cm brick + 7 cm cavity + 11 cm limestone + 1 cm plaster; U = 1,75 W/K
Roof parameters: sloping; U = 3,00 W/K
Window parameters: single glass; U = 5,10 W/K

The total current U-value[1] for the residential building is 867 W/K.
The current K-value[2] for the residential building is 208,80 W/m²K.

**Envelope renovation measures:**
Insulation measures are taken for walls (exterior wall insulation), roof (insulation on the outside) and windows (double glazing). Following U-values are assumed:

Walls: U = 0,24 W/K
Roof: U = 0,20 W/K
Windows: U = 1,40 W/K

This allows to achieve a K-value of 35,41, which is slightly below 40 which is the limit to allow for the heat production options below.

Associated investment budget: €56.463

**Two heating options** have been analysed:

Option 1: replace existing gas-boiler (80%) with a new condensing gas-boiler (94%). Associated investment €4.000. Total Investment €60.463.

---

[1] U-value is the expression of the thermal transmittance which is the transfer rate of heat through material.
[2] A k-value is a measure of the thermal conductivity of a material.

Option 2: replace existing gas-boiler by a heat-pump (13kW); add buffer and PV (6.5kWp) as well. Associated investment €15.283. Total Investment €71.463. Investment for supporting DR: €1.500.

This has allowed for the **comparison of the business case of the two options** by combining energy cost quantifications (for EEM only in both options, and for EEM + DR in the heat-pump option) resulting from the ABEPeM tool (see D2.2) with economic and financial quantifications from the E&FCM tool.

The **methodology** applied consists of 2 steps:

**Step 1: calculation of Project Cash Flow KPIs for an analysis period of 40 year**
(note: maintenance costs were left out in this analysis).

The Project Cash Flow KPIs (Investment Return Rate (IRR), NPV, Discounted Payback Period) characterise the strength of the business case. For IRR and NPV, positive is better than negative. Positive IRR and NPV indicate that the net present value of the total sum of saving cash flows exceeds the initial investment amount. The higher these values the higher the financial return. Negative IRR and NPV indicate that the net present value of the savings cash flows do not recover the initial investment amount. The Discounted Payback period indicates how much time is needed for the initial investment to be paid back by the discounted savings cash flows. The lower this value the shorter the payback period, the higher this value the longer the payback period. It is thus a sort of indicator of risk, the longer it takes to recover the initial investment amount the higher the risk associated with the project. The project cash flow KPIs make it possible to judge whether there is a positive business case from a financial point of view, and to compare different design options (e.g. sticking with gas versus electrification with a heat-pump, with and without DR valorisation) independent of the chosen financing model with associated model parameters and ESCO contract duration. Therefore, for comparing Project Cash Flow KPIs, financing can be ignored by selecting none of the financing options in the E&FCM tool (i.e., no First In, no First out, no Shared Savings and financing based on reimbursement fees).

TABLE 18 COMPARISON OF KEY PARAMETERS FOR RENOVATION SCENARIOS (GAS BOILER VS. HEAT PUMP)

| | | Project Cashflow KPIs | | |
|---|---|---|---|---|
| | | IRR | NPV | Discounted Payback Period |
| Option 1: gas | EEM only | 5,00 % | € 27.616 | 26,07 years |
| Option 2: HP | EEM only | 4,90 % | € 30.789 | 26,63 years |
| | EEM + DR | 5,10 % | € 33.702 | 26,00 years |

In this specific example, and from a financial point of view, option 2 (EEM only) where gas is replaced by a heat-pump, delivers a worse business case than option 1 where one sticks to gas, if judged by the Project Cash Flow KPIs IRR and Discounted Payback period, even though it shows a higher NPV in absolute value. This higher NPV, expressed as a relative value, i.e., the generated NPV divided by its initial investment amount results in the ratio of 0.431 versus 0.457 for Option1 Option 1 delivers a higher NPV-to-Investment

ratio or a higher NPV per invested EURO. It is only when also DR valorisation is taken into account, that option 2 delivers a better business case than option 1 for all Project Cash Flow KPIs, with an NPV that is 22% higher than the one for Option 1. The NPV-to-Investment-ratio is here 0.462 versus 0.457 for Option 1. In this example, a DR valorisation quantification was done for a self-consumption optimisation under no-net-metering conditions with a consumption cost of 27,3ct/kWh and an injection fee of 4 cent/kWh.
In this illustrative quantification, we ignored additional subsidies that would apply for the switch to a heat-pump and the installation of PV, which would otherwise further improve the option 2 business case.

**Step 2: calculation of Financing Cash Flow KPIs**

**TABLE 19 COMPARISON OF FINANCING OPTIONS**

| | | IRR | NPV | Discounted Payback Period | EPC contract duration |
|---|---|---|---|---|---|
| Project Cash Flow KPI / No financing | | | | | |
| | | 5,1% | € 33.702 | 26,00 | |
| Financing Based on Reimbursement fees (2%) | | | | | |
| Loan Term | 40 yrs | | € 25.597 | | |
| | 35 yrs | | € 23.981 | | |
| First Out | | | | | |
| | | | € 24.856 | | 34 yrs* |
| | | | | | |
| First In (> € 300 result in ESCO project durations > 40 yrs) | | | | | |
| Acquired Savings by the Beneficiary | € 300 | | € 26.940 | | 40 yrs* |
| | € 200 | | € 26.070 | | 38 yrs* |
| | € 100 | | € 25.369 | | 38 yrs* |
| Shared Savings (< 90% result in ESCO project durations > 40 yrs) | | | | | |
| Shared Savings percentage for reimbursement | 90% | | € 26.968 | | 40 yrs* |
| | 95% | | € 25.711 | | 37 yrs* |

*Redemption period = minimum ESCO contract duration

In Table 19, the financing cash flows for all financing options are calculated on the basis of an applicable interest rate of 2% and a discount rate of 5%. A higher Equity NPV indicates a higher return to the project owner (the equity owner). Under normal circumstances, in our specific business case, the project owner would thus choose the financing option with the highest NPV. This NPV is the result of the time value of money (the present value) of the cash flows. The lower the reimbursement amounts (negative cash flows) the lower their net present value, and the higher the Equity NPV will be. Nevertheless, the lower the amounts applied to the reimbursement of the investment the longer the reimbursement period will be (and thus the EPC period). For the Shared Savings financing option this is illustrated as follows: A shared savings percentage of 90% means that 90% of the savings go to the reimbursement of the investment amount which is a lower reimbursement amount compared to the 95% shared savings amount. The 90% shared savings has a higher NPV than the 95% shared savings (€ 26.968 versus € 25.711) but has also a longer reimbursement period (40 years versus 37 years). At first sight the 90% shared savings option would be preferred by the project owner, the longer the reimbursement period the better. But, longer reimbursement periods are being associated with higher risk and this would prompt the financiers to possibly wanting to apply higher interest rates, resulting in a decrease of the Equity NPV, meaning less attractive financing conditions. The financing options First In and First Out are basically variations of the shared savings financing model, all or part of the savings are being allocated to the reimbursement of the investment. The First Out option has a lower NPV than the First In variations as all of the shared savings (higher amounts compared to First In) are being used to reimburse the debt. The First Out option has also a shorter EPC period. The finance option based on the provision of a loan shows the same results, the shorter the reimbursement period, the higher the reimbursement amount and the lower the Equity NPV.

Choosing a financing option is very much related to the kind of relation that the project owner wants to have with the service provider or the ESCO. The financing option based on the loan reimbursement allows to define the loan term independently from the energy savings, and permits the project owner to engage in a shorter EPC duration if desired. Choosing one of the other financing options links the reimbursement amounts with the shared savings as, depending on the financing option First In, First Out or Shared Savings, the totality or part of the shared savings can be used to reimburse the investment. As already indicated, the smaller the part of the savings that goes to the reimbursement the longer the EPC period thus the longer the project owner is tied to the ESCO. Project owners who don’t want to engage in excessively long ESCO contract durations will most probably choose to allocate high portions of the savings or all savings to service the debt (reimburse the investment).

The choice of the financing option might also depend on the project owner’s ability to obtain financing from its usual financier. If this is not the case the project owner might be prompted to look for financing options offered by the ESCO. This might come with a higher price, longer ESCO contract durations and/or sharing of savings and thus resulting in uncertainties and risks.

Annex B contains a more detailed description of the first step of the business case for this residential building as well as for a school building.

# 6. EVALUATION OF RESULTS AND CONCLUSIONS

The analysis of the eco-system, the concept for AEPC and the way value can be created has led to the determination of the basic elements of the AEPC Business model. Based on the analysis of further parameters, like the type of buildings typically addressed by ESCOs, the financing options that are typically available for AEPC financing and the way they are occupied, owned or rented has allowed determining different variations of the Business model. Finally, both implicit and explicit demand response options provide further variations to build the AEPC Business model. In particular variations in the way Explicit DR is being offered, focused on the role of the ESCO as an aggregator to the end-customer or working with aggregators, have allowed creating a comprehensive picture of the AEPC business model and 13 variations, 5 based on explicit DR, 8 on implicit DR.

The Business Model has been applied to a first type of building (a stand-alone 4-facades residential building, being occupied by a single-family owner-occupier, using implicit DR and ESCO Financing. This has allowed studying two business cases: 1) a traditional one for insulation and the replacement of an existing gas boiler by a new condensing gas boiler and 2.a) one based on the AEPC model, involving the replacement of the existing gas boiler by an electrical heat pump and solar PV panels. On top of this second business case, an extended business case was built by 2.b) adding active control that allows to improve the level of self-consumption of the solar PV production and valorise the flexibility via implicit DR.
This first simulation study, for this particular case, shows roughly a 10% improvement in the NPV between business case Option 1 and 2a, and another 10% improvement between Option 2a and 2.b.

Finally, the E&CFM-tool that was developed was presented, including a detailed manual (provided in annex A) for users.

The existence and relevance of an AEPC Business Model was proven and both the basic Business model and several key variations were described. This highlights the key relations between various actors or stakeholders that are involved in the model.
The model shows how they interact, which services are being offered and which financial flows go from one actor to another.
The Business Model builds on the basic EPC Business Model, offering scalability, performance guarantees and financing options and opportunities, but is extended with flexibility valorization potential that can lead to extra cost savings and extra emission reductions.
The first business case, supported by the first version of the ABEPeM tool, including the E&CFM tool, has shown that if applied to certain types of buildings, the business case for AEPC can be positive.
The purpose is to investigate further these business cases in the following phases of the AmBIENCe project.

Active managed Buildings with
Energy performaNce Contracting

## ANNEX A: E&FCM USER GUIDE

# AmBIENCe User Guide Economic & Financial Calculation Module

The AmBIENCe Consortium

April | 2021

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# 1. INTRODUCTION

The Economic and Financial Calculations Module (E&FCM) is an integral part of the ABEPeM platform (Active Buildings Energy Performance Modelling) and actually builds the financial business case for an energy efficiency project based on the AmBIENCe's Active building Energy Performance Contracting (AEPC) concept. E&FCM, which is an Excel spreadsheet tool, calculates relevant economic and financial Key Performance Indicators (KPIs) based on the cash flows resulting from investments, from changed operational expenses and changed energy cost cash flows (savings or additional income) resulting from Demand Response activation (i.e., the active control of flexibility).

The purpose of this E&FCM is to support the ESCO and other AEPC beneficiaries in the process of deciding whether a proposed investment in selected energy efficiency measures combined with DR flexibility makes sense from a financial and economic point of view.

This module has a key role in the process of AEPC development because it determines the savings and/or revenues of the project by providing the relevant cash flows and the financial key performance indicators (KPIs).

The E&FCM includes the relevant cash flows, discounted to reflect the time value of money, resulting from the investment in the selected energy efficiency measures and the application of active control (DR flexibility) over the analysed or observed period (usually the lifetime of the asset) of the energy efficiency project. It shows both the cash flows related to benefits and cost reductions such as energy savings, savings from active control, maintenance savings, additional income (when applicable) and residual building value as well as cash flows related to relevant expenses such as initial capital expenditures, maintenance, repairs, operating expenses, capital replacements and energy service fees.

In order to provide the additional value of DR Flexibility the E&FCM builds on two different cash flow tables:

- the first one showing the relevant project cash flows after implementation of the Energy Efficiency Measures (EEM) only and
- the second one showing the cash flows after the additional implementation of DR Flexibility (active control measures).

The results from these two cash flow worksheets are included in a KPI worksheet providing all financially important Key Performance Indicators of the energy efficiency project to be included in the business case.

## 2. HOW TO USE

The E&FCM is built up as a Workbook consisting of a number of worksheets or tabs having a specific functionality with their own specific tab colour. The most relevant worksheets have a **blue**, **burgundy**, **black** or **aquamarine colour** as follows:

The **blue worksheets** (General Input table, Price evolutions, Input Table_DR FLEXIBILITY) are the only worksheets including input fields or input cells allowing entry of parameters or input variables. Input Table_DR FLEXIBILITY also performs some calculations. The blue worksheets include all necessary input for further calculation in the other worksheets in E&FCM. Values in the entry fields or cells with **blue text colour** and **blue background** can be entered manually by the user or by interfacing with other external systems or applications, such as the Energy Cost Cash Flow Quantification Module and the Configuration Form which are also part of the ABEPeM platform. All other cells in these worksheets are protected with a password and should only when necessary be unprotected.

The worksheet with a **burgundy background colour** (Loan Amortisation Table EEM, Loan Amortisation Table EEM+DR, First In_Out Redemption EEM, First In_Out Redemption EEM+DR, Shared Savings Redemption EEM and Shared Savings Redemption EEMDR) are calculation worksheets only. They serve only as intermediate calculation sheets to provide financing cashflows to the Cash Flow worksheets.

The **black background coloured** worksheets (Cash Flow EEM ONLY and Cash Flow EEM+DR) include the cash flow tables of E&FCM. The data processed in these cash flow worksheets is obtained from the different Input worksheets (blue) and amortization/redemption worksheets (burgundy).

The Key Performance Indicators worksheets (KPI) has an **aquamarine background** colour. It includes the results from the cash flow worksheets and the input worksheets and shows all important Key Performance Indicators of the energy efficiency project.

E&FCM does not calculate any VAT (Value Added Tax) and does neither calculate any income tax or corporation tax due to or levied by public authorities.

# 3. E&FCM BUILDING BLOCKS

The E&FCM is implemented as an Excel workbook consisting of 12 worksheets or tabs structured in the following four groups:

- Input worksheets,
- Auxiliary worksheets,
- Cash flow worksheets,
- KPI worksheet.

Data can only be entered in the E&FCM in the different **Input Worksheets**. There are three input worksheets:

- General Input table,
- Price evolutions,
- Input Table DR_FLEXIBILITY.

The Input tabs will be fed manually by the user of the E&FCM or by other ABEPeM modules such as the "Energy Cost Cash Flow Quantification Module" and/or the "Configuration Form". These input tabs include all necessary and required data to run the cash flow analysis in the Cash Flow worksheets and perform the calculations in the Auxiliary worksheets when the latter are applicable.

The core of the E&FCM are the two **Cash flow worksheets**: one showing the relevant project cash flows after implementation of the Energy Efficiency Measures (EEM) only, and another showing the cash flows after the implementation of DR Flexibility (active control measures), thus in addition to the first EEM only scenario.

These two cash flow tabs feature all relevant information, on a year-on-year basis, grouped in the following cash flow groups:

- Operating income (e.g. rent income, rent charges income),
- Operating expenses (e.g. rent expense, rent charges, energy expenses and energy/DR Flexibility savings, maintenance expenses and other relevant expenses),
- Initial Outlay (e.g. capital expenditures and other initial outlays), and
- One-off Income (e.g. subsidies or grants and sales or residual value of the asset).

Both cash flow tabs also include separate financing cash flows to show the effect of the financing cash flows from ESCO (Shared Savings Agreements, First-In or First-Out agreements, …) or third-party financing when applicable.

The data in the cash flow tabs is being obtained from the different Input tabs and Auxiliary tabs (for the financing cash flows) within the E&FCM tool.

The **Auxiliary worksheets** calculate the financing cash flows depending on the financing option chosen in the General Input table (No third-party financing, third party financing based on lending or ESCO financing) and ESCO payment models (Shared Savings, First In, First Out).

Project owners and other specific stakeholders look at Key Performance Indicators (KPI) and other relevant financial information when making investment decisions. E&FCM provides this relevant information in the **KPI worksheet**. The KPI are grouped in Investment, Energy, Financial and Other KPI.

The following Figure 1 shows the high-level architecture and building blocks of the E&FCM.

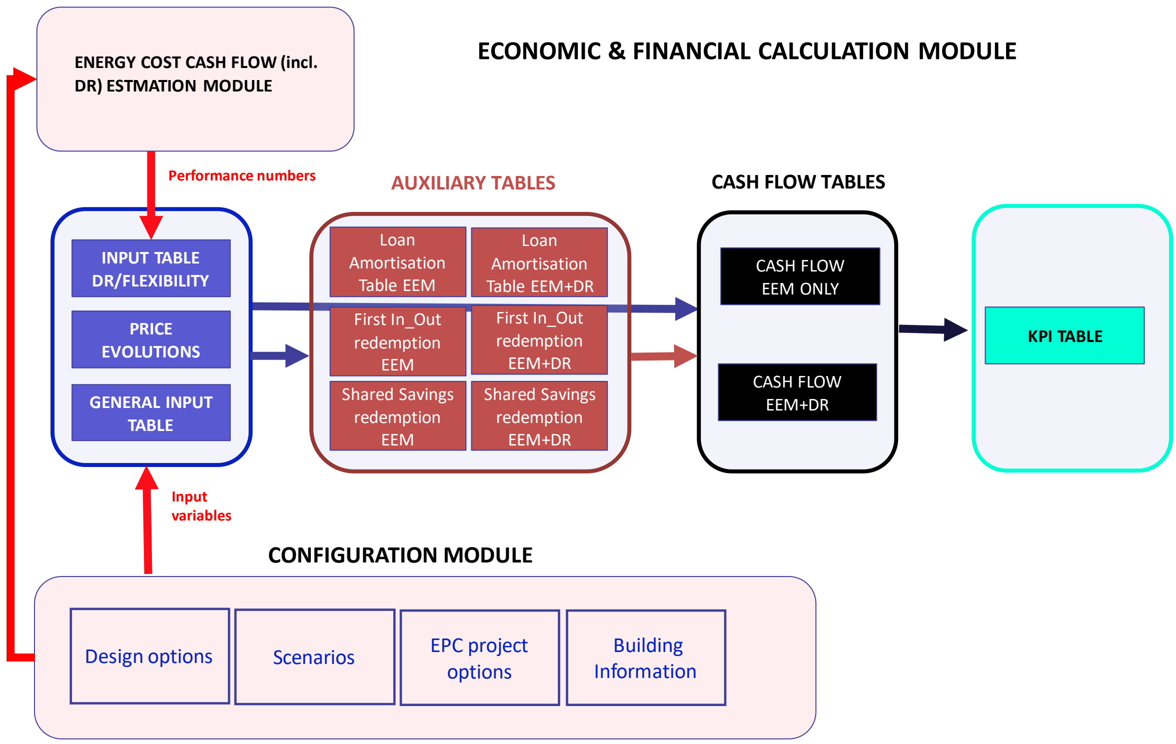


FIGURE 1 – HIGH-LEVEL ARCHITECTURE & BUILDING BLOCKS OF THE E&FCM

# 4. INPUT WORKSHEETS

The information that is needed to perform the different calculations in the auxiliary tabs, the cash flow tabs and the KPI tab is obtained from the input worksheets. E&FCM includes 3 different input tables:

- General input table,
- Price evolutions,
- Input Table DR/ flexibility.

## 4.1 GENERAL INPUT TABLE

The General Input table groups all the input variables that are required to calculate the cash flows of the underlying project . This tab feeds the following tabs in the E&FCM:

- Input table DR_Flexibility,
- Loan Amortisation table EEM,
- Loan Amortisation table EEM+DR,
- First In_Out redemption EEM,
- First In-Out redemption EEM+DR,
- Shared Savings Redemption EEM,
- Shared Savings Redemption EEM+DR,
- Cash flow EEM ONLY,
- Cash flow EEM+DR,
- KPI.

The General Input table consist of 7 sections which are further on explained in detail:

- Project details,
- Project general parameters,
- Asset General details,
- Rent, additional rent and other income details,
- Operating expenses,
- Investment details,
- Financing details.

### 4.1.1 PROJECT DETAILS

**TABLE 1 – GENERAL INPUT TABLE - PROJECT DETAILS**

| PROJECT DETAILS | |
|---|---|
| Project name | Free text |
| Scenario | Free text |
| E&FCM user | Dropdown list |
| AEPC Beneficiary | Dropdown list |
| Life Cycle of project | Years |
| EPC contract duration EEM only | Years |
| EPC contract duration EEM + DR | Years |

### (1) PROJECT NAME

The project name of the business case can be entered here as a free text as it is intended for information purposes only and is thus not referenced with other worksheets.

### (2) SCENARIO

The scenario or the name of the business case can be entered here as a free text as it is intended for information purposes only and is thus not referenced with other worksheets. It is to be noticed that every set scenario is normally based on a series of assumptions, user profiles, assumed forecasts, configuration of energy efficiency measures, etc.,… and will provide a fixed performance or fixed results. By changing parameters such as indexes, discount rates, expenses, investment rates or interest rates in this E&FCM the E&FCM User can further explore the business case and analyse its sensitivity.

### (3) E&FCM USER

The following user type can be chosen from a dropdown list: ESCO, Facilitator, Owner, Other. This field merely indicates who is entering information in the E&FCM and has no incidence on other tabs nor is it referenced with other tabs. E&FCM is intended to be used by business managers or users knowledgeable of investment analysis, in cooperation with beneficiaries and the engineering department of the solutions providers, for instance, the ESCO and the providers of information from the Energy Cost Cash Flow Quantification Module which is part of the ABEPeM Platform.

### (4) AEPC BENEFICIARY

The AEPC beneficiaries are the stakeholders for whom the business case (the results of the E&FCM) is intended. In E&FCM three types of AEPC beneficiaries are defined: Lessee, Owner-Occupier and Owner-Lessor. The choice of one of these three types determines which information is shown in the different Cash Flow worksheets and in the KPI worksheet as only information relevant to the AEPC beneficiary type appears. As to the General Input Table, only input data or input variables related to the AEPC beneficiaries' type will need to be recorded.

#### (A) LESSEE

The Lessee-type (or Tenant) normally leases or rents a house, apartment or any type of dwelling, from an Owner-Lessor (Landlord). In a typical energy efficiency project, the Lessee does not bear the investment effort (the initial outlay) resulting from the implemented Energy Efficiency measures though it enjoys all of the subsequent energy and flexibility savings. Landlords will be very reluctant to invest their financial resources if they are not able to recover at least some part of the invested resources. In this case, an energy efficiency project will only be feasible if the Lessee is willing to trade off part or the whole of the potential energy and flexibility savings against, for instance, increased comfort and health by accepting an increase of the rent or rent charges.

For the Lessee Beneficiary, E&FCM shows Current Rent Expense, Current Rent charges (expense) and Current Energy expenses in the "Cash Flow before energy efficiency measures" section. After energy efficiency measures and flexibility (if applicable) have been implemented the Cash Flow worksheets show in the "Cash Flow after energy efficiency measures" the resulting Rent Expense, Rent charges and Energy Expenses.

### (B) OWNER-OCCUPIER

An Owner-Occupier is being defined as the party that owns and at the same time occupies or uses the dwelling or the building. Owner-Occupiers invest their money in energy efficiency measures and flexibility, normally with the intention to trade this investment against future savings (energy savings and savings or income from flexibility), possible increased building value and increased comfort and health.

E&FCM shows for the Owner-Occupier the following type of cash flows: Operating Expenses, Initial Outlay and One-Off Income. These data shown depend on the chosen input variables. In the Operating Expenses section of the cash flows the module shows Current Energy Expenses and other expenses (Maintenance, Insurance, Property taxes...) in the "Cash Flow before energy efficiency measures" case and in the "Cash Flow after energy efficiency measures" case the same type of expenses resulting from the energy efficiency measures and the flexibility (implicit DR and explicit DR). In the One-off Income section, the module shows sales or residual value of real estate in case asset valuation is being performed and possibly subsidies when these are applicable (after energy efficiency renovation). Investment values are shown in the Initial Outlay section of the "Cash Flow after energy efficiency measures" case. In case the Owner-Occupier chooses to have the investment, amounts being financed by a 3rd party, such as a financial institution, or by the ESCO the module will also provide the financing cash flows in the Financing Cash flows section.

### (C) OWNER-LESSOR

The Owner-lessor (also known as Landlord) typically owns a property (building, house, ...) and leases or rents out this property to lessees or tenants. The Owner-lessor invests in energy efficiency measures if he has the perspective of recovering the investment within a defined period and considering a certain return or profit on this investment.

For the Owner-lessor type of user the E&FCM shows the following type of cash flows: Operating Income, Operating Expenses, Initial Outlay and One-Off Income. In the "Cash flow before energy efficiency measures' the Operating Income refers to rents and rent charges, and the Operating Expenses include expenses such as maintenance, insurance , property taxes, and other expenses, and in the "Cash flow after energy efficiency measures" case the same type of Operating Income and Operating Expenses would be shown after the impact of the energy efficiency measures (for example, additional cash flows in the Operating Income section can be: Increased rent income due to energy savings and Rent charges after EEM implementation). In the One-off Income section, the module shows sales or residual value of real estate in case asset valuation is being done and possibly subsidies when these are applicable (after energy efficiency measures). Investment values are shown in the Initial Outlay section of the "Cash Flow after energy efficiency measures" case. In analogy with the Owner-Occupier user type, in case the Owner-Occupier chooses to have the investment amounts being financed by a 3rd party, such as a financial institution, or by the ESCO the module will also provide the financing cash flows in the Financing Cash flows section.

### (5) LIFE CYCLE OF PROJECT

The life cycle of the project corresponds to the observed period for which financial analysis is applied with a maximum of 40 years. Relevant yearly cash flows will be available during the set life cycle of the project. Cash flows beyond the observed period will have zero values.

#### (6) EPC CONTRACT DURATON EEM ONLY

This input variable refers to the contract term with the ESCO. It fixes the period for which maintenance will have to be paid to the ESCO. It determines the period for which cash flow values for maintenance in the “Cash Flow EEM ONLY” worksheet is applicable.

#### (7) EPC CONTRACT DURATON EEM+DR

This input variable refers to the contract term with the ESCO when flexibility is added to the EEM only cash
flow worksheet. It fixes the period for which maintenance will have to be paid to the ESCO. It determines the period for which cash flow values for maintenance in the “Cash Flow EEM+DR” worksheet are applicable.

**It should be noted that normally the EPC contract duration for both EEM ONLY and EEM+DR should be the same. This will not be the case when the initial investment in the energy efficiency measures is being financed by the ESCO under one of the following financing methods: First In, First Out or Shared Savings. If this is the case the corresponding EPC contract duration must be equal to the corresponding Redemption table. E.g. if a Shared Savings financing method has been chosen in the Financing Details section of the General Input Table the EPC contract period must equal the period necessary to reimburse the investment as evidenced in the Shared Savings Redemption EEM and the Shared savings Redemption EEMDR spreadsheets. The period corresponds to the year where the Ending Balance of the investment becomes zero.**

### 4.1.2 PROJECT GENERAL PARAMETERS

**TABLE 2 – GENERAL INPUT TABLE - PROJECT GENERAL PARAMETERS**

| PROJECT GENERAL PARAMETERS | |
|---|---|
| Discount rate (or WACC when appropriate) | % |
| 1st discount period to base date | Years |

#### (1) DISCOUNT RATE (OR WACC WHEN APPROPRIATE)

The discount rate is actually the interest rate used in the E&FCM to calculate the present value of the future cash flows, hence taking into consideration the time value of money.

#### (2) 1ST DISCOUNT PERIOD TO-BASE-DATE

The 1st discount period to-base-date is the discount period that is allocated to the first year (Year 1) in the cash flow worksheets. Year 1 is usually the year when the energy efficiency measures are being implemented and the works are being carried out. An input value of 0,25 means that Year 1 is being discounted for 0,25 years or 3 months, Year 2 for 1,25 years or 15 months. An input value of 0,5 means that Year 1 is discounted for 6 months, Year 2 for 18 months, Year 3 for 30 months, etc. An input value of 1,0 means that all cash flows incurred in Year 1 are deemed to take place at the end of Year 1 (31st of December) and thus discounted to the 1st day of Year 1.

### 4.1.3 ASSET GENERAL DETAILS

**TABLE 3 – GENERAL INPUT TABLE - ASSET GENERAL DETAILS**

| ASSET GENERAL DETAILS | |
|---|---|
| Asset valuation applicable | Yes/No |
| Surface of the building | $m^2$ |
| Sales rate of building | €/$m^2$ |

#### (1) ASSET VALUATION APPLICABLE

If this parameter is put to “No” then there will be no valuation of the asset (the building). This means that the user of the E&FCM does not quantify the possible impact of the energy efficiency renovation on the future value of the building. If the parameter is put to “Yes” E&FCM valuates the current value of the building as a multiplication of the Surface of the building in $m^2$ and the sales rate of the building, which is a price per $m^2$. This current value is then adjusted in the Price Evolutions worksheet on a yearly basis to reflect the evolution of the real estate value for the two main situations: before implementation of the energy efficiency measures and flexibility and after implementation of the energy efficiency measures and flexibility.

#### (2) SURFACE OF THE BUILDING

This is the number of square meters of the building that can be taken into account to calculate the sales value of the building.

#### (3) SALES RATE OF BUILDING

This number represents the sales price per $m^2$ of the building at the beginning of the energy efficiency project.

### 4.1.4 RENT, ADDITIONAL RENT & OTHER INCOME DETAILS

This section of the General Input Table is only applicable to the AEPC Beneficiary types Lessee and Owner-Lessor. This section provides information on the current rent and rent charges (common, service or maintenance charges and individual/private charges) situation, i.e., before energy efficiency measures are implemented and future rent and rent charges, after implementation of the energy efficiency measures, in those cases that these rent and rent charges can be increased.

**TABLE 4 – GENERAL INPUT TABLE - RENT, ADDITIONAL RENT & OTHER INCOME DETAILS**

| RENT, ADDITIONAL RENT & OTHER INCOME DETAILS | |
|---|---|
| Current rent | €/Year |
| New rent after EEM only | €/Year |
| Rent charges before EEM implementation | €/Year |
| Rent charges after EEM implementation | €/Year |

#### (1) CURRENT RENT

Is the yearly rent that a Lessee or tenant is paying (and thus the Owner-Lessor or Landlord is receiving) at the beginning of the project period.

#### (2) NEW RENT AFTER EEM ONLY

Refers to the yearly rent that the tenant is paying (and the landlord is receiving) after the energy efficiency measures have been implemented. The difference between this new rent and the current rent would normally be the yearly fee that the tenant is paying during the lease term for the investment in energy efficiency measures borne by the landlord.

#### (3) RENT CHARGES BEFORE EEM IMPLEMENTATION

These are the yearly charges, at the beginning of the project period, on top of the rent, typically related to e.g. common service charges, common maintenance charges, but also individual/private charges that, when applicable, are being charged through by the landlord on a cost basis (e.g. energy and water consumption, some taxes, ...).

#### (4) RENT CHARGES AFTER EEM IMPLEMENTATION

Refers to the yearly rent charges, as described in the previous paragraph, that are being charged through by the landlord on a cost basis after implementation of the energy efficiency measures. The increase in these rent charges is normally the direct result of additional expenses incurred by the landlord as a direct consequence of the implementation of the energy efficiency measures. These expenses could be additional maintenance, facilities management, insurance, property taxation, etc.

### 4.1.5 OPERATING EXPENSES

Depending on the AEPC Beneficiary this section provides information on typical operating expenses such as maintenance, insurance, property taxes and other expenses (property/facilities management, …) that are being incurred by Owner-Occupiers and Owner-Lessors. The information for these types of expenses needs to be provided for the following three situations: before any energy efficiency measures, after EEM only and after EEM + DR. Specifically the DR/Flexibility services input variables relate to expenses linked to the DR portion (thus additional to the EEM implementation).

TABLE 5 – GENERAL INPUT TABLE - OPERATING EXPENSES

| OPERATING EXPENSES | |
|---|---|
| **Before EEM implementation** | |
| Maintenance expenses before EEM | €/Year |
| Insurance expenses before EEM | €/Year |
| Other expenses (Facilities, property management, …) | €/Year |
| Property taxes | €/Year |
| **After EEM implementation** | |
| Maintenance expenses during EPC-contract period | €/Year |
| Maintenance expenses after EPC-contract period (inception value) | €/Year |
| Insurance expenses after EEM | €/Year |
| Other expenses (Facilities, property management,…) | €/Year |
| Property taxes | €/Year |
| **DR/Flexibility services** | |
| DR Service Expense (Fee) | €/Year |
| Explicit DR service fee (as % of Explicit DR Income) | % |

#### (1) MAINTENANCE EXPENSES

Maintenance expenses include regular maintenance of the building and installations, repairs and replacements. After the EEM implementation these maintenance expenses are split into maintenance expenses during the EPC-contract period as defined in the input variables under the Project Details section and maintenance expenses after the EPC-contract period (when the ESCO is not engaged anymore). The maintenance expenses of both periods can be different but that doesn't necessarily have to be the case.

#### (2) INSURANCE EXPENSES

This is the property or equipment/installations insurance premium paid to get coverage for damages or losses related to the dwelling or the equipment/installations.

#### (3) OTHER EXPENSES (FACILITIES, PROPERTY MANAGEMENT, ...)

These are any other relevant expenses that are not included in the other expense types under this Operating Expenses section, e.g., facilities or property management fees.

#### (4) PROPERTY TAXES

Relates to property taxes that are relevant to the business case and that could change as a result of the implementation of the EEM and DR.

#### (5) DR SERVICE EXPENSE (FEE)

This input variable indicates the yearly amount payable to the service provider in case there is an expense associated to the provision of DR services. This expense is additional to the maintenance fees paid to the ESCO or service provider after implementation of the EEM.

#### (6) EXPLICIT DR SERVICE FEE (AS % OF EXPLICIT DR INCOME)

This input variable is only applicable when Explicit Demand Response is being included in the business case, thus when savings from Explicit DR are being calculated in the Energy Cost Cash Flow Quantification Module within the ABEPeM tool. The percentage amount of this input variable equals the retention portion that the aggregator or service provider is withholding from the Explicit DR income generated as remuneration of its services. This expense is additional to the maintenance fees paid to the ESCO or service provider after implementation of the EEM and to the DR Service expense fee.

### 4.1.6 INVESTMENT DETAILS

In this section of the General Input table the user provides values for the investments related to the EEM and to the DR/Flexibility services and, if applicable, provides values for subsidies or grants.

**TABLE 6 – GENERAL INPUT TABLE - INVESTMENT DETAILS**

| INVESTMENT DETAILS | |
|---|---|
| Investment amount classic EEM | € |
| Additional investment amount DR/Flexibility | € |
| Other initial investment outlay | € |
| Grants and/or subsidies obtained (deductible) | € |

#### (1) INVESTMENT AMOUNT CLASSIC EEM

This input variable relates to the amount of the initial investment required for the implementation of the EEM only.

#### (2) ADDITIONAL INVESTMENT AMOUNT DR/FLEXIBILITY

This input variable indicates the amount of the initial investment required for additional DR and Flexibility services.

#### (3) OTHER INITIAL INVESTMENT OUTLAY

This input variable includes any other initial investment outlay or expense that has not been included in the other input variables. This input variable is E&FCM driven and has no relation with the investment amounts resulting from the EEM and the Flexibility. It's up to the user to include these other one-off expenses in the business case if needed.

#### (4) GRANTS AND/OR SUBSIDIES OBTAINED (DEDUCTIBLE)

If subsidies or grants apply the related amounts must be indicated in this input variable. These amounts are being deducted from the overall investment amounts.

### 4.1.7 FINANCING DETAILS

Project owners have to decide whether they finance the initial investments with their own resources, this means by using their own funds though they can also decide to have the initial investments financed by a 3rd party, mostly financial institutions, or by the ESCO. When the ESCO is the financing party the financing method can be based on a First Out principle, on a First In principle, on a Shared Savings principle or on a loan amount basis. The input variables in this financing details section allow to calculate the different investment redemption tables and the loan amortization tables that are part of the Auxiliary Worksheets. The calculations in these Auxiliary Worksheets provide the financing cash flows in the cash flow worksheets. These financing cash flows are shown under the Financing Cash Flows section.

**TABLE 7 – GENERAL INPUT TABLE - FINANCING DETAILS**

| FINANCING DETAILS | |
|---|---|
| ESCO Financing interest rate | % |
| ESCO Financing based on First Out principle? | Yes/No |
| | |
| ESCO Financing based on First In principle? | Yes/No |
| Amount of acquired savings by the beneficiary when First In principle | € |
| | |
| ESCO Financing based on Shared Savings? | Yes/No |
| Shared Savings percentage allocated to the ESCO | % |
| | |
| 3rd party or ESCO financing based on reimbursement fee? | Yes/No |
| Loan amount EEM | € |
| Loan amount DR Flexibility | € |
| Annual interest rate applicable | % |
| Loan terms | Years |
| Start date of loan | MM/YY |
| | |

**None or only one financing method out of the four financing methods can be chosen. If no financing of the investment by a 3rd party or the ESCO is in place then all four financing options must be set to "No".**

### (1) ESCO FINANCING INTEREST RATE

This input variable needs to be filled out if any of the following financing methods is being used: First Out, First In or Shared Savings. The value here is the annual interest rate that the ESCO is applying on the reimbursement by the project owner of the initial investment amount.

### (2) ESCO FINANCING BASED ON FIRST OUT PRINCIPLE?

If this variable is set to "Yes" it means that the ESCO is financing the investment based on the First Out financing method. In this case, the achieved energy savings are being fully used to remunerate the ESCO for its services including the reimbursement of the investment. The achieved savings amount is thus the sum of the maintenance fee payable, the principal amount reimbursement and the interest payable.

### (3) ESCO FINANCING BASED ON FIRST IN PRINCIPLE?

If this variable is set to “Yes” it means that the ESCO is financing the investment based on the First In financing method. This financing method differs from the First Out financing method in the sense that in the First In financing method the achieved energy savings are being only partially used to remunerate the ESCO for its services including the reimbursement of the investment. Indeed, by convention a fixed part of the achieved savings are immediately acquired by the project owner during the whole contract period. The achieved savings amount is thus the sum of the amount of savings acquired by the project owner, the maintenance fee payable, the principal amount reimbursement and the interest payable.

### (4) AMOUNT OF ACQUIRED SAVINGS BY THE BENEFICIARY WHEN FIRST IN PRINCIPLE

Refers to the fixed amount of savings that is being allocated to the project owner as from the beginning of the contract period.

### (5) ESCO FINANCING BASED ON SHARED SAVINGS?

If this variable is set to “Yes” it means that the ESCO is financing the investment based on the Shared Savings financing method. In this case, the achieved energy savings are shared between the ESCO and the project owner, and the ESCO’s share is being used to remunerate the ESCO for its services, including the reimbursement of the investment. This Shared Savings financing method differs from the First In in the sense that with Shared Savings a percentage of the achieved savings are immediately acquired by the project owner, e.g. 10% of the achieved savings, during the whole contract period. The achieved savings amount is thus the sum of the amount of savings acquired by the project owner, the maintenance fee payable, the principal amount reimbursement and the interest payable.

### (6) SHARED SAVINGS PERCENTAGE ALLOCATED TO THE ESCO

Refers to the share, as a percentage, of savings that is being allocated to the ESCO as from the beginning of the contract period.

### (7) 3RD PARTY OR ESCO FINANCING BASED ON REIMBURSEMENT FEE?

If this variable is set to “Yes” it means that the ESCO or a third-party financier is financing the investment on a loan basis. This loan can cover the whole investment amount or only part of it, depending on the financing decision made by the project owner. Reimbursement of the loan will include principal amounts and interest amounts.

### (8) LOAN AMOUNT EEM

This value refers to the loan amount obtained (from a third party or from the ESCO) to finance the EEM. The cash flow values calculated in the Loan Amortisation table EEM appear in the Cash Flow EEM ONLY worksheet.

### (9) LOAN AMOUNT EEM+DR FLEXIBILITY

This value refers to the loan amount obtained (from a third party of from the ESCO) to finance the investments in EEM and the investments in DR Flexibility. The cash flow values calculated in the Loan Amortisation table EEM+DR appear in the Cash Flow EEM+DR worksheet.

### (10) ANNUAL INTEREST RATE APPLICABLE

The value here refers to the annual interest rate that the financier or ESCO is applying to the loan.

### (11) LOAN TERMS

The value here, expressed in years, refers to the reimbursement period of the loan.

### (12) START DATE OF LOAN

Refers to the start date of the loan and is intended for information purposes only and is thus not referenced with other worksheets.

## 4.2 PRICE EVOLUTIONS

The Price evolutions table provides the input information for different general indexations or price escalations of future expenses such as operating expenses (e.g., maintenance, facilities, property management, ...), energy prices, DR/Flexibility savings, rent income (or rent expense for the lessee) and property taxes and other levies. It also includes the possibility to simulate the market value evolution of the asset (the building, the dwelling, …) if no EEM are implemented and if EEM are implemented thus providing the asset value change (normally increase) at sales or disposal of the asset (based on the market value evolution assumptions). The values can be changed individually for all years (from one to forty years).

**TABLE 8 – PRICE EVOLUTIONS TABLE**

| PRICE EVOLUTION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|
| **General Indexations (Price escalations)** | | | | | | | | | | |
| Operating expenses | 2,00% | 2,00% | 2,00% | 2,00% | 2,00% | 2,00% | 2,00% | 2,00% | 2,00% | 2,00% |
| Energy price | 2,00% | 2,00% | 2,00% | 2,00% | 2,00% | 2,00% | 2,00% | 2,00% | 2,00% | 2,00% |
| DR/Flexibility savings | 2,00% | 2,00% | 2,00% | 2,00% | 2,00% | 2,00% | 2,00% | 2,00% | 2,00% | 2,00% |
| Rent expense/income | 2,00% | 2,00% | 2,00% | 2,00% | 2,00% | 2,00% | 2,00% | 2,00% | 2,00% | 2,00% |
| Property Tax and various levies | 1,50% | 1,50% | 1,50% | 1,50% | 1,50% | 1,50% | 1,50% | 1,50% | 1,50% | 1,50% |
| **Asset market value evolution** | | | | | | | | | | |
| Market value evolution no EEM | 0,75% | 0,75% | 0,75% | 0,75% | 0,75% | 0,75% | 0,75% | 0,75% | 0,75% | 0,75% |
| Market value evolution with EEM | 1,25% | 1,25% | 1,25% | 1,25% | 1,25% | 1,25% | 1,25% | 1,25% | 1,25% | 1,25% |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 40 |

### 4.2.1 GENERAL INDEXATIONS (PRICE ESCALATIONS)

Indexations or price escalations can be set for the following cash flow items:

- Operating expenses
- Energy price
- DR/Flexibility savings
- Rent expense/income
- Property Tax and various levies

### (1) OPERATING EXPENSES

The set rates are influencing the future cash flows of the following operating expenses in the cash flow tables:

- Maintenance expenses
- Insurance expenses
- Other expenses (Facilities/property management)

### (2) ENERGY PRICE

The energy price indexation rates influence the future energy expenses and the energy savings cash flows.

### (3) DR/FLEXIBILITY SAVINGS

These indexation rates influence specifically the future DR/Flexibility savings and Explicit DR cash flows (Gross income and Service retention). As DR/Flexibility savings can have a component not based on kWh and thus not based on energy prices these indexations might be, but not necessarily, different than the energy price indexations.

### (4) RENT EXPENSE/INCOME

Indexation of the rent expense/income impacts the cash flows of the following items in the cash flow tables:

**Operating income section**:

- Current rent income
- Current rent charges
- Rent prior to renovation
- Increased rent income due to Energy Savings
- Rent Charges after EEM implementation

**Operating expenses section**

- Current Rent Expense
- Current Rent Charges (expenses)
- Rent expense before renovation
- Increased rent expense due to Energy Savings
- Rent Charges after EEM implementation

### (5) PROPERTY TAX AND VARIOUS LEVIES

The property tax (and other levies) indexation rates influence the future property taxes cash flows.

### 4.2.2 ASSET MARKET VALUE EVOLUTION

Adjusting the values in this section offers the possibility to simulate the market value evolution of the asset (the building, the dwelling, …) if no EEM are implemented and if EEM are implemented, thus providing the asset value change (this would normally be an increase as a consequence of the improved conditions of the building after EEM are implemented) at sales or disposal of the asset (based on the market value evolution assumptions).

**The market value evolution assumption is based on the premise that the real estate value of a non-renovated asset (building, house, dwelling) evolves differently over time than a well renovated asset. This is often referred to as Brown Discount (price on a non-renovated asset does not increase at the same pace than a renovated one or even decreases) and Green Premium. Real estate markets in different regions and countries might differ substantially, hence a local knowledge of the real estate market and the impact of energy efficiency improvements on the local real estate value is paramount. When real estate valuation is being simulated the tool user should adjust the yearly real estate value evolution to the local real estate market situation.**

#### (1) MARKET VALUE EVOLUTION NO EEM

The values entered in the 'Market value evolution no EEM'-row define the yearly percent change of the value of the asset when no EEM are implemented.

#### (2) MARKET VALUE EVOLUTION WITH EEM

The values entered in the 'Market value evolution with EEM'-row define the yearly percent change of the value of the asset after EEM have been implemented.

### 4.3 INPUT TABLE DR_FLEXIBILITY

The Input tab DR_FLEXIBILITY is being fed by the Energy Cost Cash Flow Quantification module, which is a module within the ABEPeM tool. It provides, on a year-on-year basis and in kWh and EURO, the Reference/Baseline energy consumption information, the consumption after EEM only and the energy consumption after also valorising DR Flexibility (EEM + DR) for Implicit DR and, if applicable, Explicit DR. The provided information by the Energy Cost Cash Flow Quantification Module allows to calculate, again in kWh and EURO, the savings after Energy Efficiency Measures, the savings after addition of Implicit DR and the savings after addition of Explicit DR. From the provided information the worksheet derives the monetary value of the Implicit DR only as well as the monetary value of the Explicit DR only. The former value is determined by a scenario based optimization that optimizes WHEN energy is consumed. The latter value is the basis for the calculation of the Explicit DR retention fees, if any.

**TABLE 9 – INPUT TABLE_DR FLEXIBILITY-YEARLY CONSUMPTION AND YEARLY SAVINGS**

| YEARLY CONSUMPTION (FROM ENERGY COST CASH I | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Yearly Input variables** | | | | | | | | | | |
| **Reference/Baseline consumption** | | | | | | | | | | |
| Energy Consumption in kWh | 8.500,00 | 8.500,00 | 8.500,00 | 8.500,00 | 8.500,00 | 8.500,00 | 8.500,00 | 8.500,00 | 8.500,00 | 8.500,00 |
| Energy Consumption in € | € 7.000,00 | € 7.000,00 | € 7.000,00 | € 7.000,00 | € 7.000,00 | € 7.000,00 | € 7.000,00 | € 7.000,00 | € 7.000,00 | € 7.000,00 |
| **Consumption after Energy Efficiency Measures Only** | | | | | | | | | | |
| Energy Consumption in kWh | 4.300,00 | 4.300,00 | 4.300,00 | 4.300,00 | 4.300,00 | 4.300,00 | 4.300,00 | 4.300,00 | 4.300,00 | 4.300,00 |
| Energy Consumption in € | € 3.550,00 | € 3.550,00 | € 3.550,00 | € 3.550,00 | € 3.550,00 | € 3.550,00 | € 3.550,00 | € 3.550,00 | € 3.550,00 | € 3.550,00 |
| **Consumption after EEM and Implicit DR** | | | | | | | | | | |
| Energy Consumption in kWh | 4.250,00 | 4.250,00 | 4.250,00 | 4.250,00 | 4.250,00 | 4.250,00 | 4.250,00 | 4.250,00 | 4.250,00 | 4.250,00 |
| Energy Consumption in € | € 3.000,00 | € 3.000,00 | € 3.000,00 | € 3.000,00 | € 3.000,00 | € 3.000,00 | € 3.000,00 | € 3.000,00 | € 3.000,00 | € 3.000,00 |
| **Consumption after EEM, Implicit DR and Explicit DR** | | | | | | | | | | |
| Energy Consumption in kWh | 4.350,00 | 4.350,00 | 4.350,00 | 4.350,00 | 4.350,00 | 4.350,00 | 4.350,00 | 4.350,00 | 4.350,00 | 4.350,00 |
| Energy Consumption in € | € 2.750,00 | € 2.750,00 | € 2.750,00 | € 2.750,00 | € 2.750,00 | € 2.750,00 | € 2.750,00 | € 2.750,00 | € 2.750,00 | € 2.750,00 |
| YEARLY SAVINGS | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 40 |
| **Savings after Energy Efficiency Measures Only** | | | | | | | | | | |
| Energy Savings in kWh | 4.200,00 | 4.200,00 | 4.200,00 | 4.200,00 | 4.200,00 | 4.200,00 | 4.200,00 | 4.200,00 | 4.200,00 | 4.200,00 |
| Energy Savings in € | 3.450,00 | 3.450,00 | 3.450,00 | 3.450,00 | 3.450,00 | 3.450,00 | 3.450,00 | 3.450,00 | 3.450,00 | 3.450,00 |
| **Savings after EEM and Implicit DR** | | | | | | | | | | |
| Energy Savings in kWh | 4.250,00 | 4.250,00 | 4.250,00 | 4.250,00 | 4.250,00 | 4.250,00 | 4.250,00 | 4.250,00 | 4.250,00 | 4.250,00 |
| Energy Savings in € | 4.000,00 | 4.000,00 | 4.000,00 | 4.000,00 | 4.000,00 | 4.000,00 | 4.000,00 | 4.000,00 | 4.000,00 | 4.000,00 |
| **Savings after EEM, Implicit DR and Explicit DR** | | | | | | | | | | |
| Energy Savings in kWh | 4.150,00 | 4.150,00 | 4.150,00 | 4.150,00 | 4.150,00 | 4.150,00 | 4.150,00 | 4.150,00 | 4.150,00 | 4.150,00 |
| Energy Savings in € | 4.260,00 | 4.260,00 | 4.260,00 | 4.260,00 | 4.260,00 | 4.260,00 | 4.260,00 | 4.260,00 | 4.260,00 | 4.260,00 |
| ENERGY SERVICES FEE CALCULATION | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 40 |
| **After DR/Flexibility** | | | | | | | | | | |
| Savings Implicit DR | 550,00 | 550,00 | 550,00 | 550,00 | 550,00 | 550,00 | 550,00 | 550,00 | 550,00 | 550,00 |
| Savings/Income Explicit DR | 260,00 | 260,00 | 260,00 | 260,00 | 260,00 | 260,00 | 260,00 | 260,00 | 260,00 | 260,00 |
| Explicit DR: Service retention | 78,00 | 78,00 | 78,00 | 78,00 | 78,00 | 78,00 | 78,00 | 78,00 | 78,00 | 78,00 |

The cash flows calculated in this table are being fed into the two Cash flow worksheets.

The cash flows related to the Baseline energy consumption in € are shown in the two cashflow worksheets in the "Cash Flow before energy efficiency measures"-section as Current energy expenses. In the "Cash Flow after energy efficiency measures"-section they show up as Energy expenses before renovation.

The cash flows related to the Savings after Energy Efficiency Measures Only in € are shown in both cash flow worksheet in the "Cash Flow after energy efficiency measures"-section as Energy savings after renovation only.

The cash flows related to the Savings Implicit DR are shown in the Cash Flow EEM+DR worksheet in the "Cash Flow after energy efficiency measures"-section as DR/Flexibility savings.

The cash flows related to the Savings/Income Explicit DR are shown in the Cash Flow EEM+DR worksheet in the "Cash Flow after energy efficiency measures"-section as Explicit DR: Gross Income.

The Explicit DR: Service retention calculation is shown in the Cash Flow EEM+DR worksheet in the "Cash Flow after energy efficiency measures"-section as Explicit DR: Service Retention.

# 5. AUXILIARY WORKSHEETS

E&FCM consists of six Auxiliary worksheets that calculate the financing cash flows of the energy efficiency project if one of the four financing option have been chosen in the Financing Details section of the General Input table:

- Third-party/ESCO financing based on reimbursement fee (=loan)
- ESCO financing based on First Out principle
- ESCO financing based on First In principle
- ESCO financing based on Shared Services

All six Auxiliary worksheets are calculation-only worksheet and don't require any manual input.

The first two auxiliary worksheets, Loan Amortisation table EEM and Loan Amortisation table EEM+DR, calculate the financing cash flows related to the loan financing possibility, for both cash flow worksheets (EEM ONLY and EEM+DR).

The following two auxiliary worksheets, First In_Out Redemption EEM and First In_Out Redemption EEM+DR, calculate the financing cash flows related to the ESCO financing possibility based on the First In or First Out principle, whichever has been defined in the General Input table, for both cash flow worksheets (EEM ONLY and EEM+DR).

The last two auxiliary worksheets, Shared Savings Redemption EEM and Shared Savings Redemption EEM+DR, calculate the financing cash flows related to the ESCO financing possibility based on the Shared Savings principle, for both cash flow worksheets (EEM ONLY and EEM+DR).

**If the First In, First Out or Shared Savings financing option has been chosen in the Financing Details section of the General Input table the user of E&FCM must pay particular attention to the possible warnings that can appear in the related Auxiliary Calculation worksheets. The underlying business principle of the mentioned financing options is that the ESCO or Service Provider recovers the initial investment outlay within the EPC contract duration. Whenever the EPC contract duration set in the General Input table differs from the calculated redemption periods in the redemption tables (Auxiliary Worksheets) some warnings will appear. These warnings are being explained under each related Auxiliary Worksheet.**

## 5.1 LOAN AMORTISATION TABLE EEM

This auxiliary worksheet calculates the financing cash flows related to the loan reimbursement details defined in the General Input table under Loan Amount EEM and feeds the **Cash Flow EEM ONLY**.
The amorisation table in this worksheet shows for each and all periods (years) defined in the General Input table the following relevant elements: Payment period, Beginning Balance, Annuity payment (which is the sum of the principal amount and the interest), Principal amount, Interest amount and Ending Balance. The Annuity payment is shown in the Financing Cash Flows section of the Cash Flow EEM ONLY worksheet as 'Principal reimbursement and interests (loan redemption)'.

## 5.2 LOAN AMORTISATION TABLE EEM+DR

In analogy with the Loan Amortisation table EEM this auxiliary worksheet calculates the financing cash flows related to the loan reimbursement details defined in the General Input table under Loan Amount EEM+DR Flexibility and feeds the **Cash Flow EEM+DR** worksheet.
The amorisation table in this worksheet shows for each and all periods (years) defined in the General Input table the following relevant elements: Payment period, Beginning Balance, Annuity payment (which is the sum of the principal amount and the interest), Principal amount, Interest amount and Ending Balance. The Annuity payment is shown in the Financing Cash Flows section of the Cash Flow EEM+DR worksheet as 'Principal reimbursement and interests (loan redemption)'.

## 5.3 FIRST IN_OUT REDEMPTION EEM

The First In_Out Redemption EEM auxiliary worksheet calculates the financing cash flows related to the ESCO financing method First Out or First In defined in the General Input table for the **EEM only** case and feeds the **Cash Flow EEM ONLY** worksheet. These two ESCO financing methods are based on the principle that the achieved energy savings of the energy efficiency projects are being fully used (First Out) or partially used (First In) to remunerate the ESCO for its services and to reimburse the investment borne by the ESCO. The achieved savings amount is being split into a maintenance fee component, the principal amount reimbursement, the interest payable and, in case of the First In financing option, the acquired savings amount by the beneficiary. The redemption schedule in this worksheet shows on a year-on-year basis the following elements: Payment number, Beginning Balance, Maintenance Fee, Total Payment (the achieved savings that can be allocated to the maintenance fee, the principal amount and the interest, but after deduction of the acquired savings by the beneficiary), the Scheduled Payment (Total Payment minus the maintenance fee), the Principal amount, the Interest payable and the Ending Balance.

The auxiliary worksheet also shows the number of periods (years) necessary to reimburse the investment to the ESCO referred to as '# of redemption periods'. If the number of redemption periods is different than the EPC contract period defined in the General Input table the following warning appears **"EPC contract period not equal to redemption periods!".** The table should also show a zero value next to the item 'Not recovered balance'. This means that the investment has been reimbursed within the EPC contract period set in the General Input table.

However, if the value next to the item '# of redemption periods' shows an **"Error!"** text this means that the ESCO investment has not been reimbursed within the EPC contract period. The value next to the item 'Not recovered balance' will then show the balance of the investment that has not been recovered.

## 5.4 FIRST IN_OUT REDEMPTION EEM+DR

The First In_Out Redemption EEM+DR auxiliary worksheet calculates the financing cash flows related to the ESCO financing method First Out or First In defined in the General Input table for the **EEM and DR Flexibility** case and feeds the **Cash Flow EEM+DR** worksheet. These two ESCO financing methods are based on the principle that the achieved energy savings of the energy efficiency projects are being fully used (First Out) or partially used (First In) to remunerate the ESCO for its services and to reimburse the investment borne by the ESCO. The achieved savings amount is being split into a maintenance fee component, the principal amount reimbursement, the interest payable and, in case of the First In financing option, the acquired savings amount by the beneficiary. The redemption schedule in this worksheet shows on a year-on-year basis the following elements: Payment number, Beginning Balance, Maintenance Fee, Total Payment (the achieved savings that can be allocated to the maintenance fee, the principal amount and the interest, but after deduction of the acquired savings by the beneficiary), the Scheduled Payment (Total Payment minus the maintenance fee), the Principal amount, the Interest payable and the Ending Balance.

The auxiliary worksheet also shows the number of periods (years) necessary to reimburse the investment to the ESCO referred to as '# of redemption periods'. If the number of redemption periods is different than the EPC contract period defined in the General Input table the following warning appears **"EPC contract period not equal to redemption periods!".** The table should also show a zero value next to the item 'Not recovered balance'. This means that the investment has been reimbursed within the EPC contract period set in the General Input table.
However, if the value next to the item '# of redemption periods' shows an **"Error!"** text this means that the ESCO investment has not been reimbursed within the EPC contract period. The value next to the item 'Not recovered balance' will then show the balance of the investment that has not been recovered.

## 5.5 SHARED SAVINGS REDEMPTION EEM

The Shared Savings Redemption EEM auxiliary worksheet calculates the financing cash flows related to the Shared Savings ESCO financing method as indicated in the General Input table for the **EEM only** case and feeds the **Cash Flow EEM ONLY** worksheet. The financing principle here is that the achieved savings are shared between the ESCO and the project owner, and the ESCO's share is being used to remunerate the ESCO for its services and to reimburse the investment borne by the ESCO. The ESCO share of the achieved savings amount is being split into a maintenance fee component, the principal amount reimbursement and the interest payable. The redemption schedule in this worksheet shows on a year-on-year basis the following elements: Payment number, Beginning Balance, Maintenance Fee, Total Payment (ESCO's share of achieved savings that can be allocated to the maintenance fee, the principal amount and the interest), the Scheduled Payment (Total Payment minus the maintenance fee), the Principal amount, the Interest payable and the Ending Balance.

The auxiliary worksheet also shows the number of periods (years) necessary to reimburse the investment to the ESCO referred to as '# of redemption periods'. If the number of redemption periods is different than the EPC contract period defined in the General Input table the following warning appears **"EPC contract period not equal to redemption periods!"**. The table should also show a zero value next to the item 'Not recovered balance'. This means that the investment has been reimbursed within the EPC contract period set in the General Input table.
However, if the value next to the item '# of redemption periods' shows an **"Error!"** text this means that the ESCO investment has not been reimbursed within the EPC contract period. The value next to the item 'Not recovered balance' will then show the balance of the investment that has not been recovered.

## 5.6 SHARED SAVINGS REDEMPTION EEM+DR

The Shared Savings Redemption EEM auxiliary worksheet calculates the financing cash flows related to the Shared Savings ESCO financing method as indicated in the General Input table for the **EEM+DR** case and feeds the **Cash Flow EEM+DR** worksheet. The financing principle here is that the achieved savings are shared between the ESCO and the project owner, and the ESCO's share is being used to remunerate the ESCO for its services and to reimburse the investment borne by the ESCO. The ESCO share of the achieved savings amount is being split into a maintenance fee component, the principal amount reimbursement and the interest payable. The redemption schedule in this worksheet shows on a year-on-year basis the following elements: Payment number, Beginning Balance, Maintenance Fee, Total Payment (ESCO's share of achieved savings that can be allocated to the maintenance fee, the principal amount and the interest), the Scheduled Payment (Total Payment minus the maintenance fee), the Principal amount, the Interest payable and the Ending Balance.

The auxiliary worksheet also shows the number of periods (years) necessary to reimburse the investment to the ESCO referred to as '# of redemption periods'. If the number of redemption periods is different than the EPC contract period defined in the General Input table the following warning appears **"EPC contract period not equal to redemption periods!".** The table should also show a zero value next to the item 'Not recovered balance'. This means that the investment has been reimbursed within the EPC contract period set in the General Input table.
However, if the value next to the item '# of redemption periods' shows an **"Error!"** text this means that the ESCO investment has not been reimbursed within the EPC contract period. The value next to the item 'Not recovered balance' will then show the balance of the investment that has not been recovered.

# 6. CASH FLOW WORKSHEETS

The E&FCM features two cash flow tables: one for EEM ONLY and one for EEM + DR. These cash flow tables include all yearly cash flows (income, expenses and capital expenditures) relevant to the business case over an analysis or life-cycle period of maximum 40 years. The two cash flow tables have, in principle, the same structure, though the cash flow values will obviously be different when DR valorisation is considered in the EEM + DR case.

The cash flow tables calculate the Net Present Value (NPV) of all yearly cash flows, i.e. the income, the expenses and the capital expenditures cash flows to reflect the time value of money. The information required to calculate the cash flows in the cash flow tables is being obtained from the input tables and the Auxiliary worksheets.

## 6.1 COMMON STRUCTURE OF THE CASH FLOW WORKSHEETS

The cash flow tables incorporate four major sections which are the same for the EEM ONLY and EEM+DR cash flow worksheets, namely:

- Auxiliary calculations
- Cash Flow before measures
- Cash Flow after measures
- Financing cash flows

### 6.1.1 AUXILIARY CALCULATIONS

The Auxiliary Calculations section calculates parameters related to the analysis period, EPC-contract period, discount factors, general indexations or price escalations and asset market value evolution. This table is being fed by the General Input table and the Price evolutions table.

**TABLE 10 – CASH FLOW WORKSHEETS - AUXILIARY CALCULATIONS TABLE**

| AUXILIARY CALCULATIONS | 1 | 2 | 3 | 4 | 5 | 6 | 40 |
|---|---|---|---|---|---|---|---|
| **Analysis period** | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **EPC contract period EEM Only** | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| | | | | | | | |
| **Discount factor** | | | | | | | |
| Discount factor | 1,0136 | 1,0412 | 1,0697 | 1,0989 | 1,1289 | 1,1597 | 2,8976 |
| Disocunt factor Equity | 1,0223 | 1,0683 | 1,1163 | 1,1666 | 1,2191 | 1,2739 | 5,6898 |
| **Indexations (Price escalations)** | | | | | | | |
| Operating expenses | 1,0200 | 1,0404 | 1,0612 | 1,0824 | 1,1041 | 1,1262 | 2,2080 |
| Energy price | 1,0200 | 1,0404 | 1,0612 | 1,0824 | 1,1041 | 1,1262 | 2,2080 |
| DR/Flexibility retribution | 1,0200 | 1,0404 | 1,0612 | 1,0824 | 1,1041 | 1,1262 | 2,2080 |
| Rent income | 1,0200 | 1,0404 | 1,0612 | 1,0824 | 1,1041 | 1,1262 | 2,2080 |
| Property Tax and various levies | 1,0150 | 1,0302 | 1,0457 | 1,0614 | 1,0773 | 1,0934 | 1,8140 |
| **Market Value Evolution** | | | | | | | |
| Market value evolution no renovation | 1,0075 | 1,0151 | 1,0227 | 1,0303 | 1,0381 | 1,0459 | 1,3483 |
| Market value evolution with renovation | 1,0125 | 1,0252 | 1,0380 | 1,0509 | 1,0641 | 1,0774 | 1,6436 |
| Disposal of Asset | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

### 6.1.2 CASH FLOW BEFORE MEASURES

The Cash Flow before Measures section calculates all relevant cash flows for the Building-As-Is, **without any measures**. These cash flows are clustered into the following cash flow groups:

- Operating Income: Current Rent Income and Current Rent Charges (for the Owner-Lessor if applicable)
- Operating Expenses:
  - Current Rent Expense and Current Rent Charges (for the Lessee/Tenant if applicable);
  - Current Energy expenses (for the Lessee/Tenant or Owner-occupier);
  - Other operating expenses such as maintenance, insurance, Facilities/Property Management expenses, Property taxes (Owner-Occupier or Owner-Lessor).
- One-off income: Sales or residual value of the asset

The section then calculates the Yearly Cash flows, the Net Present value of the Yearly Cash Flows and provides the Net Present Value (NPV) of the sum of all Cash Flows. This NPV of the sum of all cash flows is also the Total Cost of Ownership (TCO) of the Building-As-Is situation.

The table 11 exhibits all items of the Cash flow before Measures section.

**TABLE 11 – CASH FLOW WORKSHEETS - CASH FLOW BEFORE MEASURES**

| CASH FLOW BEFORE MEASURES | | 1 | 2 | 3 | 4 | 5 | 40 |
|---|---|---|---|---|---|---|---|
| **Operating Income** | | | | | | | |
| Current Rent income | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 |
| Current Rent Charges | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 |
| Total Income | | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 |
| **Total Operating Income** | | **€ 0** | **€ 0** | **€ 0** | **€ 0** | **€ 0** | **€ 0** |
| **Operating Expenses** | | | | | | | |
| **Lessee or Owner-Occupier** | | | | | | | |
| Current Rent Expense | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 |
| Current Rent Charges (expenses) | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 |
| Current Energy expenses | | € 7.140 | € 7.283 | € 7.428 | € 7.577 | € 7.729 | € 15.456 |
| **Owner-Occupier & Owner-Lessor** | | | | | | | |
| Maintenance Expenses | | € 1.020 | € 1.040 | € 1.061 | € 1.082 | € 1.104 | € 2.208 |
| Insurance Expenses | | € 1.020 | € 1.040 | € 1.061 | € 1.082 | € 1.104 | € 2.208 |
| Other expenses (Facilities, Property Mgt,...) | | € 2.550 | € 2.601 | € 2.653 | € 2.706 | € 2.760 | € 5.520 |
| Property Taxes | | € 3.553 | € 3.606 | € 3.660 | € 3.715 | € 3.770 | € 6.349 |
| **Total Operating Expenses** | | **€ 15.283** | **€ 15.570** | **€ 15.864** | **€ 16.163** | **€ 16.467** | **€ 31.742** |
| **One-off income** | | | | | | | |
| Sales/Residual value of real estate | | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 |
| **Total one-off income** | | **€ 0** | **€ 0** | **€ 0** | **€ 0** | **€ 0** | **€ 0** |
| **Yearly Cash Flows** | | **-€ 15.283** | **-€ 15.570** | **-€ 15.864** | **-€ 16.163** | **-€ 16.467** | **-€ 31.742** |
| Net present Value of Yearly Cash Flows | | -€ 15.078 | -€ 14.954 | -€ 14.831 | -€ 14.709 | -€ 14.588 | -€ 10.954 |
| **Net present Value of Cash Flows** | **-€ 516.115** | | | | | | |

### 6.1.3 CASH FLOW AFTER MEASURES

The Cash Flow after Measures section has basically the same structure (the same cash flow groups) and performs the same calculations as described for the Cash Flow before measures section. But obviously many or possibly all the cash flow values will be different because of the **impact of the implemented measures** on savings, income and expenses.

This section introduces a new cash flow group that is not present in the Cash Flow before Measures, namely the Initial Outlay.  This cash flow group includes the investment amounts related to the measures as well as any other one-off expense that is specifically related to the energy efficiency project but is not included in the investment amounts linked to the measures.

Additional cash flows (cash flow drivers) are also introduced as a consequence of the involvement of the ESCO, as well as specific (implicit and explicit) DR service expenses and income (incentives).
These additional cash flows depend on the business case beneficiary (Owner-Occupier, Owner-Lessor, Lessee/Tenant) and the measures implemented (EEM or EEM + DR cash flow cases). The different additional cash flows applicable to the two different Cash Flow Worksheets (EEM and EEM+DR) are being described further and the specific tables are also exhibited.

The section then calculates the Yearly Cash flows, the Net Present value of the Yearly Cash Flows and provides the Net Present Value (NPV) of the sum of all Cash Flows.   This NPV of the sum of all cash flows is also the Total Cost of Ownership (TCO) of the Building-To-Be situation for both EEM and EEM+DR cash flow cases.

This section further calculates for both cash flow cases (EEM and EEM + DR) the difference between the cash flows before the measures and the cash flows after the measures, thus providing Total Net Cash Flows (versus Business-as-usual) and NPV of the yearly Net Cash Flows. These cash flow data allow for calculating the NPV of the Total Cash Flows, the Internal Rate of Return (IRR) and the Discounted Payback period of the financial business case.

### 6.1.4 FINANCING CASH FLOWS

The Financing Cash Flows section is only relevant in case one of the financing methods defined in the Financing Details section of the General Input table has been chosen, i.e. when financing by a Third-Party financier (e.g. financial institution or investor) or by the ESCO is being envisaged. This section shows condensed Project Cash flows and Financing Cash Flows.

The Project Cash Flows section provides yearly cash flows per the following cash flow groups: Total one-off expenses (investments in EEM and other one-off expenses), Total one-off income, Total operating income and Total operating expenses.  The Project Cash Flows section also provides the sum of the Yearly Cash Flows, and calculates the NPV of the Total Cash Flows (the Project NPV), the Internal Rate of Return (IRR) and the Discounted Payback period of the financial business case.

The Financing Cash Flows section is being divided in Incoming Financing Cash flows, providing the Equity Contributions (Own funds or own contribution to financing) and Third Party or ESCO contributions to financing, and Outgoing Financing Cash Flows, reimbursements of loans/investment and interests per the chosen financing method, and ultimately providing the cash flows to the Equity Holders (Own funds). When relevant Equity NPV, Equity IRR and Equity Discounted Payback is calculated.

The Table 12 exhibits the items of the Financing Cash Flows.

**TABLE 12 – CASH FLOW WORKSHEETS - FINANCING CASH FLOWS TABLE**

| FINANCING CASH FLOWS | | 1 | 2 | 3 | 4 | 5 | 40 |
|---|---|---|---|---|---|---|---|
| **PROJECT CASH FLOWS** | | | | | | | |
| Total one-off expenses (Investment) | | € 56.000 | € 0 | € 0 | € 0 | € 0 | € 0 |
| Total one-off income | | € 5.000 | € 0 | € 0 | € 0 | € 0 | € 0 |
| Total Operating Income | | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 |
| Total Operating Expenses | | -€ 3.519 | -€ 3.589 | -€ 3.661 | -€ 3.734 | -€ 3.809 | -€ 7.618 |
| **Total Yearly Cash Flows** | **€ 161.555** | **-€ 47.481** | **€ 3.589** | **€ 3.661** | **€ 3.734** | **€ 3.809** | **€ 7.618** |
| **NPV of Yearly Cash flows** | | **-€ 46.846** | **€ 3.447** | **€ 3.423** | **€ 3.398** | **€ 3.374** | **€ 2.629** |
| **Project IRR** | **9,0%** | | | | | | |
| **Project NPV** | **€ 70.939** | | | | | | |
| **Project Discounted Payback Period** | **15,24** | | | | | | |
| **FINANCING CASH FLOWS** | | | | | | | |
| **Incoming financing cash flow** | | | | | | | |
| Equity Contribution (Own Funds) | | € 10.000 | | | | | |
| 3rd Party Loan Contribution/ESCO financing amount | | € 41.000 | | | | | |
| ESCO financed investment amount | | € 0 | | | | | |
| **Outgoing financing cash flow** | | | | | | | |
| Principal reimbursement and interests (loan redemption) | | € 1.845 | € 1.825 | € 1.804 | € 1.784 | € 1.763 | € 1.046 |
| ESCO investment reimbursement First In/Out principle | | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 |
| ESCO investment reimbursment shared savings principle | | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 |
| **Cash Flow to Equity Holders** | **€ 144.745** | **-€ 8.326** | **€ 1.765** | **€ 1.857** | **€ 1.951** | **€ 2.046** | **€ 6.572** |
| **NPV of Cash Flow to Equity Holders** | **€ 50.145** | **-€ 8.145** | **€ 1.652** | **€ 1.664** | **€ 1.672** | **€ 1.678** | **€ 1.155** |
| **Equity IRR** | **25,8%** | | | | | | |
| **Equity NPV** | **€ 50.145** | | | | | | |
| **Equity Discounted Payback Period** | **5,88** | | | | | | |

## 6.2 CASH FLOW EEM ONLY

The Cash Flow EEM ONLY worksheet includes all yearly cash flows (income, expenses and capital expenditures) relevant to the business case of the EEM only case, i.e. the case where only energy efficiency measures are being implemented **without** any additional DR Flexibility.

Specific cash flows pertaining to this Cash Flow EEM ONLY compared to the cash flows of the Building-As-Is case, i.e. the case without any measures, are:

- Operating Income:
  - Increased rent income due to energy savings;
  - Rent charges after EEM implementation;

  Both income cash flows are related to the Owner-Lessor type AEPC beneficiary.

- Operating Expenses:
  - Increased rent expense due to energy savings (applicable to the Lessee only),
  - Rent charges after EEM implementation (applicable to the Lessee only),
  - Energy savings after renovation only (deduction or decrease),
  - Maintenance expenses during EPC contract period (ESCO fees),
  - Maintenance expenses after PC contract period (ESCO fees),

- Initial Outlay:
  - Investments
  - Other initial outlays

- One-off income: Subsidies (or grants)

All the above-mentioned additional cash flows are included in the Cash Flow after Measures section.

The Table 13 exhibits the items of the Cash Flow after Measures section.

### TABLE 13 – CASH FLOW EEM ONLY-CASH FLOWS AFTER MEASURES

| CASH FLOW AFTER MEASURES | | 1 | 2 | 3 | 4 | 5 | 40 |
|---|---|---|---|---|---|---|---|
| **Operating Income** | | | | | | | |
| Current Rent income | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 |
| Increased Rent income due to Energy Savin | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 |
| Rent income after EEM implementation | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 |
| Rent Charges after EEM implementation | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 |
| **Total Operating Income** | | **€ 0** | **€ 0** | **€ 0** | **€ 0** | **€ 0** | **€ 0** |
| **Operating Expenses** | | | | | | | |
| **Lessee or Owner-Occupier** | | | | | | | |
| Rent expense before renovation | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 |
| Increased rent expense due to Energy Savin | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 |
| Rent expense after renovation | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 |
| Rent Charges after EEM implementation | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 |
| Energy expenses before renovation | | € 7.140 | € 7.283 | € 7.428 | € 7.577 | € 7.729 | € 15.456 |
| Energy savings after renovation only (-) | | € 3.519 | € 3.589 | € 3.661 | € 3.734 | € 3.809 | € 7.618 |
| Energy expenses after renovation | | € 3.621 | € 3.693 | € 3.767 | € 3.843 | € 3.919 | € 7.839 |
| **Owner-Occupier & Owner-Landlord** | | | | | | | |
| Maintenance expenses during EPC-contract period | | € 1.020 | € 1.040 | € 1.061 | € 1.082 | € 1.104 | € 0 |
| Maintenance expenses after EPC-contract period | | € 0 | € 0 | € 0 | € 0 | € 0 | € 2.208 |
| Insurance expenses after EEM | | € 1.020 | € 1.040 | € 1.061 | € 1.082 | € 1.104 | € 2.208 |
| Other expenses (Facilities, property management,…) | | € 2.550 | € 2.601 | € 2.653 | € 2.706 | € 2.760 | € 5.520 |
| Property taxes | | € 3.553 | € 3.606 | € 3.660 | € 3.715 | € 3.770 | € 6.349 |
| **Total Operating Expenses** | | **€ 11.764** | **€ 11.981** | **€ 12.203** | **€ 12.428** | **€ 12.658** | **€ 24.124** |
| **Initial Outlay** | | | | | | | |
| Investments | | € 55.000 | | | | | |
| Other initial outlays | | € 1.000 | | | | | |
| **Total initial outlay** | | **€ 56.000** | **€ 0** | **€ 0** | **€ 0** | **€ 0** | **€ 0** |
| **One-off income** | | | | | | | |
| Subsidies | | € 5.000 | | | | | |
| Sales/Residual value of real estate | | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 |
| **Total one-off income** | | **€ 5.000** | **€ 0** | **€ 0** | **€ 0** | **€ 0** | **€ 0** |
| **Yearly Cash Flows** | | **-€ 62.764** | **-€ 11.981** | **-€ 12.203** | **-€ 12.428** | **-€ 12.658** | **-€ 24.124** |
| Net present Value of Yearly Cash Flows | | -€ 61.924 | -€ 11.507 | -€ 11.408 | -€ 11.310 | -€ 11.213 | -€ 8.325 |
| **Net present Value of Cash Flows** | **-€ 445.176** | | | | | | |
| **Total Net Cash Flows (versus BAU)** | | **-€ 47.481** | **€ 3.589** | **€ 3.661** | **€ 3.734** | **€ 3.809** | **€ 7.618** |
| **NPV of Net Cashflows (versus BAU)** | | **-€ 46.846** | **€ 3.447** | **€ 3.423** | **€ 3.398** | **€ 3.374** | **€ 2.629** |
| | | -€ 46.846 | -€ 43.399 | -€ 39.976 | -€ 36.577 | -€ 33.203 | € 70.939 |

| | |
|---|---|
| **Net Present Value versus BAU** | **€ 70.939** |
| **Internal Rate of Return** | **9,0%** |
| **Discounted Payback period** | **15,24** |

## 6.3 CASH FLOW EEM+DR

The Cash Flow EEM+DR worksheet includes all yearly cash flows (income, expenses and capital expenditures) relevant to the business case of the EEM+DR case, i.e. the case whereby **DR Flexibility is implemented** on top of the energy efficiency measures.

This Cash Flow EEM+DR worksheet is very similar to the Cash Flow EEM ONLY worksheet and has the same structure. This means that the specific cash flows pertaining to the EEM ONLY case as described in the previous caption are also applicable to this EEM+DR case. Nevertheless, this EEM+DR worksheet differs from the latter as in the EEM+DR case the DR valorization is considered. Not only cash flow values from same cash flow drivers (e.g. maintenance) will obviously be different, the EEM+DR case includes additional cash flows or cash flow drivers related to both Implicit and Explicit DR.

These specific cash flows pertaining to Implicit and Explicit DR are to be found in the Operating Expenses section of the Cash Flow after Measures table and are the following:

- DR/Flexibility savings (deduction or decrease),
- DR/Flexibility service expenses,
- Explicit DR: Gross Income (deduction or decrease),
- Explicit DR: Service retention,
- Explicit DR: Net Income (deduction or decrease).

The Table 14 exhibits the items of the Cash Flow after Measures section.

## TABLE 14 – CASH FLOW EEM+DR - CASH FLOWS AFTER MEASURES

| CASH FLOW AFTER MEASURES | | 1 | 2 | 3 | 4 | 5 | 40 |
|---|---|---|---|---|---|---|---|
| **Operating Income** | | | | | | | |
| Rent prior to renovation | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 |
| Increased rent income due to Energy Savings | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 |
| Rent income after renovation | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 |
| Rent Charges after EEM implementation | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 |
| Total income after DR/Flexibility | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 |
| **Total Operating Income** | | **€ 0** | **€ 0** | **€ 0** | **€ 0** | **€ 0** | **€ 0** |
| **Operating Expenses** | | | | | | | |
| **Lessee or Owner-Occupier** | | | | | | | |
| Rent expense before renovation | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 |
| Increased rent expense due to Energy Savings | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 |
| Rent expense after renovation | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 |
| Rent Charges after EEM implementation | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 |
| Energy expenses before renovation | | € 7.140 | € 7.283 | € 7.428 | € 7.577 | € 7.729 | € 15.456 |
| Energy savings after renovation only (-) | | € 3.519 | € 3.589 | € 3.661 | € 3.734 | € 3.809 | € 7.618 |
| DR/Flexibility savings (-) | | € 561 | € 572 | € 584 | € 595 | € 607 | € 1.214 |
| DR/Flexibility service expenses | | € 255 | € 260 | € 265 | € 271 | € 276 | € 552 |
| Explicit DR: Gross Income (-) | | € 265 | € 271 | € 276 | € 281 | € 287 | € 574 |
| Explicit DR: Service retention | | € 80 | € 81 | € 83 | € 84 | € 86 | € 172 |
| Explicit DR: Net Income (-) | | € 186 | € 189 | € 193 | € 197 | € 201 | € 402 |
| Energy expenses after renovation | | € 3.129 | € 3.192 | € 3.256 | € 3.321 | € 3.387 | € 6.774 |
| **Owner-Occupier & Owner-Landlord** | | | | | | | |
| Maintenance expenses during EPC-contract period | | € 1.020 | € 1.040 | € 1.061 | € 1.082 | € 1.104 | € 0 |
| Maintenance expenses after EPC-contract period | | € 0 | € 0 | € 0 | € 0 | € 0 | € 2.208 |
| Insurance expenses after EEM | | € 1.020 | € 1.040 | € 1.061 | € 1.082 | € 1.104 | € 2.208 |
| Other expenses (Facilities, property management,...) | | € 2.550 | € 2.601 | € 2.653 | € 2.706 | € 2.760 | € 5.520 |
| Property taxes | | € 3.553 | € 3.606 | € 3.660 | € 3.715 | € 3.770 | € 6.349 |
| **Total Operating Expenses** | | **€ 11.272** | **€ 11.480** | **€ 11.691** | **€ 11.907** | **€ 12.126** | **€ 23.060** |
| **Initial Outlay** | | | | | | | |
| Investments | | € 56.500 | | | | | |
| Other initial outlays | | € 1.000 | | | | | |
| **Total initial outlay** | | **€ 57.500** | **€ 0** | **€ 0** | **€ 0** | **€ 0** | **€ 0** |
| **One-off income** | | | | | | | |
| Subsidies | | € 5.000 | | | | | |
| Sales/Residual value of real estate | | € 0 | € 0 | € 0 | € 0 | € 0 | € 0 |
| **Total one-off income** | | **€ 5.000** | **€ 0** | **€ 0** | **€ 0** | **€ 0** | **€ 0** |
| **Yearly Cash Flows** | | **-€ 63.772** | **-€ 11.480** | **-€ 11.691** | **-€ 11.907** | **-€ 12.126** | **-€ 23.060** |
| Net present Value of Yearly Cash Flows | | -€ 62.919 | -€ 11.025 | -€ 10.930 | -€ 10.835 | -€ 10.742 | -€ 7.958 |
| **Net present Value of Cash Flows** | **-€ 429.715** | | | | | | |
| **Total Net Cash Flows (versus BAU)** | | **-€ 48.489** | **€ 4.091** | **€ 4.173** | **€ 4.256** | **€ 4.341** | **€ 8.682** |
| **NPV of Net Cashflows (versus BAU)** | | **-€ 47.841** | **€ 3.929** | **€ 3.901** | **€ 3.873** | **€ 3.846** | **€ 2.996** |
| | | -€ 47.841 | -€ 43.912 | -€ 40.011 | -€ 36.138 | -€ 32.292 | € 86.400 |

| | |
|---|---|
| **Net Present Value versus BAU** | **€ 86.400** |
| **Internal Rate of Return** | **10,0%** |
| **Discounted Payback period** | **13,69** |

# 7. KPI WORKSHEET

The KPI table shows financial Key Performance Indicators calculated by the E&FCM for both the EEM only and the EEM + DR cases:

- Total Cost of Ownership: before measures, after EEM measures, after EEM + DR measures;
- Net Present Value: after EEM measures, after EEM + DR measures;
- Internal Rate of Return: after EEM measures, after EEM + DR measures;
- Discounted payback period: after EEM measures, after EEM + DR measures.

It also provides, for the selected design option and scenario, an overview of the project's key numbers related to:

- Investments:
  - Initial investment amount,
  - Other initial outlay,
  - Subsidies (-),
  - Total investment.
- Energy consumption and cost:
  - Adjusted Baseline energy consumption kWh/year,
  - Adjusted Baseline energy consumption €/year,
  - Average Yearly energy consumption savings kWh for EEM and EEM + DR,
  - Average Yearly energy cost savings € (non-indexed) for EEM and EEM + DR,
  - Yearly energy consumption and energy cost savings (in %) for EEM and EEM + DR.

The KPI table 15 shows the financial KPI and the project's key numbers.

**TABLE 15 – KPI TABLE**

| KEY PERFORMANCE INDICATORS | EEM only | EEM+DR |
|---|---|---|
| **Investment KPI** | | |
| Initial investment amount | € 55.000 | € 56.500 |
| Other inititial outlay | € 1.000 | € 1.000 |
| Subsidies (-) | € 5.000 | € 5.000 |
| **Total investment** | **€ 51.000** | **€ 52.500** |
| | | |
| **Energy KPI** | | |
| Baseline energy consumption kWh/year | 8.500 | 8.500 |
| Baseline energy consumption €/year | € 7.000 | € 7.000 |
| Average Yearly energy savings kWh | 4.200 | 4.150 |
| Average Yearly energy savings € (non indexed) | € 3.450 | € 4.260 |
| Yearly savings % | 49% | 61% |
| | | |
| **Financial performance KPI** | | |
| Total Cost of Ownership (TCO) before renovation | € 516.115 | € 516.115 |
| Total Cost of Ownership (TCO) after renovation | € 445.176 | € 429.715 |
| Net Present Value | € 70.939 | € 86.400 |
| Internal Rate of Return | 8,99% | 9,99% |
| Discounted payback period (Years) | 15,24 | 13,69 |
| | | |
| **Other KPI** | | |
| Average Yearly Value DR/Flexibility services | | € 810 |

Active managed Buildings with
Energy performaNce Contracting

ANNEX B: DESCRIPTION AND RESULTS OF THE BUSINESS CASES FOR THE AMBIENCE-PROJECT

# DESCRIPTION AND RESULTS OF THE BUSINESS CASES FOR THE AMBIENCE-PROJECT

The AmBIENCe Consortium

April | 2021

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 847054.

# DOCUMENT CONTROL PAGE

| | |
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| **PROJECT ACRONYM** | AmBIENCe |
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| **OFFICIAL REVIEWER/s** | Nilufar Neyestani (INESC TEC),<br>Marialaura Di Somma (ENEA),<br>Ainhoa Galarza (CEIT) |

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# 1. INTRODUCTION

## 1.1 PURPOSE OF THE STUDY

The purpose of this study is to decide which buildings can be included within the AmBIENCe-project (to insulate and electrify) and for which ones it's better to be demolished and rebuilt. An attempt is made to clearly define the scope of this project, so these decisions can be made in an unambiguous manner.
By looking at the effects of certain insulation measures, several possible future K-values of a building are being calculated. For each K-value, the accompanied investment costs, yearly costs, yearly emissions and the return on investment are calculated. This way, the different scenarios can easily be compared to each other, after which the most fitting scenario can be chosen for the said building. The goal is to reach a K-level of less than 40, in order to be able to electrify.

# 2. CLIMATE GOALS

The AmBIENCe project fits within the broader EU objectives related to energy. Looking at 2030, Europe has set a goal of 40% reduction in $CO_2$ emissions (compared to 1990), minimum 32,5% energy savings (compared to 2007) and at least 32% of the energy must be renewable.
Europe distinguishes between ETS (Emission Trading Sector) and non-ETS sectors. The energy sector and heavy industry are part of the ETS sector. They have to save a little more proportionally, and Europe is directly responsible for this. For all other sectors, including buildings, the non-ETS target of 30% $CO_2$ savings generally applies. Different targets are set for different member states. For Belgium, this means 35% $CO_2$ savings by 2030. The Flemish Energy and Climate Plan (2021-2030) follows this target.
To achieve the 2030-objectives, looking from a building perspective, there's not a lot of time left. Therefore, it's better to already focus on the 2050-objectives. The most important objective to remember is that we must be climate neutral by 2050. This means that $CO_2$ emissions must be reduced to zero by then. After significant energy savings, the entire remaining energy requirement must therefore be met with renewable energy.
On May 29$^{th}$, 2020, the Flemish government approved the long-term renovation strategy (LTRS) for buildings. This strategy outlines the logical path to a climate-neutral building stock for heating, domestic hot water, cooling and lighting by 2050. The government sees an exemplary role for public buildings. The aim is to be climate neutral by 2045. The healthcare and education sectors are exceptions, they may use 2050 as a finish line.
According to current insights, the energy consumption of non-residential buildings will have to be reduced by 33% by 2050 compared to the energy consumption of 2020 in order to achieve this goal. To achieve the target, intermediate targets have also been set within the LTRS for 2030 and 2040 (Figure ).

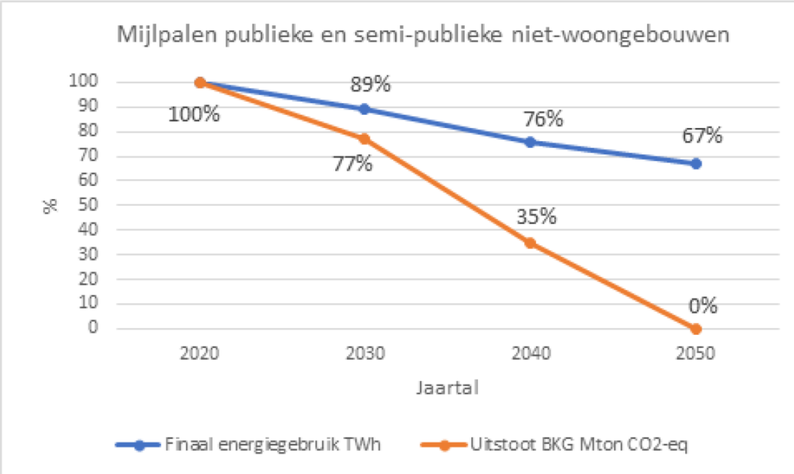


**FIGURE 1: MILESTONES FOR PUBLIC AND SEMI-PUBLIC NON-RESIDENTIAL BUILDINGS IN FLANDERS (BLUE = FINAL ENERGY USE [TWH]; ORANGE = GHG EMISSION [MTON $CO_2$-EQ])**

So in 2030, we aim for 11% energy savings compared to 2020 and 23% $CO_2$ savings by 2030. In 2040, we would have to achieve 24% energy savings and 65% $CO_2$ savings. However, these percentages are just a picture of the current situation. The only fixed target is climate neutrality by 2045 or 2050. How we get there can still shift, depending on how far we are.

The central government continues to focus on the Energy Efficiency Action Plan to achieve the target. The annual savings in primary energy will be increased from 2,09% to 2,5%. The multi-year strategy to achieve this saving must also be included in the business plan by central governments for their own buildings.

## 2.1 ADVICE RELATED TO CLIMATE GOALS

When drawing up a long-term strategy, the bar is often rightly set high and a choice is made for energy-neutral new construction, major energy renovations and/or the abandonment of the most energy-consuming buildings. The Flemish energy policy plan (‘Energieplan 2021-2030’) therefore aims to encourage rebuilding after demolition.

To achieve the 2030 objectives from a building perspective, there’s not a lot of time left. In addition, climate neutrality is envisaged by 2050 (Paris, COP21). To achieve this, efforts must be made in 3 areas:

1. An insulation level that allows full electrification (which allows heating with heat pumps);
2. Residual consumption that is fully covered with renewable energy (e.g. solar panels);
3. The demolition and reconstruction of all buildings where an acceptable insulation level cannot be achieved with conventional insulation measures. In the latter case, it goes without saying that energy-neutral (and ideally climate-neutral) new construction is used. Energy-neutral homes are homes that generate as much energy as is consumed during a whole year. Climate-neutral means that all $CO_2$ emissions, including emissions linked to the materials used, must be reduced to zero.

The most difficult exercise in this road to 2050 is where we have to draw the line between in-depth renovation (‘heat pump ready’) and demolition with new construction. One line of thought that we want to put forward here is that we want to achieve a minimum K-level of 40 in the context of energetic

renovation. When we make an abstraction of infiltration and ventilation losses, this is a figure that regularly pops up among experts when asked about the possibilities of heating with a heat pump.
The K-level is defined by VEA (Vlaams EnergieAgentschap) as follows:

> The K-level of a house is an index to indicate the degree of thermal losses through the building envelope. The term takes into account not only the degree of insulation of a building (U-value), but also the degree of compactness of a building: a building that is well insulated, but has a large contact surface with the outside (or unheated spaces) will also lead to larger heat losses.

VEA, EPB-pedia

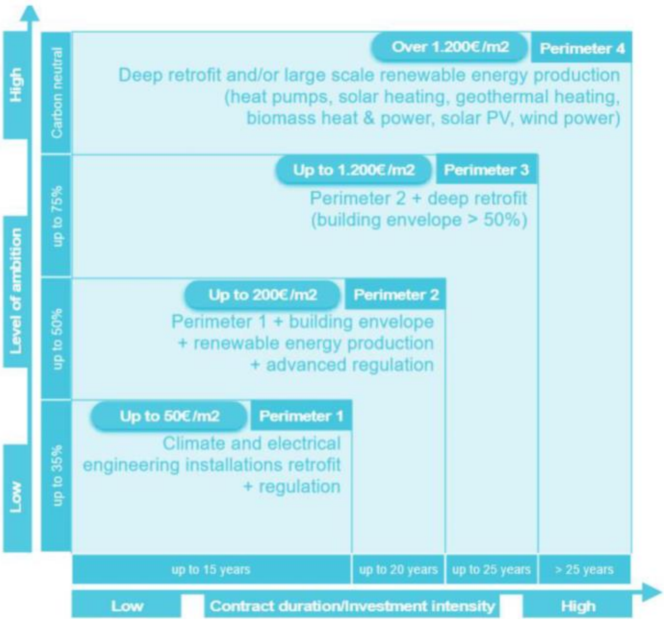


**FIGURE 2: INVESTMENT INDICATORS (CITYINVEST, 2015)**

# 3. DESCRIPTION OF THE APPROACH

## 3.1 CASE-STUDIES

In order to get a better understanding of the possibilities of reaching a K-level lower than 40 and investigating which trade-offs would be possible between insulation and electrification, two case-studies were built. The first one looks at a residential building with a floor area of 137 m². The second case-study covers a sporting hall with a floor area of 924 m². Both buildings are assumed to consists out of a simple, beam-shaped structure.
Following parameters were used, specified for each case, see table 1:

**TABLE 1 – PARAMETERS PER CASE**

| | Residential building | Sporting hall | Remarks |
|---|---|---|---|
| Floor area | 137 m² | 924 m² | |
| Window-to-wall percentage | 0,4 | 0,2 | |
| Ceiling height | 3 m | 7 m | |
| Natural gas cost | 0,050 €/kWh | 0,050 €/kWh | |
| Electricity cost | 0,200 €/kWh | 0,200 €/kWh | |
| Inflation rate | 2,5% | 2,5 % | |
| Inside temperature | 21°C | 16°C | |
| Internal gains | 3°C | 2°C | e.g. through appliances, people, lighting, solar radiation etc. |
| Reduction for interruption | 2°C | 3°C | e.g. by night, during the weekend/holidays etc. |
| Average internal temperature | 16°C | 11°C | Automatically calculated |
| Hours per year | 5.800 h | 5.075h | = total hours within a heating season. This season is different for residential buildings (8 months) and sport infrastructure (7 months) |

For both of the cases, following average outside air temperatures (°C) are assumed but only in the heating season, which is different for residential buildings (8 months) and sport infrastructure (7 months):

**TABLE 2 – MONTHLY TEMP VALUES**

| Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3,1 | 3,2 | 6,4 | 8,9 | 12,9 | 15,6 | 18,4 | 17,4 | 14,5 | 10,9 | 6,6 | 4,9 |

Calculations are done by using the average inside temperature and comparing these to the outside air temperature (=Δt). This value gets corrected by taking into account the free heat gains through lighting, appliances, solar radiation, presence of people etc.

In several buildings, the setpoints are not constant and go down during the evening/night or during weekends. This is anticipated by taking into account the 'reduction for interruption' and therefore achieving a lower Δt, which equals a lower energy consumption.

Following table (Figure 3) shows generally accepted figures drawn from literature for these two parameters:

| Reduction for interruption (night, weekend, holidays,...) | |
|---|---|
| Hospital, elderly home, nursing home | 0° |
| Building with night reduction | 2° |
| Offices | 3° |
| Schools with classes during the evening | 4,5° |
| Schools with classes during the evening and low thermal inertia | 6° |
| | |
| **Free heat gains (appliances, persons, lighting, sun)** | |
| Very few windows and very low occupancy | 1° |
| Typical - lower occupancy / few windows | 2° |
| Typical - higher ocupancy / more windows | 3° |
| High thermal inertia / insulation internal heat gains | 4° |

**FIGURE 3: REDUCTION FOR INTERRUPTION & FREE HEAT GAINS**

## 3.2 DESCRIPTION OF THE CURRENT SITUATION

By calculating the current K-value of each case (based on the norm NBN N62-301), the current heat-insulation of the building can be measured. In order to do this, the U-value (= the degree of insulation of the building) needs to be calculated for each of the different wall elements of the heat loss surface. These are:

- Translucent walls, windows, skylights;
- Exterior doors and gates;
- Exterior walls, facades;
- Roofs (flat or sloping) or upper ceilings under non-frost-free rooms;
- Floors above outdoor environment;
- Floors above adjacent areas that are non-frost-free (crawl space);
- Floors above adjacent frost-free areas (cellars);
- Floors on open ground;
- Exterior walls in contact with the ground (buried walls);
- Walls between protected volume and non-frost-free space;
- Walls between protected volume and frost-free space.

As can be seen in
Figure 4, only four different wall-elements are used in the case-studies: windows, exterior walls, roofs and floors on open ground. The walls of the buildings in the case-study are cavity walls without insulation. The windows are single glass. Following U-values are assumed:

- Walls: U = 1,75 W/K
- Roof: U = 3,00 W/K
- Windows: U = 5,10 W/K

Also the effect of cold bridges is taken into account. The sum of all these U-values gives the total heat loss through the heat loss surface in [W/K] (Figure 4 & Figure 5).

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Overall insulation level according to NBN N62-301 | | | | | | | |
| | Wall-elements of the heat loss surface | As (m²) | kj (W/m²K) | kmax (W/m²K) | Aj (m²) | kj Aj (W/K) | Σ kJ Aj (W/K) | aj | Σ aj kj Aj (W/K) |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| 1 | Translucent walls, windows, skylights | | 5,10 | 2,5 | 56 | 287 | 287 | 1,00 | 287 |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| 2 | Exterior doors and gates | | | 2,5 | | 0 | 0 | 1,00 | 0 |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| 3 | Exterior walls, facades | | 1,75 | 0,6 | 84 | 148 | 148 | 1,00 | 148 |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| 4 | Roofs (flat or sloping) or upper ceilings under non-frost-free rooms | | 3,00 | 0,4 | 137 | 412 | 412 | 1,00 | 412 |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| 5 | Floors above outdoor environment | | | 0,6 | | 0 | 0 | 1,00 | 0 |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| 6 | Floors above adjacent areas that are non-frost-free (crawl space) | | | 0,6 | | 0 | 0 | 1,00 | 0 |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| 7 | Floors above adjacent frost-free areas (cellars) | | | 0,9 | | 0 | 0 | 0,67 | 0 |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| 8 | Floors on open ground | | 0,45 | 1,2 | 137 | 62 | 62 | 0,33 | 21 |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| 9 | Exterior walls in contact with the ground (buried walls) | | | 0,9 | | 0 | 0 | 0,67 | 0 |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| 10 | Walls between protected volume and non-frost-free space | | | 0,6 | | 0 | 0 | 1,00 | 0 |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| 11 | Walls between protected volume and frost-free space | | | 0,9 | | 0 | 0 | 0,67 | 0 |
| Total | Total surface of the renovated or rebuilt walls s = Σ As (m²) = | 0,00 | | | | | | | |
| | Heat loss surface At= Σ Aj (m²) = | | | | 415 | | | Σ aj kj Aj (W/K) = | 867 |
| | Cold bridges according to NBN B62-002 | kij (W/mK) | lj (m) | kj lj (W/K) | | | | | |
| | | | | 0 | | | | | |
| | | | | 0 | | | | | |
| | | | | 0 | | | | | |
| 14 | | | | 0 | | | | | |
| Total | Σ kij lj (W/K) = | | | 0,00 | | | | | |

**FIGURE 4: CURRENT U-VALUE OF THE RESIDENTIAL BUILDING**

The total current U-value for the **residential building** is **867 W/K**.

| | Overall insulation level according to NBN N62-301 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Wall-elements of the heat loss surface | As (m²) | kj (W/m²K) | kmax (W/m²K) | Aj (m²) | kj Aj (W/K) | Σ kJ Aj (W/K) | aj | Σ aj kj Aj (W/K) |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| 1 | Translucent walls, windows, skylights | | 5,10 | 2,5 | 170 | 868 | 868 | 1,00 | 868 |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| 2 | Exterior doors and gates | | | 2,5 | | 0 | 0 | 1,00 | 0 |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| 3 | Exterior walls, facades | | 1,75 | 0,6 | 681 | 1.192 | 1.192 | 1,00 | 1.192 |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| 4 | Roofs (flat or sloping) or upper ceilings under non-frost-free rooms | | 3,00 | 0,4 | 924 | 2.772 | 2.772 | 1,00 | 2.772 |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| 5 | Floors above outdoor environment | | | 0,6 | | 0 | 0 | 1,00 | 0 |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| 6 | Floors above adjacent areas that are non-frost-free (crawl space) | | | 0,6 | | 0 | 0 | 1,00 | 0 |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| 7 | Floors above adjacent frost-free areas (cellars) | | | 0,9 | | 0 | 0 | 0,67 | 0 |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| 8 | Floors on open ground | | 0,45 | 1,2 | 924 | 416 | 416 | 0,33 | 139 |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| 9 | Exterior walls in contact with the ground (buried walls) | | | 0,9 | | 0 | 0 | 0,67 | 0 |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| 10 | Walls between protected volume and non-frost-free space | | | 0,6 | | 0 | 0 | 1,00 | 0 |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| | | | | | | 0 | | | |
| 11 | Walls between protected volume and frost-free space | | | 0,9 | | 0 | 0 | 0,67 | 0 |
| Total | Total surface of the renovated or rebuilt walls s = Σ As (m²) = | 0,00 | | | | | | | |
| | Heat loss surface At= Σ Aj (m²) = | | | | 2.699 | | | Σ aj kj Aj (W/K) = | 4.970 |
| | Cold bridges according to NBN B62-002 | kij (W/mK) | lj (m) | kj lj (W/K) | | | | | |
| | | | | 0 | | | | | |
| | | | | 0 | | | | | |
| | | | | 0 | | | | | |
| 14 | | | | 0 | | | | | |
| Total | Σ kij lj (W/K) = | | | 0,00 | | | | | |

**FIGURE 5: CURRENT U-VALUE OF THE SPORTING HALL**

The total current U-value of the **sporting hall** is **4.970 W/K.**
Next, the current K-values of both buildings can be calculated, using following formula:

If $V/A_t <= 1$:

$$K - value = 100 * \frac{U_m}{U_{m,ref}}$$

If $1 < V/A_t < 4$:

$$K - value = 300 * \frac{U_m}{U_{m,ref}} / \left(\frac{V}{At} + 2\right)$$

For which:

- $U_m$ = the average heat transmission coefficient, which is the ratio of the total heat transfer coefficient to the loss area of the building
- $U_{m,ref}$ = reference value, based on the compactness of the building. The lower the compactness, the higher (and therefore worse) the K-value.

**THE K-VALUE IS THEREFORE A COMBINATION OF THE COMPACTNESS AND THE INSULATION LEVEL OF A BUILDING.**

Figure 6 and Figure 7 show the calculation of the K-value for both cases.

| | | | | |
|---|---|---|---|---|
| | | **Overall insulation level according to NBN N62-301** | | |
| 15 | Heat loss from the loss surface | | Σ aj kj Aj + Σ kij lj (W/K) = | 867 |
| 16 | Average heat transfer coefficient | | ks (W/m²K) = | 2,09 |
| 17 | Protected volume | | V (m³) = | 412 |
| 18 | Volume compactness | | V/At (m) = | 0,99 |
| 19 | Level of ovarll heat insulation | If V/At<=1 | K = ks x 100 = | 208,80 |
| | | If 1<V/At<4 | K = ks x 300 / (V/At +2) = | - |
| | | If V/At>=4 | K = ks x 50 = | - |
| | K-value of the walls and floors between two protected volumes or between apartments | | kmax (W/m²K) | k (W/m²K) |
| 20 | Wall | | 1,00 | |
| | Wall | | | |
| | Wall | | | |

| | | | |
|---|---|---|---|
| **Maximum values for K-value** | Maximum K-value | | Berekende k-peil |
| New constructions | | | 208,80 |
| For residential buildings (>=30% of the total surface) | K <= 55 | | |
| For office buildings and school buildings | K <= 65 | | |
| Renovation with change of use | | | |
| For residential buildings (>=30% of the total surface) | K<= 55 +10 At/s = | | |
| For office buildings and school buildings | K<= 60 +10 At/s = | | |

**FIGURE 6: CURRENT K-VALUE OF THE RESIDENTIAL BUILDING**

| | | | | | |
|---|---|---|---|---|---|
| | | Overall insulation level according to NBN N62-301 | | | |
| 15 | Heat loss from the loss surface | | | Σ aj kj Aj + Σ kij lj (W/K) = | 4.970 |
| 16 | Average heat transfer coefficient | | | ks (W/m²K) = | 1,84 |
| 17 | Protected volume | | | V (m³) = | 6.468 |
| 18 | Volume compactness | | | V/At (m) = | 2,40 |
| 19 | Level of ovarll heat insulation | If V/At<=1 | | K = ks x 100 = | - |
| | | If 1<V/At<4 | | K = ks x 300 / (V/At +2) = | 125,66 |
| | | If V/At>=4 | | K = ks x 50 = | - |
| | K-value of the walls and floors between two protected volumes or between apartments | | | kmax (W/m²K) | k (W/m²K) |
| 20 | Wall | | | 1,00 | |
| | Wall | | | | |
| | Wall | | | | |

| | | | | |
|---|---|---|---|---|
| | **Maximum values for K-value** | Maximum K-value | | Berekende k-peil |
| | New constructions | | | 125,66 |
| | For residential buildings (>=30% of the total surface) | K <= 55 | | |
| | For office buildings and school buildings | K <= 65 | | |
| | Renovation with change of use | | | |
| | For residential buildings (>=30% of the total surface) | K<= 55 +10 At/s = | | |
| | For office buildings and school buildings | K<= 60 +10 At/s = | | |

**FIGURE 7: CURRENT K-VALUE OF THE SPORTING HALL**

The current K-value for the residential building is **208,80 W/m²K** and for the sporting hall **125,66 W/m²K**.

## 3.3 DESCRIPTION OF THE SITUATION AFTER ENERGY-SAVING MEASURES

For these cases, insulation measures are taken for walls (exterior wall insulation), roof (insulation on the outside) and/or windows (double glazing). Following U-values are assumed:

- Walls: U = 0,24 W/K
- Roof: U = 0,20 W/K
- Windows: U = 1,40 W/K

Based on these values and the methods used above, the new K-values of both cases can be calculated. For the residential building, following K-values can be achieved (Figure 8):

| | K value |
|---|---|
| Windows | 158,69 |
| Walls | 178,12 |
| Roof | 116,21 |
| Windows + Walls | 128,01 |
| Windows + Roof | 66,09 |
| Walls + Roof | 85,53 |
| Windows + Walls + Roof | 35,41 |

**FIGURE 8: K-VALUE AFTER INSULATION MEASURES, RESIDENTIAL BUILDING**

A K-value of less than 40 can only be achieved by carrying out insulation measures for windows, walls as well as the roof.
Regarding the sporting hall, following K-values can be achieved (Figure 9):

| | K value |
|---|---|
| Windows | 109,72 |
| Walls | 99,64 |
| Roof | 60,25 |
| Windows + Walls | 83,71 |
| Windows + Roof | 44,32 |
| Walls + Roof | 34,23 |
| Windows + Walls + Roof | 18,30 |

**FIGURE 9: K-VALUE AFTER INSULATION MEASURES, SPORTING HALL**

A K-value lower than 40 is possible when insulating the walls and the roof, or insulating walls, roof as well as the windows. In the case of insulating windows and roof, a K-value of 40 can almost be achieved.

## 3.4 ESTIMATION OF THE NEEDED POWER FOR THE HEATING SYSTEM

### 3.4.1 HEATING

An estimation of the needed power for the new heating system is calculated by taking following parameters into account:

- Heated volume ($m^3$);
- Heat loss surface ($m^2$);
- New K-value: calculated in the previous step.

Also, the outdoor temperature and the set indoor temperature are of importance. This results in an indication of the specific power (expressed in W/m³) and the total useful power (kW) that needs to be installed.
It's important to know that these calculations only give a rough indication of the needed power for the heating system. The actual sizing of the installation must be based on the calculation of the building losses according to the NBN B62-003 standard.

#### 3.4.2 DOMESTIC HOT WATER

Extra power is needed to provide in domestic hot water. This estimation is based on following parameters:

**TABLE 3 – ESTIMATION PARAMETERS**

| | Residential building | Sporting hall |
|---|---|---|
| Average water use per person per day | 95 l/person/day | 29 l/person/day |
| Supply temperature | 49°C | 49°C |
| Average cold-water temperature | 10°C | 10°C |
| Equivalent full load hours of operation | 2446h | 2446h |
| Number of m² per person | 45 | 20 |
| Average occupancy | 4 | 47 |

For the residential building, this results in an extra **3kW** needed, for the sporting hall is this **10kW**. These figures have been rounded upwards.

# 4. DESCRIPTION OF THE RESULTS

## 4.1 HEATING CALCULATION FOR BASELINE

The total heating loss for the baseline (both for residential building and sporting hall) is calculated by taking into account the transmission losses, ventilation losses and in-/exfiltration losses.

#### 4.1.1 TRANSMISSION LOSSES

Transmission losses are taken into account for exterior walls, roof and windows by looking at the surface and U-value for each element. For the residential building, the losses due to transmission are **6.180 W** (Figure 10).

| | Surface | U-value | Losses |
|---|---|---|---|
| | [m²] | [W/m²K] | [W] |
| Exterior Wall | 84,4 | 1,75 | 1.078 |
| Roof | 137,3 | 3,00 | 3.008 |
| Floor | 137,3 | 0,00 | 0 |
| Window | 56,3 | 5,10 | 2.094 |
| | | | **6.180** |

**FIGURE 10: CURRENT TRANSMISSION LOSSES RESIDENTIAL BUILDING**

For the sporting hall, these losses add up to **22.778 W** (Figure 11).

| | Surface | U-value | Losses |
|---|---|---|---|
| | [m²] | [W/m²K] | [W] |
| Exterior Wall | 680,9 | 1,75 | 5.617 |
| Roof | 924,0 | 3,00 | 13.068 |
| Floor | 924,0 | 0,00 | 0 |
| Window | 170,2 | 5,10 | 4.093 |
| | | | **22.778** |

**FIGURE 11: CURRENT TRANSMISSION LOSSES SPORTING HALL**

### 4.1.2 VENTILATION LOSSES & IN-/EXFILTRATION LOSSES

Losses related to ventilation and in-/exfiltration are calculated by using following formulas:

$F_{V,HR} = 0{,}34 * b * V_L * \Delta T_{HR}$ [W]

$F_{V,I/E} = 0{,}34 * g * i * V_L * \Delta T_B$ [W]

With:

0,34 = thermal capacity of air [Wh/m³K] (= energy needed to heat up 1m³ air with 1°C)

b = mechanical ventilation rate of the room

$V_L$ = volume of the room

$\Delta T_{HR} = \eta_{vent.efficiency} * (T_{inside} - T_{outside}) + T_{outside}$ (HR = Heat Recovery)

g = 0,5 for orientation facades / wind direction

i = 0,3 addition in-/exfiltration

$\Delta T_B = T_{inside} - T_{outside}$

For the **residential building**, losses related to ventilation and in-/exfiltration are **1.380 W**. For the **sporting hall**, these are **13.996 W.**

### 4.1.3 TOTAL ANNUAL CURRENT HEATING CONSUMPTION

To calculate the total annual heating consumption, the heating losses are combined with the efficiency of the current heating system and the heating hours per month. This adds up to a total current heating consumption of **54.812 kWh/year for the residential building** and **233.285 kWh/year for the sporting hall**.

## 4.2 HEATING & ELECTRICITY CALCULATION FOR BOILER

First, the scenario of installing a new, more efficient, condensing gas boiler is investigated with a total system efficiency of 94% (including production, distribution, emission and regulation). Also a PV-system is added to the building. The current electricity use of the residential building is set at 3.500 kWh/year and for the sporting hall at 29.568 kWh/year (32kWh/m²).
By combining all costs and gains and taking into account the degression of performance of the PV-installation and an inflation of energy prices, following table is made showing the return on investment of the scenario. For the residential building, this shows a **total investment cost of €64.352** with a **pay-back time of 19 years** (Figure 12 & Figure 13). For this scenario, insulation measures are done for walls, windows as well as the roof.

| Depreciation table | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | Total Investment | Total Electricity Saving kWh/year | Total Natural Gas Saving kWh/year | Unit Cost per electricity kWh | Unit Cost per natural gas kWh | Extra Cost | Utility Price € | ROI |
| 1 | 64.352 | 3.500,0 | 45.561,52 | 0,200 | 0,050 | | 2.978,08 | -61.374,31 |
| 2 | | 3.479,0 | 45.288,15 | 0,205 | 0,051 | | 3.034,21 | -58.340,10 |
| 3 | | 3.458,1 | 45.016,42 | 0,210 | 0,053 | | 3.091,41 | -55.248,69 |
| 4 | | 3.437,4 | 44.746,33 | 0,215 | 0,054 | | 3.149,68 | -52.099,01 |
| 5 | | 3.416,8 | 44.477,85 | 0,221 | 0,055 | | 3.209,05 | -48.889,96 |
| 6 | | 3.396,3 | 44.210,98 | 0,226 | 0,057 | | 3.269,54 | -45.620,42 |
| 7 | | 3.375,9 | 43.945,71 | 0,232 | 0,058 | | 3.331,17 | -42.289,24 |
| 8 | | 3.355,6 | 43.682,04 | 0,238 | 0,059 | | 3.393,97 | -38.895,28 |
| 9 | | 3.335,5 | 43.419,95 | 0,244 | 0,061 | | 3.457,94 | -35.437,33 |
| 10 | | 3.315,5 | 43.159,43 | 0,250 | 0,062 | | 3.523,12 | -31.914,21 |
| 11 | | 3.295,6 | 42.900,47 | 0,256 | 0,064 | | 3.589,54 | -28.324,67 |
| 12 | | 3.275,8 | 42.643,07 | 0,262 | 0,066 | | 3.657,20 | -24.667,47 |
| 13 | | 3.256,2 | 42.387,21 | 0,269 | 0,067 | | 3.726,14 | -20.941,34 |
| 14 | | 3.236,6 | 42.132,89 | 0,276 | 0,069 | | 3.796,37 | -17.144,96 |
| 15 | | 3.217,2 | 41.880,09 | 0,283 | 0,071 | 1500 | 2.367,94 | -14.777,03 |
| 16 | | 3.197,9 | 41.628,81 | 0,290 | 0,072 | | 3.940,85 | -10.836,18 |
| 17 | | 3.178,7 | 41.379,04 | 0,297 | 0,074 | | 4.015,13 | -6.821,05 |
| 18 | | 3.159,6 | 41.130,76 | 0,304 | 0,076 | | 4.090,82 | -2.730,23 |
| 19 | | 3.140,7 | 40.883,98 | 0,312 | 0,078 | | 4.167,93 | 1.437,70 |
| 20 | | 3.121,8 | 40.638,67 | 0,320 | 0,080 | | 4.246,49 | 5.684,19 |
| 21 | | 3.103,1 | 40.394,84 | 0,328 | 0,082 | | 4.326,54 | 10.010,73 |
| 22 | | 3.084,5 | 40.152,47 | 0,336 | 0,084 | | 4.408,10 | 14.418,83 |
| 23 | | 3.066,0 | 39.911,56 | 0,344 | 0,086 | | 4.491,19 | 18.910,02 |
| 24 | | 3.047,6 | 39.672,09 | 0,353 | 0,088 | | 4.575,85 | 23.485,86 |
| 25 | | 3.029,3 | 39.434,06 | 0,362 | 0,090 | | 4.662,10 | 28.147,97 |

**FIGURE 12: DEPRECIATION TABLE GAS BOILER + PV, RESIDENTIAL BUILDING**

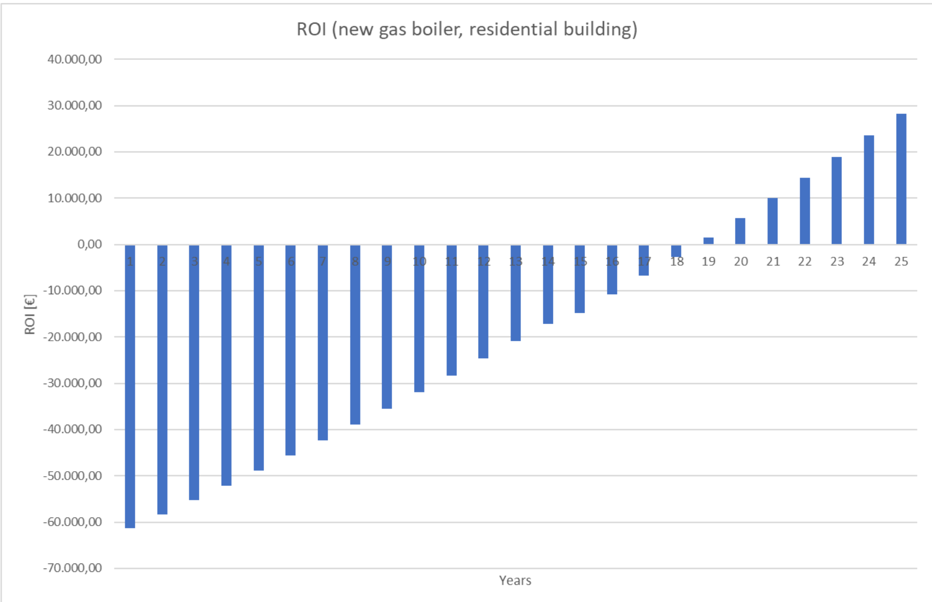


**FIGURE 13: RETURN ON INVESTMENT FOR NEW GAS BOILER + PV, RESIDENTIAL BUILDING**

For the sporting hall, the **total investment cost is €312.729** and the **payback time is 17 years** (Figure 14 & Figure 15). Also, for this scenario, measures are taken for the walls, the roof as well as the windows.

| Depreciation table | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | Total Investment | Total Electricity Saving kWh/year | Total Natural Gas Saving kWh/year | Unit Cost per electricity kWh | Unit Cost per natural gas kWh | Extra Cost | Utility Price € | ROI |
| 1 | 312.729 | 29.568,0 | 203.243,84 | 0,200 | 0,050 | | 16.075,79 | -296.653,48 |
| 2 | | 29.390,6 | 202.024,37 | 0,205 | 0,051 | | 16.378,82 | -280.274,66 |
| 3 | | 29.214,2 | 200.812,23 | 0,210 | 0,053 | | 16.687,56 | -263.587,10 |
| 4 | | 29.039,0 | 199.607,35 | 0,215 | 0,054 | | 17.002,12 | -246.584,98 |
| 5 | | 28.864,7 | 198.409,71 | 0,221 | 0,055 | | 17.322,61 | -229.262,36 |
| 6 | | 28.691,5 | 197.219,25 | 0,226 | 0,057 | | 17.649,14 | -211.613,22 |
| 7 | | 28.519,4 | 196.035,94 | 0,232 | 0,058 | | 17.981,83 | -193.631,39 |
| 8 | | 28.348,3 | 194.859,72 | 0,238 | 0,059 | | 18.320,79 | -175.310,61 |
| 9 | | 28.178,2 | 193.690,56 | 0,244 | 0,061 | | 18.666,13 | -156.644,47 |
| 10 | | 28.009,1 | 192.528,42 | 0,250 | 0,062 | | 19.017,99 | -137.626,48 |
| 11 | | 27.841,1 | 191.373,25 | 0,256 | 0,064 | | 19.376,48 | -118.250,00 |
| 12 | | 27.674,0 | 190.225,01 | 0,262 | 0,066 | | 19.741,73 | -98.508,28 |
| 13 | | 27.508,0 | 189.083,66 | 0,269 | 0,067 | | 20.113,86 | -78.394,42 |
| 14 | | 27.342,9 | 187.949,16 | 0,276 | 0,069 | | 20.493,00 | -57.901,41 |
| 15 | | 27.178,9 | 186.821,46 | 0,283 | 0,071 | 1500 | 19.379,30 | -38.522,12 |
| 16 | | 27.015,8 | 185.700,53 | 0,290 | 0,072 | | 21.272,87 | -17.249,25 |
| 17 | | 26.853,7 | 184.586,33 | 0,297 | 0,074 | | 21.673,87 | 4.424,62 |
| 18 | | 26.692,6 | 183.478,81 | 0,304 | 0,076 | | 22.082,42 | 26.507,04 |
| 19 | | 26.532,4 | 182.377,94 | 0,312 | 0,078 | | 22.498,67 | 49.005,71 |
| 20 | | 26.373,2 | 181.283,67 | 0,320 | 0,080 | | 22.922,77 | 71.928,48 |
| 21 | | 26.215,0 | 180.195,97 | 0,328 | 0,082 | | 23.354,87 | 95.283,34 |
| 22 | | 26.057,7 | 179.114,79 | 0,336 | 0,084 | | 23.795,10 | 119.078,45 |
| 23 | | 25.901,4 | 178.040,10 | 0,344 | 0,086 | | 24.243,64 | 143.322,09 |
| 24 | | 25.745,9 | 176.971,86 | 0,353 | 0,088 | | 24.700,63 | 168.022,73 |
| 25 | | 25.591,5 | 175.910,03 | 0,362 | 0,090 | | 25.166,24 | 193.188,97 |

**FIGURE 14: DEPRECIATION TABLE GAS BOILER + PV, SPORTING HALL**

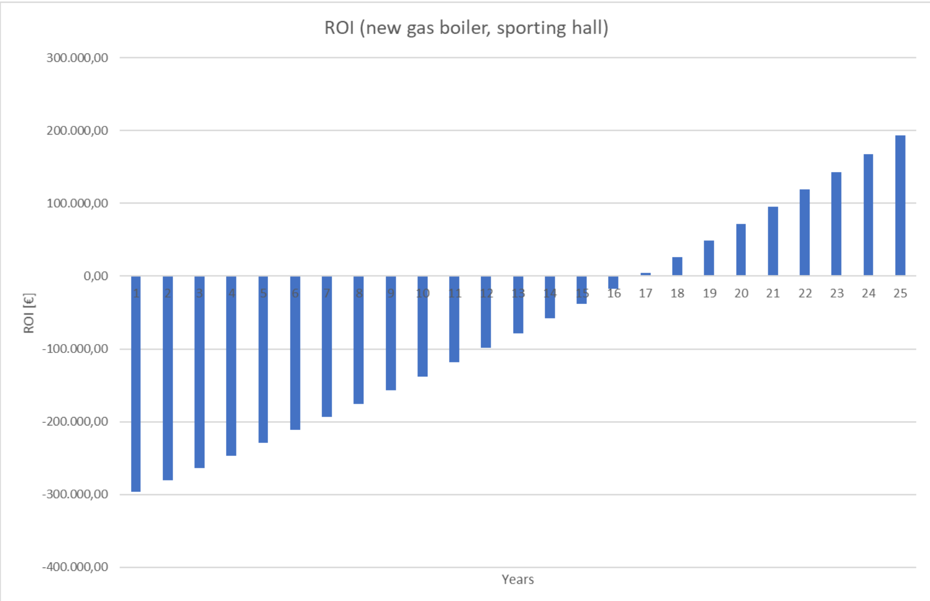


**FIGURE 15: RETURN ON INVESTMENT FOR NEW GAS BOILER + PV IN SPORTING HALL**

## 4.3 HEATING AND ELECTRICITY CALCULATION FOR HEAT PUMP

### 4.3.1 HEAT PUMP EFFICIENCY

The efficiency of a heat pump depends on the outside air temperature and the needed supply temperature. The lower the supply temperature, the better the efficiency of the heat pump as shown in the graph below (Figure 16). On the y-axis, the COP is shown in function of the outside air temperature (x-axis). The different colours show different supply temperatures.

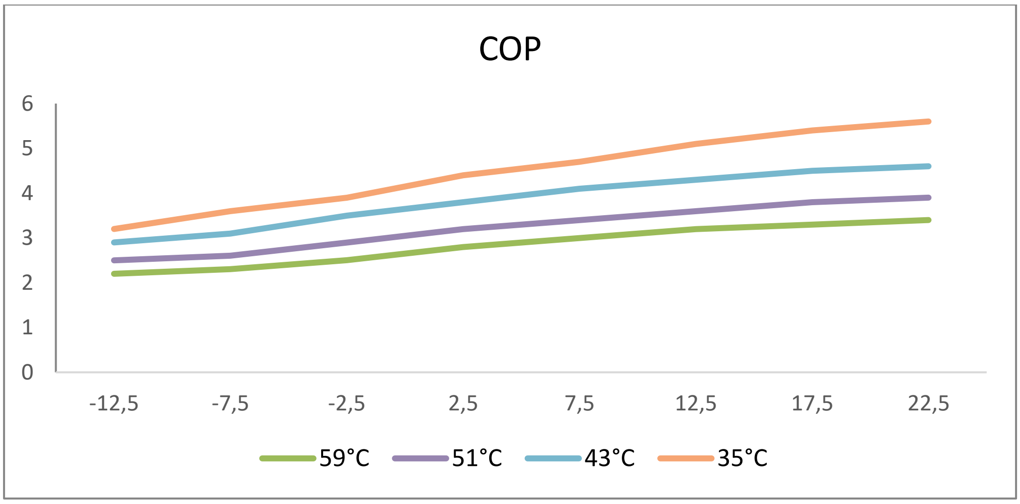


**FIGURE 16: EFFICIENCY HEAT PUMP IN FUNCTION OF OUTSIDE AIR TEMPERATURE**

The efficiency of a heat pump is not constant through the year but varies with the different seasons, as can be seen in the graph below (Figure 17). In summer, the COP is always higher than in winter.

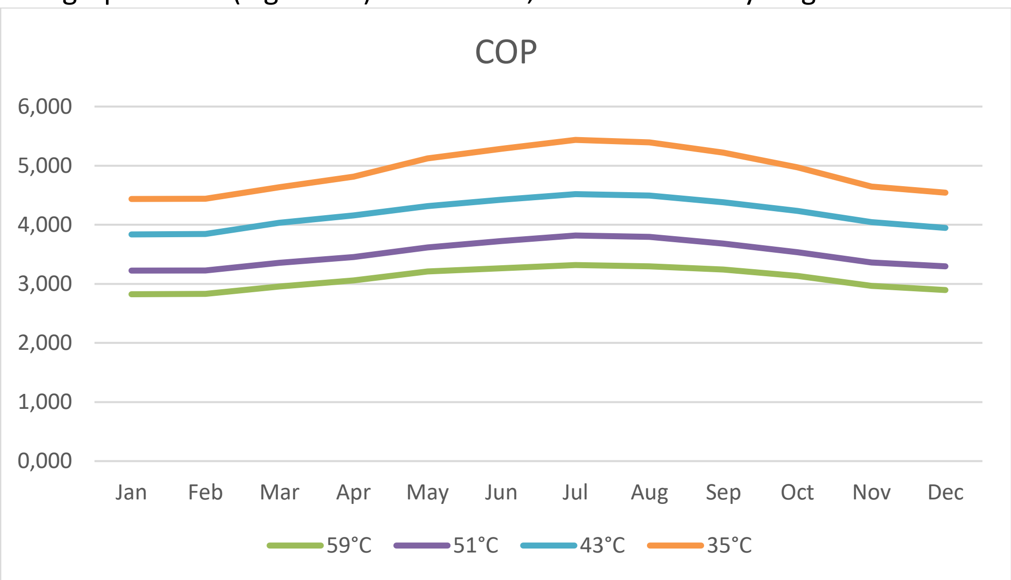


**FIGURE 17: EFFICIENCY HEAT PUMP IN FUNCTION OF THE SEASONS**

As stated in the Hysopt webinar of February 25th, 2021, even without changing the current heat releasing elements (e.g. radiators), the installation of a heat pump on a low temperature regime can be feasible. However, we expect higher flow rates, so the electricity consumption would increase.

### 4.3.2 RETURN ON INVESTMENT FOR HEAT PUMP, HIGH TEMPERATURE (HT)

For following scenarios, a supply temperature of 59°C is assumed. A PV-installation is also included in the scenario. The installation of a heat pump causes the electricity consumption to go up, which can be anticipated by installing a PV-installation. Currently, the reversing meter makes this easy. However, this situation will change in the future because of the introduction of the digital meters. This will mainly be an issue in winter, because overproduction during the summer won't be able to make up for the extra needed electricity for heating in winter anymore.
For the residential building, an installation of **11,28 kWp** is estimated with an efficiency of 900 kWh/kWp. Investment costs are estimated at €1/Wp. For the sporting hall, an installation of **76,18 kWp** is estimated. The efficiency and investment costs per Wp are identical to the residential building-scenario.
For the residential building, the **total investment cost is €70.975** with a **payback time of 18 years** (Figure 18 & Figure 19). Insulation measures for walls, windows and roof are taken into account.

| Depreciation table | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | Total Investment | Total Electricity Saving kWh/year | Total Natural Gas Saving kWh/year | Unit Cost per electricity kWh | Unit Cost per natural gas kWh | Extra Cost | Utility Price € | ROI |
| 1 | 70.975 | 3.500 | 54.811,56 | 0,200 | 0,050 | | 3.440,58 | -67.534,90 |
| 2 | | 3479,00 | 54.482,69 | 0,205 | 0,051 | | 3.505,43 | -64.029,47 |
| 3 | | 3458,13 | 54.155,80 | 0,210 | 0,053 | | 3.571,51 | -60.457,96 |
| 4 | | 3437,38 | 53.830,86 | 0,215 | 0,054 | | 3.638,83 | -56.819,12 |
| 5 | | 3416,75 | 53.507,88 | 0,221 | 0,055 | | 3.707,43 | -53.111,70 |
| 6 | | 3396,25 | 53.186,83 | 0,226 | 0,057 | | 3.777,31 | -49.334,39 |
| 7 | | 3375,87 | 52.867,71 | 0,232 | 0,058 | | 3.848,51 | -45.485,87 |
| 8 | | 3355,62 | 52.550,50 | 0,238 | 0,059 | | 3.921,06 | -41.564,82 |
| 9 | | 3335,49 | 52.235,20 | 0,244 | 0,061 | | 3.994,97 | -37.569,85 |
| 10 | | 3315,47 | 51.921,79 | 0,250 | 0,062 | | 4.070,27 | -33.499,57 |
| 11 | | 3295,58 | 51.610,26 | 0,256 | 0,064 | | 4.147,00 | -29.352,57 |
| 12 | | 3275,81 | 51.300,60 | 0,262 | 0,066 | | 4.225,17 | -25.127,40 |
| 13 | | 3256,15 | 50.992,79 | 0,269 | 0,067 | | 4.304,81 | -20.822,59 |
| 14 | | 3236,61 | 50.686,83 | 0,276 | 0,069 | | 4.385,96 | -16.436,63 |
| 15 | | 3217,20 | 50.382,71 | 0,283 | 0,071 | 1500 | 2.968,64 | -13.468,00 |
| 16 | | 3197,89 | 50.080,42 | 0,290 | 0,072 | | 4.552,87 | -8.915,13 |
| 17 | | 3178,70 | 49.779,94 | 0,297 | 0,074 | | 4.638,69 | -4.276,44 |
| 18 | | 3159,63 | 49.481,26 | 0,304 | 0,076 | | 4.726,13 | 449,69 |
| 19 | | 3140,67 | 49.184,37 | 0,312 | 0,078 | | 4.815,22 | 5.264,91 |
| 20 | | 3121,83 | 48.889,26 | 0,320 | 0,080 | | 4.905,98 | 10.170,90 |
| 21 | | 3103,10 | 48.595,93 | 0,328 | 0,082 | | 4.998,46 | 15.169,36 |
| 22 | | 3084,48 | 48.304,35 | 0,336 | 0,084 | | 5.092,68 | 20.262,04 |
| 23 | | 3065,97 | 48.014,52 | 0,344 | 0,086 | | 5.188,68 | 25.450,72 |
| 24 | | 3047,58 | 47.726,44 | 0,353 | 0,088 | | 5.286,49 | 30.737,21 |
| 25 | | 3029,29 | 47.440,08 | 0,362 | 0,090 | | 5.386,14 | 36.123,35 |

**FIGURE 18: DEPRECIATION TABLE HEAT PUMP + PV, RESIDENTIAL BUILDING (HT, 59°C SUPPLY)**

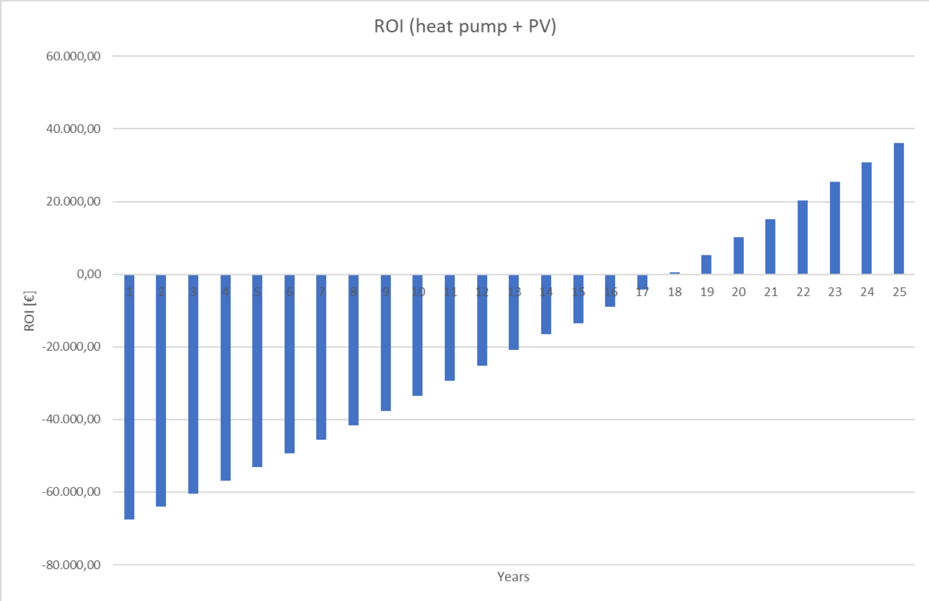


**FIGURE 19: RETURN ON INVESTMENT FOR HEAT PUMP AND PV, RESIDENTIAL BUILDING (HT, 59°C SUPPLY)**

For the sporting hall, the **total investment cost is €357.920** with a **payback time of 18 years** (Figure 20 & Figure 21), when taking into account insulation measures for walls, windows as well as the roof.

| Depreciation table | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | Total Investment | Total Electricity Saving kWh/year | Total Natural Gas Saving kWh/year | Unit Cost per electricity kWh | Unit Cost per natural gas kWh | Extra Cost | Utility Price € | ROI |
| 1 | 357.920 | 29.568 | 233.284,83 | 0,200 | 0,050 | | 17.577,84 | -340.341,96 |
| 2 | | 29390,59 | 231.885,12 | 0,205 | 0,051 | | 17.909,18 | -322.432,78 |
| 3 | | 29214,25 | 230.493,81 | 0,210 | 0,053 | | 18.246,77 | -304.186,01 |
| 4 | | 29038,96 | 229.110,85 | 0,215 | 0,054 | | 18.590,72 | -285.595,29 |
| 5 | | 28864,73 | 227.736,18 | 0,221 | 0,055 | | 18.941,16 | -266.654,13 |
| 6 | | 28691,54 | 226.369,77 | 0,226 | 0,057 | | 19.298,20 | -247.355,93 |
| 7 | | 28519,39 | 225.011,55 | 0,232 | 0,058 | | 19.661,97 | -227.693,96 |
| 8 | | 28348,28 | 223.661,48 | 0,238 | 0,059 | | 20.032,60 | -207.661,36 |
| 9 | | 28178,19 | 222.319,51 | 0,244 | 0,061 | | 20.410,21 | -187.251,14 |
| 10 | | 28009,12 | 220.985,59 | 0,250 | 0,062 | | 20.794,95 | -166.456,20 |
| 11 | | 27841,06 | 219.659,68 | 0,256 | 0,064 | | 21.186,93 | -145.269,27 |
| 12 | | 27674,02 | 218.341,72 | 0,262 | 0,066 | | 21.586,30 | -123.682,96 |
| 13 | | 27507,97 | 217.031,67 | 0,269 | 0,067 | | 21.993,21 | -101.689,76 |
| 14 | | 27342,92 | 215.729,48 | 0,276 | 0,069 | | 22.407,78 | -79.281,98 |
| 15 | | 27178,87 | 214.435,10 | 0,283 | 0,071 | 1500 | 21.330,16 | -57.951,82 |
| 16 | | 27015,79 | 213.148,49 | 0,290 | 0,072 | | 23.260,51 | -34.691,30 |
| 17 | | 26853,70 | 211.869,60 | 0,297 | 0,074 | | 23.698,97 | -10.992,33 |
| 18 | | 26692,58 | 210.598,38 | 0,304 | 0,076 | | 24.145,70 | 13.153,37 |
| 19 | | 26532,42 | 209.334,79 | 0,312 | 0,078 | | 24.600,85 | 37.754,22 |
| 20 | | 26373,23 | 208.078,78 | 0,320 | 0,080 | | 25.064,57 | 62.818,79 |
| 21 | | 26214,99 | 206.830,31 | 0,328 | 0,082 | | 25.537,04 | 88.355,83 |
| 22 | | 26057,70 | 205.589,33 | 0,336 | 0,084 | | 26.018,41 | 114.374,24 |
| 23 | | 25901,35 | 204.355,79 | 0,344 | 0,086 | | 26.508,86 | 140.883,10 |
| 24 | | 25745,94 | 203.129,66 | 0,353 | 0,088 | | 27.008,55 | 167.891,65 |
| 25 | | 25591,47 | 201.910,88 | 0,362 | 0,090 | | 27.517,66 | 195.409,31 |

**FIGURE 20: DEPRECIATION TABLE HEAT PUMP + PV, SPORTING HALL (HT, 59°C SUPPLY)**

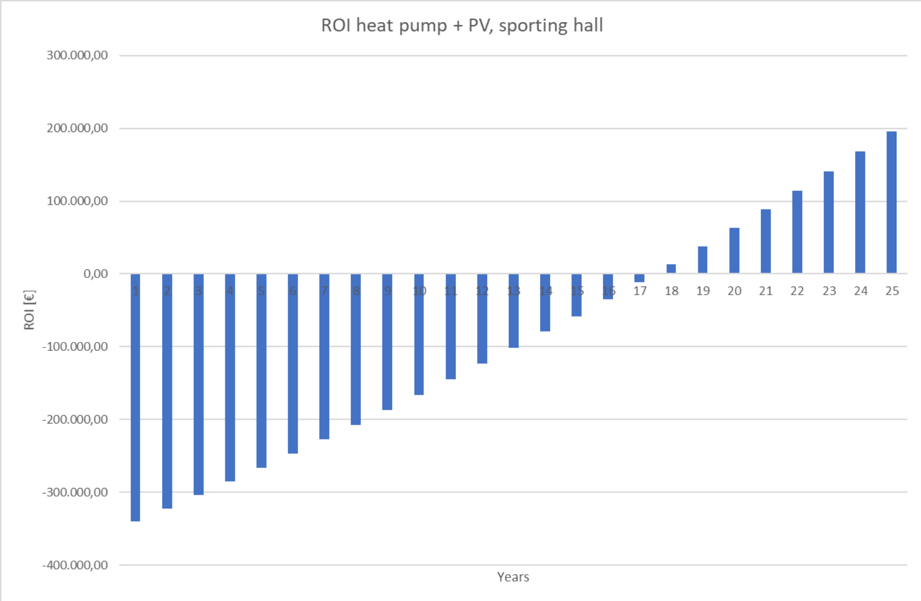


**FIGURE 21: RETURN ON INVESTMENT FOR HEAT PUMP + PV, SPORTING HALL (HT, 59°C SUPPLY)**

The sporting hall can also obtain a K-level smaller then 40 when only focusing on the walls and the roof. This results in an **investment cost of €292.784** and a **payback time of 15 years** (Figure 22 & Figure 23).

| Depreciation table | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | Total Investment | Total Electricity Saving kWh/year | Total Natural Gas Saving kWh/year | Unit Cost per electricity kWh | Unit Cost per natural gas kWh | Extra Cost | Utility Price € | ROI |
| 1 | 292.784 | 29.568 | 233.284,83 | 0,200 | 0,050 | | 17.577,84 | -275.205,82 |
| 2 | | 29390,59 | 231.885,12 | 0,205 | 0,051 | | 17.909,18 | -257.296,63 |
| 3 | | 29214,25 | 230.493,81 | 0,210 | 0,053 | | 18.246,77 | -239.049,86 |
| 4 | | 29038,96 | 229.110,85 | 0,215 | 0,054 | | 18.590,72 | -220.459,14 |
| 5 | | 28864,73 | 227.736,18 | 0,221 | 0,055 | | 18.941,16 | -201.517,98 |
| 6 | | 28691,54 | 226.369,77 | 0,226 | 0,057 | | 19.298,20 | -182.219,78 |
| 7 | | 28519,39 | 225.011,55 | 0,232 | 0,058 | | 19.661,97 | -162.557,81 |
| 8 | | 28348,28 | 223.661,48 | 0,238 | 0,059 | | 20.032,60 | -142.525,21 |
| 9 | | 28178,19 | 222.319,51 | 0,244 | 0,061 | | 20.410,21 | -122.114,99 |
| 10 | | 28009,12 | 220.985,59 | 0,250 | 0,062 | | 20.794,95 | -101.320,05 |
| 11 | | 27841,06 | 219.659,68 | 0,256 | 0,064 | | 21.186,93 | -80.133,12 |
| 12 | | 27674,02 | 218.341,72 | 0,262 | 0,066 | | 21.586,30 | -58.546,81 |
| 13 | | 27507,97 | 217.031,67 | 0,269 | 0,067 | | 21.993,21 | -36.553,61 |
| 14 | | 27342,92 | 215.729,48 | 0,276 | 0,069 | | 22.407,78 | -14.145,83 |
| 15 | | 27178,87 | 214.435,10 | 0,283 | 0,071 | 1500 | 21.330,16 | 7.184,33 |
| 16 | | 27015,79 | 213.148,49 | 0,290 | 0,072 | | 23.260,51 | 30.444,85 |
| 17 | | 26853,70 | 211.869,60 | 0,297 | 0,074 | | 23.698,97 | 54.143,82 |
| 18 | | 26692,58 | 210.598,38 | 0,304 | 0,076 | | 24.145,70 | 78.289,52 |
| 19 | | 26532,42 | 209.334,79 | 0,312 | 0,078 | | 24.600,85 | 102.890,37 |
| 20 | | 26373,23 | 208.078,78 | 0,320 | 0,080 | | 25.064,57 | 127.954,94 |
| 21 | | 26214,99 | 206.830,31 | 0,328 | 0,082 | | 25.537,04 | 153.491,98 |
| 22 | | 26057,70 | 205.589,33 | 0,336 | 0,084 | | 26.018,41 | 179.510,39 |
| 23 | | 25901,35 | 204.355,79 | 0,344 | 0,086 | | 26.508,86 | 206.019,25 |
| 24 | | 25745,94 | 203.129,66 | 0,353 | 0,088 | | 27.008,55 | 233.027,80 |
| 25 | | 25591,47 | 201.910,88 | 0,362 | 0,090 | | 27.517,66 | 260.545,46 |

**FIGURE 22: DEPRECIATION TABLE HEAT PUMP + PV, SPORTING HALL (WALLS + ROOF) (HT)**

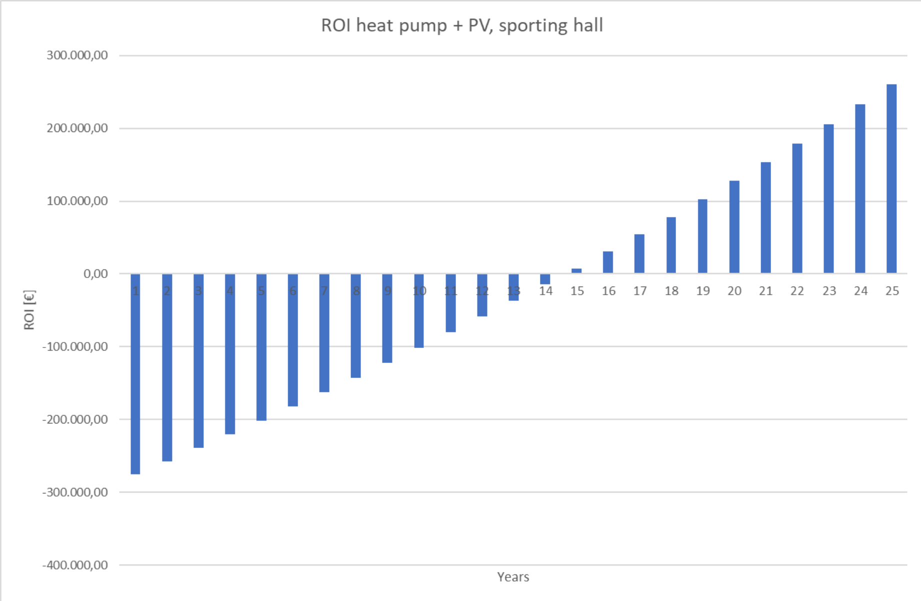


**FIGURE 23: RETURN ON INVESTMENT HEAT PUMP + PV, SPORTING HALL (WALLS + ROOF) (HT)**

By only insulating the walls and roof of the sporting hall, the demanded comfort levels can still be achieved but with a lower investment cost (capex). A better return on investment and net present value (NPV) at 25 years can be attained, compared to when insulation measures are carried out for walls, roof and windows.
The use of green electricity will be of importance, otherwise the $CO_2$ emissions will increase. A sporting hall is an ideal building to implement a PV-installation. It has a large, flat roof and the intrinsic consumption is rather low (29.568 kWh/year). Therefore, the total electricity consumption could be covered by the PV-installation.

### 4.3.3 RETURN ON INVESTMENT FOR HEAT PUMP, LOW TEMPERATURE (LT)

For following scenarios, a supply temperature of 35°C is assumed. A PV-installation is also included in the scenario. No changes are made regarding the heat releasing elements. A difference in COP between HT and LT will cause differences in yearly $CO_2$ emissions and yearly savings.
For the residential building, the **total investment cost is €69.732** with a **payback time of 18 years** (Figure 24 & Figure 25). Insulation measures for walls, windows and roof are taken into account.

| Depreciation table | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | Total Investment | Total Electricity Saving kWh/year | Total Natural Gas Saving kWh/year | Unit Cost per electricity kWh | Unit Cost per natural gas kWh | Extra Cost | Utility Price € | ROI |
| 1 | 69.732 | 3.500 | 54.811,56 | 0,200 | 0,050 | | 3.440,58 | -66.291,71 |
| 2 | | 3479,00 | 54.482,69 | 0,205 | 0,051 | | 3.505,43 | -62.786,28 |
| 3 | | 3458,13 | 54.155,80 | 0,210 | 0,053 | | 3.571,51 | -59.214,76 |
| 4 | | 3437,38 | 53.830,86 | 0,215 | 0,054 | | 3.638,83 | -55.575,93 |
| 5 | | 3416,75 | 53.507,88 | 0,221 | 0,055 | | 3.707,43 | -51.868,51 |
| 6 | | 3396,25 | 53.186,83 | 0,226 | 0,057 | | 3.777,31 | -48.091,20 |
| 7 | | 3375,87 | 52.867,71 | 0,232 | 0,058 | | 3.848,51 | -44.242,68 |
| 8 | | 3355,62 | 52.550,50 | 0,238 | 0,059 | | 3.921,06 | -40.321,63 |
| 9 | | 3335,49 | 52.235,20 | 0,244 | 0,061 | | 3.994,97 | -36.326,66 |
| 10 | | 3315,47 | 51.921,79 | 0,250 | 0,062 | | 4.070,27 | -32.256,38 |
| 11 | | 3295,58 | 51.610,26 | 0,256 | 0,064 | | 4.147,00 | -28.109,38 |
| 12 | | 3275,81 | 51.300,60 | 0,262 | 0,066 | | 4.225,17 | -23.884,21 |
| 13 | | 3256,15 | 50.992,79 | 0,269 | 0,067 | | 4.304,81 | -19.579,40 |
| 14 | | 3236,61 | 50.686,83 | 0,276 | 0,069 | | 4.385,96 | -15.193,44 |
| 15 | | 3217,20 | 50.382,71 | 0,283 | 0,071 | 1500 | 2.968,64 | -12.224,80 |
| 16 | | 3197,89 | 50.080,42 | 0,290 | 0,072 | | 4.552,87 | -7.671,94 |
| 17 | | 3178,70 | 49.779,94 | 0,297 | 0,074 | | 4.638,69 | -3.033,24 |
| 18 | | 3159,63 | 49.481,26 | 0,304 | 0,076 | | 4.726,13 | 1.692,89 |
| 19 | | 3140,67 | 49.184,37 | 0,312 | 0,078 | | 4.815,22 | 6.508,10 |
| 20 | | 3121,83 | 48.889,26 | 0,320 | 0,080 | | 4.905,98 | 11.414,09 |
| 21 | | 3103,10 | 48.595,93 | 0,328 | 0,082 | | 4.998,46 | 16.412,55 |
| 22 | | 3084,48 | 48.304,35 | 0,336 | 0,084 | | 5.092,68 | 21.505,23 |
| 23 | | 3065,97 | 48.014,52 | 0,344 | 0,086 | | 5.188,68 | 26.693,91 |
| 24 | | 3047,58 | 47.726,44 | 0,353 | 0,088 | | 5.286,49 | 31.980,40 |
| 25 | | 3029,29 | 47.440,08 | 0,362 | 0,090 | | 5.386,14 | 37.366,54 |

**FIGURE 24: DEPRECIATION TABLE HEAT PUMP + PV, RESIDENTIAL BUILDING (LT)**

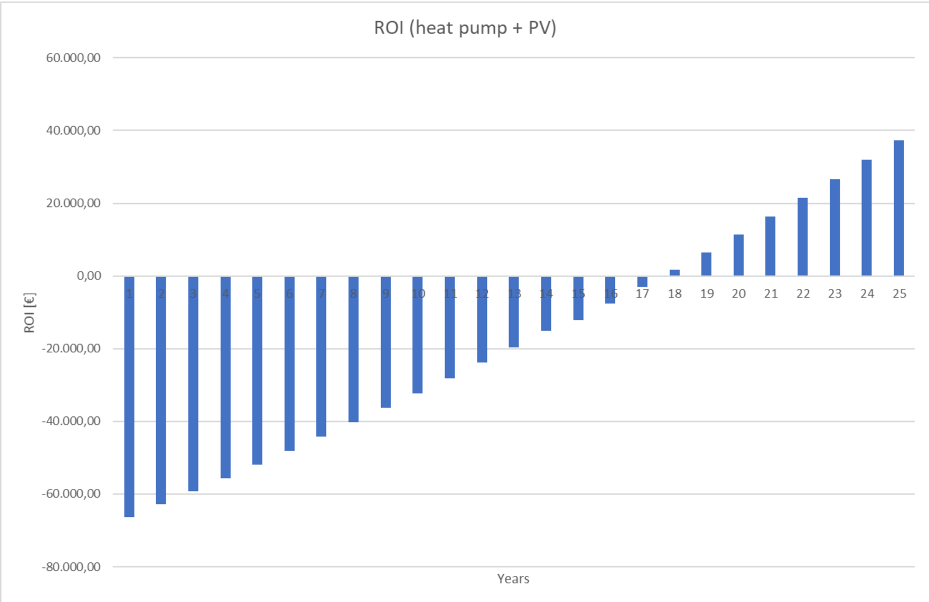


**FIGURE 25: RETURN ON INVESTMENT HEAT PUMP + PV, RESIDENTIAL BUILDING (LT)**

For the sporting hall, the **total investment cost is €353.882** with a **payback time of 18 years** (Figure 26 & Figure 27), when taking into account insulation measures for walls, windows as well as the roof.

| Depreciation table | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | Total Investment | Total Electricity Saving kWh/year | Total Natural Gas Saving kWh/year | Unit Cost per electricity kWh | Unit Cost per natural gas kWh | Extra Cost | Utility Price € | ROI |
| 1 | 353.882 | 29.568 | 233.284,83 | 0,200 | 0,050 | | 17.577,84 | -336.304,50 |
| 2 | | 29390,59 | 231.885,12 | 0,205 | 0,051 | | 17.909,18 | -318.395,32 |
| 3 | | 29214,25 | 230.493,81 | 0,210 | 0,053 | | 18.246,77 | -300.148,55 |
| 4 | | 29038,96 | 229.110,85 | 0,215 | 0,054 | | 18.590,72 | -281.557,82 |
| 5 | | 28864,73 | 227.736,18 | 0,221 | 0,055 | | 18.941,16 | -262.616,66 |
| 6 | | 28691,54 | 226.369,77 | 0,226 | 0,057 | | 19.298,20 | -243.318,47 |
| 7 | | 28519,39 | 225.011,55 | 0,232 | 0,058 | | 19.661,97 | -223.656,49 |
| 8 | | 28348,28 | 223.661,48 | 0,238 | 0,059 | | 20.032,60 | -203.623,90 |
| 9 | | 28178,19 | 222.319,51 | 0,244 | 0,061 | | 20.410,21 | -183.213,68 |
| 10 | | 28009,12 | 220.985,59 | 0,250 | 0,062 | | 20.794,95 | -162.418,74 |
| 11 | | 27841,06 | 219.659,68 | 0,256 | 0,064 | | 21.186,93 | -141.231,81 |
| 12 | | 27674,02 | 218.341,72 | 0,262 | 0,066 | | 21.586,30 | -119.645,50 |
| 13 | | 27507,97 | 217.031,67 | 0,269 | 0,067 | | 21.993,21 | -97.652,30 |
| 14 | | 27342,92 | 215.729,48 | 0,276 | 0,069 | | 22.407,78 | -75.244,52 |
| 15 | | 27178,87 | 214.435,10 | 0,283 | 0,071 | 1500 | 21.330,16 | -53.914,35 |
| 16 | | 27015,79 | 213.148,49 | 0,290 | 0,072 | | 23.260,51 | -30.653,84 |
| 17 | | 26853,70 | 211.869,60 | 0,297 | 0,074 | | 23.698,97 | -6.954,87 |
| 18 | | 26692,58 | 210.598,38 | 0,304 | 0,076 | | 24.145,70 | 17.190,83 |
| 19 | | 26532,42 | 209.334,79 | 0,312 | 0,078 | | 24.600,85 | 41.791,68 |
| 20 | | 26373,23 | 208.078,78 | 0,320 | 0,080 | | 25.064,57 | 66.856,25 |
| 21 | | 26214,99 | 206.830,31 | 0,328 | 0,082 | | 25.537,04 | 92.393,29 |
| 22 | | 26057,70 | 205.589,33 | 0,336 | 0,084 | | 26.018,41 | 118.411,70 |
| 23 | | 25901,35 | 204.355,79 | 0,344 | 0,086 | | 26.508,86 | 144.920,56 |
| 24 | | 25745,94 | 203.129,66 | 0,353 | 0,088 | | 27.008,55 | 171.929,11 |
| 25 | | 25591,47 | 201.910,88 | 0,362 | 0,090 | | 27.517,66 | 199.446,77 |

**FIGURE 26: DEPRECIATION TABLE HEAT PUMP + PV, SPORTING HALL (ROOF + WALLS + WINDOW) (LT)**

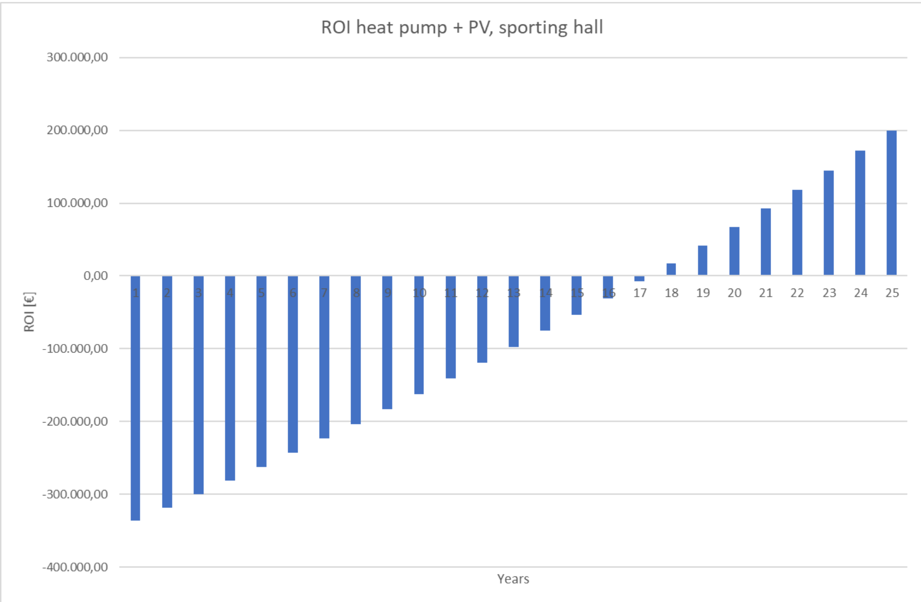


**FIGURE 27: RETURN ON INVESTMENT HEAT PUMP + PV, SPORTING HALL (ROOF + WALLS + WINDOW) (LT)**

The sporting hall can also obtain a K-level smaller then 40 when only focusing on the walls and the roof. This results in an **investment cost of €286.592** and a **payback time of 15 years** (Figure 22 & Figure 23).

| Depreciation table | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | Total Investment | Total Electricity Saving kWh/year | Total Natural Gas Saving kWh/year | Unit Cost per electricity kWh | Unit Cost per natural gas kWh | Extra Cost | Utility Price € | ROI |
| 1 | 286.592 | 29.568 | 233.284,83 | 0,200 | 0,050 | | 17.577,84 | -269.013,87 |
| 2 | | 29390,59 | 231.885,12 | 0,205 | 0,051 | | 17.909,18 | -251.104,68 |
| 3 | | 29214,25 | 230.493,81 | 0,210 | 0,053 | | 18.246,77 | -232.857,91 |
| 4 | | 29038,96 | 229.110,85 | 0,215 | 0,054 | | 18.590,72 | -214.267,19 |
| 5 | | 28864,73 | 227.736,18 | 0,221 | 0,055 | | 18.941,16 | -195.326,03 |
| 6 | | 28691,54 | 226.369,77 | 0,226 | 0,057 | | 19.298,20 | -176.027,83 |
| 7 | | 28519,39 | 225.011,55 | 0,232 | 0,058 | | 19.661,97 | -156.365,86 |
| 8 | | 28348,28 | 223.661,48 | 0,238 | 0,059 | | 20.032,60 | -136.333,26 |
| 9 | | 28178,19 | 222.319,51 | 0,244 | 0,061 | | 20.410,21 | -115.923,05 |
| 10 | | 28009,12 | 220.985,59 | 0,250 | 0,062 | | 20.794,95 | -95.128,10 |
| 11 | | 27841,06 | 219.659,68 | 0,256 | 0,064 | | 21.186,93 | -73.941,17 |
| 12 | | 27674,02 | 218.341,72 | 0,262 | 0,066 | | 21.586,30 | -52.354,87 |
| 13 | | 27507,97 | 217.031,67 | 0,269 | 0,067 | | 21.993,21 | -30.361,66 |
| 14 | | 27342,92 | 215.729,48 | 0,276 | 0,069 | | 22.407,78 | -7.953,88 |
| 15 | | 27178,87 | 214.435,10 | 0,283 | 0,071 | 1500 | 21.330,16 | 13.376,28 |
| 16 | | 27015,79 | 213.148,49 | 0,290 | 0,072 | | 23.260,51 | 36.636,80 |
| 17 | | 26853,70 | 211.869,60 | 0,297 | 0,074 | | 23.698,97 | 60.335,77 |
| 18 | | 26692,58 | 210.598,38 | 0,304 | 0,076 | | 24.145,70 | 84.481,47 |
| 19 | | 26532,42 | 209.334,79 | 0,312 | 0,078 | | 24.600,85 | 109.082,32 |
| 20 | | 26373,23 | 208.078,78 | 0,320 | 0,080 | | 25.064,57 | 134.146,89 |
| 21 | | 26214,99 | 206.830,31 | 0,328 | 0,082 | | 25.537,04 | 159.683,93 |
| 22 | | 26057,70 | 205.589,33 | 0,336 | 0,084 | | 26.018,41 | 185.702,34 |
| 23 | | 25901,35 | 204.355,79 | 0,344 | 0,086 | | 26.508,86 | 212.211,20 |
| 24 | | 25745,94 | 203.129,66 | 0,353 | 0,088 | | 27.008,55 | 239.219,75 |
| 25 | | 25591,47 | 201.910,88 | 0,362 | 0,090 | | 27.517,66 | 266.737,41 |

**FIGURE 28: DEPRECIATION TABLE HEAT PUMP + PV, SPORTING HALL (ROOF + WALLS) (LT)**

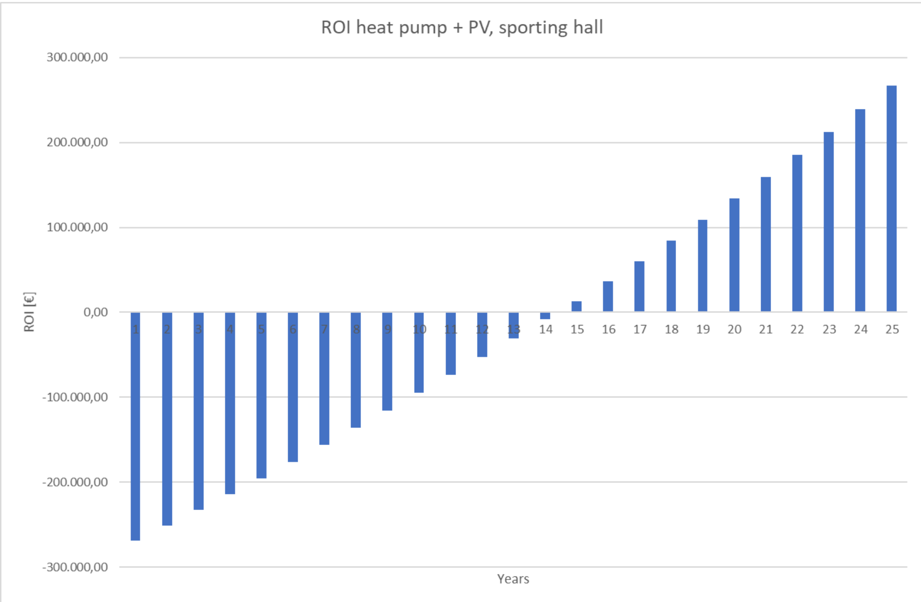


**FIGURE 29: RETURN ON INVESTMENT HEAT PUMP + PV, SPORTING HALL (ROOF + WALLS) (LT)**

Also, in the scenario of a LT heat pump for the sporting hall, the demanded comfort levels can be achieved by only insulating the walls and roof, which lowers the investment costs compared to insulating walls, roof as well as windows. A better return on investment and NPV at 25 years can be attained.
In the scenario with LT heat pumps, the investment costs are slightly lower than in the scenarios with HT heat pumps. However, these small differences don't cause large changes of payback times.

# 5. OVERVIEW

In this overview, only the costs and effects of the insulation measures and the new heating elements are included. This means that the PV-installation is excluded in these calculations and comparisons.

## 5.1 RESIDENTIAL BUILDING

Looking at the case of the residential building, a K-level of less than 40 can only be reached by combining insulation measures for the windows, the walls as well as the roof. The installation of a heat pump is therefore only advised in this scenario. By installing a HT heat pump, the yearly heating costs and yearly heating emissions would go down with 78% and by installing a LT heat pump, they would lower with 86%. In the other scenarios, the installation of a new, more efficient gas boiler can lower the yearly heating costs and yearly heating emissions with on average 15%. To provide enough domestic hot water, and extra power of 3 kW is needed on top of the power needed for heating. This is already included in the sizes shown in the figure below (Figure 30).

| **New more efficient gas boiler** | Size (kW) hence cost depends on heating demand. Must also provide DHW. | |
|---|---|---|
| | efficiency (G2H) | 94,00% % |

| **Gas boiler replacement Investment cost.** (make abstraction of maintenance cost : assume a fixed number independent of size for this) (make abstraction of replacement cost) | **Size (kW)** | **Cost (+new boiler)** | **yearly heating cost** *(will also be calculated with ABEPeM, with and without active control of flex, and for various price structure scenarios)* | | **yearly heating emissions** *(will also be calculated with ABEPeM, with and without active control of flex, and for various dynamic carbon intensity profiles)* | |
|---|---|---|---|---|---|---|
| Windows | 32 | 30.719 EURO | Windows | 1.864 EURO | Windows | 7.082 kg CO2 |
| Walls | 33 | 15.138 EURO | Walls | 2.045 EURO | Walls | 7.773 kg CO2 |
| Roof | 27 | 19.107 EURO | Roof | 1.466 EURO | Roof | 5.572 kg CO2 |
| Windows + Walls | 29 | 41.857 EURO | Windows + Walls | 1.577 EURO | Windows + Walls | 5.992 kg CO2 |
| Windows + Roof | 20 | 45.826 EURO | Windows + Roof | 998 EURO | Windows + Roof | 3.791 kg CO2 |
| Walls + Roof | 23 | 30.244 EURO | Walls + Roof | 1.179 EURO | Walls + Roof | 4.482 kg CO2 |
| Windows + Walls + Roof | 13 | 56.963 EURO | Windows + Walls + Roof | 711 EURO | Windows + Walls + Roof | 2.701 kg CO2 |

| **LT Heatpump** | Size (kW) hence cost depends on heating demand. Must also provide DHW. | |
|---|---|---|
| | Efficiency/COP heating (P2H) | 4,436 |
| | Efficiency/COP DHW | 3 |

*Red indicated values: K-value in these situations is greater than 40, so the installation of a HP is not advised. Therefore, no cost-estimations have been made

Need to replace radiators ?
Underfloor heating advised but in practise mostly not possible ?
Grey-out cells that correspond to too low insulation leavels that rule out HP deployment.

| **HP related Investment cost.** (make abstraction of maintenance cost : assume a fixed number independent of size for this) (make abstraction of replacement cost) | **Size (kW)** (assume air-water ?) | **Cost (+ air-water HP)** | **yearly heating cost** *(will also be calculated with ABEPeM, with and without active control of flex, and for various price structure scenarios)* | | **yearly heating emissions** *(will also be calculated with ABEPeM, with and without active control of flex, and for various dynamic carbon intensity profiles)* | |
|---|---|---|---|---|---|---|
| Windows | 32 | K-value greater than 40, installation heat pump not advised | Windows | 1.580 EURO | Windows | 1.185 kg CO2 |
| Walls | 33 | | Walls | 1.734 EURO | Walls | 1.300 kg CO2 |
| Roof | 27 | | Roof | 1.243 EURO | Roof | 932 kg CO2 |
| Windows + Walls | 29 | | Windows + Walls | 1.336 EURO | Windows + Walls | 1.002 kg CO2 |
| Windows + Roof | 20 | | Windows + Roof | 846 EURO | Windows + Roof | 634 kg CO2 |
| Walls + Roof | 23 | | Walls + Roof | 1.000 EURO | Walls + Roof | 750 kg CO2 |
| Windows + Walls + Roof | 13 | 60.035 EURO | Windows + Walls + Roof | 602 EURO | Windows + Walls + Roof | 452 kg CO2 |

| **HT Heatpump** | Size (kW) hence cost depends on heating demand. Must also provide DHW. | |
|---|---|---|
| | Efficiency/COP heating (P2H) | 2,824 |
| | Efficiency/COP DHW | 3 |

*Red indicated values: K-value in these situations is greater than 40, so the installation of a HP is not advised. Therefore, no cost-estimations have been made

No need to replace radiators ? But would it make sense to do so ?
Grey-out cells that correspond to too low insulation leavels that rule out HP deployment.

| **HP related Investment cost.** (make abstraction of maintenance cost : assume a fixed number independent of size for this) (make abstraction of replacement cost) | **Size (kW)** (assume air-water ?) | **Cost (+air-water HP)** | **yearly heating cost** *(will also be calculated with ABEPeM, with and without active control of flex, and for various price structure scenarios)* | | **yearly heating emissions** *(will also be calculated with ABEPeM, with and without active control of flex, and for various dynamic carbon intensity profiles)* | |
|---|---|---|---|---|---|---|
| Windows | 32 | K-value greater than 40, installation heat pump not advised | Windows | 2.481 EURO | Windows | 1.861 kg CO2 |
| Walls | 33 | | Walls | 2.723 EURO | Walls | 2.043 kg CO2 |
| Roof | 27 | | Roof | 1.952 EURO | Roof | 1.464 kg CO2 |
| Windows + Walls | 29 | | Windows + Walls | 2.099 EURO | Windows + Walls | 1.575 kg CO2 |
| Windows + Roof | 20 | | Windows + Roof | 1.328 EURO | Windows + Roof | 996 kg CO2 |
| Walls + Roof | 23 | | Walls + Roof | 1.570 EURO | Walls + Roof | 1.178 kg CO2 |
| Windows + Walls + Roof | 13 | 60.035 EURO | Windows + Walls + Roof | 946 EURO | Windows + Walls + Roof | 710 kg CO2 |

**FIGURE 30: OVERVIEW SCENARIO RESIDENTIAL BUILDING**

## 5.2 SPORTING HALL

Looking at the case study of a big sporting hall (42m x 22m x 7m), the biggest gains in the K-level can be obtained by insulating the roof (K-value = 60,52 vs. 125,66 without measures).
To achieve the goal of a K-level smaller or equal to 40, several measures have to be combined. Possible combinations are:

- Insulation of walls and roof: K-level = 34,23
- Insulation of windows, walls and roof: K-level = 18,30
- By combining measures for windows and roof, a K-level smaller than 40 can almost be obtained (44,32). *Possibly*, this scenario could also be taken into consideration for the AmBIENCe-project.

By installing a new boiler, the yearly heating emissions can go down with 15%, compared to the old boiler. By installing a HT heat pump, they would go down with 78% and by installing a LT heat pump, they would lower with 86%. To provide enough domestic hot water, an extra power of 10 kW is needed on top of the power needed for heating. This is already included in the sizes shown in the figure below (Figure 31). Also, a well-insulated buffer vessel is needed, in order to assure the comfort levels during peak flow rates. Downtime losses are assumed to be marginal, but this is anticipated by choosing a conservative COP (3) for the production of domestic hot water.

| **New more efficient gas boiler** | Size (kW) hence cost depends on heating demand. Must also provide DHW. | |
|---|---|---|
| | efficiency (G2H) | 94,00% % |
| | 30,2 kW needed for DHW (in this scenario) | |

| **Gas boiler replacement Investment cost.** (make abstraction of maintenance cost : assume a fixed number independent of size for this) (make abstraction of replacement cost) | **Size (kW)** | **Cost (+new boiler)** | **yearly heating cost** *(will also be calculated with ABEPeM, with and without active control of flex, and for various price structure scenarios)* | | **yearly heating emissions** *(will also be calculated with ABEPeM, with and without active control of flex, and for various dynamic carbon intensity profiles)* | |
|---|---|---|---|---|---|---|
| **Windows** | 172 | 84.857 EURO | **Windows** | 9.125 EURO | **Windows** | 34.677 kg CO2 |
| **Walls** | 161 | 93.879 EURO | **Walls** | 8.619 EURO | **Walls** | 32.751 kg CO2 |
| **Roof** | 117 | 105.640 EURO | **Roof** | 6.635 EURO | **Roof** | 25.211 kg CO2 |
| **Windows + Walls** | 143 | 174.736 EURO | **Windows + Walls** | 7.817 EURO | **Windows + Walls** | 29.705 kg CO2 |
| **Windows + Roof** | 99 | 186.497 EURO | **Windows + Roof** | 5.833 EURO | **Windows + Roof** | 22.165 kg CO2 |
| **Walls + Roof** | 88 | 195.519 EURO | **Walls + Roof** | 5.326 EURO | **Walls + Roof** | 20.239 kg CO2 |
| **Windows + Walls + Roof** | 70 | 276.376 EURO | **Windows + Walls + Roof** | 4.525 EURO | **Windows + Walls + Roof** | 17.193 kg CO2 |

| **LT Heatpump (air-water)** | Size (kW) hence cost depends on heating demand. Must also provide DHW. | |
|---|---|---|
| | Efficiency/COP heating (P2H) | 4,436 |
| | Efficiency/COP DHW | 3 |
| *Red indicated values: K-value is slightly greater than 40. Possibly, this scenario could also be taken into consideration to place a heat pump. | Need to replace radiators ? Underfloor heating advised but in practise mostly not possible ? Grey-out cells that correspond to too low insulation leavels that rule out HP deployment. | |

| **HP related Investment cost.** (make abstraction of maintenance cost : assume a fixed number independent of size for this) (make abstraction of replacement cost) | **Size [kW]** | **Cost (+ air-water HP)** | **yearly heating cost** *(will also be calculated with ABEPeM, with and without active control of flex, and for various price structure scenarios)* | | **yearly heating emissions** *(will also be calculated with ABEPeM, with and without active control of flex, and for various dynamic carbon intensity profiles)* | |
|---|---|---|---|---|---|---|
| **Windows** | 172 | K-value greater than 40, installation heat pump not advised | **Windows** | 7.735 EURO | **Windows** | 5.801 kg CO2 |
| **Walls** | 161 | | **Walls** | 7.305 EURO | **Walls** | 5.479 kg CO2 |
| **Roof** | 117 | | **Roof** | 5.623 EURO | **Roof** | 4.218 kg CO2 |
| **Windows + Walls** | 143 | | **Windows + Walls** | 6.626 EURO | **Windows + Walls** | 4.969 kg CO2 |
| **Windows + Roof** | 99 | 236.353 EURO | **Windows + Roof** | 4.944 EURO | **Windows + Roof** | 3.708 kg CO2 |
| **Walls + Roof** | 88 | 239.391 EURO | **Walls + Roof** | 4.514 EURO | **Walls + Roof** | 3.386 kg CO2 |
| **Windows + Walls + Roof** | 70 | 310.456 EURO | **Windows + Walls + Roof** | 3.835 EURO | **Windows + Walls + Roof** | 2.876 kg CO2 |

| **HT Heatpump (air-water)** | Size (kW) hence cost depends on heating demand. Must also provide DHW. | |
|---|---|---|
| | Efficiency/COP heating (P2H) | 2,824 |
| | Efficiency/COP DHW | 3 |
| *Red indicated values: K-value is slightly greater than 40. Possibly, this scenario could also be taken into consideration to place a heat pump. | No need to replace radiators ? But would it make sense to do so ? Grey-out cells that correspond to too low insulation leavels that rule out HP deployment. | |

| **HP related Investment cost.** (make abstraction of maintenance cost : assume a fixed number independent of size for this) (make abstraction of replacement cost) | **Size [kW]** | **Cost (+air-water HP)** | **yearly heating cost** *(will also be calculated with ABEPeM, with and without active control of flex, and for various price structure scenarios)* | | **yearly heating emissions** *(will also be calculated with ABEPeM, with and without active control of flex, and for various dynamic carbon intensity profiles)* | |
|---|---|---|---|---|---|---|
| **Windows** | 172 | K-value greater than 40, installation heat pump not advised | **Windows** | 12.150 EURO | **Windows** | 9.113 kg CO2 |
| **Walls** | 161 | | **Walls** | 11.475 EURO | **Walls** | 8.606 kg CO2 |
| **Roof** | 117 | | **Roof** | 8.833 EURO | **Roof** | 6.625 kg CO2 |
| **Windows + Walls** | 143 | | **Windows + Walls** | 10.408 EURO | **Windows + Walls** | 7.806 kg CO2 |
| **Windows + Roof** | 99 | 236.353 EURO | **Windows + Roof** | 7.766 EURO | **Windows + Roof** | 5.825 kg CO2 |
| **Walls + Roof** | 88 | 239.391 EURO | **Walls + Roof** | 7.091 EURO | **Walls + Roof** | 5.319 kg CO2 |
| **Windows + Walls + Roof** | 70 | 310.456 EURO | **Windows + Walls + Roof** | 6.024 EURO | **Windows + Walls + Roof** | 4.518 kg CO2 |

**FIGURE 31: OVERVIEW SCENARIO SPORTING HALL**

# 6. CONCLUSION

Looking at the residential building, a K-level of less than 40 could only be achieved by taking insulation measures for the walls, the windows as well as the roof.

**TABLE 4 – RESIDENTIAL BUILDING**

| Measures | K-level | Heating system | Investment cost (+PV) | Payback time |
|---|---|---|---|---|
| Walls + roof + windows | 35,41 | Boiler (21kW)* | €64.352 | 19 year |
| Walls + roof + windows | 35,41 | Heat pump (13kW) | €70.975 | 18 year |

*Instead of 13 kW, the power of the installed boiler is 21 kW. This to make sure that the needed peak power for domestic hot water can be reached, even without a buffer vessel. Also, 21 kW is typically the smallest power we find in the market.

Looking at the sporting hall, more trade-offs are possible, as a K-value of less than 40 is reached in two situations (walls + roof & walls + roof + windows).

**TABLE 5 – SPORTING HALL**

| Measures | K-level | Heating system | Investment cost (+PV) | Payback time |
|---|---|---|---|---|
| Walls + roof | 34,23 | Boiler (88 kW) | €231.872 | 14 year |
| Walls + roof | 34,23 | Heat pump (88 kW) | €292.784 | 15 year |
| Walls + roof + windows | 18,30 | Boiler (70 kW) | €312.729 | 17 year |
| Walls + roof + windows | 18,30 | Heat pump (70 kW) | €357.920 | 18 year |

Generally, it is clear that the bigger the building, the better the compactness and therefore the better the K-value to start with. This opens up more opportunities for trade-offs between insulation and electrification.

If the current heating system in a building would already be built to heat at low temperatures (for example by oversized radiators or floor heating), more possibilities for trade-offs will be possible. Also, a lower supply temperature clears the path for more options. However, according to Hysopt, even with already existing emission elements and a better hydraulic balance, retrofits using LT would be possible, as long as the K-value is low enough.

For these case studies, the possibility for floor insulation is not taken into account. If this measure would be included, it would be an ideal moment to install floor-heating at the same time, in order to optimise the use of a heat pump. However, the costs of this measure are high and with these cases, it is proven that these costs are not necessarily needed to electrify a building.

Moreover, the boundaries for deep refurbishment have not been pushed. For example, only double glass was taken into account for insulating windows. One step further could be the use of triple glazing.

# ABBREVIATIONS AND ACCRONYMS

| | |
|---|---|
| ACO | Association of Co-Owners |
| ABEPeM | Active Building Energy Performance Modelling |
| AEPC | Active Building EPC |
| BEMS | Building Energy Management System |
| BMS | Building Management System |
| BRP | Balance Responsible Party |
| DR | Demand Response |
| DSO | Distribution System Operator |
| EE | Energy Efficiency |
| EEM | Energy Efficiency Measures |
| E&FCM | Economic and Financial Calculations Module |
| EPC | Energy Performance Contract |
| EMS | Energy Management System |
| ESCO | Energy Services Company |
| FI | Financial Institution |
| HP | Heat Pump |
| IPMVP | International performance measurement and verification protocol |
| IRR | Investment Return Rate |
| KPI | Key Performance Indicator |
| M&V | Measurement and Verification |
| NPV | Net Present Value |
| PV | Photovoltaic |
| SHC | Social Housing Company |
| TCO | Total Cost of Ownership |
| TSO | Transport System Operator |