Mapping of renewable energy projects with regional impact

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Mapping of renewable energy projects with regional impact

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Abstract

The objective of this study is to provide supporting evidence which analyses the role of renewable energy generation projects with regional impact as a driver for more successful implementation of the Fit for 55 package and the increased ambition for renewable energy and support the swift implementation of such projects.

The study aims to assist the Commission in implementing the policy for support of the deployment of renewables in line with the European Green Deal objectives and the increased ambition for renewables by the revised Renewable Energy Directive, by utilising the untapped potential of the cooperation between Member States on renewables.

This study provides a clear overview on the existing and planned concrete renewable energy projects having cross-border relevance, by defining a set of criteria for defining renewable energy projects that are relevant in a regional context. It identifies the various administrative, financial, political or legal barriers to regional and cross-border cooperation and propose solutions for overcoming them as wel as concrete means to support the implementation of such projects.

The assessment focuses on the lessons learnt (what worked, what didn't and why?) to derive recommendations for actors / EU Member States that may wish to engage in regional cooperation for RES deployment. This clear state of play of regional and cross-border projects and the options to address existing barriers aim to allow the Commission and the Member States to address such barriers, to share successful examples of policies and measures, and to agree on intensifying the cooperation in a more effective manner.

This study aims to explore and analyse regional and cross-border cooperation in renewable energy within the European Union, focusing on the frameworks, practices, and impacts of these cooperations.

Specific objectives include:

- Defining the scope and criteria for what constitutes effective regional cooperation in renewable energy projects.
- Mapping existing projects that fit the proposed scope and criteria.
- Identifying barriers to effective cooperation and proposing solutions to enhance the efficacy of these cooperative efforts.
- Highlighting successful cooperation models and extracting actionable insights that can guide future policy and implementation.

Executive summary

Member States have a collective responsibility for achieving the 2030 targets for renewable energy sources (RES). Not all Member States possess the same potential for renewable energy, thus implying diverse strategies and necessitating a collaborative approach to harnessing the full potential of RES across Europe.

The Renewable Energy Directive (RED II) facilitates such cooperation through various mechanisms outlined in articles 7 to 11 such as joint projects, statistical transfers, or joint support schemes between member states. They ensure coordinated efforts and shared benefits in achieving EU renewable energy targets. Historically, Member States have predominantly utilised statistical transfers to meet their RES targets. This method, while effective in aligning with the stipulated goals, often does not lead to the actual realisation of cross-border renewable energy projects (CB RES). Going forward, Member States are expected to move beyond this virtual approach towards the development of tangible CB RES projects as required by the revised Renewable Energy Directive (RED III)[1].

This report, 'Mapping of Renewable Energy Projects with Regional Impact', was commissioned by the European Commission's Directorate-General for Energy. It provides a comprehensive analysis of renewable energy projects across the EU that have significant regional implications. These projects are essential to supporting the EU's commitment to the European Green Deal and the objectives outlined in the RED II. The focus is on fostering cross-border cooperation and enhancing the EU's energy security and sustainability.

The primary objective of this report is to identify and map significant renewable energy projects that illustrate or can facilitate regional cooperation among Member States. It aims to assess the potential of these projects to contribute to the EU's energy targets by highlighting lessons learned on the challenges and opportunities they present.

The methodology employed in this study includes a comprehensive literature review, interviews with key stakeholders and extensive desk research. The selection criteria for projects focused on their scale, regional impact, involvement of multiple countries and alignment with EU energy policies. Overall, 200 projects were identified, representing a diverse range of renewable energy sources including wind (both onshore and offshore), solar, hydroelectric, biomass and emerging technologies like Power-to-X.

Final definition and criteria

In the course of the study, the following final definition and criteria for renewable energy projects with regional impact were developed:

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[1] By 31 December 2025, each Member State shall agree to establish a framework for cooperation on joint projects with one or more other Member States for the production of renewable energy

A renewable energy project with regional impact is an installation generating renewable energy in Europe and concerning one or more other countries because of either

1. The direct involvement of another country
2. The impact on the regional electricity grid or market
3. The potential (indirect) impact on the regional energy systems and environment

Each set of criteria corresponds to specific project types. Under the first criterion, the following types of projects are mapped:

- *1. Projects officially **recognised by the EU** as having regional impact and/or **directly involving** at least **two countries.*** [2]

Under the second criterion fall the following projects:

- *2a. Renewable energy installations subject to a **cross-border PPA** above 8 GWh*
- *2b. Transmission grid-connected renewable electricity installations with nominal capacity **above 2% of the country's total outgoing interconnection capacity,** with a minimum of 100MW**.***

Under the third criterion fall the following projects:

- *3a. Renewable energy installations generating renewable energy from regional flows of **renewable fuel** totalling at least **120GWh per year;***
- *3b. Renewable **Power-to-X** production installations exporting **at least 120GWh per year.***

Key Findings

Project Types and Analysis

Diversity of projects: The projects vary significantly in terms of technology, scale and regional coverage, indicating a robust engagement across the EU in renewable energy development and no one-size-fits all approach.

RES technology: The 193 identified projects cover all major RES (renewable energy source) generation technologies and in many cases a combination of them. Wind technology is used from 59% of the identified projects (of which 54% are onshore and 46% are offshore). Solar photovoltaic (PV) follows with a share of 19% and then hydroelectric with a share of 12%. From the remaining technologies, 9% of the projects use Power-to-X where we see the emergence

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[2] Projects officially recognised by the EU as having regional impact and/or directly involving at least two countries are those that meet specific criteria and are included in certain key lists or initiatives. These projects are typically part of the Connecting Europe Facility (CEF), the Cross-Border Renewable Energy (CB RES) mechanism, or the Projects of Common Interest (PCI) list. Inclusion in these lists means that the projects are acknowledged by the EU for their strategic importance in enhancing cross-border cooperation, improving regional energy infrastructure, and contributing to the EU's renewable energy and climate goals. These recognitions often come with certain benefits, such as access to funding, streamlined regulatory processes, and enhanced political and technical support.

Direct involvement of at least two countries in a project typically implies the existence of cooperation agreements under Renewable Energy Directive (RED) articles 7 and others. These agreements facilitate joint projects, statistical transfers, or joint support schemes between member states, ensuring coordinated efforts and shared benefits in achieving renewable energy targets.

of H2 as an energy vector, 4% are related to biomass and 1% use geothermal or biogas. Cooperation mechanisms such as statistical transfers cover 8% of the cases.

Geographic spread: The projects' geographic location is spread across Europe as a function of the available primary resources. The majority, i.e. 53% of the identified projects, are located in the North Seas Energy Cooperation (NSEC) region, of which 37% use wind technology. The Baltic Energy Market Interconnection Plan (BEMIP) region follows with 30% of the identified projects where again the vast majority are wind farms (72%). It is in these two regions that we see i) the emergence of new concepts such as the hybrid projects (combination of RES and interconnection) with expected capacities at the GW scale and ii) the use of the cooperation mechanisms such as joint support schemes and statistical transfers. On the contrary, the majority of identified projects in the South-West Europe (21% of all identified projects) use solar PV (58%) with power purchase aggrements (PPAs) financing 43% of the cases. Interestingly, the emergence of virtual PPAs is pronounced in this region with a share of 67% from all the identified projects across Europe. Finally, 19% of the identified projects are located in the CESEC region with an almost equal share among PV, Wind, Hydroelectric and Power-to-X.

Project capacities: 12% have capacities less than 100 MW, 28% have capacities between 100 MW and 200 MW, 33% have capacities between 200 MW and 500 MW and finally 28% have capacities above 500 MW. Specifically for the big projects with capacities above 500 MW, 76% use wind technology and 13% are related to Power-to-X (mainly projects described as H2 valleys and H2 clusters). Interestingly, 73% of those big projects are located in Northern Europe where we also see the emergence of the hybrid projects (27% of the > 500 MW projects).

Financing of RES installations: From all identified projects, 8% have received EU funding with the majority (75%) being projects located in Northern Europe. Power purchase aggreements finance 13% of the projects of which 65% are located in the South-West Europe while 62% of them are virtual PPAs.

Cross-border collaboration: A significant number of projects involve collaboration between two or more Member States, demonstrating a strong regional integration, ashared commitment to renewable energy goals and the relevance of the existing cooperation mechanisms.

Challenges

The report uncovers several key challenges that hinder the execution of cross-border renewable energy projects:

1. **Regulatory divergence**[3]: variations in national regulations create complex administrative environments that can delay or deter project implementation. Different Member States have distinct permitting processes for renewable energy projects, which can vary widely in terms of length, complexity and requirements. For instance, one country might offer a streamlined, expedited permitting process for wind farms, while a neighbouring country could have a more cumbersome and lengthy process

[3] For example, Spain has implemented a series of reforms to simplify the administrative procedures for solar photovoltaic (PV) projects. This includes the Royal Decree-Law 15/2018, which aimed to eliminate barriers to renewable energy deployment, including the simplification of the administrative and permit-granting procedures for small-scale solar installations. On the other hand, Italy has a more complex regulatory environment that can be a challenge for new solar projects. The Italian permitting process involves multiple administrative steps and can vary significantly between different regions, affecting the consistency and predictability of project timelines.

involving multiple levels of government approvals. This variation can deter developers from initiating projects where the bureaucratic process is perceived as a barrier, despite the availability of EU funds or policy support.

2. **Lack of technical harmonisation**[4]: compliance with different grid code requirements. Grid codes, which define the technical and operational requirements for connecting to and using the electrical grid, also vary between countries. Compliance with these codes is mandatory for the integration of renewable energy sources into the national grid. For example, a renewable energy project that spans multiple countries may need to meet different technical standards in each country for frequency and voltage control, which can complicate the design, increase the cost, and extend the timeline of the project.
3. **Financial constraints**[5]: limited access to financial resources and high-risk perceptions can stymie the development of large-scale renewable projects. The barrier of financial constraints and high-risk perceptions can be more pronounced in specific regions within the EU, particularly affecting the development of large-scale renewable energy projects. These financial challenges often vary by region due to economic disparities, the maturity of the financial markets and the existing energy infrastructure. In all these regions, overcoming financial constraints often requires innovative financing solutions such as public-private partnerships, EU-backed funding mechanisms or the use of green bonds and other financial instruments designed to lower the risk profile of renewable energy investments. Enhanced EU-wide financial support and more stable, predictable regulatory environments can help mitigate these challenges and unlock the potential for renewable energy development across different regions.
4. **Infrastructure challenges**: ageing and weak distribution grids. In many parts of the EU, especially in eastern and southern Europe, the existing electrical grid infrastructure is ageing and not fully equipped to handle the influx of variable renewable energy sources. The integration of renewables often requires upgrades to transformers, substations and transmission lines to handle higher loads and maintain grid stability. In addition, the process and costs associated with connecting to the grid can be prohibitive, especially in remote areas where the grid infrastructure may be weaker. For instance, in remote regions of Portugal or Bulgaria, connecting a new solar or wind farm to the nearest grid point can involve extensive and costly transmission lines. Moreover, the financial burden of these upgrades often falls on the project developers, adding to the overall cost of renewable energy projects.

Recommendations

To address these challenges, the report recommends the following strategic actions:

1. **Regulatory harmonisation**: Regulatory harmonisation, including the standardisation of network codes, is crucial for simplifying the integration and operation of renewable energy projects across the EU. It reduces administrative barriers, enhances cross-

[4] Germany and France have different requirements for the integration of renewable energy systems, particularly concerning the reactive power capability and voltage control. A renewable energy project that spans these two countries would need to ensure that its systems can comply with both sets of standards, potentially increasing the complexity and cost of the project.

[5] Member states in Central and Eastern Europe region, including Bulgaria, Romania, and Hungary, often face significant financial challenges in developing large-scale renewable projects. These countries typically have less developed financial markets and fewer domestic financial institutions that can provide the necessary capital for large projects. Moreover, these regions sometimes have higher perceived political and regulatory risks, which can deter foreign investment and increase the cost of capital. Investors may be cautious due to concerns about stability in regulatory frameworks, the enforcement of agreements, and the potential for sudden policy changes. Similarly, Member States in the southern Europe region such as Greece, Italy, and Spain have experienced economic turbulence and fiscal crises in the past, which have impacted their ability to finance large-scale renewable projects. Although these countries have substantial solar and wind resources, the financial crises and subsequent austerity measures have constrained public and private spending in the energy sector. These financial constraints are compounded by high levels of public debt and reduced credit ratings, which can make it more expensive and challenging to secure financing for renewable energy projects.

border energy trade and creates a more attractive investment environment by providing predictable and consistent regulatory standard.

2. **Enhanced financial support**: The EU should consider expanding existing financial instruments and introducing new incentives to support cross-border renewable energy projects, particularly in regions that lack adequate funding, as explained in the previous section on challenges.
3. **Strengthened infrastructure**: Investment in cross-border electricity transmission infrastructure needs to be prioritised to ensure efficient energy transmission and integration of renewable sources across the EU. This means enhancing the physical links that allow electricity to be transmitted across borders, which is crucial for integrating renewable energy sources effectively. Enhanced interconnections help balance the variable supply of renewable energy, such as solar and wind, by enabling excess electricity to be shared across regions and countries. This facilitates a more stable and resilient energy grid, optimises resource use and supports the EU's goals for a single energy market and energy security.
4. **Stakeholder engagement**: It is crucial to cultivate a cooperative environment where governments, industry players and local communities engage actively and consistently from the initial planning stages through to the implementation of projects. This engagement ensures that all parties contribute to and support the development, resulting in projects that are not only technically and economically viable but also broadly accepted by the community.

Conclusion

The 'Mapping of Renewable Energy Projects with Regional Impact' report underscores the essential role these projects serve in fulfilling the EU's energy and climate goals. By addressing identified challenges and maximising opportunities for collaboration, the EU can bolster its energy security, achieve sustainability objectives and enhance the regional integration of its energy markets. For Member States and project developers, cooperation on these impactful projects not only pools resources and expertise, enhancing the efficiency and scale of renewable energy deployment, but also improves access to financial support mechanisms like the Connecting Europe Facility (CEF). One of the many examples of successful cooperation under the Renewable Energy Directive (RED) framework supported by CEF is the Baltic Energy Market Interconnection Plan, which has significantly advanced the integration of electricity and gas markets across the Baltic Sea region, demonstrating the tangible benefits of cross-border collaboration.

While many of the identified projects benefit from alignment with key EU policy frameworks and receive financial support from various EU funds, there remains a significant untapped potential for cross-border renewable energy projects. Addressing the barriers identified in this report, and notably enhancing the harmonisation of national regulatory frameworks, could further facilitate project development and implementation. This strategic alignment, coupled with continued financial backing from the EU, is crucial for realising the full potential of cross-border initiatives and achieving broader regional energy goals.

Structure of the report

Chapter One outlines the context of regional and cross-border cooperation for renewable energy within the European Union. It introduces the concept of cooperation between two or more countries aimed at enhancing renewable energy deployment through various mechanisms, such as joint projects and support schemes. This chapter sets the stage by discussing the EU's legislative framework, including the recast Renewable Energy Directive and the Energy Union Governance Regulation, which facilitate this cooperation. It also highlights the strategic roles of High-Level Groups in steering and monitoring these cooperative efforts, which is crucial for achieving the EU's climate neutrality goals.

Chapter Two establishes the definitions and criteria used to evaluate regional cooperation in renewable energy projects. It discusses the parameters for assessing the impact of these projects, including economic, environmental and technical aspects, which will be instrumental in mapping and analysing the projects in subsequent chapters.

Chapter Three provides a comprehensive mapping of current renewable energy projects that fall within the previously defined criteria. It examines the distribution, scale and types of cooperation across the EU, offering a detailed look at how these projects contribute to regional energy goals.

Chapter Four identifies and explores the main challenges hindering effective regional cooperation. It also assesses opportunities that could potentially enhance collaboration among Member States, focusing on policy, financial mechanisms and administrative processes.

The concluding Chapter Five summarises the study's key findings and offers recommendations for improving regional cooperation on renewable energy within the EU. It outlines strategic directions and policy suggestions aimed at enhancing the implementation and effectiveness of cross-border renewable energy projects.

Abbreviations

ACER	EU Agency for the Cooperation of Energy Regulators
BEMIP	Baltic Energy Market Interconnection Plan
CBCA	Cross-border Cost Allocation
CB-RES	Cross Border Renewable Energy Sources
CEF	Connecting Europe Facility
CESEC	Central and South Eastern Europe Energy Connectivity
CfD	Contract for Difference (Scheme in Estonia designed to promote the use of Renewable Energy Sources)
CINEA	European Climate, Infrastructure and Environment Executive Agency
DG ENER	Directorate-General for Energy
EC	European Commission
EEA	European Environment Agency
EU	European Union
Eurostat	European Statistics
GDP	Gross Domestic Product
GoO	Guarantee of Origin
GWh	Gigawatt hours
HLG	High-Level Group
HVDC	High-voltage Direct Current
IRENA	International Renewable Energy Agency
kV	Kilovolt
MOU	Memorandum of Understanding
MS	Member State
MW	Megawatt
NECP	National Energy and Climate Plans
NGO	Non-Governmental Organization
NSEC	North Sea Energy Cooperation
NTSO	National Transmission System Operator
NUTS	Nomenclature of Territorial Units for Statistics
PCI	Project of Common Interest
PESTLE	Political, Economical, Social, Technological, Legal, Environmental
PMI	Project of Mutual Interest
PPA	Power Purchase Agreement
PV	Photovoltaics
RE	Renewable Energy
RED	Renewable Energy Directive
RES	Renewable Energy Sources
TEN	Trans-European Network
TEN-E	Trans-European Networks for Energy
TRL	Technology Readiness Levels
TSO	Transmission System Operator
UK	United Kingdom

1. Introduction

1.1. Existing mechanisms for regional cooperation. State of play

Regional and cross-border cooperation in the context of this study primarily involves collaboration between two or more countries to deploy renewable energy sources through joint projects, support schemes and the shared utilisation of resources. Such cooperation is key to achieving a climate-neutral energy system, as emphasised by the EU's strategic framework.

The revised Renewable Energy Directive (2023/2413/EU) provides Member States with a set of instruments to facilitate cross-border renewable energy cooperation. These range from ex-post transfers of statistical benefits to the development of joint projects or joint support schemes.

Furthermore, the Energy Union Governance Regulation (Regulation (EU) 2018/1999) enhances this framework by requiring Member States to outline specific measures for regional cooperation in their National Energy and Climate Plans (NECPs). These plans should detail actions for improving market integration, enhancing energy security and facilitating the transition towards renewable energy, with a focus on sharing excess production and benefits across borders.[6]

The EU also supports these initiatives through financial instruments and dedicated programmes, such as the Connecting Europe Facility for cross-border renewable energy projects (CEF CB RES) and the EU Renewable Energy Financing Mechanism (REFM), which help to harmonise actions and finance joint projects.

This structured approach to regional cooperation ensures that Member States can effectively meet their energy and climate targets while fostering economic integration and ensuring a secure and sustainable energy supply across the continent.

The subsections below describe these different types of cooperation mechanisms.

1.1.1. National support schemes or joint support schemes

A policy development in the EU that favours cross-border cooperation is the (partial) opening of the regular national support schemes to installations located in other countries. In practice, opening a national support scheme means that a Member State holds a cross-border auction. Such an auction can be take several forms: the Member State can unilaterally open its support scheme; both parties can mutually open their support schemes; and the cooperating parties can jointly design a joint support scheme. In Article 5, the revised Renewable Energy Directive (2018/2001/EU) calls upon the Member States to voluntarily open their support schemes to another Member State.

Two or more EU countries can also co-fund a joint support scheme to spur renewable energy production in one or both of their territories. This form of cooperation can involve measures such as a common feed-in tariff, a common feed-in premium and a common quota and certificate trading regime.

In November 2022, the Commission published the report 'Guidance on cost-benefit sharing in RES cooperation project', which aims to support EU countries willing to engage in cross-border cooperation projects in the area of renewable energy generation, helping them find a mutually beneficial solution to share the related costs and benefits. Despite being a promising avenue

[6] Annex I, part 1, Policies and Measures, dimension decarbonisation - RES, 3.1.2 ii.

for cooperative renewable energy promotion, the application of joint support schemes has been scarce. This mechanism involves shared financial incentives such as feed-in tariffs or premiums across borders. The primary deterrent has been the complexity of aligning national policies and financial commitments. A pilot joint support scheme initiated by Germany and Denmark in 2021 demonstrated potential benefits, such as reduced costs and increased market integration. However, the scheme also highlighted challenges, including the need for a robust framework to handle the discrepancies in national energy pricing and subsidy structures.

1.1.2. Joint renewable energy projects

According to Article 9 of the recast Renewable Energy Directive (2018/2001/EU), two or more Member States may cooperate on all types of joint projects with regard to the production of electricity, heating or cooling from renewable sources. Such cooperation may involve private operators.

According to Article 11 of the revised Renewable Energy Directive (2018/2001/EU), “one or more Member States may cooperate with one or more third countries on all types of joint projects with regard to the production of electricity from renewable sources”. The article further specifies prerequisites for the cooperation.

Joint projects defined in line with the revised Renewable Energy Directive (2018/2001/EU) can be supported by a new funding line laid down in the revised Connecting Europe Facility (CEF) regulation for “cross-border renewables projects” with funding from the Multiannual Financial Framework 2021-2027, as explained further below.

Joint projects, as envisioned by Article 9 of the Renewable Energy Directive, allow Member States to collaborate on renewable energy production facilities. Despite the potential for cost savings and efficiency improvements, the uptake of joint projects has been limited. For example, between 2018 and 2022, only a handful of joint projects were initiated, and even fewer reached completion. The slow adoption can largely be attributed to high initial coordination costs and legal complexities involved in cross-border agreements. An exemplary case is the Baltic Wind Connection project between Estonia and Latvia, which, despite its eventual success, faced prolonged negotiations and regulatory hurdles that delayed its implementation by nearly three years.

1.1.3. Statistical transfers

According to Article 8 of Directive (EU) 2018/2001, Member States may agree on the statistical transfer of a specified amount of energy from renewable sources from one Member State to another. In a statistical transfer, an amount of renewable energy is deducted from one country's progress towards its target and added to another's. This is simply an accounting procedure, as no actual energy changes hands. By allowing transfers of this kind, this cooperation mechanism provides EU countries with an added incentive to exceed their targets, since they can receive a payment for energy transferred to others. It also allows countries with less cost-effective renewable energy sources to achieve their targets at a lower cost.

In November 2021, the Commission launched the Union Renewables Development Platform to facilitate statistical transfers of renewable energy between EU countries. It provides national EU administrations with relevant information and offers a tool to help countries find potential partners and agree on the conditions of a statistical transfer. The platform can help EU countries increase their statistical share of renewable energy to meet both the national 2020 target and the planned contribution to the 2030 target.

Statistical transfers are the most utilised cooperation mechanism, primarily due to their simplicity and the directness of their implementation. These allow countries with excess renewable production to transfer part of their surplus to countries falling short of their targets, purely through accounting measures without physical energy flows. Luxembourg and Malta have frequently engaged in statistical transfers, benefiting from the flexibility this mechanism offers to meet their renewable targets economically. The preference for statistical transfers underscores a strategic choice by smaller nations to leverage financial efficiency over infrastructural investments.

1.1.4. EU renewable energy financing mechanism

Cross-border auctions are planned to be implemented by the EU Renewable Energy Financing Mechanism as laid down in Article 33 of the Governance Regulation. It brings together countries that financially support renewable energy projects with countries that accept to host these installations. The statistical benefits are shared on a 80-20% basis per default. The European Commission facilitates this process by organising a cross-border auction, with the support of the executive ageny CINEA, that is tailored to the participating countries preferences in terms of technological focus, capacity volumes and other relevant parameters. The mechanism is open to non-EU countries, which may, however, participate as hosting countries only.

1.1.5. Connecting Europe Facility – Cross border renewable energy projects window

For the period 2021-2027, the Connecting Europe Facility (CEF) 2.0 has been allocated substantial funds to drive significant advancements in transport, energy and digital infrastructures across the EU. Specifically, the energy sector is set to receive around €5.8 billion aimed at enhancing the trans-European energy network.

Article 7 of Regulation (EU) 2021/1153 outlines the support for cross-border renewable energy projects that are pivotal to the EU's decarbonisation efforts. A designated 15% of the CEF's energy budget, around €875 million, is earmarked for projects that directly contribute to the decarbonisation agenda, the completion of the internal energy market and bolstering the security of energy supply.

Those projects shall be included in a cooperation agreement or in any other kind of arrangement between two or more Member States or arrangements between one or more Member States and one or more third countries as set out in Articles 8 (See also Section 1.1.3), 9, 11 (See also Section 1.1.2) and 13 of Directive (EU) 2018/2001. Those projects shall meet the objectives, the general criteria and the procedure laid down in Part IV of the Annex to the Regulation.

By acquiring the official CB RES status, projects are eligible for financial support for studies and works under the CEF Programme. In August 2022, the European Commission established the first list of renewable energy cross-border projects under the Connecting Europe Facility, marking the start of the CEF Programme's dedicated window. This inaugural list includes three projects involving a total of seven Member States: a hybrid offshore wind park between Estonia and Latvia; a cross-border district heating grid based on renewable energy sources (RES) between Germany and Poland; and a project spanning Italy, Spain, and Germany to produce renewable electricity for green hydrogen production, transportation and utilisation in the Netherlands and Germany. The second list adds two more projects, expanding support to diverse technologies such as onshore wind, further elements of the RES fuels value chain and additional RES integration in district heating systems.

1.2. Role of High-Level Groups

The Commission has established four High-Level Groups (HLGs)[7] in different regions of the EU. They consist of representatives from Member States, the European Commission, energy agencies and other stakeholders. HLGs have increasingly become pivotal in shaping energy policy and fostering cooperation within the EU. They can play a strategic role in steering policy directions, facilitating discussions and overcoming barriers to cooperation in the renewable energy sector.

North Seas Energy Cooperation – NSEC aims to advance the development of an offshore grid to tap into the vast renewable energy potential in the region, with Member States including Belgium, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands and Sweden, along with Norway and the European Commission. Following Brexit, the UK rejoined the NSEC in December 2022 under a new Memorandum of Understanding.

Interconnections for South-West Europe – The regional High-Level Group for South-West Europe, established in 2015, oversees the integration of the Iberian Peninsula's energy markets with Europe, ensuring progress on infrastructure projects outlined in the Madrid Declaration. The group includes representatives from the European Commission, ministries, transmission system operators and national regulatory authorities in France, Spain and Portugal.

Central and South Eastern Europe energy connectivity – The CESEC group accelerates gas and electricity market integration in the region, expanding its focus in 2017 to include electricity markets, energy efficiency and renewable energy development.The CESEC High-Level Group was set up by Austria, Bulgaria, Croatia, Greece, Hungary, Italy, Romania, Slovakia and Slovenia and the EU in February 2015.

Baltic energy market interconnection plan – The BEMIP seeks to integrate the Baltic Sea region's electricity and gas markets, ending the energy isolation of Baltic states.The BEMIP members are Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland and Sweden. Norway participates as an observer.

1.2.1. The function and impact of High-Level Groups

1. Steering policy and strategic developments:

By bringing together policymakers, experts, and stakeholders, these groups ensure that the renewable energy agenda aligns with broader EU objectives, such as the Green Deal and the Fit for 55 package. For example, the North Seas Energy Cooperation (NSEC) has been instrumental in developing a coordinated approach to offshore wind energy, which is critical for achieving the EU's renewable energy targets.[8]

2. Facilitating dialogue and partnerships:

HLGs facilitate dialogue between countries and regions, helping to build partnerships that are essential for cross-border energy projects. By providing a platform for regular interactions, these groups enhance mutual understanding and trust among stakeholders, which are crucial for successful collaboration.

3. Addressing barriers with tailored solutions:

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[7] https://energy.ec.europa.eu/topics/infrastructure/high-level-groups_en

[8] https://commission.europa.eu/news/members-north-seas-energy-cooperation-grasp-historic-opportunity-accelerate-europes-move-towards-2022-09-12_en

HLGs actively work to identify and address barriers to cooperation, such as regulatory inconsistencies, lack of infrastructure and financing challenges. They propose solutions and advocate for necessary changes at the EU and national levels. For instance, the Baltic Energy Market Interconnection Plan (BEMIP) has successfully addressed issues related to energy market integration in the Baltic region. Additionally, Estlink 1 and 2 (Estonia, Finland) facilitates the exchange of electricity between the two countries, allowing surplus energy from one side to be transmitted to the other. This interconnection allows for more efficient energy distribution and management, facilitating the integration of renewable energy into the grid. By enabling surplus renewable energy from one country to be shared with another, these links help overcome variability and intermittency issues associated with RES, such as wind or solar power. This ensures a more reliable and steady supply of renewable energy, contributing to regional energy security and the broader goals of the EU's energy market integration and sustainability objectives.

1.2.1. Potential impact of High-Level Groups

1. Streamlining cross-border regulatory frameworks:

High-Level Groups are instrumental in aligning regulatory requirements across borders, which is vital for facilitating cross-border renewable energy projects. By addressing divergent national regulations and standards that can stall project development, HLGs enhance regulatory coherence. This streamlining process enables a smoother initiation and execution of cross-border initiatives, such as the integration of renewable energy grids between neighbouring countries.

2. Fostering shared investment and financial models:

HLGs can advocate for and help develop shared investment schemes and financial models that distribute costs and benefits equitably among participating countries to overcome barriers related to the complexity of financing such projects. This approach not only makes projects more attractive to investors but also ensures that financial burdens and rewards are fairly shared, increasing project viability and sustainability.

3. Enhancing infrastructure development:

Cross-border renewable energy projects frequently require sophisticated infrastructure, such as interconnected grids that can handle variable energy loads and ensure consistent energy supply across borders. HLGs can play a crucial role in prioritising and accelerating infrastructure development, helping to secure funding, streamline permissions and coordinate between national grid operators. This coordination is essential for projects, such as the development of offshore wind farms that benefit multiple countries along the coast.

4. Monitoring and progress evaluation:

HLGs play a pivotal role in fostering significant advances on renewable energy across the EU. By systematically monitoring, evaluating and reporting on the progress of energy projects, they could enable the replication of successful initiatives and facilitate necessary adjustments in areas requiring more support. For instance, the comprehensive evaluations conducted by HLGs can lead to strategic policy recommendations and enhancements in project execution. These activities not only drive forward the EU's energy objectives but also catalyse improvements in cross-border energy cooperation, regulatory alignment, and infrastructure development, ultimately contributing to a more sustainable and integrated European energy market.

5. Promoting technology exchange and capacity building:

HLGs facilitate the exchange of technology and expertise between countries, which is essential for the adoption of advanced renewable technologies in less-developed regions. Through workshops, conferences and joint projects, HLGs encourage a transfer of knowledge that helps all participants enhance their technological capacities and adopt best practices in renewable energy production.

6. Catalysing regional energy markets:

By promoting policies that encourage the creation and expansion of regional energy markets, HLGs contribute to the development of a more integrated European energy market. These markets enable easier energy trading across borders, optimise renewable energy usage and balance supply and demand across regions. This not only improves energy security but also drives down costs and stimulates further investments in renewable energy.

7. Encouraging public and political support:

HLGs can harness their collective voice to advocate for cross-border renewable energy projects, influencing public opinion and political support. By demonstrating the mutual benefits of such projects, these groups can help overcome local resistance and gain the necessary backing from governmental bodies necessary for the projects' success.

The strategic interventions by HLGs have the potential to substantially enhance cross-border cooperation in the renewable energy sector within the EU. Through their efforts in regulatory convergence, financial model development, infrastructure advancement and fostering of regional markets, these groups are pivotal in creating an environment conducive to large-scale renewable energy projects that span national boundaries. Their continued influence will be critical in achieving the EU's ambitious energy and climate targets, making the role of these groups indispensable in Europe's green transition.

2. Defining a "renewable energy project with regional impact"

2.1. Methodology and data sources

Although the topic of regional cooperation has been extensively discussed in previous research, the literature lacks a clearly defined scope and measurable criteria for "regional or cross-border impact" within renewable energy projects. Acknowledging this gap, our initial task was to establish a robust framework for the study, which involved crafting a precise definition of what constitutes regional impact in the context of renewable energy cooperation. This foundational work was crucial not only for guiding our research direction but also for ensuring the relevance and applicability of our findings.

We undertook comprehensive desk research to map existing projects that could potentially illustrate regional impact. This mapping process was integral as it both informed and was shaped by the evolving definitions and criteria, allowing for a dynamic refinement based on real-world examples. The preparatory work highlighted set the stage for the literature review in the following section. The literature review aims to further solidify our definitions and criteria by integrating broader academic and industry perspectives, ensuring that our approach is not only comprehensive but also aligned with current understandings and practices in the field of renewable energy cooperation.

The methodology included the following steps:

- A review of the existing literature on renewable energy projects with cross-border aspects, international support or regional impact. The literature review covered 36 sources, with a focus on attempted renewable energy projects with regional impact in the EU and the factors preventing them from being implemented. They are detailed in Annex 1. It yielded the following insights:
  - Transnational cooperation, according to EU rules, is by and large the dominant scope of the papers that the team assessed. As a result, a vision of regional impact going beyond the official EU collaboration mechanisms is to be developed by the consortium and not simply lifted from the literature.
  - The field has been largely shaped by the 2014 reference study 'Cooperation between EU countries under the RES directive'[9], which is cited and the scope of which is followed in most of the subsequent papers. The main drivers behind cooperation across borders are consistent across papers with a focus on more efficient siting of renewable projects across the EU and avoided costs. National compliance with the 2020 RE targets was also commonly cited as a driver.
  - Several papers, however, explore specific cross-border impacts in the case of renewable energy projects, giving the consortium fragmented hallmarks for impact across countries that are to be reconciled.
- In order to validate the above conclusions from the literature review and confront the first conclusions with experts' perspectives, four advisory interviews were subsequently held. Interviewees and question topics are given in Annex 2. They confirmed no consensual definition of regional impact exists and no comprehensive list of relevant projects is available to the public. They also showed that RED II-compatible

[9] https://energy.ec.europa.eu/publications/cooperation-between-eu-countries-under-res-directive-0_en

cooperation projects have decreased since the 2020 binding RE targets for EU Member States passed their deadline. Other mechanisms have become central instead, including CEF, CB-RES, and the PCI – PMI.

- The scope of the research was refined, in particular its boundaries regarding the geographical focus, the technologies considered and the types of project. This is detailed at the top of section below.
- A stakeholder survey was sent to experts to present the working definition and list of criteria. Its content and answers are detailed in Annex 3. The criteria presented in the survey were thus validated by the survey and presented to DG ENER and CINEA, leading to the framework presented hereafter.

2.2. Definition and the criteria

Beyond a confirmation of the state of play on regional and cross-border cooperation defined through the literature review, the advisory interviews also allowed the project team to test different hypotheses and criteria for impact with expert stakeholders. Their feedback, both on the working definition and what should or should not count as regional impact, allowed the project team to settle on a final definition for each component of "renewable energy projects with regional impact". The following decisions were taken:

- "Renewable energy" was defined as energy transformation based on one of the following technologies: biogas, biomass, geothermal, hydro, marine, solar photovoltaics, solar thermal, wave or wind energy, as well as any green molecules generated from these technologies according to EU regulation.
- "Renewable energy projects" was defined as an implemented, planned or cancelled installation in Europe producing renewable energy from the list above.

"Regional impact" was defined as impacting another country than its location country, at least one of which was in the EU. This impact could be either through joint involvement in the project, direct effects on its electricity grid or indirect effects outside of the electricity grid.

2.2.1. Final definition and criteria

Building on the steps presented above, the final definition and criteria proposed for renewable energy projects are the following:

A renewable energy project with regional impact is an installation generating renewable energy in Europe and concerning one or more other countries because of either

1. the direct involvement of another country
2. the impact on the regional electricity grid or market
3. the potential (indirect) impact on the regional energy systems and environment

Each set of criteria corresponds to specific project types. Under the first criterion, the following types of projects are mapped:

- *1. Projects officially **recognised by the EU** as having regional impact and/or **directly involving** at least **two countries.*** [10]

Under the second criterion fall the following projects:

- *2a. Renewable energy installations subject to a **cross-border PPA** above 8 GWh*
- *2b. Transmission grid-connected renewable electricity installations with nominal capacity **above 2% of the country's total outgoing interconnection capacity,** with a minimum of 100MW**.***

Under the third criterion fall the following projects:

- *3a. Renewable energy installations generating renewable energy from regional flows of **renewable fuel** totalling at least **120GWh per year;***
- *3b. Renewable **Power-to-X** production installations exporting **at least 120GWh per year.***

2.2.2. Lessons learned

The development of this methodological framework yielded the following takeaways:

- This work follows in the footsteps of reference works with a different scope: "cross-border renewable energy projects", which could not be abandoned at once. This work was conducted looking primarily at the EU, whose rules in place remain consistent with the "cross-border collaboration" framework and constitute an unsurpassable reference. In particular, past best practices, such as the common green certificate support schemes between Norway and Sweden, would not be defined today as a renewable energy project. It is, however, a rare consensual project with regional impact, being referenced by more than half of the papers examined and by all four experts with whom advisory interviews were held.
- The concept of regional impact seemed rather unintuitive for renewable energy projects, with stakeholders' feedback regularly integrating purely local renewable energy projects, international political instances not linked to renewable energy and conventional energy infrastructure. Another issue was the term "regional", which for many actors meant "national regions", not "European regions", and needed to be explained throughout the project team's external interactions. This lack of clarity, presumably linked to the previous two points, may have decreased the quality of the responses and the engagement levels.
- It was possible to provide the missing theoretical definition not only for renewable energy projects with regional impact, but also to make it compatible with publicly available data in order to reference all corresponding projects.

The scope, definition and criteria presented in this work are thus a compromise between an attempt at defining a novel concept, desk research criteria to map projects in Chapter 3, and

[10] Projects officially recognised by the EU as having regional impact and/or directly involving at least two countries are those that meet specific criteria and are included in certain key lists or initiatives. These projects are typically part of the Connecting Europe Facility (CEF), the Cross-Border Renewable Energy (CB RES) mechanism, or the Projects of Common Interest (PCI) list. Inclusion in these lists means that the projects are acknowledged by the EU for their strategic importance in enhancing cross-border cooperation, improving regional energy infrastructure, and contributing to the EU's renewable energy and climate goals. These recognitions often come with certain benefits, such as access to funding, streamlined regulatory processes, and enhanced political and technical support.

Direct involvement of at least two countries in a project typically implies the existence of cooperation agreements under Renewable Energy Directive (RED) articles 7 and others. These agreements facilitate joint projects, statistical transfers, or joint support schemes between member states, ensuring coordinated efforts and shared benefits in achieving renewable energy targets.

a guideline for which facets of renewable energy projects to focus on in future works. They are designed with flexibility, coherence and neutrality in mind, allowing, as much as possible, situations to evolve.

The triple focus on projects that are being operated, are planned or were abandoned means projects from the 1960s cohabit with projects planned for the 2030s. Between those time periods, many factors have changed and no one-to-one comparison can be made. The criteria also currently allow virtual projects (statistical transfers, virtual PPAs, expected energy flows) which may develop rapidly or fall out of fashion in the future. Criterion 2b, in particular, should remain valid even with the expected development of interconnection in the future, and the threshold can be tweaked if necessary. Similarly, Criterion 1 can be adjusted by future European or national actors to account for future policy priorities.

The tensions between fields and concepts may be mere symptoms of the novelty that these considerations represent for renewable energy actors. Regardless, they may constitute significant obstacles to any future work and should be addressed.

3. Mapping of projects

3.1. Methodology and data sources

With the aim advancing the deployment of renewable energy across the European Union, a meticulous process of project mapping has been undertaken as part of this comprehensive study. This effort aligns with the broader objectives of the European Green Deal and the specific mandates outlined in the Renewable Energy Directive (RED II), emphasising the importance of cross-border cooperation among Member States. A total of 193 projects were identified and mapped, each fitting the established criteria and definition set forth for renewable energy initiatives with regional significance. These projects span a wide range of renewable energy sources, including wind (onshore and offshore), solar, hydro, biomass and Power-to-X, showcasing the diverse potential for sustainable energy production across the EU. The full list of these projects, along with detailed descriptions and their respective locations, was meticulously compiled and is presented in Annex 3 of this report.

Data sources mobilised for this mapping included the range of tools available within the project's scope, including:

- The literature review, which cited 12 implemented or attempted projects. Eight of these concrete projects were selected as fitting this report's criteria;
- The advisory interviews, which cited 13 implemented or attempted projects, seven of which overlapped with those from the literature review;
- Survey 1, which did not yield any project suggestion;
- Survey 2, which yielded 17 implemented or announced projects. Overlap with the previous steps was limited to five projects; and
- Two phases of desk research, first in 2023 while scoping criteria and then in 2024, using the validated set of criteria for impact, which yielded the bulk of the projects mapped and validated or rejected the projects suggested in the earlier steps.

To enhance the accessibility and understanding of these projects, the project team developed concise and easy-to-read project fiches for each of the 200 initiatives. These fiches serve as individual profiles, providing key information on the project scope, objectives, involved parties, anticipated impact and current status. Designed to be user-friendly, these fiches aim to facilitate quick and efficient comprehension of each project's essence, allowing stakeholders, policymakers, and the public to gain a clear overview of the renewable energy landscape within the EU. By presenting this information in a structured and digestible format, the report not only underscores the potential for renewable energy development but also highlights the collaborative efforts required to achieve the ambitious goals set by the European Green Deal and RED II directive.

Figure 1: Example of the project fiche (ELWIND project)

3.2. Mapping conclusions and lessons learned

3.2.1. Projects officially recognised by the EU as having regional impact and/or directly involving at least two countries

For this criterion where a direct involvement of at least two countries is required, we have on the one hand the projects that are officially recognised by the EU (having a CB-RES status or using a cooperation mechanism according to RED II) and on the other hand projects that are being co-developed based on bilateral agreements between countries or because they are using the same natural resources (e.g. a river which is a common border).

Five projects have already been granted the CB-RES status by the European Commission. The location of the project is limited to a few countries adjacent to the Baltic Sea (Estonia, Latvia, Poland and Germany) as well as Spain and the Netherlands (Figure 2). Although the CB-RES status is a relatively new concept, the countries having such a status are countries that have already projects with cross-border elements in their portfolio, highlighting the importance of existing links which play a role in defining common projects and applying for funding.

Figure 2: RES projects with direct involvement of another country: CB-RES status

For the type of regional impact related to RES projects with direct involvement of another country according to RED II, we mainly see here the existing statistical transfers between various countries, the Germany-Denmark joint support scheme and the joint electricity certificate market between Norway and Sweden (**Figure 3**).

Figure 3: RES projects with direct involvement of another country according to RED II

Regarding statistical transfers, the main driving factor for deciding this option was the timing constraints related to whether the 2020 targets could be met at the national level. This had an impact on the choice of the seller country. In particular, the main argument was an efficient and straight-forward administration process for a reasonable price[11]. For example, Belgium followed the choice of the Netherlands, which had already successfully negotiated with Denmark. Since the objective was to meet the renewable energy targets in a timely and cost-effective way, confidence in existing cases was preferred, highlighting the importance of practicality. It is for this reason that the Czech Republic chose this mechanism since it was the simplest tool. It is expected that the first cases of statistical transfers, which is mainly exploited by only a few Member States (Belgium, Ireland, Luxembourg, Malta, Slovenia and the Netherlands), will act as an example to be followed by other Member States that might need to feel more confident in the process, since building on existing programmes increases confidence and reduces the initial burden. While this mechanism is and will be used as a way to drive countries which already reach their targets to proceed with RES deployment, an opposite view says that countries should develop their own strategies and well-defined, concrete plans to reach the target on their own. Following the same direction, certain obligations, such as for the seller countries to reinvest the revenue in the deployment of RES and energy-efficiency projects, are included in the agreement by the buyer countries.

The two cases of the joint support schemes (Denmark-Germany and Sweden-Norway) highlighted that sufficient time and resources must be allocated for negotiations. Moreover, good governance and trust are key for successful cooperation while careful consideration of national conditions and timing are important. We should again stress that the two cases which opted for the joint support schemes involved countries that have been already involved in common planning in the past and that have developed a sufficient level of trust to proceed with negotiations.

Most bilateral cooperation agreements (**Figure 4**) have occurred in the North Sea region, where there are co-developed concepts and planned projects (hybrid projects combining offshore wind and interconnectors between/among neighbouring countries), indicating that there are common drivers to exploit the RES potential of the region. The hybrid projects of this region play a significant role in highlighting the barriers to cross-border cooperation among Member States that could be used as role models for future projects. By contrast, southern EU countries seem to lack such a strong commitment to common planning, and it is only recently that memoranda of understanding (e.g. France-Spain-Portugal (on cross-border energy interconnections in the southwest) and Greek-Bulgaria) have been signed to enable cross-border cooperation. Finally, projects have developed around natural borders, such as the River Danube and the Alps. Examples include cross-border cooperation on joint hydropower plants between Bulgaria and Romania, Romania and Serbia, France and Switzerland, and Germany and Austria.

[11] Caldés, N.; Del Río, P.; Lechón, Y.; Gerbeti, A. Renewable Energy Cooperation in Europe: What Next? Drivers and Barriers to the Use of Cooperation Mechanisms. Energies 2019, 12, 70. https://doi.org/10.3390/en12010070

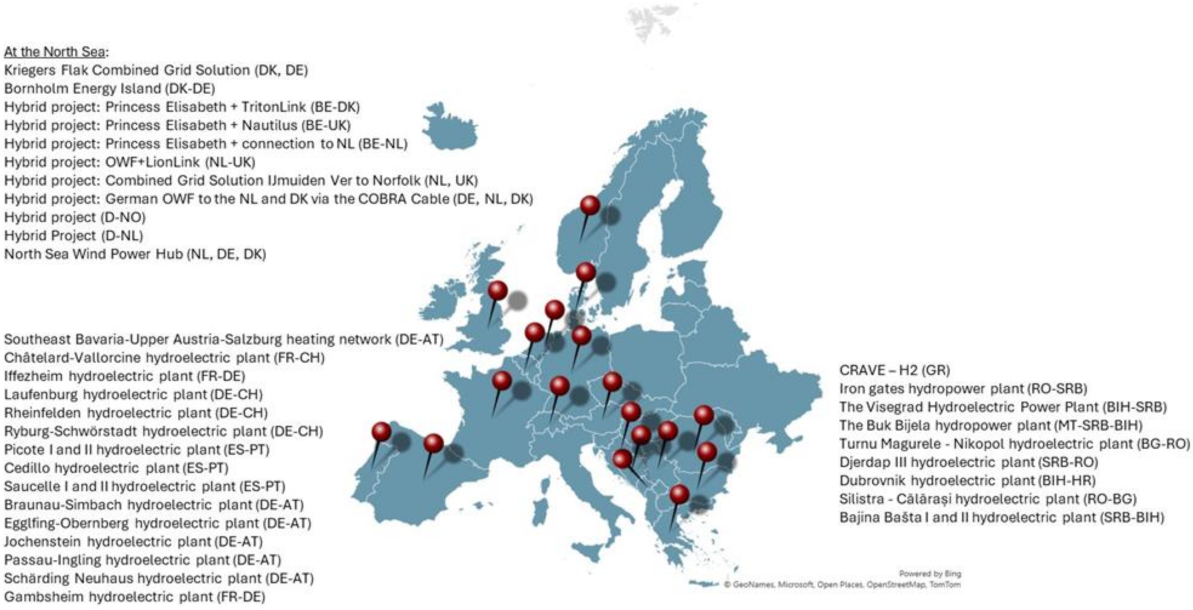

Figure 4: RES projects with direct involvement of another country: co-developed projects based on bilateral agreements or co-generation because of common natural resources

3.2.2. Renewable energy installations subject to a cross-border PPA above 8 GWh

Physical cross-border power purchase agreements (PPA) are quite rare due to the need for interconnection and the respective price risk. There are cases where we see the use of PPAs related to physically connected installations such as the Mageli hydropower plant in southern Norway, which is connected to Germany via the Nordlink North Sea cable and is supplying Germany with 190 GWh per year. However, virtual cross-border PPAs have been recently gaining popularity, especially among corporate buyers, which are trying to reduce their carbon footprint. In a virtual cross-border PPA model, the electricity generated by the power producer is sold in the wholesale power market of the generation asset's location (market A). The power producer receives payments based on the fluctuating wholesale power price in market A, which are then offset against the agreed-upon PPA price with the corporate buyer. The corporate buyer continues to procure electricity for its facilities through local contracts in the market where its load is located (market B). Since the virtual cross-border PPA contract involves financial transactions, there's no need for a physical network connection between the generation asset(s) and the load. Such a scheme is preferred by companies since it overcomes regulatory barriers while allowing them to choose the projects with the most favourable terms not necessarily limited to one location. This explains why the majority of the virtual cross-border PPAs are located in the southwest Europe, especially Spain (**Figure 5).** A corporate buyer located in a region with low levels of sunlight and low solar energy production and therefore low load factor[12] will achieve a better yield and price from a solar PPA procured in a market

[12] Meaning the solar panels generate less electricity due to lower solar radiation.

with higher load factors where higher solar radiation is translated into higher electricity production.

Figure 5: RES projects which concluded at least one cross-border PPA for a minimum of 8GWh of electricity

3.2.3. Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country’s total outgoing interconnection capacity, with a minimum of 100MW

For the projects satisfying this criterion (**Figure 6**), interconnection is of course an important element. By setting a minimum capacity of 100 MW and ensuring that the nominal capacity exceeds 2% of the interconnection capacity, only projects with significant energy flows are considered. The RES technology of the projects that meet these thresholds is closely linked to resource availability and topography. For example, the relevance of the sea basin for wind farm installations means we predominantly see wind farms in northern Europe and photovoltaic (PV) installations in southern Europe.

In northern Europe, wind farms of several hundred megawatts (MW) are common, and the concept of hybrid offshore projects—where renewable energy sources are combined with interconnectors—is gaining traction, particularly around the North Sea. In southern Europe, especially in Spain, large-scale solar farms with capacities of several hundred MW are being deployed. These projects meet the requirements by taking advantage of the regional resource strengths and interconnection capacities.

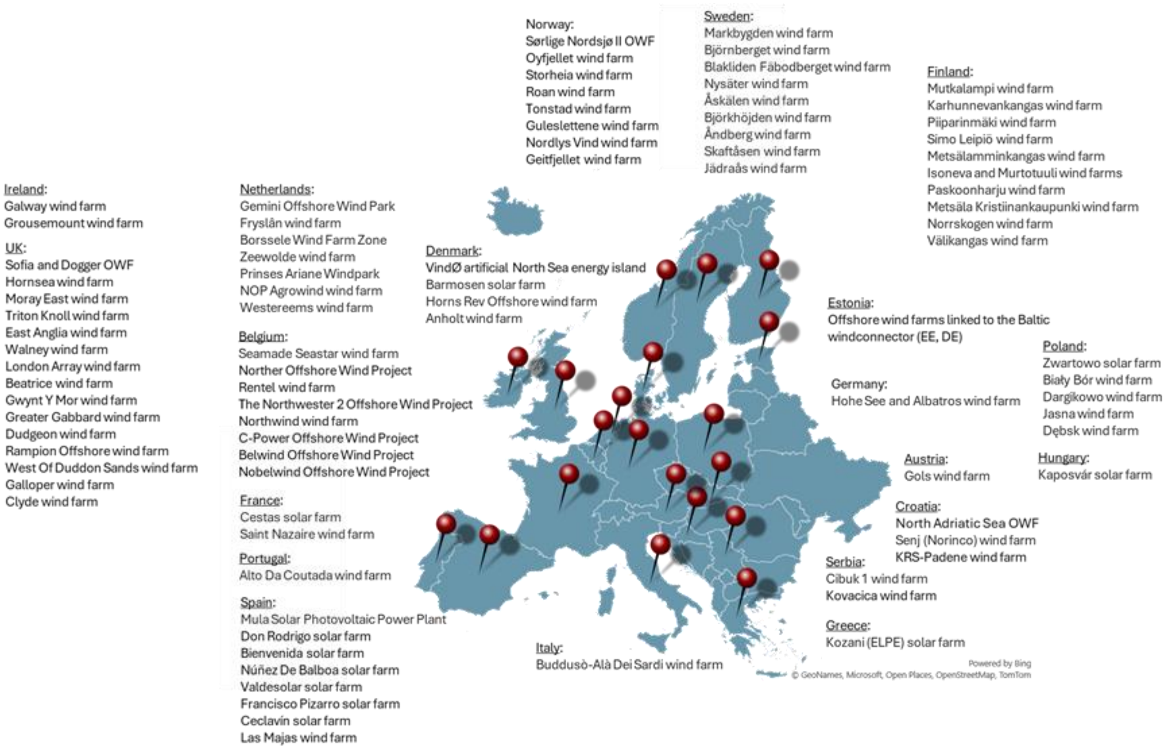

Figure 6: Transmission grid-connected RES installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW

3.2.4. Renewable energy installations generating renewable energy from regional flows of renewable fuel totalling at least 120GWh per year

Regarding installations generating renewable energy from regional flows of renewable fuel totalling at least 120 GWh per year (**Figure 7**), the project team identified some biomass power stations in Belgium, Ireland and Sweden that import biomass from another country. Notable among them was the combined heat and power plant in Värtaverket, Stockholm, where about 60% of the plant's biomass needs arrives by boat and is imported from the Baltic Sea area. The list of relevant projects is likely longer, but we only focused on information based on verified claims for the origin of biomass.

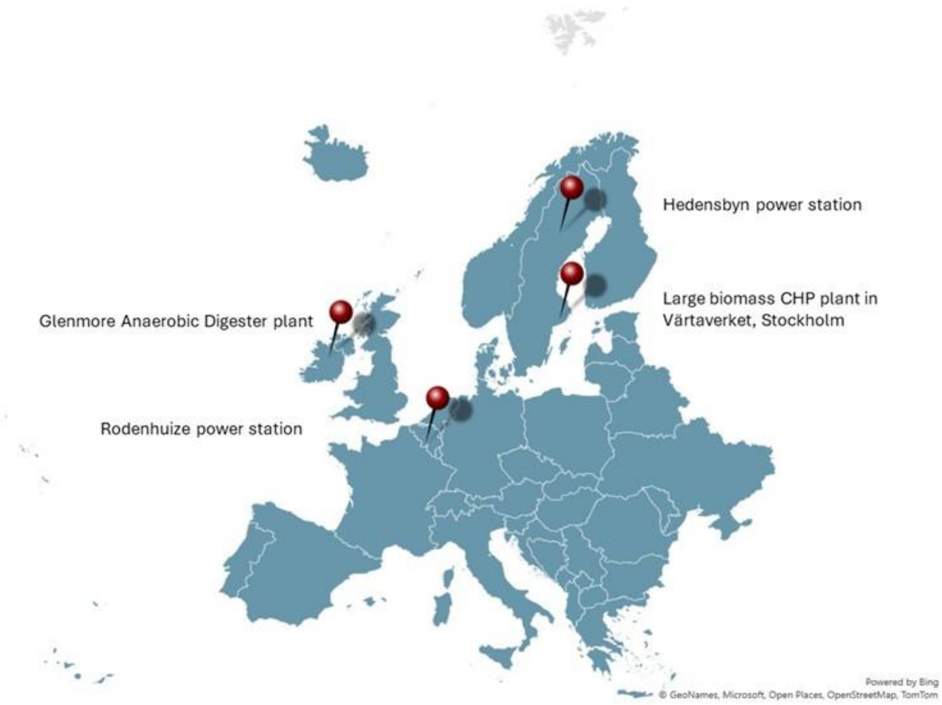

Figure 7: RES installations generating regional flows of renewable fuel totalling at least 120GWh per year

3.2.5. Renewable Power-to-X production installations exporting at least 120GWh per year.

Finally, a significant number of projects related to renewable Power-to-X production installations exporting at least 120 GWh per year were mapped **(Figure 8).** These are typically announced projects, mainly due to the emergence of H2 and its derivatives in the energy landscape. The deployment of large-scale projects, such as hydrogen valleys where different applications across the value chain are considered, have been promoted in recent years. There seems to be a balanced distribution of such projects across the EU, revealing the flexibility of H2 and the need for alternatives in sectors that are hard to decarbonise.

Figure 8: Renewable Power-to-X production installations exporting at least 120GWh per year

3.3. Common trends and lessons learned

While the EU is targeting cooperation among Member States in order to achieve its renewable energy targets, the divergence in national renewable energy policies is creating barriers for the participation of foreign actors in support schemes. As a result, the mechanisms become inefficient and lack cost-effectiveness[13]. Their use has thus far been limited, leading to scepticism about their future use. Luxembourg was the first country to opt for the statistical transfer option in 2017, and it was only in 2020 that the rest of the involved countries took action. Overall, there are findings that indicate that such schemes are "overly generous and economically inefficient"[14].

EU cooperation mechanisms are mainly exploited by the central and northern EU countries. Statistical transfers were used the most because they offered a quick solution for achieving targets. Projects based on bilateral agreement are also mainly seen in the central European region, highlighting a stronger commitment to reaching RES capacities and working towards common goals.

While physical PPAs are rare, virtual PPAs are used more frequently and are mainly used as a tool to decarbonise corporates. At present, there seems to be a preference for solar PV farms in Spain, but once the use of such a mechanism becomes more widespread then cross-border virtual PPAs have the potential to contribute to the deployment of RES in Europe as long as there is a supportive environment enabling their use.

By putting thresholds (2% of interconnection capacity and 100 MW minimum capacity) we could filter the largest installations (mainly PV in the south and wind in the north) in a more or less uniform way across the EU. Although the southwest region is not as well interconnected

[13] Caldés, N.; Del Río, P.; Lechón, Y.; Gerbeti, A. Renewable Energy Cooperation in Europe: What Next? Drivers and Barriers to the Use of Cooperation Mechanisms. Energies 2019, 12, 70. https://doi.org/10.3390/en12010070

[14] HAAR, LAURA N., and LAWRENCE HAAR. "An Option Analysis of the European Union Renewable Energy Support Mechanisms." Economics of Energy & Environmental Policy 6, no. 1 2017: 131–48. https://www.jstor.org/stable/26189575 .

as the northwest, a recent MOU among France, Portugal and Spain, along with a concrete future planning for interconnectivity in this region, could result in the development of more RES projects with regional relevance. Finally, there is an obvious lack of such projects in the CESEC region, although the plans for interconnectivity among those countries along with recent MOUs (e.g. Bulgaria and Greece) could result in more projects with the direct involvement of neighbouring countries. The scope and pace of implementation of the EU *acquis* in Third Countries in the region varies. Therefore, cooperation in the framework of joint projects is likely more difficult to achieve compared to other areas of the EU.

Although combined heat and power plants generating renewable energy from regional flows of renewable fuel are located throughout the EU, the origin of the renewable fuel was not easy to track down. As a result, the list of projects in this criterion is rather limited but still relevant as long as there are verified claims for the origin of biomass.

Finally, Power-to-X projects are entering the energy landscape in increasing numbers and the flexibility of H2 to be produced from either wind or solar energy technologies results in a uniform deployment across Europe.

The future potential is illustrated by the maps presented so far. Hybrid projects where the renewable energy generation and the interconnection infrastructure is combined are gaining momentum. In this context, various concepts are being developed and concrete steps are being taken to develop GW scale RES installations. Given the resources in the south and the commitment towards common future goals, the cooperation mechanisms from the EU, such as the CB-RES status, could be further exploited. The extensions of the electrical and gas grids throughout Europe could help improve interconnection and therefore more regional flows. Countries have set clear targets for increasing interconnection capacity, while at the same time a larger deployment of RES is carried out. As a result, the 2% criterion will remain relevant and involve installations of at least a few hundred MWs. Additionally, large-scale projects, such as hydrogen valleys where hydrogen is produced in one location and transported to other countries, would help decarbonise sectors that are challenging to electrify.

4. Barriers to regional cooperation on renewable energy projects and recommendations for the way forward

4.1. Methodology and data sources

Following the definition of renewable energy projects with regionl impact and the mapping of corresponding projects, the work moved to studying their real-life implementations. This section consisted in exploring and surveying the barriers to and drivers for cross-border collaboration on renewable energy.

The methodology for this section included the three main following steps:

- The literature sources collected in the first phase and detailed in Table 2 were consulted again, this time with a focus on barriers to cooperation or regional impact. Those that were mentioned with confidence within the papers (either as a consensual tenet of the field, as a validated result or as a conclusion) were listed in a working table. The resulting list amounted to 84 barriers from 27 unique sources.
- These barriers were first sorted into PESTLE[15] (political, economical, social, technological, legal, environmental) categories, with many issues featuring in several categories and many overlaps between the barriers. Two rounds of further analysis led to a table of 39 unique barriers, each in a unique PESTLE category. All categories comprise six barriers, except for the social and environmental types of impact that have four barriers each. The outcome from this aggregation, after validation by DG ENER, is presented in **Error! Reference source not found.** below.
- Finally, the barriers resulting from this analysis were included in a survey of project developers with experience or expertise in cross-border projects. The contents and responses are detailed in Annex 5. Participants were asked to name examples of projects which informed their view, and then presented with the barriers and asked to cite those which seemed most relevant. The survey received 16 valid responses and allowed for the subsequent detailed analysis of barriers to be conducted.

[15] Environmental scanning and forecasting in strategic planning—the state of the art: Fahey, L., King, W. R. And Narayanan, V. K.Long range planning,14 (1), 32–39 (February 1981), Long Range Planning, Volume 14, Issue 3, 1981, Page 127, ISSN 0024-6301, https://doi.org/10.1016/0024-6301(81)90201-6.

Table 1: PESTLE categorisation of the selected barriers to projects with regional impact

Political

- A project improving the global situation may not align with the local needs and opportunities.
- Diverging political goals, e.g., prioritisation of different energy sources.
- Projects with regional impact require intense coordination between member states, including negotiations about costs and benefits.
- Renewable energy projects with regional impact may go against established energy stakeholders.
- Low support from policymakers due to a preference for national control of renewable energy deployment.
- Possible competition between many offtaker countries regarding cooperation with a given host country.

Economic

- Varying maturity, or lack of, wholesale market integration (e.g., weak price convergence, low liquidity)
- Different energy taxation and electricity prices, e.g., social tariffs or fossil fuel subsidies in place
- Heterogeneous support schemes: - Inconsistent support levels - Inconsistent eligibility - Risk of overcompensation if multiple support schemes apply
- Investment in beneficial and innovative technologies with higher costs is likely to be unattractive for joint project agreements.
- Lack of investment security and higher financial risk for cross-border projects compared to projects under national support schemes.
- Difficulty to assess costs and benefits, including indirect ones like impact on system costs

Social

- Lack of public awareness on the potential and benefits of cross-border energy cooperation
- Preference of spending taxpayers/consumers' money for reaping RES benefits nationally (e.g., jobs)
- Uncertain impact on employment, e.g., job creation or potential job destruction in fossil fuel sectors
- Renewable energy projects with regional impact may reduce local control over the social benefits of energy projects

Technological

- Lack of international interconnections
- Actual, or perceived, lack of RES resource potential for cross-border cooperation
- Prioritisation of non-RES in the electricity grid
- Lack of coordination regarding future grid development
- There is so far no clear solution to assess how much energy from one specific project is exported
- Many possible exporter countries have rapidly increasing electricity demand, limiting the realizable exports

Legal

- Potential incompatibility of cooperation mechanisms with national and EU legislation
- EU rules (RED, State Aid, Governance of Energy) on cross-border RES cooperation set a general framework, but not a model ready for implementation across countries
- Different regulations across different Member States, including repartition of responsibilities between actors
- Complexity and length of administrative procedures, including those for statistical transfers and joint projects
- No special regime was envisaged for collaboration between EU member states and non-EU countries beyond the general provisions for inclusion of non-EU countries, including in RED II
- Lacking progress in implementing domestic legislation, e.g., Czechia was not ready to go into collaboration before its solar market picked up

Environmental

- National environmental issues may not align with international preoccupations
- Inadequate spatial planning of RE deployment
- Loss of control over project siting and environmental impact
- Renewable energy installations with positive impact across borders may concentrate environmental impacts in one specific area

4.2. Barriers to cross-border renewable energy cooperations – insights from the research

Stakeholders in the survey strongly validated some barriers for impact, such as differences between national support schemes, and strongly discounted other potential barriers, such as concerns about rising national energy demand. All categories featured at least one barrier validated by eight respondents or more. In addition to the social category, they all featured two such consensual barriers. This validates the PESTLE approach and highlights that the issue of regional impact is multifaceted.

The most commonly cited barriers include:

- Heterogeneous support schemes (11/16). This includes several aspects potentially hampering projects with intentional regional impacts, such as those producing energy in a country for consumption in another:

  - Inconsistent support levels

  - Inconsistent eligibility

  - Risk of overcompensation if multiple support schemes apply

- Lack of public awareness on the potential and benefits of cross-border energy cooperation (11/16). This means that, due to a low appreciation from the general public, cross-border projects are often accomplished in a top-down manner and do not receive much credit outside of the experts aware of them, such as the joint auctions between Germany and Denmark or Finland and Luxemburg.

- Projects with regional impact require intense coordination between Member States, including negotiations about costs and benefits (10/16). The lack of a clear vision for costs and compensations was cited as one of the reasons behind the abandonment of the promising joint UK-Ireland offshore wind farm.

- Lack of international interconnections (10/16). This strongly limits the regional impacts renewable electricity projects can have, whether intentional or accidental, as there is a low capacity of electricity that can be exported across borders when interconnectors are insufficient.

- Actual, or perceived, lack of RES resource potential for cross-border cooperation (10/16). Some sites in the Balkans have limited renewable wind resources, while northern Europe's solar irradiance[16] is on average predictably lower. These limits on available capacity makes them more likely to focus on national impact than on regional impact.

- EU rules (RED, state aid, governance of energy) on cross-border RES cooperation set a general framework, but not a model ready for implementation across countries (10/16). Linked to the barrier on the intense cooperation needed, the survey results highlight the political complexity of collaboration, with every point of a project's joint development being potentially debated without a reference model.

- Renewable energy installations with positive impact across borders may concentrate environmental impacts in one specific area (9/16). Local areas with high solar penetration rates, such as those in Spain, may experience even more extensive coverage of PV panels if projects with regional impact increase. This could result in

[16] Rferring to the power per unit area received from the Sun.

significant land use changes or alterations in the surface reflectivity (albedo) of the area.

- Difficulty to assess costs and benefits, including indirect ones like impact on system costs (9/16). The third barrier, tied to complexities in practical implementation of projects with regional impact, reflects the uncertain responsibilities when a project in one country benefits another one. For a power plant being set up to sell part of its electricity abroad on a consistent basis, cross-border compensation may not be required to partially cover traditional national grid costs.

No additional category of impact was suggested. Within each category, no additional barriers proposed were found to be relevant. Suggestions for additional challenges were largely already featured in the proposed barriers like the complexity of obtaining permits, which is adressed in the legal section, or policymakers' preference for national advancement above regional impact, which is featured in the political section.

Public acceptability is a key issue for any energy project, and survey respondents identified "lack of public awareness" as one of the most significant barriers. This barrier was tied for the most consensually relevant among all identified barriers. All four social barriers proposed, along with several political ones (detailed in Annex 6), were identified as potential causes for the lower acceptance of projects with regional impact. Among these barriers, stakeholders highlighted a fundamental issue: the general public is often unaware of the benefits and necessity of renewable energy projects that extend beyond national borders.

4.3. Challenges in cross-border renewable energy cooperation - insights from the project developers

The survey allowed for a qualification of the different barriers to projects with regional impact. In order to go beyond and look for solutions, deeper discussions and collection of best practices were necessary for a richer and more robust analysis. The survey results were therefore supplemented by discussions with project developers. The list of developers interviewed is presented in Annex 6.

These discussions took the shape of semi-structured interviews with project developers and national experts. The review allowed for the projects's implementation to be analysis considering these barriers and for lessons to be drawn that could be applicable to other Member States in the region.

Some of the common challenges highlighted by the project developers are highlighted below, while the lessons learned fiches per project can be found in Annex 7.

- **Regulatory flexibility and harmonisation:** A recurring challenge across various projects is the need for more flexible and harmonised regulatory frameworks. Projects often encounter barriers due to rigid regulations that do not account for the complexities of cross-border or multi-sector cooperation. For instance, projects like BalticSeaH2 highlighted the difficulties of aligning regulations across different countries, which can hinder investment and development.

- **Integrated planning and stakeholder engagement:** Another common issue is the lack of integrated planning and coordination among stakeholders. Many projects fail to incorporate a holistic view from the start, leading to fragmented efforts and inefficiencies. Projects like the BalticSeaH2 emphasise the importance of a unified vision and coordinated action among all stakeholders, from planning through to execution, to ensure that projects are not only viable but also capable of achieving their intended impact.

- **Financial and economic challenges:** Financing remains a significant hurdle, with many projects experiencing difficulties in securing sufficient funding due to the high costs involved and the perceived risks. Projects like the hybrid RES+Interconnector initiatives demonstrate the need for new funding mechanisms that can accommodate the large-scale financial requirements of innovative energy projects. Suggestions include the creation of specialised funds or financial instruments tailored to support these types of projects.
- **Cross-border coordination and infrastructure development:** The challenges of cross-border coordination and infrastructure development are prominently noted, especially in projects involving multiple countries. The lack of existing infrastructure and differences in grid capacity and regulatory frameworks can severely impact project scope and feasibility, as seen in the Han Windfarm project. Improved cross-border agreements and cooperation on infrastructure planning are essential to mitigate these challenges.

In conclusion, these projects illustrate the critical need for enhanced cooperation between public and private sectors, streamlined regulatory frameworks, robust financial support mechanisms, and comprehensive planning and stakeholder engagement to successfully deploy and scale renewable energy projects across Europe. By addressing these challenges, the EU can advance its energy transition goals more effectively, leveraging the full potential of its diverse energy resources and technological capabilities.

4.4. Common challenges in cross-border renewable energy cooperation – insights from the HLGs

The High-Level Group workshops have shed light on the shared and unique challenges faced by EU Member States in executing cross-border renewable energy projects. These challenges primarily revolve around the complexities of planning, financing, and regulatory alignment, as well as the disparities between the capabilities and needs of larger versus smaller countries.

1. Complex planning and regulatory hurdles:

Navigating the regulatory landscape for cross-border renewable energy projects involves coordinating across different national legal frameworks, which often have conflicting requirements or priorities. This complexity extends beyond mere compliance, impacting the planning stages with extensive paperwork, multiple approval loops, and the need for continual alignment between involved parties. These bureaucratic processes can significantly delay project timelines and increase the risk of misalignment on project goals and execution strategies. To mitigate these issues, there is a pressing need for streamlined procedures that synchronise regulatory practices across borders, possibly through an EU-wide framework specifically designed for cross-border energy projects.

2. Financing and cost-sharing issues:

Securing funding for large-scale renewable energy projects that span multiple countries is a daunting challenge, primarily due to the high initial investment required and the ongoing costs associated with maintaining and upgrading infrastructure. The uncertainty about long-term financial returns complicates these efforts. Furthermore, devising equitable cost-sharing mechanisms that satisfy all participating countries, each with its economic constraints and policy priorities, adds another layer of complexity. Financial instruments and subsidies provided at the EU level could be structured to better support these projects, ensuring that financial risks and rewards are balanced fairly among the stakeholders.

3. Economic justification:

For many countries, especially smaller or economically less powerful ones, the costs associated with cross-border renewable energy projects may outweigh the immediate benefits. These projects often require substantial upfront investment in infrastructure and technology, with returns that materialise over long periods. This disparity can deter investment, particularly when the direct benefits are diffuse or primarily accrue to neighbouring regions rather than the investing country itself. Enhancing economic incentives, such as through guaranteed pricing, tax benefits or direct subsidies for cross-border energy exchange, could improve the economic viability of these projects.

4. Infrastructure disparities:

Large disparities in existing infrastructure between larger, more economically robust countries and their smaller counterparts can lead to imbalances in the development and benefits of cross-border renewable energy projects. Larger countries often have more developed networks and can implement larger projects more efficiently, which might not be the case for smaller countries lacking similar resources. This imbalance can result in a skewed distribution of project benefits and burdens. A cooperative approach, supported by EU policies that provide technical assistance and funding to less-developed regions, is essential to ensure that infrastructure development benefits all parties equitably.

Specific Country Perspectives on Cross-Border Renewable Energy Cooperation

In assessing the challenges of cross-border renewable energy projects within the EU, several key issues emerge from different member states, reflecting a diverse landscape of economic and logistical barriers:

1. **Complex market conditions and infrastructure:** Some larger Member States note the intricate challenges of initiating and planning cross-border renewable energy projects, emphasising the high costs and complex negotiations involved in cost-sharing. These complexities are attributed to the varying market conditions and resources available to larger versus smaller countries.

2. **Financing and coordination:** Smaller Member States face significant hurdles in securing financing for these projects, particularly from EU-level sources, which are seen as limited and complex. The coordination required to manage joint operations across multiple countries also presents substantial challenges, especially in aligning financial capabilities and interests among diverse nations.

3. **Economic viability of energy export:** Some countries express concerns over the economic challenges associated with exporting energy, including the substantial costs and unclear cost-benefit ratios that complicate decision-making and financial planning for potential projects.

4. **Domestic priorities and EU-wide frameworks:** Some countries prioritise meeting domestic energy needs before considering exports, reflecting strategic energy goals that emphasise domestic stability over international trade. The absence of an EU-wide model for managing and evaluating cross-border projects complicates participation and calls for clearer frameworks and predictable outcomes.

5. **Cost-benefit sharing:** The ambiguity in sharing costs and benefits of cross-border projects is highlighted, with a need for clearer mechanisms to equitably distribute these financial aspects among participating countries. This issue is often influenced by both political and technical factors.

4.5. Lessons learned

Firstly, the establishment of a streamlined yet adaptable framework for cross-border cooperation on renewable energy projects is essential. This framework should offer clear, simplified guidelines for forming joint projects, while also promoting the sharing of resources and best practices. Importantly, it must facilitate an equitable distribution of costs and benefits, and include effective mechanisms for dispute resolution. To ensure flexibility and encourage innovation, the framework could incorporate provisions for regulatory sandboxing, allowing temporary regulatory relaxations for pioneering projects to test new ideas without full-scale regulatory commitments. This approach acknowledges the need for compliance with overarching EU regulations, yet provides room for adjustments based on project feedback and evolving market needs. Furthermore, the European Commission, in collaboration with Member States should support this framework by launching a dedicated platform to facilitate dialogue, share best practices, and match project partners. This platform would also serve as a repository for information on technologies, funding opportunities, and successful case studies, helping to streamline procedures and make cross-border cooperation not just a requirement but a mutually beneficial opportunity.

Secondly, addressing the barriers to cross-border cooperation requires a multifaceted approach. Administrative hurdles can be mitigated by harmonising procedures and standards across Member States, thereby simplifying the regulatory environment for renewable energy projects. Political commitment is essential to overcome legal barriers, and this can be fostered through high-level agreements that prioritise renewable energy projects on the political agenda. Furthermore, the development of financial instruments and incentives to support cross-border projects is critical. These could include enhanced access to funding through existing EU financial mechanisms, as well as new tools specifically designed to mitigate the risks associated with such projects.

Lastly, fostering a culture of innovation and mutual learning among Member States is crucial for the long-term success of cross-border cooperation in the renewable energy sector. This entails not only the exchange of knowledge and best practices but also joint research and development efforts to advance technology and infrastructure. The implementation of pilot projects could serve as a practical means of demonstrating the feasibility and benefits of cooperation, encouraging wider adoption. Additionally, project promoters should give sufficient importance to stakeholder engagement, including local communities, industry players, and NGOs, in the planning and implementation phases of projects. This inclusive approach ensures that the projects are well-received and have a lasting positive impact on the regions involved.

5. Conclusions

This report has comprehensively analysed the current state and effectiveness of regional and cross-border cooperation in the deployment of renewable energy projects within the European Union. Our study aimed to identify the drivers, barriers and the impact of such cooperation, focusing particularly on joint projects, support schemes and other cooperative mechanisms outlined in EU directives.

While the existing mechanisms provide a foundation for cooperation, their effectiveness is often hampered by complex regulatory, financial and administrative challenges. Addressing these challenges through targeted reforms could significantly enhance the scale and impact of regional cooperation, thereby contributing to the EU's climate neutrality objectives and the successful implementation of the Green Deal. For Member States and project developers, cooperation on these impactful projects not only pools resources and expertise, enhancing the efficiency and scale of renewable energy deployment, but also improves access to financial support mechanisms like the Connecting Europe Facility (CEF).

Many of the identified projects already benefit from alignment with key EU policy frameworks and receive financial support from various EU funds, there however remains a significant untapped potential for cross-border renewable energy projects. Addressing the barriers identified in this report, and notably enhancing the harmonisation of national regulatory frameworks, could further facilitate project development and implementation. This strategic alignment, coupled with continued financial backing from the EU, is crucial for realising the full potential of cross-border initiatives and achieving broader regional energy goals.

5.1. Key findings

Project Types and Analysis

Diversity of projects: The projects vary significantly in terms of technology, scale and regional coverage, indicating a robust engagement across the EU in renewable energy development and no one-size-fits all approach.

RES technology: The 193 identified projects cover all major RES (renewable energy source) generation technologies and in many cases a combination of them. Wind technology is used from 59% of the identified projects (of which 54% are onshore and 46% are offshore). Solar photovoltaic (PV) follows with a share of 19% and then hydroelectric with a share of 12%. From the remaining technologies, 9% of the projects use Power-to-X where we see the emergence of H2 as an energy vector, 4% are related to biomass and 1% use geothermal or biogas. Cooperation mechanisms such as statistical transfers cover 8% of the cases.

Geographic spread: The projects' geographic location is spread across Europe as a function of the available primary resources. The majority, i.e. 53% of the identified projects, are located in the North Seas Energy Cooperation (NSEC) region, of which 37% use wind technology. The Baltic Energy Market Interconnection Plan (BEMIP) region follows with 30% of the identified projects where again the vast majority are wind farms (72%). It is in these two regions that we see i) the emergence of new concepts such as the hybrid projects (combination of RES and interconnection) with expected capacities at the GW scale and ii) the use of the cooperation mechanisms such as joint support schemes and statistical transfers. On the contrary, the majority of identified projects in the South-West Europe (21% of all identified projects) use solar PV (58%) with power purchase aggrements (PPAs) financing 43% of the cases. Interestingly, the emergence of virtual PPAs is pronounced in this region with a share of 67%

from all the identified projects across Europe. Finally, 19% of the identified projects are located in the CESEC region with an almost equal share among PV, Wind, Hydroelectric and Power-to-X.

Project capacities: 12% have capacities less than 100 MW, 28% have capacities between 100 MW and 200 MW, 33% have capacities between 200 MW and 500 MW and finally 28% have capacities above 500 MW. Specifically for the big projects with capacities above 500 MW, 76% use wind technology and 13% are related to Power-to-X (mainly projects described as H2 valleys and H2 clusters). Interestingly, 73% of those big projects are located in Northern Europe where we also see the emergence of the hybrid projects (27% of the > 500 MW projects).

Financing of RES installations: From all identified projects, 8% have received EU funding with the majority (75%) being projects located in Northern Europe. Power purchase aggreements finance 13% of the projects of which 65% are located in the South-West Europe while 62% of them are virtual PPAs.

Cross-border collaboration: A significant number of projects involve collaboration between two or more Member States, demonstrating a strong regional integration, ashared commitment to renewable energy goals and the relevance of the existing cooperation mechanisms.

Challenges

The report uncovers several key challenges that hinder the execution of cross-border renewable energy projects:

1. **Regulatory divergence**[17]: variations in national regulations create complex administrative environments that can delay or deter project implementation. Different Member States have distinct permitting processes for renewable energy projects, which can vary widely in terms of length, complexity and requirements. For instance, one country might offer a streamlined, expedited permitting process for wind farms, while a neighbouring country could have a more cumbersome and lengthy process involving multiple levels of government approvals. This variation can deter developers from initiating projects where the bureaucratic process is perceived as a barrier, despite the availability of EU funds or policy support.
2. **Lack of technical harmonisation**[18]: compliance with different grid code requirements. Grid codes, which define the technical and operational requirements for connecting to and using the electrical grid, also vary between countries. Compliance with these codes is mandatory for the integration of renewable energy sources into the national grid. For example, a renewable energy project that spans multiple countries may need to meet different technical standards in each country for frequency and voltage control, which can complicate the design, increase the cost, and extend the timeline of the project.

[17] For example, Spain has implemented a series of reforms to simplify the administrative procedures for solar photovoltaic (PV) projects. This includes the Royal Decree-Law 15/2018, which aimed to eliminate barriers to renewable energy deployment, including the simplification of the administrative and permit-granting procedures for small-scale solar installations. On the other hand, Italy has a more complex regulatory environment that can be a challenge for new solar projects. The Italian permitting process involves multiple administrative steps and can vary significantly between different regions, affecting the consistency and predictability of project timelines.

[18] Germany and France have different requirements for the integration of renewable energy systems, particularly concerning the reactive power capability and voltage control. A renewable energy project that spans these two countries would need to ensure that its systems can comply with both sets of standards, potentially increasing the complexity and cost of the project.

3. **Financial constraints**[19]: limited access to financial resources and high-risk perceptions can stymie the development of large-scale renewable projects. The barrier of financial constraints and high-risk perceptions can be more pronounced in specific regions within the EU, particularly affecting the development of large-scale renewable energy projects. These financial challenges often vary by region due to economic disparities, the maturity of the financial markets and the existing energy infrastructure. In all these regions, overcoming financial constraints often requires innovative financing solutions such as public-private partnerships, EU-backed funding mechanisms or the use of green bonds and other financial instruments designed to lower the risk profile of renewable energy investments. Enhanced EU-wide financial support and more stable, predictable regulatory environments can help mitigate these challenges and unlock the potential for renewable energy development across different regions.
4. **Infrastructure challenges**: ageing and weak distribution grids. In many parts of the EU, especially in eastern and southern Europe, the existing electrical grid infrastructure is ageing and not fully equipped to handle the influx of variable renewable energy sources. The integration of renewables often requires upgrades to transformers, substations and transmission lines to handle higher loads and maintain grid stability. In addition, the process and costs associated with connecting to the grid can be prohibitive, especially in remote areas where the grid infrastructure may be weaker. For instance, in remote regions of Portugal or Bulgaria, connecting a new solar or wind farm to the nearest grid point can involve extensive and costly transmission lines. Moreover, the financial burden of these upgrades often falls on the project developers, adding to the overall cost of renewable energy projects.

5.2. Recommendations

To overcome the identified barriers and enhance the effectiveness of regional cooperation in renewable energy within the EU, we recommend the following:

Revising legislative frameworks/ regulatory harmonisation: Advocating for legislative adjustments that introduce more flexibility and tailor cooperation approaches to specific project needs. This can include provisions for pilot projects, which allow for testing innovative cooperation models under real-world conditions. Regulatory harmonisation, including the standardisation of network codes, is crucial for simplifying the integration and operation of renewable energy projects across the EU. It reduces administrative barriers, enhances cross-border energy trade and creates a more attractive investment environment by providing predictable and consistent regulatory standard

Simplifying administrative procedures: Recommending actions to streamline the complexity currently associated with managing cross-border renewable energy projects. Establishing a unified digital portal for project management could centralise and simplify

[19] Member states in Central and Eastern Europe region, including Bulgaria, Romania, and Hungary, often face significant financial challenges in developing large-scale renewable projects. These countries typically have less developed financial markets and fewer domestic financial institutions that can provide the necessary capital for large projects. Moreover, these regions sometimes have higher perceived political and regulatory risks, which can deter foreign investment and increase the cost of capital. Investors may be cautious due to concerns about stability in regulatory frameworks, the enforcement of agreements, and the potential for sudden policy changes. Similarly, Member States in the southern Europe region such as Greece, Italy, and Spain have experienced economic turbulence and fiscal crises in the past, which have impacted their ability to finance large-scale renewable projects. Although these countries have substantial solar and wind resources, the financial crises and subsequent austerity measures have constrained public and private spending in the energy sector. These financial constraints are compounded by high levels of public debt and reduced credit ratings, which can make it more expensive and challenging to secure financing for renewable energy projects.

administrative processes, making it easier for project stakeholders to navigate the regulatory landscape.

Enhancing financial instruments and economic incentive structures: Develop and implement EU-level financial instruments specifically designed for cross-border renewable energy projects. These could include risk-sharing facilities, multi-country investment funds, or tailored grants that provide initial capital and reduce the financial risks. Additionally, create equitable cost-sharing mechanisms that reflect the economic capabilities and energy needs of each participating country, ensuring a fair distribution of costs and benefits. Introduce enhanced economic incentives such as guaranteed pricing for energy generated by cross-border projects, tax benefits for investors, and direct subsidies to offset upfront costs. These incentives should aim to make the economic benefits more immediate and tangible, particularly for smaller or economically weaker countries that may bear a disproportionate share of upfront costs.

Provide infrastructure development support: Implement an EU policy that supports infrastructure development in economically weaker regions, ensuring that these areas can also benefit from cross-border projects. This could involve technical assistance, capacity-building programmes, and financial subsidies that are specifically targeted at improving the energy infrastructure in less-developed regions. Promote the development of shared infrastructure projects that serve multiple countries and offer mutual benefits, thus ensuring more balanced development. Investment in cross-border electricity transmission infrastructure needs to be prioritised to ensure efficient energy transmission and integration of renewable sources across the EU. This means enhancing the physical links that allow electricity to be transmitted across borders, which is crucial for integrating renewable energy sources effectively. Enhanced interconnections help balance the variable supply of renewable energy, such as solar and wind, by enabling excess electricity to be shared across regions and countries. This facilitates a more stable and resilient energy grid, optimises resource use and supports the EU's goals for a single energy market and energy security.

Promoting successful cooperation models: Emphasising the importance of documenting and disseminating successful models of regional cooperation. Utilise the existing project mappings and analyses to highlight effective practices and encourage more Member States to adopt similar strategies. This could be supported by an EU-led platform that not only facilitates information sharing but also provides tools and resources to replicate successful projects.

Integrated support platform: European Commission, in conjunction with Member States, could launch a dedicated platform to facilitate dialogue, share best practices and match project partners. This platform could serve as a comprehensive repository for technology information, funding opportunities and case studies, and include tools for project planning and financial modeling.

Develop cross-border legal and technical advisory services: Establish EU-funded advisory services to assist Member States and project developers in navigating the legal and technical complexities of cross-border renewable energy projects. This service could offer expert guidance on regulatory compliance, environmental assessments and technical specifications to ensure that projects meet both national and EU standards.

Stakeholder engagement: It is crucial to cultivate a cooperative environment where governments, industry players and local communities engage actively and consistently from the initial planning stages through to the implementation of projects. This engagement ensures that all parties contribute to and support the development, resulting in projects that are not only technically and economically viable but also broadly accepted by the community.

Annex 1: Literature review

Literature on cross-border cooperation in the EU is abundant. Its subset applying to the field of renewable energy, however, is varied but less populated. Papers found represent various disciplines, from microeconomics to political science through the study of electrical networks. Many of them study cross-border RE projects based primarily on economic efficiency aspects.

It is worth noting that the notion of RE projects' regional/international/transnational impact is not a central topic in the literature; none of the sources perused contained a definition of "regional energy impact". The dominant objective of the literature is instead cross-border collaboration or cooperation on renewable energy, which typically only includes the RED II cooperation mechanisms. However, few attempts at defining impact beyond this definition were observed. Most papers do define the scope of the projects with regional impact that they do consider, albeit as a set scope rather than something to be weighed, discussed, and shaped by the work. Examples of such scopes include "hypothetical projects which certain countries could set up abroad to reach RE 2020 targets" or "cross-border auctions for renewable energy".

As a consequence, only 12 concrete examples of renewable energy projects were referenced in a way compatible with the idea of regional impact. This includes operating installations, ongoing developments and abandoned leads. This number is notably lower than the number of hypothetical projects developed in the literature (18).

The full list of sources is given in Table 2 below.

Table 2: List of reviewed sources

Publication title	Publishing structure	Date
Cross-border regional cooperation for deployment of renewable energy	European Environment Agency	2020
Driving regional cooperation forward in the 2030 renewable energy framework	Heinrich Böll Stiftung	2015
Cross-border renewables cooperation – the impact of national policies and regulation on the cost of onshore wind across the PENTA region and priorities for cooperation;	Agora Energiewende	2018
Renewable Energy Cooperation in Europe: What Next? Drivers and Barriers to the Use of Cooperation Mechanisms	Energies	2018
Analysis of the Barriers to the Use of the Cooperation Mechanisms for Renewable Energy in the EU	MUSTEC (Market Uptake of Solar Thermal ElectriCity) project	2018
Design options for cooperation mechanisms under the new European renewable energy directive	Energy Policy	2010
Promoting Solar Electricity Exports from Southern to Central and Northern European countries	Publications Office of the European Union	2018
Enhancing Regional Renewables Cooperation in the EU Experiences and policy recommendations from a Study Tour to the North Sea Region;	Heinrich Böll Stiftung & World Future Council	2016
On international renewable cooperation mechanisms: The impact of national RES-E support schemes	Energy Economics	2019
Design options for cross-border auctions	DTU	
Renewable Energy Prospects for Central and South-Eastern Europe Energy Connectivity (CESEC)	IRENA	2020
Study on the Central and South-Eastern Europe energy connectivity (CESEC) cooperation on electricity grid development and renewables	Ecorys	2022
2019 Study on Baltic offshore wind energy cooperation under BEMIP	European Commission	2019
Renewables cross-border cooperation in the Energy Community	AURES II	2020
Bringing Europe and Third Countries Closer Together through Renewable Energies Summary Report	BETTER Research Project	2015
Cooperation Mechanisms to Achieve EU Renewable Targets	Renew. Energy	2014

Promotion of Electricity from Renewable Energy in Europe Post 2020: The Economic Benefits of Cooperation	Zeitschrift fur Energiewirtschaft	2013
Cooperation between EU countries under the RES directive: Task 1 report	European Commission	2014
Case study: Statistical Transfer between Estonia and Luxembourg	European Commission	2014
Joint Projects/Statistical Transfer between Malta and Italy	European Commission	2014
Joint Projects between the Netherlands and Portugal	European Commission	2014
Offshore wind park in the North Sea: NL, BE, UK, LX	European Commission	2014
Joint support schemes	European Commission	2014
Regional cooperation in the context of the new 2030 energy governance	German Institute for Economic Research DIW Berlin	2014
Grenzüberschreitende Förderung erneuerbarer Energien im europäischen Strombinnenmarkt	NOMOS	2017
Measuring the Benefits of Cross-Border Renewable Auctions in Central and Eastern Europe – the Theoretical Case of Hungary	Energy Reports	2020
Auction-theoretic aspects of cross-border auctions	AURES	2019
Financing Renewable Energy: The way forward	PolIMP	2014
Redistribution effects resulting from cross-border cooperation in support for renewable energy	EWI, Uni Köln	2014
The evolution of flexibility mechanisms for achieving European renewable energy targets 2020- ex-ante evaluation of the principle mechanisms	Energy Policy	2009
The yearly trends and projections including cross border	EEA	2022
Barriers and Critical Success Factors for the Implementation of Cooperation Mechanisms	RES4Less Deliverable 3.1	2012
Roadmap and action plan for the first cross-border solar project	Joint Research Centre	2019
Understanding the absence of electricity imports to the European Union	International Journal of Energy Sector Management	2016
Cost-Efficient and Sustainable Deployment of Renewable Energy Sources towards the 20% Target by 2020, and beyond. Summary of case studies for cooperation mechanisms	RES4Less project	2013

Annex 2: Advisory interviews

In order to validate the above conclusions from the literature review and confront the first conclusions with experts' perspectives, the project team reached out to 19 stakeholders from the private sector, academia, European public actors and regulators. Four advisory interviews were subsequently held in Summer 2023, with Javier Esparrago from the European Environment Agency, Andreas Tuerk from JoanneumResearch, Patrick Luickx from ACER, and Nicolo Rossetto from the Florence School of Regulation.

The four interviews that took place led to rich discussions, with four different perspectives being obtained. In particular, one discussion centred on statistical transfers and their potential for regional impact while another one focused on renewable energy installations of continental importance due to their size. The two remaining interviews started from the past work conducted by the interviewees, discussed concrete attempts at cross-border collaboration and then branched out to reach a more qualitative discussion of the nature of regional impact. 13 projects of interest were cited, including 6 new ones.The interview guide is given below.

Advisory Interview Guide: Assessing Regional Impact of Renewable Energy Projects

Interview Questions:

1. Identification of Impactful Projects

Q1: "Could you name some renewable energy projects that you believe have had a significant regional impact?"

Follow-up: "What specific aspects of these projects contribute to their regional impact?"

2. Outcomes and Insights

Q2: "What have been the outcomes of these projects? Have they met the expected impacts on regional energy systems or environmental goals?"

Follow-up: "Is there any additional insight or unexpected outcomes from these projects that you could share?"

3. Criteria for Regional Impact

Q3: "In your opinion, what criteria should a renewable energy project meet to be considered as having regional impact?"

Probing Question: "Can you give examples of how these criteria apply to any known projects?"

4. Recent Developments and Future Trends

Q4: "Since the conclusion of your work on cross-border impacts of renewable energy projects, what significant developments have you observed in the field?"

Probing Question: "How do these developments influence the future trajectory of regional cooperation in renewable energy?"

Annex 3: Survey validating the definition and criteria

The first survey focused on gathering feedback from expert stakeholders regarding the working definition and criteria at the time. The survey gathered 21 responses between December 8th, 2023, and February 21st, 2024.

The stakeholders targeted were the following groups of experts:

- Academia
- Public institutions
- National regulators and grid operators
- European energy actors

Respondents were presented with the intermediate list of criteria for regional impact presented in Table 3: Intermediate criteria for regional impact, as presented in the Survey on the definition and criteriaTable 3 below. They were then asked to qualify each criterion as per the following options:

- That criterion is relevant and appropriate
- That criterion is relevant but should be modified
- That criterion is not relevant

The complete content of the survey is presented below, followed by an analysis of the results.

Table 3: Intermediate criteria for regional impact, as presented in the Survey on the definition and criteria

Criterion number	Criterion text
1	Projects officially recognised by the EU as having regional impact, or jointly developed by two EU Member States
2A	Projects generating cross-border electricity flows: - Renewable energy generation projects which concluded at least one cross border PPA for a minimum of 8GWh of electricity - Renewable energy generation projects providing offers above 1MW on another country's wholesale electricity market
2B	Transmission grid-connected renewable energy projects above 1% of the country's total interconnection capacity
2C	Renewable energy installations of any size providing ancillary services to another country's grid for at least 1MW.
3A	Renewable energy installations generating regional flows of renewable fuel totaling at least 120GWh per year
3B	Renewable Power-to-X production installations exporting at least 120GWh per year

Survey contents

This survey is carried out as part of the study of the European Commission on renewable energy projects with regional impact in the European Union. The objective of the study is to analyse renewable energy generation projects with impact beyond one country. In the context of further increased ambition for renewable energy in line with the European Green Deal objectives and the recently agreed revision of the Renewable Energy Directive (Directive (EU) 2018/2001), the Commission intends to explore further the potential of cooperation between countries in the area of renewables by examining concrete projects that concern directly or indirectly more than one Member State.

This study aims to:

1. Establish a broader category of renewable energy projects with regional impact, which complements and expands the existing categories of cooperation on projects in the area of renewables according to the Renewable Energy Directive;

2. Identify a pool of renewable energy projects with regional impact, structure them in an easy-to-navigate format and provide essential information about them;

3. Understand the challenges to renewable projects with regional impact and improve the legislative and policy framework in order to tap into the potential of cooperation in the area of renewables.

The results of the study will be published by the summer of 2024.

Respondent's information [1/3]

Name:

Institution or company:

E-mail address:

Criteria to identify renewable projects with regional impact [2/3]

In this section, the project team explores what should count as regional impact. Our working definition is the following:

A renewable energy project with regional impact is an installation generating renewable energy in an EU member state and concerning one or more other countries because of either the direct involvement of another country, its impact on the regional electricity grid or through the potential impact on the regional energy systems and environment.

Our aim is to capture all types of impact that a renewable energy project can generate beyond the borders of the country where it is built. Validation of this working definition would help us define what type of projects have regional relevance. These projects would then be the focus of further research within this study.

Based on the definition, the project team defines the following categories, to be used when researching and identifying renewable energy projects with regional impact:
1. Renewable energy projects with direct involvement of another country
2. Renewable energy projects with direct impact on regional energy systems
3. Renewable energy projects with indirect impact on regional energy systems

For each category, you will be presented with a criterion for regional impact. You will be asked to rate the adequacy of each criterion. If you have any feedback or question regarding the working definition, please provide it here:

Do you think the categories of projects with impact are suitable? Would you propose additional categories which you think are relevant in order to better capture renewable energy projects with regional impact?

1. Evaluating renewable energy projects with direct involvement of another country

This category focuses on renewable energy projects that feature a regional aspect by definition. These are:

1a. Projects officially recognised by the EU as having regional impact. These are known already and feature the following statues:

- Projects with cross-border renewable energy sources (CB-RES) status
- Cross-border renewable energy projects according to the Renewable Energy Directive.

1b. Renewable energy projects linked to bilateral cooperation agreements between countries.

Do you agree with criterion 1b. above?

- That criterion is relevant and appropriate
- That criterion is relevant but should be modified
- That criterion is not relevant

If you wish, please explain your answer:

1c. Do you have suggestions for other types of projects featuring direct involvement of another country?

2. Evaluating renewable energy projects with direct impact on regional energy systems

Projects considered in this section are:

2a. Projects generating cross-border electricity flows:
- Renewable energy generation projects which concluded at least one cross-border PPA for a minimum of 8GWh per year of electricity
- Renewable energy generation projects providing offers above 1MW on another country's wholesale electricity market

2b. Transmission grid-connected renewable electricity installations with nominal capacity above 1% of the country's total outgoing interconnection capacity

2c. Renewable energy installations of any size providing ancillary services to another country's grid with a volume of at least 1MW

Do you agree with criterion 2a. below?
2a. Projects generating cross-border electricity flows:
- Renewable energy generation projects which concluded at least one cross border PPA for a minimum of 8GWh of electricity
- Renewable energy generation projects providing offers above 1MW on another country's wholesale electricity market.

- That criterion is relevant and appropriate
- That criterion is relevant but should be modified
- That criterion is not relevant

If you wish, please explain your answer:

Do you agree with criterion 2b. below?

2b. Transmission grid-connected renewable energy projects above 1% of the country's total interconnection capacity.
These projects are being considered since they are likely to generate significant electricity flows impacting neighbouring countries.
- That criterion is relevant and appropriate
- That criterion is relevant but should be modified
- That criterion is not relevant

If you wish, please explain your answer:

Do you agree with criterion 2c. below?

2c. Renewable energy installations of any size providing ancillary services to another country's grid for at least 1MW.
These offers must be awarded in a procurement procedure for ancillary services, regardless of whether the bid was eventually activated or not.
Examples include a large pumped hydro storage plant bidding for another country's capacity market or a solar plant with batteries providing Frequency Containment Reserve for another country.
- That criterion is relevant and appropriate
- That criterion is relevant but should be modified
- That criterion is not relevant

If you wish, please explain your answer:

2d. Do you have suggestions for other types of impact on regional electricity systems?

3. <u>3. Evaluating renewable energy projects with indirect impact on regional energy systems</u>

This category focuses on renewable energy projects with regional impact not directly via the energy they produce, but through other indirect aspects of the process of planning, implementing and monitoring the projects for more than one country.

The types of projects evaluated in this category are:

3a. Renewable energy installations generating regional flows of renewable fuel totaling at least 120GWh per year

3b. Renewable Power-to-X production installations exporting at least 120GWh per year

Do you agree with criterion 3a. below?

3a. Renewable energy installations generating regional flows of renewable fuel totalling at least 120GWh per year
Examples include a biomass plant in one Member State importing wood pellets worth 120GWh in heating power. Conversions between mass and energy contents are uniformally done via Lower Calorific Power.

- That criterion is relevant and appropriate
- That criterion is relevant but should be modified
- That criterion is not relevant

If you wish, please explain your answer:

Do you agree with criterion 3b. below?

3b. Power-to-X production installations producing at least 120GWh of renewable fuel per year. Fuel is to be classified as renewable or not according to EU regulation. Conversions between mass and energy contents are uniformally done via Lower Calorific Power.

- That criterion is relevant and appropriate
- That criterion is relevant but should be modified
- That criterion is not relevant

If you wish, please explain your answer:

3c. Other types of impact, namely economic and environmental impact, have been considered, but no satisfactory criteria backed up by existing publicly available data could be found.

Regional economic impact was considered through the angles of:
- projects generating certain amounts of revenue in another country, either as a raw amount or as a portion of local GDP.
- projects generating a certain amount of employment in another country, either as a raw amount or as a portion of employment in a specific region.
However, no trustworthy public data on these, at or beyond the NUTS-3 level, was found.
If you believe regional economic impact should be taken into account in the survey, please let us know what data would be appropriate to take into account:

Regional environmental impact was considered through the following criterion:

Renewable energy projects in a Member State impacting any of the following 6 categories in another country at a level incompatible with that country's national regulation:

- climate change;
- freshwater eutrophication;
- particulate matter formation;
- terrestrial acidification;
- freshwater ecotoxicity;
- and land occupation.

3d. Do you have suggestions for other types of indirect regional impacts?

However, no public, project-specific data exists yet. If you believe regional environmental impact should be taken into account in the survey, please let us know what data would be appropriate to take into account:

Overview of renewable energy projects with regional impact [3/3]

The aim in this section is to expand the list of renewable energy projects with regional impact. In this section please provide examples of such projects that you are involved with or familiar with.

As a reminder, our working definition of projects with regional impact is the following: *A renewable energy project with regional impact is an installation generating renewable energy in an EU member state and concerning one or more other countries because of either the direct involvement of another country, its impact on the regional electricity grid or through the potential impact on the regional energy systems and environment.*

If you are aware of any project(s) with regional impact being implemented or operated, please write so here:

Our most sincere thanks for your time and precious input.

Analysis

Suggestions for improvement from stakeholders were not found as actionable. Many exposed gripes with the scope of the project and in particular with specific types of renewable energy projects, biomass being the most contentious one.
Several commenters described Criteria 3a and 3b as discriminating between fuel types whereas they are precisely transposable one-to-one.

Several commenters also presented disagreements with Criterion 1b, suggesting to include other types of joint project development, such as multilateral agreements. This suggestion was implemented, with Criteria 1a and 1b being merged into a single criterion for "direct involvement of another country", the definition for which is presented in section **Error! Reference source not found.**.

Several answers encouraged the implementation of environmental or economic criteria, with various types of impact including value and job creation or greenhouse gases emissions. Most of these suggestions did not typically apply at a regional scale, with job and value creation being concentrated in the energy flows that are already taken into account. On the other hand, greenhouse gases sadly have a global effect and are unlikely to specifically affect neighboring countries. These suggestions were explored further but ultimately not integrated, as presented in section **Error! Reference source not found.**.

One of the more detailed responses suggested introducing a minimal threshold of 1GW to Criterion 2b, so as to limit the number of small projects with insignificant impacts. This suggestion was investigated, tweaked and implemented, with the result being shown in section **Error! Reference source not found.**.Several answers also suggested to make all the quantitative thresholds flexible, so as to better take into account the diverse situations. No method of scaling the criteria up or down was however suggested. The project team explored options such as the country's population, GDP per capita, energy consumption per capita or existing renewable energy market size but no implementable method to correct the criteria could be found.

Annex 4 : Detailed rationale behind the criteria

Criterion 1: the direct involvment of another country

Covering direct involvement of another country, is the most straightforward category of project. It includes projects certifided by the EU as possessing a relevant cross-border impact, through the RED II cooperation, CB-RES and/or PCI/PMI frameworks.

Besides, projects that are co-developed by actors representing their Member State. Private developers venturing into a new country, or development agencies funding a project abroad, does not mean the project itself will have impact beyond its host country and are thus not sufficient to match this criterion. Most archetypal projects envisioned in the literature, such as a plant in one country exporting all of its electricity to another, should fit within category 1.

Criterion 2: the impact on the regional electricity grid

Given that electrons follow the path of least electrical resistance, electrical power crossing a border does not necessarily reflect intentional regional impact. Beyond, grid flows between nodes or countries cannot as of today be attributed to one installation. It was thus decided to focus on two types of projects: those with energy flows across borders, and those likely to sollicitate interconnections between countries. The former is **Criterion 2a** uses a threshold of 8GWh per year, or around 1MW of average power over the year. 1MW is the minimum bidding size on many electrical markets and was thus chosen as a threshold.

The latter is **Criterion 2b,** the threshold for which was validated through several case studies, notably those of Austria, Ireland, the Netherlands and Spain. A quantitative limit for what size of projects qualfiies is arbitrary by nature; this criterion serves as a way to gather a number of representative projects. Rather than exhausting all plants above a certain fixed size, the relevance of which would be debatable, the project team chose to reference a short list of renewable energy plants with a large impact on their country's interconnection, aiming for diversity in technology and geographical zone.

- The first case study was Austria. According to Ember Climate Data, Austria features 5700 MW of interconnection. This means 1% of its interconnection capacity represents 57MW, which represents a significan size for most renewable energy installations. However, endowed with large resources for hydroelectricity, 42 of Austria's hydroelectric plants trump that threshold; this number in one single country means 1% threshold would lead to an unproductive amount of projects with regional impact. The project team thus tested 2% of the interconnection capacity, which still led to 28 hydro projects being selected only in Austria. This indicates that hydroelectric power plants skew the criterion; a reconciliation is thus necessary, and is presented in Section **Error! Reference source not found.**.
- The second case study was Ireland. Ember Climate Data lists its outgoing interconnection capacity as 630MW. 2% of the interconnection capacity thus represents 13 MW, a number clearly too small to represent energy projects generating significant cross-border flows, as it would include any medium-sized solar plant. It was thus decided to add a minimal threshold; no project below 100MW, which represents the high tier for renewable energy installations, was to be selected.
- The third case study was the Netherlands. According to Ember Climate Data, the Netherlands feature 7750 MW of interconnection capacity. The 1% threshold therefore has 20 wind farms and 4 solar farms matching it, which is too high for the sample size desired. However, the 2% threshold leads to a productive list of projects, with 7

operational wind farms above it and no solar farm. This matches what is expected for a Northwestern European country and validates the 2% threshold in the case of a well-interconnected country with high wind potential.

- The final case study was Spain. According to Ember Climate Data, Spain features 6000 MW of interconnection capacity, with France and Portugal. The 1% threshold leads to a project list of 7 wind farms and 28 solar farms, which would again likely lead to an unhelpful project mapping. On the other hand, the 2% threshold leads to 1 operational wind farm and 9 operational solar farms, better matching the expected renewable resource potential of Spain. The Spanish case study therefore further validates the 2% threshold in the case of a country with high solar potential and relatively low interconnection capacity.

As a conclusion, the case studies validate the threshold of 2% interconnection capacity with a 100 MW floor. It filters out small projects with capacities of a couple of tens of MW that are only significant for countries like Ireland, Malta, Latvia, or Lithuania, but not necessarily for a European region. The statistics for those case studies are summarised in **Error! Reference source not found.** below.

Table 4: Summary of the case studies feeding into Criterion 2b

EU Member State	Outgoing Interconnection capacity (MW), source: Ember	1% Interconnection criterion (MW)	Projects matching	2% Interconnection criterion (MW) + 100 MW threshold	Projects matching
Austria	5710	57	42 hydro projects + 3 wind	114	28 hydro projects + 1 wind
Ireland	630	6	2 hydro + 20 PV and 120 wind	13	2 hydro + 2 wind
The Netherlands	7750	78	20 wind + 4 PV	155	7 wind
Spain	6000	60	55 hydro+ 7 wind+28 pv	120	38 hydro+1 wind + 9 pv

Criterion 3 translates electricity impacts into other energy vectors, like hydrogen, biogas or solid biomass. In order for the criteria to remain technology-neutral, the quantitative thresholds used are consistent across categories 2 and 3. Several options, like power-to-X transformation capacity (e.g., electrolyser capacity) or yearly power consumption, were explored. The project team chose to formulate **Criteria 3a and 3b** as GWh of exported green molecules for the following reasons:

- It allows uniform comparison of all molecules: biomass, synthetic methane, hydrogen, ammonia or any other future use based on their embedded energy.
- It focuses on electrolysers' (and others') concrete production output rather than electrolyser capacity, since there is much uncertainty as to how much of the announced nominal capacity of electrolysers will materialise and as to which capacity factor they will have.
- The 120 GWh threshold across 3a and 3b represents the average the yearly heat consumption of 10,000 inhabitants in Europe (source: Odysse-mure, Eurostat). It also represents a reasonable threshold for an amount of hydrogen or similar fuels.
- Finally, the threshold is sensible. For a green hydrogen project, 120GWh/year represents 40 MW of electrolyser capacity, which with common capacity factors would

produce 3,600 tonnes of hydrogen per year. This represents a large but realistic renewable power-to-X installation, with many larger ones being announced already.

Besides flows of renewable fuel, **Criterion 3** also attempted to take into account economic and environmental impacts across countries. Renewable energy projects (once more, especially hydroenergy) can generate large environmental impacts across borders, and any project can generate economic flows across borders. However, no objective criteria backed by publicly verifiable data could be established. The following discarded options are however presented as references for possible future frameworks around projects with regional impact.

Regional economic impact was considered through the angles of:

- projects generating certain amounts of revenue in another country, either as a raw amount or as a portion of local GDP.
- projects generating a certain amounts of employment in another country, either as a raw amount or as a portion of employment in a specific region. However, no trustworthy public data on these, at or beyond the NUTS-3 level, was found.

Regional environmental impact was considered through the following criterion:

Renewable energy projects in a Member State impacting any of the following 6 categories in another country at a level incompatible with that country's national regulation:

- climate change;
- freshwater eutrophication;
- particulate matter formation;
- terrestrial acidification;
- freshwater ecotoxicity;
- and land occupation.

While this type of impact is in theory very relevant, no clear solutions to monitor and research it could be found by the project team or suggested by the engaged stakeholders. No significant cross-border economic or environmental impact was discovered in the course of the study, besides the RES-ULP project between Estonia and Latvia which assessed its environmental impact across the border from both sides. However, that project's regional impact resides in the direct involvement of both countries much more than in its environmental impact and does not on its own warrant taking environmental criteria into account.

Reconciliation for hydroelectric power plants

As apparent in the above case studies validating the criteria, hydroelectricity is an outlier in many types of impact. Given hydroelectricity's longstanding history and acceptance by conventional grid actors, they do not face many of the same roadblocks as decentralised renewables, and therefore are typically not representative of other renewable energy sources.

In particular, hydro power plants are so frequently above 100MW that they fit Crterion 2b more often than not, despite having a production profile flexible enough to manage their impact on interconnectors. Examples of hydroelectric power plants with proven grid benefits, through flexibility in their operating hours or pumped storage, are numerous enough to focus on hydro plants with proven impact and not include them in Criterion 2b.

Hydroelectricity provided another type of unique challenge for category 3: quantifying energy flows linked to natural water flows poses a technical challenge unlike those for any other energy source. Besides, regional environmental impact, which the project team considered adding, only really fit for hydro power plants which may, e.g., divert a river from its natural course, thus impacting neighbouring countries. Assessing this specific impact is not in this project's scope and the consortium thus decided to include hydroelectricity in a way consistent with its history and scale compared to e.g. wind and solar.

As such, hydroelectricity projects are excluded from Criteria 2b in order not to overload the project list. They do however feature prominently in other categories, most notably in Criterion 1 – direct involvement of another country, thanks to the many hydroelectric plants involving 2 neighbouring countries.

Annex 5: List of projects with regional impact

Project title	Type of regional impact	Involved countries
ELWIND - Estonian Latvian Joint Hybrid Offshore Wind Project	Renewable energy project with direct involvement of another country: CB-RES status	Latvia, Estonia
Crete-Aegean Hydrogen Valley (CRAVE-H2)	Renewable energy project with direct involvement of another country	Greece
North Sea Wind Power Hub	Renewable energy project with direct involvement of another country	Netherlands, Denmark, Germany
Large biomass CHP plant in Värtaverket, Stockholm	Installations generating renewable energy from regional flows of renewable fuel totaling at least 120GWh per year	Sweden
BalticSeaH2	Renewable Power-to-X production installations exporting at least 120GWh per year	Finland, Estonia, Latvia, Lithuania, Poland, Germany, Denmark, Norway, Sweden
NAHV (North Adriatic H2 valley)	Renewable Power-to-X production installations exporting at least 120GWh per year	Slovenia, Italy, Croatia
Sofia and Dogger offshore wind farms	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	UK, Denmark, Germany
Bornholm Energy Island	Renewable energy project with direct involvement of another country	Denmark, Germany
UNITED HEAT - Climate-neutral district heating in the european cities Goerlitz-Zgorzelec	Renewable energy project with direct involvement of another country: CB-RES status	Poland, Germany
SLOWP – Saare-Liivi Offshore Wind Park	Renewable energy project with direct involvement of another country: CB-RES status	Latvia, Estonia
ULP-RES WP – Utilitas Lode-Penuja RES Wind park	Renewable energy project with direct involvement of another country: CB-RES status	Latvia, Estonia
Northern Adriatic Sea offshore wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Croatia, Italy
CICERONE Green hydrogen	Renewable energy project with direct involvement of another country: CB-RES status	Italy, Spain, Germany, Netherlands

Project title	Type of regional impact	Involved countries
Kriegers Flak Combined Grid Solution	Renewable energy project with direct involvement of another country	Denmark, Germany
Hybrid project: Princess Elisabeth Island in Belgium and Nautilus	Renewable energy project with direct involvement of another country	Belgium, UK
Hybrid project: Princess Elisabeth Island in Belgium and Tritonlink	Renewable energy project with direct involvement of another country	Belgium, Denmark
Hybrid project: Princess Elisabeth Island in Belgium and interconnection to the Netherlands	Renewable energy project with direct involvement of another country	Belgium, Netherlands
Hybrid project: Dutch offshore wind farm and LionLink	Renewable energy project with direct involvement of another country	Netherlands, UK
A hybrid project (RES+interconnector) between Germany and Norway in the North Sea	Renewable energy project with direct involvement of another country	Germany, Norway
A hybrid project (RES+interconnector) between Germany and the Netherlands in the North Sea	Renewable energy project with direct involvement of another country	Germany, Netherlands
Estonian offshore wind farms linked to the Baltic windconnector	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Estonia, Germany
Rodenhuize power station	Installations generating renewable energy from regional flows of renewable fuel totaling at least 120GWh per year	Belgium
Bristaverket CHP plant	Installations generating renewable energy from regional flows of renewable fuel totaling at least 120GWh per year	Sweden
Hybrid project: Combined Grid Solution IJmuiden Ver to Norfolk	Renewable energy project with direct involvement of another country	Netherlands, UK
Hybrid project: German offshore wind farm to the Netherlands and Denmark via the COBRA Cable	Renewable energy project with direct involvement of another country	Denmark, Netherlands, Germany
VindØ artificial North Sea energy island	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Denmark
Hedensbyn power station	Installations generating renewable energy from regional flows of renewable fuel totaling at least 120GWh per year	Sweden, Poland, Finland

Project title	Type of regional impact	Involved countries
Cross-border virtual PPA from solar PV plants in Seville, Spain	Renewable energy installations subject to a cross-border PPA above 8 GWh	Spain
Cross-border virtual PPA from a solar PV plant in Aragon, Spain	Renewable energy installations subject to a cross-border PPA above 8 GWh	Spain
Cross-border virtual PPA from the Alcalá solar PV project in Spain	Renewable energy installations subject to a cross-border PPA above 8 GWh	Spain
Cross-border virtual PPA from a wind farm in Ljungbyholm, Sweden	Renewable energy installations subject to a cross-border PPA above 8 GWh	Sweden, Poland
Cross-border virtual PPA from solar projects in Spain	Renewable energy installations subject to a cross-border PPA above 8 GWh	Spain
Cross-border virtual PPA from the Tico wind farm in Aragon, Spain	Renewable energy installations subject to a cross-border PPA above 8 GWh	Spain
Cross-border virtual PPA from the Pinos Puente solar PV park, Spain	Renewable energy installations subject to a cross-border PPA above 8 GWh	Spain
Cross-border virtual PPA from the Mutkalampi onshore wind farm, Finland	Renewable energy installations subject to a cross-border PPA above 8 GWh	Finland
Sørlige Nordsjø II offshore wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Norway
Cross-border virtual PPA for the Herrerias wind farm in Zaragoza, Spain	Renewable energy installations subject to a cross-border PPA above 8 GWh	Spain
Cross-border virtual PPA for the Acampo Arpal solar power plant in Cadiz, Spain	Renewable energy installations subject to a cross-border PPA above 8 GWh	Spain
Cross-border virtual PPA for the Señora de la Oliva solar power plant in Cadiz, Spain	Renewable energy installations subject to a cross-border PPA above 8 GWh	Spain
PPA from wind farms in Lithuania to Estonia and Denmark	Renewable energy installations subject to a cross-border PPA above 8 GWh	Lithuania, Estonia, Denmark

Project title	Type of regional impact	Involved countries
PPA from the Anykščiai, Rokiškis, and Jonava wind farms in Lithuania	Renewable energy installations subject to a cross-border PPA above 8 GWh	Switzerland, Lithuania
PPA from Hollandse Kust Zuid offshore wind farm	Renewable energy installations subject to a cross-border PPA above 8 GWh	Netherlands, Belgium, Luxembourg
PPA from Hollandse Kust Zuid 1-4 offshore wind farm	Renewable energy installations subject to a cross-border PPA above 8 GWh	Netherlands
PPA from Northwester 2 in Belgium	Renewable energy installations subject to a cross-border PPA above 8 GWh	Germany, Belgium
Mågeli hydropower plant in southern Norway	Renewable energy installations subject to a cross-border PPA above 8 GWh	Norway, Germany
Cross-border Virtual PPAs from three solar pv projects in Spain	Renewable energy installations subject to a cross-border PPA above 8 GWh	Switzerland, Spain
Virtual PPA from the Ucedo and Porqueros onshore wind projects in the Leon province, Spain	Renewable energy installations subject to a cross-border PPA above 8 GWh	Spain
Cross-border virtual PPA from a Solar farm located in Andalusia, Spain	Renewable energy installations subject to a cross-border PPA above 8 GWh	Spain
PPA from the Picón solar park in Castilla-La-Mancha, Spain	Renewable energy installations subject to a cross-border PPA above 8 GWh	Spain, Portugal
Cross-border virtual PPA for onshore wind farms in Spain	Renewable energy installations subject to a cross-border PPA above 8 GWh	Spain
PPA from a wind farm in Spain	Renewable energy installations subject to a cross-border PPA above 8 GWh	Portugal, Spain
PPA from the Solara4 solar PV farm in Vaqueiros, Portugal	Renewable energy installations subject to a cross-border PPA above 8 GWh	Spain, Portugal
Cross-border virtual PPA from a Solar farm in Andalusia, Spain	Renewable energy installations subject to a cross-border PPA above 8 GWh	Spain

Project title	Type of regional impact	Involved countries
Lithuania - Luxembourg Statistical transfers	Renewable energy project with direct involvement of another country: according to RED II	Lithuania, Luxembourg
Estonia - Malta Statistical transfers	Renewable energy project with direct involvement of another country: according to RED II	Estonia, Malta
Estonia - Luxembourg Statistical transfers	Renewable energy project with direct involvement of another country: according to RED II	Estonia, Luxembourg
Denmark - Netherlands Statistical transfers	Renewable energy project with direct involvement of another country: according to RED II	Denmark, Netherlands
Denmark - Belgium (Flanders) statistical transfers	Renewable energy project with direct involvement of another country: according to RED II	Denmark, Belgium (Flanders)
Denmark - Ireland Statistical transfers	Renewable energy project with direct involvement of another country: according to RED II	Denmark, Ireland
Estonia - Ireland Statistical transfers	Renewable energy project with direct involvement of another country: according to RED II	Estonia, Ireland
Finland - Belgium (federal government) Statistical transfers	Renewable energy project with direct involvement of another country: according to RED II	Finland, Belgium (federal government)
Finland - Belgium (Flanders) Statistical transfers	Renewable energy project with direct involvement of another country: according to RED II	Finland, Belgium (Flanders)
Lithuania - Belgium (Brussels region) statistical transfers	Renewable energy project with direct involvement of another country: according to RED II	Lithuania, Belgium (Brussels region)
Finland - Belgium (Brussels region) statistical transfers	Renewable energy project with direct involvement of another country: according to RED II	Finland, Belgium (Brussels region)
Czech Republic - Slovenia Statistical transfers	Renewable energy project with direct involvement of another country: according to RED II	Czech Republic, Slovenia
Czech Republic - Slovenia Statistical transfers	Renewable energy project with direct involvement of another country: according to RED II	Czech Republic, Slovenia
Denmark - Belgium (Federal government) Statistical transfers	Renewable energy project with direct involvement of another country: according to RED II	Denmark, Belgium (Federal government)
Denmark - Luxembourg Statistical transfers	Renewable energy project with direct involvement of another country: according to RED II	Denmark, Luxembourg
Germany - Denmark Joint Support Scheme	Renewable energy project with direct involvement of another country: according to RED II	Germany, Denmark
The joint electricity certificate market set up between Norway and Sweden	Renewable energy project with direct involvement of another country: according to RED II	Norway, Sweden

Project title	Type of regional impact	Involved countries
Green Hydrogen@Blue Danube	Renewable Power-to-X production installations exporting at least 120GWh per year	Romania
White Dragon H2 cluster	Renewable Power-to-X production installations exporting at least 120GWh per year	Greece
Black Horse H2 Valley	Renewable Power-to-X production installations exporting at least 120GWh per year	Slovakia, Czech Republic, Poland, Hungary
H2U H2 Valley - Reni	Renewable Power-to-X production installations exporting at least 120GWh per year	Ukraine, Romania
H2U H2 Valley - Zakarpattia	Renewable Power-to-X production installations exporting at least 120GWh per year	Ukraine, Slovakia
Iron Gates - Romania and Serbia joint hydropower plant	Renewable energy project with direct involvement of another country	Romania, Serbia
Andalusian Green H2 Valley	Renewable Power-to-X production installations exporting at least 120GWh per year	Spain, Netherlands
GREEN CRANE (WESTERN ROUTE)	Renewable Power-to-X production installations exporting at least 120GWh per year	Spain, Netherlands, France, Italy
H2EU+Store	Renewable Power-to-X production installations exporting at least 120GWh per year	Ukraine, Slovakia, Austria, Germany, Netherlands, Belgium
H2 Cross Border	Renewable Power-to-X production installations exporting at least 120GWh per year	Austria, Germany
H2Sines.RDAM	Renewable Power-to-X production installations exporting at least 120GWh per year	Portugal, Netherlands
SeaH2Land	Renewable Power-to-X production installations exporting at least 120GWh per year	Belgium, Netherlands
Amplifhy Rotterdam	Renewable Power-to-X production installations exporting at least 120GWh per year	Netherlands
The Visegrad Hydroelectric Power Plant	Renewable energy project with direct involvement of another country	Bosnia and Herzegovina and Serbia
The Buk Bijela hydropower plant	Renewable energy project with direct involvement of another country	Montenegro, Serbia, Bosnia and Herzegovina

Project title	Type of regional impact	Involved countries
Glenmore Anaerobic Digester plant	Installations generating renewable energy from regional flows of renewable fuel totaling at least 120GWh per year	Ireland, UK
Emil'Hy	Renewable Power-to-X production installations exporting at least 120GWh per year	France, Germany
CarlHYng	Renewable Power-to-X production installations exporting at least 120GWh per year	France, Germany
Cestas solar farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	France
Kozani (ELPE) solar farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Greece
Kaposvár solar farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Hungary
Zwartowo solar farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Poland
Barmosen solar farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Denmark
Mula Solar Photovoltaic Power Plant	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Spain
Don Rodrigo solar farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Spain
Bienvenida solar farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Spain
Núñez De Balboa solar farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total	Spain

Project title	Type of regional impact	Involved countries
	outgoing interconnection capacity, with a minimum of 100MW	
Valdesolar solar farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Spain
Francisco Pizarro solar farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Spain
Ceclavín solar farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Spain
Seamade Seastar wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Belgium
Norther Offshore Wind Project	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Belgium
Rentel wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Belgium
The Northwester 2 Offshore Wind Project	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Belgium
Northwind wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Belgium
C-Power Offshore Wind Project	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Belgium
Belwind Offshore Wind Project	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Belgium

Project title	Type of regional impact	Involved countries
Nobelwind Offshore Wind Project	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Belgium
Saint Nazaire wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	France
Châtelard-Vallorcine hydroelectric plant	Renewable energy project with direct involvement of another country	France, Switzerland
Iffezheim hydroelectric plant	Renewable energy project with direct involvement of another country	Germany, France
Laufenburg hydroelectric plant	Renewable energy project with direct involvement of another country	Germany, Switzerland
Rheinfelden hydroelectric plant	Renewable energy project with direct involvement of another country	Germany, Switzerland
Ryburg-Schwörstadt hydroelectric plant	Renewable energy project with direct involvement of another country	Germany, Switzerland
Picote I and II hydroelectric plant	Renewable energy project with direct involvement of another country	Portugal, Spain
Turnu Magurele - Nikopol hydroelectric plant	Renewable energy project with direct involvement of another country	Bulgaria, Romania
Djerdap III hydroelectric plant	Renewable energy project with direct involvement of another country	Serbia, Romania
Cedillo hydroelectric plant	Renewable energy project with direct involvement of another country	Spain, Portugal
Saucelle I and II hydroelectric plant	Renewable energy project with direct involvement of another country	Spain, Portugal
Braunau-Simbach hydroelectric plant	Renewable energy project with direct involvement of another country	Austria, Germany
Egglfing-Obernberg hydroelectric plant	Renewable energy project with direct involvement of another country	Austria, Germany
Jochenstein hydroelectric plant	Renewable energy project with direct involvement of another country	Austria, Germany

Project title	Type of regional impact	Involved countries
Passau-Ingling hydroelectric plant	Renewable energy project with direct involvement of another country	Austria, Germany
Schärding Neuhaus hydroelectric plant	Renewable energy project with direct involvement of another country	Austria, Germany
Gambsheim hydroelectric plant	Renewable energy project with direct involvement of another country	France, Germany
Dubrovnik hydroelectric plant	Renewable energy project with direct involvement of another country	Bosnia and Herzegovina, Croatia
Silistra - Călărași hydroelectric plant	Renewable energy project with direct involvement of another country	Romania, Bulgaria
Bajina Bašta I and II hydroelectric plant	Renewable energy project with direct involvement of another country	Serbia, Bosnia and Herzegovina
Buddusò-Alà Dei Sardi wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Italy
Gols wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Austria
Las Majas wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Spain
Senj (Norinco) wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Croatia
KRS-Padene wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Croatia
Alto Da Coutada wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Portugal
Horns Rev Offshore wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Denmark

Project title	Type of regional impact	Involved countries
Anholt wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country’s total outgoing interconnection capacity, with a minimum of 100MW	Denmark
Gemini Offshore Wind Park	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country’s total outgoing interconnection capacity, with a minimum of 100MW	Netherlands
Fryslân wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country’s total outgoing interconnection capacity, with a minimum of 100MW	Netherlands
Borssele Wind Farm Zone	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country’s total outgoing interconnection capacity, with a minimum of 100MW	Netherlands
Zeewolde wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country’s total outgoing interconnection capacity, with a minimum of 100MW	Netherlands
Prinses Ariane Windpark	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country’s total outgoing interconnection capacity, with a minimum of 100MW	Netherlands
NOP Agrowind wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country’s total outgoing interconnection capacity, with a minimum of 100MW	Netherlands
Westereems wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country’s total outgoing interconnection capacity, with a minimum of 100MW	Netherlands
Hohe See and Albatros wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country’s total outgoing interconnection capacity, with a minimum of 100MW	Germany
Galway wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country’s total outgoing interconnection capacity, with a minimum of 100MW	Ireland

Project title	Type of regional impact	Involved countries
Grousemount wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Ireland
Biały Bór wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Poland
Dargikowo wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Poland
Jasna wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Poland
Dębsk wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Poland
Oyfjellet wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Norway
Storheia wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Norway
Roan wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Norway
Tonstad wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Norway

Project title	Type of regional impact	Involved countries
Guleslettene wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Norway
Nordlys Vind wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Norway
Geitfjellet wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Norway
Markbygden wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Sweden
Björnberget wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Sweden
Blakliden Fäbodberget wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Sweden
Nysäter wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Sweden
Åskälen wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Sweden
Björkhöjden wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Sweden
Åndberg wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Sweden

Project title	Type of regional impact	Involved countries
Skaftåsen wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Sweden
Jädraås wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Sweden
Mutkalampi wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Finland
Karhunnevankangas wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Finland
Piiparinmäki wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Finland
Simo Leipiö wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Finland
Metsälamminkangas wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Finland
Isoneva and Murtotuuli wind farms	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Finland
Paskoonharju wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Finland

Project title	Type of regional impact	Involved countries
Metsäla Kristiinankaupunki wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Finland
Norrskogen wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Finland
Välikangas wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	Finland
Hornsea wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	UK
Moray East wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	UK
Triton Knoll wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	UK
East Anglia wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	UK
Walney wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country's total outgoing interconnection capacity, with a minimum of 100MW	UK

Project title	Type of regional impact	Involved countries
London Array wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country’s total outgoing interconnection capacity, with a minimum of 100MW	UK
Beatrice wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country’s total outgoing interconnection capacity, with a minimum of 100MW	UK
Gwynt Y Mor wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country’s total outgoing interconnection capacity, with a minimum of 100MW	UK
Greater Gabbard wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country’s total outgoing interconnection capacity, with a minimum of 100MW	UK
Dudgeon wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country’s total outgoing interconnection capacity, with a minimum of 100MW	UK
Rampion Offshore wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country’s total outgoing interconnection capacity, with a minimum of 100MW	UK
West Of Duddon Sands wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country’s total outgoing interconnection capacity, with a minimum of 100MW	UK
Galloper wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country’s total outgoing interconnection capacity, with a minimum of 100MW	UK
Clyde wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country’s total outgoing interconnection capacity, with a minimum of 100MW	UK

Project title	Type of regional impact	Involved countries
Cibuk 1 wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country’s total outgoing interconnection capacity, with a minimum of 100MW	Serbia
Kovacica wind farm	Transmission grid-connected renewable electricity installations with nominal capacity above 2% of the country’s total outgoing interconnection capacity, with a minimum of 100MW	Serbia
Southeast Bavaria-Upper Austria-Salzburg heating network	Renewable energy project with direct involvement of another country	Germany, Austria

Annex 6: Survey on the barriers to regional impact

Survey 2 focused on the study of the parameters influencing projects with regional impact. The focus was thus on barriers and obstacles that project developers encountered, with some other questions aiming to better understand the drivers and opportunities, particularly financial, that led to projects emerging.

The survey received 16 valid answers between January 23rd and April 5th, 2024.

The detailed content of the survey is given below, followed by a summary of the answers.

Survey contents

Respondent's information [1/3]

Name:

Institution or company:

Email address:

Overview of renewable energy projects with regional impact [2/3]

In this section, the project team explores what should count as regional impact. Our working definition is the following:

A renewable energy project with regional impact is an installation generating renewable energy in an EU member state and concerning one, or more, other countries because of either the direct involvement of another country, its impact on the regional electricity grid, or through the potential impact on the regional energy systems and environment.

Our aim is to capture all types of impact that a renewable energy project can generate beyond the borders of the country where it is built. Validation of this working definition would help us define what type of projects have regional relevance. These projects would then be the focus of further research within this study.

Please note that these projects can be diverse:

A. Projects within collaborative European programmes

B. Other projects outside of European programmes

C. Formal cross-border collaboration within the EU renewable energy directive. These projects are known already. They consist of:

1. The joint green certificate scheme within Norway and Sweden
2. The cross-border solar auctions between Germany and Denmark
3. The auction for solar in Finland funded by Luxemburg
4. The abandoned joint offshore wind farm between the UK and Ireland before Brexit

If you are aware of any project(s) that may suit the working definition highlighted above, please mention which one(s) here:

If you are aware of any project(s) that aimed to generate regional impact but did not, or that did not materialise, please mention which one(s) here:

Drivers and Challenges [3/3]

As a reminder, the scope of this study is renewable energy projects with regional impact, our working definition of which is the following:

"A renewable energy project with regional impact is an installation generating renewable energy in an EU member state and concerning one or more other countries because of either the direct involvement of another country, the direct impact on the energy system of another country or the indirect impact on the environment, the economy or the policy framework of another country."

Here, you are asked to identify which challenges are faced by renewable energy projects with regional impact, as well as what the drivers are to attempt such projects. We aim to address political, economic, social, technical, legal, and environmental challenges.

Our goal is to better understand the obstacles and the priorities of stakeholders to make such cooperation more likely.

<u>A. Drivers for renewable energy projects with regional impact</u>

Question 1. If you named any project, attempted or realised, with regional impact in the previous section, please list the institutional sources of funding from which it or they benefited:

If applicable, including the funding rates, e.g. "ERDF: 60% of eligible costs" and links to the relevant programmes would be very helpful

Question 2. If you named any renewable energy project, attempted or realised, in the previous section, please explain what the goals and reasons for its regional dimension were:

<u>B. Challenges for renewable energy projects with regional impact</u>

Question 1. The literature lists the factors below as political challenges to cooperation on renewable energy projects. Please tick the most relevant ones in your experience:

Renewable energy projects with regional impact may go against established energy stakeholders

Possible competition between many offtaker countries regarding cooperation with a given host country

Projects with regional impact require an intense coordination between member states

Drawing an appropriate cost and benefit sharing is an arduous and risky political task. In particular, indirect costs (such as system and grid integration costs), and indirect benefits (such as energy security, jobs, innovation) are difficult to quantify

Low support from policymakers due to a preference for national control of renewable energy deployment

A project improving the global situation may not align with the local needs and opportunities

Political goals, regulations and support measures differ between Member States

Question If you think one or more political challenges to regional impact are missing from the above list, please list it or them here:

Question 2. The literature lists the factors below as economic challenges to cooperation on renewable energy projects. Please tick all the most relevant ones in your experience:

Projects with regional impact represent an increase in financial risk

Lack of investment security for RES projects, partly due to fossil fuel subsidies and low electricity prices

Investment in beneficial and innovative technologies with higher costs is likely to be unattractive for joint project agreements

Heterogeneous support schemes

Lacking market integration, like the absence of a liquid day-ahead wholesale market across potential partners

Private project developers lack an incentive to go beyond the national borders and the support schemes in place within them

Heterogenous energy prices

Projects with regional impact may not fit into any support schemes/benefit from multiple ones and abuse it

If you think one or more economic challenges to regional impact are missing from the above list, please list it or them here:

Question 3. The literature lists the factors below as social challenges to cooperation on renewable energy projects. Please tick all the most relevant ones in your experience:

Communicating to the national electorate the benefits of cooperation over reliance on domestic resources

Preference of spending taxpayers/consumers’ money for reaping the RES benefits nationally (e.g. jobs)

Limited information and awareness about the potential of exports

The fossil fuel industries and the people who work in them can resist against large-scale efforts to develop renewable energy

Renewable energy projects with regional impact may reduce local control over the social benefits

Lack of an adequate, skilled workforce

Question If you think one or more social challenges to regional impact are missing from the above list, please list it or them here:

Question 4. The literature lists the factors below as technological challenges to cooperation on renewable energy projects. Please tick all the most relevant ones in your experience:

Grid connections are inadequate, esp. for Baltic States, the Iberian Peninsula, and island states. Even those that do reach the target of 15% interconnection by 2030 are constrained

Few countries are planned to have excess renewable energy that could be the basis for projects with regional impact

Any quantification of renewable cooperation should also account for impact on the electricity grid and market

Prioritisation of non-RES in the energy mix

Lack of coordination regarding future grid development

Countries lack certaintly over their own RES deployment and thus do not know their needs/availabilities

There is so far no clear solution for the monitoring of electricity exports

Many possible exporter countries have rapidly increasing electricity demand, limiting the realisable exports

If you think one or more technological challenges to regional impact are missing from the above list, please list it or them here:

Question 5. The literature lists the factors below as legal challenges to cooperation on renewable energy projects. Please tick all the most relevant ones in your experience:

No special regime was envisaged for collaboration between EU member states and non-EU countries beyond the general provisions for inclusion of non-EU countries, including in RED II

Complexity and length of administrative procedures, including those for statistical transfers and joint projects

Different regulations across different Member State, including sharing responsibilities between actors

Potential incompatibility of cooperation mechanisms with national and EU legislation

EU rules currently do not offer a consistent framework for implementation

Negotiations over indirect costs (such as system and grid integration costs) and indirect benefits (such as energy security, jobs, innovation) go way beyond the EC's guidelines

Lacking progress in implementing domestic legislation

If you think one or more legal challenges to regional impact are missing from the above list, please list it or them here:

Question 6. The literature lists the factors below as environmental challenges to cooperation on renewable energy projects. Please tick all the most relevant ones in your experience:

National environmental issues may not align with international preoccupations

Loss of control over project siting and environmental impact

Inadequate spatial planning of RES deployment

Renewable energy installations with positive impact across borders may concentrate environmental impacts in one specific area

If you think one or more environmental challenges to regional impact are missing from the above list, please list it or them here:

Question 7. Finally, if you think an important challenge to renewable energy projects with regional impact is not captured in the six categories above, please input it here:

Results

Table 5: Survey results on political barriers

Political barrier to projects with regional impact	Number of respondents who named it as significant
A project improving the global situation may not align with the local needs and opportunities	3/16
Diverging political goals, e.g., prioritisation of different energy sources	8/16
Projects with regional impact require intense coordination between member states, including negotiations about costs and benefits	10/16
Renewable energy projects with regional impact may go against established energy stakeholders	6/16
Low support from policymakers due to a preference for national control of renewable energy deployment	5/16
Possible competition between many offtaker countries regarding cooperation with a given host country	1/16

In the literature, the political barriers were the most cited ones. The survey with project developers shows a different conclusion, with two barriers being consensually insignificant and only one barrier being validated by the majority of respondents. This may be attributable to different perspectives between project developers and academia, who did not indeed report many purely political challenges in their feedback.

Table 6: Survey results on economic barriers

Economic barrier to projects with regional impact	Number of respondents who named it as significant
Varying maturity, or lack of, wholesale market integration (e.g., weak price convergence, low liquidity)	3/16
Different energy taxation and electricity prices, e.g., social tariffs or fossil fuel subsidies in place	4/16
Heterogeneous support schemes: - Inconsistent support levels - Inconsistent eligibility - Risk of overcompensation if multiple support schemes apply	11/16
Investment in beneficial and innovative technologies with higher costs is likely to be unattractive for joint project agreements	3/16
Lack of investment security and higher financial risk for cross-border projects compared to projects under national support schemes	6/16
Difficulty to assess costs and benefits, including indirect ones like impact on system costs	9/16

The survey showcased two consensual barriers: a general one linked to differences between countries, and a specific one that applies only to intentionally cross-border projects. The differences between support schemes is tied for the most consensual barrier in the survey, and was emphasised by respondents elsewhere as distorting the opportunities and needs. It is also tied to barrier 4, with these differences across borders adding risk and uncertainty.

Table 7: Survey results on social barriers

Social barrier to projects with regional impact	Number of respondents who named it as significant
Lack of public awareness on the potential and benefits of cross-border energy cooperation	11/16
Preference of spending taxpayers/consumers' money for reaping RES benefits nationally (e.g. jobs)	4/16
Uncertain impact on employment, e.g., job creation or potential job destruction in fossil fuel sectors	4/16
Renewable energy projects with regional impact may reduce local control over the social benefits of energy projects	3/16

The social category featured fewer barriers and only one of the four was validated: lack of public awareness. It is tied with the differences between national support schemes for most consensual barrier. Notably, respondents voted for the lack of public awareness and not for the preference of spending taxpayer money nationally, meaning that project developpers consider socio-political resistance to be a solvable problem.

Table 8: Survey results on Technological barriers

Technological barrier to projects with regional impact	Number of respondents who named it as significant
Lack of international interconnections	10/16
Actual, or perceived, lack of RE resource potential for cross-border cooperation	10/16
Prioritisation of non-RE in the electricity grid	4/16
Lack of coordination regarding future grid development	6/16
There is so far no clear solution to assess how much energy from one specific project is exported	2/16
Many possible exporter countries have rapidly increasing electricity demand, limiting the realisable exports	0/16

Two technological barriers were validated as relevant: renewable energy is not seen as abundant everywhere, and where it is, interconnections are lacking to consider exports. A good example is the grid congestion in Italy slowing down further wind uptake in the South for consumption in the North, even within the country. This problem is only exacerbated at the international scale. Beyond, the absence of coordination regarding grid development does not allow for the emergence of regional corridors that would allow international exports to get off the ground. The development of Power-to-X and battery storage may alleviate these problems, but not in the immediate short term.

Table 9: Survey results on legal barriers

Legal barrier to projects with regional impact	Number of respondents who named it as significant
Potential incompatibility of cooperation mechanisms with national and EU legislation.	6/16
EU rules (RED, State Aid, Governance of Energy) on cross-border RE cooperation set a general framework, but not a model ready for implementation across countries.	10/16
Different regulations across different Member State, including repartition of responsibilities between actors	8/16
Complexity and length of administrative procedures, including those for statistical transfers and joint projects	8/16
No special regime was envisaged for collaboration between EU member states and non-EU countries beyond the general provisions for inclusion of non-EU countries, including in RED II	3/16

Lacking progress in implementing domestic legislation, e.g., Czechia was not ready to go into collaboration before its solar market picked up	1/16

When it comes to legal barriers, the survey validated three of the six barriers at a close-to-majority level, suggesting that the rules and processes in place may be a large issue. The most consensual legal barrier was the partial actionability of EU rules for RE cooperation. This feeds back into the political barrier of intense coordination required that was previously highlighted. Besides, the complexity of processes to get a cross-border project off the ground is clearly validated by barriers 3 and 4.

Table 10: Survey results on environmental barriers

Environmental barrier to projects with regional impact	Number of respondents who named it as significant
National environmental issues may not align with international preoccupations	1/16
Inadequate spatial planning of RE deployment	8/16
Loss of control over project siting and environmental impact	3/16
Renewable energy installations with positive impact across borders may concentrate environmental impacts in one specific area	9/16

While few environmental barriers were presented, two of the four were validated by the respondents: inadequate spatial planning of RE deployment and concentration of environmental impacts. These two barriers can be linked: project developers consider that in the absence of a concerted European policy on RE siting, the development of projects with regional impact may lead to undesirable outcomes. One can imagine how a concentration of solar farms for export in South Europe, or an unconcerted development of biomass plants sourcing their fuel from the same forest regions, may cause ballooning impacts. The need for designated zones for cooperation, taking resource endowment and environmental characteristics into account, is therefore needed for uptake of projects with impact.

Annex 7: Project developers interviewed

- Spyridos Economou – Eunice (GR) for the CRAVE-H2 project
- Iaroslav Kryl – Hydrogen Ukraine (UA) for the Hydrogen Valeys in Zakarpattia and Reni
- Jatta Jussila – Clic Innovation Oy (FI) for the BalticSeaH2
- Kainz Markus – RAG-Austria (AT) for the H2EU+Store project
- Klaus Thostrup – Energinet (DK) for the hybrid project of princess elisabeth island and TritonLink among others
- Anders Lenborg and Sebastian Prause – Cloudberry (NO) for the Han windfarm
- Joshua Atkins and Matthew Hinde – National Grid (UK) for the hybrid project of princess elisabeth island and Nautilus among others
- Maarten Konings – Elia (BE) for the hybrid projects of princess elisabeth island and interconnectors (TritonLink, Nautilus etc)
- Rene Tammist and Kristina Nauuts – Utilitas (EE) for the CB-RES projects SLOWP and RES-ULP

Annex 8: Lessons learned fiches

BALTICSEAH2
Description: The BalticSeaH2 project creates a large-scale, cross-border valley around the Baltic Sea. The main valley is between southern Finland and Estonia. Through BalticSeaH2, over 20 demonstration cases and over 10 investment cases will showcase the diverse applications of hydrogen across multiple sectors. By project completion, the production potential for hydrogen is set to reach 50,000-60.000 tons of H2 annually, enabling various industries involved in the project to utilize or sell hydrogen and its derivatives.
Barrier 1 When combining various partners and most importantly involving several different demonstration and investment cases within one project, it becomes clear that the discussion, at a European level, is done within and not across various sectors. Recommendation There should be more discussion between the private and public sectors so that trust is built up. Once trust is established, industry could invest more easily following the direction from the political decision-making process. For example, within a framework where regulations are well-written, uncertainties will be minimised and investment decisions could be taken without the fear of surprises which might arise in the future during the implementation of a project. Barrier 2 The current system of project development consists of simple models of demonstration and investment cases which are mostly isolated in local areas and thus not sufficient to enable a transition. Recommendation A shared vision of the future system and a unified pathway towards this integrated, more sustainable energy system are necessary. Therefore, a holistic approach should be rather considered. This ensures that all stakeholders can progress in a coordinated manner along the same trajectory. For this project, the approach to build the full hydrogen economy which connects not only various sectors along the value chain but also countries across borders was preferred. Following such a holistic approach, all relevant players are part of the project since the beginning of its inception and participate in the planning and development phases. Therefore, the discussions from big projects like BalticSeaH2 should be easier to be brought up to the political level and form a strong voice so as to have an impact towards change and thus enable a system transition. Finally, the transition to the new system will require substantial investments in new infrastructure, which must be standardized and coordinated within an integrated cross-border framework. Barrier 3

The lack of flexibility from the regulatory bodies to consider large scale cross-border projects with several demonstration and investment cases.

Recommendation

The regulatory bodies should become more flexible with respect to legislation/regulations in order to maintain and support such incentives. This becomes even more pronounced since the permitting process is long and it should align among different countries. The BalticSeaH2 project started with scanning all regulatory and financial issues across the various actors of the value chain and in different countries. This process highlighted the lack of flexibility from the regulatory bodies. As an example, a partner had to withdraw from the project because of regulations blocking their specific activity within the framework of a renewable energy project. In this particulat case, the CO2 which was sourced from waste incineration processes was considered, and was therefore treated, as fossil fuel.

Overall, for such complex projects with several demonstration and financial cases, a higher degree of flexibility would be needed. This is relevant not only from the early stages during funding application which is still formulated and approached as if there is only one investor and not a collection of demonstration cases and investors (i.e. a H2 valley) but also during implementation as mentioned above.

THE HAN WINDFARM

Description: The wind farm is located in Sweden. However, connected to the grid in Norway and the turbines feed renewable electricity into the attractive NO1 price area.

Lessons learnt: This case is quite unique since the windfarm is located in one country but connected to the grid of its neighbouring country. The initial idea was not to make a cross-border wind farm but issues arose already once the environmental permit was granted. The lack of grid capacity in the Swedish region of Värmland and the limited grid capacity in Norway resulted in the reduction of the project capacity by 30%, i.e. down to 21 MW, hence it was not possible to use the full environmental permit.

The main drivers for this cross-border project were related to the grid planning since the region where the farm is located was not a prioritized one for grid expansion in national plans. In fact, with the current expansion rate, the grid connection for additional renewable energy projects is foreseen for as late as 2031. As a result, municipalities that are close to the border fall behind in terms of business expansion and development due to energy shortage, regional exporting companies risk becoming less competitive and overall there is a slower transition towards RES production.

This cross-border RES project faced various challenges throughout its different phases of development because of its unique case, location and connection to the grid since it had to go through two different legislations and two different authorities.

During the early planning phase, double consultations were needed (regular and ESPOO), the permit phase was prolonged more than usual and the project developers had to go through three different processes for cross-border grid and import of electricity, i.e. with the Swedish Government, Ministry of Rural Affairs and Infrastructure, the Norwegian Government, Ministry of Energy and the Norwegian Water Resources and Energy Directorate. As an example, there were a lot of issues with the actual permit for the production cable to the substation located in Norway. While according to the Swedish legislation there is no special permit to connect to the grid and cables can be put in the ground up to a specific level of voltage, this was not the case once across the border into Norway. The legislation changes across the border and a special permit is needed.

During the construction phase, a double supervision was done by the Norwegian NVE and the Swedish County Administrative Board while two municipal processes for building permits and consultations were needed.

Finally, related to the windfarm's operation, a measurement point for produced electricity had to be selected between the two countries. The measurement point was eventually in Norway. Issuing the GoOs was initially denied in both countries. From the point of view of Norway, the production was in Sweden while from the Swedish point of view the measurement point was in Norway. The GoOs were only later approved in Sweden.

HYBRID PROJECTS (RES+INTERCONNECTOR) FROM THE PRINCESS ELISABETH ISLAND IN THE BELGIAN NORTH SEA

Description: The Princess Elisabeth Island is an extension of the electricity grid in the North Sea. It connects wind farms from the sea to the mainland and creates new connections with neighboring countries. There are three different projects that are being developed by Elia, the Belgian TSO.

Nautilus, which will link Belgium and the UK together allowing them to trade electricity with each other, will be linked to offshore wind farms in the North Sea enabling electricity generated by these wind farms to be transported to either country.

TritonLink will begin at an onshore HVDC converter station in Belgium, run through the Princess Elisabeth Island, cross the North Sea to reach an offshore platform that Denmark will build off its coast and end at an HVDC converter station on the Danish mainland.

Apart from Nautilus (connection to the UK) and Tritonlink (connection to Denmark), there is a new connection to the Netherlands that has been announced (MOU signed between the two countries).

Barrier 1

There is a lack of relevant mechanisms to ensure that costs are shared among the countries that benefit from the development of such hybrid projects.

Recommendation

These hybrid projects combine the RES generation and the interconnector for the sake of simplicity and therefore cost reductions. The regulatory framework at the moment covers the development of either the RES generation or the interconnection and not both at the same time or for more than one country. A change in the regulatory framework is therefore needed to ensure that costs and benefits are shared not only among the involved countries but also among countries that are indirectly benefiting from such projects. In parallel, the infrastructure for the wind turbines should be part of the project calculations and simulations, something which is not happening at the moment since the RES generation is not taken into account for the TEN-E regulations and financing. The design of the projects should be done with all the countries that are involved since the beginning since those projects are by default regional.

Barrier 2

The entire process for the cross-border cost allocation (CBCA) and TEN-E regulation takes a long time and in the meantime the cost allocations upon which two parties have agreed are actually not the same as when starting the simulations/calculations.

Recommendation

A prioritised regulatory treatment could enable a faster development of the first hybrid projects and thus gain valuable knowledge in terms of technology and regulations to scale up their implementation. Initial financial modelling should also lay the groundwork for future revisions and, ideally, include a sensitivity analysis for the evolution of certain critical parameters.

Barrier 3

Simpler ways to allocate funding are needed which also cover a bigger percentage of the overall costs.

Recommendation

Funding mechanisms such as the CEF fund is enough for only a small percentage of the whole project costs. For that reason, new funds from sources like an offshore investment bank should be accessible.

H2U HYDROGEN VALLEYS IN RENI AND ZAKARPATTIA

Description: Hydrogen Ukraine intends to construct green hydrogen production plants in Reni and Zakarpattia. Apart from the hydrogen generation plant, the project also includes a solar facility and wind installations. This ambitious endeavor aims for seamless integration into Ukraine's Unified Energy System, incorporating new substations and power lines. The export of hydrogen is intended to be via a pipeline to neighboring countries (e.g. from the sites at Reni and Zakarpattia to a metallurgical plant in Romania and Slovakia, respectively).

Barrier 1

External (to the project development and planning) circumstances that block the development of the project, e.g. the ongoing war.

Recommendation

Although prefeasibility studies had been signed and started a few years ago (e.g. the analysis of the potential for H2 production from RES was completed at the end of 2021 and the wind measurement campaign was completed in October 2023) the project development had to freeze because of the ongoing war. Moreover, because the facilities are located in regions of Ukraine where war operations are ongoing, some infrastructure has been impacted.

There are external (to the project development and planning) circumstances like the war or other political reasons that should be taken into account. While this could be seen as a reason not to rely on specific regions, the main message here is that a stable geopolitical situation is needed. Further funding is needed to proceed with the project development to reduce the uncertainties and make the investment decisions easier.

HYBRID PROJECT (RES+INTERCONNECTOR) FROM AN OFFSHORE WIND FARM IN THE NETHERLANDS CONNCTED TO THE LIONLINK INTERCONNECTOR TO UK

Description: This project delivers a new electricity link between the Netherlands and the United Kingdom. Like a conventional interconnector, LionLink enables cross-border electricity transmission and trade. The project is referred to as a Multi-Purpose Interconnector / Hybrid Interconnector because it will connect the two countries via a Dutch 2 GW offshore wind farm.

Barrier 1

While permitting and planning is an overall problem for such cross-border projects, Brexit added extra issues and barriers to cooperate in the North Sea (e.g. after brexit the UK is not part of the NTSO-E anymore).

Recommendation

The UK-EU post-brexit cooperation should improve and new approaches to the planning process and the relevant mechanisms would enable a more centralised viewpoint on developing such projects. All players should be involved in the planning since the beginning.

Barrier 2

It is not easy to justify costs to tax payers when the benefits are going to be exported to another country.

Recommendation

Funding coming from concepts like an offshore wind bank is an interesting idea to bring the discussion from the political down to the practical level and achieve a better social acceptance of such projects.

H2EU+STORE

Description: H2EU+Store is an international industry partnership founded by RAG Austria AG to accelerate the market ramp-up of green hydrogen in Central Europe. The focus of H2EU+Store is on the one hand to ramp up and accelerate the production of green hydrogen in Ukraine to be prepared for a climate-neutral hydrogen supply to Central Europe. Therefore, the first step is to create the necessary foundation for renewable energy and hydrogen production in Ukraine. In addition, the industry partnership H2EU+Store is pursuing the inevitable expansion of storage volumes (both for production balancing and to balance the seasonal demand) as well as adaptations in the area of gas transport from Ukraine to Central Europe.

Barrier 1

External (to the project development and planning) circumstances that block the development of the project

Recommendation

There are external (to the project development and planning) circumstances like the ongoing war in Ukrain or other political reasons that should be taken into account. While this could be seen as a reason not to rely on specific regions, the main message here is that a stable geopolitical situation is needed.

Barrier 2

Certification scheme for H2 production is not as easy as it should be

Reccomendation

An effective certification scheme for H2 production is needed inside but also outside the EU in order to have the required garanties of origine.

Lack of funding schemes for projects at high TRL levels

Recommendation

Ukraine has a clear strategy to decarbonise and they are willing at the same time to export the produced energy (electricity and H2). If the gas piplines from Ukraine could be used they would need to be first repurposed, something that requires funding. Projects as big as H2EU+Store with infrastructure at high TRL levels would need funding from flexible investment schemes which could enable such initiative in order to avoid using public money. By stimulating the market and increasing exposure of such big projects with several involved countries, the investment decision and the funding schemes would align for realising similar future projects. All stakeholders should work together in order to make the sector evolve.

STATISTICAL TRANSFERS

Description: Statistical transfers is one of the 3 cooperation mechanisms set up under the Renewable Energy Directive (EC/2018/2001). It involves an amount of renewable energy being deducted from one country's progress towards its targets and added to another's. This cooperation mechanism provides added incentive for EU countries to exceed their targets, because they can receive a payment for energy they transfer to others. It also allows countries with less cost-effective renewable energy sources at their disposal to achieve their targets at a lower cost.

Lessons learned:

The main reason for engaging in statistical transfers was the failure to meet the EU's mandatory 2020 targets. Various instances of statistical transfers demonstrate their function in immediate adjustments, while also setting the stage for potential future adoption of renewable energy.

Luxemburg – Lithuania: This statistical transfer exemplifies the ideal method for facilitating the tangible implementation of renewable energy projects. In Lithuania, the funds obtained through this transfer were directed towards decentralized energy production facilities through tenders in 2020. Approximately 7 million euros were specifically earmarked for supporting renewable energy initiatives within communities, among farmers, and among small and medium-sized enterprises, aimed at small-scale renewable projects.

The Netherlands – Denmark: This instance underscored the significance of pragmatic and effective decision-making, driven by the goal of achieving renewable energy targets promptly and economically. Denmark intended to utilize the funds to expand power-to-X technologies, emphasizing the production of green hydrogen. Following the lead of the Netherlands, Flanders subsequently engaged in a statistical transfer with Denmark, leveraging Denmark's prior experience with this mechanism.

Estonia – Malta: Malta possessed the flexibility to adjust the quantity of renewable energy transferred based on its energy requirements. Ultimately, a transfer of 20 GWh was executed, showcasing Malta's dedication to employing cooperation agreements for statistical transfers as a final recourse measure. The agreement stipulated that Estonia must reinvest the generated revenue into the advancement of renewable energy production and energy efficiency projects.

CRAVE-H2

Description: The Cretan-Aegean Hydrogen Valley aims to establish a production and distribution centre for green hydrogen, allowing for the reuse of energy stored in the grid through fuel cells and Green H2 Road Transport. It covers all the necessary steps in the hydrogen value chain, ranging from production to high-pressure storage and distribution to hydrogen filling stations, as well as potential other off-takers. The project will be located at the port of Atherinolakkos and will facilitate the 580 MW Aegean Wind Energy project, along with the new Greek-Egypt electricity transmission interconnection, introducing cost-effective African PV power into Greece.

Barrier 1: Lack of concrete national plans for hydrogen

Recommendation: Although hydrogen for energy related applications is an emerging technology, the need to have concrete national plans which also align with other countries in the european union is needed to enable future projects. Without concrete national plans there is no clear prioritisation for such projects.

Barrier 2: Limitations in the existing regulations/legislation with respect to space and safety procedures as well as hydrogen operations.

Recommendation: At the moment, the existing legislation covers only the use/operations for pharmaceutical hydrogen. The safety operations with their limitations should be well-documented. Moreover, any limits for safety considerations/limitations should be well-justified. As an example, the regulatory framework states that hydrogen-related operation cables should be further than 45 meters from power lines, something which practically makes it difficult to install hydrogen refuelling stations within the limits of a city.

Barrier 3: Lack of licences and regulations for fuels cells to be connected to the grid.

Recommendation: At the moment there is no legislation to connect fuel cells producing electricity from green hydrogen to the grid. The NTSEO-g should be involved in the planning and execution of such projects so as to enable such a connection easier (via potentially a preferential sandbox status) until all relevant regulations are in place.

SLOWP AND RES-ULP

Description: Estonian developer Utilitas leads two cross-border wind energy projects linked to Estonia and both selected for CB-RES status. They are:

- SLOWP, an offshore wind park in the Gulf of Riga. It plans to participate in the announced Estonian governmental tender for offshore wind contracts for differences, to be decided in 2026. Commissioning planned for 2030. It represents a cooperation between Estonia and Luxemburg, which cannot procure offshore wind on its own. Luxemburg is committed but there is no clear vision for the transfer of benefits to Luxemburg (virtual cross-border PPA, statistical transfer...). This cooperation follows in the footsteps of Luxemburg's past statistical transfer.
- RES-ULP, an onshore wind park in Lode-Penuja, on both sides of the Latvia-Estonia border, and to be connected to the most recent Latvia - Estonia interconnector on the Latvian side. This is because the Latvian side of the project is going faster and because the Estonian legislation on connection policy for the 330kV lines is being redefined (to introduce a fixed fee per MW connected, e.g.). That interconnector also has free capacity, especially on the Latvian side where wind capacity is lower than 100 MW. RES-ULP also targets the Estonian CfD tender for onshore wind parks; there is no equivalent for Latvia. The project should be eligible to apply to the Estonian tender for the turbines located on Estonian soil, regardless of their electricity connections.

Drivers for the projects include:

- Estonia's decarbonisation target is more voluntary and proactive than other EU countries,
- National Estonian scheme for CfD tenders,
- CB-RES Grant,
- Estonian experience in offshore wind since 2006, which now allows to go for more complex projects such as cross-border installations. Optimisations are now present, e.g., SLOWP included a spatial plan since its inception, as opposed to other offshore wind projects like Saare Wind, which took more than a decade of work.

Barrier 1: Lack of a clear timeline for the CB-RES subsidy allocation. The developer communicated that this barrier impacted their financial modelling, risk assessment, and, crucially, their ability to secure third-party financing, including from public European actors.

Recommendation: Responsible European executive agency CINEA could provide a conservative, or even worst-case, timeline for the subsidy transfer. This could give guarantees to the developers and projects financers without endangering CINEA’s ability to carry out its mission.

Barrier 2: Separate and disjointed permitting procedures. The RES-ULP project showcases the differences between procedures from one country to the next. In Latvia, the environmental bureau approves permit applications, whereas in Estonia it is the local municipalities. Permitting timespans are accordingly different. The Estonian and Latvian sides of the project thus end up becoming two sub-projects.

Recommendation: Since several aspects of permitting are assessed across the border for both sides (visual impact, minimal turbine - house distance, noise limit, avian species impact), the public inquiry within permitting has to be done cross-border too. The project team suggests publishing a more detailed case study for permitting of the pioneering RES-ULP project after the fact and building on it to make the process simpler in the future.

Barrier 3: Uncertain eligibility to national support schemes. Estonia has support schemes in place in the form of the aforementioned offshore and onshore wind CfD tenders, but they have so far not included provisions for cross-border projects' inclusion. The perimeter of the next wave of Estonian tenders, particularly regarding cross-border projects' participation, is a critical parameter to their success.

Recommendation: Actors like CINEA and/or ACER could produce guidelines for a gradual and measured opening up of the national tender schemes to cross-border projects. This would provide countries like Estonia with a reference, facilitating their potential future tender design, but also giving cross-border projects visibility and institutional backing.

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