

Key challenges in crossborder interconnector finance

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Abstract

This paper assesses causes for, and challenges related to, the funding gap in infrastructure required for a large scale increase of renewable energy in the European energy mix, specifically crossborder interconnectors to transport renewable electricity from areas with high renewable energy potential and production to centres of energy consumption. We identify eight barriers that need to be addressed in order to make investment in interconnectors more attractive. We delineate both technological and governance/legislative barriers to investments in this area. Our analysis is based on a scoping literature review and a workshop that was held in London involving finance and legal experts.

Keywords

Energy transition; climate change; investment barriers; funding gap

1. Introduction

Investment needs for an extensive upscaling of renewable energy (RE) are not being met – we are experiencing a green funding gap (Hafner et al., 2020; Jones, 2015; Jacobsson & Jacobsson, 2012; Yoshino et al., 2019). Often attention to this funding gap has focused on investments required to deploy RE power generation infrastructure itself (McCollum et al., 2018; Egli, Steffen & Schmidt, 2018; Mazzucato & Semieniuk, 2018). However, due to intermittency and regionally disparate potential, as well as significant changes to energy demand including through electric cars, large-scale addition to, and upgrading of, the electricity network infrastructure will be required. Therefore, a large scale expansion of grid reinforcement, storage and interconnectors is needed.

The European Union's (EU) internal electricity interconnection target is 15% by 2030. That is by 2030 it was expected that 15% of all electricity production in the EU would be interconnected between Member States. However, the 2030 target was agreed in a radically different situation – the EU wind and solar energy share was 2%, while it is expected to make up 30% of the EU's electricity in 2030 (EC, 2017). Financing for interconnectors alone would need to go up from between €0.9 to €1.5 billion annually to €3.6 billion per year in moderate or high RE deployment scenarios (van Nuffel, 2017). Member states are required since 2014 to inform the European Commission of any planned infrastructure for the next five years. Based on this, the European Commission produces a report every two years on the European energy systems and any gaps in infrastructure that may arise. However, in the past the member state data provided has been of poor quality (van Nuffel et al., 2017).

Since 2013, the European Commission publishes a list every two years of Projects of Common Interest (PCI). Energy infrastructure projects must lead to an energy market integration in at least two EU member countries to qualify. Qualifying as a PCI, an infrastructure project can ask for financing from several EU sources, such as the Connecting Europe Facility (CEF). A designated PCI project is supposed to benefit from fast-tracked environmental impact assessment and overall permitting procedures, which in theory are supposed to be granted a maximum of 3.5 years after the application. Overall, the average time to get a permit to build a new high voltage line is 7 years, with one quarter of all permits taking more than 15 years to be granted. Additionally, the PCI status conferment provides a signal boost to investors. EU funding available to PCIs is however *“increasingly shifting to repayable financial instruments rather than grants”* (Ammermann et al., 2016, p. 8).

In its 2015 progress report on the state of PCIs, the Agency for the Cooperation of Energy Regulators (ACER) identified significant delays in many PCIs. A key reason for these delays in project completion and delivery were issues relating to financing. The Ten-Year Network Development Plan 2018 reported that of 329 projects, 120 projects were “delayed” or “rescheduled” investments.

The ITRE report (van Nuffel et al., 2017) concluded that *“the financing gap to achieve the targets and goals associated with the European energy transition is substantial (ca. 1% of EU-wide GDP on an annual basis between 2021-2030)”* and that *“Currently, the vast majority of energy expenditure comes from private investors, as well as (non-EU) public sources in Member States. The volume of EU finance (i.e. from the EU Budget) is too small to close the financing gap alone; and there appears to be no prospect of an increase of the order of magnitude likely to change this”* (van Nuffel et al., 2017, p.55). Puka and Szulecki (2014) call the investment gap, the difference between current finance and what is needed for a renewable energy transition, the “grid-lock”, while Cepeda speaks of the “sub-optimality of interconnection investments” (Cepeda, 2018, p. 31).

Given a financing gap has been highlighted there is a need to identify the barriers that contribute to this gap so that solutions can be developed. This finance gap in cross border energy infrastructure is likely to exist across all geographies, however, here we focus within the EU given its explicit

commitment to increase the interconnectedness of its electricity grid and therefore more specific barriers (above and beyond geopolitical issues) can be understood.

This paper presents data from a scoping literature review and a stakeholder workshop. We identify eight priority barriers to scaling up investments in crossborder transmission infrastructure, and two overarching themes namely technological barriers and governance/legislative barriers.

2. Materials and Methods

A scoping literature review (Rumrill, Fitzgerald & Merchant, 2010; Pham et al., 2014; Peters et al., 2015) of barriers in both academic and grey literature was conducted. The review identified articles and reports published between 2010 and 2019. The earlier cut off date was chosen as this was post the Copenhagen Conference of the Parties in 2009 which, by failing to agree a comprehensive international framework for climate change action, changed the perception of investment risk within the capital markets.

The scoping review was based on the use of keywords to identify and collect relevant papers and reports. The keywords used were combinations of a) “electricity”, “renewable energy” and b) “interconnector” or “interconnection” and c) “European” or “crossborder” or “transnational” and d) “finance” or “funding” or “Investment”. These papers and reports were then examined to identify those of particular relevance to interconnector barriers within the European Union context which resulted in a total of 98 papers and reports (see appendix A).

A thematic review (Braun & Clarke, 2006) of those articles was conducted. Code words were identified and then collated together into themes. This was led by the lead and fourth authors and then checked by the second author of the paper. This led to the identification of twelve emergent sub-themes which highlighted a number of barriers to interconnector investment. These sub-themes were collected together under three overall themes which were:

- A) cross-border cost-benefit allocation
- B) legal, jurisdictional and governance issues
- C) barriers to financing projects that involve both EU and non-EU countries.

On November 30, 2018, a workshop on Cross-border Electricity Infrastructure Finance was held in London. The workshop consisted of a presentation on the electricity infrastructure finance gap emergent themes from the scoping review. Different cross-border infrastructure projects and their financing and regulatory issues were presented as case studies. These case studies had been identified during the scoping literature review as particularly salient to the barriers identified. The workshop was run by the first and third author of the paper.

Participants for the workshop were sought from individuals with experience in securing financing or influencing policies associated with interconnector projects. An initial list of invitees was drawn up from the network of the authors and a search based on the case studies identified during the scoping review. Further invitees were sought through a snowball sampling where initial confirmed participants were asked to recommend others. Seventeen participants took part (see Table 1), including representatives from transmission systems operators (TSOs), regulatory authorities, banks (both European and third country), investment funds, engineering companies, electricity companies, financial advisors, lawyers advising largescale electricity infrastructure projects, academics and consultancies.

Table 1: Participant organisations represented at the workshop

<i>Organisation type</i>	<i>Organisation name</i>
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TSO	1. ENTSO-E 2. Ofgem 3. Tennet
Bank & Investment	4. MUFG 5. Triodos
Electricity company	6. EDF Renewables
Governmental think tank	7. Carbon Trust
Interconnector developer	8. Transmission Investment
Auditing and consultancies	9. ARUP 10. Baringa 11. Boston Consulting Group 12. FTI Consulting 13. KPMG
Law	14. Pinsent Masons 15. Squire Boggs Patton
Academics	16. Diplomatic Academy Vienna 17. University of Cambridge

After the initial presentations and a group discussion, the participants were split up into three smaller groups to discuss barriers further. The three overall emergent themes from the scoping review were used as a prompt for these small group discussions. Each group discussed each of the three topics.

The workshop was held under the Chatham House rule (no attribution of comments to any individual). Participants gave informed consent to take part in the workshop with formal ethics approval having been sought under the University's ethics approval process. The workshop was audio-recorded and the small group and plenary discussions then transcribed. Notes were also taken throughout the workshop by the facilitators. These notes and transcriptions were then thematically analysed (Pham et al., 2014) allowing any new themes to emerge or be confirmed from those identified during the scoping review. The themes gathered from the workshop were used to create a list of barriers which were then refined to ensure as little overlap between the barriers as possible (Pham et al., 2014). This was led by the two first authors of this paper. Two overall themes were identified with a number of sub-themes.

The next section presents the data gathered at the workshop. The themes, sub-themes and policy recommendations are then presented in the final section.

3. Results

Many issues impacting the financing for cross-border infrastructure are exactly the same as a national project. Workshop participants estimated that only about a quarter of the financing risks stem from its cross-border nature. It is therefore important to specify whether an issue is inherent irrespective of whether it is cross-border or not. An example of this is construction risk which is the same irrespective of whether a project is national or cross-border infrastructure. However, participants highlighted the fact that the investment structure in an interconnection project follows the revenue structure of the operational phase of the project. This revenue structure, and what is permitted or not, will differ from country to country making an investment more complex.

A lawyer advising interconnection projects asserted that the major factor in cross-border projects is political and regulatory uncertainty. This includes sudden political changes in member states. For this reason, it is *"nearly impossible to get financing externally for such projects"* since investments are perceived to be too high risk. There are then issues pertaining to which national laws apply to the

interconnector and who to sue in which forum in case of an issue.

The long lifespan of the project versus the regulatory uncertainty, especially given the lifespan of regulation can be short, is a mismatch. Political changes in Bulgaria, capacity market remuneration in the UK, and German renewable energy regimes changes have all contributed to a perception of considerable regulatory risk. The more investments are being made, the more costs are generated and with that also comes higher political pressure of managing those costs. The regulatory authority faces public and political pressure so it cannot be ruled out that adjustments are made which then conflict with the viability of the investment. However, it is of course possible to insure against political risk and the risk can be shared between project partners. Other attendees did not rank regulatory risk as highly. An investor would either like a regulator's track record or see that there has been delays in previous interconnections or projects due to regulatory issues and would then not invest in that member state in the first place.

Another workshop participant pointed out that there was a cultural difference in inspection between countries. In the UK, it is quite common to have a third party building an interconnector. That situation is not the norm on the continent. This adds another layer of complexity when it comes to cross-jurisdictional issues in interconnection. In a project, in which there are more UK investors, the technological structure becomes a crucial element of the project because it is possible to get European revenues in a tax-optimised way. The question is then *"what do you structure as equity or as dead financing so that you have deductible interest payments which are taxed more in a country where you invest."*

One reason why some transmission line projects are predominantly financed by banks is that these already possess certain environmental and social compliance principles needed. A representative from a commercial bank explained three different finance sources. Firstly, on balance sheet investment by utilities and TSOs on the Regulatory Asset Base (RAB) model. Secondly, the use of credit facilities to take some of that debt off their own balance sheets. There is thirdly project finance, which on the transmission side is mainly limited to the Offshore Transmission Owners (OFTO) regime in the UK. The strong contractual arrangement in this regime is very attractive to equity participants and to debt participants. This was thus deemed a great way to inject private financing into the regime. In general, other interconnector revenue flow regimes are less clear and less attractive for banks. The regulator also put in place an extensive information campaign and "Investor bridge" on the OFTO regime.

One attendee pointed out the issuance of bonds for financing the construction as well as grid acquisition. Another participant recalled their work on a merchant interconnector and the advantage of arbitrage – whether regarding a price differential or a time differential price. The slow elimination of these differentials and thus the self-eliminating nature and usage of an interconnector are difficult to forecast. It also cannot be easily comparable to OFTO, where the revenue stream is more straightforward to forecast. A bank representative highlighted the attractiveness of OFTO for investors as an "availability payment" and advocated the expansion of the regime to areas other than offshore wind. A regulatory agency participant stated that in the OFTO and its revenue stream – if it is seen as a fixed revenue stream, then it is quite clear to investors what their revenue from the interconnector is. The cost of debt on the asset is paid by the regulator and the regulatory asset base that is paid not just from the gearing portion, but the whole RAB. This means that equity still gets a return in a worst-case scenario.

However, a representative from a bank emphasised the issue of temporality. The revenue stream timeframe, which was definitely not *"regularly (every) six months"* was not as attractive for banks.

While the cost of debt and the return to equity may be clear, it is still not on a deep level of project finance asset by asset basis. As a large utility with a very big portfolio this is easier to hedge against.

An attendee from a utility noted that price differentials, arbitrage, were becoming less important for interconnection than in the past. This was now not as relevant anymore as future interconnection would need to be much more about transmitting RES from the wind and solar power houses of Europe to the urban centres of consumption and industry. One participant wished to highlight the distinction between an interconnector between two large grids allowing electricity to flow in time of arbitrage and an high-voltage direct current (HVDC) cable which connects a windfarm to a grid which is instead a unidirectional flow of one connection asset. Often this is a regulated asset with a regulated rate of return and thus different legally to an interconnector – those are two different types of assets.

For capital subsidies, especially in the case of the project cost that EU financial pots will be willing to pay for a PCI, one participant felt that in order to qualify the project needed to basically be “uneconomic” by default – *“you need to be in the broader social interest of the EU, but you can't really be particularly profitable or economic. [...] but the difficulty is, in order for you to proceed as a project you need regulatory approval on both sides of the link, which essentially provides for the revenue model, be it exempt or capital flaw or tariff [...] and that approval will very rarely be forthcoming if you're not economic [...]. So, there is a little bit of a mismatch from the national perspectives for the regulatory approvals and how the support coming from the European level is forthcoming.”*

Attendees also discussed German Feed-in-Tariffs (FiTs) and how they created arbitrage requiring interconnections. Most attendees favoured auctions to FiTs. Of greater urgency, since auctions had to be “won”, were long-term and day ahead ability for system operators to interrupt the pre-prescribed plan of the interconnector owner and what level of compensations could be applied by whom. This issue, of the day ahead markets was seen as a potential real risk to investors. It could potentially require a redesign of the electricity markets in member countries. Market design is key to ease congestion and interconnectors could even worsen this. The example of NorthConnect connecting Scotland to Norway was given as an interconnector that could just as easily worsen or ease congestion.

An engineer emphasized that the amount of internal capacity within members states was considerably higher in most countries than external capacity and then often interconnection has to be HVDC purely from a technical standpoint.

Issues around the cap and floor regime as well as environmental consenting were also discussed.

3.1. Cost benefit allocation

Interconnector projects are assessed with regards the benefits of connecting to producers, consumers, and markets. The ENTSO-E methodology uses information from all member states, TSOs and projections to understand if a project would be in the best interest of the EU as a whole and then additionally, each member state will assess the impact on their own country. If a project is beneficial for one country, but not for the other a framework has to be put in place to allow the projects to proceed if there is an overall benefit compared to the capital need to build the project.

There are certain differences between member states regarding the producer benefits and costs. For example, countries in Northern Europe with large hydro potential and a large industry that relies on cheap electricity, focus more on the potential financial impact of projects and tariffs on producers. Countries with fuel poverty instead focus more on the consumer side and raising tariffs to finance an interconnection is more sensitive. These different considerations and poverty/industry levels need to be taken into account and need to be brought together into a coherent structure.

One participant cautioned that in the future, these cost-benefit allocations would become much more complex due to the intermediate category of prosumer. Cost-benefit allocation processes of interconnection or storage projects in the future will need to account for an expansion of this intermediate category and while it is clear that this category *will* expand in the future, it is by no means clear to what extent or in which ways or where geographically. All of this makes designing or improving cost-benefit allocation mechanisms more complex. Large consumers or producers may have interests diametrically opposed to those of future prosumers.

An expert from a regulatory agency agreed, both regarding prosumers and interconnector cost-benefit analysis and around different member states' preferences on whose interests to emphasise. If an interconnector can benefit both consumers and producers in a given country then this is a simpler model. However, price inflation benefitting producers is more difficult even within one country. It is important to understand how different countries structure revenue returns. If there is sufficient difference between them, the process to finding a solution might be onerous. It could be that a project is identified as being beneficial to the EU as a whole, and then gets PCI status, but at member state level the view could be different.

An academic argued that uncertainty of revenue streams and regulatory risk are what really kills a project – and the consumer or producer focus is less relevant, as long as the revenue arrangements are crystal clear and not likely to change.

A developer stated that this clarity, or lack thereof, of course determined the revenue stream. Another major factor in financing is the timeframe of any approvals necessary. They pointed out that the Ten-Year Network Development Plan only being published every two years was problematic, as two year old data was not particularly useful. However, it was being used by financiers as a key metric to determine whether a project will proceed or not - although this had never been the plan's intended purpose. It would be beneficial from a developer's perspective for a project to get all approvals necessary already in the early PCI stage. While there are reasons this may be difficult including lack of certainty regarding the overall costs of a project, for a developer it would be a major improvement.

Developers generally supported the EU moving away from an equal allocation of revenue and costs for cross-border infrastructure and that this would also help a project to get funding from the market. Nonetheless, in cases in which one state believed it should be equal, it was still complex and the decision reached needed to also work for regulators, developers and other stakeholders. Equally, there is the risk of member states not being prepared to accept less than 50%, be it ownership costs or revenues, from a territorial sovereignty perspective or simply a perceived governance of project perspective, which can cause some difficulties.

A representative of a regulating agency explained that there was not yet a structure in place to address issues of practicality in terms of how finance prices future risk, e.g. how a *force majeure* would be defined. Many states have different perceptions on what risks should be covered. These differences again create greater risk and make the project less attractive for investors. There are furthermore unaddressed issues surrounding reaching an acceptable income or what will happen if a fixed revenue stream falls away. If all these issues cannot be solved in ways that provide sufficient clarity for lenders/investors, then the projects will fail to attract the investments needed. One partner in an interconnector explained that the issue was the proof or definition of *force majeure* and what was outside of the other partners' hands.

A developer underlined that there was also an issue of temporality creating difficulties and increased risk for cross-border projects – if the countries involved had different timeframe preferences or a

differing sense of urgency and this could not be aligned, then investors would perceive this risk again as too high. There are additionally differences in who is perceived to be a suitable, acceptable investor in cross-border interconnection projects. On the European continent, project partners for critical national infrastructure in this sector are almost exclusively the national monopoly TSOs who know each other very well and frequently cooperate. Such trust will be more complex if the party providing the funding, the equity participant or the project partners are, like is the case in the UK, not from that country.

3.2. Legal, jurisdictional and governance issues

Coordination of different regimes is key. There is a need for cross-jurisdictional authority. On one hand, in projects with two jurisdictions, project investors understand that it will be more difficult to effect a change – positively or negatively. However in this case countries will be less likely to fundamentally change the income factors of an electricity project in this case, which makes it less risky from a finance perspective.

One key issue that the group discussed was the lack of regulatory certainty and how this makes actually investing quite difficult, because since investors may not know what their return is going to be in five years, ten years, fifteen years' time and infrastructure investments require much larger sums invested in single assets.

Arbitrage risks were another key point in discussion and that while this de-risks the project for the investor, it moves it onto the consumer. Several attendees highlighted that regulators imposing certain regulations on interconnector projects did not seem to fully understand how this meant that the risk was moved from developer to consumer. There needs to be arbitrage coordination, but the group could not agree on the parameters for that. Another key point that was made concerned the EU's opposition to merchant investments or the EU not allowing the use of transmission revenue for anything other than to lower prices or to re-invest. This in and of itself deterred a lot of private capital, especially from abroad.

Ultimately too many countries focus a lot on security of energy supply, but not on the positive role interconnectors could play in this.

3.3. Projects between EU and non-EU countries

Since third countries are not covered by EU legislation, there are obvious jurisdictional issues and the investors have to deal with national laws first. The European Commission in such a case would be required to put in place a renewables recognition agreement, as ruled by the November 2014 ECJ case "Green Network v Autorità per l'energia elettrica e il gas" (ECJ, 2014). In the case in question, the ECJ was asked to rule about the Free Trade Agreement with Switzerland and renewable energy certificates in Italy. The Italian Electricity and Gas Authority had fined the Italian Green Network company for failing to purchase green certificates in an amount corresponding to the quantity of electricity which that company had imported into Italy from Switzerland. Green Network argued that they had supplied guarantees of origin proving the renewable energy characteristics of such electricity and thus considered their obligation under Italian law to have a certain amount of renewable energy in their energy supply mix to be met. Italian law provided that guarantees of origin from third countries, i.e. outside the European Union [like Switzerland], would be eligible for meeting this obligation subject to the existence of an international agreement to that end and Italy had such an agreement with Switzerland (Fouquet, D. and Nysten, J. 2014). The European Court of Justice ruled that the EU enjoyed "*exclusive external competence relating to the promotion of electricity from renewable energy sources*

through guarantees of origin in the Internal Market' – therefore Italy's bilateral agreement with Switzerland had been in conflict with European law.

Remaining in the area of legal issues, shareholder rights might change as the interconnector crosses from the third party to the EU country. This would mean that it may be necessary to have a single buyer to circumvent third party access issues. Nonetheless, some participants reasoned that arbitrage, thus electricity price differences between the two countries, *may* give the third country a lower incentive to adopt the EU norms.

One attendee reasoned that cost-benefit allocations would play a major role in the future in 3rd country connections – since many of the countries wishing to export renewable energy to the EU are less wealthy than the EU, e.g. Northern African states. In this case it is important that a transmission line does not mean that the social or environmental cost of energy is exported. Another participant added that this is not only an issue for 3rd countries, especially those with a lower purchasing power, but also a dilemma even for UK-France interconnectors as the nuclear risk is borne predominantly by France.

Regarding actual construction of infrastructure, while engineering standards drive for conformity of equipment, there could be various construction contract issues e.g. delay damages, enforceability of claims. Similarly, there is a large political risk for third countries, both for North Africa as well as interconnections to get solar energy from Turkey. These concerns would make investment riskier and thus potentially less attractive – especially for pension funds.

When the small group discussion turned to Brexit and infrastructure finance with the UK as a future 3rd country, participants expressed concerns about major investment delays and strong cost of capital for electricity infrastructure and interconnections involving the UK. Construction costs themselves would go up regardless, especially in a No Deal Brexit, due to British pound exchange rate issues and necessary import of materials. In case of a No Deal Brexit, there would be major uncertainty and the EU Renewable Energy Directive (2009) would no longer apply. The UK would have to put in place a statutory instrument. The UK will also fall out of EU trade agreements with (other) 3rd countries and would be hit with the GATT 97 tariff wall. Even trading electricity with Ireland without an EU deal would be an issue.

4. Discussion

Through this analysis and the scoping review we have identified eight priority barriers (sub-themes) under two overall themes – governance/legislative barriers and technological barriers. The following summarise each of those two themes and sub-themes.

4.1 Technological barriers including cost of technology solutions

4.1.1. HVDC technology; converters; overland lines; transformers

Other than Spain and Poland, the areas furthest behind in interconnection are Malta, Cyprus and large Greek and Italian islands (Crete, Sicily) (Puka, & Szulecki, 2014; Micallef, 2011; Silva et al., 2017). Some studies also identify the “offshore triangle” of the British Isles, Norway and Germany as in need of further interconnection. It has been designated by TEN-E (Trans-European Networks for Energy) as one of four priority electricity infrastructure corridors (Sunila et al., 2019). Connecting the European islands or any offshore wind farm to mainland Europe requires more expensive underwater HVDC cables (Andersen, 2014). Since HVDC can only transmit 1000 MW, for bulk transmission many cables have to be installed in parallel, increasing costs further. Additionally, there is a small number of suppliers of HVDC cables. Andersen (2014) thus cautions that due to technical immaturity, financing for HVDC is particularly challenging to find.

Offshore wind farms in Europe are often relatively close to several states and so it may be beneficial to create connections with more than one country. Meshed offshore grids (MOGs) are such *“integrated offshore infrastructure where offshore wind power hubs are interconnected to several countries as opposed to radial connection linking the wind farm to one single country and market”* (Sunila, et al., 2019; PROMOTION, 2019). However, the majority of undersea trading cables are line-commutated convertors (LCC), which cannot be cheaply upgraded to transnational wind-farms.

Voltage source convertors (VSCs) for this are costly and lead to a lower Energy Return on Investment (EROI). There is, additionally to VSC immaturity, the technical issue of breakers for HVDC – these currently do not exist. This means that if there is an outage in one windfarm, the entire meshed offshore grid is taken out. This leads to energy companies’ and TSOs’ reluctance to invest in MOGs. German windfarms use HVDC which lends itself to easier meshing and enables transmission of longer distances, but UK, Danish and Dutch offshore windfarms mainly use cheaper HVAC transmission systems, which cannot be connected. The reason that this approach was taken is that the windturbines themselves use alternating current (AC) and German windfarms thus require expensive AC-DC converters at sea - also prone to outage (Andersen, 2014).

More expensive DC underground cables are also needed for crossborder interconnections on land due to poor public acceptance of overhead lines (Ciupuliga, & Cuppen, 2013; Menges, & Beyer, 2014). It may be that the public would be even less inclined to accept lines for energy export (Ciupuliga, & Cuppen, 2013; Devine-Wright, 2013). For example, the Baixas-Santa Llogaia interconnector, “Europe’s first integrated onshore HVDC interconnection” (Francos et al., 2012), between France and Spain took 30 years to be approved and built. In order to cope with public protests against overhead lines, in 2006 France and Spain asked the European Commission to provide a European facilitator/mediator for the project (Ciupuliga, & Cuppen, 2013).

Costly transformers are also needed to equalize voltage between different TSOs (Newman, 2015; ENTSO-E, 2017).

4.1.2. Loop flows

A loop flow occurs when electricity generated in one place encounters congestion in the grid and therefore flows through other (countries’) grids, to reach the consumer. Loop flows, unscheduled flows, lead to free-riding, congestion and issues of cost-sharing. Currently only about 30% of physical electricity infrastructure capacity is used for trade (European Parliament, 2019; Simon, 2018). TSOs usually shut off cross-border trade in case of congestion due to loop flows.

4.2. Governance/legislative barriers

4.2.1. Finance model

Under the Regulated Asset Base (RAB) model, capital expenditures are usually passed on to consumers. This is problematic as member states with some of the more significant interconnection needs are former communist and poorer Mediterranean states already experiencing high energy poverty (Bouzarovski & Tirado Herrero, 2017). Raising electricity prices to the level that would trigger the required investment is thus politically too sensitive.

Merchant model financing is the norm in many locations outside the European Union, especially in North America. In the EU, it is only allowed in very limited circumstances. Financial risk is higher under the merchant model and thus investors expect a shorter payback period, making it in that sense more attractive. EU opposition to the merchant model in and of itself deters a lot of private capital, especially from abroad.

Due to longer payback periods under the RAB model, long term-oriented pension funds and insurance companies would be natural investors. However, these often choose to invest in already operating assets over planned projects. Pension funds are also regionally specific and predisposed to investment in their national territories (OECD, 2015).

Additionally, many TSOs are restricted in their access to equity by their country's regulatory framework (European Commission, 2018). With the exception of Elia and TenneT, all TSOs are purely national (de Clercq, Jewkes & Davies, 2013). Nonetheless, even TenneT placed transmission restrictions on their Denmark – Germany connection, for which they were fined by the European Commission as an antitrust breach (Eckert, 2018).

4.2.2. Electricity monopolies, unbundling

About one third of European TSOs are not unbundled, thus still own both power plants and the transmission infrastructure (Council of European Energy Regulators, 2016, p.7). This represents further perverse incentives to not expand transmission as additional electricity imports would create competition for the power plants owned. National electricity companies are often close to monopolistic in their respective nation states (van Nuffel et al., 2017) and thus have strong lobbying power to thwart further interconnection.

Profit from interconnectors comes from price differences between two electricity zones and congestion in the network. TSOs are the entities in charge of building additional interconnection and yet gain from auctioning off capacity in times of grid congestion. This provides a perverse incentive. To counter this issue, EU regulations stipulate that TSOs need to reinvest income from grid congestion auctions either to build more interconnection – which however then would lower their future income from congestion auctions – or to lower their tariffs. Neither of these options would incentivise investment. Flynn argues that British wind investors are not interested in further crossborder interconnection since *“their core business model is selling wind electricity into the UK and gaining premiums for that via CfD auctions”* (Flynn, 2016). Engie, RWE, Scottish Power and EDF all argued against interconnection in the case of the Greenlink project, stating that this would create unwanted economic competition for them (Dutton & Lockwood, 2017).

4.2.3. Lack of harmonisation across Member States

Due to RE intermittency, several countries introduced capacity remuneration mechanisms (CRM) for coal plants and other conventional power plants to provide continued capacity – even though this otherwise could become uneconomic. CRMs are not harmonised. Foreign generators and interconnection are not taken into account. This is a disincentive to further interconnection investment. CRMs accord different participation rights to imported electricity/interconnectors: from Spain and Portugal, where they cannot participate at all, to the UK (Höschle, Le Cadre, & Belmans, 2018), where from 2019/2020 onwards in theory interconnectors will be able to contribute 2900 MW, a figure which will be deducted from installed capacity generation (Cepeda, 2018). While Hoeschle, Le Cadre and Belmans (2018) believe inclusion of imported capacity provides a positive investment signal, Mastropietro, Rodilla and Batlle (2015) caution that *“paradoxically [...] the presence of cross-border interconnection could increase the amount of capacity to be procured and could result in overinvestment in the country implementing the CRM.”* Meyer and Gore (2015) believe CRMs are detrimental for consumers and producers. Grigorjeva (2015) instead recalls that the German government has argued that France's CRM will be good for German consumers, since due to crossborder interconnection greater capacity in France will result in cheaper prices for German consumers without further investments.

In the case of a crossborder interconnection transporting RE or connecting an offshore wind farm, a project would likely be able to benefit from subsidies – but these are national. This has led to conflicts and European Court of Justice (ECJ) cases. In the 2014 cases “Ålands Vindkraft vs. Swedish Energy Agency” (C-573/12) and “Essent vs Flanders DSO” (C-204 to 208/12), the European Court of Justice upheld member states’ rights to exclude foreign RE entities from accessing generation subsidies in certain circumstances (Durand & Keay, 2014; Szydło, 2015). This favours national electricity production, the disparate geographical RE potential in Europe notwithstanding. However, the subsequent C-492/14 case (2016), again involving energy company Essent importing Dutch RE to Flanders, ruled preferential grid tariffs could not exclude electricity import (Penttinen, 2018). Due to the subsidies issues, the COBRA cable, a PCI by Dutch-German TenneT and Danish Energinet and going through German waters, was not interconnected to Germany initially (Flynn, 2016).

Other harmonisation issues are the crossborder day-ahead market (PCR) and the intraday market (XBID). Crossborder interconnection use improved for countries after joining the PCR (Gomez et al., 2019). XBID, under the Target Model, allows for participants to order electricity in one market and for that to automatically be met by capacity from another market if transmission capacity is available (Le, Ilea & Bovo, 2019). Glachant (2016) nonetheless argues that the Target Model is deeply flawed as it continues national TSO fiefdoms and pre-dates RE expansion, which the system cannot cope with well. Whereas for PCR and XBID, pricing “*is based on implicit auctions (uniform clearing price for energy reflecting cross-zonal congestion)*”, “*in the continuous trading mode [...] the associated cross-zonal capacity [is] allocated for free [...]*” (Glachant, 2016). Balancing markets similarly have not been harmonised yet and operating reserve types to be used need to be decided at European level (Gomez et al., 2019).

Issues of harmonisation besieged the KriegersFlak project, the first “hybrid project” - offshore wind energy project feeding electricity into more than one market. Initially, German, Danish and Swedish TSOs did a cost-benefit analysis regarding a trilateral project. However, regulatory differences meant investment by Sweden would not make sense and the Swedish TSO withdrew from KriegersFlak in 2010 (Meeus, 2014; Mekonnen, Huang & de Vos, 2016). There are three competing régimes which make cross-border cooperation complex - countries either apply deep connection, shallow connection or supershallow connection charging policies. In the case of a deep connection charging policy, the wind farm developers are responsible for the costs of connecting the windfarm to the main grid and any reinforcement requirement. A shallow connection charging policy means that the generators are only responsible for the costs of the wind farm connection to the main grid. Finally, in a supershallow connection charging system the TSOs are instead responsible for the costs of the connection to the main grid (van Nuffel et al., 2017).

The grid tariffs that a regulated electricity company is allowed to charge are also not harmonised – it can be either “cost-plus”, “incentive-based”, “performance-based” or “output-based”. In the cost-plus remuneration system, the company is entitled to OPEX and an ‘allowed’ profit margin, which critics argue means that one way for the company to make more money is to artificially increase ‘costs’ (Matschoss et al., 2019). The remuneration can furthermore depend on whether it is calculated based on the grid congestion level or on physical capacity transmitted (van Nuffel et al., 2017; Mekonnen et al., 2016).

4.2.4. Inter-TSO compensation (ITC)

A country may function primarily as transmission transit state and while interconnectors will be physically on their soil, they will not benefit from the increased transmission. In the case of electricity export demand from a country with higher electricity prices, the price may even go up. It is therefore necessary to find ways to remunerate transit countries. To address this, the Inter-TSO Compensation mechanism (ITC) was created. It is however in need of reform. The biggest issue is that the ITC treats

existing lines and planned lines in the same way – thus countries with existing lines can get the most money (Neuhoff, Boyd & Glachant, 2012). Hadush, de Jonghe and Belmans (2015) in their assessment find no strong correlation between actual transit and Inter-TSO compensation (ITC). Currently, the ITC is too small to entice investment, too complex to be explained to potential private investors easily and is not taken into account in investment decisions.

4.2.5. Investment volume needed surpasses TSOs' capacity

Former communist and smaller island states' TSOs are under greater financial pressure due to previous lack of interconnection while often lacking knowledge of how to attract funding. Some TSOs have little experience of outside finance and a PCI may have been the first time the TSO interacts with outside finance (Ammermann et al., 2016).

4.2.6. Capital reserve requirements

The 3rd Basel Accord contains international banking regulations, to be implemented by 2019. Basel III redefined assets that qualify as capital and increased the minimum amount capital a bank needs to hold. Similar regulations exist for insurance companies and pension funds (European Commission directive Solvency II, IORP II). Insurance companies are a major investor in interconnection projects. These requirements mean a higher cost of capital for any infrastructure project (Narbel, 2013; Breitschopf & Pudlik, 2013; Ang, Röttgers & Burli, 2017).

5. Conclusions

In this paper we have delineated key barriers to investment in crossborder interconnection in Europe found after a scoping literature review and workshop with stakeholders in energy, law and finance.

While infrastructure risk remains even without crossborder connections to reduce the crossborder specific risks further European harmonisation is tantamount. This includes the voltage that we use, subsidies for renewable energy as well as CRMs and charging regimes. Unbundling of TSOs will need to be completed to avoid internal disincentives to investment. Permitting has to become further streamlined. To solve the systemic incongruences concerning meshed offgrid, Gorenstein-Dedecca et al. (2018) and Sunila et al. (2019) urgently suggest the introduction of a European supranational TSO responsible for all offshore windfarms.

In order to make projects more attractive to outside investors, the introduction of Offshore Transmission Owner (OfTO) style licences to European projects other than offshore wind has been suggested. In the British OfTO remuneration, the cost of the debt on the asset is paid across the whole RAB and not just the particular invested asset lowering the risk on equity investments (Fitch-Roy, 2016; Bhagwat & Lind, 2018; Meeus, 2014). Another suggestion has been the expansion of also predominantly British YieldCo, where RE assets are bundled together to de-risk these energy infrastructure projects. To tackle some TSOs' unattractiveness for outside investment due to bad risk ratings, Ammermann et al. (2016) suggest separating PCIs from the rest of the TSO's work to de-risk the PCI.

It likely that technological barriers can be overcome with more research and development as well as more deployment of HVDC breakers and subsea cables so that the technology learning curve can help drive prices to a more affordable level. Therefore, it is key that the EU prioritises this research investment through programmes such as Horizon Europe. To address loop flows, the European Commission Expert Group on Interconnection suggests that *"the costs of remedial actions should be shared based on the 'polluter-pays principle', where the unscheduled flows over the overloaded network elements should be identified as 'polluters' and they should contribute to the costs in proportion to their contribution to the overload"* (EC, 2017, p.16).

These suggestions nonetheless do not address all underlying dilemmas concerning perverse incentives stemming from the overall business model – intrinsic issues. This includes the lobbying power of the almost monopoly companies, congestion rent and price differentials as driving force for (non)investment. As long as there is no sensible price on carbon and regulatory questions of crossborder interconnection projects, conservative investors like pension funds may still prefer fossil fuels or national RE projects. However, the growing momentum towards zero carbon targets coupled with campaigns for divestment from fossil fuels represents an opportunity for radical change within the energy sector.

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7. Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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9. Appendix A

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