Ref. Ares(2021)4299902 - 01/07/2021

Risk reduction for Building Energy Efficiency investments

Energy Efficiency Investment Evaluation Framework

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n. 833112

Abstract

The EEnvest project is aimed at developing an innovative risk evaluation platform that minimizes uncertainty and reduces the informational gap embedded in deep energy efficiency projects. The project presents a multi-dimensional approach to analyze energy efficiency investments that includes energy and non-energy related benefits and thus increasing the level of attractiveness of these investments. In this quest, three major workstream led the construction of this Deliverable.

First, extensive research was carried around the underlying rationale that guides the ultimate investment decision and several case examples are presented. The outcome of this effort showcases how investors are widening their valuation methodologies by including environmental, social and governance factors into their analysis. High-level initiatives, such as the EU Taxonomy and the Principles for Responsible Investments are mapped.

Second, all existing impact incurred when investing in a deep energy project are defined. One of the main contributions of this Deliverable is a set of KPIs that encompasses the non-energy dimension of this type of projects. These KPIs unfolds the hidden benefits of energy efficiency.

Last, an Energy Efficiency Investment Evaluation Framework is defined in order to elaborate an innovative valuation methodology to assess the investment case and further analyze how the asset value changes if non-energy factors are included in the assessment.

Since the Energy Efficiency Investment Evaluation framework is defined, the actual valuation methodology will be developed and described in D4.3. As such, the present work sets the foundation for ulterior work.

Document information

Authors	Patricio Cartagena, Fernando Salat and Jaime Gomez-Ramirez (GNE Finance) Patricio Cartagena, GNE Finance p.cartagena@gnefinance.com Phone: +56 9 98958622
Quality reviewers	Emmanuelle Causse, UIPI Annalisa Andaloro, Eurac Research
Deliverable type:	Report
Dissemination level:	Public
Actual delivery date:	6 November 2020
Version:	Final
Keywords:	DER investments, Framework, Energy Efficiency, Valuation Methodologies, EU Taxonomy, Principles for Responsible Investments, Fiduciary Duty, Investment Objectives.
Project title	Risk reduction for Building Energy Efficiency investments
Project acronym	EEnvest
Project website	http://www.eenvest.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement n. 833112.

Version Log			
Issue Date	**Rev. No.**	**Author**	**Change**
14/08/2020	0.1	Patricio Cartagena	Draft
31/08/2020	0.1	Fernando Salat	Review
29/09/2020	0.1	Patricio Cartagena	Draft
05/10/2020	0.1	Emmanuelle Causse	Review
09/10/2020	0.1	Patricio Cartagena	Draft
13/10/2020	0.1	Fernando Salat	Review
15/10/2020	0.1	Patricio Cartagena	Final Draft
27/10/2020	0.1	Emmanuelle Causse	Final Review
28/10/2020	0.1	Annalisa Andaloro	Final Review
06/11/2020	0.1	Patricio Cartagena	Final Version
01/07/2021	0.1	Patricio Cartagena	Revision of formatting upon request of the European Commission

Table of Contents

List of figures

List of Tables

List of abbreviations and acronyms

EE	Energy Efficiency
DER	Deep Energy Retrofits
MBs	Multiple-Benefits
SDG	Sustainable Development Goals
ESG	Environmental, Social and Governance
PRI	Principles for Responsible Investments
EU	European Union
EC	European Commission

Executive Summary

This report presents part of the work under WP4 *Investment evaluation models for energy efficiency including multiple-benefits*. With the objective of stablishing a framework for assessing energy efficiency investments, D4.1 was developed in parallel with T4.2 *Creating a business case for non-energy related benefits* to offer a holistic investment assessment and thus it's fully presented in Annex B.

Renovating the EU building stock is essential to achieve the EC climate goals for 2030 and 2050 and hence proper access to financing, either private or public financing, is crucial. In addition, there are widely acknowledged barriers that hinder the upscale of renovation projects across Europe that must be tackled. In order to provide a solid energy efficiency valuation framework, this report exposes these barriers and focuses on two of them that are explained below.

First, DER projects are usually not attractive to investors due to the lack of standardized valuation methodologies, scarce information to conduct risk-analysis and long payback periods. These characteristics are deeply embedded in DER projects and hence investors are reluctant to deploy capital towards these endeavors.

Second, DER projects have been historically assessed mainly based on energy reduction metrics and in some cases, maintenance costs metrics are included in the analysis. However, the impact of DER projects goes far beyond these two aforementioned metrics. Recently literature in the matter has unveiled the hidden benefits of DER projects and classified them as multiple-benefits or non-energy benefits. If multiple-benefits are properly (i) identified, (ii) measured, and (iii) communicated, investors may perceive higher incentives to invest in DER projects.

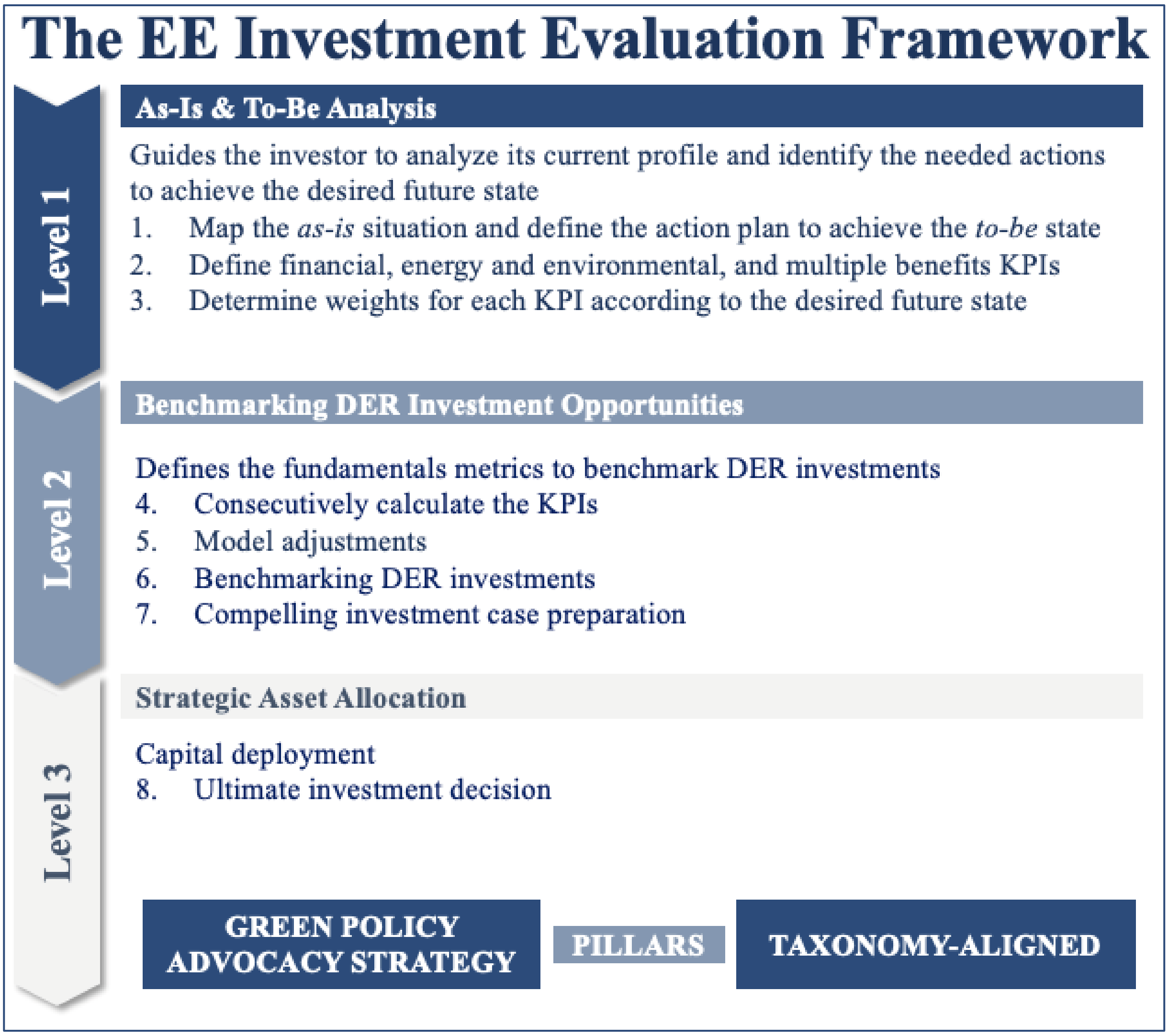
In this context, the first section of this report, Chapter 2, exposes the underlying rationales that guides the investment decision-making process and pinpoint high-level initiatives aimed at encouraging investors to consider environmental, social and governance (ESG) components as part of the investment assessment. As result, investors are being encouraged to include ESG factors as part of their fiduciary duty and therefore are adapting their in-house investment assessments methodologies. Other high-level initiatives aimed at this task are the Principles for Responsible Investments and the EU Taxonomy. Annex A presents a deep-dive in this topic and it's support by two cases: BlackRock's approach to ESG and Climate related investments and the Institutional Investors Group on Climate Change's Net Zero Framework.

The second part of this report, Chapter 3, 4 and 5 builds the case for defining the non-energy benefits' key performance metrics (KPIs) that are crucial for assessing DER projects. In order to construct a compelling DER investment case, a selected set non-energy benefits KPIs is proposed. These are:

KPI	NEB Values Range relative to Energy Savings	Consistency across programs [1..5]	Investor Weight [1..5]
Thermal Comfort	[1% , 51%]	4	3
Acoustic Comfort	[5%, 35%]	2	3
Visual Comfort	[1% , 44%]	3	3
Air Quality(Environmental)	[5% , 50%]	2	4
Perceived Physical/ Mental Health	[2% , 47%]	3	3

Productivity per employee	[5% , 33%]	3	4

In the quest of building a holistic DER investment case that takes into account ESG factors, Chapter 6 presents an Energy Efficiency Investment Valuation Framework that is aimed at walking investors through all key areas to properly assess a DER investment opportunity. The Framework outlines the essential topics for investors relations and further positions DER investments as a mean for decarbonizing investors' portfolio. Last, it facilitates the access for financing to building owners and tenants.



The Energy Efficiency Investment Valuation Framework is the steppingstone for T4.3 *Case Studies & Sensitivity Analysis based on Business Model* and T4.4 *Valuation methodology for EE investment including Multi-benefit.*

1 INTRODUCTION

Although energy efficiency renovations are widely considered as a cornerstone to reach the EU climate targets, there are several limitations that constraint a full-force display of these type of investments. These barriers are deeply embedded in energy efficiency retrofits and affects all stakeholders present in the renovation process: building owners, investors, energy experts, contractors and tenants. Acknowledging the complex context of EE renovation projects, the Consortium's work is primarily focused on institutional investors and asset managers (i.e. not focused on individual investors). Further, the scope of the EEnvest project is aimed at renovation works in commercial buildings or commercial real estate (CRE), as stablished by the European Systemic Risk Board in (ESRB, 2015) and reinforced in (ESRB, 2019)[1].

To this end, the Consortium leverages on a 2011 Buildings Performance Institute Europe's publication (BPIE, 2011) and a (Alam, et al., 2019) study that clusters these barriers into four categories: (i) Financial, (ii) Institutional and Administrative, (iii) Awareness, Advice and Skills and (iv) Separation of expenditure and benefits. These hurdles are exhaustively discussed in recent literature (Hamilton, Brahmbhatt , & Liu, 2017) and the Consortium supported its' expertise on the matter with a 2020 JRC[2] Technical Report written by (Shnapp, Paci, & Bertoldi, 2020) and a report written by (Palm & Reindl, 2017). As result, the main barriers for EE retrofits are listed below:

- Presence of informational gaps within buildings' renovation value chain;
- Shortage of specialized technical contractors to boost demand on retrofits;
- Absence of information regarding benefits other than energy benefits;
- Little knowledge about EE measures, equipment and sustainable materials; and
- Discrepancies between predicted and actual energy savings.

Consequently, these barriers are directly transferred to a strong scarcity of tailor-made EE financing products. In detail, from an investor standpoint, lack of information hinders the investment assessment and hence investors are less attracted to undertake energy efficiency investments. Such a context represents a significant hurdle for the development of the sector and in particular for the activation of large-scale investments with the support of financial institutions. The existing barriers on the financing realm are presented below:

- DER projects usually have long payback periods;
- Investors may be reluctant to invest capital in the short term for longer term returns;
- Financier may not be the one receiving the full benefit of the retrofit;
- Lack of standardized financial valuation models and frameworks; and
- Insufficiency of available data to construct reliable and scalable models.

In spite of such a challenge, the EEnvest project is strategically stablished to close the gap between investors and demand of investments in deep energy retrofits (henceforth DER) projects in commercial buildings. To achieve this objective, it is imperative to facilitate key economic, financial and technical information to investors in order to ease the investment decision. In this sense, minimizing the discrepancy between predicted and actual energy savings is crucial as it represent the main source of revenue stream for the financial analysis to be put in place by investors. Some EU H2020 projects are contributing to this task, this is notably the case of the Alliance for Deep Renovation in Buildings Project (ALDREN Project[3]) whose key contribution is to conduct a reliable assessment of the actual current

[1] These two guidelines are predominant throughout the present Deliverable. As such, the consortium's work does not address individual investors nor residential properties.
[2] European Commission's Joint Research Center
[3] For further information, please refer to: https://aldren.eu.

energy performance and indoor environmental quality of a building and provide a prediction of future energy performance after implementation of energy-related investment[4].

As ultimate outcome of the EEnvest Project, key data that allows a compelling investment assessment will be presented as investor-ready parameters that will be displayed in the form of an all-in-one platform secured by blockchain technology. Further, standardized frameworks for technical and financial due-diligence will be proposed in order to position energy efficiency investments as appealing for the financial market.

In the quest of reducing energy efficiency investments uncertainty, prior WPs focused exhaustively on risk mitigation. Specifically, technical risks (WP2) and financial risks (WP3). The output of these WPs is presented as parameters for the web-based platform that is being developed on WP5. The present work, WP4, contributes with an Energy Efficiency Investment Framework that includes KPIs that are relevant for investors and proposes as focal point how non-energy related benefits may impact the investment assessment and property value. The next paragraphs offer an overview of each WP.

WP2 assessed the technical risks embedded in energy efficiency investments and proposed a calculation methodology to determine technical risks through two key indicators. These indicators, energy gap and damage, are combined to determine the probabilistic trend of several occurrence linked to the specific renovation scenario (i.e. tailored to each investment case).

WP3 focused on developing an exhaustive methodology for financial risk analysis. First, a standardize framework is proposed to map energy efficiency investments context. Second, a risk model is stablished to ultimately quantify the risks and its' impact on the financial analysis. Last, all key financial information is presented in a selected set of investor-ready parameters.

WP4 is aimed at providing a compelling methodology for energy efficiency investment assessment, that not only includes financial and technical parameters, but also energy and non-energy parameters that are crucial to assess the investment opportunity in a holistic manner. Therefore, the main contribution of WP4 is the inclusion of energy and non-energy benefits[5] into the financial assessment, with strong emphasis in non-energy benefits arena.

As part of WP4, D4.1 objective is to provide investors with an Energy Efficiency Investment Evaluation Framework that is aimed at guiding the investment assessment. The main contribution of The Framework is the inclusion of non-energy benefits to the investment assessment as well as linking DER investments as part of ESG investments. As such, the present Deliverable is built on extensive academic research including several H2020 EU Projects, WP2, WP3, interview with experts and the Consortium's vast expertise with investors. It is also built upon T4.2[6], which is attached in Appendix B.

D4.1, as part of T4.1, also feeds the development of *T4.4: Valuation Methodology for EE investments including multiple-benefits*. This work will be presented in D4.3 and it is aimed at unveiling all impact incurred when investing in DER projects. As such, D4.3 will also analyze the variation in the asset value: ex and post DER project. The proposed methodology will be sustained by three components:

1. Evidence based;
2. Investor-ready information: user-friendly and jargon-free (input from T4.1 and T4.2); and
3. Digital: presented in the web-based platform (WP5).

[4] The ALDREN Project has synergies with WP2 and it may be reviewed, specifically the proposed sustainability metrics, for T4.4.
[5] In this report, non-energy benefits and multiple-benefits are used as synonyms.
[6] T4.2 is not conceived as a Deliverable. However, the Consortium defines T4.2 as an extremely valuable source of insights for D4.1 and for current and further research on Multiple Benefits. For an extensive review please see Appendix B.

Strongly supported by literature, three principles guided the development of the present Deliverable:

1. Stand-alone financial assessment is not sufficient to properly assess energy efficiency investment opportunities. As such, a holistic approach is proposed.
2. Split incentive: Landlord may be hesitant to invest in new energy efficiency equipment, as they are responsible for the capital cost, while the tenant is the one benefiting from lower energy bills.
3. Non-energy benefits ultimately determine the intrinsic -but yet difficult to quantify- financial market value of the asset:
    a. Tenant: pay higher rent due to all benefits undertaken
    b. Owner: sell property at a higher price due to renovation measures (greemium).

Considering these principles, WP4 -specifically T4.1 and T4.2- leverages on the risk analysis performed in WP2 and WP3 to ultimately include energy and non-energy benefits into the investment assessment.

Chapter 2 depicts the energy efficiency investment case and the relevance of these investments to reach EU 2030 goals. Strongly supported by Annex A, this chapter offers an overview of ESG investment flows at European-level and it defines the underlying objectives and goals that guides the investment decision making process of EE investments. As such, Chapter 2 builds the case for including non-energy benefits in the investment assessment.

Chapter 3 presents an overview of KPIs relevant for EE cases and consequently, Chapter 4 -strongly based on literature review- outlines the relevance of multiple benefits and its' contribution to perform an accurate investment assessment. As result, this Chapter provides a short list of KPIs that quantifies, whenever possible, the impact of MBs in the asset value: greemium.

Chapter 5 takes a practical approach and presents EE investment cases in order to set the ground for MBs inclusion in the financial assessment of EE projects. This work is connected with T4.4 and other EU H2020 Projects.

Chapter 6 presents the EE Investment Framework that includes energy and non-energy related benefits. This output is the foundation of T4.3 and T4.4. And Chapter 7 proposes the Consortium final remarks.

As final note, the Consortium presents in Annex A an exhaustive review of high-level initiatives aimed at easing investors' inclusion of ESG factors as part of their investment objectives and presents two cases to better illustrate this effort. Further, the work performed during T4.2: *Creating a business case for non-energy related benefit* is fully presented in Annex B as it was performed in parallel with D4.1 and it also represent significant work and thus it's one of the major contributions of WP4.

2 THE ENERGY EFFICIENCY INVESTMENT CASE

2.1 CONTEXT AND THE INVESTMENT OPPORTUNITY

Environmental and climate policy is one of the key areas of intervention for the EU, taking into account the long-term vision of becoming a carbon neutral continent by 2050. To this end, as part of the European Green Deal the EC proposed in September 2020 a more ambitious target: to raise the 2030 greenhouse gas emission reduction target, including emissions and removals, to at least 55% compared to 1990 levels (EC, 2020). Complementary 2030 goals are defined in (ECa, 2019), stating as necessary to account with no less than 32% share for renewable energy and at the minimum of 32.5% improvement in energy efficiency.

In order to meet the EC goals, significant work must be put in place at all levels in regards of legislative and financing efforts. Thus, the EC widely acknowledges the relevance of sustainable finance in making these objectives reachable and it is constantly working towards creating the ideal framework to encourage all financial institutions and private investors to play their part in the quest of becoming a carbon neutral continent. Figure 1 below depicts the role of sustainable finance according to the EC definition on the matter and Figure 2 illustrates the capital flow required to tap the investment gap.

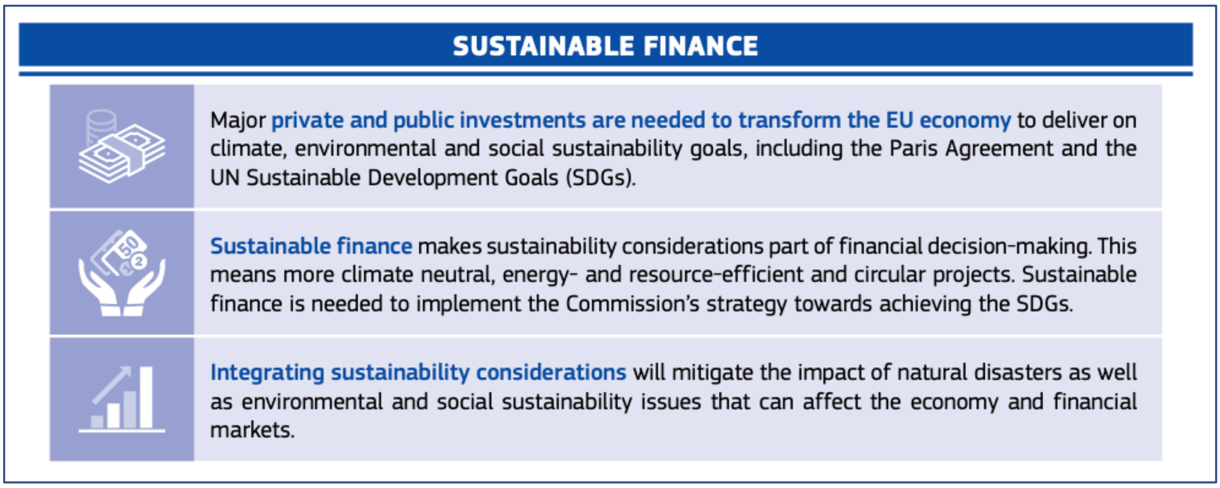


Figure 1: Sustainable Finance's relevance and definition

Source: European Commission 2020

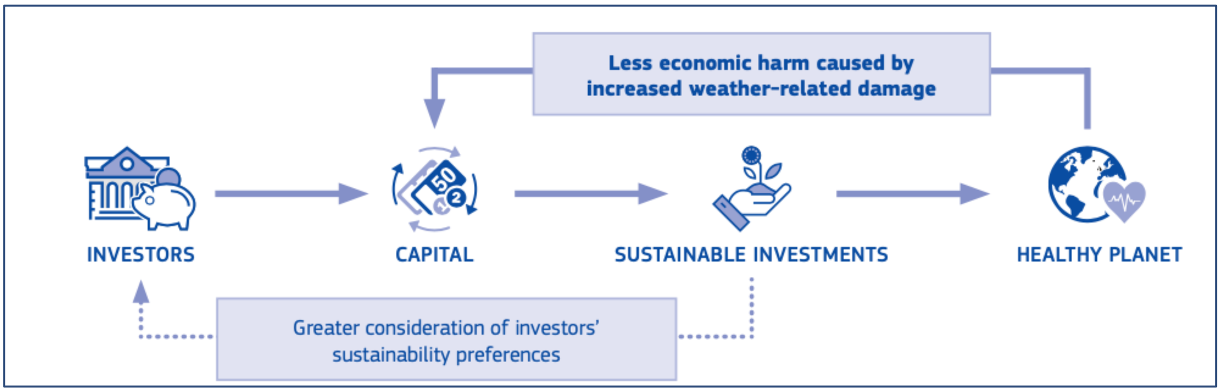


Figure 2: Capital workflow for sustainable investments

Source: European Commission 2020

In parallel to enabling sustainable finance at large scale, a common-for-all framework needs to be put together. With this objective, the EC is currently working on a Taxonomy Regulation to determine whether an economic activity can be classified as environmentally sustainable (i.e. Taxonomy-aligned). The implications of the EU Taxonomy are significant and affect not only the financial sector, but rather all stakeholders and issuers within the EU and beyond. In brief, the financial sector will be motivated or even obliged to base their investment analysis considering the environmental impact of their portfolios.

Under the EU Taxonomy Regulation work stream, the European Commission established a Technical Expert Group on Sustainable Finance in order to provide thorough recommendations -primarily focused on climate change mitigation and adaptation. The (TEG, 2020) report was released earlier this year and it represents the cornerstone for the development of the EU Taxonomy. The report contains (i) recommendations relating to the overarching design of the EU taxonomy and it further provides (ii) guidance to use and disclose against the Taxonomy. For a deep-dive on this topic please refer to Annex A.

Acknowledging the relevance of the EU Taxonomy, the Consortium promotes and encourages all stakeholders to closely monitor and adopt further work on the matter as it is expected that the Taxonomy will become a common standard to define, classify and ultimately, approve any sort of economic activity and financial investment.

In the light of achieving the EC climate targets, a comprehensive review of the EU building stock is mandatory -scope of the EEnvest Project-. It represents 40% of all energy consumption in the EU and 75% of these buildings are considered as energy *inefficient* (i.e. not at an energy performance level needed to meet EU 2050 decarbonization goals) (EC, 2019). Further, the building stock is currently being renovated at a modest rate of 1-1.5% and such a rate is considered extremely low by the European Commission, stating that in order to achieve 2050 targets the renovation rate must be at least triplicated to reach an annual renovation rate of 3-5% (EC, 2019; Shnapp, Paci, & Bertoldi, 2020). Such challenging quest requires significant capital that must be deployed from both public and private entities. It is estimated that an investment of 177 billion Euros per year is needed to meet 2030 targets and that specifically 133 billion Euros, 70% of the estimated investment needed, should be allocated to propel the energy performance of the EU building stock (EC, 2016) . As an attempt to magnify the investment demand for energy efficiency investments, the Building Performance Institute Europe constructed in 2011 a "Deep" scenario that reflects a present value of cumulative investment demand of 937 billion EUR until 2050 (BPIE, 2011). This amount cannot be financed from the public sector alone and therefore strong engagement of the private sector is urgently needed (Bleyl J. W., et al., 2019).

Under this context, in 2011 the United Nations launched an overarching global initiative named Sustainable Energy for All (SE4All[7]). This endeavor is aimed at three interlinked 2030 objectives: "1.

[7] For an overview of the Project, please refer to: https://www.seforall.org

Ensuring universal access to modern energy services; 2. Doubling the global rate of improvement in energy efficiency; and 3. Doubling the share of renewable energy in the global energy mix." Specifically Point 2 outlines the key role that energy efficiency plays in tackling major environmental challenges that affects the whole globe. Indeed, the International Energy Agency (IEA) and scholars world-wide denote energy efficiency as the *first fuel* for economic development and for the EU 2030 climate and energy policy framework (Zancanella, Bertoldi, & Boza-Kiss, 2018). Energy efficiency is also perceived as the *low hanging* fruit in the clean energy transition (IEA, 2019). Bearing this context, it is fair to conclude that energy efficiency is widely perceived as a clear vehicle to meet EU climate goals whilst promoting three pillars of sustainable development: economic development, social development, and environmental protection (Ferreira, Almeida, & Rodrigues, 2017).

To strengthen the case for energy efficiency retrofits in the building sector, the EPBD requires Member States (MS) to develop long-term renovation strategies to decarbonize the building stock by 2050. It also mandates nearly zero-energy buildings (NZEB) as the standard for all new buildings. Specifically, the EPBD signals *in "Article 4(1) that MS shall take the necessary measures to ensure minimum energy performance requirements for buildings or building units are set with a view to achieving cost-optimal levels".* Although the energy saving, environmental an societal impact of retrofitting the EU building stock is enormous (Bleyl, y otros, 2017) to fully unlock its potential several social, financial, technical and administrative barriers need to be addressed as energy efficiency investments typically impact different stakeholders (Zancanella, Bertoldi, & Boza-Kiss, 2018).

In order to better understand why the EE gap exists, several scholars took a deep dive in the matter over the past quarter century. Supported by the Consortium's knowledge on the subject, the following factors are exposed: (i) principal-agent issues, (ii) short-term managerial decisions, (iii) capital market imperfections, (iv) lack of information on equipment performance, (v) energy price uncertainty, and (vi) transactions costs among other factors.

The overarching barrier is that there are several informational gaps within the buildings' renovation value chain. As result, from an investors standpoint, the informational gap is immediately translated into higher risks embedded in the investment case, as there is scarce information to include as input for financial valuation models.

Further, access to competitive financial instruments is not the first bottleneck and nor the only barrier. Overall misinformation, lack of reliable valuation models and poor reliability of the performance energy efficiency equipment represents only a subset of barriers that hinders the uptake of DER investments (Hamilton, Brahmbhatt , & Liu, 2017; Palm & Reindl, 2017). Consequently, risks related to energy efficiency retrofits are evaluated on an ad hoc basis and without a systematic approach.

All the aforementioned effects create the so-called investors' dilemma (e.g. lack of information to properly assess an investment opportunity). As result, investors do not perceive concrete incentives nor possess access to the necessary tools to properly assess EE investments. The informational gap is untangled below:

- Technical market fragmentation: lack of standardization with regards to technologies and implementation processes, hindering project quality and deviating the expected energy performance;
- Investment yield unpredictability: lack of KPIs and benchmarks to set comprehensive economic rationales for EE in buildings. Moreover, current financial valuations methods are merely based on financial indicators with strong emphasis on payback expectation;
- Lack of one-stop-shops, structured databases and reliable tools to ease the decision-making process for investors. Furthermore, the lack of these components limits the understanding of DER investments and hence obstructs investors to include different dimensions of impact:

O&M cost reduction, property increased value (greemium), increased productivity, non-energy related benefits, security and brown discount[8].

Considering all the aforementioned barriers that hinders the uptake of EE investments, it is fair to conclude that the overall context for these investments type is highly uncertain. As such, a fraction[9] of financial institutions, asset managers and private investors do not perceive concrete incentives to undertake these investments and hence they tend to prefer other investment opportunities that are not necessarily linked with the EU climate goals.

However, strong efforts led by the EC and major entities are gaining force to minimize risks embedded in EE investments. Several EU-level projects are currently being developed in order to provide all necessary tools to fully comply with the investment demand for energy efficiency. For instance, the RenoValue Project[10] has developed an exhaustive toolkit for property valuation professionals on how to factor sustainability into the valuation process. The underlaying rationale of the Project is that high performing buildings do not only perform better in terms of energy efficiency but also financially, commanding higher rents or resale prices (i.e. *greemium*). Another major conclusion of the RenoValue Project is that consumers and investors will respond favorably to energy efficiency and renewable energy sources if these are presented to them in a way that offers them value. These conclusions will be further reviewed in T4.4. as they may contribute to the valuation methodology to be developed in WP4.

Another relevant remark that must be taken into consideration when implementing valuation methodologies for EE investments, is the life cycle of buildings. Analyzing a building over the course of its entire life aids to comprehend the inherent costs that are incurred at different stages of the life span of the asset. These stages are defined in (Kotaji, 2003) as the design, construction, operation, demolition and waste treatment phases. From a financial standpoint, understanding the Life Cycle Cost Analysis (LCCA) of buildings is crucial to define the cost of a structure of the asset over its expected life along with operational and maintenance cost. LCCA can be improved by adopting alternative modern techniques, such as EE measures, without much alteration in the building (Kale, Joshi, & Menon, 2016). Bearing the scope of the EEnvest Project, the Consortium leverages on a (Bleyl J. W., et al., 2019) study to fully understand the implication of the building life cycle in the financial assessment. The study applies a dynamic Life Cycle Cost & Benefit Analysis (LCCBA) to model the cash flows (CF). The proposed model also includes an appraisal of debt and equity financing implications and it is the basis for the valuation methodology to be yet proposed in T4.4.

As expected outcome of all EC's initiative and scholars, the total amount of EE investments will constantly increase due to the creation of standardized methodologies to utterly assess energy efficiency investments and hence, minimizing risks for public and private investors. In this regard, the crucial question relies on whether the supply for EE investments will arrive on time to accomplish EU 2030 and 2050 goals.

In the light of building a sound framework for EE investment for investors, the next section explores investors' underlying rationales that guides investment decisions and pinpoints the opportunity to build a compelling investment case for EE.

---

[8] A brown discount occurs when low-efficiency buildings loose rent and sales value due to their poor energy performance.

[9] As presented along the report, there are some investors that pursuit EE investments. In this regard, the Consortium's work is aimed at increasing the capital flow toward EE projects -which is indeed the scope of the EEnvest Project.

[10] For an overview of the Project, please refer to: http://renovalue.eu.

2.2 INVESTORS RATIONALE

In order to explore opportunities to enhance the EE investment case for different investors profiles, a compelling understanding of the main drivers that guide the investment decision-making process must be understood.

As first step, regardless the investor profile, investors are guided by a specific investment objective. In other words, investors typically set the foundations and principles that must be pursued when investing in a specific project. Fair is to mention that these goals and principles are commonly shared, understood and agreed between investors or a specific investment firm. Evidently, different type of investors (or investment firms) pursue different goals and hence valuation methodologies may vary from one financial institution to another.

Once these drivers are defined and become a common objective for the investment team, as second step, investors define the specific metrics that will guide the investment assessment. These metrics are highly dependent on investors' profile and can be easily communicated amongst investment partners and key stakeholders.

The third step entails a financial analysis, where valuation methodologies assess a specific project and therefore it depicts the project performance in a single set of key metrics to ultimately benchmark the investment opportunity against other projects. Consequently, the latter exercise determines whether to invest in a specific project or not. This decision represents the fourth and final step and it is heavily supported by specific thresholds set by the investment team or moreover, by the investment firm as all of its' investments must comply with the investment principles, objectives and values of the respective firm.

Acknowledging the general but yet common investment framework emplaced by investors, it is plausible to state that historically, investors on average have constantly prioritized financial returns over any other type of possible return or positive impact such as social and environmental impact. This prioritization can be explained by two simple concepts that are strongly rooted in the investment decision making process:

1. Fiduciary duty: Fiduciaries act on behalf of another person or entities to manage assets and hence the fiduciary owes to that other entity the duties of good faith and trust when managing the assets. This can be defined as the fiduciary responsibility.
2. Uncertainty: High levels of uncertainty are translated into higher perception of risks. Consequently, the larger the possible outcomes are, the more likely the outcome can be negative or in this case, can produce an extensive loss of capital. Accordingly, when investing in high-risk investments, the higher the cost of capital and the higher the expected return: risk premium.

Analyzing the aforementioned concepts together, investors must comply with their fiduciary duty to the best of their knowledge and must constantly report to their clients about the performance of the investments. Thus, the less uncertainty present in the investment, the easier it is to assess the investment opportunity and consequently the investment reporting that must take place along the time horizon defined by the investment or project. All in all, historically investors experienced strong disincentives to invest in projects that are highly uncertain and moreover, with little financial returns and long payback periods – both factors are deeply embedded in DER projects.

However, strong policies and high-level initiatives are taking place in order to set the ground for green investments and hence supporting investors to decarbonize their portfolio by incurring to ESG, SDG or Climate related investments. In the quest for green portfolios, investors world-wide are re-assessing their valuation methodologies, investment goals and firms' principles. The Consortium proposes the EU Taxonomy as the appropriate source of guidance to navigate such transition. In addition, Annex A presents the Institutional Investors Group on Climate Change Net Zero Framework Initiative.

In spite of building a common framework for EE investments, the Consortium conducted in-depth research to determine which initiatives, mandates and metrics are easing investors' transition towards greener portfolios. This exhaustive work is fully presented in Appendix A and the three major conclusions are presented below.

First, high-level initiatives are aiding investors to include ESG related factors into their investment assessments and further report the performance of their portfolios. However, it is expected that those investors that do not consider ESG components as part of their fiduciary duty may be penalized due to future regulations such as the EU Taxonomy. All in all, financing is now defined as the guiding vehicle to invest in endeavors with positive impact and therefore some investors will have to divest large parts of their portfolios.

Second, shifting the scope of the investment is not an easy task and it requires support from all stakeholders. For instance, initiatives such as the Principles for Responsible Investments and the trend for Sustainable Financing represents a valuable source of guidance and best practices that must be leveraged in order to lower portfolios' CO2 emissions, amongst other metrics. Annex A offers a deep-dive in the matter and also presents illustrative cases such as BlackRock's hands-on approach towards ESG and Climate related investments.

Last, measuring different types of impacts is the key activity that must be properly addressed and standardized in order to set common ground for investment valuations and subsequently reporting. This challenging task requires significant effort and it relates with the core of this report: The Energy Efficiency Valuation Framework.

Taking into account the aforementioned conclusions plus Annex A, the following Chapters, 3, 4 and 5 are aimed at building the case of an exclusive set of KPIs that enhance the investment assessment of DER projects and thus these KPIs pave the way for linking DER investments with ESG, Sustainable Financing, SDG and best investment practices components. These findings are foreseen to standardize how DER projects are evaluated.

3 KEY PERFORMANCE INDICATORS IN EE - OVERVIEW

The importance of Key Performance Indicators (KPIs) in any form is widely acknowledged in different professional fields and in literature. In the quest of designing a compelling Framework for EE investments, this section is aimed at identifying which KPIs are of interest of investors in order to increase EE investments' attractiveness. Therefore, KPIs to be included in the Framework and further presented in the EEnvest Platform (WP5), are expected to be used for benchmarking investment opportunities.

As opening stop, the Consortium conducted extensive literature review to identify a non-exhaustive set of KPIs for further analysis and peer-to-peer discussion. This approach led directly to the European Federation of Financial Analysists Societies' (henceforth EFFAS) work published in 2009 under the name of *KPIs for ESG – A Guideline for the Integration of ESG into Financial Analysis and Corporate Valuation* (EFFAS, 2009) . The work has been widely applauded in Europe and it's strongly backed by investment professionals and thus the work is recognized as an official EFFAS Standard.

Throughout extensive analysis and internal discussion, two main Figures are extracted from the EFFAS' work as they set the foundation for the KPIs to be included in the EE Framework. First, the EFFAS' defined nine areas of work that applies for all industries. These are exposed in Figure 3 below.

	E **Environmental**	**S** **Social**	**G** **Governance**	**V** **Longterm Viability**
General: ESGs which apply to all industry-groups	ESG 1 Energy efficiency ESG 2 GHG emissions	ESG 3 Staff turnover ESG 4 Training & qualification ESG 5 Maturity of Workforce ESG 6 Absenteeism rate	ESG 7 Litigation risks ESG 8 Corruption	ESG 9 Revenues from new products

Figure 3: Eligible ESG endeavors for all industry groups.

Source: EFFAS[11]

Guided by these areas of work, the Consortium defined the following conclusions:

1. EE is perceived as cornerstone of ESG topics and therefore it can guide the investment narrative and also be proposed as a mean to decarbonize investors' portfolio. Further, it also enhances investors' corporate image;
2. GHG emissions are evidently a relevant topic. If it's possible to determine a specific method for quantification, it can be used to benchmark different investment opportunities; and
3. In the Social category, ESG 3 Staff Turnover and ESG 6 Absenteeism Rate may be included in the EE Investment Framework as these KPIs may decrease[12] when incurring DER.

[11] Retrieved from (EFFAS, 2009).

[12] A decrease in turnover or absenteeism rate is considered as beneficial from any perspective, as the employee may feel more joy when working and therefore its' major input may cause higher business output -from the perspective of the business owner.

Second, the EFFAS' proposed a set of KPIs to measure the nine topics of work mentioned in Figure 3 above. The KPIs list proposed by the EFFAS is exposed in Figure 4 below.

ESG	KPI
ESG 1 Energy efficiency	ESG 1-1 Energy consumption, total
	ESG 1-2 Energy consumption, specific (intensity); Options: per unit of revenue, per employee, per unit of production volume (tons of steel, for example)
ESG 2 GHG emissions	ESG 2-1 GHG emissions, total
	ESG 2-2 GHG emissions, specific; Options: per unit of revenue, per employee, per unit of production volume (tons of steel, for example)
ESG 3 Staff turnover	ESG 3-1 Percentage of employees leaving p.a./total employees (FTE?)
ESG 4 Training & qualification	ESG 4-1 Percentage of trained employees p.a./total employees (FTE?)
	ESG 4-2 Average expenses on training per employee p.a
ESG 5 Maturity of workforce	ESG 5-1 Age structure/distribution (number of employees per age group, 10 year intervals)
	ESG 5-2 Percentage of workforce to retire in next 5 years
ESG 6 Absenteeism rate	ESG 6-1 Number of mandays lost per employee p.a.
ESG 7 Litigation risks	ESG 7-1 Expenses and fines on filings, law suits related to anti-competitive behavior, anti-trust and monopoly practices
	ESG 7-2 Reserves on preventive measurements against anti-competitive behaviour, anti-tust and monopoly practices
	ESG 7-3 (other) litigation payments, total
	ESG 7-4 (other) litigation payments, reserves
ESG 8 Corruption	ESG 8-1 Percentage of revenues in regions with TI corruption index below 6.0
ESG 9 Revenues from new products	ESG 9-1 Percentage of revenues from products at end of life-cycle
	ESG 9-2 Percentage of new products or modified products introduced less than 12 months ago

Figure 4: EFFAS' KPIs that are relevant for the EEnvest Project.

Source: EFFAS[13]

As additional remark, the Consortium outlines that climate resilience may gain relevance in the upcoming years as in the quest to adapt to the new reality, infrastructure plays a crucial role. In specific, buildings can be vulnerable to climate change and this implies a possible increase in the risk of collapse and significant loss of value as results of climate conditions such as storms, snow and water encroachment (Climate ADAPT, 2020). However, this topic needs further work and it is acknowledged as out of the scope of the present Deliverable.

The non-exhaustive list specified by the EFFAS provided both, an initial understanding on which KPIs are relevant to investors and possible methodologies for KPIs quantification and subsequent monitoring and reporting. In order to narrow the scope, the quantification methodologies proposed by the EFFAS have been reviewed by the Consortium and they supported the development of Chapter 4. Additionally, three main conclusions supported our investigation to build the EE Investment Framework. These are:

1. There's a clear distinction between KPIs that are related to environment (energy consumption and GHG emissions) and to social aspects. The latter may be difficult to quantify but a comprehensive understanding of non-energy KPIs must be emplaced in order to build a compelling EE Investment Framework. Evidently, these KPIs emanate from DER;
2. The KPIs to be yet proposed must have a universal focus and therefore are based on the Consortium experience with investors and experts' contributions; and

[13] Retrieved from (EFFAS, 2009)

3. KPIs are strongly subjected to investors' profile. Therefore, a thorough clustering of KPIs have to be designed in order to cope with EE Investments uncertainty from a holistic standpoint. In this sense, the EE Investment Framework must tailor its' approach to the EEnvest Project, which is focused in commercial buildings.

Last and extremely relevant to EE Investments, ESG-related KPIs needs to be accompanied by explicit and measurable financial KPIs, as investors demand a certain degree of return on investments. It is plausible to stress that regarding KPIs weighting, it's primarily dependent on investors' objectives, principles and goals.

Taking into consideration the previous analysis regarding how a DER project impact not only the environment but also social and economic aspects, the following Chapter narrows the scope exclusively to the EEnvest project: DER in commercial buildings. Under this frame, Chapter 4 takes a deep-dive into KPIs selection for the EE Investment Framework.

4 KPIs FOR THE EE INVESTMENT FRAMEWORK

The proposed KPIs are aimed at setting the foundations for EE investments parameters that are of the interest of investors and thus included in valuation methods. Due to the strong relevance of T4.2 to the overall WP4 output, the Consortium developed the T4.2 in parallel with the present report. Although T4.2 is not a Deliverable *per se*, the Consortium acknowledges this report as extremely valuable to the non-energy benefits literature and thus it is fully presented in Appendix B. Consequently, this Chapter presents its' main findings and conclusions.

All work related to KPIs selection involved exhaustive high-level research, H2020 Project analysis, key interviews with experts, consortium-level discussions and several brainstorming sessions. The Consortium KPIs proposal is based on a set of principles that were concluded throughout the EEnvest Project and the prior research exposed in this report. These overarching principles are:

1. Finance is changing. Investors are decarbonizing their portfolios and therefore pursuing sustainable investments;
2. Large firms are assessing sustainable investments as long-term value drivers and therefore part of their fiduciary duty;
3. Sustainable investments encompass DER investments and as such, the whole lifecycle of buildings play an important role for investment assessments. Consequently, DER involves energy efficiency measures;
4. Small changes in the sustainability of buildings can have large effects on the lifetime of buildings, on the greenhouse gas emissions and on energy efficiency in the economy (Eichholtz, Kok, & Quigley, 2013). However, traditional energy efficiency investments, programmes and policies are commonly designed based mainly on energy savings, which leads to an underestimation of their full impact. Furthermore, energy savings are often not high enough to build a stand-alone business case (Bleyl, y otros, 2017; Rohde & Cooremans, 2019);
5. Achieving sustainable buildings is currently not cost-optimal under the traditional investment project profitability assessment: NPV, IRR and Payback Period (Cooremans, 2011). Regarding DER projects, Payback Period is the most used method (Cooremans & Schönenberger, 2017) and it is usually long enough to disincentive investors;
6. Sustainable building features can produce benefits different from energy savings. These additional benefits are defined as multiple benefits or non-energy benefits;
7. Multiple benefits can exceed the direct benefits connected to the investment (Kats, 2006; Ürge-Vorsatz & Novikova, 2014). Additionally, multiple benefits have a positive impact on building values (Eichholtz, Kok, & Quigley, 2010; Kok & Jennen, 2011; Chegut, Eichholtz, & Kok, 2013; Fuerst & McAllister, 2011); and
8. The inclusion of multiple benefits indicators could enhance the investment case narrative and therefore propel DER investments.

These eight principles are the logical foundations of the current work. Taking into consideration that multiple benefits are the main path to enhance the EE investment case for investors, exhaustive work was undertaken on this specific topic in T4.2: *Creating a business case for non-energy related benefits*[14].

However, as any investment case, ultimately the investment decision will be guided by the investor profile. Thereupon, the EEnvest Project defined investor types according to their role using the EEnvest Search & Match Platform. This work can be found in D3.1. and it's also presented in Figure 5 below. The definition of investors' profile is considered a key insight to define the set of KPIs to be included in DER investment assessments.

[14] As Appendix B unfolds, T4.2 was solely focused on multiple benefits and therefore it is the source of the proposed set of KPIs.

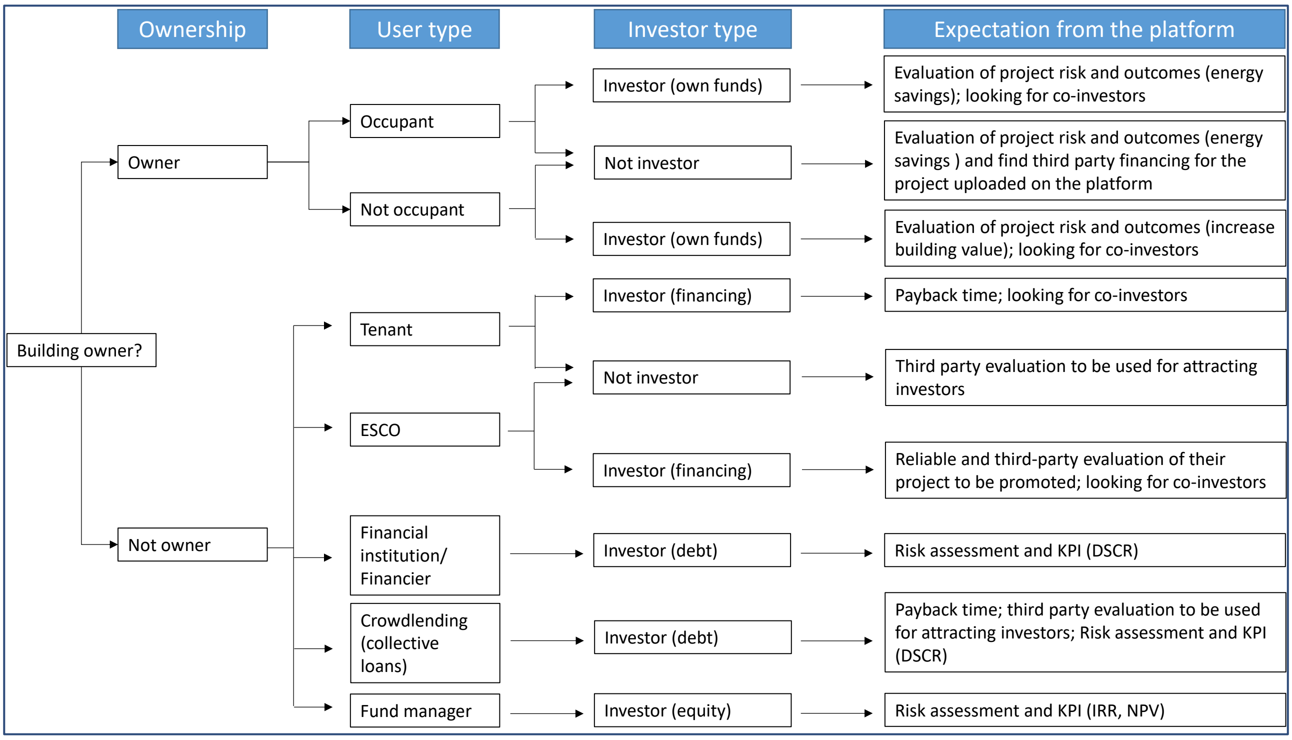


Figure 5: Types of users of the EEnvest Platform.

Source: WP3[15]

As Figure 5 depicts, DER projects involves several stakeholders in the whole value chain and each stakeholder may utilize a different method to assess the DER investment case. For instance, equity owners and investors are not the only actors to be considered in the DER's value chain, the occupants of buildings in which a DER project takes place, should be considered as these stakeholders are exposed to changes in their comfort, productivity and the monthly rent they pay. Consequently, there is a potential trade off that needs to be understood and quantified. On one side, renters preferences for DER measures and on the other side, occupants who may not be able to afford an increase in rent in their post-renovated property.

Furthermore, building owners may be reluctant to invest in DER projects as they undertake the investment whilst the tenant is the one benefiting from EE measures, such as higher thermal comfort and lower energy bills. This is often known as the split incentive as previously defined in this report.

In order to cope with the split incentive, the Energy Efficiency Investment Framework identifies the ramifications that the energy efficient buildings may have -multiple benefits-, owners and investors will be given the right incentives to invest in energy efficiency measures in their buildings, aligning both renters and occupants and efficiently addressing the split incentive issue.

In the following section, a thorough review of the ramification of benefits embedded in DER projects is presented. The proposed classification is Multiple Benefits, and this encompasses Energy and Non-Energy benefits. This exhaustive work is fully attached in Appendix B.

[15] Retrieved from D3.1.

4.1 MULTIPLE BENEFITS: LITERATURE REVIEW AND KPIS FOR INVESTMENT ASSESSMENT

Multiple benefits (henceforth MBs) are an emerging approach to enhance the investment case of energy efficiency deep energy retrofits (DER) projects. MBs are also conceived as an important factor to contribute with energy efficiency policy. In a sense, MBs motivates a to reconsider the traditional approach for assessing EE projects -mainly based on energy savings and GHG emission reduction- and proposes a holistic approach, considering all possible benefits that occurs when incurring in a DER project.

The initial purpose of T4.2 (Appendix B) was to provide a predictive model to accurately quantify multiple benefits for each investment case. However, three shortcomings hindered the definition of a standard and scalable predictive model. First, multiple benefits are difficult to quantify accurately and hence detailed assessment of the whole array of multiple benefits is rather complicated to defined. Second, according to the investor type some benefits may be of more interest than others and therefore the weight assigned to each benefit is strongly dependent on the investor goals, principles and objectives. Last, although there's a widespread agreement amongst stakeholders and experts of the great potential of multiple benefits from the point of view of either the investor or the building's tenant, the lack of data availability of MB is anything but encouraging. Consequently, as of November 2020, there's no appropriate data to create a standardized predictive model for multiple benefits. As result, the Consortium proposed a short list of KPIs which are of interest of investors and are aimed at providing sound insights for proper EE investment assessments.

In order to elevate the MB discussion, a brief recapitulation of relevant policies is presented. For instance, the implementation of the EPBD into the law of different European countries, properties offered for sale or rented out are required to have an Energy Performance Certificate (EPC). Furthermore, the Article 13 in the EU Directive establishes mandatory advertisement of energy performance of buildings during the sales process. This directive has had a positive effect in both rental and sale prices of properties. All things being equal, a building with a high EPC will have a higher market price than another with a lower EPC (Cespedes-Lopez, 2019). However, evidence-based research with large datasets that include changes in asset valuation pre and post renovation are sorely needed.

For the scope of the EEnvest Project, Multiple Benefits are defined as benefits that occur in addition to energy savings that are produced via energy efficiency interventions. The term *multiple benefits* aim to capture the idea that investment in energy efficiency can provide supplementary benefits to multiple stakeholders derived from the reduction in energy consumption. The canonical benefits in energy efficiency are reductions in energy demand and greenhouse gas (GHG) emissions. While these *first-order benefits* have been extensively studied and measured, there is however a set of *second-order benefits* or *multiple benefits* that are poorly understood and therefore not recognized by stakeholders and absent in investment models. Under this context, the present work is aimed at including multiple benefits into investment assessment and further encourage investors reshape their valuation methodologies.

In order to narrow the scope, *multiple benefits* are classified into three groups that reflect the target group, namely *Utility, Participant* and *Societal* (ILSAG, 2018). All three groups are of interest from the standpoint of the investor. The Consortium stablishes the Participant group which comprises building owners and tenants the, a priori, most relevant group of the three. See Figure 6 for a representation of this ontology.

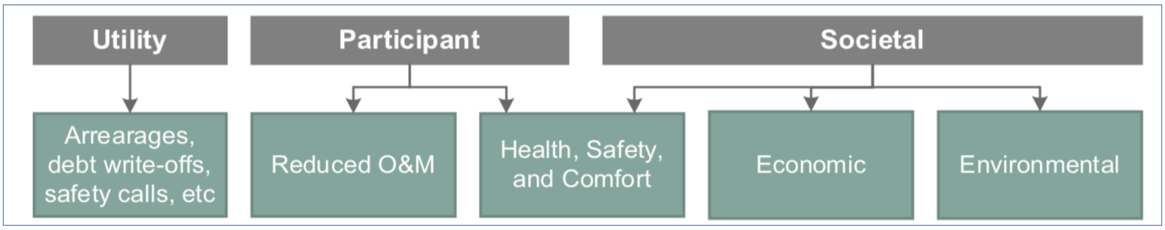


Figure 6: Energy Benefits and its' three main classes.

Source: T4.2[16]

Figure 6 presents the three main classes that composes the Energy Benefits. On the same line, a description of each cluster is defined (Navigant, 2018)**:**

- **Participant**: both building owners and tenants. Improvements in health, safety, comfort and reduction in operations and maintenance costs.
- **Utility**: savings that accrue to the utility company and subsequently may result in lower rates for energy consumers. For example, administrative activities related to late payments, uncollected bills, customer calls etc.
- **Societal**: improvements to the economy as a whole, environment, and health, safety, and comfort of citizens.

The prior clustering analysis reinforces the case that DER projects impact several stakeholders. This classification of MBs further supports the alignment with the PRI and also ESG Investments, as defined in Chapter 2.

Considering MBs potential impact but also its difficulty to appropriately quantify them, five sectors are proposed as focal points as the impact of MBs on these sectors may be greater. Considering the scope of the EEnvest project, the current focus is on the last two – Health and well-being and worker productivity – in particular in the context of office buildings and keeping in mind the point of view of investors. These sectors are:

1. Energy delivery cost for energy utilities;
2. Macroeconomic development;
3. Public budgets, reducing government expenditures, reduced budget for unemployment payments when energy efficiency policies lead to job creation;
4. Health and well-being, e.g., reduced stress, depression, better air quality, reduction in acoustic noise; and
5. Industrial productivity, change in the perception of energy from the current view of energy as an operational cost to a value-generating proposition.

4.1.1 Quantifiable multiple benefits

In order to propose a holistic method to assess EE investments, MBs must be -whenever possible- quantified. This effort is considered as the first step in order to select KPIs to be included in valuation models such as DCF or financial Life Cycle Cost Benefit Analysis (LCCBA). One of the first classification of Non-Energy Benefits (aka Multiple Benefits) financially quantifiable is suggested by (Pearson & Skumatz, 2002) and (Skumatz, 2014). The four *multiple benefits* readily quantifiable according to Pearson & Skumatz are:

1. Work productivity increase
2. Building rental and/or sales price increase
3. GHG emissions reduction

[16] Figure 6 can also be found in Appendix B.

4. Maintenance cost savings

It ought to be remarked that *Building rental and/or sales price increase,* from an investor's standpoint cannot be a benefit, it is rather the outcome out of which we are trying to identify the benefits. In other words, the building rental and/or sales price is the measured outcome while the non-energy benefits are the treatment. Thus, the price increases can't be both, treatment and outcome, or as it shown in the following equation, the price premium or outcome *Y* is explained by a linear combination of benefits *X*. For further details see Annex B.

$$Y = \sum_{k=1}^{n} w_k X_k$$

In the light of defining a standard and reliable set of KPIs that can be included in the investment assessment, further research is sorely needed. T4.2 exhaustively performed this task and the findings are presented in the following paragraphs.

4.2 State of the art, energy and non-energy Benefits

T4.2 exhaustively analyzed +30 academic papers that assessed on the current matter. The main findings are divided in two realms: Energy and Non-Energy Benefits. T4.2 was developed in parallel with T4.1 (i.e. D4.1, the present Deliverable) and therefore the following sections extract T4.2's main findings and leverages on this work to build the EE Investment Framework. For a comprehensive review, see Appendix B.

4.2.1 Energy Benefits

Energy benefits are widely known and accepted in the industry. One of the main assumptions in developing market-based policy instruments is that energy efficiency classification will promote an increment in the willingness to invest in new energy efficiency measures in buildings. These benefits are often easier to measure and thus it motivates the discussion of energy performance and consequently, energy performance certificates (henceforth EPC).

Several studies states that EPC-rate is a useful metric to compare EE performance, hence it is considered as an investor-ready input to benchmark investment opportunities and therefore included in the decision-making process of investors. See (Jensen, Hansen, & Kragh, 2016) for a comprehensive review.

Other authors scope of work exposed that there is a positive relationship between EE and properties' sale price. In specific, an EE score (EPC) increase of 1% let to 0,1% increase in asset value (Fuerst F. , McAllister, Nanda, & Wyatt, 2015).

However, as T4.2 concluded, the relationship between EPC rating and asset value may in some cases suffer from methodological issues, in particular model bias and model identification problems. Studies also conclude that the behavioral energy consumption patterns of people inside the building may be relevant, as it may impact the predicted energy savings or alternately, the energy consumption resultant from the DER project.

T4.2 also paves the way to better understand the impact of energy related benefits on the transactional price (sales or rental) of the asset. In specific, a recent study containing a particularly large dataset of 56,000 residential property sales from Portugal showed a positive correlation between energy efficient properties and price premium. In particular, apartments display higher price premiums than houses 13% and 6% respectively (Evangelista, Ramalho, & e Silva, 2020).

Further, as T4.2 evidences, a 2011 study on financial performance of green office buildings in Australia (Newell, MacFarlane, & Kok, 2011), used a significant portfolio of green office buildings in Sydney and Canberra benchmarked against a portfolio of non-green office buildings, and the property financial performance premiums attached to green office buildings empirically assessed, including rent, value, outgoings, yield and occupancy rate premiums. Among the key findings of the study is that the Australian energy Performance Rating (Green Star) showed a green premium in value of 12%.

Another study published in 2017 analyzed rental unit listings collected for 10 US cities, energy efficient features increases the units' rent, overall from 6% to 14% (Im, Seo, Cetin, & Singh, 2017).

And lastly, a (IEA, 2019) Report analyzed the literature that estimates the increment of green office space value and it's presented in Figure 7 below.

Summary of US green office space value

Study	Rental premium	Sale price premium
Miller et al	4% - 5%	25-26%
Eichholtz et al (a)	3.3-5.2%	11-19%
Eichholtz et al (b)	2.1-5.8%	11-13%
Pivo & Fisher	2.7%	8.5%
Wiley et al	7-17%	16-18%
Miller et al	9%	NA

Figure 7: Summary of US green office space value -literature review.

Source: IEA 2019

Backed up by Table 1[17] below, T4.2 concludes that that the energy efficiency certificate has a positive effect on the building valuation. Although there is overwhelming evidence about the sign (positive) of the correlation between EPC and price, the degree, that is, by how much the EPC rating affect the asset reevaluation is still under discussion. Hence it hinders the design of a standardized predictive model for estimating the greemium.

T4.2 stated the factors related to the lack of robustness in building price prediction models and these are:

1. Studies use both appraisal and transaction prices (Evangelista, Ramalho, & e Silva, 2020);
2. house attributes are sometimes absent in the model which may distort the price premium; and
3. Most models do not include the second order energy benefit variables, here called *multiple benefits*.

[17] The table provides the reference, whether the study has available the dataset, the location in which the study takes place and a brief description of the main results of the study.

Following this rationale, the next section is solely focused on multiple benefits.

Reference	DB	Country	Description
(Evangelista, Ramalho, & e Silva, 2020)	N	Portugal	Hedonic Regression on residential transaction prices using EPC. 13% premium in apartments, 5-6% in houses
(Dell'Anna, Bravi, Marmolejo-Duarte, Bottero, & Chen, 2019)	N	Spain & Italy	Hedonic Regression on residential transaction prices. 1.88% premium for the Spanish sample and 6.33% for the Italian sample
(de La Paz, Perez-Sanchez, Mora-Garcia, & Perez-Sanchez, 2019)	N	Spain	Hedonic Regression on residential transaction prices. 1.8% and 1.1% premium for low-rated EPC. 29.9:34.4% premium coastal region house prices.
(de Ayala, Galarraga, & Spadaro, 2016)	N	Spain	Semi-logistic hedonic model on residential transaction prices. 9.8% premium energy efficiency houses
(Im, Seo, Cetin, & Singh, 2017)	N	USA	Propensity score matching & conditional mean model on rental prices. 6-14% premium by EE features
(Fuerst F. , McAllister, Nanda, & Wyatt, 2016)	Y	Wales	Hedonic regression model on residential transaction prices. 11.3% premium for A and B-rated, 2.1% for C-rated
(Fuerst F. , McAllister, Nanda, & Wyatt, 2015)	Y	UK	Hedonic regression on residential transaction prices fixing the EPC-rate. 5% premium on top rated, 1.8% C-rated, -1:-7% lowest rated
(Hyland, Lyons, & Lyons, 2013)	N	Ireland	Hedonic regression on residential transaction prices. 79:64% premium cost-savings for F-B1 EPC-upgrade, 55:14% for rental premium
(Jensen, Hansen, & Kragh, 2016)	Y	Denmark	Regression on residential transaction prices. 6.2:6.6% premium on top rated, -9.23:- 24.3% on G-rated
(Newell, MacFarlane, & Kok, 2011)	N	Australia	Regression on office transaction prices. 9% premium on top rated offices, 1:3% on lowest rated
(Eichholtz, Kok, & Quigley, The economics of green building, 2013)	N	USA	Logit regression on office transaction prices. 7.9% rent premium in EPC's rated offices. 3.5% rent increase and 4.9% market value increase
(Lung, McKane, Leach, & Marsh, 2005)	N	USA	Cost of conservation supply curve on commercial buildings. 56.4% premium quantified ancillary savings
(Stenqvist & Nilsson, 2012)	N	Sweden	Theory based evaluation of the cost-benefits of energy efficiency in industrial sector. 1.84 to 2.84 times the gross net impact expected
(Poortinga, Jiang, Grey, & Tweed, 2018)	N	UK	Multilevel time-series regression. Indoor temperature increase (0.84Kº) associated to -37% gas usage
(Alavy, Li, & Siegel, 2020)	N	Canada	Residential HVAC efficiency Linear regression. PSC systems maintain airflow rate, 40% more power. ECM are 43% more efficient and reduce airflow rate -10:-23%
(Ngo, 2019)	N	Taiwan	Machine learning models on cooling load simulated data. ANN model, ANN-CART ensemble model, ANN-CART-LR ensemble model: R=0.98~0.99, RMSE=158.77~237.78kW
(Bleyl, y otros, 2017)	N	Germany	Life Cycle Cost-Benefit to model a commercial building cash flows (CF). 85% of cash-flow savings can re-finance the efficiency projects
(Bleyl J. , y otros, 2019)	N	Germany	Life Cycle Cost-Benefits on office buildings. 1:5.3% rental price premium; 2.5:6.5% transaction price; 6:79€/T emissions-savings;

			2.1:3€/T/m²/y maintenance costs-savings; 219:439€/m2 work productivity increase
(Hirvonen, Jokisalo, Heljo, & Kosonen, 2019)	N	Finland	Life Cycle Cost in residential building. 19% increment on emissions reduction with high cost non-economical investments. 41:92% and 24:85% emission reduction for old and new building
(Berggren et al., 2018)	N	Sweden	Co-benefits and cost-saving's life cycle-cost in a NZEB building. Base-lines scores of increase productivity value, reduced employee turnover costs, and reduced sickness absence salary
(Limsombunchai, 2004)	N	New Zealand	Hedonic Regression and Artificial Neural Network comparison on residential prices.
(Aydin, Brounen, & Kok, 2015)	N	Netherlands	Multi-logarithmic regression on residential prices. As 10% efficiency increase, 2.2% market value increase. As 10% gas usage decrease, 0.7% residential price increase

Table 1: Academic studies of Energy Benefits.

Source: T4.2[18]

4.2.2 Non-Energy Benefits aka Multiple Benefits

Multiple Benefits or *Non Energy Benefits* are benefits that occur in addition to energy savings that are produced via energy efficiency programs. NEBs are categorized into three groups: utility, participant, and societal. Utility NEBs accrue to the utility and result from reductions in administrative costs. Participant NEBs accrue to building owners and tenants and include improvements in health, safety, and comfort and reduced operations and maintenance costs. Societal NEBs accrue to society and include improvements to the economy, environment, health, safety, and comfort of citizens (ILSAG, 2018).

The most important operational framework in which the non-energy benefits can be studied is the Deep Energy Retrofit (DER). A DER is a major building renovation project in which site energy use intensity, including plug loads, is reduced by at least 50% from the pre-renovation baseline. Energy benefits are important but there is more to that in an Energy Retrofit program. A 2002 study (Pearson & Skumatz, 2002) showed that benefits related to fewer tenant complaints and higher tenant satisfaction, safety issues, productivity increase are particularly relevant. The authors suggested that selling programs on "efficiency" or even just bill savings might not the most effective approach because it ignores critical information on the benefits with value for the participants.

Some NEBs referred in the above mentioned study are better lightening, lower maintenance, comfort, aesthetics, productivity, increased equipment life etc. Employees working in an energy efficient building had 26% higher cognitive function, 6% higher sleep quality and 30% fewer symptoms of 'sick building syndrome' (a condition typically marked by headaches and respiratory problems caused in part by poor ventilation) (worldgbcnews, 2016).

Improved aesthetics can also be considered a Non-Energy benefit; the efficient buildings must "not only feel good but look good, too". Green roofs, sunshades, window glazing, sleek low-flow water features, and other measures in an efficient building can improve the building's aesthetic and appreciation to the dwelling's eye (Vrabel, 2018).

Thermal comfort and tenant satisfaction are also benefits that have a measurable economic effect, for example in reducing tenant turnover and decreasing maintenance cost. Studies (GSA, 2011) have shown that tenant satisfaction can increase 27% by adopting energy efficiency improvements, which lead to tenants staying longer and accepting higher rents.

[18] Table 1 can also be found in Annex B.

Increasing evidence supports that improving the quality of a rented space through energy efficiency renovations can achieve increased thermal, noise and light comfort, improved health, safety and security, and reduction of energy bills, operational costs, aesthetics, and increased equipment life (Pearson & Skumatz, 2002). These benefits can translate into improve tenant satisfaction and productivity of the workers in an office building. From the point of view of the landlord, energy efficiency renovations have a measurable effect in reduced vacancy and tenant turnover.

Importantly, the multiple benefits approach can help us to address the challenge of the invisibility of energy efficiency. Presenting the energy benefits as non-used energy, the benefits are seen as a reduction in cost. The multiple (non-energy) benefits on the other hand, can be shown in a positive light by crediting the positive impact. Table 2 shows academic studies with focus on Non-Energy Benefits.

Reference	List of NEBs	Dataset	Description
(Mansilla, y otros, 2019)	Comfort, pro-environmental initiative	https://zenodo.org/record/2610102#.XuN8sEUza00 https://www.mdpi.com/1996-1073/13/7/1700	Questionnaire of behavior and persuasive strategies to enhance energy efficiency in offices. Feedback and self-monitoring are the top ranked strategies; 8.5% increase of pro-environmental initiatives.
(Paige, Agee, & Jazizadeh, 2019)	Comfort, Energy performance control device and HERC (EPC), EE knowledge Attitudes	https://osf.io/2qy9b/	Questionnaire of energy consumption and behavior and perceptions on a residential case study experiment.
(team & Galev, 2019)	Comfort, Environmental and sustainable attitudes	https://zenodo.org/record/3523916#.Xuapu0Uza01	Questionnaire of energy consumption and behavior, mobility, willingness to install energy efficiency measures, and environmental concerns of mobility
(Buylova, 2020)	Socio-economic and demographic factors associated with high energy use	https://zenodo.org/record/3703524#.XvnQjCgza01 https://pubag.nal.usda.gov/catalog/6873537	Residential USA buildings database. Estimates Energy Cost Index. Older housing, low-income households, energy burden/costs, racial minorities and low education has higher level of energy use intensity
(Földváry Ličina, y otros, 2018)	Thermal climatic and subjective comfort, air quality	https://datadryad.org/stash/dataset/doi:10.6078/D1F671	Database compilation of location, weather, buildings specification and efficiency systems in relation to comfort, air quality and individual characteristics
(Reichl, y otros, 2019)	Comfort, efficiency measurements hedonics, lifestyle. Attitudes and energy efficiency policies	https://zenodo.org/record/3524917#.XuczaEUza03 https://db.echoes-project.eu/echoes/home	Energy efficiency cities survey on residents. Retrofit collective action as a suitable solution; socio-economic conditions influences project investment and the energy source preference.
(Chiara, y otros, 2019)	Type, capacitance, conductivity and proficiency indices of efficiency measures related to comfort and air quality	https://zenodo.org/record/3256270#.XueFnkUza00	UE simulated database of energy performance, installation and maintenance of efficiency measures and the environmental impact (primary energy consumption and CO2 emissions)
(Energy Information Administration, s.f.)	Household Energy Insecurity and health implications	https://www.eia.gov/consumption/residential/data/2015/#structural	Questionnaire of energy consumption, building's characteristics, efficiency systems performance and costs, and ancillary benefits.

(Kmetty, Bent, Shreeve, & Virág, 2017)	Comfort and well-being, willingness to develop energy efficiency measures	https://zenodo.org/record/820364#.Xvow2ygza01	Questionnaire of household income, energy costs-savings, personal interest, and factors and attitudes behind energy consumption.
(Galata, Brogan, & Cunningham, 2019)	Saving goals, (qualitative) ancillary benefits and estimated payback (years)	https://zenodo.org/record/3468951#.Xvpj-Cgza01 http://www.hit2gap.eu/	Residential energy management module project to compare the actual and theoretical energy performance, energy consumption and prices and improvement opportunities
(Bahrar, Coillot, Laaroussi, Frutos Dordelly, & El Mankibi, 2020)	Renovation potential and costs, barriers	https://zenodo.org/record/3626699#.XvprqSgza01	Country-level project to analyze the depth of efficiency renovation by the climatic zone, building typology and energy usage
(Norris, 2017)	Energy efficiency needs and barriers awareness	https://zenodo.org/record/401009#.Xv2cMSgza00	Needs and barriers perceived from the actors involved in energy efficiency office renovation study-case project
(De Cock, 2016)	Amenities proximities, material and finish quality, overall condition rating, heating quality and condition, rooms and utilities quality and conditions, fireplaces quality	https://www.kaggle.com/c/house-prices-advanced-regression-techniques/data	Dataset to predict residential transaction prices considering building structural and transaction conditions, and efficiency systems

Table 2: Academic studies of Non-Energy Benefits.

Source: T4.2[19]

4.3 KEY PERFORMANCE INDICATORS FOR MULTIPLE BENEFITS

This section is considered as the key output of T4.2 and it was developed in parallel with the present deliverable. As such, the main findings are fully extracted and incorporated below.

In this section the Consortium identifies and proposes a set of Key Performance Indicators (KPIs) related to non-energy related benefits (i.e. multi-benefits, co-benefits) of interest to investors in DER and energy efficiency renovations in commercial buildings. The selected set of KPIs will guide, support and ultimately, ease the investment decision making process. Specifically, the selected KPIs are defined so that they can be operationalized in the platform that is being built at EEnvest.

One of the key outcomes of WP4 entails a comprehensive assessment of co-benefits incurred in DER. Backed-up by literature; the multiple-benefit analysis is aimed at quantifying the multi-dimensional impact of DER. Under this realm, different methodologies have been proposed, mostly based on linear modeling in particular hedonic regression, and more recently based on machine learning techniques. However, the great potential of non-linear modeling for prediction and classification such as artificial neural network and random forests has been limited due to the lack of datasets that contain both energy and non-energy benefits. Unfortunately, as of November 2020, there are concrete signals that such

[19] Table 2 can also be found in Annex B.

database may not exist yet and, therefore, building a predictive model that assesses the weight of the different co-benefits in the price premium is unfeasible.

The methodology to propose the KPIs list, presented in Appendix B, was the following:

1. Literature selection
2. Research on selected literature
3. Interview with experts
4. H2020 project's analysis
5. Deep-dive into multiple benefits quantification methodologies
6. Long list of KPIs
7. Filtering according to Consortium's criteria[20]
8. Initial short list of KPIs
9. Consortium-level discussion
10. Final set of KPIs

Long list of KPIs

KPI	ID	Cluster Group(Beneficiaries)	Specific Goals	Evaluation	Benchmark	Rating	Description
Thermal Comfort [Tmin, Tmax]	TC_mM	Comfort (Tenants)	Assess whether the indoor recommended temperature is within the optimal range according to the season	Room thermometer	ANSI/ASHRAE Standard 55	[Tmin <=T <= T max] Tmin in winter 17C	Used as indicator for compliance within range of indoor temperature conditions
Thermal Comfort PPD	TC_PPD	Comfort (Tenants)	Assess thermal satisfaction based on survey	Real satisfaction Index / Predicted Satisfaction Index	ANSI/ASHRAE Standard 55	Ratio	Predicted Mean Vote (PMV) Predicted Percentage of Dissatisfied (PPD)
Visual Comfort	VC_DA	Comfort (Tenants)	Assess local availability of sufficient day lighting level in a time period	Use threshold according to standard (e.g 500 lux.)	Threshold 500 lux	Binarized (threshold)	Calculated according to the Daylight Autonomy(DA) that quantifies the local availability of a sufficient day lighting level in the considered reference period. The threshold can vary according to the standards (i.e 500 lux)
Visual Comfort (Daylight Factor)	VC_DF	Comfort (Tenants)	Assess illuminance inside building compared to outside illuminance	DF= Ei/Eo (indoor /outdoor illuminance)	Ratio. DF has no units. Ei and Eo measured in lux.	Ratio	Iluminance equation: E = P/ 4πd^2, P is the luminous flux (lm) of the source and d is its distance from the surface

[20] For an extensive review on the Consortium's systematic approach for analyzing the KPIs please refer to Appendix B.

Acoustic Comfort (dB)	AC_dB	Comfort (Tenants)	Assess noise conditions	Smart noise sensor, measure room noise in dB	Threshold	Binarized(threshold)	Safe range of sound pressure level (dB) encoded in 5 levels, being 1 harmful and 5 ideal
Acoustic Comfort (survey)	AC_su	Comfort (Tenants)	Assess noise conditions	Survey based assessment of Noise conditions		Likert scale (1-5)	Noise assessed from 1 to 5
GHG emissions	GHG	Environmental (societal)	Measure reduction of GHG emission level	Quantify total NOx, CO2 emitted by building		% reduction matched with non DER building or Likert scale (1-5)	Percentage reduction in NOx emissions (NO and NO2) - % in tons
Air Quality	AQ	Environmental (Societal)	Estimates Indoor Air Quality	Survey based assessment AQ conditions		Likert scale (1-5)	AQ encoded 1 to 5
Perceived Physical Health	PPH	Health & Well being (Tenants)	Self-assessed physical health inside the building	Survey based assessment		Likert scale (1-5)	Encoded 1 to 5. It refers to tenants, is an average of subjects
Perceived Mental Health	PMH	Health & Well being (Tenants)	Self-assessed mental health inside the building	Survey based assessment		Likert scale (1-5)	Encoded 1 to 5. It refers to tenants, is an average of subjects
Physical Health Conditions	PHC	Health & Well being (Tenants)	Reported physical health conditions or diseases directly or indirectly associated with work at the office (headaches, fatigue, asthma, eye damage, skin irritation, back pain, cardiovascular disease etc.)	Clinical report		Encoded binarized conditions [0,1] e.g. Asthma:1, COPD:0	N-dim vector each dim is a condition encoded with 0 (absent) and 1 (present)
Mental Health Conditions	MHC	Health & Well being (Tenants)	Reported mental health conditions or diseases directly or indirectly associated with work at the office (stress, depression, seasonal affective disorder etc.)	Clinical report		Encoded binarized conditions [0,1] e.g. Stress:1, Depression:1	N-dim vector each dim is a condition encoded with 0 (absent) and 1 (present)
Increase Productivity Value	IPV	Productivity (business owner, employee)	Increase in productivity derived from DER in office buildings	IPV=ExSCxI The salary cost per employee (SC) x number of employees (E) Increase in Productivity (I~5%)	Typical Value: 0.5% Range: [0.3%-0.76%]	IPV refers to building, it requires the Increase Productivity per employee ~5%	Productivity gain in office buildings (euros or euros/m2) can be discounted with the risk free rate of return r
Turnover	PRO_T	Productivity (business owner, employee)	Reduction in turnover employee derived from DER in office buildings	Turnover/year count	Typical Value:0.5%	Nb employees variation/Nb Total employees	Difference between employees before and after the DER weighted by the total of employees in a time period

Sick days	PRO_S	Productivity (business owner, employee)	Number of sick days claimed by the employee	Sick days count	Typical Value:4.5 days. Baseline 7.5%	2 alternatives: i. count the number of sick days, or ii. compute increase in productivity by the reduce loss of work force days	Reduction in the number of sick days on average for a building. Alternatively, possible to use the productivity gain in % related to the reduction of sick days (7.5%)
Building Sale Price	BSP	Financial (business owner, tenant)	Increase in the building price sale (market value) of the building after DER	Sale transaction Price or Appraisal in euros.	Typical Value 5% Range [<4%-20%]	[2.5%-6.5%]	Increase in % of the market value of the building, based on actual transaction or more likely appraisal with matched buildings
Rental Income	RII	Financial (business owner, tenant)	Rental Income increase after DER	Monthly rent in euros	Typical value 3% Range [<4%, 26%]	[1%-5.3%]	Increase in % of the market value in monthly rent income based on actual market value or matched buildings
Maintenance Costs Savings	MCS	Financial (business owner, tenant)	Variations (+/-) in maintenance cost after DER	Euros/m2/year	Typical value: [2.1-3] eur/m2/y	Euros per surface and year	Monetary increase given in eur/m2/y units.

Table 3: Long List of KPIs

Source: T4.2[21]

Rationales for the each KPI is provided in Annex B. The KPIs have been grouped into 5 groups: Comfort, Environmental, Health and Wellbeing, Productivity and Financial. Each group or cluster affects different stakeholders. For instance, Comfort KPIs affect the tenants or workers in the office building, the Environmental KPIs affect to the entire society, the Health and Wellbeing benefit tenants and workers, the Productivity cluster affects both workers and business owners and finally the Financial KPI is of interest to the business owner.

Figure 8 shows the relationship with the target group –Tenant, Worker, Owner/Investor and Society– and the different groups of KPIs – Comfort, Environmental, Health and Wellbeing, Productivity and Financial. The Figure also tries to help the reader to reflect about the issue of the interdependencies between KPIs which is missing from the literature. For example, Comfort, Health & Wellbeing and Productivity and very likely strongly correlated.

[21] Table 3 can also be found in Annex B.

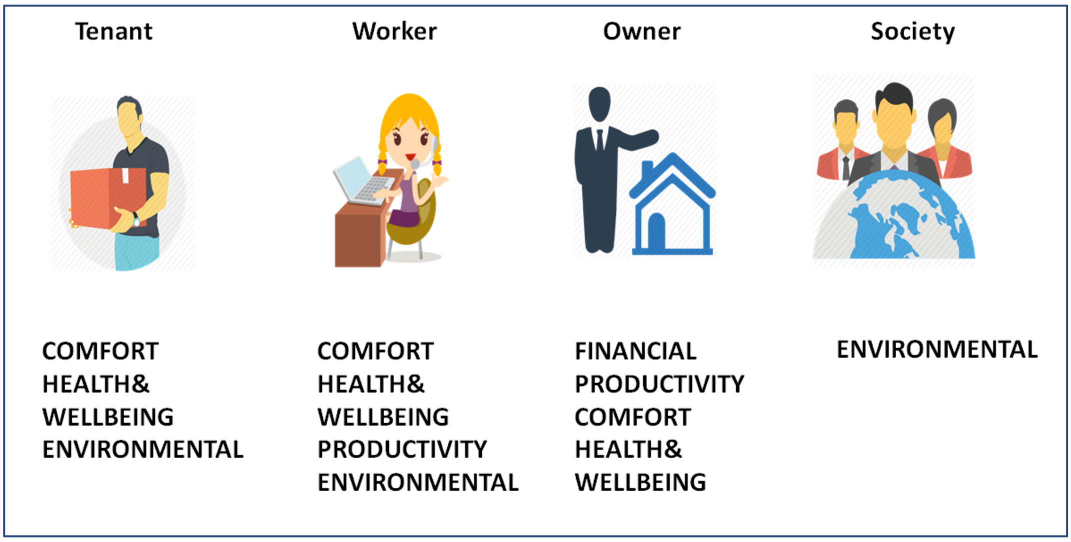


Figure 8: Target of KPIs on selected groups: Tenant, Worker, Building Owner/Investor and Society.

Source: T4.2[22]

The KPIs exposed in Figure 8 are in order of importance. For example, for the Tenant group the most important KPIs are comfort and Health & Wellbeing, for the Worker group, productivity must be taken into account and for the Business owner or investor group, the Financial KPIs are first in the list. For society the most direct KPI is environmental but all KPIs have a potential indirect effect.

Figure 9 below shows the dependencies path for each KPIs category group. From the graph we can infer that Comfort affects both Productivity and Health, the same goes for Environmental KPIs. Health affects Productivity and finally Productivity affects Financial KPIs. Although the only direct path to Financial KPIs is from Productivity, the graph shows that indirect connections from any cluster to Finance. For example, Comfort, Environment and Health affect Finance indirectly via Productivity but it would be worth exploring whether Comfort is causally related to Financial KPIs or is as the Figure suggests always mediated by Productivity.

[22] Figure 8 can also be found in Appendix B.

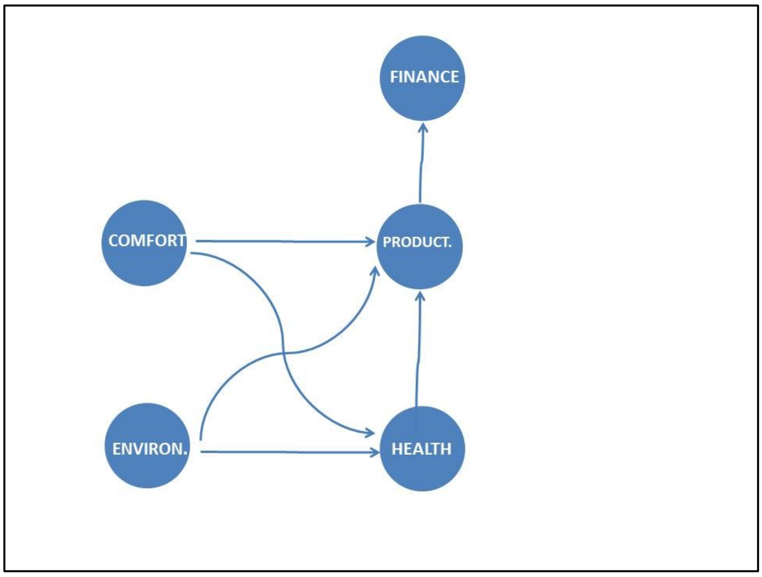


Figure 9: Illustration of dependencies between the 5 cluster of KPIs identified.

Source: T4.2[23]

4.3.1 Short List of KPIs

The proposed short list of KPIs was also based on the survey performed in D3.1 focused on gathering key insights from stakeholders. These stakeholders were asked to complete a 11-question survey divided in two parts. The first part was aimed at identifying the potential user for the EEnvest Platform. The second set of questions were designed to map all investors' expectations regarding the output of the Platform. The main findings of this effort are presented in the next paragraphs.

Figure 10 maps the stakeholders' profile. Figure 11 illustrates the main financial indicators of interest for the investment case. Last, Figure 12 depicts and initial rank of multiple benefits of interest for investors.

[23] Figure 9 can also be found in Appendix B.

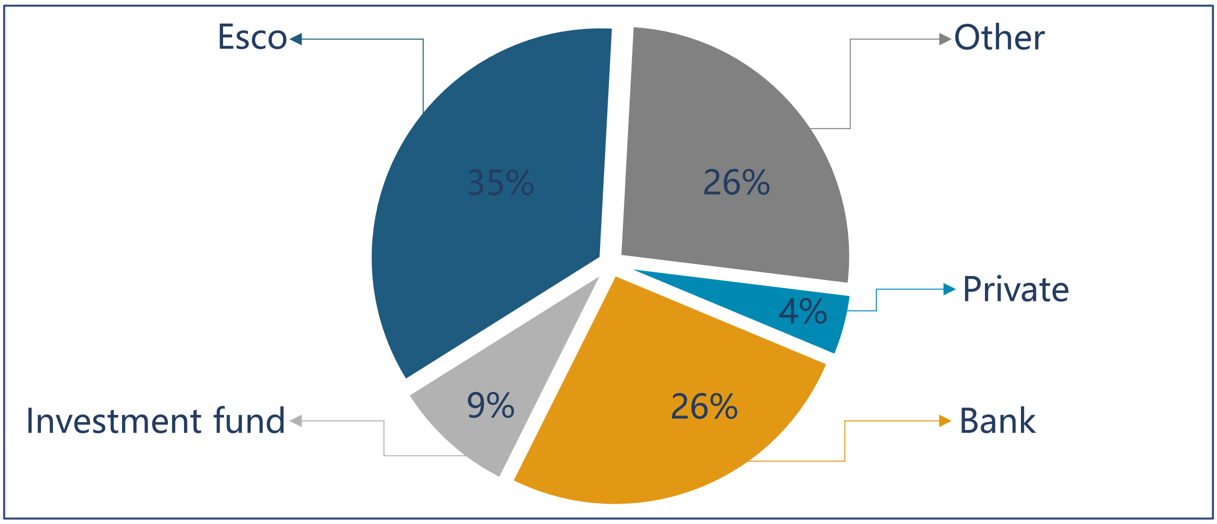


Figure 10: Distribution of user types.

Source: WP3[24]

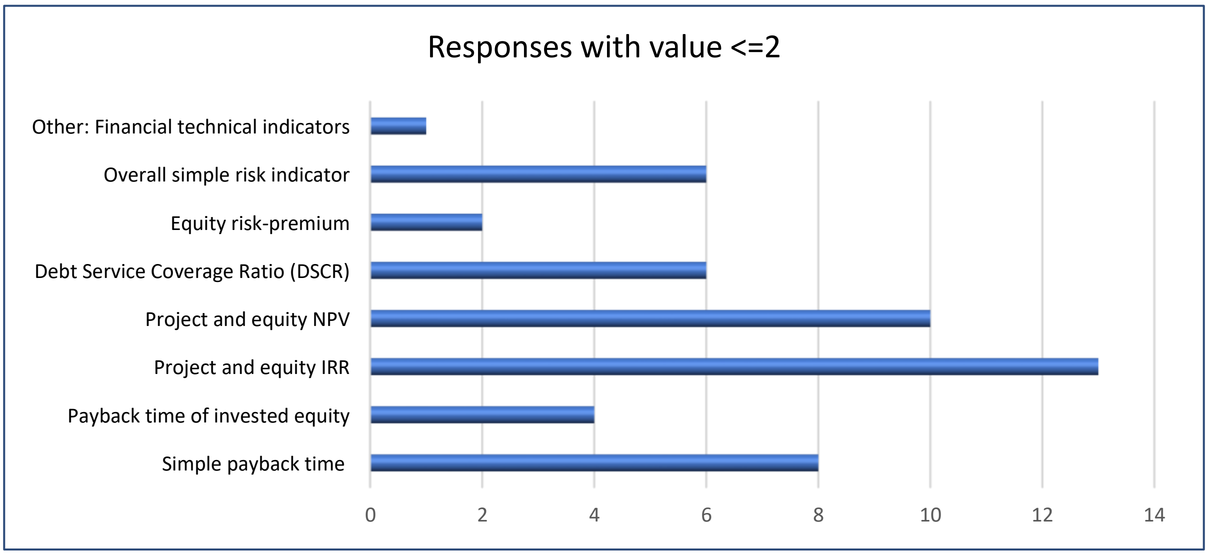


Figure 11: Indicators of importance. Results from questionnaire elaborated in WP3.

Source: WP3[25]

The evidence compiled signals that the IRR, NPV and Simple Payback Period are of interest of investors. Further, the Consortium once again pinpoints the urge of including multiple benefits into the investment assessment as this inclusion may enhance the investment case and therefore improve this set of financial KPIs. Consequently, a non-exhaustive rank of multiple benefits of interest are mapped in Figure 12 below.

[24] Retrieved from D3.1.
[25] Retrieved from D3.1.

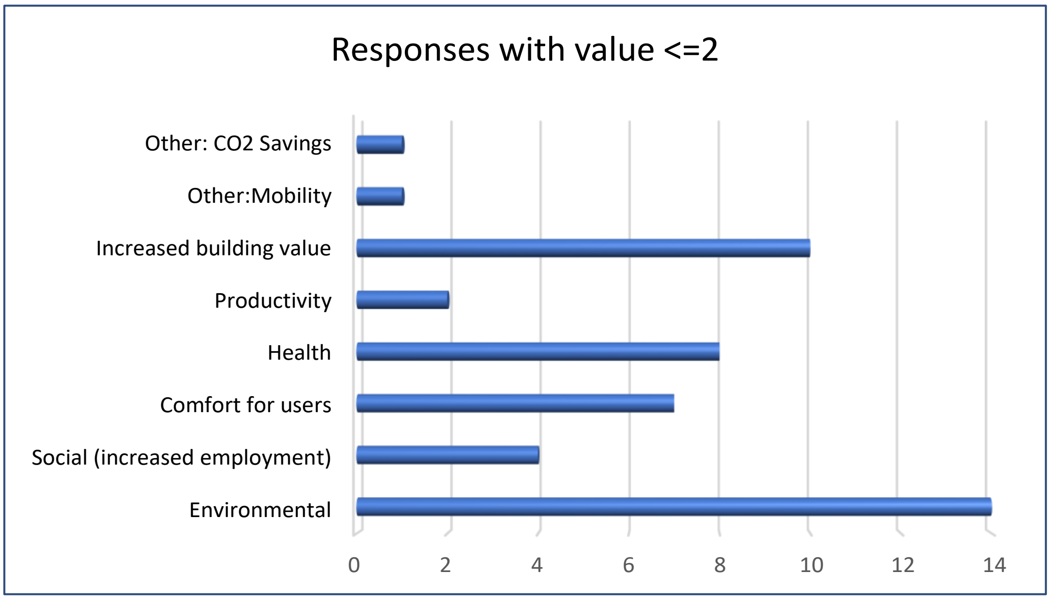


Figure 12: Multiple-Benefits importance. Results from questionnaire elaborated in WP3. Source: WP3[26]

The interviewed group determined that environmental KPIs are the most important for EE investments and further maps the relevance of determining the increment of the building value post retrofit along with the importance of health.

Following the outcome of T4.2, the proposed short list of KPIs is the following:

KPI	NEB Values Range relative to Energy Savings	Consistency across programs [1..5]	Investor Weight [1..5]
Thermal Comfort	[1% , 51%]	4	3
Acoustic Comfort	[5%, 35%]	2	3
Visual Comfort	[1% , 44%]	3	3
Air Quality (Environmental)	[5% , 50%]	2	4
Perceived Physical/ Mental Health	[2% , 47%]	3	3
Productivity per employee	[5% , 33%]	3	4

Table 4: Proposed Non-Energy Benefits KPIs, subjected to energy savings. Source: T4.2[27]

Table 4 includes the estimate as a range rather than a point estimate, the evidence weight or consistency found across programs which can work as a proxy for KPI robustness plus the investor's weight which represents the relevance of the KPI from the investor's point of view. The sum up of all the multipliers in Table 4, assuming all the KPIs are independent which they are not (e.g. thermal and acoustic comfort

[26] Retrieved from D3.1.
[27] Table 4 can also be found in Appendix B.

are related and the same goes for air quality and perceived health) gives us [19%, 260%] relative to bill savings. The wide broad range responds to our deliberately conservative take imposing a very low range on the KPIs, never larger than 5%. The typical value of the multiplier, we believe lies much closer to the upper bound than to the lower bound, that is, we would expect between 150% and 200% NEB multiplier relative to EB. The rationale for this directly follows from the very conservative approach taken here in which the lower bounds of each KPI are very small, below 5%.

Although the values range have been built based on the scrutiny of a very extensive literature including academic literature, governmental, research projects as well as numerous interviews with experts, they are certainly debatable and prone to modification. Nevertheless, the index provided is a necessary first step to build predictive models of price/rental premium relative to NEBs. The index can also work as evidence based baseline to calculate the premium of individual projects relative to the lower and upper bounds included in the index KPIs.

The proposed set of KPIs is aimed at being implement in WP5. The EEnvest Radar (WP5) is being designed to compare buildings performance. The selected KPIs bring together readily quantifiable indicators to construct a coherent picture for the investor. Technical KPIs (Damage, Energy gap) and Financial KPIs (Payback time, Maturity, Internal Rate of Return, Net Present Value on Investment, Debt-Service Coverage) are put together in a common representational framework. Thus, the EEnvest Radar as shown in Figure 13 brings together Multiple Benefits KPIs, Financial KPIs and Technical KPIs for a total of 13 individual KPIs.

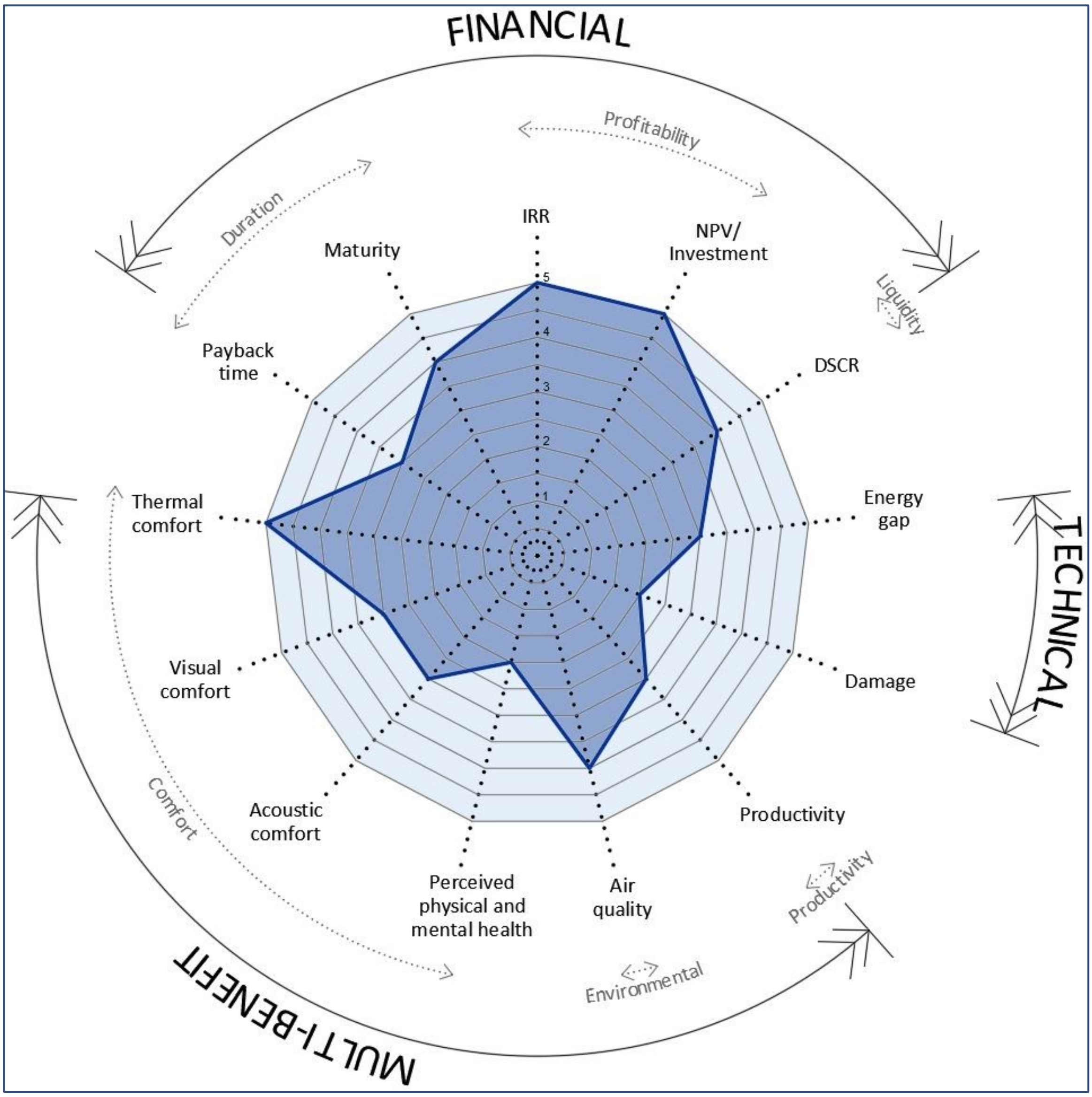


Figure 13: Example of the overall graphical EEnvest Radar representation (12 KPIs). Source: WP5[28]

In the light of strengthening the case for including multiple benefits into the investment assessment, the Consortium presents a set of investment cases based on EU H2020 Projects and key academic papers. The following section also paves the ground for T4.4: *Valuation Methodology for EE investments including Multi-benefits.* T4.4 is the last work regarding WP4 and it will be strongly focused on including MBs into the financial analysis (DCF) and asset valuation (greemium).

[28] Retrieved from D5.1.

5 EE Investment Case Studies

In order to validate the hypothesis that EE investment opportunities would become more attractive to investors if a compelling investment assessment is proposed, the present section takes a deep dive into real cases and on-going H2020 projects in order to unfold the relevance and impact of including other dimensions than the financial realm.

The Consortium proposes three cases aimed at (i) reflecting how traditional financial analysis are affected when including MBs, at (ii) taking a practical approach to sharpen the understanding of DER Investments and at (iii) paving the way for further research on compelling valuation methods for DER investments.

5.1 Productivity and Work performance measuring through Comfortmeter Tool

Employees spend at least 40 hours a week in the office, a total of 2080[29] hours per year. Considering that work implies a major amount of time for people, it is plausible to consider that employees desire for a workplace that promotes productivity and health. From another point of view, visual comfort involves lower staff turnover, increased productivity, reduced sick leaves, reduced vacancy, health benefits. Acoustic comfort may increase the level of satisfaction and the capacity of concentration, leading to increased productivity of the occupants (CraveZero, 2020). On this line, early studies for EE programs suggested that productivity gains could be among the most significant benefit of DER investments (Wargocki, Wyon, Baik, Clausen, & Fanger, 1999; Miller, 2009; Fisk, 2002).

Increased productivity can be estimated with reduced absenteeism or via proxy variables such as lighting, ventilation, thermostat control and energy adjustments which lead to overall worker betterment and productivity (Bleyl J. , et al., 2019).

In the light of quantifying the impact of an increment in employees productivity, the authors utilize the Comfortmter Tool.

A successful DER project in a low-performing building is estimated to increase the overall comfort score between 2 and 4% (Coolen, Klonek, & Wuyts, 2012). The econometric model of the Comfortmeter illustrate than a 1% increment in the overall comfort enhances work performance on an average of 0.19% (Helsen & Coolen, 2013). Consequently, the aforementioned DER project would augment work performance between 0.38% and 0.76% [(2 to 4) × 0.19%]. With the prior data, the authors presented the following case for a DER project:

Information:

- Average Belgian employee of 75,000 EUR/employee (i.e., salary cost, non-salary cost (ICT, facilities, ...), and profit margin)
- Average overall office space of 27.5 m^2 per employee (or 0.0364 employees per m^2)
- Work performance increase: 0.38 10.4 to 20.8 €/m^2 [(0.38 to 0.76%) × 75,000 × 0.0364]

The increase on work performance can be presented as an additional source of revenue for business owners and therefore, included in the Energy Efficiency Investment Assessment undertake prior to investing in the DER Project. Consequently, this additional revenue can be included in the Discounted Cash Flow analysis and therefore may impact financial KPIs such as IRR, NPV and Payback Period.

[29] 40 hours a week x 52 working weeks.

This ground-breaking finding have the potential to redefine the investment narrative and assessment and ultimately, attract investors at large scale.

Further, as concluded in (Killip, y otros, 2019), savings are on average 1.4 times higher when multiple benefits are included, compared with the energy cost savings as a stand-alone case. Moreover, other studies showed higher savings when other multiple benefits are monetized: up 20 2-3 times rather than the financial benefit of energy savings.

As result, it is now clear that including multiple benefits in the financial assessment can demonstrate sound business cases and therefore influence the decision-making process.

5.2 COMBI PROJECT, EU H2020 PROJECT

The COMBI Project is aimed at evaluating the impact of multiple benefit in EE renovation projects at country level. COMBI also provides relevant findings for multiple benefits monetization. For instance, the Project states that the total amount of euros per year that can be attributed to multiple benefits of energy efficiency actions in Europe range from a conservative € 65 billion to € 291 billion (COMBI, 2015). Each scenario is estimated based on the level of investment, depth of efficiency scenario, baseline and future scenario year used by each individual study.

Two of the main studies that COMBI is built-upon are presented. The first, an (IEA, 2017) study that estimated monetisation of multiple benefits suggests a permanent annual benefit to society of €104 - 175 billion in 2020 in the EU. And the second, a (Copenhagen Economics, 2012) study that found that energy efficient renovations can stimulate benefits accruing to € 153 - 291 billion in Europe. As result, one of the COMBI's contribution is presented in Figure 14 below. As it is shown, there's a clear €65 billion split in energy efficiency per action required.

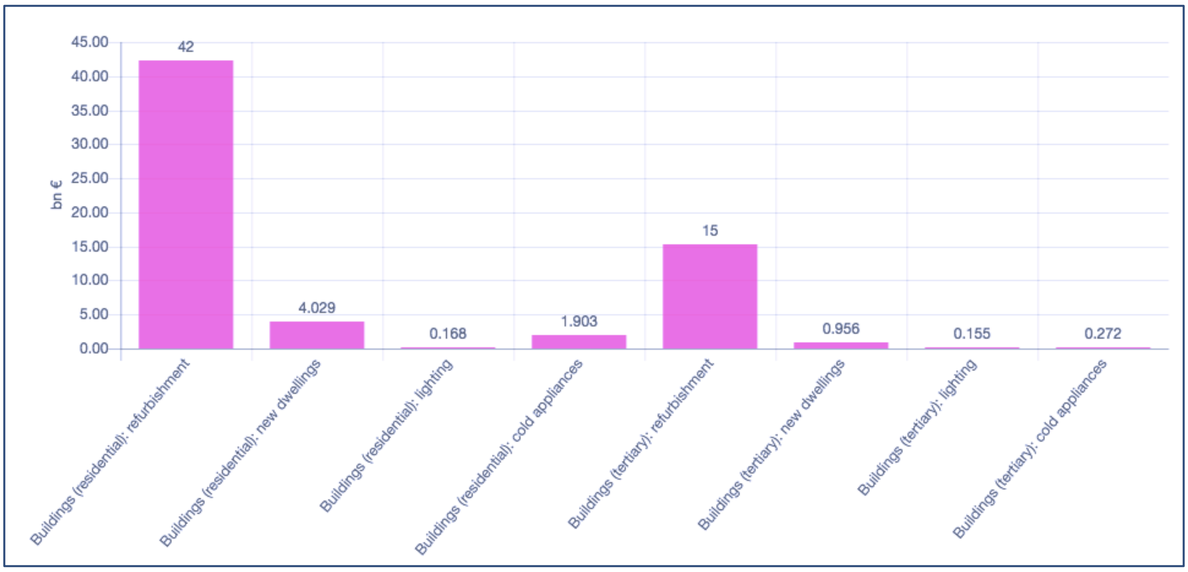


Figure 14: Energy Efficiency investment gap -breakdown by specific actions.

Source: COMBI Project.

Considering the Figure above, it is plausible to conclude that the investment opportunities are rather large and fairly straightforward. The COMBI Project is considered as a direct source of insights for T4.1 and most importantly, T4.2.

5.3 M-BENEFITS PROJECT, EU H2020 PROJECT

The M-benefits Project addresses the methodology of how traditional EE projects are being analyzed and therefore the Project proposes a new methodology that positions multiple benefits as a strong source for enhancing companies' competitive advantages and value proposition. By elevating EE projects to a strategic standpoint, EE projects are aimed at being considered by the top-management team of firms as EE measures may strengthen firms' competitive advantages.

Under this frame, the M-benefits project leverages on their extensive literature review (Fawcett & Killip, 2018) presented in their Deliverable 2.1. One of its' major conclusions is that energy and associated cost savings arguments generally are not reflective of the competitive needs and interests of firms, thus many energy projects lack appeal with companies' top management .

The Consortium took a deep-dive into the M-Benefits Project and scheduled a discussion on MBs with Catherine Cooremans, proclaimed researcher on the matter and active participant of the M-Benefits project. The discussion held on September 2020 was focused on understanding MBs, MBs quantification and estimation methods. As major insight, an exhaustive review of the software developed by the M-Benefits Project was presented. This tool is currently being tested in several pilot projects across Europe. These pilot projects are pinpointed as highly relevant for T4.3, as an exhaustive analysis of MBs inclusion in financial valuations will be performed. Although the results of these pilot projects will be shared later on 2020, the Consortium analyzed the public cases exposed in the Projects' official website (here). M-Benefits approach and real cases are presented below.

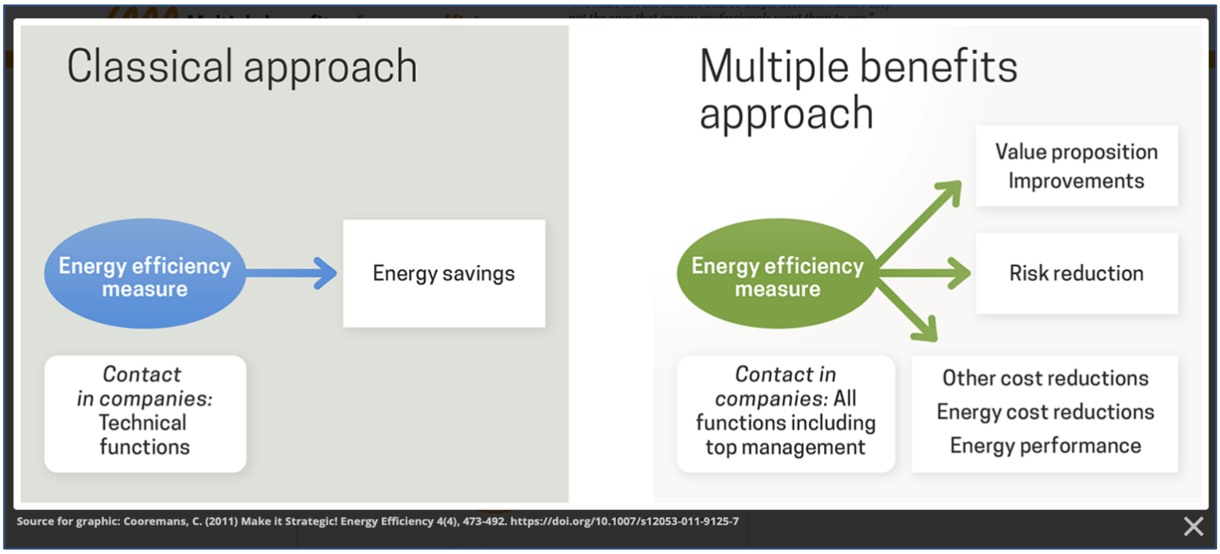


Figure 15: Multiple-Benefits approach.

Source: Multi-Benefits Project

There are strong similarities between the M-Benefits and the EEnvest Project. In particular, the first one quantifies -whenever possible- multiple benefits and include them into the financial assessment case-by-case. This Project is also building a software to ease the DER process. On the other hand, the EEnvest Project is foremost focused on investors and it's also building an online tool to guide the investment decision making process. In regard of valuation methodologies, ulterior analysis will be performed in T4.4. To better illustrate M-Benefits applicability, Figure 16, Figure 17, and Figure 18 below illustrate some of the cases that are presented in this project.

1. Multiple-benefit Example 1: High-Precision Mechanical Work (here).

Financial analysis

Energy benefits only:

- CAPEX: 30'000 €
- NPV: -11'483 €
- IRR: -7.5%
- Simple payback: 13 years

All benefits included:

- CAPEX: 30'000 €
- NPV: 5'898 €
- IRR: 11.5%
- Simple payback: 4.7 years

Discount rate: 6 %
Investment duration: 8 years (i.e. the number of years taken into account to compute NPV and IRR)
See slides 13 & 14 for detailed calculations

Figure 16: Financial analysis -including MBs- for investment case #1.

Source: Multiple-Benefit Project.

Investment (MBs) Financial Analysis												
Investment project (EEM): Change in hot water supply of milling washers												
ASSUMPTIONS FOR CALCULATIONS			t0	t1	t2	t3	t4	t5	t6	t7	T8
Description		Figures		(€)							
Initial expenditure in t0	€	30'000.00		--	--	--	--	--	--	--	--
Subsidy	€	0.00		--	--	--	--	--	--	--	--
Terminal value	€	0.00		--	--	--	--	--	--	--	--
Energy benefits (EBs = energy cost reduction) per year:											
- Electricity	€	2415.00		2'415	2'415	2'415	2'415	2'415	2'415	2'415	2'415
TOTAL	Ebs	2'415.00		2'415	2'415	2'415	2'415	2'415	2'415	2'415	2'415
Non-energy benefits (NEBs) per year:											
- NEB1 : less consumables (formic acid)	€	405.00		405	405	405	405	405	405	405	405
- NEB2 : reduction of water consumption	€	303.00		303	303.60	303.60	303.60	303.60	303.60	303.60	303.60
- NEB3 : lower maintenance costs (tank change)	€	240.00		240	240	240	240	240	240	240	240
- NEB4 : lower equipment costs (tank)	€	3000.00		3'000	3'000	3'000	3'000	3'000	3'000	3'000	3'000
- NEB5 : lower equipment costs (protection equipment)	€	50.00		50	50	50	50	50	50	50	50
TOTAL	NEBs	3'998.00		3'998	3'999	3'999	3'999	3'999	3'999	3'999	3'999
Investment income			t0	t1	t2	t3	t4	t5	t6	t7	T8
				(€)							
Investment income before taxes											
- Total energy benefits				2'415	2'415	2'415	2'415	2'415	2'415	2'415	2'415
- Total non-energy benefits				3'998	3'998	3'998	3'998	3'998	3'998	3'998	3'998

Figure 17: Financial analysis -including MBs- for investment case #1. Breakdown.

Source: Multiple-Benefit Project.

2. Multiple-benefit Example 2: Treatment industry (here)

Step 4: Financial analysis

Without Multiple Benefits	
Net present value (NPV)	10,489 CHF
Internal rate of return (IRR)	6.9%
Simple payback	6 years

All Benefits	
Net present value (NPV)	1,904,476 CHF
Internal rate of return (IRR)	118%
Simple payback	0.85 years

Investment duration = 8 years (number of years taken into account to compute NPV and IRR)
Discount rate 6%

Figure 18: Financial analysis -including MBs- for investment case #2.

Source: Multiple-Benefit Project

Although the scope of project may be slightly different, it is clear that multiple benefits can impact the financial analysis by improving the NPV, IRR and shortening the Payback Period. These impacts may be a game-changer for DER investment assessments. The results of further analysis on this project will feed Task 4.4 *Valuation methodology for EE investment including Multi-benefit* and will be presented in D4.3.

Built up the case for MBs inclusion in DER investment assessments, the following Chapter unfolds the EE Investment Framework proposed by the Consortium.

6 The Energy Efficiency Investment Valuation Framework

The Energy Efficiency Investment Framework (henceforth The Framework) is designed by investors for investors. The Framework settles as the cornerstone for easing the transition towards greener and responsible portfolios that are to be Taxonomy-aligned. Moreover, it guides investors to analyze deep energy efficiency (DER) projects as a driver of long-term value. As such, The Framework incorporates criteria to assess different areas of impact aligned with ESG endeavors.

The EE Investment Framework objectives are fourfold. These are:

1. To encourage investors to comply with their fiduciary duties as defined in Appendix A. It further guides investor to assess their investment principles and to include the following topics as part of their investment rationales:
    a. EU Taxonomy Regulation
    b. Principles for Responsible Investments
    c. Environmental, Societal and Governance (ESG)
    d. Sustainable Development Goals (SDGs)
2. To propose and motivate the use of holistic valuation models for DER investments, including financial and non-financial KPIs such as environmental and multiple benefits.
3. To trigger active stakeholder engagement, adopting a green policy advocacy strategy and a Taxonomy-aligned behavior.
4. To define a set of standard KPIs and proclaimed tools to assess EE investments such as the EEnvest Platform, the Multiple Benefit's Software, EU Taxonomy guidelines, GRESB ESG Benchmark for Real Assets, and the Excellence in Design for Greater Efficiencies (EDGE) green building certification[30].

The Framework is the result of still on-going work performed in WP4. It also feeds directly to the development of T4.4 *Valuation Methodology for EE investments including Multi-benefits*. Further, The Framework will be tested in T4.4 where the Consortium will perform a deep dive into the available tools to assess DER investments. Thus, The Framework will be reviewed if later research suggests improvements.

The sources of major input for the EE Investment Framework have been presented along this Deliverable. It comes from an array of relevant literature (Table 1, Table 2, Table 3 and Table 4), Multilateral Organizations assessment plus deep research on recent publications, key interviews with investors and other stakeholders and exhaustive EU H2020 Projects review. Furthermore, additional input may be proposed as part of T4.4, specifically in regard to KPIs and valuation methodologies. To recapitulate, below are the key topics that guided The Framework's construction:

1. EU Taxonomy: Technical Expert Group on Sustainable Finance recommendations (Appendix A);
2. EFFAS KPIs guidelines (3);
3. IIGCC's Net Zero Framework (Appendix A);
4. MSCI and GSIA's research (Appendix A);
5. Principles for Responsible Investments (Appendix A);
6. Fiduciary Duty in the 21st Century (Appendix A);
7. M-Benefits EU H2020 Project (5.3); and
8. GNE Finance's experience with investors, multiple benefits and investment valuation methodologies.

[30] These tools may be thoroughly analyzed in T4.4 in order to set the basis for a standard DER investment valuation methodologies. As such, The Framework may assess but it is not limited to the tools mentioned in this point.

6.1 The Framework - Breakdown

The EE Investment Framework consist of eight steps clustered in three different levels. All steps are consecutive and are dependent on the investor profile. Despite that The Framework is primarily focused on Financial Institutions and Asset Managers, it is proposed as a user-friendly tool capable of attract all investors type mapped out in Figure 5. In this regard, The Framework facilitates the access for financing to business owners and tenants plus it serves as guidance for investors relations.

On the other hand, The Framework delimits the key areas that needs to be addressed to propel DER investments at large scale. With this objective, The Framework pinpoints the relevant topics that investors must consider when assessing DER investments and it also prepares the ground for T4.4, specifically focused in valuation methodologies. In this respect, The Framework is presented as a steppingstone for further standardization of KPIs election and quantification methodologies.

Levering on specific investor profiles, it is plausible to state that different investors may select different KPIs for investment evaluation and strategic decisions. However, regardless the ultimate investment decision, all investors that utilize the Energy Efficiency Investment Framework will access the necessary information, best practices, tools and valuation methodologies (T4.4) to accurately assess DER investments.

The three levels that compose The Framework walk investors through internal and external analysis aimed at mapping existing gaps to achieve a climate-aligned portfolio. Each level possesses different steps that guides investors towards building a compelling energy efficiency investment case. Figure 19 unfolds the Energy Efficiency Investment Framework and it is followed by a thorough explanation of each step and expected outcome.

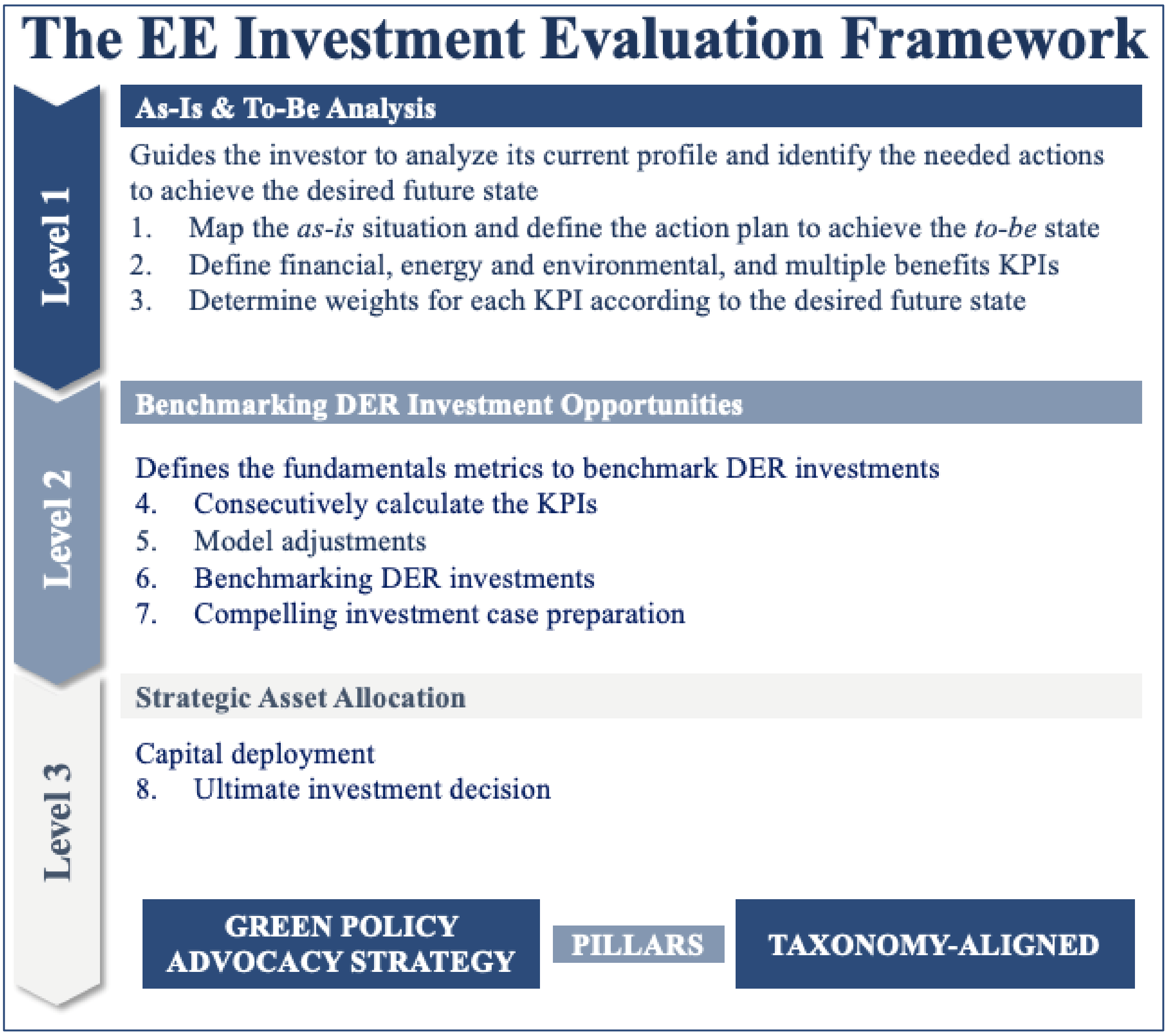


Figure 19: The Energy Efficiency Investment Evaluation Framework

Source: GNE Finance

Ultimately, The Framework is guided by two transversal activities that eases investors' stakeholder management. These activities are (i) to define and enact a policy advocacy strategy and to (ii) strongly engage with stakeholders and pursuit a Taxonomy-aligned behavior.

6.1.1 Level 1 – Investor Objectives and Portfolio Alignment

The first level addresses the investor profile with strong emphasizes on investors' path to include sustainable investments as part of their fiduciary duty. As such, Level 1 is divided in three steps that defines the basis for a holistic valuation methodology including three type of KPIs: Financial, Energy and Environmental and Multiple Benefits KPIs.

The election of KPIs must be aligned with investors' principles and objectives. Therefore, the ultimate outcome of Level 1 is the determination of the weight of each KPI. Subsequentially, these KPIs and respective weights serve as input for building sound valuation models. Ultimately, these models will allow investors to benchmark DER investment opportunities.

6.1.1.1 Step 1: As-Is & To-Be Analysis

Step 1 motivates investors to assess their current and desired investors profile. This process is achieved through an As-Is & To-Be Analysis that pinpoints the existing gap to reach the desired objective (To-Be): greener investor profile. Important is to note that some investors may already have an aligned portfolio. Nevertheless, we strongly encourage investors to perform this analysis in order to map areas of improvement. Figure 20 facilitates a template to perform the analysis. It also proposes key topics that are aimed at identifying best practices to align the investment decision making process. These topics are defined below.

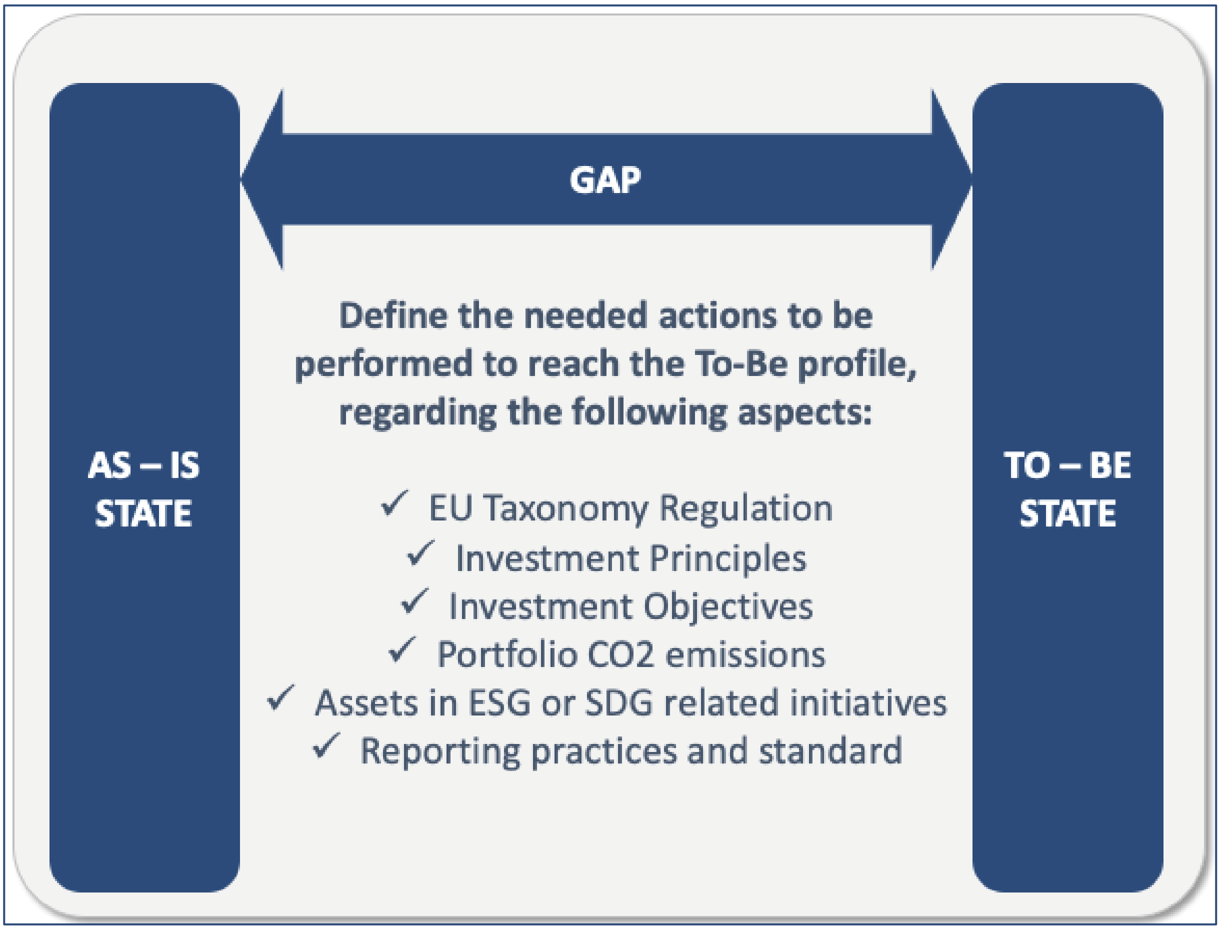


Figure 20: As-Is & To-Be Analysis Template

Source: GNE Finance

1. As-Is
   State the following:
   a. EU Taxonomy Regulation Alignment
   b. Investment Principles
   c. Investment Objectives
   d. Portfolio CO2 emissions
   e. Assets in ESG or SDG related initiatives
   f. Reporting practices and standard

2. To-Be
   Map the desired state of the following:
   a. EU Taxonomy Regulation Alignment

b. Investment Principles
c. Investment Objectives
d. Portfolio CO2 emissions
e. Assets in ESG of SDG related initiatives
f. Reporting Practices and Standard

3. Gap definition and investor alignment

The Gap is defined as the needed actions to be performed in order to reach the To-Be profile. Bearing this context, The Framework proposes as ideal objective to become a signatory of the Principles of Responsible Investments due to its' global relevance and implications of becoming a signatory. Figure 21 below exposes the benefits of becoming part of the PRI signatories.

Benefits

- Invitations to over a 100 events and workshops each year, including PRI in Person.
- Resources for reporting and assessing your organisation's ESG activities.
- Access to other signatories' reports and assessments through the PRI Data Portal.
- Support from a regional relationship manager with local market knowledge.
- Use of the Collaboration Platform to network with signatories and engage with ESG research.
- Guidance on how to incorporate ESG factors into investment decision-making and ownership.

Figure 21: Benefits of being a PRI signatory

Source: UNEP FI[31]

In the quest of decarbonizing investors' portfolio, the benefits of joining the global network of signatories represents a solid opportunity to ramp-up the integration of ESG factors into the investment decision-making process. Under this frame, the Consortium suggests leveraging on this existing network and to actively interact with signatories. For further details on how to become a PRI signatory, please refer to this link.

However, the Consortium comprehends that not all investors have the capacity nor the financial conditions[32] to become a signatory. In this regard, The Framework signals key topics to encourage investors to begin their climate-aligned investment behavior by conducting research on the following topics:

a. EU Taxonomy Regulation
b. ESG Metrics
c. Sustainable Investments Alignment
d. Fiduciary Duty
e. Sustainable Development Goals Alignment

6.1.1.2 Step 2: Holistic KPIs for DER Investment Assessment

Once investors defined the existing gap they aim to narrow, they can select the KPIs and their respective weighting to monitor performance. For this purpose, Step 2 narrows the scope to investments in EE.

[31] Retrieved from https://www.unpri.org/signatory-resources/become-a-signatory/5946.article#How_to_apply
[32] The annual fee to become a signatory depends on the investor profile. The PRI classifies investors under three categories: Asset Owners, Investment Managers and Service Providers. For further details on the annual fee please refer to this link.

Specifically, in DER projects. The Framework enhances the traditional financial assessment by incorporating two additional sets of KPIs that measure environmental, societal and economic impact.

The Energy Efficiency Investment Framework introduce a holistic methodology to investors to assess DER investments. The holistic approach takes into consideration all stakeholders embedded in the DER project. As a result, investors will obtain an investor-ready fact sheet[33] with all KPIs.

a. Financial KPIs
    a. Simple Payback Period
    b. Net Present Value (NPV)
    c. Internal Rate of Return (IRR)
    d. Debt Service Coverage Ratio (DSCR)

As defined in D3.1, the Consortium defines the Discounted Cash Flow Model (DCF) as most suitable financial methodology to assess DER investments. In this regard, the aforementioned KPIs are the result of the DCF valuation and are strongly dependent on the estimation of all possible revenue streams incurred when investing in a DER project. The subsequent set of KPIs are defined to expose different areas of impact and outlines possible additional revenues streams that could be included into the DCF model.

b. Energy and Environmental KPIs

These KPIs are aimed at estimating the positive impact in CO2 emissions and energy consumption reduction. As such, investors may include these results as part of their portfolio assessment. Ultimately, the Energy and Environmental KPIs are the mean to strip CO2 emissions from investors' portfolio. The KPIs are:

    a. Energy savings
    b. CO2 emission reduction

The Framework sets forward energy savings as the primary source of revenue prevenient from DER investments as it's linked with higher levels of available revenue from the perspective of the property owner. In this respect, energy savings must be thoroughly estimated in order to minimize any possible discrepancies between predicted and actual energy savings. Whereas the estimation of CO2 emission reduction serves as direct input to align investors' portfolio metrics and to further enhance their compromise to decarbonize their investments.

Important is to note that in some industries CO2 emission reduction may be attributable as an extra source of revenue due to the possibility to commercialize emissions permits as defined in the EU ETS guidelines. For an exhaustive review on this topic, refer to this link.

c. Multiple Benefits KPIs

The Multiple Benefits KPIs offers a compelling assessment of the impact on different stakeholders when investing in DER. These KPIs are proposed based on their relevance for investors, quantification methodology and impact magnitude. The inclusion of Multiple Benefits into the investment assessment is twofold. For instance, as (i) a direct source of valuable information for the investment case or alternatively, as (ii) an indirect source of revenue due to an increase in productivity.

The proposed KPIs are:

a. Thermal Comfort
b. Acoustic Comfort
c. Visual Comfort
d. Air Quality

[33] These results will be displayed in the EEnvest Platform, that's being developed in WP5.

e. Perceived Physical/Mental Health
f. Productivity

The respective quantification methodology is presented in T4.2 (Appendix B). As the prior work shows, Multiple Benefits values are relative to Energy Savings. Table 5 better illustrates MBs KPIs possible values.

KPI	NEB Values Range relative to Energy Savings	Consistency across programs [1..5]	Investor Weight [1..5]
Thermal Comfort	[1% , 51%]	4	3
Acoustic Comfort	[5%, 35%]	2	3
Visual Comfort	[1% , 44%]	3	3
Air Quality (Environmental)	[5% , 50%]	2	4
Perceived Physical/ Mental Health	[2% , 47%]	3	3
Productivity per employee	[5% , 33%]	3	4

Table 5: Recapitulation of Multiple-Benefits KPIs proposed by the Consortium. Source: T4.2[34]

6.1.1.3 Step 3: KPIs Weighting

Following KPIs election, investors must determine the weight of each KPI related to their investment principles and objectives, as defined in the As-Is & To-Be Analysis performed in Step 1. The objective of weighting KPIs relies on defining the relevance, in a measurable and comparable manner, of each KPIs. The ultimate outcome of weighting KPIs is to construct a final score that can be used to benchmark all investment opportunities and thus investors will have, in a single snapshot, all investment opportunities ranked according to their individual performance (i.e. individual KPI) and overall performance (i.e. overall scoring). This process is crucial to select the most appropriate investment opportunity, as defined in Step 6.

It ought to be stated that significant effort regarding KPIs weighting, benchmarking and scoring will be undertaken in T4.4, where DER projects will be analyzed in practical fashion.

As final remark, The Framework acknowledges that weight definition is solely dependent on each investors type and therefore, we encourage investors to set KPIs' weight to the best of their knowledge. On this subject, The Framework highlights the relevance of the previous steps to support investors' definition of KPI's weighting in order to align them with their objectives. KPIs will guide investors through the entire investment process, since the investment decision until the periodic ex-post impact assessment and revaluation of assets. Investors can expect that a fine tuning of weightings can occur once an ex-post impact assessment is performed in order to reach their goals in the three dimensions (financial, energy-related and non-energy).

[34] Table 5 can also be found in Appendix B.

6.1.2 Level 2 – Benchmarking DER Investment Opportunities

Level 2 is composed by 4 steps. Each step is aimed at preparing investors to benchmark DER investment opportunities. The election of all possible investments must be aligned with the investment objectives stated in Level 1. Consequently, Level 2 walks investors through the fundamentals to assess DER investment opportunities.

6.1.2.1 Step 4 – Holistic Investment Assessment

The Consortium proposes a progressive scenario assessment for DER investments. Correspondingly, a progressive scenario assessment implies that the investment opportunity must be analyzed sequentially, where each scenario builds upon its' prior. The scenarios are based on the multi-stakeholder impact that occurs when investing in a DER project. Under this frame, each scenario subsequently incorporates the KPIs defined in Step 2 and therefore are aligned with the investment principles stated in Step 1.

Important is to note that an exhaustive analysis on KPIs inclusion in valuation models will be performed in T4.4 and presented in D4.3. Therefore, the progressive scenarios presented below must incorporate the KPIs defined in Step 2, as a direct source of insights for the investment assessment. Further, as T4.4 will argue, KPIs contribution to the investment assessment may be two folded: (i) to enhance the investment narrative or alternatively, (ii) as an additional revenue stream to be included in the DCF analysis -depending on each investment case.

Although The Framework outlined the KPIs in Step 2, a brief recapitulation of the three progressive scenarios is presented below:

Financial Scenario

The Financial Scenario is represented by the calculation of the four financial KPIs defined in Step 2. As such, this initial scenario valuates the investment opportunity only considering direct input such as capital requirements and expected energy cost savings. With this input, investors should build and run the DCF model.

Financial & Environmental Scenario

This scenario depicts the environmental impact of the DER investment. Aligned with the KPIs defined in Step 2, this scenario incorporates the environmental impact of the investment opportunities. The output of the Financial & Environmental Scenario must be aligned with the Investment Principles defined in Step 1.

Consequently, investors may utilize the Environmental KPIs as direct input for deciding on which DER investment complies with investors' CO2 emission reduction target. These KPIs are the same of Step 2.

Financial, Environmental & Multiple Benefit Scenario

The inclusion of Multiple Benefits into the DER investment case, a standard method to calculate the impact of Multiple Benefits will be further analyzed in Task 4.4. In this regard, the present scenario highlights the benefits that occurs beyond energy and environmental factors. These benefits are mapped in the set of KPIs proposed in Table 5.

Further, as the EE Investment Cases presented in Chapter 5 presented, non-energy benefits may be included in the financial assessment of DER projects. The exact determination of how these benefits can be included in valuation methodologies will be performed in T4.4.

6.1.2.2 Step 5 – Model Adjustments and Added Value Capture

As of November 2020, the industry does not use a standard method to include other benefits than energy and environmental benefits into valuation methods. Acknowledging the prior, The Framework proposes the Step 5 as a mean to adjust the valuation model. In specific, The Framework further guides investors to define the following values, if possible, by including additional benefits into the DCF model:

a. Financial value of the EE
b. Financial value of the Environmental Impact
c. Financial value of the MBs impact

Equally relevant, The Framework sets the foundations to estimate all value created when investing in DER and also pinpoints which value can be monetized (value captured) and therefore included in valuation methodologies[35]. Exhaustive on this topic will be discussed performed in T4.4 and presented in D4.3.

6.1.2.3 Step 6 – DER Investments Benchmark

Once defined the foundations to properly assess DER investments, The Framework guides investors to a peer-to-peer benchmark. The Consortium proposes the EEnvest Platform as the most appropriate tool to benchmark DER investment opportunities. Further analysis on the software developed by the Multiple-Benefits Project and the applicability of the EDGE green certification criteria will be performed[36] in T4.4. The Consortium expects to find strong synergies with these projects -in respect of valuation methodologies and asset value post retrofit.

In order to assess the DER investment opportunities, Figure 22 below proposes a scorecard to compare the selected projects according to the selected set of KPIs. A project with the highest score, considering weightings defined on Step 3, should be the best investment option available related to evaluation of KPIs. In order to validate the proposed methodology to benchmark DER investment opportunities, the Consortium will analyze investment cases in T4.4 and adjust, if necessary, The Framework proposed in the present Deliverable.

[35] For an initial glimpse on non-energy quantification and monetization, please refer to Business Case 3: Multiple Benefits and Annex B.

[36] As of November 2020, these two projects are considered as highly valuable for the development of T4.4. However, the Consortium may consider new projects or discard existing ones for ulterior work. This analysis will be part of T4.4.

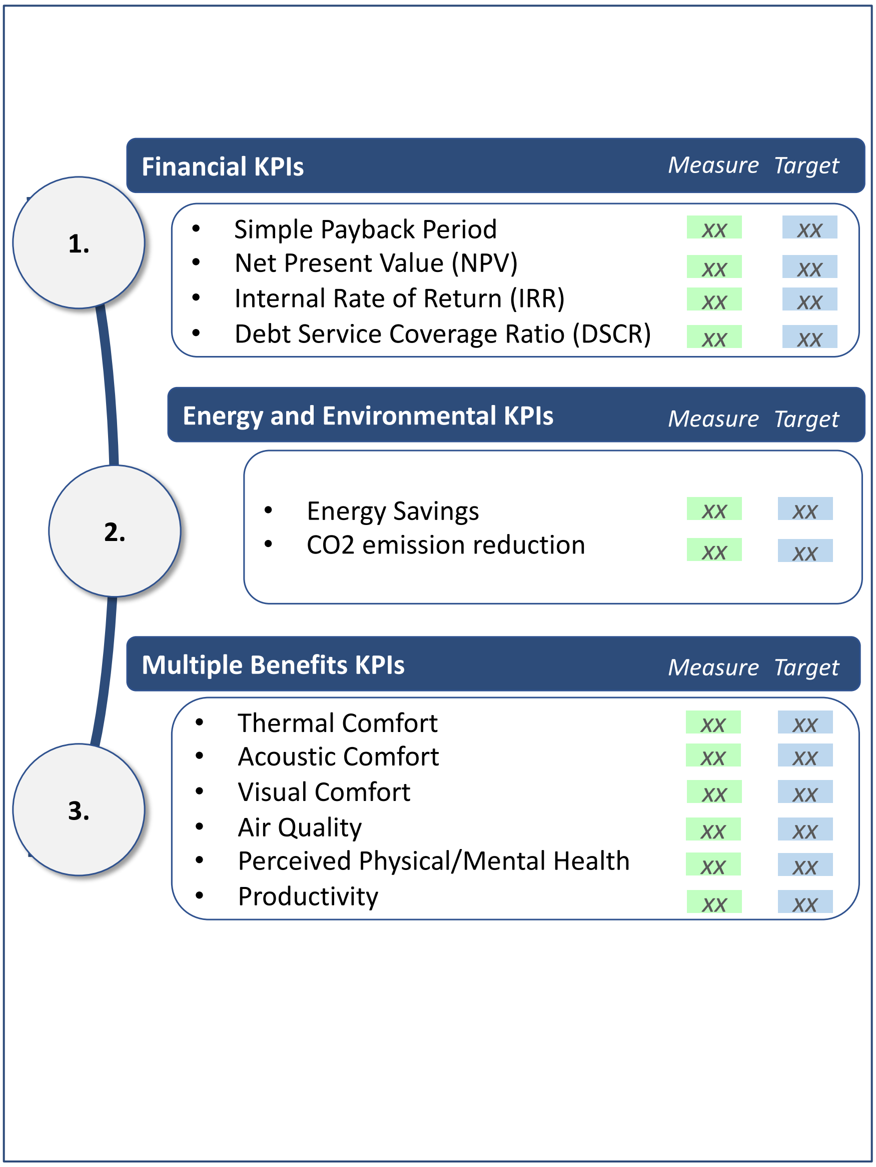


Figure 22: Scorecard for benchmarking DER investments

Source: GNE Finance

6.1.2.4 Step 7 – Compelling Investment Case Preparation

At this stage, investors already selected, analyzed and benchmarked DER investment opportunities. Under this context, The Framework walks investors through an investment case preparation. In this step, investors must prepare the investment narrative highlighting the investment objectives mapped in Step 1.

To achieve a sound investment narrative, the following guidelines are proposed:

a. Investment objectives accordingly with fiduciary duties and the EU Taxonomy
b. Progressive scenario analysis of the investment case
c. Environmental and Multiple Benefits Analysis
d. Value created and value captured

e. Investment case conclusion

The Consortium highlights the relevance of estimating all possible value created when investing in a DER project. As one of the main outcomes of WP4, T4.4. will take a deep-dive in this specific topic and will propose a method to separate the value created from value captured. Evidentially, this finding will impact the investment narrative and it's considered as extremely relevant for the overall WP4's output.

6.1.3 Level 3 - Strategic Asset Allocation

The Strategic Asset Allocation level determines the ultimate investment action. As such, the Consortium defines Strategic Asset Allocation as the act of investing capital in an individual or a set of DER projects. Consequently, the investment decision must be congruent with the investment objectives defined in Step 1. Acknowledging the definition of Strategic Asset Allocation, the ultimate investment decision represents the final step of The Framework, which is Step 8.

As final remark of The EE Investment Evaluation Framework, it is extremely relevant that investors constantly monitor the real impact of their DER investments as a mean to sustain their Taxonomy-aligned portfolio. In this quest, the Consortium motivates investors to stablish internal procedures to assess whether the impact of the investment is achieving the initial estimations.

7 Closing Remarks and Reflections

The present Deliverable sets foundations to build a valuation methodology to assess DER investments in a holistic manner (T4.4). In this quest, the presented work highlighted how investors are adapting their investment objectives to a rather sustainable approach (Appendix A). This current shift is strongly needed to achieve the European Commission climate targets and it is further presented as the necessary step to invest in a more sustainable and resilient planet. Consequently, the EC is emplacing strong efforts and initiatives to speed up the transition towards greener and social investments and with this purpose, the EU Taxonomy Regulation is envisaged to play a crucial role on providing the necessary guidelines and standardizations to ease the investments transformation. The Consortium acknowledges that the upcoming years are crucial to delimitate playground for the financial industry.

Under the same rationale, DER investments are indeed a candid opportunity to diminish GHG emissions and further create new jobs whilst improving the overall wellbeing of society. Bearing this context, it is absolutely imperative to join forces to ultimate define a standard methodology to (i) assess, (ii) communicate and (iii) report the impact of these investments. This challenging task may be the necessary steppingstone to reliable upscale the investment flow required to unleash the full potential of Energy Efficiency. During the research performed to write this Deliverable, the Consortium mapped several EU H2020 Projects that are working around similar topics. In the course of this work, major overlapping with other projects arose and one of the key conclusions -shared with the M-Benefits Project- is that stronger synergies between H2020 Projects must take place in the light of standardizing the procedure to assess DER investments. This rationale will be the backbone of T4.4 were an exhaustive valuation methodology will be proposed.

In regards of the financial assessment of DER investments, it is important to stress the impact of including additional revenue stream into the discounted cash flow analysis, as presented in Chapter 5. The standardization of KPIs and quantification of all impacts embedded in DER projects may be a game-changer for this type of investments. However, it is still not clear the degree of reliability of such inclusion due to innate multi-stakeholder complexity of DER investments. Nevertheless, it is precisely on this topic were T4.4 plays a crucial role and the outcome of this effort will be exhaustively validated in order to pave the way to a standard valuation methodology for DER investments that includes non-energy benefits.

Last, as some of the benefits that emanate from DER projects are largely unknown or unthink of, it is absolutely relevant to develop strong marketing campaigns aimed at communicating the hidden benefits of these projects. Consequently, these campaigns must address all stakeholders embedded in the renovation process and if properly implemented, society may increase its awareness on the relevance of EE and its' direct and measurable impact on people's daily life. This is indeed the inner motivation that fueled the elaboration of this Deliverable.

8 Bibliography

Eichholtz, P., Kok, N., & Quigley, J. (2013). The economics of green building. *Review of Economics and Statistics, 95*(1), 50-63.

Cespedes-Lopez, e.-a. (2019). Meta-Analysis of Price Premiums in Housing with Energy Performance Certificates (EPC). *Sustainability*, 6303.

ILSAG. (2018). *Quantifying Non-Energy Benefits fromComEd's Income Eligible Programs:Findings and Recommendations from Secondary Research.*

Navigant. (2018). *Quantifying Non-Energy Benefits from ComEd's Income Eligible Programs.*

Pearson, D., & Skumatz, L. (2002). Non-energy benefits including productivity, liability, tenant satisfaction, and others: what participant surveys tell us about designing and marketing commercial programs. *Proceedings of the 2002 Summer Study on Energy Efficiency in Buildings*, (p. 2).

Skumatz. (2014). *NON-ENERGY BENEFITS / NON-ENERGY IMPACTS (NEBs/NEIs).*

Jensen, O., Hansen, A., & Kragh, J. (2016). Market response to the public display of energy performance rating at property sales. *Energy Policy, 93*, 229-235.

Fuerst, F., McAllister, P., Nanda, A., & Wyatt, P. (2015). Does energy efficiency matter to home-buyers? An investigation of EPC ratings and transaction prices in England. *Energy Economics, 48*, 145-156.

Evangelista, R., Ramalho, E., & e Silva, J. (2020). On the use of hedonic regression models to measure the effect of energy efficiency on residential property transaction prices: Evidence for Portugal and selected data issues. *Energy Economics, 86*, 104699.

Newell, G., MacFarlane, J., & Kok, N. (2011). Building better returns--A study of the financial performance of green office buildings in Australia. *University of Western Sydney, Sydney*.

Im, J., Seo, Y., Cetin, K., & Singh, J. (2017). Energy efficiency in US residential rental housing: Adoption rates and impact on rent. *Applied energy, 205*, 1021-1033.

Dell'Anna, F., Bravi, M., Marmolejo-Duarte, C., Bottero, M., & Chen, A. (2019). EPC Green Premium in Two Different European Climate Zones: A Comparative Study between Barcelona and Turin. *Sustainability, 11*(20), 5605.

de La Paz, P., Perez-Sanchez, V., Mora-Garcia, R.-T., & Perez-Sanchez, J.-C. (2019). Green premium evidence from climatic areas: A case in Southern Europe, Alicante (Spain). *Sustainability, 11*(3), 686.

de Ayala, A., Galarraga, I., & Spadaro, J. (2016). The price of energy efficiency in the Spanish housing market. *Energy Policy, 94*, 16-24.

Fuerst, F., McAllister, P., Nanda, A., & Wyatt, P. (2016). Energy performance ratings and house prices in Wales: An empirical study. *Energy Policy, 92*, 20-33.

Hyland, M., Lyons, R., & Lyons, S. (2013). The value of domestic building energy efficiency—evidence from Ireland. *Energy economics, 40*, 943-952.

Lung, R., McKane, A., Leach, R., & Marsh, D. (2005). Ancillary savings and production benefits in the evaluation of industrial energy efficiency measures. *Proceedings of the 2005 American*

Council for an Energy-Efficient Economy Summer Study on Energy Efficiency in Industry. Washington, DC: ACEEE.

Stenqvist, C., & Nilsson, L. (2012). Energy efficiency in energy-intensive industries—an evaluation of the Swedish voluntary agreement PFE. *Energy Efficiency, 5*(2), 225-241.

Poortinga, W., Jiang, S., Grey, C., & Tweed, C. (2018). Impacts of energy-efficiency investments on internal conditions in low-income households. *Building Research and Information, 46*(6), 653-667.

Alavy, M., Li, T., & Siegel, J. (2020). Energy use in residential buildings: Analyses of high-efficiency filters and HVAC fans. *Energy and Buildings, 209*, 109697.

Ngo, N. (2019). Early predicting cooling loads for energy-efficient design in office buildings by machine learning. *Energy and Buildings, 182*, 264-273.

Bleyl, J., Casas, M., Hulshoff, A., Robertson, M., Bareit, M., Bruyn, B., & Mitchell, S. (2017). Building deep energy retrofit : Using dynamic cash flow analysis and multiple benefits to convince investors. *ECEEE Summer Study Proceedings*(Bpie).

Bleyl, J., Bareit, M., Casas, M., Chatterjee, S., Coolen, J., Hulshoff, A., . . . Ürge-Vorsatz, D. (2019). Office building deep energy retrofit: life cycle cost benefit analyses using cash flow analysis and multiple benefits on project level. *Energy Efficiency, 12*(1).

Hirvonen, J., Jokisalo, J., Heljo, J., & Kosonen, R. (2019). Towards the EU emission targets of 2050: Cost-effective emission reduction in Finnish detached houses. *Energies, 12(22)*.

Limsombunchai, V. (2004). House price prediction: hedonic price model vs. artificial neural network. *New Zealand agricultural and resource economics society conference*, (pp. 25-26).

Aydin, E., Brounen, D., & Kok, N. (2015). Capitalization of Energy Efficiency in the Housing Market. *Working Paper*.

CraveZero. (2020). *D6.4: Co –Benefitsof nZEBs.* https://www.cravezero.eu/wp-content/uploads/2020/05/CRAVEzero_D64_CoBenefits.pdf.

BPIE. (2011). *Europe's buildings under the microscope - A country-by-country review of the energy performance of buildings. Buildings Performance Institute Europe.*

Jenny Palm, K. R. (2017, July 26). Understanding barriers to energy-efficiency renovations of multifamily dwellings.

Shnapp, S. P. (2020). *Untapping multiple benefits: hidden values in environmental and building policies. EUR 30280 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-19983-0, doi:10.2760/314081, JRC120683.*

Shnapp, S., Paci, D., & Bertoldi, P. (2020). *Untapping multiple benefits: hidden values in environmental and building policies. EUR 30280 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-19983-0, doi:10.2760/314081, JRC120683*. JRC.

Alam, M., Zou, P. X., Stewart, R. A., Bertone, E., Sahin, O., Buntine, C., & Marshall, C. (2019). Government championed strategies to overcome the barriers to public T building energy efficiency retrofit projects. *ELSEVIER*, 56-69.

Palm, J., & Reindl, K. (2017). *Understanding barriers to energy-efficiency renovations of multifamily dwellings.* Crossmark.

Hamilton, Brahmbhatt , & Liu. (2017). *Multiple benefits from climate change mitigation: assessing the evidence.*

EC. (2019). Retrieved from : https://ec.europa.eu/clima/policies/strategies/2030_en

EC. (2016b). 860 final Communication from the Commission to the European Parliament, The Council, The European Economic and Social Committee, The Committee of the Regions and the European Investment Bank Clean Energy for All Europeans. Brussels, 30.11.2016 COM(2016).

EC. (2016b). *860 final Communication from the Commission to the European Parliament, The Council, The European Economic and Social Committee, The Committee of the Regions and the European Investment Bank Clean Energy for All Europeans. Brussels, 30.11.2016 COM(2016).*

EC. (2016b). *860 final Communication from the Commission to the European Parliament, The Council, The European Economic and Social Committee, The Committee of the Regions and the European Investment Bank Clean Energy for All Europeans. Brussels, 30.11.2016 COM(2016).*

EC. (2016). *860 final Communication from the Commission to the European Parliament, The Council, The European Economic and Social Committee, The Committee of the Regions and the European Investment Bank Clean Energy for All Europeans. Brussels, 30.11.2016 COM(2016).*

BPIE. (2011). *Europe's buildings under the microscope. A country-by-country review of the energy performance of buildings.*

Bleyl, J. W., Bareit, M., Casas, M. A., Chatterjee, S., Coolen, J., Hulshoff, A., . . . Ürge-Vorsatz, D. (2019). *Office building deep energy retrofit: life cycle cost benefit analyses using cash flow analysis and multiple benefits on project level.* CrossMark.

IEA. (2019). *IEA (2019), Energy efficiency is the first fuel, and demand for it needs to grow, IEA, Paris https://www.iea.org/commentaries/energy-efficiency-is-the-first-fuel-and-demand-for-it-needs-to-grow*. Retrieved from https://www.iea.org/commentaries/energy-efficiency-is-the-first-fuel-and-demand-for-it-needs-to-grow

IEA. (2019). *Energy efficiency is the first fuel, and demand for it needs to grow, IEA, Paris https://www.iea.org/commentaries/energy-efficiency-is-the-first-fuel-and-demand-for-it-needs-to-grow.*

Zancanella, P., Bertoldi, P., & Boza-Kiss, B. (2018). *Energy efficiency, the value of buildings and the payment default risk, EUR 29471 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92- 79-97751-0, doi:10.2760/267367, JRC113215.*

Ferreira, M., Almeida, M., & Rodrigues, A. (2017). *Impact of co-benefits on the assessment of energy related building renovation with a nearly-zero energy target.*

UNPRI. (2020). Retrieved from https://www.unpri.org/pri/about-the-pri

UNEP FI & PRI. (2019). *Fiduciary Duty in the 21st Century .*

MSCI. (2020). Retrieved from https://www.msci.com/what-is-esg

BPIE. (2020). *Building Renovation: A kick-starter for the EU recovery.*

Florini, A., & Sovacool, B. (2009). *Who governs energy? The challenges facing global energy governance.* Energy Policy.

GSIA. (2018). *Global Sustainable Investment Review.*

BlackRock. (2020). Retrieved from https://www.blackrock.com/corporate/investor-relations/larry-fink-ceo-letter

BlackRock. (2020a). Retrieved from https://www.blackrock.com/corporate/investor-relations/larry-fink-ceo-letter

BlackRock. (2020b). Retrieved from https://www.blackrock.com/corporate/investor-relations/blackrock-client-letter

NYTIMES. (2020). Retrieved from https://www.nytimes.com/2020/01/14/business/dealbook/larry-fink-blackrock-climate-change.html

Forbes. (2020). Retrieved from https://www.forbes.com/sites/michaelperegrine/2020/07/19/blackrock-heats-up-climate-change-pressure-on-boards/#3d2d40bf38cd

Reuters. (2020). Retrieved from https://www.reuters.com/article/us-esg-blackrock-breakingviews/breakingviews-blackrock-warrants-a-spot-on-its-climate-watchlist-idUSKBN24F0ZX

Financial Times. (2020). Retrieved from https://www.ft.com/content/8809032d-47a1-47c3-ae88-ef3c182134c0

IIGCC. (2020). Retrieved from https://www.iigcc.org/our-work/paris-aligned-investment-initiative/

Financial Times. (2020b). Retrieved from https://www.ft.com/content/88f3819c-a0a0-40e4-8a21-dba35512a02c

IIGCC. (2020b). *Paris Aligned Investment Initiative: Net Zero Investment Framework for Consultation.*

EFFAS. (2009). *KPIs for ESG – A Guideline for the Integration of ESG into Financial Analysis and Corporate Valuation .*

Rohde, C., & Cooremans, C. (2019). *Value Multiple Benefits! - Improve Energy Efficiency!*

Cooremans, C. (2011). *Make it strategic! Financial investment logic is not enough.* Energy Efficiency.

Cooremans, C., & Schönenberger, A. (2017). *Energy management: a key driver of energy-efficiency investment?* ECEE Summer Study, European Council for an Energy Efficient Economy.

Kats. (2006). *Greening America's Schools: Costs and Benefits. https://www.usgbc.org/ShowFile.aspx?DocumentID=2908* .

Ürge-Vorsatz , & Novikova. (2014). *Counting good: Quantifying the co-benefits of improved efficiency in buildings.*

Eichholtz, P., Kok, N., & Quigley, J. M. (2010). *The economics of green building.*

Kok, N., & Jennen, M. (2011). *The value of Energy labels in the European Office Market 2011.*

Chegut, A., Eichholtz, P., & Kok, N. (2013). *Supply, Demand and the Value of Green Buildings, 2013.*

Fuerst, F., & McAllister, P. (2011). *Green Noise or Green Value? Measuring the Effects of Environmental Certification on Office Values.* Real Estate Economics.

IEA. (2019). Retrieved from https://www.iea.org/reports/multiple-benefits-of-energy-efficiency

IEA. (2019). *Iea report multiple benefits of energy efficiency. https://www.iea.org/.*

RMI. (2015). *The Path to Deep Energy Retrofit.* https://rmi.org/wp-content/uploads/2017/04/2015-02_Path_to_DR_using_ESPC.pdf.

UNEP. (2016). *Towards zero-emission efficient and resilient buildingsGLOBAL STATUS REPORT 2016.* https://www.worldgbc.org/sites/default/files/GABC_Global_Status_Report_V09_november_FINAL.pdf.

USGBC. (2020). *https://www.usgbc.org/press/benefits-of-green-building.* https://www.usgbc.org/press/benefits-of-green-building.

GBC, W. (2017). *Global Status Report 2017.* {https://www.worldgbc.org/news-media/global-status-report-2017.

Toosi, H. (2020). Life Cycle Sustainability Assessment in Building Energy Retrofitting; A Review. *Sustainable Cities and Societ*, 102248.

Jensen, O., & al., e. (2016). Market response to the public display of energy performance rating at property sales. *Energy Policy*.

Chegut, A., Eichholtz, P., & Kok, N. (2019). The price of innovation: An analysis of the marginal cost of green buildings. *Journal of Environmental Economics and Management, 98*.

De Cock, D. (2016). *House Prices: Advanced Regression Techniques - Competition Rules*. Retrieved from https://www.kaggle.com/c/house-prices-advanced-regression-techniques/data

Taltavull, P., & al, e. (2019). Green premium evidence from climatic areas: A case in Southern Europe, Alicante (Spain). *Sustainability*.

worldgbcnews. (2016). *Workers in certified green buildings record higher cognitive functions scores.* https://www.worldgbc.org/news-media/workers-certified-green-buildings-record-higher-cognitive-functions-scores-finds-study.

Vrabel, K. (2018). *Beyond the dollar sign non energy benefits to energy efficiency.* https://www.waypoint-energy.com/post/beyond-the-dollar-sign-non-energy-benefits-to-energy-efficiency.

GSA. (2011). *Green Building Performance.* https://www.gsa.gov/cdnstatic/Green_Building_Performance2.pdf.

Mansilla, D., Papageorgiou, D., Borges, C., Tsolakis, A., Kamara, O., Krinidis, S., . . . Ipiña, D. (2019, 3 16). (PRE) Socio-economic and cultural dataset in relation to Persuasive Strategies to boost Energy Efficiency and in the UK, Spain, Greece and Austria.

Paige, F., Agee, P., & Jazizadeh, F. (2019). *OSF | flEECe Survey Dataset v3 8_28_19.xlsx*. Retrieved from flEECe, an energy use and occupant behavior dataset for net-zero energy affordable senior residential buildings: https://osf.io/2qy9b/?show=view

team, E., & Galev, T. (2019, 10 31). *ENABLE.EU H2020 project dataset and questionnaire from a survey of households on energy use and energy choices*. Retrieved from https://zenodo.org/record/3523916

Buylova, A. (2020, 3 10). *Investigating dynamics between energy use and socio-demographic characteristics in spatial modeling of residential energy consumption*. Retrieved from https://zenodo.org/record/3703524

Földváry Ličina, V., Cheung, T., Zhang, H., de Dear, R., Parkinson, T., Arens, E., . . . Kaam, S. (2018). *ASHRAE Global Thermal Comfort Database II*. Retrieved from Dataset: https://datadryad.org/stash/dataset/doi:10.6078/D1F671

Reichl, J., Cohen, J., Kollmann, A., Azarova, V., Klöckner, C., Royrvik, J., . . . Bird, N. (2019, 11 1). *International survey of the ECHOES project*. Retrieved from https://zenodo.org/record/3524917

Chiara, D., Roberto, F., Alessandro, B., Marcus, G., Fabian, O., & Chris, B. (2019, 6 25). *iNSPiRe FP7 - Retrofit solutions database*. Retrieved from https://zenodo.org/record/3256270

Energy Information Administration. (n.d.). *Residential Energy Consumption Survey (RECS) - Data - U.S. Energy Information Administration (EIA)*. Retrieved from https://www.eia.gov/consumption/residential/data/2015/

Kmetty, Z., Bent, C., Shreeve, G., & Virág, Z. (2017, 6 28). *NATCONSUMERS - main factors and attitudes behind energy consumption*. Retrieved from https://zenodo.org/record/820364

Galata, A., Brogan, M., & Cunningham, J. (2019, 10 2). *ENERIT module outcomes for the 3 pilot sites on which the module has been deployed during the HIT2GAP project*. Retrieved from https://zenodo.org/record/3468951

Bahrar, M., Coillot, M., Laaroussi, Y., Frutos Dordelly, J., & El Mankibi, M. (2020, 1 24). *HEART 2.2 analysis data*. Retrieved from https://zenodo.org/record/3626699

Norris, F. (2017, 3 20). *Questionnaire on needs and requirements for energy performance gap reduction at the operational level of a building*. Retrieved from https://zenodo.org/record/401009

SENSEI. (2020). *PAY-FOR-PERFORMANCE to drive energy efficiency in Europe.* https://senseih2020.eu/.

Crazevero Project. (n.d.). *https://cravezero.eu/.*

COMBI Project, C. (n.d.). Multiple Benefits of Energy Efficiency. *https://combi-project.eu/.*

Comfotmeter. (2018). The Comfortmeter survey.

Acosta, I. (2018). Minimum Daylight Autonomy: A New Concept to Link Daylight Dynamic Metrics with Daylight Factors. *Leukos*, 251-269.

Canada Safety. (n.d.). *Office Noise and Acoustics.* https://canadasafetycouncil.org/office-noise-and-acoustics/.

ETDE. (2001). *Pollution source control and ventilation improve health, comfort and productivity .* https://www.osti.gov/etdeweb/biblio/20397142.

Hänninen. (2013). *Efficient reduction of indoor exposures - Health benefits from optimizing ventilation, filtration and indoor source controls.* https://www.julkari.fi/handle/10024/110211.

Berggren. (2017). International conference on Energy, Environment and Economics. *International conference on Energy, Environment and Economics.*

Thatcher. (2014). Changes in productivity, psychological wellbeing and physical wellbeing from working in a 'green' building . *Work*.

Singh. (2009). Effects of Green Buildings on Employee Health and Productivity . *AJPH*.

Miller. (2009). Green Buildings and Productivity. *Journal of Sustainable Real state*.

Berggren, B. (2018). Lcc Analysis of a Swedish Net Zero Energy Building – Including Co-Benefits. *(July 2019)*, 2-9.

HealthVent. (2012). *Report on the association between health and ventilation, and on the scientific basis for health-based ventilation.*

Milton. (2001). Risk of Sick Leave Associated with Outdoor Air Supply Rate, Humidification, and Occupant Complaints. *Indoor Air*.

Lohse, R., & Zhivov, A. (2019). *Deep Energy Retrofit Guide for Public Buildings: Business and Financial Models.* Springer.

Selim, H. (2009). Determinants of house prices in Turkey: Hedonic regression versus artificial neural network. *Expert systems with Applications, 36*(2), 2843-2852.

EC. (2020). *Renovation wave initiative in the buildings sector.* https://www.europarl.europa.eu/legislative-train/theme-a-european-green-deal/file-renovation-wave.

WELL. (2020). WELL Certification (www.wellcertified.com).

Star, E. (2020). Energy Star Certification https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/earn-recognition/energy-star-certification.

LEED. (2020). LEED rating system (www.usgbc.org/leed).

Lohse, R., & Zhivov, A. (2019). *Deep Energy Retrofit Guide for Public Buildings: Business and Financial Model.* Springer.

Copiello, S. (2017). Building energy efficiency: A research branch made of paradoxes. *Renewable and Sustainable Energy Reviews, 69*, 1064-1076.

Zancanella, P., Bertoldi, P., & Boza-Kiss, B. (2018). *Energy efficiency, the value of buildings and the payment default risk.*

Zakeri, B., & Syri, S. (2015). Electrical energy storage systems: A comparative life cycle cost analysis. *Renewable and Sustainable Energy Reviews, 42*, 569-596.

Ürge-Vorsatz, D., Herrero, S., Dubash, N., & Lecocq, F. (2014). Measuring the co-benefits of climate change mitigation. *Annual Review of Environment and Resources, 39*, 549-582.

Moran, P., O'Connell, J., & Goggins, J. (2020). Sustainable energy efficiency retrofits as residenial buildings move towards nearly zero energy building (NZEB) standards. *Energy and Buildings, 211*, 109816.

Liu, S., Schiavon, S., Das, H., Jin, M., & Spanos, C. (2019). Personal thermal comfort models with wearable sensors. *Building and Environment, 162*, 106281.

Ferreira, M., Almeida, M., & Rodrigues, A. (2017). Impact of co-benefits on the assessment of energy related building renovation with a nearly-zero energy target. *Energy and Buildings, 152*, 587-601.

Encinas, F., Marmolejo-Duarte, C., De La Flor, F., & Aguirre, C. (2018). Does energy efficiency matter to real estate-consumers? Survey evidence on willingness to pay from a cost-optimal analysis in the context of a developing country. *Energy for Sustainable Development, 45*, 110-123.

Dunse, N., & Jones, C. (1998). A hedonic price model of office rents. *Journal of property valuation and investment*.

Daim, T., Li, X., Kim, J., & Simms, S. (2012). Evaluation of energy storage technologies for integration with renewable electricity: Quantifying expert opinions. *Environmental Innovation and Societal Transitions, 3*, 29-49.

Blomqvist, E., & Thollander, P. (2015). An integrated dataset of energy efficiency measures published as linked open data. *Energy Efficiency, 8*(6), 1125-1147.

Quantifying Non-Energy Benefits fromComEd's Income Eligible Programs:Findings and Recommendations from Secondary Research. (n.d.).

Less, B., & Walker, I. (2015). *14Deep Energy Retrofits -Reducing Costs and Increasing Cost-Effectiveness.* https://basc.pnnl.gov/sites/default/files/resource/DERs_CostEffectiveness.pdf.

Copiello, S. (2017). Building energy efficiency: A research branch made of paradoxes. *Renewable and Sustainable Energy Reviews*.

Argunhan. (2018). Statistical Evaluation of Indoor Air Quality Parameters in Classrooms of a University. *Advances in Meteorology*.

NOAO.edu. (2000). Recommended Light Levels (Illuminance) for Outdoor and Indoor Venues.

EC. (2020, September). Retrieved from https://ec.europa.eu/clima/policies/strategies/2030_en

TEG. (2020). *Taxonomy: Final report of the Technical Expert Group on Sustainable Finance.*

EC d. (2020). Retrieved from https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/eu-taxonomy-sustainable-activities_en

Sustainalytics. (2019). Retrieved from https://www.sustainalytics.com/esg-blog/eu-taxonomy-developments-from-trilateral-negotiations/?utm_term=&utm_campaign=Leads-Search-20&utm_source=adwords&utm_medium=ppc&hsa_acc=4619360780&hsa_cam=11145778763&hsa_grp=108965194933&hsa_ad=465929335428&hsa_src

ECf. (2020). Retrieved from https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/what-sustainable-finance_en

Climate ADAPT. (2020). Retrieved from https://climate-adapt.eea.europa.eu/eu-adaptation-policy/sector-policies/buildings

ESRB. (2015). *Report on commercial real estate and financial stability in the EU.*

ESRB. (2019). *RECOMMENDATION OF THE EUROPEAN SYSTEMIC RISK BOARD.*

ECa. (2019). Retrieved from https://ec.europa.eu/clima/policies/strategies/2030_en

ECb. (2020). Retrieved from https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/eu-taxonomy-sustainable-activities_en

ECc. (2019). Retrieved from https://ec.europa.eu/info/news/new-rules-greener-and-smarter-buildings-will-increase-quality-life-all-europeans-2019-apr-15_en

Wargocki, P., Wyon, D. P., Baik, Y. K., Clausen, G., & Fanger, P. (1999). *Perceived air quality, sick building syndrome (SBS) symptoms and productivity in an office with two different pollution loads.*

Fisk, W. J. (2002). *How IEQ affects health, productivity.* ASHRAE Journal.

Coolen, J., Klonek, F., & Wuyts, S. (2012). *Report of comfort surveys by Comfortmeter.*

Helsen, L., & Coolen, J. (2013). *Comfort experience of users in offices with and without Geotabs ('Comfortervaring in kantoren mét en zonder Geotabs'.*

Killip, G., Cooremans, C., Krishnan, S., Fawcett, T., Crijns-Graus, W., & Voswinkel, F. (2019). *Multiple benefits of energy efficiency at the firm level: a literature review.*

COMBI. (2015). *Calculating and operationalising the multiple benefits of energy efficiency in Europe.*

IEA. (2017). *Co-benefits of energy related building renovation - Demonstration of their impact on the assessment of energy related building renovation (Annex 56) Energy in Buildings and Communities Programme.*

Copenhagen Economics. (2012). *Multiple benefits of investing in energy efficient renovation of buildings: Impact on Public Finances Commissioned by Renovate Europe.*

Fawcett, T., & Killip, G. (2018). *Literature Review - methodology and preliminary findings.*

Kotaji, S. (2003). *Life-cycle assessment in building and construction: a state-of-the-art report.* FL: Society of Environmental Toxicology and Chemistry.

Kale, N. N., Joshi, D., & Menon, R. (2016). *Life Cycle Cost Analysis of Commercial Buildings with Energy Efficient Approach.*

Annexes

Annex 1: Deep-dive into investors' rationale and sustainable financing

Annex 2: Creating a business case for non-energy related benefits, related to task T4.2

Annex 3: Specification of Multiple Benefits Input in the EEnvest Radar

EEnvest

Risk reduction for Building Energy Efficiency investments

Annex 1
Deep-dive into investors' rationale and sustainable financing

Table of Contents

List of Figures

Author	Patricio Cartagena (GNE Finance)
Contributors	Fernando Salat and Jaime Gomez-Ramirez (GNE Finance)

1 Annex 1 - Deep-dive: contribution to the EE Investment Evaluation Framework

1.1 EU TAXONOMY

The EU Taxonomy sets performance thresholds (i.e. technical screening criteria) for economic activities which:

1. Make a substantive contribution to one of the six environmental objectives. These objectives are:
    - Climate Change Mitigation;
    - Climate Change Adaptation;
    - Sustainable and protection of water and marine resources;
    - Transition to a circular economy;
    - Pollution prevention and control; and
    - Protection and restoration of biodiversity and ecosystems.

2. Do not significant harm to the other five objectives

3. Meet minimum safeguards (e.g., OECD Guidelines on Multinational Enterprises and the UN Guiding Principles on Business and Human Rights)

Additionally, the report is accompanied by a technical Annex that contains (ECb, 2020):

- Updated technical screening criteria for 70 climate change mitigation and 68 climate change adaptation activities, including criteria for do no significant harm to other environmental objectives; and
- An updated methodology section to support the recommendations on the technical screening criteria.

1.2 PRINCIPLES FOR RESPONSIBLE INVESTMENTS

Stablished in 2006 by the United Nations, the Principles for Responsible Investments (henceforth PRI) are aimed at encouraging investors to use responsible investments as a two-fold mean to (i) enhance returns and (ii) better manage risks associated with investments. As a truly independent entity, the PRI works in close partnership with the United Nations Environmental Program Finance Initiative (henceforth UNEPFI) and the United Nations Global Compact. PRI's two major areas of work are (UNPRI, 2020) :

1. To understand the investments implications of environmental, social and governance (ESG) factors; and
2. To support its international network of investors signatories in incorporating these factors into their investments and ownership decisions.

Considering the scope of PRI's work, the institution determines two long term interests. These are:

1. Of its signatories; and
2. Of the financial markets and economies in which they operate and ultimately for the environment and society as a whole.

With the aforementioned PRI's scope of work and long-term objectives, the PRI defined six principles that were developed by investors for investors in order to ease the transition towards suitable portfolios and therefore building a sustainable global financial system. As Figure below reflects, the PRI has over 3.000 signatories worldwide and its constant increment is considered as crucial to understand how investors are redefining their investment strategies and priorities. The principles are the following:

- **Principle 1**: We will incorporate ESG issues into investment analysis and decision-making processes.
- **Principle 2:** We will be active owners and incorporate ESG issues into our ownership policies and practices.
- **Principle 3:** We will seek appropriate disclosure on ESG issues by the entities in which we invest.
- **Principle 4:** We will promote acceptance and implementation of the Principles within the investment industry.
- **Principle 5:** We will work together to enhance our effectiveness in implementing the Principles.
- **Principle 6:** We will each report on our activities and progress towards implementing the Principles.

Figure 1: Principles for Responsible Investments

Source: UNPRI[37]

[37] Retrieved from: https://www.unpri.org/pri/about-the-pri

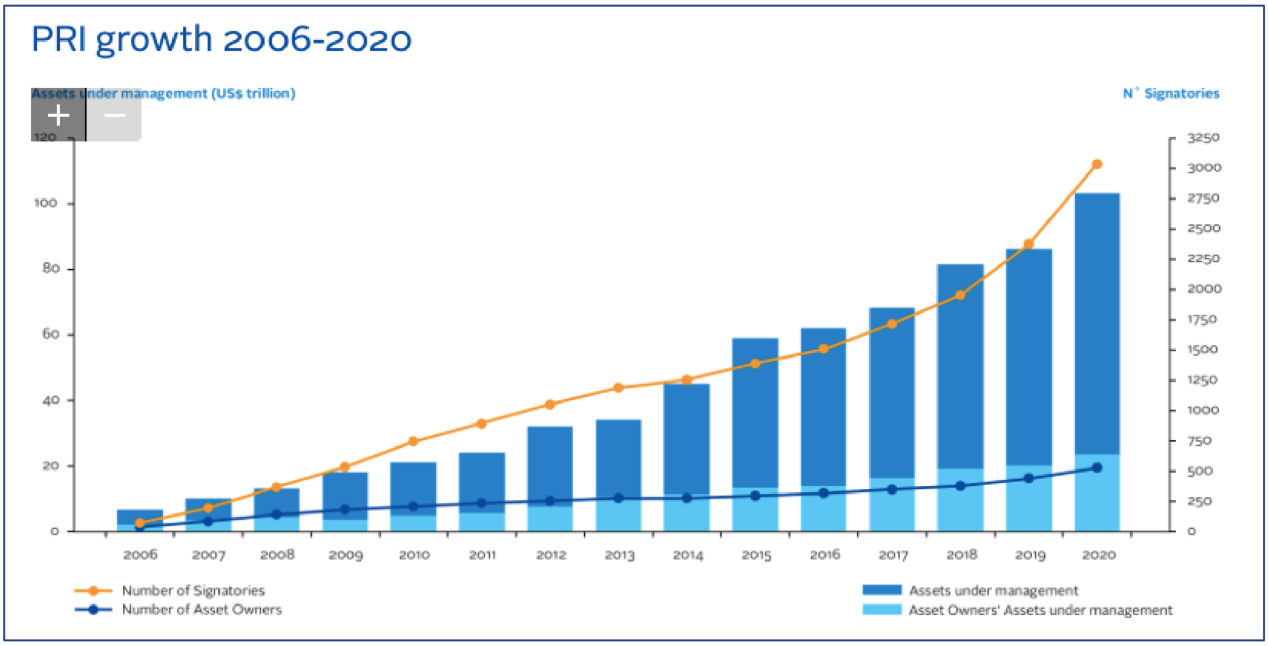


Figure 2: Principles for Responsible Investment's Growth 2006-2020 Period.

Source: UNPRI[38]

Figure 1 and Figure 2 depicts investors' growing interest for including responsible principles to guide investment decisions. The Consortium predicts constant grow for both, the number of Signatories and the number of Asset Owners. Moreover, as Figure 6 reflects, investors are positioning ESG investments as an essential part of their portfolio.

In order to obtain a concrete understanding of how investors are including ESG investments as part of their portfolio and hence achieving their fiduciary duty, the next subchapter exposes the new definition of fiduciary duty proposed by the UNEP FI and the PRI.

As final remark, the Consortium highlights that the UN PRI showcases the firms with the highest performance on a specific investing theme. The themes to be evaluated are set on a year-basis and this year's theme was climate reporting. The PRI Leader's Group 2020 is composed by 16 asset owner and 20 investment manager signatories. The selected group is presented in the following link and the Consortium encourages investors to closely monitor the best performing firms, specifically on their disclosure practices, in order to pinpoint best practices and incorporate them as part of their investment principles and objectives.

1.3 Fiduciary Duty in the 21st Century

In 2016, the PRI and UNEP FI launched a four-year project aimed at clarifying investors' obligations and duties (e.g. fiduciary duties) in relation with the integration of ESG components in investment practices and decision-making process. One of the main outcomes of this initiative was an exhaustive report under the name of Fiduciary Duty in the 21st Century (UNEP FI & PRI, 2019) and it's presented as a cornerstone for all investors to include ESG into their investment strategies and strategic asset allocation.

[38] Retrieved from: https://www.unpri.org/pri/about-the-pri

The report highlights three main reasons for the inclusion of ESG issues into investment practices. These are:

1. ESG incorporation is an investment norm

Backed-up by Figure 5, it is nowadays clear that investors are including these factors into their investment strategies and hence, as the report exhaustively states, the incorporation of ESG endeavors has become a crucial part of the investment analysis. In short, financial institutions must comply with the PRI and respective reporting methods as a mean of achieving full transparency of their investment strategies and therefore maintaining their strategic position in financial markets.

2. ESG issues are financially material

As stated along this Deliverable, empirical and academic evidence states that including ESG factors can be related to major sources of investment value. Furthermore, neglecting ESG analysis may cause the mispricing of risk and therefore poor performance when allocating assets. As result, investors may fail accomplishing their fiduciary duty as Climate Change effects alter the performance of certain industries -impacting the performance of investments.

3. Policy and regulatory frameworks are changing to ensure ESG incorporation

Policies at global level, such as the EU Taxonomy and the Sustainable Finance Initiative, are changing to encourage investors to allocate assets in topics of major concern that can be alluded to ESG initiatives. As the report states, there are over 730 hard and soft-law policy revisions across 500 policy instruments that reinforces the fact that ESG endeavors are a source of long-term value. Bearing the context of the EEnvest Project, Figure 3 exposes two examples of EU policy instruments that promote sustainable investment in pension funds.

EU	Proposal for a Regulation of the European Parliament and of the Council on disclosures relating to sustainable investments and sustainability risks and amending Directive (EU) 2016/2341	2019	Financial market participants shall include descriptions of the following in precontractual disclosures: (a) the procedures and conditions applied for integrating sustainability risks in investment decisions; (b) the extent to which sustainability risks are expected to have a relevant impact on the returns of the financial products made available; (c) how the remuneration policies of financial market participants are consistent with the integration of sustainability risks and are in line, where relevant, with the sustainable investment target of the financial product.
EU	Directive (EU) 2016/2341 of the European Parliament and of the Council of 14/12/2016 on the activities and supervision of institutions for occupational retirement provision (IORPs)	2016	"The system of governance shall include consideration of environmental, social and governance factors related to investment assets in investment decisions, and shall be subject to regular internal review."

Figure 3: EU's policies examples for promoting sustainable investment in pension funds.

Source: UNPRI

Considering the aforementioned rationales, the report defines, proposes and stresses the new approach for investors' fiduciary duties. These are presented in Figure 4.

The fiduciary duties of investors require them to:

- Incorporate environmental, social and governance (ESG) issues into investment analysis and decision-making processes, consistent with their investment time horizons.
- Encourage high standards of ESG performance in the companies or other entities in which they invest.
- Understand and incorporate beneficiaries' and savers' sustainability-related preferences, regardless of whether these preferences are financially material.
- Support the stability and resilience of the financial system.
- Report on how they have implemented these commitments.

Figure 4: 21st Century Fiduciary Duties.

Source: UNPRI

In order to narrow down the scope and to fully understand how investors are obeying their fiduciary duty, the next subchapter analyses ESG and Sustainable Investment trends to unfold the concrete metrics and initiatives that are being emplaced to measure investments' impact and portfolios' alignment.

1.4 Sustainable, Responsible and ESG Investments

The Consortium proposes a detailed overview of the investment flow related to ESG funds as these investments reflect the transition on how investors are selecting their investment strategies and strategic asset allocation.

Firstly, a standard definition of ESG investments must be settled. For this purpose, the Consortium leverages on the definition provided by Morgan Stanley Capital International[39] (henceforth MSCI) and also the Global Sustainable Investment Alliance (henceforth GSIA) approach due to its' global relevance and also advance research on the matter.

According to (MSCI, 2020), ESG Investing is a term that is often used synonymously with sustainable investing, socially responsible investing, mission-related investing, or screening. In this regard, MSCI ESG Research defines it as the consideration of environmental, social and governance factors alongside financial factors in the investment decision-making process. Furthermore, as Figure 5 below reflects, EE investments accrue to the "E" category of ESG.

[39] For a simple but yet exhaustive overview of ESG investing definition and investors approach, please refer to: https://www.msci.com/what-is-esg

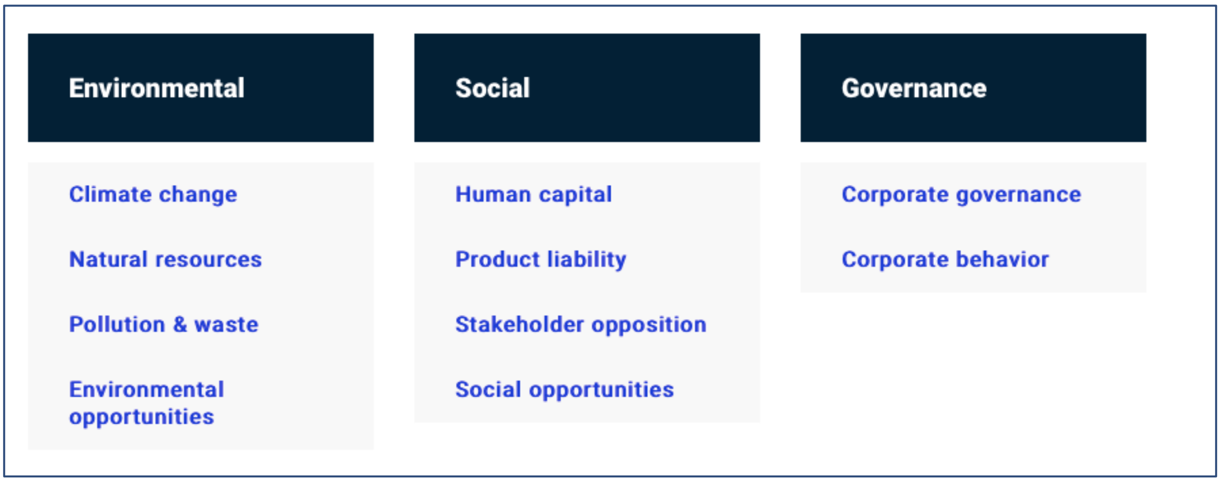


Figure 5: EE initiatives as part of the environmental realm of the definition of ESG.

Source: MSCI[40]

In order to strengthen the ground for investors and hence boost investors' confidence when evaluating these investments, a more precise connection between of EE investments and ESG investments is presented in the next paragraphs.

Broad literature acknowledges that EE investment possess strong potential to directly impact the environment and indirectly society and the economy. These rationales are well recognized by the EC and Member States and are indeed present EU Taxonomy mentioned in the previous section. These proclaimed acknowledgements serve as the foundation to boost EE investments and also for policy creation (i.e. Taxonomy Regulation). Further rationales to include EE investments as part of ESG investments are listed below:

Environment: EE investments are directly linked with reducing greenhouse gas (GHG) emissions. In order to unarguably state how EE investments in buildings positively impacts the environment, the Consortium bases its' rationales on a (ECc, 2019) statement: "…Buildings are responsible for approximately 40% of energy consumption and 36% of CO2 emissions in the EU. Currently, about 35% of the EU's buildings are over 50 years old and almost 75% of the building stock is energy inefficient, while only 0.4-1.2% (depending on the country) of the building stock is renovated each year. Therefore, more renovation of existing buildings has the potential to lead to significant energy savings – potentially reducing the EU's total energy consumption by 5-6% and lowering CO2 emissions by about 5%...".

Society: The net effect of EE investments also impacts society and the economy. A Building Performance Institute Europe study (BPIE, 2020) estimated that every $1 million invested in energy renovation of buildings, an average of 18 jobs will be created in the EU. Evidently, the numbers of jobs created fluctuates according to individual national context. For instance, the number of jobs created for Croatia would be 29, Finland 16, Italy 15 and in Spain, 18. The study is considered as highly relevant for the Consortium as the findings are backed up by an exhaustive review of 35 research reports.

The same study signals that EE renovation of office buildings increases productivity by about 12%, leading to a potential benefit of about €500 billion to the economy per year. Further analysis on how DER investments impact productivity are presented in ulterior sections of this Deliverable.

Governance: As (Florini & Sovacool, 2009) defined, governance is defined as the process and effort undertaken by a determined group to achieve a desired outcome. Acknowledging that EE investments

[40] Retrieved from: https://www.msci.com/what-is-esg

are crucial to accomplish EU's goal on Climate Change, it is plausible to state that efforts at C-level[41] and at Board-level to pursuit EE investments are aligned with proper firm behavior and therefore linked with the obedience of their fiduciary duty. Furthermore, in order to tailor the link between governance and EE investments, the IEA introduced in 2010 the term of EE governance as the use of political influence, resources and organizations by decision making agents to deliver higher levels of EE improvements.

Despite the Consortium attempt to standardize the approach for investors in ESG topics, ESG investments can still be considered as broad. Nevertheless, there's a clear trend amongst investors to constantly shift their valuation methodologies and investment goals towards ESG-related endeavors. Figure below better illustrates the uptake of ESG funds between 2009 and 2019.

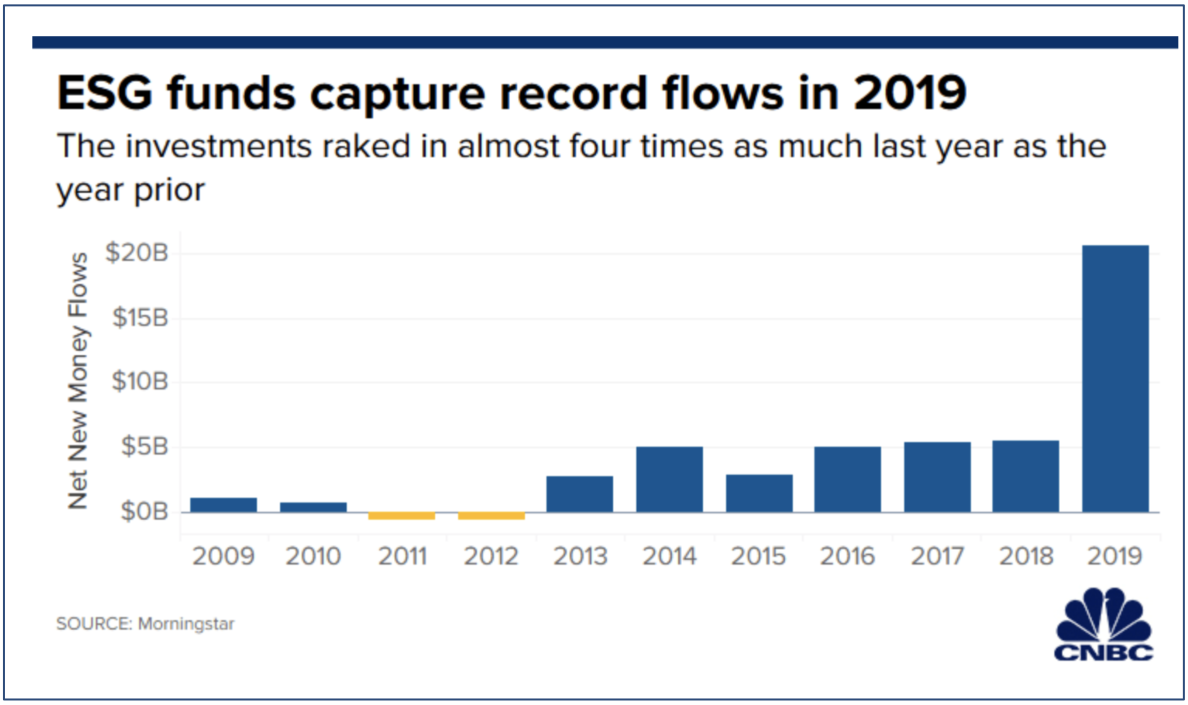


Figure 6: ESG funds flow from 2009 to 2019.

Source: Morningstar[42]

As Figure 6 reflects, the evolution of ESG funds from 2009 until 2018 has been rather steady but, between 2018 and 2019, a significant increase took place. In specific, new money flowing to ESG funds, in 2019, represented four times the previous year. This behavior in investment flows can be directly linked with a growing trend towards prioritizing ESG, SDG and Climate related investments. In other words, investors are shifting their investment behavior, goals and hence valuation methodologies to reach decarbonized and greener portfolios. Moreover, scholars state that fund firms are decarbonizing their portfolio in order to enhance their strategic asset allocation towards initiatives that are climate aligned and overall, produce measurable impact to society and the economy. This trend is expected to be sustained in the upcoming years due to two factors. First, society is increasingly becoming aware of major topics that can be grouped in the Sustainability Development Goals. Second, as Chapter 2 accurately depicted, there are strong policies taking place in order to propel climate-aligned investments. If this trend continuous, new product offering will constantly supply the increasing demand for investors producing a virtuous circle and hence, augmenting the ESG investment flow.

[41] C-level, also called the C-suite, is an adjective used to describe high-ranking executive titles within an enterprise. For instance: CEO, CFO and CMO.

[42] Retrieved from: https://www.cnbc.com/2020/01/14/esg-funds-see-record-inflows-in-2019.html.

Most recently, amid the Coronavirus Pandemic, ESG funds marked a new record. As Figure 7 shows, assets in sustainable funds during the second quarter of 2020 reached $1 trillion of which $61 billion accounts for Europe's contribution. All in all, a clear trend of change in investors' behavior is clearly taking place.

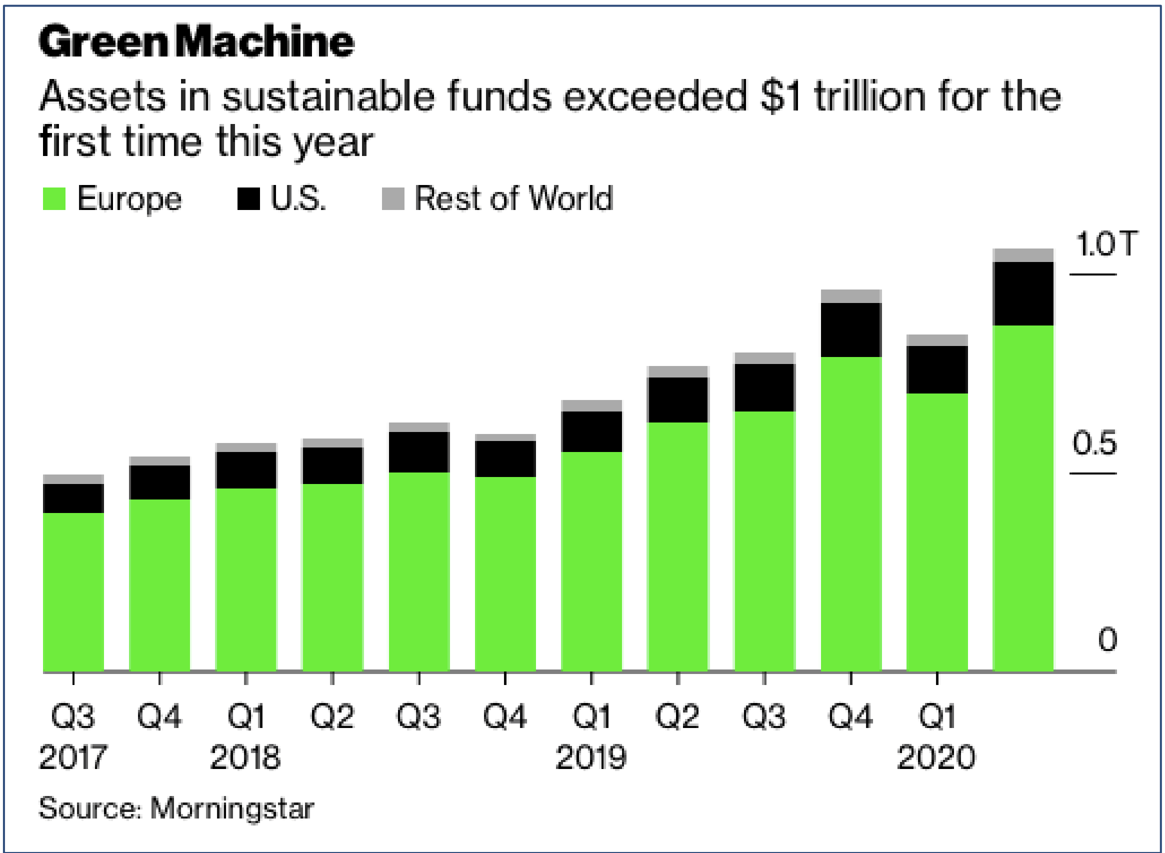


Figure 7: Assets in sustainable investments fluctuation from Q3 2017 to Q1 2020.

Source: Morningstar

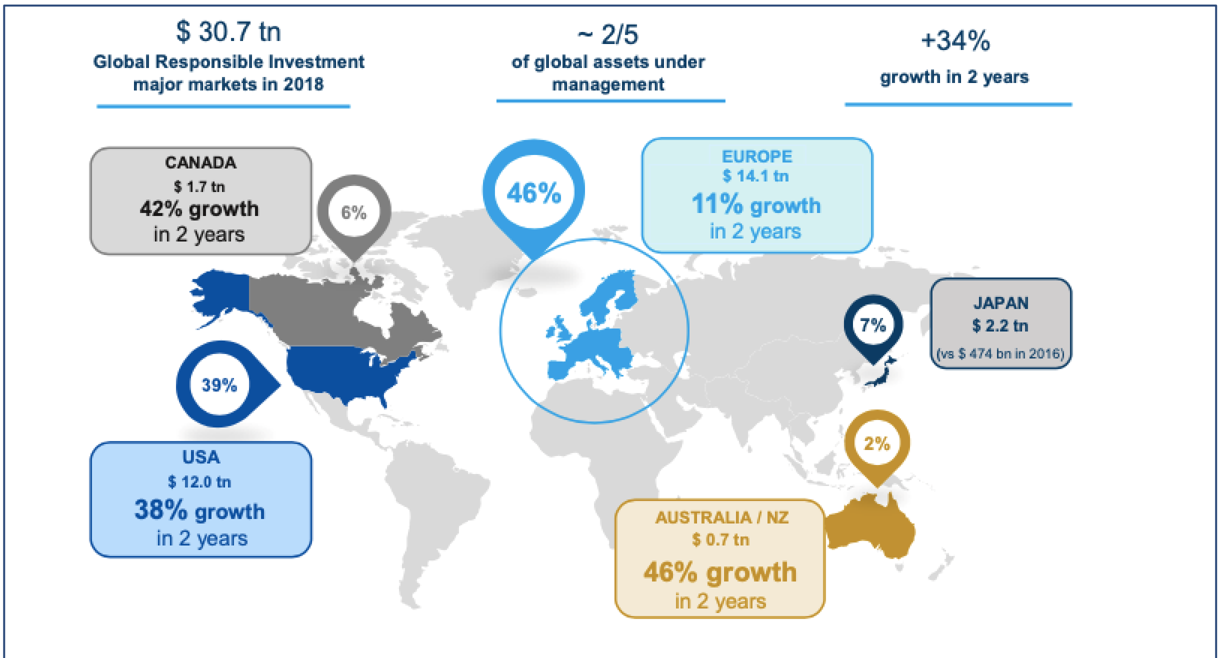
ESG investments may be difficult to classify as numerous types of investments can be linked directly or indirectly to ESG investments, hindering the quantification of the net investment flow and therefore ESG quantification may vary from one source to another. However, the Consortium leverages on the proved fact that there's a trend towards ESG related investments and hence a closer analysis is needed to fully understand how investors are assessing these types of investments and more importantly, pinpoint best practices to build a universal framework for EE investment assessment.

In order to narrow down the scope of ESG funds, a broader overlook of sustainable investing is adopted. As result, holistic approach is adopted that is based on The Global Sustainable Investment Alliance research and studies. The rationale to define the GSIA as a source of exhaustive input for the EE investment framework is based on the global overview that GSIA provides. In specific, GSIA provides a detailed snapshot of sustainable investing in respect of the following regions: Europe, the United States, Japan, Canada and Australia and New Zealand. In order to produce the *Global Sustainable Investment Review* (GSIA, 2018), GSIA realizes in-depth analysis of regional and national reports from GSIA members – Eurosif, US SIF, Japan Sustainable Investment Forum (JSIF), Responsible Investments Association Australasia and RIA Canada.

The GSIA stablishes that sustainable investments encompasses 7 key activities and strategies. In order to narrow the scope to the present Deliverable, the definition set by the GSIA is provided in the relevant strategies for the EEnvest project. These are the following (GSIA, 2018):

1. Negative/exclusionary screening;
2. Positive/best-in-class screening;
3. Norms-based screening;
4. ESG integration: the systematic and explicit inclusion by investment managers of environmental, social and governance factors into financial analysis;
5. Sustainability themed investing: investment in themes or assets specifically related to sustainability (for example clean energy, green technology or sustainable agriculture);
6. Impact/community investing: targeted investments aimed at solving social or environmental problems, and including community investing, where capital is specifically directed to traditionally underserved individuals or communities, as well as financing that is provided to businesses with a clear social or environmental purpose; and
7. Corporate engagement and shareholder action.

Figure 8 reflects how the Global Responsible Investment markets performed in 2018 by region.



Source: Global Sustainable Investment Alliance (2019).

Figure 8: Global Responsible Investment Markets 2018 performance.

Source: GSIA[43]

As the EEnvest project is focused in the Europe region, a closer look to Europe's performance is explained. According to (GSIA, 2018) report, the total assets committed to sustainable and responsible investments strategies grew by 11% from 2016 to 2018 to reach €12.3 trillion. However, Europe's market share declined from 53% to 49% of total managed assets. This may be due to stricter standards and definitions adopted by Eurosif[44]. On the other hand, ESG integration experienced growth of 60%, jumping to €4.2 trillion in 2018. Figure 9 below better illustrate Europe's performance.

[43] Retrieved from (GSIA, 2018).

[44] Part of this reduction can be linked due the robust on-going debate to define sustainable investing. For instance, exhaustive work on the taxonomy for sustainable investing have been focused on Green bond standard and eco-labels. As result, European Asset managers reported fewer sustainable asset values for 2018 in comparison with 2016 Eurosif Survey.

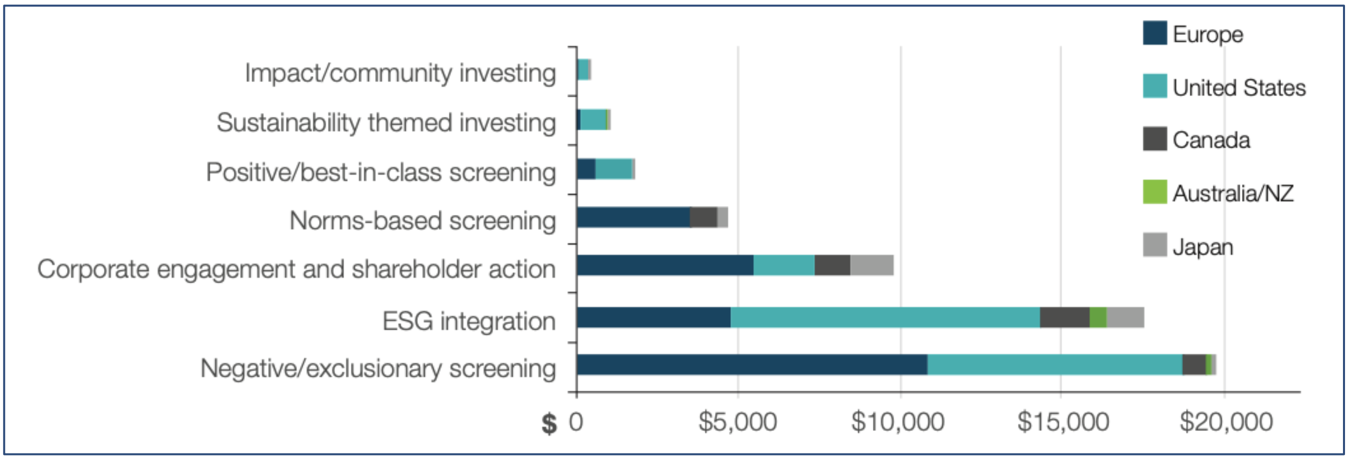


Figure 9: Europe's 2018 performance on sustainable investments.

Source: GSIA[45]

In the quest of reinforcing the definition and relevance sustainable investments/finance, the Consortium presents the definition provided by the European Commission on the topic. As stated in (ECf, 2020), "… In the EU's policy context, sustainable finance is understood as finance to support economic growth while reducing pressures on the environment and taking into account social and governance aspects. Sustainable finance also encompasses transparency on risks related to ESG factors that may impact the financial system, and the mitigation of such risks through the appropriate governance of financial and corporate actors…". Consequently, it is expected that financial institutions and investors will constantly adopt this approach as it is reinforced by the EU Taxonomy mentioned in previous sections.

To illustrate the previous overview of investors' modern behavior, investment strategies and sustainable investments in practice, the Consortium took a deep-dive into the latest press releases and articles published by renown sources (Forbes, Financial Times, Green Bloomberg and Reuters) to pinpoint top-tier cases. The selected two cases are explained in the following paragraphs.

45 Retrieved from: (GSIA, 2018)

2 Case Studies

2.1 BlackRock hands-on approach towards ESG and Climate related investments

As the world's biggest asset manager, BlackRock has been always on close watch by the general and private public. In this regard, the fund has been under scrutiny for its role tackling global warming and ESG-related topics, supported by society's higher level of awareness of these topics.

In a letter from Larry Flink, BlackRock's CEO, to clients published earlier on 2020, announced that in order to comply with the firms' fiduciary duties, sustainability will be a decisive factor in their standard for investments. Some of the key strategies to be deployed by the firm are (BlackRock, 2020a; BlackRock, 2020b; NYTIMES, 2020; Forbes, 2020; Reuters, 2020; Financial Times, 2020):

- Sustainability as Their Standard Offering in Solutions;
- Strengthening Sustainability Integration into the Active Investment Processes;
- Reducing ESG Risk in Active Strategies;
- Putting ESG Analysis at the Heart of Aladdin[46];
- Enhancing Transparency of Sustainable Characteristics for All Products;
- Doubling Their Offerings of ESG ETFs;
- Simplifying and Expanding ESG iShares, Including ETFs with a Fossil Fuel Screen; and
- Expanding Sustainable Active Investment Strategies.

A following letter, this time directed to companies' CEOs, reinforced BlackRock's approach to sustainable investing. This act unfolds Blackrock's approach in respect of their investment strategy and further acknowledges the reshaping of finance – now considering Climate issues as direct impact to long-term value creation. The letter also encourages that every firm, government and shareholder must confront Climate Change.

It follows that in the first semester of 2020, BlackRock was constantly under pressure from the media to enact their announcement of setting sustainable investing as part of their investment principles. As result, several press releases published in mid-July 2020 exposed BlackRock's hands-on approach on firms that have not perform well on tackling Climate Change. Specifically, BlackRock voted against managers of 53 firms with poor Climate-Related initiatives. Some of these companies are Exxon Mobile, Volvo and Air Liquide. Further, the firm stablished its own "watch list" for potential voting action on 191 companies that are not performing on coping with Climate Change.

As conclusion, BlackRock's case depicts that Climate Change is speeding the reshaping on finance and therefore, investing firms are including sustainable related factors in their assessments. The case also acknowledges that new methodologies to guide investment decisions and impact value will be highly demanded in financial markets. As ultimately result, new frameworks will be proposed and it is of our interest to further explore high-level initiatives to build a universal framework for EE investments.

[46] Blackrock defines Aladdin as an end-to-end operating system for investment professionals that provides a compelling vision of their portfolio and risk exposure.

2.2 Pension Funds and a Net Zero Framework to Decarbonize Portfolios

In the middle of increasing pressure from society on investing firms to take action on Climate related issues, an exemplary top-down initiative can be found in pension funds.

As the (Financial Times, 2020b) published early on August 2020, a coalition of 70+ pension funds, representing assets of $16 trillion, joined efforts to design a net zero framework aimed at decreasing CO2 emissions from their portfolios by year 2050. Aligned with this initiative, the Institutional Investors Group on Climate Change[47] (henceforth IIGCC) published a blueprint document (IIGCC, 2020) that provides pension funds with the required tools to implement portfolio decarbonization. The document also emphasizes the relevance of three key areas of sustainable investments: (i) Renewable Energy Projects, (ii) Low-carbon Buildings and (iii) Energy Efficiency Technologies.

As the purpose of this Deliverable is to design a Framework for Energy Efficiency Investments, the Consortium analyzed in extensive detail the IGCC's framework in order to identify synergies and hence preparing the narrative for investors deciding on investing in EE. The results are presented in the following section.

2.2.1 IIGCC Net Zero Investment Framework

The development of the Net Zero Investment Framework (IIGCC, 2020b) is the foundation for portfolio decarbonization. It is also conceived as the first output of IIGCC's Paris Aligned Investment Initiative (henceforth PAII) launched in May 2019. The Framework was created by investors for investors and its specific purpose lies on ensuring that investors are maximizing their contribution to limit Global Warming below 1.5ºC, as agreed upon the Paris Agreement in 2015, by investing in Climate solutions. Figure 10 below the IIGCC's Net Zero Investment Framework role.

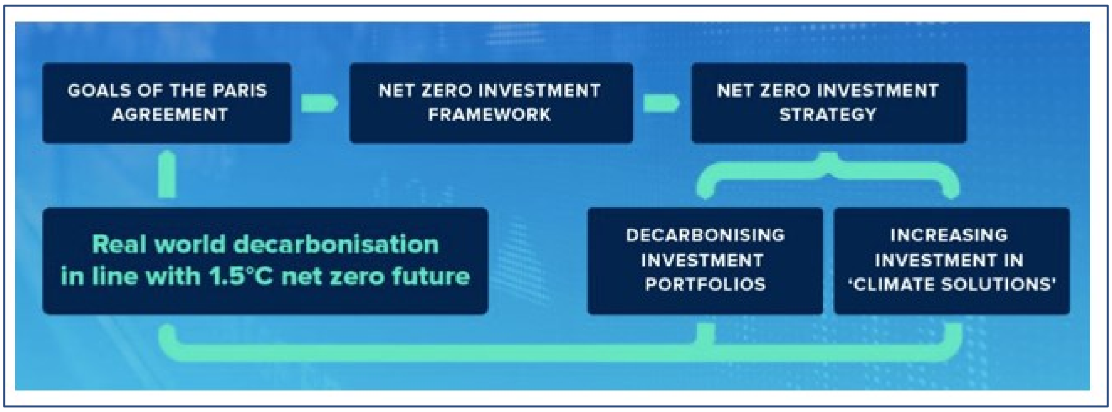


Figure 10: IIGCC's Net Zero Framework Role.

Source: IGCC[48]

Although the IIGCC's Framework is aimed at portfolios rather than individual investments, it is perceived as high-level input for setting the foundations and to strengthen the investment narrative of the EE Investment Framework. Important is to note that The Framework is currently under consultation. The final version will be published by the end of 2020. Figure 11 below illustrate the aforementioned Framework and the following section outlines the insights identified by the Consortium.

[47] IIGCC is the European membership body for investor collaboration on CC.
[48] Retrieved from: (IIGCC, 2020).

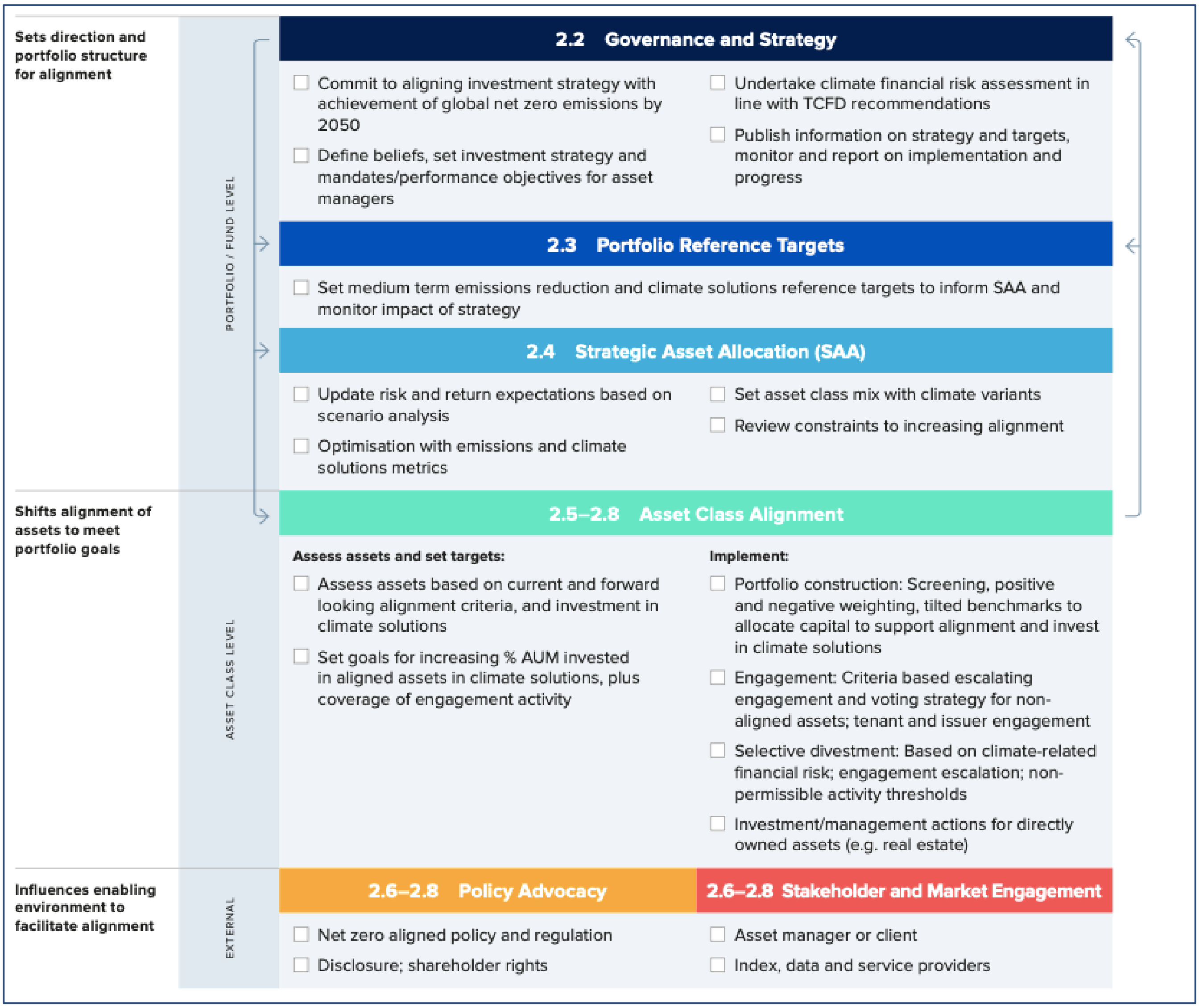


Figure 11: The IIGCC's Net Zero Investment Framework.

Source: (IIGCC, 2020b)

2.3 Contribution to EE Investment Framework

Both case study unfolds how at global level, finance is changing. This change is oriented towards sustainable investments and as such, investors are adjusting their valuation methodologies in order to map and quantify all sort of impact. Financial Institutions are aligning their investment objectives towards initiatives related to ESG endeavors. As ultimate outcome, investors' will utilize standard valuation methodologies and reporting practices to elucidate the real impact of their investments.

Since investors will constantly seek for investment opportunities that contains environmental and societal impact, The Consortium presents the opportunity for re-position DER investments as a tangible investment opportunity with measurable impact. However, it is precisely the quantification component of these investments the most important and yet most difficult barrier to tackle. As exposed throughout this document, high-level initiatives are specifically aimed at solving this challenge by implementing standard and reliable methodologies to (i) identify, (ii) quantify and ultimately, (iii) report the real impact of investors' portfolios.

The two case studies previously analyzed are an excellent example of how investors are complying with their fiduciary duty. The cases further expose how investors are joining forces to standardize solid investment practices that create a better world for all. In short, investors recognize that their assets under management possess the capacity to generate positive impact whilst creating long-term value. In this context, it is expected that more and more investors shift their investment principles and adopt environmental and societal components in their assessments.

Blackrock's case is proposed as benchmark for all financial institutions in the world. The firm's unique position enables asset managers to put pressure on boards and to encourage firms to pursuit climate-aligned endeavors. If successful, Blackrock's hand-on approach may lead to a strong contribution to GHG emission reduction and further positive at large scale. This case was also presented with the purpose of unveiling strategies that investors can adopt to redefine their investment principles. The Consortium leveraged on these strategies to analyze them and further propose them to investors seeking to redefine their investment strategies. Moreover, the Consortium encourages investors to closely monitor Blackrock's investment methodologies to pinpoint best practices on ESG impact quantification and reporting. Additional efforts on this case will be performed during T4.4, where a DER valuation methodology will be proposed.

The IIGCC Net Zero Investment Framework paves the way to ease investors' transition on SDG investment inclusion. This case was selected due to its' exhaustive work on standardizing a roadmap to align investors' portfolio with climate initiatives. Its' contribution to the EEnvest Project lies on providing the foundations to walk investors through the process to align their investment objectives and further facilitate the investment assessment. The Framework adopts a holistic understanding of the procedure to decarbonize portfolios and it's framed in different levels. The Consortium extracts this systematic approach and proposes a progressive scenario analysis, where each scenario will gradually include the different areas of impact of a DER investments. As defined in T4.2, these areas of impact can be separated in two realms: (i) energy and (ii) non-energy benefits.

Under this frame, the Consortium leveraged on the finding that key performance indicators (KPIs) are strongly relevant for investors as it is the mean to determine whether an investment is aligned with firm's objective, principles and goals. In this regard, an analytical approach was undertaken to find which KPIs are necessary for guiding investors' assessment of Energy Efficiency Investment opportunities.

Bibliography

Zancanella, P., Bertoldi, P., & Boza-Kiss, B. (2018). *Energy efficiency, the value of buildings and the payment default risk.*

Zakeri, B., & Syri, S. (2015). Electrical energy storage systems: A comparative life cycle cost analysis. *Renewable and Sustainable Energy Reviews, 42*, 569-596.

Ürge-Vorsatz, D., Herrero, S., Dubash, N., & Lecocq, F. (2014). Measuring the co-benefits of climate change mitigation. *Annual Review of Environment and Resources, 39*, 549-582.

team, E., & Galev, T. (2019, 10 31). *ENABLE.EU H2020 project dataset and questionnaire from a survey of households on energy use and energy choices*. Retrieved from https://zenodo.org/record/3523916

Stenqvist, C., & Nilsson, L. (2012). Energy efficiency in energy-intensive industries—an evaluation of the Swedish voluntary agreement PFE. *Energy Efficiency, 5*(2), 225-241.

Selim, H. (2009). Determinants of house prices in Turkey: Hedonic regression versus artificial neural network. *Expert systems with Applications, 36*(2), 2843-2852.

Reichl, J., Cohen, J., Kollmann, A., Azarova, V., Klöckner, C., Royrvik, J., . . . Bird, N. (2019, 11 1). *International survey of the ECHOES project*. Retrieved from https://zenodo.org/record/3524917

Poortinga, W., Jiang, S., Grey, C., & Tweed, C. (2018). Impacts of energy-efficiency investments on internal conditions in low-income households. *Building Research and Information, 46*(6), 653-667.

Pearson, D., & Skumatz, L. (2002). Non-energy benefits including productivity, liability, tenant satisfaction, and others: what participant surveys tell us about designing and marketing commercial programs. *Proceedings of the 2002 Summer Study on Energy Efficiency in Buildings*, (p. 2).

Paige, F., Agee, P., & Jazizadeh, F. (2019). *OSF | flEECe Survey Dataset v3 8_28_19.xlsx*. Retrieved from flEECe, an energy use and occupant behavior dataset for net-zero energy affordable senior residential buildings: https://osf.io/2qy9b/?show=view

Norris, F. (2017, 3 20). *Questionnaire on needs and requirements for energy performance gap reduction at the operational level of a building*. Retrieved from https://zenodo.org/record/401009

Newell, G., MacFarlane, J., & Kok, N. (2011). Building better returns--A study of the financial performance of green office buildings in Australia. *University of Western Sydney, Sydney*.

Moran, P., O'Connell, J., & Goggins, J. (2020). Sustainable energy efficiency retrofits as residenial buildings move towards nearly zero energy building (NZEB) standards. *Energy and Buildings, 211*, 109816.

Lung, R., McKane, A., Leach, R., & Marsh, D. (2005). Ancillary savings and production benefits in the evaluation of industrial energy efficiency measures. *Proceedings of the 2005 American Council for an Energy-Efficient Economy Summer Study on Energy Efficiency in Industry. Washington, DC: ACEEE*.

Liu, S., Schiavon, S., Das, H., Jin, M., & Spanos, C. (2019). Personal thermal comfort models with wearable sensors. *Building and Environment, 162*, 106281.

Limsombunchai, V. (2004). House price prediction: hedonic price model vs. artificial neural network. *New Zealand agricultural and resource economics society conference*, (pp. 25-26).

Kmetty, Z., Bent, C., Shreeve, G., & Virág, Z. (2017, 6 28). *NATCONSUMERS - main factors and attitudes behind energy consumption*. Retrieved from https://zenodo.org/record/820364

Jensen, O., Hansen, A., & Kragh, J. (2016). Market response to the public display of energy performance rating at property sales. *Energy Policy, 93*, 229-235.

Im, J., Seo, Y., Cetin, K., & Singh, J. (2017). Energy efficiency in US residential rental housing: Adoption rates and impact on rent. *Applied energy, 205*, 1021-1033.

Hyland, M., Lyons, R., & Lyons, S. (2013). The value of domestic building energy efficiency—evidence from Ireland. *Energy economics, 40*, 943-952.

Galata, A., Brogan, M., & Cunningham, J. (2019, 10 2). *ENERIT module outcomes for the 3 pilot sites on which the module has been deployed during the HIT2GAP project*. Retrieved from https://zenodo.org/record/3468951

Fuerst, F., McAllister, P., Nanda, A., & Wyatt, P. (2016). Energy performance ratings and house prices in Wales: An empirical study. *Energy Policy, 92*, 20-33.

Fuerst, F., McAllister, P., Nanda, A., & Wyatt, P. (2015). Does energy efficiency matter to home-buyers? An investigation of EPC ratings and transaction prices in England. *Energy Economics, 48*, 145-156.

Földváry Ličina, V., Cheung, T., Zhang, H., de Dear, R., Parkinson, T., Arens, E., . . . Kaam, S. (2018). *ASHRAE Global Thermal Comfort Database II*. Retrieved from Dataset: https://datadryad.org/stash/dataset/doi:10.6078/D1F671

Ferreira, M., Almeida, M., & Rodrigues, A. (2017). Impact of co-benefits on the assessment of energy related building renovation with a nearly-zero energy target. *Energy and Buildings, 152*, 587-601.

Evangelista, R., Ramalho, E., & e Silva, J. (2020). On the use of hedonic regression models to measure the effect of energy efficiency on residential property transaction prices: Evidence for Portugal and selected data issues. *Energy Economics, 86*, 104699.

Energy Information Administration. (n.d.). *Residential Energy Consumption Survey (RECS) - Data - U.S. Energy Information Administration (EIA)*. Retrieved from https://www.eia.gov/consumption/residential/data/2015/

Encinas, F., Marmolejo-Duarte, C., De La Flor, F., & Aguirre, C. (2018). Does energy efficiency matter to real estate-consumers? Survey evidence on willingness to pay from a cost-optimal analysis in the context of a developing country. *Energy for Sustainable Development, 45*, 110-123.

Eichholtz, P., Kok, N., & Quigley, J. (2013). The economics of green building. *Review of Economics and Statistics, 95*(1), 50-63.

Dunse, N., & Jones, C. (1998). A hedonic price model of office rents. *Journal of property valuation and investment*.

Dell'Anna, F., Bravi, M., Marmolejo-Duarte, C., Bottero, M., & Chen, A. (2019). EPC Green Premium in Two Different European Climate Zones: A Comparative Study between Barcelona and Turin. *Sustainability, 11*(20), 5605.

De Cock, D. (2016). *House Prices: Advanced Regression Techniques - Competition Rules*. Retrieved from https://www.kaggle.com/c/house-prices-advanced-regression-techniques/data

de Ayala, A., Galarraga, I., & Spadaro, J. (2016). The price of energy efficiency in the Spanish housing market. *Energy Policy, 94*, 16-24.

Daim, T., Li, X., Kim, J., & Simms, S. (2012). Evaluation of energy storage technologies for integration with renewable electricity: Quantifying expert opinions. *Environmental Innovation and Societal Transitions, 3*, 29-49.

Copiello, S. (2017). Building energy efficiency: A research branch made of paradoxes. *Renewable and Sustainable Energy Reviews, 69*, 1064-1076.

Chiara, D., Roberto, F., Alessandro, B., Marcus, G., Fabian, O., & Chris, B. (2019, 6 25). *iNSPiRe FP7 - Retrofit solutions database*. Retrieved from https://zenodo.org/record/3256270

Chegut, A., Eichholtz, P., & Kok, N. (2019). The price of innovation: An analysis of the marginal cost of green buildings. *Journal of Environmental Economics and Management, 98*.

Buylova, A. (2020, 3 10). *Investigating dynamics between energy use and socio-demographic characteristics in spatial modeling of residential energy consumption*. Retrieved from https://zenodo.org/record/3703524

Blomqvist, E., & Thollander, P. (2015). An integrated dataset of energy efficiency measures published as linked open data. *Energy Efficiency, 8*(6), 1125-1147.

Bahrar, M., Coillot, M., Laaroussi, Y., Frutos Dordelly, J., & El Mankibi, M. (2020, 1 24). *HEART 2.2 analysis data*. Retrieved from https://zenodo.org/record/3626699

Quantifying Non-Energy Benefits fromComEd’s Income Eligible Programs:Findings and Recommendations from Secondary Research. (n.d.).

de La Paz, P., Perez-Sanchez, V., Mora-Garcia, R.-T., & Perez-Sanchez, J.-C. (2019). Green premium evidence from climatic areas: A case in Southern Europe, Alicante (Spain). *Sustainability, 11*(3), 686.

Alavy, M., Li, T., & Siegel, J. (2020). Energy use in residential buildings: Analyses of high-efficiency filters and HVAC fans. *Energy and Buildings, 209*, 109697.

Aydin, E., Brounen, D., & Kok, N. (2015). Capitalization of Energy Efficiency in the Housing Market. *Working Paper*.

Ngo, N. (2019). Early predicting cooling loads for energy-efficient design in office buildings by machine learning. *Energy and Buildings, 182*, 264-273.

Hirvonen, J., Jokisalo, J., Heljo, J., & Kosonen, R. (2019). Towards the EU emission targets of 2050: Cost-effective emission reduction in Finnish detached houses. *Energies, 12(22)*.

Berggren, B. (2018). Lcc Analysis of a Swedish Net Zero Energy Building – Including Co-Benefits. *(July 2019)*, 2-9.

Bleyl, J., Bareit, M., Casas, M., Chatterjee, S., Coolen, J., Hulshoff, A., . . . Ürge-Vorsatz, D. (2019). Office building deep energy retrofit: life cycle cost benefit analyses using cash flow analysis and multiple benefits on project level. *Energy Efficiency, 12*(1).

Bleyl, J., Casas, M., Hulshoff, A., Robertson, M., Bareit, M., Bruyn, B., & Mitchell, S. (2017). Building deep energy retrofit : Using dynamic cash flow analysis and multiple benefits to convince investors. *ECEEE Summer Study Proceedings*(Bpie).

Mansilla, D., Papageorgiou, D., Borges, C., Tsolakis, A., Kamara, O., Krinidis, S., . . . Ipiña, D. (2019, 3 16). (PRE) Socio-economic and cultural dataset in relation to Persuasive Strategies to boost Energy Efficiency and in the UK, Spain, Greece and Austria.

IEA. (2019). *Iea report multiple benefits of energy efficiency. https://www.iea.org/.*

ILSAG. (2018). *Quantifying Non-Energy Benefits fromComEd's Income Eligible Programs:Findings and Recommendations from Secondary Research.*

RMI. (2015). *The Path to Deep Energy Retrofit.* https://rmi.org/wp-content/uploads/2017/04/2015-02_Path_to_DR_using_ESPC.pdf.

UNEP. (2016). *Towards zero-emission efficient and resilient buildingsGLOBAL STATUS REPORT 2016.* https://www.worldgbc.org/sites/default/files/GABC_Global_Status_Report_V09_november_FINAL.pdf.

USGBC. (2020). *https://www.usgbc.org/press/benefits-of-green-building.* https://www.usgbc.org/press/benefits-of-green-building.

Less, B., & Walker, I. (2015). *14Deep Energy Retrofits -Reducing Costs and Increasing Cost-Effectiveness.* https://basc.pnnl.gov/sites/default/files/resource/DERs_CostEffectiveness.pdf.

Toosi, H. (2020). Life Cycle Sustainability Assessment in Building Energy Retrofitting; A Review. *Sustainable Cities and Societ*, 102248.

Jensen, O., & al., e. (2016). Market response to the public display of energy performance rating at property sales. *Energy Policy*.

Taltavull, P., & al, e. (2019). Green premium evidence from climatic areas: A case in Southern Europe, Alicante (Spain). *Sustainability*.

worldgbcnews. (2016). *Workers in certified green buildings record higher cognitive functions scores.* https://www.worldgbc.org/news-media/workers-certified-green-buildings-record-higher-cognitive-functions-scores-finds-study.

Vrabel, K. (2018). *Beyond the dollar sign non energy benefits to energy efficiency.* https://www.waypoint-energy.com/post/beyond-the-dollar-sign-non-energy-benefits-to-energy-efficiency.

GSA. (2011). *Green Building Performance.* https://www.gsa.gov/cdnstatic/Green_Building_Performance2.pdf.

Navigant. (2018). *Quantifying Non-Energy Benefits from ComEd's Income Eligible Programs.*

Lohse, R., & Zhivov, A. (2019). *Deep Energy Retrofit Guide for Public Buildings: Business and Financial Model.* Springer.

SENSEI. (2020). *PAY-FOR-PERFORMANCE to drive energy efficiency in Europe.* https://senseih2020.eu/.

Lohse, R., & Zhivov, A. (2019). *Deep Energy Retrofit Guide for Public Buildings: Business and Financial Models.* Springer.

EC. (2020). *Renovation wave initiative in the buildings sector.* https://www.europarl.europa.eu/legislative-train/theme-a-european-green-deal/file-renovation-wave.

WELL. (2020). WELL Certification (www.wellcertified.com).

Star, E. (2020). Energy Star Certification https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/earn-recognition/energy-star-certification.

LEED. (2020). LEED rating system (www.usgbc.org/leed).

Comfotmeter. (2018). The Comfortmeter survey.

Copiello, S. (2017). Building energy efficiency: A research branch made of paradoxes. *Renewable and Sustainable Energy Reviews*.

Cespedes-Lopez, e.-a. (2019). Meta-Analysis of Price Premiums in Housing with Energy Performance Certificates (EPC). *Sustainability*, 6303.

Crazevero Project. (n.d.). *https://cravezero.eu/*.

GBC, W. (2017). *Global Status Report 2017.* {https://www.worldgbc.org/news-media/global-status-report-2017.

Acosta, I. (2018). Minimum Daylight Autonomy: A New Concept to Link Daylight Dynamic Metrics with Daylight Factors. *Leukos*, 251-269.

Canada Safety. (n.d.). *Office Noise and Acoustics.* https://canadasafetycouncil.org/office-noise-and-acoustics/.

ETDE. (2001). *Pollution source control and ventilation improve health, comfort and productivity* . https://www.osti.gov/etdeweb/biblio/20397142.

CraveZero. (2020). *D6.4: Co –Benefitsof nZEBs.* https://www.cravezero.eu/wp-content/uploads/2020/05/CRAVEzero_D64_CoBenefits.pdf.

Hänninen. (2013). *Efficient reduction of indoor exposures - Health benefits from optimizing ventilation, filtration and indoor source controls.* https://www.julkari.fi/handle/10024/110211.

Berggren. (2017). International conference on Energy, Environment and Economics. *International conference on Energy, Environment and Economics.*

Thatcher. (2014). Changes in productivity, psychological wellbeing and physical wellbeing from working in a 'green' building . *Work*.

Singh. (2009). Effects of Green Buildings on Employee Health and Productivity . *AJPH*.

Miller. (2009). Green Buildings and Productivity. *Journal of Sustainable Real state*.

HealthVent. (2012). *Report on the association between health and ventilation, and on the scientific basis for health-based ventilation.*

Milton. (2001). Risk of Sick Leave Associated with Outdoor Air Supply Rate, Humidification, and Occupant Complaints. *Indoor Air*.

COMBI Project, C. (n.d.). Multiple Benefits of Energy Efficiency. *https://combi-project.eu/*.

Skumatz. (2014). *NON-ENERGY BENEFITS / NON-ENERGY IMPACTS (NEBs/NEIs).*

Argunhan. (2018). Statistical Evaluation of Indoor Air Quality Parameters in Classrooms of a University. *Advances in Meteorology*.

NOAO.edu. (2000). Recommended Light Levels (Illuminance) for Outdoor and Indoor Venues.

Shnapp. (2020). *Untapping multiple benefits: hidden values in environmental and building policies.* JRC.

EPA. (2018). *Quantifying the Multiple Benefits of Energy Efficiency and Renewable Energy. A Guide for State and Local Governments.*

Srinivasan. (2018). *Renovating Houses in The Netherlands to nearly Zero Energy standard- Important drivers of economic feasibility.*

Chepesiuk. (2005). Decibel Hell: The Effects of Living in a Noisy World. *Environ Health Perspect.* .

CDC. (2019). *What Noises Cause Hearing Loss?*

ECb. (2020). Retrieved from https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/eu-taxonomy-sustainable-activities_en

UNPRI. (2020). Retrieved from https://www.unpri.org/pri/about-the-pri

UNEP FI & PRI. (2019). *Fiduciary Duty in the 21st Century* .

MSCI. (2020). Retrieved from https://www.msci.com/what-is-esg

ECc. (2019). Retrieved from https://ec.europa.eu/info/news/new-rules-greener-and-smarter-buildings-will-increase-quality-life-all-europeans-2019-apr-15_en

BPIE. (2020). *Building Renovation: A kick-starter for the EU recovery.*

Florini, A., & Sovacool, B. (2009). *Who governs energy? The challenges facing global energy governance.* Energy Policy.

GSIA. (2018). *Global Sustainable Investment Review.*

ECf. (2020). Retrieved from https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/what-sustainable-finance_en

BlackRock. (2020a). Retrieved from https://www.blackrock.com/corporate/investor-relations/larry-fink-ceo-letter

BlackRock. (2020b). Retrieved from https://www.blackrock.com/corporate/investor-relations/blackrock-client-letter

NYTIMES. (2020). Retrieved from https://www.nytimes.com/2020/01/14/business/dealbook/larry-fink-blackrock-climate-change.html

Forbes. (2020). Retrieved from https://www.forbes.com/sites/michaelperegrine/2020/07/19/blackrock-heats-up-climate-change-pressure-on-boards/#3d2d40bf38cd

Reuters. (2020). Retrieved from https://www.reuters.com/article/us-esg-blackrock-breakingviews/breakingviews-blackrock-warrants-a-spot-on-its-climate-watchlist-idUSKBN24F0ZX

Financial Times. (2020). Retrieved from https://www.ft.com/content/8809032d-47a1-47c3-ae88-ef3c182134c0

Financial Times. (2020b). Retrieved from https://www.ft.com/content/88f3819c-a0a0-40e4-8a21-dba35512a02c

IIGCC. (2020). Retrieved from https://www.iigcc.org/our-work/paris-aligned-investment-initiative/

IIGCC. (2020b). *Paris Aligned Investment Initiative: Net Zero Investment Framework for Consultation.*

Risk reduction for Building Energy Efficiency investments

Annex 2
Creating a business case for non-energy related benefits

Abstract

The multiple benefits (MB) are an emerging approach to energy efficiency policy. MB represents a step forward towards a more holistic understanding of the impact of energy efficiency in buildings and in the life of their dwellers. The multiple benefits approach is predicated on the increasing availability of large and heterogeneous datasets to capture benefits of investment in energy efficiency. Although there is a widespread agreement among stakeholders and experts of the great potential of multiple benefits from the point of view of either the investor or the building's tenant, the lack of data availability of MB is anything but encouraging. The document explores the state of the art of both energy and non-energy related benefits and selects a set of KPIs of interest for investors in deep energy efficiency renovations (DER). We provide as well a robust methodology to quantify non-energy KPIs and we highlight a set of recommendations that, if followed, can bring us closer to having a proper understanding of the multiple benefits in the context of energy efficiency renovation projects. Finally, this work expects to pave the way for building predictive models that integrate dimensions other than energy reduction and greenhouse emissions.

Author	Jaime Gomez-Ramirez (GNE Finance)
Contributors	Patricio Cartagena, Fernando Salat (GNE Finance)

Table of Contents

List of figures

List of tables

List of abbreviations and acronyms

EE	Energy Efficiency
MB	Multiple Benefits
NEB	Non-Energy Benefits
EB	Energy Benefits

1 Annex 2 - Creating a business case for non-energy related benefits - INTRODUCTION

Research on climate change suggests that small improvements in the sustainability of buildings can have large effects on greenhouse gas emissions and on energy efficiency in the economy (Eichholtz, Kok, & Quigley, The economics of green building, 2013). Regulatory bodies such as the European Commission have pushed the agenda towards energy efficient buildings. In particular, the Energy Performance of Buildings Directive (EPBD), introduced in 2002 and revised in 2010, was set to provide the legal framework and the incentives to increase the energy performance of buildings across the European Union.

Following the implementation of the EPBD into the law of different European countries, properties offered for sale or rented out are required to have an Energy Performance Certificate (EPC). Furthermore, the Article 13 in the EU Directive establishes mandatory advertisement of energy performance of buildings during the sales process. This directive has had a positive effect in both rental and sale prices of properties. All things being equal, a building with a high EPC will have a higher market price than another with a lower EPC (Cespedes-Lopez, 2019).

However, the financial advantage of building owners and investors to perform energy savings projects is not entirely clear, and evidence based research with large datasets that include changes in asset valuation pre and post renovation are sorely needed.

Equity owners and investors are not the only actors that should be considered, the occupants of buildings, in which energy renovations projects are implemented, are exposed to changes in their comfort, productivity and the rent they pay. In this respect, there is a potential trade off that needs to be understood and put into numbers: on the one hand renters' preferences for efficient buildings and on the other hand, the occupants, who may not be able to afford an increase in rent in their current post-renovated property (IEA, 2019). In addition to this, a landlord may be hesitant to invest in new energy efficiency equipment, as they are responsible for the capital cost, while the tenant is the one benefiting from lower energy bills. This is often known as the **split incentive**. By identifying the ramifications that the energy efficient buildings may have (multiple benefits), owners and investors will be given the right incentives to invest in energy efficiency measures in their buildings, aligning both renters and occupants and efficiently addressing the **split incentive** issue.

1.1 Defining Multiple Benefits in Energy Efficiency Buildings

Energy savings projects can produce benefits different than reduced energy consumption and managing peak demand. We refer to these additional benefits as *multiple benefits*. The term *multiple benefits of energy efficiency,* can be found in the literature under different denominations such as *co-benefits*, *ancillary benefits* and *non-energy benefits*. All these terms are equivalent and can be used interchangeably[49].

Definition.
Multiple Benefits are benefits that occur in addition to energy savings that are produced via energy efficiency interventions.

The term *multiple benefits* aims to capture the idea that investment in energy efficiency can provide supplementary benefits to multiple stakeholders derived from the reduction in energy consumption. The canonical benefits in energy efficiency are reductions in energy demand and greenhouse gas (GHG) emissions. While these *first-order benefits* have been extensively studied and measured, there is

[49] It must be noted that non-energy benefits can have both positive and negative impacts provided by energy efficiency programs beyond kilowatt-hour savings (Skumatz, 2014).

however a set of *second-order benefits* or *multiple benefits* that are poorly understood and therefore not recognized by stakeholders and absent in investment models.

In terms of the scope, *multiple benefits* can be classified into three groups that reflect the target group, namely *Utility, Participant* and *Societal* (ILSAG, 2018). All three groups are of interest from the standpoint of the investor, so we will discuss all of them next. Nevertheless, it is the Participant group which comprises building owners and tenants the, a priori, most relevant group of the three. See Figure 1 for a representation of this ontology.

- **Participant**: both building owners and tenants. Improvements in health, safety, comfort and reduction in operations and maintenance costs.
- **Utility**: savings that accrue to the utility company and subsequently may result in lower rates for energy consumers. For example, administrative activities related to late payments, uncollected bills, customer calls etc.
- **Societal**: improvements to the economy as a whole, environment, and health, safety, and comfort of citizens.

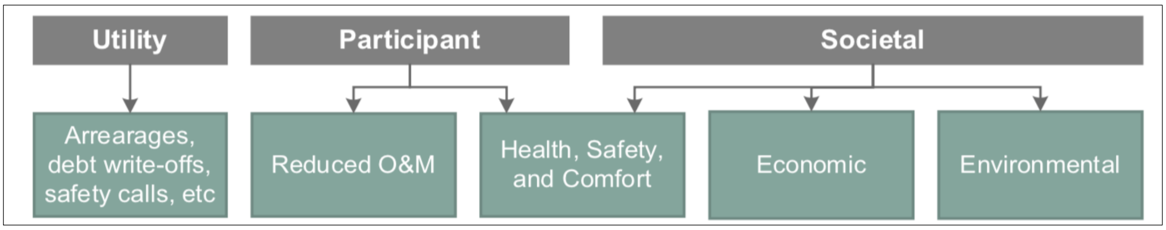


Figure 1 The figure shows an Energy Benefits ontology with the three main classes: utility or savings that accrue to the utility, participant (both building owners and tenants) and societal (improvements to the economy, environment, and health, safety, and comfort of citizens) **(Navigant, 2018)**

A non-exhaustive list of *multiple benefits* of energy efficiency might include: energy security, energy delivery, energy prices, macroeconomic impact, industrial production, poverty alleviation, health and well-being (reduced symptoms of stress and depression, reduced symptoms of chronic obstructive pulmonary disease (COPD), emphysema, and chronic bronchitis, reduced symptoms of arthritis, reduced symptoms of diabetes, reduced occurrences of trips and falls), employment, local air pollution, resource management, public budgets, disposable income, asset values etc.

We can also provide some structure to the above list of *multiple benefits* and delineate a few Sectors in which *multiple benefits* have a measurable impact and hence can be included into investment models, for example, in terms of worker's productivity and the overall improvement of the liveability conditions of the building. Accordingly, we indicate next five sectors in which multiple benefits have a relevant impact. Our focus is on the last two – Health and well-being and worker productivity – in particular in the context of office buildings and keeping in mind the point of view of investors.

6. Energy delivery cost for energy utilities
7. Macroeconomic development
8. Public budgets, reducing government expenditures, reduced budget for unemployment payments when energy efficiency policies lead to job creation
9. Health and well-being, e.g., reduced stress, depression, better air quality, reduction in acoustic noise
10. Industrial productivity, change in the perception of energy from the current view of energy as an operational cost to a value-generating proposition

1.1.1 Quantifiable multiple benefits

The identification of the multiple benefits and their ontological classification in Sectors are a necessary first step. However, from the point of view of the investor, the *multiple benefits* need to be quantified if they are to be included in economic and financial Life Cycle Cost Benefit Analysis (LCCBA). One of the first classification of Non Energy Benefits (aka Multiple Benefits) financially quantifiable is suggested by (Pearson & Skumatz, 2002) and (Skumatz, 2014). The four *multiple benefits* readily quantifiable according to Pearson & Skumatz are:

5. Work productivity increase
6. Building rental and/or sales price increase
7. GHG emissions reduction
8. Maintenance cost savings

It ought to be remarked that *Building rental and/or sales price increase,* from an investor's standpoint cannot be a benefit, it is rather the outcome out of which we are trying to identify the benefits, or using an experimental nomenclature, the building rental and/or sales price is the measured outcome while the non-energy benefits is the treatment. Thus, the price increases can't be both, treatment and outcome, or as it shown in the following equation, the price premium or outcome *Y* is explained by a linear combination of benefits *X*.

$$Y = \sum_{k=1}^{n} w_k X_k$$

Work productivity increase, on the other hand, is a proper Non-Energy related benefit. Changes in work performance can be estimated via building users' survey in which the occupants (e.g. workers in a commercial or industrial building) rate aspects of comfort that may have an impact in their work performance. The rationale is that aspects of comfort (e.g. thermal comfort, air quality, acoustics, lighting, individual control and cleanliness) have an effect on the work environment which translates into work productivity. Increased productivity can be estimated with reduced absenteeism or via proxy variables such as lighting, ventilation, thermostat control and energy adjustments which lead to overall worker betterment and productivity (Bleyl J. , et al., 2019). Furthermore, there is increasing evidence that a healthy efficient building leads to improved sleep and a healthier workforce, cutting employee sick days by up to 40% (RMI, 2015).

Globally, the potential of emissions savings could be as much as 84 gigatonnes of CO2 by 2050, through direct energy efficiency measures in building. Furthermore, the building sector has the potential to make energy savings of at least 50% in 2050 (UNEP, 2016). Thanks to the introduction of energy certificates such as the EPC in Europe, the Green Star certification in Australia or the LEED in the US, there are reliable estimates of energy savings at the building level. For example, the Green Star certification showed 62% fewer greenhouse gas emissions than average by Australian buildings, and the LEED certification showed 25% less energy and 11% less water, than non-green buildings in the US (USGBC, 2020).

These four benefits are quantifiable and important indicators to investors and will be explored in more detail in Section 2. But first we need to survey the literature of both Energy Benefits and Non Energy Benefits. By reviewing the work done in EB and NEB respectively, we will gain the necessary understanding about the impact of both kind of benefits in the valuation of the building, and most importantly how do relate to each other.

1.2 STATE OF THE ART, ENERGY AND NON-ENERGY BENEFITS

1.2.1 Energy Benefits

A 2017 report of the UN Environment and the International Energy Agency (GBC, 2017), estimated that buildings and their construction together account for 36% of global energy use and 39% of energy-related carbon dioxide emissions annually. It follows that without implementing energy retrofit programs, the building sector will remain a major contributor to environmental emissions (Toosi, 2020).

One of the main assumptions in developing market-based policy instruments is that energy efficiency classification will promote an increment in the willingness to invest in new energy efficiency measures in buildings. A number of studies have shown that EPC-rate is a useful metric to compare energy efficiency performance, facilitating the investor decision of capital allocation according to the EPC rating of the building. See (Jensen, Hansen, & Kragh, 2016) for a comprehensive review.

In (Fuerst F. , McAllister, Nanda, & Wyatt, 2015), the authors found that, as expected, there is a positive relationship between energy efficiency and dwelling sale price, in particular an energy efficiency score (EPC) increase of 1% led to 0,1% increase in asset value. In (Hyland, Lyons, & Lyons, 2013), the authors found that new construction urban buildings are more likely to have high EPC scores than suburban dwellings. Furthermore, the same authors in a posterior study (Fuerst F. , McAllister, Nanda, & Wyatt, 2016) found a strong association among EPC rates and building's age, in particular, the authors found that only 6% of dwellings built before 1900 have an EPC rating of C or higher, on the other hand, 92% of dwellings constructed since 2007 have C or higher score.

The study of the relationship between EPC rating and asset value may in some cases suffer from methodological issues, in particular model bias and model identification problems. For example, (Fuerst F. , McAllister, Nanda, & Wyatt, 2016) select a restricted sample of dwellings built since 2000 in order to remove unobserved improvements bias, while at the same time potentially introducing sample selection bias by choosing non-random data for statistical analysis. As noted in (Hyland, Lyons, & Lyons, 2013), selecting only EPC-rated dwellings might introduce selection bias, because EPC rated properties core characteristics might be different from data properties extracted from large, generic repositories e.g. municipal or national datasets, making particularly difficult to extract valid inferences. Furthermore, the behavioral energy consumption patterns of people inside the building may be relevant. the authors propose the Building Energy Rating (BER) certificate, a home energy performance that rates the energy performance of homes on a scale of A-G.

The underrepresentation of high EPC scores might result in an imbalanced dataset problem that if not properly treated might compromise the reproducibility and scope of the results. For instance, (de Ayala, Galarraga, & Spadaro, 2016) using a dataset with a 1489 homes in Spain, found that almost 7 out of 9 buildings have a very low EPC rate (52% of E and 25% of F and G). In (Fuerst F. , McAllister, Nanda, & Wyatt, 2015), researchers used a hedonic model to test the effect of energy efficiency rating on house prices in England. The study showed that dwellings in the EPC bands A and B sell for a 5% premium and 1.8% for the C band, all things being equal. However, it is worth noting that the results might not particularly robust since there is considerable variation in these effects by region and property types.

In a 2016 study (Jensen & al., 2016) , property transaction data from 2007 till 2012 showed that energy performance ratings had an impact on property sales prices. Transactions prior to the EU requirement to display the energy performance rating (June 2010) showed, on the other hand, a modest impact in prices. The authors concluded accordingly that public display of the energy performance rating is fundamental for market response. Of note, highly efficient building's renovation projects may introduce additional costs. (Chegut, Eichholtz, & Kok, 2019) found top-rated EPC buildings have higher project costs, spend 30% more time to complete and buildings' design fees are almost double than non-rated and medium-EPC buildings.

A large sample study in Wales, 192,000 transactions, investigated the capitalization of energy efficiency ratings into house prices (Fuerst F. , McAllister, Nanda, & Wyatt, 2016), finding that low-EPC rated dwellings traded at a significant discount in rental. Interestingly, the authors suggested that in addition to energy cost differences, the price effect may be due to additional benefits of energy efficient features such as improved security and noise reduction.

Unlike other European housing markets, the Spanish one lacks market data on energy efficiency (EE) labels and thus their impact on housing price cannot be easily estimated. There is however market data on EE at regional level. In (De Cock, 2016) determined the EE ratings of a sample of 1507 homes across Spain. The study found that homes labeled A, B and C account for less than 10% of the housing stock. Energy efficient dwellings have a price-premium between 5.4% and 9.8%, ceteris paribus. Another Spain-based study in the coastal province of Alicante showed that price responses have a distinct variation between the coast and the cooler climatic zone of the interior. The authors suggest that energy efficiency incentive policies should discriminate by climatic areas (Taltavull & al, 2019).

A recent study containing a particularly large dataset of 56,000 residential property sales from Portugal showed a positive correlation between energy efficient properties and price premium. In particular, apartments display higher price premiums than houses 13% and 6% respectively (Evangelista, Ramalho, & e Silva, 2020).

A comparative study of the cities of Turin and Barcelona showed that Turin's buyers pay more attention to the EPC label, while in Barcelona, buyer value more single characteristics, such as air conditioning and having a swimming pool which are intrinsically related to climate zone. The study also indicates that the implementation of the EPC schemes is still irregular in EU countries and must be strengthened through a standardized rating model (Dell'Anna, Bravi, Marmolejo-Duarte, Bottero, & Chen, 2019).

A 2011 study on financial performance of green office buildings in Australia (Newell, MacFarlane, & Kok, 2011), used a significant portfolio of green office buildings in Sydney and Canberra benchmarked against a portfolio of non-green office buildings, and the property financial performance premiums attached to green office buildings empirically assessed, including rent, value, outgoings, yield and occupancy rate premiums. Among the key findings of the study is that the Australian energy Performance Rating (Green Star) showed a green premium in value of 12%.

And lastly, a 2017 study of rental unit listings collected for 10 US cities, energy efficient features increases the units' rent, overall from 6% to 14% (Im, Seo, Cetin, & Singh, 2017).

The studies shown in Table , Academic studies of Energy Benefits, indicate that the energy efficiency certificate has a positive effect on the building valuation. Although there is overwhelming evidence about the sign (positive) of the correlation between EPC and price, the degree, that is, by how much the EPC rating affect the asset reevaluation is still under discussion. There are a number of factors related to this lack of robustness in building price prediction models. First, studies use both appraisal and transaction prices (Evangelista, Ramalho, & e Silva, 2020). Second, house attributes are sometimes absent in the model which may distort the price premium and last but not least, most models do not include the second order energy benefit variables, here called *multiple benefits*.

In the next section we explore the incipient but rapidly growing literature of *multiple benefits* in energy renovation projects.

Reference	DB	Country	Description
(Evangelista, Ramalho, & e Silva, 2020)	N	Portugal	Hedonic Regression on residential transaction prices using EPC. 13% premium in apartments, 5-6% in houses
(Dell'Anna, Bravi, Marmolejo-Duarte, Bottero, & Chen, 2019)	N	Spain & Italy	Hedonic Regression on residential transaction prices. 1.88% premium for the Spanish sample and 6.33% for the Italian sample
(de La Paz, Perez-Sanchez, Mora-Garcia, & Perez-Sanchez, 2019)	N	Spain	Hedonic Regression on residential transaction prices. 1.8% and 1.1% premium for low-rated EPC. 29.9:34.4% premium coastal region house prices.
(de Ayala, Galarraga, & Spadaro, 2016)	N	Spain	Semi-logistic hedonic model on residential transaction prices. 9.8% premium energy efficiency houses
(Im, Seo, Cetin, & Singh, 2017)	N	USA	Propensity score matching & conditional mean model on rental prices. 6-14% premium by EE features
(Fuerst F. , McAllister, Nanda, & Wyatt, 2016)	Y	Wales	Hedonic regression model on residential transaction prices. 11.3% premium for A and B-rated, 2.1% for C-rated
(Fuerst F. , McAllister, Nanda, & Wyatt, 2015)	Y	UK	Hedonic regression on residential transaction prices fixing the EPC-rate. 5% premium on top rated, 1.8% C-rated, -1:-7% lowest rated
(Hyland, Lyons, & Lyons, 2013)	N	Ireland	Hedonic regression on residential transaction prices. 79:64% premium cost-savings for F-B1 EPC-upgrade, 55:14% for rental premium
(Jensen, Hansen, & Kragh, 2016)	Y	Denmark	Regression on residential transaction prices. 6.2:6.6% premium on top rated, -9.23:- 24.3% on G-rated
(Newell, MacFarlane, & Kok, 2011)	N	Australia	Regression on office transaction prices. 9% premium on top rated offices, 1:3% on lowest rated
(Eichholtz, Kok, & Quigley, The economics of green building, 2013)	N	USA	Logit regression on office transaction prices. 7.9% rent premium in EPC's rated offices. 3.5% rent increase and 4.9% market value increase
(Lung, McKane, Leach, & Marsh, 2005)	N	USA	Cost of conservation supply curve on commercial buildings. 56.4% premium quantified ancillary savings
(Stenqvist & Nilsson, 2012)	N	Sweden	Theory based evaluation of the cost-benefits of energy efficiency in industrial sector. 1.84 to 2.84 times the gross net impact expected
(Poortinga, Jiang, Grey, & Tweed, 2018)	N	UK	Multilevel time-series regression. Indoor temperature increase (0.84Kº) associated to -37% gas usage
(Alavy, Li, & Siegel, 2020)	N	Canada	Residential HVAC efficiency Linear regression. PSC systems maintain airflow rate, 40% more power. ECM are 43% more efficient and reduce airflow rate -10:-23%
(Ngo, 2019)	N	Taiwan	Machine learning models on cooling load simulated data. ANN model, ANN-CART ensemble model, ANN-CART-LR ensemble model: R=0.98~0.99, RMSE=158.77~237.78kW
(Bleyl, y otros, 2017)	N	Germany	Life Cycle Cost-Benefit to model a commercial building cash flows (CF). 85% of cash-flow savings can re-finance the efficiency projects
(Bleyl J. , y otros, 2019)	N	Germany	Life Cycle Cost-Benefits on office buildings. 1:5.3% rental price premium; 2.5:6.5% transaction price; 6:79€/T emissions-savings; 2.1:3€/T/m^2/y maintenance costs-savings; 219:439€/m2 work productivity increase
(Hirvonen, Jokisalo, Heljo, & Kosonen, 2019)	N	Finland	Life Cycle Cost in residential building. 19% increment on emissions reduction with high cost non-economical investments. 41:92% and 24:85% emission reduction for old and new building

(Berggren et al., 2018)	N	Sweden	Co-benefits and cost-saving's life cycle-cost in a NZEB building. Base-lines scores of increase productivity value, reduced employee turnover costs, and reduced sickness absence salary
(Limsombunchai, 2004)	N	New Zealand	Hedonic Regression and Artificial Neural Network comparison on residential prices.
(Aydin, Brounen, & Kok, 2015)	N	Netherlands	Multi-logarithmic regression on residential prices. As 10% efficiency increase, 2.2% market value increase. As 10% gas usage decrease, 0.7% residential price increase

Table 1: Academic studies of Energy Benefits. The table provides the reference, whether the study has available the dataset, the location in which the study take place and a brief description of the main results of the study.

1.2.2 Non-Energy Benefits aka Multiple Benefits

Multiple Benefits or *Non Energy Benefits* are benefits that occur in addition to energy savings that are produced via energy efficiency programs. NEBs are categorized into three groups: utility, participant, and societal. Utility NEBs accrue to the utility and result from reductions in administrative costs. Participant NEBs accrue to building owners and tenants and include improvements in health, safety, and comfort and reduced operations and maintenance costs. Societal NEBs accrue to society and include improvements to the economy, environment, health, safety, and comfort of citizens (ILSAG, 2018).

The most important operational framework in which the non-energy benefits can be studied is the Deep Energy Retrofit (DER). A DER is a major building renovation project in which site energy use intensity, including plug loads, is reduced by at least 50% from the pre-renovation baseline. Energy benefits are important but there is more to that in an Energy Retrofit program. A 2002 study (Pearson & Skumatz, 2002) showed that benefits related to fewer tenant complaints and higher tenant satisfaction, safety issues, productivity increase are particularly relevant. The authors suggested that selling programs on "efficiency" or even just bill savings might not the most effective approach because it ignores critical information on the benefits with value for the participants.

Some NEBs referred in the above mentioned study are better lightening, lower maintenance, comfort, aesthetics, productivity, increased equipment life etc. Employees working in an energy efficient building had 26% higher cognitive function, 6% higher sleep quality and 30% fewer symptoms of 'sick building syndrome' (a condition typically marked by headaches and respiratory problems caused in part by poor ventilation) (worldgbcnews, 2016).

Improved aesthetics can also be considered a Non-Energy benefit; the efficient buildings must "not only feel good but look good, too". Green roofs, sunshades, window glazing, sleek low-flow water features, and other measures in an efficient building can improve the building's aesthetic and appreciation to the dwelling's eye (Vrabel, 2018).

Thermal comfort and tenant satisfaction are also benefits that have a measurable economic effect, for example in reducing tenant turnover and decreasing maintenance cost. Studies (GSA, 2011) have shown that tenant satisfaction can increase 27% by adopting energy efficiency improvements, which lead to tenants staying longer and accepting higher rents.

Increasing evidence supports that improving the quality of a rented space through energy efficiency renovations can achieve increased thermal, noise and light comfort, improved health, safety and security, and reduction of energy bills, operational costs, aesthetics, and increased equipment life (Pearson & Skumatz, 2002) (Table 3). These benefits can translate into improve tenant satisfaction and productivity of the workers in an office building. From the point of view of the landlord, energy efficiency renovations have a measurable effect in reduced vacancy and tenant turnover.

Importantly, the multiple benefits approach can help us to address the challenge of **the invisibility of energy efficiency**. Presenting the energy benefits as non-used energy, the benefits are seen as a reduction in cost. The multiple (non-energy) benefits on the other hand, can be shown in a positive light by crediting the positive impact. Table 2: Academic studies of Non-Energy Benefits. shows academic studies with focus on Non Energy Benefits.

Reference	List of NEBs	Dataset	Description
(Mansilla, y otros, 2019)	Comfort, pro-environmental initiative	https://zenodo.org/record/2610102#.XuN8sEUza00 https://www.mdpi.com/1996-1073/13/7/1700	Questionnaire of behavior and persuasive strategies to enhance energy efficiency in offices. Feedback and self-monitoring are the top ranked strategies; 8.5% increase of pro-environmental initiatives.
(Paige, Agee, & Jazizadeh, 2019)	Comfort, Energy performance control device and HERC (EPC), EE knowledge Attitudes	https://osf.io/2qy9b/	Questionnaire of energy consumption and behavior and perceptions on a residential case study experiment.
(team & Galev, 2019)	Comfort, Environmental and sustainable attitudes	https://zenodo.org/record/3523916#.Xuapu0Uza01	Questionnaire of energy consumption and behavior, mobility, willingness to install energy efficiency measures, and environmental concerns of mobility
(Buylova, 2020)	Socio-economic and demographic factors associated with high energy use	https://zenodo.org/record/3703524#.XvnQjCgza01 https://pubag.nal.usda.gov/catalog/6873537	Residential USA buildings database. Estimates Energy Cost Index. Older housing, low-income households, energy burden/costs, racial minorities and low education has higher level of energy use intensity
(Földváry Ličina, y otros, 2018)	Thermal climatic and subjective comfort, air quality	https://datadryad.org/stash/dataset/doi:10.6078/D1F671	Database compilation of location, weather, buildings specification and efficiency systems in relation to comfort, air quality and individual characteristics
(Reichl, y otros, 2019)	Comfort, efficiency measurements hedonics, lifestyle. Attitudes and energy efficiency policies	https://zenodo.org/record/3524917#.XuczaEUza03 https://db.echoes-project.eu/echoes/home	Energy efficiency cities survey on residents. Retrofit collective action as a suitable solution; socio-economic conditions influences project investment and the energy source preference.
(Chiara, y otros, 2019)	Type, capacitance, conductivity and proficiency indices of efficiency measures related to comfort and air quality	https://zenodo.org/record/3256270#.XueFnkUza00	UE simulated database of energy performance, installation and maintenance of efficiency measures and the environmental impact (primary energy consumption and CO2 emissions)
(Energy Information Administration, s.f.)	Household Energy Insecurity and health implications	https://www.eia.gov/consumption/residential/data/2015/#structural	Questionnaire of energy consumption, building's characteristics, efficiency systems performance and costs, and ancillary benefits.
(Kmetty, Bent, Shreeve, & Virág, 2017)	Comfort and well-being, willingness to develop energy efficiency measures	https://zenodo.org/record/820364#.Xvow2ygza01	Questionnaire of household income, energy costs-savings, personal interest, and factors and attitudes behind energy consumption.
(Galata, Brogan, & Cunningham, 2019)	Saving goals, (qualitative) ancillary benefits and estimated payback (years)	https://zenodo.org/record/3468951#.Xvpj-Cgza01 http://www.hit2gap.eu/	Residential energy management module project to compare the actual and theoretical energy performance, energy consumption and prices and improvement opportunities

(Bahrar, Coillot, Laaroussi, Frutos Dordelly, & El Mankibi, 2020)	Renovation potential and costs, barriers	https://zenodo.org/record/3626699#.XvprqSgza01	Country-level project to analyze the depth of efficiency renovation by the climatic zone, building typology and energy usage
(Norris, 2017)	Energy efficiency needs and barriers awareness	https://zenodo.org/record/401009#.Xv2cMSgza00	Needs and barriers perceived from the actors involved in energy efficiency office renovation study-case project
(De Cock, 2016)	Amenities proximities, material and finish quality, overall condition rating, heating quality and condition, rooms and utilities quality and conditions, fireplaces quality	https://www.kaggle.com/c/house-prices-advanced-regression-techniques/data	Dataset to predict residential transaction prices considering building structural and transaction conditions, and efficiency systems

Table 2 Academic studies of Non-Energy Benefits. The table provides the reference, the list of NEBs studied, the dataset and a brief description of the main results of the study.

1.3 Datasets of Multiple Benefits Research Projects

In the last years a number of studies addressing multiple benefits in energy renovation projects have taken place. Although the field is still in its early years, it is expected a rapid and continuous growth in the years to come when quantifiable evidence of the impact on multiple benefits make unavoidable for investors, regulators and the citizenry as a whole to recognizes the importance of Non Energy Benefits. In this section we walk through some of the most recent and relevant research projects that tackle the issue of multiple benefits in energy efficiency renovation projects.

Table 3 Research projects focused on energy efficiency projects in buildings**. The table contains the project reference, whether the dataset is freely available and a short description of the project.**

shows a number of research projects focused on energy efficiency projects in buildings. Some energy efficiency projects shown also provide relevant metrics -key performance indicators or baseline scores- related to multiple benefits such as comfort, environmental, well-being and health of the building's tenants. For example, the H2020 project, CraveZero, studies the costs involved at all stages on Nearly Zero Energy Buildings (NZEBs) in order to assess the multiple benefits associated with NZEBs. Another H2020 project, COMBI, evaluates energy efficiency energy renovation projects in order to quantify the multiple impacts providing country-level reports including monetized multiple benefits. The DEEP-EEFIG platform compiles a wide array of energy efficiency projects including investment value, energy performance and price, asset value and quantitative-measured multiple benefits information. Of interest also is the Buildings Performance Institute Europe (BPIE) which focuses on energy efficiency policy, emissions and societal benefits associated to well-performing buildings.

The SENSEI project is based on the California initiative called CalTRACK and the Comfortmeter which is a survey based study in Belgium, which aims at building a comfort ranking for buildings. SENSEI explores the pay for performance (P4P) in 11 cases in North-America and elsewhere to then provide a set of implications and recommendations which should speed up the rate of energy efficiency improvement in the EU's buildings (SENSEI, 2020). The comfort scores in the Comfortmeter project are on the other hand expected to make informed decisions that increased workers' productivity. The schematics of the Comfortmeter project are highlighted in Figure 2. Both projects, SENSEI and Comfortmeter, take a quantitative approach of NEBs of direct application for investors and building owners. For a more in detail information about the project and the dataset associated with each project see Table 3 Research projects focused on energy efficiency projects in buildings. **The table contains the project reference, whether the dataset is freely available and a short description of the project.**

Project	Availability	Description
(Crazevero Project)	Free	H2020. Nearly Zero Energy Buildings (NZEBs), life cost reduction, online energy dashboard.
(De-Risk Energy Efficiency Platform)	Free	National reports and indices for investment value, energy consume, energy costs, energy performance, asset value and qualitative multiple benefits.
(COMBI Project)	Free	EU country level database for residential, office and industry building. Monetized multiple benefit indices.
(SENSEI, 2020)		Smart Energy Services Integrating the Multiple Benefits from Improving the Energy Efficiency of the European Building Stock.
(Comfotmeter, 2018)	Proprietary	Surveys of the Public Employment Service of Flanders to produce satisfaction scores of each building in the Comfortmeter database.
(Odyssee & Mure)	Free for EU ministries, partners and researchers for no-commercial uses.	DDBB and Key Indicators. Market diffusion, Decomposition, Benchmarking, Energy savings and Indicators scoreboard.
(NILM Datasets)	Free	International non-intrusive load monitoring projects and datasets collection.
(Buildings Performance Institute Europe)	Free	Knowledge dissemination and independent analysis platform. Energy efficiency policy in building's construction and renovation. Emissions indices and other societal benefits.
(CommONEnergy)	Free	Mall retrofit database. Energy consumption and emissions indices, estimated energy savings, investment cost, operational energy cost, payback time, NPV and maintenance costs.
(CITYKeys)	Free	H2020, develop and validate KPI and data sources to provide measurement, monitoring and comparable tools during the implementation of energy efficiency projects in different European cities.
(Building Performance Database)	Free	USA state-benchmark relative to office, residential and industry buildings. EPC rating, energy cost and price.

(International Energy Agency)	Free	International global reports database. Energy production, supply and intensity indices by source, emissions indices.
(Better Places for People)	Free	Campaign fund by The World Green Building Council's to promote the demand-supply of efficient well-performing office and retail buildings by proving the energy efficiency features or systems have a measurable impact on health, well-being and productivity and making available several reports, case studies, research and toolkits.

Table 3 Research projects focused on energy efficiency projects in buildings. The table contains the project reference, whether the dataset is freely available and a short description of the project.

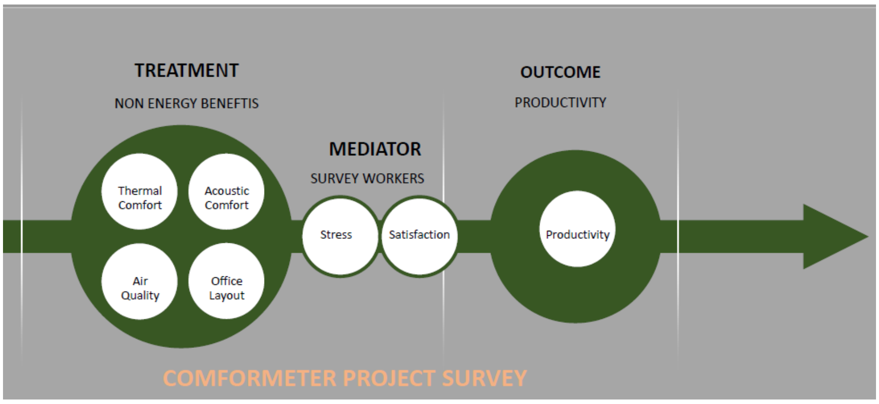


Figure 2 The Comfortmeter project is a survey-based project interested in studying how stress and satisfaction level of workers mediate between Non-Energy benefits and workers productivity.

2 Key Performance Indicators (KPI) of Multiple Benefits

In this Section identify a set of Key Performance Indicators (KPIs) related to non-energy related benefits (i.e. multi-benefits, co-benefits) of interest to investors in DER and energy efficiency renovations in commercial buildings. The selected set of KPIs will guide, support and ultimately, ease the investment decision making process. Specifically, the selected KPIs are defined so that they can be operationalized in the platform that is being built at EEnvest.

One of the key outcomes of WP4 entails a comprehensive assessment of co-benefits incurred in DER. Backed-up by literature; the multiple-benefit analysis is aimed at quantifying the multi-dimensional impact of DER. Under this realm, different methodologies have been proposed, mostly based on linear modeling in particular hedonic regression, and more recently based on machine learning techniques. However, the great potential of non-linear modeling for prediction and classification such as artificial neural network and random forests has been limited due to the lack of datasets that contain both energy and non-energy benefits. Unfortunately, as of September 2020, there are concrete signals that such database may not exist yet and, therefore, building a predictive model that assesses the weight of the different co-benefits in the price premium is unfeasible.

Although efforts to gather data are still on-going, a new approach for assessing multi-benefits emerged at a consortium-level. As result, in this Section we propose an initial set of KPIs that was built upon selected literature on multi-benefit identification and quantification, expert validation, H2020 projects among others, and several internal iterations. Out of the set of KPIs here selected, 6 of them have been included in the EEnvest Radar implemented in WP5 that is being designed to compare buildings performance. The Multiple Benefits KPIs selected are: Thermal comfort, Acoustic Comfort, Visual Comfort, Air Quality, Perceived Physical and Mental Health and Productivity Value, The selected KPIs bring together readily quantifiable indicators to construct a coherent picture for the investor. Technical KPIs (Damage, Energy gap) and Financial KPIs (Payback time, Maturity, Internal Rate of Return, Net Present Value on Investment, Debt-Service Coverage) are put together in a common representational framework. Thus, the EEnvest Radar as shown in Figure 3 brings together Multiple Benefits KPIs, Financial KPIs and Technical KPIs for a total of 13 individual KPIs.

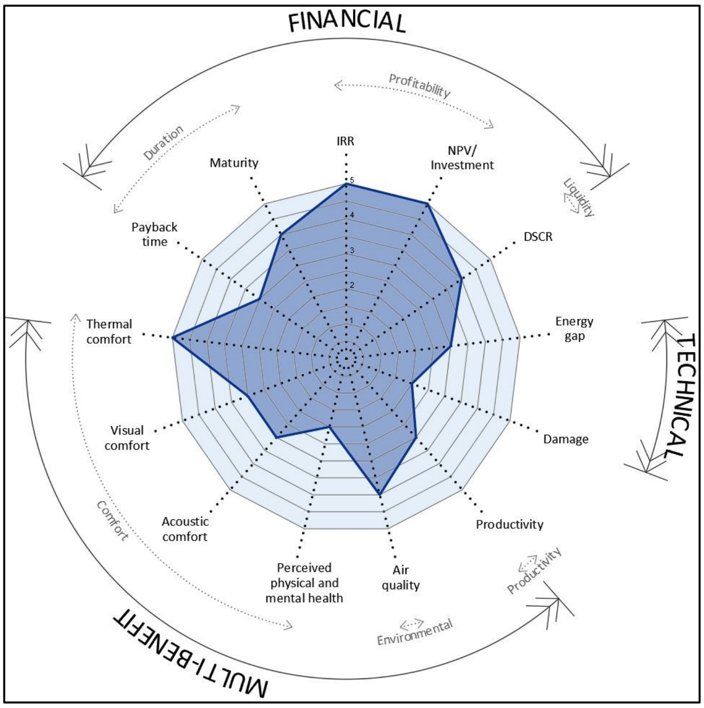


Figure 3 EEnvest Radar representation including three classes of KPIs: Financial, Technical and Multi-Benefits. The codification of the Multi-Benefits is described in the Appendix.

2.1 Breakdown of Multi-Benefit KPIs, Evaluation and Cross Dependencies

Here we explore the Multi-Benefit KPIs in depth, trying to provide the rationale and technical justification of each one of the MB KPIs. In order to collect the Multi-Benefit KPIs we have paid particular attention to previously funded projects by the European Commission that were also interested in co-benefits in energy efficiency projects and described in Section 1.3. The collection of KPIs included in Table 4 has been elaborated considering multiple sources, such as the Energy Efficiency projects, CraveZERO, ExcEED, COMBI and others, interviews with experts and the academic literature.

KPI	ID	Cluster Group(Beneficiaries)	Specific Goals	Evaluation	Benchmark	Rating	Description
Thermal Comfort [Tmin, Tmax]	TC_mM	Comfort (Tenants)	Assess whether the indoor recommended temperature is within the optimal range according to the season	Room thermometer	ANSI/ASHRAE Standard 55 / EN-1822 / ISO 7730 or equivalent	[Tmin <=T <= T max] Tmin in winter 17C	Used as indicator for compliance within range of indoor temperature conditions
Thermal Comfort PPD	TC_PPD	Comfort (Tenants)	Assess thermal satisfaction based on survey	Real satisfaction Index / Predicted Satisfaction Index	ANSI/ASHRAE Standard 55 / EN-1822 / ISO 7730 or equivalent	Ratio	Predicted Mean Vote (PMV) Predicted Percentage of Dissatisfied (PPD)
Visual Comfort	VC_DA	Comfort (Tenants)	Assess local availability of sufficient day lighting level in a time period	Use threshold according to standard (e.g 500 lux.)	Threshold 500 lux	Binarized (threshold)	Calculated according to the Daylight Autonomy(DA) that quantifies

							the local availability of a sufficient day lighting level in the considered reference period. The threshold can vary according to the standards (i.e 500 lux)
Visual Comfort (Daylight Factor)	VC_DF	Comfort (Tenants)	Assess illuminance inside building compared to outside illuminance	DF= Ei/Eo (indoor /outdoor illuminance)	Ratio. DF has no units. Ei and Eo measured in lux.	Ratio	Illuminance equation: $E = P/4\pi d^2$, P is the luminous flux (lm) of the source and d is its distance from the surface
Acoustic Comfort (dB)	AC_dB	Comfort (Tenants)	Assess noise conditions	Smart noise sensor, measure room noise in dB	Threshold	Binarized(threshold)	Safe range of sound pressure level (dB) encoded in 5 levels, being 1 harmful and 5 ideal
Acoustic Comfort (survey)	AC_su	Comfort (Tenants)	Assess noise conditions	Survey based assessment of Noise conditions		Likert scale (1-5)	Noise assessed from 1 to 5
GHG emissions	GHG	Environmental (societal)	Measure reduction of GHG emission level	Quantify total NOx, CO2 emitted by building		% reduction matched with non DER building or Likert scale (1-5)	Percentage reduction in NOx emissions (NO and NO2) - % in tons
Air Quality	AQ	Environmental (Societal)	Estimates Indoor Air Quality	Survey based assessment AQ conditions		Likert scale (1-5)	AQ encoded 1 to 5
Perceived Physical Health	PPH	Health & Well being (Tenants)	Self-assessed physical health inside the building	Survey based assessment		Likert scale (1-5)	Encoded 1 to 5. It refers to tenants, is an average of subjects
Perceived Mental Health	PMH	Health & Well being (Tenants)	Self-assessed mental health inside the building	Survey based assessment		Likert scale (1-5)	Encoded 1 to 5. It refers to tenants, is an average of subjects
Physical Health Conditions	PHC	Health & Well being (Tenants)	Reported physical health conditions or diseases directly or indirectly associated with work at the office (headaches, fatigue, asthma, eye damage, skin irritation, back pain, cardiovascular disease etc.)	Clinical report		Encoded binarized conditions [0,1] e.g. Asthma:1, COPD:0	N-dim vector each dim is a condition encoded with 0 (absent) and 1 (present)
Mental Health Conditions	MHC	Health & Well being (Tenants)	Reported mental health conditions or diseases directly or indirectly associated with work at the office (stress, depression, seasonal	Clinical report		Encoded binarized conditions [0,1] e.g. Stress:1, Depression:1	N-dim vector each dim is a condition encoded with 0 (absent) and 1 (present)

			affective disorder etc.)				
Increase Productivity Value	IPV	Productivity (business owner, employee)	Increase in productivity derived from DER in office buildings	IPV=ExSCxI The salary cost per employee (SC) x number of employees (E) Increase in Productivity (I~5%)	Typical Value: 0.5% Range: [0.3%-0.76%]	IPV refers to building, it requires the Increase Productivity per employee ~5%	Productivity gain in office buildings (euros or euros/m2) can be discounted with the risk free rate of return r
Turnover	PRO_T	Productivity (business owner, employee)	Reduction in turnover employee derived from DER in office buildings	Turnover/year count	Typical Value:0.5%	Nb employees variation/Nb Total employees	Difference between employees before and after the DER weighted by the total of employees in a time period
Sick days	PRO_S	Productivity (business owner, employee)	Number of sick days claimed by the employee	Sick days count	Typical Value:4.5 days. Baseline 7.5%	2 alternatives: i. count the number of sick days, or ii. compute increase in productivity by the reduce loss of work force days	Reduction in the number of sick days on average for a building. Alternatively, possible to use the productivity gain in % related to the reduction of sick days (7.5%)
Building Sale Price	BSP	Financial (business owner, tenant)	Increase in the building price sale (market value) of the building after DER	Sale transaction Price or Appraisal in euros.	Typical Value 5% Range [<4%-20%]	[2.5%-6.5%]	Increase in % of the market value of the building, based on actual transaction or more likely appraisal with matched buildings
Rental Income	RII	Financial (business owner, tenant)	Rental Income increase after DER	Monthly rent in euros	Typical value 3% Range [<4%, 26%]	[1%-5.3%]	Increase in % of the market value in monthly rent income based on actual market value or matched buildings
Maintenance Costs Savings	MCS	Financial (business owner, tenant)	Variations (+/-) in maintenance cost after DER	Euros/m2/year	Typical value: [2.1-3] eur/m2/y	Euros per surface and year	Monetary increase given in eur/m2/y units.

Table 4 Proposed Multi-Benefit KPIs. The table includes the KPI name and ID, the potential beneficiaries of the KPI, Goal or Goals of the KPI, Evaluation, Benchmark, Rating and Description of each KPI.

Next, we provide the rationale for each of the KPIs described in Table 4, commenting on the typical value, range of values and also discussing the dependencies to be expected among them. The KPIs have been grouped into 5 groups: **Comfort, Environmental, Health and Wellbeing, Productivity** and **Financial**. Each group or cluster affects different stakeholders. For instance, Comfort KPIs affect the tenants or workers in the office building, the Environmental KPIs affect to the entire society, the Health and Wellbeing benefit tenants and workers, the Productivity cluster affects both workers and business owners and finally the Financial KPI is of interest to the business owner.

Shows the relationship the target group –Tenant, Worker, Owner/Investor and Society– and the different groups of KPIs – Comfort, Environmental, Health and Wellbeing, Productivity and Financial, The Figure below tries to help the reader to reflect about the issue of the interdependencies between KPIs which is missing from the literature. For example, Comfort, Health&Wellbeing and Productivity and very likely strongly correlated.

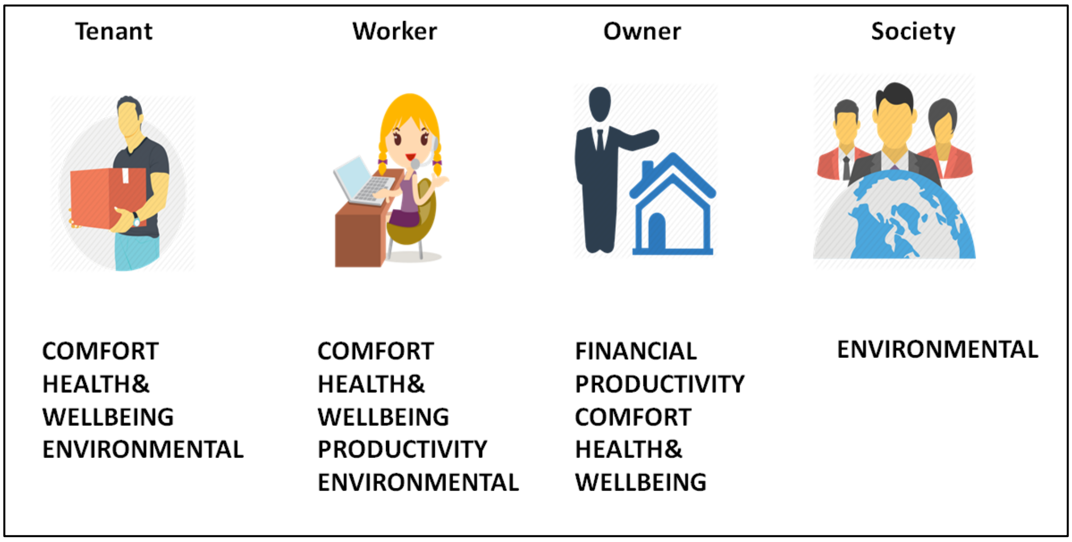


Figure 4 Target of KPIs on selected groups: Tenant, Worker, Building Owner/Investor and Society. The KPIs are in order of importance. For example, for the Tenant group the most important KPIs are comfort and Health&Wellbeing, for the Worker group, productivity must be taken into account and for the Business owner or investor group, the Financial KPIs are first in the list. For society the most direct KPI is environmental but all KPIs have a potential indirect effect.

Comfort (Tenants)

TC_mM assess whether the room temperature is within the range of acceptable temperatures for winter and summer. It can be binarized, 0 for room temperature that is not acceptable and 1 otherwise. Calculations can be made according with the ANSI/ASHRAE Standard 55: Thermal Environmental Conditions for Human Occupancy establishes the ranges of indoor environmental conditions to achieve acceptable thermal comfort for occupants of buildings.

TC_PPD is survey-based, it calculates the Real satisfaction Index / Predicted Satisfaction Index. The range is [0,1] 0 for no satisfaction, 1 for experience satisfaction as predicted.

VC_DA is based on Daylight Autonomy (DA), it quantifies the local availability of a sufficient day lighting level in a time period, for example using a threshold 500 lux (Acosta, 2018). Thus, it can be binarized, 0 does not reach the threshold of luminosity, 1 otherwise.

VC_DF Daylight Factor (DF) computed as the ratio between illuminance indoor and outdoor. The DF is defined as the ratio of horizontal indoor (Ein) to outdoor illumination (Eout) by daylight under continuous overcast sky conditions. The range is [0,1] 0 for Ein 0 and 1 for Eout == Ein.

AC_dB acoustic comfort due to noise conditions measured as number of decibels. The safe range of sound pressure level (dB) should be between 0dB (no sound) to 60dB . Above 90dB is considered risk range and above 120dB is harmful (Canada Safety). We suggest to code this KPI in 5 categories 1(harmful noise) to 5 (best), specifically 1:+120dB; 2:[90,100]dB, 3:[70,80]; 4:[40,60]dB, 5:[0,50]dB.

AC_su acoustic comfort estimated via survey using the Likert scale, the user assess her noise conditions from 1 (harmful) to 5 (ideal)

<u>Dependencies</u>: Thermal comfort helps to improve a person's concentration ability which improves work performance. For instance, 1.7% improvement in productivity (mainly quality of work) can be achieved after controlling the room temperature within 21–25 °C (ETDE, 2001). Direct sunlight has the greatest impact in our lives, it provides not only visible light but also ultraviolet and infrared (heat). Visual comfort co-benefits involve lower staff turnover, increased productivity, reduced sick leaves, reduced vacancy, health benefits. Acoustic comfort may increase the level of satisfaction and the capacity of concentration, leading to increased productivity of the occupants (CraveZero, 2020).

Environmental (Societal)

GHG The energy-related CO2 and nitroxides emissions account for the environmental impact due to building operations. It can be measured as the expected percentage reduction in NOx emissions (NO and NO2) - % in tons or CO2 emissions matched against a non DER building. This KPI can be encoded as a percentage [0,1] reflecting the reduction in GHG emissions or additionally using a Likert scale from 1 to 5.

AQ relies upon having an installed an efficient heating ventilation and air conditioning (HVAC). This KPI can be encoded using the Likert scale from 1 to 5.

Dependencies: The kind of HVAC that is installed in a DER building can reduce up to 58% of global burden of disease at EU-26 level (Hänninen, 2013). Poor indoor air quality can also affect the quality of work, fresh air which replenishes attention and boosts up the energy to work. Furthermore, in (Singh, 2009) researchers found that shifting into an energy efficient building, employers can gain an additional 2.02 work hours per person per year because workers were feeling less mental stress

Health & Wellbeing (Societal)

PPH and **PMH** Perceived Physical Health and Perceived Mental Health are self-assessed via survey. There are numerous tests that can be done online, we however, recommend using the Likert scare (1 to 5) for consistency with the other KPIs. The KPIs refer to subjects inside the building not the building therefore using a meaningful statistic is advised.

PHC and **MHC** Physical Health Conditions and Mental Health Conditions consist on clinical diagnosis of conditions or diseases that may have been originated or affected by the work place characteristics. Ideally, in a DER building, subjects may notice an improvement in certain conditions such as stress, depression or pulmonary and airborne diseases. The KPIs can be encoded as a N-dimensional array each variable encoded as a binary category that reflect the presence or absence of the condition, for example PHC = [Back pain, asthma, COPD] = [1, 0, 0]. Note that as it is the case of PPH and PMH KPIs above, PHC and MHC refer to subjects not the building therefore using a meaningful statistic is advised.

Dependencies: Health benefits derived from DER are particularly complicated to quantify and a comprehensive theoretical framework and effective methodology that tackle this problem are missing. However, Health and Wellbeing KPIs are known to have a major impact across different dimensions, including productivity, public health and macroeconomic indicators. A healthy and happy workforce is more productive (less sick leaves and lower turnover). The Health & Wellbeing KPIs impact on Public Health and Public safety can be translated in a reduction of excess winter morbidity due to inadequate heating and cooling. Social welfare can also be affected by these KPIs, for example a reduction in indoor dampness can lead to a lesser asthma incidence due to dampness in the building. Research shows that 23% of lung cancer is caused due to indoor exposure[5], diseases such as lung cancer and cardiovascular diseases caused by indoor exposure have an impact not only on working days but on life span.

Work Productivity (Business Owner & Employees)

IPV Increase productivity value, is calculated based on the estimated increase of individual workers (e.g. 5%) the number of workers and their salary cost. The methodology to calculate the IPV is described in (Berggren, 2017). In brief, the IPV is calculated as the product of the number of employees, the average salary costs per employee, and the increased productivity per employee and can be discounted in time by R, the annual discount rate. Studies show that employees in nearly zero energy buildings perceive a positive effect of their working environment and productivity (Thatcher, 2014). Based on the existing literature it is to be expected an increase in productivity between 0.3 % (or 8 €/m2 in a 10,000 m2 office building) (Singh, 2009) to 0.5% (Bleyl J. , et al., 2019) and most likely within a range of [0.3%-0.78%] according to the econometric model of the Comfortmeter project (Comfotmeter, 2018) which is based on an estimated average 0.19% work performance increase (Singh, 2009) which scaled 2 and 4 times gives a work performance increase between 0.38 and 0.76% [(2 to 4) × 0.19%].

PRO_T Turnover employee reduction affect positively productivity of the work force. A US study showed that around 20-25 % of 534 companies reported higher employee morale, easier recruitment of staff and more effective customer meetings (Miller, 2009). In addition, 19 % reported lower employee turnover. However, a more modest and likely realistic baseline at 0.5% is proposed in (Berggren B. , 2018).

PRO_S Reduction in the number of sick days claimed by the employee. The typical value used in this KPI is 4.5 active work days/person per annum can be gained by having more deeply retrofitted buildings, passive houses, and nearly zero energy buildings. According to (Thatcher, 2014) and (Singh, 2009) the baseline in percentage is 7.5%. Note that the baseline value for this KPI is particularly important since it is several times larger than other KPIs. For instance PRO_S baseline 7.5% is 15 times larger than PRO_T at a 0.5% baseline, 25 times larger than IPV at a 0.3% baseline and even 1.5 times larger than Higher rent at 5% baseline and 2 times larger than reduced vacant at 3.5% baseline (See Table 2 in CRAVEZero D6.4 (CraveZero, 2020)).

Dependencies: The expected increase in productivity in DER office building is 0.5%. Labor productivity change can be related to at least two main factors: (1) active days gained by reduction of sick days, healthy life years and (2) work-force performance improvements as a result of increased comfort. Air quality thanks to proper ventilation rate, i.e., more than 12 L/s per person can reduce sick days by 1.2–1.9 days per person per year (HealthVent, 2012), (Milton, 2001).

Financial (Business Owner & Tenant)

BSP and **RII** The Building Sale Price Increase and the Rental Income Increase reflect the variations in asset value after DER in office buildings. The literature supporting these KPIs is convincing, there is a price/rental premium related to DER. On the other hand, the value estimate increase can be hardly quantified with a simple statistic such as the mean, the standard deviation of percentage increase is likely large. For example, according to (Bleyl J. , y otros, 2019) investing in energy efficiency (sustainable building certification), translates to higher rent ranging from below 4% up to 21%. Numbers for higher market valuations (transaction or sales prices) range from below 10% to up to 30% (USA) or 26% (Europe). A more workable estimate of rental and price increases is [1-5%-3%] for rental income and [2.5%-6.5%] for building sale price increases (Tables 1 and 4).

BSP Maintenance Cost savings is a KPI that could have negative impact, that is to say, the maintenance cost of the new equipment could be more expensive and/or difficult to maintain and operate than the standard passive building equipment. If we adopt a positive scenario, the expected impact can be estimated around 2 and 3 euros/m2/year.

Dependencies: From the point of view of the investor, all the KPIs should in one way or another have a financial impact; however we are not in a position to derive sensible financial models that incorporate co-benefits like well-being or comfort. Likely this situation will change in the future when high quality datasets become available. The datasets should incorporate not only as is the case today energy certificate but also non energy benefits in order to understand how both types of benefits can predict asset price changes.

Figure 5 shows the dependencies path for each KPIs category group. The graph is intended to indicate the causal relationship between KPIs. From the graph we can infer that Comfort affects both Productivity and Health, the same goes for Environmental KPIs. Health affects Productivity and finally Productivity affects Financial KPIs. Although the only direct path to Financial KPIs is from Productivity, the graph shows that indirect connections from any cluster to Finance. For example, Comfort, Environment and Health affect Finance indirectly via Productivity but it would be worth exploring whether Comfort is causally related to Financial KPIs or is as the figure suggests always mediated by Productivity.

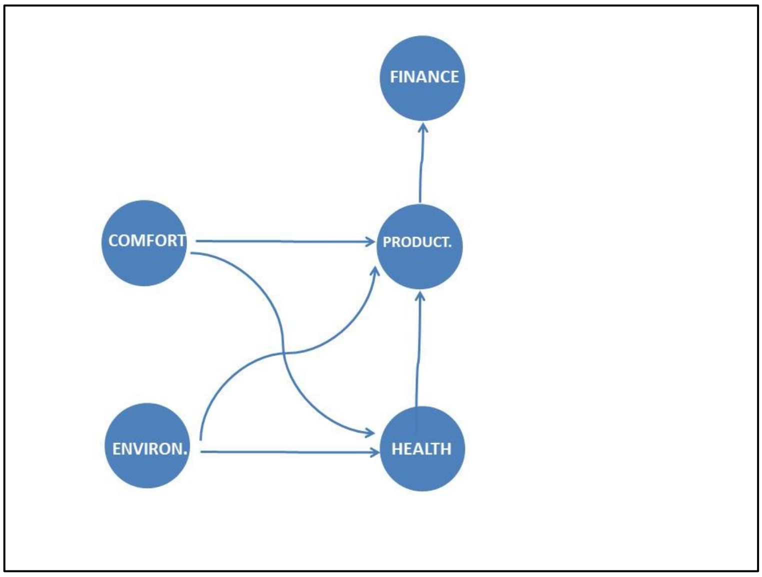


Figure 5 The figure shows the graph of dependencies between the 5 clusters of KPIs identified, namely, Comfort, Environmental, Productivity, Health & Well Being and Financial.

3 Business Case

There is a growing literature that tries to integrate second order effects of energy efficiency improvements into traditional price models (Table 2 and Table 3). Thus, in order to study how energy efficiency renovations in a building affect its rental or sale price, we might be interested in finding three sets of predictors in our model: Building factors (e.g. surface, location etc.), Energy efficiency factors which can be more or less safely translated into the EPC scoring, and Non-Energy Benefits e.g. productivity, well-being etc. discussed in Section 2. See Figure 6 for a graphical representation of the underlying idea.

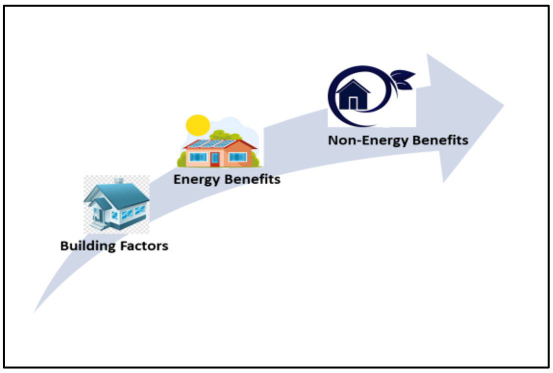


Figure 6 The Energy Benefits are built from the building characteristics such as location, surface etc., and the Non-energy Benefits are second order benefits derived from the energy efficiency conditions achieved.

Nearly all Deep Energy Renovation (DER) projects include additional dwelling upgrades, including new finishes and deferred maintenance. Overall repairs and the annual energy cost savings can equal or exceed the annual loan costs (Less & Walker, 2015). The financial incentives of DER projects are multiple although not well characterized in the literature for lack of project data that include pre and post DER project assessment. Nevertheless, in (Lohse & Zhivov, 2019) the authors identified non-energy-related operative cost savings such as avoided maintenance costs for replaced worn-out equipment, reduced operation costs after the implementation of building automation services, and reduced building and machinery insurance risk premiums. The authors estimated that DER can increase energy cost savings by 30%–120%. Furthermore, recent studies (Bleyl J. , et al., 2019) have quantified the impact of DER on the indoor climate and on the occupant satisfaction in monetary terms, determining that a DER project may add another 50%–150% to the value of energy cost savings, that is to say, Non-Energy benefits bring a monetary value that could overcome the energy savings and most importantly, they bring in asset valuation premium on the building. Thus, from the point of view of the investor, the Non-Energy benefits are those worth paying close attention to.

Figure 6 shows the rationale of NEBs in energy efficiency projects from the point of view of the investor. The financial value of EE are not only undisputed but most importantly neutral from the investor's standpoint, since it is the person that makes use of the building, rather than the building owner or the investor for that matter who reaps the benefits of energy savings. However, and from the point of view of the investor, it is the financial value and the strategic value associated with the NEBs what need to be incorporated in the business case.

Figure 7 Financial value of EE + Financial value of NEBs + Strategic value of NEBs = Better Business Cases = More Capital Flow

Figure 8 shows the model for predicting the financial outcome from an energy renovation project taking into consideration NEBs. Both the Input and the Output in the model are NEBs. Specifically, since investors are interested in the financial KPIs, the model's output includes the Price/Sales premium. The input of the model includes other KPIs described in Section 2: Comfort, Environmental, Health & Wellbeing and Productivity.

Once we have designed the model architecture, that is, the Input and Output features or in the statistical lexicon the predictors and the outcomes, we pass to briefly comment on the methodological choices for the statistical inference model. As it was already described in Section 1.2, regression modeling, in particular, hedonic regression is the model of choice to test the effect of energy efficiency rating on dwelling prices. A few studies, in order to overcome the limitations of linear modeling, are using non-linear modeling such as Artificial Neural Networks (ANN) and Ensemble methods (e.g. Random Forest) (Selim, 2009) (Limsombunchai, 2004).

Although the use of machine learning and deep learning must be welcome, especially as it is the case of Energy Efficiency studies which are heavily reliant on regression modeling, in Non-Energy Benefits we are still in a pre-EPC era. By this we mean that we are simply lacking the data necessary to properly understand the financial impact of Non-Energy Benefits such as Comfort or Health and Wellbeing of workers and customers in a commercial building.

However, we can build on the growing literature of Non-Energy Benefits and try to estimate the effect that the Input KPIs have on the Financial KPIs as shown in Table 5

KPI	NEB Values Range relative to Energy Savings	Consistency across programs [1..5]	Investor Weight [1..5]
Thermal Comfort	[1% , 51%]	4	3
Acoustic Comfort	[5%, 35%]	2	3
Visual Comfort	[1% , 44%]	3	3
Air Quality (Environmental)	[5% , 50%]	2	4
Perceived Physical/ Mental Health	[2% , 47%]	3	3
Productivity per employee	[5% , 33%]	3	4

Table 4: Proposed Non-Energy Benefits KPIs, subjected to energy savings.

Source: T4.2

. Our goal is to build an index of NEBs supported by the academic literature and projects commented in detail in Section 2. The index is a list of KPIs selected from Table 4 with an estimated range of percent increase in the Price/Rental value, together with a weight to indicate how reliable the KPI are according to the current evidence plus another weight parameter that reflects investor's interest in the KPI.

Important is to note that the Investor Weight column is strongly dependent on investors' preferences and objectives, as such, Table 5 provides an initial approach to weight KPIs- it does not represent an irrefutable categorization.

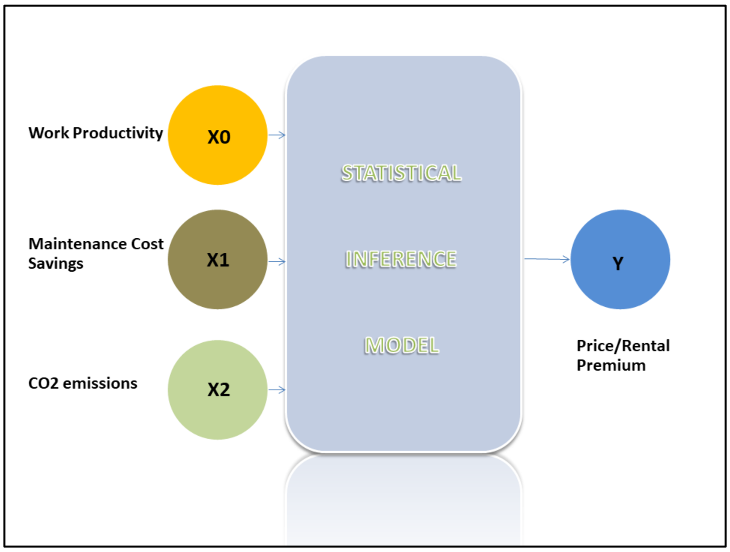


Figure 8 Statistical Inference Model Architecture which tries to predict multiple benefits, such as price/rental premium, work productivity, maintenance cost reduction and Green House Gas emission reduction.

KPI	NEB Values Range relative to Energy Savings	Consistency across programs [1..5]	Investor Weight [1..5]
Thermal Comfort	[1% , 51%]	4	3
Acoustic Comfort	[5%, 35%]	2	3
Visual Comfort	[1% , 44%]	3	3
Air Quality(Environmental)	[5% , 50%]	2	4
Perceived Physical/ Mental Health	[2% , 47%]	3	3
Productivity per employee	[5% , 33%]	3	4

Table 5 Non-Energy Benefits KPIs effect on Financial KPI. The table includes the estimate as a range rather than a point estimate, the evidence weight or consistency found across programs which can work as a proxy for KPI robustness plus the investor's weight which represents the relevance of the KPI from the investor's point of view.

The sum up of all the multipliers in Table 5, assuming all the KPIs are independent which they are not (e.g. thermal and acoustic comfort are correlated with productivity and the same goes for air quality and perceived health) gives us [19%, 260%] relative to bill savings. The wide broad range responds to our deliberately conservative take imposing a very low range on the KPIs, never larger than 5%. The typical value of the multiplier, we believe lies much closer to the upper bound than to the lower bound, that is, we would expect between 150% and 200% NEB multiplier relative to EB. The rationale for this directly follows from the very conservative approach taken here in which the lower bounds of each KPI are very small, below 5%.

Although the values range have been built based on the scrutiny of a very extensive literature including academic literature, governmental, research projects as well as numerous interviews with experts, they are certainly debatable and prone to modification. Nevertheless, the index provided in Table 5

KPI	NEB Values Range relative to Energy Savings	Consistency across programs [1..5]	Investor Weight [1..5]
Thermal Comfort	[1% , 51%]	4	3
Acoustic Comfort	[5%, 35%]	2	3
Visual Comfort	[1% , 44%]	3	3
Air Quality (Environmental)	[5% , 50%]	2	4
Perceived Physical/ Mental Health	[2% , 47%]	3	3
Productivity per employee	[5% , 33%]	3	4

Table 4: Proposed Non-Energy Benefits KPIs, subjected to energy savings.

Source: T4.2

is a necessary first step to build predictive models of price/rental premium relative to NEBs. The index can also work as evidence-based baseline to calculate the premium of individual projects relative to the lower and upper bounds included in the index KPIs. From a methodological standpoint, the KPIs defined here have a physical correlate, so to speak, measured via smart sensors. Thus, parameters such as noise level, temperature, humidity, and indoor air quality -PM2.5, PM10, CO2, volatile organic compounds (VOCs), etc. may all be made available at a relatively low cost. For example, smart sensors for air quality that collect information on humidity, CO2, CO, VOC, and formaldehyde levels are in a price range of 300-400 euros. It is, however, the actual relationship between these parameters and the benefits as perceived by the person living in the house that is still poorly understood.

3.1 MONETIZING AND CALCULATING MULTIPLE BENEFITS

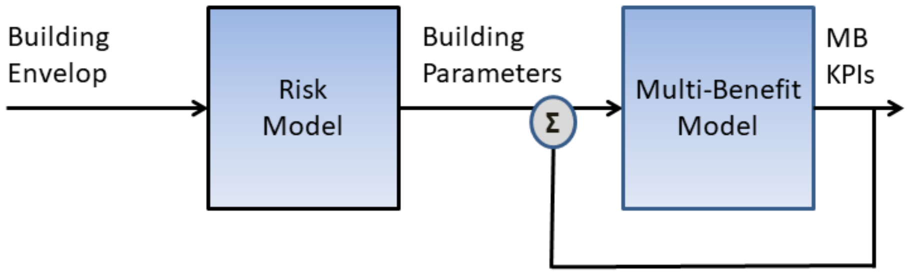
There is an emerging literature describing mechanisms for calculating and monetizing multiple benefits in energy renovation projects (EPA, 2018), (Srinivasan, 2018), (COMBI Project). However, it must be stated that the monetized value for the multiple benefits has been so far addressed always at large organizational levels i.e. nation-states. The EU funded project COMBI (COMBI Project). has reviewed and computed the MB in the different European Member States, providing an in-depth comparative analysis across different macroeconomic indicators for the 27 Member states of the EU. However, there is a mismatch between the interests and motivations of the individual investor, and the existing methodologies for monetization of MB such as those described in COMBI and Copenhagen Economics (Shnapp, 2020). From the point of view of the investor, it is the positive variations in the habitability of the building that follows after a DER has taken place what matters. The improvement in comfort, wellbeing, and productivity of the occupants is what needs to be understood and quantified as a *conditio sine qua non* for the monetization of the multiple benefits.

To calculate the effect of increased investments in energy renovations, not generically as in a nation, but for a specific project, the investor needs to have at her disposal information regarding both the building and the preferences of the occupants. This is an important point that deserves clarification. There is a clear distinction between modeling the building's envelop effect on measurable quantities such as the concentration of PM2.5 or the intensity of light in a room, and modeling how these same quantities result in the actual experience of the building occupants. There may be a connection between the PM2.5 concentration, the luminosity or the noise in a room and the wellbeing or the productivity of the building's occupant, but there may not be a closed formula valid for all cases and able to describe the relationship between parameters e.g. PM2.5, PM10 concentrations and the mental or physical wellbeing. For example, let us say that we have a smart sensor that has collected the humidity level, the temperature, and the air velocity together with air quality measurements such as formaldehyde concentration (exposure to formaldehyde has been shown to cause cancer in laboratory test). We can next build a phenomenological model relating the parameters with their respective KPIs. For instance, the KPI thermal comfort is affected by the parameters humidity, temperature, and air velocity and the KPI for physical health may be affected by formaldehyde present at high levels (>> 0.03 ppm). To make the model explicit we must rely upon computational simulations, especially for the KPIs related to mental and physical health since experimental testing is excluded.

Figure 9 shows the general architecture for the methodological undertaking of the project. As the figure depicts, the Risk Model and the Multi-Benefit Model are connected via the building parameters. Thus, the Risk model builds a model to help us understand how variations in the building envelop result in quantitative changes in temperature, humidity, air quality, etc. The Multi-Benefits, on the other hand, incorporate those quantitative measurements to infer the non-energy benefits. Of note, the NEBs are a function of both the building parameters such as humidity or temperature and the user's preferences or expectations. Formally, the Multi-Benefit function φ is:

φ *(Building parameters, Preferences and expectations of KPIs) = KPIs*

The Risk Model in Figure 9 is built from first principles, whereas the Multi-Benefit model is, on the other hand, a phenomenological model; that is to say, it is not directly derived from theory, since we are lacking a theory of human experience, but based on empirical evidence aiming at describing the relationships between variables included in the model. Although there is no ideal model or one-size-fits-all approach in the multiple benefits of energy renovation projects, it is, however, possible to provide a coherent framework, as the one shown below, to guide the investor's decision-making process.



Risk Model

<u>Input</u>: Features related to the actual building envelop *i.e.* the physical separator between the conditioned and unconditioned environment of a building including the resistance to air, water, heat, light, and noise transfer.

<u>Output</u>: Building Parameters measured with meters and smart sensors *e.g.* humidity, air velocity, PM2.5, PM10, [CO2], [VOC], [Formaldehyde]

Multi-Benefit Model

<u>Output</u>: KPIs –thermal, acoustic and visual comfort, mental and physical health, productivity. The model is fit by reducing the error between the expected KPIs, set a priori and defined by the home owner's preferences and the actual KPIs.

Figure 9 The figure shows the model schematics of the Risk Model derived from first-principles and the phenomenological Multi-Benefit Model. The MB model's input is defined by the Risk Model's output. The MB model is conceived as a feedback model because contrary to the Risk model there is not a quantitative universally accepted metric for the KPIs. For instance, the comfort and health KPIs are always referred to as personal preferences.

4 Discussion and Conclusions

Smart meters represent a large untapped opportunity in the newly approved by the EC *Renovation Wave Initiative* (EC, Renovation wave initiative in the buildings sector, 2020). This initiative is programmed to be adopted in the third quarter of 2020 and is expected to boost significantly the rate of renovations in buildings which currently languishes at a 1% per year. According to the EC, a faster rate of renovation is a necessary stepping stone to improve energy efficiency, reduce greenhouse gas emissions and with favorable ramifications as well regarding citizens' well-being (air quality, job creation etc.) and work productivity.

Smart meters combined with Artificial Intelligence allow a greater insight into energy use with potential benefits to both the consumer and the supply sides. The smart devices are fed with real-time data energy consumption, machine learning algorithms can identify patterns and give feedback to the end user by suggesting more cost effective ways of energy use. This large stream of data can also be used by energy production companies to detect patterns of energy consumption and so being able to produce and store energy in more effective and socially responsible ways.

We are, however, far from this scenario of rich data availability. If there is one important take home lesson from this Work Package is that despite the wide spread agreement that Non-Energy Benefits are more important for investors than Energy Benefits, having the former a larger premium, there is regrettably a severe lack of data based evidence that support this idea. The difficulty is not only in finding the correlation between a NEB, let us say, air quality, and the asset price premium, as a matter of fact, most of the time there is not even a direct way to compute the NEBs itself.

We can distinguish between two types of NEBs; benchmark NEBs and metric NEBs. The benchmark NEBs are those for which there is an industry standard, for example, thermal comfort can be easily measured and assessed with the ANSI/ASHRAE Standard 55. On the other hand, the metric KPIs are those that are typically measured and assessed via surveys due to lack of more objective methods. For example, perceived physical or mental health are self-assessed. The responses in survey studies are typically encoded with Likert scales (Table 4). The Likert scale is a discrete ordered set made of questions in a well-defined questionnaire in which the person is asked about her personal preference. The options cover a range of possible answers, and are ordered, like 'fully dissatisfied, 'disagree', 'no opinion', 'agree', and 'fully satisfied' and accordingly encoded from 1 to 5.

The challenge, thus, we are trying to solve is to study systematically and in a quantitative framework, benefits that are poorly understood due to the lack of data and appropriate methodology. Figure 10 tries to convey the message that the more subjective and the less transparent the process to measure and validate the benefit, the higher the risk of disputes between the parties, the lower the bankability, and the higher the risk premium, which is usually expressed by the level of interest rate. The basic intuition behind Figure 10 is that easiness of quantification has a negative effect on the risk premium for multiple benefits. Arguably, we are in a pre-EPC era and therefore we must learn lessons from the EPC certification. In order to be financially considered, benefits must be measured and verified by third parties who will be in charge of providing the performance guarantee.

Building owners can obtain certifications such as WELL (WELL, 2020), ENERGYSTAR (Star, 2020) or the LEED rating system in British Columbia (LEED, 2020) which provide a comprehensive framework for occupant satisfaction. The Comfortmeter survey (Comfotmeter, 2018) is another step in this direction. The survey collected the comfort conditions of 2800 employees in 20 office buildings across Flanders. See Section 2 for a more in more depth discussion of this project and the database it generated.

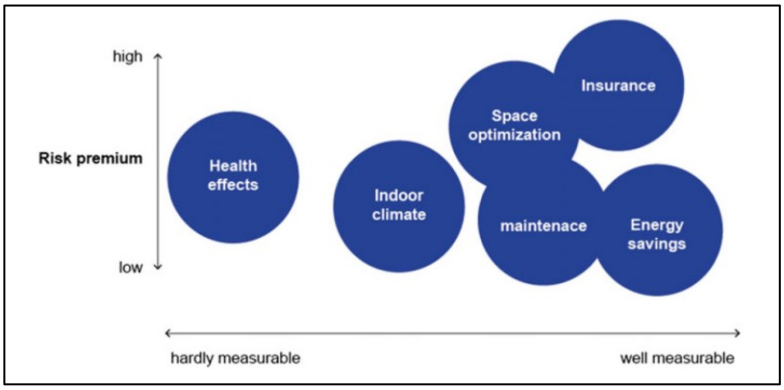


Figure 10 The Figure shows the relationship between measurability and risk premium. Although approximately, the figure indicates that the more subjective the measuring, the lower the bankability and the higher the risk premium (Lohse & Zhivov, 2019)

We are in uncharted waters, and precisely for that we need to collect all the available evidence and also try to reach out experts in the emerging field of Non Energy Benefits and listen to them very carefully about where they think the field is moving on. Among the most repeated statements across the multiple interviews we held with experts we would like to pinpoint the following ones:

- Quantifying now the Non-Energy Benefits (NEBs) is getting ahead of the curve and will likely pay off investors that care about NEBs now.
- There is a lack of publically available, high quality datasets containing NEBs.
- NEBs very likely outweigh the Energy Benefits (EB), especially from the investor's point of view.
- We may not expect to find a simple metric from the user perspective in NEB and therefore the elaboration of coherent and comprehensible KPIs is advisable.
- Just as the EPC certification achieved the alignment between investors, building owners, tenants and regulators, a NEB-based EPC certification may produce a similar outcome.
- EB & NEB have comparable lifetime cycles, but the NEB are much harder to quantify.
- The NEBs are expected to produce 5-25% increase in asset value.

A number of studies shown in Section 2 depicted the dollar/euro value of NEBs values in energy renovation projects. However, the different methods, the small sample size of most of the studies and the heterogeneity of the dataset used in each study make particularly hard to compare the results. In order to cope with this **uncertainty**, we chose to provide a wide range low-high for the KPIs proposed in Table 5.

One of most celebrated ideas of J.M. Keynes is that because the future is uncertain, private investment depends on confidence or business psychology and not on the mathematically calculated expected returns. He called this "animal spirits". It is however possible that despite Keynes' predicament in the 30s, in today's over mathematized economics, investors are pondering even more heavily on formulae comfortably packaged in software libraries that calculate future returns, oblivious though of their own intuition or psychology. As it has been mentioned before, despite the commonly shared belief among experts that NEBs have a larger impact in asset value than EBs, NEBs are omitted from Life Cycle Cost Benefit Analysis and the rest of the usual investor "toolkit".

In order to address this conundrum, we propose a set of recommendations that if considered and implemented by regulators could permeate market forces and consolidate the use and understanding of NEBs in energy renovation projects. In particular, in dynamic cash flow modeling and sensitivity analysis of the KPIs to determine the range of values for NEBs contribution. The recommendations proposed are as follows:

- Incentivize to take surveys for all new energy renovation projects, compiling information about NEBs, including the tenant's health and wellbeing and comfort.
- A consultative group of experts appointed by the EC could evaluate the appropriateness of having a Non-Energy Benefits Performance Certificate. Such certificate would provide information about the expected NEBs according to the KPIs proposed here or others. The group of experts would also make recommendations about how to increase the secondary effects derived from energy efficient building renovations.
- The KPI indoor air quality deserves special mention here. The EC and the competent Executive and Legislative Bodies can revise, in light of the coronavirus which is being transmitted by aerosols, the standards of indoor air quality design, in at least hospitals and schools, to accommodate for the new pandemic and give response to a warranted societal concern.
- Push for the creation of a European repository of NEBs data in energy renovation projects, freely accessible and indexing projects, academic literature and aggregate data of individual energy renovation projects.

All the above recommendations revolve around actions conducive to acquire a data-based understanding of NEBs in energy efficient buildings. The construction building sector has historically being particularly recalcitrant of adopting technological innovation; this is patently obvious if we compare it with the automotive or the process industry sectors, just to cite two. In order to harness the Big Data revolution that is affecting all sectors from health care to education and governance, the building sector need to equip itself with large and high quality datasets. Buildings and their construction together account for 36% of global energy use and 39% of energy-related carbon dioxide emissions annually (GBC, 2017), these are staggering numbers that are in need of a comprehensive, ambitious and evidence based strategy.

Admittedly, progress and technological achievement is not free of setbacks and adverse side effects. Take for example the Jevons' paradox:

``technological progress or government policy increases the efficiency with which a resource is used (reducing the amount necessary for any one use), but the rate of consumption of that resource rises due to increasing demand''.

The Jevons' paradox in the context of eco-friendly building renovation projects might imply that savings due to transition to high-performance buildings produce an increase in consumption (Copiello, 2017). There is however one way out of this paradox and is no other than data-informed decision-making. The time is due to turn the insights and common understanding of NEBs into data-informed practices and both effective and ambitious policies in energy renovation projects.

References

Acosta, I. (2018). Minimum Daylight Autonomy: A New Concept to Link Daylight Dynamic Metrics with Daylight Factors. *Leukos*, 251-269.

Alavy, M., Li, T., & Siegel, J. (2020). Energy use in residential buildings: Analyses of high-efficiency filters and HVAC fans. *Energy and Buildings, 209*, 109697.

Argunhan. (2018). Statistical Evaluation of Indoor Air Quality Parameters in Classrooms of a University. *Advances in Meteorology*.

Aydin, E., Brounen, D., & Kok, N. (2015). Capitalization of Energy Efficiency in the Housing Market. *Working Paper*.

Bahrar, M., Coillot, M., Laaroussi, Y., Frutos Dordelly, J., & El Mankibi, M. (2020, 1 24). *HEART 2.2 analysis data*. Retrieved from https://zenodo.org/record/3626699

Berggren. (2017). International conference on Energy, Environment and Economics. *International conference on Energy, Environment and Economics.*

Berggren, B. (2018). Lcc Analysis of a Swedish Net Zero Energy Building – Including Co-Benefits. *(July 2019)*, 2-9.

Better Places for People. (n.d.).

Bleyl, J., Bareit, M., Casas, M., Chatterjee, S., Coolen, J., Hulshoff, A., et al. (2019). Office building deep energy retrofit: life cycle cost benefit analyses using cash flow analysis and multiple benefits on project level. *Energy Efficiency, 12*(1).

Bleyl, J., Casas, M., Hulshoff, A., Robertson, M., Bareit, M., Bruyn, B., et al. (2017). Building deep energy retrofit : Using dynamic cash flow analysis and multiple benefits to convince investors. *ECEEE Summer Study Proceedings*(Bpie).

Blomqvist, E., & Thollander, P. (2015). An integrated dataset of energy efficiency measures published as linked open data. *Energy Efficiency, 8*(6), 1125-1147.

Building Performance Database. (n.d.).

Buildings Performance Institute Europe. (n.d.).

Buylova, A. (2020, 3 10). *Investigating dynamics between energy use and socio-demographic characteristics in spatial modeling of residential energy consumption*. Retrieved from https://zenodo.org/record/3703524

Canada Safety. (n.d.). *Office Noise and Acoustics.* https://canadasafetycouncil.org/office-noise-and-acoustics/.

Cespedes-Lopez, e.-a. (2019). Meta-Analysis of Price Premiums in Housing with Energy Performance Certificates (EPC). *Sustainability*, 6303.

Chegut, A., Eichholtz, P., & Kok, N. (2019). The price of innovation: An analysis of the marginal cost of green buildings. *Journal of Environmental Economics and Management, 98*.

Chiara, D., Roberto, F., Alessandro, B., Marcus, G., Fabian, O., & Chris, B. (2019, 6 25). *iNSPiRe FP7 - Retrofit solutions database*. Retrieved from https://zenodo.org/record/3256270

CITYKeys. (n.d.).

COMBI Project, C. (n.d.). Multiple Benefits of Energy Efficiency. *https://combi-project.eu/*.

Comfotmeter. (2018). The Comfortmeter survey.

CommONEnergy. (n.d.).

Copiello, S. (2017). Building energy efficiency: A research branch made of paradoxes. *Renewable and Sustainable Energy Reviews, 69*, 1064-1076.

Copiello, S. (2017). Building energy efficiency: A research branch made of paradoxes. *Renewable and Sustainable Energy Reviews*.

CraveZero. (2020). *D6.4: Co –Benefitsof nZEBs*. https://www.cravezero.eu/wp-content/uploads/2020/05/CRAVEzero_D64_CoBenefits.pdf.

Crazevero Project. (n.d.). *https://cravezero.eu/*.

Daim, T., Li, X., Kim, J., & Simms, S. (2012). Evaluation of energy storage technologies for integration with renewable electricity: Quantifying expert opinions. *Environmental Innovation and Societal Transitions, 3*, 29-49.

Dallas Fed report. (n.d.).

de Ayala, A., Galarraga, I., & Spadaro, J. (2016). The price of energy efficiency in the Spanish housing market. *Energy Policy, 94*, 16-24.

De Cock, D. (2016). *House Prices: Advanced Regression Techniques - Competition Rules*. Retrieved from https://www.kaggle.com/c/house-prices-advanced-regression-techniques/data

de La Paz, P., Perez-Sanchez, V., Mora-Garcia, R.-T., & Perez-Sanchez, J.-C. (2019). Green premium evidence from climatic areas: A case in Southern Europe, Alicante (Spain). *Sustainability, 11*(3), 686.

Dell'Anna, F., Bravi, M., Marmolejo-Duarte, C., Bottero, M., & Chen, A. (2019). EPC Green Premium in Two Different European Climate Zones: A Comparative Study between Barcelona and Turin. *Sustainability, 11*(20), 5605.

De-Risk Energy Efficiency Platform. (n.d.).

Dunse, N., & Jones, C. (1998). A hedonic price model of office rents. *Journal of property valuation and investment*.

EC. (2020). *Renovation wave initiative in the buildings sector.* https://www.europarl.europa.eu/legislative-train/theme-a-european-green-deal/file-renovation-wave.

Eichholtz, P., Kok, N., & Quigley, J. (2013). The economics of green building. *Review of Economics and Statistics, 95*(1), 50-63.

Encinas, F., Marmolejo-Duarte, C., De La Flor, F., & Aguirre, C. (2018). Does energy efficiency matter to real estate-consumers? Survey evidence on willingness to pay from a cost-optimal analysis in the context of a developing country. *Energy for Sustainable Development, 45*, 110-123.

Energy Information Administration. (n.d.). *Residential Energy Consumption Survey (RECS) - Data - U.S. Energy Information Administration (EIA)*. Retrieved from https://www.eia.gov/consumption/residential/data/2015/

ETDE. (2001). *Pollution source control and ventilation improve health, comfort and productivity* . https://www.osti.gov/etdeweb/biblio/20397142.

Eurostat Index. (n.d.).

Evangelista, R., Ramalho, E., & e Silva, J. (2020). On the use of hedonic regression models to measure the effect of energy efficiency on residential property transaction prices: Evidence for Portugal and selected data issues. *Energy Economics, 86*, 104699.

Ferreira, M., Almeida, M., & Rodrigues, A. (2017). Impact of co-benefits on the assessment of energy related building renovation with a nearly-zero energy target. *Energy and Buildings, 152*, 587-601.

Földváry Ličina, V., Cheung, T., Zhang, H., de Dear, R., Parkinson, T., Arens, E., et al. (2018). *ASHRAE Global Thermal Comfort Database II*. Retrieved from Dataset: https://datadryad.org/stash/dataset/doi:10.6078/D1F671

Fuerst, F., McAllister, P., Nanda, A., & Wyatt, P. (2015). Does energy efficiency matter to home-buyers? An investigation of EPC ratings and transaction prices in England. *Energy Economics, 48*, 145-156.

Fuerst, F., McAllister, P., Nanda, A., & Wyatt, P. (2016). Energy performance ratings and house prices in Wales: An empirical study. *Energy Policy, 92*, 20-33.

Galata, A., Brogan, M., & Cunningham, J. (2019, 10 2). *ENERIT module outcomes for the 3 pilot sites on which the module has been deployed during the HIT2GAP project*. Retrieved from https://zenodo.org/record/3468951

GBC, W. (2017). *Global Status Report 2017.* {https://www.worldgbc.org/news-media/global-status-report-2017.

GSA. (2011). *Green Building Performance.* https://www.gsa.gov/cdnstatic/Green_Building_Performance2.pdf.

Hänninen. (2013). *Efficient reduction of indoor exposures - Health benefits from optimizing ventilation, filtration and indoor source controls.* https://www.julkari.fi/handle/10024/110211.

HealthVent. (2012). *Report on the association between health and ventilation, and on the scientific basis for health-based ventilation.*

Hirvonen, J., Jokisalo, J., Heljo, J., & Kosonen, R. (2019). Towards the EU emission targets of 2050: Cost-effective emission reduction in Finnish detached houses. *Energies, 12(22)*.

Hyland, M., Lyons, R., & Lyons, S. (2013). The value of domestic building energy efficiency—evidence from Ireland. *Energy economics, 40*, 943-952.

IEA. (2019). *Iea report multiple benefits of energy efficiency. https://www.iea.org/.*

ILSAG. (2018). *Quantifying Non-Energy Benefits fromComEd's Income Eligible Programs:Findings and Recommendations from Secondary Research.*

Im, J., Seo, Y., Cetin, K., & Singh, J. (2017). Energy efficiency in US residential rental housing: Adoption rates and impact on rent. *Applied energy, 205*, 1021-1033.

IMF report. (n.d.).

International Energy Agency. (n.d.).

Jensen, O., & al., e. (2016). Market response to the public display of energy performance rating at property sales. *Energy Policy*.

Jensen, O., Hansen, A., & Kragh, J. (2016). Market response to the public display of energy performance rating at property sales. *Energy Policy, 93*, 229-235.

Kmetty, Z., Bent, C., Shreeve, G., & Virág, Z. (2017, 6 28). *NATCONSUMERS - main factors and attitudes behind energy consumption*. Retrieved from https://zenodo.org/record/820364

LEED. (2020). LEED rating system (www.usgbc.org/leed).

Less, B., & Walker, I. (2015). *14Deep Energy Retrofits -Reducing Costs and Increasing Cost-Effectiveness.* https://basc.pnnl.gov/sites/default/files/resource/DERs_CostEffectiveness.pdf.

Limsombunchai, V. (2004). House price prediction: hedonic price model vs. artificial neural network. *New Zealand agricultural and resource economics society conference*, (pp. 25-26).

Liu, S., Schiavon, S., Das, H., Jin, M., & Spanos, C. (2019). Personal thermal comfort models with wearable sensors. *Building and Environment, 162*, 106281.

Lohse, R., & Zhivov, A. (2019). *Deep Energy Retrofit Guide for Public Buildings: Business and Financial Model.* Springer.

Lohse, R., & Zhivov, A. (2019). *Deep Energy Retrofit Guide for Public Buildings: Business and Financial Models.* Springer.

Lung, R., McKane, A., Leach, R., & Marsh, D. (2005). Ancillary savings and production benefits in the evaluation of industrial energy efficiency measures. *Proceedings of the 2005 American Council for an Energy-Efficient Economy Summer Study on Energy Efficiency in Industry. Washington, DC: ACEEE*.

Mansilla, D., Papageorgiou, D., Borges, C., Tsolakis, A., Kamara, O., Krinidis, S., et al. (2019, 3 16). (PRE) Socio-economic and cultural dataset in relation to Persuasive Strategies to boost Energy Efficiency and in the UK, Spain, Greece and Austria.

Miller. (2009). Green Buildings and Productivity. *Journal of Sustainable Real state*.

Milton. (2001). Risk of Sick Leave Associated with Outdoor Air Supply Rate, Humidification, and Occupant Complaints. *Indoor Air*.

Moran, P., O'Connell, J., & Goggins, J. (2020). Sustainable energy efficiency retrofits as residenial buildings move towards nearly zero energy building (NZEB) standards. *Energy and Buildings, 211*, 109816.

Navigant. (2018). *Quantifying Non-Energy Benefits from ComEd's Income Eligible Programs.*

Newell, G., MacFarlane, J., & Kok, N. (2011). Building better returns--A study of the financial performance of green office buildings in Australia. *University of Western Sydney, Sydney*.

Ngo, N. (2019). Early predicting cooling loads for energy-efficient design in office buildings by machine learning. *Energy and Buildings, 182*, 264-273.

NILM Datasets. (n.d.).

Norris, F. (2017, 3 20). *Questionnaire on needs and requirements for energy performance gap reduction at the operational level of a building*. Retrieved from https://zenodo.org/record/401009

Odyssee & Mure. (n.d.).

Paige, F., Agee, P., & Jazizadeh, F. (2019). *OSF | flEECe Survey Dataset v3 8_28_19.xlsx*. Retrieved from flEECe, an energy use and occupant behavior dataset for net-zero energy affordable senior residential buildings: https://osf.io/2qy9b/?show=view

Pearson, D., & Skumatz, L. (2002). Non-energy benefits including productivity, liability, tenant satisfaction, and others: what participant surveys tell us about designing and marketing commercial programs. *Proceedings of the 2002 Summer Study on Energy Efficiency in Buildings*, (p. 2).

Poortinga, W., Jiang, S., Grey, C., & Tweed, C. (2018). Impacts of energy-efficiency investments on internal conditions in low-income households. *Building Research and Information, 46*(6), 653-667.

Quantifying Non-Energy Benefits fromComEd's Income Eligible Programs:Findings and Recommendations from Secondary Research. (n.d.).

Reichl, J., Cohen, J., Kollmann, A., Azarova, V., Klöckner, C., Royrvik, J., et al. (2019, 11 1). *International survey of the ECHOES project*. Retrieved from https://zenodo.org/record/3524917

RMI. (2015). *The Path to Deep Energy Retrofit.* https://rmi.org/wp-content/uploads/2017/04/2015-02_Path_to_DR_using_ESPC.pdf.

Selim, H. (2009). Determinants of house prices in Turkey: Hedonic regression versus artificial neural network. *Expert systems with Applications, 36*(2), 2843-2852.

SENSEI. (2020). *PAY-FOR-PERFORMANCE to drive energy efficiency in Europe.* https://senseih2020.eu/.

Singh. (2009). Effects of Green Buildings on Employee Health and Productivity . *AJPH*.

Skumatz. (2014). *NON-ENERGY BENEFITS / NON-ENERGY IMPACTS (NEBs/NEIs).*

Star, E. (2020). Energy Star Certification https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/earn-recognition/energy-star-certification.

Stenqvist, C., & Nilsson, L. (2012). Energy efficiency in energy-intensive industries—an evaluation of the Swedish voluntary agreement PFE. *Energy Efficiency, 5*(2), 225-241.

Taltavull, P., & al, e. (2019). Green premium evidence from climatic areas: A case in Southern Europe, Alicante (Spain). *Sustainability*.

team, E., & Galev, T. (2019, 10 31). *ENABLE.EU H2020 project dataset and questionnaire from a survey of households on energy use and energy choices*. Retrieved from https://zenodo.org/record/3523916

Thatcher. (2014). Changes in productivity, psychological wellbeing and physical wellbeing from working in a 'green' building . *Work*.

Toosi, H. (2020). Life Cycle Sustainability Assessment in Building Energy Retrofitting; A Review. *Sustainable Cities and Societ*, 102248.

UNEP. (2016). *Towards zero-emission efficient and resilient buildingsGLOBAL STATUS REPORT 2016.* https://www.worldgbc.org/sites/default/files/GABC_Global_Status_Report_V09_november_FINAL.pdf.

Ürge-Vorsatz, D., Herrero, S., Dubash, N., & Lecocq, F. (2014). Measuring the co-benefits of climate change mitigation. *Annual Review of Environment and Resources, 39*, 549-582.

USGBC. (2020). *https://www.usgbc.org/press/benefits-of-green-building.* https://www.usgbc.org/press/benefits-of-green-building.

Vrabel, K. (2018). *Beyond the dollar sign non energy benefits to energy efficiency.* https://www.waypoint-energy.com/post/beyond-the-dollar-sign-non-energy-benefits-to-energy-efficiency.

WELL. (2020). WELL Certification (www.wellcertified.com).

worldgbcnews. (2016). *Workers in certified green buildings record higher cognitive functions scores.* https://www.worldgbc.org/news-media/workers-certified-green-buildings-record-higher-cognitive-functions-scores-finds-study.

Zakeri, B., & Syri, S. (2015). Electrical energy storage systems: A comparative life cycle cost analysis. *Renewable and Sustainable Energy Reviews, 42*, 569-596.

Zancanella, P., Bertoldi, P., & Boza-Kiss, B. (2018). *Energy efficiency, the value of buildings and the payment default risk.*

Annex 3 - Specification of Multiple Benefits Input in the EEnvest Radar

The variables of interests and KPIs discussed in Section 2 are here codified in order to make them fully operational for the EEnvest Radar. The Radar integrates Financial, Technical and Multiple Benefits in a computational engine aiming at equipping the investor with a self-contained and intuitive decision support system. Here we will focus exclusively on the codification of the Multiple Benefits, namely Thermal Comfort, Visual Comfort, Air Quality, Perceived Mental and Physical Health and Worker Productivity.

Thermal Comfort

The thermal comfort assesses whether the room temperature is safe and well-balanced. Thermal comfort must first of all protect the health of the tenants during the cold and hot seasons. Furthermore it helps creating an optimal living and working environment. The codification of this factor relies upon compliance with ANSI/ASHRAE Standard 55. The ASHRAE 55 recommends that floor temperatures stay in the range of 19–29 °C. We codify around the mean and the standard deviation of this range (μ=24°C, σ=5°C). Thus, the lowest codification value (1) is for temperature outside the ANSI/ASHRAE Standard 55 range and the best valuation (5) is for room temperature between 23°C and 25°C as explained in Table 1.

1	2	3	4	5
$\mu \pm \sigma$ T<19 or T>29	$\mu \pm (4/5)\,\sigma$ T = [19,29]°C	$\mu \pm (3/5)\sigma$ T = [21,27]°C	$\mu \pm (2/5)\sigma$ T = [22,26]°C	$\mu \pm (1/5)\sigma$ T = [23,25]°C

Table 1 Codification of thermal comfort for the EEnvest Radar

Visual Comfort

The visual comfort assesses the illuminance inside compared to outside illuminance of buildings. The visual comfort is calculated according to the Daylight Autonomy (DA) that quantifies the local availability of a sufficient day lighting level in the considered reference period. The light level is commonly considered to be in the range [500, 1000]lux- depending on activity. For example, for work that required detailed visual inspection and precision, the light level may even approach [1500, 2000] lux. The codification of the Visual Comfort described in Table 2 is calculated based on the most common value for optimal indoor illuminance i.e. 500 lux (NOAO.edu, 2000). We encode visual comfort accordingly as described inTable 2

1	2	3	4	5
L<500 or L>750	L=[650,750]lux	L =[600,650]lux	L =[550,600]lux	L =[500,550]lux

Table 2 Codification of visual comfort for the EEnvest Radar

Acoustic Comfort

Noise pollution is a major environmental problem, and it is estimated that 120 million people worldwide have disabling hearing problems (Chepesiuk, 2005). Noise problem in building envelopes can be the result of impact noise or airborne noise, both needs to be properly taken into account. The WHO recommends < 30 db(A) of noise for bedrooms and < 35 db(A) in classrooms to allow for good teaching and learning environments (CDC, 2019).

1	2	3	4	5
>50 db(A)	[40,50] db(A)	[35,40] db(A)	[30,35] db(A)	[20,30] db(A)

Table 3 Codification of acoustic comfort for the EEnvest Radar

Air Quality (Environmental)

Air Quality (AQ) relies upon having an installed an efficient heating ventilation and air conditioning (HVAC) and is an environmental KPI that is gaining importance in the midst of the COVID pandemic. Air Quality can be considered an environmental factor but it affects health and productivity of building tenants. The most important indoor pollutants are PM2.5 (fine particle matter), Volatile Organic Compounds (VOC), Carbon monoxide (CO), Radon and Carbon dioxide (CO_2). Table 4 shows the codification of the most commonly AQ factor, the CO_2 level measured in ppm and according to the guidelines of the EU specifications (Argunhan, 2018). The codification shown in Table 4 can be directly extended depending on the availability of other pollutants (CO, PM2.5, PM10 etc.). For example, PM2.5 $< 35\ \mu g/m^3$ and PM10 $< 20\ \mu g/m^3$.

1	2	3	4	5
$CO_2 > 2500$ ppm	$CO_2 < 2500$ ppm	$CO_2 < 2000$ ppm	$CO_2 < 1500$ ppm	CO_2 [800,1000] ppm

Table 4 Codification of air quality for the EEnvest Radar

Perceived Physical and Mental Health

The perceived physical and mental health is assessed via questionnaire screeners. There are a number of questionnaires that address physical and mental health of individuals. For example, The Global Physical Activity Questionnaire developed by the WHO or the generic 12-item Short Form Health Survey (SF-12) to measure the physical and mental wellbeing and to be compared with baseline scores. The results of the questionnaire can be directly be translated into the Likert scale as shown in Table 5 The ideal dataset for this KPI is having reliable information about the physical/mental health before and after the energy renovation project, tenants can compare their health status before and after the project as shown in the last row of Table 5.

1	2	3	4	5
Unhealthy, mental and/or physical pathologies	Declining health	Neutral	Healthy	Very healthy
Marked worsening	Slight Worsening	Same	Slight Improving	Marked Improving

Table 5 Codification of perceived physical and mental wellbeing for the EEnvest Radar

Productivity

As it was discussed in detail in Section 2, we contemplate at least three dimensions in which productivity gain after an energy renovation project can be measured.

- Increase productivity value (IPV) is calculated based on the estimated increase of individual workers (e.g. 5%), the number of workers and their salary cost. Baseline 0.5%
- Turnover employee reduction. Lower employee turnover is thought to affect positively productivity in the work force. Baseline 0.5%
- Number of sick days claimed by the employee. The typical value used is 4.5 active work days person/annum can be gained in deeply retrofitted buildings, passive houses, and nearly zero energy buildings. Baseline 7.5%

Table shows the codification of the Productivity KPI in relation with the productivity dimension above mentioned. Each dimension, IPV, Turnover and Sick days, comes with a baseline that is discussed in Section 2. For example, assuming we have available productivity data of sick leave (third point above) the baseline that applies is 7.5% of productivity gain. Accordingly and as described in Table 6, 10% or more above the BL is codified as 5, 5% above the baseline is 4, same as the baseline is 3, 5% below the baseline is 2 and 10% or less below the baseline is 1. In case more than one productivity dimension data is available; we can obtain the codification by simply linear combination of all the baselines normalized.

1	2	3	4	5
0.9*BL	0.95*BL	BL	1.05*BL	1.1*BL

Table 6 Codification of productivity for the EEnvest Radar