Grid-Scale Battery Energy Storage Systems in Germany: Responsible Business Opportunities and Challenges in Aligning Deployment with Societal Goals

Leander Sieler

Dissertation written under the supervision of Professor Nuno Moreira da Cruz

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Abstract

Grid-scale Battery Energy Storage Systems (BESS) are considered a critical flexibility technology for the energy transition. However, it is unclear whether the German market framework enables their deployment and operation in ways that align with societal objectives and electricity system needs. Based on the concepts of Creating Shared Value, Triple Bottom Line, and the Sustainable Development Goals, this dissertation examines the responsible business opportunities of grid-scale BESS, as well as the market barriers that may prevent this alignment.

A qualitative research approach was used, involving nine semi-structured expert interviews with BESS market actors, grid operators and consultants. The findings show that grid-scale BESS represent an attractive business opportunity, with revenues primarily generated through electricity arbitrage and ancillary services. Meanwhile, BESS can create significant societal value by supporting the integration of renewables, improving grid stability and reducing overall electricity system costs. Yet, this alignment between economic and societal value does not emerge automatically. Current market structures fail to incentivize deployment and operation of facilities that would best serve the system. Key barriers include missing locational price signals, grid connection bottlenecks and regulatory uncertainty.

The findings suggest that market actors behave rationally in response to existing incentives. Achieving system-optimal market outcomes, in line with societal objectives, therefore depends mainly on policymakers to create a coherent, predictable and incentive-aligned framework.

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Sumário

Os sistemas de armazenamento de energia em baterias (BESS) à escala da rede são uma tecnologia essencial para a transição energética. No entanto, não é claro se o quadro regulamentar alemão permite a sua implantação e operação de forma alinhada com os objetivos sociais e as necessidades do sistema elétrico. Com base nos conceitos de Creating Shared Value, Triple Bottom Line e Sustainable Development Goals, esta dissertação examina as oportunidades de negócio responsáveis dos BESS e as barreiras que podem impedir esse alinhamento.

Foi utilizada uma abordagem qualitativa com nove entrevistas semiestruturadas a especialistas do mercado, operadores de rede e consultores. Os resultados mostram que os BESS representam uma oportunidade atrativa, com receitas geradas principalmente através da arbitragem de eletricidade e serviços auxiliares, podendo simultaneamente criar valor social ao apoiar a integração das energias renováveis, melhorar a estabilidade da rede e reduzir os custos do sistema. Contudo, este alinhamento não surge automaticamente. As estruturas de mercado não incentivam a implantação das instalações mais benéficas, sendo as principais barreiras a ausência de sinais locacionais de preço, as limitações na ligação à rede e a incerteza regulatória.

A obtenção de resultados ótimos depende sobretudo da criação, pelos decisores políticos, de um quadro coerente, previsível e baseado em incentivos adequados.

Título: Sistemas de Armazenamento de Energia em Baterias à Escala da Rede na Alemanha: Oportunidades de Negócio Responsável e Barreiras à Alinhamento com Objetivos Sociais

Autor: Leander Sieler

Palavras-chave: BESS; Armazenamento de energia; Negócios responsáveis; Transição energética; Concepção do mercado da eletricidade

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List of Abbreviations

aFRR	Automatic Frequency Restoration Reserves
AgNes	General Electricity Grid Tariff Structure (German: Allgemeine Netzentgeltsystematik Strom)
BESS	Battery Energy Storage System
BMWK	Federal Ministry for Economic Affairs and Climate Protection (German: Bundesministerium für Wirtschaft und Klimaschutz)
CSR	Corporate Social Responsibility
CSV	Creating Shared Value
EnWG	Energy Industry Act (German: Energiewirtschaftsgesetz)
FCAs	Flexible grid Connection Agreement
FCR	Frequency Containment Reserves
GFGA	German Federal Grid Agency (German: Bundesnetzagentur)
GHG	Greenhouse gases
MiSpeL	Market integration of storage facilities and charging stations (German: Marktintegration von Speichern und Ladepunkten)
SDGs	Sustainable Development Goals
TBL	Triple Bottom Line

1 Introduction

1.1 Research Topic Context

The emission of greenhouse gases (GHG) through human activities has caused global warming, with global surface temperatures already reaching 1.1 °C above pre-industrial levels (IPCC, 2023). As summarized by the Intergovernmental Panel on Climate Change in its Sixth Assessment Report, the growing speed and scale of climate change increasingly threaten human health, livelihoods and ecosystems (IPCC, 2023). Limiting human-caused global warming to 1.5 °C or 2 °C, as agreed upon in the Paris Agreement, requires fast and lasting reductions in GHG emissions across all sectors, including energy, industry and infrastructure (IPCC, 2023).

Being the largest economy (Ostermayer et al., 2026) and second-largest electricity producer (ENTSO-E, 2025) in the European Union, Germany's energy transition is a critical component of international climate mitigation efforts. Historically, the German energy system has been highly dependent on nuclear and fossil fuel-based energy, which covered 69.6 % of its electricity generation in 2016 (Burger & Gandhi, 2026). To tackle climate change, reduce the risks linked to nuclear energy and respond to new climate policies, such as the introduction of the EU Emissions Trading Scheme in 2005, Germany initiated the energy transition (Bohn & Gümüsay, 2024). It is a broad policy effort shaped by ambitious targets and phase-out milestones. The overarching goal, as outlined by the Federal Ministry for Economic Affairs and Climate Protection (Bundesministerium für Wirtschaft und Klimaschutz, BMWK), is to achieve complete GHG neutrality across all sectors by 2045, with the energy sector being almost entirely decarbonized a decade earlier, by 2035 (BMWK, 2023). To achieve this, renewables shall cover 80 % of gross electricity consumption by 2030, which implies an annual renewable electricity output of approximately 600 - 700 TWh by the end of this decade (Ostermayer et al., 2026). To put this in perspective, in 2025, 260 TWh of renewable power were generated, equivalent to 57.1 % of Germany's electricity generation (Burger & Gandhi, 2026).

The need for Germany to reduce its reliance on fossil fuels is not only driven by ecological concerns. For decades, Germany relied on cheap fossil fuel imports, particularly natural gas from Russia, which made up 55 % of its natural gas supply until 2021 (BP p.l.c, 2021). Russia's war on Ukraine and the following instrumentalization of the energy supply have led to a tremendous change in the German energy debate (Wiertz et al., 2023). The revealed weaknesses due to limited gas supplies have shown that energy policy is strongly interconnected with national security and sovereignty. In German politics, renewable energy sources were consequently increasingly framed as *freedom energies*[1] that would reduce the nation's dependence on autocracies (Wiertz et al., 2023).

1.2 Problem Description

The energy transition is not only a technological and regulatory challenge but also raises fundamental questions about the role businesses play in addressing societal issues. From a theoretical perspective, frameworks such as the Triple Bottom Line (TBL) (Elkington, 1998) and Creating Shared Value (CSV) (Porter & Kramer, 2011) emphasize that firms should not only generate economic returns but also environmental and social value. In the context of energy, this implies that businesses are increasingly expected to align their activities with societal objectives, including decarbonization and the provision of affordable and reliable energy (United Nations, 2015). In this regard, grid-scale Battery Energy Storage Systems (BESS)[2] provide a particularly relevant case. Their core business models are closely linked to supporting the integration of renewable energy and maintaining grid stability, which indicates a strong potential for creating both economic and societal value. However, it is questionable whether this potential is actually being realized in practice.

The investment climate for grid-scale BESS in Germany has improved considerably in recent years, largely driven by regulatory reforms that have strengthened the profitability of BESS projects and increased overall market activity (BMWK, 2023; Figgener et al., 2023). Yet, there still exist significant barriers that potentially hinder a sufficient and efficient deployment of storage capacity. Existing literature suggests that investment decisions are largely driven by market-based revenues, which do not necessarily incentivize storage deployment in locations or ways that best serve the electricity system (Ostermayer et al., 2026). Moreover, regulatory barriers and uncertainty, as well as complex grid connection processes, create significant risks for investors (Gährs & Knoefel, 2020; Ostermayer et al., 2026). Consequently, there might be a threat of underinvestment and suboptimal deployment of BESS, which would limit the integration of renewable energy, threaten grid stability and increase overall costs of the electricity system (Coester et al., 2020; Thimet & Mavromatidis, 2023). This highlights a potential misalignment between market-driven investment decisions and societal needs in the

[1] Translated from German: Freiheitsenergien

[2] Grid-scale BESS refer to large, stationary battery energy storage systems that are connected directly to the electricity grid, usually in a standalone facility. A more detailed definition follows in Chapter 2.

energy transition and raises questions about the role and responsibility of businesses and policymakers in addressing these gaps.

1.3 Research Objectives and Questions

Looking at these challenges, this thesis aims to assess whether the current German market framework enables a deployment of grid-scale BESS that is aligned with societal objectives, such as decarbonization, grid stability and minimizing overall system costs. Furthermore, the objective is to identify existing market imperfections and barriers and to derive implications for key players involved in the energy system.

To achieve this, the study is guided by the following research questions:

RQ1: What business opportunities do grid-scale BESS offer, and to what extent do deployment and operation patterns align with societal goals?

RQ2: What market misalignments and regulatory barriers prevent grid-scale BESS from contributing to societal goals?

RQ3: How can policymakers, grid operators, as well as BESS market actors[3] address these barriers and improve the alignment of BESS deployment and operation with societal goals?

1.4 Significance of the Research

From a theoretical perspective, this research contributes to the literature on energy economics, market failures and responsible business. Several studies have already explored the role of BESS in the energy system, for example, Coester et al. (2020), Figgener et al. (2023) and Klausen (2017). Others have identified regulatory barriers, such as Gährs & Knoefel (2020), Klausen (2017) and Sioshansi et al. (2012). However, since the market framework for BESS is evolving and regulation changes frequently (Figgener et al., 2023), much of the existing literature only reflects specific points in time. This thesis, therefore, aims to provide a more recent view on current barriers and investment decisions. Furthermore, there has been little research on the extent to which market design, economic incentives and responsible business are connected. By linking the economic opportunities of grid-scale BESS with its societal value and analyzing the German market, this thesis aims to help close this gap.
Methodologically, the study is based on qualitative insights from expert interviews with key stakeholders, including BESS market actors, grid operators and consultants with industry

[3] The stakeholder group *BESS market actors* refers to firms involved in the development, financing and operation of grid-scale BESS.

expertise. This approach allows for a detailed assessment of barriers, investment incentives and coordination problems.

The findings carry practical relevance for policymakers, grid operators and BESS market actors. For policymakers, the study points to areas where market design and regulatory frameworks may need adjustment to ensure that investment aligns with long-term system needs. For grid operators and BESS market actors, the thesis offers insights into how market conditions influence decision-making on each side and whether responsible, system-serving business is achievable under current conditions.

To sum up, this thesis contributes to a better understanding of how economic incentives, regulatory structures and corporate behavior interact throughout the energy transition. By focusing on grid-scale BESS, the study examines the broader question of how market systems can be designed to ensure that critical infrastructure supports society's sustainability goals.

1.5 Outline

The thesis is structured as follows. Chapter 2 presents the literature review. The theoretical foundations of responsible business are outlined, the role of grid-scale BESS within the German energy system is shown, and the market failures and barriers identified in the existing literature are presented. Chapter 3 describes the research methodology, which includes the qualitative research design with data collection through expert interviews. Chapter 4 presents the findings derived from the interviews. Chapter 5 discusses these findings in the context of the existing literature and research questions, outlines limitations and provides recommendations for future research. Finally, Chapter 6 concludes the thesis by summarizing the main insights.

2 Literature Review

2.1 Responsible Business Opportunities in grid-scale BESS in Germany

2.1.1 Theoretical Foundations of Responsible Business

The growing number of challenges related to environmental and social sustainability has led to increasing attention to the role of businesses in addressing these issues (Agudelo et al., 2019; Kramer et al., 2019). Two prominent theoretical concepts that describe the relationship between business activity and societal value creation are the TBL and CSV. Both frameworks highlight that companies can no longer evaluate performance only through financial outcomes but must also consider broader social and environmental impacts.

Triple Bottom Line

The concept of the TBL, introduced by John Elkington in the 1990s, expands the traditional measurement of corporate success beyond financial performance (Elkington, 1998). The framework suggests that a company must account for and balance its social, environmental and economic impacts, commonly referred to as *the three Ps*: people, planet and profits (Slaper & Hall, 2011). In doing so, instead of evaluating success exclusively on shareholder returns, TBL urges organizations to assess the impact of their activities on human and environmental capital (Agudelo et al., 2019; Slaper & Hall, 2011). Firms are therefore encouraged to integrate sustainability considerations into their strategies and decision-making processes. The environmental dimension typically includes issues such as resource efficiency, emissions reduction and environmental protection, while the social dimension relates to topics such as labor conditions and community well-being (Slaper & Hall, 2011).
Although the TBL framework has become a widely used concept in sustainability management and corporate reporting (Slaper & Hall, 2011), scientists have also highlighted several limitations. Critics argue that the three dimensions are often difficult to measure consistently and that organizations frequently prioritize financial performance when trade-offs arise (Norman & MacDonald, 2004). Despite these challenges, the concept remains an important foundation for understanding how businesses can contribute to sustainable development.

Creating Shared Value

Building on the concept of Corporate Social Responsibility (CSR), Michael E. Porter and Mark R. Kramer introduced the theory of CSV in 2006 and fully conceptualized it in 2011. CSV argues that the fundamental purpose of the corporation must be redefined around generating shared value, which means identifying and strengthening the links between societal and economic progress (Porter & Kramer, 2011). Porter and Kramer (2011) debate that CSV should entirely replace CSR. They characterize traditional CSR as flexible, driven by external pressures, focused on reputation and separated from profit maximization. CSV, on the contrary, is fundamental to a company's profitability and competitiveness. It aims to increase the pool of economic and societal value rather than just redistributing existing wealth, such as through philanthropy or fair-trade pricing (Porter & Kramer, 2011). According to Porter and Kramer (2011), companies can create shared value in three main ways: by redesigning products and markets to address the needs of society, by redefining productivity in the value chain through improvements such as resource efficiency or better working conditions, and by supporting the development of local clusters that strengthen the surrounding business environment.

Thus, the shared value perspective highlights that addressing societal challenges can create new opportunities for innovation, competitiveness and market growth (Porter & Kramer, 2011). However, the concept has also faced criticism. Some papers state that CSV overlaps significantly with existing concepts such as CSR and does not sufficiently address potential conflicts between profit maximization and societal goals (Crane et al., 2014). Nevertheless, the framework has contributed considerably to the discussion on how companies can integrate societal value creation into their core business models.

Sustainable Development Goals

Building on these firm-level perspectives, the United Nations' Sustainable Development Goals (SDGs) provide a global framework that translates the integration of economic, social and environmental value into concrete objectives. The SDGs were adopted in 2015 as a "[…] shared vision of humanity […]" and "[…] blueprint for success" (Ban, 2015, para. 1), leading the world up to 2030. Consisting of 17 overarching goals and 169 specific targets, the SDGs are highly interconnected and address a wide range of global challenges, including climate change, eliminating poverty and hunger and the promotion of sustainable consumption and innovation (United Nations, 2015). The framework is guided by five core principles: People, Planet, Prosperity, Peace and Partnering.

Figure 1: Sustainable Development Goals (United Nations, 2025)

As this paper focuses on the energy transition, SDG 7 (Affordable and Clean Energy) is especially relevant. SDG 7 aims to "Ensure access to affordable, reliable, sustainable and modern energy for all" (United Nations, 2015, p. 19). In particular, target 7.1 emphasizes universal access to affordable, reliable and modern energy services, while target 7.2 focuses on substantially increasing the share of renewable energy in the global energy mix (United Nations, 2015). Achieving these objectives requires not only public policy action but also active private sector participation, as the SDGs were explicitly designed to engage businesses in mobilizing the scale, efficiency and innovation needed to address global societal challenges (Kramer et al., 2019).

Grid-scale BESS are an especially convincing example of how the private sector can contribute to societal objectives while creating economic value and thereby reflect the core principles of TBL and CSV. In this way, BESS have the potential to directly contribute to the achievement of SDG 7. The following chapter explores in detail the societal and system value that grid-scale BESS can create.

2.1.2 Societal Value Creation through grid-scale BESS

Definition grid-scale BESS

Grid-scale BESS, also referred to as utility-scale or large-scale storage systems, are typically deployed as front-of-the-meter assets and thus directly connected to the electricity grid. They generally possess a storage capacity of ≥ 1 MWh or a storage power of ≥ 1 MW (Figgener et al., 2020). Physically, these systems are usually installed as stand-alone facilities, such as modular containerized units or dedicated buildings, which distinguishes them from small-scale residential home storage (Baur et al., 2023). Unlike other energy storage technologies, such as pumped hydro storage, grid-scale batteries are not constrained by strict geographic or topographical requirements. As a result, they can be deployed with great flexibility in terms of location (Baur et al., 2023). In practice, they are often located next to existing substations to enable direct grid integration without requiring extensive new transmission infrastructure (BMWK, 2023). This geographical flexibility, combined with high efficiency, rapid ramp rates and declining costs, has led lithium-ion BESS to become the dominant technology in the grid-scale energy storage segment (Bae et al., 2025; Faunce et al., 2018).

Societal and System Value Contribution

The terms *system value* and *system-optimal*, as used throughout this thesis, refer to the deployment and operation of BESS in ways that support the overall objectives of the electricity system in Germany. In line with the energy policy triangle, this includes contributing to security of supply, economic efficiency and environmental sustainability (Fischer & Geden, 2020). While this overlaps with the concept of *societal value*, which is used in this thesis, these terms should be differentiated, as societal value is understood more broadly through the lens of SDG 7, emphasizing affordable, reliable and sustainable energy (United Nations, 2015).

The rapid expansion of intermittent renewable energy sources, particularly wind and solar power, increases the need for flexibility in the German electricity system, as their generation is weather-dependent and often does not match with demand (Maia and Zondervan, 2019). Coester et al. (2020) state that grid-scale BESS support the integration of renewable energy by temporarily storing excess electricity during periods of high generation and releasing it when renewable output is lower. Thus, by shifting electricity across time, BESS prevent feed-in restrictions for renewables, reduce reliance on fossil fuels and help balance supply and demand (Coester et al., 2020). When charging during periods of low prices and demand and discharging during peak periods, it also reduces the load on the grid infrastructure and smooths price volatility (Coester et al., 2020). Overall, as Gaete-Morales et al. (2019) concluded, BESS lead to lower electricity costs.

In Germany, renewable generation capacity, especially wind power, is concentrated in the northern regions, while major demand centers are located in the south (Ostermayer et al., 2026). This imbalance requires large volumes of electricity to be transported over long distances and can lead to congestion when transmission capacity is insufficient. As renewable deployment continues to outpace transmission grid expansion, the German grid increasingly faces these bottlenecks (Ostermayer et al., 2026). To address this challenge, transmission system operators are developing *grid booster pilot plants* (Figgener et al., 2023). These exceptionally large grid-scale BESS are placed at critical network nodes to temporarily absorb excess power or supply deficits. By actively managing congestion, they help optimizing the use of existing transmission infrastructure, reduce the need for costly redispatch[4] measures, and thus reduce the overall systemic costs of the energy transition (Figgener et al., 2023; Ortega et al., 2023).

Another important application for grid-scale BESS in Germany is the provision of ancillary services, such as frequency containment reserves (FCR) or automatic frequency restoration reserves (aFRR) [5] (Figgener et al., 2023). Due to their ability to charge or discharge within milliseconds to seconds in response to grid frequency deviations, BESS are highly effective in maintaining the stability of the European electricity grid at 50 Hz (Klausen, 2017). Beyond operational balancing services, grid-scale BESS also contribute to system security by buffering against sudden disruptive events and helping to prevent power outages (Wigger et al., 2024). In addition, they can provide black-start services. In the event of a complete grid collapse, grid-scale batteries can autonomously re-energize transmission lines and synchronize subsystems to support the restoration of the power network without the need for an external electricity supply (Klausen, 2017). Traditionally, these services were provided by the spinning reserves of coal and natural gas plants. BESS are faster and more precise, emit no GHG and thus play a crucial role in phasing out fossil fuel infrastructure while ensuring a reliable power supply for cities and communities (Castillo & Gayme, 2014; Faunce et al., 2018).

In the BESS industry, profitability is often achieved through *energy stacking,* which is to provide two or more services simultaneously, such as combining energy arbitrage with frequency regulation within a single storage asset (Bae et al., 2025). When a BESS stacks services, it maximizes its investment return while simultaneously increasing its societal and system value contribution. Bae et al. (2025) provide the example that a battery can optimize its state of charge through arbitrage trading, which potentially saves renewable energy from feed-in restrictions, while offering its remaining capacity to stabilize grid frequency. Research

[4] In redispatch, grid operators intervene in the operational planning of power plants in a targeted manner. If a congestion point is approaching in a specific section of the grid, power plants upstream of the congestion point are instructed to reduce their output, while plants downstream of the congestion point increase their output. This redirects the flow of electricity in a targeted manner and prevents overloading (Klausen, 2017).

[5] In the European electricity grid, FCR automatically stabilizes the grid frequency within seconds after a disturbance, while aFRR is activated shortly afterwards to restore the frequency to its nominal level and relieve FCR (Bundesnetzagentur & Bundeskartellamt, 2025).

indicates that this simultaneous stacking can approximately double the profit of a standalone service (Bae et al., 2025). This illustrates how business models in the BESS sector can align economic incentives with societal value creation, reflecting the core logic of CSV and TBL.

Some of these contributions to society are also researched by Hannan et al. (2021), who analyze the impact of BESS towards achieving the SDGs. The authors found that by supporting the integration of renewable energy, BESS act as a strong enabler for climate change mitigation and positively influence 60 % of the targets under SDG 13 (Climate Action). For SDG 7 (Affordable and Clean Energy), all targets (100 %) are positively impacted. Likewise, BESS contribute to the development of sustainable infrastructure, for example, by enabling eco-friendly urban transport systems or providing power for telecommunication networks in remote areas. In doing so, the study identified that 75 % of SDG 9 (Industry, Innovation and Infrastructure) targets are positively affected.

However, Hannan et al. (2021) also identified significant ecological trade-offs in the deployment of BESS. The extraction of raw materials like lithium leads to water depletion, soil contamination and air pollution, which negatively impacts ecosystem targets (SDG 15.8). Furthermore, if batteries are improperly disposed of in landfills, toxic chemicals can enter into the groundwater and cause long-lasting landfill fires. Overall, while BESS involve some environmental trade-offs, their positive contribution across the SDGs (35.5 % of targets), compared to a smaller share of negative impacts (13 %), suggests that they create substantial societal value.

2.1.3 Current Deployment Status and Expected Demand

The deployment of grid-scale BESS in Germany has accelerated significantly in recent years. By the end of 2025, approximately 4 GWh of grid-scale battery capacity were in operation, which represents a 70 % increase compared to 2024 (ISEA RWTH Aachen, 2026). This rapid expansion is largely driven by declining lithium-ion battery costs, which have fallen by more than 70 % over the past decade (BloombergNEF, 2024). Many studies suggest that BESS prices will continue to fall in the coming years, with Goldman Sachs Research (2023) projecting battery pack prices to decline by an average of 11 % per year between 2023 and 2030. Thus, BMWK (2023) concluded that battery costs are unlikely to pose a significant barrier to future deployment. In addition, attractive market-based business models, primarily price arbitrage and the provision of short-term ancillary services, have stimulated investments, largely without direct government subsidies (Ostermayer et al., 2026).

Looking ahead, however, the demand for grid-scale BESS capacity in Germany is expected to grow even more significantly in the coming years, even though the forecasts of various studies vary widely. For example, Burger and Gandhi (2026) estimate that Germany will require between 100 - 170 GWh of BESS capacity by 2030. Thimet and Mavromatidis (2023) project a total battery storage capacity of 140 GWh - 200 GWh by 2050. However, both projections include not only grid-scale storage but also residential home storage systems. An energy system optimization model by Maia and Zondervan (2019), which is focused specifically on grid-scale storage, concludes that up to 120 GW of battery power may be required by 2050. By the end of 2025, 2.7 GW of grid-scale battery power had been installed (ISEA RWTH Aachen, 2026).
Official planning scenarios of the German Federal Grid Agency[6] (GFGA) also indicate a strong growth in grid-scale battery storage. In its *Scenario Framework for the Network Development Plan 2025 - 2037/2045*, the GFGA develops projections for the future electricity system that take into account different assumptions regarding the pace of electrification, growth in electricity consumption and the deployment of renewable energy sources. These projections are explicitly designed to align with Germany's energy transition targets, in particular the decarbonization of the electricity system, and indicate the level of flexibility technologies, such as grid-scale BESS, that would be required to meet these objectives (Bundesnetzagentur, 2025). Depending on the assumed scenario pathway, installed grid-scale BESS power is expected to reach between 41.1 GW in a low scenario and 94.1 GW in a high scenario by 2037. In terms of battery capacity, this corresponds to approximately 81.5 GWh and 187.5 GWh (Bundesnetzagentur, 2025). Interestingly, the GFGA assumes that grid-scale BESS deployment will stagnate between 2037 and 2045, as the market is expected to reach saturation by the late 2030s (Bundesnetzagentur, 2025). Overall, as can be seen in Figure 2, the low scenario implies a capacity increase of around 1900% between 2025 and 2037, while the high scenario predicts growth of more than 4500 % over the same period. These numbers reflect the system requirements to achieve Germany's energy transition goals, rather than current market readiness.
This brings up the question of whether such rapid expansion is actually feasible under current market conditions, as investment incentives may not fully reflect the societal and system needs. In this context, appropriate regulatory and market frameworks are necessary to ensure not only sufficient deployment, but also system-optimized site selection and operation of BESS, as reviewed in the next chapter.

[6] Translated from German: Bundesnetzagentur

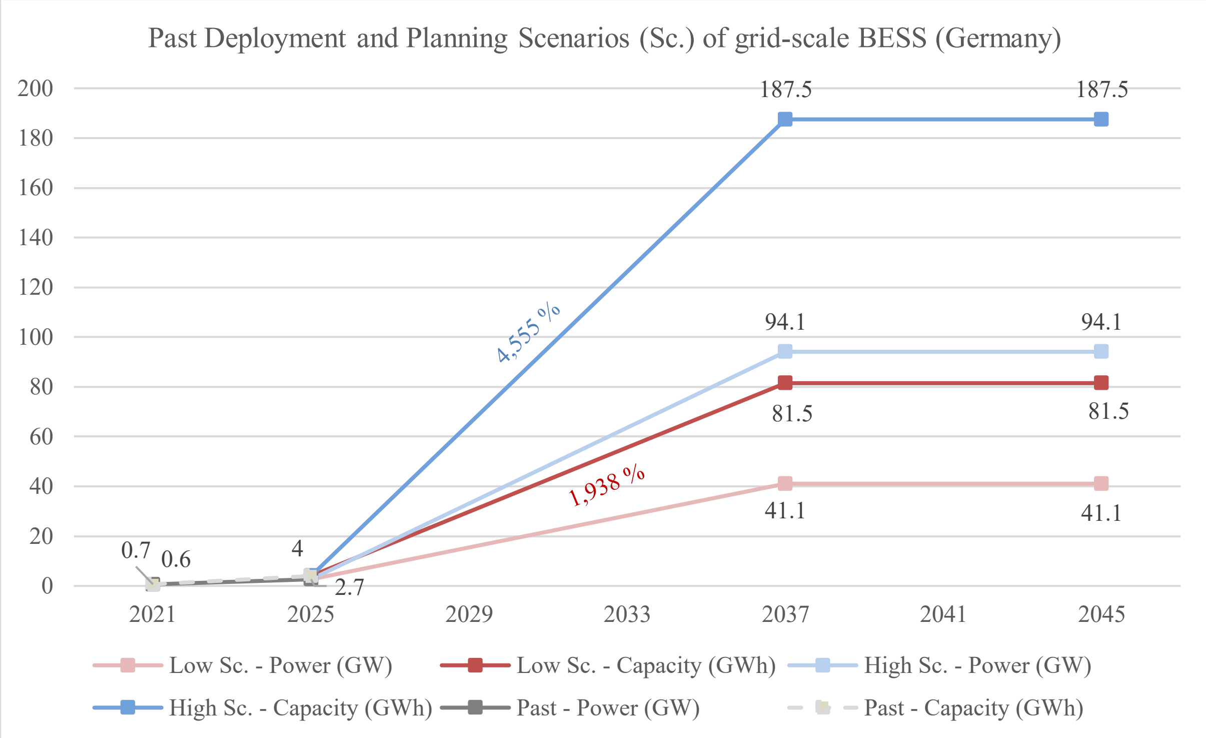

Figure 2: Past and Future Deployment of grid-scale BESS in Germany (Own Illustration – Data source: Bundesnetzagentur, 2025; ISEA RWTH Aachen, 2026)

2.2 Market Failures and Responsibilities

2.2.1 Market Failures and Barriers in Deployment

Given the rapid developments in the German BESS industry, recent academic research on deployment barriers and market failures remains relatively limited. Therefore, this review also builds on policy papers and industry studies to capture current market developments and challenges. Nevertheless, the analysis is limited by the scope of available published sources and may not fully capture all barriers encountered in practice. Additional barriers identified through primary research will be discussed in the findings section.

One key market failure Sioshansi et al. (2012) identified in the deployment of grid-scale BESS is the presence of incomplete markets for flexibility services. While BESS provide multiple system services, many of these services are not fully monetized within existing electricity market structures. Current revenue streams primarily come from energy arbitrage and ancillary service markets such as FCR and aFRR (Figgener et al., 2023). However, the range of services batteries provide, such as congestion management, renewable integration and local grid support, is often not adequately priced in the market (Castillo & Gayme, 2014; Sioshansi et al., 2012). As a result, batteries deliver significant system value without receiving proportional financial compensation, which potentially reduces the incentive for investors.

Moreover, the deployment of grid-scale BESS is severely delayed by inadequate grid connection procedures and a lack of transparency. As stated by the scientists Ostermayer et al. (2026) of the independent think tank Agora Energiewende, network access is currently granted based on the order of application. Due to a lack of transparency regarding available grid capacities, project developers often submit multiple, speculative connection requests across different network nodes to keep their options open. This clogs the pipeline and prevents efficient grid planning (Ostermayer et al., 2026), which might lead to delays in investment decisions.

In addition, as noted by the BMWK (2023), there are regionally different and unpredictable grid connection costs[7]. Furthermore, planning and approval procedures at the federal and state levels are generally considered complex and lengthy, for example, due to building regulations and fire safety regulations, which further delay project implementation (Gährs & Knoefel, 2020).

Next, battery storage operators in Germany have historically faced double charges due to the absence of a clear legal classification for storage assets. As a result, batteries have been treated as a final consumer when charging electricity from the grid and as a generator when discharging it, which exposed operators to network tariffs, levies and fees twice (Klausen, 2017). To address this issue, the German government introduced exemptions under §118 (6) of the Energy Industry Act[8] (EnWG), which exempts assets commissioned before 2029 from network tariffs for twenty years (BMWK, 2023; Klausen, 2017). However, these provisions are explicitly designed as transitional arrangements, which might create uncertainty regarding the long-term regulatory framework for storage operators. Furthermore, the GFGA has published proposals to start phasing out the exemptions starting already in 2026, leading to complete elimination as of 2029 (Baker McKenzie, 2025). This might cause even more doubt for BESS developers and a barrier for future investment.

Another market failure relates to locational market incentives. Germany operates a single national electricity price zone (Egerer et al., 2016). Thus, wholesale prices do not reflect regional grid bottlenecks, and to manage the resulting physical overloads, grid operators rely on expensive redispatch measures (Egerer et al., 2016). For BESS developers, this means that signals are missing regarding where flexibility resources, such as batteries, would deliver the greatest system benefits (Sioshansi et al., 2012). The think tank Agora Energiewende states that currently grid-scale BESS in Germany are not operated in a system-serving manner, and grid

[7] Translated from German: Baukostenzuschuss
[8] Translated from German: Energiewirtschaftsgesetz

operators complain that some battery operators even worsen existing grid bottlenecks rather than resolving them (Ostermayer et al., 2026).

From a responsible business perspective, this raises the question of whether BESS developers and operators are actually contributing to societal benefits described in Chapter 2.1.2, or whether their decisions are primarily guided by short-term economic incentives.

2.2.2 Responsibilities of Regulators, Grid Operators and BESS Market Actors

Addressing these barriers, therefore, requires actions by multiple actors, including policymakers and regulators, grid operators, as well as BESS market actors. As academic research on responsibilities and solutions within the rapidly evolving BESS market remains relatively limited, this section also draws on policy reports and industry studies. Together, these sources identify several responsibilities and recommended actions for the different stakeholders, which are outlined below.

Responsibilities of Policymakers and Regulators

Policymakers and regulators play a central role in correcting market failures and establishing a framework for sufficient storage investments. As suggested by Gährs and Knoefel (2020), this would include transforming the temporary exemptions for double grid fee payments under §118 (6) EnWG, which are currently limited until 2029, into a reliable and predictable regulatory framework. Or, as the BMWK (2023) acknowledged, at least the GFGA must engage with all stakeholders early on to discuss and establish follow-up regulations.

A second responsibility concerns the uniform wholesale prices that do not reflect regional grid constraints. In December 2025, the GFGA published a proposal that would better reflect system conditions, such as dynamic grid tariffs or more granular locational price signals (Ostermayer et al., 2026). Such reforms would guide BESS investments to locations where they provide the greatest system benefits, as already flagged by Sioshansi et al. (2012).

Finally, sources highlight the role of policymakers in reducing administrative barriers related to permitting and grid connection (Ostermayer et al., 2026). Simplifying procedures, standardizing connection requirements and increasing transparency regarding connection costs would accelerate the deployment of storage infrastructure required for the energy transition as outlined by the BMWK (2023).

Responsibilities of Grid Operators

Literature highlights the important role of grid operators in improving the digitalization and transparency of electricity networks. Enhanced monitoring, data infrastructure, and greater visibility of local grid conditions are essential for the efficient integration and system-serving operation of flexibility resources such as BESS (Reibsch et al., 2023). Literature further stresses the role of regulators and grid operators in expanding market-based procurement mechanisms for system services. While recent developments, such as market-based procurement of reactive power and structured processes for black-start capability, represent important progress (Bundesnetzagentur & Bundeskartellamt, 2025), congestion management in Germany still relies largely on cost-based redispatch (Ostermayer et al., 2026). Since there is no transparent market for redispatch, as Klausen (2017) argues, BESS operators have difficulties engaging in this market.

Responsibilities of grid-scale BESS Market Actors

BESS developers and operators also play an important role in ensuring that storage deployment contributes not only to their own profitability but also to societal objectives and system value.

One key responsibility concerns the choice of location for the BESS. Even without strong locational price signals, developers can improve system efficiency by placing storage where it supports renewable integration or reduces grid congestion, thereby generating both economic returns and system benefits (Castillo & Gayme, 2014; Prakash et al., 2022).

As identified by Frontier Economics (2025), storage assets are often operated based on short-term market signals rather than system needs, which can lead to inefficient and grid-harming outcomes. By aligning charging and discharging strategies with grid conditions, BESS can contribute to congestion management and grid stability instead of worsening existing bottlenecks (Frontier Economics, 2025; Ostermayer et al., 2026). This highlights a responsible business dimension, where BESS operators consider the impact on the system when making operational decisions, rather than focusing their actions entirely on arbitrage profits.

Finally, developers must consider social acceptance and environmental responsibility when developing storage projects. Transparent engagement with local communities and committing to high safety and environmental standards can help mitigate resistance to energy infrastructure. Baur et al. (2023) and BMWK (2023) suggest that this may include adapting the architectural design of BESS installations to surrounding environments, complying with strict environmental and recycling standards and exploring financial participation models, such as enabling municipalities to benefit from trade tax revenues.

2.3 Synthesis of Literature

The literature highlights the growing importance of grid-scale BESS for the German energy transition. As renewable energy deployment increases and electrification accelerates, BESS are expected to play a significant role in ensuring grid stability and enabling the efficient integration of renewable energy sources. At the same time, theoretical perspectives such as the TBL and CSV suggest that businesses can generate economic value while contributing to the SDGs and societal goals like decarbonization and energy system reliability.

Grid-scale BESS represent a strong example of such responsible business opportunities, as their revenue streams are closely linked to system-serving services. However, realizing this potential depends not only on the overall scale of deployment, but also on where BESS are located and how they are operated within the system.

While the available academic literature remains limited, it has identified several regulatory and market barriers that may prevent grid-scale BESS from being deployed and operated in a socially and systemically optimal manner. Building on these aspects, this research provides a recent perspective by examining how market design, economic incentives and responsible business considerations are connected in the German BESS market.

3 Methodology

3.1 Research Approach

This study adopts a qualitative research approach to investigate the responsible business opportunities, barriers and responsibilities associated with grid-scale BESS in Germany. Qualitative methods are particularly suitable for exploring complex, context-dependent phenomena where limited prior empirical research exists and where multiple stakeholder perspectives are relevant (Flick, 2009). Also, in such a setting, where the German market for grid-scale BESS is still evolving, and academic literature on regulatory barriers and responsible business opportunities remains limited, qualitative approaches enable a deeper understanding of underlying mechanisms, actor perceptions and institutional dynamics that cannot be captured through quantitative analysis (Gephart, 2004).

To address the research questions, semi-structured expert interviews were conducted with key stakeholders in the German battery storage environment. Expert interviews are widely used in qualitative research when the objective is to access specialized knowledge, professional experience and insider perspectives on complex systems (Bogner & Menz, 2002).
The selected interviewees represent the main stakeholder groups relevant to the grid-scale BESS market:

- BESS market actors: firms involved in the development, financing and operation of grid-scale BESS
- Grid operators: representing the electricity network and broader system perspective; responsible for integrating BESS into the grid
- Consultants: industry experts, who provide holistic perspectives on market opportunities, barriers and stakeholder responsibilities

This multiple-stakeholder approach enables the collection of various perceptions, which enhances the robustness and validity of qualitative findings (Denzin, 1989; Eisenhardt & Graebner, 2007). It is particularly relevant for this study, as the research questions explicitly address the roles and responsibilities of different actors in enabling socially optimal deployment of BESS.
Semi-structured interviews were chosen because they combine comparability across interviews with flexibility to explore certain themes in depth (Flick, 2009). A core interview guide was developed from the literature review findings and was aligned with the research questions to ensure coverage of key topics, including (1) the business opportunities of BESS, (2) market

failures and barriers and (3) potential solutions and responsibilities. Depending on the stakeholder group, slight changes were made to the interview guide. Open-ended questions allowed interviewees to elaborate on issues they considered particularly relevant. Also, to minimize bias, questions were formulated in a neutral and open-ended manner. Where necessary, follow-up prompts were used to explore barriers identified in the literature. The interview questions were shared with interviewees in advance to allow for preparation. The core interview guide can be found in Appendix 1.

3.2 Sampling Strategy

The study employs a purposive sampling strategy, which, as Etikan et al. (2015) describe, selects interviewees based on their expertise and relevance to the research topic. Purposive sampling is appropriate in qualitative research when the objective is not statistical representativeness, but rather the inclusion of relevant interviewees that can provide meaningful insights into the phenomenon under study (Etikan et al., 2015).

Interview partners were identified through professional networks, industry reports and platforms such as LinkedIn. Particular emphasis was placed on selecting participants with direct experience in the German BESS market. A total of 37 people were contacted (18 BESS market actors; 6 grid operators; 11 consultants; 2 regulatory authorities), of whom 10 agreed to conduct an interview. Unfortunately, no interviews with regulatory authorities could be arranged, as their internal guidelines prohibit staff from sharing individual perspectives. However, the interviews conducted with consultants provided a broader perspective that also contained insights into the regulatory viewpoint. One interview was conducted with a salesperson from a company specialized in residential home storage systems, thus significantly smaller systems than grid-scale BESS. As the insights from this interview were not relevant to the focus of this study, they have not been included in the thesis. The remaining nine interviews averaged 34:09 minutes in length and were conducted via MS Teams, with the exception of one interview, which took place via telephone. All interviews were conducted in German and were recorded and transcribed. An overview of the interviewees can be found in Appendix 2. The interviewees are identified by codes such as “INT1”, “INT2”, etc., to protect their anonymity.

3.3 Data Analysis

To analyze the interviews, a thematic analysis was conducted, which is a widely used method for identifying, analyzing and interpreting patterns within qualitative data (Braun & Clarke, 2006). The analysis combined deductive and inductive coding.

Deductive coding was guided by key themes identified in the literature review, including:

- Business opportunities of BESS
- Market misalignments and barriers
- Potential solutions and responsibilities

At the same time, inductive coding allowed for the identification of emerging themes that were not explicitly covered in the literature. This combination enhances both the theoretical grounding and the exploratory depth of the analysis (Flick, 2009). The findings are structured according to the research questions, which allows for a comparison of perspectives across different stakeholder groups.

In total, nine semi-structured expert interviews were analyzed, including perspectives from four BESS market actors, two grid operators, and three industry consultants. The findings are structured according to the research questions and thematic categories identified through the coding process. This enables a systematic comparison of stakeholder perspectives on barriers, investment incentives and opportunities for more system-serving BESS deployment. An overview of the thematic categories and stakeholder perspectives is provided in Appendix 3.

4 Findings

4.1 Business Opportunities and Alignment with Societal Goals (RQ1)

4.1.1 Business Opportunities and Future Projections

In all interviews, a consistent picture appears, showing that grid-scale BESS operate in a market-driven environment where profitability depends on participation in various electricity markets. The most frequently mentioned business model is a multi-market approach that combines several revenue streams, which primarily include electricity trading and the participation in ancillary service markets such as FCR and aFRR (e.g. INT2, INT4 BESS market actors). In terms of relative importance, one consultant (INT8) notes that more than half of revenues can currently be generated through ancillary services, but a shift towards energy arbitrage is expected in the future. This view is supported by other interviewees who see electricity trading as an increasingly important source of income.

In addition to established revenue streams, several respondents point to new market opportunities, such as the provision of inertia, reactive power and black-start capabilities (e.g. INT 4, BESS market actor; INT9, Consultant). These services are expected to grow in importance as conventional power plants are slowly phased out and grid stability requirements increase. INT8 (Consultant) notes, however, that while such services are technically promising, no significant revenue is expected yet compared to established markets.

In general, the interviewees agree that the market for grid-scale BESS is currently highly attractive. Several participants describe a strong increase in project development activity and a growing number of market participants (e.g. INT4, BESS market actor; INT8, Consultant). They point out that existing revenue opportunities are sufficient to drive investment, despite the absence of direct subsidies for BESS compared to other technologies such as gas-fired power plants (INT9, Consultant).

Regarding the feasibility of the GFGA's scenario framework that projects between 82 and 188 GWh of installed grid-scale BESS capacity by 2037, opinions among respondents differ. INT1 (Grid operator) and INT2 (BESS market actor) consider the target achievable overall. INT2 emphasizes that the private sector project pipeline is already more than sufficient, the binding constraint is the regulatory and political framework. INT4 (BESS market actor) and INT9 (Consultant) are more skeptical and argue that scaling capacity by a factor of 40 to 50 within eleven years is barely feasible given the current conditions. Across stakeholder groups, there is agreement that the willingness to invest is not the constraint but rather the surrounding market and regulatory framework, which might prevent the targets from being achieved.

4.1.2 Societal Value and Deployment Misalignment

There is broad agreement across all stakeholder groups that grid-scale BESS play a central role in achieving the societal and systemic objectives of the energy transition.

A key function mentioned frequently is the ability of BESS to balance the temporal mismatch between renewable generation and electricity demand. Especially in systems with high shares of solar power, large amounts of electricity are generated during the day, while demand patterns do not necessarily align with this production profile. Batteries help to store excess energy and release it when needed, thereby increasing the usability of renewable energy (INT1, INT5 Grid operators). In addition, BESS contribute to grid stability, particularly through their ability to provide fast response services. INT7 (Consultant) and INT4 (BESS market actor) highlight their importance for maintaining frequency stability and reacting to sudden changes in supply and demand. Their technical flexibility and fast reaction times make them particularly suitable for these tasks.

Furthermore, INT7 (Consultant) points out that BESS can support the integration of decentralized renewable generation assets and reduce the need for redispatch measures. This also decreases requirements for grid expansion and consequently lowers overall system costs.

While the importance of BESS for the energy transition is widely recognized, a central theme across the interviews is the misalignment between market-driven deployment decisions and system-level needs. Grid operators, specifically, highlight a clear gap between where BESS are installed and where they would provide the greatest benefit to the electricity system. INT1 (Grid operator) explains that BESS are typically located where grid connection is easiest or cheapest, rather than where they would provide the greatest benefit to the system. Another grid operator adds to this point that, from a system-serving perspective, current BESS operation appears almost random, as it is not guided by grid needs but by market signals (INT5, Grid operator).

BESS developers and operators largely confirm this perspective. They acknowledge that deployment decisions are driven by economic considerations. As one interviewee puts it:

> "There is no company that places a BESS somewhere out of goodwill and operates it purely grid-serving, nobody does that. The only question is whether grid operators pay enough to make it worth it" (INT4, BESS market actor).[9]

[9] Translated from German: "Also es gibt ja keine Firma, die als Gutmensch irgendwo einen Batteriespeicher hinsetzt und den nur Netz dienlich betreibt, weil sie so toll sind, dass das macht keiner. Es ist einfach nur die Frage, zahlen Netzbetreiber genug, um es Netz dienlich zu machen oder eben nicht?"

At the same time, one consultant (INT8) emphasizes that this behavior is consistent across the energy sector, meaning that conventional power plants, pumped storage facilities and other market participants also operate based on profit maximization instead of system benefits. INT7 (Consultant) further argues that the issue lies in the current market design, where existing price signals do not adequately reflect local grid conditions, which limits the ability of the market to steer BESS deployment toward system-optimal outcomes and societal benefits

4.2 Market Misalignments and Barriers (RQ2)

4.2.1 Incomplete Market Design

A key misalignment already pointed out in the previous chapter is the lack of market signals for incentivizing system-friendly deployment and operation of BESS. INT1 (Grid operator) makes it clear that the system value is not reflected in market prices, meaning that BESS market actors have no financial reason to prioritize locations or operational strategies that would support the grid. The most important underlying cause, mentioned by several interviewees across groups, is Germany's single electricity price zone, which prevents grid constraints from being signaled through price differences and thus removes a fundamental locational steering mechanism (e.g. INT5, Grid operator; INT3, BESS market actor).

Another gap in the market design relates to the participation of BESS in the redispatch market, as pointed out by both grid operators. They note that there is much more potential for integrating BESS in this market. The current lack of grid transparency and the regulatory framework, including remuneration structures, prevent BESS from participating in the market (INT1, Grid operator). INT5 (Grid operator) describes an ongoing pilot process addressing this barrier, involving multiple stakeholder groups, including the federal authority GFGA, which is, however, still in its early stages.

Moreover, INT9 (Consultant) states a barrier for BESS co-located[10] with renewable power plants. While co-location projects benefit from a public subsidy, operators lose this support if the BESS are charged from the grid rather than exclusively from the co-located generator. This constraint prevents the asset from providing grid services during periods of low local generation, which reduces its commercial value and its system value.

[10] Explanation: Co-located means that the battery is installed at the same site as a renewable power plant and both share a single grid connection point (Castillo & Gayme, 2014).

4.2.2 Grid Connection as key Bottleneck

The grid connection process is identified by almost every interviewee across all groups as the most significant practical barrier to BESS deployment. INT2 (BESS market actor) says:

> "Right now, 90 - 99 % of a project is the grid connection. […] You can manage everything somehow, but you need the network connection. That is simply an absolutely scarce resource."[11]

The reason recognized by most interviewees is the first-come-first-served process, which allowed speculative applications to reserve network capacity with no requirement to demonstrate project readiness. INT9 (Consultant) explains that many BESS developers submitted applications for locations they never expected to build a battery park, just to reserve as much grid capacity as possible. A further contributing factor, acknowledged by INT1 (Grid operator), is the absence of publicly available information on where network capacity exists and where it does not. Without this transparency, developers had no basis for targeting applications strategically, which reinforced the incentive to apply broadly and speculatively. The resulting volume of requests has created significant uncertainty regarding processing times. INT6 (BESS market actor) describes a wide disparity between grid operators, with some responding within a few weeks, and others taking a year or more, and some failing to respond at all.

A new maturity-based assessment process[12] is being introduced to address these problems, but views are mixed among the stakeholder groups. INT1 (Grid operator) evaluates it positively as an important step toward more organized capacity allocation. INT2 (BESS market actor) agrees that it improves the previous system, but it raises a chicken-and-egg concern, as developers must commit significant capital to demonstrate project maturity before knowing whether a connection is even possible.

4.2.3 Regulatory Uncertainty

The network fee exemption for BESS, which exempts assets commissioned before 2029 from network tariffs for twenty years, is the dominant source of regulatory uncertainty identified across BESS market actors and consultants. Its planned expiry and the unresolved question of what framework will replace it risk creating an investment stop in the sector. INT8 (Consultant) describes a two-layer problem, which is the uncertainty about the post-2029 design and the

[11] Translated from German: "Ich würd mal sagen, 90 – 99 % eines Projektes macht den Netzanschluss aus aktuell. Alles kriegst du irgendwo noch gebacken, aber du musst den Netzanschluss haben und der ist einfach das absolut rare Gut aktuell."

[12] Translated from German: Reifegradverfahren

GFGA's signaled right to bring forward the end of the exemption, which alone could trigger a multi-year standstill as investors wait for clarity. The scale of potential impact is underlined by INT4 (BESS market actor):

> "Well, I think that if the grid fee exemption for battery storage systems is repealed starting in 2029, or perhaps even earlier, then 80 - 90 % of the battery storage systems that would have operated purely on the open market will likely be written off."[13]

Beyond the network fee question, several other unresolved regulatory processes discourage investment right now. INT8 (Consultant) highlights the ongoing *General Electricity Grid Tariff Structure*[14]- (*AgNes) process*, which aims to reform the general cost structure of network tariffs, but in doing so introduces significant uncertainty about future costs for BESS operators. INT7 (Consultant) adds two further processes: the revision of the grid connection procedure discussed in the previous chapter and the *Market integration of storage facilities and charging stations*[15]- (*MiSpeL) process*, which seeks to clarify the market integration of co-located storage assets. These unresolved processes create a regulatory environment in which long-term project planning is difficult.

4.3 Responsibilities and Recommendations (RQ3)

Interviewees largely agree that primary responsibility for aligning BESS incentives with societal goals and system-optimal outcomes falls to policymakers and the regulatory authority GFGA, with grid operators playing a supporting role. The question of whether BESS operators bear any responsibility is more disputed, and this disagreement is examined at the end of the section.

On the regulatory side, the most consistent demand across all groups is for investment certainty. Interviewees argue that legal certainty matters more than any specific regulatory outcome. A clear and stable framework, even a less favorable one for the BESS business case, is preferable to ongoing ambiguity (INT4, BESS market actor; INT9 Consultant). INT4 (BESS market actor) warns against measures that distort competition in favor of established technologies. An example mentioned by INT4 is a published proposal of the energy company RWE to the Federal Ministry for Economic Affairs and Energy that would set criteria for capacity reserves in such a way that BESS systems would be effectively excluded in favor of gas-fired power plants.

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[13] Translated from German: "Also, ich glaube, wenn die Netzentgeltbefreiung ab 2029 aufgehoben wird für Batteriespeicher oder vielleicht sogar rückwirkend, dann werden wahrscheinlich 80 bis 90 Prozent der Batteriespeicher, die rein am freien Markt hätten handeln sollen, eingestampft."

[14] Translated from German: Allgemeine Netzentgeltsystematik Strom

[15] Translated from German: Marktintegration von Speichern und Ladepunkten

INT1 (Grid operator) expresses a desire to fundamentally reform the regulatory framework in order to move beyond the ongoing practice of incremental revisions, but acknowledges that this is hardly feasible in the short term. In the meantime, the *AgNes-process* is regarded by INT1 (Grid operator) as the most consequential ongoing initiative, with the expectation that its outcome will produce stronger system-serving incentives for BESS and a more efficient market overall. In contrast, INT8 (Consultant) is rather skeptical about the reform process and identifies itself as the dominant source of investment uncertainty rather than a reliable path to reform.

On specific policy instruments, interviewees offer several recommendations aimed at incentivizing more system-serving deployment and operation of BESS. The most widely supported short-term measure is the introduction of dynamic grid fees, which would tie the network tariff in a given region to the current state of the grid, creating a market-based incentive for BESS to operate in a system-serving manner. This is seen as the most practical solution across stakeholder groups. INT1 and INT5 (Grid operators) acknowledge the benefit but flag a significant implementation challenge, which is the real-time visibility of grid conditions, a prerequisite for dynamic fees. It is not yet available for many distribution system operators and is particularly difficult to achieve for smaller operators with limited digital capabilities. INT5 (Grid operator) also notes that grid operators generally prefer *command-and-control mechanisms* over *incentive-based approaches*, as these offer greater certainty of control.

Going further, several interviewees argue for splitting Germany's single electricity price zone into smaller regional zones (e.g. INT3, BESS market actor; INT8, Consultant). This would produce a similar locational steering effect to dynamic grid fees but would do so through wholesale market prices rather than network charges, which would simplify the market structure and generate the strongest possible incentives for system-aligned BESS behavior (INT8, Consultant). INT7 (Consultant) recommends an additional instrument, namely, to differentiate the one-time grid connection fees by location and reduce them in areas where BESS deployment would be most beneficial to the network.

On the question of flexible grid connection agreements (FCAs), which is described in the existing legal framework under §17 Abs. 2b EnWG and allows grid operators to offer connections with prescribed operational parameters, views differ across stakeholder groups. INT1 (Grid operator) already applies this provision and sees it as a useful interim instrument for directing BESS investment toward sites where grid capacity is constrained, even where a conventional connection would not be possible. INT8 (Consultant), by contrast, is critical of these arrangements, arguing that they represent a *command-and-control approach* that sets rules without incentives, that cannot be optimized around by BESS operators and can range from somewhat restrictive to devastating for the project. Severe ramp-rate restrictions are cited as an example that might lead to arbitrage strategies being unviable. BESS market actors share this concern, pointing to the significant bankability risks that need to be evaluated carefully prior to an investment (INT2, INT4, INT6, BESS market actors).

On grid operators, interviewees call for more consistent and transparent connection processes, faster integration of BESS into redispatch frameworks and improved real-time network monitoring (INT1, INT5 Grid operators; INT7, INT9 Consultants). INT5 (Grid operator) frames data exchange as a two-way obligation. Better operational data from BESS operators would allow grid operators to offer greater grid transparency in return, enabling BESS to react to actual grid conditions rather than solely to market prices. INT9 (Consultant) demands a uniform connection process across all grid operators as a basic prerequisite for a functioning national market. More broadly, INT9 argues that grid operators should enable rather than constrain the technical capabilities that BESS already possess, to allow them to participate in all relevant markets instead of being restricted by frameworks designed for conventional generators. INT5 (Grid operator) supports this direction and confirms that grid operators are actively working to improve BESS integration in redispatch processes.

On the responsibility of BESS market actors themselves, the interviews reveal disagreement. INT5 (Grid operator) argues that BESS market actors should operate their assets in a more responsible, system-serving manner and cooperate more closely with grid operators, for example, by providing operational data. INT5 frames this as a matter of self-interest, as a poorly functioning grid ultimately harms BESS operators too. INT2, INT4 and INT6 (BESS market actors) express active willingness to cooperate with grid operators on operational schedules, as in a flexible grid connection agreement, if constraints are clearly specified and compatible with a viable business case. The consultants take a market-based view and argue that in a liberalized market, voluntary system-serving behavior cannot be expected or demanded. INT7 (Consultant) states that if the regulatory framework does not promote system-serving behavior, it is more out of goodwill that operators behave accordingly, but it cannot be demanded.

5 Discussion

5.1 Discussion of Main Findings

5.1.1 Business Opportunities and Responsible Business Potential

Business Opportunities

The findings confirm that grid-scale BESS currently represent an attractive business opportunity in Germany, consistent with the literature. As outlined in Chapter 2, declining lithium-ion battery costs and the growing demand for flexibility in a renewables-heavy electricity system have made market-driven investment in BESS increasingly viable without direct public subsidies (BloombergNEF, 2024; Ostermayer et al., 2026). The multi-market approach, which combines arbitrage with ancillary service revenues such as FCR and aFRR, reflects the revenue stacking logic described by Bae et al. (2025), which allows BESS to maximize returns by operating in multiple service categories simultaneously. The interview findings confirm this picture. All BESS market actors and consultants describe the current market environment as highly attractive.

However, the findings also reveal an important tension that the literature does not yet fully address. The transition from ancillary service revenues toward arbitrage as the dominant income stream, expected by most interviewees, carries a self-limiting dynamic. As more and more BESS capacity enters the market and increasingly meets the demand for balancing services, margins are shrinking, and operators are being pushed increasingly toward arbitrage trading. However, arbitrage revenues are also subject to a similar logic of cannibalization, as pointed out by INT7 (Consultant). As batteries become more widespread, BESS activities smooth out the price volatility that makes arbitrage profitable in the first place.

Responsible Business Potential

From the perspective of the CSV and TBL frameworks, the BESS sector represents a strong case of a responsible business opportunity, where commercial logic and societal value creation are essentially aligned. As Porter and Kramer (2011) argue, shared value arises when firms generate economic returns while addressing societal needs. In the case of grid-scale BESS, this alignment occurs quite naturally, as core revenue streams such as arbitrage, FCR and aFRR directly correspond to system services that support the energy transition.

The empirical findings confirm this perspective. Across all stakeholder groups, BESS are described as essential infrastructure for integrating renewable energy, maintaining grid stability and reducing system costs (e.g. INT1, Grid operator; INT4, BESS market actor; INT7, Consultant). This supports previous research highlighting the strong contribution of BESS to sustainability goals, including SDG 7 and SDG 13 (Hannan et al., 2021).

However, the findings also reveal an important limitation of this alignment. While the sector as a whole is structurally oriented toward societal value creation, the actual deployment and operation of individual assets often deviates from system-optimal outcomes. BESS are typically located where grid connections are available rather than where system needs are greatest, and are operated based on market prices that do not reflect local grid conditions. This is also supported by a recent study published by NEON, which argues that BESS operators currently base their operations on uniform market prices, while local grid bottlenecks are not economically visible to market participants (Lohr et al., 2025). A key insight of this thesis is that this misalignment should not be interpreted as irresponsible business behavior. Instead, it reflects rational economic behavior within a market framework that does not price system value. As one interviewee states, companies do not operate BESS in a system-serving manner out of goodwill, but only when it is economically viable (INT4).

This finding aligns with both CSV and TBL, which suggest that lasting societal value creation depends on aligning financial incentives with social outcomes rather than on voluntary sacrifices by firms. As Porter and Kramer (2011) argue:

> "The right kind of government regulation can encourage companies to pursue shared value; the wrong kind works against it and even makes trade-offs between economic and social goals inevitable" (p. 14).

The findings of this dissertation strongly support this argument. Responsible business outcomes in the BESS sector cannot be expected without an appropriate market design. Instead of demanding more responsible behavior from BESS operators, the regulatory framework must be structured in a way that profit-maximizing decisions lead to outcomes that benefit society.

5.1.2 Market Misalignments and Incentives for System-Optimal Deployment

The literature identifies the absence of locational price signals as a key market failure for BESS deployment (Ostermayer et al., 2026; Sioshansi et al., 2012), and the findings strongly confirm this diagnosis. Germany's single electricity price zone means that wholesale prices are identical across the country, regardless of where congestion occurs, providing no price incentive for BESS to be installed at a particular location or to operate in a way that relieves local bottlenecks. Organizations, including the *European Network of Transmission System Operators* and the *German Expert Commission on the Energy Transition,* have repeatedly advocated for splitting the German bidding zone, arguing that regional price signals are necessary to accurately reflect grid constraints and align investment with the physical state of the network (Ostermayer et al., 2026). The findings provide empirical support to this position. All proposed short-term solutions, including dynamic network fees, FCAs and differentiated connection costs, are second-best compromises for a fundamental problem that a price zone split would address more directly. INT8 (Consultant) describes dynamic network fees as local price signals and as a "price zone split introduced through the back door."[16]

This points to an important structural tension that the existing literature does not yet adequately address. Dynamic network tariffs can only function as an effective incentive for system-serving BESS operation if those assets are actually subject to network charges. Under the current regulation, which exempts BESS commissioned before 2029 from tariffs for twenty years, the assets whose behavior the tariffs are intended to steer are not exposed to them. Introducing dynamic fees would therefore not provide effective signals for BESS until the exemption expires. Resolving this requires either an earlier phase-out for newly commissioned assets or a positive incentive mechanism like a rebate or bonus for system-serving behavior.

More generally, the findings reveal a fundamental disagreement regarding how system-serving behavior should be achieved in practice. Grid operators favor *command-and-control* mechanisms, such as FCAs, because these offer network control, while BESS market actors and consultants advocate for *incentive-based* instruments such as dynamic network fees, differentiated connection costs and a price zone split. Prioritizing *incentives* over *control* mechanisms in the BESS context is beneficial for two reasons. First, BESS are highly flexible assets that can respond to price signals in near real-time, making them well-suited to market-based coordination. *Command-and-control* approaches that prescribe fixed operational envelopes, such as the ramp-rate restrictions cited by INT8 (Consultant) as potentially eliminating arbitrage viability, sacrifice this flexibility without equivalent system benefit. Second, the bankability problem identified by INT2, INT4 and INT6 (BESS market actors) is directly caused by the unpredictability of discretionary feed-in restrictions. Investors can plan based on a known tariff system, but cannot account for access restrictions that are not clearly defined. Lohr et al. (2025) support these arguments. In their study, they found that dynamic price signals improve the system-serving behavior more effectively and with lower welfare losses than static tariffs or restrictive operational constraints.

[16] Translated from German: "Durch die Hintertür, ist es ein Preiszonensplit, wenn man so will."

The grid operator's preference for control reflects partly the current absence of real-time digital network monitoring. Investment in grid digitalization is therefore a prerequisite for transitioning toward incentive-based coordination. Until then, there is likely no alternative to *command-and-control* mechanisms such as FCAs.

5.1.3 Structural Barriers to BESS Deployment

The grid connection process is described in literature as a major deployment barrier, characterized by a lack of transparency and long processing times (Ostermayer et al., 2026). In the interviews, BESS market participants confirm that obtaining a grid connection is the biggest challenge of all. Developers, who submitted multiple speculative grid connection requests to increase their chances of securing capacity, acted rationally. However, when many actors followed this strategy, it led to an overloaded and inefficient application pipeline. Two factors mainly contributed to this situation. Foremost, the first-come-first-served process created little incentive to avoid speculative applications. Next, as acknowledged by INT1 (Grid operator), there was no publicly available information on where grid capacity was actually available, making it difficult for developers to target applications strategically.

The recently announced maturity-based process addresses the first cause by raising the cost of speculative applications, but it does not resolve the second one and introduces a new problem, which is that developers must commit significant capital to demonstrate project maturity before knowing whether any connection is available. A more coherent solution would combine the maturity aspect with a proactive publication of grid capacity.

Another grid connection-related barrier identified in the literature is the regional variation in grid connection costs, which creates planning uncertainty and reduces investment predictability for developers (BMWK, 2023). The interview findings, however, show a more differentiated view. Instead of seeing different connection costs purely as a problem, INT7 (Consultant) considers them a potential instrument for incentivizing BESS deployment in regions where additional flexibility is particularly beneficial for the electricity system. From this perspective, differentiated grid connection fees could contribute to more system-serving siting decisions if they reflect actual network conditions and system needs. The findings, therefore, suggest that the main issue is not necessarily the existence of varying connection costs itself, but rather the lack of transparency and predictability surrounding them. Publicly available information and a clear, understandable methodology for calculating fees could reduce planning uncertainty and still keep their potential steering effect.

In the literature, the lack of clarity regarding the grid tariff framework after 2029 and a possible premature change to the regulations are described as a significant source of investment uncertainty (Baker McKenzie, 2025; Hanny et al., 2022), and the interview results confirm this. According to INT4 (BESS market actor), an early termination of the exemption could result in approximately 80 - 90 % of planned projects being put on hold. From an investment theory perspective (Dixit & Pindyck, 1994), this reflects a classic problem in option evaluation. Under conditions of irreversibility and uncertainty, rational investors postpone their decisions even when the expected project value is positive. The investment pause INT8 (Consultant) describes is therefore not irrational behavior but a predictable collective response to policy risk. The consistent message across stakeholder groups is that legal certainty matters more than any specific regulatory outcome. A stable and predictable framework, even an imperfect one, is preferable to continued ambiguity (e.g. INT2, INT4 BESS market actor).

One aspect raised in the interviews receives little attention in the existing literature, namely, the influence of political interests on the regulatory framework. Several interviewees pointed to a lack of political support for BESS in Germany (e.g. INT4, BESS market actor; INT9, Consultant). These concerns are reinforced by publicly discussed developments. Media reports show that the Federal Ministry for Economic Affairs and Energy commissioned the preparation of arguments against BESS and that a ministry-commissioned strategy for reserve capacity procurement included auction criteria that effectively disadvantaged battery storage in favor of gas-fired power plants (Schultz, 2026).

While this thesis does not examine these political dynamics in depth, the findings suggest that some regulatory gaps and delays potentially result from political resistance toward a stronger role of BESS within the energy system. The underlying interests and motivations behind these developments remain unclear.

5.2 Implications

5.2.1 Theoretical Implications

This study contributes to the literature on responsible business, market failures and energy economics by showing that the alignment between economic and societal value does not emerge automatically, even in sectors where business models are essentially system-serving. While frameworks such as CSV and TBL suggest that firms can generate shared value by integrating societal goals into their core activities, the findings demonstrate that this alignment depends strongly on the surrounding market and regulatory design. This is in line with Porter and Kramer (2011), who stated that regulation can either hinder or support the creation of shared value.

The study also suggests an important distinction between business model alignment and operational alignment. While the core business model of grid-scale BESS is structurally linked to societal value creation, individual investment and operational decisions may still differ from system-optimal outcomes. Existing responsible business frameworks do not explicitly account for this distinction, as they primarily focus on the alignment of business activities and societal goals at a strategic level rather than on the institutional conditions shaping operational decision-making.

The findings also reinforce insights from energy economics literature on market failures in electricity systems, particularly the absence of locational signals and incomplete markets for flexibility services. Furthermore, this study adds a multi-stakeholder perspective that illustrates how these failures translate into concrete investment and operational decisions.

5.2.2 Practical Implications

From a practical perspective, the thesis highlights that the barriers identified across the findings cannot be resolved by any single regulatory instrument but require a coherent and coordinated policy framework. The focus is on the need to introduce effective locational and temporal price signals that align economic incentives with system needs. While a price zone split would represent the most consistent solution, it has effectively been ruled out by the previous and current German Federal Government and is therefore unlikely in the near future (Ostermayer et al., 2026). As a result, dynamic network tariffs are the most feasible alternative. However, their effectiveness is currently constrained by the regulatory framework. As long as BESS remain exempt from network charges, dynamic tariffs cannot provide meaningful incentives. The reform of the exemption rule and the introduction of dynamic tariffs must therefore be developed jointly, an aspect addressed in the ongoing regulatory *AgNes-process* (INT1, Grid operator).

In parallel, the grid connection process requires structural reform, particularly greater transparency regarding available grid capacity and more standardized procedures across grid operators. The current lack of transparency contributes to inefficient allocation of grid capacity and delays project development.

Another key element is the integration of BESS into redispatch and congestion management processes. While BESS are technically well suited to replace costly generation-based redispatch, as shown by the literature (Figgener et al., 2023), and the findings (INT1, INT5; Grid operators), the main barriers are regulatory and information- and data-wise. Clear remuneration mechanisms and improved grid digitalization would enable BESS to participate more actively, which would improve system efficiency, while creating additional revenue streams for BESS operators.

The findings also clarify the role of BESS operators. In a liberalized electricity market, voluntary system-serving behavior cannot be expected, and if system-optimal outcomes depend on voluntary cooperation by market actors, they are likely to be underprovided. The observed behavior of BESS market actors is therefore a rational adaptation to existing incentives, rather than a lack of responsibility. Consequently, policymakers and regulators have the main responsibility to design a framework in which profit-maximization leads to system-beneficial and society-desirable outcomes. One area where BESS operator engagement remains important is data sharing and coordination with grid operators. Improved data exchange can enhance grid transparency and support more system-oriented operation, while it also facilitates participation in redispatch markets.

5.3 Limitations and Future Research

This study is subject to several limitations. First, the qualitative design and relatively small sample size of nine expert interviews limit the generalizability of the findings. While the inclusion of multiple stakeholder groups enhances the validity of insights, the sample does not fully represent all relevant perspectives within the German BESS context. In particular, the lack of supervisory authorities during the interviews limits the ability to gain a detailed understanding of the intentions and constraints faced by policymakers. In addition, the study may be affected by self-selection bias, as participation was voluntary, and stakeholders with particularly strong interests or opinions regarding BESS regulation may have been more likely to participate.

Second, the findings may also be influenced by social desirability bias. Interviewees may have presented their own actions or institutional positions in a more favorable manner, particularly when discussing topics related to responsibility and system-serving behavior. Although this risk was mitigated by using neutral and open-ended questions, such biases cannot be fully excluded in qualitative interview research.

Furthermore, the study was conducted in a rapidly evolving regulatory environment, characterized by ongoing reforms such as the *AgNes*- and *MiSpeL-processes*. As a result, the findings reflect a temporary state of the market and can change as the regulatory framework develops further. This limits the long-term validity of the findings.

Finally, the limited availability of academic literature on recent regulatory and market developments in the German BESS sector represents a further limitation. Given the rapid pace of development in this field, the study drew in part on policy documents, industry reports and selected non-academic sources to capture current trends. While these sources provide timely and practically relevant insights, they may reflect institutional perspectives or strategic interests that differ from peer-reviewed academic research.

There are several areas in which future research could build on this study. First, future studies could quantitatively assess the effectiveness of different regulatory instruments, such as dynamic network tariffs, a price zone split or flexible connection agreements, in incentivizing system-serving deployment and operation of BESS. This would add to the qualitative findings of this thesis with a more detailed assessment of economic and system-level impacts.

Second, further research should include policymakers, regulatory authorities and political actors in order to better understand the institutional and political dynamics shaping the German BESS framework. This is particularly relevant as some interviewees identified political resistance toward a stronger role of BESS within the energy system.

Third, a study that analyzes and compares the BESS regulatory framework of different countries could provide useful insights for future policy design. In particular, analyzing how different approaches to pricing zones, congestion management and storage regulation influence BESS deployment and system integration could help identify more effective regulatory models.

Finally, future research could further investigate the relationship between BESS deployment and grid expansion. Some interviewees emphasized that storage should not be viewed as a substitute for transmission expansion, but rather as a complementary flexibility solution. A more detailed analysis of this interaction could improve the understanding of how different infrastructure investments together contribute to the energy transition.

6 Conclusion

This thesis researched the responsible business opportunities, market barriers and challenges associated with grid-scale BESS in Germany. Based on nine semi-structured expert interviews with BESS market actors, grid operators and consultants, the study analyzed how current market structures influence the deployment and operation of BESS and to what extent investment incentives align with societal goals, including decarbonization and the provision of affordable and reliable energy.

Regarding the first research question, the findings show that grid-scale BESS currently represent a highly attractive business opportunity. Existing revenue streams, particularly electricity arbitrage and ancillary services, already provide sufficient economic incentives to drive strong private sector interest. At the same time, the study confirms that BESS can create considerable societal value by supporting renewable integration, improving grid stability, reducing redispatch needs and thereby lowering overall system costs. In this sense, the BESS sector represents a strong example of a responsible business opportunity in which commercial and societal interests are fundamentally aligned. However, the thesis also demonstrates that this alignment does not emerge automatically in practice. Current market structures fail to reflect local grid conditions and system needs, resulting in deployment and operational patterns that are often not system-optimal. Batteries are typically installed where grid connections are easiest to obtain rather than where they would provide the greatest benefit to the electricity system. The findings suggest that this behavior should not be understood as irresponsible, but rather as a rational response to existing economic incentives.

Concerning the second research question, the study identifies several barriers that prevent BESS from contributing to societal goals. In particular, the lack of locational price signals, grid connection bottlenecks, limited integration into redispatch processes and regulatory uncertainty currently limit the ability of the market to steer BESS toward societal objectives and system-serving deployment and operation.

With respect to the third research question, the thesis shows that responsible business outcomes depend significantly on the surrounding regulatory framework. Addressing the identified barriers, therefore, requires a coherent and predictable framework that aligns economic incentives with system needs. Interviewees generally favor incentive-based approaches over restrictive command-and-control mechanisms, although improved grid digitalization, transparency and stronger coordination between market actors and grid operators are necessary prerequisites for more effective system integration.

Overall, the thesis contributes to the literature by combining perspectives from responsible business theory and energy economics. It shows how market design influences the relationship between economic incentives and societal value creation in an infrastructure sector. The findings imply that achieving Germany's ambitious energy transition and BESS deployment targets will depend less on technological readiness or investor willingness and more on whether policymakers and regulators succeed in establishing a clear, stable and system-oriented framework for storage deployment.

Appendices

Appendix 1: Interview Guide

1. Role and Context

- Could you briefly describe your role and your organization's involvement with grid-scale battery storage?

2. Role of BESS in energy transition

- What role do grid-scale battery storage systems play in the electricity system?
- Which revenue streams currently drive investments in BESS?
- In your view, do current revenue opportunities sufficiently reward the societal benefits these systems provide?

3. Market barriers and failures

- To what extent do market and regulatory uncertainties influence investment decisions in the BESS market? Which uncertainties should be highlighted?
- Are grid-scale BESS currently being deployed in locations and in ways that maximize economic returns, or in ways that provide the greatest benefit to the power grid?
- Should grid-serving behavior of BESS be driven solely by market mechanisms, or do you also see an active responsibility on the part of developers and operators themselves?

4. Solutions and responsibilities

- In your view, what changes to market design or regulation would be most important to enable the expansion of battery storage in a way that benefits the system?
- Do you think that the capacities for grid-scale BESS projected in the Federal Network Agency's 2025 Scenario Framework, 82 - 188 GWh by 2037, are realistically achievable under current market and regulatory conditions?
- Is there anything else you want to mention in the context of grid-scale BESS that we haven't discussed?

Appendix 2: Interviewee Overview

ID	Stakeholder Group	Organization type	Position	Years of experience	Area of expertise	Interview duration	Date
INT1	Grid operator	Distribution Grid Operator	Expert for flexibility and smart grids	6 years	Grid flexibility, smart grids, battery storage solutions in the distribution grid of Bavaria	38:53 min	30.03. 2026
INT2	BESS market actor	BESS project developer and operator	Project developer BESS	4 years	Development and siting of battery storage assets, including permitting process in Germany	34:42 min	31.03. 2026
INT3	BESS market actor	BESS operator	Working Student - Operation of BESS	2 years	Operation of grid scale BESS, Ancillary services	18:18 min	04.04. 2026
INT4	BESS market actor	BESS manufacturer and project developer	Inhouse Strategy Consultant	1 year	Business model development, sales strategy development	42:06 min	07.04. 2026
INT5	Grid operator	Distribution Grid Operator	System Require-ments Engineer	5 years	Redispatch in the distribution grid of Baden-Württemberg	28:12 min	08.04. 2026
INT6	BESS market actor	BESS project developer, owner and operator	Project developer grid-scale BESS	6 years	Project development of grid-scale BESS; renewable energy generation UK and Germany	31:16 min	08.04. 2026
INT7	Consultant	Consultant	Consultant	5 years	Renewable Energies, Battery Energy in Germany	36:00 min	10.04. 2026
INT8	Consultant	Consultant	Consultant	2 years	Energy storage with focus on grid-scale BESS in Germany	33:30 min	13.04. 2026
INT9	Consultant	Consultant	BESS Project Consultant	3 years	BESS and Renewable Energy Engineering	45:00 min	14.04. 2026

Appendix 3: Structured Overview of Interview Findings

Full interview transcripts are available from the author upon request (s-lsieler@ucp.pt).

Topic (RQ1)	Sub-Topic	Mentioned by	Key findings
RQ1 - Business Opportunities and Future Projections	Revenue streams	• BESS market actors (4/4) • Consultants (3/3)	• Multi-market approach: arbitrage + FCR / aFRR • >50 % of revenues currently from ancillary services; shift to arbitrage expected • Emerging: inertia, reactive power, black-start promising but not yet material
RQ1 - Business Opportunities and Future Projections	Market attractiveness	• BESS market actors (4/4) • Consultants (3/3)	• Market highly attractive; no direct subsidies needed • Strong growth in project activity and new entrants
RQ1 - Business Opportunities and Future Projections	Future Projections	Mixed views among groups • Achievable (2/9) • Barely feasible (3/9) • Not sure (4/9)	• Mixed views on GFGA's scenario framework projections • Some consider them achievable, others as barely feasible given current conditions
RQ1 - Societal value and Deployment Misalignment	Role in energy transition	• All interviewees (9/9)	• Essential for bridging temporal gap between renewables and demand • Key for frequency regulation and grid stability • Can reduce curtailment and grid expansion needs
RQ1 - Societal value and Deployment Misalignment	Deployment misalignment	• BESS market actors (3/4) • Consultants (3/3) • Grid operators (2/2)	• BESS sited where connections are available, not where system needs them • Operation guided by market signals, not grid conditions; effectively random from a system perspective • But, behavior consistent with other market participants

Topic (RQ2)	Sub-Topic	Mentioned by	Key findings
RQ2 - Incomplete Market Design	Single price zone	• BESS market actors (2/4) • Consultants (2/3) • Grid operators (2/2)	• Prevents locational price signals, thus no steering mechanism for system-optimal siting and operation
RQ2 - Incomplete Market Design	Redispatch gap	• Grid operators (2/2)	• Untapped potential for BESS in redispatch • Blocked by missing grid transparency and unclear remuneration framework • Pilot process underway but at early stage
RQ2 - Incomplete Market Design	Co-location market imperfection	• Consultants (2/3)	• Co-located BESS lose subsidy if charged from the grid • Prevents system-serving behavior during periods of low local generation
RQ2 - Grid Connection as key Bottleneck	Grid connection scarcity	• BESS market actors (3/4) • Consultants (3/3) • Grid operators (2/2)	• Biggest practical barrier • Available capacity effectively exhausted across Germany
RQ2 - Grid Connection as key Bottleneck	First-come-first-served failures	• BESS market actors (3/4) • Consultants (3/3) • Grid operators (2/2)	• Enabled many speculative applications • No public capacity maps, which led to broad, untargeted applications • Response times: weeks to >1 year, sometimes no response
RQ2 - Grid Connection as key Bottleneck	New application process	• BESS market actors (2/4) • Consultants (2/3) • Grid operators (1/2)	• New maturity-based process improves the previous system • But: chicken-and-egg problem; capital required for BESS developers before connection is confirmed
RQ2 - Regulatory Uncertainty	Network fee exemption (post-2029)	• BESS market actors (3/4) • Consultants (3/3)	• Main source of investor uncertainty • Premature curtailment would lead to ~80-90 % of planned projects being put on hold
RQ2 - Regulatory Uncertainty	Unsolved regulatory processes	• Consultants (3/3)	• AgNes-, MiSpeL-process and revision of grid application procedure • Outcome of processes unclear which leads to uncertainty

Topic (RQ3)	Sub-Topic	Mentioned by	Key findings
RQ3 - Regulatory Side	Investment certainty	• BESS market actors (3/4) • Consultants (3/3)	• Stable rules, even imperfect ones, preferred over ambiguity • No market distortions favoring established market participants (e.g. gas-biased capacity criteria)
RQ3 - Regulatory Side	Dynamic grid fees	• BESS market actors (3/4): support • Consultants (3/3): support • Grid operators (2/2): flag barriers	• Most widely supported short-term instrument • Barrier: real-time grid monitoring lacking at many grid operators • Grid operators prefer command-and-control over incentive mechanisms
RQ3 - Regulatory Side	Price zone split	• BESS market actors (1/4) • Consultants (1/3) • Grid operators (2/2)	• Most structurally effective locational instrument • Stronger incentives than dynamic fees
RQ3 - Regulatory Side	Flexible connection agreements	• BESS market actors (3/4): critical • Consultants (3/3): mixed views • Grid operators (2/2): supportive	• Useful interim tool to enable connections in constrained areas • Risk: vague or severe constraints (e.g. ramp-rate limits) might destroy bankability • Seen as command-and-control, not incentive-based mechanism
RQ3 - Grid operators	Grid operator reforms	• Consultants (3/3) • Grid operators (2/2)	• Uniform connection process across >800 operators needed • Two-way data exchange: better BESS data leads to better grid visibility which leads to system-serving deployment • Enable BESS participation in all markets; don't restrict to conventional frameworks
RQ3 - BESS market actors	Responsibility	• BESS market actors (3/4) • Consultants (3/3) • Grid operators (2/2)	• Grid operators: BESS actors should act responsible • BESS market actors: willing to cooperate if constraints are clear and bankable • Consultants: voluntary system-serving behavior cannot be demanded, regulation must set right incentives

References

Agudelo, M. a. L., Jóhannsdóttir, L., & Davídsdóttir, B. (2019). A literature review of the history and evolution of corporate social responsibility. *International Journal of Corporate Social Responsibility*, *4*(1). https://doi.org/10.1186/s40991-018-0039-y

Bae, J., Kapuscinski, R., & Silberholz, J. (2025). Cost-Saving synergy: Energy stacking in battery energy storage systems. *Management Science*. https://doi.org/10.1287/mnsc.2022.03477

Baker McKenzie. (2025). *Germany: Potential deterioration of market conditions for battery storage systems from upcoming grid fee reform*. https://insightplus.bakermckenzie.com/bm/energy-mining-infrastructure_1/germany-potential-deterioration-of-market-conditions-for-battery-storage-systems-from-upcoming-grid-fee-reform

Ban, K.-M. (2015). *Launch of new sustainable development agenda to guide development actions for the next 15 years*. United Nations Sustainable Development. https://www.un.org/sustainabledevelopment/blog/2015/12/launch-of-new-sustainable-development-agenda-to-guide-development-actions-for-the-next-15-years/

Baur, D., Baumann, M. J., Stuhm, P., & Weil, M. (2023). Societal acceptability of large stationary battery storage systems. *Energy Technology*, *11*(6). https://doi.org/10.1002/ente.202201454

BloombergNEF. (2024). *Lithium-Ion battery pack prices see largest drop since 2017, falling to $115 per Kilowatt-Hour: BloombergNEF*. https://about.bnef.com/insights/commodities/lithium-ion-battery-pack-prices-see-largest-drop-since-2017-falling-to-115-per-kilowatt-hour-bloombergnef/

Bogner, A., & Menz, W. (2002). Das theoriegenerierende Experteninterview. In *VS Verlag für Sozialwissenschaften eBooks* (pp. 33–70). https://doi.org/10.1007/978-3-322-93270-9_2

Bohn, S., & Gümüsay, A. A. (2024). Growing institutional complexity and field transition: towards constellation complexity in the German energy field. *Journal of Management Studies*. https://doi.org/10.1111/joms.13004

BP p.l.c. (2021). *Statistical Review of World Energy 2021 | 70th edition*. https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2021-full-report.pdf

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Bundesministerium für Wirtschaft und Klimaschutz (BMWK). (2023). Stromspeicher-Strategie. https://www.bundeswirtschaftsministerium.de/Redaktion/DE/Downloads/S-T/stromspeicherstrategie-231208.pdf?__blob=publicationFile&v=6

Bundesnetzagentur. (2025). Genehmigung des Szenariorahmens für den Netzentwicklungsplan Strom 2025-2037/2045. https://www.netzentwicklungsplan.de/sites/default/files/2025-04/Genehmigung%20Szenariorahmen%202025_0.pdf

Bundesnetzagentur & Bundeskartellamt. (2025). *Monitoringbericht 2025*. https://data.bundesnetzagentur.de/Bundesnetzagentur/SharedDocs/Mediathek/Monitoringberichte/MonitoringberichtEnergie2025.pdf

Burger, B., & Gandhi, L. (2026). *Electricity generation in Germany in 2025*. Fraunhofer ISE. https://www.energy-charts.info/downloads/electricity_generation_germany_2025.pdf

Castillo, A., & Gayme, D. F. (2014). Grid-scale energy storage applications in renewable energy integration: A survey. *Energy Conversion and Management*, *87*, 885-894. https://doi.org/10.1016/j.enconman.2014.07.063

Coester, A., Hofkes, M. W., & Papyrakis, E. (2020). Economic analysis of batteries: Impact on security of electricity supply and renewable energy expansion in Germany. *Applied Energy*, *275*, 115364. https://doi.org/10.1016/j.apenergy.2020.115364

Crane, A., Palazzo, G., Spence, L. J., & Matten, D. (2014). Contesting the value of "Creating shared value." *California Management Review*, *56*(2), 130-153. https://doi.org/10.1525/cmr.2014.56.2.130

Denzin, N. K. (1989). *The Research Act* (3rd ed.). Englewood Cliffi, NJ: Prentice Hall.

Dixit, R. K., & Pindyck, R. S. (1994). Investment under Uncertainty. In *Princeton University Press eBooks*. https://doi.org/10.1515/9781400830176

Egerer, J., Weibezahn, J., & Hermann, H. (2016). Two price zones for the German electricity market - Market implications and distributional effects. *Energy Economics*, *59*, 365-381. https://doi.org/10.1016/j.eneco.2016.08.002

Eisenhardt, K. M., & Graebner, M. E. (2007). Theory building from Cases: Opportunities and challenges. *Academy of Management Journal*, *50*(1), 25-32. https://doi.org/10.5465/amj.2007.24160888

Elkington, J. (1998). Partnerships from cannibals with forks: The triple bottom line of 21st-century business. *Environmental Quality Management*, *8*(1), 37-51. https://doi.org/10.1002/tqem.3310080106

ENTSO-E. (2025). Statistical Factsheet 2024. In *ENTSO-E Central Transparency Platform*. https://eepublicdownloads.blob.core.windows.net/public-cdn-container/clean-documents/Publications/Statistics/Factsheet/entsoe_sfs2024_web.pdf

Etikan, I., Musa, S. A., & Alkassim, R. S. (2015). Comparison of convenience sampling and purposive sampling. *American Journal of Theoretical and Applied Statistics*, *5*(1). https://doi.org/10.11648/j.ajtas.20160501.11

Faunce, T. A., Prest, J., Su, D., Hearne, S. J., & Iacopi, F. (2018). On-grid batteries for large-scale energy storage: Challenges and opportunities for policy and technology. *MRS Energy & Sustainability*, *5*(1). https://doi.org/10.1557/mre.2018.11

Figgener, J., Hecht, C., Haberschusz, D., Bors, J., Spreuer, K. G., Kairies, K., Stenzel, P., & Sauer, D. U. (2023). The development of battery storage systems in Germany: A market review (status 2023). *arXiv (Cornell University)*. https://doi.org/10.48550/arxiv.2203.06762

Figgener, J., Stenzel, P., Kairies, K., Linßen, J., Haberschusz, D., Wessels, O., Robinius, M., Stolten, D., & Sauer, D. U. (2020). The development of stationary battery storage systems in Germany - status 2020. *Journal of Energy Storage*, *33*, 101982. https://doi.org/10.1016/j.est.2020.101982

Fischer, S., & Geden, O. (2020). Die europäische Energie- und Klimapolitik. In *Handbuch Europäische Union* (pp. 887-905). https://doi.org/10.1007/978-3-658-17409-5_35

Flick, U. (2009). *An introduction to qualitative research* (4th ed.). SAGE Publications Ltd. https://vivauniversity.wordpress.com/wp-content/uploads/2014/02/flick-2009-an-introduction-to-qualitative-research-full-book.pdf

Frontier Economics. (2025). *Instrumente für eine systemdienliche Integration von Batteriespeichern.* https://www.frontier-economics.com/de/de/nachrichten-einblicke/news/news-article-i21371-instrumente-fuer-eine-systemdienliche-integration-von-batteriespeichern/

Gaete-Morales, C., Gallego-Schmid, A., Stamford, L., & Azapagic, A. (2019). A novel framework for development and optimisation of future electricity scenarios with high penetration of renewables and storage. *Applied Energy*, *250*, 1657-1672. https://doi.org/10.1016/j.apenergy.2019.05.006

Gährs, S., & Knoefel, J. (2020). Stakeholder demands and regulatory framework for community energy storage with a focus on Germany. *Energy Policy*, *144*, 111678. https://doi.org/10.1016/j.enpol.2020.111678

Gephart, R. P. (2004). Qualitative Research and the Academy of Management Journal. *Academy of Management Journal*, *47*(4), 454-462. https://doi.org/10.5465/amj.2004.14438580

Goldman Sachs Research. (2023). *Electric vehicle battery prices are falling faster than expected*. https://www.goldmansachs.com/insights/articles/electric-vehicle-battery-prices-falling.html

Hannan, M., Al-Shetwi, A. Q., Begum, R., Ker, P. J., Rahman, S., Mansor, M., Mia, Muttaqi, K., & Dong, Z. (2021). Impact assessment of battery energy storage systems towards achieving sustainable development goals. *Journal of Energy Storage*, *42*, 103040. https://doi.org/10.1016/j.est.2021.103040

Hanny, L., Wagner, J., Buhl, H. U., Heffron, R., Körner, M., Schöpf, M., & Weibelzahl, M. (2022). On the progress in flexibility and grid charges in light of the energy transition: The case of Germany. *Energy Policy*, *165*, 112882. https://doi.org/10.1016/j.enpol.2022.112882

IPCC. (2023). Climate Change 2023: Synthesis report. *Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, H. Lee and J. Romero (Eds.)]. (pp. 35–115). IPCC, Geneva, Switzerland, pp. 35-115. doi: 10.59327/IPCC/AR6-9789291691647

ISEA RWTH Aachen. (2026). *Battery Charts - Battery Data & Insights*. Battery Data Center. Retrieved March 10, 2026, from https://battery-charts.de/

Klausen, M. (2017). Market Opportunities and Regulatory Framework Conditions for Stationary Battery Storage Systems in Germany. *Energy Procedia*, *135*, 272-282. https://doi.org/10.1016/j.egypro.2017.09.519

Kramer, M. R., Agarwal, R., & Srinivas, A. (2019). *Business as usual will not save the planet*. Harvard Business Review.

Lohr, C., Eicke, A., & Hirth, L. (2025). Netzdienlichkeit von Großbatterien. In *https://neon.energy/Neon-Netzdienlichkeit-Großbatterien.pdf*. Neon Neue Energieökonomik GmbH.

Maia, L. K. K., & Zondervan, E. (2019). Optimization of energy storage and system flexibility in the context of the energy transition: Germany's power grid as a case study. *BMC Energy*, *1*(1). https://doi.org/10.1186/s42500-019-0009-2

Norman, W., & MacDonald, C. (2004). Getting to the bottom of "Triple bottom line." *Business Ethics Quarterly*, *14*(2), 243–262. https://doi.org/10.5840/beq200414211

Ortega, P. C., Gómez, P. D., Sánchez, J. C. M., Camarero, F. E., & Pardiñas, Á. Á. (2023). Battery Energy Storage Systems for the New Electricity Market Landscape: Modeling, State Diagnostics, Management, and Viability-A Review. *Energies*, *16*(17), 6334. https://doi.org/10.3390/en16176334

Ostermayer, M., Hartz, K., Zackariat, M., Godron, P., Bläsius, J., Bohl-Zeller, R., Fischer, C., Herrndorff, M., Huneke, F., Kraus, A., Tinius, M., Wauer, N., Wenzel, M., Wilz, F., Metz, J., Mohnen, L., Wietschel, J., & Elmer, C.-F. (2026). *Die Energiewende in Deutschland: Stand der Dinge 2025*. Agora Energiewende. https://www.agora-energiewende.de/publikationen/die-energiewende-in-deutschland-stand-der-dinge-2025

Porter, M. E., & Kramer, M. R. (2011). Creating shared value. *Harvard Business Review (January - February)*.

Prakash, K., Ali, M., Siddique, M. N. I., Chand, A. A., Kumar, N. M., Dong, D., & Pota, H. R. (2022). A review of battery energy storage systems for ancillary services in distribution grids: Current status, challenges and future directions. *Frontiers in Energy Research*, *10*. https://doi.org/10.3389/fenrg.2022.971704

Reibsch, R., Blechinger, P., & Kowal, J. (2023). The importance of battery storage systems in reducing grid issues in sector-coupled and renewable low-voltage grids. *Journal of Energy Storage*, *72*, 108726. https://doi.org/10.1016/j.est.2023.108726

Schultz, S. (2026, April 15). Geplantes Strom-Backup: Reiche-Ministerium bat Gaslobby um Argumente für Gaskraftwerke. *DER SPIEGEL, Hamburg, Germany*. https://www.spiegel.de/wirtschaft/katherina-reiches-ministerium-bat-enbw-um-argumente-fuer-gaskraftwerke-a-1ce69ada-8eff-444b-a7f9-4eaf4d6e5447

Sioshansi, R., Denholm, P., & Jenkin, T. (2012). Market and policy barriers to deployment of energy storage. *Economics of Energy and Environmental Policy*, *1*(2). https://doi.org/10.5547/2160-5890.1.2.4

Slaper, T. F., & Hall, T. J. (2011). The Triple Bottom Line: What Is It and How Does It Work? *Indiana Business Review*, *86*(1). http://econ2.econ.iastate.edu/classes/crp274/swenson/CRP566/Readings/Triple%20Bottom%20Line.pdf

Thimet, P., & Mavromatidis, G. (2023). What-where-when: Investigating the role of storage for the German electricity system transition. *Applied Energy*, *351*, 121764. https://doi.org/10.1016/j.apenergy.2023.121764

United Nations. (2015). *Transforming our world: the 2030 Agenda for Sustainable Development*. United Nations. https://docs.un.org/en/A/RES/70/1

United Nations. (2025, July 21). *Communications materials - United Nations Sustainable Development*. United Nations Sustainable Development. https://www.un.org/sustainabledevelopment/news/communications-material/

Wiertz, T., Kuhn, L., & Mattissek, A. (2023). A turn to geopolitics: Shifts in the German energy transition discourse in light of Russia's war against Ukraine. *Energy Research & Social Science*, *98*, 103036. https://doi.org/10.1016/j.erss.2023.103036

Wigger, H., Torres, F. S., Bartels, J., Feller, L., Brand-Daniels, U., & Vogt, T. (2024). Quantitative assessment of sector coupling battery energy storage systems and their contribution to the resilience of the power system. *International Journal of Energy Research*, *2024*(1). https://doi.org/10.1155/2024/8812115

AI Declaration

I acknowledge the use of generative AI tools during the preparation of this dissertation. The tools were used to improve some parts of the text, particularly for language refinement, proofreading and to eliminate redundancies.

The research concept, theoretical structure, methodology, data collection, analysis, discussion and conclusion were developed by me. All Al-generated suggestions were critically reviewed, adapted where appropriate, or rejected. Generative Al was not used as a scientific source, and all theoretical arguments, empirical findings and external information are based on the cited literature and data sources.