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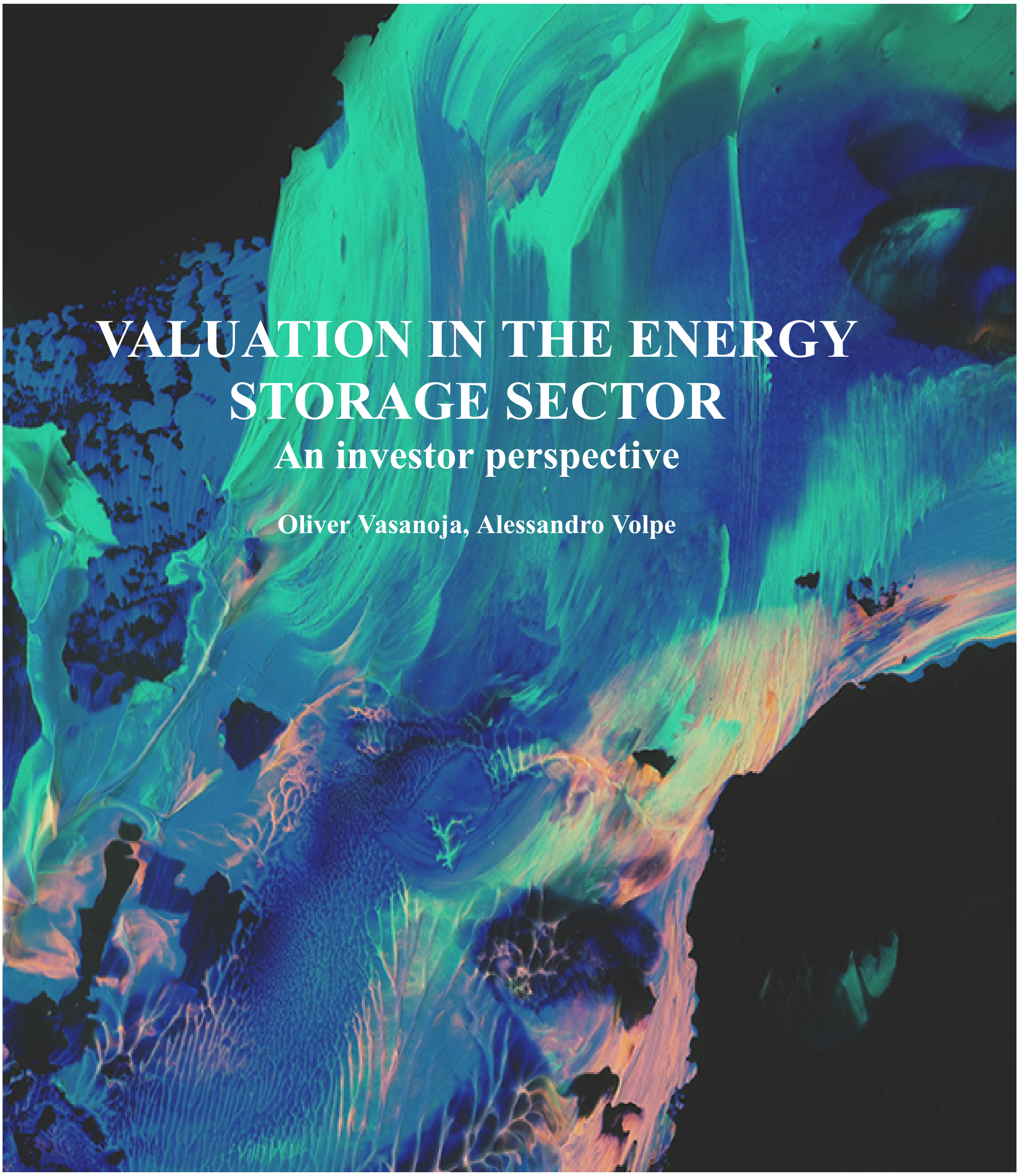

VALUATION IN THE ENERGY STORAGE SECTOR

An investor perspective

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ABSTRACT

This study will examine a strategy for evaluating energy storage projects by integrating valuation metrics from finance and the energy sector. Uncertainty is one of the key barriers to investment in the energy sector (Shimbar & Ebrahimi, 2017, p. 349) and therefore financial modeling that allows comprehensive valuation of energy investment is necessary (Berrada, 2022, p. 407). The purpose of the study is to propose a strategy for evaluating energy storage projects that applies to investors and decision makers.

LCOS is a necessary component of energy storage project valuation, as it considers both the financial and technical performance of energy storage systems (ESS). Existing research in the field has contradictory opinions regarding the usefulness of LCOS and traditional financial valuation models for investment decisions in the energy storage sector. Few studies have combined modeling from the financial and energy sector. The authors have identified a need to introduce an investor perspective to business research in the energy storage sector.

The authors conduct an explorative mixed-method study with an underlying non-positivist philosophical position. The case study design includes creation of five hypothetical energy storage projects to simulate an investment scenario. The authors utilize a point-base system to integrate valuation models from the energy and financial sectors, which include NPV, IRR, payback period, LCOS and technological maturity. Experts in the field provide input for which metrics are emphasized by practitioners. The projects are ranked based on stand-alone metrics, an integrated model and expert opinion.

The results indicate that integrating numerous valuation metrics is necessary for analyzing and comparing energy storage investments. The financial viability of projects change based on individual metrics and integrated financial models. Furthermore, the results indicate that LCOS should be reinforced by financial indicators when making investment decisions. The expert input shows that investors emphasize valuation metrics differently, which indicates that the economic attractiveness of energy storage projects varies among investors. IRR is used by practitioners as a primary indicator for profitability.

Future research should investigate a method for including sustainability indicators in the valuation process. Furthermore, as data accessibility is an issue in the field of study, future studies should collaborate with practitioners to generate more secondary data sources. Lastly, the impact of discount rates, risk premiums and investor preferences should be researched to better understand investment in the sector.

Keywords: Energy storage, project finance, sustainable finance, investor rationality, financial valuation, levelized cost of storage, net present value, internal rate of return, payback period, technological maturity.

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CAES……………….Compressed Air Energy Storage
CAPEX……………..Capital Expenditure
CAPM………………Capital Asset Pricing Model
CFC…………………Cash Flows to Capital
DCM………………...Debt Capital Markets
DOE…………………Department of Energy
DPP…………………Discounted Payback Period
DSCR………………..Debt Service Coverage Ratio
EMH………………...Efficient Market Hypothesis
ESG…………………Environmental, Governance, and social elements
ESS…………………Energy Storage System
FCF…………………Free Cash Flow
GES…………………Gravity Energy Storage Systems
GW…………………Gigawatt
IRR…………………Internal Rate of Return
KPI…………………Key Performance Indicators
KW…………………Kilowatt
LCOE ………………Levelized Cost of Energy
LCOS……………….Levelized Cost of Storage
Li-ion……………….Lithium-Ion batteries
LLCR………………Loan Life Coverage Ratio
MARR……………...Minimum Accepted Rate of Return
MRP………………..Market Risk Premium
MW…………………Megawatt
NPV…………………Net Present Value
OPEX……………….Operating Expenses
PHES……………….Pumped Heat Electrical Storage
PHS…………………Pumped Hydro Storage
PI……………………Profitability Index
POT…………………Pecking Order Theory
PP……………………Payback Period
PV…………………...Present Value
ROIC………………..Return on Invested Capital
Sod. Nickel………….Sodium Sulphur batteries
SPP…………………Simple Payback Period
SPV…………………Special Purpose Vehicle
T-bill………………...Treasury bill
TOT…………………Trade-Off Theory
WACC………………Weighted Average Cost of Capital

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1. Introduction

The following chapter will introduce the reader to our research topic, including practical and theoretical perspectives. First, we will discuss the background that outlines our choice of study, followed by problematization. We will then discuss the research gap, research question and purpose. Finally, we will present delimitations and disposition of our thesis.

1.1. Background

1.1.1. Practical background

The Paris Climate Accord, signed by 196 countries in 2015, set a target of limiting the increase in global temperature to 2 degrees Celsius, or less, preferably 1,5 degrees, compared to pre-industrial levels (UNFCCC, 2015). Our society is becoming increasingly electrified, while energy is scarce and creates externalities (Grigoroudis et al., 2019, p. 1845). The energy industry is a major source of global emissions, making it a sector that must decarbonize by using zero-carbon solutions (Akaev & Davydova, 2021, p. 2). Therefore, the demand for reliable, fossil-free, flexible, limitless and affordable energy is increasing (Dell & Rand, 2001, p. 2). Achieving these goals require adequate financial modeling that can support innovation and ensure profitability.

The implementation of renewable energies is necessary for decarbonization. In the past, our energy mix was dependent on fossil fuels, like coal, oil and natural gas (Akaev & Davydova, 2021, p. 2). To adhere to the climate goals set in 2015, shifting our attention toward renewable energy sources such as solar and wind power is essential (Akaev & Davydova, 2021, p. 2). Various renewable energy sources have advantages and drawbacks, but for purposes of this thesis, the fluctuation in energy supply based on weather conditions is discussed. Solar energy is produced on sunny days, and wind energy on days with wind. However, we do not consume energy according to the weather conditions (Leonard et al., 2019, p. 952). The mismatch between supply and demand can lead to grid imbalances, which refers to fluctuations in energy supply and demand, where too much or too little energy can lead to power outages (Stein, 2014, p. 711). Gür (2018, p. 2696) states that integrating 20% renewable energy into our production mix can cause significant grid imbalances. Furthermore, Leonard et al. (2019, p. 951) argues a share of 25-30% of renewables in annual energy production could cause significant harm to the electrical grid, requiring large-scale storage capacity to manage it. Using renewable resources like sun and wind is widely prevalent, and therefore the opportunity cost of not investing in energy infrastructure or energy storage is millions of MWh wasted from not being able to expand the use of renewable energy (Stein, 2014. p. 699).

Large-scale energy storage can provide the necessary services to assist the transition to renewable energy with our current energy infrastructure (Xue et al., 2022, p. 1). According to Gür (2018, p. 2696), grid-scale storage can solve inefficiency problems, integrate renewable energy and manage power supply. For example, during a windy night, when there is high frequency in the grid, energy can be stored and used later when there is low frequency. This is beneficial as weather and seasonal conditions cause renewable energy supply to fluctuate (Cebulla et al., 2017, p. 452), as solar energy produces large amounts seasonally and wind energy production can fluctuate daily or hourly. Thus, energy storage is necessary to increase the share of renewable energy as it often produces production peaks that are wasted without storage and grid balancing services (Gür, 2018, p. 2699).

The development and implementation of numerous energy storage technologies is essential to decarbonize the energy system (Gür, 2018, p. 2696) and thus achieve the net-zero targets by 2030 that are set forth in the Paris Climate Accord (UNFCCC, 2015). Currently, the most commonly used large-scale energy storage technology is pumped hydro storage (Gür, 2018, p. 2743). Alternative storage solutions include battery storage, flywheels, compressed air storage, power-to gas, underground pumped hydro storage, among others. The cost of energy storage is expected to decrease by at least one third between 2030 and 2050 (Schmidt et al., 2019, p. 81). The International Energy Association expects that between 2014 and 2050, global energy storage capacity must triple to keep global warming below 2 degrees (Xylia et al., 2019, p. 9). Therefore, progress must be made before 2030 to achieve the preferable limit of global warming at 1,5 degrees Celsius. A recent update from BloombergNEF (2022) predicts that global energy storage installations in 2030 will be 15 times higher than in 2021 due to developments in energy policy. According to Precedence Research (2022), the energy storage market size will grow from 210.92 billion USD in 2021 to 435.32 billion USD in 2030 with an annual compound growth rate of 8.4%.

The economic, social and environmental aspects of sustainability must be considered in the energy transition. In the energy storage industry, economic sustainability could involve ensuring stable net cash flows throughout the project life, so that the project does not place a financial burden on future generations. Social sustainability can include enabling affordable energy and reliable energy distribution, while considering the cultural impacts of projects (Rooij et al., 2022, p. 224). Environmental sustainability maintains and enhances environmental resources for future generations (Alhaddi, 2015, p. 8), and therefore the trade-off between decarbonization and ecological effects of projects must be considered. Since 2004, renewable energy investment has increased from 50 billion USD to 300 billion USD (Chatziantoniou et al., 2022. p. 1). Thus, sustainable finance is an essential trend (Zhang, 2018, p. 1688) that benefits sustainable energy development (Zhang & Wang, 2021, p. 3451).

1.1.2. Theoretical background

Since the energy sector must undergo a transition toward renewable energies for decarbonization, models that allow comprehensive financial analysis of energy storage projects are necessary (Berrada, 2022, p. 405). Renewable energy and energy storage technologies are complex and different both financially and technologically (Hoff & Lin, 2019, p. 1), and therefore a direct comparison using one metric may not capture the value or risks associated with a project (Tao & Finenko, 2016, p. 757). Renewable energy and energy storage technologies are nascent compared to traditional power plants, and therefore often have a higher cost of capital (Tao & Finenko, 2016, p. 751). Therefore, financial models that allow a comprehensive valuation and comparison of projects is necessary to decrease uncertainty of investors and decision makers (Berrada, 2022, p. 407).

Raikar & Adamson (2020, p. 7) argue that a key aspect of renewable energy finance is analyzing investments on a project level, rather than viewing investment on a corporate level. Energy investments are often analyzed on a project level, even if they are a part of a portfolio (Polzin et al., 2019, p. 1250). Therefore, the authors will view energy storage investment from a project finance perspective, by using metrics from financial valuation and levelized cost. Investments often involve considerable transaction costs (Raikar & Adamson, 2020, p. 24), but a project-level analysis can reduce agency costs and opportunistic behavior (Raikar & Adamson, 2020, p. 26), which have been an issue that has led to irrational overinvestment in the energy industry (Zhang, 2018, p. 1688). Furthermore, analysis on a project level can remove barriers to investment, such as debt restrictions (Raikar & Adamson, 2020, p. 27). Energy corporate finance is understudied, and there is a need to understand financing, investment (Zhang, 2018, p. 1691) and the willingness of various actors to invest in the energy sector (Elie et al., 2021, p. 2).

In the project valuation process, investors will consider metrics such as Net Present Value (NPV), Internal Rate of Return (IRR) and Payback Period (PP) (Berrada, 2022, p. 411-412). The energy sector includes additional metrics for valuation and comparison, which are Levelized Cost of Energy (LCOE) and Levelized Cost of Storage (LCOS). There is a need to reanalyze financial valuation metrics (Dobrowolski & Drozdowski, 2022, p. 1), as energy investment decisions should be based on more than one method (Dobrowolski & Drozdowski, 2022, p. 4).

If the project valuation metrics indicate acceptance of the project, investors should consider the risks associated with the project (Berrada, 2022, p. 405). For example, energy technologies have various market, political, financial and technological risks (Berrada, 2022, p. 405). The valuation metrics and the risks associated with the project will be reflected in the cost of capital, as they determine the required rate of return that investors want (Berrada, 2022, p. 407). Investments in the energy sector are often significant, require a lengthy implementation that contributes to higher risk, and have substantial effects on the business and political environments (Dobrowolski & Drozdowski, 2022, p. 11). Investors and financiers often require a risk premium for renewable energy investment compared to conventional energy plants (Tao & Finenko, 2016, p. 751). Thus, technological maturity is a critical factor in determining the required rate of return. Risk premiums have a considerable effect on the financial viability of energy projects that are often understated due to uncertainty (Shimbar & Ebrahimi, 2017, p. 349).

NPV is the difference between present values of cash inflows and outflows (Talavera et al., 2005, p. 451). It is easy to understand, as anything above NPV=0 will yield a positive return. The NPV method requires an assumption regarding the discount rate and cash flows a project will generate (Jurcevic et al., 2022, p. 2).

IRR can provide investors an estimation of profitability, as it is the discount rate that leads to NPV=0 (Talavera et al., 2005, p. 452). This means that as long as the Weighted Average Cost of Capital (WACC) used in NPV is below IRR, the return on investment will be positive. The IRR method can be useful for comparison of financial feasibility, as it accounts for both the entire project life and time value of money (Jurcevic et al., 2022, p. 2).

The payback period is the time required for cash inflows to equal the outflows of a project (Talavera et al., 2005, p. 451). The payback period can either be simple or discounted. The simple payback period does not consider time value of money (Jurcevic et al., 2022, p. 2), whereas the discounted payback period uses the present value of cash flows (Talavera et al., 2005, p. 451).

LCOE is used to compare the costs of energy production technologies. It discounts the costs over a project lifetime, considering energy produced, into a unit of financial costs per unit of energy produced (Pawel, 2014, p. 69). Therefore, it represents the minimum energy tariff a project can have to be profitable (Sung & Jung, 2019, p. 1). The same principle is applied to energy storage, but the storage aspect requires an adjustment of the LCOE model (Pawel, 2014, p. 70). LCOS is used to compare energy technologies on an equal playing field (Jülch, 2016, p. 1594). The LCOS model discounts the costs over the project lifetime into a unit of financial costs per unit of energy stored (Jülch, 2016, p. 1596).

Levelized cost models are useful tools that assist the investment decision, but are not valuation metrics that determine the investment decision (Tao & Finenko, 2016, p. 751). The traditional valuation models are easier to implement into decision-making, as rules for accepting and declining projects are firmly implemented in theory and practice. If NPV is positive for a single project, the project can be accepted. The same rule applies if IRR is higher than the discount rate, as the project will generate a positive return. The payback period must be shorter than the project life, so that the project will have a positive net cash flow. When applied to comparison of projects, decision makers can choose projects with the most attractive valuation metrics.

How does the LCOS model assist the financial process of energy storage investments? The model allows comparison between technologies that considers project life, costs and performance in both monetary and energy terms (Jülch, 2016, p. 1596). LCOS can evaluate cost trends and provide updates on the cost-effectiveness of various technologies (Jülch, 2016, p. 1605). Furthermore, LCOS is used for forecasting, as it provides an estimation of how costs will incur throughout the project life relative to the performance of the system (Schmidt et al., 2019, p. 82). In all, LCOS can answer why one technology attracts more investment than another technology (Schmidt et al., 2019, p. 81). Investors can use LCOS to compare the discounted costs, taking into account the performance of the system. Therefore, including levelized costs into the financial valuation process gives investors and decision makers a holistic understanding of energy storage projects.

1.2. Problematization

The main problems related to our research are underinvestment and financial modeling in the energy storage sector. In the following section, the practical problematization will discuss reasons for underinvestment. The theoretical problematization will discuss financial modeling and the need to integrate traditional valuation models from finance and technical valuation from the energy sector.

1.2.1. Practical problem

Our climate goals may be unattainable for the energy industry unless it receives significant investment from both public and private investors. To achieve adequate decarbonization, renewable energies must account for 65% of total production by 2050 (Raikar & Adamson, 2020, p. 7), whereas the current grids can only manage 25-30% integration of renewable energy (Leonard et al., 2019, p. 951). Thus, a significant share of annual investment in the energy sector must be directed toward energy storage.

The most cost-effective or financially attractive technology may not always be optimal, as projects must evaluate both economic attractiveness and energy security (Dobrowolski & Drozdowski, 2022, p. 1). Various production mixes in the electrical grid require different performance characteristics from the corresponding energy storage system (Gür, 2018, p. 2750). Thus, various storage technologies into the energy mix must be implemented (Cebulla et al., 2017, p. 456). There is a need to recognize and address barriers to energy storage development, such as regulatory uncertainty, financial uncertainty and uncertainty regarding market forces in the sector (Stein, 2014, p. 700-701).

Private capital accounts for 90% of renewable energy investment, and therefore there is a need to involve a variety of private investors in global funding (Raikar & Adamson, 2020, p. 8). The energy sector can better attract private investors if they receive understandable and accurate predictions about profitability and growth (Mazzucato & Semieniuk, 2018, p. 19). However, it can be difficult to fully harness capital markets by only using a foundation of neoclassical financial theory (Hall et al., 2015, p. 280). Thus, we must consider mechanisms to target a variety of investors (Hall et al., 2015, p. 295).

Investment in the energy sector involves uncertainty and sequential decision making (Loncar et al., 2017, p. 354), where the uncertainty and transaction costs are reflected in higher discount rates. This uncertainty creates financial barriers for investment, which results in underinvestment in the sector (Tao & Finenko, 2016, p. 749). High discount rates in valuation can understate the financial viability of projects (Tao & Finenko, 2016, p. 756), which makes them less competitive economically (Sung & Jung, 2019, p. 1). Hall et al. (2015, p. 294) states that we try to solve complex issues like decarbonization and underinvestment with neoclassical financial assumptions, which hinders progress and innovation.

In determining an adequate valuation model for energy storage investments, the interests and needs of various stakeholders must be considered. Equity investors can look at capital structure, return on investment and development possibilities, whereas lenders consider payback period and payback stability (Sung & Jung, 2019, p. 2). The economic attractiveness of investments may differ for various stakeholders and therefore a valuation process that provides a thorough financial analysis is necessary (Sung & Jung, 2019, p. 1). There are complex strategies that can provide accurate valuation, but they must be easy to comprehend for most decision-makers, as overly complex valuation models may result in counterproductive decisions (Aid, 2014, p. 40). Research must find reduced investment rules for the energy sector that can convince investors and decision makers (Aid, 2014, p. 40). A comprehensive and understandable valuation process that provides adequate information for a variety of investors is therefore necessary.

1.2.2. Theoretical problem

The NPV model has disadvantages as an individual metric for energy storage projects. First, the model fails to decide between projects that have the same NPV but different initial investment and project life (Talavera et al., 2005, p. 451). Furthermore, the NPV model requires predictable cash flows, which for energy storage investments requires knowledge of future energy prices (Basher & Raboy, 2018, p. 224). Dobrowolski & Drozdowski (2022, p. 1) stated that there is a need to reanalyze the usefulness of financial metrics like NPV and IRR for investments in the energy sector, and proposed a modified NPV model that considers risks of firms in emerging markets.

The payback period method is simple to understand, but it ignores cash flows and financial opportunities after the payback period (Talavera et al., 2005, p. 451). Therefore, the payback period model must be complemented by metrics that consider the whole project life. Tao & Finenko (2016, p. 754) analyze impact of financing structure on payback period in connection to energy production, and state that long payback times can decrease the attractiveness of energy projects for private investors.

The IRR method can be a useful profitability indicator for investors. For example, Jurcevic et al. (2022) used IRR to compare the profitability of battery storage systems. However, using IRR as comparison of long-term energy projects can have drawbacks as it may hinder allocation of financial resources (Shimbar & Ebrahimi, 2017, p. 349), which is necessary for the development of the energy storage sector. The IRR method may not be suitable for projects with unique cash flows, as it can yield several rates of return (Dobrowolski & Drozdowski, 2022, p. 4). The IRR method is suitable when there is controversy regarding the discount rate, but does not consider the size of the investment or express return in monetary terms (Tao & Finenko, 2016, p. 754).

The Levelized Cost methodologies (LCOE and LCOS) are used by businesses and decision makers to compare different renewable energy or energy storage projects (Tao & Finenko, 2016, p. 751). According to Tao & Finenko (2016, p. 751), the LCOE method can be misleading because it does not consider revenues nor financing details of projects. The discount rate has an enormous impact on levelized cost, as it discounts both the cost and value of electricity (Tao & Finenko, 2016, p. 752). Levelized Cost studies often uses uniform discount rates to compare various technologies in general terms, which may be useful for policymakers, but lack practicality for corporate decision making (Sung & Jung, 2019, p. 1). For real investment decisions, the discount rate should reflect the risk profile of a given project (Tao & Finenko, 2016, p. 752).

Classic valuation methods may indicate that energy technologies are not financially feasible because of faulty risk incorporation, whereas the projects are actually economically viable (Shimbar & Ebrahimi, 2017, p. 349). The Levelized Cost method does not account for revenues or financing details, and must therefore be complemented with corporate valuation methods when presenting the feasibility of projects to investors and decision makers (Tao & Finenko, 2016, p. 757).

There have been several studies exploring the feasibility of energy storage technologies using LCOS, such as Jülch (2016), Gür (2018), Schmidt et al. (2019), Mostafa et al. (2020), Giap et al. (2022) and Berrada (2022). These studies are necessary to policymakers and technical audiences by providing analysis on cost competitiveness of various storage technologies in general terms. The connection to corporate finance in existing research is nascent, especially studies conducted for an investor audience. Tao

& Finenko (2016) and Sung & Jung (2019) connect valuation methods in finance and energy production by exploring the impact of financing methods on LCOE, IRR, and payback period or debt management metrics. Both studies agree that LCOE is useful for comparing lifecycle costs, but must be reinforced with additional financial indicators in business. Berrada (2022) uses a similar structure to analyze the financial viability of large-scale gravity energy storage systems with LCOS, NPV and IRR. Berrada (2022) sets a foundation for future analysis of the financial modeling, but corporate finance in the energy storage sector is still understudied. This study will use Tao & Finenko (2016), Sung & Jung (2019), and Berrada (2022) studies to integrate methodologies from business and the energy sector, so that our study applies to a broad range of investors and decision-makers.

1.3. Research gap

The research gap is that there is a need for financial modeling for energy storage projects that applies to an audience of investors. There is a need to understand financing and investment in the energy sector (Zhang, 2018, p. 1691), and therefore this study will investigate which valuation metrics are emphasized in investment decisions for energy storage projects. Energy finance is an understudied field (Zhang, 2018, p. 1691) and energy storage is an emerging segment within the energy sector. This is a research gap in itself, because numerous types of business research within the field is necessary (Zhang, 2018, p. 1691) to decrease financial uncertainty in the sector (Stein, 2014, p. 697). The research gap is identified through neglect spotting, a gap-spotting strategy defined by Sandberg & Alvesson (2011, p. 30) as an understudied area in which little research has been conducted.

Energy production is more studied than energy storage, and therefore there are more studies including LCOE than LCOS. Research indicates that levelized cost methodologies alone may be useful for policymakers, but are not enough for making decisions in business (Tao & Finenko, 2016, p. 757). Classic valuation methods may understate the financial viability because of incorrect risk incorporation (Shimbar & Ebrahimi, 2017, p. 347). Therefore, there is a need for numerous valuation metrics (Dobrowolski & Drozdowski, 2022, p. 4) to give investors and decision-makers a comprehensive but understandable analysis of energy storage project viability. Tao & Finenko (2016) and Sung & Jung (2019) analyze valuation for energy production, but similar studies are necessary for the energy storage segment. Berrada (2022) introduces a financial model to analyze the financial viability of large-scale energy storage technologies. Building on the foundation of Tao & Finenko (2016), Sung & Jung (2019) and Berrada (2022), the authors have identified a need to analyze the valuation process of energy storage projects and investigate how comprehensive financial modeling affects investment decisions. Thus, this study is positioned within project finance by evaluating energy storage systems from an investor perspective. This study provides a necessary addition to current literature by analyzing energy storage project valuation in a way that applies to investors and decision-makers.

1.4. Research question

How can investors and corporate decision makers integrate valuation metrics in the energy storage industry?

<u>Sub-questions</u>

- What valuation metrics do experts prioritize in energy storage project valuation?
- How can LCOS be integrated with financial valuation?

1.5. Research purpose

The authors are conducting a mixed method study by creating energy storage projects for valuation, analyzing their key performance indicators (KPI) and asking experts in the field how they evaluate energy storage projects. The purpose of creating an investment scenario is to shed light on the valuation process in the energy storage sector from an investor perspective. The authors integrate valuation metrics used in finance and the energy sector and compare how they affect investment decisions, as stand-alone metrics and integrated. The valuation metrics involved include NPV, IRR, PP, LCOS, hurdle rate and technological maturity. To include practical input, this study will involve expert analysis of the projects to explore what metrics are prioritized by practitioners.

Five hypothetical energy storage projects are created based on available information, and show how energy storage projects can be analyzed from an investor perspective. This study will also examine if investors and decision makers can benefit from integrating LCOS into financial valuation by analyzing what additional value it can provide to the financial valuation process. Involving expert analysis can shed light on whether LCOS can be integrated into classic financial valuation and investment decisions. The projects are assumed to be in Europe, as it affects the risk profile that determines the discount rate applied to each project.

Our study will build on financial modeling used in existing research to propose a valuation strategy for energy storage investments that applies to an investor audience. In a broad perspective, the energy sector needs funding but has issues with underinvestment because of financial barriers and uncertainty. This is concerning when considering the rapid development needs set forth by the Paris Climate Accord. The decarbonization of the energy sector requires either a significant upgrade of electrical grids (Gür, 2018, p. 2747), or large amounts of energy storage capacity (Cebulla et al., 2017, p. 456). By analyzing energy storage investments on a project level, the purpose of this study is to give investors a better understanding of how to evaluate investments in the sector. Therefore, an underlying aim of this study is to contribute to sustainable development by conducting business research of the energy storage sector that applies to a broad range of investors and decision makers.

1.6. Delimitations

Delimitations refer to intentional limits set by the authors to make the objective of the study more achievable (Theofanidis & Fountouki, 2018, p. 157). In this section, the authors will discuss the boundaries of the study. Limitations will be discussed in section 7.6, and refer to potential concerns that the researcher cannot control, which can be related to data accessibility, research model or research design (Theofanidis & Fountouki, 2018, p. 156).

This study is not intended to provide a cost update, cost trend analysis or technological analysis. Therefore, from a practical perspective, the results used in comparison will not guide investment or policy for specific energy storage technologies. This study can account for the financial viability of the projects that are created, but the financial results are not applicable to decision making regarding real projects. Research that provides regular cost- and development updates for technological comparison and analysis of actual energy storage projects are therefore necessary. This study assumes that the energy storage projects are located in Europe, and therefore the geographical restriction can be considered a delimitation. Different regions change the risk profile of systems and there can be differences in risk among countries. Although risk profiles are unique for each investment, the authors strive to make the valuation process generalizable to help investors and decision makers direct funds toward the sector.

Currently, there is increased political and market uncertainty in the energy sector as a result of the Russia-Ukraine war and increased energy prices. Furthermore, costs and performance capabilities continuously change due to technological development. Thus, our assumed time period includes unique political, technological and market circumstances. However, as cash flows are assumed constant for the project life, the study cannot account for future volatility in revenue, energy prices or cost. Therefore, time period and assumptions regarding future cash flows are delimitations of our study.

This study will evaluate energy storage projects on an equal basis, which means the authors cannot account for potential differences among energy storage projects. This can include differences in power capacity or energy storage system size, unique risk profiles or optimal capital structure. Thus, the authors must intentionally set boundaries for and standardize inputs that may differ in reality. The inputs that are standardized in scenario creation are identified in section 7.6. By identifying inputs that may affect the valuation process in reality, investors can better understand how to apply the strategy set forth in this study.

1.7. Disposition

This thesis is structured into seven chapters: Introduction, Theoretical framework, Methodology, Research method, Data and Results, Analysis and Discussion, and Conclusion. In the Introduction chapter, background and problematization related to our research topic is presented, which led to the research questions, purpose, expected contributions and delimitations. In the Theoretical framework chapter, the authors discuss the theoretical foundation of our research topic, review existing research in the field, interpret existing findings and present the position of our thesis. The Methodology chapter will include both scientific methodology and research methodology, and therefore the authors discuss philosophical assumptions, scientific approach and research design. The Research method chapter will present the practical method and dataset used in the study. The Data and Results chapter will present the steps in the data collection process, the empirical data and our findings, connecting to our research design. The Analysis and Discussion chapter will include the discussion regarding our findings, with connection to earlier studies, theoretical framework and practical applications. Finally, the Conclusion chapter will connect to the research question and purpose, evaluating how the purpose has been achieved, how the research questions were answered, and stating our suggestions for future research.

2. Theoretical framework

In this chapter, we will discuss relevant theories, concepts and models, theoretical foundations within our field of study relevant to energy storage. The key concepts in this chapter include project finance, sustainability. investor rationality and valuation models. First, the theoretical point of departure along with previous studies in the field will be discussed. Second, a theoretical analysis will be presented. Third, empirical models relevant to the study will be discussed.

2.1. Theoretical point of departure

2.1.1. Project finance

The Oxford Institute for Energy Studies (2022) states there are three common elements which all project finance share. First is the creation of a Special Purpose Vehicle (SPV) which allows the segregation of assets. Second is in regards to funding which can incorporate a combination of equity funding or debt. Lastly is the differentiation of the cash flows by priority base, moving from repayment of project costs and taxes to debt repayment and shareholders involved. Project finance is an advantageous feature for governments and many multinationals because it allows the groups involved to share the project risk (Mawutor & Kwadwo, 2014, p. 182). Some of the parties involved are usually shareholders, lenders, grantors (governments) and contractors (Mawutor & Kwadwo, 2014, p. 182). Fight (2006) indicates that these types of projects usually have long lifespans and can range from 5-10 years of age at least (Mawutor & Kwadwo, 2014, p. 182).

Unlike corporate finance, which concerns itself with how a company obtains funds in order to manage its operations and make profits (Encyclopedia Britannica), project finance manages its operations through non recursive debt, by financing a project through the revenues generated from it (Mawutor & Kwadwo, 2014, p. 181). Fight (2005) states that project finance deals with loan repayment differently since it is extracted from the cash flows of the project, once in operation. This method is common for financing large scale projects in different areas, one of which is the electricity sector (Mawutor & Kwadwo, 2014, p. 181).

Advantage of project finance comes in the form of the inability of the lender to recuperate investment from means different from the cash flow of the project and also allows off-balance sheet treatment of the debt financing held by shareholders (Oxford, 2022, p. 12). A disadvantage in comparison to corporate finance is toward the higher agency cost, since project finance allows more independence on the projects (Mawutor & Kwadwo, 2014, p. 183), and the time and costs associated with its set up are usually higher (Oxford, 2022, p. 13).

Project finance is relevant to our study since projects in energy storage are financed through this type of investment method, and investors should keep in mind this option as the most suitable if ever investing in these types of technologies.

2.1.2. Sustainable finance

Sustainability is a focal concept in the energy storage industry and must therefore be defined and related to the industry. Our society is becoming increasingly electrified, while energy is scarce and creates externalities (Grigoroudis et. al, 2019, p. 1845). Therefore, sustainability is a core concept in the energy industry (Grigoroudis et. al, 2019, p. 1845), as the demand for reliable, fossil-free, flexible, limitless and affordable energy is increasing (Dell & Rand, 2001, p. 2). Sustainability consists of three pillars: economic, social and environmental sustainability. Sustainable development should address and synergize all three pillars of sustainability (Goodland, 1995, p. 3). Therefore, defining each component is necessary to direct sustainable action (Goodland, 1995, p. 2). For example, in the energy storage industry, economic sustainability could involve ensuring long-term stable energy prices, social sustainability revolves around ensuring access to a stable electrical grid to all citizens, and environmental sustainability to reduce carbon emissions from energy production. Goodland (1995, p. 5) states that environmental sustainability does not allow economic growth. From a neoclassical economic standpoint, the purpose of a corporate decision should be to maximize profit (Friedman, 1970), which does not consider the environmental or social aspects of a project. Our current financial models are based on maximizing shareholder wealth and do not consider social or environmental externalities (Fatemi & Fooladi, 2013, p. 110). However, we must account for economic, social and environmental aspects in decision-making (Fatemi & Fooladi, 2013, p. 110).

The concept of sustainable finance (Zhang & Wang, 2021, p. 3435) integrates economic, environmental and financial aspects. From a sustainable development perspective, it is important to promote the economic perspective to investors (Zhang & Wang, 2021, p. 3436). The urgency of addressing climate change has raised awareness of the need for sustainable investments, resulting in investors increasing the inclusion of green investment in their portfolios (Chatziantoniou et. al, 2022, p. 1). As profitability remains emphasized, there is a need to create a contributive environment with incentives for private investors (Kim & Lee, 2021, p. 20). Investors need opportunities for investing sustainably, and therefore public authorities and banks have a critical component in promoting sustainable investment. (Zhang, 2018, p. 1690). Since 2004, renewable energy investment has increased from 50 billion USD to 300 billion USD (Chatziantoniou et. al, 2022. p. 1). Thus, sustainable finance is an essential trend (Zhang, 2018, p. 1688) that benefits sustainable energy development (Zhang & Wang, 2021, p. 3451).

Energy storage projects must consider the three pillars of sustainability. The projects have long lifetimes, and therefore economic sustainability involves ensuring that projects have stable net cash flows now and in the future. A project that places a financial burden on future generations but favors current generations is therefore not economically sustainable. Social aspects of sustainability can involve considering cultural sensitivity (Rooij et. al, 2022, p. 224) and enabling affordable energy and reliable energy distribution. Considering environmental sustainability, there is often a tradeoff between ecological effects and decarbonization. Energy storage projects decrease carbon emissions, which combats climate change, but require space and adequate conditions. The conflict of land use from wind power developments and effects on Sámi reindeer herding areas (Rooij et. al, 2022, p. 224) is an example of trade-off within environmental sustainable development. Therefore, decision-making requires balancing decarbonization and ecological effects.

In all, there is no quantifiable metric for sustainability that can be integrated into the valuation process. However, as sustainability is a focal concept in the energy storage industry and energy transition, it is important to consider in relation to investment decisions. As the trend of sustainable finance continues along with the energy transition, the three dimensions of sustainability are critical aspects of the investment profile of energy storage projects.

2.1.3. Previous studies on financial modeling in the energy sector

A literature review summarizes the research conducted in the field and reviews the existing knowledge that serves as a foundation to the research question (Rowley & Slack, 2004, p. 31). Our literature review consists of research with both technical and financial aspects, from energy production and energy storage. There are not many studies that combine aspects of financial valuation and energy systems from a decision maker perspective. Each of the following studies serve as a foundation for this study, as the authors attempt to integrate aspects from financial and energy sector valuation.

Tao & Finenko (2016), Sung & Jung (2019), Berrada (2022), and Yamujala et al. (2022) use project valuation metrics to evaluate economic feasibility in various applications. Tao & Finenko (2016) found that levelized cost can be misleading and should be reinforced by financial metrics. Sung & Jung (2019) also state that LCOE as a stand-alone metric is not sufficient for business decisions and that stakeholders have different preferences regarding the importance of specific valuation metrics. Berrada (2022) found that IRR indicates financial viability of energy storage projects, whereas LCOS can show competitiveness relative to other energy storage systems. Yamujala et al. (2022) state that individual parameters may not attract sufficient investment, but revenue stacking can improve the economic viability of energy storage systems. Cekirge & Erturan (2019), Mostafa et al. (2020) and Giap et al. (2022) propose alternative levelized cost applications for decision-making and argue that modified methodologies can provide investors more comprehensive models. Aid (2014) presents economic models that can provide optimal investment decision rules but states that the models may be difficult to apply in practice. Jülch (2016), Gür (2018), Schmidt et al. (2019), and Hoff & Lin (2019) provide cost updates for energy storage technologies, discuss the application of LCOS in decision making and the importance of numerous economically viable energy storage technologies. Dobrowolski & Drozdowski (2022) and Shimbar & Ebrahimi (2017) critique the applicability of NPV for capital-intensive energy projects and propose modified methods for valuation, whereas Basher & Raboy (2018) discuss the need for considering dynamic price volatility in NPV calculation.

Existing research in the field is summarized in Appendix 1. Based on the research gathered in Appendix 1, we have identified a need for introducing two perspectives to business research in the field. First, there is a need to discuss financial modeling in the sector in a manner that targets a broad range of investors and decision makers. Tao & Finenko (2016) discuss financial modeling for energy production and the usefulness of levelized cost for decision making. Berrada (2022) introduces financial modeling in the energy storage sector and serves as a foundation for our study. However, no existing study analyzes the financial viability of energy storage projects by simulating actual investment decisions through ranking. Thus, our study discusses how investors can use the information for decision making. Second, there is a need to understand whether investors have different preferences regarding financial metrics when making investment decisions in the sector. Sung & Jung (2019) state that economic attractiveness of investments is dynamic, as stakeholders have different preferences regarding the importance of financial metrics. Our study therefore includes investor preferences by including input from practitioners on the financial viability of our hypothetical projects. Several studies have proposed modified alternatives to levelized cost (Cekirge & Erturan, 2019; Mostafa et al., 2020; Giap et al., 2022) and NPV (Dobrowolski & Drozdowski, 2022; Shimbar & Ebrahimi, 2017; Basher & Raboy, 2018), and therefore practitioners are asked whether they consider additional metrics in the valuation process. This way, we can evaluate whether modified methodologies are used in practice.

2.2. Conceptual framework

2.2.1. Rationality

Rational decisions are based on utilizing all available information through logical thinking (Kumar & Goyal, 2016, p. 270). In neoclassical economics, the traditional perspective of rationality is that a person is homo economicus (economic man), which implies that self-interest is the motive behind our decisions (Urbina & Ruiz-Villaverde, 2019, p. 63). Neoclassical economic theory is based on the assumption of homo economicus, as consumers are expected to maximize their utility and firms are expected to maximize profit (Urbina & Ruiz-Villaverde, 2019, p. 64). The theory of rational choice implies that a decision is made based on evaluating alternatives in various perspectives before making an informed decision (Kumar & Goyal, 2016, p. 270).

Homo economicus connects to investor rationality, as the rational investor is expected to maximize return (Lydenberg, 2007, p. 467) by making decisions based on all available information (Kumar & Goyal, 2016, p. 272). The assumption of rationality is also widely prevalent in financial theory, as investor rationality is a core assumption of the efficient market hypothesis (EMH) (Fama, 1970) and expected utility theory (Kumar & Goyal, 2016, p. 271).

Homo economicus is strongly connected to neoclassical economics and has received criticism for oversimplifying the behavior of people and entities. Behavioral economics indicates that people are not perfectly rational as our analytical constraints and bias affect our decisions (Urbina & Ruiz-Villaverde, 2019, p. 85). Investors can be biased by overconfidence, disposition effect and herding, which can cause irrational decisions (Kumar & Goyal, 2016, p. 272-273). Complete rationality requires unlimited cognitive capability (Kumar & Goyal, 2016, p. 270), whereby cognitive capacity has a significant role in decision making. Simon (1956) suggested a concept of "bounded rationality", which states that humans are irrational, or bounded rational, because of lack of knowledge and cognitive limitations.

Furthermore, we may not consistently act in our best self-interest, as our decisions are influenced by values and norms (Urbina & Ruiz-Villaverde, 2019, p. 85). Value-driven decision making is referred to as *wertrational,* where our beliefs and ethical norms guide our decisions (Nicholls, 2010, p. 77). This may sometimes contradict our self-interests (Cohen et al., 1975, p. 235). Value-driven rationality can often include various forms of philanthropy (Nicholls, 2010, p. 84), and therefore a wertrational investor is not focused on maximizing return, but rather matching returns with personal values (Nicholls, 2010, p. 78). Traditionally, the duty of a firm is to maximize profit (Friedman, 1970), but the rational decision for a value driven firm may be to maximize utility by acting on personal values.

Means-driven rationality (*zweckrational)* can be influenced by values, but accounts for the means and effects involved in decisions (Nicholls, 2010, p. 77). Means-driven investment focuses on resource efficiency and results (Nicholls, 2010, p. 77) and is therefore more connected to traditional investor rationality than value-driven rationality. Investment in renewable energy can be means-driven if the investor seeks to maximize individual return, but within a specific field (Nicholls, 2010, p. 79). For example, investments in renewable energy provide investors an opportunity to contribute to sustainable development while maximizing return (Nicholls, 2010, p. 79).

Finally, natural ecosystems are not homo economicus*,* as the interconnectedness of various elements is more complex than neoclassical economics suggest (Urbina & Ruiz-Villaverde, 2019, p. 85). If rational decisions reflect all available information (Kumar & Goyal, 2016, p. 270), then the interconnectedness of natural ecosystems and full effects of our decisions must be known. While the aforementioned is difficult, sustainable economic thinking requires us to expand our view of rationality to a holistic perspective of economics and ecology (Urbina & Ruiz-Villaverde, 2019, p. 85). In the energy storage industry, a holistic perspective considers the economic, environmental and social implications of the investment.

2.2.1.1. What is rational when investing in the energy storage industry?

In neoclassical economics, the core assumption of rationality is that individuals and entities are expected to maximize their utility based on self-interest (Urbina & Ruiz-Villaverde, 2019, p. 63). Utility can be defined in numerous ways, but traditional investor rationality aims for maximizing financial return (Nicholls, 2010, p. 77). However, return can be subjective and therefore utility can mean personal satisfaction (Nicholls, 2010, p. 78). Furthermore, policymakers are expected to make decisions based on a holistic perspective of the needs in the industry. Energy storage systems are necessary to assist the energy transition, and therefore the industry cannot solely rely on investment that maximizes investor return. Various energy mixes may require different performance characteristics from the system and therefore the investment with the most promising return on investment may not always be optimal from a practical perspective.

The evaluation criteria of energy storage systems may also differ for investors and policymakers. Investors, policymakers and the industry as an entity may have different perspectives of rationality and utility maximization. The attractiveness of an energy storage system can be viewed from numerous perspectives, such as financial feasibility, level of risk, system performance, decarbonization impact and ecological effect. Furthermore, policymakers must ensure the technological development of the industry and therefore innovation is necessary (Sivaram et al., 2018, p. 1639). If financial feasibility and cost effectiveness are the rational evaluation criteria, then there is a risk of technological lock-in (Sivaram et al., 2018, p. 1639) where innovation will suffer (Schmidt et al., 2019, p. 81). Since the Paris Climate Accord serves as a guide for our climate goals, we must have a holistic perspective of the needs of the industry and how to meet them.

Investor rationality affects how investors perceive the economic attractiveness of energy storage investments. Therefore, investor rationality may be subjective, as wertrational and zweckrational investors may perceive an investment differently. Furthermore, if investors consider the interconnectedness of natural ecosystems in project valuation, an environmental perspective must be applied. Rationality affects which metrics or project characteristics investors prefer in project valuation and therefore affects the individual subjective ranking of investments.

2.2.2. Efficient market hypothesis (EHM)

This theory was originally analyzed by Samuelson (1965) and Fama (1963, 1965). It states that all the information present in the market and all the new information recently acquired by the market is immediately reflected in the stock's prices (Fama, 1970). Because of this factor EMH states that it is impossible to generate a consistent alpha (also called excess return/abnormal rate of return) which is a measure of performance for strategies which beat the market. Therefore concluding that it's impossible to beat the market on a constant rate due the fact that stocks always trade at fair value making it impossible to buy undervalued stocks or sell those that reflect inflated prices. Therefore, the theory implies that an investor cannot obtain excess returns by market timing, which is the process of moving money in and out of the financial market, but would rather have to acquire riskier investments in order to obtain higher returns or conduct trades in a purely speculative manner. EMH is exemplified in three ways for basic understanding, denominated in weak form (past price), semi-strong form (speed of price adjustment) and strong form (monopolistic access by groups) (Fama, 1970 p. 388). The weak form implies that no technical analysis is worth using since the data already reflects all historical information available, and as of today it is the most common method of testing the market (Rosini, & Shenai, 2020 p.124) . Semi-strong believes that since all the public information regarding stocks is already incorporated in their pricing and since the private information is not, conducting any form of analysis would render the process useless and unable to provide returns above the market. The strong form believes that both private and public information are already implemented in the pricing thus making it impossible for an investor to gain an exponential advantage from it without everyone doing so as well.

Although still relevant till today, the theory has had multiple contestation, one of which is by Burton G. Malkiel (2003), who identified three challenges. The first is momentum investing which combines both technical (analysis of stock´s historical performance in order to predict future patterns) and fundamental analysis (the analysis of stocks by looking into their book value) impling that some momentum investing patterns are replicable over time due to short term correlations among stock prices. The second is behavioral finance stating that the majority of investors guide their trades through emotion rather than rationality by overreacting or underreacting to the market stimuli from the market. The third is through fundamental analysis where certain ratios, upon analysis, could provide overperformance or underperformance in the future. Other anomalies of the theory come in the form of neglected firm theory effect, which are the companies not covered rigorously by analysts and therefore priced incorrectly. The

January effect where stock prices display a rise in appreciation due to an increase in purchasing behavior opposed to the month of December (Rosini & Shenai, 2020, p. 129) and others like the The Halloween effect, The January effect and The Turn-of-the-month-effect (Rosini & Shenai, 2020).

EMH is particularly important in this paper since it relates to WACC by the calculation of CAPM and cost of capital through the required rate of return (Ardalan, 2004). The assumption that the market self prices itself and therefore easier to predict in the future based on historical information (weak market hypothesis) is a crucial capstone when evaluating LCOS projects . But in reality, energy prices in the market are quite volatile and susceptible to external pressure. Thus, standardizing the WACC figure in the LCOS formula, potentially creates drawbacks in economic and financial evaluation.

2.2.3. Adaptive market hypothesis (AMH)

The theory was first introduced by professor Andrew Lo (2004) and tries to bring together the EMH theory and behavioral finance which believes markets to be inefficient and irrational due to over activeness and overconfidence by investors under periods of high volatility (Noreen et al., 2022, p. 3). The core concept of the theory resides in the fact that markets are cyclical (Rosini & Shenai, 2020, p. 123) and its interactions learn from their mistakes and will consequently adjust to them until they find a successful strategy which holds until possible failure in the future. The market is seen as a metaphor of natural selection, forcing its participants to adapt and survive with the flow (Rosini & Shenai, 2020).

The theory relates to the topic since it offers an alternative to EMH since the energy storage market is volatile thus difficult to yet understand and predict, and promotes the idea that the development of the market itself is in relation to how well the investors in it understand it and decide to operate when dealing with the overall market fluctuations. Our paper is looking to provide better understanding of the ESS analysis methods to the investors by understanding better how to move in the market and be part of the "survivor" group of investors.

2.2.4. Debt capital markets (DCM)

Capital markets are a significant part of external financing for companies for equity and debt markets (Liu et al., 2006, p. 43). Debt capital market (DCM) is a type of market where long term funds are raised through debt. These markets have as their main component interest rates assessed through the risk index associated with the loan (Liu et al., 2006, p. 241).

A critical aspect for selecting DCM is associated with the longevity of the projects. Many companies cannot afford to sustain projects for long periods without obtaining any profits. This is why DCM are highly favored under these circumstances. Energy storage projects rely heavily on funding by investment banks or contractors like the governments in order to set up and develop the investment plan for the energy storage project.

Retained earnings are generally preferred to debt by small and medium enterprises since they are less risky and there is no repayment to deal with in the long term. That said, firms prefer to rely on debt when equity seems less favorable due to the high adverse selection costs (Doukas et al., 2011, p. 79). The Trade-off Theory (TOT) also supports this line of thought. Kraus & Lintzenberger (1973); Scott (1977); & Kim (1978) all state that a business should focus on finding the best equilibrium through the maximization of debt and minimizing bankruptcy risk, while exploiting the debt tax-shield (Serrasqueiro & Caetano, 2015, p. 446).

An additional reason for selecting debt financing is backed up by the Pecking Order Theory (POT) which also according to Myers & Majluf (1984), is the best method of financing through the utilization of internal funds at first and consequently moves toward debt financing, concluding with equity financing (Qureshi et al., 2015, p. 344).

2.3. Empirical models

2.3.1. Capital asset pricing model (CAPM)

CAPM was originally proposed by William Sharpe (1964) and John Lintner (1965). According to Sharpe, there are two main risks which investors are wary of, systematic and unsystematic. Systematic risk is also referred to as Beta (ß) or Market Risk and is non-diversifiable, which means it equally affects the returns of all stocks like war or interest rates, while unsystematic risk is a specific risk associated with a company or a sector and is usually hedged through diversification (Sharpe, 1964, p. 438-439). Overall, CAPM is used to identify the required rate of return by weighing against one another expected return and risk during a specific period of time.

Drawbacks appear in its assumptions regarding the reliability of the information provided by the market and the assumption that the information clearly reflects the market and that the market is rational and dominated by sound investors. Because of these assumptions which unfortunately are not always true, the results obtained from CAPM are not always reliable.

CAPM estimations in the energy sector are assessed differently by agencies and laboratories like NREL, IRENA or IEA in their reports. For example, NREL uses an estimated value calculating both market and simulated data, while IRENA tends to utilize market prices or price indicators in general and lastly IEA uses assumptions on technology and costs in relation to historical knowledge from previous data while analyzing the geographical environment (Rubio-Domingo & Linares, 2021, p. 2).

$$CAPM = R_f + \beta * (R_m - R_f)$$

The CAPM formula is as demonstrated above, where Rf is risk free rate, β represents market beta, Rm is market return, and (Rm-Rf) is the market risk premium. Specific inputs will be discussed further in Section 4.4.

2.3.2. Weighted average cost of capital (WACC)

The purpose of using WACC is to derive the present value, taking in consideration the tax benefits as deductibles toward the interest (Koziol, 2014, p. 655). The method discounts the after-tax cash flows at the weighted average cost of debt and equity (Schauten, 2013, p. 64), which is the rate at which the company pays to finance its assets. The equity return required is estimated as the minimum rate of return met by the financial sponsor, while the debt rate is obtained from the market interest rate (Ye & Tiong, 2000, p. 229).

The WACC is crucial in the calculation of the NPV since it is utilized as a discount factor in the evaluation of a project when cash flows are discounted to the present (Mian & Vélez-Pareja, 2007, p. 21). This metric is utilized by investors when comparing which investment seems more valuable to pursue. The figure can be utilized either as a discount rate for future cash flows in the NPV formula or as hurdle rate and compared against ROIC (Return On Invested Capital) (Bando, p. 22).

The shortcomings of utilizing WACC is reflected in the cost of equity which does not have a standard value and can be reported differently by different parties. Also when calculating debt and equity from an outsider perspective it's not certain that these values truly reflect the company´s since many enterprises tend to keep the information private, making the value of WACC not accurate (Bando, p. 25). Other shortcomings of the WACC method are highlighted by Ondraczek et al. (2015) in relation to the variation of cost of capital across different countries. Reasons for such differences are tied to systematic risk and its perception by different investors, differences in demand and supply in relation to finances which may affect interest rates and other factors like governmental policies, inflation and access to capital (Ondraczek et al., 2015, p. 893).

The formula for WACC is stated below, where D refers to debt, E refers to equity, Rd is cost of debt, Tc is corporate tax rate and Re is cost of equity.

$$WACC = \frac{D}{D+E} \times i^{*} \times (1 - T_C) + \frac{E}{D+E} \times R_e$$

2.3.3. Discounted cash flow model (DCF)

DCF is a model used for financial valuation. It is a method utilized in project, company and asset valuation which believes that the value of the asset being reviewed can be estimated through the present value of its future projected cash flows (Svetlova, 2012, p. 424). The process of discounting is to acknowledge that a dollar worth today is better than a dollar worth tomorrow. The model has the purpose of comparing different projects or assets and determining which investment will return more profits.

The projections assumed by this method are obtained through a series of assumption like growth rates, profit margin and others, but at its core the module takes close consideration to the discount rate (Svetlova, 2012, p. 424)

The traditional DCF assumes a constant discount rate regardless of the variation of risk over time which may differ for factors such as technology, performance and other types.

It is possible though, to contain these uncertainties through a risk adjusted discount rate but the issue is not fully solved since the variation of cash flow risk is not accounted for over time. (Pless et al., 2016, p. 379).

The limitation of the model comes through the inputs needed in the formula which reflect future assumptions of the cash flow while also having to deal with uncertain non-quantifiable factors like macroeconomic conditions, such as inflation or currency development, political risks associated with tax policies or political instability, company related issues like management quality or corporate governance (Svetlova, 2012, p. 426). Therefore, one might argue that the valuation method works best when attempting to generate future scenarios regarding an investment option which may be optimistic, pessimistic or realistic scenarios depending on the different inputs utilized when calculating it (Janiszewski, 2011, p. 96)

The authors use the DCF model for calculating the present value of cash flows in this study. It is the most commonly used method by investors in order to evaluate different projects, especially when the information available is limited (Laitinen, 2019, p. 2998). Assumptions regarding cash flows will be specified in Section 4.4. The DCF formula is stated below, where CF refers to cash flows and r is the discount rate.

$$DCF = \frac{CF_1}{(1+r)^1} + \frac{CF_2}{(1+r)^2} + \frac{CF_n}{(1+r)^n}$$

2.3.4. Net present value (NPV)

NPV refers to the difference between the initial investment and the present value of cash flows and is therefore a useful indicator for the profitability of an investment. Thus, the method includes the cash flows of a specific time period and discounts them to a present value (Remer & Nieto, 1995, p. 81). It is common that a positive NPV signals some kind of returns associated with a long term project, but that factor is not always enough to dictate whether or not a project is a good option. If the project is deemed too risky, a positive NPV would not be enough insurance for investors (Kraus & Litzenberger, 1973, p. 217). The discount rate used in the NPV formula acts as a display of the project risk. The disadvantages associated with this model are due to the fact that the size of the project is ignored, there are multiple assumptions being made and it’s not a method well understood by non-practitioners (Remer & Nieto, 1995, p. 89).

NPV can be perceived as superior to IRR due to ranking conflicts between projects when utilizing IRR, the theoretical and practical shortcomings which requires intermediate cash flows to be reinvested to obtain an IRR and the use of multiple IRR values to solve issues related to sign changes throughout cash flow periods (Plath & Kennedy, 1994, p. 78).

The NPV method displays some levels of distrust in its application due to uncertainty in cash flows, forecast and volatility of certain variables which tend to skew results in the long run (Monjas-Barroso & Balibrea-Iniesta, 2013, p. 336). Also, even though both NPV and IRR both incorporate time value of money thus facilitating the profitability forecast of a project in the future, they are limited by the assumption they propose of actual certain cash flows (Ye & Tiong, 2000, p. 227). NPV will be calculated as one of the KPIs for the comparison of the five energy storage investments.

2.3.5. Internal rate of return (IRR)

The IRR is the discount rate that makes the present value of cash flows equal zero. Therefore if the project value equals the IRR the worth of the project breaks even (Remer & Nieto, 1995, p. 90). Unlike the Minimum Accepted Rate of Return (MARR), the IRR does not represent the external factors to the cash flow. It is common to prefer an IRR of higher value or at worst equal to the MARR. A negative IRR indicates a loss of money from the project (Berrada, 2022, p. 421). For accepting the project, the IRR must be higher than WACC so that the project will yield a positive NPV.

IRR will be used as a profitability metric for our project ranking by computing the discount rate that makes NPV zero. Thus, the investor can easily recognize that the discount rate must be lower than IRR for the project to be profitable.

2.3.6. Hurdle rate

The hurdle rate is the minimum return an investment has to generate in order to be accepted (Liesch & Knight, 1999, p. 387). These numbers are usually set to provide managers with objective figures for profitability before making an investment decision (Cheng et al., 2003, p. 49). It is common for companies to utilize the value obtained for WACC as hurdle rate, but utilizing hurdle rates higher than WACC is also common practice, in order to isolate those projects which would provide higher profitability (Chen & Ward, 2000, p. 298). The hurdle rate is represented as the discount rate in the NPV, and in order for it to be positive and accepted by the project, the rate of return needs to exceed the discount rate (Hornung et al., 2016, p. 441). It is commonly agreed that hurdle rate is based on its cost of capital (Brigham, 1975, p. 19). Utilizing the cost of capital as the benchmark, is the method mostly agreed on for deducting the discount rate (Hornung et al., 2016, p. 442).

It is also agreed that if the hurdle rate figure is high so will be the annual payment to be repaid over the lifetime of the investment, making as a result the total cost higher too. In the case of our literature, since the hurdle rate affects the investment cost for capital intensive technologies like most renewables (García-Gusano et al., 2016, p. 59).

Drawbacks associated with this rate are due to its durability. Since hurdle rates reflect both capital market and the firm´s scenario with the estimated capital to be raised, it should be mandatory for companies to revise the rate frequently in order to continuously have the rightful figures (Brigham, 1975, p. 20). But as per Brigham (1975) companies review their rate less than once a year.

Hurdle rate will be used as an easily understood profitability indicator in this study, as it indicates how profitable IRR is in relation to WACC. However, as IRR is already used for our integrated ranking, it is not included in the point base system to avoid overemphasizing IRR.

2.3.7. Payback period

The payback method is utilized to evaluate capital projects in order to value whether the returns are worth the investment (Lefley, 1996, p. 208). In its simplest terms, the payback period identifies the number of years needed for the project to break even and start making a profit on its investments (Lau et al., 2021, p. 4). A main rule to follow when accepting a project in relation to its payback period is the fact that the investment will have to pay off before the lifetime of the project in order for it to be profitable (Gorshkov et al., 2018, p. 64).

There are multiple criteria to assess how valuable an investment is. Our literature will focus on Simple Payback Period (SPP) and Discounted Payback Period (DPP). The SPP limits itself to calculating the break-even point of a project, not placing emphasis on the time value of money and the returns or profitability of a project; while the DPP uses future cash flows and discounts them to the present (Maghsoudi & Sadeghi, 2020, p. 6).

The widely used SPP method is common due to its simplicity in comparing different projects and its straightforward applicability in relation to expenses and returns (Kessler, 2017, p. 2) while since the DPP discounts each cash flow it shows as a result the cumulative discounted cash flow that makes the project zero.

Drawback of this method is due the fact that the method identifies the length it takes to recuperate the investment but not measuring profitability (Lefley, 1996, p. 208-209). The two main drawbacks of the method when it comes to financial appraisal are the disregards of the returns after payback period (point is countered by the fact that setting a payback time is crucial for the planning) and ignoring the timing of the returns (this point is partly fixed by the DPP method) (Lefley, 1996, p. 210). Other shortcomings of the method come in the form of estimating future cash flows when the periods are longer. The longer the periods the higher the uncertainties and risk associated with it (Lefley, 1996, p. 213).

Payback period will be used as one of the KPIs in this study, as it is an easily understood indicator that shows how well the project can cover the initial investment.

2.3.8. Levelized cost of storage (LCOS)

This metric displays the minimum value of kWh an ESS should produce in order for the NPV to be zero and not deliver losses (Melnikov et al., 2019, p. 1). In its easiest terms, the formula displays the annual cost of the project over energy discharged by the system in the number of years “n” (Berrada, 2022, p. 416). The purpose of the equation is to evaluate the economic performance of different storages and provide a metric to compare them during project valuation (Trevisan et al., 2021, p. 3).

$$LCOS = \frac{Capex + R + \frac{\sum_{n-1}^{N} O\&M}{(1+i)^n} + \frac{EF}{(1+i)^{N+1}}}{n_c \times DoD \times C \times \eta \times \frac{\sum_{n-1}^{N} (1+Dg)^n}{(1+i)^n}} + \frac{P_e}{\eta}$$

As displayed in the formula above, the components which make up the equation are the system’s end of life value divided by the sum of cost, depth of discharge and the degradation rate (Berrada, 2022, p. 416). The Capex represents the project investment cost ($). R is the replacement cost ($) which is the cost associated with insuring the machine in case of damages or replacement needs, and OPEX is the operation and maintenance cost ($). EF is the value/cost of the project end of life ($), which represents the value the machinery has once not able to operate anymore and sold. Pe is the electricity price ($/kWh), whereas C refers to system capacity (MWh), which is the maximum MW capacity a technology can release. DoD is the depth of discharge (%) which indicates the percentage of battery remaining relative to the total capacity since the battery will never fully be discharged. Nc is the number of cycles which represents the number of times a technology can charge and discharge completely before dropping in capacity and performance. Lastly, Dg is the degradation rate (%) which represents the rate at which the technology is losing efficiency, and N is the project lifetime which highlights the years in which the technology will be operational.

Factors affecting LCOS can be categorized into four main groups: energy supply economics, scenario characteristics, energy storage technology characteristics and energy storage economics (Luerssen et al., 2021, p. 1). Even though this metric of valuation is frequently used and accepted by experts in the field, the metric does not support a common definition. This is because different technologies and experts implement parameters which are ignored by others like cost parameters like replacement, disposal or capacity degradation. Homogeneity on the topic is also slowed down due to the lack of information shared in academic publications on storage applications and lack of transparency in the LCOS methods (Schmidt et al., 2019, p. 81).

We will use LCOS as one of the KPIs in our integrated project valuation model, as it allows comparison of energy storage projects on an equal basis. Furthermore, LCOS introduces system performance, which is a valuable addition to the integrated valuation model.

2.4. Conclusion

Our thesis investigates the valuation process of energy storage systems from a project finance perspective. This provides a necessary addition to the current literature, which often discusses technical aspects of energy storage systems and uses LCOS for comparison. Financial valuation for energy storage projects is still understudied. Thus, this study evaluates the use of individual valuation metrics and provides a holistic financial perspective of hypothetical energy storage projects by using numerous established valuation methods. This thesis adds to the financial modeling presented by Berrada (2022) by discussing an investor perspective and targets a business-oriented audience. Investments are ranked by using individual metrics and each investment gets ranking points based on the individual metric. Then, the metrics are integrated by ranking the projects based on total points. The opinion of experts in the field is also included in the study, which provides a unique perspective to the field, as financial viability of energy storage technologies is often discussed but not actual investment decisions. Thus, this thesis serves as a guide for investors and provides a foundation for future business research in the energy storage sector.

3. Methodology

In this chapter, the methodological choices, positions and strategies of this study will be discussed. First, the authors will present philosophical positions that relate to scientific methodology. Second, the authors will present choices connected with research methodology. Lastly, the authors will discuss literature search, source criticism and ethical considerations.

3.1. Research philosophy

Research philosophy can be defined as the underlying philosophical assumptions that determine research methodology and methods, which affect how we analyze and apply information (Scotland, 2012, p. 14). There are various philosophical concepts, like ontology, epistemology and axiology that all affect how we conduct research and analyze information. Marsh & Furlong (2002, p. 17) relates to these philosophical assumptions as a skin, not a sweater. This means that our philosophical position cannot be changed or turned off, and it affects how we perceive the world. Killam (2013, p. 5) relates to our philosophical assumptions as a lens because they define the manner in which we perceive the world. Thus, even though the topic may seem vague, it is important for us as authors to define our philosophical position, as it serves as a baseline for our scientific assumptions, research, analysis and conclusions.

An important aspect of our research philosophy is determining our paradigm, as it serves as a baseline for our scientific assumptions (Killam, 2013, p. 5). A paradigm consists of ontology, epistemology, methodology, and methods (Scotland, 2012, p. 9). Paradigm can be defined as a set of underlying assumptions that affect how we perceive the world and relationships between various actors and phenomena (Brand, 2008, p. 430). According to Scotland (2012, p. 9), it is impossible to establish a research method without determining the underlying philosophical assumptions in the paradigm.

There are two distinctly different paradigms, positivism and non-positivism (Brand, 2008, p. 432). Positivism has been the dominant paradigm of research, and is a belief system in which matters that are researched should be perceived objectively and not be influenced by individual perspective (Brand, 2008, p. 432). Therefore, objective reality in the positivist paradigm remains constant (Brand, 2008, p. 432). Positivist research involves identifying causes for certain outcomes (Scotland, 2012, p. 10). For example, research in the positivist paradigm can involve hypothesis testing and experimentation (Brand, 2008, p. 433).

The non-positivist (Brand, 2008, p. 433), or interpretive (Scotland, 2012, p. 12) paradigm does not revolve around objective clarity to the same extent as positivism. Non-positivism is subjective, as the paradigm is based on the notion that reality is subjective, or relative (Brand, 2008, p. 433). Therefore, uncovered truths in research constantly change, as they are based on individual perspectives (Bell et al., 2019, p. 27). The non-positivist, or interpretivist, paradigm does not have a foundation of objective knowledge, as matters are subjective and based on interpretation (Scotland, 2012, p. 12). Research in the non-positivist paradigm is often highly qualitative with subjective outcomes that are difficult to generalize (Scotland, 2012, p. 12). However, the lack of generalization can also be a benefit, as it can generate outcomes that are free from the predetermined borders in the positivist paradigm.

Our scientific assumptions will be aligned with the non-positivist paradigm in this study, as we acknowledge that investor perspective influences economic attractiveness (Sung & Jung, 2019, p. 2). This study includes the opinion of experts and therefore there are influences of non-positivism. Financial viability of projects can be considered objective and positivist, but ranking investments can be subjective and non-positivist. The theoretical and conceptual foundation is considered to be objective knowledge, however, the research method and strategy is unique and therefore is susceptible to subjectivism. Thus, the non-positivist paradigm aligns best with the research process, although there are influences of positivism in the theoretical and conceptual framework.

3.1.1. Ontology

Ontology relates to our scientific assumptions as our ontological position determines how we perceive and analyze information (Marsh & Furlong, 2002, p. 18). Ontology is a philosophical concept that refers to the "theory of existence", and deals with our perception of reality, existence and the relationships between various entities (Marsh & Furlong, 2002, p. 19). There are different ontological positions, each with its own assumptions regarding reality and relationships.

One approach to ontology is objectivism, which is a positivist approach to ontology that states that reality is objective and independent of individual perception (Scotland, 2012, p. 10). Guba & Lincoln (1994, p. 109) state that positivist ontology revolves around realism, as according to objectivism, there is a 'real' reality which is not affected by our beliefs and assumptions. Positivism and objectivism are common scientific assumptions in research, as it entails that the natural world can be studied and analyzed with empirical observations and various scientific methods (Brand, 2008, p. 432). Furthermore, positivism states that reality is constant and objective, and therefore the findings in research uncover objective truths about the world (Brand, 2008, p. 432).

Another approach to ontology is constructivism (Guba & Lincoln, 1994, p. 109), which is in the non-positivist paradigm. This shifts ontological position from realism to relativism (Guba & Lincoln, 1994, p. 109). Thus, constructivism suggests that reality is dynamic (Brand, 2008, p. 433). Contrary to objectivism, reality is affected by subjective perspective which means reality constantly changes by individual perspectives (Bell et al., 2019, p. 27). Thus, various social phenomena evolve continuously, as they are influenced by individual perspectives and how the social phenomena are experienced (Guba & Lincoln, 1994, p. 110). Reality is therefore subjective, and should be interpreted differently by individuals (Guba & Lincoln, 1994, p. 111). In research, a constructivist ontological position could study how various actors experience social phenomena and analyze their individual perspectives. Since constructivism assumes that reality is dynamic, the conclusions in constructivist research will likely be ambiguous and involve the researcher's individual perspective on the topic.

The authors believe that the valuation metrics indicate financial viability objectively, as they are independent from our individual beliefs. However, the KPI's are influenced by a discount rate that can include investor perspective. Furthermore, ranking investments includes investor preferences, and therefore the valuation process of the energy storage process includes both objectivism and constructivism. Therefore, this study aligns with constructivism because the economic attractiveness of energy storage projects can vary among investors (Sung & Jung, 2019, p. 2), which suggest that reality in energy storage valuation is dynamic.

3.1.2. Epistemology

Epistemology can be defined as the "theory of knowledge" (Bell et al., 2019, p. 29-30) and is relevant to our research because it determines what we perceive as real knowledge. Thus, our epistemological position influences the process of determining what information is acceptable, true, or relevant (Marsh & Furlong, 2002, p. 19). For example, we can either make assumptions that certain knowledge is true in an objective reality, or that we interpret information as true in a subjective reality (Guba & Lincoln, 1994, p. 108). Therefore, determining an epistemological position is important to research, as it influences how we conduct and analyze information depending on what information we perceive as true and acceptable (Saunders et al., 2019, p. 127). Our epistemological position is influenced by our chosen paradigm, positivist or non-positivist, and our ontological assumptions (Scotland, 2012, p. 9). Our ontological position influences our epistemological position but does not determine it.

One epistemological position is positivist, and naturally derives from the positivist paradigm and an objectivist ontological position (Scotland, 2012, p. 10). As the positivist paradigm implies that matters that are researched should be investigated objectively (Brand, 2008, p. 432), and an objectivist ontological position involves an objective reality (Scotland, 2012, p. 10), a positivist epistemological position assumes that real knowledge exists and is independent of our interpretation (Guba & Lincoln, 1994, p. 110). For research, a positivist epistemological position therefore means that we assume that certain knowledge is real regardless of who interprets the information. This knowledge then serves as a baseline to draw conclusions and is therefore a critical aspect of research.

Another epistemological position is interpretivist which is in the non-positivist paradigm (Scotland, 2012, p. 11). In the non-positivist paradigm, there are no absolutes of objective reality and therefore reality is based on perspective and interpretation (Brand, 2008, p. 433). Therefore, an interpretivist epistemological position indicates that researchers interpret information differently and can have various perspectives of what is acceptable knowledge (Marsh & Furlong, 2002, p. 19). This relates to a constructivist ontological position, which assumes that reality is subjective and changes based on individual perspective (Brand, 2008, p. 433). Therefore, an interpretivist epistemological position implies that there is less certainty regarding the outcome of research (Scotland, 2012, p. 12), and a topic can have various outcomes based on who holds the information.

This research process is based on an interpretivist epistemological position, which implies that investor perspective on economic attractiveness of projects is dynamic. It is up to individual investors to interpret the importance of performance indicators and therefore there are influences of interpretivism in this study. The financial metrics that indicate financial viability can be considered true knowledge and therefore there are influences of objectivism in this study. However, as this study includes investor perspective and uses a subjective valuation strategy, the epistemological position aligns with interpretivism, which is consistent with the non-positivist paradigm.

3.1.3. Axiology

Axiology is a philosophical concept that can be considered as the "theory of behavior" (Killam, 2013, p. 6). It relates to our research philosophy because our axiological position guides the ethical manner in which we conduct research, as it is based on our values and beliefs (Killam, 2013, p. 6). When it comes to research, our axiological position has a crucial role in guiding the ethical conduct of our study because it guides the manner in which we present our findings (Aliyu et al., 2015). Thus, our axiologial position connects our ontological and epistemological positions into practice in the research process (Aliyu et al., 2015). By being mindful of our axiological position, we can ensure consistency throughout the research process. We align our axiological position with the non-positivist paradigm and subjective approach to knowledge, which reflects how we frame our research question, collect and analyze data, and draw conclusions. Recognizing the viability of our research findings relate to axiology, as we understand that the valuation process includes influences from both the positivist and non-positivist paradigms. Understanding the influences of subjective perspective allows us to remain transparent and ethical in our research.

3.1.4. Theory

It is essential to consider the type of theory we use in the research process. Sandberg & Alvesson (2021, p. 487) state that we must understand what theory is to develop scientific knowledge in research. They present six criteria for defining theory, that include purpose, an empirical phenomenon and boundary conditions for application (Sandberg & Alvesson, 2021, p. 491). Theory is often considered as a framework that explains a phenomenon, which puts most theory in a category of explanatory theory (Sandberg & Alvesson, 2021, p. 495). However, not all phenomena can be explained, and therefore there is a need for additional and alternative categories of theory (Sandberg & Alvesson, 2021, p. 491). For example, comprehending theory revolves around understanding the meaning of phenomena (Sandberg & Alvesson, 2021, p. 498) and can therefore allow a theory to interpret phenomena instead of explaining it. A theory can also aim to challenge a phenomenon. According to Sandberg & Alvesson (2021, p. 496), theory can be provocative and question established beliefs regarding phenomena. This can be beneficial for challenging knowledge that has been force-fit into the commonly used explanatory category (Sandberg & Alvesson, 2021, p. 504).

The Capital Asset Pricing Model (CAPM) is an example of explanatory theory, as it provides a theoretical foundation for minimum required rate of return. However, researching complex developing topics like sustainability requires an expanded perspective on theory as not all topics can be objectively explained. Therefore, it can be beneficial to analyze the meaning of sustainability or to challenge established beliefs in the topic. The authors align the scientific assumptions with non-positivism, which perceives knowledge subjectively. However, the theoretical foundation is in the explanatory category. Thus, it is essential to have an expanded perspective on theory to get a thorough understanding of various topics. A comprehensive perspective of theory allows us to critically evaluate established assumptions and this way get a deep understanding of the topic.

3.1.5. Conclusion scientific methodology

The authors will position this study in the non-positivist paradigm, as our scenario creation is a unique research method and investor perspective is included. Our ontological position assumes that investment decisions can be dynamic and therefore aligns with constructivism. To remain consistent with our chosen paradigm and ontological position, our epistemological position will be interpretivist. The axiological position guides the way we present information and defines our goal of presenting information transparently throughout the thesis. Lastly, our assumptions regarding the definition of theory include multiple categories of knowledge, as stated in Sandberg & Alvesson (2021). Table 1 below summarizes our scientific assumptions.

Table 1. Summary of Scientific Method

Scientific assumption	Position	Implication
Paradigm	Non-positivist	Research process includes subjective perspective
Ontology	Constructivism	Reality is dynamic
Epistemology	Interpretivism	Reality is subjective
Axiology	Non-positivist	Acknowledge subjective influences of research process
Theory	Non-positivist	Expand theory into numerous categories

3.2. Research strategy

A research strategy is defined as the steps taken in order to answer the research question (Saunders et al., 2019, p. 189). There are three research strategies that can be applied, which include quantitative, qualitative and mixed methods (Williams, 2007, p. 65). Quantitative studies often involve numerical data, qualitative studies involve interpretative and non-numerical elements, while mixed method studies include both quantitative and qualitative aspects (Williams, 2007, p. 65). Thus, the authors must define the research strategy according to philosophical position and ability to answer research questions with the chosen strategy. This is a mixed method study that utilizes both quantitative and qualitative aspects.

A quantitative approach is traditionally the most common strategy and attempts to generate knowledge by analyzing numerical data (Williams, 2007, p. 66). Quantitative studies are often conducted in the positivist paradigm and therefore involve objectivism (Yilmaz, 2013, p. 311). A quantitative strategy is appropriate when the researcher can expect to access adequate data to answer the research question (Williams, 2007, p. 65). The advantage of quantitative research is that data is quantifiable and is therefore not affected by context or individual perspective (Queirós et al., 2017, p. 370-371). However, numerical analysis limits flexibility and the researcher´s ability to investigate the context of the phenomenon (Queirós et al. 2017, p. 370-371).

A qualitative study is influenced by individual perspective and therefore allows the researcher to examine the phenomenon in detail (Williams, 2007, p. 67). Thus, qualitative studies are conducted in the non-positivist paradigm, which involves a constructivist philosophical position (Yilmaz, 2013, p. 323). This strategy allows the researcher to carefully analyze and describe the data and gathered information, which can generate new perspectives to the field of study (Williams, 2007, p. 67). The advantage of qualitative research includes an ability to analyze the phenomenon in-depth without being restrained by objectivism of numerical data (Queirós et al., 2017, p. 370). However, this also means that the findings may not be quantifiable (Yilmaz, 2013, p. 312) or considered as true knowledge in positivist research.

Mixed method studies include both quantitative and qualitative aspects. For example, a mixed method is appropriate when a purely quantitative strategy risks neglectance of important aspects of the phenomenon (Echambadi et al., 2006, p. 1815). Implementing a qualitative strategy can provide valuable insight and perspective, while a quantitative strategy can assist the research process with statistical data for analysis (Echambadi et al., 2006, p. 1815). Thus, this research strategy allows the use of both numerical data and individual perspective to answer the research question (Williams, 2007, p. 69). The advantage of a mixed method strategy includes using strengths from both paradigms while avoiding limiting drawbacks (Williams, 2007, p. 70). Howe (1988) suggests that paradigms should not be interconnected, whereas Johnson & Onwuegbuzie (2004, p. 14) argue that utilizing both aspects can improve the result.

The authors choose a mixed method research strategy for this study. Financial data for energy storage projects is currently not publicly accessible. Therefore, implementing a purely quantitative strategy that relies on objective numeric data and statistical analysis is difficult as practitioners do not want to publicize sensitive project information. However, numeric data is essential for analyzing the financial viability of energy storage projects and therefore quantitative aspects must be included in the study. A qualitative research strategy allows flexibility and exploration (Williams, 2007, p. 67). Therefore a qualitative approach is also applicable to this study, as it allows flexibility to create financial profiles of energy storage projects and to shed light on an understudied field by involving the input of practitioners. The combination of quantitative analysis with input from practitioners allows the authors to explore how valuation metrics are prioritized in reality. By being mindful of the use of both strategies, along with scientific assumptions, a mixed method strategy enables research in an understudied field despite limited access to data, and provides the authors an opportunity to answer the research questions.

3.3. Research approach

The research approach is a form of reasoning that is based on our philosophical positioning and is manifested in our research methods (Scotland, 2012, p. 9). There are three main research approaches that can be applied to our research process: deductive, inductive and abductive. Each research approach has advantages and drawbacks, and they are suitable in various research applications. The following section will discuss each research approach individually and how they could be applied to our research topic. Lastly, the research approach used in this study will be defined and related to the research process.

Deduction is a commonly used research approach in scientific research that aims to verify or falsify theory by using propositions related to existing theoretical framework (Saunders et al., 2019, p. 153). Thus, it starts with a theory that is then tested through various propositions (Saunders et al., 2019, p. 153). A deductive approach revolves around phenomena that *must be* because of the theoretical framework (Mcauliffe, 2015, p. 303). If the results of a deductive approach are not in line with the theoretical explanation, the theory must be rejected or modified (Saunders et al., 2019, p. 154). Thus, deduction requires a research process that is replicable, where the facts are measurable and the result is generalizable (Saunders et al., 2019, p. 154). The result of our research process may not be generalizable, and the financial modeling is still emergent. Therefore, a deductive approach is not appropriate, as the aim is not to test whether a theoretical explanation can be verified or falsified.

An inductive approach explores phenomena and various patterns to create a logical explanation or framework, and is therefore suitable for generating or developing theory (Saunders et al., 2019, p. 153). Induction revolves around phenomena that *actually are,* which involves considering facts and finding correlations between theory and findings (Mcauliffe, 2015, p. 303). In induction, theory is generated in the research process based on the data, and is therefore highly dependent on the research context. (Saunders et al., 2019, p. 155). Induction is often interpretive (Saunders et al., 2019, p. 155) and is therefore suitable for research in the non-positivist paradigm.

Abductive reasoning uses data collection to explore a phenomenon and various patterns, relate this to a theoretical framework and conduct tests through data collection (Saunders et al., 2019, p. 153). An abductive approach allows continuous interaction between theory and data, which allows flexibility in the research process (Saunders et al., 2019, p. 156). Therefore, abduction is something that *may be* (Mcauliffe, 2015, p. 303). There are two types of abductive reasoning, explorative and exploitative (Bamberger, 2018, p. 3-4). Exploratory abductive reasoning is a process of recognizing facts and testing various frameworks that can explain a phenomenon (Bamberger, 2018, p. 4). Exploitative abduction involves a process of compiling facts and observations to establish a suitable framework that explains a phenomenon (Bamberger, 2018, p. 3).

This study will use exploitative abductive reasoning in our research process. Valuation in the energy storage sector is an emerging topic but is still understudied, which is suitable for abduction as it often revolves around phenomena that is not investigated adequately in existing research (Bell et al., 2019, p. 24). Exploitative abduction involves using available facts to establish a framework. Creating project profiles is an example of exploitative abduction, as the research process involved using available information and making assumptions that resulted in realistic project profiles. The interplay between strategies or general rules, and empirical phenomenon, allows us to apply new knowledge that we encounter to develop our understanding of the topic throughout the research process. Figure 1 visualizes the interconnectedness of general rule, empirical observation and explanation in abductive reasoning.

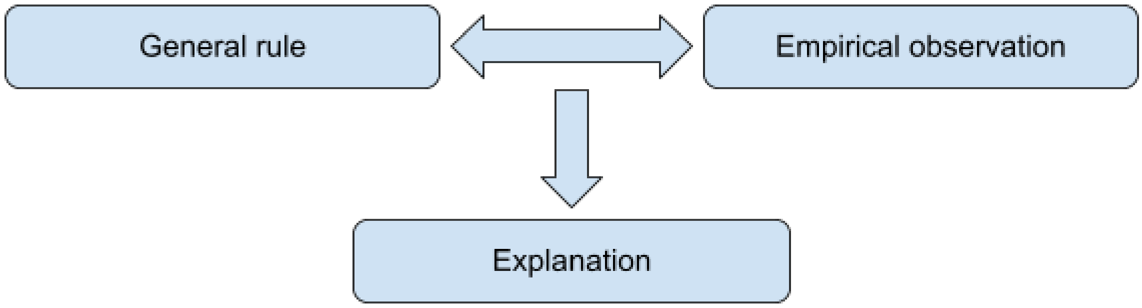

Figure 1. Abductive reasoning.

3.4. Research design

Research design allows the author to structure the research process by evaluating the starting point, having a goal and determining a successful research process to reach that goal (Silver et al., 2013, p. 53). Thus, determining a research design assists the authors in designing the steps in the research process to allow consistent progress toward a set goal. There are three different approaches to research design: descriptive, exploratory and causal (Silver et. al, 2013, p. 53). There are differences in how previous studies name the different categories, but the general definitions remain consistent. In this section, each approach to research is discussed and the research design of this study is defined.

A descriptive approach is traditionally used in quantitative research and assumes that reality is constant and can be uncovered by objective research (Williams, 2007, p. 66). Descriptive research often uses hypothesis-testing and therefore involves structure and certainty (Silver et al., 2013, p. 71). For example, a descriptive strategy can involve identifying factors that influence a phenomenon and investigate the correlation between various elements (Williams, 2007, p. 66). The descriptive approach is less flexible than exploratory research, but is advantageous in creating quantifiable and valid results (Silver et al., 2013, p. 72).

An exploratory, or experimental approach, investigates the effect of implementing new variables (Williams, 2007, p. 65). Exploratory research may not have a clearly defined goal for the study and is therefore useful for uncovering new perspectives to the phenomenon (Silver et al., 2013, p. 55). Thus, an exploratory research design allows flexibility in the research process and is useful for qualitative research. This is useful when investigating understudied topics, as new insight can be uncovered that is subject to further research. However, exploratory research decreases the ability to control the results, which can reduce the validity of the study (Williams, 2007, p. 66).

A causal strategy is useful for exploring the relationship between variables (Williams, 2007, p. 65). This strategy involves manipulating a specific variable, measuring the effect, and controlling whether the change can be isolated to that specific variable (Silver et al., 2013, p. 76). By separating independent and dependent variables, the researcher can investigate the interconnectedness between variables (Williams, 2007, p. 66). The advantage of a causal design is that it can uncover important relationships that can be useful for decision-making, however, it can be a time-consuming process that may not generate useful results (Silver et al., 2013, p. 76).

This study uses an exploratory research design to investigate an understudied topic. Therefore, the research process requires flexibility and curiosity. A descriptive approach is not applicable, as investor perspective is not objective and there is not enough data available to generate quantifiable results. There are influences of causality as integrating valuation metrics allows investigation of relationships among results. However, this study does not manipulate a variable such as WACC to explore the impact and control the results. Thus, the exploratory approach is appropriate and can generate results that inspire future descriptive or causal research in the field.

3.5. Literature search

The authors ensure the credibility of this study by prioritizing peer-reviewed scientific journals. To find relevant sources, the authors have used the Umeå University library and Google Scholar as primary search engines. Discussing the literature search process is essential for the reader to understand the thoroughness of the literature review (Brocke et al., 2009, p. 1), which increases the credibility and overall quality of the study. The authors have prioritized the data available in existing peer-reviewed literature for scenario creation.

As energy finance is understudied and data accessibility is an issue in the field, the authors have found relevant information from non-peer reviewed sources that are considered credible. For example, the inputs necessary for scenario creation are retained from the European Database for Energy Storage. Publicly available reports provide an opportunity discussing the current market outlook, such as reports by Lazard (2018) and BloombergNEF. Public information, such as index prices and interest rates, are gathered from Yahoo Finance and Wall Street Journal. The authors have also utilized information from previous courses in the Umeå University School of Business, Economics and Statistics as deemed relevant. The utilization of external sources will be discussed further in section 3.6.

Keywords used in literature search include: financial valuation, valuation metrics, project finance, energy storage, sustainable energy, LCOS, LCOE, NPV, IRR, energy finance, sustainable finance.

3.6. Source criticism

Source criticism involves critically evaluating the sources used in the research process (Steensen, 2019, p. 188). As discussed in section 3.5, the authors have prioritized peer-reviewed articles from scientific journals as they are deemed the most credible source of information. However, the credibility among peer-reviewed articles may differ. Steensen (2019, p. 189) argues that every source has a different motive, and therefore must be evaluated critically and compared to other sources in the field. For example, literature regarding financial valuation of energy storage and energy projects is scarce. Therefore, this study must rely on the peer-reviewed articles that are available. Most of the existing studies in the field are recent, as energy finance is an emerging field. However, the authors prioritize recent studies as the energy industry is rapidly developing and therefore updated peer-reviewed literature is essential. This study relies heavily on the studies conducted by Berrada (2022), Tao & Finenko (2016) and Sung &

Jung (2019). However, neither of these studies discuss data collection or source criticism in-depth. Therefore, it is the authors responsibility to understand that credibility among peer-reviewed sources may also differ, and that critical review of the sources used is necessary. The credibility of this study is ensured by relying on current peer-reviewed articles, however, reliability would be increased if there was more existing literature in the field to review. By remaining consistent and transparent in the use of sources, the authors can increase the credibility of this study.

The authors have used non-peer reviewed sources in this study, as they have been necessary for scenario creation and current market updates. The authors consider the use of market updates through Lazard (2018) and BloombergNEF valid, as they are also mentioned in existing peer-reviewed literature. As project data is scarce, inputs from the European Database of Energy Storage is necessary. This data derives from an official public entity, the European Commission, and is therefore considered valid for purposes of this study. By minimizing non-peer reviewed sources, and prioritizing recent scholarly articles, the authors implement a strategy for ensuring credibility and dependability in the research process.

3.7. Ethical considerations

Research ethics guides the way we conduct our study. Thus, our ethical considerations are closely related to our philosophical position. According to Bell & Bryman, (2007, p. 67-69), the ethical challenges that arise in business research include conflict of interest, power relations, wrongdoing and confidentiality. Furthermore, we must conduct research based on our quality criteria, which include credibility, transferability, dependability and confirmability.

Conflict of interest can arise, especially if the research is related to funding or has other economic implications (Bell & Bryman,, 2007, p. 67). The authors will not alter the results of this study to influence funding toward any particular energy storage technology or sustainable energy project. Therefore, it is the ethical responsibility of researchers to explain the research process thoroughly and present the results transparently, instead of manipulating them to get a study published or influence funding. Our study involves aspects that benefit the interests of both practice and academia. Therefore, there may be conflict of interests when conducting business research in the energy storage sector. As most energy storage projects are still in early phases, financial information is sensitive and therefore project owners may be unwilling to publicize it in the interests of academia. Thus, creating hypothetical project profiles based on publicly available data and involving input from practitioners can be considered a compromise of the interests between practice and academia.

The challenge of power relations arises when researchers involve input from individuals or organizations (Bell & Bryman,, 2007, p. 67). The researchers have a responsibility of establishing informed consent to the participants in the study (Bell & Bryman,, 2007, p. 67). We contacted numerous experts in the field to get input from practitioners. Our letter to experts can be found in Appendix 2, which can be considered the informed consent sent to practitioners. This is an example of voluntary participation, as the participants willingly participated in the study without being pressured to do so.

Research can cause harm if information is presented wrongfully (Bell & Bryman, 2007, p. 68). The authors address this risk by clearly defining the intentions and limitations of this study. For example, this study does not intend to demonstrate which energy storage technology is superior to the other. Therefore, maintaining transparency and ensuring replicability reduces the risk of wrongdoing in the research process.

Confidentiality and anonymity is a challenge when using external participants and information from external sources (Bell & Bryman, 2007, p. 69). Regarding anonymity, the participants were informed that their project ranking decisions would remain anonymous in the text. As this study only involves publicly available information, the authors minimize the risk of confidentiality issues. By being mindful of the ethical challenges that can arise in business researchers, the authors can ensure the integrity of this study.

Finally, the authors must consider whether it is ethical to conduct a mixed-method study. Researchers can decide on a strategy that allows them to answer the research questions and achieve the purpose of the study. Traditionally, it may have been considered unethical to mix quantitative and qualitative approaches, as portrayed in Howe (1988). However, a mixed-method study can improve the result of the study compared to traditional approaches (Johnson & Onwuegbuzie, 2004, p. 14). The authors consider the mixed-method to be appropriate for achieving the research purpose of shedding light on the valuation process of energy storage projects, and integrating valuation metrics from the finance and energy sectors. The ethical integrity of this study is maintained by consistent non-positivism, an exploratory research design and abductive research approach. The purpose of the study is clearly defined, and the authors have made methodological choices that provide a foundation for answering the research questions. Furthermore, the authors establish credibility by transparently outlining data sources, data collection issues and steps involved in the data collection process. The integrity of the study is established by identifying several limitations associated with the research process in Section 7.6. Finally, the quality of the study is assessed critically in Section 7.4 based on the qualitative aspects of this study. Thus, the authors have strived to establish the ethical integrity of a mixed-method study by clearly defining choices, discussing reasoning for research strategy and transparently outlining the research process.

4. Research method

In this chapter, the practical method of the study will be presented. This includes the research model, dataset, and strategies for data collection. Finally, the authors will discuss additional inputs used in scenario creation to eliminate confusion going into the next chapter.

4.1. Research model

The authors implement a case study model in creating an investment scenario that sheds light on financial analysis of energy storage technologies. The authors utilize a mixed method strategy, with numerical data analysis as a quantitative strategy, and utilization of expert input as a qualitative strategy. The goal of the study is to demonstrate financial modeling that investors can use when analyzing the viability of energy storage projects. An exploratory research design is necessary, as this research strategy has not been used in existing literature to our knowledge. In the section below, the case study model and exploratory research design will be discussed further.

The case study model involves gathering information from a variety of sources to examine a process or event thoroughly (Creswell, 2009, p. 30). This method is especially appropriate for investigating understudied topics (Williams, 2007, p. 68). A case study often includes both participants in the study and data from other available sources (Williams, 2007, p. 68). In this study, we are examining the valuation process for energy storage projects. This case study involves data inputs from existing literature, public entities and practitioners in the field. Each source of data and information is purposeful for creating a realistic project finance scenario that sheds light on the valuation process of energy storage projects.

This study uses an exploratory research design to examine a strategy for integrating valuation methods from finance and the energy industry. This is a commonly used strategy in qualitative research, which often involves using numerous methods in the research process (Silver et al., 2013, p. 56). A characteristic of exploratory research is using multiple sources of information for investigating a phenomenon (Silver et al., 2013, p. 55). The authors explore a strategy for integrating valuation metrics by creating a point-base system that gives a holistic perspective on the financial viability of the energy storage project. The point-base system used in this study indicates an exploratory research design, as the unique method serves as a foundation for future research.

The practical study will be structured in three steps. First, each project will be ranked based on individual metrics. Second, the projects will be ranked based on a point-base system. Finally, practitioners in the field will rank the projects based on their perspective of economic feasibility.

4.2. Dataset

This study uses secondary data to create the financial profiles of five energy storage projects. Secondary data refers to information that originates in another study or purpose but is found relevant to answer the current research question (Hox & Boeije, 2005, p. 593). Relevant secondary data in the field of study is scarce and therefore the authors must combine available data from numerous sources. Secondary data from peer-reviewed articles such as Berrada (2022) and Sung & Jung (2019) is prioritized in scenario creation. Hox & Boeije (2005, p. 594) state that the advantage of using secondary data includes the ability to tailor the sources to fit the research design, research process and therefore improve the ability to answer the research question.

In this study, the authors have used the results and inputs from previous similar studies, such as Berrada (2022), to recreate the financial profiles of the projects in the article. Thus, this study involves using secondary data and financial modeling, such as the connection between WACC, CAPEX and NPV, to find annual cash flow and get a complete financial profile of the technologies in peer-reviewed articles. However, the inputs from peer-reviewed articles do not provide sufficient information for creating geographically specific project profiles to Europe. Thus, the authors utilize secondary data inputs from the European Database of Energy Storage to create projects that specifically represent the European market. This is an example of sequential exploratory research, where the researcher creates a process because existing information is inadequate or incomprehensive (Creswell, 2009, p. 195).

The authors use the CAPM model to calculate the cost of equity, which includes risk-free rate, market beta and market return. To maintain the geographical consistency of the study, the authors have chosen values specific to the European market. The inputs in CAPM involve secondary data inputs from publicly available sources which are available in Table 5.

As case studies involve input from participants (Williams, 2007, p. 68), the authors have surveyed practitioners in the field to include primary data in the study. Primary data refers to information gathered in the research process that tailors the specific characteristics of the study (Hox & Boeije, 2005, p. 593). An important aspect of gathering primary data is reanalysis, which involves a new perspective of the gathered data (Hox & Boeije, 2005, p. 593). Reanalysis of data is applicable to this study, as practitioners are asked to evaluate the energy storage projects from an investor perspective to get an additional perspective to the point-base system.

The specific inputs used and their purpose will be discussed and summarized in section 5.1.

4.2.1. Sample

This study uses five energy storage technologies to portray an investment scenario. Evaluating and comparing numerous technologies is consistent with current studies in the field, as Berrada (2022), Sung & Jung (2019) and Jülch (2016), analyze between three and eight energy technologies. The authors have used the European Database for Energy Storage to obtain technical information for our chosen technologies: Pumped Heat Energy Storage, Pumped Hydro Energy Storage, Compressed Air Energy Storage, Lithium Ion Battery Storage and Sodium Sulphur Battery Storage. The technologies are similar to the energy storage technologies in Berrada (2022) in terms of capacity, CAPEX, construction time and project lifetime. As the authors have created the financial profiles for each project, the name of each technology is not included in project ranking. Instead, the technologies are referred to as Storage A, Storage B and so on. This way, information will not be misleading regarding the financial viability of the specific technology, but will rather illustrate an investment scenario. The specific technologies are stated in Table 2 below.

Table 2. Energy storage technologies utilized in this study.

Storage A	Pumped Heat Electrical Storage (PHES)
Storage B	Pumped Hydro Storage (PHS)
Storage C	Compressed Air Energy Storage (CAES)
Storage D	Lithium Ion batteries (Li-ion)
Storage E	Sodium Sulphur Batteries (Sod. Nickel)

4.2.2. Survey

To gain a deeper understanding of investor perspective in the field, the authors contacted experts in the energy field and requested their analysis of our results through a series of questions. Surveys can portray the subjective perspective of participants (Hox & Boeije, 2005, p. 594), which is a valuable addition to research. Furthermore, direct communication with participants is a flexible and efficient strategy for gathering information regarding attitudes and perspectives (Silver et al., 2013, p. 121). The benefit of qualitative research is that the authors can choose participants that are able to provide valuable insight that is relevant to the research question (Hox & Boeije, 2005, p. 594).

Participants were contacted by email and asked to answer a mail questionnaire, which is a commonly used communication method of gathering primary data (Silver et al., 2013, p. 121). The email to experts can be found under Appendix 2. The participants were provided with a brief introduction regarding the purpose of the thesis and requested to rank the different technologies with reasoning for their choices. Participants were also asked whether they utilized metrics which were not included in the study.

The purpose of obtaining expert feedback is to discover whether the results are in alignment with what people in the field believe and whether there is or isn't homogeneity when assessing these types of technologies. By adding expert's opinions, the authors provide an additional ranking system to the point-base system. This way, the study includes an additional perspective of the economic attractiveness of energy storage technologies.

4.2.3. Participant selection

The authors contacted a total of five experts and obtained feedback from two of them. This portrays the disadvantage of the communication method, as participants often choose not to participate in the study (Silver et. al, 2013, p. 121). The participants chosen and considered as experts hold managerial positions that include decision making. The organizations involved are consulting firms and energy firms in the energy sector. The companies are located in Sweden and Finland, which is consistent with the geographical location of the projects in this study. The authors chose to only include participants from the energy sector as they can provide knowledgeable insight regarding a developing industry and cater a target group of professional investors. Both experts requested to remain anonymous in their answers. The authors are grateful for the participants in this study.

One of the expert responses came from a representative from a regional electricity company tasked with the supply of electricity networks along with providing district cooling, heating and broadband services. Energy storage can have a significant role in balancing electrical grids in the future, and therefore the authors deemed a representative from a regional electricity distributor to be a suitable participant for our study. This entity is not directly in line with energy storage but has interest in providing energy to consumers which forces them to evaluate energy provision.

The second expert opinion comes from a representative in the energy storage sector. This contact is actively involved with financial aspects of energy storage projects and therefore provides a valuable perspective to our study. This expert provides an investor perspective that is not restricted by the duty of representing the customers in the local electrical network, but rather makes decisions based on financial incentives and risk mitigation. Therefore, the second expert provides an interesting perspective to ranking energy storage project investments.

4.2.4. Data collection issues

The authors have encountered moderate issues in accessing public data on real energy storage projects. There is sporadic public data available on investment size and some elements of financing structures in databases, such as Refinitiv. However, comprehensive information regarding cash flows, operational characteristics, cost and financing structure is not available publicly, to our knowledge. Annual reports conducted by Lazard (2018) include detailed information that can be used for valuation studies. However, the data is not available for public use without prior consent, which is an issue related to data collection.

A possible explanation for this issue is that energy storage is an emerging sector, and numerous projects are still in planning, awaiting investment, or in the pre-study phase, which makes real project data difficult to access for purposes of this study. This also indicates that there is a need for further research in the field. Existing studies have not publicized detailed information regarding the financial aspects of the energy projects, but have rather compared the resulting valuation metrics for space purposes.

Therefore, the authors must rely on the best possible available data to achieve our research purpose. This study simulates an investment scenario between various energy storage technologies. This requires complete information regarding cash flows, capital expenditures, operating expenses, project life and energy performance aspects. The public data includes capital expenditures, cost data and performance related metrics for various energy storage technologies that can be used to create a project simulation.

4.3. Methods used in similar research

Previous studies such as Tao & Finenko (2016), Berrada (2022) and Sung & Jung (2019) have investigated the financial viability of energy projects through traditional valuation metrics and levelized cost methodologies. Thus, this study is similar in regards to the financial models utilized, such as LCOS. However, previous studies rarely mention research methods or data collection unlike this study. Also, the majority of the studies available do not attempt to use a universal EU standard of evaluation, unlike this study does, through the computing of WACC, CAPM and other metrics from a EU standpoint rather than country based. Current literature fails to do so, since the only country which is currently in possession and operating multiple energy storage systems is the United States of America. While other countries still limit themselves to a couple or more energy storage technologies. The reason for such scarcity in the implementation of these technologies across the globe, is related to the substantial financial requirement needed for building, implementing and maintaining these projects. This can also be seen from the values obtained in the final calculations the authors came up with to support the findings of this thesis, which closely resemble real technologies in current literature. These factors are likely to cause many countries and investors to test these technologies before committing to them through expensive investment projects. In order to reduce the risk associated with the investment, they ought to first handedly conduct and conclude the investment project throughout their lifetime before coming up with a conclusion regarding their viability, returns and whether or not it is sustainable from a financial standpoint.

Seen the novelty of the storage technologies, most literature is still discovering the new ways of how energy storage systems operate and their characteristics, therefore the majority of the papers currently available limit themselves to comparing available data of similar technologies in energy storage, with a possible novel technology not yet being implemented, constructed or analyzed from a literature point of view. The process of evaluation in current literature is conducted through the comparison of the LCOS values in order to provide experts in the field with a more complete picture of what investing in such technologies would result in and how the unexplored energy storage technology relates to the ones already in use or already analyzed.

Current literature available also focuses their studies and research on the evaluation and comparison of these technologies through the calculation and comparison of LCOS solely (economic evaluation) and does not venture into financial valuation like the authors have conducted in the current paper. The only report which the authors have found among literature, which attempts to shed light and this literature, in regards to LCOS, is the Berrada (2022) article which has been used as close reference for the completion of this thesis. Considering that the publication of the Berrada (2022) article is in 2022, the authors have deducted that literature on the combination of economic, technological and financial factors is currently understudied in literature.

Unlike this study, previous studies have likely had access to real project data, which has made our data collection process unique. We have gathered available data, made justified assumptions, found connections and through reverse engineered created realistic project profiles. Thus, the research method is unique compared to previous studies. Furthermore, we analyze the financial viability of energy projects through valuation metrics. However, this study ranks investments from an investor perspective and incorporates expert's input on investment decisions regarding the results obtained. Thus, this includes an investor perspective, which is an understudied area in the field.

4.4. Additional variables used in study

This section includes a description of inputs and assumptions that influence the financial profiles of the energy storage projects. The section is divided into inputs for discount rate and cash flows, along with a definition for maturity. By including this section, the authors intend to clarify the assumptions and inputs used in creation of the financial profiles involved in the practical experiment.

4.4.1. Discount rate

This section includes inputs that are used in the CAPM model for calculating cost of equity. The authors have strived to calculate a discount rate that is specific to the energy market in Europe, and therefore each input aligns with the chosen market or geographic region.

4.4.1.1. Risk-free rate

As per Lee et al. (1999, p. 1737), in order to minimize the error on the risk free rate, the best method is to utilize a short term treasury bill (T-bill) rather than a longer one since it tends to outperform in the long run due to better empirical estimates of intrinsic value. The most common risk free rate utilized in literature is the US T-bill, but we will be utilizing the German T-bill instead due to our target group being situated in Europe and selecting specifically Germany due to its recognized economy and higher bond ratings. Utilizing a risk free rate from Germany allows the authors to imply that the selected rate is the most stable in the continent and offer the least volatility possible in the eyes of the investors.

4.4.1.2. Market risk premium

This value represents the additional return expected due to the risk associated with the investment. The measure is calculated by computing the difference between expected return and the risk free rate. The values for the MRP are selected from the STOXX Europe 600 index, which incorporates small, medium and large public traded companies among eighteen EU countries (Farlex Financial Dictionary, 2012). The calculations are as follows: (ending value - beginning value)/beginning value from 2012-2022. Thus, the MRP in this study represents a 10 year annual average. The year 2023 was missing at the time of data collection, which is why it was excluded from the calculation.

4.4.1.3. Beta

The value of the beta (β) is an indicator of the volatility of a security compared to the systematic risk of the market therefore usually used as a measure of risk for an investment (Damodaran, 2023). If the value of the beta is higher than 1.0 it can be implied that the security or portfolio is more volatile than the market thus more susceptible to price changes and perceived as riskier. Consequently, a beta lower than 1.0 implies a safer security which tends to produce less returns but fluctuate less in relation to the market (Fama & French, 2004; Berk & DeMarzo, 2017).

Since this study is centered around Europe, the authors have selected the average beta of companies in the energy industry (Damodaran, 2023). The authors determined that calculating the energy storage market beta was not necessary, as the using the beta for green and renewable energies in Europe (Damodaran, 2023) suited the purposes of this study.

4.4.2. Project cash flow

In this section, the authors will discuss the cash flows associated with energy storage projects so that inputs associated with the practical experiment are clearly defined.

4.4.2.1. Free cash flow (FCF)

A project is determined as viable and worth attempting according to its cash flow analysis, which takes in consideration all cash inflows and outflows of a project (Mawutor & Kwadwo, 2014, p. 183). Cash inflows come from the annual revenues that an energy storage system generates, while outflows include OPEX and depreciation. Annual FCF is assumed to be constant in each of the projects in this study, as secondary data regarding annual revenues and expenses is not available.

4.4.2.2. CAPEX

In the energy storage industry, CAPEX is often stated per unit of power and therefore the initial investment depends on power capacity (Rubio-Domingo & Linares, 2021, p. 4). It is common for the cost to be expressed also in provided energy in KWh or MWh, the difference resides in the fact that capacity is the maximum output of electricity produced and energy is the amount of electricity produced and consumed over time. This study will use power capacity to calculate initial investment.

4.4.2.3. OPEX

OPEX refers to the annual costs associated with operating an energy storage system. This is often stated as an annual percentage of CAPEX, as in Berrada (2022). Thus, for forecasting purposes, the annual OPEX is expected to be constant throughout the project life.

4.4.2.4. Depreciation

In project finance, the depreciation method must be defined as it affects annual cash flow. For our calculations we will use the straight line method. This means that the energy storage technology will depreciate at a constant annual rate toward a salvage value of zero at the end of the project. As annual cash flow is assumed to be constant, the straight line method of depreciation aligns well with this study.

4.4.3. Maturity

The maturity of the technologies represents how established a technology is in the market, the higher the years the more secure and more data is available. Most of the ESS have not yet implemented or are still under construction therefore there is little information available on how well an ESS is performing or the difficulties in implementing and running a technology.

The information regarding Storage A-D was retrieved from the European Database of Energy Storage, while the technological maturity regarding Storage E (sodium sulphur batteries) had to be assumed based on similar electrochemical technologies.

5. Data and results

This chapter begins with detailed discussion regarding the steps involved in data collection. Moreover, the results will be presented by ranking the investments based on individual valuation metrics, overall project ranking by integrating valuation metrics and the ranking by experts.

5.1. Data collection

This section entails the steps involved in data collection. The goal of this process was to create five financial profiles of energy storage technologies that represent an investment scenario in Europe. The authors have explored strategies for using available data, which aligns with the exploratory research design. As discussed in section 4.2., this study involves data from numerous sources. The data collection process in this study is path dependent and interconnected, and therefore each step is clearly demonstrated for simplifying the reading experience.

5.1.1. Step 1: Recreate financial dataset based on Berrada (2022)

The goal of Step 1 is to find annual cash flows of each of the five energy storage technologies in Berrada (2022). To have complete financial profiles of energy storage projects, the authors needed information regarding initial investment (CAPEX), discount rate (WACC), project lifetime and annual free cash flow (FCF) of energy storage projects. Annual cash flows can involve revenues, operational expenses and depreciation. As secondary data regarding energy projects is scarce, the authors rely on Berrada (2022), which is the only peer-reviewed financial study regarding energy storage projects.

In Berrada (2022), the authors find inputs demonstrated in Table 3**,** which include CAPEX, WACC, NPV, construction time and project lifetime. Revenue streams are not mentioned in (Berrada, 2022) and therefore information regarding annual operating expenses (OPEX) and depreciation is not useful for scenario creation. Operating expense is stated as an annual percentage of CAPEX (Berrada, 2022, p. 412). Thus, the authors necessarily assume that annual FCF is a constant annual percentage of CAPEX throughout the project life. Annual FCF is found by utilizing the formula below.

$$NPV = PV(CAPEX) + PV(FCF)$$

As the formula indicates, the present value of annual cash flows can be found by using CAPEX, NPV and WACC. With sufficient information regarding construction time and project lifetime from Berrada (2022, p. 412), constant annual FCF that makes the mathematical relationship above true can be found. The authors utilized the goal seek function in Microsoft Excel (MS) and stated annual FCF as a percentage of CAPEX. The inputs used and result of Step 1 is demonstrated in Table 3 below.

Table 3. Inputs used in Step 1 calculations and resulting annual FCF.

		Energy storage technologies					
Input	**Unit**	**GES**	**PHES**	**CAES**	**Li-ion**	**NaS**	**Source**
CAPEX - power	($/KW)	692	1349	896	282	454	Berrada (2022)
Power	GW	1	1	1	1	1	Berrada (2022)
Initial investment	$	$ 692 000 000	$ 1 349 000 000	$ 896 000 000	$ 282 000 000	$ 454 000 000	Berrada (2022)
Constuction time	years	3	5	5	1	1	Berrada (2022)
Project lifetime	years	60	60	20	10	15	Berrada (2022)
WACC	%	8%	8%	8%	8%	8%	Berrada (2022)
NPV	$	$ 367 800 000	$ 368 600 000	$ 538 200 000	$ 104 700 000	$ 164 800 000	Berrada (2022)
Annual FCF/CAPEX	**%**	**13,75%**	**12,48%**	**16,69%**	**20,44%**	**15,92%**	**Calculations**

5.1.2. Step 2: Identify inputs available for European projects

The goal of step 2 is to find secondary data inputs that represent energy storage projects specifically in Europe. The European Database of Energy Storage contains a dataset with technological characteristics of existing energy storage technologies in Europe. To create realistic financial profiles of energy technologies, the authors chose inputs for the same technology as Berrada (2022), or a technology with similar capacity and project lifetime. The specific technologies are mentioned in Section 4.2.1.

To calculate valuation metrics of the chosen energy storage technologies, information regarding initial investment, financial lifetime, construction time, annual cash flows and discount rate is necessary. As annual cash flows are not available, the authors can utilize construction time from Berrada (2022) and FCF/CAPEX from the calculations in Step 1. The European Database of Energy Storage includes a ranking for technological maturity. The authors consider this as a valuable addition to this study, as technological uncertainty is a barrier for investment in the sector (Tao & Finenko, 2016, p. 749). The inputs used in scenario creation are demonstrated in Table 4.

Table 4. Secondary data inputs for European energy storage market.

		Energy storage technologies					
Input	**Unit**	Storage A	Storage B	Storage C	Storage D	Storage E	**Source**
CAPEX - Power	€/MW	€ 350 000	€ 1 000 000	€ 800 000	€ 725 000	€ 575 000	(Directorate-General for Energy, 2020)
Power	MW	100	100	100	100	100	Assumption
Initial investment	EUR	€ 35 000 000	€ 100 000 000	€ 80 000 000	€ 72 500 000	€ 57 500 000	(Directorate-General for Energy, 2020)
Construction time	years	3	5	5	1	1	Berrada (2022)
Financial lifetime	years	30	60	40	10	15	(Directorate-General for Energy, 2020)
Annual FCF	%	13,75%	12,48%	16,69%	20,44%	15,92%	Calculations Step 1
Technological maturity (1: not mature, 3: very mature)	Level	1	3	2	2	2	(Directorate-General for Energy, 2020)

5.1.3. Step 3: Calculate WACC for European energy market

The goal of Step 3 is to obtain a discount rate that represents energy storage projects in Europe. The CAPM model was used to calculate the cost of equity. The values for CAPM included the beta value of the market obtained from the Western Europe green and renewable energy sector **(**Damodaran, 2023**)**, the risk-free rate obtained from the 10 year German government market bond and the risk premium obtained from the STOXX Europe 600 from 2012 - 2022 period. By using a beta, risk-free rate and market return specific to the energy sector in Europe, the geographical and market consistency of this study is maintained.

The interest rate used for calculating the discount rate is 7%. An interest rate of 3% represents low-risk in a stable market, 7% represents a rate for investors in a moderately stable market, and 10% represents a risky project in a volatile market (Sung & Jung, 2019, p. 5). As the energy storage technologies in this study range from emerging to established, the authors consider 7% to be a realistic interest rate as it represents a moderately stable market.

The capital structure was assumed to be 50% debt and 50% equity. We are aware that capital structure would affect to a significant extent the calculation of the NPV and final valuation, but seeing the data available to us and the multiple literature still unexplored in the field, we decided to concentrate our efforts in a different area leaving the discussion regarding capital structure to future research.

The corporate tax rate used in calculating WACC was 21,625%, which is the average corporate tax rate of all countries in the EU (Bray, 2022). The WACC resulted in 5.494%, which is the discount rate used for all projects in our investment scenario. This represents a realistic discount rate for energy projects, as discount rates often range from 5% to 10% (Tao & Finenko, 2019, p. 751). Inputs for Step 3 and resulting discount rate are summarized in Table 5 below.

Table 5. Inputs used for calculating discount rate.

Input	Value	Explanation	Source
Risk-free rate (%)	2,327%	10-year German government bond. Retrieved 2023-04-03.	Wall Street Journal
Beta (Levered)	0,91	Beta value for Green & Renewable Energy in Europe.	Damodaran (2023)
Market return (%)	5,815%	Average annual STOXX 600 return from 2012-2022.	Yahoo Finance
Corporate tax rate (%)	21,625%	Average corporate tax rate for all EU countries	Bray (2022)
Cost of equity	5,500%	Cost of equity from CAPM	CAPM model
Cost of debt	7%	Interest rate before tax	Sung & Jung (2019)
WACC	**5,494%**	**Weighted Average Cost of Capital**	

5.1.4. Step 4: Create financial profiles for energy storage projects

The goal of Step 4 is to create the financial profiles for the five energy storage technologies in this study. In the previous steps, the authors have gathered the information necessary to create financial profiles for energy storage projects that yield realistic valuation metrics and are relevant to the European energy storage market. The necessary information includes CAPEX, construction time, project life, discount rate and FCF. By creating financial profiles for the five energy storage technologies, the authors can obtain the financial valuation metrics that are used by investors.

In this step, the authors make a five key assumptions that enable creation of the financial data:

1. All technologies have a power capacity of 100 MW, which allows equal comparison. In Berrada (2022), the power capacity is constant for all technologies at 1 GW, although the power capacity of technologies may differ in reality.

2. CAPEX is assumed to be spread equally on the construction time of the project. This assumption affects PV(CAPEX).

3. Annual FCF is assumed to be a constant percentage of CAPEX over the project lifetime. In Berrada (2022), OPEX is stated as a constant annual percentage of CAPEX. With a straight line method of depreciation, this assumption entails that revenue streams are held constant throughout the project life.

4. The calculated FCF from Berrada (2022) is assumed to apply to the chosen technologies in this study. The authors have addressed this by choosing inputs for the same or similar technology as Berrada (2022).

5. All energy storage projects are assumed to have the same WACC.

5.1.5. Step 5: LCOS

The goal of step 5 is to find LCOS values for the five chosen energy storage technologies. Accurate secondary data regarding annual cost and system performance is not available. Thus, the authors did not calculate LCOS with the created dataset to avoid unrealistic results. Instead, LCOS values for each technology from peer-reviewed articles are used. This way, the values are representative of each technology and enable a realistic investment scenario.

A key assumption in Step 5 is that the LCOS of Storage A is the same as GES, although the technology is different from Berrada (2022). The authors made this assumption to maintain consistency in the research process and therefore call the project Storage A instead of referring to the specific technology. The LCOS values for each project are summarized in Table 6 below.

Table 6. LCOS values for energy storage projects.

Project	Technology	LCOS		Source
Storage A	Pumped Heat Electrical Storage (PHES)	€	441,30	Assumed to be same as GES in Berrada (2022)
Storage B	Pumped Hydro Storage (PHS)	€	201,50	Berrada (2022)
Storage C	Compressed Air Energy Storage (CAES)	€	190,00	Berrada (2022)
Storage D	Lithium Ion batteries (Li-ion)	€	290,00	Berrada (2022)
Storage E	Sodium Sulphur Batteries (Sod. Nickel)	€	308,00	Tian & Xi (2022)

5.1.6. Step 6: Calculate valuation metrics used in analysis

In step 6, the goal is to use the project data to calculate NPV, IRR and PP. This step finalizes the quantitative aspect of dataset and investment scenario creation. The authors used the NPV and IRR function in MS to calculate the valuation metrics for each project. Hurdle rate is intended to be an additional profitability indicator for investors and is stated as IRR/WACC. As annual cash flows are constant for each project, the payback period is found by computing CAPEX/annual FCF. Technological maturity is obtained from the European Database of Energy Storage. The resulting KPI's for each project are summarized in Table 7 below, with the most attractive value bolded and underlined for each metric.

Table 7. Valuation metrics used in investment scenarios.

Thesis KPI's	Unit	Storage A	Storage B	Storage C	Storage D	Storage E
NPV	€	29 694 472,91	85 947 866,49	**101 065 048,78**	39 212 310,09	34 444 507,74
IRR	%	11,82%	10,16%	12,82%	**15,67%**	13,56%
Hurdle Rate	IRR/WACC	2,15	1,85	2,33	**2,85**	2,47
Payback period	years	7,27	8,01	5,99	**4,89**	6,28
LCOS	€/MWh	441,30 €	201,50 €	**190,00 €**	290,00 €	308,00 €
Maturity	Level	1	**3**	2	2	2

5.1.7. Step 7: Acquire input from practitioners

The goal of Step 7 is to gather input from experts in the field. Table 7 is sent in the letter found in Appendix 2. Analysis from the two respondents will be discussed in Section 5.2.6.

5.2. Results

The projects are ranked based on individual valuation metrics, which include NPV, IRR, PP and LCOS. The valuation metrics are then integrated by using a point-base system, which will be discussed further in section 5.2.5. Lastly, experts rank the investments based on their preferences as investors. Table 7 provides an overview of KPI's of the energy storage projects.

5.2.1. Ranking based on NPV

The technology with the highest NPV is regarded as the most attractive option. Based on NPV, Storage C is the best option and Storage A is the least attractive. However, it is important not to overemphasize the single metric since projects with longer lifetime are likely to have higher values for NPV as they have more cash flows available. Therefore, projects with lower values for NPV are not necessarily a worst option, but would rather be smaller projects which would ideally also cost less to implement and manage throughout their lifetime. The results are portrayed in Table 8 below.

Table 8. Project ranking based on NPV.

Ranking Net Present Value (NPV)	Unit	Value	Rank
Storage A	€	29 694 472,91	5th
Storage B	€	85 947 866,49	2nd
Storage C	€	101 065 048,78	1st
Storage D	€	39 212 310,09	3rd
Storage E	€	34 444 507,74	4th

5.2.2. Ranking based on IRR

IRR can be considered as the valuation metric that indicates which investment will yield the highest return. Said that, the higher the value of the IRR, the more impressive the project is in the eyes of the investors. Our results display Storage D as the best option and Storage B as the worst. Also, this value is not to be evaluated individually in every situation. Lower IRRs could be a better solution in case the intangible benefits associated with the asset are greater; in our scenario these could be geographical and meteorological aspects of the area in which the technology is to be constructed or simply due to competitive advantage toward competitors in the area. Another reason for being wary of ranking through this method is because smaller projects may have higher IRR in comparison to bigger projects, but at the same time these might generate lower cash flows in comparison to bigger projects. The results are portrayed in Table 9 below.

Table 9. Project ranking based on IRR.

Ranking IRR	Unit	Value	Rank
Storage A	%	11,82%	4th
Storage B	%	10,16%	5th
Storage C	%	12,82%	3rd
Storage D	%	15,67%	1st
Storage E	%	13,56%	2nd

5.2.3. Ranking based on payback period

Payback period indicates the time needed for the project to pay back its initial investment. The lower the value, the better it is for investors since from that point on all earnings can be perceived as official returns. Our table shows Storage D as the best option and Storage B as the worst. When comparing PP values it is crucial to keep in mind the neglectance the metric has toward the time value of money. Even if a project has a better PP it does not mean that future cash flows are going to be lower when compared to a project with lower PP. The results based on PP are portrayed in Table 10 below.

Table 10. Project ranking based on payback period.

Ranking Payback Period	Unit	Value	Rank
Storage A	years	7,27	4th
Storage B	years	8,01	5th
Storage C	years	5,99	2nd
Storage D	years	4,89	1st
Storage E	years	6,28	3rd

5.2.4. Ranking based on LCOS

LCOS indicates the minimum value needed of energy produced in order for the project to break even (Melnikov et al. 2019). As a result, higher values of LCOS imply the need for higher provision of energy by the storage and therefore harder to satisfy. Therefore, LCOS values are more attractive the lower they are, placing Storage C as the best option in our scenario and Storage A as the worst. As already mentioned, the focal point of our thesis is the concern that LCOS is not sufficient enough when evaluating different energy storage projects, not only because the technologies are different one from the other, but the formula could be tailored to a specific industry and still be generalized as LCOS since it computes cost over energy generation, discounted over the project life. Table 11 below summarizes project ranking based on LCOS.

Table 11. Project ranking based on LCOS.

Ranking LCOS	Unit	Value	Rank
Storage A	€/MWh	441,30	5th
Storage B	€/MWh	201,50	2nd
Storage C	€/MWh	190,00	1st
Storage D	€/MWh	290,00	3rd
Storage E	€/MWh	308,00	4th

5.2.5. Ranking based on integrated model

The valuation metrics of the projects are integrated with a point-base system, which provides a holistic overview for the investor. Each technology will have points attributed to their KPI from a range of one to five. The best values get a score of five and the worst values get a score of one. Thus, the second best will have four points, third ranked will have three points and so on. This point-base system applies to NPV, IRR, PP and LCOS. Technological maturity is added separately with a point-base system of 1-3, based on the European Database of Energy Storage ranking. For technological maturity, the most mature technology will receive three points. Table 12 summarizes the individual metric ranking, whereas Table 13 portrays the points attributed to each project.

Table 12. Overview of project ranking based on individual metrics.

Individual metric ranking	Rank	NPV	IRR	Payback period	LCOS
	Storage A	5th	4th	4th	5th
	Storage B	2nd	5th	5th	2nd
	Storage C	1st	3rd	2nd	1st
	Storage D	3rd	1st	1st	3rd
	Storage E	4th	2nd	3rd	4th

Table 13. Overview of points assigned based on individual metrics.

Points for total ranking	Points	NPV	IRR	Payback period	LCOS	Maturity
Rank 1: 5 points	Storage A	1	2	2	1	1
Rank 5: 1 point	Storage B	4	1	1	4	3
Very mature: 3 points	Storage C	5	3	4	5	2
Not mature: 1 point	Storage D	3	5	5	3	2
	Storage E	2	4	3	2	2

In summary, Storage C has the highest total value with 19 points. Storage A has the lowest total ranking with 7 points. Storage C & D and Storage B & E have close total point values. The authors rank Storage B over E based on a more attractive NPV, LCOS and technological maturity. The total point ranking is displayed in Table 14.

Table 14. Project ranking based on the point-base system.

Total ranking	Rank	Storage system	Points
	1	Storage C	19
	2	Storage D	18
	3	Storage B	13
	4	Storage E	13
	5	Storage A	7

5.2.6. Ranking by experts

This section includes analysis from experts in the field. The email template we used to contact the different experts is available in Appendix 2. Before stating their professional opinion, it is necessary to mention that none of the experts had the chance of reviewing specific calculations, or the methods used for the evaluation of our KPI's. Thus, their answers are based solely on the results available from Table 7 and the different types of technologies we took in consideration. Therefore their opinion, ranking and feedback hypothesized that our results are realistic and reliable.

The authors will keep the participants anonymous in their responses and refer to them as experts plus a number. The order in which the experts are presented is also random and has no hierarchical innuendo.

5.2.6.1. Expert 1

Expert 1 prioritized expected rate of return, risk profile and investment time horizon in ranking the investments. The investor does not consider only financial elements, as sustainability factors associated with the investment are also emphasized. LCOS values play a crucial part in the ranking of the technologies while being weighed against the respective CAPEX. LCOS is looked at in tandem with the technology´s maturity since it provides additional investment security due to lower risk attributed to more information regarding the technology. Storage B ranks highest in technological maturity and IRR, while having a long investment time horizon. Therefore, Expert 1 considers Storage B as the most financially attractive.

Storages D and E were ranked lower due to their higher values in LCOS caused by the shorter lifetimes of the projects and also due to sustainability related factors. The environmental aspect is due the fact that these electrochemical technologies operate on rare and expensive materials which are often mined in developing countries with adverse working conditions. Storage A was ranked in last position due to its lowest score of maturity, which makes the investment risky. Furthermore, the financial return was average when compared to technologies which had more experience in the market. In conclusion, Expert 1 prioritized IRR, LCOS and technological maturity from the metrics in this study, and emphasized the importance of considering environmental factors in the valuation process. Expert 1 ranking is displayed in Table 15 below.

Table 15. Expert 1 investment ranking.

Expert 1	Rank
Storage A	5th
Storage B	1st
Storage C	2nd
Storage D	3rd
Storage E	4th

5.2.6.2. Expert 2

Expert 2 prioritized IRR in ranking the investments. This metric is valued above the others because the company has a minimum target profitability which they have to uphold within every investment. If additional information is needed in decision making, Expert 2 considers payback period as a secondary metric in the valuation process. Thus, Expert 2 has ranked the investments based on IRR, which is identical to the ranking in Table 9.

The participant mentions that their business focus is not in energy production, but rather distribution. This affects their business model, as they are unable to own energy production sites by law, which can force them to stay away from these types of investments. Another critical aspect of Expert 2 analysis is that the valuation of investment is affected by minimum regulatory standards, which must be compared to the benefits from utilizing the energy system. In conclusion, Expert 2 prioritizes IRR and payback period, as the investment must meet the minimum profitability requirements set forth by the company. Furthermore, the regulatory requirements of the company and industry must be considered, along with the technical benefits from using the system. Expert 2 ranking is displayed in Table 16 below.

Table 16. Expert 2 investment ranking.

Expert 2	Rank
Storage A	4th
Storage B	5th
Storage C	3rd
Storage D	1st
Storage E	2nd

6. Analysis and discussion

This chapter consists of three parts. First, the authors will discuss the results of the study related to the research question. Second, the results will be analyzed from a theoretical and conceptual perspective. Third, the authors compare the findings with previous studies.

6.1. Valuation of energy storage projects

The research question challenges the current methods used in evaluating ESS and explores alternative metrics to be included in the valuation mix which could be useful for investors and decision makers. In the process of doing so, the authors tried to isolate which metrics are deemed more important when evaluating and comparing the technologies, and evaluated how important the LCOS metric is in relation to the other metrics tested.

The study positions itself well with the research questions since it offers evidence to the investors that alternative valuation metrics would be useful in the energy storage sector since they offer an additional angle from which to analyze the technologies, while offering additional information when deciding between similar attractive results obtained.

The combination obtained from the KPIs calculated, expert opinions and the ranking method established by the authors, allows the reader to understand the need for using multiple valuation metrics when assessing these projects.

The point-base system is a simple strategy of involving numerous metrics in the valuation process of energy storage systems, as each valuation metric has drawbacks. In this study, the point-base system assumes equal importance of valuation metrics. The investor must understand inputs associated with project valuation to assess the weight individual metrics should have in the integrated model. This can be power capacity, system performance or financial lifetime, as both technological and financial aspects are considered in the valuation process. The authors ranked the investments based on individual metrics first, before integrating them to a total project ranking by using a point-base system. The results based on individual metrics differed from the total ranking, which indicates a need for using numerous metrics in the valuation process. For example, Storage C ranked third in IRR but first in the total project ranking, as it had an attractive NPV, LCOS and payback period. Storage D ranked third in LCOS but second in the total project ranking, as it gained valuable points from IRR and payback period.

Ranking energy storages based on payback period may not consider the technological differences among energy storage technologies. For example, battery storages often have a shorter project life than pumped hydro storages. Therefore, the investor must understand inputs that influence valuation metrics. For example, Storage B has the longest project life, which can lead to a longer payback period compared to the projects with a shorter lifetime. However, Expert 1 considered a longer investment horizon to decrease the risk of the investment, which increases the economic attractiveness of Storage B from the participant's perspective. Expert 2 uses PP to support investment decisions that are made based on IRR. Thus, practitioners use PP in individual assessment of projects rather than for comparative purposes. For the professional investor, this can influence the weight PP has in utilizing the point-base system.

Ranking projects based on NPV may not consider the size of the investment. CAPEX is often expressed per unit of power in the energy storage sector, and therefore initial investment depends on power capacity. The power capacity of Storage B and an electrochemical storage, such as Storage D or E can be vastly different. In this study, power capacity is equal for each project. Storage B ranked second based on NPV but had the lowest IRR, whereas Storage D had the most attractive IRR while ranking third in NPV. Thus, this study indicates investors should not compare projects only in monetary terms without involving additional profitability metrics.

IRR is viewed as a valuable profitability indicator by experts in the field. Expert 2 based the project ranking on IRR as the primary valuation metric. Expert 1 considers IRR to be a key indicator for profitability, while considering additional factors in evaluation. However, ranking projects only based on IRR may not consider risk or technological factors. For example, Storage B has the lowest IRR but is the most proven technology and offers a long investment horizon, with a payback period that is attractive in relation to the project life. Thus, Storage B ranked third based on the point-base system and first in Expert 1 ranking. In this study, the discount rate is held constant for all technologies although project-specific discount rates are likely to be applied in practice based on individual risk profiles. Thus, the investor can consider the weight of IRR in relation to additional valuation metrics in tailoring the point-base system to their preferences.

One of the sub-questions explored by the authors questioned the usefulness of LCOS when analyzed singularly among different projects. The authors did not try to question the usefulness of the metric but rather to display its full effectiveness when standing alone when in comparison. From the results obtained by adopting only the LCOS evaluation method, it showed that LCOS is quite relevant in the evaluation process, but may come short when deciding between the top options available. Projects which displayed higher values of LCOS subsequently performed better in our ranking system, but when experts gave their opinion it wasn't always the highest value for LCOS which determined the most favored project. Similarly the ranking system established by the authors displayed the highest values for LCOS as the most suitable options but shuffled around the top three options when ranking according to the point system established. These factors should be enough in stating that LCOS should be considered a must when evaluating energy storage technologies but additional metrics may be imperative when making an investment decision.

The study also manages to compare how LCOS relates to other valuation metrics when making investment decisions. Through the results obtained, an investor can gauge how the value of LCOS performs in relation to other important metrics. The results obtained do not support the fact that high LCOS values will subsequently have better values among financial valuation metrics, such as IRR or PP. By evaluating how close the LCOS values are to the different KPIs tested, investors should now be able to rudimentary hypothesize how well LCOS describes a project and which additional methods should be calculated for the comparison of different projects. The fact that the authors provide preferences from experts allows an interesting addition to the study. The results indicate that LCOS has more weight, when technological maturity and risk mitigation is emphasized. On the other hand, when financial aspects are emphasized, results indicate that LCOS has less weight in the investment decision. Since the number of participants is limited, investor preferences is an area in need of further investigation.

Concluding, it is evident from the expert´s feedback, that investors have different preferences regarding valuation metrics when selecting a project. IRR is prioritized in financial valuation, but LCOS is also considered as a valuable metric for comparing economic competitiveness of various ESS. These factors should assist investors in understanding that some metrics have more weight than others when computing a final decision, but at the same time the results obtained also portray the fact that different experts have different preferences when examining various KPIs.

6.2. Theoretical analysis

6.2.1. Rationality

As per literature, a rational investor is one who uses rational thinking with the help of available information to come up with a decision. This theory directly links its statement toward the findings of this paper and the purpose of allowing investors to analyze their decision by looking at more information in regards. The results obtained from the experiment do show that current literature is not completely wrong by assessing energy storage viability through LCOS metrics. The literature is in congruence with our findings, where the technologies which resulted with more appetible levels of LCOS also scored better in the overall valuation. Said that, a rational investor would also take an extra step and evaluate which are the differences between the top results available, causing LCOS alone not to assist an investor with a rational answer. As the results show, higher LCOS values are linked to projects with better financial results. What the data does not display is additional ranking depending on various KPIs being taken into account. When this additional information is added it's possible to see a different hierarchical positioning of the projects, since better LCOS values do not imply better results across other KPIs, such as IRR or or payback period.

This is where the KPIs calculated assist the rational investor in making a final decision on which energy storage is more suitable for the situation. The deduction made by the authors is also supported by the feedback obtained by the two experts who provided feedback. Investors in different situations or different energy sectors, view the same investment project through different evaluating eyes making certain KPIs more important than others when evaluating projects.

The two participants each show indications of both value-driven and means-driven rationality. Expert 1 emphasizes the importance of considering various elements of sustainability, which include the economic, environmental and social aspects of energy storage projects. Value-driven investors are willing to trade financial return for matching the investment with personal or corporate values (Nicholls, 2010, p. 78). Expert 1 mentions adverse sustainable aspects of battery storages, which include inhumane working conditions in the mining process. Although financial aspects such as IRR and investment horizon, and technical aspects such as LCOS and technological maturity, guide the investment of Expert 1, it is evident that the investor is influenced by value-driven rationality. Expert 2 states that investment decisions are made by using

IRR as a main profitability indicator, and reinforcing the investment decision with PP. The investment must meet minimum profitability standards set forth by the company. This investment strategy portrays means-driven rationality, in which investors are result-oriented (Nicholls, 2010, p. 79).

6.2.2. Sustainable finance

Sustainability and ESG factors play a crucial role for multiple companies around the world. Energy storage technologies are intended to assist the transitioning toward lower carbon emission solutions when in energy production. This is why energy storage technologies are viewed as innovative and likey indispensable in the near future. Said that, different energy storage types have a significant impact on the geographic environment they operate in. From raw material extraction for their construction, to the possible repercussions on the geographical area they are implemented in, aspects of sustainability may play a significant role when investors make the decision to commit to a project.

ESG factors have become a critical factor for multiple multinationals around the globe, since it signals to stakeholders the willingness to commit toward a more sustainable future. Therefore, it should have come without surprise that one of the two experts imposed ESG as one of the main parameters to take into consideration when committing to one of these projects. Unfortunately the authors could not get a bigger sample of feedback from experts, which causes the statement of ESG integration not to be as reliable. But nonetheless it is a valuable factor to take in consideration by any investor around the world, regardless of the type of industry they venture in.

Current literature on energy storage technologies does not include quantifiable metrics for sustainability, such as ESG scores. This may be possible in the future, when companies in the energy storage market are more established. Sustainable investment includes economic, environmental and social aspects (Fatemi & Fooladi, 2013, p. 110). The current valuation models only consider financial and technical aspects. However, Expert 1 emphasizes that the three dimensions of sustainability must be considered in investment decisions. Means-driven investors such as Expert 2 may be motivated to emphasize aspects of sustainability if there is a quantifiable sustainability metric that can be used as a minimum benchmark. As this aspect of financial valuation in the energy storage sector remains underdeveloped, sustainable and financial aspects in the energy storage sector are best evaluated on a project level. Regardless, the energy storage sector can be associated with sustainable development as it assists the transition toward renewable energy. The development of strategies to assess the sustainable aspects of energy storage projects are subject to future research, which will be discussed in Section 7.7.

6.2.3. Debt capital markets and project finance

DCM encompasses all the financial projects which require debt financing in order to be implemented. As previously mentioned in Section 2.2.4, these projects are implemented through substantial amounts of initial investment and therefore are expected to generate meaningful returns in the future in order to be able to cover both the initial loan and the interest. The experiment carried out by the authors does not go in depth into this topic even though this factor is crucial for investor evaluation. The experiment conducted selected a debt to equity ratio of 50%. It is not unrealistic for investing companies to have much more debt than equity when committing to these projects. Obviously, different levels of debt and equity would show different results in the project's final data, due to higher or lower interest levels to be repaid over the period. Different levels of debt and equity would also show a significant difference in the values for WACC.

Project finance is also part of the similar discussion of DCM. Project finance states that the financing of the project happens through the revenues generated from it (Mawutor & Kwadwo, 2014, p. 181). Therefore, many projects are approved after DCM and project finance information have been carefully analyzed. Therefore, as expected, the feedback we received from one of the experts is exactly as such. When selecting a project to invest in, the future revenue flow is essential in establishing how viable an investment is. Investors will keep a close eye to the IRR values to assess profitability, and PP to understand when an investment will break even and start generating profit.

Most energy storage projects are still in the pipeline which means the energy storage sector is still developing. As portrayed in this study, energy storage technologies are financially complex, have long financial lifetimes and have unique risk profiles. Therefore, the authors conclude that project finance is an adequate model for analyzing energy storage technologies. Regardless of the type of investment, the energy storage technology must be analyzed on a project level to get a nuanced understanding of the financial and technological aspects associated with the investment. The valuation metrics used in this study portray the financial and technological viability of energy storage technology, and therefore provides investors with an adequate valuation strategy.

6.2.4. EMH and AMH

EMH relates to our experiment and results from two different perspectives. The first is in relation to the results obtained and the multiple assumptions which had to be implemented to come up with them. The second is in relation to the energy price fluctuation in the market.

Efficient Market Hypothesis relates to our experiment and findings from a data inclusiveness perspective. EMH concentrates mainly on the stock price evaluation, but the principle which we attempt to discuss relates also to our case. The authors of this paper, just like EMH, believe that information inclusiveness in the market assists in the stabilization of prices and information in the energy storage industry. A failure to provide adequate information uniformly to the market may result in a phenomenon called asymmetrical information. In corporate finance this phenomenon occurs when an insider (in this case the holder of information regarding a type of ESS) is in possession of better information than market participants (investors interested in ESS) (Klein & Peters, 2022, p. 318). As per Rundo & Di Stallo (2019, p. 8), poor transparency of information leads to the generation of hidden costs. As a result, investors and policy makers may be reluctant toward the support of these types of projects since information is not evenly distributed.The experiment conducted was useful since it displayed hidden information, but at the same time the answers obtained remain subjective toward the scenario set up by the authors because of the limited availability of the data. If the authors had had the opportunity to utilize real reliable and available data, they could have assessed more firmly that the findings reflect an objective scenario for the whole EU to look at and base conclusions on. Therefore more inclusiveness of information and more availability of data would allow investors of different types to conduct personalized experiments which may result in better decision making, project assessment and better managerial investment decisions.

Energy price fluctuation in the market is nothing new to investors in general. These price fluctuations may result in different parties over exploiting the price fluctuation during periods. The technique of arbitrage happens when a party takes advantage of economic differences in order to profit from a transaction; that is buying and reselling an asset (Kallio & Ziemba, 2007, p. 2284). This may result in the sale of overpriced electricity to different regions or the purchase of energy from outside of the country itself due to lower prices. No-arbitrage is a necessary condition for price equilibrium in the market (Kallio & Ziemba, 2007, p. 2282). This paper unfortunately does not explore how volatility in energy prices affects the KPI valuation of energy storages. Metrics like LCOS would be affected since they incorporate energy price in the equation, and different results could show significant findings in literature for investors. What the authors argue is that if more information regarding the energy storage units was available to investors and in the market, it would assist investors not only in making more accurate investments, thus stabilizing the prices; but also assist energy prices stabilize since demand for these storage technologies would increase creating a more stable market for demand and supply thus lowering price spikes due to overproduction or underproduction of energy.

6.3. Comparing results with previous studies

Literature regarding the assessment of energy storage technologies, such as LCOS comparison, is still limited and not deeply explored like the previous LCOE model. Berrada (2022) takes in consideration gravity energy storage systems (GES) and compares its performance against other technologies. These types of studies are very common in current literature, since technologies have not yet been implemented or operational and therefore need to be assessed economically before starting a project. The article is revolutionary in its terms since it explores the viability of the project through capital budgeting techniques and the analysis of cash flows. Since the study currently stands alone in the literature, it is not possible for the authors to compare the results obtained with similar research in the field. The article which is closely relatable is the one produced by Berrada (2022).

As per Berrada (2022, p. 405), research regarding energy economic assessment is available to the public; what is currently missing in the literature is research in financial analysis for energy storage technologies and a financial comparison between existing storages. Current studies are simplistic and ignore crucial factors like debt terms and financing resources. The goal of the article is to provide financial and economic assessment to gravity energy storage for those with an interest in investing and evaluating. Berrada (2022) is similar to this paper since it attempts to explore the accessibility of energy storages from both a financial and economic standpoint. However, unlike this paper there is a greater focus on the weight that debt has on the project which is evaluated through the DSCR (debt-service coverage ratio) and LLCR (loan life coverage ratio).

Similarly to Berrada (2022), this study analyzed the economic and financial viability of the energy storage projects. However, less emphasis has been put on financing elements and rather focused on determining how valuable it is to assess numerous valuation metrics instead of simply considering the LCOS values. Berrada (2022) does not provide a method for their calculation and does not inform the reader how to replicate the experiment. Making the conducted study of particular interest toward all those investors who have limited knowledge on the subjects and are interested in exploring the valuation methods to be implemented when looking at these types of projects for the first time.

The findings of this study align with Berrada (2022) and Tao & Finenko (2016), that levelized cost analysis should be combined with traditional financial valuation methods. The analysis of each project based on individual metrics show that LCOS analysis can bring a valuable system performance perspective to the valuation process, but may not be optimal for valuation as a stand-alone metric. Input from Expert 1 revealed that LCOS is valuable in assessing the competitiveness of technologies, and is therefore a metric that should be included in the valuation process.

The main differences between the Berrada (2022) article and the one completed by the authors, is the geographical location which the project has been assessed by. The inputs utilized to calculate and later assess the different projects, has been carried under the assumption of calculating these projects from a EU perspective. Most articles currently available in the literature are based in the United States, thus utilize risk levels tailored to their geographical area. Finally, this article differs from Berrada (2022) since the calculations computed have the purpose of comparing different technologies and not providing a final result of which is best, by exploring the fact that the implementation of additional KPIs would aid a better evaluation between technologies which display similar results.

Julch (2016) follows more closely the current rhetoric of utilizing LCOS as a benchmark value and placing the evaluation of the technology in close relation to the characteristics of the technology itself. Features like the feasibility through energy arbitrage, transmission and distribution, support and frequency regulation (p. 1595) are analyzed in tandem with the LCOS values. The article also attempted to separate the evaluation of the different technologies by differentiating them between long term and short term storage which as a result exert different amounts of energy discharged. Unlike Julch (2016), this study ignores the technical viabilities of the various technologies and rather tries to compare them as neutrally as possible. Since technologies have different power output, storage capacity and charging power to name a few; comparing technologies which are significantly different one for another would reveal itself an arduous and inefficient method when compared. That is why Julch (2016) differentiates the options by dividing them between long term and short term storages.

Creating an investment scenario and clearly defining the various financial elements associated with project finance in the energy storage industry is a valuable addition to current literature. Exploring and defining various inputs associated with energy storage projects is not discussed in current literature. Therefore, this study sheds light on a project finance perspective of energy storage technologies. The creation of an investment scenario and obtaining valuation metrics of the project allowed the authors to gather input from practitioners in the field, which has not been explored in the field of study. The point-base system is a strategy that can be used for making an investment decision, whereas previous studies have only mentioned whether a specific technology is economically feasible. By doing so, we show the reader that technical properties aside, technologies should be compared through multiple metrics.

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7. Conclusion

This chapter summarizes the findings in this study. Based on this, the authors present theoretical and practical contributions, along with social and ethical implications. The quality of the study is evaluated based on quality criteria. Lastly, the authors discuss limitations and summarize suggestions for further research.

7.1. Concluding remarks

This study is conducted to answer the main research question "*How can investors and corporate decision makers integrate valuation metrics in the energy storage industry"*. In the research process, the authors strive to also answer two sub-questions. First, "*What valuation metrics do experts prioritize in energy storage project valuation?",* and second, *"How can LCOS be integrated with financial valuation?".* To answer the research questions, the authors conducted an exploratory mixed-method study, which involved creating an investment scenario involving five energy storage projects and gathering expert analysis on their respective valuation metrics.

The scenario creation had the purpose of displaying how the use of multiple financial valuation metrics, in addition to LCOS, could better assist investors in decision making. If an investor decides to utilize LCOS as the most important metric of evaluation, storage C and Storage B would be chosen as the most attractive options. However, when integrating numerous valuation metrics, the two most viable options shift to Storace C and Storage D according to the point-base system utilized by the authors. Therefore, the results indicate that LCOS alone is not enough to make a decision between the top three storages B, C, and D. This supports the findings of Tao & Finenko (2016) and Sung & Jung (2019), which indicate that levelized cost must be reinforced by corporate profitability indicators in investment decisions. Berrada (2022) discussed individual project profitability based on IRR and compared economic competitiveness with LCOS. This aligns with the input from Expert 1, who considers LCOS and IRR as primary metrics in project valuation.

Investors and corporate decision makers can integrate valuation metrics in the energy storage industry by utilizing a point-base system that involves NPV, IRR, PP and LCOS. Technological risk can be included in the valuation strategy by including a ranking for technological maturity. To remain neutral toward the usefulness of individual metrics, these have been equally weighted in the study. This is a strategy which allows LCOS to be integrated in harmony with traditional financial valuation.

Expert input indicates that IRR along with payback period, is preferred by practitioners as a financial valuation metric. Technological maturity is a key aspect of risk mitigation for practitioners, whereas LCOS is used for direct comparison of technologies in investment decisions. The different project ranking among experts suggests that investors have different preferences when it comes to evaluating different options. Involving feedback from practitioners showed that investors and decision-makers prioritize valuation metrics differently. The experts in the field ranked investments based on their individual preferences, and the results obtained not only differed from the integrated ranking set up by the authors, but also among each other. Therefore, investors must determine themselves which metrics to prioritize and the weight each individual metric has compared to the others, if utilizing a point-base system.

The analysis by experts indicates that both means-driven rationality and value-driven rationality is prevalent among investors. The introduction of quantifiable metrics for sustainability can therefore enhance investment in the field, as value-driven investors can emphasize sustainability aspects of projects, whereas means-driven investors can set minimum targets for sustainability along with profitability requirements. Applying individual weights to valuation metrics in the point-base system allows investors to rank investments based on their rational preferences.

Future studies should include both financial and sustainability aspects of energy storage projects. Furthermore, as the number of participants in this study is limited, additional studies that introduce an investor perspective would enhance the understanding of investor preferences, which can benefit funding opportunities in the energy storage sector. In all, this study demonstrates a method by which a broad range of investors can integrate valuation metrics from the financial and energy sector to make investment decisions in the energy storage sector. Thus, the authors determine that the research questions have been answered.

7.2. Theoretical contribution

This thesis contributes to theory by connecting traditional valuation metrics and levelized costs. Business research in the energy sector is nascent, and therefore this study bridges the gap between the fields of study, by integrating models used in practice. The connection between business research and the energy storage systems is found in the discount rate, which has a significant effect on several valuation metrics. This thesis also serves as an evaluation of the usefulness of the LCOS model from an investor and decision-maker perspective in financial valuation. Levelized cost models are prevalent in the engineering field, but are not yet utilized in business research. Thus, this study can inspire the use of levelized cost in future research regarding financial viability of technologies in the energy sector.

The study indicates that the valuation process of energy storage projects should include financial, technical and sustainability aspects. This study merges financial and technical aspects in valuation, but a professional investor may want to introduce aspects of sustainability in decision-making. Thus, this study uncovers the possibility of introducing a sustainable finance perspective to the valuation process. Analyzing investor rationality in relation to valuation in the energy storage sector demonstrates that rationality is not necessarily bound to profit-maximization. Therefore, a holistic valuation process that caters both means-driven and value-driven investors can attract more investment.

Finally, the creative research design and unique data collection process portray a strategy for conducting research in an understudied field with little secondary data available. The exploratory nature of this study can be applied to business research in developing and emerging fields of study, such as the energy storage sector.

7.3. Practical contribution

This thesis is based on practical issues, such as climate change and finite natural resources. From a broad perspective, this thesis assists the decarbonization of the energy sector by addressing financial barriers that result in underinvestment or lack of innovation. The energy storage sector must develop rapidly to achieve our climate goals, and therefore research in the field is necessary. The valuation process must create a holistic perspective of energy storage investments and must be understandable for a broad range of investors and decision makers. There is a need for numerous energy storage technologies to address our varying need of storage performance, which enhances the importance of innovation in the field. Thus, our thesis does not aim to find which specific technology is financially or technologically superior, but rather develops a valuation process for various energy storage systems from an investor perspective.

The energy transition will require significant funding toward the energy storage sector, as it requires growth of existing technology application and innovation. Of annual renewable energy investments, 90% is funded by private investors (Raikar & Adamson, 2020, p. 8). Private investors may be more risk averse than public investors and therefore financial modeling that provides accurate and understandable predictions about growth and profitability is necessary (Mazzucato & Semieniuk, 2018, p. 18). Furthermore, the metrics used in valuation are emphasized differently by various stakeholders with different investment preferences (Sung & Jung, 2019, p. 1). Therefore, this study contributes to practice by using financial metrics in valuation that address the interests of various stakeholders. Expert analysis of our project financial metrics is involved to evaluate the importance of individual metrics in practice. A key aspect of our practical contribution is directing the thesis toward investors. Although project finance for energy storage projects can be technical, this study addresses aspects that can be used in practice by investors and decision-makers.

7.4. Quality criteria

The authors will evaluate quality based on criteria for qualitative research. Although this is a mixed-method study, quantitative truth criteria such as reliability, validity and replicability do not fully encompass the exploratory nature of this study. As philosophical assumptions in qualitative research are different from the positivist nature of quantitative studies, quality should be evaluated differently (Yilmaz, 2013, p. 319). Therefore, evaluating the quality of the thesis based on qualitative aspects is appropriate, as it aligns best with the chosen non-positivist paradigm and exploratory research design. The quality of this study is evaluated based on truth criteria presented by Lincoln & Guba (1985), which include credibility, transferability, dependability, and confirmability.

Credibility means that participants involved in the research process consider the results credible (Yilmaz, 2013, p. 320). This criterion is achieved by transparency in demonstrating steps in research process, research method and data collection. Credibility involves recognizing areas of uncertainty (Yilmaz, 2013, p. 319). The authors have clearly stated a preference for secondary data, discussed difficulties in the research process and justified which assumptions were made. Furthermore, as integrating valuation metrics through a point-base system is a new method in the field of study, the authors gathered unbiased input from practitioners in the field to ensure credibility through additional perspectives. By discussing each step involved in the research process thoroughly and transparently, the authors have strived to establish trustworthiness.

Transferability refers to whether the results can be applied practically or in other studies (Yilmaz, 2013, p. 320). This study applies to the field of project finance generally and to the energy storage sector specifically. Thus, the research method and results can be applied both theoretically and practically. The authors demonstrate a new way of integrating valuation metrics that consider both technical and financial aspects, which encompasses the exploratory research design. As the study includes both an unweighted and unbiased ranking strategy, and the subjective ranking of investors, the study gives a holistic perspective on valuation in the energy storage sector that is transferable practically in the field and theoretically to other studies.

Dependability in the research process arises from consistency in applying research strategy and justification of selected methods (Yilmaz, 2013, p. 320). This is similar to the reliability criterion in quantitative studies. The authors have conducted a study in an understudied field with little secondary data available regarding financial aspects of energy storage technologies. This does not mean that business researchers should avoid studying this topic. The authors have addressed this by clearly defining philosophical assumptions in the non-positivist paradigm, justifying the need for a mixed-method study, and demonstrating an exploratory research design by a unique data collection process. Thus, the authors have defined and adjusted selected methods to achieve the goal of shedding light on financial valuation in the energy storage sector. As the goal of the study is clearly defined, and research methods are applied accordingly, the dependability criterion is met.

Confirmability of a study means that the analysis and findings are clearly based on collected data (Yilmaz, 2013, p. 320). The authors establish confirmability in this study by clearly defining steps in data collection, the sources of data inputs and the assumptions made in the process. Furthermore, the results are clearly presented, which makes it assists the reader in confirming that the results and analysis are based on collected data. Thus, the authors consider that the study meets the criteria of confirmability.

7.5. Social and ethical implications

The authors of this paper are Master's students from Umeå University School of Business, therefore abide by the rules and regulations established by the institution and the Swedish academic standards regarding ethical conduct and societal contributions this paper may bring to the finance community. In congruence with the institution, the authors have had the primary objective of adding and supporting literature pertaining financial evaluation toward LCOS and energy storage technologies.

World leaders and climate activists have been advocating for greener reforms regarding energy consumption and alternative energy sources. This paper has the purpose of assisting the narrative of lowering carbon emissions, by adding literature toward alternative investment and project valuation in the energy consumption sector, which should trigger interest for the topic among more investors. This study does not challenge or rediscover anything new in existing literature, besides identifying that there is a need for additional research. There are still multiple gray areas of understanding concerning energy storage system project evaluations, which may create a barrier for new investors interested in the field, or discourage current investors from moving even further. Through the paper, the authors are looking to assist future research, investors in the field and obtain a more clear picture regarding ways to evaluate different investment options in the energy storage sector. By doing so, there is a belief to assist the EMH theory which would allow a better stabilization of prices in the energy storage market, through better decisions by more informed investors. As per EMH, a stable market is one which encompasses as much information as possible to the majority of the investors in the market (Fama 1970). Thus, by identifying that there is a need for business research regarding energy storage investment, and that the transition toward renewable energies require energy storage technologies, the authors shed light on a current societal issue that can be addressed by additional research and increased investment.

From an ethical aspects, the authors are not trying to discredit the current methods utilized in the current literature of energy storage evaluation, but rather assist the narrative and promote interest toward these investments, so that the use of this type of technology becomes more widespread in the investor community, triggering additional sources of investment toward the research and the realization of more energy storage projects around the world. All in order to battle global warming and lower greenhouse emissions. The authors have also kept the responses from the interviewees anonymous, this has been done in compliance with the respondents request and also due the fact that the paper does not reflect a real life scenario but rather an hypothetical close representation due to lack of data. Therefore the authors are well aware that readers should not take the feedback from experts as absolute. The study maintains a focus on demonstrating a strategy for investors and does not attempt to direct investment toward a particular technology. Thus, the authors avoid misrepresenting the financial viability of a particular technology by assigning the projects neutral titles, such as *Storage A*. This way, the authors maintain the ethical integrity of this study. Expert 1 emphasized the importance of analyzing the sustainable aspects of investments, which implies that sustainable finance and value-driven rationality is pertinent in the field. This introduces an ethical implication that valuation in the energy storage sector may not only be motivated by financial aspects, but that introducing aspects of sustainability in future research is critical for attracting a broader range of investors.

7.6. Limitations

In this section, the authors address and identify potential weaknesses and concerns of the study. This includes limitations related to the research design, data collection and research strategy. Section 1.6 addresses the intentional boundaries set forth by the authors, whereas limitations are concerns that arise during the research process.

The project data is a limitation because it is not from real energy storage projects. The projects are created based on publicly available data, justified assumptions and previous literature, but the study cannot account for how well it replicates real energy storage projects. Cash flows are assumed to be constant, and therefore our projects do not account for volatility of energy prices or changes in costs throughout the project life. Although the data obtained through calculation is similar to the data in other reports, we cannot accept the results as realistic and universal.

The discount rate used is based on calculated cost of equity and an assumed interest rate, but the same discount rate is applied to each project. Lenders and investors may require premiums based on market risk or technology maturity, which can be individual for each project. Capital structure is also assumed to consist of 50% equity and 50% debt. The study comes short of analyzing how different levels of debt and equity affect these types of investment and whether some levels of debt are too dangerous for investors.

Berrada (2022) assumed a power capacity of 1 GW for all technologies. To create an equal investment scenario for comparison of technologies, all projects are assumed to have a power capacity of 100 MW. However, this is unrealistic according to the European Database of Energy Storage technologies, where each technology has a range of capacities in accordance to performance characteristics. For our study, there was not a power capacity that fit the range for all technologies. For example, Pumped Hydro Storage has a power capacity of 100 MW-1 GW, whereas battery storage systems can have a maximum capacity of 10 MW. Therefore, an equal power capacity of 100 MW may not reflect the initial investment required for the individual project.

The technologies selected have disadvantages when compared to one another. The authors tried to select the energy storage technologies as different as possible in order to provide a wider picture for investors. Ideally, some of these technologies cannot be compared due to the geographical requirement they need in order to be built and implemented and the fact that projects with shorter lifetime will eventually have less of a return and lower results, while being cheaper. This forces multiple investors to concentrate on specific factors before investing, like technology lifetime and initial investment required. The LCOS metrics are based on findings from previous literature, as the authors did not have sufficient information regarding energy generation. Thus, the authors assume a level of annual generation that results in a realistic LCOS value for the individual technologies.

The number of participants in the study is a limitation, as the participant response rate was only 40%. The field of energy storage is technical and therefore identifying expert analysts limits the sample size. Although two participants provides a valuable addition to the unweighted point-base system, a larger amount of primary data would have provided valuable perspectives on investor preferences in the field. In all, data accessibility creates several limitations when conducting business research in the field, as most projects are still in the pipeline and therefore project owners may not be willing to publicize sensitive project information.

7.7. Suggestions for future research

Including actual project data is necessary for enhancing research in the field. However, real project data is difficult to obtain as project owners are unwilling to publicize sensitive information. Therefore, collaboration with practitioners may be necessary for conducting valuable business research in the energy storage sector, until project data becomes publicly available.

There is currently no quantifiable indicator for sustainability regarding energy storage projects. As sustainable finance is a critical aspect of the energy transition, researching how investors can incorporate sustainability into investment decisions could assist investment in the sector. Future studies could therefore include a method for analyzing sustainable aspects of energy storage projects in the valuation process.

Future research could investigate the impact of the discount rate on energy storage projects by analyzing the impact of capital structure, cost of debt and cost of equity. Including the input of actual investors could provide necessary insight into the risk premiums that energy storage projects could have. It is useful to understand the impact that project characteristics, such as technological maturity, has on the discount rate and investment decisions. Therefore, using actual energy storage project profiles provides opportunities for future research to investigate investor perspectives on energy storage projects. Thus, future research could also investigate the preferences and risk appetites of various stakeholders and investors. Understanding the factors that impact the discount rate and economic attractiveness of energy storage projects could increase investment and research in the field, and is therefore a necessary topic in future research.

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Appendix 1. Review of existing studies.

Author(s) & article	**Aim of research**	**Theoretical framework**	**Findings**	**Future research**
Berrada, A. (2022). Financial and economic modeling of large-scale gravity energy storage system. *Renewable Energy,* 192, 405-419.	To assess the financial performance of gravity energy storage and compare financial viability of gravity storage with other energy storage technologies.	Financial accounting, project finance, debt management, valuation. Uses NPV, Project IRR, payback period and LCOS.	A proposed financial model for decision-making regarding energy storage projects. Gravity energy storage is financially viable based on IRR metrics. LCOS metric makes gravity storage more competitive than other storage systems in the study.	Incorporate energy production with storage for financial modeling. Integrate more data about the system. Add technical details to the financial model. Use other valuation options.
Tao, J., & Finenko, A. (2016). Moving beyond LCOE: impact of various financing methods on PV profitability for SIDS. *Energy Policy,* 98, 749-758.	Investigate why grid parity may not apply to private sector investments, as it should be reinforced with a business perspective that includes profitability metrics.	Capital structure, discounted cash flow model, LCOE, NPV, IRR, PP.	Financing structure and cost has a large impact on project viability and therefore should be emphasized in development efforts. LCOE may be misleading and should be supported by corporate profitability metrics.	The paper presents policy recommendations that include: public database with project data, improve financing conditions, decrease tariff uncertainty and remove market barriers such as high corporate tax rate.
Sung, S., & Jung, W. (2019). Economic Competitiveness Evaluation of the Energy	Compare valuation metrics for wind, coal and nuclear power projects and analyze	Project finance and debt management. Uses LCOE, Project IRR, Equity IRR, Debt Service	LCOE is not a complete metric for business decisions. Tariff growth rate should be considered	Include external cost and test variables quantitatively. Find optimization value to

Sources: Comparison between a Financial Model and Levelized Cost of Electricity Analysis. *Energies,* 12. 4101.	economic competitiveness based on financial indicators.	Coverage Ratio.	in business. Shorter loan periods can improve IRR. Stakeholders have different interests and should improve variables of their preference.	improve the energy mix.
Cekirge, H. & Erturan, S. (2019). Modified Levelized Cost of Electricity or Energy and Modified Levelized Avoidable Cost of Electricity or Energy, MLACE and Decision Making. *American Journal of Modern Energy,* 5(1), 1-4.	Improve LCOE and LACE methodologies by presenting a modified approach. The new approach aims to support power plant investment decisions.	LCOE, LACE, MLCOE, MLACE, debt management.	The modified methodologies may be a more accurate prediction of the relationship between production cost, interest rate and loan payback metrics. The modified methodologies can give projects healthier discount rates.	Use both Modified Levelized Cost of Energy and Modified Levelized Avoided Cost of Energy for additional project calculations and scenarios to enhance the implementation of the methodologies.
Julch, V. (2016). Comparison of electricity storage options using levelized cost of storage (LCOS) method. *Applied Energy,* 183, 1594-1606.	Analyze costs of various storage systems by using LCOS to determine cost minimization strategies. Conduct sensitivity analysis to test variables that affect LCOS.	LCOS. Energy storage systems.	Show the minimum price for which stored energy can be sold for eight storage technologies. Design of plant, storage capacity, and energy market variables impact economic feasibility in terms of LCOS.	Include additional storage technologies and updated cost data in future studies. Provide continuous cost updates to reflect technological development and increased production.
Gür, T. (2018). Review of electrical energy storage technologies,	Provide a comprehensive overview of the energy storage industry,	Technical details for mechanical, thermal, electrochemical and	Operational characteristics of storage systems must be matched	Continue to support innovation and investment by providing

materials and systems: challenges and prospects for large-scale grid storage. *Energy & Environmental Science,* 11, 2696-2767.	including technologies, opportunities and challenges.	chemical storage systems. Levelized cost.	with power generation and therefore numerous storage technologies are necessary for energy transition. Policy must support transition so that the sector receives necessary investment.	research in the field. Investigate how synergies between storage systems can be achieved and which combinations can be complementary.
Aid, R. (2014). A Review of Optimal Investment Rules in Electricity Generation. *Quantitative Energy Finance,* 3-40.	Present a model for optimal investment decision rules in electricity generation by combining methods from practice and academia.	Control theory, real options, continuous-time finance, NPV.	The methods used were adequate models as they portray effects of uncertainty, competitive pressure and allow analysis of various economic settings. There is still a gap between theory and practice regarding optimal investment methodology.	Conduct studies with realistic price models and examine realistic risk representations. Examine valuation for investment with bankruptcy threshold. Develop a simpler approach for valuation based on optimal investment.
Mostafa, M., Abdel Aleem, S., Ali, S., Ali, Z. & Abdelaziz, A. (2020). Techno-economic assessment of energy storage systems using annualized life cycle cost of storage (LCCOS) and levelized cost of energy (LCOE) metrics. *Journal*	Present a cost model for long-, medium- and short-term energy storage systems that considers technical and economic aspects to assist investment decisions.	Life Cycle Cost of Storage (LCCOS), LCOE. Energy storage systems.	LCCOS can be a useful economic indicator for decision makers because it includes numerous technical aspects and has the same annual operating hours. Project lifetime, efficiency and other technical inputs cause costs to differ among existing studies.	Evaluate hybrid combinations of different energy storage systems by using LCOE and LCCOS. Investigate the dependence between depth of discharge and life cycle.

of Energy Storage, 29, 101345.			LCCOS is significantly affected by project life, electricity price, efficiency and discharge time.	
Schmidt, O., Melchior, S., Hawkes, A., & Staffell, I (2019). Projecting the Future Levelized Cost of Electricity Storage Technologies. *Joule,* 3, 81-100.	Shift perspective from investment cost to lifetime cost. Determine cost of 9 energy storage technologies. Provide insight in the competitiveness of energy storage systems to enhance research, policy and investment.	LCOS, energy storage systems, cost efficiency.	Energy storage systems will become more competitive 2030-2050, as LCOS is expected to decrease 30-50% in the time period. Lithium ion batteries will be the most cost efficient storage solution.	Improve performance and cost efficiency of various storage technologies so that they can compete with lithium ion batteries in the future.
Giap, V., Lee, Y., Kim, Y. & Bui, T. (2022). New definition of levelized cost of energy storage and its application to reversible solid oxide fuel-cell. *Energy,* 239, 1222220.	Propose a new design of levelized cost to include off-design characteristics of energy storage systems.	LCOS, Modified LCOS (LCOES2). Total revenue requirement and levelized total revenue requirement.	The standard LCOS overstated cost by 7.7-14.8% compared to LCOES2, as the modified metric is more sensitive to system efficiency and less sensitive to fluctuation in cost.	No suggestion for future research.
Hoff, M. & Lin, R. (2019). Development and practical use of a Levelized Cost of	To introduce a cost comparison method for energy storage systems that can be used in decision-making. Show	LCOS, lifetime utilization factor, cost efficiency, energy storage systems,	Levelized cost is a useful tool to compare costs of different storage technologies, same system with different	No suggestion for future research.

Storage (LCOS) metric. *NEC Energy Solutions,* 1.	that the investment decision can be made by using one metric.		applications and trade-offs in storage system characteristics.	
Yamujala, S., Jain, A., Bhakar, R., & Mathur, J. (2022). Multi-service based economic valuation of grid-connected battery energy storage systems. *Journal of Energy Storage,* 52, 104657.	Analyze economic feasibility of battery energy storage systems by combining grid-services. Encourage consideration of multiple services in valuation.	Valuation, IRR, Payback Period, Discounted Payback Period, battery energy storage systems, electrical grids.	Stacking revenues improves the economic viability of battery energy storage systems, which improves the economic attractiveness for investors. Individual parameters are not likely to attract investment. Profitability is affected by market prices and share of renewable energy.	Include fluctuation of price and demand with corresponding uncertainty. Analyze optimal size of battery energy storage systems with various service stacking combinations.
Dobrowolski, Z., & Drozdowski, G. (2022). Does the Net Present Value as a Financial Metric Fit Investment in Green Energy Security. *Energies,* 15(1), 353.	Analyze the usefulness of NPV and conventional financial valuation metrics in energy sector investments. Propose a modified NPV method.	Valuation, time value of money, discounted cash flow method, IRR, NPV.	The conventional NPV method is not applicable to volatile and emerging markets with fluctuating interest rates. The modified NPV considers volatility of interest rate over a long-term period, which gives investors better outcomes.	Conduct additional studies on investment processes by using the modified NPV formula. Investigate whether other financial valuation metrics like IRR should be modified with a similar methodology.
Basher, S., & Raboy, D. (2018). The misuse of net present value in energy	Show how NPV methodology can ignore volatility and price	NPV, random walk theory.	A predicted trend for energy prices is often used in NPV	Continue to evaluate the usefulness and credibility of NPV by analyzing key

efficiency standards. *Renewable and Sustainable Energy Reviews,* 96, 218-225.	fluctuation in the energy industry.		calculations, which can give misleading results because it was found that energy prices follow a random walk.	assumptions.
Shimbar, A., & Ebrahimi, S. (2017). Modified-Decoupled Net Present Value: The Intersection of Valuation and Time Scaling of Risk in Energy Sector. *Environmental Energy and Economic Research,* 1(4), 347-362.	Propose a modified NPV method that better reflects the dynamic risk and rate of return of long-term energy projects.	NPV, Decoupled Net Present Value, Certainty Equivalent Method, risk management.	The M-DNPV method provides investors a comprehensive framework to evaluate risk of various energy projects. The M-DNPV method gave investors an indication to not invest in the project, whereas conventional NPV indicated to accept the project.Valuation of long-term energy projects is not reliable unless it accounts for the dynamic nature of risk and uncertainty.	No suggestion for future research. The M-DNPV method can improve the valuation process, by providing a tool that can accurately analyze and prioritize risk for better investment decisions.

Appendix 2. Letter to experts.

We are contacting you to get an expert input on key performance indicators for our master's thesis regarding financial valuation of energy storage projects. The purpose of our study is to inform a non-technical audience of how investors analyze the financial viability of energy storage projects. We have created five project profiles based on available data that replicate realistic energy storage projects for five different technologies.

Why are we contacting you?
We hope that you can provide insight on what KPI's experts in the field look at when making investment decisions regarding energy storage projects. We have created five hypothetical energy storage projects and hope that you select the most attractive project from an investor perspective and discuss which indicator(s) led to your decision.

How do we intend to use your input?
We intend to compare your expert input to our findings in our analysis and conclusion. Our findings include a ranking of the projects based on equal importance of each KPI.

Questions

- Which energy storage project is the most attractive from an investor perspective and why?
- Can you rank the projects based on economic attractiveness and state which KPI's you emphasize in the decision? Rank 1-5, where 1 is the most attractive from an investor perspective.
- What additional metrics could be considered financial valuation of energy storage projects?

Acknowledgement
If you participate in the study, we will gladly thank you in the Acknowledgement section of the thesis by including name and company name. If you participate but wish to remain anonymous, we will not include your name or company in the thesis. <u>Please inform us whether you wish to be acknowledged or remain anonymous.</u>

In presenting your input in the text, we will refer to you as an "expert in the field" without connecting you personally to your input.

Best regards,
Oliver Vasanoja & Alessandro Volpe