D6.1

The ex-ante evaluation of financial benefits in the SENSEI P4P scheme

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Smart Energy Services to Improve the Energy Efficiency of the European Building Stock

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Abbreviations and Acronyms

Acronym	Description
BAU	Business As Usual (reference scenario)
BPC	Building Performance Contract
DER	Deep Energy Retrofit (project) or Distributed Energy Resource
DSO	Distribution System Operator
EE	Energy Efficiency
EEM	Energy Efficiency Measure
EES	Energy Efficiency Service
EPC	Energy Performance Contract
ESCO	Energy Service Company
ESG	Environment, Social, and Corporate Governance (metrics)
GHG	Greenhouse Gases
LCCBA	Life Cycle Cost Benefit Analysis
M&V	Measurement & Verification
NPV	Net Present Value
O&M	Operation and Maintenance
OEPC	O&M and Energy Performance Contracts
P4P	Pay-for-Performance (scheme/programme)
PMV	Predictive Mean Vote
PPD	Percentage of Dissatisfied
RES	Renewable energy sources
TCO	Total cost of ownership
TPI	Third Party Investor
TSO	Transmission System Operator
WP	Work package

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Executive summary

This report describes a methodology for **ex-ante estimation of the financial benefits** of implementing Energy Efficiency Measures (EEMs) in a P4P scheme. The ex-ante estimation of the multiple benefits is an important task for the aggregator when developing a P4P scheme. The outcome of the estimation is instrumental in attracting potential financiers of P4P schemes.

EEMs in buildings have for long been known to deliver more benefits than solely the primary energy cost savings. In the report a selection is provided of methods to quantify and monetize the multiple benefits of an energy retrofit project:

- energy cost savings,
- employee productivity increase due to increase comfort
- increased building value,
- optimized operation and maintenance costs,
- avoided costs for the power system.

The assessment methodology referred to in this report, is based on the **principle of internalizing the multiple benefits into the energy retrofit's business case.** The internalisation principle is elaborated in the Life Cycle Cost Benefit Analysis (LCCBA) (IEA, 2015), which is put forward as the recommended estimation method. In the report a calculated LCCBA-example of a deep energy retrofit of an office building is provided. It demonstrates how to integrate all monetary values of multiple project benefits into one business case, based on the concept of Net Present Value

With respect to the energy cost savings, the report also investigates the minimum data required by the energy efficiency aggregator to assess the benefits from an EEM plan, hence to assess to potential contribution to a P4P programme. The minimum building dataset consists in:

- envelope structure
- energy consumption systems
- renewable energy production systems
- energy performance (energy consumption and production)
- administrative identification data

Finally, the report makes a first attempt to investigate the contractual arrangements to allocate the benefits in a P4P scheme, with particular focus on the investor perspective. These contractual relationships will be further explored elsewhere in the project. An

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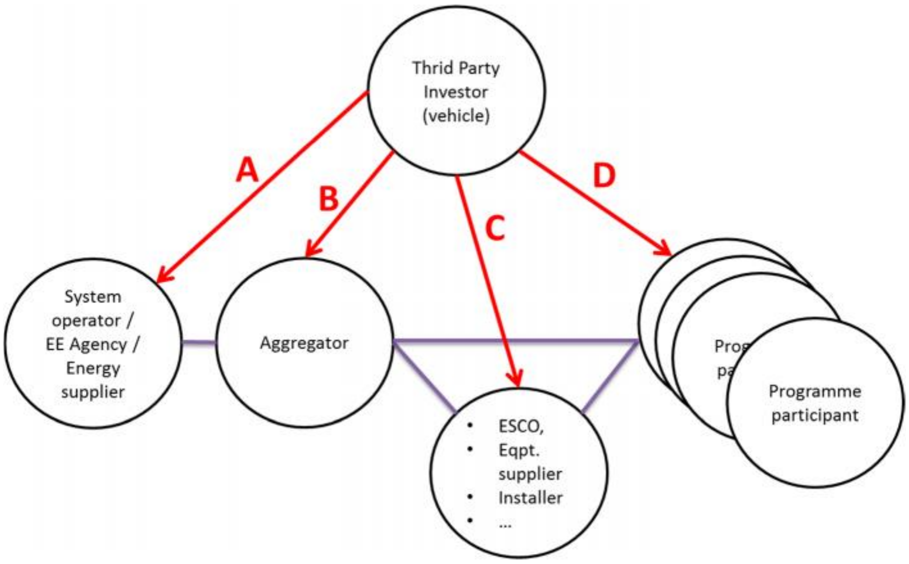
important finding at this stage, however, is the **better insight into the potential investor relationships**:

- option A. financing the P4P programme through the System Operator (energy efficiency as a resource financing)
- option B. financing the P4P programme through the Aggregator ("programme structured fund" financing)
- option C. financing the P4P programme per individual project through the ESCO ("EPC project +" financing)
- option D. financing the P4P programme through individual programme participants

The options are visualized in the graph underneath:



Each option can offer some degree of guarantee, making investment more or less attractive, depending on the guarantees that the different actors can offer in their respective contractual interfaces (purple lines). The option of choice will also determine which party carries risk commitment and how cash flows will take place. The preferred option (or combination of options) will further be selected in the second term of the SENSEI project after having consulted relevant external stakeholders from the energy efficiency financing community:

Throughout the report, a '**stacked' approach**[1] was followed, sometimes referred to as 'enhanced EPC approach'[2]. In such an approach it is assumed that the benefits (avoided costs) for the power system resulting from load reduction, load shifting, demand flexibility

[1] This approach is also adopted in P4P schemes in the US: https://www.recurve.com/

[2] http://ambience-project.eu/; http://novice-project.eu/;

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etc. , come *on top of* the energy efficiency benefits that have in the first place been identified as per the approach of EPC contracting.

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1 Multiple benefits of energy efficiency that can become an investable asset

1.1 Multiple benefits of energy efficiency

The traditional focus on energy savings as the main goal of energy efficiency policy has led to an underestimation of the full value of energy efficiency. Energy efficiency can bring multiple benefits, such as enhancing the sustainability of the energy system, supporting strategic objectives for economic and social development, promoting environmental goals and fostering the economy. Identifying and quantifying a broader range of impacts of energy efficiency, repositions energy efficiency as a mainstream tool for economic and social development, and has the potential to motivate higher uptake of energy efficiency opportunities in the market. (IEA 2014).

The concept of "Multiple Benefits of Energy Efficiency" is a methodology to capture and internalise these additional benefits, revenues and drivers. The challenge consists in developing an approach to monetise the multiple benefits of an energy retrofit project. This will contribute to making its business case more attractive, especially for Deep Energy Retrofit (DER) projects and programs. By identifying and quantifying a broader range of impacts of energy efficiency, the multiple benefits approach repositions energy efficiency as a mainstream tool for economic and social development, and has the potential to motivate higher uptake of energy efficiency opportunities in the market.

1.2 Stacking benefits (enhanced EPC)

It is important to stress that we assume in the SENSEI project a so-called "stacked" approach whereby P4P financial benefits come on top of the existing financial benefits of energy retrofit projects as already being executed today (e.g. Energy Performance Projects, EPC). The P4P payments will help improve the business case of these EPC projects.

Also, this enhanced approach will avoid that only low-hanging fruit EEMs would be implemented. This might happen when only focussing on the "Energy as a resource" P4P financing (cf. D4.4). In this report, we will explain in more detail the additional benefits, the linked financial flows and the allocation of these flows to the specific party (building owner, installer, aggregator, DSO, …).

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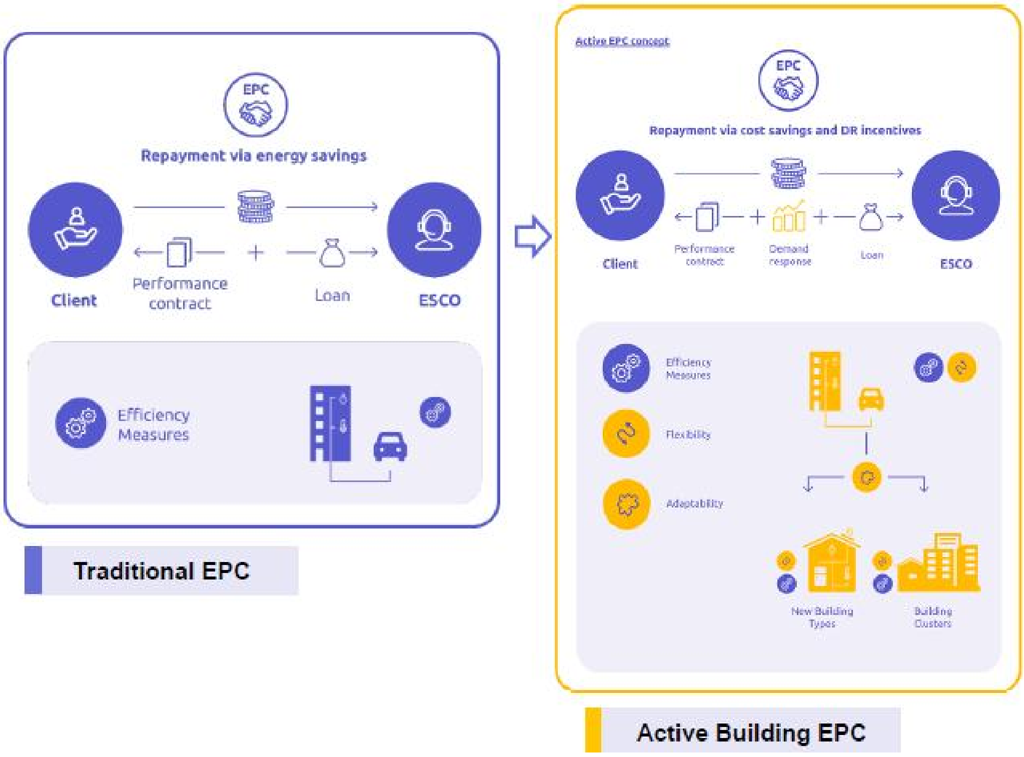
A quite similar approach is adopted by the AmBIENCe project (http://ambience-project.eu/) as is illustrated in Figure 1.

Figure 1 - AmBIENCe project: comparison traditional EPC and 'active building EPC'
(Source: AmBIENCE website)



We will therefore initially focus on the *existing* assessment methodologies used in the 'classic' energy efficiency services market model: e.g. investment grade audits, Life Cycle Cost Benefit Analysis (LCCBA) (Bleyl, J. et al.(2018)), etc. In particular the latter approach will be extensively used as methodological basis throughout this chapter.

The classic energy efficiency services approach uses modified-versus-baseline verification for all benefits that may become part of a contractual agreement. However, benefits such as comfort improvements (hence employee productivity) or building value upgrades will have to be verified based on other parameters than energy consumption. Including benefits other than merely the energy cost savings or measurable benefits, will offer "convincing arguments" to one or more actors to join in the P4P programme, rather than offering quantifiable financial benefits.

Further in this document we will explore how to integrate the various benefits into one single value, a figure that reflects the total value of the energy retrofit project.

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1.3 Inclusion of multiple benefits in energy retrofit projects

This section presents methods for including multiple benefits in energy retrofit projects that are being implemented these days. These projects typically are an implementation of EEMs in one or several buildings, within an agreed contractual framework between a building owner and an ESCO. The best known example is EPC (Energy Performance Contracting).

1.3.1 Energy Performance at project level

At the level of the single energy retrofit projects (as opposed to energy efficiency programs which represent a large portfolio of projects), the EPC contract involves an agreement between a building owner and an ESCO. The contract contains the obligation for the ESCO to deliver a certain level of energy performance against an agreed cost for implementing this energy performance. It is up to the ESCO to quantify ex-ante the energy performance it is capable to realize as well as the cost/investment to make this happen. This estimation subsequently becomes a binding KPI in the EPC.

The following benefits are already commonly included today in a contractual arrangements of energy efficiency services, or mentioned as additional financial incentives that may positively influence energy retrofit investment decisions:

- load reduction (energy cost savings)
- reduction of operational and maintenance costs (O&M)
- Increase of real estate value
- Increase of rent value
- comfort improvements resulting in increased employee productivity (in office buildings)
- GHG emission reductions

In recent years, performance based contractual frameworks with a scope enlarged to multiple benefits, have evolved out of the EPC concept. This is for example the case for the OEPC (O&M and Energy Performance Contracts) and BPC (Building Performance Contracts (Factor4, 2020), which include O&M, comfort level performance, and building value performance).

Figure 2 illustrates how the value of additional benefits results in several contractual financial flows between an ESCO and building owner. In this case, in addition to energy cost savings, the ESCO delivers comfort improvements and a higher residual value of the building. Because all aspects are governed by a contractually agreed performance, the building owner pays a fixed annuity covering investments and maintenance. A

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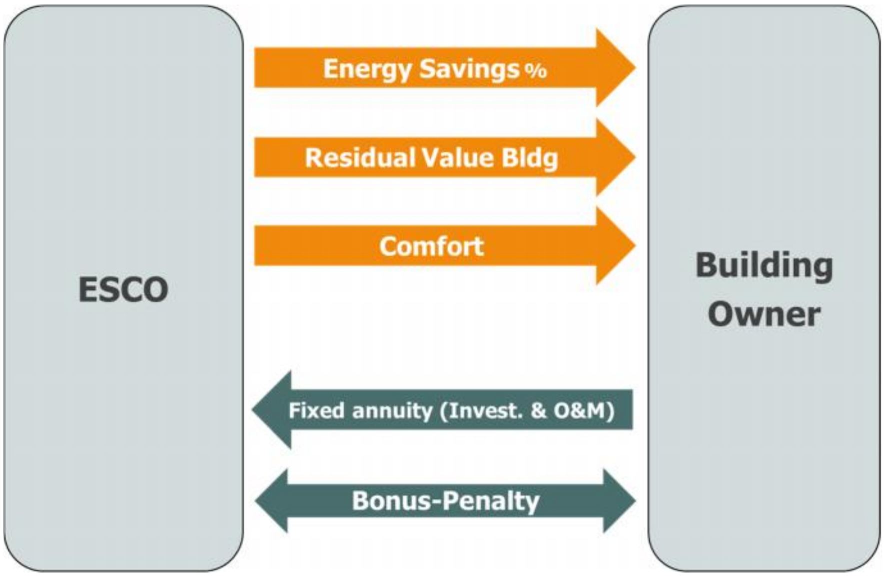
system of bonus and penalty is foreseen to correct deviations from the agreed performance.

Figure 2 - Building Performance Contract (BPC) (Source: Factor4)



Not only for individual projects, but also for analysis of policies and programs can the inclusion of additional benefits be used to encourage positive investment decisions in energy efficiency projects. It is key to include and exploit both unquantified and quantified non-financial benefits since they have a role in convincing regulators and system operators to develop incentive schemes for financial and/or economic support of P4P programs.

1.3.2 Life Cycle Cost Benefit Analysis (LCCBA)

The full theoretical basis for the multiple benefits EPC type contracts is described in a research paper entitled "*Office building deep energy retrofit: life cycle cost benefit analyses using cash flow analysis and multiple benefits on project level*" (Bleyl et al., 2018). The method put forward in that publication, combined with the multiple benefit *Building Performance Contracting* framework (BPC) (Factor4, 2020), serves as basis for the methodology proposed in this deliverable. In essence, the inclusion of other benefits from energy retrofit projects, on top of the energy cost savings, will improve the financial result of the energy retrofit project, and make it more attractive for project initiators and investors.

The primary challenge to include multiple benefits in the energy retrofit project's business case exists in *quantifying* the identified benefits. However, even when not fully quantifiable, additional benefits should be taken into consideration when evaluating ex-

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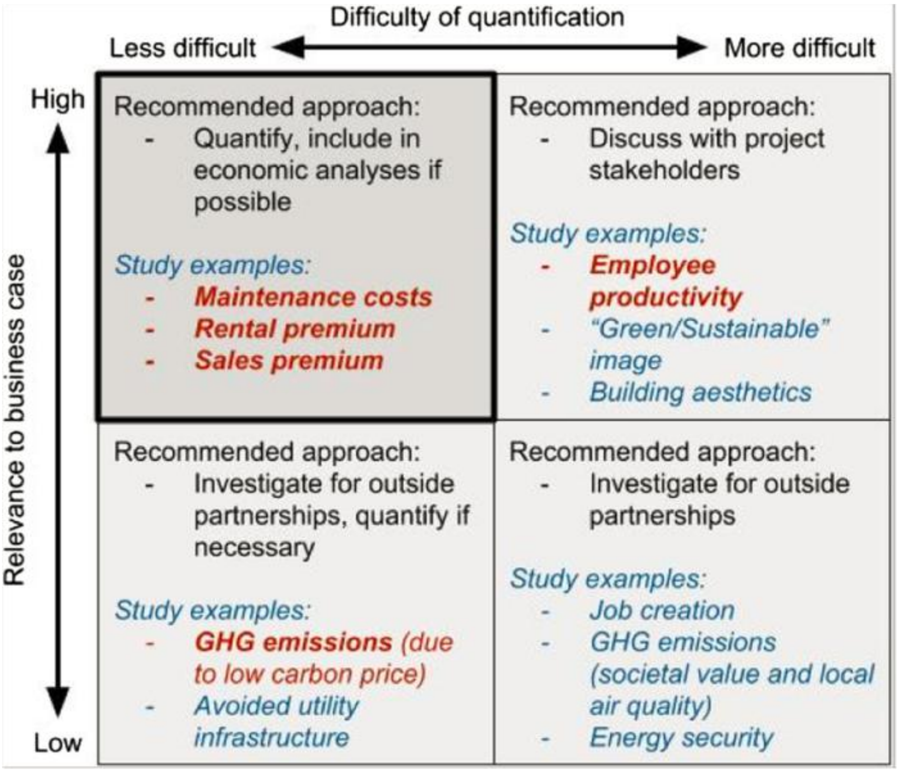
ante the project's financial viability, as these may positively impact the business case, hence influence the investment decision.

This is well illustrated in Figure 3 suggesting a method for deciding on the inclusion of benefits in a project.

Figure 3 - Multiple benefits: relevance for business case vs. difficulty of quantification (Source: Bleyl et al, 2018).



Bleyl *et al* use the following methodology to deal with multiple benefits:

1. List all potentially significant benefits for the energy retrofit project
2. Classify each benefit according to the primary beneficiary: Participant, Utility, or Society, as well as any important sub-classification. Estimate the difficulty in quantifying each benefit. Plot each benefit on a grid similar to the one in Figure 3
3. Select appropriate quantification methods and quantify chosen multiple benefits in either financial or non-financial terms
4. Incorporate significant financial results into the economic analysis
5. Consider unquantified and quantified non-financial benefits as additional arguments to support the project.

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A final key element in the model is that all involved project (or programme) parties agree on the methodology(y)(ies) to quantify the value of BAU and proposed performance levels of the benefits, as well as the costs.

1.3.3 **Calculated example**

Table 1 presents an estimation of the monetary values of multiple project benefits (MPB) of a deep energy retrofit (DER) of an office building, made via a dynamic Life Cycle Cost & Benefit Analysis (LCCBA). The table presents the upper and lower estimations of the annual benefits (EUR/m²/year) as well as the present value (PV) of these benefits, where the considered time span is 25 year.

The analysis is based on a case study that concerns a 1960s era office building with 1.680 m^2 of heated area, situated in southern Germany.

The building was renovated to the "Passive House^ standard in the years 2010–2011. The DER included ceiling, wall, and basement insulation, window and doors replacement (with cost-efficient Passive House components), improvements to airtightness, ventilation, and heating systems, and a lighting retrofit. The investment costs of the DER amounted to 0.56 million EUR or 330 EUR/m^2.

The energy costs before the renovation (baseline) were 45,000 EUR/year (36,500 EUR/year for gas and 8500 EUR for electricity). After DER, gas costs reduced by 88%; electricity cost savings were limited to a 17% reduction due to the additional ventilation systems. The energy and all other price increases are assumed to be on average 1.5%/year.

Financing of the investment is modelled with a mix of 75% debt capital (20-year term with an effective interest rate of 2.52%) and 25% equity with a yield expectation of 4.5%. No subsidies were accounted for to avoid distorting the results.

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Table 1 - Monetary values of multiple project benefits of DER (in [EUR/m2]—annually and present values of project cash flows

Multiple project benefits of DER	Range	Valuation	
		[EUR/(m² * y)]	PV: [EUR/m²]
1. Work productivity increase (0.57–1.14%)	Lower	10,4	219
	Upper	20,8	439
2a. Rental income increase (1–5.3%)	Lower	1,2	25
	Upper	6,4	134
2b. Building sales price increase (2.5–6.5%)	Lower		100
	Upper		260
3. CO_2 savings (6–79 EUR/t)	Lower	0,3	6
	Upper	3,8	79
4. Maintenance cost savings (2.1–3 EUR/m2/y)	Lower	2,1	44
	Upper	3,0	63
5a. Energy cost savings project term (25 years)	Lower	16,8	354
	Upper	16,8	354
5b. Add. energy cost savings over techn. lifetime (40 years)	Lower	16,8	157
	Upper	16,8	157

Source: BLEYL, J.; COOLEN, J. et al (2018)

Several studies for energy efficiency programs suggest that **work productivity** gains could be among the most significant benefits of building-related energy efficiency investments.

The active days gained by reduction of sick days and healthy life years is a first positive impact on work productivity. DER typically generates a better indoor ventilation – due to the installation of a more performant mechanical ventilation system - and the lower infiltration of unfiltered outdoor air – due to a higher airtightness of the building envelope. This contribute to less sick days and more healthy life years which increase the number of active days.

The increased productivity – i.e. the produced output of an employee – has an additional positive impact on work productivity. Comfortmeter is an online survey tool that objectifies the subjective comfort experience and self-reported productivity of building users. As explained in par. 1.4.2.2, the DER would generate a workforce performance increase of 10.4 to 20.8 €/m², which is included in the business case as a MPB quantification.

Several studies demonstrate that sustainable building features like energy efficiency, and its MPBs, have a positive impact on **rental incomes** and **building values**. The studies compare certified green buildings with non-certified buildings and find a positive correlation with rental rates and the transaction prices of commercial property (corrected for non-energy efficiency-related characteristics such as location, age, and size). According to these sources, investing in energy efficiency, and thus obtaining green or sustainable building certification, translates to higher rent ranging from below 4% up to

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21%. Numbers for higher market valuations (transaction or sales prices) range from below 10% to up to 30% (USA) or 26% (Europe).

Higher energy productivity leads to a reduction in final fuel and electricity demand, and thus **CO_2-savings**. The cost of one ton CO_2 in the European Emissions Trading System (EU ETS) was in 2017-2018 about 8 EUR/ton. Switzerland introduced a CO_2-tax and charges 84 Swiss Francs (approx. 79 EUR) per ton CO_2. This is a significantly higher value than the current EU ETS prices.

Applied to the DER case study, 318 MWh of natural gas and 6 MWh of electricity are saved, which results in GHG savings of about 80 ton/year of CO_2eq.

Valued at current EU ETS prices, this results in savings of about 400 EUR/year. Valued with the Swiss GHG levy on heating fuels, savings of about 6300 EUR/year result.

Building DER also encompasses retrofit of existing, and often aged, building technologies. Besides energy cost savings, this leads to a net reduction of **maintenance cost** and/or replacement investment for the building owner.

Table 2 allocates the benefits to different groups of beneficiaries. This underlines the necessity to differentiate between different beneficiaries also for MPB analysis. Occupant-owners have the highest total benefit values of the different types of building owners, but tenants also have substantial net benefits.

When comparing differential DER investments of 330 EUR/m² to the MPB values, the occupant-owner's benefits are greater than the cost by a factor of between 2.4 and 3.3; for tenants, values are between 1.7 and 2.2.

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Table 2 – Allocation of the monetary values of multiple project benefits of DER (in [EUR/m²]—annually and present values of project cash flows

		Beneficiaries				
		Valuation	*Different owner perspectives*			
Multiple project benefits of DER	Range	PV in [EUR/m²]	Property develop	Occupant-owner	Lessor-owner	Tenant
1. Work productivity increase	Lower	219	–	219	–	219
	Upper	439		439		439
2a. Rental income increase	Lower	25	–	–	25	−25
	Upper	134			134	−134
2b. Building sales price increase	Lower	100	100	[100]	[100]	–
	Upper	260	260	[260]	[260]	
3. CO2 savings	Lower	6	–	6	–	6
	Upper	79		79		79
4. Maintenance cost savings	Lower	44	–	44	44	–
	Upper	63		63	63	
5a. Energy cost savings project	Lower	354	–	354	–	354
	Upper	354		354		354
5b. Add. energy cost savings over techn. lifetime	Lower	157	–	157	–	[157]
	Upper	157		157		[157]
Totals	Lower		100	780	69	554
	Upper		260	1092	197	738

[a] Except for the "property developer," the values in 2b. for the building sales price are in parentheses and not co1nsidered in the totals, because they depend on the time of sale; similar logic for 5b "tenant" values

Source: BLEYL, J.; COOLEN, J. et al (2018)

1.4 Methods and tools for identifying and quantifying EEM benefits

The methodology for identifying and quantifying EEM benefits basically consists in calculating ex-ante the financial value of each benefit for the building owner by comparing the proposed scenario with the BAU scenario. Subsequently, all financial values have to be aggregated over the entire project cycle into one financial parameter. This is done by means of calculating the **Net Present Value (NPV)**. This figure reflects the value of the entire project for the building owner and is a more appropriate assessment parameter than payback time. In the subsequent paragraphs, we will apply this general methodology to those benefits which are considered relevant for the SENSEI project.

This chapter describes the quantification approach and methodology. The detailed quantification data requirements and calculations are developed in chapters 3.3 and 3.4 of the Annex.

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1.4.1 Energy cost savings (load reduction)

1.4.1.1 Methodology 1: benchmarking

Benchmarking data against which specific actual building consumption data can be compared, typically are dependent on the type of building, as well as on the source database (national, regional, multi-site real-estate organisation having its own data,…).

In most cases, only some key building parameters are needed (number of m² and pupils for schools, number of m² and beds for hospitals, etc) to enable the comparison of consumption to "a standard range", and get an indication of the building's energy performance.

The benchmark normally applies to a building's total annual consumption, not to daily 15' consumption profiles. Exceptions exist for very specific types of buildings like data centers or other buildings with very typical daily consumption profiles.

For many reasons one will often find buildings with good benchmarks but with still large untapped savings potential and vice versa. This may be explained by the fact that same types of buildings often host other types of side-usages (e.g. a restaurant in a school, shops in office buildings, etc.).

Many benchmarking databases exist, on regional, national and European level, as well as for specific activity sectors (retail, industrial,…). An example of a software tool for benchmarking, containing a world database of benchmark figures for specific types of buildings and industrial activities, is RETScreen[3], which is a software tool for energy efficiency project feasibility analysis as well as for energy performance monitoring in ongoing projects. It also allows for energy benchmarking of buildings with the minimum possible set of data, per building type.

Based on the energy benchmark of a certain group of building(s) (types), a first selection can be made. For the aggregator the benchmarking will probably be the main source of analysis material when developing a quantified P4P offer.

Not only can the aggregator decide on which building(s) (types) to target, the benchmarking step can provide a first ex-ante estimate of the energy cost savings per building or for the targeted group of building(s) (types).

[3] https://www.nrcan.gc.ca/maps-tools-publications/tools/data-analysis-software-modelling/RETScreen/7465

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1.4.1.2 Methodology 2: energy audit

The next step in the ex-ante calculation of energy cost savings, is to conduct a detailed performance analysis, called the audit. This requires a lot more data, it is the essence of the ESCO's preparatory work and it proceeds iteratively. Typical data collected at this point:

- Technical installation/machine power data inventory: lights, heat pumps, boiler rooms, air-conditioning, swimming pool etc…
- Technical installation/machine consumption profile measurements (selective)
- Hours of operation: heating, cooling, ventilation, lighting, opening hours, visiting groups and numbers outside normal hours etc.
- Conditions of operation (temperatures, pressure levels, Lux intensity, fresh air ratios

Please refer to chapters 3.3 and 3.4 in the Annex for the detailed quantification data requirements and calculations.

The audit step can vary from simple and very approximate to complex and more accurate in its prediction. An example of the latter is the "Investment Grade Audit" which ESCOs and third party investors will use in a contractual energy performance setting. An example of the former, the simplified method is the "Virtual energy analyzer" of RETScreen, based on archetypical buildings and standard sets of EEMs commonly seen in specific types of buildings.

The amount of streams of different data available will improve precision of the estimation, which is visualized in Figure 4.

Figure 4 - Relation between data availability and precision of financial estimate

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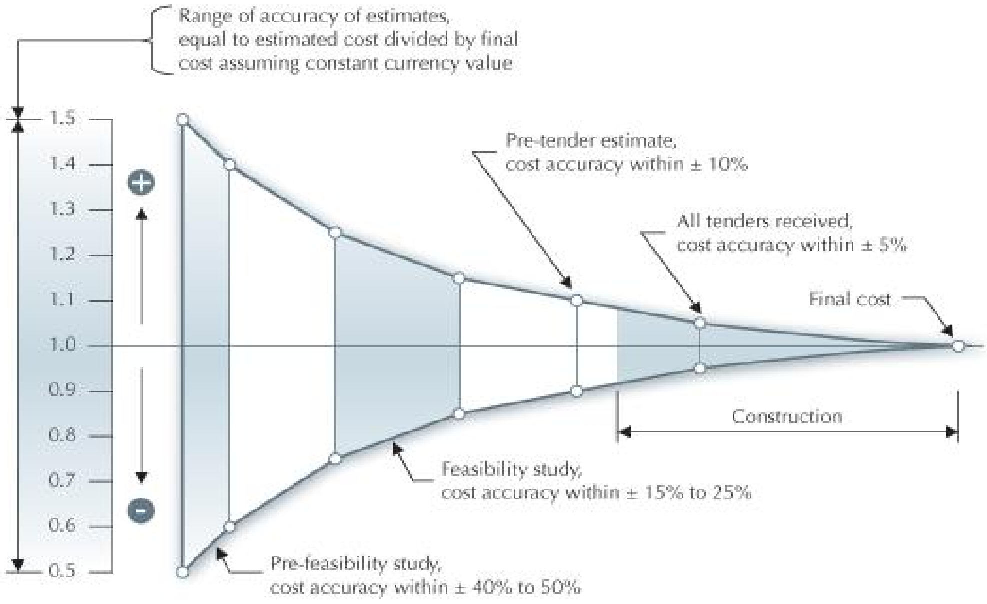

1.4.1.3 **Example: RETScreen**

In the RETScreen software tool is a dedicated module 'Expert' that allows energy professionals and decision-makers to identify, assess and optimize the technical and financial viability of potential clean energy projects. Its decision intelligence software platform also allows managers to measure and verify the actual performance of facilities, helps identify additional energy savings/production opportunities, and allows for the management of multi-facility portfolios. The software is available in 36 languages and can significantly reduce the financial and time costs associated with identifying and assessing potential renewable energy and energy efficiency projects.

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Figure 5 - Screenshot of RETScreen 'Expert' module

RETScreen Expert models a full range of both traditional and non-traditional sources of clean energy as well as conventional energy sources and technologies, including energy efficiency (from large industrial facilities to individual houses), heating and cooling (e.g., biomass, heat pumps, and solar air/water heating), power (including renewables like solar, wind, wave, hydro, geothermal, etc. but also conventional technologies such as gas/steam turbines and reciprocating engines), and combined heat and power (or cogeneration). Integrated into the analytical worksheets are product, project, benchmark, hydrology and climate databases, as well as links to worldwide energy resource maps.

RETScreen Expert Decision Engine

Virtual Energy Analyzer feature allows for the rapid and accurate estimation of the energy production and savings potential for any location in the world employing a five-star benchmark ranking system and without requiring a site visit. A Smart Project Identifier accurately identifies the best projects to be implemented at the facility and intelligently completes a pre-feasibility analysis or energy audit for further refinements onsite. A Financial Risk Assessor automatically assesses the financial risk of the proposed investment and systematically determines the sensitivity of key parameters on a project's viability. A Performance Tracker comprehensively measures and verifies the actual performance of implemented projects and helps find opportunities for further energy improvements at the facility.

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Project Life-Cycle Analysis

RETScreen Expert has analysis capabilities covering an entire project life cycle.

Benchmark Analysis allows the user to establish reference climate conditions at a facility site for any location on earth and compare the energy performance of various types of reference (benchmark) facilities with the estimated (modeled) or measured (actual) annual energy consumption of a facility. Energy benchmarking allows designers, facility operators, managers and senior decision-makers to quickly gauge a facility's energy performance, i.e., expected energy consumption or production versus reference facilities, as well as scope for improvements.

Feasibility Analysis permits decision-makers to conduct a five step standard analysis, including energy analysis, cost analysis, emission analysis, financial analysis, and sensitivity/risk analysis. Fully integrated into this five-step analysis are benchmark, product, project, hydrology and climate databases, as well as links to worldwide energy resource maps. Also built in is an extensive database of generic clean energy project templates as well as specific case studies.

Performance Analysis allows a user to monitor, analyse, and report key energy performance data to facility operators, managers and senior decision-makers, including a facility's actual energy performance versus predicted performance. The Performance Analysis module integrates near real-time satellite-derived weather data from NASA for the entire surface of the planet.

Portfolio Analysis allows a user to manage energy across a large number of facilities, spanning multiple energy efficiency measures in a single residential property to a portfolio comprising thousands of buildings, factories and power plants in multiple locations. Within the software, a user can create a new portfolio or open an existing file. The "My portfolio" database file is made up of individual facilities analysed with RETScreen. Additional facilities can easily be added to the portfolio database. Sub-portfolios can be created to allow for comparison across different facility types and geographic regions, and a mapping tool helps the user visualize assets across the globe. With a populated database, the user can enable a portfolio-wide analysis dashboard. The dashboard can be configured to include the results of benchmark, feasibility and performance analysis for each individual facility in the portfolio. The dashboard allows the user to consolidate results to readily track energy consumption and/or production, as

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well as costs and greenhouse gas emissions, all of which can be sorted by facility type, fuel type, country, etc. These results can then be used to report key metrics to various stakeholders.

Virtual Energy Analyzer

The user can start a new project using the Virtual energy analyser. By selecting the facility information and location, the software can rapidly determine the energy production and savings potential for any location in the world employing a five-star benchmark ranking system, and without requiring an actual site visit.

The Virtual Energy Analyzer's comprehensive database of Facility Archetypes allows a user to quickly and inexpensively start a pre-feasibility study or energy audit for a facility. Archetypes are available for a full complement of facility types, including power generation, industrial, commercial/institutional, residential and agricultural. Individual measures can also be selected.

The Virtual Energy Analyzer's five-star benchmark rating system provides a snapshot of the amount of detail in any given archetype. A five-star archetype provides a significant amount of information (including estimated incremental costing of the proposed project) and can be used as an initial draft of a pre-feasibility study or energy audit. An archetype that is rated less than five-stars will still contain a large amount of valuable information, but will benefit from additional user inputs to help refine the analyses built into the archetype.

For example, loading the five-star "Large Office" archetype (Facility type: Commercial/Institutional; Type: Office Building; Description: Office - Large) will rapidly model the energy profile, costs, emissions, financial returns, and risk of an archetypical large office building in the chosen location, automatically adjusting calculations for geographic location. This archetype may in and of itself be sufficient to provide a basic idea of the value of retrofitting a large office building (compared to, say, expending capital on another potential project). But the user can also modify the archetype, depending on the needs of the proposed project and the information that is available at the preliminary stage. For example, the target facility may be considerably larger than the default size modelled in the archetype. Or the user may prefer to work in square feet and Btu, change the fuel input costs, add financial incentives, or set ambitious targets for energy efficiency. The user can simply adjust the relevant values in the archetype and all other values automatically recalculate.

Existing archetypes are updated as necessary (particularly the integrated cost data) and new archetypes are continuously under development.

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1.4.1.4 Final EEM Plan

To come to an investment plan, the final step will be to select those EEMs that will be implemented. This is not a financial-technical decision only. Each of the different actors in the contractual model will have specific requirements for the final selection. The building (pool) owner or user might take real-estate considerations into account like re-arrangement of building functionality, architectural aspects, esthetical aspects, etc.

As experienced in large retrofit programs undertaken in the past, energy efficiency, financial return and environmental (compliance) aspects are definitely not the main considerations taken into account by the different stakeholders when deciding on EEM implementation. This point will have to be addressed when defining the specific contractual arrangements and adherence process for P4P programmes.

1.4.2 Comfort satisfaction and productivity

1.4.2.1 Methodology

There is ample evidence that health, well-being and productivity of building users is to a large extent impacted by the indoor comfort they experience in the buildings they work and live in. Therefore comfort (or indoor environmental quality (IEQ) as it is sometimes referred to), has become an important parameter in investment decisions for upgrades of buildings, in particular office buildings. Indoor comfort is quantified in two complementary ways:

- by measuring a selection of physical parameters that are considered key in contributing to a good or bad indoor comfort, e.g. temperature, quality of air, light and acoustics
- by conducting surveys ('post-occupancy surveys') that poll the comfort satisfaction of the building users

1.4.2.2 Example: Comfortmeter survey

Comfortmeter[4] is an example of survey tool that objectifies the subjective comfort experience of building users. The online survey polls building users on 6 aspects of comfort (thermal comfort, air quality, acoustics, lighting, individual control, and office environment & cleanliness), on the work performance impact (productivity increase) of

[4] http://www.comfortmeter.eu

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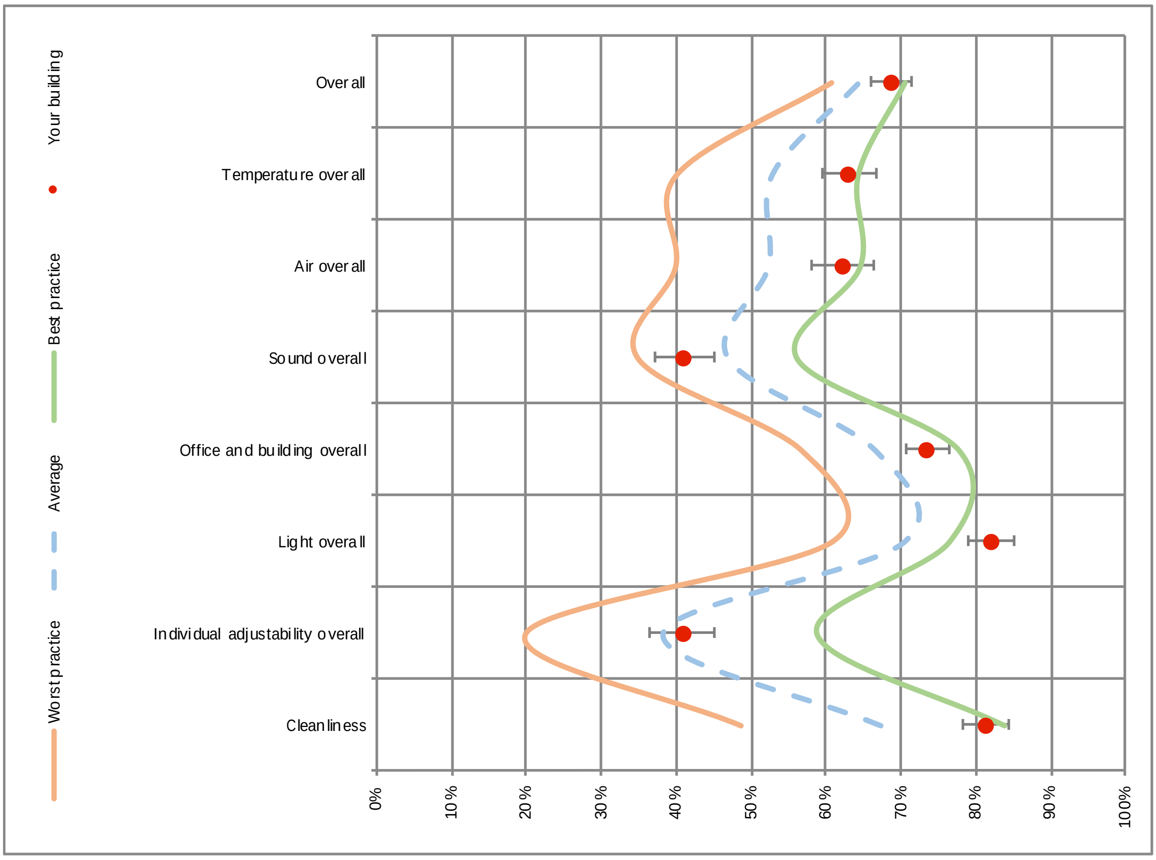
their working environment and on personal characteristics (age, gender, stress level, job satisfaction, …).

Figure 6 - Graph that visualizes the outcome of a post-occupancy survey (demo report)



It calculates comfort scores of the building which are benchmarked against similar buildings in the Comfortmeter database, and it proposes measures to improve the scores and ranks them according to their expected impact on productivity. In case of a successful energy retrofit project of a low performing building, the overall comfort score of the building is expected to increase between 2 and 4% (COOLEN et al. 2013) . This increase of overall comfort score will be generated mainly by the improved thermal comfort, indoor air quality, lighting, and acoustics in the building. The econometric model of the Comfortmeter shows that a 1% increase in overall comfort score results in an average 0.19% work performance increase. Thus, the energy retrofit project would

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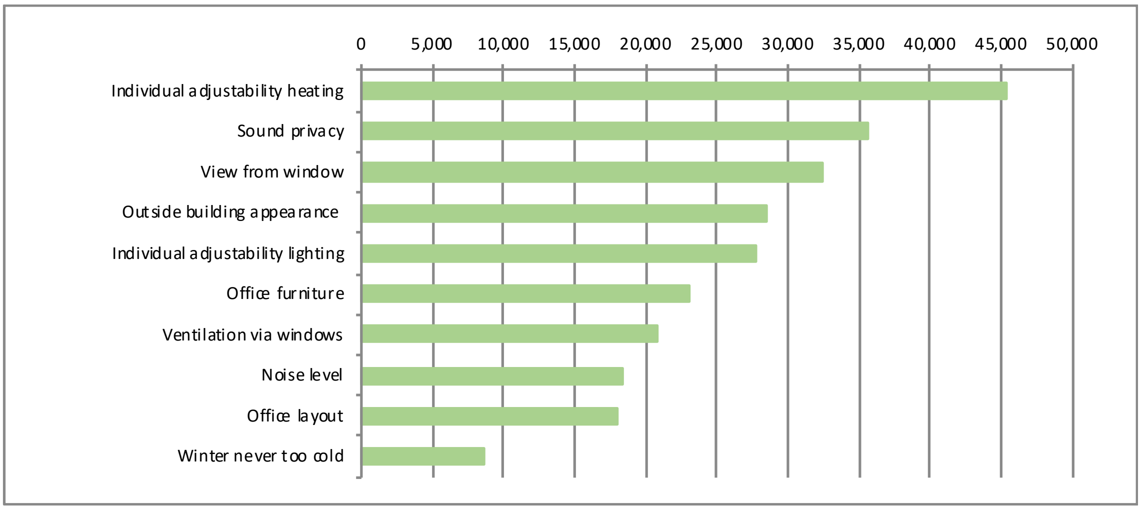
generate a work performance increase between 0.38 and 0.76%[5]. For the benefit assessment, the work performance of an average West-European employee of 75 000 €/employee (i.e., salary cost, non-salary cost, and profit margin) and an average overall office space of 27.5 m^2 per employee is considered. Thus, the energy retrofit project would generate a workforce performance increase of 10.4 to 20.8 €/m^2 [6].

Figure 7 - Productivity improvement potential after investing in comfort enhancing measures (€/year) (demo report)



Similar results are also confirmed by a literature survey (BOERSTRA, A ET AL. (2015)) that was conducted in the Netherlands. The survey gives an overview of empirical evidence of the correlation between productivity and the four elements of indoor climate— thermal comfort (temperature), air quality, acoustics, and light.

1.4.3 Building value

1.4.3.1 General

One of the often-neglected benefits when calculating the financial value of an energy retrofit project, is that the replacement of older technical installations and infrastructure (the "building elements") by newer ones with the goal to improve the energy efficiency, also results in higher residual value of the building at the end of an energy efficiency project.

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[5] (2 to 4)×0.19%

[6] (0.38 to 0.76%) × 75,000 / 27.5

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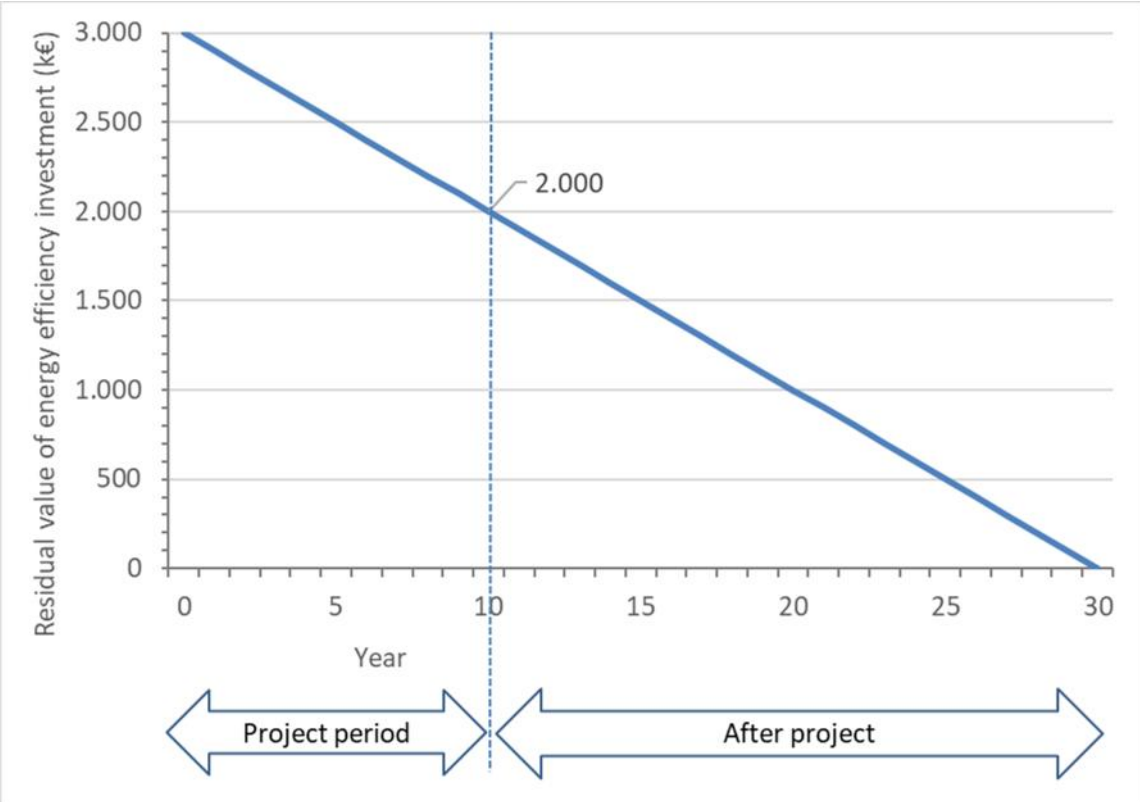
This is illustrated in (in a simplified way) in **Error! Reference source not found.** for an EPC-project with a project duration of 10 years. During an EPC-project, the ESCO will typically guarantee a certain amount of energy saving (e.g. 35% energy saving) and pay a penalty in case of underperformance and receive a bonus in case of over performance. Factor4 developed an EPC-contract where the ESCO not only has to guarantee the amount of energy saving, but also the residual value of the energy efficiency investment at the end of the project. This residual value is measured at the end of the project. Similarly, as with the guaranteed energy saving, the ESCO will pay a penalty if the measured residual value at the end of the project is lower than the guaranteed and receive a bonus in the opposite case.

Figure 8 - Evolution of residual value of energy efficiency investment during and after an EPC project



The methodology for measuring the residual value is discussed in the following paragraph.

1.4.3.2 Methodology of measuring the residual value

The determination of the residual value of an energy efficiency investment is based on the condition score and the new value of the elements composing the investment. A

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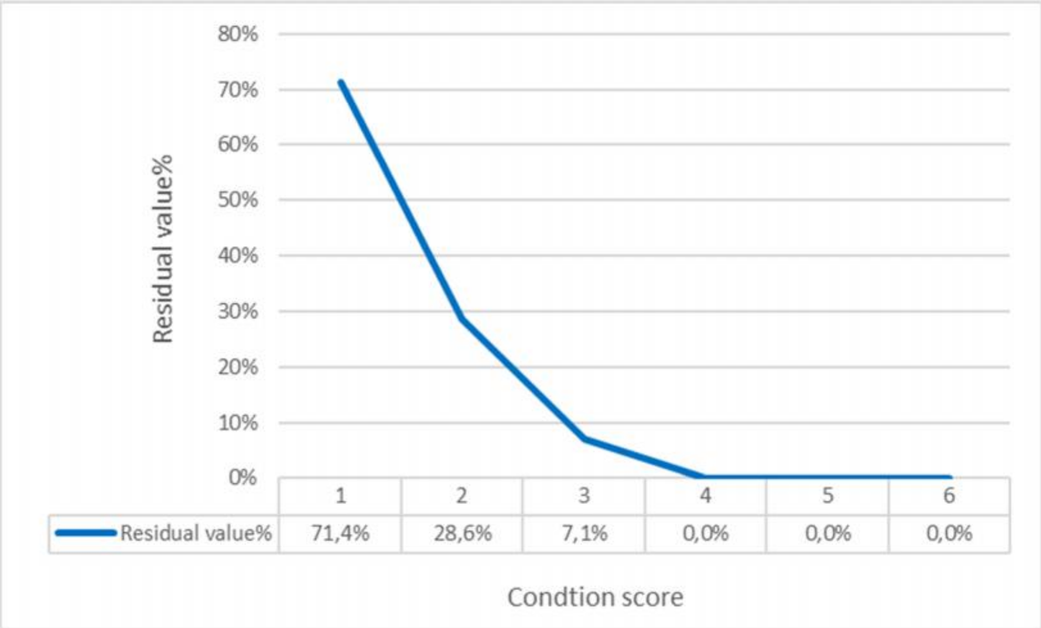
building element can be a heat boiler, a PV-system, a group of windows, roof insulation, etc.

The **condition score** is assessed using the NEN 2767 standard, that provides an unambiguous methodology to assess the condition of all types of building elements. The standard attributes a figure from 1 to 6 to each building element, whereby 1 is best (a new building element) and 6 worst (a building element is not functioning anymore). Based on this condition score and using its relation with the residual value% (see Figure 9), the **residual value%** of each element can be calculated.

Figure 9 - Residual value % as a function of the NEN2767 condition score



Furthermore, the **new value** of each element is determined. The new value is the all-in cost (material, labour costs,…) for the placement of the element taken into account the market prices.

By multiplying the residual value% of an element with its new value, the residual value of the element is obtained. The residual value ('building value') of the energy efficiency investment at the end of the project equals the sum of the residual value of all elements that are part of this investment.

Of course, this is a theoretical valuation of the value generated by the investment. The actual real estate (residual) value for the building will depend on many other factors too. Nevertheless, this method provides a quantified basis for contractual arrangements ex-ante.

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1.4.3.3 Advantages

The advantages of valuing the residual value of energy efficiency investment in general ,and integrating the residual value in an EPC-contract more specifically, are amongst other:

- the investment in elements with a high lifespan (e.g., insulation) - that thus keeps a high residual value% at the end of an EPC-project and thus can continue contributing to further energy saving even after the project – is rewarded more than the investment in elements with a shorter life span (e.g., HVAC equipment). The EPC-project will thus reward ESCO's that propose an investment plan considering a long-term perspective and thus in general lead to more rationale and cost-efficient investments.
- by improving the maintenance of the building, the condition score of the elements will be lower – and thus better – and consequently the residual value% will increase. The ESCO thus is motivated to performer proper (preventive) maintenance and more over invest in high quality equipment and materials that still have a high residual value at the end of the EPC-project.

1.4.4 Operation and Maintenance (O&M) savings

1.4.4.1 Methodology

Building energy retrofitting also encompasses retrofitting existing, and often aged, building technologies. Besides energy cost savings, this leads to a net reduction of maintenance cost and/or replacement investment for the building owner, which can be factored into the business case. This approach is applied in energy saving contracts with energy service companies (ESCOs). In the case of performance-based outsourcing of maintenance in the energy retrofit project (in compliance with the NEN 2767 standard), the contractor is nudged towards choosing installations with lower maintenance costs and optimize the maintenance process. This positive cost saving effect could be partially offset, however, due to increased maintenance costs that result from a more complex and maintenance-intensive building, generated by the retrofit project.

1.4.4.2 Example: NEN 2767 standard

In an energy retrofit project case study, two effects on maintenance costs were observed: (1) a cost reduction of 2.1 €/m^2 for the existing systems and (2) additional maintenance cost of 0.9 €/m^2 due to the added ventilation systems. In a Belgian office building case study, maintenance cost savings were found to be 3 €/m^2 (Coolen et al. 2012). These numbers are based on the assumption that in the reference scenario, the maintenance

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in the building is conducted in a standard approach and that the corresponding maintenance costs are made.

An interesting metric to measure maintenance levels of technical systems was identified in the Netherlands. The Dutch maintenance standard NEN 2767 advises on a uniform way to inspect and assess the construction and installation of technical infrastructures and to assess their technical condition by assigning so-called "condition scores" (cf. chapter 1.4.3). This allows quantification of maintenance levels in an objective way and can be applied as a metric.

1.4.5 Avoided costs for the power system due to load reduction/shifting

1.4.5.1 Methodology

Energy efficiency and demand side management

Energy efficiency is about *permanently* reducing power consumption (**load reduction**). This is major difference compared to demand response, where power consumption is reduced in response to a signal from the utility (explicit DR) or in response to a price signal (implicit DR).

This said, if part of these permanent power consumption reductions are realized at peak consumption times (e.g. by means of technologies that enable pre-cooling or pre-heating based on thermal buffering or inertia), their value for the power system is likely to increase, as **flattening the demand curve** can directly contribute to improved system and grid reliability (**load shifting**).

Both load reduction and load shifting will bring benefits to the power system (grid operator, balancing responsible party, energy provider, etc). The benefits are threefold:

- avoided capacity increase investments (cf. power production)
- avoided grid extension investments (cf. power distribution), which is sometimes referred to as the "non-wire alternatives"
- avoiding costs of decarbonising the power system

It is one of the main goals of SENSEI to internalize and capture these benefits in the financial (and contractual) flows around energy retrofit projects in the project's (and programme's) business case. Hence, energy retrofits in buildings may become part of a larger set of '**behind-the-meter-solutions'** which contribute to demand side management. This demand flexibility has a financial value which may be exploited through market-based mechanisms, in which aggregators are likely to play an important role by bundling individual contributions to reduce and/or shift load, and as such enabling a sizeable and reliable proposal to the power system operators (e.g. concept of the Virtual Power Plant).

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Referring to what was said in the executive summary about "Stacking benefits", and in several other deliverables[7] of the SENSEI project about the stacked approach, this may represent an additional stream of revenues for the energy retrofit project, based on metered performance. The challenge will exist in capturing these revenue streams by smart agreements among stakeholders.

Case study: value of energy efficiency for the US power system.

In 2013, a paper entitled *Recognizing the Full Value of Energy Efficiency* was published by Lazar and Colburn (RAP). It comprehensively identifies, characterizes, and provides guidance regarding the consideration and valuation of the benefits provided by energy efficiency investments that save electricity. They distinguished 3 categories of benefits:

- benefits to the power system
- benefits to the implementers of the EEMs (e.g. building owners/users)
- benefits to society

A metaphor of a 'layered cake' was put forward to visualize the stacked nature of these benefits (Figure 10).

[7] Please also refer to D4.3 "The Boundary Cases for the P4P rates" chapter 4 "Estimating the P4P rates".

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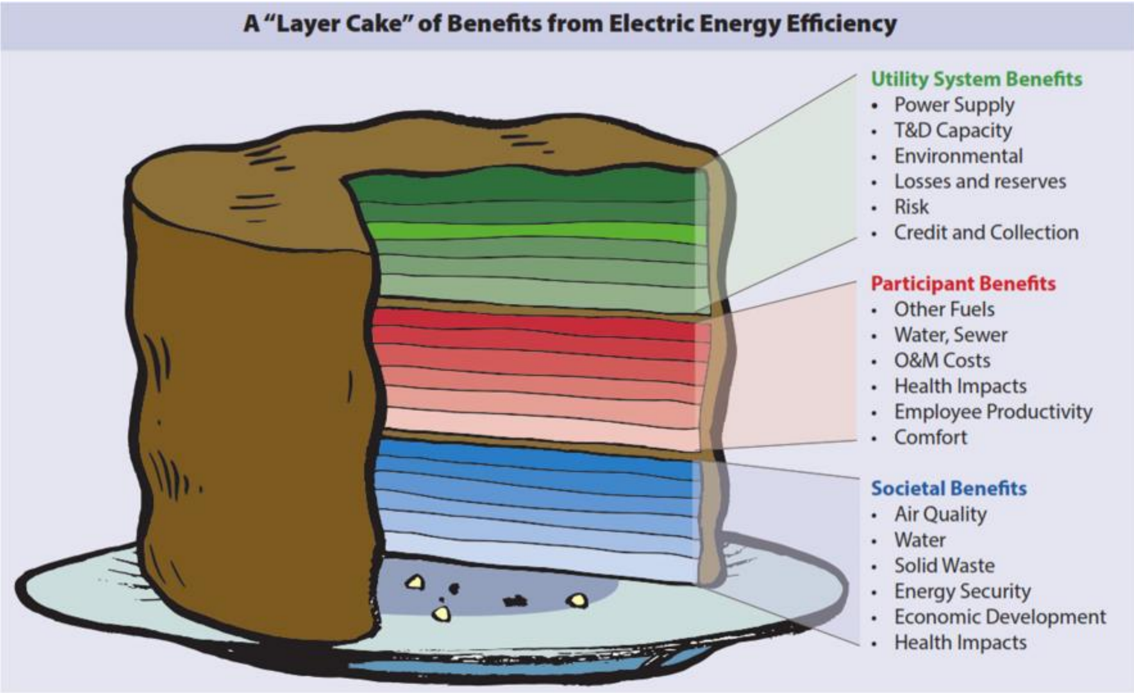
Figure 10 - A "layer cake" of benefits from electric energy efficiency (Source: RAP)



In an elaborately quantified example from Efficiency Vermont (2010), the following benefits were identified and calculated:

- Avoided production energy costs
- Avoided production capacity costs
- Avoided transport and distribution costs
- Avoided line losses
- Avoided reserves
- O&M savings
- Other resource benefits

Adding together all of the financial values for energy efficiency benefits that Vermont calculated and/or assumed for the benefits, results in a total value of $149.74/MWh – nearly 15 cents per kWh. By comparison, the overall cost for efficiency measures delivered in Vermont in 2010 (i.e., program costs plus net participant costs plus incentives plus third party costs) was 4.0 cents/kWh. These figures clearly prove the cost-effectiveness of implementing certain types of energy efficiency programmes. So, apart from providing a well-structured method for identifying and monetizing various benefits, they concluded that the non-energy benefits of efficiency measures can be quite large, often equal to or greater than the energy benefits themselves.

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1.4.5.2 Example: CalTRACK

CalTRACK[8] is an open source set of specifications which were developed in California to describe methods for the **calculation of avoided energy use after implementation of EEMs** such as energy efficiency retrofits or consumer behaviour modifications. CalTRACK methods follow the same principles as energy efficiency measurement and verification (M&V) methods described in ASHRAE Guideline 14 and IPMVP Option C.

CalTRACK methods yield whole building, site-level savings outputs. Portfolio-level savings confidence is measured by aggregating the performance of a number of individual sites and calculating portfolio fractional savings uncertainty.

The primary CalTRACK use case is energy efficiency procurement (such as Pay-for-Performance and Non-Wires Alternatives). As such, key considerations are replicability and availability of data. The methods described in the specification require only commonly-available site-level meter and weather data.

The tool openEEmeter[9], for example, is based on CalTRACK.

The SENSEI project, has also developed in 2021 an automated approach to M&V with the tool eensight[10].

1.5 Methodology to be used by the aggregator to calculate the benefits

How could an aggregator envisaging to set up a P4P scheme based on energy retrofits in buildings, now implement the methods and corresponding tools that were explained in the previous chapter? The process boils down to the following steps:

- Step 1 - Determine the **scope of a P4P scheme**, by choosing appropriate compensation schemes, and searching for matching types of EEMs and buildings accordingly. The potential scope is described in the forthcoming *Deliverable 5.2.*

8 http://docs.caltrack.org/en/latest/methods.html

9 https://www.recurve.com/open-source

10 The tool is described in the report: *Sotiris Papadelis. (2021). Methods for the dynamic measurement and verification of energy savings.* ; and can be found on GitHub at https://github.com/hebes-io/eensight

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Guidelines for the design of P4P schemes, part 1: 'Boundary conditions for a conceptual P4P scheme'.

If compensation schemes do not yet exist on the energy (efficiency) market, an aggregator may consider designing a P4P scheme and advocate it to the authorities that oversee the power system. Of course, this is a process that is likely to take more time and effort, as it will imply changes to the procurement legislation.

- Step 2 - **List all potentially significant benefits** for the energy retrofit projects included in the programme scope
- Step 3 - **Allocate each benefit to a primary beneficiary**: Participant, Utility, or Society, as well as any important sub-classifications. Estimate the difficulty in quantifying each benefit. Plot each benefit on the grid in Figure 3.
- Step 4 - Select **quantification methods** and quantify chosen EEMs in either financial or non-financial terms (see chapters 3.3. and 3.4 in the Annex)
- Step 5 - Incorporate significant financial results into **economic analysis** (calculation of Net Present Value)
- Step 6 - Consider **non-financial EEMs (both unquantified and quantified) as additional arguments** to support the project and potential regulator or system operator incentive schemes for the P4P scheme.

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2 Contractual arrangements to allocate the benefits in a P4P scheme

2.1 Existing arrangements in performance contracting

Over the years, the energy efficiency services (EES) sector has developed many types of contractual arrangements between companies (ESCOs) delivering these EES and their customers, the building owners. This has led to the development of performance contracts of which many variants exist, to name just a few:

- Energy Performance Contracts
- Energy Supply Contracts
- Integrated Energy Contracting
- Shared savings contracts
- Shared profit contracts
- No Cure No Pay contracts

A Building Performance Contract (BPC) is yet another variant including other benefits on top of the energy cost saving benefit, such as optimisation of maintenance and indoor comfort.

All contracts try to achieve a **balanced allocation of risks and benefits**.

Typical **risks** comprise:

- Technical performance risk, which is managed/borne by the ESCO,
- Financial risk (creditworthiness), which is managed/borne by the Third Party Investor (if any)
- Business performance risk, which is managed/borne by the building owner, e.g. change in use of a building, change of production volume in a manufacturing company

A well designed measurement and verification (M&V) plan is key to measure performance and filter out the different risk components in case of under- or over-performance. An M&V-plan has to be designed in such a way that root-cause parameters can be identified for deviating project performance.

An additional risk management aspect is the pooling of (large) numbers of buildings, since the under- and over-performing projects will compensate for each other, which will stabilize the performance of the pool of projects to the expected level.

Finally performance risks are also managed through the quality of the performance analysis ex-ante (the energy audit). This happens through quality standards for the audit

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("Investment Grade Audit") and through variance and risk analysis on the calculation results ex-ante (Monte-Carlo Analysis, see also EBAR-"Energy budgets at Risk"[11]).

The sharing of **benefits** follows the allocation of risks to the different parties involved in a performance contractual arrangement. The better the risk management and verification protocol and allocation to the different parties, the easier it will be for third party investors to be convinced. The financing parties will also pool many (pools of) projects into thematic funds, obligations etc.

All the above is applicable to the sharing of risks/benefits that are quantifiable in financial terms. The benefits that cannot be guaranteed in financial terms (e.g. increased comfort/increased productivity), could be used as argument to convince parties to proceed with the project(s).

2.2 Potential additional risk management and benefit sharing arrangements at P4P scheme level

2.2.1 P4P benefits layered on top of existing benefits

As already indicated, in the chosen approach to rolling out a P4P scheme, additional power system related benefits are stacked on top of the existing energy efficiency benefits, which were identified in buildings by ESCOs. This means that an additional income stream can be internalized in the project's business case. The potential additional P4P benefits that may be internalised in such a way are linked to benefits for the power system, in terms of:

- grid extension avoidance ("non-wire" alternatives)
- capacity extension avoidance
- GHG emission avoidance (decarbonization of energy production)

These parameters are quantifiable at the utility meter and may be monitored by any stakeholder in the P4P scheme, e.g. the system operator, the aggregator, etc. Moreover for schemes/programmes with a large enough number of sites, these benefits have a good statistical predictability.

[11] http://www.energybudgetsatrisk.com/ebarbackground.htm

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2.2.2 **Pooling of buildings by aggregator**

An inherent advantage of the concept of a P4P programme is the pooling of a large number of buildings. This will average out – hence lower - risk levels for deviating performance as explained above.

Given this large scale of the programmes, it is even conceivable to include third party investors in the design (or "structuring") of the programmes, more specifically for the design of risk management and financial flow mechanisms. This is actually already a practice today in "structured energy efficiency funds", bringing together financial and technical parties, or in "public-private ESCOs". Complementary, policymakers could advance inequality-reducing policies by including obligations for a minimum share of households in/at risk of energy poverty in structured portfolios, and their reflection in ESG metrics.

2.2.3 **Performance guarantee by aggregator**

In the same way as the ESCO does on project level, the aggregator can build in a second layer performance contractual arrangement with the P4P tendering authority at the programme level. So this second layer guarantee comes on top of the existing project-level performance guarantee between the ESCO and the building owner.

This way, the financial flows that exist at project level (the typical EPC financial flows) can be integrated in a broader picture, where (a part of) the remuneration transits through the aggregator to the third party investor.

2.3 Possible contractual arrangements

From the point of view of the third party investor (vehicle), there are basically 4 options (A, B, C and D) for financing (parts) of a P4P programme, or even a combination of one or more of these options. These are pictured in Figure 11 - *Potential investor relationships* .

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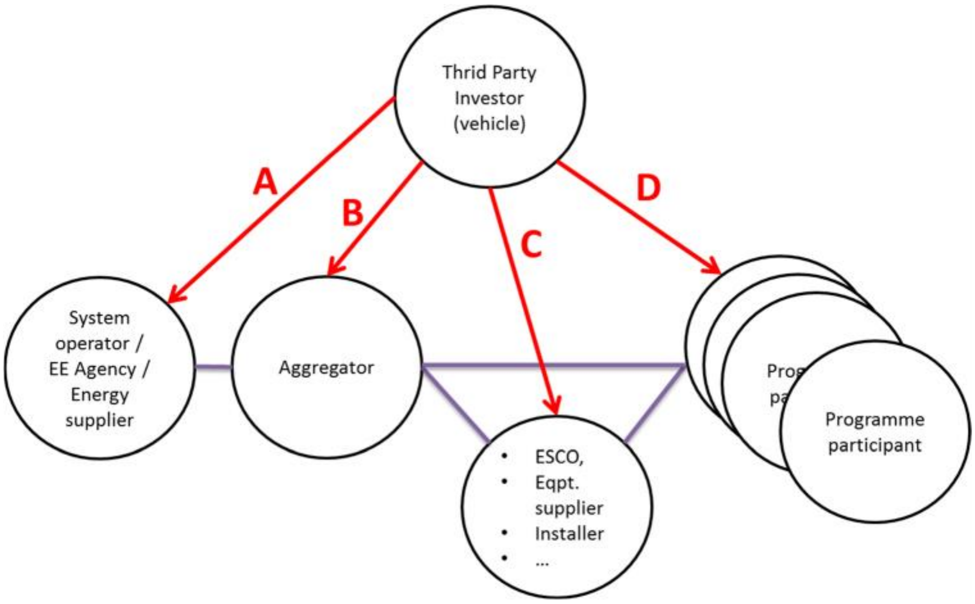

Figure 11 - *Potential investor relationships*

Each option can offer some degree of guarantee, making investment more or less attractive, depending on the guarantees that the different actors can offer in their respective contractual interfaces (purple lines). The option of choice will also determine which party carries risk commitment and how cash flows will take place. The preferred models (combination of options) are being selected in the course of the SENSEI project in consultation with relevant stakeholders from the energy efficiency financing community, and included in the report: *Variants of P4P schemes to engage third party investors in energy efficiency*.

2.3.1 Option A – financing the P4P programme through the System Operator (energy efficiency as a resource financing)

In this case the system operator will deal with a third party investor (TPI) to secure financing for the P4P programme, much in the same way as securing financing for infrastructure investments, in fact it will probably be integrated with funds financing the infrastructure. Please also refer to the deliverable "*The Boundary Cases for the P4P rates*" chapter 4 "Estimating the P4P rates", where this option is discussed.

Advantages:

- System operators are at the source of energy consumption data and have a direct connection to grid consumers.
- The financial risk is low, since solvency of grid operators is good
- Guarantee mechanisms foreseen at the level of the aggregator, ESCO and programme add up to each other, which makes financing highly securitized

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Potential disadvantage:

- The system operator does not control nor manage the programme adherence and its selection criteria, and cannot guarantee the success, i.e. the volume magnitude of it, which is a task of the aggregator. That disadvantage can be (partly) overcome by setting binding contractual targets between the system operator and the aggregator.
- For the system operator, the energy retrofit project is only perceived through the impact it will have on its network capacity. The economics of broader benefits of the retrofit project (i.e direct energy cost savings for the building owners, needed technology investments etc) are outside of the focus of the system operator. This makes the system operator a less preferred energy efficiency pre-aggregator
- It is even questionable if the system operator would engage in channelling financing to a P4P program, since it is itself only paying when metered benefits for the network are realised.

2.3.2 Option B – financing the P4P programme through the Aggregator ("programme structured fund" financing)

In this case, aggregator and third party investor define the programme specifics together, i.e. scope and programme selection criteria and participation process, to meet the system P4P benefit requirements from the grid operator. An aggregator could decide to combine several programmes for financing needs, and could decide to incorporate financing for the total investment in EEMs, not reducing it to solely the metered EEMs delivered grid benefits.

This option most closely resembles what exists today in the framework of energy efficiency funds, aimed at financing projects in specific sectors or types of buildings or public-private ESCOs aimed at a captive building segment.

Advantages:

- Flexibility for both aggregator and TPI to define (together) all programme execution and financing specifics
- Scale up thanks to the possibility for the aggregator to combine several programmes
- Reasonably highly secured financing

Disadvantage

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- The financial solvency risk will be higher for an independent aggregator, i.e. not incorporated in a system operator

The cash flow from the system operator for energy efficiency as a resource (or grid benefit) is an additional income strengthening the business case for the aggregator and the TPI, and potentially but not necessarily for the individual EEM projects.

2.3.3 Option C – financing the P4P programme per individual project through the ESCO's EPCs ("EPC project +" financing)

This is the classical EPC financing. Compared to option A and B this option has the main disadvantage of not capturing the massive scale-up bonus for lower risk, since each project is treated individually.

Applying this classic model in the framework of a P4P program, has some advantages though, like can be seen in some energy efficiency project financing funds that are operated in this way (but not at the same level of integration of option B):

- The selection of program participants by the aggregator could guarantee higher return projects, where a good energy efficiency potential is secured by compliance to selection criteria
- The aggregator can organise the program so that projects are executed by only a few preselected ESCO's, and impose common program quality parameters and procedures to minimize performance risks
- The aggregator can also impose standard financing approval procedures that have to be followed for each project, which would bring standardisation and thus lower financing approval process costs per individual project

2.3.4 Option D – financing the P4P programme through individual programme participants

This option does not include the EPC guarantees, which makes it the least appropriate to capture the (scale) benefits of a P4P programme.

The only remaining advantage is the new income stream for the energy retrofit projects created by the P4P system operator benefit, which increases the return for energy efficiency investments (slightly, depending on the rate system operators will be ready to pay).

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2.3.5 **Combination of options**

Given the fact that the SENSEI contractual model intrudes in an existing market governed by existing contractual arrangements and guarantees and cash-flows, it is probable that a variety of combinations of above options will be applied, depending on the programme specifics like scope, regulatory and financial context and culture (e.g. "project financing" is not widely accepted as financing in Europe).

The main attention point in any arrangement will have to be that a new "bonus" income will be stacked on the existing benefits of EEM projects, and that can be used to stimulate both larger scale implementation of and third party investment in EE.

This topic will be further explored in other work in the SENSEI project when involving stakeholders from the financial world (investors, banks, financial institutions). The results of the stakeholder engagement efforts are captured in forthcoming deliverables[12].

[12] Navigate to https://senseih2020.eu/publicdeliverables/ for: *Variants of P4P schemes to engage third party investors in energy efficiency ; Proposal on the specifications for P4P project data; The specialization of the P4P schemes for the buildings of GENCAT* ;

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Annex – Minimum data requirements for the energy efficiency aggregator to quantify the benefits from an EEM plan

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3.1 The aggregator as broker of energy efficiency benefits towards interested external stakeholders

In the redesigned electricity market fostered by the EU, new roles have been introduced (EU) 2019/944[13], which replace Electricity Directive (2009/72/EC), such as aggregators and ESCOs. Aggregators accumulate the contributions of numerous individual stakeholders and turn these into products/services to serve the needs of other stakeholders in the power system. **This annex presents the minimum data requirements that enable an aggregator to quantify the benefits** that were described in the previous chapters.

Based on this quantification, an aggregator should be able to decide whether to start investigating more deeply and whether or not to include a building in its P4P portfolio.

Normally an aggregator does not start from scratch when conducting the assessment. In principle, an ESCO has already performed such an analysis in more detail before entering into an EPC contract with a building owner. Of course, an ESCO focuses on reducing energy consumption, whereas an aggregator has a wider scope and will screen beyond sheer energy performance.

3.2 Assessing the energy efficiency potential in buildings

The European Union building stock is extremely varied across the continent even within individual countries in terms of technology, construction methods, envelope structure, etc. Changes on existing buildings can be made to reduce the use of energy. These could include small steps such as the renewal of lighting systems with more efficient luminaires (LED), or more important interventions such as insulation of surfaces, change of energy vector, introduction of more efficient technologies, etc.

In this chapter we **summarise the characteristics of the main energy efficiency interventions**, in accordance with what has been developed in Deliverable "The boundary cases for the P4P rates" of the SENSEI project. Afterwards we **define the minimum data requirements in order to quantify the benefits from an EEM plan that could become an investable asset**.

This complex operation starts from the basis of models that are already in use, and consists in an easily reproducible and adaptable dynamic methodology which, starting

[14] To develop industries energy audits refer to DIRECTIVE 2012/27/EU

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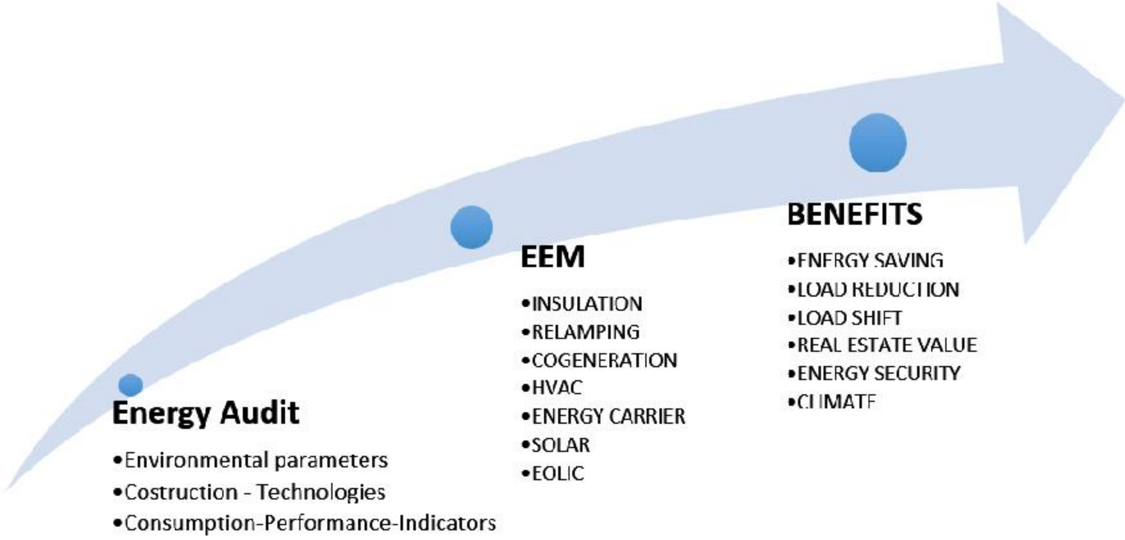
from some input data, allows the evaluation and optimization of technical and financial feasibility of the project itself.

Therefore, in order to evaluate the benefits ex-ante, a step-by-step methodology was developed based on the RETScreen software model, for the study of technical-economic feasibility of the project and followed by an evaluation that the intervention generates on the different actors of the SENSEI model. The approach used is shown in Figure 12.

Figure 12 - Process of assessing benefits of EEMs



The steps of Figure 12 can be summarised as follows:

1. Energy Audit: Definition of the Environmental - Construction - Technological - Energy Consumption (Energy bills) - Indicators and Building Performance parameters;

2. Energy efficiency Measure and saving definition;

3. Identification of the minimum requirements for the aggregator in relation to the benefits identified in subtask 6.1.1.

3.3 Energy Audit

The first part of the work for the definition of data requirements about a building starts from the energy audit: different parameters of the energy audit, necessary for planning the EEMs, may be used by the aggregator to reduce transaction costs. The goal is to develop a systematic procedure, to acknowledge the energy consumption profile of a building (or group of buildings) also for different sectors (industrial, commercial or residential) aimed at identifying and quantifying cost-benefit savings opportunities.

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3.3.1 Environmental parameters

The environmental parameters from the RETScreen tool are closely related to the geographical position that has to be analysed and related to the users localization, therefore altitude and latitude confer the main characteristics to the site: in fact from these derive the climate, the rainfall, the solar radiation etc. To date, energy analyses are based on monthly average daily data, but the technique is evolving towards dynamic models based on monthly average hourly data; it is clear that this entails a series of difficulties on finding data and on their accuracy and will not allow to define on all occasions this considerable amount of information. Clearly where possible, an extremely more precise analysis can be carried out, in order to evaluate energy savings and the associated benefits with greater precision.

The environmental type parameters can be summarized as follows:

1. **Location (**please see figure Figure 13**):**
   - **A.** Latitude, Longitude, Altitude;
   - **B.** Climate zone.
   - **C.** Heating-Cooling design, Earth Temperature-Amplitude) [°C];
2. **Thermo-hydrometric parameters:**
   - **A.** Temperature (monthly-Hourly average);
   - **B.** U.R. (monthly-hourly Average) [%];
   - **C.** Pressure (monthly-hourly average) [kPa];
   - **D.** Precipitation (monthly-hourly average) [mm].
3. **Wind:**
   - **A.** Wind Speed (Monthly-Hourly Average, Cubic average, Measuring height, etc.) [m/s];
   - **B.** Direction [°].

4. **Global horizontal irradiation (**please see Figure 14**):** (monthly-hourly) [kWh/m2]

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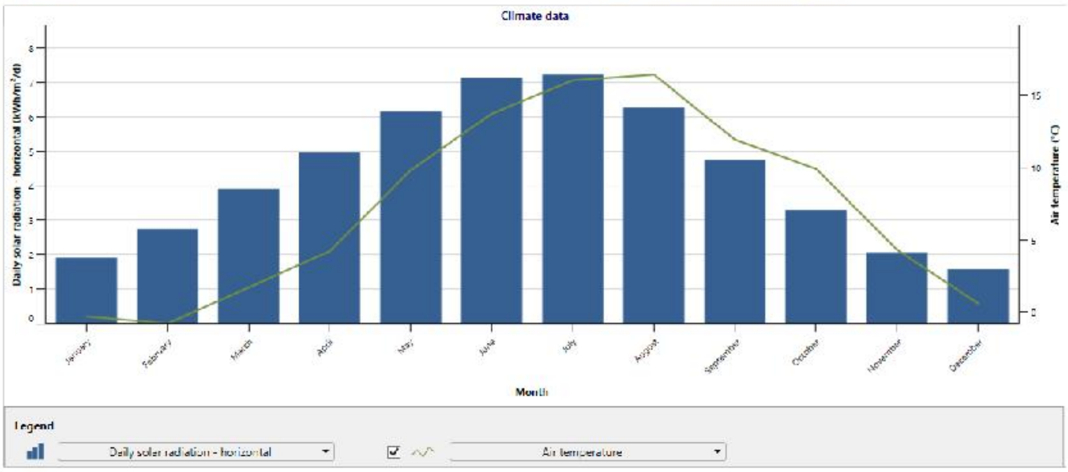
Figure 13 - Example climate data location (Software RETScreen)

	Unit	Climate data location	Facility location	Source
Latitude		39,3	39.3	
Longitude		15,4	16.3	
Climate zone		5A - Cool - Humid		Ground+NASA
Elevation	m	1720	184	Ground – Map
Heating design temperature	°C	-8,0		Ground
Cooling design temperature	°C	23,0		Ground
Earth temperature amplitude	°C	17,2		NASA

Figure 14 - Average climate data (Software RETScreen)

Month	Air temperature	Relative humidity	Precipitation	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days 18 °C	Cooling degree-days 10 °C
	°C	%	mm	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January	-0,3	84,4%	104,78	1,91	96,3	3.9	8.0	567	0
February	-0,8	84,1%	91.56	2,75	96,1	4.1	7.8	526	0
March	1,7	78,6%	81.84	3,92	96,1	4.0	9.7	505	0
April	4,2	73,8%	69.30	4.97	95,9	3.6	12,2	414	0
May	9,8	74,5%	39.68	6.16	96,1	2.9	16,7	254	0
June	13.7	70,1%	24.90	7.15	96,2	2.5	21,6	129	111
July	16.0	68,6%	19.51	7,23	96,2	2,2	25,1	67	186
August	16.4	69,1%	24.18	6,27	96,2	2.0	25,6	50	198
September	11.9	80,7%	65.40	4,76	96,3	2.4	21,4	183	57
October	9,9	78,9%	83.39	3,30	96,4	2.3	17,3	251	0
November	4,3	82,8%	113,40	2,07	96,2	3.4	12,8	411	0
December	0,6	89,9%	122,76	1,58	96,3	4.3	9.3	539	0
Annual	**7.3**	**78.4%**	**840.72**	**4.35**	**96.2**	**3.1**	**15.7**	**3.892**	**552**
Source	Ground	Ground	NASA	NASA	NASA	Ground	NASA	Ground	Ground
Measured at					m	10	0		



3.3.2 Construction type and technological parameters

The construction and technological parameters, as mentioned above, are very varied and are a function of the intended use or production activity. In this first analysis, residential and commercial buildings will be considered with greater interest and only

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industrial[14] plant technologies will be mentioned. Defining the main characteristics of the building precisely is of fundamental importance in order to better develop the type of energy efficiency intervention that best suits the analysed case. We summarise below the main categories:

1. **Intended use (or "sector"):**
    - **A.** Residential;
    - **B.** Commercial;
    - **C.** Industrial.

2. **Structures and thermal characteristics:**
    - **A.** Construction Features (Stone, Masonry, Ferro-concrete, Steel, Wood, etc.)
    - **B.** Thermal characteristics Opaque and transparent casing (Thermal transmittance, Thermal capacity, Phase shift, Periodic thermal transmittance, etc.).

3. **Energetic and Technologic services:**
    - **A.** Residential & Commercial:
        - Air conditioning (Heating - Cooling - DHW);
        - Thermal plant (Fluid carrier, Generation, Accumulation, Distribution, Emission, Regulation)
        - Operating temperatures of the systems (Low-medium-high temperature);
        - Systems and subsystems efficiency;
        - Lighting (Technology, distribution, regulation)

[14] To develop industries energy audits refer to DIRECTIVE 2012/27/EU

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B. Industrial:

- Production technology (ovens, dryers, electric motors, etc.)
- General Services (Air Conditioning - Lighting - etc.)
- Auxiliary services (technological steam - compressed air - etc.)

4. Energy carriers:

A. Electricity;

B. Gas;

C. Biomass;

D. Oil;

E. Etc.

5. Energy expenditure:

A. Electric Bill;

B. Gas Bill;

C. Etc.

3.3.3 Performance indicators (benchmarking)

The identification of energy performance indicators for a building, with the aim of structuring the agreement of a possible Sensei P4P scheme, are listed below. The analysis takes mainly into consideration residential and commercial buildings, though also some industrial aspects will be taken into account: for example the amount of energy actually consumed or that is expected to be necessary to meet the various needs associated with a standard use of the building, including heating, cooling, hot water, ventilation and lighting. This quantity is expressed by one or more descriptors calculated taking into account the insulation, the technical and installation characteristics, the position in relation to the climatic aspects, the exposure to the sun and the influence of

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the adjacent structures, the existence of generation systems proper to energy and other factors, including the indoor climate, which influences energy needs.[15]

It is also necessary to define standard features needed to compare the case; this comparison model is called benchmarking.

In accordance with the European Performance of Building Directive (and its updates) the most indicative parameters are shown below.

3.3.3.1 Building Dimensional Data:

The first key element is building envelope. Building envelope is defined as the parts of a building that form the primary thermal barrier between interior and exterior, also known as the building shell, fabric or enclosure. The energy performance of building envelope components including external walls, floors, roofs, windows and doors, is critical in determining levels of comfort[16].

In Table 3 we summarize the dimensional parameters of buildings.

Table 3 - Dimensional and thermal parameter about a building

DESCRIPTION OF THE BUILDING	
Parameter	**Units of measurement**
Heating area [S]	m2
Gross volume [V]	m3
Form Factor [S/V]	1/m
Dispersant surfaces	m2
Thermal capacity	kJ/K
Heat transfer coefficient [U]	W/m2 K
Periodic thermal transmittance	W/m2 K
Phase shift	h
Global exchange coefficient	W/m2 K
Heat load	W

[15] EPBD 2002/91/CE

[16] https://refomo.eu/wp-content/uploads/sites/105/2015/11/Review-on-techniques-for-energy-efficient-retrofitting-of-heritage-buildings_Final.pdf

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The data listed in Table 3 could be included in a single indicator named in the following text as *PERFORMANCE INDICATOR OF ENEVOPLE STRUCTURE* that represents the building's thermal insulation health status and is defined in relation to a reference building established by law.

3.3.3.2 **Energy vectors:**

The fundamental aspect for energy carriers is that, in order to define the quantity consumed, it is necessary to evaluate, according to their characteristics, the Primary Energy Factor (PEF) which in fact indicates the quantity of primary energy used to generate a unit of electricity or usable thermal energy. This allows to make quantitative comparisons on primary energy consumed for end uses even if this energy is obtained from different sources and through different vectors[17]. The evaluation of the project by the aggregator cannot be separated from the energy carrier chosen for the Energy Efficiency intervention. Furthermore, greenhouse gas emissions as a function of fuel must be considered in accordance with the REDII directive[18]: In Table 4 we summarize the energy carrier parameters that must be developed for each one fuel.

Table 4 - Summary table of energy carrier

Energy Carrier	
Fuel	
Peak Power	kW
Calorific value	kWh/u.m.
Emission factor CO2	kgCO2/kWh
Primary energy	TEP
Primary energy Factor Renewable	-
Primary energy Factor not Renewable	-

3.3.3.3 **Energy Demand:**

The energy building demand resumes the consumption for different plant technological services. In Table 5 we can resume the Energy carrier parameters:

[17] In accordance with Directive 2012/27/EU

[18] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001&from=EN

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Table 5 - Summary table of energy Demand

Energy Demand	
Thermal energy demand for Heating	kWh
Thermal energy demand for Hot Water	kWh
Average of efficiency Heating	%
Average of efficiency Hot Water	%
Electricity demand	kWh
Self-consumed electricity	kWh
Exported energy	kWh
Percentage of energy from RES Heating	%
Percentage of energy from RES Hot Water	%

3.3.3.4 Overall energy performance:

It represents the amount of non-renewable global primary energy and expresses the building's energy class and is expressed in:

- **Residential:**
  - [k /m]
- **Industrial:**
  - **Electric** [k e/t]
  - **Thermic** [k t /t]

In Table 6 we resume the main indicators necessary to summarize the buildings performance.

Table 6 - Energy performance indicators

Indicators of performance	
Energy performance index of Heating	kWh/m2 year
Energy performance index of Cooling	kWh/m2 year
Energy performance index of Hot Water	kWh/m2 year
CO2 Emission for heating	kgCO2
CO2 Emission for Cooling	kgCO2
CO2 Emission for Hot Water	kgCO2
CO2 Total Emission	kgCO2/m² anno

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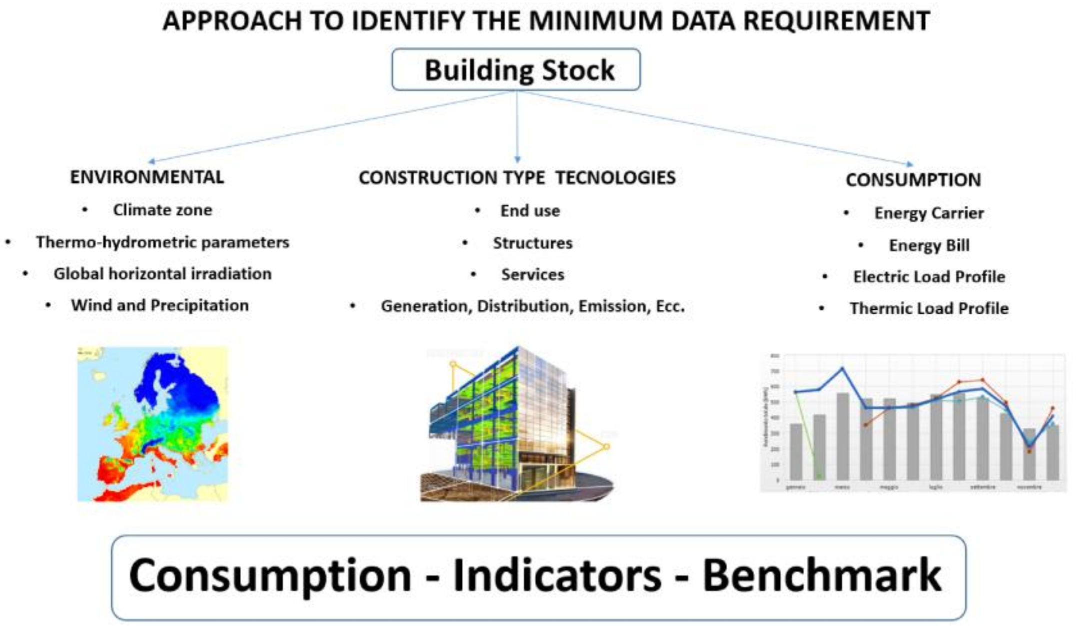
3.3.4 Summary

The approach for the energy performance analysis of a building stock is achieved through different steps of analysis and calculation, as used to put the basis for a more detailed energy audit. Each step is completing the total energy picture. This has an impact on the minimum data set required, as the set will be different depending on the step of the analysis.

An aggregator will need the data as required to perform a benchmarking exercise.

Figure 15 - Approach for identifying the minimum data requirements



3.4 Technical and financial parameters for quantifying energy savings of energy efficiency plans

Technical and financial parameters needed to develop an EEMs analysis are different depending on the type of intervention. Starting from the study and the analysis carried out in the SENSEI project (see report: “Identify the P4P rates energy providers would be willing to offer”), we are going to define the potential energy savings through simple indicators and/or parameters.

3.4.1 Insulation

We can consider different types of insulation:

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1. Opaque
2. Transparent

Opaque:

The first evaluation level concerns the integrated building materials. Within this framework an extended database of the most common building materials used in the EU construction practice was developed[19]. Thermal insulation is the basis of energy efficiency measures therefore we may consider the aspects listed below:

1. **Technical Parameters:**
   - Material of insulation (Type, Density, Thermal conductivity, Permeability, Mechanical Resistance, Thermal capacity, Fire resistance class, etc.);
   - Overall heat transfer coefficients [W/m^{2}K];
   - Phase shift [h];
   - Periodic transfer coefficient [W/m^{2}K].
2. **Environmental parameters:**
   - Emissions from production, transportation and installation procedures (CO_2 – SO_2 - PO_4 - C_2H_4 equivalent;
   - Impacts like climate change, acidification, eutrophication, and photochemical oxidation etc.
3. **Financial Parameters:**
   - Cost of investment [€];
   - O&M cost [€/year];
   - Heat Load [W];
   - Energy saving [kWh/year].

The objective in this case is to guarantee the optimal transfer coefficient and phase shift and this depends on the initial situation of the structure.

[19] https://www.researchgate.net/publication/223382071_An_assessment_tool_for_the_energy_economic_and_environmental_evaluation_of_thermal_insulation_solutions

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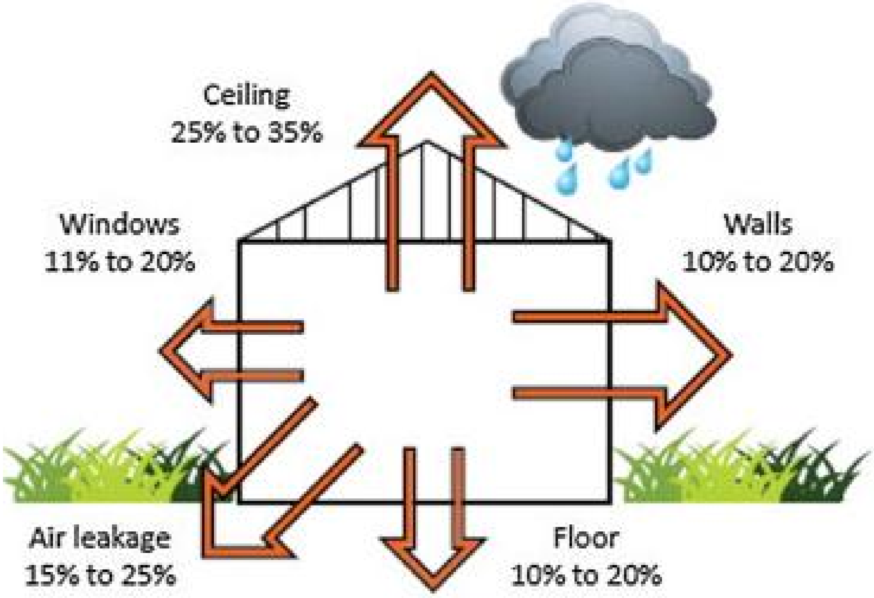
Figure 16 - Graphical view of the heat loss[20]



The materials used must be chosen with care and the main parameters must be optimized. In fact wall systems with significant thermal mass have the potential to reduce buildings annual heating and cooling energy requirements[21].

Transparent

A study made by Ardente et al 22. indicated that one of the most significant benefits of energy consumption assessment was the improvement of glazing.

Different parameters must be considered which can be summarized as follows:

1. **Type of Glass** (reflection- transmission- adsorption coefficient, low emissivity)**;**
2. **Frame** (Material)**;**
3. **Gas** (Air, Argon, etc.)**;**
4. **Heat transfer coefficient.**

[20] https://www.sciencedirect.com/science/article/pii/S1110016817301734#b0025

[21] *https://web.ornl.gov/sci/buildings/docs/Thermal-Performance-and-Wall-Ratings.pdf*

[22] F. Ardente, et al. Energy and environmental benefits in public buildings as a result of retrofit actions Renew. Sustain. Energy Rev., 15 (1) (2011), pp. 460-470

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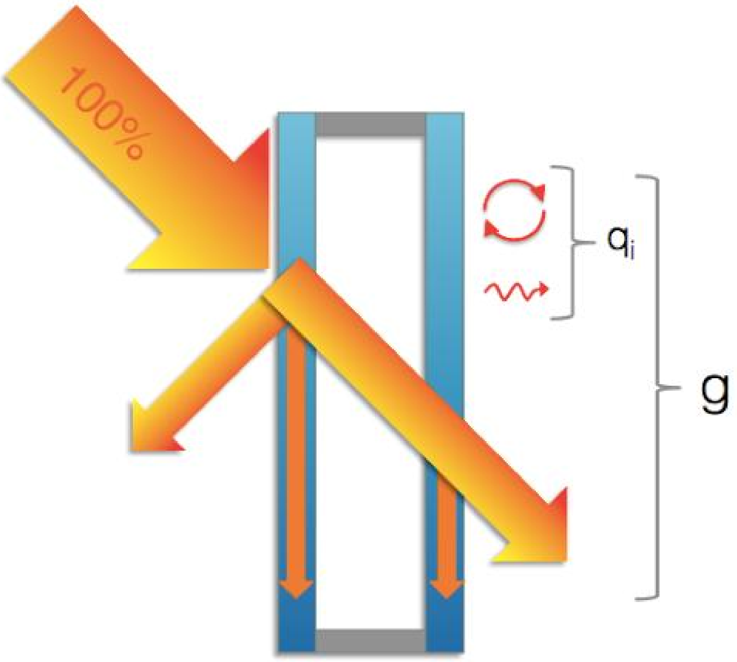
The objective is to choose the technologies which can be applied, based on the previously analysed energy performance parameters[23].

Financial Parameters

To consider the quality of investment in economic terms we can consider the following parameters:

1. Cost of investment [€];
2. O&M cost [€/year];
3. Energy saving [kWh/year]

Figure 17 - Solar radiation on glass



[23]https://www.researchgate.net/publication/265110993_Transparent_insulating_materials_for_buildings_energy_saving_experimental_results_and_performance_evaluation

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3.4.2 Re-lamping

Re-lamping concerns the installation of new lamps inside or outside of a building. For optimal energy performance results, daylight dependent dimming control and presence detection systems can be added.

Technological parameters[24] are:

1. Lamp Technologies (luminous flux, luminous intensity distribution, spectrum, correlated colour temperature CCT);
2. Lamp Lumen Output;
3. Light Output Ratio;
4. Peak Power [W];
5. Deterioration Functions;
6. Equivalent hours [h].

To evaluate the energy saving of re-lamping we consider the following parameters:

- **Power of actual lamps [P_{in}];**
- If consumption profile energy of lamps line is possible, otherwise the usage knowledge of building's owner (or occupants) to define the **equivalent hours per year [h];**
- **Power of new Lamps** that will be installed **[P_{fin}];**

The ex-ante energy saving is then easily obtained through the mathematical formula expressed below:

$$E = (P_{in} - P_{fin}) * h$$

Financial Parameters

1. Investment cost [€];
2. O&M cost [€/year/kWh];
3. Fee energy carrier [€/kWh];

[24] http://fuuu.be/polytech/LANGH300/LED/Linear%20LED%20tubes%20versus%20fluorescent%20lamps%20-%20An%20evaluation.pdf

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4. Life time [years];
5. Net Present Value [NPV] [€].

3.4.3 Combined heat and power systems (cogeneration)

Cogeneration can play a key role for energy transition, because, managed intelligently, it can contribute not only to the decarbonisation required by the EU but also to the grid management. Furthermore, the possibility of using different types of fuel in cogeneration plants makes them extremely versatile (with uses from residential to rural to agricultural context)[25]. In the future, biomass will play a fundamental role in the Union's energy strategies; in the context of this document, the technical characteristics of the cogeneration plant will be defined without considering the fuel input.

On the other hand, this technology requires more onerous design activity, management and maintenance. That fact must be considered when processing the technical and financial project.

We first define the usage profiles of the cogeneration plant.

The parameters necessary to accurately process the size of the cogeneration plant are:

1. Electric Profile or Consumption (monthly or hourly);
2. Thermic Profile or Energy Carrier Consumption (monthly or hourly);
3. Electric -Thermic Peak;
4. Type of end use and Temperatures required (Hot Water, Steam, etc);
5. Technology and modulation capacity (MCI, Turbine, etc.);
6. Energy Carrier (Fundamental Parameter);
7. CHP Runtime (h/year)

Financial Parameter

To consider the quality of investment in economic terms we can consider the following parameters:

1. Cost of investment [€];
2. O&M cost [€/kWhe];

[25] https://www.nrel.gov/docs/fy17osti/68579.pdf

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3. Fee electric energy [€/kWh];
4. Cost of energy carriers [€/mc];
5. Energy consumed internally;
6. Energy valorisation;
7. Real use of thermal Energy.

3.4.4 **Change of energy carrier**

Electrification is seen as an important global contributor to mitigation of climate change, because low carbon electricity can, in theory, replace current fossil fuel use in buildings and surface transport.

3.4.4.1 **Heat pump**

A protagonist technology in the energy transition is definitely the heat pumps, which guarantee high quality standards and low consumption when installed and commissioned correctly. The heat pump is a technology that guarantees maximum convenience when coupled with low temperature heat delivering systems, and running on electricity from renewable sources.

Heat pumps are used more and more to provide heating and/or cooling for buildings of all types and sizes. They can play a double role in energy transition, first by reducing energy consumption and thus the cost, and then by reducing carbon emissions compared to traditional combustion based equipment[26].

Demand response (DR), peak reduction and workload shifting in combination with local generation are an important aspect of the future smart grid; the heat pump system is an ideal end use system to optimize the valorisation of electricity from RES[27].

To evaluate the energy saved by the heat pump we must consider:

1. Power [W]
2. Operating temperature [h]
3. COP [-]
4. Energy source [Air, geothermic, water, etc.]

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[26] https://www.slideshare.net/sustenergy/heat-pumps-for-larger-buildings-148993616

[27] https://www.researchgate.net/publication/306287421_Demand_Response_for_heating_and_cooling_purposes_in_smart_houses

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Financial Parameters

The quality of investment in economic terms can be considered through the following parameters:

1. Cost of investment [€];
2. O&M cost [€/kWhe];
3. Fee electric energy [€/kWh];
4. Cost of energy carriers [€/mc];
5. Energy saving.

3.4.4.2 **Electric Storage**

One of the technologies that will be key to deployment of RES and EE projects will be the electric battery. Considering the trend towards electrification of consumption, electric batteries will become common in the network modernization, and will contribute to the operationalisation of demand response.

Technological parameters of the Electric Storage can be summarized as follows:

1. Total energy [kWh];
2. Usable energy [kWh];
3. Capacity [Ah];
4. Maximum power [kW];

Financial Parameter

From economic perspective we can consider the following parameters:

1. Cost of investment [€];
2. O&M cost [€/kWhe];
3. Fee electric energy [€/kWh];
4. Internal consumption;
5. Energy saving.

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Different types of energy storage technologies are promising for the future[28], and can contribute to the growth of demand Response services [29].

3.4.4.3 Electric Vehicles

In the future electric vehicles will see a strong expansion, contributing substantially to the decarbonisation of transport[30]. In addition, with the electrification of consumption in mind, EV will guarantee part of the electricity storage needed for the deployment of demand response, thus involving the individual citizen in the electricity market.

The Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU contains many elements that will help to enable smart charging. For instance, it allows to provide consumers with more accurate price signals that reflect real costs when smart meters are in place. The role of aggregators is also identified, allowing EV owners to participate in two-way markets (consumer-provider).

Technological parameters :

1. Technologies [Hybrid, Full Electric, etc.]
2. Total energy [kWh];
3. Usable energy [kWh];
4. Capacity [Ah];
5. Maximum power [kW];

Financial Parameter

From economic perspective we can consider the following parameters:

1. Cost of investment [€];
2. O&M cost [€/kWhe];
3. Fee electric energy [€/kWh];

[28] http://large.stanford.edu/courses/2013/ph240/cabrera1/docs/SAND2013-5131.pdf

[29] http://www.raponline.org/wp-content/uploads/2016/05/synapse-hurley-demandresponseasapowersystemresource-2013-may-31.pdf

[30] https://www.iea.org/reports/global-ev-outlook-2020#the-global-electric-vehicle-fleet-expanded-significantly-over-the-last-decade-underpinned-by-supportive-policies-and-technology-advances

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4. Energy consumption from RES ;

3.4.5 Building Automation Control System (BACS)

Home automation will be increasingly present in the homes of every citizen, as these technologies will deployed in the context of smart cities and load management. Furthermore, the latest European directive EPBD III sets the mandatory installation of BACS technology in residential buildings. Intelligent management systems will be able to guarantee, together with all the EE technologies mentioned earlier, the optimization of energy flows inside and outside our homes. The key elements in this deployment will be:

1. **Smart production:**

New production technologies that allow collaboration between all the elements present in the production or collaboration between operator, machines and tools;

2. **Smart service:**

All the "IT infrastructures" and techniques that allow to integrate the systems; but also all the structures that allow, in a collaborative way, to integrate suppliers and consumers between themselves, and with the external structures (roads, hub, waste management, etc.).

3. **Smart energy:**

Creating more efficient systems and reducing energy waste according to typical paradigms of sustainable energy.

First, the load definition is necessary to identify the potential control solutions[31] and will be summarized as follows :

1. **Stand-by:**

Remain in stand-by when people are absent

2. **Permanent:**

[31] https://www.researchgate.net/publication/267264415_Electricity_Load_Management_in_Smart_Home_Control

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Devices that are continuously switched on like fridge, freezer. No control (green devices with a stable energy consumption.

3. **Shiftable:**

Loads that can be shifted in time.

4. **Priority:**

Normal loads that must be supplied when required for their normal running.

Second we can assess how the reduction of building electricity consumption and the modification of the building load profile, due to load automation, combined with suitable load control programs, can improve network reliability and distribution efficiency[32]

3.4.6 Renewable Energy

3.4.6.1 PV System

To evaluate the generation capacity of photovoltaic systems, it is necessary to start from the analysis of solar radiation. To date there are different calculation methods and different databases to deduce the data, and these can vary up to 10%. In this analysis we start by considering monthly average data, even though the technique is directing towards the analysis of average daily hourly data.

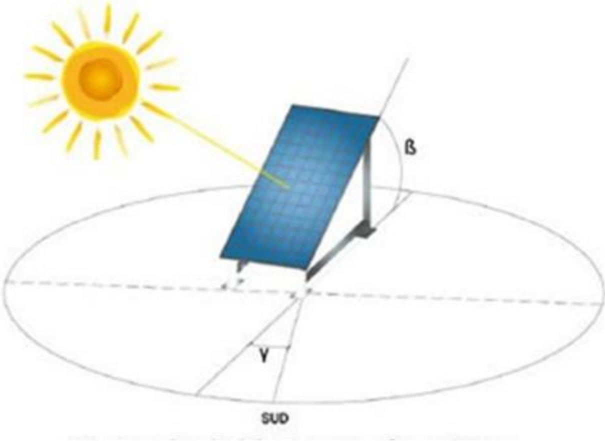
After having defined the solar radiation to calculate the PV energy production we will need to consider the following **technical parameters**:

1. Angle of inclination of solar panel [Slope angle];
2. Azimuth angle;
3. PV Technologies;
4. Tracking PV;
5. Shading;
6. Installed peak PV power [kWp];

[32] https://www.researchgate.net/publication/323789877_Building_Automation_and_Control_Systems_and_Electrical_Distribution_Grids_A_Study_on_the_Effects_of_Loads_Control_Logics_on_Power_Losses_and_Peaks

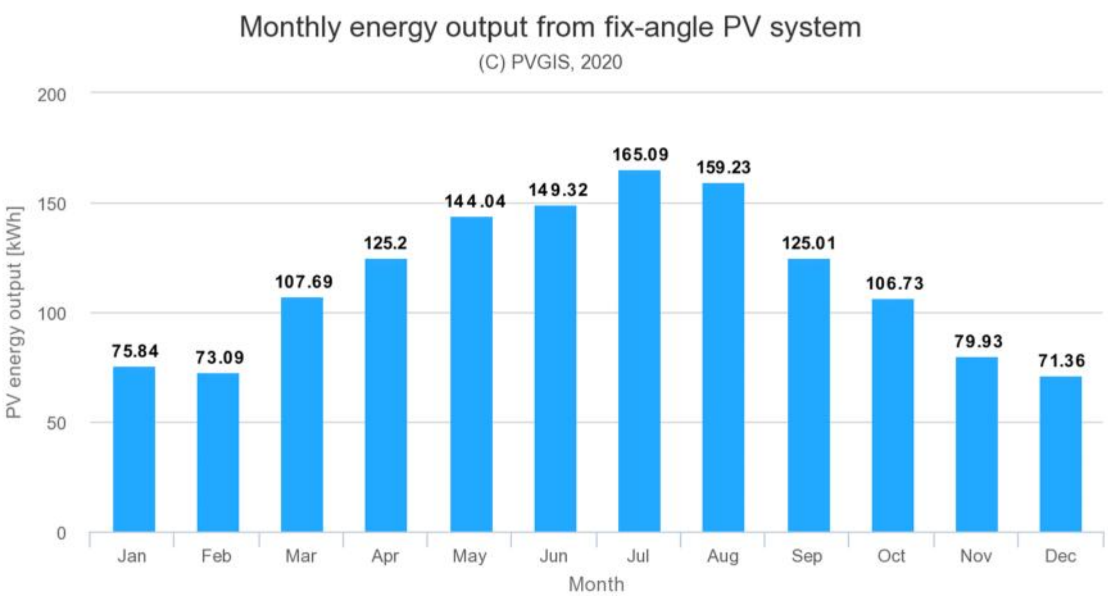
This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 847066.

Figure 18 - Slope and azimuth angles



With this information we then calculate the theoretical energy production of solar PV on a monthly base for the given circumstances, as follows:

Figure 19 - Producibility of solar PV monocrystalline [PV GIS]



From this data we can deduce the yearly PV energy production [kWh]:

$$E = 1\quad .5\quad k\quad /k$$

This value varies with the geographical location of the PV installation.

Financial Parameters

1. Cost of investment [€]:
2. Cost of organization and Maintenance [€/year/kW]:

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3. Self-consumed electricity and Exported energy.
4. Fee electricity (buying and selling) [€/kWh];
5. Life time [years];
6. Net Present Value [NPV] [€].

TOOLS

There are several programs for calculating the technical economic feasibility of the project, to cite just two:

- *PHOTOVOLTAIC GEOGRAPHICAL INFORMATION SYSTEM:*

An instrument made available by the European authorities to calculate the energy production of a photovoltaic system is presented at the following link:

PV GIS: https://re.jrc.ec.europa.eu/pvg_tools/it/#PVP

- *RETSCREEN:*

RETScreen is a Clean Energy Management Software system for energy efficiency, renewable energy and cogeneration project feasibility analysis as well as ongoing energy performance analysis. This software is presented at the following link:

http://www.retscreen.net/

3.4.6.2 **Solar Collector**

Solar thermal is a technological solution that can be applied in different sectors, from domestic hot water to space heating, as well as in industrial processes at low and medium temperatures[33]. The use of solar heating systems has increased, due to and the relatively simple structure[34]. The main component of these heating systems is the solar collector. The potential is currently untapped in the EU, partly due to climatological constraints since climate zones in Europe are very diverse and not always suited for Solar Thermal installations.

[33] https://www.rhc-platform.org/content/uploads/2019/05/ESTTP_SRA_RevisedVersion.pdf

[34] http://newfaculty.azad.ac.ir/file/download/articlesInPublications/161_2017-05-28_07.38.08_exergy%20flat.pdf

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As with photovoltaics, we start by defining the solar radiation and the temperatures which are part of the previously defined environmental parameters, then we will calculate the actual energy production through the following parameters:

In the same way for solar PV after having defined the solar radiation, we will calculate the energy production considering the following technical parameters:

1. Angle of inclination of solar panel [Slope angle];
2. Azimuth angle;
3. Technology;
4. Solar Keymark;
5. Shading;
6. Area installed [m^2].

Financial Parameters

1. Cost of investment [€];
2. Cost of organization and Maintenance [€/year/kWh];
3. Fee energy carrier [€/kWht];
4. Life time [years];
5. NPV [€].

3.4.6.3 Wind Power

Wind represents one of the renewable sources that has grown most rapidly in the last two decades together with photovoltaics. It is an average stable source from year to year, but with a significant variation on shorter time scales: the intermittence of the wind creates production variability with consequences on the electricity network which requires special balancing measures. There are several methods for managing the variable power that is produced, such as storage systems, geographically distributed turbines, energy export and import agreements with neighbouring areas or reduction of demand when wind production is low, which can significantly reduce these problems.

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Furthermore, weather forecasts allow the electricity grid to be prepared according to the changes expected in production.

The key to define the feasibility and quality of a project, for the correct sizing of the wind turbine, is the knowledge of the environmental data and consequently the historical anemometric data of the location. Especially for an ex-ante evaluation, the more information available, the more precise the turbine manufacturability will be.

The **technological parameters** that must be kept in mind are:

1. Wind characteristics (Probability density, Weibull[35]);
2. Technologies (two-tree bladed, HAWT, VAWT etc.36);
3. Hub height;
4. Peak Power [W];
5. Electric Producibility [kWh];
6. Equivalent hours [h].

Financial Parameters

1. Cost of investment [€];
2. Cost of organization and Maintenance [€/year/kWh];
3. Fee energy carrier [€/kWh];
4. Life time [years];
5. Net Present Value [NPV] [€].

3.5 Minimum Data Requirements

In order to select those EEMs that are beneficial for the different actors in a P4P scheme (building owners, the power system and third financial parties), the aggregator has to identify which data about a building are necessary and sufficient to structure the different

[35]https://www.researchgate.net/profile/Noel_Djongyang/publication/276288648_Statistical_analysis_of_wind_speed_distribution_based_on_six_Weibull_Methods_for_wind_power_evaluation_in_Garoua_Cameroon/links/555d773c08ae9963a11277bf/Statistical-analysis-of-wind-speed-distribution-based-on-six-Weibull-Methods-for-wind-power-evaluation-in-Garoua-Cameroon.pdf

https://www.sciencedirect.com/science/article/pii/S2211467X19300689

[36] https://www.sciencedirect.com/topics/engineering/horizontal-axis-wind-turbine

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 847066.

agreements of a proposed SENSEI P4P approach. In a preliminary assessment, these parameters (or a subset) could be used by the aggregator itself in order to evaluate the suitability of specific EEMs. The parameters chosen for the evaluation by the aggregator are a subset of the parameters set out in the section 3.3, parts "*Energy Audit*" and "*Technical and financial parameters for quantifying the energy savings of EE plans*", also partly based on the ESCO perspective.

We have identified a set of main indicators that can be a solid basis for the aggregator to quantify the benefits that may be part of a P4P scheme.

The parameters are classified in six different areas:

- Identification Data,
- Envelope Structure,
- Energy Systems and performance,
- Energy consumption,
- Energy bill and
- Renewables.

The different parameters of each area are listed below.

3.5.1 Identification data (general data)

a. *End Use:*
    - *Description*
    - *Year of construction*
    - *People*
b. *Localization:*
    - *Region*
    - *City*
    - *Address*
    - *Floor*
    - *Sub*
    - *Coordinates*
    - *Zone Climate*
c. *Surface-volume air-conditioned:*
    - *Surface and Volume affected by winter and summer conditioning.*
    - *Heated surface [m^2]*

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- *Heated volume [m^3]*
- *Cooling Surface [m^2]*
- *Cooling Volume [m^3]*

Figure 20 - Example of a summary of data identification about a building

Identification Data

End Use - **Residential**

Description - **Block of flats formed by 52 apartments**

Region	*Italy*	Climate Zone	*Humid - Temperate*
City	*Cosenza*	People	*186 pers.*
Address	*Via Popilia*	Heated surface	*3856 m^2*
Floor	-	Heated volume	*10405 m^3*
sub	-	Cooling surface	-
Coordinates	*39.322532, 16.254040*	Cooling volume	-
Year of construction	*1978*		

3.5.2 Envelope structure:

a. *Dimensional:*

- *Dispersant surfaces [m^2]:*

Represents the surfaces delimiting the heated volume.

- *Heated Volume [m^3]:*
- *Form Ratio S/V [1/m]:*

Represents the shape ratio of the building

b. *Thermic Performance:*

- *Average Global thermal coefficient [W/m^2 K]:*

Represents the average heat loss for the entire enclosure.

- *Average Transmittance Thermic Periodic [W/m^2 K]:*

Periodic thermal transmittance (UNI EN ISO 13786) is a parameter that expresses the ability of a building component to attenuate and offset the thermal flow from the outside that crosses over a twenty-four hours period.

- *Performance for heating [%]:*

The performance of the casing reference is calculated as the ratio between the performance of the building in question and the baseline set by regulations.

- *Performance for cooling [%]:*

Like the previous one but for the winter.

c. *Thermal Load:*

Thermal load is calculated from the demand for heating and cooling power under reference conditions, in fact we will divide it in:

- *Heating Load [kW]Cooling Load [kW]*

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d. Comfort [PPD-PMV]:

Represents a methodology to evaluate the comfort through thermo-hygrometric or thermal comfort that can be represented through the theory of Fangher[37]:

- PMV summer
- PPD Winter
- PMV summer
- PPD Winter

e. Removal of harmful materials:

To improve the real estate value of the building; for example:

- *Asbestos*

Figure 21 - Example of envelope structure data

Envelope Structure			
Dispersant surfaces	*3498 m²*	Heating Performance	*1,9*
Heated Volume	*10405 m³*	Cooling Performance	*2,1*
Form Ratio S/V	*0,34*	Heating Load	306 kW
Average Global Thermal Coefficient of trasmission	*1,8 W/m² K*	Cooling Load	-
Average Trasmittance Thermic Periodic	*1,25 W/m² K*	PMV [Summer - Winter]	2,6 ; -2,2
Harmful material	Asbestos	PPD[Summer - Winter]	59 % ; 54 %

3.5.3 Energy systems and performance:

Technological services necessary for the use of the building:

- Heating
- Cooling
- Warm water
- *Storage*
- *Other or new Technologies (e.g. hydrogen storage, …)*

The following data are needed:

a. Type of technologies and energy carrier:

Summary of technological systems and the respective energy carrier.

b. Year of construction:

Could help to quantify efficiency

c. Power [kW]:

Identifies the power of the generator

d. Efficiency (Average performance) [%]:

[37] https://www.engineeringtoolbox.com/predicted-mean-vote-index-PMV-d_1631.html

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Represents the average efficiency of all subsystems.

Figure 22 - Example of a summary of technological systems in a building

Energy systems and performance				
Services	**Type tecnologies - Carrier**	**Year of installation**	**Power**	**Efficiency**
Heating	Gas boiler - Methane	1996	360 kW	75%
Cooling	-	-	-	-
Warm Water	Gas boiler - Methane	1996	360 kW	78%
Ventilation	-	-	-	-
....	-	-	-	-

Energy systems and performance				
Services	**Type technologies - Carrier**	**Year of installation**	**Power**	**Efficiency**
Heating	Gas boiler - Methane	1996	360 kW	75%
Cooling	-	-	-	-
Warm Water	Gas boiler - Methane	1996	360 kW	78%
Ventilation	-	-	-	-
....	-	-	-	-

3.5.4 **Energy consumption:**

There are several parameters to express energy consumption:

1. *Overall performance of the building:*

Represents annual energy consumption for heating, cooling and auxiliary energy requirements in different condition systems and other services auxiliary for a building:

- *Heating energy performance Index [kWh/m^2 yr]*
- *Cooling energy performance Index [kWh/m^2 yr]*

2. *Energy class (Winter/Summer) [%]:*

Is obtained from the ratio of energy performance to the reference performance calculated according to legislation.

3. *Primary energy consumption [TOE]:*

The first step is to define the energy baseline as a verified basis to calculate, monitor, and verify the energy savings of EEMs. Baselining includes heating and cooling degree adjustment[38]; consumption related to 365 days/year and a *"normalized"* operation and usage of the building in a way that eliminates abnormal disturbances such as construction, long vacancy, etc.

4. *Carriers:*

---

[38] https://iea-annex61.org/files/results/Subtask_B_BM%20Guide_2017-11-06.pdf

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It is necessary to assess all the energy carriers used in the present case and their specific consumption figures.

5. *Renewable [%]:*

Share of renewables for final use of the building.

6. *Electrification [%]:*

Share of electrification for final use of the building:

- *Share Thermal*
- *Share Mobility*
- *…*

7. *CO_2 Emission [ton]:*

Represents the amount of CO_2 gas equivalent produced

8. *Nearly Zero Energy Building [NZEB]:*

Represents if the building respects the limit about *NZEB*

Figure 23 - Example of a summary of technological system about a building

Energy consumption					
Energy class:		Heating Energy Demand	196 kWh/m² yr	Electrification	2%
		Cooling Energy Demand	-	Renewable	0,11%
		Warm Water Energy Demand	35 kWh/m² yr	Emission CO2	1490 Mton
		Prymary energy	65 TOE	nzeb	-

3.5.5 **Energy bill**

We could consider the following parameters:

a. *Average cost for each energy carrier [€/u.m.]:*

To be averaged over several years:

- Electricity [€/kWh]
- Gas [€/m^3]
- …….

b. *Peak Power [kW]:*

Represents the total power of connection to the network of the building.

c. *Electrical Energy demand (Or other carrier) [kWh]:*

Represents the amount of electricity needed for the building.

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Figure 24 - Example of a summary of technological system about a building

Energy bills			
Electric Energy		Gas methane	
Average Cost	*0,22 €/kWh*	Average Cost	*0,95 €/Smc*
Peak power	*171 kW*	Peak power	*2000 kW*
Energy Cost	*45.000 €*	Energy Cost	*91.000 €*
Elettrical Energy Demand	183 MWh	Gas Demand	*96000* m^3

Energy bills			
Electrical Energy		Gas methane	
Average Cost	*0,22 €/kWh*	Average Cost	*0,95 €/*Sm^3
Peak power	*171 kW*	Peak power	*2000 kW*
Energy Cost	*45.000 €*	Energy Cost	*91.000 €*
Elettrical Energy Demand	183 MWh	Gas Demand	*96000* m^3

3.5.6 Renewables

In this section we describe the RES technologies:

1. Type [-]: In this section you have the description of the type of renewable source used
2. Technologies [-]: This section describes the technology used.
3. Power [kW] - Production [MWh]: Power of the plant and amount of energy that can be produced or equivalent hours of operation during the year.
4. Self-consumed Energy [MWh]: Represents the amount of renewable energy produced and self-consumed.
5. Energy exported [MWh]: Represents the amount of energy produced exported to the grid.

Figure 25 - Renewables energy data

RES				
Type	**Tecnologies**	**Power - Producibility**	**Self consumed**	**Exported**
FV	-	-	-	-
Solar	-	-	-	-
Eolic	-	-	-	-
....	-	-	-	-

RES				
Type	**Tecnologies**	**Power - Producibility**	**Self consumed**	**Exported**
FV	-	-	-	-
Solar	-	-	-	-
Wind	-	-	-	-
....	-	-	-	-

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3.5.7 **Summary table**

The table below summarizes the main indicators to evaluate state of affairs of the building; this could be the possible format to resume the data about a building:

Figure 26 - Minimum data requirements from ESCO perspective

Identification Data				
End Use - **Residential**	Description - **Block of flats formed by 52 apartments**			
	Region	*Italy*	Climate Zone	*Umid - Temperate*
	City	*Cosenza*	People	*186 pers.*
	Address	*Via Popilia*	Heated surface	*3856 m²*
	Floor	-	Heated volume	*10405 m³*
	sub	-	Cooling surface	-
	Coordinates	*39.322532, 16.254040*	Cooling volume	-
	Year of costruction	*1978*		
Envelope Structure				
Dispersant surfaces		*3498 m²*	Heating Performance	*1,9*
Heated Volume		*10405 m³*	Cooling Performance	*2,1*
Form Ratio S/V		*0,34*	Heating Load	306 kW
Average Global Thermal Coefficient of trasmission		*1,8 W/m² K*	Cooling Load	-
Average Trasmittance Thermic Periodic		*1,25 W/m² K*	PMV [Summer - Winter]	2,6 ; -2,2
Harmful material		Asbestos	PPD[Summer - Winter]	59 % ; 54 %
Energy systems and performance				
Services	**Type tecnologies - Carrier**	**Year of installation**	**Power**	**Efficiency**
Heating	Gas boiler - Methane	1996	360 kW	75%
Cooling	-	-	-	-
Warm Water	Gas boiler - Methane	1996	360 kW	78%
Ventilation	-	-	-	-
....	-	-	-	-
Energy consumption				
Energy class: 	Heating Energy Demand	*196 kWh/m² yr*	Electrification	*2%*
	Cooling Energy Demand	-	Renewable	*0,11%*
	Warm Water Energy Demand	*35 kWh/m² yr*	Emission CO2	*1490 Mton*
	Prymary energy	*65 TOE*	nzeb	-
RES				
Type	**Tecnologies**	**Power - Producibility**	**Self consumed**	**Exported**
FV	-	-	-	-
Solar	-	-	-	-
Eolic	-	-	-	-
....	-	-	-	-
Energy bills				
Electric Energy		**Gas methane**		
Average Cost	*0,22 €/kWh*	Average Cost	*0,95 €/Smc*	
Peak power	*171 kW*	Peak power	*2000 kW*	
Energy Cost	*45.000 €*	Energy Cost	*91.000 €*	
Elettrical Energy Demand	183 MWh	Gas Demand	*96000 m³*	

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Identification Data

End Use - **Residential**	Description - **Block of flats formed by 52 apartments**

Region	*Italy*	Climate Zone	*Humid - Temperate*
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Address	*Via Popilia*	Heated surface	*3856 m²*
Floor	-	Heated volume	*10405 m³*
sub	-	Cooling surface	-
Coordinates	*39.322532, 16.254040*	Cooling volume	-
Year of construction	*1978*		

Envelope Structure

Dispersant surfaces	*3498 m²*	Heating Performance	*1,9*
Heated Volume	*10405 m³*	Cooling Performance	*2,1*
Form Ratio S/V	*0,34*	Heating Load	306 kW
Average Global Thermal Coefficient of trasmission	*1,8 W/m²K*	Cooling Load	-
Average Trasmittance Thermic Periodic	*1,25 W/m²K*	MV [Summer - Winte	2,6 ; -2,2
Harmful material	Asbestos	PD[Summer - Winter	59 % ; 54 %

Energy systems and performance

Services	Type technologies - Carrier	Year of installation	Power	Efficiency
Heating	Gas boiler - Methane	1996	360 kW	75%
Cooling	-	-	-	-
Warm Water	Gas boiler - Methane	1996	360 kW	78%
Ventilation	-	-	-	-
....	-	-	-	-

Energy consumption

Energy class: 	Heating Energy Demand	*196 kWh/m² yr*	Electrification	*2%*
	Cooling Energy Demand	-	Renewable	*0,11%*
	Warm Water Energy Dema	*35 kWh/m² yr*	Emission CO2	*1490 Mton*
	Prymary energy	*65 TOE*	nzeb	-

RES

Type	Tecnologies	Power - Producibility	Self consumed	Exported
FV	-	-	-	-
Solar	-	-	-	-
Wind	-	-	-	-
....	-	-	-	-

Energy bills

Electrical Energy		Gas methane	
Average Cost	*0,22 €/kWh*	Average Cost	*0,95 €/Sm ³*
Peak power	*171 kW*	Peak power	*2000 kW*
Energy Cost	*45.000 €*	Energy Cost	*91.000 €*
Elettrical Energy Demand	183 MWh	Gas Demand	*96000 m³*

For more efficient combination of parameters, identification codes have been associated with them, as shown in Figure 27 – Parameter Codying:

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Figure 27 – Parameter Codying

Parameter Category	Parameter Name	Parameter Code
Identification Data	End Use	A.1
	Description	A.2
	Region	A.3
	City	A.4
	Address	A.5
	Floor	A.6
	sub	A.7
	Coordinates	A.8
	Year of construction	A.9
	Climate Zone	A.10
	People	A.11
	Heated surface	A.12
	Heated volume	A.13
	Cooling surface	A.14
	Cooling volume	A.15
Envelope Structure	Dispersant surfaces	B.1
	Heated Volume	B.2
	Form Ratio S/V	B.3
	Average Global Thermal Coefficient of trasmission	B.4
	Average Trasmittance Thermic Periodic	B.5
	Harmful material	B.6
	Heating Performance	B.7
	Cooling Performance	B.8
	Heating Load	B.9
	Cooling Load	B.10
	PMV [Summer - Winter]	B.11
	PPD[Summer - Winter]	B.12
Energy systems and performance	Heating	C.1
	Cooling	C.2
	Warm Water	C.3
	Ventilation	C.4
Energy consumption	Heating Energy Demand	D.1
	Cooling Energy Demand	D.2
	Warm Water Energy Demand	D.3
	Prymary energy	D.4
	Electrification	D.5
	Renewable	D.6
	Emission CO2	D.7
	nzeb	D.8
RES	FV	E.1
	Solar	E.2
	Wind	E.3
Energy bills (Power)	Average Cost	F.1
	Peak power	F.2
	Energy Cost	F.3
	Elettrical Energy Demand	F.4
Energy bills (GAS)	Average Cost	F.5
	Peak power	F.6
	Energy Cost	F.7
	Gas Demand	F.8

Example: PV SYSTEM:

We analyse the case of a photovoltaic renewable source plant. In this case we consider different benefits and parameters:

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Figure 28 - PV SYSTEM: Association of the minimum data requirements to the benefits including the beneficiary and the methodology (quantification of the benefit)

PV			
BENEFITS	**BENEFICIARY**	**METHODOLOGY**	**PARAMETER**
L.R. AVOIDED COST	GRID	Power-Producibility	F.3
REAL ESTATE VALUE	BUILDING OWNER	Cost of investement	B.11 - B.12
CLIMATE	COMMUNITY	Δ (CO2)	D.8

PV			
BENEFITS	BENEFICIARY	METHODOLOGY	PARAMETER CODE
LOAD REDUCTION	GRID	POWER-PRODUCIBILITY	F.2
AVOIDED COSTS	GRID	POWER-PRODUCIBILITY	F.3
REAL ESTATE VALUE	BUILDING OWNER	INVESTMENT	B.11 - B.12
CLIMATE	COMMUNITY	CARBON DIOXIDE EMISSION	D.7

3.5.8 Conclusions

The minimum data requirement identification is a step-by-step process that requires the accurate definition of a whole series of parameters and indicators that go beyond the traditional energy performance contract. In P4P schemes an approach should be used in which the multiple benefits are taken into account joined with a set of parameters that go beyond simple energy savings.

Therefore, in order to really quantify the benefits, it is necessary to take into account the indicators obtained through energy efficiency measures and the simple methods used to divide the financial flows between the subjects of the SENSEI model.

In this chapter we have exposed the parameters that are necessary for the ESCO to quantify the energy savings and the benefits; we see now a possible approach that the aggregator can use in order to quickly assess the EEM plan.

While for the aggregator it is necessary to have specific indicators that effectively summarize the energy efficiency plan, it is also clear that a sub-set of the ESCO parameters that express the quality of the intervention is needed. In this perspective we can summarize the EEM with 2 simple indicators:

Benchmark:

It is a photograph of the state of affairs of the building.

Target:

Shows the state of the building after the energy efficiency intervention. As shown in the following image:

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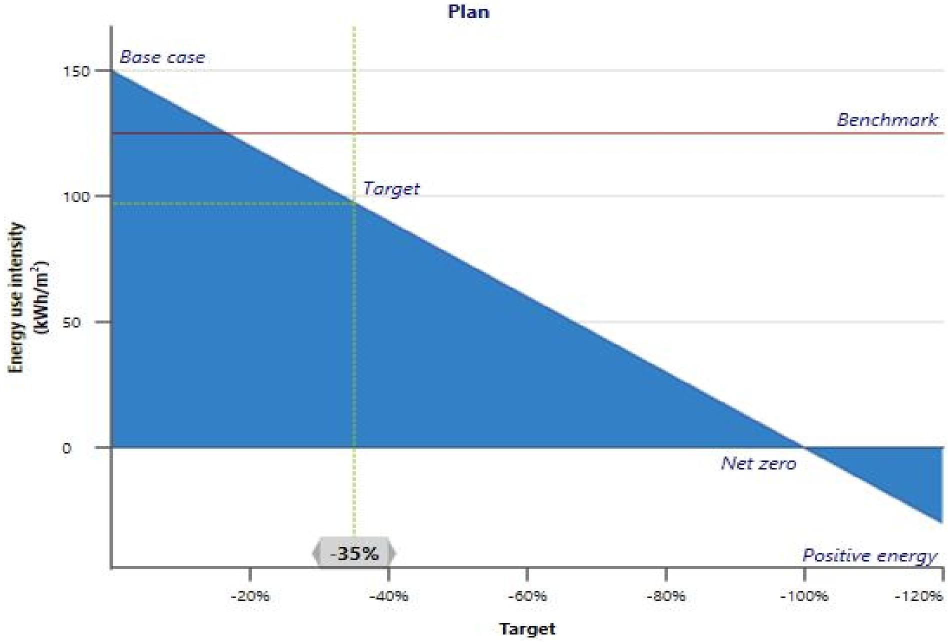
Figure 29 - PV SYSTEM: RETScreen Model for representing the energy saving



To get a more complete picture the aggregator could rely on a subset of parameters of ESCO, which we summarize below:

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Figure 30 - Minimum Data Requirements Aggregator-Side

AREA		Code	Main Indicators	u.m
B	Envelope Structure	B.7	heating Performance	-
		B.8	Cooling Performance	-
c	Energy Systems and performance	C.2	Carrier	-
		C.5	Efficiency	%
D	Energy Consumption	D.1	Energy Class	-
		D.6	Electrification	%
		D.7	RES	%
E	Energy Bills	E.2	Peak Power	kW
		E.4	Electrical Energy Demand	MWh

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		D.6	Electrification	%
		D.7	RES	%
E	Energy Bills	E.2	Peak Power	kW
		E.4	Electrical Energy Demand	MWh

With these few indicators the aggregator will be able to assess the state of the building and the constructive qualities of the impact that this has on the network and on the environment. Moreover the quality of the participation will be able to be appraised and like this it will affect the various actors of the sensei model.

Energy efficiency projects must be accompanied by the introduction of renewable energy sources of RES in order to partially or totally meet the building's needs. All buildings must aim at net-zero-energy through the transformation from consumer to prosumer and subsequently to non-sumer, according to the following steps:

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Figure 31 – Representation of the ideal path to optimize the single consumer

The key to the energy transition is that today's consumers will be tomorrow's active agents. A clear implication is that being an active agent involves managing actively the demand and to interact with the active user. To carry out these steps a great effort of the communities will be necessary but the transition will ultimately improve everyone's life.

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3.5.9 Acronyms

Acronym	Description	Units of measurement
A	Area	m^2
COP	Coefficient of Performance	-
E	Primary energy referred to surface unit	kWh/m^2
Kg	Kilogram	kg
kWh	Kilowatt-hour	kWh
kWh_e	Electric-Kilowatt-hour	kWh
kWh_{th}	Thermic-Kilowatt-hour	kWh
kWp	Kilowatt-peak	kWp
MWh	Megawatt-hour	MWh
T	Temperature	°C
ton	Ton	Ton
u.m.	Unit of measurement	
V	Volume	m^3

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