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Energy Efficiency and Saving Projects: barriers, the role of ESCos, their business model and risk management solutions.

Supervisor
Ch. Prof. Loriana Pelizzon
Graduant
Daniel Dalla Palma
Matriculation Number: 877687
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ABSTRACT

Energy efficiency and saving are the workhorses of the clean energy world. Although renewable energy technologies usually take the spotlight, they often work quietly in the background. The International Energy Agency estimates that to meet the goal to stay under the two-degree limit by 2035, investments in energy efficiency must represent at least half of all the global energy investments. While there is a broad agreement at the international level that there is an unexploited economic and technical energy efficiency potential, the measures implemented to improve the overall energy consumption haven't been enough so far to stay on track to reach the targets and overcome all the barriers affecting the implementation of any energy efficiency or saving project. Energy Savings Companies (ESCos) could play a crucial role in providing technical and financial expertise for the project development. Through the implementation of an Energy Performance Contract, they can correctly evaluate the technologies to be applied, define a correct project business plan, intervene in the financing phase of the projects using their own- or third-party resources and even more, putting clarity in the division of responsibilities related to the project, thus allowing a correct risks management. In addition to the classic technical/financial tools, the potential of blockchain technology has recently been studied as a solution to speed up the implementation of projects, being able to solve enormous impediments such as trust between the parties, the accuracy of efficiency estimates, potentially making the market for certificates of functional efficiency and central to developments in the sector.

SUMMARY

INTRODUCTION

“Climate change is the defining challenge of our time” United Nations Secretary-General António Guterres stated in the 2020 World Meteorological Organization. *“Time is fast running out for us to avert the worst impacts of climate disruption and protect our societies from the inevitable impacts to come”.* We have known for decades that climate change and all the related weather events are mainly caused by the release of Greenhouse Gases (GHG) in the atmosphere due to human activity. Unfortunately, instead of reducing them, we have reached the highest GHG air concentration in 3 million years[1] and emissions are still rising. Energy production and consumption is the largest source of global GHG emissions therefore, it plays a critical role in countries’ efforts to develop and implement long-term strategies to meet climate goals. Energy efficiency is one of the main options for mitigating climate change. An accurate representation of various mechanisms of energy efficiency is vital for the assessment of its real potential.

This thesis aims to analyse the role of energy efficiency and saving projects in climate change, trying to build a macrolevel view of all the variables involved with their implementation. Initially, the focus is set on all the barriers and limitations that are affecting the achievement of their full development. To better understand the market, however, it is necessary to analyse all the actors involved. In addition to introducing the activity carried out by policymakers, particular attention is given to the role of Energy Savings Companies, analysing their business model, how they work financially and what are the risk transfer solutions available. Finally, space is given to a long-term vision, deepening the role of technological innovations such as blockchain or IoT systems. The latter has the opportunity to revolutionize the sector, accelerating its growth, reducing costs, and eliminating some of the barriers present. The thesis is divided into five chapters.

The first chapter presents the problem of climate change, which are the main drivers and elements to consider when defining political intervention. Subsequently, the focus is shifted to the current regulatory framework and global and European political objectives, deepening in detail the sometimes-underestimated difference between efficiency and energy saving. At the end of the chapter, the concept of "energy efficiency GAP" is introduced, central in the identification of all the solutions to reduce or cancel it.

[1] ‘High-Level Synthesis Report of Latest Climate Science Information Convened by the Science Advisory Group of the UN Climate Action Summit 2019’ (United Nations, 2019).

The second chapter analyses in detail all the barriers affecting the implementation of energy efficiency and saving projects, whether they derive from the market or economic failures, underdevelopment or slowdown of technological innovation, regulatory impediments, or behavioural and cultural limitations.
The third chapter introduces the role of energy saving companies (ESCos), explaining in detail their business model, project evaluation methods and financial sources. Great attention is given to innovative solutions for project evaluation, such as LEEC, and alternative financing solutions. The section concludes with the description of the White Certificates, a scheme of energy efficiency obligation that in Italy has made it possible to achieve an important development of the energy efficiency market as well as the achievement in advance of the efficiency objective set by Europe.
In the fourth chapter the risks that ESCos face in the management of their business is described, analysing how risk management procedures, merged with innovative solutions for risks transferring, such as energy saving insurance or the development of a credit risk model, would allow them better operational security and greater development.
In the last chapter, the fifth, the future role that blockchain can play is analysed, looking deeper in the context of energy efficiency. Solutions such as smart contracts related to white certificates, trading of energy saved and automation of the processes of verification and certification, could generate a further stimulus to the development of the sector, significantly reducing some barriers analysed in chapter two and making the activity of ESCos significantly less risky.

CHAPTER 1: CLIMATE CHANGE: THE ROLE OF ENERGY EFFICIENCY AND ENERGY SAVING

I. Climate change and the main drivers

Our civilization is characterized by massive consumption, not just of goods and services, but also of energy. We consume energy to light our houses, shops, streets, as fuel for our cars, trains and for many other things. The disposal of it has changed the progression of humankind over the last epochs. Over the years, new sources of energy have been discovered, fossil fuels, nuclear and recently the focus has moved on renewable sources. Unfortunately, the quantity of energy required and consumed has been drastically increased in every country around the world, averaging about 1% to 2% YoY increase[2]. It is important to highlight that energy production and consumption is strictly related to the emission of Greenhouse Gases and based on the recent report done by IEA (International Energy Agency), it is one of the main drivers of total Greenhouse Gas emitted in 2020[3].

This relationship is incorporated in the Kaya Identity[4], which is one of the key indicators that track the movement of GHG emissions. Not only the Identity exploits the weight of energy in the GHG, but it also explains the role of the other 3 main drivers causing its raising, which are:

- The growth of the total global population
- The increase of the global GDP per capita
- The energy intensity and energy efficiency
- The energy carbon intensity

The population growth isn't just a matter of the number of people in fact, the number is related to the amount of consumption of food, water, but more importantly the amount of energy required by everything and everyone. We can easily state that: the more people the higher the energy consumed. According to the United Nations, by 2100 there will be 11 billion people in the world which is around 40% more than today[5].

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[2] Hannah Ritchie and Max Roser, 'Energy Production and Consumption', Our World in Data, 2020.

[3] 'World Energy Investment 2020 – Analysis', IEA, n.d., https://www.iea.org/reports/world-energy-investment-2020.

[4] Glen P. Peters et al., 'Key Indicators to Track Current Progress and Future Ambition of the Paris Agreement', *Nature Climate Change* 7, no. 2 (February 2017): 118–22.

[5] United Nations, Department of Economic and Social Affairs, 'How Certain Are the United Nations Global Population Projections?', *Population Facts*, December 2019.

To better understand the problem and derive other assumptions, it is important to look at the energy consumption per capita. Figure 1.

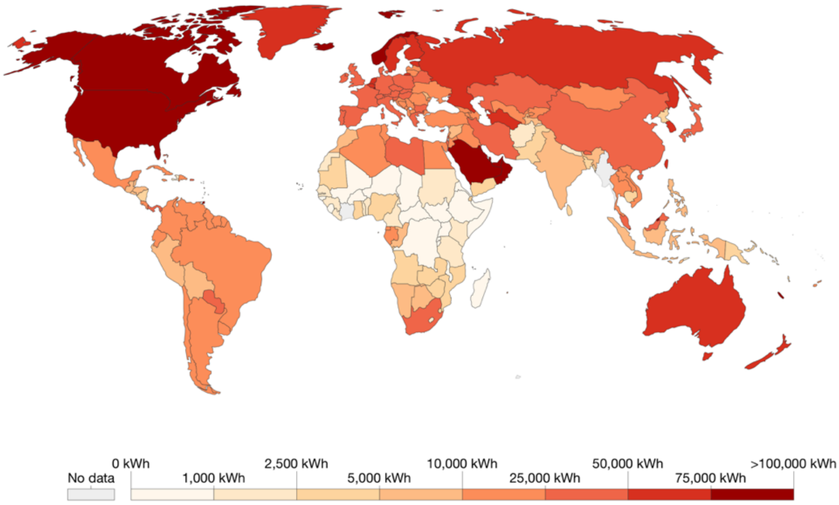

Figure 1: Energy use per capita 2019 – Our World in Data based on BP & Shift Data Portal

There are massive differences across the world. The largest energy consumers are United States, Canada, Norway, Australia, Iceland and rising wealthy nations in the Middle East such as Oman, Saudi Arabia, and Qatar. The average person in these countries consumes as much as 100 times more than the average person in some of the poorest countries. Now, to project the problem further over time, to comprehend how this trend is evolving, we need to look at the Year over Year change in energy consumption and mixing it with the data coming from the YoY growth in population.

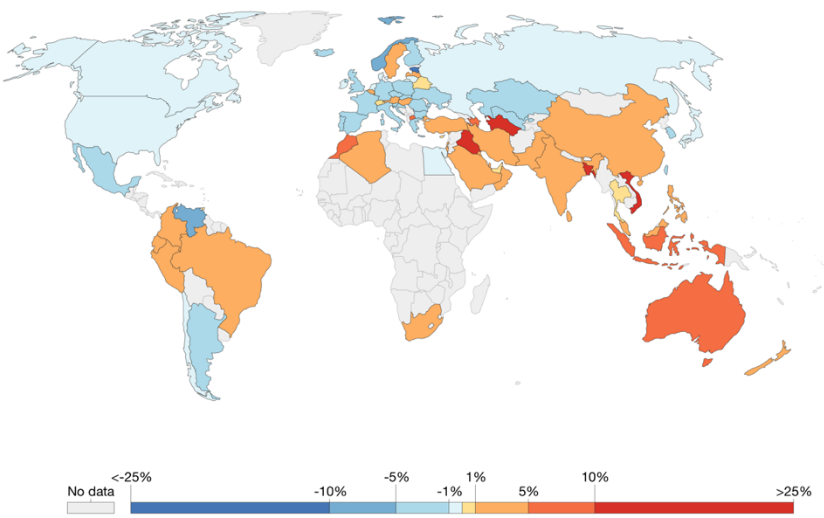

Figure 2: Annual change in primary energy consumption in 2020[6]

[6] British Petroleum, 'Statistical Review of World Energy' 69 (2020): 68.

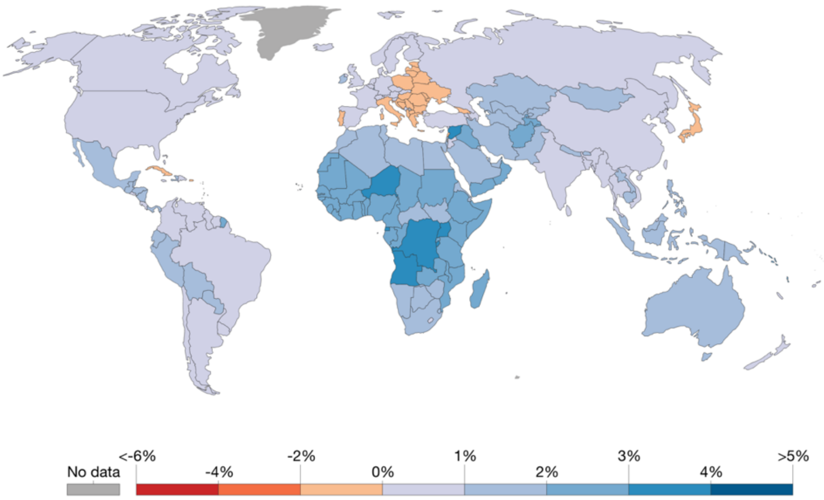

Figure 3: Annual rate of population change in 2020 – Our World in Data[7]

States like Australia, China, India, and South America are the one that has registered the highest growth in primary energy consumption, Figure 2, and have, among developing and developed countries, the highest annual rate of population growth, see Figure 3. States like the USA, Japan, Russia, or Europe have the lowest growth rate in energy primary consumption, being more focused on energy efficiency. Europe and Japan for example has a negative population growth rate, pushing energy consumption even deeper. Dealing with population growth is one of the possible solutions to solve climate change, nevertheless, the real and only feasible way to slow down it is through investment in healthcare and education, reducing the number of children per family[8]. It requires massive investments and time for changes to happen, probably taking too many years to provide the needed reduction in GHG emissions.

The second driver highlights the connection between carbon emission and population wealth. This problem has been researched by the World Bank in 2018[9], founding that global inequality, which is another international problem, emerges also by relating emissions with the income and the nation studied. When we look at total energy consumption, differences across countries often reflect differences in size and level of wealth. Those with the wealthiest population tend to consume a higher amount of energy than poorer countries. Since the world's wealth is growing almost everywhere, although far from being evenly distributed, the

[7] United Nations, 'World Population Prospects - Population Division 2019', n.d., https://population.un.org/wpp2019/Download/Standard/Interpolated/.

[8] United Nations, 'World Population Prospects: The 2017 Revisiony - United Nations Department of Economic and Social Affairs', n.d., https://www.un.org/development/desa/publications/world-population-prospects-the-2017-revision.html.

[9] Max Roser and Hannah Ritchie, 'CO2 Emissions', Our World in Data, August 2020.

inequality will rise and the global emission too. Indeed, it will become of vital importance for governments around the world to discuss it and find possible solutions to redistribute the growth opportunities, making the field more even and competitive but also cleaner.
Energy intensity, the third element, can be split into two very important concepts, how energy is produced and how efficiently is consumed. The energy production, to help the reduction of GHG, must be as clean as possible, using more renewable and unpolluted sources. Investments in cleaner energy sources have been raising since 2004 significantly. Developing countries like China, India and others have risen their investment in renewables from $ 8 bn in 2004 to approximately $ 152 bn in 2019. On the other hand, developed countries have risen from $ 32 bn in 2004 to a maximum peak in 2011 at around $ 187 bn, then consolidating at $ 130/140 bn until 2019[10]. Investments that are significant but not enough to reduce at the required pace GHG emissions and global warming. The energy efficiency, following the EU Energy Efficiency Directive released in 2012, in Article 2, comma 4, is defined as: "*the ratio of output of performance, services, goods or energy, to input of energy*". Since the GDP of a state or union is the sum of such outputs, it is usually compared to the total amount of energy used, defining an economic-wide measure, the Kwh/GDP. The European Commission reported several times that consider energy efficiency a strategic priority for the Union and decided to treat it as an energy source on its own like solar or wind energy. According to the International Energy Agency (IEA), energy efficiency measures could result in 40% of the GHG emission reduction goal set out in the 2015 Paris Agreement. In the October Briefing of 2015, the European Parliament stated that: "*The implementation of energy efficiency policies is challenging, and the full potential of energy efficiency is far from realized, for financial, behavioural and regulatory reasons. Obstacles include high upfront investment costs, access to finance, lack of information, split incentives and rebound effects*".
The last element is carbon intensity, which refers to the amount of CO^2 emitted to make one unit of energy. When electricity is generated using coal power stations, the carbon intensity value is high while when it is generated via solar plants, the carbon intensity value is low.

[10] ReGlobal, 'Global Trends in Renewable Energy Investment 2020', REGlobal, 2020, https://reglobal.co/global-trends-in-renewable-energy-investment-2020/.

II. World targets and EU policy framework

1979 represents a landmark for the environment, being the year of the first World Climate Conference. Since then, there have been well over 20 worldwide meetings, in which countries have defined targets, solutions and timing for actions to be taken to prevent global warming and other climate-related issues. The first element of notice is the creation of the United Nations Framework Convention on Climate Change (UNFCCC) in Rio de Janeiro in 1992. The aim was to set a long-term target to avoid all those man-made actions that could threaten the climate system. Briefly, the agreement between nations was reached on the reduction of GHG through:

- The establishment of the principle of "common but differentiated responsibilities and respective capabilities" (CBDRRC), identifying how countries differ in their influences on climate change and capabilities to tackle it, so the rising obligations must be differentiated rather than equal for all.
- The creation of a commission by developed countries aimed to assist developing countries in reducing emissions and coping with climate impacts.
- The establishment of the Conference of Parties (COP), which will meet "annually", defining that UNFCCC serves as the foundation of an evolving global climate effort.

UNFCCC entered in force only lately in 1994 and started its multilateral negotiation looking for a global response to climate change. Since COP 1 in 1995, countries have decided to accelerate their climate effort by starting the negotiation for the first international agreement upon targets, measures, and timing. The agreement was reached in 1997 at COP 3 in Japan, called the Kyoto Protocol, which set the targets for GHG emission limits for a specific commitment period, limits to be respected only by developed countries. Unfortunately, due to the insistence of the USA, it included a "flexible" or "market-based" mechanism called Clean Development Mechanism (CDM), that could have allowed developed countries to trade their emissions limits with others to achieve their targets more "cost-effectively". Due to some internal political conflicts in the USA, after the election of George Bush, the ratification of the agreement was suspended, letting other countries alone. The agreement, without the US, entered in force only lately in 2005, with its initial emission targets through 2012.

When it came time to negotiate the new targets through 2020, several other developed countries declined to go along. Hence, the Kyoto Protocol remains in force on paper, being able to tackle a small fraction of the global emissions having zero support and being without any expectation on future targets. The only element that stayed in place and used was the CDM. The UNFCCC having understood that the Kyoto Protocol was faltering, have tried in 2007 in Bali, in 2009 in Copenhagen and in Cancun in 2010 to establish a new one. Finally, in 2015 with the COP 21 in Paris, a new agreement was reached. It was, and still is, a legally binding international treaty on climate change, adopted by 191 parties on 12th December 2015 and entered into force on 4th November 2016. Its goal is to limit global warming to well below 2°C, preferably to 1.5°C, compared to pre-industrial levels. To achieve this long-term temperature goal, countries aim to reach global peaking of greenhouse gas emissions as soon as possible, looking for climate neutrality by mid-century. The Paris Agreement is a landmark in the multilateral climate change process since, for the first time, a binding agreement between "all" nations was set.

Starting from 2012, the IEA (International Energy Agency) has presented annually an outlook that quantifies the opportunities for policymakers and investors on all the known economic viable measures available that could drive the GHG emission reduction (Figure 5). Energy efficiency and saving, summed together into the concept of *"Efficiency"*, play the largest role in the development of a sustainable world, letting renewables in the second place.

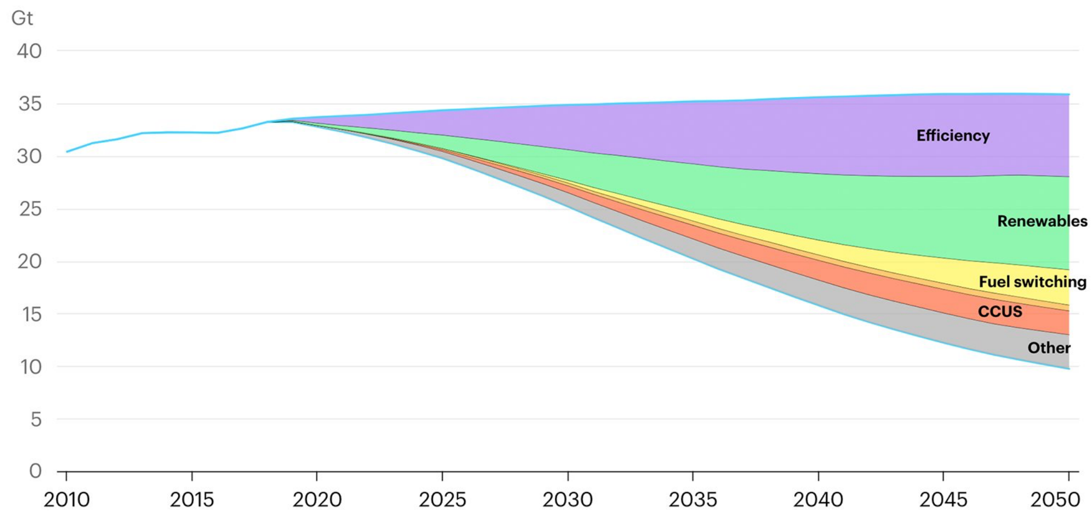

Figure 4: IEA outlook

The transformation of the global energy system needs to accelerate to meet the targets defined in the Paris Agreement. In 2019 the IRENA (International

Renewable Energy Agency) has estimated that the world needs investments across the period 2019-2050 of at least $ 110 trillion shared as follow[11]:

- $ 37 trillion for Energy Efficiency (which is 35%)
- $ 27 trillion for Renewables Infrastructure (the 24%)
- $ 26 trillion for rebuilding the Electrification Infrastructure (23%)
- $ 20 trillion for Fossil Fuel and other (18%)

The IEA has also developed a summary describing in deep all the benefits associated with investments in efficiency, to acknowledge the policymaker and the other stakeholders with all the relevant notions and tools that maximize the potential for positive outcomes.

Looking at Europe, the Commission has stated on several occasions that consider energy efficiency a strategic priority for the Union, treating it as an energy source on its own. Investing as a Union, looking for reducing consumption through technology improvement and infrastructural changes, the total demand should be reduced, leading to less dependence on energy imports, improving the energy security (a current European problem), lower cost for final users and lower air pollutants and GHG. The European climate framework has changed several times and the targets have been updated. In the year 2000, the EU launched the ECCP (European Climate Change Program) which surveyed an extensive range of sectors and instruments having the potential of reducing GHG emissions, developing common and coordinated strategies to fulfil the 1997 Kyoto targets. Furthermore, following the possibility to trade GHG emission caps, the EU has introduced the EETS (European Emissions Trading Scheme) and has also proposed new elements redesigning the field of energy labelling, the promotion of cogeneration, biofuels, and others.
In 2007, the EU leaders set three key non-binding targets for 2020:

- 20% decrease in GHG (from 1990 level)
- 20% at least of energy coming from renewables
- 20% improvement in energy efficiency

The latter was then entrenched in the Energy Efficiency Directive (EED 2012/27/EU) along with the establishment of a framework of measures for the promotion of energy efficiency in the EU, aiming to remove barriers and overcome market failures that obstruct efficiency in the supply and use of energy. The EED

[11] 'Investment Needs', IRENA, n.d., https://www.irena.org/financeinvestment/Investment-Needs.

defines also several important measures including, obligation schemes for energy companies to achieve yearly energy saving of at least 1.5% of annual sales to final consumers, the request for large companies to run energy audits at least every four years, the requirement of investment in building renovation owned and occupied by governments bodies of at least 3% per year and many others. Each state then has implemented the Directive, founding different solutions for the same requirements and targets. In July and October of 2014, the European Commission and the European Council proposed the adjustment of targets, requiring the achievement by 2030 of an energy consumption reduction of 30% and an EU-wide target of 27% energy efficiency improvement. In 2018, the EC approved the Directive 2018/2002 amending the EED of 2012, including the update of the targets and the policy framework up to 2030 and beyond. The key element was a new revised energy efficiency target of 32,5% to be achieved within 2030, set relative to the 2007 model estimation. To achieve those ambitious goals, the Commission has estimated that the economy will require at least € 260 billions of additional annual investment[12], necessitating the combination of both the private and public sectors. Nevertheless, investments without adequate policy structure cannot generate all the returns projected. The role of the policymaker, at the EU and national level, is to build a simple and efficient framework to coop with, helping the system to overcome all the barriers characterizing the energy efficiency and energy saving field.

The European Commission in 2019 has released the European Green Deal, which is the new framework set to rethink and redefine completely all the energy chain, from production to the final usage. It highlights how benefits outweigh costs and set the roadmap of key policies and measures needed[13]. Figure 4 below illustrates the various elements of the Green Deal.

[12] European Commission, «United in delivering the Energy Union and Climate Action - Setting the foundations for a successful clean energy transition», 18 June 2019.

[13] European Commission, «European Green Deal», 11 December 2019.

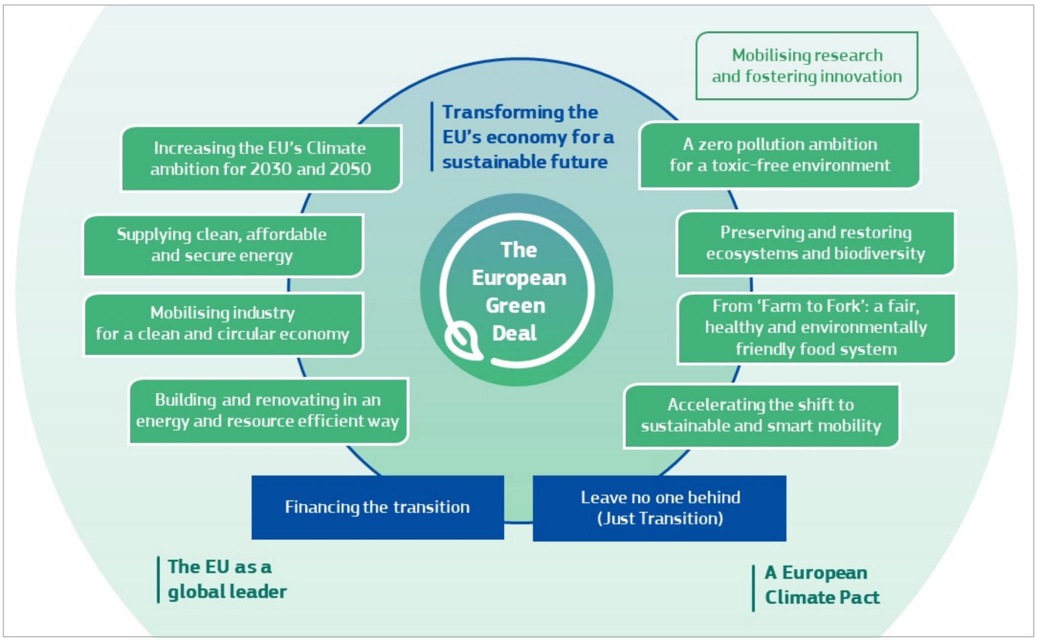

Figure 5: European Green Deal

The policy path, provided in 2020 by the European Green Deal Investment Plan, aims to mobilize €1 trillion of sustainable investments over the next decade through the European Investment Bank. EIB will focus those resources on climate and environmental action, incentivizing private and public operations, encouraging green budgeting, and facilitating procedures for funding. The plan is to invest €500 billions, coming from the European Budget and the remaining will come from private and national resources. The EU also defined the JTM (Just Transition Mechanism), embedded in the Green Deal, which is a key tool financed with €100 billions, created to ensure that the transition toward a climate-neutral economy happens in a fair way, not leaving behind anyone[14].

Unfortunately, the European Green Deal instead of being a total redefinition of the rules is just adding new rules on top of the existing ones, making things now a bit confused. The recent Covid pandemic has required from the EU a strong economic response to support the economy of the Union and the decision to link those new resources, coming from a shared debt to ESG factors, represents an important decision toward climate and energy efficiency.

[14] European Commission, 'Financing the Green Transition', European Commission, January 2020.

III. Energy efficiency and energy saving

Energy efficiency and energy saving are related but have distinct definitions in the energy world. Energy efficiency usually describes the adoption of a particular technology that shrinks the overall energy consumption, without changing consumer behaviour. The specification regarding technology is the key, investments in research and development that look for new and better energy production and consumption solutions, have the potential to cut energy-related emissions, improving the environment and energy security.

On the other hand, energy savings or energy conservation involves the usage of less energy by adjusting behaviour habits or by decreasing economic activities. The first part essentially requires investments in education, teaching people about the importance of energy, how it is produced, empowering them with knowledge, looking to cut in energy waste. The second one, unfortunately, goes against the human purpose and the current economic scheme of growth and advancement (capitalism), being slightly complex to be categorized as a solution.

These are two different points of view of the same picture, both essential for the achievement of the set targets at the international level on GHG emissions. Both Energy Efficiency and Energy Saving interest has begun to evolve, progressing from the lack of attention, in the past were referred to as "hidden fuel", to increase importance, giving them the recognition of "first fuel", at the same level of renewable energies.

IV. The Gap

Many analysts have long believed that efficiency and savings offer an enormous "win-win" opportunity; through aggressive energy related policies, we can both save money and reduce negative externalities associated with its use[15].

For a variety of reasons, households, businesses, manufacturers, and government agencies all have failed to take full advantage of cost-effective energy-efficiency opportunities, resulting in a significant gap between the current and the optimum levels of energy efficiency investment[16]. This gap has gained considerable attention among energy policy analysts since its existence suggests that society has forgone an opportunity that could significantly reduce energy consumption, lower its cost, improve energy security and that could also potentially drive both

[15] Hunt Allcott and Michael Greenstone, 'Is There an Energy Efficiency Gap?', *Journal of Economic Perspectives* 26, no. 1 (February 2012): 3–28.

[16] Eric Hirst and Marilyn Brown, 'Closing the Efficiency Gap: Barriers to the Efficient Use of Energy', *Resources, Conservation and Recycling* 3, no. 4 (June 1990).

private and public return, in the form of economic, environmental, and social benefits. First introduced by Eric Hirst and Marilyn Brown in a paper titled "Closing the Efficiency Gap: Barriers to the Efficient Use of Energy" in 1990, the problem has been analysed in different ways, looking for the causes, identifying several barriers. Jaffe and Stavins in 1994[17], in one of the most cited articles regarding the energy efficiency GAP, have explained how its magnitude differs depending on the barriers, the definition of energy efficiency potential, and the perspective used. By distinguishing between economic potential, which can be achieved by removing market failures, and technological potential, which includes the elimination of various market barriers such as risk, uncertainties, and environmental externalities, allowing the implementation of all technologically advanced and available measures, a higher energy efficiency potential could be achieved, which goes beyond the current level. See Figure 6 for a graphical interpretation on how this prospective impact. All the cited barriers will be discussed in the next chapter.

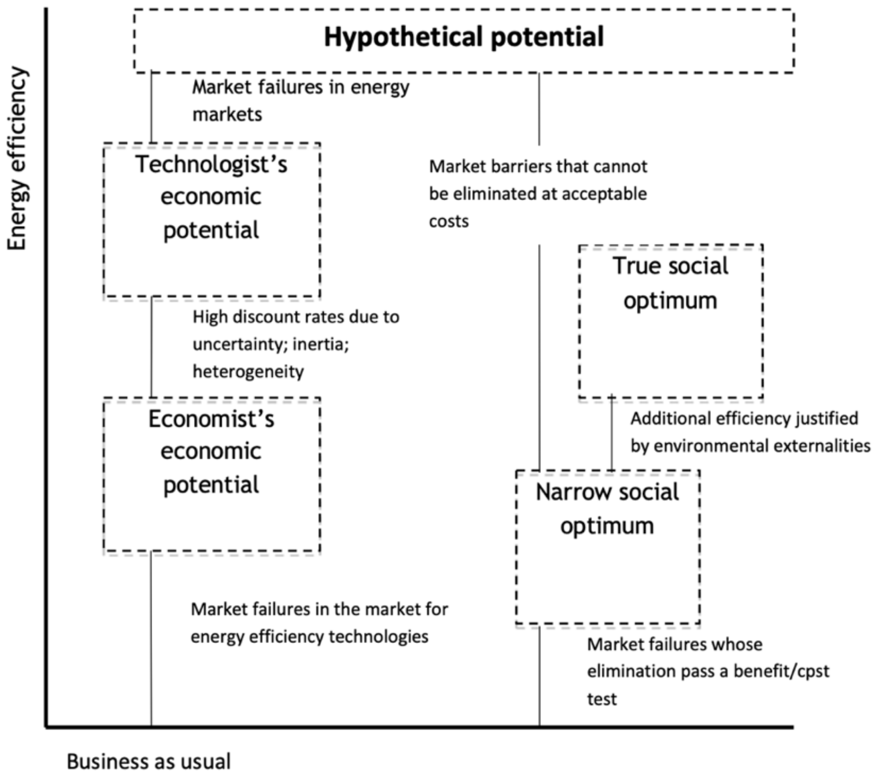

Figure 6: Different potentials for energy efficiency

[17] Adam B. Jaffe and Robert N. Stavins, 'The Energy-Efficiency Gap What Does It Mean?', *Energy Policy*, Markets for energy efficiency, 22, no. 10 (1 October 1994): 804–10, https://doi.org/10.1016/0301-4215(94)90138-4.

CHAPTER 2: BARRIERS FOR ENERGY EFFICIENCY AND SAVING PROJECTS

Despite extraordinary promotion and commitment from various nations, there are numerous barriers affecting investments in Energy Efficiency and Energy Saving projects. Following Weber[18] and Sorrell et al.[19], the term "barrier" can be seen as the sum of three components:

- An objective obstacle (e.g., persons, attitudes, or regulations)
- A subject impaired (e.g., consumes, managers, or politicians)
- An action impaired (e.g., need for more efficient equipment or lower energy taxation)

The importance of each element varies significantly from developed to developing countries, nevertheless, following a bottom-up approach suggested by Daniel Hill[20], the barriers rising from these three elements can be classified into five main interrelated levels.

I. Market Level

In the context of energy efficiency, the term market barrier refers to any market-related factor that prevents energy efficiency improvements. The energy-efficiency literature described several market barriers that prevent increasing the levels of energy efficiency. Moreover, energy policy analysts, commonly identify a subset of market barriers called market failures. This separation follows the neoclassical view of economics, identifying only these failures as drivers for the inefficient allocation of resources. Hence, according to this, government intervention is justified because it can deliver the much sought-after Pareto efficiency, establishing a situation in which no rearrangement of those resources can make someone better off without making another worse off. These failures include:

- Imperfect competition

It occurs when there are problems in the market for a product or a service and prices may be inefficient due to limited suppliers (monopoly or oligopoly) or

[18] Lukas Weber, 'Some Reflections on Barriers to the Efficient Use of Energy', *Energy Policy* 25, no. 10 (August 1997): 833–35.

[19] Steve Sorrell, Alexandra Mallett, and Sheridan Nye, 'Barriers to Industrial Energy Efficiency: A Literature Review', *UNIDO*, Together for a sustainable future, 10 (2011): 99.

[20] Daniel R. Hill, 'Energy Efficiency Financing: A Review of Risks and Uncertainties' (European Commission, August 2019).

problems related to the entrance barriers (high upfront investments, patents protecting technological improvements, etc.)

- Split incentives

This failure occurs when participants in an economic trade have different goals or incentives. This can lead to fewer investments in energy efficiency than could be achieved if the participants had the same goals. A classic example in energy efficiency literature is the ‘landlord-tenant problem’, where the landlord provides the tenant with appliances, but the tenant is responsible for paying the energy bills. In this case, landlords and tenants face different goals: the landlord typically wants to minimize the capital cost of the appliance (with little regard to energy efficiency), and the tenant wants to maximize the energy efficiency of the appliance to save on energy costs.

- Asymmetric and inadequate information

Information has a fundamental public good attribute, once created it can be used without limit with little or no additional cost. The underinvestment in energy efficiency and saving is heavily related to the final user knowledge. Having asymmetric, limited, or inaccurate information generates investors that are unable to perfectly observe the effectiveness and the benefits related to EE and ES, causing adverse selection[21]. Furthermore, when technology providers have private information that are unable to reliably communicate[22], it might kick-off the negative loop by which the underinvestment in the secondary market, drives the underinvestment in the primary market, the one investing in R&D looking for new technologies or improvements. This could impact the pace of innovation, making more complex the achievement of the environmental goals abovementioned.

The lack of relevant and reliable information can lead to a significant underestimation of the energy efficiency and energy savings that these projects can generate. Providing simple and reliable information is the most important element to allow for more convenient decisions. Governments and public agencies, having the power and trust of citizens, have the responsibility and power to activate the positive information cycle, which will then benefit the entire sector. In addition, another important element that could help overcome the barrier is the *learning by using* mechanism. For example, the adoption of new technologies by a neighbour creates a positive externality for others by providing “trusted” information about the existence, the characteristics, and the success of

[21] Karen Palmer et al., ‘Assessing the Energy-Efficiency Information Gap: Results from a Survey of Home Energy Auditors’, *Resources for the Future* 11, no. 42 (October 2011): 44.

[22] George A. Akerlof, ‘The Market for “Lemons”: Quality Uncertainty and the Market Mechanism’, August 1970.

this new technology. All fundamental elements for the development of the energy efficiency and saving industry.

The other way to look at the information problems refers to the inattentiveness, or difficult usage of already available information, affecting the investors and buyers. This problem is very much related to the following analysed behavioural biases.

- Environment externalities

In economy, an externality is a cost or benefit that is forced on a third party who did not agree to incur on it. The overall cost and benefit of a society are defined as the sum of the monetary value of benefits and costs to all parties involved, a concept that was first developed by the economist Arthur Pigou in the 1920s. A negative externality arises when a third party incur a cost, the easiest example is the air pollution caused by motor vehicles. The harmful impact is burden by all populations without having chosen to and it is not compensated for by either the producers or users of motorized transport.

All the environmental policies are designed to deal with these problems arising from the use of fossil fuels and other non-renewable sources, either by internalizing the cost, persuading the producer to make better decisions or by imposing external limits, decided by the policymaker to be fair. If all of them are not fully regulated – for political or economic reasons – the investments in R&D and the implementation of new technologies or processes, needed to reduce their environmental impact, won't be enough. The evidence for environmental negative externalities from fossil fuels emissions is strong, even if estimating the precise magnitude of them is challenging[23].

A positive externality occurs when a firm, an individual or an investment decision generates a benefit for others, non-compensating the issuer. The positive externalities associated with EEP, ESP and renewable investments, are usually not priced in the cost of the investment, increasing the disadvantages with other energy decisions. The National Renewable Energy Laboratory in 2006 noted in their survey of American Electricity Markets that low-carbon technologies were not adequately valued for at least six of the positive externalities that they provided, including risk reduction, environmental performance, investment profitability, reduced resource use, improved public image, and economic spill over effects[24].

[23] Anthony D. Owen, 'Environmental Externalities, Market Distortions and the Economics of Renewable Energy Technologies', *International Association for Energy Economics* 25, no. 3 (2004): 127–56.

[24] J. E. Pater, 'Framework for Evaluating the Total Value Proposition of Clean Energy Technologies', Technical (National Renewable Energy Laboratory, February 2006).

- Low priority for energy issues

Since energy price is not as high as it should be, taking into consideration the negative externalities generated by the energy production with fossil fuel, energy efficiency and energy savings are not a concern for most consumers and companies. Furthermore, if investing in EEP and ESP comes at a cost of forgoing other more cost-effective and priority decisions, most final users, having also limited access to funds, will lead their attention to short term day-to-day needs. From the perspective of small and medium enterprises, their main concerns regard product and service quality, marketing, competitor's actions, occupational health, and safety, to name a few – and not the problems and costs related to energy. It is even more evident in sectors where energy costs represent only a small fraction of total production costs.

II. Economic Level

As for every economic problem, the core regards the balance of costs and benefits. In this case is far more complex for investors, both for firms and households, having to compare high upfront costs with future expected benefits, which are sensitive to several factors. The main barriers are:

- Investment requirements and interest rates

The business model of using energy savings or efficiency revenue stream as the guarantee is a concept relatively foreign to banks. Palmer et al. in 2012[25] has shown how lenders may not offer loans for EEP or ESP because of credit risk, high transaction costs and asymmetric information, even if expected future savings are higher than the initial costs, granting the solvability of the borrower.

These types of projects require high-quality energy equipment that tend to have high upfront costs, with low ongoing maintenance, and that generates a low but relatively steady revenue stream. This means that customers do not see the financial benefits immediately, making access to long-term viable financing a necessity. Hence, without long-term sources, investment decisions are skewed either toward conventional technologies, which can be realized with short-term financing and lower up-front investment or toward inactivity.

The problem is far more evident in developing countries due to restrictions or unavailability of long-term lending solutions.

[25] Palmer et al., 'Assessing the Energy-Efficiency Information Gap: Results from a Survey of Home Energy Auditors'.

The interest rate charged to these types of loans represents a fundamental element in the project valuation since its fluctuation can lead to uncertainty in the cost of capital, making it even more complex. Investments in EEP and ESP, requiring long-term financing solutions, are very sensitive to any movement of the interest rates. By looking at Figure 7, we can spot how the 3-month Euribor rate today is drastically different compared to the early 2000s, being higher and more volatile.

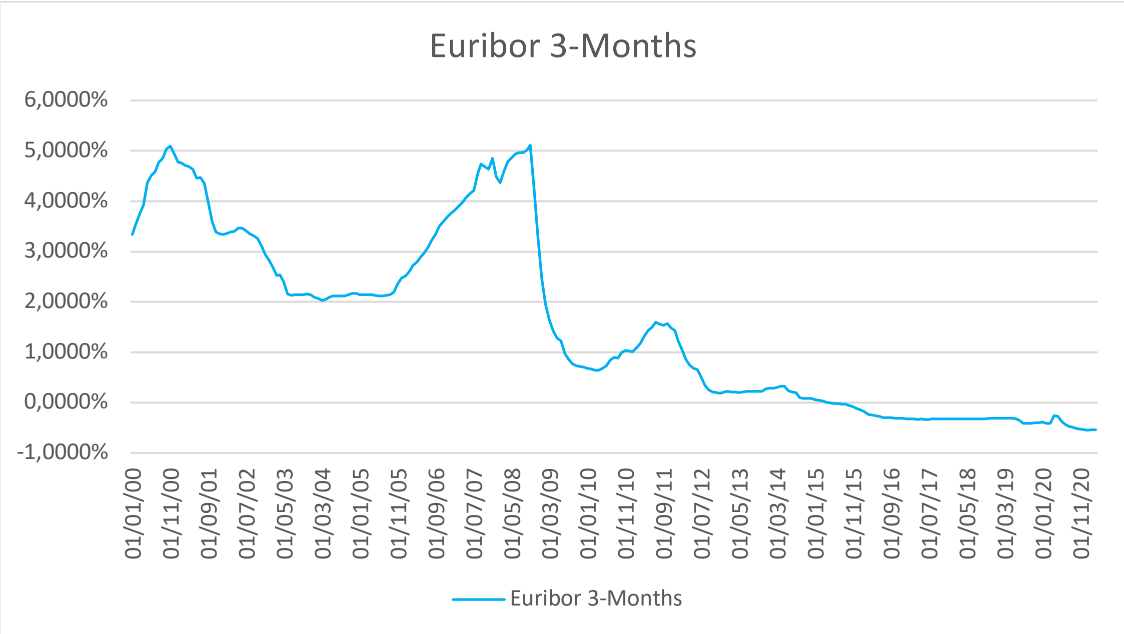

Figure 7: Euribor 3-months historical close in the Euro Area (% per Annum)

Even though a significant declining trend is observed over time, there still be short-term fluctuations. The leverage effect that debt provides could amplify the profitability of energy efficiency and saving investments if rates are lower than the internal rate of return (IRR), discussed later in the thesis, guaranteeing a positive project valuation. Forecasting interest rates is a complex procedure being linked to several economic indicators such as the state of the economy, the current and expected inflation, etc. For example, the current European Monetary Policy cannot guarantee the maintenance of this regime in the future hence, evaluating the project with fixed long-term interest rates rather than lower but floating rates is essential for EEP and ESP.

- Energy price volatility

Volatility in energy prices can play a significant role in future expected returns for EEP and ESP, changing the life cycle appraisal of the project and making the forecasted financial benefits unsteady. Such changes in energy costs may arise because of changes in fossil fuel reserves, competition for natural sources, weather problems, new technologies and political uncertainties[26]. The last study on energy prices and their impact on industry and households done by EUROSTAT[27], have shown a slow but steady increase in energy prices in the last twelve years in EU – Figure 8. If energy prices continue to increase overtime, the expected benefits from energy efficiency or saving will be higher, providing more value to EEP and ESP and so incentivizing the investments.

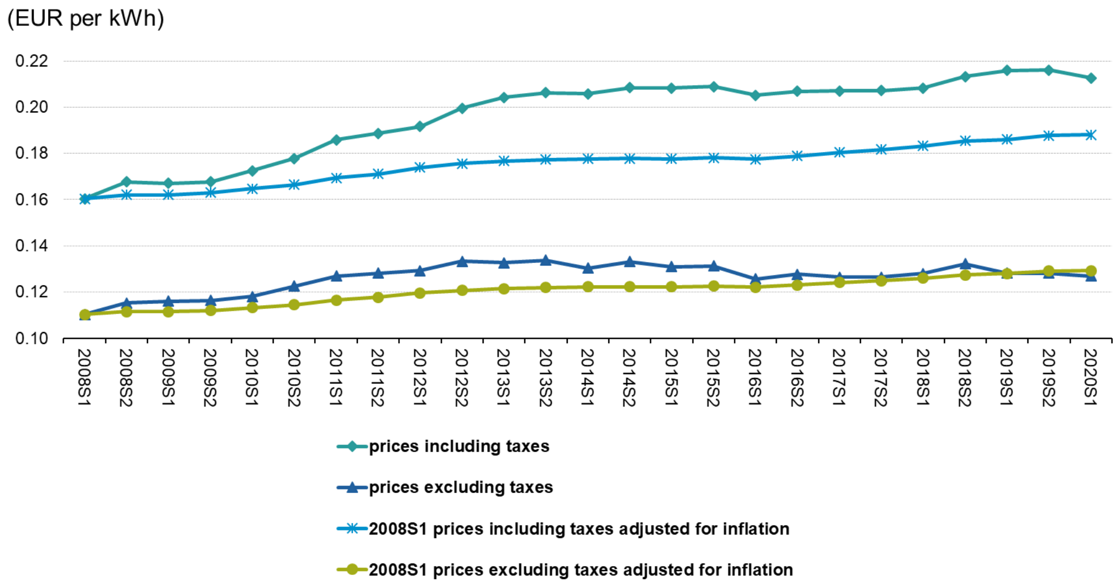

Figure 8: Development of electricity prices for household consumers, EU-27, 2008-2020 – EUROSTAT

- Fiscal instruments

They can represent both a barrier and a propellant to the achievement of environmental goals and for the improvement of the level of investments in EEP and ESP. Fiscal instruments can be divided into two main categories: tax instruments and subsidies.

Taxes and excise duties on energy could have a direct and indirect impact on the energy final user. Direct because the cost of utilities is higher, indirect because a higher cost of energy for companies pushes the cost of goods and services upwards. Therefore, taxes and excise duties are important tools available to governments, capable of significantly impacting the perception of energy and influencing decisions on investments in EEP or ESP. On the other hand, lower energy taxation due to a period of expansionary fiscal policy could further increase the inattentiveness of consumers, lowering the interest in EEP and ESP,

[26] Donald Stevens et al., 'Risks and Uncertainties Associated with Residential Energy Efficiency Investments', *Real Estate Finance* 35, no. 4 (April 2019): 14.

[27] Koen Rademaekers et al., 'Study on Energy Prices, Costs and Their Impact on Industry and Households' (European Union, October 2020).

widening the investment gap, making the achievement of global energy efficiency goals even harder than it already is.

For subsidies, accorded directly or through the tax system, households or industry investment decisions could be driven to choose specific inputs or goods. In contrast with taxes, they provide incentives by decreasing the price of a product, improving their ability to attract attention from investors. For example, if subsidies are granted to gasoline cars, making them cheaper than Hybrid or Full Electric, consumers will prefer to buy them rather than the latter. On the other hand, if those subsidies are higher for Hybrid or Electric cars, consumers will prefer to invest in them, generating a benefit for the whole system.

- Rebound Effect

The term "rebound effect" describes a wide range of problems that threaten the expected energy efficiency, saving or energy creation. Focusing on Energy Saving, studies regarding the rebound effect usually measures its impact comparing the potential energy saving (PES) with the actual energy saved (AES):

$$Rebound = \frac{(PES - AES)}{PES}$$

The numerator (PES-AES) could be split into two sub-effects:

- **Direct Rebound Effect (DRE),** which is the efficiency elasticity of energy, measuring how an improvement in energy efficiency may lead to an increase of the overall consumption, partially cancelling out the advantage.
- **Indirect Rebound Effect (IRE),** which describes the possible relation between the savings generated and the increased consumption of other goods and services. This element is very volatile due to consumer heterogeneity and expenditure preference.

Regarding DRE, Manuel Frondel and Colin Vance in 2018[28] have analysed the individual mobility by car in Germany, founding quite robust valuations for its impact, ranging between 40 and 70% (these percentages represent the loss in potential energy saved). Unfortunately, only a few studies have tried to quantify the IRE or both effects together, due to the complexity of the analysis and the necessity of detailed information on consumption and expenditure habits. Mona Chitnis et al.[29] in 2014 have tried to estimate the magnitude of both for different

[28] Manuel Frondel and Colin Vance, 'Re-Identifying the Rebound: What About Asymmetry?', *The Energy Journal* 34, no. 4 (October 2013).

[29] Mona Chitnis et al., 'Who Rebounds Most? Estimating Direct and Indirect Rebound Effects for Different UK Socioeconomic Groups', *Ecological Economics* 106 (October 2014): 12–32.

UK socioeconomic groups. They have achieved its estimation defining two connected models, namely:

- **The Expenditure Model**, used to quantify the elasticity of twelve different categories of goods and services for five different income groups; needed to limit the heterogeneity bias.
- **A Rebound Model**, measuring the net result of three different effects, the engineering, the embodied and the income.

Since GHG-intensive necessities form a larger share of total expenditure for low-income, they account for a larger proportion of total re-spending of savings. This is a reversal for high-income households, where the rebound effect is mostly caused by embodied or indirect emissions which are coming from the life cycle of the product or service. This pattern suggests that total GHG emissions may not increase at the same rate as incomes increase, but income redistribution may increase aggregate emissions. Since necessities are comparatively GHG intensive, low-income households have disproportionately high emissions relative to expenditure.

The study finds that rebound effects, in GHG terms, are modest (0–32%) for measures affecting domestic energy use, larger (25–65%) for measures affecting vehicle fuel use and very large (66–106%) for measures that reduce food waste. Their analysis also implemented in the computation the impact of capital cost and the benefits of subsidies, previously ignored. Results were quite significant, in fact when the full capital cost lies to households, the cost-saving over a given period is reduced and so are the rebound effects. On the other hand, when the advantage of subsidies is incorporated, reducing the impact on the household expenses, the savings increase as well as the rebound. These are important implications for the policymaker, in fact not taking into consideration the impact of the rebound effect could lead to an overestimation of energy and emission saving leading to missing the targets. Measures that are subsidised or affect highly taxed energy commodities may be less effective in reducing aggregate emissions. These findings highlight the importance of allowing for rebound effects within policy appraisals, as well as reinforcing the case for economy-wide carbon pricing.

- **Option to Wait and Irreversibility**

Daan P. Van Soest and Erwin H. Bulte in 2001[30] stated that might be rational to underinvest or postpone the decision on EEP or ESP, even under positive Net Present Value, since the future technological progress is uncertain, and these

[30] Daan P. Van Soest and Erdwin H. Bulte, 'Does the Energy-Efficiency Paradox Exist? Technological Progress and Uncertainty', *Environmental and Resource Economics* 18 (2001): 12.

types of investments are (at least partly) irreversible. The first element arising from their assumption is that postponing investment in EEP or ESP, even if might be costly in the short-term, since the energy savings that the project could have generated are foregone, enables the firms to benefit from an even better technology in the future that could repay the “losses”. This concept could also be declined into the Option-to-Wait (OtW), configuring the situation in which the investors will wait until the economic and financial prospect of the investment meets its necessity and targets. Furthermore, if we assume a higher rate of technological innovation, firms will be more prone to postpone their investment and wait for the arrival of even better technologies rather than invest today into EEP and ESP.
The second is irreversibility, characteristic that works with the OtW and regards the inability for the investor to be able to fully recover the investment amount if he decided to sell the EEP or ESP installed solution.

III. Technological Level

Technology risk is due to the feasibility, advancement, and technical effect of energy-saving technology. It mainly includes three aspects:

- Feasibility Risk and Technology Mismatch

Before the implementation of the project, ESCo will develop a variety of technical solutions, but it is difficult to ensure whether the energy-saving technology can achieve its expected goal or economic indicators. Installations of suboptimal products due to lack of technological know-how or the unavailability of resources could impact the return of the investment. The only solution that could be implemented is the adoption of only advanced and mature technology, choosing the equipment with reliable records and trusted performance.

- Equipment Lifetime

Uncertainty in the lifespan of installed products could have an impact on the depreciation and sustainable performance plan, driving even the possibility for a future product replacement if necessary.

But the more complex technological barrier that threats the development of new technologies regards:

- R&D Information Spillover

Innovation is fundamental for reducing energy intensity and carbon emissions without reducing the global economic growth. Unfortunately, the International Energy Agency in the Energy Efficiency 2019 report highlights that the rate at which technologies and processes are innovating is slowing down due to structural factors that are limiting the power of these technological gains. This slow-down in improvement performances has a double effect influencing the profitability of future investments in EEP and ESP, impacting the survival of businesses, while reducing the value of the option-to-wait, possibly pushing up investments.

Talking about R&D, it tends to be concentrated only in some developed countries[31] and transboundary spillover of technological innovation influences the energy efficiency and energy saving of others. This spillover may play an important role if managed since a broader distribution of new technologies and better cooperation in R&D can make energy efficiency and saving improvement easier and cheaper[32]. While there is little evidence for R&D spillover in energy efficiency and saving, there is substantial evidence of the impact in other industries. It is important to underlying that, due to possible unwilling spillover, firms tend to invest little effort in research risking that their knowledge might benefit not only them but other firms as well. This problem is far more evident in the early stages when they cannot capture the knowledge perfectly and tight it through intellectual property protection[33]. Thus, knowledge spillovers may lead to underinvestment in the development of innovations, and in the case of energy-efficient innovations, such underinvestment can increase the energy-efficiency gap with negative impacts on the overall economy. It is thus important to examine the issue of knowledge spillovers of clean energy industries and their relations to economic and competitiveness impacts of climate policies.

IV. Institutional and Regulatory Level

Institutional and regulatory risks are associated with the possible negative outcomes that changes in government policies might produce. For example, when are set more constraint standards, the existing properties are downgraded and so exposed to a value reduction. Furthermore, climate policies and regulations changes, although not directed at EEP or ESP, could be part of a larger energy policy plan that indirectly affects investment trends[34]. Regulation in the energy

[31] Valentina Bosetti et al., 'International Energy R&D Spillovers and the Economics of Greenhouse Gas Atmospheric Stabilization', *Energy Economics* 30, no. 6 (November 2008).

[32] Jonas Grafström, 'International Knowledge Spillovers in the Wind Power Industry: Evidence from the European Union', *Economics of Innovation and New Technology* 27, no. 3 (April 2018): 205–24.

[33] William Nordhaus, 'Designing a Friendly Space for Technological Change to Slow Global Warming', *Energy Economics* 33, no. 4 (July 2011): 665–73.

[34] Stevens et al., 'Risks and Uncertainties Associated with Residential Energy Efficiency Investments'.

efficiency and saving field has been trending towards harsher policies to meet the international climate goals. Notably, these regulations cannot be influenced by individual investors and landlords thus, they must consider and classify them as general and unavoidable risks that must be included in every project valuation. Langlois-Bertrand et al. in 2015 have proposed a comprehensive framework for capturing the barriers at this level, identifying three main categories[35].

- Political obstruction

The actions done by government leaders and policymakers can prevent the set-up or the implementation of energy efficiency and saving measures. Their role can be affected by two sources of obstruction; the first one, at the supranational level, is the veto obstruction, for instance, a higher number of veto players may increase the probability for incremental changes rather than major impacting changes. The second one, observable at both supranational and national levels is the corruption, lack of political stability and effectiveness. This environment prevents the implementation of energy efficiency programs, resulting in a higher risk for investors and the consequent adjustment of the discount rate[36].

- Conflicting guidelines

At the national level, conflicting interests and guidelines can be seen between different government departments, for example, the ministry of economic growth can have a different view from another dealing with the environment. At the supranational level, diverging actions are found between different agencies, in fact by having partial authority over energy efficiency they might in the long run generates problems, slowing down the pace of transaction.

- Lack of coordination

Policy coordination failures and impediments might lead to the existence of multiple non-harmonized standards internationally as well as contradictory regulations between nations that could cause a non-incentivizing structure, obstructing EE measures. The European Union has its own set of Energy Directives that must be transposed at the national level by each government. The timing and method required to implement those standards differ, generating a lack of coordination and making complex for companies to work easily throughout Europe. These regulations and institutional barriers lead to the so-called "Longevity Risk" which makes investors worried about the mismatch between the long-term nature of EEP and ESP investment and the relatively short time structure of EE regulations.

[35] Simon Langlois-Bertrand et al., 'Political-Institutional Barriers to Energy Efficiency', *Energy Strategy Reviews* 8 (July 2015): 30–38.

[36] Langlois-Bertrand et al.

V. Behavioural and Cultural Level

Under a pure psychological analysis of the gap, Dütschke et al.[37] has shown how voluntary actions by individuals, aimed to reduce their environmental impacts by investing in EEP or ESP, may let them feel to have "done their job". The consequence is an increasing probability that they will spend additional time and money on more energy-intensive goods and activities, reducing the overall benefit and providing support to the rebound theory.

Nevertheless, based on the standard neoclassical economic theory, the abovementioned barriers are the main explanation for the underinvestment in EEP and ESP. From this point of view, decision-makers (DMs) are rational and will tend to maximize their expected utility, perfectly evaluating the trade-off between higher initial investment and low and long energy saving. However, the rational framework has been questioned in several empirical studies, giving the space for a new economic field, the behavioural economy, which proposes a different interpretation, identifying a multitude of biases that characterized DMs. The founder of the field of behavioural economics, Daniel Kahneman, has demonstrated that individuals do not act as logical beings, instead, they tend to make decisions under the influence of "cognitive biases". Taking a step back, Kahneman has developed a model that explains how individuals' thinking works, identifying two systems[38]:

- **System One** enables people to make fast decisions and come to conclusions. It operates automatically and quickly, with little voluntary control. This system controls much of our day-to-day behaviour and habits.
- **System Two** allocates our limited mental capacity (or attention) to slow, effortful mental activities, and can carefully consider information, make long-term decisions, and concentrate on complex activities. However, as it requires more work, and therefore more effort and energy, it will defer to system one whenever possible.

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[37] Elisabeth Dütschke et al., 'Moral Licensing—Another Source of Rebound?', *Frontiers in Energy Research* 6, no. 38 (May 2018): 10.

[38] Interreg Europe, 'Behaviour Change for Energy Efficiency: A Policy Brief from the Policy Learning Platform on Low-Carbon Economy' (European Union - European Regional Development Fund, December 2018).

The influence of these two systems in people's decisions is strong, giving the space to 'cognitive shortcuts' through which our brains can solve problems based upon previous experiences and readily available knowledge. This thought structure drives errors in decisions, called "cognitive biases", which are:

- Conservatism bias
- Present bias
- Status quo bias
- Substitution
- Anchoring
- Blind-spot bias
- Diversification bias

Concerning the possible explanations for the underinvestment in EEP and ESP, the main behavioural biases are:

- **Time preference**

Liebermann and Ungar[39] in 2002 found that patient people select lower discount rates and tend to invest in more expensive energy-efficient projects benefiting from the complexity and long-term view required for EEP and ESP. On the other hand, impatient people tend to select a higher discount rate for the investment valuation and prefer cheaper and less energy-efficient solutions. Newell and Siikamäki[40] in 2015, further analysing the relationship between the discount rate and time preference, have found that impatient individuals not only select a higher discount rate but also gives a lower value to the future energy cost savings coming from an EEP or ESP investment, reducing even further the project value.

- **Short-sightedness (Myopia)**

Being closely related to the present bias, the investors' myopic behaviour demonstrates that the underinvestment could be explained by the tendency to overweight the importance of short-term results with absolutely no consideration on how a certain decision may affect them in the future. Myopic investors are unable to visualize the long-term effects of their current actions, an element that is fundamental for the investment decision in EEP and ESP.

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[39] Yehoshua Liebermann and Meyer Ungar, 'Efficiency of Consumer Intertemporal Choice under Life Cycle Cost Conditions', *Journal of Economic Psychology* 23, no. 6 (December 2002): 729–48.
[40] Richard G. Newell and Joha V. Siikamaki, 'Individual Time Preferences and Energy Efficiency', *NBER WORKING PAPER SERIES*, no. 20969 (February 2015): 22.

- **Loss aversion and non-linear probability**

Individuals strongly prefer gains over losses, overweighting the latter even for the same size. This infers that framing a decision to invest in EEP or ESP by focusing on the possible losses rather than the future gains, can reverse preferences[41]. The Prospect Theory of Kahneman and Tversky, developed in 1979, highlights also how people tend to overweight small probabilities and underweight moderate and large, using a non-linear probability weighting.

- **Rational inattention**

For Gerarden et al.[42], investors tend to have limited attention, a characteristic that may contribute to systematically underweight certain information, specifically those that are less noticeable. Furthermore, investors are less attentive to operating/ongoing costs compared with initial costs, leading to lower investment levels rather than optimizing the maintenance costs. Cohen et al. in 2017[43] researched if this inattention might also impact energy conservation. What they have found is that consumers underestimate future energy savings and therefore increase energy use. A correct valuation of EEP or ESP requires time and effort which may not be justified when investors have strong preferences regarding other product attributes like aesthetics.

Regarding cultural barriers, Benjamin K. Sovacool[44] in 2009 has interviewed 82 institutions, ranging from utility to non-profit companies, looking for cultural impediments to EEP and ESP. His article shows how there is a real disconnection between people and entities on how electricity is made and how it becomes available to them. The research has categorized these cultural barriers into two main groups:

- **Public apathy and misunderstanding**

Electricity is a commodity, but not the classic one. It is characterized by a unique disjuncture between the creation point and the consumption point plus, the physical and mental invisibility of it generates serious impediments to the adoption of clean power technologies. Once electricity becomes part of people's lives, we

[41] Cristina Cattaneo, 'Internal and External Barriers to Energy Efficiency: Which Role for Policy Interventions?', *Energy Efficiency* 12, no. 5 (June 2019): 1293–1311.

[42] Todd D. Gerarden, Richard G. Newell, and Robert N. Stavins, 'Assessing the Energy-Efficiency Gap', *Journal of Economic Literature* 55, no. 4 (2017): 46.

[43] Francois Cohen, Matthieu Glachant, and Magnus Söderberg, 'Consumer Myopia, Imperfect Competition and the Energy Efficiency Gap: Evidence from the UK Refrigerator Market' (London School of Economics and Political Science, April 2017).

[44] Benjamin K. Sovacool, 'The Cultural Barriers to Renewable Energy and Energy Efficiency in the United States', *Technology in Society* 31, no. 4 (November 2009).

hardly think about it and how to save it. The benefits coming from EEP, or ESP are often meaningless to people since such benefits are not directly observable, and when they are, their price tends to be bundled with other purchases, making things even more complex. See for example a better-insulated home, the value of the energy efficiency solution has its cost sunk in the base price of the house, becoming mostly invisible to the owner.

- Conceptions of consumption and abundance

Sovacool also stated: "*…consumers believe they are entitled to energy-intensive standards of living, and utilities believe it is their duty to provide it at the lowest cost possible*". The path at which the economy has evolved in the last couple of decades has been incredible, the quality of life in many developed countries has improved significantly and the focus of people drifted toward uncontrolled material progress, looking for a larger house, new appliances and all the possible high-tech solutions. For the historian Martin M. Velosi, the availability in the abundance of cheap and reliable energy, the change in the economic structure going from labour-intensive to capital-intensive operations and the possibility for countries to rely also on foreign energy sources, are the causes of such drift. For example, Americans believe they have the right to cheap and abundant electricity thanks to their economic progress, completely ignoring how it is created, made accessible and the impact it has on the environment.

Cultural obstacles to EEP and ESP are a reminder that decisions about these types of investments are about more than just economic or technical feasibility. They possess a significant political, social, economic, and cultural role, and the reasons for their growth or decline always depend on the two aspects.
Unfortunately, the cultural dimension suggests that policymakers continue to promote alternative technologies in the wrong way. Hence, instead of creating incentives to further increase the efficiency and technical capacity of such systems, policymakers should shift at least part of their effort away from economical and technical aspects to focus on efforts to increase public understanding of energy systems and challenge deeply entrenched values. Until these remaining cultural barriers are not targeted in the same way that technical impediments are, the goals to reach carbon neutrality using EEP and ESP as main drivers will remain unfulfilled.

CHAPTER 3: PROJECT VALUATION AND FINANCING SOLUTIONS FOR ESCos

I. Energy Savings Companies (ESCos)

In early 2000, there has been an increased interest in energy provision services, mainly determined by electricity and gas liberalization in the EU. Besides the offering of lower gas and electricity prices to customers, the most innovative changes in the utility market were the understanding that customers' retention and growth cannot be achieved without offering additional services with energy and gas supply[45]. These services include advice, energy audits, maintenance and operation, property management, and equipment supply.
This market requirement expansion had attracted other actors, such as equipment and system suppliers, installation, and engineering companies, which aims to expand their field of competence. Companies able to provide energy services to final energy users are known as Energy Service Provider Companies (ESPCs) but, the ones that are structured to deliver energy efficiency and saving projects financed primarily with the energy saved are called Energy Saving Companies (ESCos). More specifically, they differ from the traditional energy consultants or equipment suppliers by three characteristics[46]:

- They guarantee energy savings via the stipulation of a contract.
- Their remuneration is directly tied to the energy savings accomplished, bearing the risk of not achieving the targets.
- They can finance or assist in arranging financing requests for the investment in energy saving projects, providing savings guarantee over 7 to 10 years[47].

Hence, ESCos accept some degree of risk for the achievement of improved energy efficiency in a user's facility and have their payment for the services delivered based (either in whole or at least in part) on the achievement of those energy efficiency improvements. Their projects are wide-ranging, which means that EEP and ESP can be equipped with different solutions to achieve a higher level of efficiency, such as high-efficiency lighting, high-efficiency heating and air

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[45] Paolo Bertoldi et al., 'How Are EU ESCOs Behaving and How to Create a Real ESCO Market?' (European Commission, 2003).

[46] DG JRC, Directorate C - Energy, Transport and Climate, 'Energy Service Companies (ESCos)', European Commission, October 2015.

[47] Jon Wellinghoff et al., 'ESCos, ESPs & Small Business: A Model for Efficiency', *Deregulation of the Utility Industry and Role of Energy Services Companies (ESCOs)*, n.d., 12.

conditioning, efficient motors and variable speed drives, centralized energy management systems, etc. Usually, the comprehensive energy efficiency solutions implemented require a sizeable initial capital investment and a moderately low ongoing maintenance. The customer's debt payments are tied to the energy savings offered under the project so that the customer pays for the capital improvement with the money that comes out of the difference between pre-installation and post-installation energy use and other costs. It is of vital importance for ESCos to correctly estimate the amount of energy that will save and that any adjustment must come from a valuable Measurement & Verification procedure that, analysing data and all the viable information, can re-quantify the savings target.

The value of ESCos in unlocking the energy saving potential in the market is recognized worldwide and more specifically in Europe by the Energy Efficiency Directive (2012/27/EU; EED). At Article 18 and 19, the EED sets explicit requirements to promote the market of energy services and the access for small and medium enterprises, suggesting measures to promote energy efficiency. Being a directive, these articles must be transposed into national law and up to now, the EED has been implemented to at least some level in all Member States.
The ESCo market in the European Union has been on a solid rise for the last decades, and the growth and maturity have continued even recently.
Following the review run by the European Commission in 2019, the market has seen an overall development, showing nevertheless differences between states. Table 1 shows the speed and direction of development in the national ESCo market. The differences must be researched in the field of knowledge, awareness, energy market structure and policy framework.

Table 1: Development speed of ESCos market in Europe[48]

Declining	Stagnating	Growing	Shooting
Sweden	Austria, the Czech Republic, Bulgaria, Estonia, and Greece	Finland, France, Germany, Netherland, Ireland, Poland, Portugal, Romania, Hungary, Spain, Slovakia, and UK	Belgium, Denmark, Italy, Slovenia, and Croatia

[48] B. Boza-Kiss, A. Toleikyté, and P. Bertoldi, 'Energy Service Market in the EU: Status Review and Recommendations 2019.' (European Commission, 2019).

Even if the drivers behind the development of the ESCo market have some common features, the combination, the magnitude, and the timing could vary significantly. The EU ESCo markets can be differentiated into 3 types[49].

- **Demand-driven markets** are the more developed. The ESCo concept is known, potential clients are aware and look for them when they want to invest in ESP or EEP. They represent a fundamental part of the energy efficiency market, characterized by:
  - Peer-trusted examples, in particular projects done by municipalities.
  - Public ESCos or Super ESCos
  - Facilitators, which are entities promoting events and trusted information
  - Quality labels and insurance systems
  - High-quality financing products.
- **Supply-driven markets** are less developed and are typically pushed ahead via the activities of ESCos, association or other facilitators. Unfortunately, these markets lack in demand due to service costs and unavailability of financing solutions which increase even further the chance of failure for yet not very profitable investments. Reliance between actors is not developed, and even a failed project can have a drastic effect on the market. The most essential need for the development of this market is increasing trust and awareness between actors, which might lead to an increase in demand. Divers for the market improvement are:
  - Receptive and supportive policy framework for energy efficiency
  - Successful example and demonstration projects
  - ESCo intervention and the implementation of facilitators
  - Grants for feasible studies and audits on EEP and ESP valuations
- Lastly, **policy-driven markets** are characterized by the direct or indirect policymaker support to ESCos activity, often combined with one of the above models. The main development drivers should be:
  - Obligation to renovate buildings
  - Grants or subsidies
  - More reliable information
  - Energy Efficiency Obligations Schemes
  - Procurement framework

[49] Boza-Kiss, Toleikyté, and Bertoldi.

Another important entity in the energy markets is the previously mentioned Super ESCos. They are also referred to as “integrated organizations”, which can contract complex projects with public agencies directly and subcontracting the projects to smaller, private suppliers on a competitive and technical basis. Usually, they are created to serve the public sector while supporting the development of the private ESCos market, managing complex projects, driving down transaction and development costs through standardization of operations, facilitating project assessment and financing having more capital available. The public sector, differently from the private, is characterized by three types of barriers: awareness, budgeting, and contracting. Super ESCos must dedicate part of their balance to public awareness through specific marketing campaigns targeting municipalities and public companies. Once done that, the probability that they will scrutinize their budgets and may find little capital reserved for ‘optional’ energy efficiency improvements could increase. Furthermore, super ESCos can help to develop a budget providing incentives or financing tailored for the project. In the end, by providing standardized contracts, ESCos will assess the lack of procurement or understanding of EPC and technical knowledge that characterize smaller public entities. Figure 9 describes visually how Super ESCos work.

Figure 9: Super ESCos - IEA

II. ESCos Business Model: Energy Performance Contract and Alternative Solutions

All ESCos provide a comprehensive technical service, focusing on reducing facility energy usage and costs through a broad array of strategies that involve end-use efficiency, on-site energy efficiency and energy generation technologies. Most agreements between investors and ESCos are underpinned by the Energy Performance Contracts (EPCs). In Europe, according to the EED, an EPC is *"a contractual arrangement between the beneficiary and the provider of an energy efficiency improvement measure, where investments in that measure are paid for in relation to a contractually agreed level of energy efficiency improvement".* Following this definition, EPC projects not only focus on design and installation but also the importance of project financing and sustainability model. In their EPC business model, ESCos must rely on the stream of income from the cost savings to repay the project costs, receiving full payment for their activity only if the project achieves those targets. Hence, the final client, whether a person or a firm, have transferred the project technical, financial, and operational risks to the service provider. The European Commission also describe the EPC as a form of "creative financing" for capital improvement, allowing the financing of energy projects granted by cost reduction, more on the financial structure in the next chapter.

Compared with conventional Energy Efficiency Projects, this contractual agreement incentivizes the hosts, which will become the beneficiary, to improve its energy performance even if is lacking in funds. Figure 10 shows how it works visually[50].

[50] Bertoldi et al., 'How Are EU ESCOs Behaving and How to Create a Real ESCO Market?'

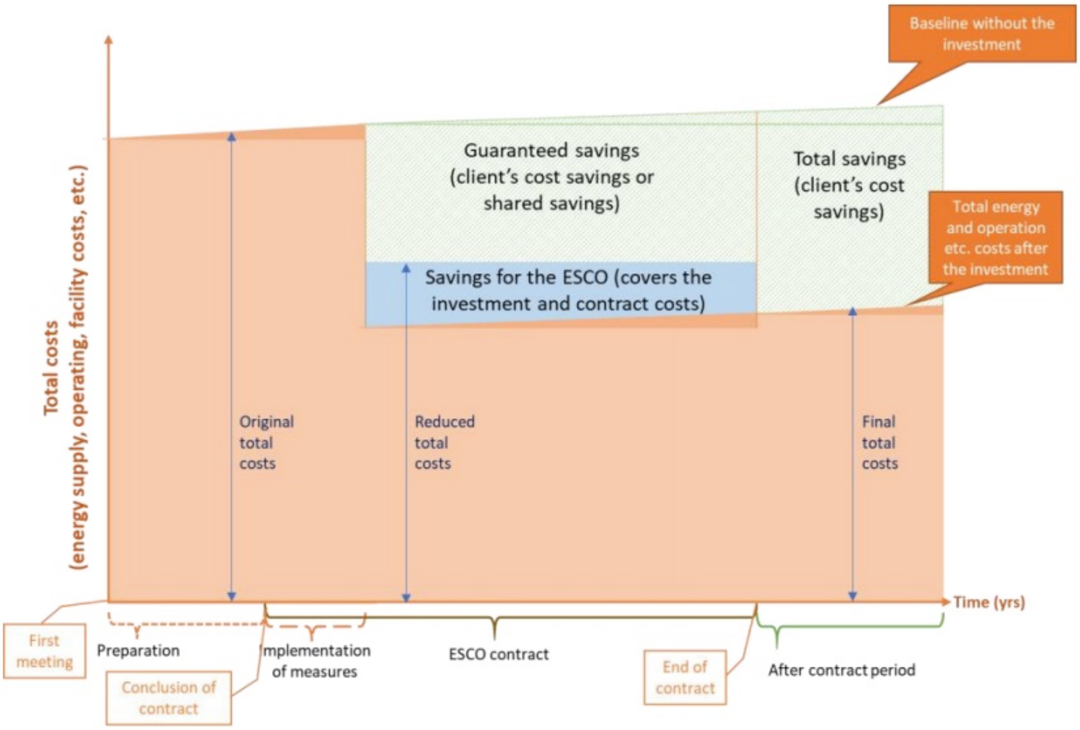

Figure 10: The costs and relative savings expected in an Energy Performance Contracting Scheme

Parties interested in doing and EPC knows that it is a long and complex process, which includes the following steps[51]:

- Pre-contracting activities

Before the sign of an EPC contract, parties need to analyse all the data and information available to determine the technical, economic, and financial feasibility of the project. Hence, the ESCo must study the current energy equipment, the real energy consumption and must propose the energy saving measures that are being implemented that could generate a defined energy saving. In doing that, it is important to use certified solutions, able to measure correctly without errors the correct energy consumption pre and post EEP and ESP implementation.

- Definition of Energy Performance Contract

The EPC establishes the rights and the responsibilities of both parties, and by signing the contract, the ESCo commits itself to obtain a determined level of energy saving through the application of specific technology solutions within a predetermined period.

[51] Alejandro Morell, 'Which Are the Steps to Follow for Developing an EPC Contract?', Leonardo Energy, April 2021.

- Implementation of energy saving measures

Once signed, the ESCO begins to develop the project, implementing all the agreed energy efficiency and saving measures, tuning the facility through several tests to fully optimize the system.

- Operation and Maintenance (O&M)

The ESCo contract define also who must run the maintenance activity following the operation protocol, needed to maintain the highest levels of energy performance. O&M that must be done during the entire life of the project.

- Measurement and Verification (M&V)

An M&V plan is highly recommended for the correct energy saved estimation. In the plan must be included all the variables, frequency and measurement equipment that will be used to assess the savings. Even though having a M&V plan is not compulsory, ESCos often include it to ensure a proper methodology for savings calculation. It represents a key phase for the EPC project since payments will be based on the M&V results.

- End of contract

At the end of the contract, the client receives the energy management back with all the benefits from the savings due to lower energy costs. The contract can be extended or amended when the client and ESCo believe it appropriate. Generally, all procedures can take from 5 to 10 years from the beginning to the end of the project.

This path and its characteristics might slightly vary depending on the type of EPC chosen between parties. The two most common types of EPCs are:

- Guaranteed Saving Model (GSM) - EPC

With GSM the ESCo guarantees to the client a certain level of energy savings if the proposed EEP or ESP is implemented. If the actual energy savings are lower than the guaranteed level, it would compensate such difference to the client. Within this contractual model, the financial sources are a matter of the investor that could choose between his internal funds or third-party financing (TPF), always having the possibility to be helped in the choice by the ESCo. If the financial system of a country is well-developed and can correctly assess the project business plan, having the possibility to retrieve financial sources from a TPF represents an overall advantage. The FIs are equipped with special funds for EEP and ESP, characterized by lower interest rates and capital requirements, allowing the investor to benefit from resources at low cost and having their repayment ensured through the cash flows that the project will generate over time. Being responsible to retrieve the financial resources needed to develop the entire project, the investor retains all the financial and business risk. The ESCo is only subject to the performance risk, which could be diversified or transferred. If the savings are not enough to cover the debt repayment, the ESCo, following the EPC, must cover the difference. On the other hand, if savings exceed the agreed level, the customers will pay a percentage to the ESCo. This contract fosters long-term growth of ESCo and financial industries that otherwise, newly established ESCos with no credit history and limited financial resources wouldn't be unable to invest or guarantee by themselves the project costs. Figures 11 and 12 illustrate the model and the risk distribution.

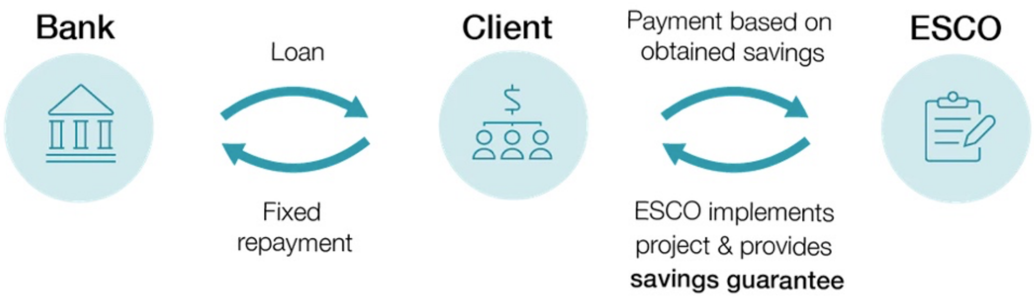

Figure 11: Guaranteed Savings Model

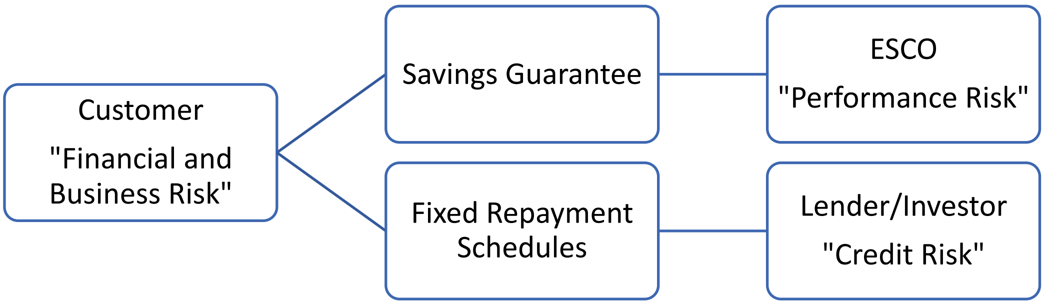

Figure 12: Guaranteed Savings Model - Dreessen 2003

- Shared Saving Model (SSM)

With SSM, the ESCo will not only provide the project development and implementation structure but also the financial sources needed for the implementation. In each Measurement and Verification (M&V) period after the project realization, the materialized energy savings will be shared between contracting parties upon an agreed percentage. There is no standard split as depends on the cost of the project, the length of the contract and the amount of risk retained by the ESCo, in this situation both the technical and the financial risk, making the EPC very valuable for the client. Unfortunately, such contractual arrangement may create leverage, increasing the capital requirements required to the ESCo if the financial sources are provided by third party financial institutions.

Since it could become too indebted and at some point, FIs may refuse to lend them, slowing down the market growth. Figures 13 and 14 shown the risk entitlement and SSM process.

Figure 13: Shared Savings Model

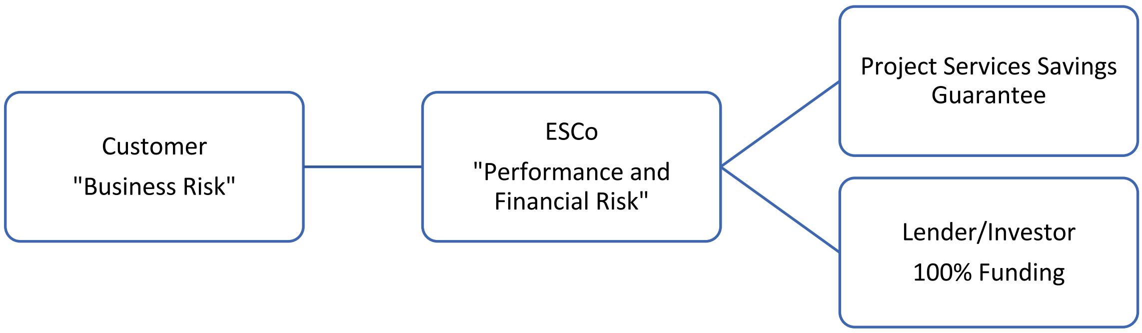

Figure 14: Shared Savings Model - Dreesser 2003

Several factors contribute to choosing one contract type over the other. Usually, GSM is more present in developed markets, with an established banking and policy structure. On the other hand, the SSM is more suited for developing countries in which the credit power of firms and individuals is not very strong, and the banking and policy structure is still developing their core elements rather than being able to focus on energy efficiency. ESCos with foreign capital could operate nimbly in these countries. Nevertheless, this differentiation is not very precise. Pan Lee et. al. in 2015 have run a survey of 137 ESCos in Hong Kong, finding that 46,2% of EPC were based on shared saving model while 38,5% used the guaranteed model, suggesting how not only there are differences between countries structures but also within each country there are differences in the usage.

There are other ways rather than GSM and SSM for structuring EPC, such as[52].

- Chauffage

It is a contract in which ESCo take over all the responsibility for the provision to the client of an agreed set of energy services like space heat, lighting etc. upon a fee calculated based on the existing bills or based on square meter measurement, with a percentage of saving (5-10%), guaranteeing an immediate advantage and result for the client. This contract can be seen as an extreme version of energy outsourcing and has usually a length of 20/30 years in which the ESCo has complete control of the structure and retain all the responsibility for the maintenance. Straightforwardly, the more efficiently and cheaply the ESCo can deliver the energy service, the greater its returns.

- BOOT (Build, Own, Operate, Transfer)

This model involves the ESCo in the design, building, financing, owning, and operating of the equipment for a defined period and then transferring this ownership across to the client. This model uses a Special Purpose Vehicle (SPV), created temporarily for a specific target. The client entering in such a contract makes a monthly payment to the SPV which includes capital and operating cost recovery for ESCo. Figure 15 shows the model composition.

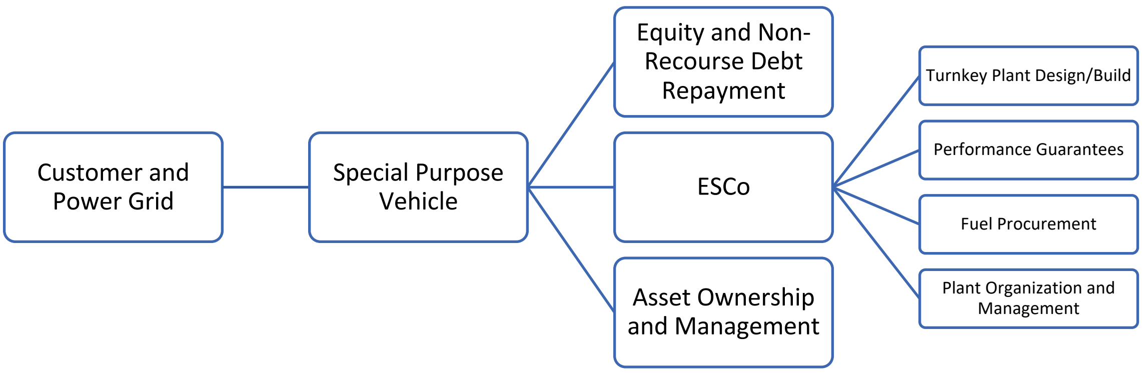

Figure 15: BOOT Model - Dreesser 2003

- Leasing

It could be seen as a financing solution but also as a contractual agreement that ESCo could suggest to the investor. In this model, the streams of savings must cover the lease payment and provide revenues for the ESCo. There are two different lease structures: capital and operating. The prior configures the lessee as the owner and it must depreciate the equipment, benefiting from potential tax cuts. For the operating leasing structure, the owner of the asset is the ESCo that

[52] Paolo Bertoldi and Silvia Rezessy, 'Energy Service Companies in Europe' (European Commission, 2005).

essentially rents it to the lessee for a fixed fee allowing it to set the equipment off its balance sheet. The latter shift the risk of O&M from the lessee to the lessor (the ESCo) but must compensate it since the ESCO will require higher payments.

III. Standard Project Valuations Methods

The EED 2012/27/EU has required industrial and other large enterprises to conduct energy audits every maximum of four years and imposes the achievement for utility companies to at least a level of energy efficiency of 1,5% per year, enhancing the attention given by management to the energy problem and its importance in the path for achieving the GHG reduction targets. Preliminary analysis like auditing represents the starting point for any energy efficiency or saving project valuation which includes also:

- Development of energy solutions, after having collected all the data, by comparing them with benchmarks, the ESCo can identify and suggest the better solutions available.
- Financing, following the previously mentioned possible contract solutions, in this step the project manager must decide the source of financing to use out of all the possible solutions which will be later discussed.
- Implementation, under the supervision of ESCo expertise, the project is realized and put in function.
- Operations and maintenance (O&M), every EEP and ESP require a high initial investment with low but steady maintenance supervision aimed to assure the correct functioning of the implemented system and the achievement of energy efficiency targets.

The predominant analysis that guides investment decisions in EEP and ESP are the common project investment valuation models:

- **Payback Period (PBP)**

There are two different types of Payback Period:

- o **Simple Payback Period (SPBP)**, which is the easiest and most used way to evaluate investment and compare alternatives. It represents the number of years required to fully repay the initial investment only with the cash inflow generated. Although is commonly used, when there are uncertainties regarding future cash flows, it can be risky and imprecise to use. It is not recommended when there are involved financial and taxation complexity and when management must decide between two mutually exclusive alternatives since investment size is not considered.

Furthermore, it ignores all the cash inflows generated after the payback threshold and the time value of money is not considered.

- **Discounted Payback Period (DPBP)**, without prejudice to all the characteristics of SPBP, the discounted payback period includes in the calculation the time value of the money, discounting future cash flows and making the evaluation of the project more realistic. The rest of the critical issues remain present in this model as well.

- Net Present Value (NPV)

NPV is the most reliable solution for any project valuation even if is complicated and subject to lots of variables. It utilizes discounted cash flows generated by the investment during its lifetime with a positive discount rate, which express the risk level of the investment and comes from an objective and subjective valuation. It compares the present value of the future net cash inflow to the initial investment, looking to determine the profitability of the investment. NPV analysis is recommended when evaluating investments that involve social costs or are mutually exclusive. NPV compared to other methods does not fail to recognize the difference in the size of investment alternatives[53]. The formula for NPV can be expressed as:

$$NPV = \sum_{t=1}^{T} \frac{CF_t}{(1+i)^t} = CF_0 + \frac{CF_1}{(1+i)^1} + \frac{CF_2}{(1+i)^2} + \cdots + \frac{CF_T}{(1+i)^T}$$

Where T is the project duration in years, i is the discounting interest rate at which the Cash Flows (CF) are discounted. Hence, investment is accepted if the NPV is overall positive. For EEP and ESP, the cash flows are coming from different sources, the energy cost saved, the incentives received, and the potential energy income if the used level is below the generated. The main uncertainty comes from the complexity of Cash Flow estimation and the identification of the correct discount rate.

- Internal Rate of Return (IRR)

The IRR is tight to the NPV since is the rate *(i)* that sets the NPV equal to 0. Its identification can be done using an iteration process or via the use of software like excel. The IRR analysis allows for the comparison of a wide variety of investment activities, nevertheless, it is not recommended for projects that require further

[53] Walter Short, Daniel J. Packey, and Thomas Holt, 'A Manual for the Economic Evaluation of Energy Efficiency and Renewable Energy Technologies' (National Renewable Energy Laboratory, 1995).

investment over time since the returns could generate multiple IRR. Its main usage is related to the simple acceptance or rejection of a project by comparing its value to a benchmark, usually called *hurdle rate*. Compared to NPV, IRR is not recommended when selecting mutually exclusive alternatives since the value and the actual economic return size of a project is not considered. A well-used solution for the project size is to apply the IRR on incremental investment. Its value can be easily compared with the return of other financial instruments like bonds or stocks.

IV. Alternative View and Project Valuation Method - LEEC

Looking for alternative investment decision methods, Philip B. Thompson from the Department of Economics of the University of Missouri-Rolla, in 1997 have proposed a different way of thinking when choosing to invest or not in a EEP or ESP. Rather than comparing investment projects between each other, it is better to decide to invest or not in EEP or ESP by comparing it with the decision of maintaining the current energy structure and its future cost. Viewing these two choices as investment decision, both characterized with uncertainty future costs, modifies how the risk is brought into the investment valuation and could help the investor understood better the magnitude. All the above mentioned and most used approaches, analyse any investment decision by only comparing the initial investment with the future energy cost savings, being a "benefit-based" approach. To include the uncertainty of the future energy cost saving, they set lower accepted payback period, increase the discount rate in NPV valuations and set a higher IRR threshold, reducing the acceptance rate for these projects.

Furthermore, another important and different investment valuation structure has been developed by Marco Chiesa and Simone Franzò[54] from the "Politecnico di Milano". In 2015 they have surveyed 130 Italian industrial firms, looking for a deeper understanding of the EEP and ESP valuation and the decision process used. They have discovered that in terms of project investment valuation indicator, all the interviewed companies use the PBP, only 20% use IRR together with PBP while NPV is used quite seldom due to its complexity. These indicators rely traditionally on a very short-term returns, since long term projections are complex and volatile, penalizing energy efficiency solutions and highlighting the need for a new model estimation. Taking as much knowledge as possible from the Life Cycle Assessment procedure (LCA), a methodology that assesses the

[54] Marco Chiesa and Simone Franzò, 'The Economic Evaluation of Energy Efficiency in Industry: An Innovative Methodology' (Politecnico di Milano, August 2015).

environmental impacts of a product, researchers have defined a new method called "Levelized Energy Efficiency Cost" (LEEC), which consider the total achievable savings accruing from an energy efficiency solution throughout its entire life cycle. In detail, the process is composed by two main steps:

- LEEC Calculation

It represents the calculation of the overall cost needed to achieve the total volume of energy saved (measured in kWh). It indicates the cost per kWh of energy saved thanks to the use of energy efficiency solutions in a specific context. The formula defined is:

$$LEEC(T) = \sum \left(\frac{\left[C_{pa:T} + CapEx_T + OpEx_T\right]}{Total\ Energy\ Saved_T} \right)$$

Where:

$C_{pa:T}$	It indicates the costs of the preliminary and implementation activities.
$CapEx_T$	It considers the cost of installed technology and the eventual cost for third party financing.
$OpEx_T$	It represents the cost of operation and maintenance needed by the efficiency solution.
$Total\ Energy\ Saved_T$	It is the sum of the energy saved each year defined in the preliminary analysis.

- LEEC Comparison

To quantify the project effectiveness, the LEEC must be compared to a benchmark value, which can be of two types:

- **Electricity-saving projects**, comparing LEEC with the cost for a kWh of energy
- **Thermal energy saving project**, comparing LEEC with the cost for producing a kWh of thermal energy.

If the LEEC turns out to be lower than the benchmark, the overall cost for the project is fully repaid by the whole achievable energy saving. The team has tested their model comparing it with the PBP investment decision method. By matching different industrial sectors, choosing the most energy intensive in the Italian market, with different energy efficiency solutions, they have evaluated the economic viability of five different EEP, full equity financed (not taking into consideration capital cost and repayment timing).

The industrial sectors chosen were metallurgy, mechanical, buildings material and pulp&paper; as for energy efficiency solutions they have selected: compressed air, electric motors, inverter, UPS (Uninterrupted Power Supply) and CHP (Combined Heat and Power). The benchmarks chosen were, 2/3-year threshold for the valuation with the PBP (coming from the data collected in the survey) and for LEEC valuation, the benchmark for the comparison were 0,10€/kWh for electricity-saving solutions and 0,047€/kWh for thermal energy-saving. Hence, if the project associated with the industrial sector has a lower PBP is accepted and if LEEC cost is lower than the benchmark the same. All LEEC value are expressed as cent hence, 1-2 means 0,01- 0,02 €/kWh. Results are shown in Table 2.

Table 2: LEEC vs PBP comparison

	Energy Efficiency Projects									
	Compressed Air		Electric Motor		Inverter		UPS		CHP	
	PBP[1]	LEEC[2]	PBP[1]	LEEC[2]	PBP[1]	LEEC[2]	PBP[1]	LEEC[2]	PBP[1]	LEEC[3]
Metallurgy	1-2	1-2	5-6	1,5-2,5	0,5-1	0,5-1	4-6	3-5	n.a.	
Mechanical	1-2,5	2,7-3,5	5,5-7	2,5-3,5	2-3	2-3	5-8	7-9	3-5	0,4-1
Buildings Materials	n.a.		5-6,5	2,5-3,5	1-1,5	0,6-1	4-6	3-5,5		
Pulp&Paper	1-2	1-2	4-6,5	2,5-3,5	0,5-1	0,5-1	3,5-5	2,5-3,5	3-5	0,3-0,7

1: Must be compared with PBP benchmark time of 2/3 years

2: Must be compared with the electricity-saving benchmark of 0,10€/kWh

3: Must be compared with the thermal-saving benchmark of 0,047€/kWh

We can easily observe how only a few projects, if valuated with PBP, result to be economically viable and so implemented while, if we look at LEEC results, we can see how almost every solution is economically viable and that should be implemented. These empirical results highlight how a decisive shift from the traditional investment evaluation methods to new solutions is needed in the field of EEP and ESP. Solutions like the LEEC evaluation method represents an opportunity to push industrial energy production and consumption toward efficiency, sustainability, and reliability, needed at the national and international level to achieve the environmental goals.

V. Financing Solutions for EEP and ESP

Investments in EEP and ESP are being characterized by different types of technologies, different types of investors and so they require distinct types of financial sources regarding several factors. Bertoldi et al. in 2020 have researched all the financial sources available to support investment in EEP and ESP, dividing them into 3 different sources: non-repayable rewards, debt financing and equity financing, looking for traditional, growing, and innovative financial solutions. See Figure 16.

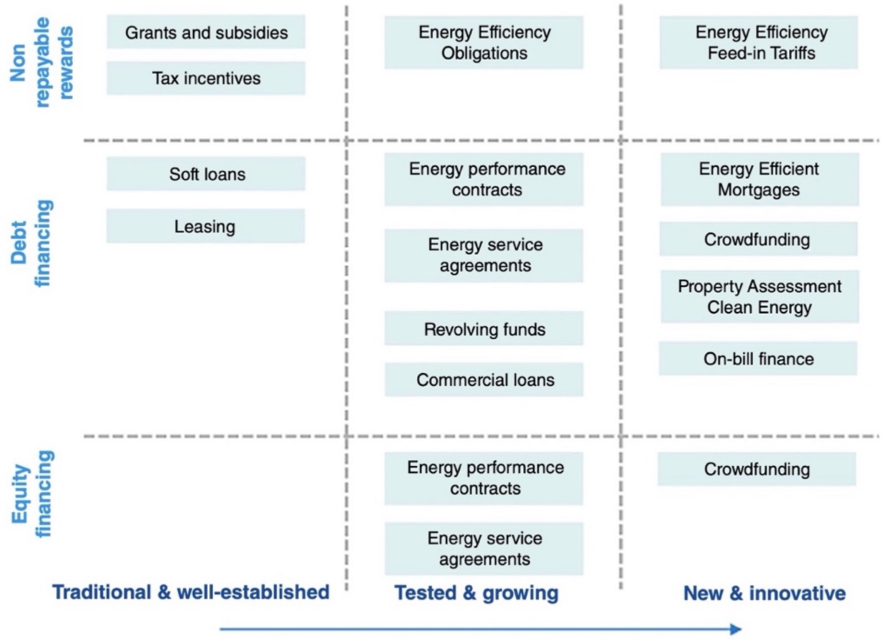

Figure 16: Overview of current financial instruments supporting EEP and ESP in EU[55]

Non-repayable rewards

- Grants and subsidies represent the simplest way for governments and public agencies to compensate for the inability of the market to provide the optimal level of investment. They aim to partially overcome the high upfront capital required by EEP and ESP, filling the financial gap and supporting the market in its initial phase.
- Tax Incentives are an important instrument available to governments that through direct solutions like tax exemptions, see the Ecobonus or the 110% Superbonus in Italy, could push interest and investment in EEP and ESP.

[55] Paolo Bertoldi et al., 'How to Finance Energy Renovation of Residential Buildings: Review of Current and Emerging Financing Instruments in the EU', *WIREs Energy and Environment* 10, no. 1 (April 2020).

- Energy Efficiency Obligation (EEO). The principle behind EEOs, first introduced in the EED of 2012, is that obliged energy companies are required to prove that they have reached a minimum of 1,5% of energy efficiency driven by their activates of promotion or by having funded projects in EE. In Italy and France, EEOs are combined with tradable White Certificates (WC), which will then be analysed in-depth in the next section.
- Energy Efficiency Feed-In Tariff (EEFIT) represents an instrument that rewards the operational performance of an investment in EE. Consumers under an EE FIT are encouraged in the reduction of energy use through an additional financial incentive besides the monetary savings from reduced energy bills. The additional financial incentive is related to the actual performance of the investment and is paid following the price set in advance in the contract. In the UK, they have replaced them with Smart Export Guarantees (SEG), looking for fixing all the original glitches. Table 3 are summered the main differences.

Table 3: FIT and SEG differences - SolarGuide UK[56]

	Feed-in-Tariff	Smart Export Guarantee
Price Tariff	Same for all applicants, regardless from the supplier	Depends on the electricity supplier
Type of Tariff	Fixed for 20/25	Fixed or flexible depending on the supplier and its offer
Electricity Payment	Two payments: one for the generated electricity and one for the exported one	Only for the exported
Payment Calculation	Generated is measured while the exported is set to be 50% of the generated (arbitrary)	Exported electricity measured by smart meter
Funds for the System	Funded by all the customers; energy bill (through taxation)	Paid by energy companies

[56] SolarGuide, 'Smart Export Guarantee vs Feed-in Tariff', SolerGuide, 2019, https://www.solarguide.co.uk/smart-export-vs-feed-in-tariff#/.

Debt financing

It refers to the acquisition of funds by borrowing from a third party. A lender provides capital to a borrower for a defined purpose over a fixed period. Debt options include corporate or project loans under recourse or limited recourse structures, leasing arrangements and full or limited guarantees. The most frequent debt financing used for energy efficiency and saving projects are loans called *soft loans*, set directly by the energy end-user (owner of the premises) or done by the project developer. It is an agreement to lend a principal sum for a fixed period, to be repaid by a certain date with an interest calculated as a percentage of the principal sum per year, plus other transaction costs such as administrative fees. Banks tend to finance these projects requiring recourse, implying the recognition of the company's asset in the event of default and the recognition on the balance sheet of the liability. Since EEP and ESP are usually categorized as side-projects in the companies' activity, they would prefer not to use the recourse structure but to fund them with only the guarantees coming from the saving cash flow, pointing out the important characteristic of projects own merits. The main characteristics of *soft loans* are below average market rates, longer payback periods and the possibility for third-party partial guarantees (usually governments guarantee through their investment banks).

Looking for tested and growing debt financing solutions, besides EPC discussed previously, we have:

- Energy Service Agreement, like EPC, is a contract that can combine different energy efficiency measures, giving service to building owners that pay for through realized energy savings without having to provide the upfront costs[57]. Since payments are based on actual energy saved, ESA sponsors give performance guarantees assuming the risk that expected savings will occur. The contract ends when all the costs of the project have been paid and after this period, the owner continue to benefit from reduced bills and the savings become its profits. The advantage of this debt structure is that allow customers to finance these improvements "off-balance sheet". See Figure 17.

[57] Charlotte Kim et al., 'Innovations and Opportunities in Energy Efficiency Finance' (Wilson Sonsini Goodrich & Rosati, May 2013).

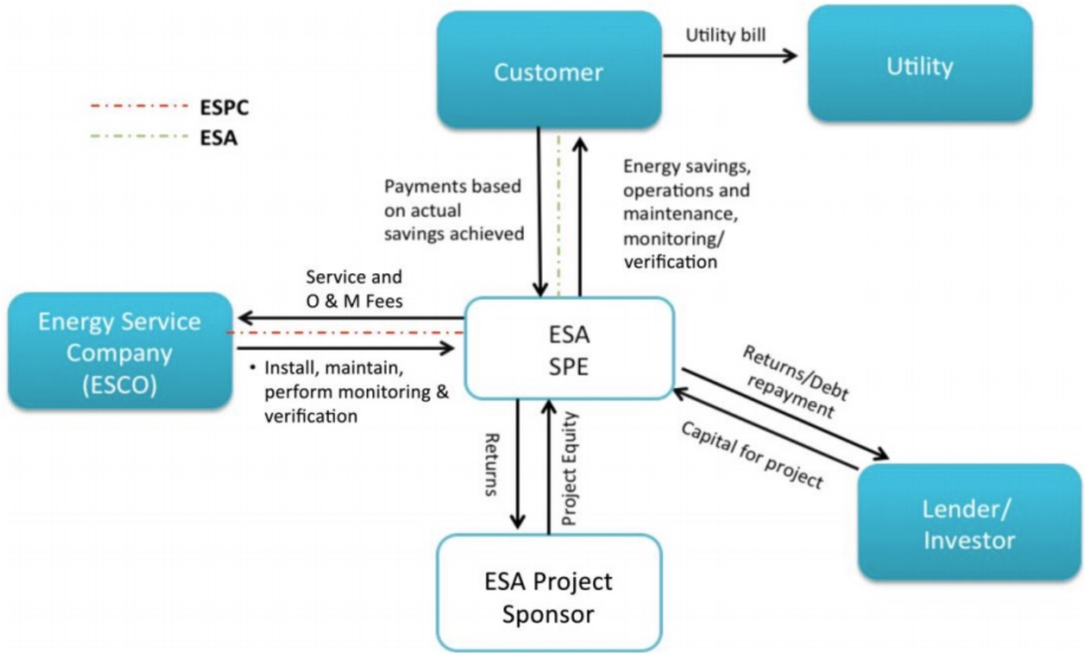

Figure 17: Basic ESA Structure – WSGR [58]

- Revolving funds, in Europe in 2003 was launched the Energy Efficiency Revolving Fund (EERF) to stimulate investments in large-scale industrial projects by increasing the availability of debt financing solutions while minimizing the borrowing cost for the project developer (ESCo). The fund typically will loan to a local bank at a 0% interest rate for a max of 7 years maturity. In exchange, the bank will finance the EEP or ESP at a max of 4% interest rate, requiring only guarantees on the project development.

For new and innovative solutions there are:

- Energy efficient mortgage is a loan with a reduced interest rate that gives recognition of the EEP and ESP value in the mortgage itself, increasing the building's value and allowing the investor to raise more financial resources. Nevertheless, it requires the label certification of efficiency, utilized by the FIs to assess the credit value of the project.
- On-bill financing (OBF) relies on a utility provider or on a third-party capital to pay for EEP, or ESP and its cost is repaid through the utility bill. This feature allows customers to immediately see the effect of energy efficiency benefits on their overall energy expenses, which often shrink immediately thanks to low interest rates and minimal up-front costs. A key element for OBF is the threat of utility disconnection. The final user tends to place a higher priority

[58] Kim et al.

on utility bill payments due to the risk of a shutdown of the service, and since OBF payments are bundled into the utility bill, shutdown rates for such bills have been lower than normal being more economic.

- PACE, another financial source are *bonds*, which are debt securities, issued by companies or governments characterized by a fixed lifetime, entitling the holder to the repayment of the principal plus interest. Through *PACE (Property Assessed Clean Energy financing*) local authorities, only in the US right now, can issue specific bonds to investors raising funds used to loan money for energy renovation in residential and commercial buildings. This type of government financing differs from other financial schemes since the repayment is done by the annual assessment of the property tax bill, delivered over 15 to 20 years. Unfortunately, this scheme is not yet available in the EU due to the legal complexity and the inability of EU municipalities to issue bonds. Figure 18 shows how PACE works.

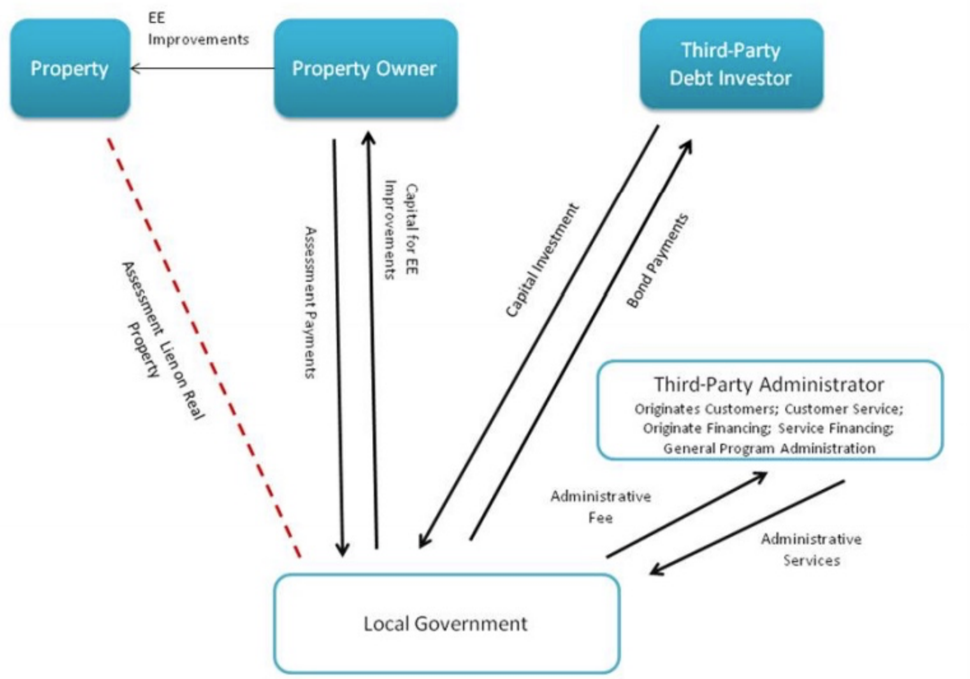

Figure 18: Basic PACE Structure – WSGR [59]

[59] Kim et al.

Equity financing

It consists of the acquisition of funds by issuing shares of common or preferred stock in exchange for income from dividends and capital gain as the value of stock rises. The equity held by private individuals is often held via mutual funds or other forms of pooled investment vehicles (ETF) unless the owner is a large company. It can also come from professional Venture Capitalists (VC) which represents a specific sub-segment of private equity investment. They aim to obtain equity shares in companies that could play an important role in a specific field. The private equity activity is essential for growing businesses that want to expand their activities, as well as for large-scale project developers. Energy performance contracts and energy service agreements, described above, can be seen partially as equity financing, having a stake in the project.

Crowdfunding

It represents a form of financing that, using internet-based platforms, connects investors directly with borrowers. In the last few years, crowdfunding has become a viable financing alternative, specifically for the early stages of projects. It can be sorted into four types depending on the funding purpose and investment method:

- Donation-based, individuals donate small amounts to meet the larger funding aim of a specific charitable project while receiving no financial or material return.
- Reward-based, that can be collectively referred to as "community crowdfunding".
- Equity-based, it represents the sale of a stake in a business to a few investors. The idea is like how common stock is bought or sold on a stock exchange, or to venture capital.
- Lending-based, which can be defined as financial return crowdfunding or investment crowdfunding.

The main benefits of this financing instrument are flexibility and reduced transition costs, comparing to traditional financing solutions. Nevertheless, it could give rise to potential problems, for example, funds are often insufficient compared to the demand from entrepreneurs or there is the possibility of online fraud due to unproven technology. In general, the returns are not enough compared to the risks related to the technology adopted projects offering better risk-adjusted returns attract relatively larger contributions.

Project financing

Unlike conventional debt financing that relies on an individual company's creditworthiness, project financing relies on a project's cash flow expectations and spreads the risk between the different actors/investors[60]. EEP and ESP developed with ESCos, if SGM, is usually financed off the balance sheet of the company through the creation of a Special Purpose Vehicle (SPV), as described previously. It is a legal entity established to perform a defined or temporary purpose, that separate the assets and liabilities from the principal company. Off-balance sheet financing is appealing from a risk management standpoint since the risks associated with those assets and liabilities go with them. Because a typical project finance structure includes a wide array of contracts between the different actors, transferring the risk and allowing adequate coverage and division, it is associated with large transaction costs, implying a very high threshold investment level.

VI. The Italian Energy Efficiency Obligation Scheme – White Certificates

The Energy Efficiency Obligation Scheme (EEOs) associated with a tradable instrument is one of the available instruments that governments can implement to stimulate investment in energy efficiency and achieve the mitigation of climate change. Worldwide there are currently more than 50 EEO schemes operating[61]. In the EU, EEOs was first introduced by Art. 7 of Directive 2012/27/UE (EED) defining specific requirement on particular "Obliged-Parties (OPs)". These entities must meet a specific quantity of energy-saving on yearly basis (1,5%), calculated on their portfolio of customers, including retail energy sales companies, energy distributors, fuel distributors and transport fuel retailers.

Italy in 2001, anticipating the EED but following the Internal Market in Energy Directive (96/92/CE), has begun evaluating the implementation of an EEO scheme associated with White Certificates (WhC), a tradable financial instrument, making it operatives only after 4 years of design and development due to its complexity. The Italian EEO is structured around yearly EE targets expressed in primary energy saving and has identified as Obliged Parties all the electric and gas companies that stay above a certain threshold of customer's number.

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[60] Silvia Rezessy and Paolo Bertoldi, 'Financing Energy Efficiency: Forging the Link between Financing and Project Implementation' (European Commission, May 2010).

[61] Eoin Lees and Edith Bayer, 'Toolkit for Energy Efficiency Obligations', *RAP - Energy Solutions for a Changing World*, February 2016, 55.

Originally, the main characteristics were[62]:

- Increasing EE targets throughout time
- Only additional energy saved is counted for the issue of tradable WhC
- All sectors, going from industry, buildings and agriculture and most energy solutions are included in the scheme
- High flexibility scheme, having third parties investing, implementing EEP and ESP and being able to monetize it through the sale of the tradable instrument to OPs
- Incentivize the ESCos market, improving the EEP and ESP schemes and the technical level of all projects

WhC gives the proof of energy saved, achieved through the implementation of projects aimed specifically to improve the EE. When a public agency (in Italy ENEA) verifies the achieved energy efficiency, releases one WhC for every TOE (a ton of oil equivalent) of energy saved. In Italy, OPs must present their report, showing the fulfilment of all their targets, before the end of May of each year. Since those EE projects can be also implemented by non-OPs, voluntary parties like ESCos, organizations with an energy management expert (UNI CEI 11339 certified) or companies with an ISO 50001 energy management system in place can receive those WhC and sell them in the market. The exchange between parties can take place on a dedicated platform managed by GME (Gestore Mercati Energetici), owned by the GSE (Gestore Servizi Energetici), or through bilateral agreements over the counter (OTC). This characteristic makes the EEO not just an obligation scheme but a market mechanism, made of demand and supply, representing an important incentive for voluntary parties to invest in EEP or ESP. The WhC after having been purchased by the OPs must be cancelled from GSE registry to accomplish the achievement of their target in EE. It can be done totally or partially, depending on the target of EE needed. They are cancelled to avoid reusage or illegal re-sold in the market. See Figure 19 for a graphical illustration of the Italian WhC Scheme stakeholder and process structure.

[62] Dario Di Santo, Enrico Biele, and Livio De Chicchis, 'White Certificates as a Tool to Promote Energy Efficiency in Industry', *FIRE Italia*, 2018.

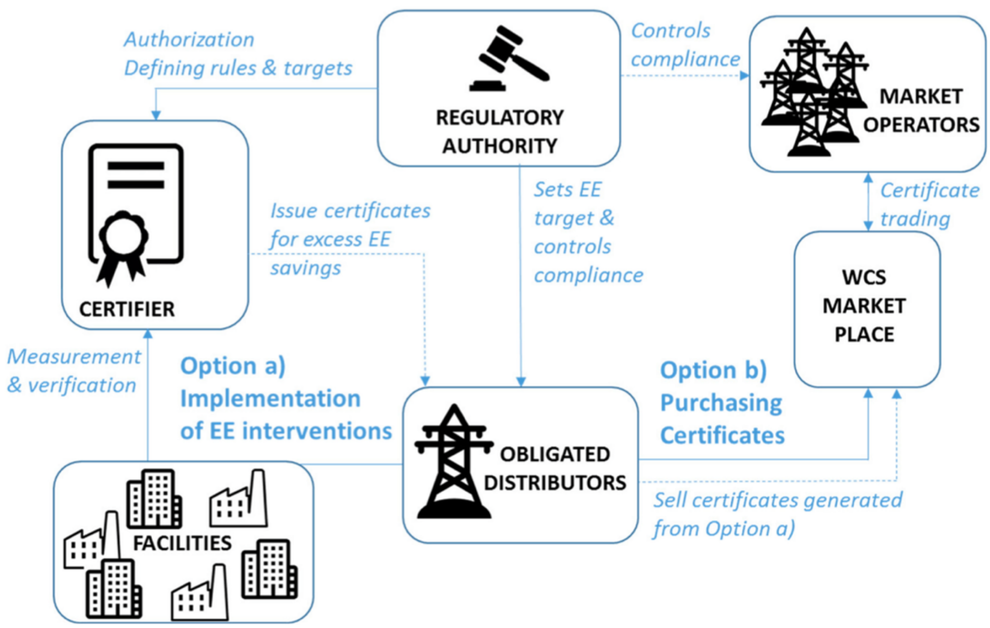

Figure 19: Stakeholders and process for WhC in Italy[63]

The Italian market has gone through five temporal phases up to now:

1. **2005 - 2007**: despite the complex scheme of EEO mixed with WhC, the first phase did very well. It was characterized by a very good supply, coming from simple Energy Efficiency Projects developed by OPs and ESCos (for householders), realized mainly in the field of energy rather than gas. It's important to notice that initially Italy decided to separate certificates coming from energy projects from the ones coming from gas. This has produced an oversupply of electric WhC that has pushed the price down from the original 80€ to 30€ per certificate, putting ESCos business model under pressure, being not more able to recover their investment having estimated different financial plans. Commodity distributors, on the other hand, benefitted from a huge gain, having the reimbursement tariff from the state fixed at 100€ for something that they were able to obtain for 30€. WhC were issued only for additional savings, excluding the savings coming from technological or market development.
2. **2008 - 2012**: through the law adjustment done via the Decree of 21 December 2007, Italy has increased its energy savings target, defined an automatic upwards target's adjustment YoY, amplified the OPs by reducing the dimensional threshold and, with other minor changes, has provided

[63] Marco Schletz et al., 'How Can Blockchain Technology Accelerate Energy Efficiency Interventions? A Use Case Comparison', *Energies* 13, no. 22 (November 2020): 5869.

positive effects increasing the WhC price. During those years, Italy has registered a level of energy saving doubled in 2008 and tripled in 2009 compared to 2007. Unfortunately, in 2010 there was a significant reduction in energy savings since initially industries and households have invested in simple but very effectively projects (light bulbs, air conditioning, etc…) leaving the complex and longer projects for the future. Furthermore, Italy ended the WhC lifetime recognition and has reduced the maximum amount achievable of energy saving level for new projects, seriously impacting targets and WhC price. To fix it, lately in 2011 was introduced the *tau coefficient*, which represents a multiplier that allows for an up adjustment on the energy saving estimation, taking into consideration that the projects will generate savings also between the end of WhC recognition and the end of its technical life. This decision brought back WhC demand, in line with targets but not enough to reach the efficiency estimated.

3. **2013 – 2016**: with the D.M 28 December 2012, Italy redefined its targets downwards even by taking into consideration the positive effect brought by the *tau coefficient*, that has partially solved the accumulated gap between energy targets and energy saved. It was however a partial recovery. The elements that in the past years have contributed to the undersupply grown again. The first element was the decision to exclude all the project already in the implementation phase hence, including only new projects. The second one was the introduction of rules to exclude all that projects that have a very short PBP. The combined effect of these two changes contributed significantly to re-amplify the undersupply issue, generating a significant drop in WhC offer, pushing the price from 110€ to 240€ per WhC by the end of 2016.
4. **2017 – 2018**: with the D.M. 11 January 2017, Italy introduced a profound redesign of WhC structure changing targets definition, saving assessment and M&V procedures. To avoid a further drop in WhC price, the *tau coefficient* was eliminated and the life period of projects available for the recognition of WhC was extended. Unfortunately, these decisions had a negative unexpected effect. The number of eligible projects dropped significantly due to the absence of the *tau coefficient* and the impact of the new M&V procedures, have brought to light a huge number of frauds attempted during that period. According to MiSE (Ministero dello Sviluppo Economico), more than 600.000 projects were blocked and 900.000 required advanced inspections in 2017, reducing at the end the supply by nearly 1.3 million certificates, with the consequence of skyrocketing the price. This highlights the main feature of the offer, inelasticity, caused mainly by the

duration of the procedure, the complexity of development and slowness on the part of state bodies in the recognition of certificates.

5. **Recent modification:** to avoid the WhC scheme to collapse, driven by skyrocketing prices and supply problems, MiSE issued new guidelines then embedded in the D.M 10 May 2018. It was another revolutionary modification, both for the supply and demand side, all structured around the problem of undersupply. New eligible project solutions, the abolition of additionality for existing facilities and the setting of a cap for distributors' reimbursement, have pushed up the demand from households for WhC.

Figure 20 shows the WhC scheme achievements and targets while Figure 21 shows the weighted average price of WhC and the traded quantity from 2006 to 2021 (first two quarters).

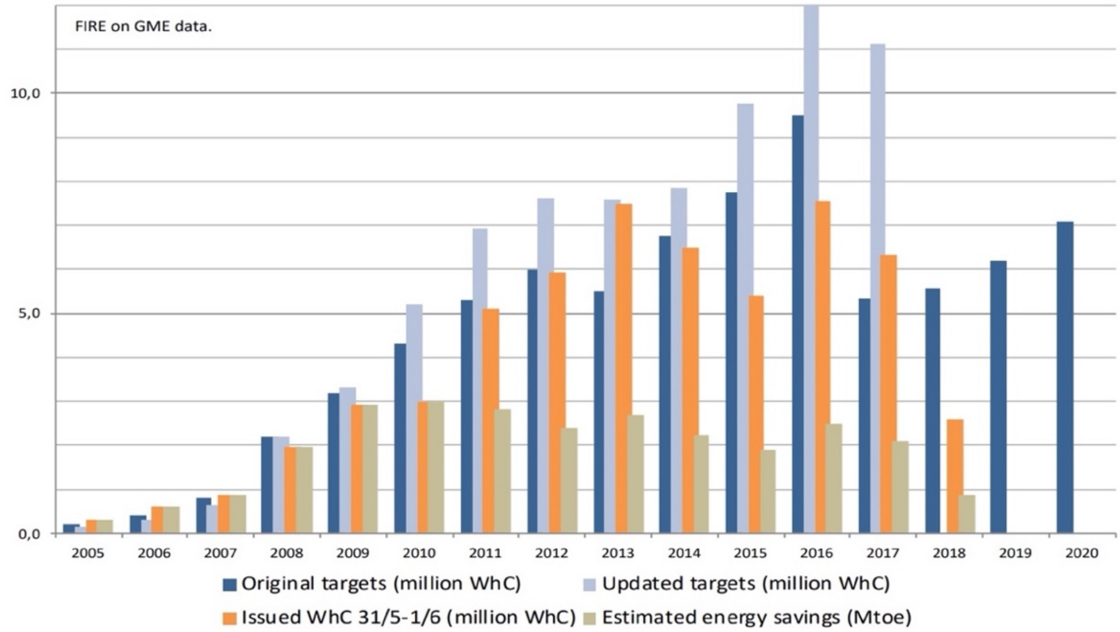

Figure 20: WhC scheme achievements and targets from 2005 to 2020[64]

[64] Dario Di Santo and Livio De Chicchis, 'White Certificates in Italy: Will It Overcome the Huge Challenges It Has Been Facing in the Last Three Years?', ECEEE SUMMER STUDY PROCEEDINGS (European Commission, July 2019).

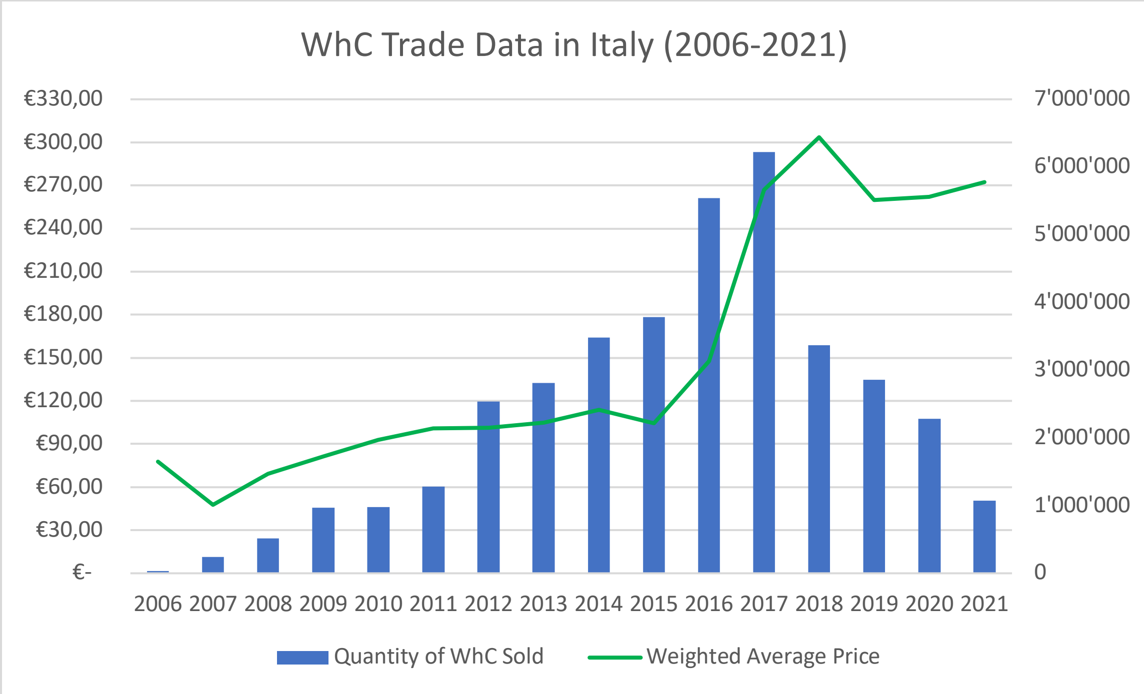

Figure 21: WhC trade history in Italy - Elaborated on GME Data[65]

We can also analyse the development path of the WhC Italian market by looking at the composition of certificate applicants[66]:

- The first period was characterized predominantly by the public and private sectors (namely households and services).
- The second one by the rise in the size of the industrial sector, which over the years has taken the lead compared to the total.

The main motif could be credited to the complexity of projects related to industries, which usually requires more time to be defined. Figure 22 shows it with numbers for the period 2006-2017.

[65] Gestore Mercati Energetici, 'GME WhC Data', GME, June 2021, http://www.mercatoelettrico.org.
[66] Santo, Biele, and Chicchis, 'White Certificates as a Tool to Promote Energy Efficiency in Industry'.

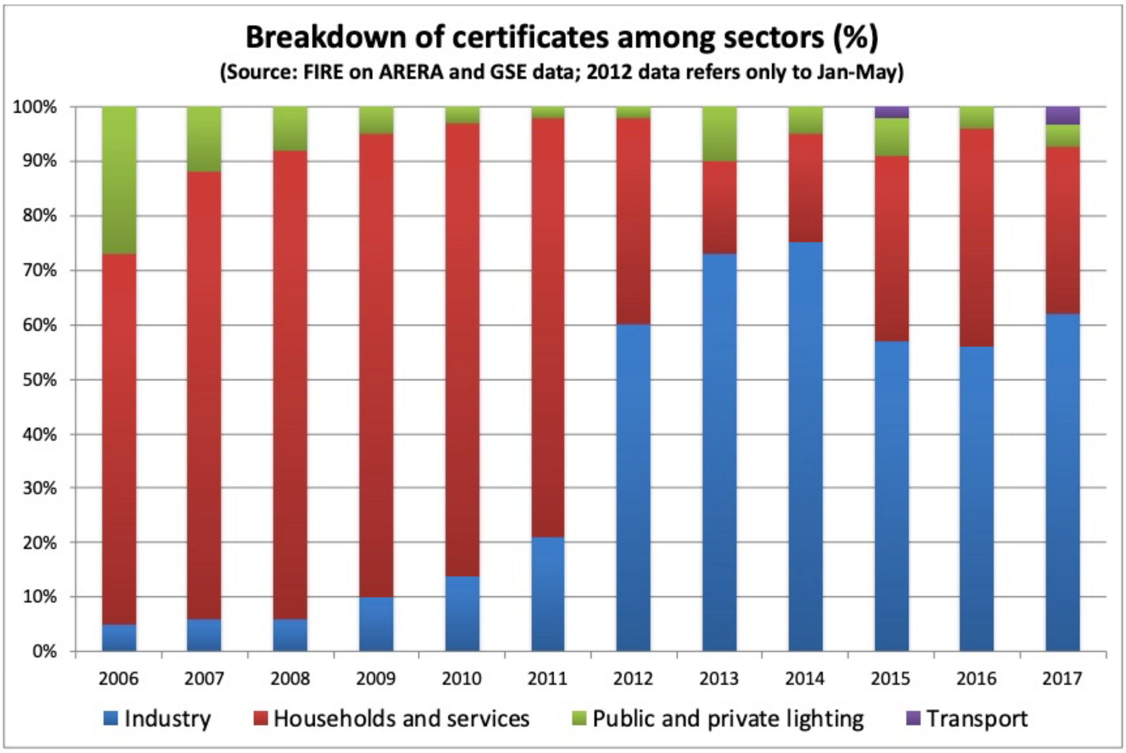

Figure 22: Energy saving applicants composition[67]

Simone Franzò et Al., in 2018-2019 have also done a multi-stakeholder analysis, in Italy, looking for empirical evidence of White Certificates benefits. Table 4 shows the results achieved comparing the chosen variables and parties involved in WhC, highlighting the positive "+" or the negative "-" impact.

Table 4: Variables effect on stakeholders

Items	State	Players in EE Value Chain	Energy User		Utility
			Industrial	Non-Industrial	
1. Direct and Indirect Costs of EEP or ESP		+	-	-	
2. Tariff contribution related to the scheme			-	-	+
3. Energy bill reduction			+	+	-
4. Tax level reduction due to bill reduction	-				+
5. Administrative costs	+		-	-	
6. Tax level increase related to EEP and ESP costs	+	-	-	-	
7. Energy import reduction					+
8. CO_2 emission reduction	+				

[67] Santo, Biele, and Chicchis.

In their research they have set an ad hoc metric for the monetary estimation of those variables, merging all the information coming from GSE, GME and ARERA (Autorità di Regolazione per Energia Reti e Ambiente) and formulating conservative and robust assumptions for missing elements. The results were also stressed out with a sensitivity analysis, assuming a better situation with a lower average unitary cost of reference for EEP and a worse situation with a higher unitary cost. The results have shown that the introduction of WhC in Italy has generated a net benefit of around €2 billion from 2006 to 2016 (with a variation of +/- 14% in the two cases), averaging an annual benefit of €180 million[68]. See Figure 23.

Multi-stakeholder evaluation of the Italian WCS – sensitivity analysis on energy efficiency technology costs (Case "A" and "B").

Items	Case A (million €)					Case B (million €)				
	State	Players in the EEVC	Energy users		Utility	State	Players in the EEVC	Energy users		Utility
			Industrial users	Non-industrial users				Industrial users	Non-industrial users	
1. Direct and indirect costs of EEMs	/	+5,674 (the remaining 2,434 mln € to foreign players)	−2,483 −8,107	−5,624	/	/	+6,934 (the remaining 2,974 mln € to foreign players)	−3,034 −9,909	−6,875	/
2. Tariff contribution related to the scheme	/	/	−1,531 −4,125	−2,594	+4,125	/	/	−1,531 −4,125	−2,594	+4,125
3. Energy bill reduction	/	/	+5,402 +16,713	+11,311	−16,713	/	/	+5,402 +16,713	+11,311	−16,713
4. Tax levies reduction related to energy bill reduction	−3,127	/	/ /	/	+3,127	−3,127	/	/ /	/	+3127
5. Administrative cost related to the scheme	/	/	−53 −141	−88	/	/	/	−53 −141	−88	/
6. Tax levies increase related to EEMs	+1,470	−1,229	−66 −240	−174	/	+1,796	−1,503	−80 −294	−214	/
7. Energy import reduction	/	/	/ /	/	+4,314	/	/	/ /	/	+4,314
8. CO_2 emission reduction	+527	/	/ /	/	/	+527	/	/ /	/	/
Net Benefit	−1,130	+4,445	+1,269 +4,100	+2,831	−5,147	−804	+5,431	+704 +2,244	+1,540	−5,147
Overall net benefit	+2,268					1,724				

Figure 23: multi-stakeholder evaluation of the Italian WCS – sensitivity analysis on energy efficiency technology costs[69]

Therefore, extending this result to 2021, we could assess that WhC has at least generated around €3 billion. The distribution of these benefits unfortunately is heterogeneous, having the State experiencing an overall negative effect counterbalanced with a huge benefit obtained by the EEVC (Energy Efficiency Value Chain) players and the final energy users.

[68] Simone Franzò et al., 'A Multi-Stakeholder Analysis of the Economic Efficiency of Industrial Energy Efficiency Policies_ Empirical Evidence from Ten Years of the Italian White Certificate Scheme' (Politecnico di Milano, February 2019).
[69] Franzò et al.

CHAPTER 4: RISK MANAGEMENT, CREDIT RISK AND TRANSFER SOLUTIONS FOR ESCos

I. Risk Management and Energy

Companies utilize risk management (RM) as a tool able to maximize the bottom line. It has been firstly introduced in the 60s and over the years has become a key element for the development of a global business strategy. The main goal of RM is to create a framework that allows the management to deal with risks and uncertainties present in all of the companies' financial and economic activities. The enterprise risk includes[70]:

- **Strategic risk** is the current and prospective impact on earnings or capital arising from an adverse or improper business decision, project implementation or lack of responsiveness to industry changes. Examples of such risk are reputational, market, technological, political, macro economical or legislative.
- **Financial risk** is often referred to as the unexpected volatility of returns, including both potentials worse or better results. It indicates that the company may not have the adequate cash flow to meet their financial obligations and can be caused by the volatility of interest rates, commodities, stock prices or due to problems regarding credit and liquidity.
- **Operational risk** is the prospect of loss coming from incorrect or failed procedures, systems, or policies, caused by employee errors, systems failures, fraud, or other criminal activity (e.g., cyber-attack) or any event that disrupts business processes such as the business or supply chain interruption.
- **Pure risk,** also called absolute risk, regards all those risks that go beyond human control and can only generate losses. It includes such incidents as natural disasters, direct and indirect damage, civil liabilities, or health-related risks.

[70] Cullen Naumoff and Anna Monis Shipley, 'Industrial Energy Efficiency as a Risk Management Strategy', *ACEEE Summer Study on Energy Efficiency in Industry*, ACEEE Summer Study on Energy Efficiency in Industry, 2007.

From a first exclusively insurance view of risk management, there's been developed a broader vision, including strategic and operational elements, looking for promoting active risk management. This vision takes both downsides and upsides of risk, changing the perspective of RM and recognizing its potential for generating opportunities and value for the enterprise. Generally, all risk management plans follow the same steps:

- **Macro context analysis**, required for the understanding of the external environment and the identification of the needed criteria to evaluate all the risks in which the companies seek to achieve their objective.
- **Risk identification** involves the identification of risk sources, events, their causes, and their potential consequences. It can require historical data, theoretical analysis, informed and expert opinions, and stakeholder's needs.
- **Risk assessment (analysis and evaluation)** should be conducted systematically, iteratively, and collaboratively, drawing on the knowledge and views of stakeholders. It should use the best available information, supplemented by a further enquiry as necessary. With the risk analysis, the RM process aims to comprehend the nature and the level of risk. It involves a detailed consideration of uncertainties, risk sources, consequences, likelihood, events, scenarios, controls, and their effectiveness. An event can have multiple causes and consequences and can affect multiple objectives. Risk quantification can be qualitative, quantitative or a combination of these, depending on the circumstances and intended use. Then, with the risk evaluation, RM must define how to support the company's decision-makers, comparing the results of the risk analysis with the established risk criteria to determine which actions to take.
- **Risk mitigation** aimed to select and implement all the available solutions for managing all the risks. The development of a plan that includes all the risk mitigation and prevention strategies together with the contingency plans are fundamental for the overall achievement of risk reduction. There are several different strategies that companies can apply[71]:
    - o **Risk avoidance or elimination** is the informed decision of not being involved in, or to withdraw from, an activity in order not to be exposed to a particular risk.
    - o **Risk reduction**, through the identification of feasible solutions the RM, aims to minimize the probability or the impact of all the identified risks.

[71] 'ISO 31000:2018, Risk Management — Guidelines', International Organization for Standardization, n.d.

- **Risk-retention**, the risk manager must quantify the *"risk appetite"*, which is the economic and financial retention capability of the company regarding a possible risk. It must be based on the risk criteria defined prior.
- **Risk sharing**. After the identification of all risks and the measurement of the amount retained, the RM focuses on the identification of the feasible solutions to transfer the remaining risks to third parties, namely insurances or the market.

- **Risk monitoring**, its purpose is to assure and improve the quality and effectiveness of process design and the implemented solutions through the verification of all available information, recording results and outcomes. Ongoing monitoring and periodic review should be a planned part of the risk management process, with responsibilities clearly defined.

Although RM can be useful for companies, it has some limitations that must be considered. First, many risk analysis procedures require the collection of large amounts of data and the development of complex models, activities that can become very expensive and do not guarantee full reliability. Being based on past data instead of the future, these models usually generate a false sense of stability. Furthermore, organizations believe to be able to correctly identify, quantify and manage every potential risk, letting opened the space for errors, avoidance, and underestimations, a condition that is usually described as *"illusion of control"*.
To optimize this process and limit as much as possible any errors via overtime improvement, several organizations like the International Organization for Standardization (ISO) have developed a series of defined and annually updated procedures, designed to help companies correctly implementing RM activities. In detail, the ISO 31000 aims to simplify risk management procedures, defining a set of clearly understandable guidelines, that should be straightforward to implement, regardless of the size, nature, or location of a business.

The cost of energy usage represents one of the most important cost elements in almost every sector, hence it becomes extremely important to consider it in every risk management project. Furthermore, in recent decades energy has become a greater risk to companies' profitability due to the volatility that exists in the oil, coal, and natural gas markets, which represents the main energy sources.

In 2012, Benedict Mculemeester, E&C consultant, has categorized the main exposed type of industries to energy price fluctuation into three groups[72]:

- **Budget risk clients** are the ones that work in a very price-stable environment. For example, the automotive or pharmaceutical sector cannot have a sudden increase in the energy budget since it will only reduce their overall margin of profitability.
- **Market risk clients** must provide products and services in a very competitive market, with very strong price competition. A reduction in the energy budget will immediately be reflected in a price reduction for their products and increased power in the market.
- **Survival risk clients,** these companies operate in an over-supplied market. Competitors are ready to sell products and services below cost production to acquire market share. The energy budget is crucial, a decrease in its price will allow them to lower prices while an increase might force them to absorb the difference without transferring the raise to the final client.

Being able to have reliable, low-cost, and clean energy sources for companies is so one of the main objectives to reduce the risks associated. Naumoff and Shipleynau[73] have researched the role of energy efficiency in a risk management strategy, stating that *"Energy efficiency and energy saving can play an important role in minimizing a company's overall risk".* It can represent an important element in any risk management portfolio or can work as a lone strategy. Companies that haven't in their structure the financial energy management, can implement EEP or ESP by working with external providers like ESCos, which through their solutions could impact both short- and long-term financial and economic forecasts, allowing for better planning and potentially creating a competitive advantage.

[72] Benedict De Meulemeester, 'A Risk Manager's Approach to Energy Sourcing', E&C Consultants, August 2012.

[73] Naumoff and Shipley, 'Industrial Energy Efficiency as a Risk Management Strategy'.

II. ESCos' Risks Management

In the previous chapter, there's been described what ESCos are and how they operate, highlighting the importance of the conclusion of an Energy Performance Contract (EPC), whether it's in the form of Shared Saving Model and Guaranteed Saving Model, which is necessary to become an active partner in the energy risk management process of a company. Their involvement allows companies to benefit from countless advantages such as experience, professionalism, knowledge of applicable solutions, project development, implementation, financial support, and monitoring and maintenance. Furthermore, through an EPC, companies can transfer to a third party the technical, financial (only under a GSM) and operation risks associated with an investment in EEP or ESP.

ESCos from their point of view must correctly define all the necessary procedures and instruments to quantify the foreseeable risks and then find all the possible solutions available to manage them. Ahmadi et. al. in 2020[74] has developed a risk assessment model for ESCos, looking for all the negative sources that can influence their overall benefit related to the development of an EEP or ESP project. For example, an increase in energy carrier price, a decrease in the overall economic health, technical incidents or increases in the labour or operational costs are all possible sources for ESCos' benefit decrease. See Figure 24.

[74] Mohsen Ahmadi et al., 'Development of an ESCO Risk Assessment Model as a Decision-Making Tool for the Energy Savings Certificates Market Regulator: A Case Study', *Applied Sciences* 10, no. 7 (April 2020): 2552.

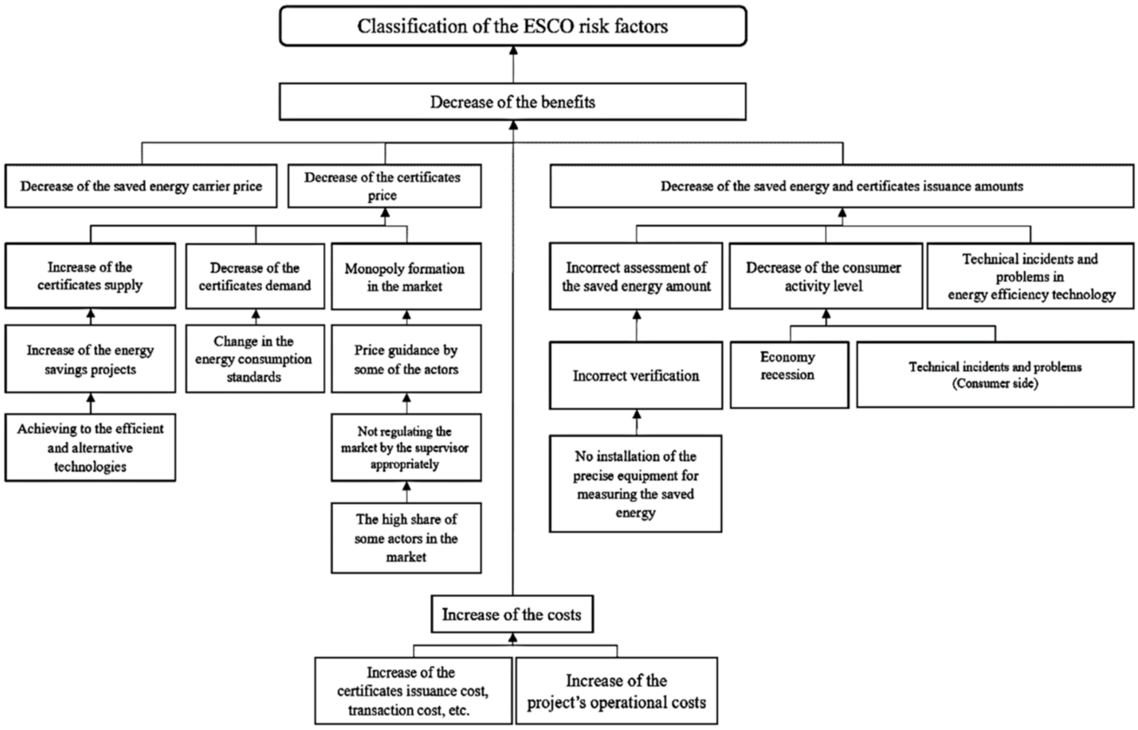

Figure 24: Risk Factors for ESCos by considering the EEP and ESP market

A more detailed risk categorization has been done by Lee et al.[75] in 2015, reviewing the studies realized by Evan Mills et al.[76] and Hu J. and Zhou E.[77], merging and amplifying their data with the additions of risk causes and consequences associated to specific EE projects. The macro-risk areas are:

Economic Risk

It represents all the possible losses resulting from changes in energy costs, demand charges, labour, and operational costs. In the SSM contract, both parties bear the risk of energy price volatility and demand charges, having accepted to share the benefits from cost reductions but also any loss if it happens. On the other hand, under a GSM, by fixing the expected level of savings achievable only ESCos bears those risks, making necessary the implementation of all the available solutions to eliminate, reduce or transfer them. Even though supply and demand are almost perfectly balanced in the market, the price of electricity is extremely more volatile than any other commodity. This is mainly because energy cannot be

[75] P. Lee, P.T.I. Lam, and W.L. Lee, 'Risks in Energy Performance Contracting (EPC) Projects', *Energy and Buildings* 92 (April 2015).

[76] Evan Mills et al., 'From Volatility to Value: Analysing and Managing Financial and Performance Risk in Energy Savings Projects', *Energy Policy* 34, no. 2 (January 2006): 188–99.

[77] Hu Jinrong and Zhou Enyi, 'Engineering Risk Management Planning in Energy Performance Contracting in China', *Systems Engineering Procedia* 1 (2011): 195–205.

stored economically, consumption largely depends on weather and macroeconomic and grid reliability conditions might vary over time. All these elements increase the possibility of extreme price movements which increase the risk of reducing economic and financial projections and the benefits of investing in EEP or ESP. ESCos through the use of derivatives such as futures or options can set the price of energy in the future, eliminating the risk of increases but, at the same time, eliminating the possibility of benefiting from a possible future price reduction that would have the opposite effect, increasing the overall economic return of projects. Another important economic risk, previously discussed in the barriers' section, is the interest rate. Its volatility could seriously impact the project valuation prospects as well as the overall cost of the project. Swaps or fixed financing are solutions available for ESCos to reduce its impact.

Financial Risk

In chapter two, there was described how funding for EEP or ESP projects could come from three sources: internal funds, ESCos funds or third-party funds. If the company uses third-party financing, to ensure the ability to repay the FI in addition to the classic physical collateral that it could ask the borrower, it may require the ESCo to ensure the achievable energy savings defined in the business plan. To provide this guarantee without affecting their financial structure, the ESCo has at its disposal different solutions such as its own collaterals, energy saving insurance or performance bonds. On the other hand, if the ESCo is the financial promoter of the EEP or ESP investment, in addition to implementing the above solutions to transfer those risks, it would also face the risk of default by the borrower and the risk that it will not repay the loan, generally described as credit risk. In addition to requiring collaterals (usually the EEP or ESP solutions implemented), adjusting the interest rate of the loan or retaining a greater percentage of the project's economic benefit, the ESCo must develop a way to manage this risk correctly. Hence, before entering an EPC, it should carry out a thorough financial assessment of the applicant and, secondly, develop its credit risk management model, which is essential for correctly assessing its risk exposure. To do that, they must learn from the financial sector how to perform it, which data are needed and how they could analyse and synthesize them in a useful and reliable way. It could have been very interesting to develop a real model of credit risk management, unfortunately, obtaining data on the loans disbursed by the FIs, with the attached specifications on the funds given to projects of EEP and ESP, is almost impossible if you do not represent a research organization. Nevertheless, for this thesis, it is important to describe all the different procedures that the ESCos should put in place to evaluate the qualitative and quantitative variables that characterize a loan, fundamental to verify the quality of the borrower. More on the credit risk modelling later in the chapter.

Operational Risk

It refers to the risk that could arise from poor maintenance, malfunctioning of equipment, bad execution of the project, changes in the use and occupation of the facility. Some of them are distinctive elements of EEP and ESP, for example:

- Wrong investment cost estimate and baseline.
- Incorrect operation and/or maintenance,
- Changes in energy prices, legislation, regulation, and/or taxation (previously examined as sources of underinvestment)

In most EPC contracts, the ESCo would not be liable for the shortfall in savings when the host does not operate the system following the agreed control strategy and procedures, giving back the risk of underperformance. Other associated risks such as doubts about whether and occupancy conditions would also affect the actual energy savings. Although an adjustment mechanism is usually incorporated in EPC contracts to address the impact arising from changes in baseline, it is rather difficult to determine these impacts, resulting in savings uncertainties.

Performance Risk

It regards the system design, due to poor information on the object of the contract, and the possible installation problems, due to specification or delays due to external factors, such as abnormal weather or permits.

III. Credit Risk: Policy Framework and Python Modelling

A credit risk model aims to compute the expected loss (EL), which is what the lender might lose due to the borrower's default or inability to repay, and it is defined as the product of three components:

$$EL = PD * LGD * EAD$$

Where:

- PD, probability of default, is the likelihood that the borrower would not be able or willing to repay its debt in full or in time and, it usually refers to a particular time horizon.
- LGD, loss given default, is the share of an asset that is lost if the borrower defaults, in other words, it is the proportion of the total exposure that cannot be recovered by the lender.
- EAD, exposure at default, is the total value that the lender is exposed to when a borrower defaults so the maximum possible loss.

The development of a credit risk model is usually structured with the use of excel or python, which is a code language designed for statistical data analysis that has recently become predominant in the industry thanks to its huge statistical libraries and practicality. Not only do Financial Institutions bear the credit risk, even ESCos, by entering in an EPC of SSM type, bear too. Even if the process for the definition of a credit risk model could be the same, ESCos differ from FIs by not having to follow the rules set by the Basel II Accord regarding capital adequacy. Briefly, this international accord requires to FIs to assess the quantity of capital to be held for every loan they grant, determined as a proportion of their assets (mainly loans) and weighted by their risk. It is set to be 8% of the total risk-weighted loans. The greater the risk associated with a loan, the greater the amount required to be held. It is one of the main elements of the first Pillar (the Minimum Capital Requirement) and, to guide FIs, the Accord has defined three internationally accepted ways to assess the risk exposure:

- Standardized Approach (SA)

Under this approach, the risk weight assessment is determined using external risk valuations. FIs must build their credit risk model using data such as FICO credit score for individuals, which uses numbers that go from a minimum of 300 points (worse valuation so higher risk) to a maximum of 850 points (higher valuation so limited risk) or the credit rating, which uses letters and are elaborated for example by S&P, Moody's and Fitch.

See Table 5 for an example of the risk weight that must be associated with a loan regarding its credit rating following the SA approach.

Table 5: Risk-Weight from Basel II Accord

Type - Rating	AAA to AA-	A+ to A-	BBB+ to BBB-	BB+ to B-	Below BB-	Unrated
Countries	0%	20%	50%	100%	150%	100%
Firms	20%	50%	100%	100%	150%	100%
Consumers and Credit Card	75%					
Mortgages	35%					

- Internal Rating Based Approach.

Since FIs grant lots of loans, they have accumulated a huge amount of data and the Basel II Accord gives to FIs the possibility to use it and build their own credit risk model. This solution allows to better assess the credit risk, reducing the capital required to be held. It could be done in two different ways:

- Foundation - Internal Ratings Based Approach (F-IRBA), under this model, FIs are allowed to model their own PD while LGD and EAD are set and given by regulators using the external dataset.
- Advanced - Internal Ratings Based Approach (A-IRBA), under this method, FIs can model all three components of Expected Loss (PD, LGD and EAD) using internal data, improving, and reducing even further their risk exposure.

FIs are very prone to build their own credit risk model since the flat requirement given by the SA approach, for example, weighting credit card loans at 75%, is very limiting. Moreover, giving the same weight to all exposure's types, regardless of their riskiness, worsen FIs ability to lend. The more precisely the credit risk estimation, the lower the risk associated, the lower the amount of capital that must be set aside and consequently, the more business FIs can generate from the same total amount of capital.

Focusing on the model creation, before everything, it is important to define when a loan is considered defaulted or non-defaulted. Under the Regulation 575/2013 at Art. 178, the European Commission has defined that a default, shall be considered to have occurred, regarding a particular obligor, when either or both of the following situations have taken place[78]:

- The institution considers that the obligor is unlikely to pay its obligations to the institution, the parent undertaking or any of its subsidiaries in full.
- The obligor is past due more than 90 days on any material credit obligation to the institution, the parent undertaking or any of its subsidiaries. Competent authorities may replace the 90 days with 180 days for exposures secured by residential property or SME commercial immovable property in the retail exposure class, as well as exposures to public sector entities. The 180 days shall not apply for the purposes of Article 127 which define the obligation to overweight the risk associated with a loan unsecured.

This definition is fundamental to perform credit risk modelling, allowing the separation of what is defaulted and what is not. Usually, any dataset requires the presence of this element, whether it is available or not, it is important to have it. Under Python, this element must be of a binary type, assigning the value one (y=1) for a defaulted loan and zero (y=0) for the non-defaulted loan. Obviously, this categorization requires the analysis of the data looking for elements that have the power to differentiate each entry between the two.
In the modelling process of data, one of the main risks are **overfitting**, the statistical model has focused on a particular dataset so much that it has missed the point, and **underfitting**, the model fails to capture the underlying logic of the data. See Figure 25 for a graphical example.

[78] THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION, 'REGULATION (EU) No 575/2013 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 26 June 2013 on Prudential Requirements for Credit Institutions and Investment Firms and Amending Regulation (EU) No 648/2012', June 2013.

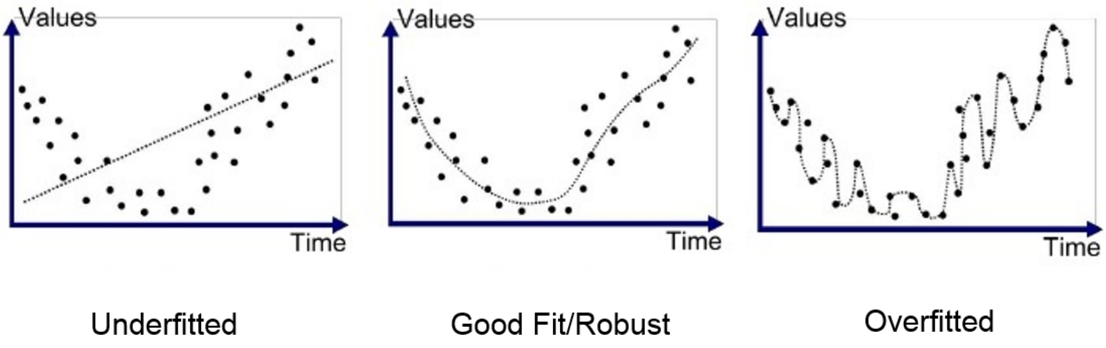

Figure 25: Overfitting and Underfitting

To solve both these problems, the easier solution is to split the original dataset into two subsets, one for training the model and one for testing it. Commonly the dataset used for training takes 80% of the initial elements while the remaining 20% is used for the test. There could be even a third subset, the validation set, which contains all the entries registered after the period under analysis and contained in the original data set. For example, if the analysis is modelled today using data of loans granted in the period between 2008 and 2018, all the following years (2019/2020) could be used as validation model, to double-check its ability to capture the researched outcome.

The credit risk modelling usually requires 5 steps:

Data Preparation

Data processing is essential for the definition of every statistical model. Usually, the variables included in the dataset could be of two types:

- *Discrete or categorical*, which takes only a certain finite number of values.
- *Continuous or numerical*, that can take any value in a given range, or in other words, they can take on an infinite number of possible values.

To make things more complicated, some discrete variables could be treated as continuous, for example, the number of credit reviews in the last 6 months. The simplest way to assess whether to treat as discrete or continuous is to try ordering the values, if it is possible, it could be treated as continuous, if not, it must be treated as discrete.

Data pre-processing for the estimation of the PD model consist in transforming all the discrete independent variables into suitable categorical variables and, if we have too many of them, it is important to combine them before becoming dummy variables.

On the other hand, for continuous variables, the procedure is slightly different having to first slice data into equally sized intervals (a procedure called *Fine Classing*) and then these intervals must be merged if have similar describing power (a procedure called *Coarse Classing*) before transforming them into dummy. The descriptive power evaluation method widely accepted and used is the Weight of Evidence (WoE). It measures to what extent an independent variable would predict a dependent variable, in our case if the loan has defaulted.

$$WoE_i = ln\left(\frac{\%(y=1)_i}{\%(y=0)_i}\right)$$

The formula of the WoE is the natural logarithm of the ratio of the proportion of obs of the defaulted loans (categorized with y=1) and the proportion of obs of the non-defaulted (y=0). The proportion of defaulted loans must be at the numerator otherwise, if in a dataset, the defaulted loans are zero, the ratio will be non-defined.

For example, the WoE computation of an independent variable that could be found in a credit card loan dataset, the "Level of Education" that has let's say only two categories, "Higher" or "Non-Higher", could be like in Table 6.

Table 6: WoE example of an Independent Variable

Level of Education	y=1 Defaulted	y=0 Non-defaulted	Proportion of y=1	Proportion of y=0	WoE	IV
Higher Education	600 obs	4.000 obs	0,15	0,25	$ln\left(\frac{0,15}{0,25}\right) = -0.51$	0.0511
Non-higher Education	3.400 obs	12.000 obs	0,85	0,75	$ln\left(\frac{0,85}{0,75}\right) = 0.125$	0.0125
Sum	4.000	16.000	1	1		0.0636

The further away from zero and positive the WoE, the better the predicting power of the independent variable in describing the dependent variable.

For discrete and continuous independent variables, after having been processed with the fine and coarse classing and having computed the WoE of each original categorization, must be grouped following similar WoE. During this step it is important to take under consideration also the number of obs of each class in order to reduce them while keeping as much differentiating power as possible in the model.

The next step is to compute the Information Value (IV) of the original independent variable with respect to the dependent variable, which is one of the most useful techniques to select important variables in a predictive model, helping the ranking process of variables based on their importance.
The formula is:

$$IV_i = \sum_{i=1}^{m} \left[(\%(y=1)_i - \%(y=0)_i) * ln\left(\frac{\%(y=1)_i}{\%(y=0)_i}\right) \right]$$

$$= \sum_{i=1}^{m} [(\%(y=1)_i - \%(y=0)_i) * WoE_i]$$

The IV value ranges from 0 to 1 providing different information. See table 7.

Table 7: IV Value Classification

Range 0-1	Predictive Power
IV < 0.02	No predictive power
0.02 < IV < 0.1	Weak predictive power
0.1 < IV < 0.3	Medium predictive power
0.3 < IV < 0.5	Strong predictive power
0.5 < IV	Suspiciously high

Following the previous example, in Table 6, it can be noticed that the IV for the "Level of Education" variable is 0.0636 so it has a relatively weak predictive power.

PD model estimation and validation

For the estimation of PD, it is usually used a decision tree model or the Logistic Regression, the latter is one of the most important statistical techniques for categorical response data. It is a generalized linear model mainly used to estimate the probability that a binary reaction occurs based on several predictor variables that produces value only between zero and one. It requires first to assess the relationship between the dependent variable and independent variable and secondly, the estimation of the regression coefficients of each independent variables selected. It is called Logistic since the curve that predicts the outcome is defined by a logistic function as in the following formula example.

$$P(Y) = \frac{e^X}{1 + e^X}$$

The probability of an event can be represented as the exponential of a linear combination of coefficients (betas) and independent variables (in the example the X), divided by one plus the same exponential. Since for the credit risk modelling is important to know the ratio between defaulted and non-defaulted, it is possible to modify the formula into:

$$\frac{P(Y=1)}{P(Y=0)} = e^{Y} = e^{\beta_0+\beta_1 X_1+\cdots+\beta_m X_m}$$

$$ln\left(\frac{P(Y=1)}{P(Y=0)}\right) = \beta_0 + \beta_1 X_1 + \cdots + \beta_m X_m$$

And it could be re-written in:

$$\ln\left(\frac{defaults}{non-defaults}\right) = \sum_{j=1}^{m} \beta_j X_j$$

$$prob(defaults) = \frac{e^{\sum_{j=1}^{m}\beta_j X_j}}{1+e^{\sum_{j=1}^{m}\beta_j X_j}}$$

Having as result the odds rather than the probability of a single event. If it is plotted a logistic curve will have an S shape bounding from 0 and 1 as in Figure 26.

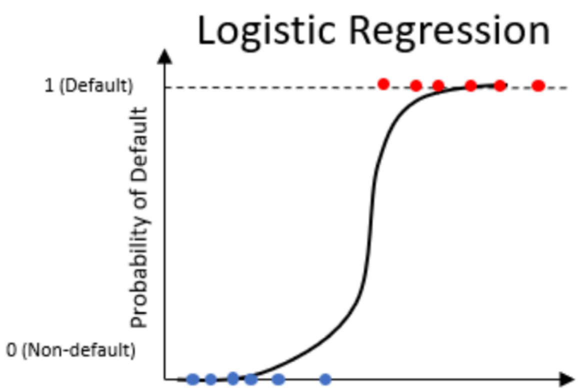

Figure 26: Logistic Regression chart for PD Model [79]

To respect the interpretability requirement, each category in each independent variable must be expressed as a dummy variable, a process that could be done in python using the function *pd.get_dummies*.

To run the logistic regression using all the dummy variables created, it is required to keep one out as a reference category, against which the impact of all others will be assessed. Usually, it is established that the category with the lowest or highest WoE is set to be the reference category. In doing that, the model wouldn't

[79] Michael Crabtree, 'Logistic Regression for Probability of Default' (Datacamp, n.d.).

fall into the "dummy variable trap" also called *multicollinearity*, in which the attributes are highly correlated (linear correlation), and one variable can be explained by the other independent variables in the category. Let's take an example using the case of gender having two values male (0) and female (1). Including both the dummy variables can cause redundancy because if a person is not male in such case that person is a female, hence, we don't need to use both the variables in the regression model.

For the logistic regression creation, Python gives an important advantage since using specific packages, namely the *LogisticRegression Package* and the *Metrics Package*, and the use of the formula *reg.fit*, the program is able to estimate both the intercept and the coefficient for all the independent variables for the PD model. To assess which independent variables between the one available contribute to predict the borrower default or non-default, the accepted solution is to check the p-values of each coefficient. In Python there are some built-in methods for calculating it using the package *sk.learn*, unfortunately they are all univariate solutions, meaning that they consider the impact of each feature on the outcome as if there aren't any other features in the regression model. In the PD model, all the features on the outcome are collective rather than independent. There are several ways to solve this problem but, since the core of this thesis is to explain generally how credit risk modelling can be done, we won't get any deeper.
After having computed all the associated p-values for the independent variables, we must assess the significance (so if the value is lower than 0.05) and decide whether to retain or to eliminate those variables, there can be only three situations:

- All the dummy variables inside an original independent variable are statistically significant, so they must all be retained.
- All the dummy variables inside an original independent variable are non-statistically significant, so they must all be eliminated.
- One or a few of the dummy variables representing the original independent variable are statistically significant, it would be best to retain all of them rather than eliminating the category.

Other accepted methods to assess the significance of each variable are[80]:

- **Forward stepwise selection**, which is a method that begins with a predictive model with no variable, tries a variable at a time and then observes how the accuracy of the model changes. If the addition of a feature brings about higher model accuracy, it stays in the model and if not, it is deleted. This process continues until there is no improvement in model performance.
- **Backward stepwise selection** is another alternative way for variable selection and its process is like the one of forward stepwise selection. However, instead of starting with a model with no predictors, this one starts from the model having all features. Then, at each step, the model deletes the feature whose elimination helps to have the largest improvement in its performance. Even if this approach is simple if the data set has many features and if its number is greater than the number of observations, this method is not preferred since it could require lots of time.

After having done this step and simplified the whole list, the result is a PD model with all the coefficients and the p-values. The interpretability relies on the ability to read the change in the odds of being defaulted taking under consideration all the observations with dummy values equal zero or one.
Taking as reference category the dummy variable inside an original independent variable with the lowest WoE, for example, gives back that if this element equals one, all the other elements above are equal to zero. The odds of being better than the worse dummy are simply the exponential of the coefficient of the selected dummy variable compared with the reference dummy.
It is important to remember that this comparison cannot be done between different categories coming from different original independent variables since they are not mutually exclusive.

PD model validation and data monitoring

The next step is to use the estimated model to predict the PD for the test dataset (the one set aside in the first part of the model estimation) and evaluates the ability of the model to estimate the probability correctly. To do that, it is important to re-run all the scripts regarding the fine and coarse classing for the test dataset and then, using the formula *logistic_regression_model.predict*, assess the predictive power.

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[80] Juan Laborda and Seyong Ryoo, 'Feature Selection in a Credit Scoring Model', *Mathematics* 9, no. 7 (March 2021): 746.

The formula does three things:

- Multiplies the variables' value of each observation by the model coefficient (the Betas), yielding the log of odds of being defaulted.
- Then an exponent is raised to the power of the log of odds, yielding the odds of being defaulted and the estimated probability.
- Then the estimated probabilities are categorized into being defaulted or non-defaulted by applying a cut-off (usually if the prob of being a non-defaulted borrower is >= to a certain percentage, it will be converted to 1 and included into the defaulted category).

The cut-off percentage must be assessed by analysing the accuracy of the model through a *confusion matrix*, also known as an error matrix, which is a specific table layout that allows the performance's visualization of an algorithm. Each row of the matrix represents the occurrences in an actual class while each column represents the results in a predicted class or vice versa. Hence, it shows how many of the predicted defaulted borrowers have defaulted and how many are incorrectly predicted, and vice versa. The more accurate the model is, the higher the loans given and the profitable the lender become. One solution to identify the correct cut-off is to use the ROC Curve (Receiver Operating Characteristic), which is a graphical representation of the rate of false-positive predicted and the rate of true positive predicted. See Figure 27.

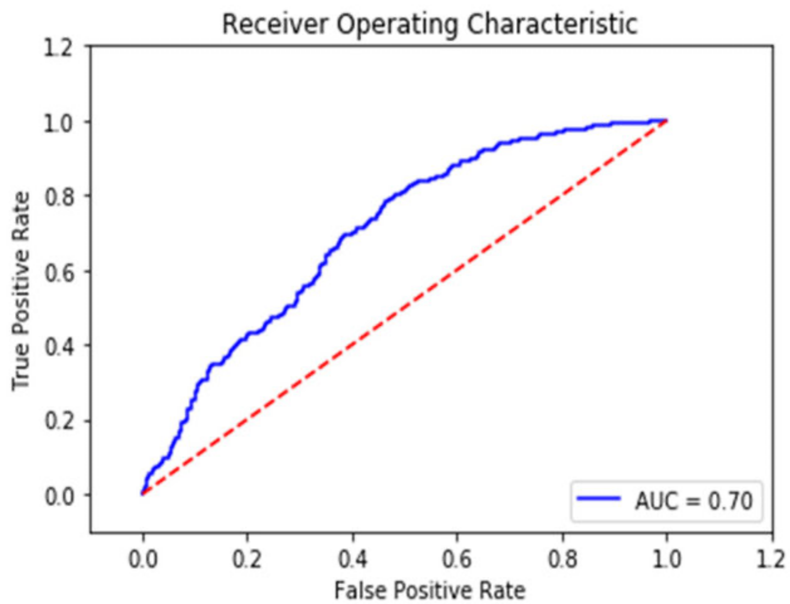

Figure 27: ROC Curve Example

Each point of the curve corresponds to one threshold point (cut-off rate) that would result in a different classification of defaulted and non-defaulted and so in a different confusion matrix. To assess if the model is correct, usually, the ROC curve is compared with a straight 45° line, having the model only two possible outcomes (loan defaulted or not). If the ROC stays above the 45° line, it means that the model has better predicting power than an estimation done by chance. To find out how much better, it is important to analyse the area under the curve or AUC, being a good overall measure to see how good a classification model is. Usually, the AUC result is evaluated in ranges. See Table 8.

Table 8: AUC result classification

Interpretation	Area under the ROC curve
Bad	50% - 60%
Poor	60% - 70%
Fair	70% - 80%
Good	80% - 90%
Excellent	90% - 100%

Since the PD is the most volatile component of the EL, from time to time, it is important to re-adjust and eventually re-develop the model. This process is usually referred to as *model maintenance*.

One of the most convenient ways to compare the past (used in the modelling) and present data is the Population Stability Index (PSI), which goal is to determine whether the two data differ from each other. It compares any discrete or continuous variable of borrowers and turns it into categories (through fine and coarse classing), then it is important to compare the distribution of the data looking for differences. Simply, by taking the sum of the difference of the proportion of these categories, multiplied by the log of the ratio of the proportion of new data over past data. The formula is similar to the IV and is:

$$PSI = \sum_{i=1}^{m} \left[(\%present_i - \%past_i) * ln\left(\frac{\%present_i}{\%past_i}\right) \right]$$

PSI takes values between zero and one, having different meaning for different range. See Table 9.

Table 9: PSI Value Interpretation

Value PSI	Population difference
PSI = 0	No difference at all
PSI < 0.1	Little to no difference
0.1 < PSI < 0.25	Little difference that requires deep investigation
PSI > 0.25	Big difference that requires deep investigation and the model updated
PSI = 1	Absolute difference

LGD and EGD modelling

Going forward with the second and third component of the EL calculation, there is the Loss Given Default (LGD), which represents the percentage of the exposure that was lost after the borrower defaulted and, the Exposure at Default (EAD), which is the amount at which the lender is exposed at the moment of default. To compute them, it is important to extrapolate from the pre-processed dataset, all the loans that are categorized as defaulted or similar. Both LGD and EAD do not require to be composed only by dummy variables since there is no obligation of being easy to understand. Hence, in this step, for the discrete variables can be created as many dummy variables as the number of categories and for the continuous variables, there's no need for fine or coarse classing. For the dependent variable under LGD, the model must assess the proportion of the total exposure that can be recovered by the lender once a default occurred, which is called the recovery rate. Using past datasets, its computation is simple, but defining a model to estimate it for future loans is all but easy. The LGD is characterized by lots of variables that must be assessed such as time, value, probability etc. For simplicity, using past data, all the required information, the funded amount and the amount recovered, should be available in any dataset for the LGD computation.

$$LGD = 1 - recovery\ rate = 1 - \frac{amount\ recovered}{funded\ amount}$$

On the other hand, the EAD represents the maximum amount that the lender is exposed to when the borrower defaults. The borrower may have repaid a significant amount of the debt at the time of default, so it varies over time plus, it could have defaulted only on a proportion of the original funded amount. The computation is:

$$EAD = funded\ amount * Credit\ Conversion\ Factor$$

$$= funded\ amount * \left(\frac{funded\ amount - total\ recovered}{funded\ amount}\right)$$

EL calculation, interpretation, and verification

Overall, the Expected Loss gives a holistic view of how well our model performs and highlights what kind of errors is making. Not having seen the test data during the modelling, it cannot overfit. FIs from their point of view, don’t care about the loss they’ll experience from a single borrower, it is negligible compared to their overall exposure so, it is much more important to assess the total EL across all borrowers, which is simply the sum of all ELs of all borrowers. This also is important for ESCos which exposures must be assessed altogether rather than for the single EPC-SSM contract. The role of EL is fundamental for capital reporting and the financial valuation of their activity.

It is also very important to develop few competing models, with different values, targets, and methods for every analytical solution, developed also by different competing modellers if possible.

IV. Energy Saving Insurance Scheme (ESI)

The European Union through the Horizon 2020 investment program, in 2014, has decided to promote the research and development of a solution to stimulate investments in EEP and ESP, trying to overcome the gap described in chapter one. Unfortunately, in the first phase of the research, it was hypothesized that the main causes for the underinvestment were the lack of awareness and financial instruments obtainable by enterprises and households. This prompted the program to grant subsidies for raising the overall awareness, made resources available to finance audit activities and, thanks to the collaboration of the banking sector, has supported the creation and issuance of specific green credit lines with advantageous interest rates and capital requirements. However, the effects of these policies were unsatisfactory since the barriers weren’t correctly identified, being many more and much more complex, see chapter 2.

One important element arose from the first research, companies and households have many competing investment opportunities to choose from and investing in EEP and ESP is simply one of them. Furthermore, these decisions are usually made based on a risk-return perception trade-off hence, the uncertainty on the actual economic viability of EEP and ESP projects, prevent them to consider any investment. Thus, the program concludes that was critical to focus all their activity on mobilizing the demand side rather than prompting-upside support, focusing on making these investments as easy and low risk as possible.

The most important solution was the creation of an insurance scheme, called Energy Saving Insurance (ESI), which is a particular surety bond type of insurance, including in the contractual agreement three parties: the ESCo (the promoter and developer of an EEP or ESP), the insurance company, and the investor (which could be a company, and household or a simple investor).
In detail, the ESI scheme agrees to pay any shortfall in energy savings below a pre-agreed baseline, defined with the support of engineering methods, less a deductible (either flat or flexible), or in some cases it will pay if the payback period is not respected. All this is provided in exchange for a single premium paid once in the first year of the investment, computed taking under consideration the overall savings the project has estimated will generate.
The goals of ESI are to provide guarantees to the investor, increasing the "bankability" of the project, reducing the probability of default for these types of projects for the lender (FIs or ESCos) and hopefully ramping up the attention by companies and households creating trust among the actors.
Figures 28 and 29, recalling the structure of the EPC described in chapter 3, highlight how the ESI is structured among all parties, specifying the activities and roles.

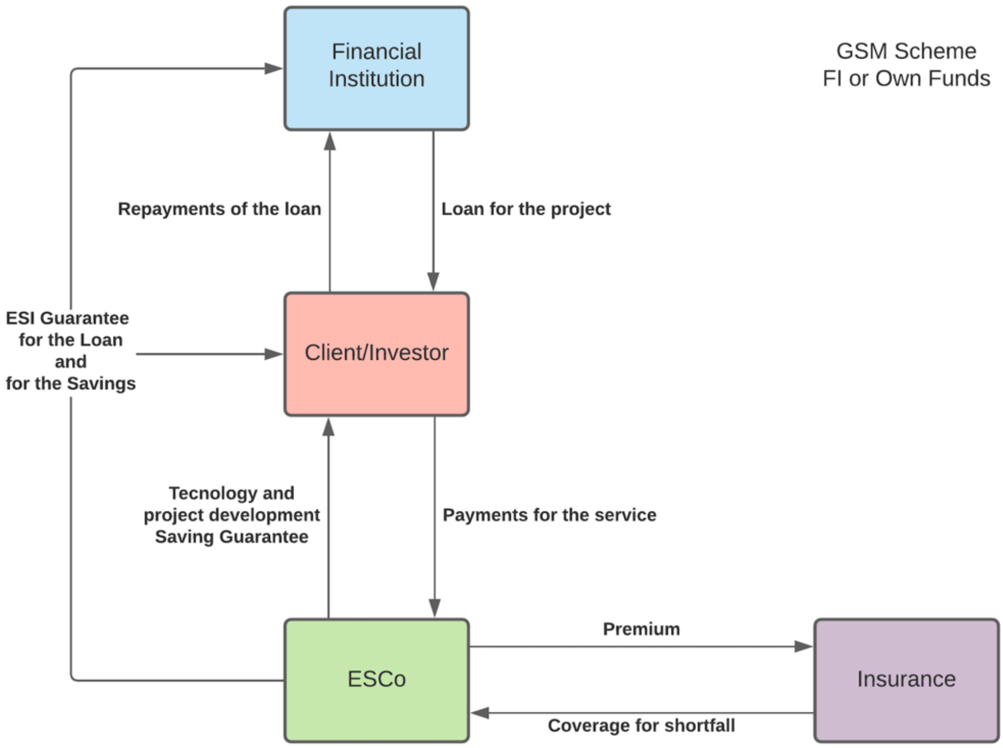

Figure 28: ESI Structure under GSM Scheme – Own Development

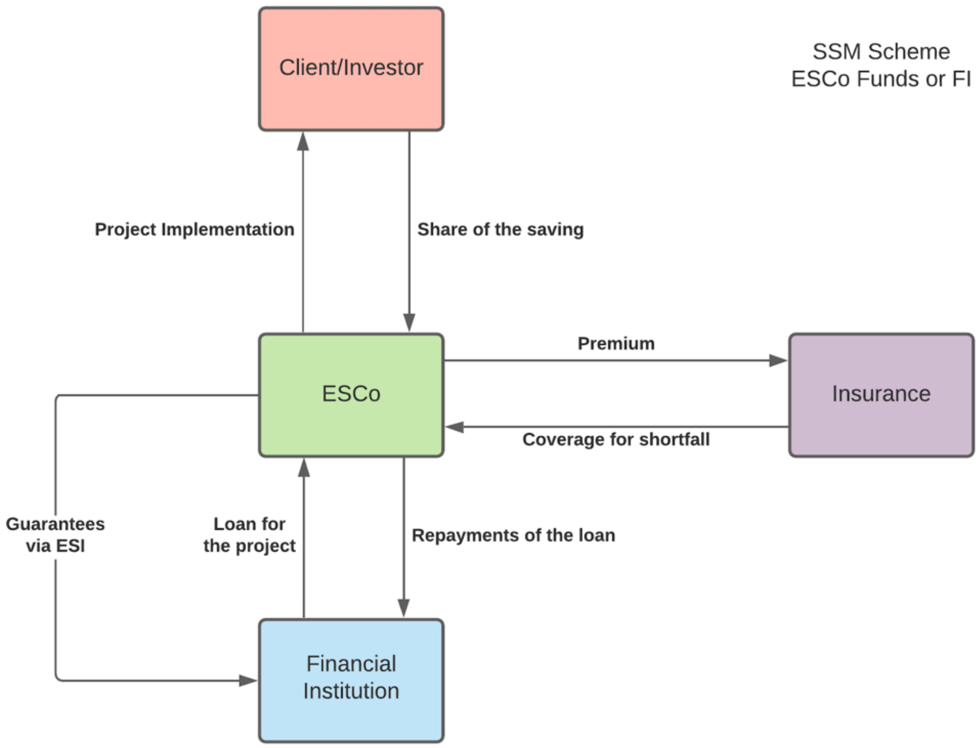

Figure 29: ESI Structure under SSM Scheme – Own Development

The ESI model includes financial and non-financial elements designed to work together and its implementation consists of 5 steps[81]:

- **Preparation Phase**, an ESCo offers a project to a potential investor, with the promised energy savings guaranteed or shared, designed taking into consideration the role of ESI elements, needed to build trust between parties and promote the investment.
- **Contract Activation,** an independent technical entity (sent by the insurance company) validates the project proposal and promised energy savings described in the project plan. The insurance provider issues the coverage by validating the project, enabling the possibility to spend this for access to a green loan.
- **Implementation Phase**, the ESCo installs the new energy efficient equipment, and the validation entity verifies and authenticates that the installation has been done following the contract.
- **Operation Phase**, with the new equipment installed, the investor must see the benefits coming from reduced electricity costs, improved energy security, better performance and higher productivity and sustainability. Maintenance services done by the ESCo ensures that the equipment is operating as expected and the efficiency generated to follow the targets (it is obliged either by the EPC and by the ESI contract, penalty the cancellation of the coverage).
- **Savings Monitoring**, the energy savings are measured and reported by the ESCo to the insurer that verifies it and, in the case that there are disagreements on the savings achieved, the validation entity steps in, and acts as an arbiter. If the realized energy savings are below the targets, the insurance will pay for the difference.
- **Insurance Coverage**, can be divided into two main components, that usually are separated into two specific contracts:
  - o Asset performance, so the ESI that covers the annual shortfall in energy savings, compared to the amount of savings insured by the policy, if due to deficiencies in the design or implementation of energy-saving measures.
  - o Material damage, covering physical damage, including breakdown, to equipment and materials installed as part of an energy-saving project to save or generate energy. Replacement of equipment is on a new-for-old basis.

[81] ESI - Europe, 'ESI: How It Works', ESI, n.d., https://www.esi-europe.org/how-it-works/.

For the insurer, the likelihood of incurring losses is reduced through various technical strategies, including:

- Engineering project design review
- Contract financials project evaluation
- Contract responsibility evaluation
- On-site inspections
- Analysis of the measurement and verification process
- Review of the maintenance scheduled process and procedures

Furthermore, contractual elements like exclusions, which are an important section in every type of insurance, aims to identify closely all the related areas or causes that could generate a loss and that will not be covered, also targeting the avoidance of “double insurance” situation. Commonly, ESI exclusions specify that the policy won’t cover any shortfall due to:

- Inadequate maintenance
- Financial default of the promoter (ESCo or the Client).
- Sabotage, misuse, or vandalism to the equipment.
- Changes in the laws or codes.
- New end-user that increases the energy use changing the project estimation plan.
- Changes in energy price (a problem that could be managed via other financial instruments - derivatives).
- The economic damages arising from environmental unsafe material released during construction or operation (usually covered by a specific pollution policy).
- Failure or malfunction of the data acquisition system.

Premiums, which for ESI are highly variable due to the number of variables to be taken under consideration, could differ from insurer to insurer but generally, they range from 0.5 to 6 per cent of the energy savings the project will generate over a period up to maximum 10 years.

One of the most structured and prepared insurance company in ESI is Munich Re that gives in its website the following example on describing how ESI works in a

real case[82]: A building where around 400 people work, has annual energy costs of €326.000. It has been constructed in the 1980s when energy efficiency was not usually high on the agenda, so the owners believed there was room for improvement. They began exploring ways to cut down consumption and brought in an ESCo, which calculated that with an investment of approximately €1.8m, up to €100.000 in energy expenditure could be saved annually – a possible reduction in costs and CO2 footprint of about 30%. Eleven energy conservation measures were implemented, including new thermal windows, heating and ventilation equipment, an upgrade of the air-conditioning system, variable frequency drives on all pumps and fans, LED lighting and lighting controls. HSB, the engineering division of Munich Re, after having assessed the project, ran its calculations, and designed a policy guaranteeing to cover the minimum annual energy savings of €80.000 over a period of five years, defined the premium of €12.000 (3 per cent) to be paid once in the first year.
It can be straightforwardly said that such a premium to insure a minimum economic energy saving of €400.000 over five years is negligible as a cost but gives an important sense of stability that otherwise, the investor wouldn't have.

Overall, the ESI provides a new method to stimulate investment in EEP and ESP, boosting demand, while boosting business and household confidence. This instrument also guarantees smaller ESCos the possibility of entering the market without having to rely on huge amounts of capital. On the other hand, larger ESCos can first self-insure against this risk and subsequently use ESI only as an alternative tool to promote their business and secure their profits. The ESI also offers an important macroeconomic advantage, being able to distribute aggregate risk over a larger pool of EEPs and ESPs than most individual providers, establishing a financial market for previously non-motorized externalities and implementing the portfolio effect in the system.

[82] Munich RE, 'Energy Efficiency Insurance: An Enabler for Energy Savings', munichre.com, n.d., https://www.munichre.com/topics-online/en/energy/energy-efficiency-insurance.html.

CHAPTER 5: THE ROLE OF BLOCKCHAIN IN ENERGY EFFICIENCY

I. Blockchain: potential application and benefits

Everyone has listened at least one time the word "blockchain" but understanding its concept is not that easy. Blockchain is a distributed ledger technology that is managed by peers on a peer-to-peer network. This technology exists without a central administrator or centralized data storage. Data could be spread across several sites and its quality is maintained by replicating and encrypting the database every time a transaction is made. The term refers to a chain of blocks where each block stores a group of information about its past, present, and will store future data. The main role of each block is to record, validate, and distribute the transactions among other blocks. Today, there are three types of blockchain[83]:

- Public, in which each participant can access the database, store a copy of the transaction, and modify it. Extremely secure as each block contain a copy of the previous transaction but, being at the disposal of everyone and having to verify and sync all the information on every node, makes the system very slow. Furthermore, over time having more and more data to store, the block size increases, requiring more resources to be processed and slowing, even more, the execution time. Its application to a widely extended network isn't optimal being very costly and energy intensive.
- Private, characterized by a central authority that manages the rights to access or modify the database, has improved security by having a limited and known group of "validators" and its development and maintenance costs are lower than a public structure. Being each node validated only one entity that must be part of that limited group of people, the system benefits from faster transaction speed and by having a built-in access control layer protocol, that allows the access of new "validators" as the system increase. A private blockchain structure is far more scalable than a public one.
- Consortium, which is a mix of the two above, having its database open to the public but not all data are accessible, and the "validators" are limited and known. The consensus process is controlled by the pre-selected nodes, where all nodes must sign every block to prove the validity of blocks. A consortium blockchain is controlled by the enterprise that has promoted the

[83] Asma Khatoon et al., 'Blockchain in Energy Efficiency: Potential Applications and Benefits', *Energies* 12, no. 17 (August 2019): 3317.

creation and has lower network congestion because only the known participants run the transactions. They have the same advantages as private blockchain and are more feasible in terms of cost but also dependent on the organizations who are collaborating as the availability of resources are subject to the different parties involved in the system.

The energy sector is in a transition phase, facing several challenges associated with the implementation of feasible energy efficiency and saving solutions that needs help to achieve its full potential. It could come from digital disruption technologies like the Internet of Things (IoT), that can automate the data capture from the source remotely (for example via smart meters or remote sensing technologies), machine learning can improve data verification, the identification of errors and prevent fraudulent behaviour (see the activity that C3.ai is doing with Enel and other utility companies[84]) and finally blockchain that automates the dissemination and synchronization of this trusted data across a network of participants and provides a tamper-resilient and immutable log[85], enabling participants to transact directly, eliminating the need for a trusted, third-party authority, and thereby eliminating the single point of control over the entire ledger, fastening the entire system. The blockchain system has been tested for various applications in the energy sector and it could provide a wide and different range of benefits as shown in Figure 30.

[84] C3.ai, 'C3.Ai - Enterprise AI for Utilities - The Case of Enel', July 2021, 3, https://c3.ai/customers/.
[85] Schletz et al., 'How Can Blockchain Technology Accelerate Energy Efficiency Interventions?'

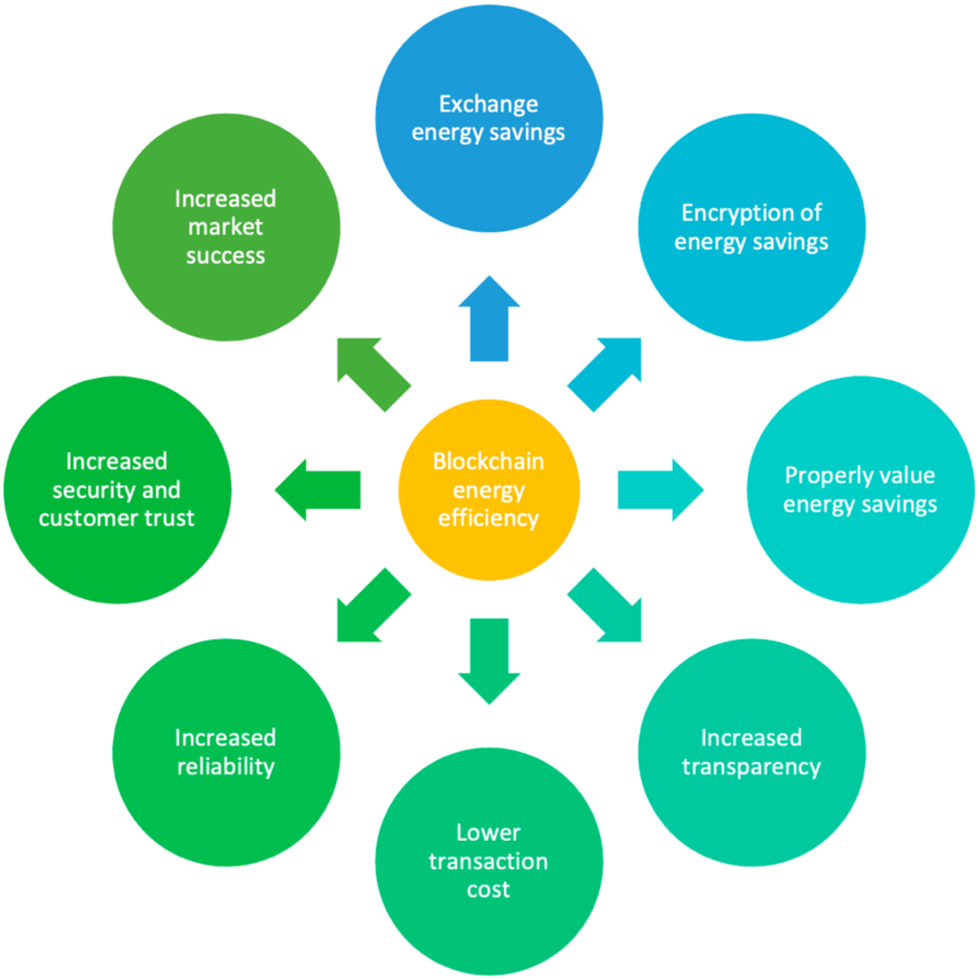

Figure 30: Benefits of blockchain in the energy efficiency sector

All these benefits associated with the implementation of a blockchain system over energy efficiency projects could help to reduce the complexity of EPC, either SSM or GSM. The American Council for an Energy-Efficient Economy (ACEEE) has highlighted how the smart contract feature, that characterize several blockchain projects, has the power to significantly reduce the transaction costs associated with these problems, improving the ability of ESCos to run simultaneously smaller projects[86]. This can help to increase the number of ESCO projects, significantly boost the total amount of EEP and ESP that can be realized. To be more "on point", the key blockchain-based energy applications that have been hypothesized and tested, also in line with this dissertation, are analysed in the following sections[87]

[86] 'How Can Blockchain Save Energy? Here Are Three Possible Ways.', n.d., https://www.aceee.org/blog/2018/10/how-can-blockchain-save-energy-here.

[87] Schletz et al., 'How Can Blockchain Technology Accelerate Energy Efficiency Interventions?'

II. Peer-to-peer (P2P) energy trading

One of the main problems affecting investment in EEP and ESP is the identification of the investor as a "prosumer" being both consumer and producer of energy during different times, depending on different variables (habits, consumption, and production patterns, etc.). Traditional energy systems are characterized by price inefficiency having their customer being charged with a single or limited multiple, fixed energy cost, although actual energy prices vary regarding demand and supply in real-time. Being also the field of prosumer very diversified regarding the type of consumption and production user and having a higher number of participants, the complexity in centralized control, management, and energy distribution increase significantly.

By enabling decentralized solutions using blockchain infrastructure, the energy production, consumption, and P2P transactions, control and management complexity should drop significantly, incentivizing investment in EEP and ESP. For the energy trading process, the security risks are fake energy bids, selling unavailable energy, a false commitment by buyers, double spending energy/money, or not delivering an already sold energy. The blockchain can enforce the terms of the contract by verifying the validity of energy bids, and that claimed energy exists before posting the sales order. After the order is settled, the smart meter receives a message from the smart contract to automatically release the energy to the buyer. Figure 31 illustrates the proposed design for a blockchain-based P2P energy trading system[88].

[88] Juhar Ahmed Abdella and Khaled Shuaib, 'An Architecture for Blockchain Based Peer to Peer Energy Trading', in *2019 Sixth International Conference on Internet of Things: Systems, Management and Security (IOTSMS)* (2019 Sixth International Conference on Internet of Things: Systems, Management and Security (IOTSMS), Granada, Spain: IEEE, 2019), 412–19.

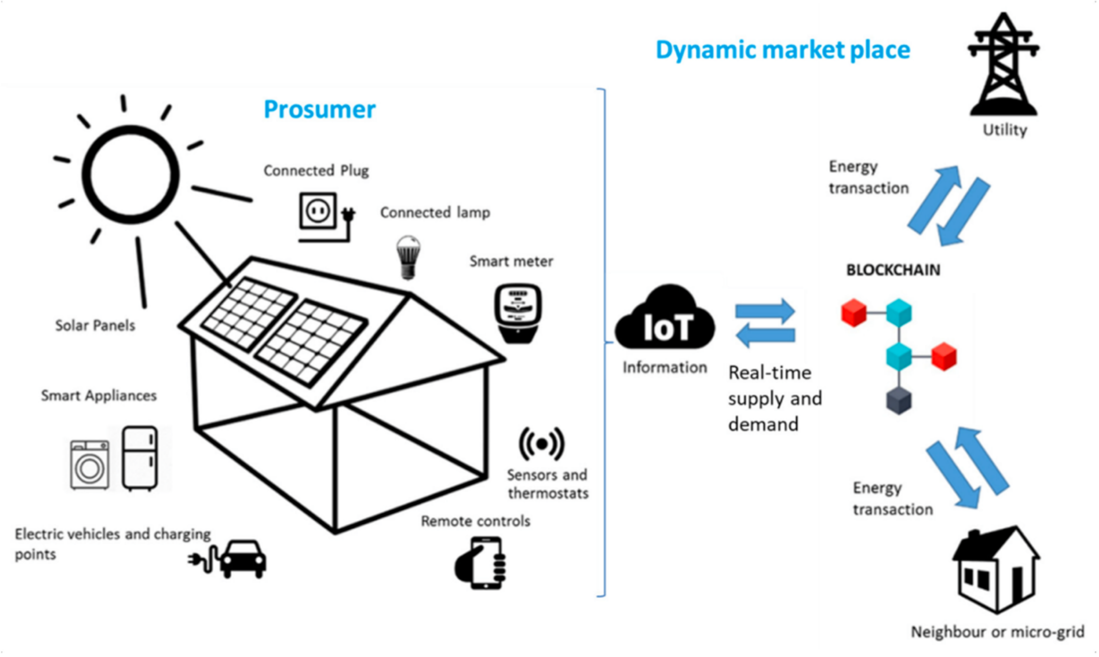

Figure 31: Blockchain-based P2P energy trading system [89]

III. Project Financing for ESCos using Token

As we have seen, ESCos operate through EPC with their customers and when the applied business solution is the Shared Saving Model, the project not only is developed and implemented but also financed by the ESCo. In the traditional model seen in chapter three, the customer does not bear any risk and benefits having invested zero in the project, on the other hand, it has to repay the installation over time using the energy savings generated. The process of raising capital for EPC is complex and risky for ESCos, thus limiting the growth of the smaller ones. When an FIs is involved, it receives a share of the payments made by the customer against the financing of the project. Unfortunately, as reported by Bertoldi et al[90] in 2017, have found that only 10% of all ESCos incorporate external financing since FIs appear to be hesitant to lending to EEP and ESP, slowing down investment in the field. In this case, a blockchain-based system can enable new financing mechanisms, enlarging the audience of possible lenders and allowing access to the global market.

[89] Schletz et al., 'How Can Blockchain Technology Accelerate Energy Efficiency Interventions?'
[90] Paolo Bertoldi and Benigna Boza-Kiss, 'Analysis of Barriers and Drivers for the Development of the ESCO Markets in Europe', *Energy Policy* 107 (August 2017): 345–55.

This aggregation of investments from different sources rather than solely FIs allows for a more efficient allocation of capital and increases inclusiveness because private investors, including retail, can directly or indirectly fund small companies, otherwise unable to access external funding (similar to crowdfunding but linked to the blockchain structure). The whole system is based on the tokenized security, which represents the legal ownership of an asset, a debt-instrument, or an equity share. Each investors receive a token that represents their share in the ESCo project (EEP or ESP), a token linked to a smart contract that communicates with a smart meter, which measures real-time energy savings. The system makes a regular transfer of money in the form of a coupon to the token owners, following contractual terms (contained in the smart contract). The bond expires when the facility owner pays the service fee to the ESCo and fully repays the initial funds received to the token owners. Being all the transactions embedded in each block of the blockchain, the whole history is traceable, secure, and tamper-proof. Figure 32 is a graphical representation of the model.

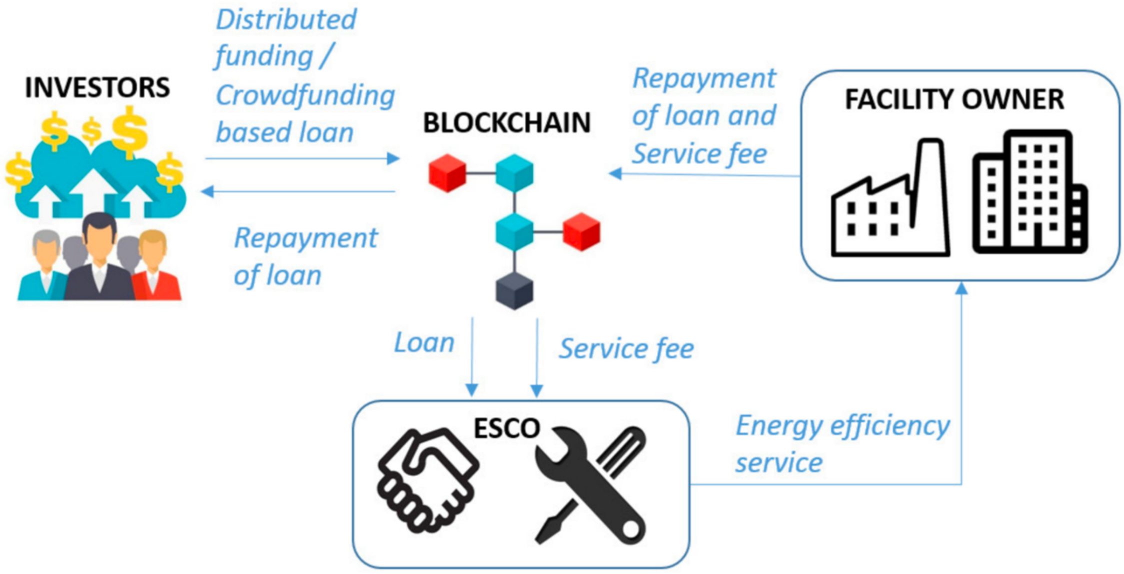

Figure 32: Blockchain-based model of operation of an ESCO

IV. Application to existing Energy Efficiency Obligation Scheme: The Italian White Certificates

As mentioned in chapter three section five, following EED at Article 7 Europe has required to define Obliged Parties the achievement of at least 1,5% of energy efficiency compared to sales YoY. Member States, to comply with this Directive, have taken a variety of solutions, one of which is the introduction of a White Certificate Scheme (WhC). The Italian design is probably the most successful and long-life program, setting an obligation to electricity and natural gas operators, that have more than 50,000 customers, to achieve the annual energy saving target either by implementing energy-efficient solutions among end-users and/or by buying WhC from other. There most significant problem the current procedure is facing regards the issuance and trading system for WhC. First, the lack of quality information on this instrument prevents investors from conducting a proper analysis of potential revenues from WhC sales, being the market illiquid, discontinued and governed by huge entities (see all the problems encountered along years and the price movements in chapter three). Second, the costs associated with the centralized information's collection, assessment, and control needed for the issuance of each WhC are high. And finally, the high fraud risk associated with WhC issuance and the current trading structure. In Italy, as described above, during the period 2017-2018 a WhC fraud with a provisional value of €700 million was discovered, of which €105 million were already obtained by requestors. The present system requires trust between operators and poses the risk of outages and data losses[91].

Blockchain-based systems deliver a trustworthy database for all parties with characteristics such as data integrity, availability, accessibility, efficient reading, and immutability. Furthermore, the ability to associate to the smart contracts an IoT device, like a smart meter, allows for continuously energy consumption collection and automatic WhC generation, all based on the energy savings calculated from the data collected compared to the energy consumption baseline. Unfortunately, IoT devices are currently costly, and their application can be limited by a lack of skilled people and limited internet access in rural areas. Furthermore, smart meters are currently not 100% secured against manipulation, making further development a necessity. Figure 33 shows how the system should work.

[91] Schletz et al., 'How Can Blockchain Technology Accelerate Energy Efficiency Interventions?'

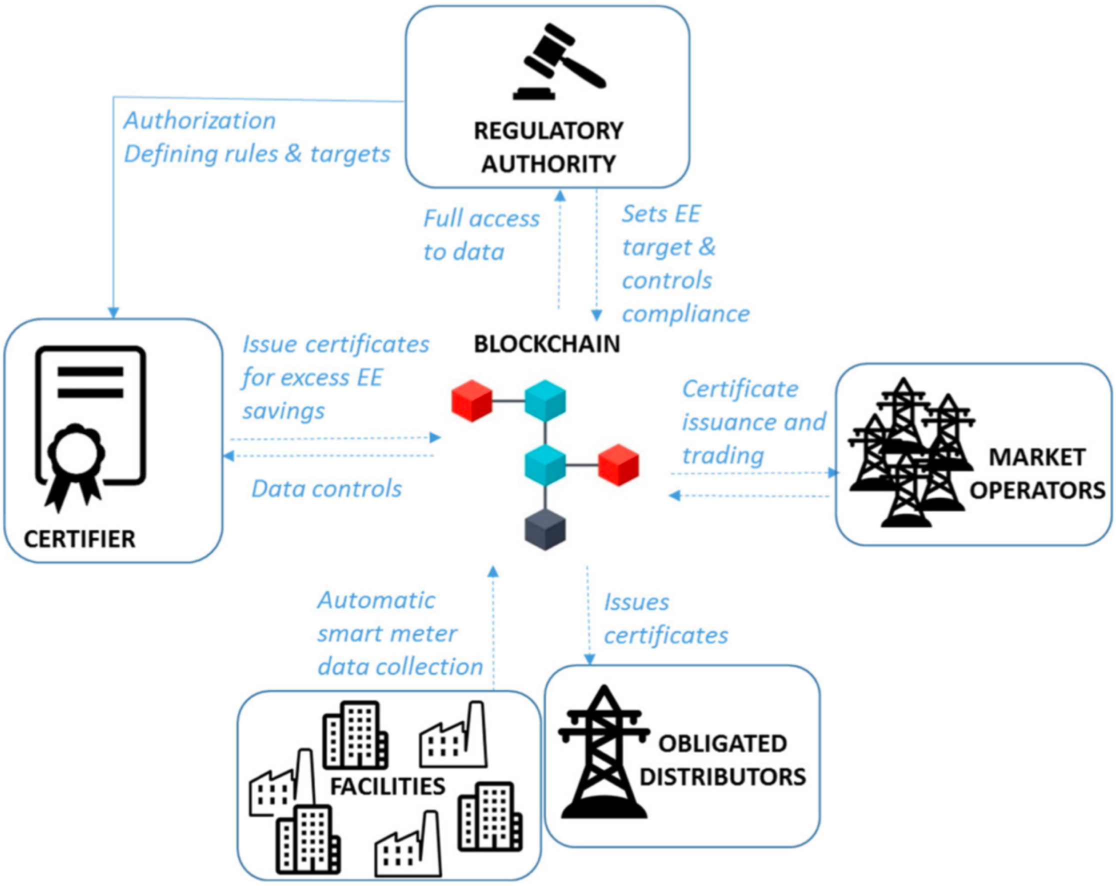

Figure 33: Blockchain-based model of a national WCS

CONCLUSIONS

Over the past decade, energy consumption has increased exponentially around the world due to an ever-growing population and the overall improvement in living standards, contributing significantly to climate change and the extreme consequences on our environment. The continuation of this trend, however, must necessarily review how society impacts the world, seeking first of all the improvement of productivity and living style while reducing energy consumption. This can only be achieved through the implementation of all available and innovative solutions in the field of energy efficiency and energy saving. Throughout the thesis, the theme that accompanied each chapter was the deep exploration of all the non-technical variables and all the subjects involved in the implementation of EEP and ESP, pursuing clarity and a logical thread.

The role occupied by the policymakers and international institutions is to stimulate the level of investment by increasing the focus and support of EEP and ESP. Both private and public sectors need to understand the dynamics underlying the barriers that influence the level of investment, their correct identification as well as the possible combinations and interactions between them. These are key steps in the development of solutions that allow their overcoming and the increase of investments in the sector. For example, let's take all the cultural and behavioural impediments analysed, the only possible way to overcome them is the development of a holistic approach by the legislator, an approach that includes programmed information towards all actors in the sector (from consumers to investors and companies) and the design of effective policies using common concepts of psychology and behavioural science. ESCos are the closest partner, knowing the basics of their activity and all the alternative and innovative measures and tools available is essential to capture all the potential at their disposal, also allowing a correct measurement of the overall impact achieved and the quantification of the achievable one. Over time their activity has been measured, with some difficulty, and all studies have shown an overall reduction in energy consumption against an increase in total production, having a long-term effect of efficiency achieved by more than 20 per cent, in line with the objective defined in the EED and the Paris Agreement. Unfortunately, this is not the same for developing countries. The world needs a strong response and change at the international level. The recent and increasingly visual effects of climate change and the prospect of missing the targets for 2030 require that the next meeting of the COP, the twenty-sixth, must be characterized by a renewed commitment by all states to collaborate in the realization of all those crucial initiatives to accelerate decarbonization, putting energy efficiency and investment in the sector first, both in developed and developing countries. Looking in-depth at the business model of ESCos, the most important element that prevents them from growing rapidly, to be addressed internationally, is their limited financial capacity to support the market. Having limited resources and facing the risk of default, when operating as a project financier, requires the intervention of governments and international agencies, the only subjects able to provide financial guarantees and tools necessary for the strengthening and acceleration of their growth. About the banking system and its role, one of the main problems related to the provision of funds for EEP and ESP projects, and therefore indirectly affecting the activities of ESCos. It is mainly due to the difficulty of collecting data[92] and quantifying their risk via the development of a credit risk model. Treaties such as Basel Accord II and capital requirements, significantly limit their ability to lend to all those activities that fall outside their remit. In addition to the mere data on loans destined for the sector, the banking system without an adequate national and international database structure is not able to collect all that non-bank information such as energy efficiency, energy consumption or information on the value of the property, fundamental for a correct understanding of the market as well as the development of risk forecasting models, further limiting their predisposition and lending capacity. Furthermore, the evaluation of EE and ES projects in different countries does not have common quality standards, and in general, project data is complex, opaque, and non-standardized. Therefore, the need for worldwide harmonization of norms and standards, to make them comparable, measurable, and useful, is more than crucial for achieving the goals that the international community has set. The representation of data could be a solution, in fact the identification of a substitute would allow credit institutions to create these new risk management models necessary for correct financial coverage. On the other hand, however, this solution could also bring with it other possible prejudices such as the inability to correctly assess the risk profile of the borrower who is looking for a dedicated EEP or ESP loan or the generation of a false sense of risk control.

I think that we cannot only count on public intervention, the need for a revolution goes beyond individual laws or conventional instruments, necessary for the expansion of a market so fundamental for the fight against climate change. Innovative tools such as blockchain, described in chapter five, would allow the solution of many of the barriers identified upstream. The transition to an intelligent and interconnected network of prosumers (individuals who are both producers

[92] Monica Billio et al., 'D6.3 - Technical Report on Risk Management Analysis.Pdf', Technical Report (EeMAP, May 2019).

and consumers), supported by the activity of specific entities such as ESCos, requires the implementation of these new technologies, capable of correctly measuring the targets reached, generating fundamental data for the realization of probabilistic models as well as bringing awareness among citizens and businesses. There are still challenges around the technology itself such as scalability, performance level, standardization of procedures and metrics, management of complexities, the actual impact on current costs but above all the current lack of professional figures capable of making them operational. Despite this, several pilot projects have been launched in recent years to test the blockchain in the management of energy efficiency in all its aspects. Recently I became aware of a project carried out by a team of Italians, assisted by the support of Steve Wozniak (co-founder of Apple) called EFFORCE. Their goal is to develop the first blockchain-based energy-saving platform that would allow contributors to benefit from the energy savings generated by EEP and ESP worldwide. Contributors can participate in the project development by acquiring tokenized future savings while companies will benefit from energy efficiency improvements at no cost, having the resulting savings written in real-time on the blockchain. A smart contract redistributes the resulting savings to token holders and the companies without intermediaries based on exact consumption/savings data. This project, still in the start-up phase, clearly suggests the potential of the technology and the significant research work that has yet to be carried out.
If technologies and projects like these have the potential to positively disrupt the energy efficiency market, it is necessary for future policy and regulatory models to adapt quickly, allowing for faster development of the energy efficiency market.

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IMAGES

TABLES

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