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Use of Vanadium based redox flow batteries to store electricity from renewable sources in buildings - Application of the Danish business model in Portugal

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Internship report

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Abstract

The damage caused by greenhouse gases from fossil fuel consumption generates bigger environmental concerns, in response the EU has set ambitious targets such as decarbonization, triggering the energy transition. However, power generation through renewable sources has some problems such as intermittency and variability, electricity storage is partly a solution.

There are several types of batteries for storing electricity, however, they need to be efficient, affordable, safe, and environmentally friendly throughout the entire life cycle, therefore, vanadium redox flow batteries emerge as an excellent and promising option.

Buildings represent a significant part of energy consumption and GHG emissions, they are also an important part of the EU's drive for energy efficiency improvements, and electricity storage systems could be key in this regard.

Prosumers are growing in number and relevance to electrical systems. Having solar photovoltaic panels with vanadium redox flow batteries, attached to their homes to generate and store energy, they can have even greater contribution to the grid, stabilizing the electrical system with the balance between supply and demand. These batteries assist the energy transition by focusing on decarbonization, while ensuring energy quality, management, and security.

The batteries are already used in Denmark, especially in condominiums and off grid sites, country where investment and government support for renewable energy has been considerable, allowing the development of these technologies.

Portugal, with excellent solar exposure, is a potential market for increased energy production and storage. The main objective of this internship is to apply VisBlue's business model in Portugal, especially for the residential segment such condominiums, verifying the existing legislative framework, understanding what the main limitations and barriers are, as well as an analysis of the knowledge and receptivity by companies in the construction and solar panel installation sectors.

Keywords: Electricity Storage Systems; Batteries legislation; Household energy consumption; Energy storage solutions; Vanadium redox flow batteries.

Resumo

Os danos provocados pelos gases de efeito de estufa provenientes do consumo de combustíveis fósseis geram maiores preocupações ambientais, em resposta a UE definiu metas ambiciosas como a descarbonização, despoletando a transição energética. No entanto, a geração de energia através de fontes renováveis tem alguns problemas como a intermitência e variabilidade, o armazenamento de eletricidade é parcialmente uma solução.

Existem diversos tipos de baterias para armazenar eletricidade, contudo, é necessário que estas sejam eficientes, acessíveis, seguras e ambientalmente corretas durante todo o ciclo de vida, portanto, surgem as baterias de escoamento *redox* de vanádio como uma excelente e promissora opção.

Os edifícios representam parte significativa dos consumos energéticos e de emissões de GEE, são também parte importante na tentativa de melhorias na eficiência energética por parte da UE, e os sistemas de armazenamento de eletricidade poderão ser fundamentais neste aspeto.

Os *prosumers* estão em crescimento passando a ser relevantes para os sistemas elétricos. Tendo painéis solares fotovoltaicos com estas baterias, acopladas às suas habitações a gerar e armazenar energia, conseguem ter maior contribuição para a rede, estabilizando o sistema elétrico com o equilíbrio entre oferta e procura. Estas baterias auxiliam a transição energética focando na descarbonização, assegurando ainda a qualidade, gestão e segurança energética.

As baterias já são utilizadas na Dinamarca, especialmente em condomínios e locais sem ligação à rede elétrica pública, país onde o investimento e apoio governamental para as energias renováveis tem sido considerável, permitindo que haja desenvolvimento destas tecnologias.

Com excelente exposição solar, Portugal é um potencial mercado para produção energética e respetivo armazenamento. Este estágio teve como principal objetivo, aplicar o modelo de negócios da VisBlue em Portugal, especialmente para o segmento residencial (condomínios), verificando o enquadramento legislativo existente, percebendo quais as principais limitações e barreiras, para além de uma análise do conhecimento e recetividade, por parte das empresas dos setores da construção e instalação de painéis solares.

Palavras-chave: Sistemas de armazenamento de eletricidade; Legislação sobre baterias; Consumo doméstico de energia; Soluções de armazenamento de energia; Baterias de escoamento *redox* de vanádio

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Abbreviations

BTM - Behind-the-meter

BTMB - Behind-the-meter batteries

DHW - Domestic Hot Water

ESS - Electricity Storage Systems

EU - European Union

EVs - Electric Vehicles

FTM - Front-of-the-meter

GHG - Greenhouse gases

ID - Identification

IPCC - Intergovernmental Panel on Climate Change

LCOE - Levelized Cost of Energy

LCOS - Levelized Cost of Storage

NZEB - Nearly Zero Energy Building

PV - Photovoltaic

R&D - Research and Development

RE - Renewable Energy

RED - Renewable Energy Directive

REDII - Recast Renewable Energy Directive

RES - Renewable Energy Sources

ROI - Return of investment

V2G - Vehicle to Grid

VRES - Variable Renewable Energy Sources

VRFB - Vanadium Redox Flow Batteries

ZBFB - Zinc Bromine Flow Batteries

1. Introduction

Electricity is considered a key asset in modern economies, because our society is extremely dependent on this utility, both for the lifestyle and comfort that it provides, but also for the correlation that it has with the economic development of the different countries around the world, that rely on energy to work. (Hirsh & Koomey, 2015; Yan et al., 2020) Electricity assumes a more important role in a domestic context, since nowadays we are totally dependent on it. The number of electronic devices and appliances in a regular household is increasing, even though appliances are becoming increasingly efficient. The preferences among users, is to get larger screens with higher resolution, and constant internet connection, sometimes even within devices, resulting in a high demand for electricity from commonly connected devices. Battery charging devices like smartphones, tablets, smartwatches, and other kinds are proliferating, giving a rise to the plug-load devices. Moreover, simultaneously, the majority of electrical household consumption occurs during peak hours, when electricity has higher demand, and in that way it is usually more expensive in the electricity markets. (Fernández et al., 2020)

Demographic growth and increasing prosperity in developing countries mean that there is a greater energy demand, while energy consumption in the developed world is decreasing due to improvements in energy efficiency. The projected China's rapid slowdown in energy demand is also being helped by energy efficiency, and from a continuous change in the composition of the economy, shifting away from energy-intensive industries. (BP, 2020)

Since the first warning, still in 1990, the scientific community has been raising a high level of alarm about the consequences of the increase in the concentration of greenhouse gases (GHG) in the climate system. (Houghton et al., 2001; Intergovernmental Panel on Climate Change (IPCC), 2007) The impacts of carbon emissions in the atmosphere caused by the usage of fossil fuels have become more commonly acknowledged. Jointly, with the relative price trends of a variety of energy sources, we have two of the main elements in promoting renewable energy (RE) production. Since these concerns with the environment have risen, goals are defined, and protocols and directives are created within the European Union (EU), to be applied between different Member States, to evolve in a "greener" sense. The kick-off was given, and we are now experiencing a new and necessary energy transition.

RE is an important player in climate change mitigation and energy transition, with the energy demand growing in the next few years, because energy can be produced without emitting GHG. (Gallo et al., 2016; Yuan et al., 2018) Besides helping to mitigate climate change, renewable energy sources (RES) increase energy security by providing a resource that is abundant, diverse, and native, without the need to be imported and without the possibility of depletion and additionally provide local and regional employment by creating opportunities in the energy industry (assembly, installation, and maintenance). (Azretbergenova et al., 2021; Kumar, n.d.; Negro et al., 2012; Oliveira et al., 2013)

Even though, there are disadvantages, for instance RE generation being intermittent, since it is dependent on the weather and daylight. In that way, intermittency and variability are the main cons of it, because ensuring the instantaneous match between demand and supply in the electric system could be difficult. (Bianco et al., 2019; Van der Welle & De Joode, 2011)

Adding to the decarbonization that is already occurring in the electric system, there are two main challenges that the electricity industries are facing due to a large penetration of RE, characterized by intermittency. (Yan et al., 2020) As stated by (2011, Energy Policy, p. 39, Van der Welle & De Joode) *"firstly, power flows in networks will become more variable as a result of the increase in generation variability. Besides, more power will be fed-in the grid at lower voltage levels ('distribution grid'), sometimes exceeding demand and implying upward flows to higher voltage levels ('transmission grids') for transportation of electricity to other load centers. Secondly, when the RES penetration reaches substantial levels, the intermittent power supply implies an increase in the need for balancing power, and more variability in market prices"*. However, these problems can be solved, to ensure energy supply security and avoid blackouts, the use of electricity storage or the complementary use of fossil fuels is necessary. (Bianco et al., 2019) Therefore, electricity storage comes as an important driver to carbon neutrality, since it is the best solution to provide a constant energy flow, satisfying the demand, while not emitting GHG, since it does not rely on fossil fuels to be powered. (de Sisternes et al., 2016)

1.1. Projections for the future

According to the analysis of BP Outlook 2020, until 2050 fossil fuels will be present in the best and worst scenarios[1], being used on backup thermal power plants. Forecasts point to an increasing global energy demand by 2050, due to increasing prosperity and better living standards in countries that are now under development. (BP, 2020)

The energy demand is likely to evolve over the next few years, fossil fuels demand will most likely decline, and the share of renewables will grow. As the consumption shifts away from fossil fuels, bioenergy might have an important increase. Electricity in final energy consumption becomes more important in the next 30 years. (BP, 2020)

Natural gas could play a key role in the rapid transition to a low carbon energy system. Beyond being considered a (near) zero-carbon power when combined with carbon capture and sequestration, it can support the shift away from coal in developing economies, while not neglecting the electricity demand in fast growth, since renewables and other non-fossil fuels possibly will not be able to meet demand to replace coal. (BP, 2020)

In the Net Zero scenario it is stated that a combination of batteries, pumped hydroelectricity and demand-side responses can be the answer to power systems with intermittency caused by the domination of wind and solar generation, within short-duration and high-frequency balancing, lasting from a few seconds to a few hours. (BP, 2020)

The Bloomberg New Energy Outlook 2020, projects in both scenarios[2], that global power sector emissions do not return to the existing levels before the Covid-19 pandemic.
In the Economic Transition Scenario, it is projected that the supply of 56% of global electricity in 2050 will be wind and photovoltaic (PV). Moreover, over the next 31 years, cheaper solar, wind, and batteries will generate a ten-fold rise in variable renewables production. Over the same period, fossil fuels account for only 24% of total generation, down from 62% now. (BNEF - Bloomberg New Energy Finance, 2020) The Figure 1 shows the global installed capacity mix of 2019 and the projection for 2050.

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[1] BP Outlook 2020 projects 3 scenarios to explore the energy transition to 2050 based on CO_2 emissions from energy use: Business-as-usual, has the highest CO_2 emissions, Rapid has substantially lower CO_2 emissions being in the middle, and at last, Net Zero with the lowest CO_2 emissions of the three scenarios.
[2] The Bloomberg New Energy Outlook 2020 creates 2 scenarios the Economic Transition Scenario, this scenario does not consider climate targets or aspirational national energy policies, and the NEO Climate Scenario, meets an emissions budget that is well-bellow two degrees.

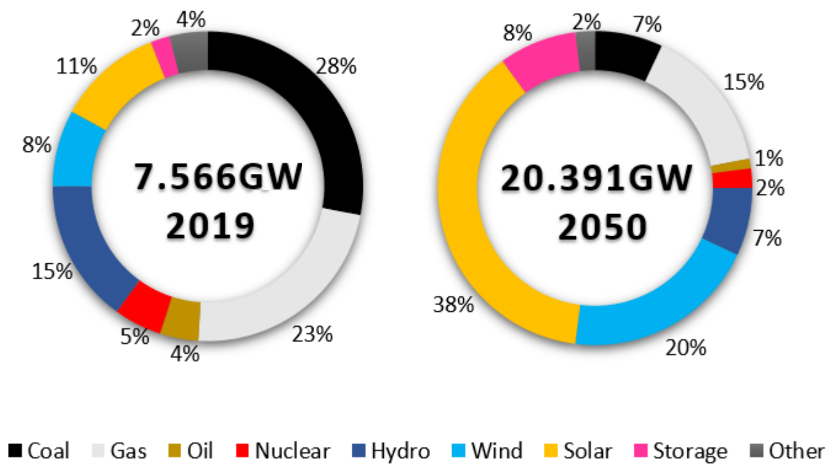

Figure 1 - Global installed capacity mix, 2019 and 2050
Source: Author elaboration based on BloombergNEF (2020)

Due to multiple trends combined in the global electricity system, a new architype of inexpensive, but inflexible, bulk RE will emerge, underpinned in flexible demand, batteries, peaking power plants, and conventional, large fossil-fuel plants running at low-capacity factor, and other dedicated flexible units. (BNEF - Bloomberg New Energy Finance, 2020)

In most markets, cheap renewables and batteries appear to have reached an economic limit of 70% to 80% penetration in most markets. This is the outcome of two dynamics, the first, renewables reducing existing coal and gas plant run-hours, removing the most expensive mid-merit generators from the market, and making the next MW of renewables marginally less viable. The second reason, when there are appropriate conditions, renewables are generating energy at the same time, with that, each subsequent plant tends to raise fleet-wide curtailment at high penetration, lowering capacity factors and weakening the economics for the following plant. (BNEF - Bloomberg New Energy Finance, 2020)

Through synergies with increasing battery demand for electric vehicles (EVs), storage batteries will become less expensive in the future. In sunny areas, batteries coupled with PV, take advantage of the hours of highest energy production and lowest consumption to use this stored energy after sunset. This takes place in areas where alternative types of peaking capacity are costly and wind resources are very seasonal. Up to 2030, battery demand reaches 2TWh, being that demand 230GWh in 2019. By 2050, there will be roughly 4.500GWh of storage available for load shifting. (BNEF - Bloomberg New Energy Finance, 2020)

The Economic Transition Scenario also predicts that around $15.1 trillion are going to be invested in additional power capacity until 2050, being 8% of this value allocated to storage and 73% is going to renewables. While, the NEO Climate Scenario, projects that the investment needed to expand and decarbonize the power system staying on track for a warming below 1.75 Celsius degrees would require almost the double of the Economic Transition Scenario, with around $35.1 trillion. (BNEF - Bloomberg New Energy Finance, 2020)

1.2. Motivation

Decarbonization, decentralization and digitalization still have a lot of problems to be solved and electricity storage systems (ESS) are part of the answer and have an important role in this energy transition being essential to achieve a carbon neutral economy.

Since the main objective of this report is to apply in Portugal, the business model that VisBlue has in Denmark especially for condominiums, it is important to know which legislation coincides between the two countries and whether the use of this business model, and expansion of the company and product to a new market is then feasible or not, understanding which barriers are in the way and the receptivity of the technology by companies in the construction and PV installation sectors.

When introducing innovative technologies to a market there is the need for a regulatory framework to ensure that there is no market failure. The entry of this product into the market is important because the application of this technology will optimize energy efficiency, reduction of household energy consumption and solve part of the problems and challenges that the electricity system is going through.

Such a relevant topic for the future of our planet and society, I think this research is essential not only for the company that I am working for, since it can get to broader markets and if applicable the Danish business model of VisBlue especially for condominiums, probably will have more efficient results, since in average there is more sunlight exposure in Portugal throughout the year. With that, solar panels coupled with VRFB in buildings located in Portugal may reach good results. This research is also important for all the sectors that will be impacted by this, from construction to electricity, and the environment in general.

2. State of the art

2.1. Current panorama

2.1.1. Danish scenario

Danish energy and climate policy established a long-term goal, until 2050, the total energy demand must be covered by RE. In June 2018, the Danish Parliament settled an agreement, setting new targets for 2030, towards the goal of achieving a zero-carbon, fossil-fuel independent society by 2050. By 2030, 55% of Denmark's primary energy supply is expected to come from RE, it is specified that RES are going to cover all final electricity consumption. (OECD, 2019)

Household energy consumption is enormously dependent on the climate, and since Denmark is located in Scandinavia, it has harsh winters and reduced sunlight exposure during this time of the year. The sun hours of these Danish cities were selected in the Figure 2 because Copenhagen is where the first NZEB that has VisBlue batteries is located, Aalborg was also selected because it is the nearest location with data near the Livø island where there are VisBlue batteries installed as well.

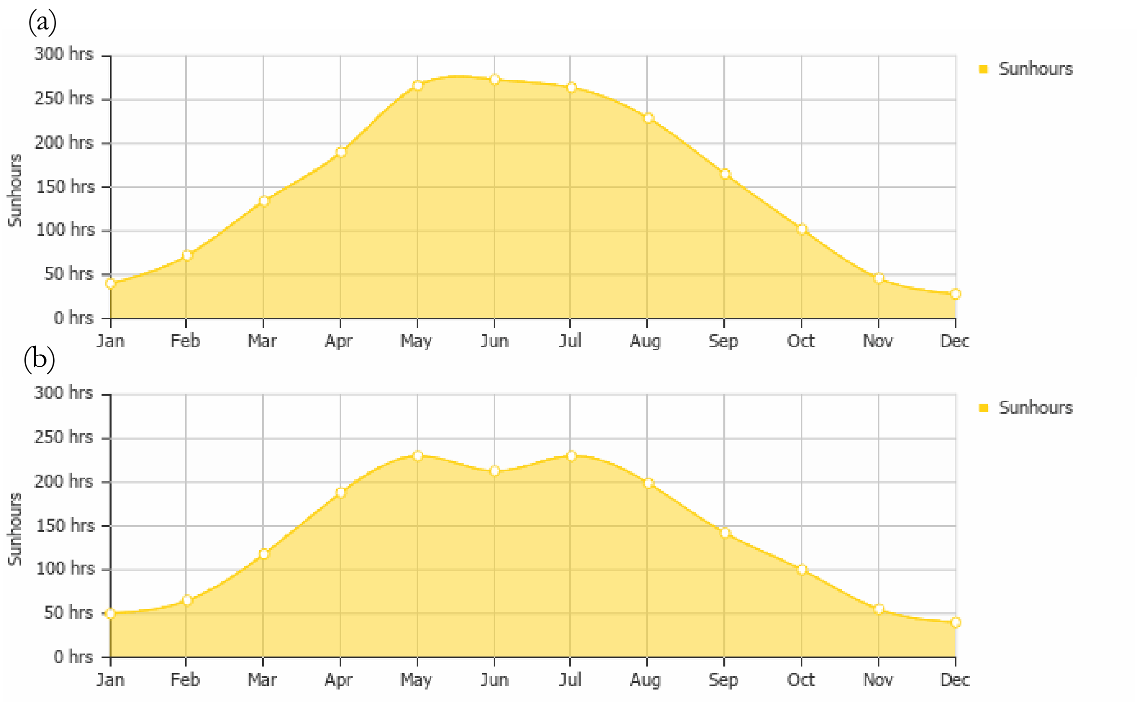

Figure 2 - Average monthly sun hours in Denmark
Graphic (a) corresponds to Aalborg and (b) to Copenhagen.
Source: weather-and-climate.com

In 2017, in Denmark, the domestic electricity consumption accounted for a share of 31.6% of the total electricity consumption, and RES generated 70.6% of the total electricity production. Projections state that by 2030, 100% of electricity will have a source of RE. (Trotta, 2020)

Domestic electrical appliances are expected to grow, in number and consumption with a rate of 2.3% and 0.3%, annually from 2017 to 2030, respectively, according to the Danish Energy Agency. Furthermore, EVs sales are increasing and are expected to account for 22% of the total sales of new cars by 2030. The electrification of the heating sector united with the larger heated floor area, will create a bigger stress to the grid. (Trotta, 2020)

In 2018 Danish households were responsible for the third biggest share of CO_2 emissions from end-use energy with a share of 18.7%. For the same year, the residential sector has the second biggest share for both final energy consumption and electricity consumption with climate adjustments. (Danish Energy Agency, 2018)

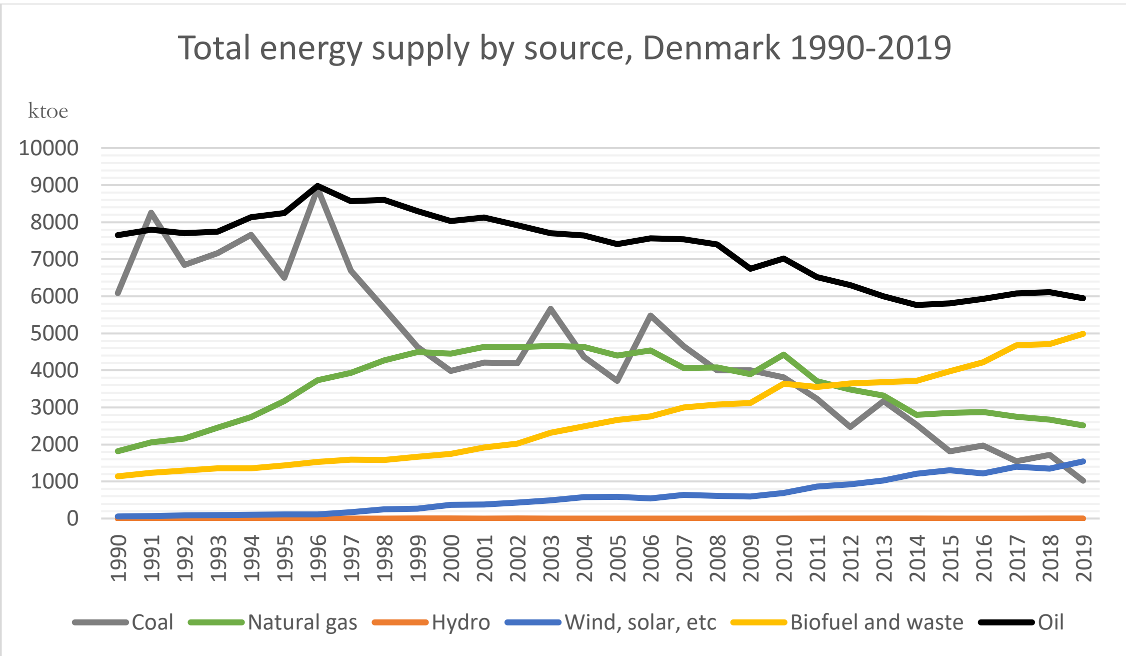

Figure 3 - Total energy supply by source in Denmark from 1990 to 2019
Source: Adapted from IEA (2020)

As it can be seen in the Figure 3, in 2019, according to IEA, approximately 59% of the energy mix of Denmark are fossil fuels with the biggest share being oil with roughly 37%, natural gas around 16% and coal about 6%. Nearly 41% of the mix come from RE, with the biggest share being biofuel and waste with around 31% and wind and solar representing almost 10%, hydro is only a small part being almost irrelevant in the total. (IEA, 2021)

The share of RES in total primary energy supply in 2017 was 35% while the share of RES in electricity production for the same year was 71%. (OECD, 2019)

2.1.2. Portuguese scenario

Even though the EU defined minimum targets for the decentralization and decarbonization to 2030, Portugal through the 2030 National Climate and Energy Plan has defined even more ambitious targets with a GHG emission reduction of 55%, energy efficiency growth of 35%, RE penetration of 47% and constructing new electricity interconnections 15% in comparison with 1990. (Bernardo, 2018; Gunst et al., 2020)

Mainland Portugal has good solar exposure in comparison with other European countries. This is an advantage in this market since PV production relies on it. The Figure 4 shows the sun hours in 4 different cities in Portugal. These cities were chosen because Lisbon and Porto are the two biggest metropolitan areas, being the biggest markets, Beja being one of the best places for PV production in the country and Ponta Delgada in Azores appears as a good business opportunity for VisBlue.

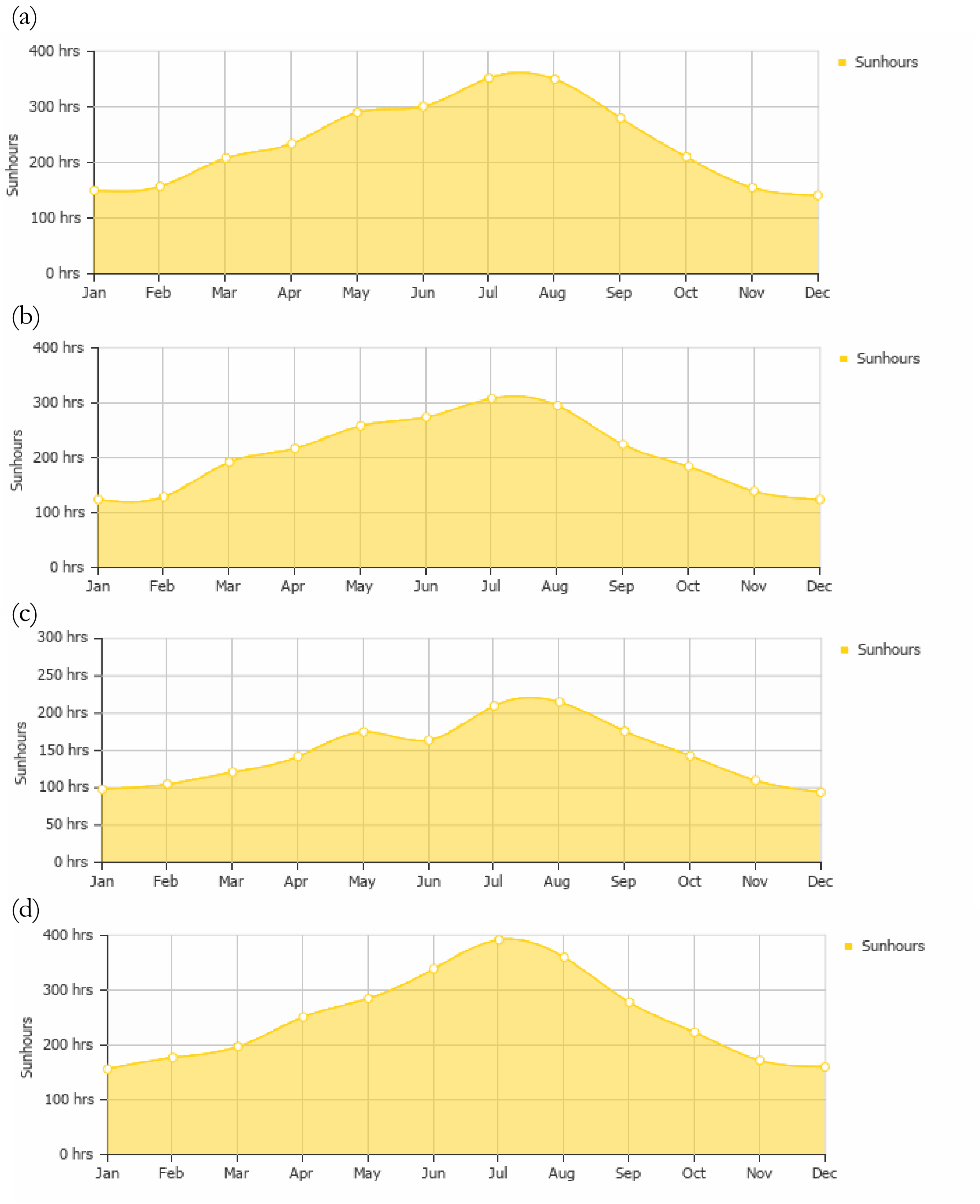

Figure 4 - Average monthly sun hours in Portugal
Graphic (a) corresponds to Lisbon, (b) to Porto, (c) to Ponta Delgada and (d) to Beja.
Source: weather-and-climate.com

In Portugal, the residential sector is responsible for the third biggest share of energy consumption according to data from 2016. For that same year, when it comes to electricity consumption, the buildings sector led with a 60.3% share, which 27.7% are correspondent to the residential sector. It is noteworthy, that the residential sector is responsible for 43.6%

of electricity energy consumption followed by RE consumption with 31.2%. From 2000 to 2015 the overall energy efficiency grew 1.9% per year in Portugal, this happened because of improvements in the major sector, residential, manufacturing and transport, with the residential being the one with the bigger growth rate per year, estimated to be 2.5%. (ADENE – Agência para a Energia, 2018)

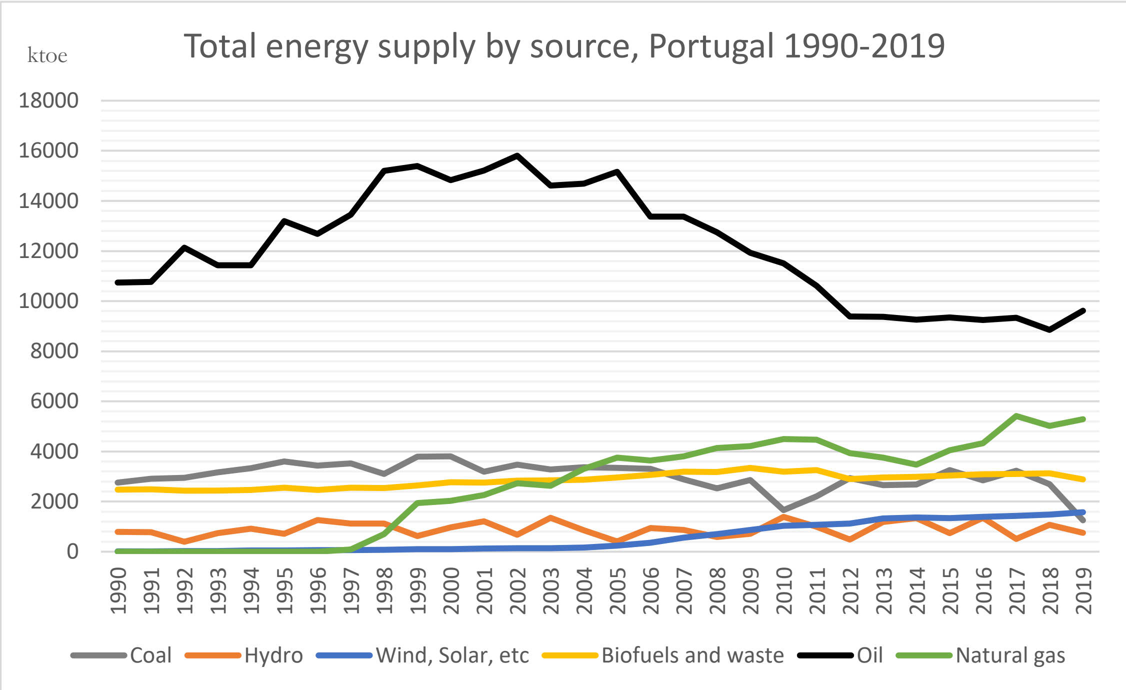

Figure 5 - Total energy supply by source in Portugal between 1990 and 2019
Source: Adapted from IEA

As it can be seen in the Figure 5, the Portuguese energetic mix is composed mainly by fossil fuels approximately 76%, being oil the biggest portion with almost 45%, followed by natural gas with nearly 25% and coal at just about 6%. The other portion of the mix is composed by renewables, being the larger part of it biofuels and waste with around 13.5%, next are wind and solar with just about 7% and at last hydro with roughly 3.5%. (IEA, 2021)

2.2. New trends in the electric systems

Furthermore, we can verify new trends that might change the electricity system panorama. Driven by sustainability concerns, the electricity sector is undergoing a transition, to the biggest share of RE production. Firstly, the primary concern was research and policy, in order to make RES reach technical and economic viability, a political move was key to achieve the decarbonization of the electricity systems. This decision made the electrical companies turn their investment with the help of governmental funds to VRES. Nowadays, the electricity sector is experiencing a different situation, renewables are diffusing quickly in the electricity grids, triggering major changes. Existing technologies, organizations and infrastructures are subjects of a complex interaction of manifold technologies, causing a decline of established technologies and business models, an intensification of economic and political difficulties within utility companies and industry associations, major challenges occur, jeopardizing the general functioning and performance of the electricity sector. (Arbabzadeh et al., 2019; Markard, 2018; Pollitt, 2019; Siksnelyte & Zavadskas, 2019)

Other turning point is the growing interest in local renewable generation, in other words, decentralization of electricity generation, and energy independence is increasing among household electricity end users. Prosumers of electricity are now emerging at a fast rate in different parts of the globe, bringing a change of behavior and role from the consumers. (Ajanovic et al., 2020; Heinisch et al., 2019)

Digitalization is undergoing rapidly and will lead the electricity system to the use of smart grids and increased flexibility. (Bloomberg New Energy Finance, 2017) Demand use is changing and evolving, the efficiency and performance of electrical appliances is advancing, EVs are rapidly spreading, electric mobility is no longer a fantasy and urban heating is still an important question to be solved, especially in countries where winter is harsher. Electricity storage might be once again a solution for urban heating, for instance, in a building with a PV system attached to it, electricity can be stored in off-load hours and used to produce heat during peak hours. (IRENA, 2017)

These changes and developments make the electrical systems more efficient and less emitting, but the main reason electric companies applied it is because they came as a cost containment feature, and when talking about decarbonization, we can definitely see companies following the right path, mostly in order to avoid carbon taxes that are expected to grow. (Nemet, 2010; World Bank Group, 2015) Hence, evolutions like these require additional storage capacities, so it might be one of the boosters of electricity storage development and expansion. (Ajanovic et al., 2020) With new challenges there is the need for innovative or improved approaches, for research and policymaking. (M. Dameto et al., 2020; Markard, 2018)

2.3. Energy demand in buildings

Therefore, with the increase of prosumers appearing in the electrical systems, and with these being a key part of the energy transition that is ahead of us, the buildings also play a prominent role, since the current society is surrounded by these, whether in the residential, cultural/entertainment, industrial sector or even commercial. Buildings are especially important, as they potentially can have both PV solar panel systems and ESS attached to them.

Moreover, policy makers have acknowledged that lowering carbon emissions and mitigating climate change risks at a global level will be unachievable without considerable improvements in energy efficiency and significant reductions in energy use on households. Several factors affect the energy demand in residential buildings, from national economic growth to climate and weather, and also demographic composition, and technological advancements. (Copiello & Gabrielli, 2017) Buildings have the greatest estimated economic mitigation potential of all sector-linked solutions evaluated, according to the Intergovernmental Panel on Climate Change (IPCC) report. There are three categories of measures that may be taken to reduce GHG emissions from buildings, firstly is lowering energy consumption and embodied energy in buildings, secondly is switching to low-carbon fuels with a higher share of RE, and finally managing non-CO_2 GHG emissions. (Ruuska & Häkkinen, 2015)

Buildings assume a relevant share in the energy consumption in the EU, according to the European Commission, buildings account for nearly 40% of energy consumption and 36% of the CO_2 emissions in the EU. It is also important to mention, that in the EU nearly 35% of buildings are over 50 years old. Thereafter, Europe has a lack of energy-efficient homes, with 75% of its building stock being energy inefficient. (European Comission, 2019) This problem is especially bad in the urban areas, where 70% of the EU's inhabitants are located. (European Investment Bank, 2020) Considering that in 2018, 46% of the people in the EU-27 lived in flats and 18.6% in semi-detached houses, electricity storage sounds like an open door with potential to achieve more efficiency in the forthcoming years. (Eurostat, 2020)

There is still a long way to go, despite the existing buildings that are renovated each year varying between 0.4 and 1.2% depending on the considered country. These renovations have a potential reduction of 5 to 6% EU's total energy consumption, diminishing CO_2 emissions by about 5%. (European Comission, 2020) In October 2020, the publication of the Renovation Wave strategy to improve the energy performance of buildings re-highlighted the effort from EU to cut 60% in GHG emissions from buildings by 2030 compared to 2015 levels and accentuated the relevance of energy efficient building renovation. This strategy aims to increase renovation rates from roughly 1% per year to at least 2% per year, over the next 10 years, with this heading to higher energy and resource efficiency. Besides the stated benefits that this strategy brings, there is also enhanced quality of life, fewer people living in energy poverty, lower GHG emissions, promoted digitalization, improved material reuse and recycling, and 160.000 new jobs created in the construction sector. (BPIE, 2020; Buildings Performance Institute Europe, 2021)

Nearly Zero Energy Buildings (NZEBs), it is the future of the construction sector, since it has very high energy performance, it requires nearly zero or very low amounts of energy to power it, and it should be covered by RES, either produced on site or nearby. In this case, the EU when issuing the Directive, gave the power to the member states, in order for them to define their targets, that way they can consider specific conditions inherent to their countries, like climate conditions, primary energy factors, building traditions and ambition level. (Azaza et al., 2020)

Furthermore, the number of PV production and electricity storage with batteries in buildings is increasing, either on communities based or neighborhood projects, or even individual residential projects. These figures are expected to increase in the upcoming years due to an estimated further decrease in costs. (Heinisch et al., 2019)

2.4. Electricity storage systems

This work only approaches ESS for stationary purposes, the difference between behind-the-meter (BTM) and front-of-the-meter (FTM) relates to the energy system's position in relation to the electric meter. FTM is the denomination for utility scale generation and energy storage, transmission and distribution, while BTM is for residential generation like solar, storage and microgrid. (Mir Mohammadi Kooshknow & Davis, 2018)

Owing to the fact that electricity storage can be applied to manage the supply and demand of electricity, integration of renewable sources, power quality, improvement of the level of use of the transport and distribution network, providing more and faster balancing energy, among other features, we have a solution for a lot of problems that electricity systems are facing at the moment. (Blanc, 2013; Xu, 2013)

That is why in a world in constant improvement, innovation and development, electricity storage might be an interesting addition, and it is predicted to be the heart of the next energy transition. There is already a market growing, but it is just the beginning of it. Besides that, there are some technology options, but there is still a potential for cost reduction and performance improving, that probably will be achieved in the upcoming years with the research and development (R&D) that is being done. (IRENA, 2017)

When supply exceeds demand, electricity storage can be utilized to store surplus energy and then dispatch it when needed, improving energy efficiency, as it can be seen in the Figure 6. Charging storage when energy spot prices are low and discharging when spot prices are high in a financial context, it is treated as an arbitrage instrument. (Crespo Del Granado et al., 2014) And while there are technologies that are geographically restricted like the traditional pumped hydro storage, there are other forms of ESS, such as battery energy storage systems. (Xu, 2013) These are beneficial either in a BTM and grid-scale context, since it can be applied almost everywhere, either in residential or commercial, or even industrial environments.

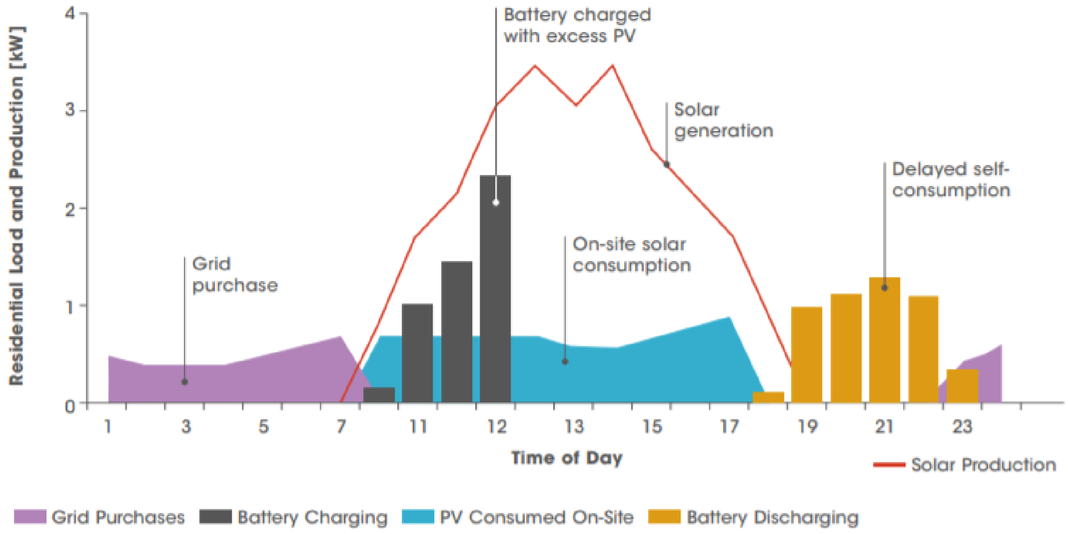

Figure 6 - Typical solar PV production and battery charging/discharging schedule
Source: IRENA (2019)

There are different types of energy being stored within different technologies such: i) mechanical via pumped hydro, compressed air, and flywheel; ii) Electrical through capacitators, supercapacitors and superconducting magnetic storage; iii) Chemical within hydrogen systems, ammonia dissociation-recombination and methane dissociation-recombination; iv) Thermal with sensible heat systems, molten salt storage and latent heat systems; v) electrochemical within the classic batteries lead-based acid, lithium iron phosphate, lithium-ion and saltwater and in flow batteries with organic flow batteries, zinc-iron flow batteries, zinc-bromine flow batteries (ZBFB) and vanadium redox flow batteries (VRFB). (Mir Mohammadi Kooshknow & Davis, 2018)

The projections for the market in stationary applications for battery electricity storage represents a significant growth until 2030, in applications BTM, particularly to enhance the self-consumption share of rooftop solar PV, as it can be seen in the Figure 7. With the distribution or generation companies incentives to manage grid feed-in, demand may increase. (IRENA, 2017)

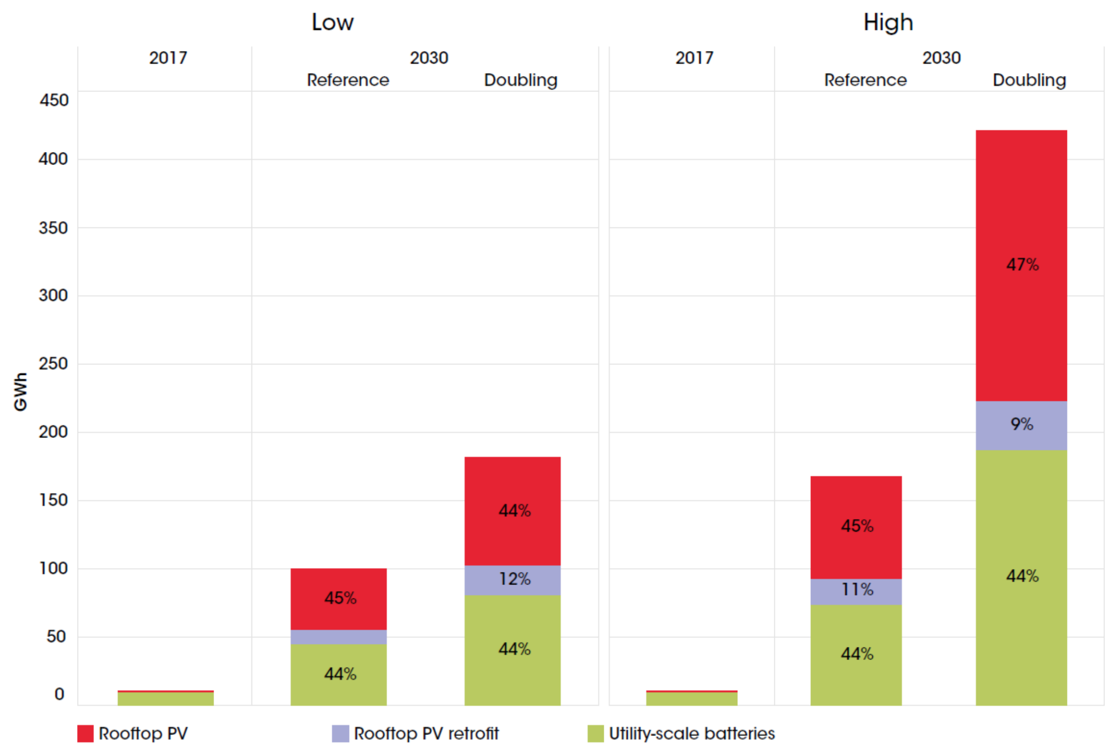

Figure 7 - Battery electricity storage energy capacity growth in stationary applications by sector, 2017-2030
Source: IRENA (2017)

There are diverse energy storage solutions, but they vary in their scope of uses, prerequisites and suitability to different RES production or energy applications. Additionally, there is a need for energy storage partly to improve the environment that is currently polluted in that way not relying on fossil fuels to power our world, but with the limitations within the geographic, climate, economic, social, and environmental aspects, it is necessary to evaluate the options before making decisions. Nevertheless, sometimes the economic features have priority over others within this full multidimensional analysis, consequently, two indicators must be considered, levelized cost of storage (LCOS) and levelized cost of energy (LCOE). (Martins et al., 2020)

A comparative analysis between the two biggest players within stationary purposes, lithium-ion batteries and VRFB is displayed in the Table 1. (Nikolaidis & Poullikkas, 2017; Parra et al., 2017; Sing et al., 2017)

Table 1 - Comparative analysis between the characteristics of the two main stationary technologies
Source: Author elaboration based on content from Nikolaidis & Poulikkas (2017), Parra et al. (2017) and Sing et al. (2017)

Technology	VRFB	Lithium-ion batteries
Specific power (W/kg)	80 - 150	500 - 2000
Specific energy (Wh/kg)	30 - 50	200
Round-trip efficiency (%)	75 - 85	85 - 95
Expected useful lifetime (years)	15 - 20	5 - 15
Maximum depth of discharge (%)	100	80 - 100
Cycles at 80% of depth of discharge	10000 - 13000	1500 - 4500
Capital cost USD$/kWh	460 - 1600	500 - 2500
Fixed operation and maintenance cost USD$/kWh-year	3.8 - 19.4	2.2 - 15.3
Variable operation and maintenance cost USD$/MWh	0.22 - 3.14	0.45 – 6.29

Within the multidimensional analysis mentioned before, the technology in a domestic context must be compact and durable, easy to maintain, to control and operate, as a turn-key project, since the user is not an expert, and yet consequently should be safe in terms of fire hazard and toxic risks. A key part of the technology is the flexibility applied to the user's needs and intents of energy use. Since we are using these technologies to improve the current environmental issues, the life cycle of the technology in question should be analyzed to minimize the impacts on the surrounding environment, besides that, the choice of materials that compose the product is important, using recycled materials or reusing, instead of opting for virgin raw materials or non-renewable resources. During operation the absence of noise and emissions is a must. And after decommissioning, the recyclability and reusability of materials must be easy and in great quantity. Along the economic analysis beyond the LCOE and LCOS, the initial investment and the cost of the capital are important issues as the return of investment (ROI). Regarding the fulfilment of the necessary requirements, electrochemical storage appears as the best option. (Martins et al., 2020)

Behind-the-meter batteries (BTMB) through demand-side management can assist the decrease of customers electricity bills, while increasing demand flexibility solving the integration of elevated percentage of variable renewable energy sources (VRES) in the grid, aggregated[3] BTMB are able to support system operation, while deferring network and peak capacity investment. Regarding to mini-grids BTMB replace diesel generators, provide back-up power and help the smoothening of VRES production. (International Renewable Energy Agency, 2019)

2.4.1. Vanadium Redox Flow Batteries

After this exhaustive analysis that reveals electrochemical energy storage as the best option, this study focus are VRFB, since it meets the requirements, and it is the technology produced by VisBlue.

The VRFB is composed of several parts including stack, tanks, pumps, hydraulic system, and sensors. The stack is composed of cells, the number and area of the cells determine the stack power, while the tank size and quantity of electrolyte determines the capacity. Each cell has two electrodes with graphite-polymer based bipolar plate and a felt electrode. Between the electrodes a polymer membrane allows the proton or anions exchange.

The technology underlying this storage system is based on the chemical element vanadium's capacity to exist in four different oxidation states, allowing the battery to have only one active material, rather than the most common in redox flow batteries technologies that have two species that are active, with this avoided cross contamination is achieved. (Monteiro et al., 2018)

[3] Aggregators, also known as virtual power plants, are third parties that bundle distributed energy resources to engage as a single entity in power or service markets

The tank contains a positive and negative electrolyte which flow to the stack, during the charge electrons are removed from the anolyte and transferred to the catholyte through an external circuit, ions are transferred through the membrane to maintain the neutrality. The process is reversed during the discharge. The Figure 8 shows the schematization of the VRFB produced at VisBlue.

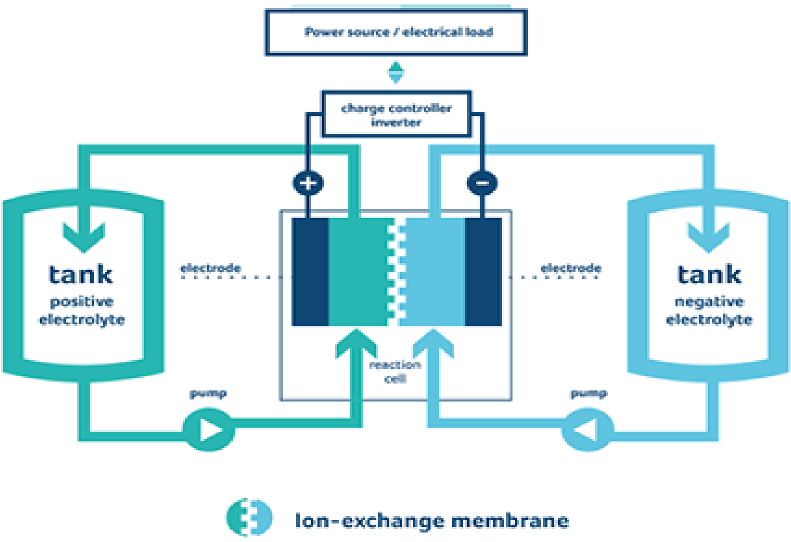

Figure 8 - VisBlue VRFB schematization

Obviously, like most kind of technology, VRFB has advantages and disadvantages these will be stated in the Figure 9.

ADVANTAGES	DISADVANTAGES
Long cycle life (10 000+ full cycles, with 10 to 20 times this possible)	Low electrolyte stability and solubility limit energy density, and low specific energy limits use in non-stationary applications
Relative high energy efficiency (up to 85%), but lower than Li-ion	Precipitation of V_2O_5 at electrolyte temperatures above 40°C can reduce battery life and reliability, although this can be managed
One of the most mature flow batteries with multiple demonstration and deployed at MW scale	High cost of vanadium and current membrane designs
Design E/P ratio can be optimised to suit specific application	Unoptimised electrolyte flow rates can increase pumping energy requirements and reduce energy efficiency
Long-duration (1-20 hours) continuous discharge and high discharge rate possible	
Quick response times	
Same element in active materials on electrolyte tanks limits ion cross-contamination	
Electrolyte can be recovered at end of project life	
Heat extraction due to electrolyte prevents thermal runaway	

Figure 9 - Advantages and disadvantages of VRFB ESS
Source: IRENA (2017)

One of the biggest assets of this type of technology is the capability of customization to energy necessities of a potential customer, being power and storage capacity totally independent. (Monteiro et al., 2018) This characteristic makes this type of technology one of the leading candidates for cost-effective stationary storage, especially when there are long discharges and long storage times. (Sánchez-Díez et al., 2021) While comparatively to other technologies, VRFB are considered slightly expensive in terms of initial investment, but it is competitive in terms of normalized cost, this technology is being used in applications that in terms of power to energy combinations, the decision-making process is driven by a unique combination of response time, flexibility and energy and power density. (Perles, 2012)

Excellent scalability, high round-trip efficiency, moderate maintenance costs, high depth of discharge and manageable and fast responsiveness, and also manageable flexibility are other features that make this technology successful for deployment. (Gouveia et al., 2020; Monteiro et al., 2018; Sánchez-Díez et al., 2021)

VRFB are considered a promising technology in stationary storage systems because of long lifetime, high efficiencies that are expected to grow, and avoided cross-contamination. In addition, studies have shown through life cycle assessments, that in the end of life, the level of recyclability of a VRFB comparing with other technologies is superior, in these comparisons, the environmental impacts are also lower, making this technology more favorable in an environmentally friendly approach that are increasingly taken into consideration. VRFB provide lower energy density when compared to lithium batteries, being only suitable for stationary purposes, being a drawback, however, from strong R&D investments, in the future these values will increase. This disadvantage is generally overcome by the more cost-effective scalability. (Gouveia et al., 2020; Sánchez-Díez et al., 2021; Weber et al., 2018)

This type of technology can be deployed for different applications, among which load levelling and peak shaving, besides that, it can be applied in the integration of wind and PV energy plants, it can also support uninterruptable power supply, and backing island electrification, other of the functionalities is the emergency backup for hospitals and air-traffic control. (Monteiro et al., 2018)

A drawback of VRFB is the high cost of vanadium, the electrolyte costs depends not only on this but also in the vanadium concentration, and this can account from 30 to 60% of the total the cost of the battery, in the majority of the studies. (Minke & Turek, 2018; Zhang et al., 2012) The demand of vanadium to produce VRFB might increase the price, but the market prices are not predictable. (Perles, 2012)

3. VisBlue and the Portuguese market

The internship took place at VisBlue, a Danish/Portuguese spinout company that was founded within the University of Porto and Aahrus University. Danish VisBlue (VisBlue AS) has been around since 2014, while Portuguese VisBlue (VisBlue Portugal) was founded in 2017 with a purpose of R&D being strongly connected with the Faculty of Engineering of the University of Porto.

The major goal of VisBlue arose from the need to develop an ESS that maximizes RE usage while it is an environmentally friendly technology. As a result of the aforementioned factors, VRFB was chosen as the most appropriate technology. VisBlue made an investment in the implementation of this electrochemical solution, giving the company a tool that could be critical in the energy transition that is ongoing.

VisBlue AS headquarters are located at Ecopark in Aarhus, Denmark. The facilities encompass offices, roughly 200 m^2 of production space and 100 m^2 of R&D area. The R&D is divided in 3 distinct parts, the 1st is a power electronics lab linked to integration of inverter/power electronics and flow-batteries, the 2nd is a thermostated flow battery test bench, flow batteries (and stacks) performance is tested here at controlled temperatures, the 3rd and last part is a smaller chemistry lab with autotitrator (pH/redox) and conductivity measurements facility. The Portuguese facilities are in the Parque da Ciência e da Tecnologia da Universidade do Porto (UPTEC) and comprise an office space and a workshop for R&D.

In late 2014, VisBlue AS received funding from the Venture Capital fund, Borean Innovation, sponsored in part by the Danish government with the aim of investing in emerging technologies. VisBlue develops, produces, and sells low-cost solutions to locally store solar energy in buildings. The solution presented is scalable, long-lived, and customized to customer needs (in terms of power and capacity). The objective of the storage system is to increase the efficiency of energy use, facilitating the introduction of RES in residences/condominiums (such as electricity production through PV panels). The company has a multidisciplinary team with expertise in flow redox batteries, electronic conversion, and control systems.

The first sale came in 2016, the battery was installed in Realdania By & Big apartment, Denmark's first net-zero building. VisBlue has booked 700.000 € in sales for deployment in 2017/2018. Notably, a battery was installed in a small island isolated from the Danish mainland and from the grid, named Livø, this island is protected by the Danish Nature Agency. Besides that, batteries were installed in Hobro, the headquarters of EuroWind, the Denmark's wind turbine administrator and in a housing association in Copenhagen, known as Lille Birkeholm. In 2021, the school of Mårslet, that had over dimensioned solar panels and only used a fraction of their electricity, selling the surplus for very little profit to the grid, got the VisBlue's batteries with 8 kW of power and 100kWh of capacity, and almost doubled the utilization rate of their solar panels, saving close to 30.000 Danish Krones per year, (around 4.000€).

According to A. Cunha (2020) assessing the positive and negative aspects of the technology and strategy of the company, is important to understand what the differentiation factors are, this can be made through a strengths, weaknesses, opportunities, and threats, a SWOT analysis. (Cunha, 2020) Table 2 presents this strategic planning method.

Table 2 - SWOT analysis

Source: Author elaboration based on Ana Miguel Leal Cunha (2020)

Strengths	**Weaknesses**
Battery/stack development Close contact with Universities (R&D) Eco-friendly solution Batteries already applied	Battery initial cost Own stack is in a prototype phase and systems include stacks from partners
Opportunities	**Threats**
Energy transition Energy storage solutions demand Legislative incentives to low carbon technologies Collaborations between suppliers and companies	Competitors development (VRFB and other technologies)

Among the different strengths referred in the analysis, the VisBlue's close contact with renowned universities in different countries, as the Faculty of Engineering of the University of Porto in Portugal, and Aarhus University in Denmark, is critical for the technology's constant and unquestionable development. As a result, the final product is a cutting-edge solution with a distinct and well-developed stack. A second advantage is that, unlike other technologies, for instance lithium batteries, VisBlue's solution contains environmentally friendly factors, such as high recyclability, reusability, and durability, this will be further analyzed. Durability is also an asset considering maintenance and long-term cost competitiveness, in addition to the environmental approach. Aside from the aforementioned features, due to VRFB technology being based on an aqueous solution making it non-flammable, VisBlue offers a safe solution, unlike the competitors, for instance lithium-ion batteries. (Cunha, 2020) In my opinion besides the strength that A. Cunha (2020) suggested, I would complement with the existence of applied batteries that can work as case studies, with this VisBlue already has some know-how of the behavior on-site and can take conclusions and decisions on the focus to improve the technology, despite this, having successful installed projects can potentially attract more customers.

The perceived weaknesses are points that are already being addressed. When evaluating the adoption of this solution, the initial cost of the battery is the most significant barrier, nonetheless, this is primarily due to a lack of long-term cost analysis. The initial investment cannot be compared to other alternatives without considering the battery's high durability as the key component, vanadium, has an infinite durability, as will be discussed further. Another flaw is the lack of mass production of stacks, even though this feature is still in the prototype phase. A variety of stacks can be used with the VisBlue energy storage system. (Cunha, 2020)

When looking at the global picture, there are numerous opportunities that benefit VisBlue market growth. The EU is enforcing an energy transition that will have a significant impact. The adoption of ESS is prompted by the development of RE production and the demand for solutions to enhance the consumption of energy from RES, as it expands RE consumption by storing it until it is needed. This shift in the energy paradigm is also influenced by legislation, which is becoming more stringent with targets and incentives that include ESS implementation. (Cunha, 2020) Additionally, besides the analysis made by A. Cunha (2020), I considered on the opportunities, the possible collaborations between suppliers and companies within the construction and PV installation sector, could be a major advantage for VisBlue, because it would probably be a way not only to disseminate the technology in companies that could recommend it or install it, but it could possibly boost the sales.

As a result of the current energy transition, new competitors are emerging, and this is the most significant threat. There are different types of competitors, with different technologies, and with VRFB. VisBlue is situated in an intermediate power level of ESS, ranging from approximately 3kW to hundreds of kW, even though there is intention to grow to MW. Whilst the competitors who do not use VRFB technology, cover the same range of power and energy capacity, and can belong to any class of ESS, being electrochemical the most direct competitors as lithium-ion. (Cunha, 2020) There are 40 companies all over the world that develop and commercialize VRFB, including VisBlue. (Soloveichik, 2015; Vanitec Ltd, 2021)

To analyze the viability of this business model, a Canva model was created, and can be seen in the Table 3. This type of model was chosen because it is a strategic tool with only nine blocks that makes possible to sketch and design business models, understanding in what way, or what strategy to adopt so that the organization will generate and deliver value. (Osterwalder et al., 2010) This model is a type of complement to the SWOT analysis, giving a multidisciplinary and simultaneously detailed view of important points for the company's business model, exploring the four points of the SWOT analysis in the different nine blocks of the Canva model.

Table 3 - VisBlue's Business Model

Source: Author elaboration based on Canva Business Model of Osterwalder & Pigneur (2010)

<table>
<tr>
<td rowspan="2">Key Partners
University of Aarhus

University of Porto

Construction companies

Electricity companies

Engineering and architecture studios

Consulting companies

Governments

Component suppliers

Companies specialized in the installation of RES</td>
<td>Key Activities
Maintenance/Support
Product demonstrations
Commercialization</td>
<td rowspan="2">Value Proposition
VisBlue’s VRFB allows storage of excess production of RES for later use.
The electrical power and storage capacity are independent allowing a customed solution for the costumer necessities. Most components – such tanks and electrolyte amongst others- are recyclable or reusable.</td>
<td>Customer Relationship
Get: Digital Marketing; Installed case studies; TV and Newspapers showcasing the technology as news, not an ad

Keep: Maintain regular contact with customers; Satisfaction surveys

Grow: Conventions and exhibitions; Establish contacts within the value chain of batteries; Public Relations; Network; Seek for collaborations</td>
<td rowspan="2">Customer Segments
Condominiums

Factories with 24/7 shifts

EVs owners

RE producers

Islands/Remote locations

Off-grid users</td>
</tr>
<tr>
<td>Key Resources
Commercials
Worker’s facilities
Digital Marketing
Partners and network</td>
<td>Key Channels
Advertising

On-site demonstrations

Close relationship with the target audience

Technical and scientific dissemination at national and international level

Website with product</td>
</tr>
<tr>
<td colspan="3">Cost structure
IT materials and consumables
Staff
Brand and product advertising
Office rentals
Product R&D
Utilities</td>
<td colspan="2">Revenue Streams
Sale of assets (Technology + Installation) - Product
Maintenance – Service
Leasing plan (pay initial value + deposit + monthly fee and giving the option to buy the technology after 5-10 years) – Product and service
Leasing plan (pay initial value + monthly fee + value per each kWh stored and consumed) – Product and service
Value per each kWh stored and consumed - Service</td>
</tr>
</table>

A PESTEL analysis was also made to evaluate and identify the impact of the company's operating environment, besides providing data and information that will facilitate VisBlue to anticipate future situations and scenarios. Being this type of analysis a precondition analysis that should be used in strategic management, to analyze the macro business environment external to a firm. This tool was used as a complement to the gaps of the SWOT analysis that might overemphasize internal strength, softening external threats, and overlooking the external environment. (*PESTEL Analysis of Construction Productivity Enhancement Strategies: A Case Study of Three Economies*, 2019; Yüksel, 2012) This analysis is represented in the Table 4.

Table 4 - PESTEL Analysis

Source: Author elaboration

Political	EU and Government incentives the energy transition (+) Tariffs for self-consumers (-)
Economic	Increasing purchasing power, globally (+) Economic losses caused by COVID-19, with reduced economic activity (-)
Social	There may be less purchasing power affected by COVID-19 (-) Increase in jobs in this sector (+)
Technological	Technological incentives (+) Digitalization of the electricity grid (+) Rapid and continuous development of RE production technologies in terms of performance and price (+) High penetration of RES demands for ESS (+)
Environmental	Greater and more widespread environmental awareness, recognizing climate change (+) Some RE production is dependent on weather and climate conditions (-)
Legal	By now regulation allows ESS (+) In the future, new legislation might condition the activity (-)

3.1. Surveys

In an attempt to give an answer to the research question, it was suggested to use questionnaires to companies in the construction, engineering, architecture, consulting and solar panels installation and maintenance sectors in order to understand if there was interest in applying ESS in buildings. I was ambitious in trying to get responses and collected contacts from over 1350 companies, many of the emails I collected were out of date, and there was a high rate of unanswered companies, yet I got 40 responses to the survey consisting of 17 questions that were divided in 2 sectors. The survey is shown in the Annex.

The universe of this survey is composed by 835 architecture and engineering studios, 65 building planners, 410 contractors and construction companies, 45 consulting companies, 30 companies specialized in the installation and maintenance of solar panels. These were contacted by me via e-mail with a link to a google forms. The survey was open to answers in 2021, from 15th of March to 30th of March and from 17th of June to 2nd of July.

There was a disproportionate stratification of sample groups with non-proportionate probabilities, this happened because there was a bigger presence of architecture and engineering studios online, it was easier to collect these contacts in comparison for instance with companies specialized in the installation and maintenance of solar panels.

The questionnaire was divided in two sectors, the first one was used to characterize the companies while the second one was made to understand how the companies evaluated and recognized ESS. When it comes to the outcome of the answers to the questionnaire that was sent, further on it will be demonstrated.

The first question was open and asked in which district of Portugal was the company located. The answers are represented in the Figure 10.

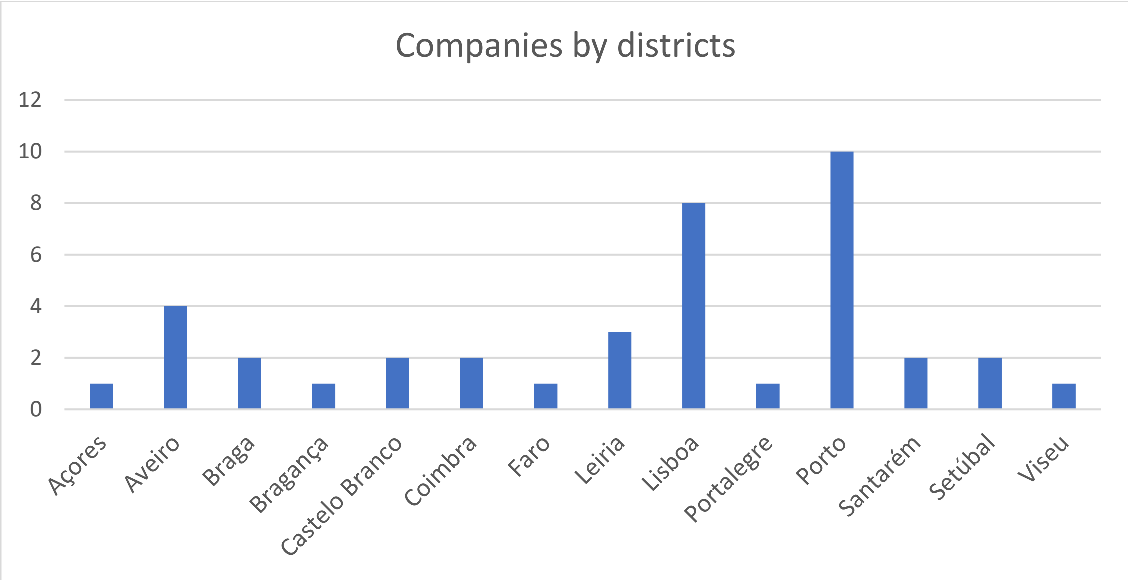

Figure 10 - Companies by districts

The second question was also open, asking the locality of the company. The answers are represented in the Figure 11.

Figure 11 - Companies by locality

The third question was the sector of the company, with a multiple choice with 6 options, being these "architectural and engineering studios", "contractor and construction companies", "building planners", "consulting companies", "companies specialized in the installation and maintenance of solar panels" and the option for other answers, but only one answer could be selected. The Figure 12 exposes the answers to this question.

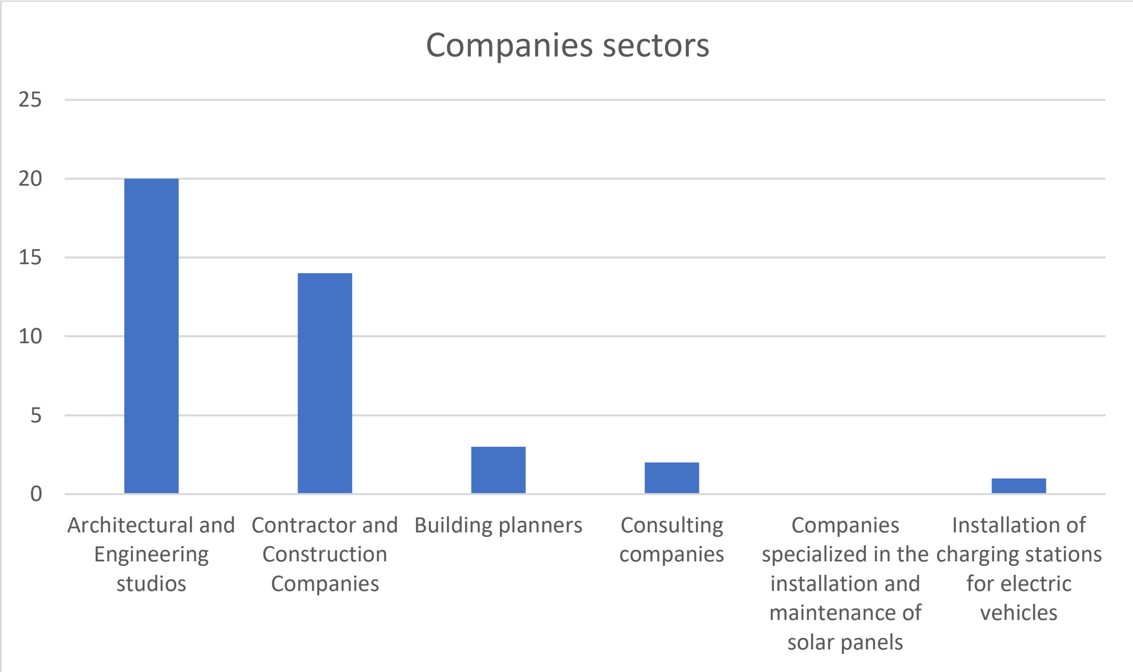

Figure 12 - Companies sectors

The fourth question was the size of the company in terms of employees that is present in Figure 13, there were only 3 options of answer and only one could be selected, being these "less than 10", "between 10 and 50" and "more than 50".

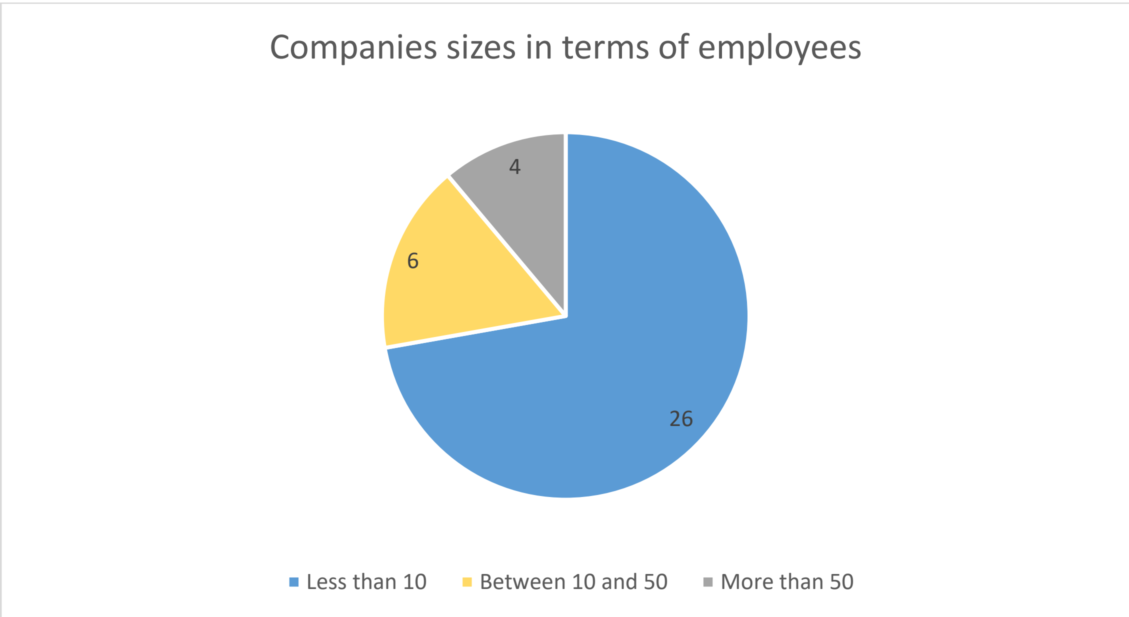

Figure 13 - Companies sizes in terms of employees

The fifth and last question regarding the company's characterization is the only optional response question in the survey, and it is the annual turnover. The choice of leaving the answer optional, had the goal to not discourage potential companies from responding to the survey. The answers to this question are displayed in the Figure 14.

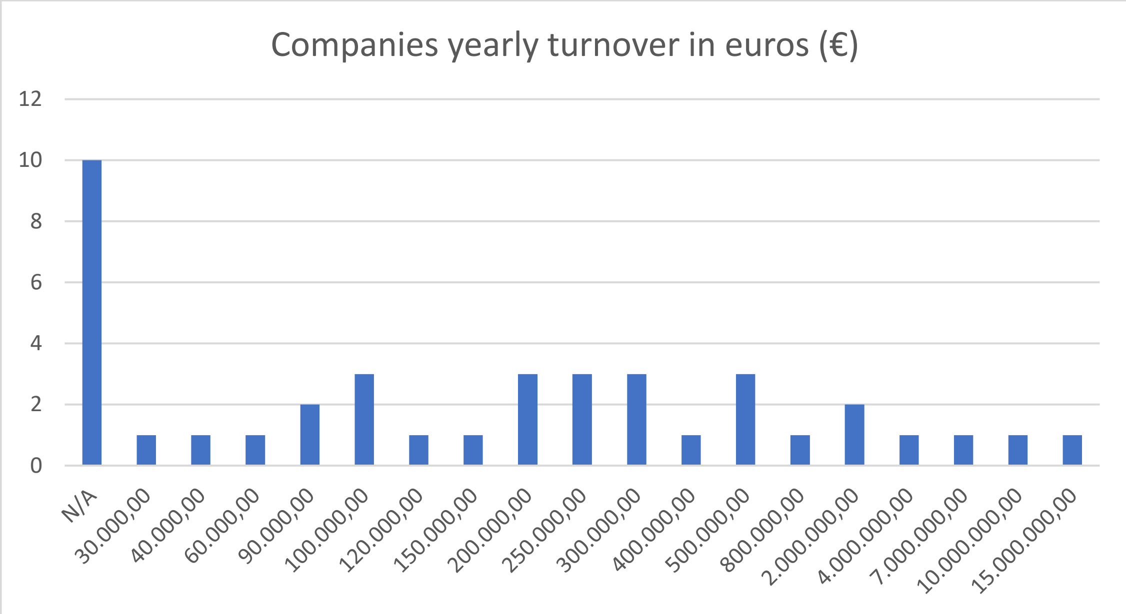

Figure 14 - Companies yearly turnover in euros (€)

The second section of questions focus on the knowledge around the technology, past, current, and future use of ESS, and expected ROI of VRFB. Being the first question of this sector to evaluate if companies have already used any ESS, being the possibilities of answer, "yes" or "no". The Figure 15 shows the answers to this question.

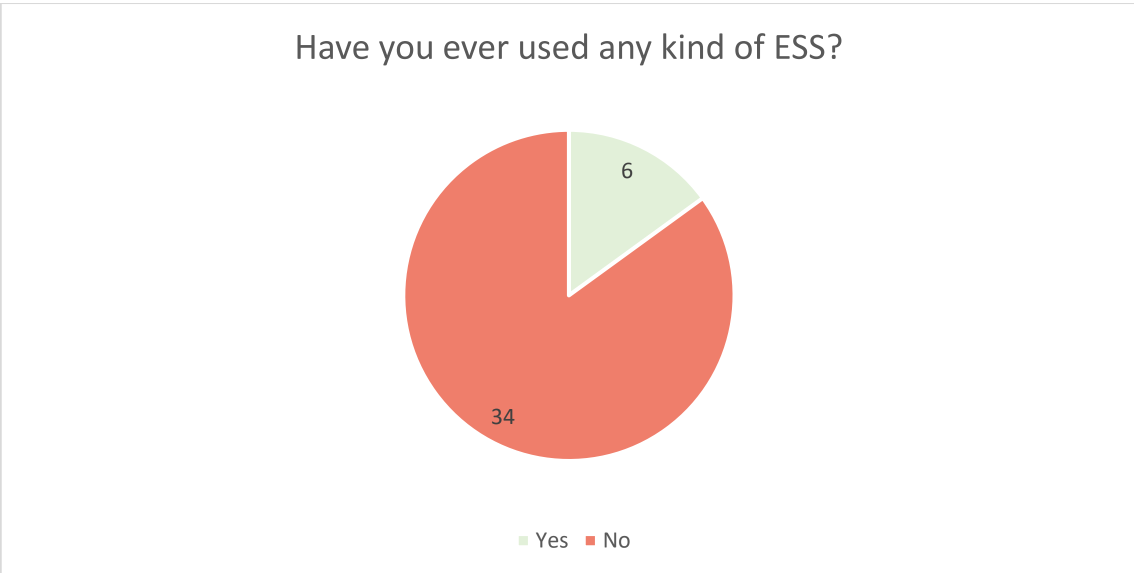

Figure 15 - Usage of ESS

The second question of this sector evaluates if the companies know VRFB. Once again there was only two possible answers, “yes” or “no”. The answers to this question are displayed in the Figure 16.

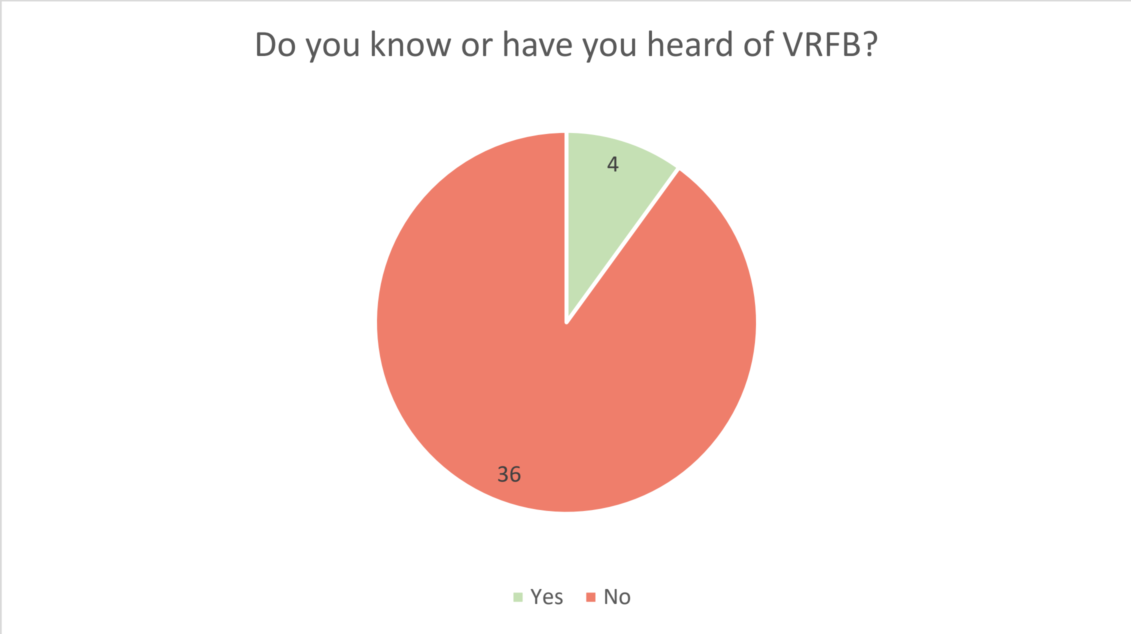

Figure 16 - Knowledge or recognition of VRFB

The third question assesses whether the companies know the advantages of VRFB in comparison with other technologies, and one more time there are only two possibilities of answers, “yes” or “no”. The answers to this question are presented in the Figure 17.

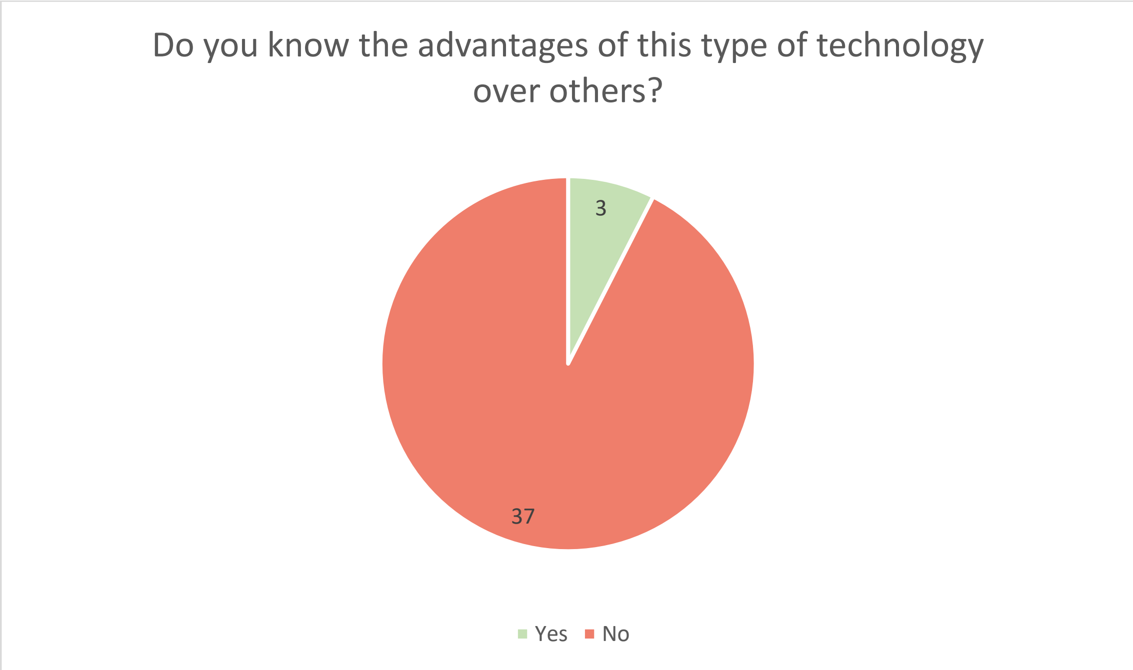

Figure 17 - Recognition of the advantages of VRFB compared with other technologies

Whilst in the fourth question of the second sector, is asked which recommendations are given in terms of technology, by the company, regarding the European Directive 2018/844, which suggests the use of batteries coupled with renewable generation systems, this question was a multiple choice with three technologies, "VRFB", "ZBFB" and "lithium-ion batteries" and it also had the options of others, so the companies could answer more freely and accurately, only one option could be selected. The Figure 18 is showing the answers to this question.

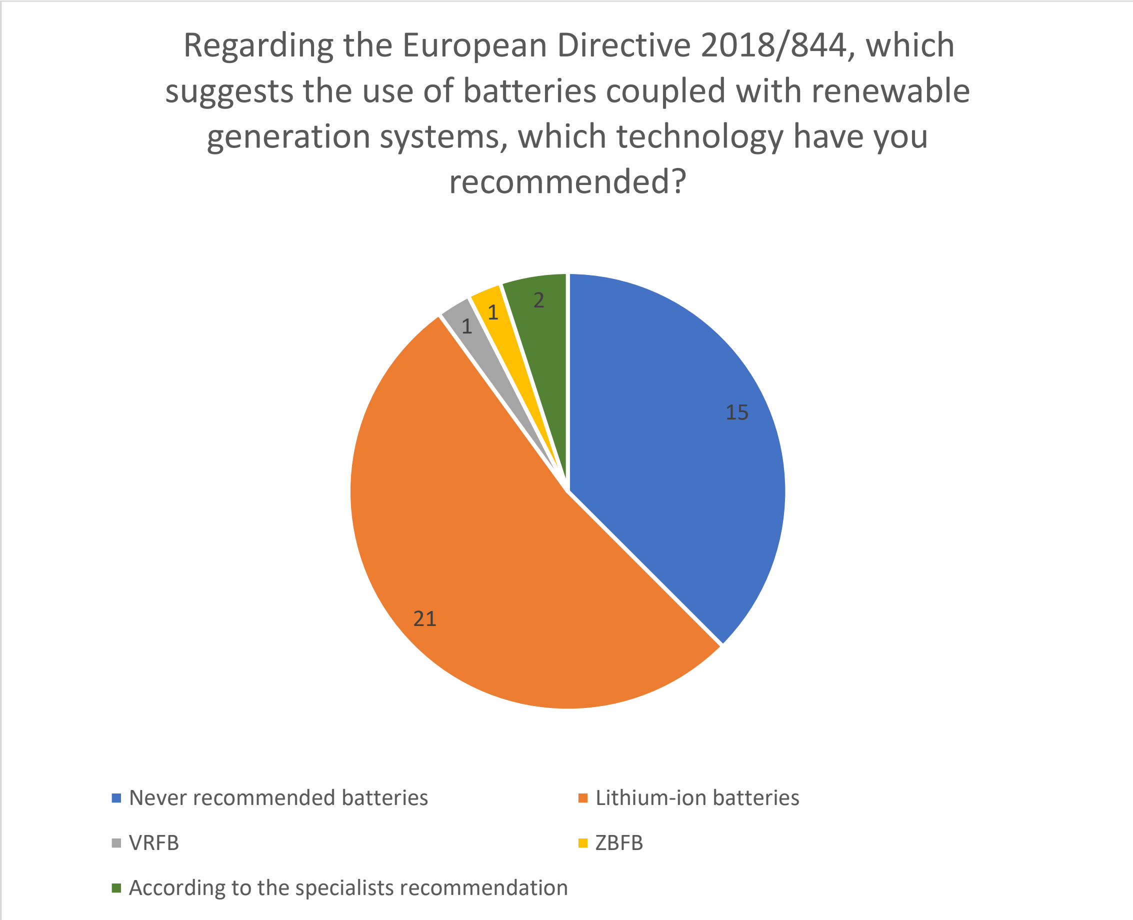

Figure 18 - Recommended technology regarding the European Directive 2018/844

The next and fifth question is a multiple choice that intended to understand, if in the buildings the companies have built/designed/planned so far, they would recommend lithium-ion batteries. The possibilities of answer were "never", "sometimes", "always" and "I don't know/not applicable", and only one could be selected. The answers to this question are represented in the Figure 19.

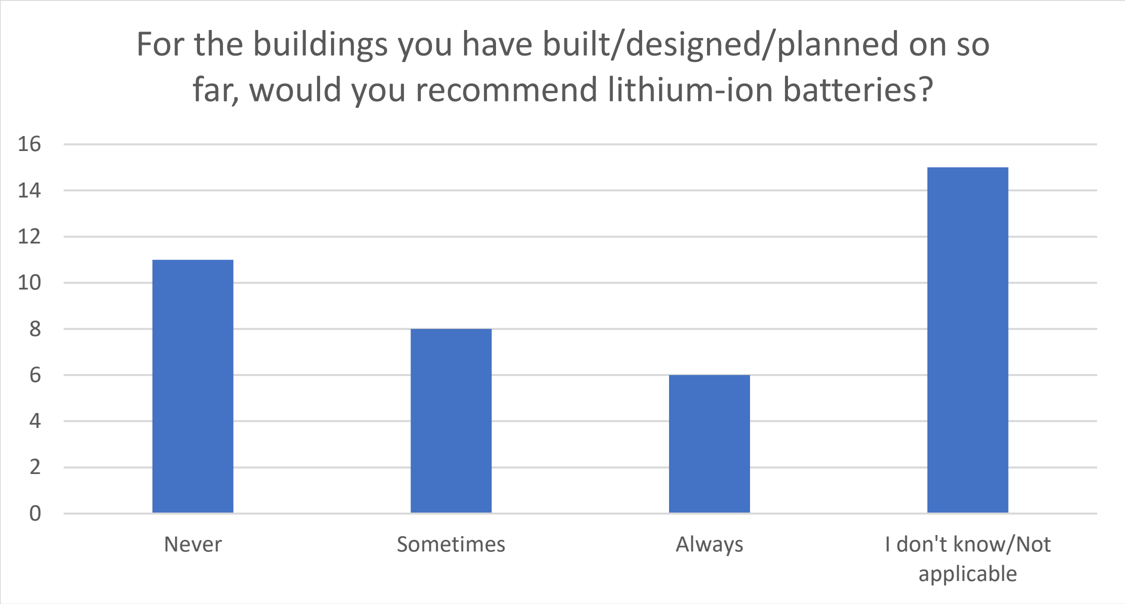

Figure 19 - Recommendation of lithium-ion batteries in previous projects

The sixth question asks the same as the previous one and has the same structure but for a different type of technology, in this case, the VRFB. Figure 20 shows the answers to this question.

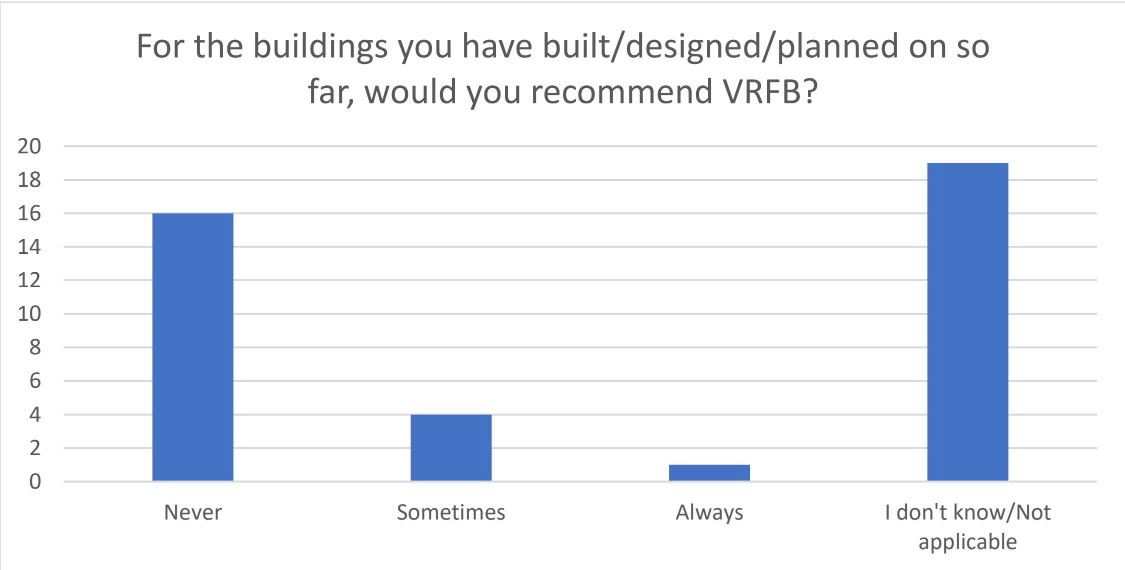

Figure 20 - Recommendation of VRFB in previous projects

Once again, the question and structure are the same but the technology that is on focus changes, this time the focus is on ZBFB. The answers to this question are displayed in the Figure 21.

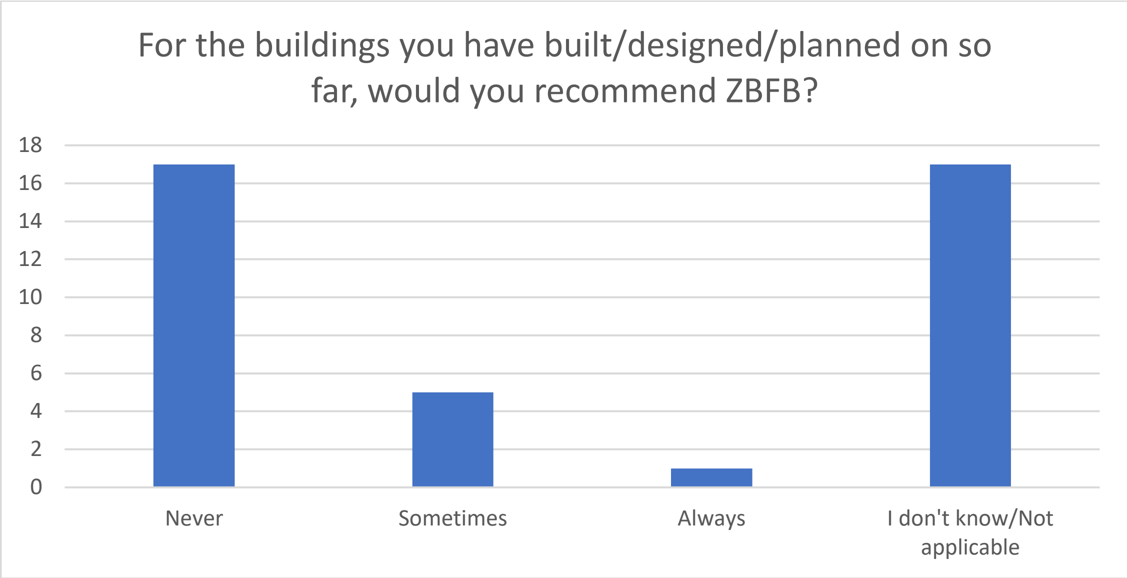

Figure 21 - Recommendation of ZBFB in previous projects

In the eighth question, a multiple choice using the same possibilities of answer as the question before, and only one answer could be selected, it was expected to comprehend if companies would advise or will implement Lithium-ion batteries on their current projects. Figure 22 shows the answers to this question.

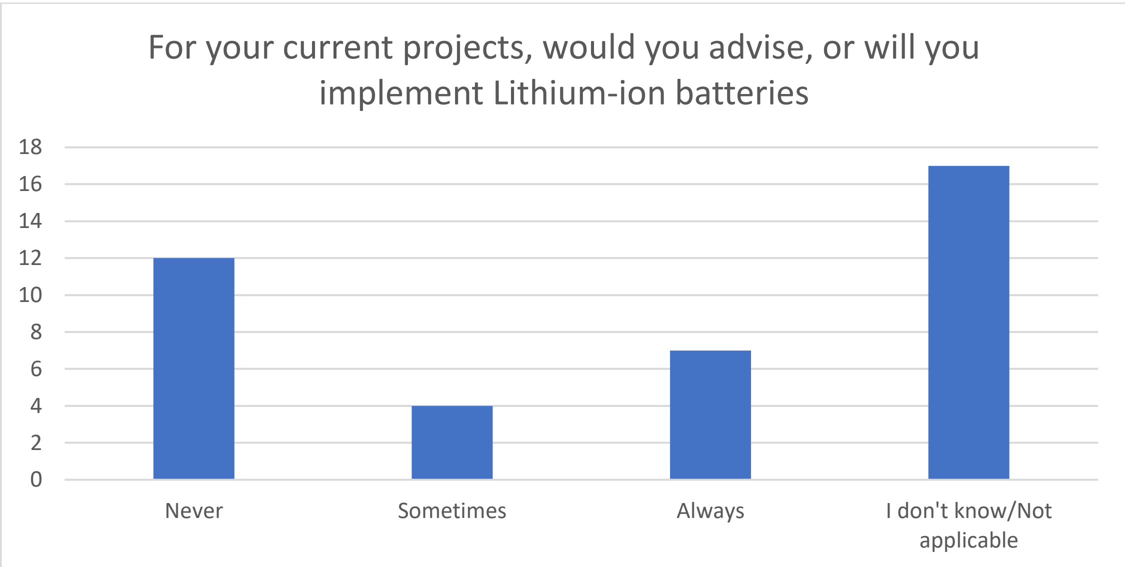

Figure 22 - Recommendation of lithium-ion batteries in current projects

The ninth question has the same intent, structure, and options as the one before but for a different technology, in this case VRFB. The answers to this question are displayed in the Figure 23.

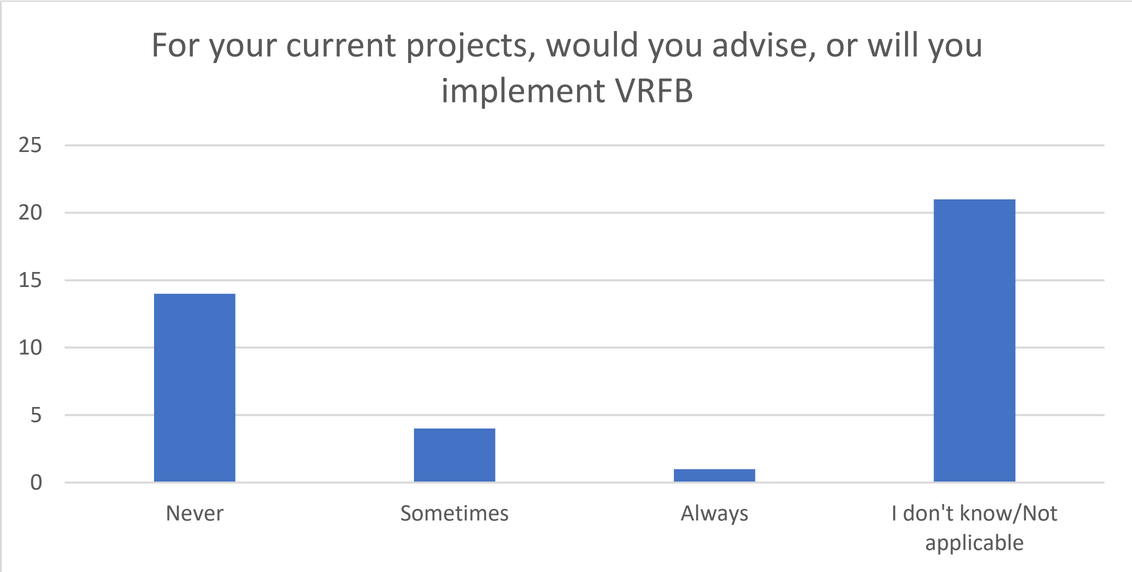

Figure 23 - Recommendation of VRFB in current projects

The tenth question also has the same intent, structure, and options as the one before but this time the technology is ZBFB. The answers to this question are represented in the Figure 24.

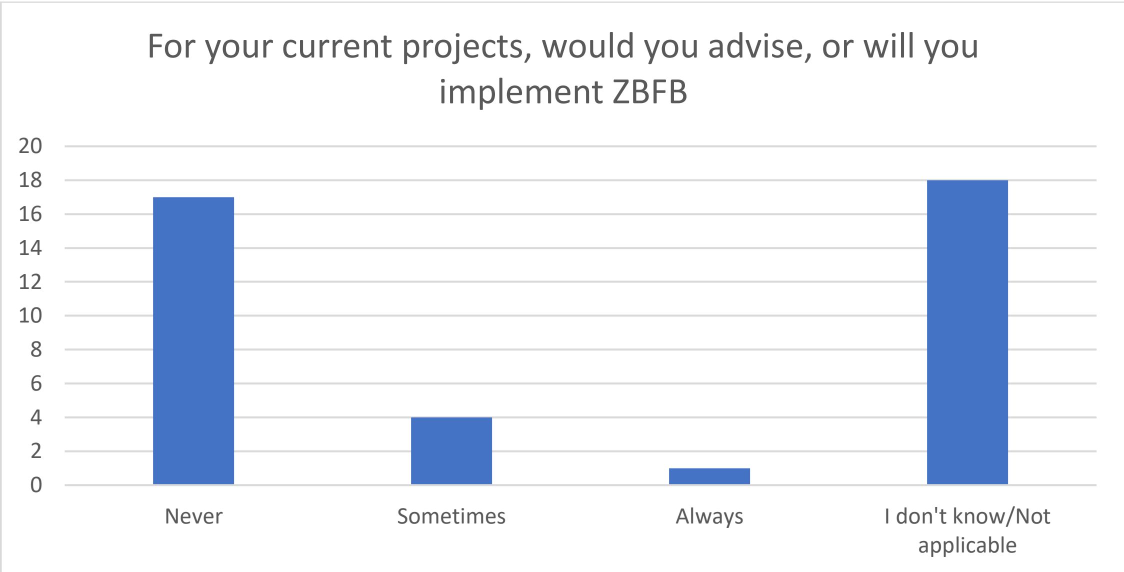

Figure 24 - Recommendation of ZBFB in current projects

The eleventh question is a multiple choice that inquiries about the main reason of the choices over the questions answered before. The possibilities of answer were "price", "performance", "security", "technical support" and it also had the options of others, so the companies could answer more freely and accurately, only one answer could be selected. Figure 25 shows the answers to this question.

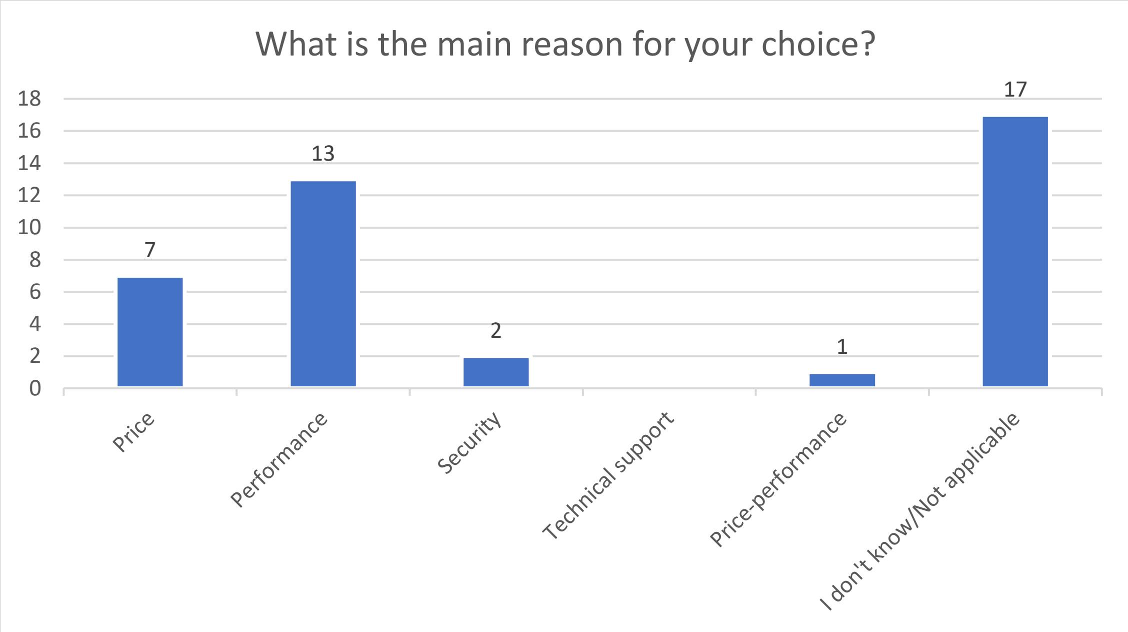

Figure 25 - Main reason for choice

Finally, the last question of the survey approaches the ROI that would be considered by the companies to install VRFB, in a multiple choice with only one possible selection, the possibilities were, "I don't know/not applicable", "1 to 3 years", "3 to 5 years", "5 to 7 years" and "7 to 10 years". The answers to this question are displayed in the Figure 26.

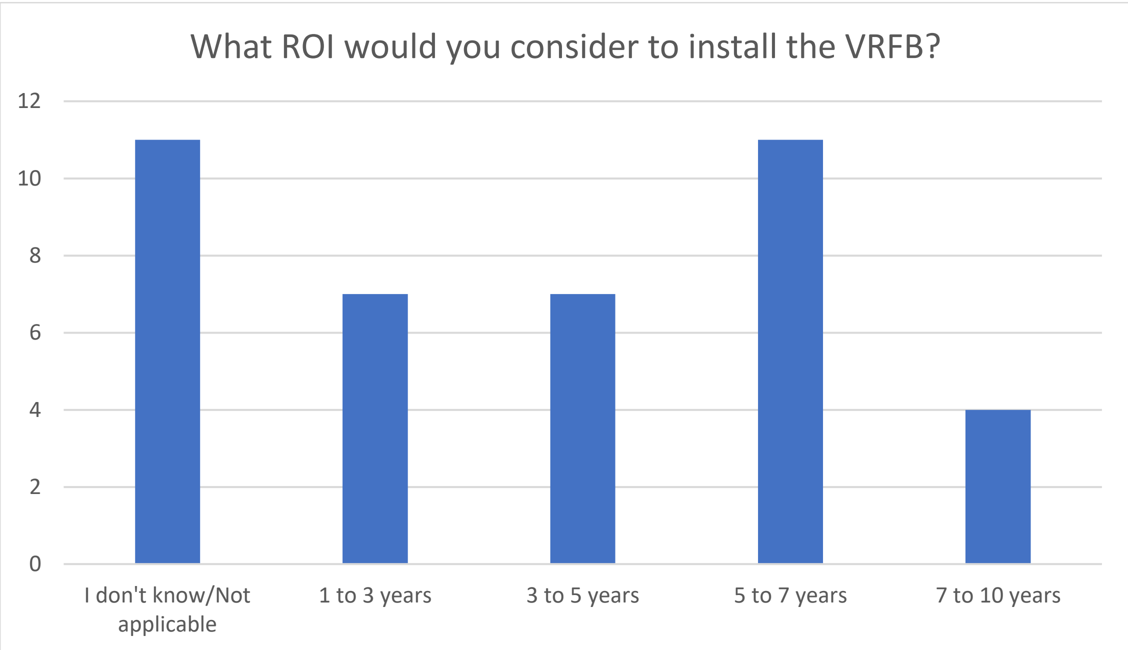

Figure 26 - Considered ROI to install VRFB

3.2 Legislation analysis

The European energy markets are mostly regulated by secondary legislation enacted by the EU. Aside from secondary legislation such as regulations directly applicable in Member States, directives subject to transposition into domestic law, decisions directly applicable and binding on the addressee, recommendations, opinions, and atypical acts, for instance, communications, guidelines white and green papers, European energy market regulation must be understood in the context of a number of bilateral and multilateral treaties. (Gunst et al., 2020)

3.2.1. The way towards Paris Agreement

Energy policy has risen to the top of international agendas in recent years, and it is currently a key concern in the EU. (Coelho et al., 2020) Firstly, the EU tried to establish a European energy framework, in 1997 with the White Paper on RE. The employment of advantageous financial mechanisms, mainly through public financial incentives, to promote and support the development of RE resources has caused a considerable increase in its participation in the energy mixes of European countries. Wind power and PV solar energy have shown impressive growth rates. This can be attributed to the simplicity of its installation, chiefly in the case of solar PV energy, the availability of technology and its greater profitability. As the percentage of RES in the electricity production system increases, considerable challenges likewise emerge in the management of the system. (Bianco et al., 2019)

Further on, in the year of 2009 brings a new directive, by the European Parliament and Council, about the renewable sources of energy, Renewable Energy Directive (RED), that revokes the prior 2001 and 2003 directives. In this Directive, the EU establishes a common framework for the production of RE and the promotion of its use. Making key changes trying to control energy consumption and increasing use of energy from renewable sources to tackle climate change. (Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the Promotion of the Use of Energy from Renewable Sources and Amending and Subsequently Repealing Directives 2001/77/EC and 2003/30/EC, 2009) This was a pivotal move from the EU showing its commitment on RE generation, seeking to reach targets of at least 20% of its total energy needs with RES by 2020, and an obligatory goal in the transportation sectors of Member States until 2020 of 10% share of energy from renewable sources. (Gunst et al., 2020)

Since one of the biggest shares of energy consumption comes from buildings, the EU has taken measures. As a mean to reduce energy consumption of buildings, the EU considered energy efficiency in buildings of all categories one of their main goals in the 2009 Energy and Climate package. This package established a target of 20% increase of building energy efficiency by the year of 2020. (Azaza et al., 2020) This theme was once again approached in 2010, with the European Directive (2010/31/EU). (Directive (EU) 2010/31 of the European Parliament and of the Council of 19 May 2010 on the Energy Performance of Buildings., 2010)

Energy efficiency was approached with a Directive (2012/27/EU), that established national indicative targets, that collectively, should help the EU in meeting its 2020 energy efficiency target of 20%. (Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on Energy Efficiency, 2012)

One of the biggest turning points made by policy makers was the Paris Agreement, a huge step in the right direction, embraced by the EU, history was made, defining ambitious targets. This agreement established *"the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels"*. (Rogelj et al., 2016) These targets were set for the parties that signed the agreement, with mitigation and adaption to climate change as a top priority, contributing to the global economy decarbonization, imposing obligations on all EU Member States.

3.2.2. From Paris Agreement to the Green Deal

In 2016, the package of Clean Energy for All Europeans proposed, comes as an update for the Third Energy Package and other EU environmental legislation. With the creation of this package, it was intended to develop some strategies in long-term plans for the European energy policy, with five key points being set out. First, decarbonization of the economy, followed by energy efficiency, energy security, European energy market and at last, research, innovation and competitiveness. (Gunst et al., 2020)

These five dimensions are divided in the following eight legislative acts, first the Energy Performance in Buildings Directive, followed by the Recast Renewable Energy Directive, the Amendment to the Energy Efficiency Directive, after that the New Regulation on the Governance of the Energy Union, then the Recast Electricity Directive, the Recast Electricity Access Regulation, next the Recast ACER Regulation and finally the new Regulation on Electricity Sector Risk-Preparedness. (Gunst et al., 2020)

In 2018, energy consumption of buildings and energy efficiency were approached once again with the Energy Performance of Building Directive and Energy Efficiency Directive (EU 2018/844). (DIRECTIVE (EU) 2018/844 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 May 2018 Amending Directive 2010/31/EU on the Energy Performance of Buildings and Directive 2012/27/EU on Energy Efficiency, 2018)

At the end of 2018, came the recast Renewable Energy Directive (REDII). It is going to be implemented on 1st of July of 2021 by the Member States, being the prior directive from 2009 repealed from that date on. The defined EU Energy strategy for 2030 determined by this directive creates some targets to be achieved by the member states like, 40% GHG emission reduction, 32.5% energy efficiency improvement, 32% RE penetration and 15% of electricity interconnections, compared with 1990 levels. The agreement also includes a clause that in 2023 these targets can be revised upwards. (Directive (EU) 2018/2001 of the European Parliament and of the Council on the Promotion of the Use of Energy from Renewable Sources, 2018; Gunst et al., 2020)

The Green Deal was presented in December of 2019, elaborating on the Energy Union, and setting the main theme on climate, sustainability, and biodiversity preservation. The biggest goal is to accomplish no net emissions of GHG by 2050, the goal has been set, and Europe hopes to be the first carbon neutral continent. (Gunst et al., 2020)

3.3.3. EU the first carbon neutral continent - how to achieve it

We can see an effort by the EU, to achieve the goals that were set out, renewables are the main key to do it, however, there are still some regulatory approaches that need some work on. By now, the EU deals with unsolved problems, nonetheless, technological development may be the right answer and the EU has already invested, through the research, innovation, and development of new and already existent technologies. For instance, the Innovation Fund is one of the world's largest funding programs, that focus on the demonstration of inventive low-carbon technologies, carbon capture and utilization, construction and operation of carbon capture and storage, RE generation and energy storage, this fund consists of 10 billion € to invest until 2030. (European Comission, n.d.-b)

It is important to refer that the European investment is not unfounded, there are some positive points in RES, being more than just a way to reduce the impact of the energy system on the global climate and achieve carbon neutrality, but also to diminish the national energy systems reliance on foreign oil and gas. (Negro et al., 2012) However, it is not enough to have a high share of RE in the electricity generation system, since it brings a problem, intermittency, which makes the need for electricity storage, that way the generation from fossil fuels can be avoided. (Bianco et al., 2019; Chabaud et al., 2017; IRENA, 2017)

Part of the innovation fund from the EU has been directed to the R&D of batteries for electricity storage. The European Battery Alliance is a strategic move from the EU to be the world leader in innovation, digitalization and decarbonization in what is considered to be the new industrial revolution. With this EU hopes to evade a technology dependence, strengthening industrial processes and securing competitiveness and full value chain in Europe, and access to raw materials. (European Comission, n.d.-a)

In July 2021, proposed a revision of the Directive (EU) 2018/2001, as part of a package to implement the European Green Deal. This proposal boosts the present legislation's ambition aiming to increase the EU's climate ambitions. Also seeking to include new measures to supplement the existing building blocks created by the 2009 and 2018 directives, as a mean to ensure that all potentials for RE production are efficiently used, which is a must for the EU, to reach climate neutrality until 2050. This proposed modification intends to ensure that RE contribute fully to the EU's 2030 climate ambition, as set out in the 2030 Climate Target plan. It also considers the conversion into EU law of concepts that were outlined like, energy system integration and hydrogen strategies. With this the European Green Deal objectives are closer to be achieved, since the energy system based in RES with hydrogen introduction come up as a feasible answer. New targets are outlined with at least 55% reduction of GHG emissions by 2030 and proposing a raise to the overall target of renewables to 40%, but also strengthening transportation, heating, and cooling policies. The Commission is also striving for a more efficient and circular energy system that supports renewables-base electrification. This revision is being considered by the Council and the European Parliament. (European Comission, 2021)

3.4. Portuguese legal framework

This task will aim to analyze the current legislation divided in different topics with the main one being the legislation for the storage of electricity, which could transform and dynamize the battery market. Not only that, but it will also consider the legislation for the use of PV solar panels, given its relevance due to its coupling with ESS, especially regarding the energy efficiency of buildings and new energy solutions for the Portuguese housing park, consequently building legislation can also be approached mainly when it is connected to RE production and energy efficiency and building performance. Since renewable energies and electricity storage is something still under development government supports are often used to encourage their use, there will be an analysis about the legislation created to promote these systems. It is also important to note that this is not just a review of legislation but also a critical analysis.

3.4.1. Solar panels

Solar panels legislation needs to be assessed since it may influence the business model because it is coupled with the VRFB, there are opportunities since their use is mandatory in new buildings of certain typologies. In the Table 5, solar panel legislation is analyzed, presenting the typology of buildings where this are applied and the mandatory and optional measures that will be taken in account.

Table 5 - PV solar panels: legislation by type of application (mandatory/optional)

Decree-Law	Type of Building	Mandatory	Optional
Decreto-Lei n.º 79/2006	Non-residential depending on size (article 2, point 1, a)) New residential buildings that require Air Conditioning systems with an installed power rating greater than a praseodymium limit (article 2, point 1, c)) Big remodulations (article 2, point 1, e)) There are exceptions (article 2, point 2)	Compulsory use of air conditioning systems that use renewable sources (article 14, point 3).	There is an option for PV solar panels (referred on the published list that is annexed in the Decree-Law)
Decreto-Lei n.º 118/2013	Residential (article 3, point 1) Non-residential depending on size (article 3, point 3, a) and b)) Every building in case of being sold or rented (article 3, point 4, a), b) and c)) There are exceptions (article 4)	Mandatory use of solar thermal systems in new houses and in buildings subject to intervention (article 27, point 2)	Replacing Solar Thermal System (SST) with another RE system can be considered if the RE produced by the alternative system is equal to or greater than that provided by the SST and the intended use is to meet domestic hot water (DHW) needs (article 27, point 3).
Decreto-Lei n.º 194/2015	Buildings or fractions, new or subject to major intervention (article 3, point 1) Commercial/services existing buildings or fractions (depends on size) (article 3, point 3)	Installing solar thermal systems for DHW, alternative renewable forms of energy are mandatory, except in situations of technical, functional, and/or economic impracticability (article 3, point 3).	Enables to choose a solar PV system (article 3, point 3)

PV solar panels offer a more friendly context for VisBlue ESS, and this is possible because PV solar panels are included in the published list by *Direção-Geral de Energia e Geologia*, only depending on technical and economic viability. This would be good since it would be producing not only electricity from a RES, but it would also store the surplus and use it to produce DHW. The main problem might be the equipment attached to the PV panels that must produce DHW. (Ministério da Economia e do Emprego, 2013; Ministério das Obras Públicas Transportes e Comunicações, 2006; Presidência do Conselho de Ministros, 2015)

3.4.2. Storage

Even though electricity storage is approached in *Decreto-Lei n.º 76/2019*, due to an exemption present in the (article 1, point 2, b)) that states that the production of electricity when associated with self-consumption is exempted of this decree-law, and with that, VisBlue does not need to take measures of any order. (Presidência do Conselho de Ministros, 2019b)

Storage is also referred in the *Decreto-Lei n.º 162/2019*, allowing self-consumers to install and operate ESS combined with facilities that produce renewable electricity for self-consumption without being subject to any duplication of charges, including grid access charges for stored electricity that is confined to their premises (article 7, point 2, e)). The metering of electric energy among other cases, it is compulsory to count the electric energy extracted or injected in storage units associated with Production Units for Self-Consumption, when they are connected to the public power grid and form part of an electrical installation separate from the Production Units for Self-Consumption or an electrical installation for use, whether associated with an electricity supply contract with a supplier, or not (article 16, point 3). Self-consumption activity can be carried out by means of Production Units for Self-consumption, regardless of the voltage level of the consumption installations by individual self-consumers (article 5, point 1, a)), collective self-consumers, organized in condominiums of buildings in horizontal property regime or not, or a group of self-consumers located in the same building or zone of apartments or houses, in close proximity, industrial, commercial or agricultural units, and other infrastructures located in a delimited area, which have Production Units for Self-consumption (article 5, point 1, b)), and by RE Communities (article 5, point 1, c)). Surplus energy from self-consumption can be traded on organized or bilateral market, including through RE purchase contract (article 4, point 1, a)) and through the market participant against payment of a price agreed between the parties (article 4, point 1, b)) and though the market facilitator (article 5, point 1, c)). This diploma classifies self-consumers in three types, individual (article 2), collective (article 6), and RE Communities (article 19), being the condominiums part of the collective self-consumers as it was stated before. Production Units for Self-consumption have mandatory exercising conditions settled in the article 3, having Production Units for Self-consumption with an installed capacity lower than 350W no need of any register, Production Units for Self-consumption with an installed capacity bigger than 350W and lower than 30kW to communicate through the Directorate-General for Energy and Geology portal, Production Units for Self-consumption with an installed capacity bigger than 30kW and lower than 1MW needs to register and get a certificate of exploration, Production Units for Self-consumption with more than 1MW of installed capacity it is subject to the granting of a production and operation license. (Presidência do Conselho de Ministros, 2019a)

The *Decreto-Lei n.º 101-D/2020* only transposes partially the EU 2019/944 on common rules for the internal market for electricity. Does not go deeply through the ESS, and with this, it is still in doubt how legislation might limit and influence VisBlue presence on the market. There is only a small reference, not requiring the use of the storage systems, but stating that it is possible to apply, considering the storage systems as part of an agglomeration of several systems, calling this set as "technical systems" (article 3, x)). (Presidência do Conselho de Ministros, 2020a)

In the archipelago of Madeira, the *Decreto Legislativo Regional n.º 1/2021/M* allows self-consumers to install and operate ESS combined with facilities that produce renewable electricity for self-consumption without being subject to any duplication of charges, including grid access charges for stored electricity that is confined to their premises (article 7, point 2, e)). This diploma states that is mandatory to count the electric energy extracted or injected in storage units associated with Production Units for Self-consumption, when they are connected to Madeira's public power grid and are part of an electrical installation separate from Production Units for Self-consumption or an electrical installation for use, whether associated with an electricity supply contract with a supplier, or not (article 16, point 3). There are similarities between this diploma and the *Decreto-Lei nº 162/2019*, because it is an adaptation of the Decree-law to archipelago of Madeira taking into account the specificities of the regional electric system. These similarities can be verified, for instance, the conditions for Production Units for Self-consumption are the same in the article 3 of both diplomas, and the requirements for access to activity in the article 5 of both diplomas. (Presidência da

Assembleia Legislativa da Região Autónoma da Madeira, 2021; Presidência do Conselho de Ministros, 2019a)

The *Regulamento n.º 373/2021* aims several times at electricity storage associated with self-consumption. It is basically an approval of the *Decreto-Lei n.º 162/2019*, that was working with limitations until the date of publication of this regulation. An abbreviation that includes storage is validated "IA" as "participating storage facility in self-consumption", this was not part of any of the diplomas reviewed before. The most relevant points within this diploma for VisBlue, are the definitions of general sharing rules, in the article 35, and fixed and proportional coefficients and allocation rules for facilities that inject into the grid, in the article 36. (Entidade Reguladora dos Serviços Energéticos, 2021; Presidência do Conselho de Ministros, 2019a)

In the *Decreto-Lei n.º 50/2021* it is established that if there are surplus from self-consumption electricity production in state buildings or public entities, the storage of electricity or the sale to a third party is allowed, according to the article 14, point d). (Presidência do Conselho de Ministros, 2021a)

Legislation about this topic is expected to come in the next few years, and should, according to the plans come out until the end of this year of 2021. The plans that were established will be approached further on this report.

3.4.3. Buildings

The legislation framework towards buildings is only relevant to VisBlue, due to the thematic framework in terms of energy efficiency and energy performance of buildings, as shown in the Table 6. (Ministério da Economia e do Emprego, 2013; Presidência do Conselho de Ministros, 2015, 2020a)

Table 6 - Important legislation approaching energy efficiency and energy performance of buildings

Decree-Law	Important information
Decreto-Lei n.º 118/2013	Transposes the European Directive 2010/31/EU on energy performance of buildings
Decreto-Lei n.º 194/2015	New buildings licensed after December 31st of 2020, or same date of 2018 in the case owned and occupied by public entities, must have near-zero energy requirements (article 16, point 3).
Decreto-Lei n.º 101-D/2020	Transposes the European Directive EU 2018/844 on the energy performance of buildings and on energy efficiency. New buildings should be NZEBs (article 6, point 1). New buildings, including their components, are subject to compliance with the requirements foreseen in the calculation methodology, to achieve high energy performance levels and, consequently, cost-optimal levels. These levels are periodically revised according to the results of cost-optimal analyses, to be carried out at intervals of no more than five years (article 6, point 2).

3.4.4. Plans

Regarding the resolutions of the council of ministers, resolutions of the legislative assembly, plans and laws of major options, there is a great diversity of legislation that addresses the subject of electricity storage, but without creating concrete rules, being only a projection of what could/should be promoted in the future, there are specific legislation only pertinent for archipelagos of Azores and Madeira.

In 2012, the Sustainable Energy Action Plan of Madeira Island and jointly the Sustainable Energy Action Plan of Porto Santo Island set a target of a 20% increase on the number of days of autonomy of primary energy storage, in comparison to 2005. They had an expected result of more than 20%. These plans strategic guidelines established was the increase of capacity of energy storage infrastructures. The plan of Madeira considered for secondary energy production installing solar PV parks and solar PV kits in micro and mini production regimes by citizens and companies. While in the Porto Santo's plan most part of the budget is aimed at the secondary energy production, this basically includes the use of electricity generation through renewable sources and dynamic and stable storage systems that make viable a greater penetration of renewables in the electricity grid of RE. In the plan of Porto Santo on the secondary energy production, not only is considered, installing solar PV parks and solar PV kits in micro and mini production regimes by citizens and companies, but also, installing energy storage and stabilization systems to mitigate instabilities in wind and solar

PV energy production on the stability of the power grid by the *Empresa de Electricidade da Madeira*. (Conselho do Governo da Região Autónoma da Madeira, Agência Regional da Energia e Ambiente da Região Autónoma da Madeira, et al., 2012; Conselho do Governo da Região Autónoma da Madeira, Madeira, et al., 2012)

In the *Orçamento do Estado para 2020* through *Lei n.º 2/2020*, the Government promotes the revision of the Energy Efficiency Program in Public Administration with the objectives of reinforce the European and national funds of this program, undertaking a major overhaul of energy services contracts in the Public Administration to include products that have been made possible by technological advances, such as solar PVs, considering a study with a view to equipping state buildings with small PV and solar electricity production units (article 30). (Assembleia da República, 2020a)

The strategy defined in this law of major options, *Lei n.º 3/2020*, sets that to continue to lead the energy transition there will be the need to support the development and evolution of storage systems, encouraging these systems in order to contribute to energy security. And supporting innovative systems and the development of pilot projects to demonstrate new technologies, such as the energy storage of renewables through fuel cells or batteries. (Assembleia da República, 2020b)

Throughout the 2030 National Climate and Energy Plan – PNEC 2030 approved through *Resolução do Conselho de Ministros n.º 53/2020*, ESS are referred several times and it is given importance to this thematic. Although its importance, it is only given an expected acting time and some action measures without any articles requiring anything. (Presidência do Conselho de Ministros, 2020c) The mentions of storage are present in:

- Acting line 2.6.1. entitled "encouraging Research and Innovation in the field of Energy Efficiency" with an expected acting time between 2020 and 2030, with the following action measures "promote energy efficiency projects in new residential buildings and thermal and energy rehabilitation (encourage adoption of sustainable solutions, local resources, innovative materials), solutions and strategies for integration of RE systems, storage and management of consumption and information".

- Acting line 3.5.1. referred as "adapt the planning criteria of the transmission and distribution networks" with an expected acting time between 2020 and 2025, with the following action measures "the new criteria to be adopted, or to be revised, should take into account the new challenges facing the electricity transmission and distribution grids towards energy transition, in particular with regard to distributed generation and self-consumption, grid intelligence, management support systems, smart meters, storage, energy management, energy communities, EVs, among other relevant issues".
- Acting line 3.8.2. named as "promote national R&I programs to support technological development" with an expected acting time amongst 2020 and 2030, the action measures refer storage as one of the programs that stand out among the programs to be developed.
- Acting line 3.8.4. denominated "promote the training of specialized technicians" with an expected acting time between 2020 and 2025, with action measures that refer storage as one of the activities that needs specialized training covering various levels of training in partnership with the entities responsible for the educational system and professional training.
- Acting line 4.1.1. designated "create the legal framework for the implementation of storage systems", with an expected acting time between 2020 and 2021, with the following action measures "proceed with the creation of the legal framework that enables and encourages the implementation of storage systems, in their different forms, particularly for the electricity sector".
- Acting line 4.1.2. dubbed as "promote a roadmap for storage in Portugal", with an expected acting time amongst 2020 and 2025, with the following action measures "this Roadmap will primarily aim to provide a practical, independent and objective analysis of the various possible trajectories for implementing storage systems, aligned with renewable and decarbonization objectives, considering security of supply, quality of service and the economic sustainability of the options to be adopted. This document should be updated at least every 5 years in order to consider the evolution of technologies and costs".
- Acting line 4.1.3. named "promote the implementation of storage projects associated with renewable power generation centers" with an expected acting time between 2020 and 2025, with the following action measures "support the development of

pilot projects that promote the implementation of technologies disseminated and not very mature, in order to improve the technical and economic viability of the same, focusing on the association between renewable production and storage".

- Acting line 4.1.4. named "promote storage in the islands", with an expected acting time between 2020 and 2030, referring in the action measures the need to increase electricity storage capacity in island territories with isolated electricity networks, using amongst other technologies batteries, in conjunction with the implementation of smart electricity grids, to increase the stability and resilience of small isolated electricity systems and increase the penetration of intermittent renewable penetration of intermittent RES.
- Acting line 4.2.5. nominated "promote the interconnection of isolated island electric systems", with an expected acting time between 2020 and 2030, with the following action measures "promote inter-island electricity interconnection as a tool to optimize production and storage resources and infrastructure, maximize the use of RE and improve the resilience and stability of small isolated electricity systems".
- Acting line 4.3.3. named as "study and promote the introduction of a Demand aggregator figure", with an expected acting time among 2020 and 2025, referring storage in the action measures as one of the activities that the demand aggregator must group and act supplying system services, participating in the electricity market, improving flexibility and the system management in terms of security of supply and promoting biggest participation of market agents.
- Acting line 4.5.3. denominated "adequate and foster the continuous improvement of network planning instruments", with an expecting time between 2020 and 2030, referring storage amongst other technologies as part of the investments considering the roadmaps to carbon neutrality, searching for a continuous improvement while developing with transparency and nurturing collaboration and dialogue between different agents.
- Acting line 4.5.4 named "create mechanisms for network planning at the local level", with an expected acting time between 2020 and 2025, referring storage as part of a range of technologies on low voltage grids, passing from being passive to integrating new concepts.
- Acting line 7.1. named "promote the industry decarbonization", with an expected acting time between 2020 and 2030, with no specific measures it just considers

storage as a technology that should be adopted in an industrial context, to be part of the industry decarbonization.

According to the *Resolução da Assembleia Legislativa da Região Autónoma dos Açores n.º 32/2020/A* the project "*Corvo Sustentável*" aimed to be a living laboratory of reference worldwide and a case study, with activities ranging from the development of energy planning models for systems with high penetration of renewable sources, the implementation and management of smart electricity grids, active demand management, energy storage, energy efficiency and the role of the consumer as an active agent of the energy system, as well as the integration of EVs with the grid in a concept of vehicle to grid (V2G). Due to the lack of funds, and the political abandon to which it was voted, the "*Corvo Sustentável*" project was never executed. Instead of becoming an island that tends to be self-sustainable in terms of energy, Corvo is today the only island in the archipelago that does not produce electricity from renewable sources. Due to this lack of investment and a great monetary effort that should be made, it was then recommended the development and implementation of a project that includes an integrated solution for the energy system of the island of Corvo, involving the production of electricity from renewable sources, electric mobility concepts, smart grids, storage and the adoption of measures that promote energy efficiency, in order to make the island of Corvo tendentially self-sustainable in terms of energy. (Presidência da Assembleia Legislativa da Região Autónoma dos Açores, 2020)

Regarding the Portugal 2030 strategy the *Resolução do Conselho de Ministros n.º 98/2020* approves it. Storage is considered stating that is a need to promote the use and also to foster research, development and innovation, this is present in the point 3.3.1 about decarbonizing society and promoting the energy transition. (Presidência do Conselho de Ministros, 2020d)

The approval of the Resource Efficiency Program in Public Administration for the period until 2030 is made through the *Resolução do Conselho de Ministros n.º 104/2020* in this diploma energy storage solutions are considered, to be integrated in Public Administration until 2030, to reach carbon neutrality. (Presidência do Conselho de Ministros, 2020b)

The approval of the Autonomous Region of Madeira's Economic and Social Development Plan 2030 – PDES Madeira 2030 is made through *Decreto Legislativo Regional n.º 17/2020/M*. Regarding the plan for sustainable energy, ESS are addressed through four points:

- Increased penetration of renewable energies in the electricity sector, associated with energy storage infrastructures and intelligent management of the electricity grid;
- Adoption of efficient technologies to produce heat and electricity with RE for local consumption and energy storage, in the residential sector, in companies and in public administration;
- Increasing the resilience of the electricity grid, through storage infrastructure and intelligent monitoring, control and management systems, to increase the penetration of RE;
- Promotion of energy efficiency and integration of RE in housing, businesses, and public administration, namely in the fields of thermal insulation of buildings and facilities, with conversion of equipment to more efficient technologies, passive solar systems in buildings, production of hot water with RE, electricity generation from renewable sources, storage of electricity and heat, intelligent charging of EVs, monitoring and energy management systems.

On the point B.2.4 – Sustainability and valorization of endogenous resources, batteries are also approached, referring that in the electric sector, they are considered as the most relevant investments in energy storage along with electric infrastructure to increase the capacity to receive renewable energies, whose growth was limited for technical reasons since Madeira and Porto Santo electric grids are isolated and of small dimension. The growth of RE production has been limited due to technical constraints; however, with the storage infrastructures being implemented, there are prospects for development of the sector. It is also stated that storage systems have an innovative character and will have a strong impact in the next decade in terms of the evolution of electricity production from renewable sources, if the regulatory instruments that allow the injection of energy from small private producers in the electricity grid are created. (Presidência da Assembleia Legislativa da Região Autónoma da Madeira, 2020)

Once again, no specific legislation is defined in this law of major options, *Lei n.º 75-C/2020*, but the long-term strategy is defined, and in this plan storage systems are referred to as an essential part of the Portuguese commitment to increase the production of RE, in order to achieve carbon neutrality by 2050. In addition, there is a small reference to the auctions for allocation of injection capacity in the grid, since that from 2020 is given the option of developers to develop storage projects. (Assembleia da República, 2020c)

In accordance with the “Clean energy for all Europeans” package and the Paris Agreement, taking into consideration the targets set through the Roadmap for Carbon Neutrality in 2050, the long-term strategy for the renovation of buildings is approved through the *Resolução do Conselho de Ministros n.º 8-A/2021*. Various packages for improving the energy efficiency of residential and non-residential buildings are therefore planned, as well as the integration of RE and electricity storage. Electricity storage has high relevance throughout this resolution being approached several times, NZEBs are also a hot topic and PV systems, even though there are no action measures nor legal obligations. (Presidência do Conselho de Ministros, 2021b)

Once more in the archipelago of Azores, more plans are defined having storage as a relevant part of it without making any legal obligations or options, neither action measures, through *Decreto Legislativo Regional n.º 17/2021/A*. Storage is considered an important bet in the medium term to the decarbonization and energy transition, stating that projects until 2025 will be fostered, setting a target of 65% penetration of clean energy for electricity generation. (Presidência da Assembleia Legislativa da Região Autónoma dos Açores, 2021a)

The Annual Regional Plan for 2021 is approved through *Decreto Legislativo Regional n.º 18/2021/A* storage is referred, stating that storage of energy from RES for self-consumption by families, businesses, cooperatives, non-profit organizations, and Private Institutions of Social Solidarity will be boosted by updating and improving financial incentives for the purchase and installation of equipment and systems. On the point 10.1.2 named Clean Energy Production and Storage, this incentives to storage are stated again. It is al so referred the new cohesion policy framework, that proposes five main goals that will guide the EU's investments in 2021-2027, and which integrate several specific objectives, including developing locally intelligent energy systems, networks, and forms of energy storage on the point 2.3 of the Programming Period 2021-2027. (Presidência da Assembleia Legislativa da Região Autónoma dos Açores, 2021b)

3.4.5. Investment incentives

When it comes to state or regional support for boosting both electricity storage and RE production there are different legislation, not only in mainland Portugal but also in the islands since Portugal accounts with two archipelagos, Madeira and Azores.

In a brief approach, surprisingly, there are monetary incentives still valid to this day that support RES, being these laws approved in 1986, through *Decreto-Lei n.º 250/86*, and at that time the euro was not even in use yet. (Ministério da Indústria e Comércio, 1986)

In 1988, more incentives were approved through *Decreto-Lei n.º 188/88*, once again for RE production, not being revoked until today. There is an amendment to this Decree-law in 1995, through *Decreto-Lei n.º 35/95*, creating the System of Incentives to the Rational Use of Energy of Regional Base, this incentive is still active upon date. (Ministério da Indústria e Energia, 1988, 1995a)

Support to RES continued through, *Despacho Normativo n.º 11-B/95*, being once again active up to the current days. Despite being amended by the *Despacho Normativo n.º 17/98*, there are no mentions for deadlines in terms of being aided by it, neither are revocations. (Ministério da Economia, 1998; Ministério da Indústria e Energia, 1995b)

The lack of legislative consistency, the successive change of governments and lack of revocation provision may have a detrimental effect on the responsible authorities, leading to long battles in the courts, even if this gap cannot be exploited.

The Table 7 displays a summarized analysis of *Decreto Legislativo Regional n.º 26/2006/A*.

Table 7 - Summarized analysis of *Decreto Legislativo Regional n.º 26/2006/A*

Decree-Law	Promoters	Projects eligible for support	Monetary Incentives
Decreto Legislativo Regional n.º 26/2006/A	Small and medium-sized companies, cooperatives, and non-profit organizations (article 2, point 2, a)). Individuals or condominiums (article 2, point 2, b)).	Investments in the exploitation of RE resources for micro-production of energy, using water resources, wind, biomass, solar PV and in the field of micro-cogeneration of electricity and heat for use in buildings (article 2, point 1, a)). Investments in the use of solar thermal and thermodynamic resources to produce hot water (article 2, point 1, b)). Investments in the installation of energy management systems in buildings which allow for a better distribution of electricity consumption (article 2, point 1, c)).	Non-refundable grant of 25% of the eligible expenses, maximum limit 250.000,00€ for projects promoted by small and medium-sized companies, cooperatives, and non-profit organizations (article 7, point 1, a)) 1.000,00€ per household for projects promoted by individuals or condominiums (article 7, point 1, b)). Investments in the islands of Santa Maria, São Jorge, Graciosa, Flores and Corvo, the rate is 35% (article 7, point 2) Investments carried out in areas without direct access to the regional electricity grid and where the cost of access is equal to or higher than 10.000,00€, the rates mentioned in the preceding cases is 50% (article 7, point 3).

In the *Decreto Legislativo Regional n.º 26/2006/A* with the threshold value available for companies being so high, and with an incentive of at least 25% of that value, it seems like an excellent opportunity for VisBlue to enter the Portuguese market, aided by the monetary incentives provided by the regional government, even though it is not directed to storage, since there is the application of PV, that part can be eligible for expenses, collaborations with companies within the PV sector could be an interesting addition in this point of view. Requires a minimum investment of 15000€, besides other details (article 4). The diploma does not mention the impossibility of accumulating this incentive with others of similar nature. (Presidência da Assembleia Legislativa da Região Autónoma dos Açores, 2006)

The summarized analysis of *Decreto Legislativo Regional n.º 14/2019/A* is present in the Table 8.

Table 8 - Summarized analysis of *Decreto Legislativo Regional n.º 14/2019/A*

Decree-Law	Promoters	Projects eligible for support	Monetary Incentives
Decreto Legislativo Regional n.º 14/2019/A	Micro, small, and medium-sized companies, including sole proprietorships, cooperatives, private social solidarity institutions, non-profit organizations, and condominiums or individuals (article 2, point 2 a) and b))	Production of electricity, storage of electricity, investments to produce hot water using solar thermal resources, heat pumps, systems using biomass, investments to produce heat using endogenous resources for space heating (article 2, point 1, a) i) ii), b) i) ii) iii) and c))	Investments in the exploitation of RES for electricity production and storage of electricity non-refundable subsidy, corresponding to 25% of eligible expenses, up to a maximum of €4.000,00 per household or establishment, (article 8, point 1) this value have a maximum limit of €20.000,00 in the case of private social solidarity institutions and non-profit organizations (article 8, point 5). Investments on the islands of Faial and Pico, the percentages are 30% (article 8, point 6). Investments made in the island of Santa Maria, the percentage is 35% (article 8, point 7). Investments on the islands of Corvo, Flores, Graciosa, and São Jorge, the percentages are 37% (article 8, point 8) Investments made in areas without direct access to the public electricity transmission and distribution grid or where the cost of interconnection is €12.000 or more, the percentage is 50% (article 8, point 9).

In the *Decreto Legislativo Regional n.º 14/2019/A* the archipelago of Azores is an excellent starting point for an experience in the Portuguese market due to incentives on electricity storage, since it is a group of islands, and the grid infrastructure is underdeveloped. Corvo still has 0% of RE production, VisBlue could improve this numbers. The purchase of batteries by an entity will always have at least 25% of government support, this is a good opportunity for VisBlue to explore. Requires a minimum investment of 500€ amongst other details (article 4). (Presidência da Assembleia Legislativa da Região Autónoma dos Açores, 2019)

Eligible expenses must be taken into account (article 6), besides that it is forbidden to accumulate the benefits granted by this diploma with others of a similar nature, foreseen in regional or national diplomas, except those of a purely fiscal nature (article 5). (Presidência da Assembleia Legislativa da Região Autónoma dos Açores, 2019)

While the subsidizing in mainland Portugal is not as big as in the archipelago of Azores, the city of Coimbra still gives some support to RE production and storage. The summarized analysis of *Regulamento n.º 312/2020* is displayed in the Table 9.

Table 9 - Summarized analysis of *Regulamento n.º 312/2020*

Decree-Law	Promoters	Projects eligible for support	Monetary Incentives
Regulamento n.º 312/2020	Individuals with permanent residence in the city of Coimbra, condominiums of buildings entirely or predominantly used for residential purposes and non-profit organizations under private law, with their headquarters in the city of Coimbra (article 7 a), b) and c))	Applications that foresee the acquisition, for self-consumption, of PV energy production and storage systems (article 3)	The purchase of PV energy production and storage systems is subsidized: 250€, for energy production systems with a power between 250 W and 750 W (article 8, point 1, a)) 500€, for systems that produce energy with an output exceeding 750 W up to 1.500 W (article 8, point 1, b)) 750€, for energy production systems with an output of more than 1500 W up to 30.000 W. (article 8, point 1, c))

The incentives established by *Regulamento n.º 312/2020*, could be VisBlue's entry into the Portuguese market in mainland Portugal, suggesting to potential clients from Coimbra to apply to this monetary incentive, having some sort of support making the initial investment a little lower. The incentives granted can be accumulated with other possible support of identical nature, namely foreseen in the law or in municipal regulations (article 8, point 2) and there are no requirements in terms of minimum investment. (Município de Coimbra, 2020)

The *Despacho n.º 6070-A/2021*, approves the incentive attribution regulation for the second phase of the More Sustainable Buildings Support Program, the summarized analysis is displayed in the Table 10. This program applies the money of the Recovery and Resilience Plan which identifies the focus on energy efficiency in buildings as a priority for economic recovery aligned with climate transition, in line with the objectives of the European Green Deal, with an overall budget of 30.000.000€. (Gabinete do Ministro do Ambiente e Ação Climática, 2021)

Table 10 - Summarized analysis of *Despacho n.º 6070-A/2021*

Decree-Law	Promoters	Projects eligible for support	Monetary Incentives
Despacho n.º 6070-A/2021	Existing single-family residential buildings, as well as multi-family buildings or their independent fractions, built and licensed for housing on or before 31st of December of 2006, throughout the national territory (point 3.1) Existing single-family residential buildings, as well as multi-family buildings or their independent fractions, built and licensed until 1st of July of 2021, only for interventions that fit into some of the typologies of this regulation (point 3.2)	Installation of PV solar panels and other RE production equipment for self-consumption with or without storage (point 4.1, d))	With a co-payment rate of 85% and a maximum limit of 2500€ (point 6.3)

ESS are eligible for support for both promoters on the table 9, this is an excellent opportunity for VisBlue. Entering the market now, being the initial cost the biggest barrier, customers will have a lower initial value of investment since it will be supported by this incentive. The deadline for submission of applications for the incentive runs until 30th of November of 2021, or until the date on which it is expected to exhaust the foreseen budget (point 10.1). (Gabinete do Ministro do Ambiente e Ação Climática, 2021)

4. Methodology

This report is focused on answering the problems of using VRFB in residential buildings coupled with RES in Portugal. How the current Danish business model, applied to condominiums, could be adapted to the Portuguese market if there are barriers, and which are these and assess the receptivity of the surrounding sectors.

With that being said, I have two research questions. The first one "is it possible to apply in Portugal the VisBlue business model/segments currently present in Denmark, what are the obstacles?" and the second one "Which companies are willing to adopt VRFB to store energy in residential buildings, and what are their expectations?"

The methodology used for the realization of this report was of a qualitative nature, more specifically it consisted of an action-research process. Considering the study theme, the purpose of this action-research will be to apply an existing business model of a Danish company to a new market, specifically, the Portuguese market.

The work I will be developing will lay emphasis on batteries for stationary purposes, focusing on the type of batteries developed at VisBlue, VRFB. With the prominent role that ESS are beginning to play, legislation covering this technology will need to be thoroughly analyzed.

Thereunto, for the collection of empirical materials, the technique used was indirect/non-interactive, through the consultation of official documents, in this case I opted to make a literature review throughout the report, moreover, and as stated before dealing with countries that are part of the EU, the European legal framework will be a constant part of the work, that way, it will be analyzed emphasizing in the Portuguese case.

Besides that, to collect data on the willingness of companies to adopt the VRFB to store energy in residential buildings, and what are their expectations, surveys were carried out to companies within different sectors related to buildings designing, planning, and constructing and PV installation/maintenance. As this new product enters a new market, an analysis through a survey was made, to verify if VRFB are recognized, possibly as an option, it also aimed to identify if the market had already some type of experience with ESS and to try to comprehend which companies are willing to adopt this energy storage model in the constructions that are being projected or that will be projected in the future and the expectations around the technology.

5. Empirical analysis

Regarding the location of the companies that answered the questionnaires, it is well spread around the Portuguese territory. The two biggest metropolitan areas of the country having more participation is a true representation of the Portuguese demographics. But being the archipelagos so important for the introduction of the VRFB in Portugal, having only one answer from Azores and none from Madeira is disappointing.

In what concerns to the sectors of the companies, obviously there are more architecture and engineering studios, answering the questionnaires. This happens because there were more companies within this sector to be contacted, even though they had the second lowest answer rate with only 2.40%. After this sector, the one with highest rate of involvement are the contractors and construction companies being the second most contacted sector, with an answer rate of 3.41%. The third sector with more answers was the building planners, having the highest answer rate of 4.62%. The fourth sector with more answers and with the second highest answer rate of 4.44% are the consulting companies. The lowest answer rate was within the companies specialized in the installation and maintenance of solar panels with 0%. Even though there was no specific contact to companies that are specialized in the installation of charging stations for EV one company in this sector answered to the survey.
In relation to companies dimensions the companies with over 50 employees are part of 2 different sectors, consulting and contractors and construction companies, with 2 companies in each sector, representing 10% of the sample.

The dimension of the companies that were comprehended between 10 and 50 employees is divided between 2 different sectors, in this case with only 1 architecture and engineering studio and with 6 contractors and construction companies, representing 17.5% of the sample. Companies with a size of less than 10 employees are the biggest share of the sample, representing 72.5%, within 4 sectors, 19 architecture and engineering studios, 6 contractors and construction companies, 3 building planners and 1 specialized in the installation of charging stations for EV.

To identify the companies a number will serve as an identification (ID), simplifying the results demonstration and evaluation of results.

Table 11 shows the companies ID within different district, locality, sector, number of employees and yearly turnover.

Table 11 - Companies ID with district, locality, sector, number of employees and yearly turnover

ID	Company district	Company locality	Company sector	Number of employees	Yearly turnover
1	Leiria	Caldas da Rainha	Contractors and Construction	>10 and <50	150.000,00€
2	Coimbra	Coimbra	Contractors and Construction	>10 and <50	800.000,00€
3	Lisboa	Paço de Arcos	Architecture and Engineering	<10	N/A
4	Castelo Branco	Castelo Branco	Contractors and Construction	<10	2.000.000,00€
5	Lisboa	Lisboa	Consulting	>50	7.000.000,00€
6	Setúbal	Caparica	Architecture and Engineering	<10	120.000,00€
7	Portalegre	Portalegre	Contractors and Construction	>10 and <50	N/A
8	Setúbal	Paio Pires	Contractors and Construction	>10 and <50	4.000.000,00€
9	Braga	Caldas das Taipas	Contractors and Construction	<10	300.000,00€
10	Porto	Gondomar	Architecture and Engineering	<10	500.000,00€
11	Leiria	Caldas da Rainha	Architecture and Engineering	<10	N/A
12	Leiria	Pombal	Building planners	<10	60.000,00€
13	Santarém	Golegã	Architecture and Engineering	<10	N/A
14	Castelo Branco	Castelo Branco	Contractors and Construction	<10	2.000.000,00€
15	Lisboa	Lisboa	Architecture and Engineering	<10	40.000,00€
16	Porto	Porto	Architecture and Engineering	<10	90.000,00€
17	Porto	Ermesinde	Contractors and Construction	>50	N/A
18	Lisboa	Lisboa	Architecture and Engineering	<10	500.000,00€
19	Porto	Porto	Architecture and Engineering	<10	300.000,00€
20	Aveiro	Aveiro	Architecture and Engineering	<10	250.000,00€
21	Viseu	Viseu	Building planners	<10	N/A
22	Porto	Vila Nova de Gaia	Contractors and Construction	<10	100.000,00€
23	Açores	Praia da Vitória	Contractors and Construction	>10 and <50	N/A
24	Porto	Fânzeres	Architecture and Engineering	<10	90.000,00€
25	Lisboa	Lisboa	Consulting	>50	10.000.000,00€
26	Porto	Lousada	Architecture and Engineering	<10	200.000,00€
27	Faro	Salir	Contractors and Construction	<10	250.000,00€
28	Santarém	Caxarias	Architecture and Engineering	<10	N/A
29	Lisboa	Sintra	Architecture and Engineering	<10	200.000,00€
30	Aveiro	Santa Maria da Feira	Architecture and Engineering	<10	100.000,00€
31	Bragança	Torre de Moncorvo	Contractors and Construction	<10	400.000,00€
32	Coimbra	Coimbra	Contractors and Construction	>50	15.000.000,00€
33	Porto	Maia	Architecture and Engineering	<10	200.000,00€
34	Porto	Penafiel	Contractors and Construction	>10 and <50	300.000,00€
35	Aveiro	Santa Maria da Feira	Architecture and Engineering	<10	100.000,00€
36	Porto	Maia	Installation of charging stations for EV	<10	N/A
37	Aveiro	Aveiro	Architecture and Engineering	<10	250.000,00€
38	Lisboa	Oeiras	Architecture and Engineering	>10 and <50	500.000,00€
39	Lisboa	Lisboa	Building planners	<10	N/A
40	Braga	Barcelos	Architecture and Engineering	<10	30.000,00€

Within the yearly turnover the companies that did not answer to this question have all sizes and sectors included, accounting for 25% of the companies that answered the survey, being 17.5% companies with less than 10 employees, 5% companies with 10 to 50 employees and

2.5% a company with more than 50 employees. The yearly turnovers are exposed on the Table 12 that compares with the dimension in terms of employees and sectors.

Table 12 - Number of companies in terms of different sectors, number of employees and yearly turnover

No. of companies	ID's	Sector	No. of employees	Yearly turnover
4	3; 11; 13; 28	Architecture and Engineering	<10	N/A
2	21; 39	Building planners	<10	N/A
1	36	Installation of charging stations for EV	<10	N/A
2	7; 23	Contractors and construction	>10 and <50	N/A
1	17	Contractors and construction	>50	N/A
1	40	Architecture and Engineering	<10	30.000,00€
1	15	Architecture and Engineering	<10	40.000,00€
1	12	Building planners	<10	60.000,00€
2	16; 24	Architecture and Engineering	<10	90.000,00€
2	30; 35	Architecture and Engineering	<10	100.000,00€
1	22	Contractors and construction	<10	100.000,00€
1	6	Architecture and Engineering	<10	120.000,00€
1	1	Contractors and construction	>10 and <50	150.000,00€
3	26; 29; 33	Architecture and Engineering	<10	200.000,00€
1	27	Contractors and construction	<10	250.000,00€
2	20; 37	Architecture and Engineering	<10	250.000,00€
1	19	Architecture and Engineering	<10	300.000,00€
1	9	Contractors and construction	<10	300.000,00€
1	34	Contractors and construction	>10 and <50	300.000,00€
1	31	Contractors and construction	<10	400.000,00€
2	10; 18	Architecture and Engineering	<10	500.000,00€
1	38	Architecture and Engineering	>10 and <50	500.000,00€
1	2	Contractors and construction	>10 and <50	800.000,00€
2	4; 14	Contractors and construction	<10	2.000.000,00€
1	8	Contractors and construction	>10 and <50	4.000.000,00€
1	5	Consulting	>50	7.000.000,00€
1	25	Consulting	>50	10.000.000,00€
1	32	Contractors and construction	>50	15.000.000,00€

Concerning the first question of the second sector, asking if the companies have already used any kind of ESS, in the 15% of the companies that answered the survey answered positively to this question, there are companies of various sizes and sectors, as we can see in the Table 13.

Table 13 - Companies ID that have already used ESS, within different sectors, number of employees and yearly turnovers

ID	Sector	No. of employees	Yearly turnover
24	Architecture and Engineering	<10	90.000,00€
9	Architecture and Engineering	<10	300.000,00€
18	Architecture and Engineering	<10	500.000,00€
8	Contractors and construction	>10 and <50	4.000.000,00€
5	Consulting	>50	7.000.000,00€
25	Consulting	>50	10.000.000,00€

Being the sample of bigger companies (more than 50 employees) not that numerous, it is possible to state that bigger companies may have more autonomy and knowledge in the state of art, since 66.66% of that part of the sample answered positively to this question. From the results provided contractors and construction companies with a bigger dimension in terms of number of employees and yearly turnover may be more autonomous and updated in terms of what is the state of the art. This is normal because there is probably a plurality of teams that explore different themes. In terms of sector, consulting companies are completely ahead since 100% of the consulting companies that answered the survey have already applied ESS.

Regarding the knowledge or recognition of the surveyed companies about VRFB, only 10% of the answers were positive, being half of these from companies that previously have installed ESS, the Table 14 shows the different sector and sizes of the companies in terms of number of employees and yearly turnover that answered positively to the second question of the second sector.

Table 14 - Companies ID that have knowledge or recognition about VRFB, within different sectors, number of employees and yearly turnovers

ID	Sector	No. of employees	Yearly turnover
7	Contractors and construction	>10 and <50	N/A
24	Architecture and Engineering	<10	90.000,00€
33	Architecture and Engineering	<10	200.000,00€
8	Contractors and construction	>10 and <50	4.000.000,00€

Since only 10% of the surveyed companies recognized VRFB, VisBlue has some work to do in terms of visibility and recognition. In this case, consulting companies do not recognize VRFB, this is a problem to solve, since these represent a third of the companies that had already used ESS. Once again, contractors and construction companies with bigger size may have an advantage in terms of autonomy and knowledge about the state of the art.

Considering the advantages of VRFB in comparison with other technologies, only 7.5% of the companies that answered the survey answered positively, being these identified in the Table 15. Despite that, 75% of the companies that knew or recognized the VRFB answered positively.

Table 15 - Companies ID that know the advantages of VRFB in comparison with other ESS, within different sectors, number of employees and yearly turnovers

ID	Sector	No. of employees	Yearly turnover
7	Contractors and construction	>10 and <50	N/A
24	Architecture and Engineering	<10	90.000,00€
33	Architecture and Engineering	<10	200.000,00€

As in the question before, VisBlue requires the use of various channels and different customer relation techniques in a marketing campaign to disseminate its technology to possible customers and partners. Surprisingly only companies with a small to medium size recognize the advantages.

About the European Directive EU 2018/844 that suggests the use of batteries coupled with RES, and which recommendation of technology has been made towards it, 52.5% recommended Lithium-ion batteries, 37.5% stated that never recommended batteries, 5% said that they left it to specialists to decide, 2.5% recommended VRFB and 2.5% ZBFB, the sizes and sectors of the companies are available on the Table 16. Lithium-ion batteries being the most known and recognized are more easily indicated for this type of functionality, even from companies who never applied ESS.

Table 16 - Companies ID and their respective recommendations in terms of ESS, within different sectors, number of employees and yearly turnovers

Recommendation	ID	Sector	No. of employees	Yearly turnover
Lithium-ion batteries	13	Architecture and Engineering	<10	N/A
	21	Building planners	<10	
	36	Installation of charging stations for EV	<10	
	7	Contractors and construction	>10 and <50	
	17	Contractors and construction	>50	
	40	Architecture and Engineering	<10	30.000,00€
	12	Building planners	<10	60.000,00€
	16	Architecture and Engineering	<10	90.000,00€
	30	Architecture and Engineering	<10	100.000,00€
	35	Architecture and Engineering	<10	100.000,00€
	6	Architecture and Engineering	<10	120.000,00€
	1	Contractors and construction	>10 and <50	150.000,00€
	29	Architecture and Engineering	<10	200.000,00€
	37	Architecture and Engineering	<10	250.000,00€
	9	Contractors and construction	<10	300.000,00€
	34	Contractors and construction	>10 and <50	300.000,00€
	2	Contractors and construction	>10 and <50	800.000,00€
	4	Contractors and construction	<10	2.000.000,00€
	14	Contractors and construction	<10	2.000.000,00€
	8	Contractors and construction	>10 and <50	4.000.000,00€
	5	Consulting	>50	7.000.000,00€
ZBFB	25	Consulting	>50	10.000.000,00€
VRFB	24	Architecture and Engineering	<10	90.000,00€
According to the specialists	33	Architecture and Engineering	<10	200.000,00€
	18	Architecture and Engineering	<10	500.000,00€
Never recommended batteries	3	Architecture and Engineering	<10	N/A
	11	Architecture and Engineering	<10	
	28	Architecture and Engineering	<10	
	39	Building planners	<10	
	23	Contractors and construction	>10 and <50	
	15	Architecture and Engineering	<10	40.000,00€
	22	Contractors and construction	<10	100.000,00€
	26	Architecture and Engineering	<10	200.000,00€
	20	Architecture and Engineering	<10	250.000,00€
	27	Contractors and construction	<10	250.000,00€
	19	Architecture and Engineering	<10	300.000,00€
	31	Contractors and construction	<10	400.000,00€
	10	Architecture and Engineering	<10	500.000,00€
	38	Architecture and Engineering	>10 and <50	500.000,00€
	32	Contractors and construction	>50	15.000.000,00€

Between the companies that had already applied ESS, 66.66% answered that they would recommend Lithium-ion batteries, 16.67% left the decision to specialists, being the remainder 16.67% for VRFB. Within the companies that applied ESS before, with the ID numbers 5, 8 and 9 recommended lithium-ion batteries, whilst with the ID number 18 left the decision to specialists, with the ID number 24 chose VRFB and finally with ID number 25 opted for ZBFB. It is important to mention that the only company that had already applied ESS, and recognized VRFB and their advantages, recommended this type of technology, having the ID number 24. The other companies that recognized VRFB and their advantages, with the ID number 7 recommended lithium-ion batteries, while the company with the ID number 33 left the decision to specialists. The company with the ID number 8, that only recognized VRFB, recommended lithium-ion batteries.

The Table 17 reveals the answers of the next three questions that asked for different types of technologies would be recommended in past projects that the companies have built/designed/worked, being these technologies lithium-ion batteries, VRFB and ZBFB.

Table 17 - Companies ID and their respective recommendations for different technologies in the past projects, within different sectors, number of employees and yearly turnovers

<table>
<tr><th>ID</th><th>Sector</th><th>No. of employees</th><th>Yearly turnover</th><th>Past projects – lithium-ion batteries</th><th>Past projects – VRFB</th><th>Past projects – ZBFB</th></tr>
<tr><td>28</td><td>Architecture and Engineering</td><td><10</td><td rowspan="4">N/A</td><td rowspan="15">I don’t know/Not applicable</td><td rowspan="15">I don’t know/Not applicable</td><td rowspan="5">I don’t know/Not applicable</td></tr>
<tr><td>21</td><td>Building planners</td><td><10</td></tr>
<tr><td>39</td><td>Building planners</td><td><10</td></tr>
<tr><td>23</td><td>Contractors and construction</td><td>>10 and <50</td></tr>
<tr><td>40</td><td>Architecture and Engineering</td><td><10</td><td>30.000,00€</td></tr>
<tr><td>24</td><td>Architecture and Engineering</td><td><10</td><td>90.000,00€</td><td>Never</td></tr>
<tr><td>26</td><td>Architecture and Engineering</td><td><10</td><td>200.000,00€</td><td rowspan="9">I don’t know/Not applicable</td></tr>
<tr><td>33</td><td>Architecture and Engineering</td><td><10</td><td>200.000,00€</td></tr>
<tr><td>20</td><td>Architecture and Engineering</td><td><10</td><td>250.000,00€</td></tr>
<tr><td>27</td><td>Contractors and construction</td><td><10</td><td>250.000,00€</td></tr>
<tr><td>34</td><td>Contractors and construction</td><td>>10 and <50</td><td>300.000,00€</td></tr>
<tr><td>31</td><td>Contractors and construction</td><td><10</td><td>400.000,00€</td></tr>
<tr><td>10</td><td>Architecture and Engineering</td><td><10</td><td>500.000,00€</td></tr>
<tr><td>38</td><td>Architecture and Engineering</td><td>>10 and <50</td><td>500.000,00€</td></tr>
<tr><td>32</td><td>Contractors and construction</td><td>>50</td><td>15.000.000,00€</td></tr>
<tr><td>3</td><td>Architecture and Engineering</td><td><10</td><td rowspan="3">N/A</td><td rowspan="11">Never</td><td rowspan="11">Never</td><td rowspan="10">Never</td></tr>
<tr><td>11</td><td>Architecture and Engineering</td><td><10</td></tr>
<tr><td>13</td><td>Architecture and Engineering</td><td><10</td></tr>
<tr><td>12</td><td>Building planners</td><td><10</td><td>60.000,00€</td></tr>
<tr><td>16</td><td>Architecture and Engineering</td><td><10</td><td>90.000,00€</td></tr>
<tr><td>22</td><td>Contractors and construction</td><td><10</td><td>100.000,00€</td></tr>
<tr><td>6</td><td>Architecture and Engineering</td><td><10</td><td>120.000,00€</td></tr>
<tr><td>19</td><td>Architecture and Engineering</td><td><10</td><td>300.000,00€</td></tr>
<tr><td>18</td><td>Architecture and Engineering</td><td><10</td><td>500.000,00€</td></tr>
<tr><td>2</td><td>Contractors and construction</td><td>>10 and <50</td><td>800.000,00€</td></tr>
<tr><td>25</td><td>Consulting</td><td>>50</td><td>10.000.000,00€</td><td>Sometimes</td></tr>
<tr><td>36</td><td>Installation of charging stations for EV</td><td><10</td><td rowspan="3">N/A</td><td rowspan="8">Sometimes</td><td>I don’t know/Not applicable</td><td>I don’t know/Not applicable</td></tr>
<tr><td>7</td><td>Contractors and construction</td><td>>10 and <50</td><td rowspan="2">Sometimes</td><td rowspan="2">Sometimes</td></tr>
<tr><td>17</td><td>Contractors and construction</td><td>>50</td></tr>
<tr><td>1</td><td>Contractors and construction</td><td>>10 and <50</td><td>150.000,00€</td><td rowspan="2">Never</td><td rowspan="2">Never</td></tr>
<tr><td>29</td><td>Architecture and Engineering</td><td><10</td><td>200.000,00€</td></tr>
<tr><td>4</td><td>Contractors and construction</td><td><10</td><td>2.000.000,00€</td><td rowspan="2">Sometimes</td><td rowspan="2">Sometimes</td></tr>
<tr><td>14</td><td>Contractors and construction</td><td><10</td><td>2.000.000,00€</td></tr>
<tr><td>8</td><td>Contractors and construction</td><td>>10 and <50</td><td>4.000.000,00€</td><td>Never</td><td>Never</td></tr>
<tr><td>15</td><td>Architecture and Engineering</td><td><10</td><td>40.000,00€</td><td rowspan="6">Always</td><td>Always</td><td>Always</td></tr>
<tr><td>30</td><td>Architecture and Engineering</td><td><10</td><td>100.000,00€</td><td rowspan="3">I don’t know/Not applicable</td><td rowspan="2">I don’t know/Not applicable</td></tr>
<tr><td>35</td><td>Architecture and Engineering</td><td><10</td><td>100.000,00€</td></tr>
<tr><td>37</td><td>Architecture and Engineering</td><td><10</td><td>250.000,00€</td><td rowspan="3">Never</td></tr>
<tr><td>9</td><td>Contractors and construction</td><td><10</td><td>300.000,00€</td><td rowspan="2">Never</td></tr>
<tr><td>5</td><td>Consulting</td><td>>50</td><td>7.000.000,00€</td></tr>
</table>

The companies that previously have stated that had applied ESS with the ID number 5 and 9, recommended lithium-ion batteries always and never VRFB or ZBFB for past projects, with the number ID 8, recommended lithium-ion batteries sometimes for previously done projects and never VRFB or ZBFB, with the number ID 18 for past projects never recommended any of the technologies, whilst with the ID number 24, stated it did not know or it was not applicable for lithium-ion batteries and VRFB, and that never would recommend ZBFB, finally with the ID number 25 recommended ZBFB sometimes and never lithium-ion batteries or VRFB. Two of the companies that stated that recognized the VRFB and their advantages, with ID number 7 recommended for previous projects all the technologies sometimes, while with the ID number 33, for the same situation, answered it did not know or it was not applicable for all the technologies.

The next three questions asked if the companies would apply or recommend lithium-ion batteries, VRFB and ZBFB in the on-going projects that the companies are building/designing/working, the answers are represented in the Table 18.

The companies that had already installed ESS with the ID number 5 and 9 answered that would always recommend or apply lithium-ion batteries, and never for the other two options, while the ID number 8 responded that would always recommend or apply lithium-ion batteries, and for VRFB and ZBFB sometimes, with the ID number 18 for on-going projects, never was the answer for the three different types of technology considered in these questions, while for the ID number 24 the answer was I do not know or not applicable for lithium-ion batteries and VRFB, and never for ZBFB, finally with the ID number 25, the answer for every type of technology considered was I do not know or not applicable.

Table 18 - Companies ID and their respective recommendations for different technologies in the on-going projects, within different sectors, number of employees and yearly turnovers

<table>
<tr><th>ID</th><th>Sector</th><th>No. of employees</th><th>Yearly turnover</th><th>On-going projects – lithium-ion batteries</th><th>On-going projects – VRFB</th><th>On-going projects – ZBFB</th></tr>
<tr><td>28</td><td>Architecture and Engineering</td><td><10</td><td rowspan="4">N/A</td><td rowspan="17">I don’t know/Not applicable</td><td rowspan="17">I don’t know/Not applicable</td><td rowspan="5">I don’t know/Not applicable</td></tr>
<tr><td>21</td><td>Building planners</td><td><10</td></tr>
<tr><td>39</td><td>Building planners</td><td><10</td></tr>
<tr><td>23</td><td>Contractors and construction</td><td>>10 and <50</td></tr>
<tr><td>40</td><td>Architecture and Engineering</td><td><10</td><td>30.000,00€</td></tr>
<tr><td>24</td><td>Architecture and Engineering</td><td><10</td><td>90.000,00€</td><td>Never</td></tr>
<tr><td>26</td><td>Architecture and Engineering</td><td><10</td><td>200.000,00€</td><td>I don’t know/Not applicable</td></tr>
<tr><td>29</td><td>Architecture and Engineering</td><td><10</td><td>200.000,00€</td><td>Never</td></tr>
<tr><td>33</td><td>Architecture and Engineering</td><td><10</td><td>200.000,00€</td><td rowspan="9">I don’t know/Not applicable</td></tr>
<tr><td>20</td><td>Architecture and Engineering</td><td><10</td><td>250.000,00€</td></tr>
<tr><td>27</td><td>Contractors and construction</td><td><10</td><td>250.000,00€</td></tr>
<tr><td>34</td><td>Contractors and construction</td><td>>10 and <50</td><td>300.000,00€</td></tr>
<tr><td>31</td><td>Contractors and construction</td><td><10</td><td>400.000,00€</td></tr>
<tr><td>10</td><td>Architecture and Engineering</td><td><10</td><td>500.000,00€</td></tr>
<tr><td>38</td><td>Architecture and Engineering</td><td>>10 and <50</td><td>500.000,00€</td></tr>
<tr><td>25</td><td>Consulting</td><td>>50</td><td>10.000.000,00€</td></tr>
<tr><td>32</td><td>Contractors and construction</td><td>>50</td><td>15.000.000,00€</td></tr>
<tr><td>3</td><td>Architecture and Engineering</td><td><10</td><td rowspan="3">N/A</td><td rowspan="12">Never</td><td rowspan="12">Never</td><td rowspan="12">Never</td></tr>
<tr><td>11</td><td>Architecture and Engineering</td><td><10</td></tr>
<tr><td>13</td><td>Architecture and Engineering</td><td><10</td></tr>
<tr><td>12</td><td>Building planners</td><td><10</td><td>60.000,00€</td></tr>
<tr><td>16</td><td>Architecture and Engineering</td><td><10</td><td>90.000,00€</td></tr>
<tr><td>22</td><td>Contractors and construction</td><td><10</td><td>100.000,00€</td></tr>
<tr><td>6</td><td>Architecture and Engineering</td><td><10</td><td>120.000,00€</td></tr>
<tr><td>19</td><td>Architecture and Engineering</td><td><10</td><td>300.000,00€</td></tr>
<tr><td>18</td><td>Architecture and Engineering</td><td><10</td><td>500.000,00€</td></tr>
<tr><td>2</td><td>Contractors and construction</td><td>>10 and <50</td><td>800.000,00€</td></tr>
<tr><td>4</td><td>Contractors and construction</td><td><10</td><td>2.000.000,00€</td></tr>
<tr><td>14</td><td>Contractors and construction</td><td><10</td><td>2.000.000,00€</td></tr>
<tr><td>36</td><td>Installation of charging stations for EV</td><td><10</td><td rowspan="3">N/A</td><td rowspan="4">Sometimes</td><td>I don’t know/Not applicable</td><td>I don’t know/Not applicable</td></tr>
<tr><td>7</td><td>Contractors and construction</td><td>>10 and <50</td><td rowspan="3">Sometimes</td><td rowspan="3">Sometimes</td></tr>
<tr><td>17</td><td>Contractors and construction</td><td>>50</td></tr>
<tr><td>1</td><td>Contractors and construction</td><td>>10 and <50</td><td>150.000,00€</td></tr>
<tr><td>15</td><td>Architecture and Engineering</td><td><10</td><td>40.000,00€</td><td rowspan="7">Always</td><td>Always</td><td>Always</td></tr>
<tr><td>30</td><td>Architecture and Engineering</td><td><10</td><td>100.000,00€</td><td rowspan="3">I don’t know/Not applicable</td><td rowspan="2">I don’t know/Not applicable</td></tr>
<tr><td>35</td><td>Architecture and Engineering</td><td><10</td><td>100.000,00€</td></tr>
<tr><td>37</td><td>Architecture and Engineering</td><td><10</td><td>250.000,00€</td><td rowspan="2">Never</td></tr>
<tr><td>9</td><td>Contractors and construction</td><td><10</td><td>300.000,00€</td><td>Never</td></tr>
<tr><td>8</td><td>Contractors and construction</td><td>>10 and <50</td><td>4.000.000,00€</td><td>Sometimes</td><td>Sometimes</td></tr>
<tr><td>5</td><td>Consulting</td><td>>50</td><td>7.000.000,00€</td><td>Never</td><td>Never</td></tr>
</table>

Whilst the next question was about the main reason for their choices on the questions answered before. The results are illustrated in the Table 19.

Table 19 - Companies ID and the main reason for their choices on questions previously answered within different sectors, number of employees and yearly turnovers

ID	Sector	No. of employees	Yearly turnover	Main Reason
3	Architecture and Engineering	<10	N/A	I don't know/Not applicable
11	Architecture and Engineering	<10		
39	Building planners	<10		
23	Contractors and construction	>10 and <50		
17	Contractors and construction	>50		
16	Architecture and Engineering	<10	90.000,00€	
22	Contractors and construction	<10	100.000,00€	
26	Architecture and Engineering	<10	200.000,00€	
27	Contractors and construction	<10	250.000,00€	
34	Contractors and construction	>10 and <50	300.000,00€	
10	Architecture and Engineering	<10	500.000,00€	
38	Architecture and Engineering	>10 and <50	500.000,00€	
2	Contractors and construction	>10 and <50	800.000,00€	
4	Contractors and construction	>10	2.000.000,00€	
14	Contractors and construction	>10	2.000.000,00€	
5	Consulting	>50	7.000.000,00€	
32	Contractors and construction	>50	15.000.000,00€	
15	Architecture and Engineering	<10	40.000,00€	Safety
8	Contractors and construction	>10 and <50	4.000.000,00€	
13	Architecture and Engineering	<10	N/A	Price
21	Building planners	<10		
36	Installation of charging stations for EV	<10		
12	Building planners	<10	60.000,00€	
6	Architecture and Engineering	<10	120.000,00€	
1	Contractors and construction	>10 and <50	150.000,00€	
25	Consulting	>50	10.000.000,00€	
28	Architecture and Engineering	<10	N/A	Performance
7	Contractors and construction	>10 and <50		
40	Architecture and Engineering	<10	30.000,00€	
24	Architecture and Engineering	<10	90.000,00€	
30	Architecture and Engineering	<10	100.000,00€	
35	Architecture and Engineering	<10	100.000,00€	
29	Architecture and Engineering	<10	200.000,00€	
33	Architecture and Engineering	<10	200.000,00€	
37	Architecture and Engineering	<10	250.000,00€	
9	Contractors and construction	<10	300.000,00€	
19	Architecture and Engineering	<10	300.000,00€	
31	Contractors and construction	<10	400.000,00€	
18	Architecture and Engineering	<10	500.000,00€	
20	Architecture and Engineering	<10	250.000,00€	Price-performance

Considering the companies that had already applied ESS, the company with the ID number 5, answers that don't know the main reason or it is not applicable, and the company with the ID number 8 states safety as the main reason, even though it chose lithium-ion batteries as the recommendation for the Directive EU 2018/844, and the answers of the six questions before that refers lithium-ion batteries as the main option in both cases, which is incoherent. The companies with the ID numbers 9, 18 and 24 stated performance, as the main reason for their choices, and finally the company with the ID number 25 answered that the main reason for its choice was price. Now concerning to the companies that stated that recognized VRFB but did not apply ESS, the companies with the ID numbers 7 and 33 defined performance as the main reason for their choices.

The answers concerning the last question about the ROI considered to install VRFB are represented in the Table 20.

Table 20 - Companies ID and the considered ROI to install VRFB, within different sectors, number of employees and yearly turnovers

ID	Sector	No. of employees	Yearly turnover	ROI
36	Installation of charging stations for EV	<10	N/A	I don't know
39	Building planners	<10	N/A	I don't know
23	Contractors and construction	>10 and <50	N/A	I don't know
40	Architecture and Engineering	<10	30.000,00€	I don't know
26	Architecture and Engineering	<10	200.000,00€	I don't know
20	Architecture and Engineering	<10	250.000,00€	I don't know
27	Contractors and construction	<10	250.000,00€	I don't know
37	Architecture and Engineering	<10	250.000,00€	I don't know
31	Contractors and construction	<10	400.000,00€	I don't know
38	Architecture and Engineering	>10 and <50	500.000,00€	I don't know
25	Consulting	>50	10.000.000,00€	I don't know
12	Building planners	<10	60.000,00€	1 to 3 years
30	Architecture and Engineering	<10	100.000,00€	1 to 3 years
35	Architecture and Engineering	<10	100.000,00€	1 to 3 years
1	Contractors and construction	>10 and <50	150.000,00€	1 to 3 years
33	Architecture and Engineering	<10	200.000,00€	1 to 3 years
34	Contractors and construction	>10 and <50	300.000,00€	1 to 3 years
18	Architecture and Engineering	<10	500.000,00€	1 to 3 years
11	Architecture and Engineering	<10	N/A	3 to 5 years
15	Architecture and Engineering	<10	40.000,00€	3 to 5 years
29	Architecture and Engineering	<10	200.000,00€	3 to 5 years
9	Contractors and construction	<10	300.000,00€	3 to 5 years
19	Architecture and Engineering	<10	300.000,00€	3 to 5 years
8	Contractors and construction	>10 and <50	4.000.000,00€	3 to 5 years
32	Contractors and construction	>50	15.000.000,00€	3 to 5 years
3	Architecture and Engineering	<10	N/A	5 to 7 years
13	Architecture and Engineering	<10	N/A	5 to 7 years
21	Building planners	<10	N/A	5 to 7 years
28	Architecture and Engineering	<10	N/A	5 to 7 years
7	Contractors and construction	>10 and <50	N/A	5 to 7 years
17	Contractors and construction	>50	N/A	5 to 7 years
16	Architecture and Engineering	<10	90.000,00€	5 to 7 years
24	Architecture and Engineering	<10	90.000,00€	5 to 7 years
2	Contractors and construction	>10 and <50	800.000,00€	5 to 7 years
4	Contractors and construction	<10	2.000.000,00€	5 to 7 years
14	Contractors and construction	<10	2.000.000,00€	5 to 7 years
22	Contractors and construction	<10	100.000,00€	7 to 10 years
6	Architecture and Engineering	<10	120.000,00€	7 to 10 years
10	Architecture and Engineering	<10	500.000,00€	7 to 10 years
5	Consulting	>50	7.000.000,00€	7 to 10 years

The expectations that VisBlue had for the ROI from previous informal contacts, before the COVID-19 pandemic would consider 6 years or less for systems of PV coupled with batteries. One company mentioned that it was group policy, for any kind of investment, whether productive or not, that the ROI should be 2 years (they gave some more latitude because of the pandemic, but not much), for this type of equipment it is impossible to achieve the ROI in such a short period of time, so the results that this survey provided interesting information. It is important to note that an evaluation of local energy production versus storage versus consumption is always done to see what the estimated ROI is. In this question 27.5% of the companies stated that did not know the considered ROI to apply VRFB, 17.5% stated that the considered ROI to apply VRFB was 1 to 3 years, 17.5% considered 3 to 5 years, 27.5% considered 5 to 7 years and 10% considered 7 to 10 years.

6. Conclusion

Due to the energy transition and targets and goals established by the EU, batteries storage systems assume an important role to balance the electricity grid with high penetrations of VRES. As a result of the growing environmental awareness, the choice for an ESS, must consider an overall analysis, contemplating amongst other specifications environmental impacts and life cycle assessments, with this VRFB appears as a promising technology for stationary purposes.

EU enforces these types of technologies and has been a critical enabler for the use of ESS, the Green Deal is expected to bring new European battery legislation, after this legislation being released VisBlue might need to evaluate scrupulously the new regulatory measures of the market, being legally updated and in compliance.

Right away, VisBlue is allowed to enter the Portuguese market at a legal level according to *Decreto-Lei n.º 162/2019* and *Regulamento n.º 373/2021*, that basically creates the possibility for storage of electricity from three different types of self-consumers, being these individual, collective and RE Communities, it is important to refer that the condominiums are a considered part of the collective self-consumers. Possibly in the future some new legislation may condition the activity. Everything indicates that soon there should be legislations at a national level aiming at least to the full transposition of the European directive EU 2019/944, and additionally there will be more support and financial incentives, which could help the technology not only to enter the market, but to develop and reach a state of maturity faster.

The Azores will probably be a good gateway, for a first experiment, due to the large monetary support that is made available despite having a less privileged solar exposure compared to the mainland. Coimbra with regional support could also be an opportunity to explore for the entrance in the market in mainland Portugal. Considering solar exposure, the south of Portugal has optimal conditions when it comes to energy production from PV, in Alentejo and Algarve.

The incentive provided through *Despacho n.º 6070-A/2021* could be a way of a potential customer recover part of the initial investment made in the VRFB. Due to the deadline and limited budget of this incentive, the entrance in the Portuguese market, and investment to publicize the technology and advantages should be done now, otherwise it would be advisable to wait for a new incentive because of the initial investment that some Portuguese customers would be inhibited to make.

The surveys show that there is still a long way to go in Portugal regarding the more widespread installation of ESS. It also demonstrated that a significant effort on VisBlue's part is essential to make VRFB and its advantages known to potential partners and customers. It should require the use of various channels and different customer relation techniques, to reach all kinds of people, scientifically educated or not. Consulting companies could be a good partnership, since from the sample in the survey this typology of company applies ESS in their projects. Nevertheless, from the expectations created from previous informal contacts, the ROI times polled were encouraging and better than expected and could be potentiated with the incentives that were approached previously.

Concluding, the biggest barriers for the introduction of the VRFB in the Portuguese market are the lack of knowledge and visibility about this type of technology and its advantages, the initial cost, and the difficulty to monetize the storage value, inhibiting the acquisition of this type of technology.

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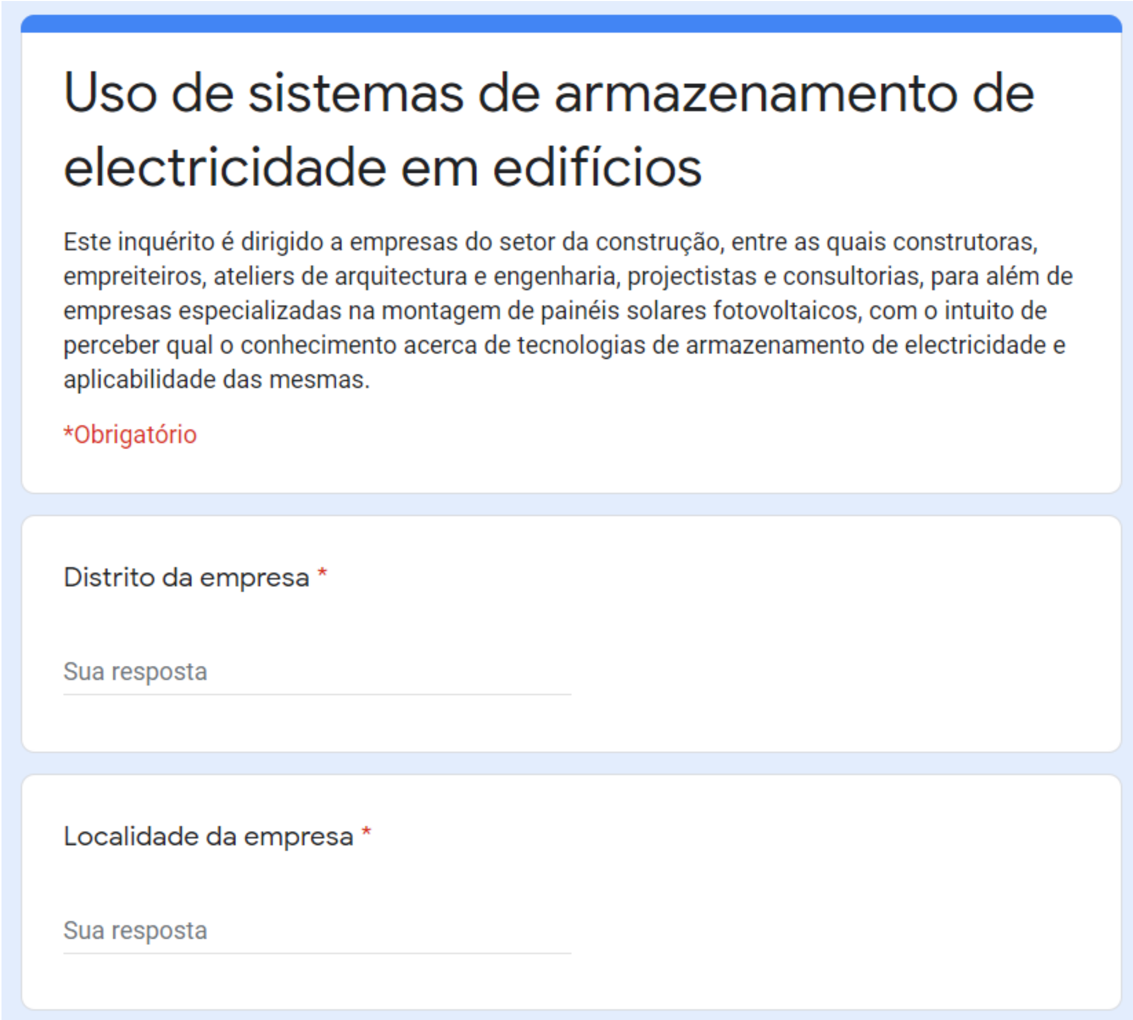
8. Annex



Uso de sistemas de armazenamento de electricidade em edifícios

Este inquérito é dirigido a empresas do setor da construção, entre as quais construtoras, empreiteiros, ateliers de arquitectura e engenharia, projectistas e consultorias, para além de empresas especializadas na montagem de painéis solares fotovoltaicos, com o intuito de perceber qual o conhecimento acerca de tecnologias de armazenamento de electricidade e aplicabilidade das mesmas.

*Obrigatório

Distrito da empresa *

Sua resposta

Localidade da empresa *

Sua resposta

Setor da empresa *

- ◯ Construtora/Empreiteiro
- ◯ Gabinete de arquitectura/engenharia
- ◯ Projectistas
- ◯ Consultoria
- ◯ Montagem/manutenção de painéis solares fotovoltaicos
- ◯ Outro: ____________________

Quantos funcionários tem a empresa? *

- ◯ Menos de 10
- ◯ Entre 10 e 50
- ◯ Mais de 50

Qual o volume de negócios anual da empresa em euros (€)

Sua resposta ____________________

Uso de sistemas de armazenamento de electricidade em edifícios

*Obrigatório

Uso de sistemas de armazenamento de electricidade em edifícios

Entre outras tecnologias mais conhecidas, as baterias de escoamento redox de vanádio são consideradas uma tecnologia promissora no que toca ao uso estacionário em edifícios para armazenamento de electricidade proveniente de geração renovável.

Já usou algum tipo de sistema de armazenamento de electricidade? *

- ◯ Sim
- ◯ Não

Conhece ou já ouviu falar nas baterias de escoamento redox de vanádio? *

- ◯ Sim
- ◯ Não

Sabe as vantagens deste tipo de tecnologia em relação a outras? *

- ◯ Sim
- ◯ Não

Face à Directiva Europeia 2018/844, que sugere o uso de baterias acopladas com sistemas de geração renovável, qual tecnologia tem recomendado? *

- ◯ Baterias de iões de lítio
- ◯ Baterias de escoamento redox de vanádio
- ◯ Baterias de fluxo de zinco e bromo
- ◯ Outro: ____________________

No caso das construções que edificou/projetou/trabalhou até ao momento recomendaria as baterias de iões de lítio? *

Escolher ▾

No caso das construções que edificou/projetou/trabalhou até ao momento recomendaria as baterias de escoamento redox de vanádio? *

Escolher

No caso das construções que edificou/projetou/trabalhou até ao momento recomendaria as baterias de fluxo de zinco e bromo? *

Escolher

Para os projetos que tem em curso, que tipos de baterias vai aconselhar, ou vai implementar - baterias de iões de lítio *

Escolher

Para os projetos que tem em curso, que tipos de baterias vai aconselhar, ou vai implementar - baterias de escoamento redox de vanádio *

Escolher

Para os projetos que tem em curso, que tipos de baterias vai aconselhar, ou vai implementar - baterias de fluxo de zinco e bromo *

Escolher

Qual o principal motivo para sua escolha ? *

- ◯ Preço
- ◯ Desempenho
- ◯ Assistência técnica
- ◯ Segurança
- ◯ Outro: ____________________

Qual o retorno de investimento que consideraria para a instalação do sistema de baterias de escoamento redox de vanádio? *

- ◯ 1 a 3 anos
- ◯ 3 a 5 anos
- ◯ 5 a 7 anos
- ◯ 7 a 10 anos
- ◯ Não sei