European Market Evaluation for Long-Duration Energy Storage

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Abstract

Long-duration energy storage (LoDES) technologies and their global use cases are quickly advancing, with non-lithium-ion technology solutions being optimized for long-duration grid applications (>24hrs of continuous energy on a single charge). These technologies can serve as bi-directional power plants located in almost any market and scaled to match energy infrastructure globally. We focused our research on European energy markets and how LoDES companies can best position themselves against competitors. Our market assessment evaluates the current energy landscape, including policies, generation mix, stakeholders, and the market's lucrative potential, such as revenue staking, wholesale prices, and competitor criteria. We identified six potential European energy storage markets from which we classified a three-country subset to develop go-to-market strategies, detailing funding opportunities and potential partnerships. This analysis aims to give LoDES companies tangible direction to pursue European market entry.

Executive Summary

The purpose of this report is to create a go-to-market strategy for long-duration energy storage in European electricity markets. We catered our research and proposal to Form Energy, a multi-day energy storage company using electrochemical technology. As a flow battery, Form Energy's technology differs from lithium-ion batteries in that it can provide utility-scale application of greater than 24-hours of continuous energy discharge (on a single charge). This continuous output serves a separate role in decarbonizing an electric grid by not only providing grid flexibility to support significant penetration of renewable energy but can also compete with fossil fuel baseload generation to bridge extended gaps in renewable intermittency. Although the value proposition for storage technologies is mounting, market adoption is still heavily reliant upon policy support. As a result, there is a varying degree of storage integration across markets. As part of our go-to-market strategy, we created a framework for evaluating attractive markets and understanding potential revenue streams.

We approached the process in three phases: (I) market criteria identification and selection, (II) market research and analysis, and (III) market focus and strategy development. In Phase I, we created both a qualitative evaluation framework and a set of quantitative directional criteria to comprehensively compare electricity markets. The qualitative evaluation considered the overall market landscape, and revenue opportunities in the transmission market, capacity market, and renewable partnering. The quantitative directional criteria considered the (1) percentage of renewable energy generation, (2) flexibility of generation sources, (3) interconnection with other markets, (4) wholesale electricity prices, and (5) market size. In Phase II, we applied the Phase I frameworks to six European countries: Germany, Ireland, Belgium, Spain, UK, and Denmark. This market analysis enabled us to work with Form to narrow our scope to only Germany, Ireland, and the UK; these three markets had a more promising business case than Belgium, Spain, and Denmark. In Phase III, we focused more on stakeholders, funding, and critical market considerations for successful market entry. The project's culmination is for Form Energy to act on our recommended partnerships or apply our framework for future market entry considerations.

Comparatively, Belgium, Spain, and Denmark lack the financial incentives and policy support to make the business case for market entry. Out of the six countries evaluated, Belgium has the lowest percentage of renewable energy penetration, and the federal government has very few initiatives to change the momentum away from natural gas. This is not a conducive market landscape for energy storage. Conversely, Spain does have the political support to incorporate battery storage; however, the market lacks clear financial pathways for storage due to a muddled regulatory framework. Like Spain, Denmark is highly committed to renewables that are appealing for long-duration energy storage but has sufficient transmission congestion relief and no capacity market, so the financial mechanisms are less compelling. Between European Union renewable energy mandates and growing storage support in neighboring countries, it is possible the policy momentum will change in the next few years. At the time of this report, Belgium, Spain, and Denmark were de-prioritized because Germany, Ireland, and the UK seemed more attractive in a 1 to 3-year time horizon.

The market size of Germany and high renewable energy penetration are compelling cases for long-duration energy storage. Specifically, the abundance of wind energy and transmission constraints in the Northeast provide potential partnerships and value propositions. Germany has numerous hydrogen storage pilot projects in the pipeline, demonstrating confidence in the market. However, hydrogen projects could also steer government funding away from long-duration flow battery technologies. To combat high competition for government funding, a potential path forward is to partner with medium- to large-scale wind asset developers in Northeastern Germany to co-locate with wind farms and distribute risk across partners.

Although a relatively small electric market, Ireland has seen a regulatory surge towards renewables and battery storage in the past couple of years. The two beneficial aspects of market entry into Ireland are the restructured balancing services market, which is conducive to storage, and the plethora of data centers attractive for private partnerships. Although Ireland has reduced barriers to entry for storage, it does not have as many pilot projects in the pipeline as Germany and the UK; therefore, Form may have the ability to lobby with the federal government and a unique opportunity to test market entry via small pilots before attempting to enter a larger market.

Lastly, the UK is an attractive market because it clearly defines storage compatibility in the regulatory framework. This has created opportunities for revenue stacking across ancillary

services, capacity market, and intra-day trading. The apparent financial pathways are validated by the increase in pilot projects of various storage technologies that have entered the UK market. There is a risk of oversaturation or government support favoring hydrogen storage; however, it is reassuring that both the public and private sectors are aware of the merits of energy storage and therefore may pose little educational barrier to overcome when proposing the use of either co-located or standalone energy storage.

Introduction

Variable renewable energy (VRE) sources play an essential role in decarbonizing the electric grid; however, they also present an increasing challenge in baseload planning and real-time balancing. This opens the electricity market to technologies that can supplement VRE and provide carbon-free, continuous baseload electricity. Long-duration energy storage (pumped-storage hydropower, compressed air, flow batteries) can fill that gap and create a more flexible and reliable decarbonized electricity grid. The past four years have seen an average of 1GW/year of utility-scale storage deployment globally[i]; however, even as the costs of these technologies decrease, market adoption is still heavily reliant upon policy support. The appetite to integrate nascent energy storage varies significantly between markets, consequently varying the monetizable benefits available for storage developers. The purpose of this report is to develop a go-to-market strategy for long-duration energy storage by way of identifying key market features that indicate the relative opportunity between markets.

Although lithium-ion batteries are currently the most ubiquitous battery technology[ii], this report will focus on long-duration storage (LoDES), defined as grid applications of greater than 24 hours of continuous energy discharge (on a single charge). This exceeds lithium-ion battery technology limitations. While shorter duration energy storage can handle intra-day variation[iii], LoDES directly competes with current fossil fuel generation by bridging significant gaps in renewable intermittency. Although the system-wide impacts are still being modeled, LoDES can reduce VRE curtailment, defer transmission investments, and replace power plants while also serving shorter duration applications, such as ancillary grid services. Thus, at scale, LoDES may capitalize on many of these value streams and achieve a more significant economic impact towards reaching a decarbonized grid.

As a part of our study, we tailored our go-to-market strategy as part of a consulting practicum for Form Energy. Therefore, although this report is largely technology agnostic, it does assume LoDES is a flow battery technology solution. Given that most storage deployed across the globe and in Europe are pumped-storage hydropower or lithium-ion batteries, direct comparison to Form Energy's business model is often not explicit in the literature, and therefore,

application assumptions have been made. This report intends to create a framework for evaluating attractive markets and understanding potential revenue streams.

Methodology

Our work with Form Energy focused on European countries, identifying markets for potential business entry and subsequently recommending go-to-market strategies in those locations. We created a project roadmap to carry this study from initial industry research to broad market entry strategies, breaking the process into three phases: (I) market criteria identification and selection, (II) market research and analysis, and (III) market focus and strategy development.

Phase I: Market Criteria Identification and Selection

In Phase I, we created a qualitative evaluation framework and a set of quantitative directional criteria to compare electricity markets comprehensively. We first conducted extensive research on electricity market conditions and LoDES, independent of Form Energy's technology. Although initially casting a wide net, we purposefully bucketed the research into

1. Market landscape (e.g., policies, regulatory players, current energy mix)
2. Transmission market (e.g., ancillary services)
3. Capacity market (e.g., long-term offtake agreements)
4. Renewable partnering (e.g., co-locating with VRE)

The availability of information inevitably sets specific markets apart from others. Based on our preliminary research and Form's input, we narrowed it down to six countries: Belgium, Denmark, Germany, Ireland, Spain, and the United Kingdom (UK). We also later applied our evaluation framework (Figure 1) in Phase II to build an electricity profile for each of these countries.

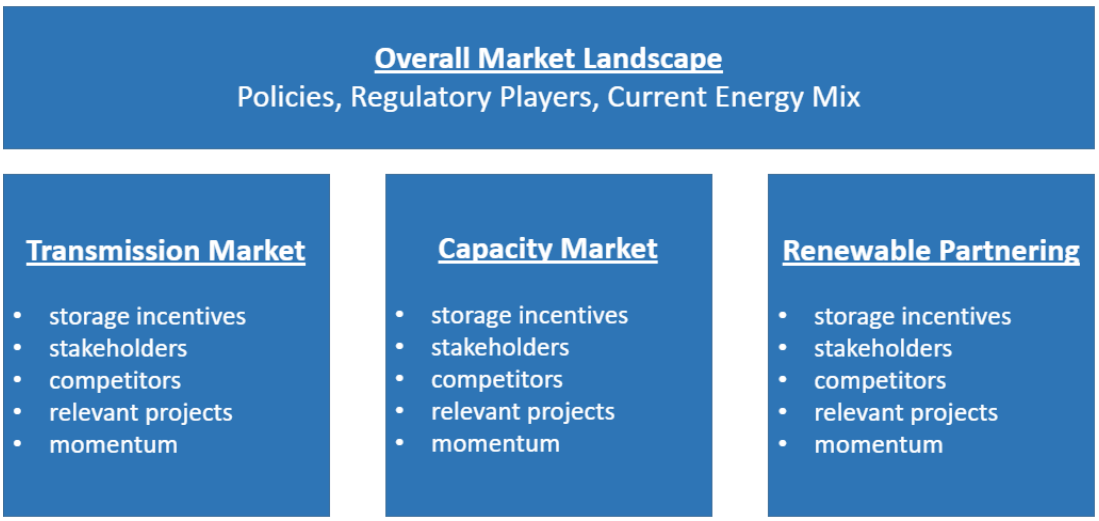


Figure 1. Evaluation Framework

In addition to our qualitative evaluative framework, we created directional criteria to provide a quantitative comparison. Outside of policy incentives, we sought to outline what makes a market attractive for grid-scale storage. Table 1 shows the five criteria we considered alongside the relationship to LoDES and the system of measurement. This enabled us to connect a country's electricity generation (using IEA 2018 data[iv]) with its compatibility for battery storage. In Phase II, we compared the six countries based on these criteria.

Criteria	Relationship to LoDES	Metric
Current and planned renewable energy generation (REGN) Mix	↑REGN = ↑ LoDES	% REGN
Flexibility of generation sources (FLEX)	↓FLEX = ↑ LoDES	Installed capacity by generation type
Interconnection with other markets (INTER)	↓INTER = ↑ LoDES	% Installed capacity interconnection
Wholesale electricity prices (PRICE)	↑PRICE = ↑ LoDES	Average wholesale price
Market size (SIZE)	↑SIZE = ↑LoDES	Market size

Table 1. Directional Quantitative Criteria for Market Attractiveness of Grid-Scale Storage

Phase II: Market Research and Analysis

The goal of Phase II was to re-apply our Phase I frameworks to further narrow down from six countries to only those electricity markets who are primed for long-duration storage and have potential revenue opportunities to explore further in Phase III. We took the four buckets from our evaluation framework and qualitatively ranked each countries' strength opportunity as weak, moderate, or strong – as defined in Table 2 below.

Evaluation Framework	Weak	Moderate	Strong
Overall Market Landscape	Minimal RE policies or commitments; complex regulatory landscape; fossil fuel emphasis persists.	The recent emergence of RE policy or commitments that show potential in a retiring energy mix	Established RE policies and commitments; federal support specific for storage
Transmission	Monopoly TSO with no information on load-leveling opportunities for storage	Load-leveling opportunities forstorage but competitive projects in the pipeline	Load-leveling opportunities for storage and strong push for transmission investments
Capacity Markets	No capacity market exists	Small to medium capacity market exists; suppressed prices and no price accommodation for storage capabilities.	A large capacity market exists with clear incentives for storage participation.
Renewable Developer Partnerships	Very few RE projects in the pipeline	Moderate RE projects in the pipeline; rare market examples of storage co-location	Significant RE projects developed and in the pipeline; history of RE developers co-locating storage.

Table 2. Opportunity zone strength definitions

We used IEA's 2018 data on electricity generation and euro/MWh to quantitatively compare Germany, Ireland, Spain, Belgium, UK, and Denmark for our directional criteria. The comparative scale used is defined in Table 3, where a full circle indicates the country's attributes are relatively positive for long-duration storage.

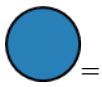
Metric	Definition	
% REGN	Averaged 2018 and 2030 renewable energy targets	 = Relatively positive for LoDES
Estimated FLEX	Provided a flexibility factor 0-1 for each generation source (Nuclear & VRE being 0, & biofuels being 1)	
% INTER	Percentage electricity interconnection level	
Average PRICE	Wholesale Price (Euro/MWh)	
Market SIZE	Compared total electricity generation relative to size of Germany	

Table 3. Relative scale for the attractiveness of long-duration storage

This analysis method created a visual of which countries aligned with market potential that could also be supplemented with detailed memorandums on each market that elucidated the underlying indications of the matrix scores. We then proposed our recommended markets and incorporated feedback from Form Energy in proceeding with a focused analysis on Germany, Ireland, and the UK in Phase III.

Phase III: Market Focus and Strategy Development

In the final phase, we concentrated our efforts on building out recommendations for how Form Energy could bring its battery technology to Germany, Ireland, and the UK. Our recommendation for partnerships and funding was catered to Form Energy's timeline and needs. In this paper, we have not called out those partnerships by name; however, our results include various scenarios on what might drive success or bring additional barriers in the future. The project's culmination is for Form to act on our recommended partnerships or apply our framework for future market entry considerations.

Results

	Germany	Ireland	Spain	Belgium	UK	Denmark
Overall Market Landscape	Strong	Strong	Strong	Weak	Strong	Strong
Transmission	Strong	Strong	Moderate	Moderate	Strong	Moderate
Capacity Markets	Weak	Moderate	Moderate	Weak	Strong	Moderate
Renewable Development	Strong	Moderate	Moderate	Moderate	Strong	Strong

Table 4. Opportunity zone strength results

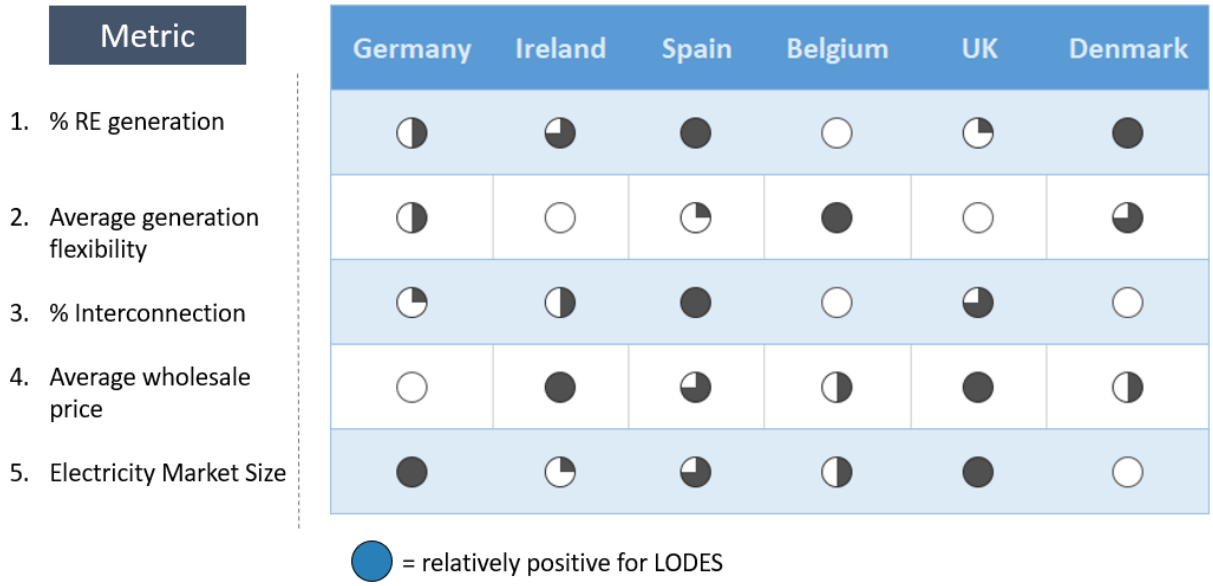


Table 5. Directional Criteria for Relative Market Attractiveness Results

Germany

Overall Market Landscape

Being a relatively large market with a high degree of renewable energy penetration, aggressive clean energy targets, and future grid balancing needs, Germany possesses several characteristics that lend to an attractive market for LoDES. With extensive and aggressive renewable energy commitments in the future, there will be a need for grid flexibility. Additionally, although not having a capacity market to capture revenue, there is considerable price volatility on the day-ahead- and inter-day-markets, including negative price scenarios. This price volatility is caused by the current mix of energy in Germany. In 2018, Germany's energy mix relied heavily on renewables at 40%, followed by coal, natural gas, and nuclear at 32%, 15%, and 12%, respectively.[v]

There are several vital features in Germany's electricity grid and policy that lend an attractive market for long-duration energy storage. With renewable portfolio standards enabled by the Renewable Energy Sources Act (EEG) and federal law driven by broader EU agreements, Germany's primary regulator for the electricity sector, Federal Network Agency (BnetzA), is empowered to enable increased renewable energy penetration. These RE generation goals include 40% RE generation in 2020 and goals for 65% and 100% by 2030 and 2050. While

demand growth is expected to remain flat over the next several years, per annum development targets, 2.9 GW of onshore wind and 2.5 GW of photovoltaic solar align with the Grid Expansion and Acceleration Act shows ample opportunity for co-located long-duration energy storage projects.[vi]

Transmission

With a largely inflexible generation mix of variable renewable energy in Germany, TSOs are faced with solid balancing needs across the country. The solution for this need has manifested in such policies as the Grid Expansion and Acceleration Act, which encourages long-distance and cross-border transmission lines to enable energy exchange with other EU countries.[vii] Primarily driven by the price volatility inherent to the renewable energy, nuclear, and CHP-driven market's wild, and sometimes negative, price swings, Germany's four TSOs, 50Hertz, Amprion, TenneT, and TransnetBW, have undergone several recent North-South German transmission lines.[viii] The goal of these transmission lines is to eliminate the rare but present curtailment of renewable energy in Germany, which retains remuneration as outlined by the German Renewable Energy Sources Act (EEG). Therefore, while several transmission lines are under construction to alleviate curtailment in the German electricity market, long-duration energy storage could enable potential deferment of these projects and enable markets to match loads to demand centers with less transmission overhaul.

Capacity Market

Germany has no capacity market and instead leverages wholesale exchange markets. Following the typical technique of dispatching the lowest cost generators first and increasing to meet demand, Germany enters into the European Energy Exchange (EEX) in Leipzig and the European Energy Exchange (EPEX SPOT) in Paris to meet around 20% of their demand needs.[ix] Additionally, however, Germany also engages in over-the-counter trading to accommodate futures, day-ahead, and intraday markets, which is where the prices can vary considerably. This is where LoDES may be able to capitalize and provide a valuable cost-hedging service for basic energy arbitrage.

Renewable Partnering

Enabled by the Renewable Energy Sources Act (EEG), Germany provides proportionate, tariff-based remuneration for new renewable resources and requires significant development to meet time-based renewable energy penetration goals. From 2020 onwards, Germany expects over 2.9 GW of onshore wind (with 15 GW of offshore by 2030) and an additional around 2.5 GW of photovoltaics each year.[x] An economic driver for renewable developers is the transition from static, 20-year contracts where remuneration to producers was set at an amount above market rate to a new auction platform available in the EEG auction. As such, direct PPAs are likely to become common as prices rise, remuneration falls, and the 20-year grandfathered set remuneration contracts to expire. Capitalizing on these economic shifts, LoDES companies could explore co-development with some of the leading renewable energy developers in Germany, such as RWE, E.ON, Vattenfall, and EnBW.

Ireland

Overall Market Landscape

Although a relatively small market, Ireland's electricity landscape has critical features that are primed for LoDES. The number of large-scale renewable projects currently in the queue and the participation of storage in their policy programs demonstrate significant momentum for battery storage market entry in this market.

Ireland has been the fastest growing economy among all IEA countries since 2014, and energy use has increased with GDP.[xi] A significant driver of electricity demand growth is Ireland being a global hub for data centers. In 2018, Ireland's electricity consumption mix was 29.9% natural gas, 16.2% wind, 4% coal, 3.9% peat, 1.3% hydro, 2.2% other renewables and wastes, and 0.3% oil.[xii] Although Ireland did not achieve their 2020 energy target under the 2009 EU Renewable Energy Directive, in the past few years, they have restructured their wholesale market, prioritized a balancing services program, and introduced a Renewable Electricity Support Scheme (RESS) that will reduce barriers to entry for renewables.

Geographically, Ireland's relative isolation from the rest of the EU could be beneficial for LoDES. It only has two interconnections with the UK, Northern Ireland, and Wales and no direct

interconnections with the EU. The UK's exit from the EU has exacerbated Ireland's grid isolation and price volatility; however, it is unclear how this relationship will affect energy exchange in the long term.[xiii]

The principal regulatory entities in Ireland's electricity market are EirGrid, Sustainable Energy Authority of Ireland (SEAI), Single Electricity Market Committee (SEMC), and the Commission for Regulation of Utilities (CRU). EirGrid is the state-owned electricity transmission system operator, working to ensure system stability and planning the future development of the transmission network. SEAI aids in renewable policies and pilot projects, which could be essential for new technologies such as LoDES. SEMC runs the wholesale electricity market in Ireland and Northern Ireland. Lastly, the CRUI is an independent regulator that is a member of SEMC.

Transmission Market

Given Ireland's grid isolation and increased intermittent penetration, battery storage can significantly impact grid stabilization through ancillary services. In 2011, EirGrid created the 'Delivering a Secure Sustainable System' (DS3) program to prioritize transmission upgrades. The three critical elements of the program are system policies, system control tools, and enhanced system performance.[xiv] Part of the enhanced system performance is to provide financial incentives for fast frequency response to maintain grid stability. Although technology agnostic, this is favorable for battery storage because payments are based on the speed of response that typically cannot be achieved by thermal plants.

Current storage projects under this program use lithium-ion technology; however, this is an additional revenue stream that LoDES technology can also capitalize on. Statkraft, in partnership with Fluence, developed an 11MW project in Kilathmoy, Ireland, that went live in 2020; although co-located with an onshore wind farm, the battery modules are also providing frequency response and power reserves to the grid through a contract with EirGrid. Statkraft is taking advantage of the 'volume uncapped' mechanism that allows for flexibility in DS3 services and revenue stacking.[xv] A concern is DS3 revenues may not be significant enough on their own and will be further suppressed once the market becomes saturated with additional players.

Since Ireland has prioritized transmission stabilization and infrastructure, other projects and technology solutions are in the pipeline. Eighteen battery storage projects with a capacity of

nearly 600MW have already obtained planning approval and have a grid-connection contract with EirGrid.[xvi] There are also interconnection projects in the queue, such as the Celtic Interconnector project to link Ireland and France's power system. This would be the only direct connection between Ireland and the EU post-Brexit, and construction is expected to start in 2022.[xvii] There is also the planning of a second Ireland – Northern Ireland line pending Northern Ireland legal approval but expected to be completed by 2025.[xviii] These additional interconnection projects could reduce the demand for standalone grid storage.

Capacity Market

Ireland's restructured wholesale market, I-SEM, went live in 2018 and covered Ireland and Northern Ireland. Their previous market design was a single market with a single system marginal price that did not provide transparency or flexibility for renewable investors. The transition to I-SEM better aligns with other EU energy markets and consists of five markets: forward, day-ahead, intraday, balancing, and capacity. This is more favorable for renewable generators, as there are more trading opportunities and more precise market signals being sent to investors.

Battery storage can compete in the capacity market but will be subject to de-rating factors. Given that Form Energy is long-duration storage (>4 hours), it is unclear how generator de-rating would be applied to such technology. However, it is promising to see the 2019 T-4 capacity auction results showed 81 MW of 'other storage' – presumably battery storage – cleared in the auction.[xix] Since battery storage is in the early stages of entering Ireland's wholesale market, it is unclear of the revenue success.

The DS3 program described above is the primary mode of entry for battery storage in Ireland; however, there is an opportunity to take advantage of volatile wholesale prices through the various I-SEM markets.

Renewable Partnering

Although over 75% of the current storage pipeline in Ireland is standalone batteries, most future developments for solar and wind have included battery storage.[xx] These projects are typically smaller in size but also expand upon price arbitrage opportunities. Ireland recently

created a Renewable Electricity Support Scheme (RESS) to promote the scaling of renewables to meet EU-wide energy targets. The RESS provides financial support to renewable electricity projects determined by a RESS auction run by EirGrid.[xxi] Although aiming to diversify the renewable energy mix, Ireland has the second-highest share of wind in Europe.[xxii] EirGrid projects the installation of an additional 2.6 GW of wind power by 2027. Most of the wind power in Ireland is onshore, although the country has a lot of offshore wind potential. Storage co-location is a growing business model that will likely grow alongside the increase in renewable projects.

As mentioned, Ireland is an international hub for data centers that presents a unique opportunity to do renewable partnering with a technology company. Many tech companies have committed to 100 percent renewable electricity targets and have already started partnerships with wind farms in Ireland. For example, Amazon Web Services committed to buying energy from a 91.2 MW farm in Donegal, Ireland.[xxiii] Long-duration storage's value proposition is the ability to supplement wind power's intermittency to ensure consistently cheap energy prices and also being able to capture excess energy generation to sell back to the grid. This would allow data centers to become more self-sufficient and support the decarbonization goals of the host country.

Spain

Overall Market Landscape

Spain's market isolation and renewables landscape make it an attractive candidate for long-duration storage; however, there are currently insufficient examples of a clear pathway for storage adoption, making the financials unviable. In 2019, Spain’s electricity generation mix was 5% coal, 5% oil, 31% natural gas, 2% biofuels and waste, 21% nuclear, 10% hydro, 5% solar PV and thermal, and 20% wind.[xxiv] The EU has a binding commitment of 32% share of renewables in gross energy end-use by 2030, but Spain's national plan is to reach an ambitious 42% and achieve a carbon-neutral economy by 2050.[xxv] In alignment with their commitments, Spain has had a renewables boom the past ten years, largely supported by their renewables remuneration system that guarantees a rate of return as well as priority dispatch for renewables over conventional plants.[xxvi] Spain and Portugal's electrical systems are strongly integrated but have

relatively low interconnectedness to the rest of the EU.[xxvii] EU has a goal of 15% interconnection ratio by 2030, which Spain vastly falls short with only 5% interconnected; however, this market isolation is favorable for investments in long-duration storage.

Although the need and potential for storage in Spain seem substantial, there is no clear path for battery storage. Spain is targeting 2.5GW of utility-scale storage by 2030, but the policy incentives are not in place.[xxviii] Storage is treated the same as other generation technologies and cannot compete with cheaper renewable sources without recognizing their value proposition in flexibility and additional capacity deferral.[xxix] It seems promising that Spain is funding R&D and pilot projects for storage technologies, including hydroelectric, but short-term commercial deployment does not have clear market signals.[xxx]

Spain's grid operator is Red Electrica de Espana (REE), a significant stakeholder for any utility-scale project. The National Commission of Markets and Competition is an independent entity overseeing the electricity market. The third major stakeholder is the Ministry of Energy, which is responsible for implementing government policies on energy and would likely be the driving force for change in the storage landscape.

Transmission Market

REE is responsible for managing Spain's balancing services. The current market mechanism is for generation market participants to modify their output to match deviations in demand.[xxxi] Currently, there is not a distinguished market entry into ancillary services for battery storage. Although this is expected to change given the 2.5 GW storage target and the potential to mimic other EU countries' market structures.[xxxii]

Capacity Market

Utility-scale storage in Spain is currently limited to R&D projects, for example, the Almacena project.[xxxiii] It does not seem explicitly excluded from renewable energy auctions, but there is no financial incentive to compete as an individual producer. Spain's market also lacks policy support for co-location because the battery is only allowed to charge from the renewable project it is coupled with and not to maximize price arbitrage opportunities.[xxxiv] Again, with the announcement of the 2030 storage target, there is hope that capacity market mechanisms will

open soon. Hydropower has more support, and the Soria-Chira hydropower plant is in development.[xxxv] Although long-duration storage might be more similar in the timescale to a hydropower storage plant than a lithium-ion battery, it is unlikely Spain will have the appetite to adapt.

Renewable Partnering

Given the amount of wind and solar PV in Spain, renewable partnering could be the best entry pathway for storage. All renewable generation bids are encouraged to include storage, but it is not financially attractive because of the additional policy constraints. For example, the auction requires 2MWh of storage installed for each MW of wind or solar.33 Additionally, storage will only be allowed to charge from the renewable project coupled with and not directly from the grid, minimizing opportunities for price arbitrage. Although Spain recognizes the need for storage, policy incentives have not made the technology competitive. In the most recent 2021 auction for 3GW of renewables, none of the winning bids included storage.[xxxvi]

Belgium

Overall Market Landscape

Although Belgium is committed to IEA's energy security, economic growth, and environmental sustainability goals, the market is not primed for LoDES. The European Forum for Renewable Energy Sources and the federal parliament set a goal of only 18.4% renewables by 2030, 40.4% in electricity, 20.6% in transport, and 12.7% in heating and cooling less aggressive than other European peers.[xxxvii] With a focus on fossil fuels, the current energy mix in Belgium is 42.3% oil, 23.9% natural gas, 6.3% coal, 16.6% nuclear, and 8.0% renewables. Additionally, with relatively ill-defined energy storage remuneration mechanisms, it becomes even less tenable for LoDES market entry. Furthermore, Belgium intends to retire many nuclear plants in the future, with plans to replace via a Belgian parliamentary passed legislation to invest in several new gas-fired power plants.[xxxviii] Despite the regional differences under the federal government of Belgium (Brussels, Flanders, and Wallonia), none of these regulatory stakeholders have outlined regionally specific policies to enable renewables or storage, further

making a market entry in Belgium bleak. One positive is the expected development of 4 GW of offshore wind expected by 2030,[xxxix] but the policies and market landscape do not lead to proper compensation for co-located storage.

Transmission Market

Elia acts as the sole transmission provider in Belgium (for anything above 70kV), and with a single TSO projecting a relatively low storage penetration, transmission market opportunities are constrained. In fact, Elia projects the total capacity for large-scale batteries to reach 0.41 GW/GWh in 2025 and 0.59 GW/GWh in 2030, indicating a relatively slow rise in penetration over the next decade.[xl] Although there is very little hydropower to compete with for LoDES, the fact that the retiring nuclear plants are mainly being replaced with natural gas plants indicates Belgium's low appetite for LoDES. Economic drivers within the realm of the transmission market indicate that overall, Belgium's economy has performed better than most Organization for Economic Co-operation and Development (OECD) countries after the 2008 crisis, and Elia projects a continued stable economic situation.[xli]

Capacity Market

With a capacity market to be implemented in the future (some sources indicate 2025[xlii]), the mechanisms for proper remuneration of LoDES are highly uncertain and require more concrete data. There is currently very little data on this, which may indicate a low appetite for such market mechanisms. As such, Belgium can expect financial de-risking mechanisms for energy storage to rely mostly on existing auction market mechanisms and very little carved out for energy storage.

Renewable Partnering

With difficulty in collaboration between the federal and regional governments, there are significantly few renewable development enabling policies available for LoDES, with the primary method of remuneration relying on market auctions. The leading renewable energy enabling policy in Belgium that does exist is the National Renewable Energy Action Plan, which a few projects have been able to capitalize upon. The federal government acts as the regulator for

all energy supply and electricity on the grid up to 70kW, including nuclear and offshore wind projects and norms. Regional governments, however, are responsible for the distribution (electricity and NG), prices, and renewable sources (except offshore), and promotion of energy efficiency. The critical competitors for LoDES, as a byproduct of the relatively unattractive market, are few and minor: one virtual power plant from Tesla at 18 MW[xliii] and one 2MW/2MWh industrial site (Alfen[xliv]) serve as the prominent examples in this market, indicating few options for storage, especially when the offshore wind projections for 2030 remain somewhat ill-defined.

United Kingdom

Overall Market Landscape

The United Kingdom (UK) is an attractive market because there are clear policy pathways for renewable energy and storage, and there are stackable revenue opportunities. These market signals are no secret, demonstrated by the emergence of low-emission technology solutions.

The UK is composed of Great Britain (England, Wales, and Scotland) and Northern Ireland and makes up the third-largest economy in Europe.[xlv] In 2019, the UK's electricity generation mix was: 2.4% coal, 0.3% oil, 40.9% natural gas, 13.0% biofuels and waste, 17.4% nuclear, 2.4% hydro, 19.8% wind, and 3.9% solar PV.[xlvi] Although no longer held to their EU RED commitments due to Brexit, the UK is working towards net zero emissions by 2050.[xlvii] The UK has been a leader in renewable energy penetration mainly driven by energy policies such as a carbon price floor, renewable obligations, feed-in tariffs, and their energy market reform of 2013 that introduced contracts difference (CfD) incentive for low carbon generation. The UK has tactically adjusted policies for storage integration and allowed revenue stacking across the capacity market, balancing mechanism, and fast frequency response (FFR) program.

The primary regulatory entities in the UK's electricity market are the Department for Business, Energy, and Industrial Strategy (BEIS), Office of Gas and Electricity Markets (Ofgem), and National Grid. BEIS is the UK government's department of energy that provides public funds for pilot projects and technology innovation. Ofgem is the main regulator of the UK

gas and electricity networks. Lastly, National Grid, specifically National Grid Electricity System Operations (NGESO), is the electricity system operator for Great Britain and the most extensive transmission owner in the UK. NGESO is the major stakeholder for transmission interconnection and market qualifications.

Brexit Impact

Since the announcement of the UK's exit from the EU in 2016, there has been much uncertainty around the long-term impact on the electricity sector. The UK is no longer bound to their European Commission RED targets for 2030; however, the government establishes other policy schemes to remain committed to emission reductions, such as carbon pricing policy to replace the EU Emissions Trading Scheme. The UK's transmission network will still physically be connected to the EU but will lose its privileges as a member of the EU internal energy market.[xlviii] Similarly, UK renewable projects will not be automatically eligible for financial support from the European Investment Bank. It is unclear if these changing market conditions make the UK electricity market more favorable or less favorable for long-duration storage.

Transmission Market

With the continued growth of renewables on the grid, NGESO's balancing services market has matured and catered to battery storage. Firm frequency response (FFR) services and the Balancing Mechanism market are the most relevant for battery storage, and their revenue streams can be stacked with each other and in conjunction with the Capacity Market.[xlix]

FFR units are meant to maintain the grid's 50Hz frequency with sub-second reaction time and are procured in a monthly tender.[l] NGESO is updating their balancing response services with a new market, Dynamic Containment (DC) services, introduced in October 2020 as a daily auction and will eventually phase out the FFR tenders. This market will more closely align with actual-time demand, elicit faster response time conducive to battery storage technology, and be more transparent in pairing with the Balancing Mechanism market.[li] The Balancing Mechanism market balances supply and demand in half-hour trading periods throughout the day. Each market participant receives balancing mechanism units based on their ability to increase or decrease generational output in short period increments.[lii] This allows battery storage's quick response to be able to capitalize on market volatility. The current FFR market is oversaturated, which has suppressed prices, but given that the DC market has more strict participation

requirements, the payout returns have increased. Individually, any of these balancing services are likely not sufficient payouts, but the true value proposition is its compatibility for revenue stacking. For example, Limejump was the first storage aggregate company to revenue stack in 2018 and has continued to see success by optimizing its revenue streams and adapting to the different markets.[liii]

Capacity Market

Battery storage bids are accepted in the UK capacity market, providing a steady and predictable revenue stream. Ofgem regulates capacity market rules, but National Grid procures capacity. Over the past ten years, most of the UK's policy schemes have been geared toward renewables, not storage, such as contracts for difference for low-carbon electricity generators, feed-in-tariffs, renewable obligations, and emissions limits. However, more recently, the UK has implemented changes to encourage more storage participation, such as reducing the minimum capacity threshold to 1MW, changing the methodology for determining the minimum amount of set-aside, eliminating the double charging of importing and exporting to grid, and allowing battery participation in all agreement lengths if the batteries meet the CAPEX threshold.[liv] Since most battery storage devices competing in the capacity market currently are short-duration (<4 hours), it is unclear how de-rating factors would change LoDES remuneration. The UK one-year ahead capacity market has recently seen record-high prices as margins are tighter with retiring coal and high winter peak demand.[lv] The expansion of the capacity market, revenue stacking, and higher market prices will facilitate more storage into the market. It is no surprise that the UK has been seen as a leader in space.

Renewable Partnering

As mentioned above, the UK has multiple policy schemes supporting renewable energy penetration into the market. For the first time, in 2018, the total renewable capacity in Great Britain, 42 GW, exceeded coal and gas generation capacity, 40.6 GW. Additionally, the UK is a world leader in offshore wind with around 7.9 GW installed capacity. Although wind and solar cannot participate in balancing services and, conversely, standalone storage cannot participate in CfD; renewable partnering is an opportunity to unlock additional revenue streams. Also, storage

co-locating can benefit from reduced costs by sharing grid connections and transmission network costs across the two projects. While previously perceived as uneconomical, co-location will become the norm of new construction.[lvi] As an example, in 2018, Vattenfall added a 22MW battery to an existing onshore in South Wales and took advantage of reduced electrical costs while playing in multiple electricity markets.[lvii] The momentum of offshore wind and the opening of market access to storage make renewable partnering attractive for Form Energy.

Denmark

Overall Market Landscape

With a commitment to 100% renewable generation by 2050[lviii], Denmark shows a high aptitude for VRE projects. Denmark has over 40% renewable generation, with over $30 billion in wind energy planned over the next few years.[lix] With already nearly 50% of their energy coming from wind (and 30% from coal and natural gas), the Danish government prioritizes wind over other types of energy for Denmark. Regulated by the Ministry for Energy Utilities and Climate, the Danish Energy Agency, the Danish Utility Regulator, and Energinet, most stakeholders support the renewable energy revolution for Denmark. Renewable's share of all energy sources in Denmark is on a steady trend and offers a tremendous opportunity for LoDES market entry at first glance.

Transmission Market

With the transmission lines wholly owned by the state, there is only one major stakeholder to consider: Energinet. Energinet operates both the western and eastern Danish transmission systems for 132, 150, and 400 kV levels.[lx] Driving the economics of the transmission system in Denmark, there are stacked revenues available that typically include frequency response, as well as balancing market mechanisms. Additionally, as is typical for transmission interconnection, connecting to the grid can be a challenge in Denmark; however, Energinet supports the development and plant to support renewable energy targets.

Capacity Market

Denmark does not currently have a capacity market but has made some moves to include one future. In the meantime, the main form of revenue for products participating in wholesale electricity sales is via an auction mechanism.

Renewable Partnering

With an absolute commitment by the federal government to reach 100% renewable energy by 2050, Denmark is already farther along the transition curve when compared to many EU nations. Aside from the historic, immense investments in wind energy, some key projects of comparable use to LoDES include the EnergyLab Nordhavn and SEAS-NVE development initiatives. The EnergyLab Nordhavn project, led by ABB, seeks to integrate electricity, heating, energy efficiency, and transport into an intelligent, flexible, and optimized energy system.[lxi] The SEAS-NVE project, alternatively, explores ways to heat rock to 600 degrees and store energy.[lxii] This shows Denmark's interest in exploring alternative forms of energy storage and bodes well for LoDES market entrants. With other types of energy storage projects breaking into the market, investors appear willing to enter into projects with developers to help distribute the risk and costs. Lastly, as LoDES pairs particularly well with wind, the 2018 Energy Agreement sets the stage for three large-scale wind projects totaling $30 billion, primarily funded by private investors, where co-location of LoDES may be warranted.[lxiii]

Discussion

For Phase III, we created a market focus and strategy development comparison for the overall market prospects, transmission market standing, capacity market opportunity, and the renewable developer partnering options available in each of the six countries. Assessing the opportunities available in each country, we found that Germany, Ireland, and the UK showed the most significant market potential, warranting additional research for market entry.

The reasons for the de-prioritization of Belgium, Spain, and Denmark were as follows. For Belgium, although the decommissioning of nuclear plants would initially show promise for renewable energy development, the federal plan to overcome the loss in generation was to

replace it mainly with natural gas. Additionally, with a federal government guiding very few mandates and little regional government initiative, the political climate for VRE development may prove generally difficult for co-located LoDES. There are signs of increasing VRE development for Spain, but the country lacks policy and financial incentives for battery storage in general, let alone LoDES in specific. Although highly committed to VRE development, Denmark also has plenty of transmission interconnection and no capacity market to increase the remuneration possibilities for LoDES.

That left Germany, Ireland, and the UK as potential markets for entry for LoDES. For Germany, having high RE penetration rates and aggressive future targets paired with a competitive and fragmented development market, there are plenty of future opportunities and potential partners. Additionally, with concentrated wind development in the Northeast, LoDES could increase the value of a wind farm when co-located. Lastly, being a much larger country than many other countries reviewed, the market opportunity is quite ample. For Ireland, there are many favorable policies specifically targeting storage, which could apply to LoDES.

Additionally, as a juxtaposition to Germany market entry benefits, Ireland is a relatively small market compared to other EU countries, making this an attractive feature for the ability to lobby with the federal government and a unique opportunity to test market entry via small pilots before attempting to enter a larger market. Lastly, for the UK, several reasons lead this market to be an attractive entry point into Europe for LoDES. First, as a leader in both onshore and offshore wind, there are plenty of potential developments to co-locate with LoDES, distributing the financial risk with potential development partners. Second, with explicit capacity and balancing mechanism market revenue stacking opportunities, the potential revenue for UK market entry is clearly defined, alleviating the risk of unclear remuneration tactics present in other markets. Third, with many other storage technologies in the pipeline in the UK, both the public and private sectors are aware of the merits of energy storage and therefore may pose an insignificant educational barrier to overcome when proposing the use of either co-located or standalone energy storage.

Conclusion

Therefore, we identified three main countries of potential interest for LoDES entrance into European electricity markets: Germany, Ireland, and the UK. In Germany**,** a potential path forward is to partner with medium- to large-scale wind asset developers in Northeastern Germany to co-locate with wind farms and distribute risk across partners in the absence of federal funding. In Ireland, approach successful RESS-1&2 developers to partner with and differentiate bids for the RESS-3 auction (and repeat), focus efforts on the growing market of data centers within the C&I sector. Furthermore, in the UK, LoDES companies could target sizeable integrated energy companies with momentum in renewables to have the flexibility to co-locate or enter the market with standalone batteries.

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