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Definition of operational transnational collaboration model

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AUTHORS'NAME AND AFFILIATION	Maria Oksa and Suvisanna Correia, VTT Spyridon Pantelis, EERA Emily Riley and Lars Brückner, DTU Maryegli Fuss, KIT Berta Matas Güell, SINTEF
REVIEWER'S NAME AND AFFILIATION	Ivan Matejak, EERA Mónica de Juan, EERA
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EXECUTIVE SUMMARY

The present Deliverable concludes the work carried out in Work Package 2, with focus on developing systemic and cross-sectoral solutions related to Clean Energy Transition objectives and fostering collaboration with industry to support National Energy and Climate Plans (NECPs).

This deliverable consists of three main chapters: a) dialogue with R&I experts and key industrial stakeholders, including five dedicated workshops, b) cross-sectorial dialogue for systemic solutions, and c) definition of an operational transnational model.

The work targeted to formulate a facilitating collaboration framework for six technological pathways, i.e., bioenergy, hydrogen, energy storage, solar energy (photovoltaics and concentrated solar power), wind energy and energy systems integration, identified in Task 2.1. For each of these six technological pathways, key research organisations, industrial stakeholders and public authorities were matched. The final result is a formulation of a comprehensive transnational collaboration model, subdivided into collaboration interfaces for the six technological pathways. In essence, the model describes the collaboration between research, industry, and governments (so-called collaboration triangle) at European, national and regional level, as well as interfaces across geographical levels, presenting at the same time best practices that could be replicated in other sectors and/or countries.

In specific, the development of this framework was initiated through dialogue among industrial stakeholders and energy experts, having as a normative basis the SET Plan Implementation Plans. To validate this approach, SUPEERA organised five topical workshops, including also regional and national clusters as well as European policy makers and innovation stakeholders. EERA Joint Programmes activities/events have been utilised as platforms for the stakeholders' collaboration. Due to the Covid-19 pandemic and the consequent impossibility of carrying out physical workshops, SUPEERA initially organised three webinars on the selected pathways to kick off with the dialogues. Finally, as of spring 2022, five workshops have been organised, whilst the remaining one (on bioenergy) will be organised before the end of the project (June 2023). The analysis of workshops' dialogues and outcomes, along with in-depth desktop research, dedicated interviews and best-practices have supported the development of the transnational collaboration model.

LIST OF ACRONYMS

AC	Associated Countries
CAPEX	Capital Expenditure
CET	Clean Energy Transition
CETP	Clean Energy Transition Partnership
CCS	Carbon Capture and Storage
CCU	Carbon Capture Utilisation
CSP	Concentrated Solar Power
EERA	European Energy Research Alliance
ERDF	European Regional Development Fund
ES	Energy Storage
ETIP	European Technology and Innovation Platform
E3S	Economic, Environmental and Social Impacts
FCH	Fuel Cells and Hydrogen
GHG	Greenhouse Gas
IP	Implementation Plan
IPCEI	Important Projects of Common European Interest
IWG	Implementation Working Group
JP	Joint Programme
JRC	Joint Research Centre
LCOE	Levelized Cost of Electricity
MS	Member State
NECP	National Energy and Climate Plan
OPEX	Operational Expenditure
PV	Photovoltaics
P2X	Power-to-X
R&I	Research and Innovation
RTO	Research and Technology Organisation
SET Plan	Strategic Energy Technology Plan
SMEs	Small and Medium-sized Enterprises
SRIA	Strategic Research and Innovation Agenda
STE	Solar Thermal Electricity
TRL	Technology Readiness Level

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INTRODUCTION

Here the described operational transnational collaboration model is based on three consecutive and complementary activities carried out during the project execution.

Firstly, in 2020 a thorough analysis of the 27 National Energy and Climate Plans, the SET Plan Implementation Plans and the MSs' Long-Term Strategies was carried out, which led to the selection of the six common pathways: bioenergy, hydrogen, energy storage, solar energy, wind energy, and energy systems integration.

This selection of pathways laid the basis for the second phase (2021-2022), which established the dialogue between industrial stakeholders, energy experts end policy makers. The dialogues kicked off via webinars (due to Covid-19) and were eventually validated by five topical in-person workshops (the last in-person workshop will be organised in June 2023).

The conclusions drawn from these topical workshops contributed finally to the third phase (2022-2023), i.e., to the definition of the transnational collaboration model that covers both dialogue with R&I experts and key industrial stakeholders, and cross-sectoral discussion to explore systemic solutions.

The common denominators of each workshop/discussion were represented by relevant elements such as research and innovation, industry uptake of the technologies, policy aspects, and novel components (e.g., citizens' engagement for the Fair Transition), as well as the collaboration with public bodies (e.g., governments).

The target was to identify the existing **best practices within identified pathways** that could be transferred and extrapolated across different countries/regions or technological pathways; detect and analyse the **obstacles and barriers** that hinder the collaboration and knowledge transfer among research, industry and government; and explore the **potential opportunities** in the cross-sectorial challenges that can contribute to achieving the goals of Clean Energy Transition.

The objective of this model is to produce tangible results and impacts by facilitating the dialogue and sharing the knowledge accumulated within the SUPEERA project as well as offer valuable insights into ongoing policy and industrial activities related to low-carbon energy research.

I Dialogue with R&I experts and key industrial stakeholders

Based on the above, the following workshops have been organised:

1. Wind Energy and Energy Systems Integration, Delft, the Netherlands, April 20, 2022
2. Energy Storage and Fuel Cells & Hydrogen, Padova, Italy, May 10, 2022
3. Energy Storage and Concentrated Solar Power, Almeria, Spain, November 15, 2022
4. Offshore Wind & Biodiversity, Copenhagen, Denmark, December 15, 2022
5. Energy Storage and Solar Photovoltaics, Karlsruhe, Germany, March 21, 2023

1.1 Wind Energy and Energy Systems Integration

The workshop in **Delft, the Netherlands**, brought together stakeholders from the fields of **wind energy and energy system integration** to discuss the topic of collaboration between the research community and industry. During the workshop, several examples of R&I projects on renewable energy were presented, which varied from EU-funded projects, being the collaboration between industry and research at its core, to those mainly led by industry and national energy agencies.

Both speakers and participants (mainly representing EERA Joint Programmes Wind Energy and Energy Systems Integration) agreed that increased collaboration between the research community and industry is essential. To that end, the role of R&I is crucial to spur innovation and enable faster carbon-free technologies uptake by industry.

In the Netherlands, offshore wind is considered a crucial technology, with the entire value chain being developed domestically. However, floating offshore wind, being a less commercially mature technology still requires large amounts of R&I projects. The focus on energy system integration and sustainability issues would be a key enabler for decreasing the overall electricity costs. In this regard, establishing the right regulatory framework would enable renewable electricity to be highly competitive against fossil fuels.

The participants also highlighted that while offshore wind and hydrogen represent a promising combination of renewable energy production and utilisation, the objectives of any implementation strategy at national level must be clearly defined. For instance, it is essential to determine whether the aim is to utilise hydrogen for meeting electricity demand or to exporting clean hydrogen to the rest of the world.

Confidentiality issues and intellectual property rights were noted as two main obstacles that hamper effective collaboration between research and industry. Additionally, it was remarked that within the framework of an EU-funded project the required dissemination level of some key technology-related results might not be in line with corporate confidentiality policies, raising competitiveness concerns and making EU funding less attractive to industrial innovators. A comprehensive summary can be found on Appendix I.

1.2 Energy Storage and Fuel Cells & Hydrogen

The workshop in **Padova, Italy**, on **energy storage and fuel cells and hydrogen** provided an excellent opportunity to discuss and reflect on how to accelerate innovation and uptake of new technologies by bringing research and industry closer within these two technological pathways.

These aspects were addressed by contributions from the research community (EERA Joint Programmes Energy Storage and Fuel Cells & Hydrogen), as well as from two world-leading Italian energy companies (SNAM, Eni, Enel Green Power).

Key take-aways from the research community were the establishment of dedicated frameworks to identify industrial needs and provide research solutions to such needs through, for instance, including EERA JPs experts as observers in existing EU Partnerships would guarantee the presence of both industrial players and research organisations.

The speakers representing the private sector showcased how research activities support their businesses both in terms of new solutions, with the potential to reach competitiveness targets

and acceleration in up-scaling to enter the market, as well as in terms of improvement of existing technologies through design and modelling. The speakers also stated the importance of establishing proper ecosystems where all main stakeholders across the value chain can work together, from technology providers through researchers to end-users. A final key takeaway from industry was the need to leverage internal know-how through dedicated collaboration network platforms with external R&I players through, for instance, Joint Research Centres. A comprehensive summary can be found on Appendix II.

1.3 Energy Storage and Concentrated Solar Power

The workshop organised in **Almeria, Spain**, on **energy storage** and **concentrated solar power** gave the opportunity to discuss research-industry cooperation in the topics of Energy Storage and Concentrated Solar Thermal (Power & Heat) technologies (CSP/CST). Representatives from various sectors, namely SET Plan IWG CSP, EERA Joint Programmes Energy Storage (ES) and Concentrated Solar Power research community organisations and industrial players from Spain contributed their valuable insights to the discussion.

The main discussion points were centred around the collaboration between the private sector and R&I institutes, highlighting future R&I collaboration opportunities (e.g., development, testing and qualification of innovative components). Furthermore, the discussion underlined the importance of specific regulation for storage technologies, which should differ from the regulatory framework currently applied to generation technologies. It was noted that the most crucial issues that will help accelerate innovation and development of the CSP market are, for example, the establishment of a stable regulatory framework, the optimisation of tenders, the minimisation of CAPEX costs, and closer cooperation between research and industry. It was also featured that R&I plays a crucial role in overcoming challenges in the deployment of technologies.

JP ES presented its flagship project, StoRIES, whose main objective aim at fostering a European ecosystem of industry and research organisations on hybrid energy storage technologies and providing access to world-class research infrastructures related to materials and energy storage. A comprehensive summary can be found on Appendix III.

1.4 Offshore Wind and Biodiversity

The workshop **on offshore wind and biodiversity** was organised in Copenhagen, Denmark. This event complimented the workshop organised in Delft, putting the focus on increasingly pressing issues related to the “coexistence” between renewable energy and biodiversity.

Central point of the discussion was the prospected establishment of 10,000 offshore wind turbines in the North Sea in the coming years and the impact that this intervention will have to the environment, to marine biodiversity. It was explained that biodiversity includes different species, individuals, interactions, and ecosystems, and proposed an action plan to stop its decline. It was also mentioned that the North Sea as a disturbed ecosystem is already under pressure from human activities and climate change. In this regard, Ørsted's strategy aims to have a net positive impact on biodiversity, which includes bubble curtains, artificial reefs, and nest towers. Challenges include understanding and measuring biodiversity, managing stakeholders' expectations, and potential conflicts with other sea users. Investing in nature restoration projects elsewhere may also be necessary. A comprehensive summary can be found on Appendix IV.

1.5 Energy Storage and Solar Photovoltaics

The workshop on **energy storage and solar photovoltaics** was held in Karlsruhe, Germany and it was part of the Energy Conversion and Storage Days. It brought together experts from various fields in the research sector, local organisations, R&I agencies, and industry representatives.

During the discussion, participants highlighted the importance of collaboration among different actors and investment from both the private and public sectors in the European energy sector. The need for diverse funding approaches to encourage private investors to invest in initial scale-up projects and support start-ups in the fields of energy storage and photovoltaics was also emphasised. Collaboration between research and industry on the topics of circularity, sustainability and low carbon footprint are crucial to increase the competitiveness of European low carbon industry, and the exploration and promotion of other energy storage technologies should look beyond batteries.

The workshop also touched upon the impact of individual MS's energy policies and emphasised the essential role of collaboration among investors, research, and industry in promoting new technology solutions. In the second part of the workshop, speakers stressed the importance of lobbying efforts and standardisation at the national and European level to achieve sustainable energy solutions. A comprehensive summary can be found on Appendix V.

II Cross-sectoral dialogue for systemic solutions

This chapter describes the cross-sectorial challenges pertaining the CET process and the established dialogue potentially able to address them via systemic solutions.

2.1 Background

2.1.1 Identification and categorisation of cross-cutting issues in energy

The Deliverable 2.2 "*Systemic and cross-sectorial issues pertaining to the Clean Energy Transition objectives*" defines a template for identifying and categorising cross-cutting issues in low-carbon energy sector covering non-technological and technological topics. The non-technological topics, for example, include aspects focusing on environmental sustainability and socio-economic sustainability. The technological topics, on the other hand, relate to the development and improvement of specific technology, integration with other technologies, connection to cross-cutting technological solutions, and standardisation. The template provides a comprehensive framework for identifying and addressing the various challenges and opportunities that arise from the Clean Energy Transition objectives.

2.2 Dialogue on non-technological cross-cutting topics

Regarding the **environmental sustainability**, the main discussion points referred to:

- **Protection of wildlife during the construction phase**. An example demonstrating how policy and legislation interact with the cross-cutting issues and how they can be used to push forward the dialogue were presented.

- **Energy sites as an opportunity to foster wildlife proliferation.** A Dutch example regarding offshore wind showed how landscaping, choice of materials and seeding structures can improve growth of corals and oysters.
- **Definition of the common EU roadmap regulating the use of the sea(s) for CET purposes**. It was noted that the various boards, agencies and bodies across Europe must coordinated so that the human presence at seas causes the least possible damage. There is also a need to agree on what to prioritise, as it is unlikely for humans to undertake all desired activities to the same extent, without having massively negative consequences for biodiversity.
- **A baseline for biological richness.** This is particularly crucial for stakeholders engaged in offshore wind farms. Cooperation among all parties interested in this endeavour is important. To comprehend the impact of a specific offshore wind farm on biological richness, data and a baseline for biological richness are required. The wind turbine industry and consultants collect large amounts of data in connection with their activities, e.g., in connection with impact and assessment, and they are willing to make this data available for research purposes.
- **Wider issues related to environmental sustainability.** These for instance include costs associated with environmental sustainability and the corresponding financing options; EU-wide coordination for unification of best practices; cross-cutting guidelines between technologies and sites as well as drivers for environmental sustainability (e.g. corporate values and contractual requirements).

For **socio-economic sustainability**, the dialogue was more varied, covering:

- **Creation of supply chain infrastructure and matching demand,** where, for example, hydrogen was the focus regarding centralisation vs decentralisation; repurposing the existing natural gas infrastructure; projected demands and how to meet them. Beyond hydrogen, a system that incentivises flexible demand and integration with renewable energy sites is needed.
- **Development of regulatory framework** for transport and storage of hydrogen as well as for offshore wind and grid development.
- **Involvement of the entire value chain** with key issues such as asset readiness, system design and value chain development.
- **Identification, evaluation and initiation of cross-border infrastructure projects** that require alignment over key conditions and enablers, including financing and risk allocation, energy regulation, CO_2 allocation policy, industry policy, decarbonisation incentive schemes, spatial planning, and environment and safety.
- **Creation of a pan-European education ecosystem** to reduce the cost of reskilling workers and secure the quality of educational programmes to address the anticipated transformative developments across multiple industries.
- **Upscale and lack of commercial experience with CSP** as a bottleneck to implementation despite the importance of CSP technologies for the decarbonisation of energy-intensive industrial processes.

2.3 Dialogue on technological cross-cutting topics

For **integration with other technologies**, the topics of discussion included:

- **Energy storage** is necessary for energy independence, use of renewables and decarbonisation. A hybrid model of different energy storage technologies is expected, with consideration given to both gravimetric and volumetric energy density. Importance of cross-cutting issues related to **concentrated solar power**, such as the integration of CSP and PV.
- **Energy systems integration**, with a focus on the connections between wind and hydrogen. However, there is no need to produce the time but each at the right time. Flexible demand from electrolysis can lead to additional emission reductions and the efficient utilisation of surpluses.
- **Further cross-cutting integration with agriculture**, linking energy systems to biomass opportunities, greenhouse heating, and hydrogen fuel for tractors.
- **Integrations with specific industries with hydrogen**, such as steel, glass, transport, and ceramics industries as well as with natural gas pipelines. Beyond hydrogen, the maritime industry is piloting more integration at ports. The maritime industry is also piloting more integration at ports, with efforts to expand the system to provide green electricity to vessels.
- **Further digitisation,** to accelerate the development and reduce overall costs. In the case of CSP technologies, digitisation can reduce both capital and operating expenses, increase reliability and facilitate system integration. Wireless technology is an important aspect for cost reduction for wiring and other expensive materials.

For **connection to the cross-cutting technological solutions**, the discussion points were:

- **Modelling supply, demand, and production** for hydrogen and utilising those models to match demand and predict required infrastructure.
- **Integration of modelling and scenario building,** enabling prompt data retrieval from pilots for research and providing industry with optimisation advice. Coherent data sets, including power production, market conditions, meteorology, heat production, and grid conditions, are important for this purpose.
- **Challenges that need to be tackled to improve the scalability of CSP technologies**, such as those related to CSP tenders and grid access, levelised cost of electricity (LCOE) and key aspects relevant to the regulatory framework.

For **standardisation**, technical standards are under development with the participation of focus groups to establish common rules on hydrogen in Italy and Europe. This is also connected to the future regulatory frameworks, which requires collaborating with policymakers across various countries.

III Definition of operational transnational collaboration model

The core of this report is based on a common principle that the transition to a climate-neutral economy is above all a transnational challenge for the European Union and Associated Countries that requires new approaches and ways of thinking as well as cross-country debates, where collaboration is a crucial aspect of this transition time. In this regard, collaboration models are strategic approaches to disclose how actors (directly or indirectly involved) communicate and coordinate to accomplish goals and activities, including cross-sectorial aspects and energy technologies.

To facilitate and enhance this collaboration, SUPEERA partners developed a so-called operational transnational collaboration model. This model embodies a coherent form to map and discuss how (energy) technologies and cross-sectoral aspects correspond to the energy transition at different geopolitical levels. It focuses on the involvement and interconnections of actors committed to realise regional ideals mirroring the national and transnational (European) ones and vice-versa. The proposed operational transnational collaboration model follows the principles of mental models and agent-based models[1,2]. The guide taken from mental models focuses on learning with actions how to think better by mapping existing connections and opportunities and making them visible to all. The best-identified practices simplify complexity and create new options based on consistent decisions. The principle of agent-based models brings the knowledge to consider the interactions between the actors by identifying critical players associated with the goal or ideal set, in this case, the transition to a climate-friendly economy.

The operational transnational collaboration model (Figure 1*)*, consisting of three main interconnected pillars, i.e., communication, coordination, and cooperation, is targeted to bring transnational awareness to support the energy transition in Europe. For the purposes of the current report, these three pillars are to be applied between three main sectors, namely the research community, industry and governments.

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[1] Vosniadou, S. (2002). ” Mental Models in Conceptual Development” In: Magnani, L., Nersessian, N.J. (eds), “Model-Based Reasoning”. Springer, Boston, MA. https://doi.org/10.1007/978-1-4615-0605-8_20

[2] Helbing, D. (2012).” Agent-Based Modeling”. In: Helbing, D. (eds), “Social Self-Organization. Understanding Complex Systems”. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-24004-1_2

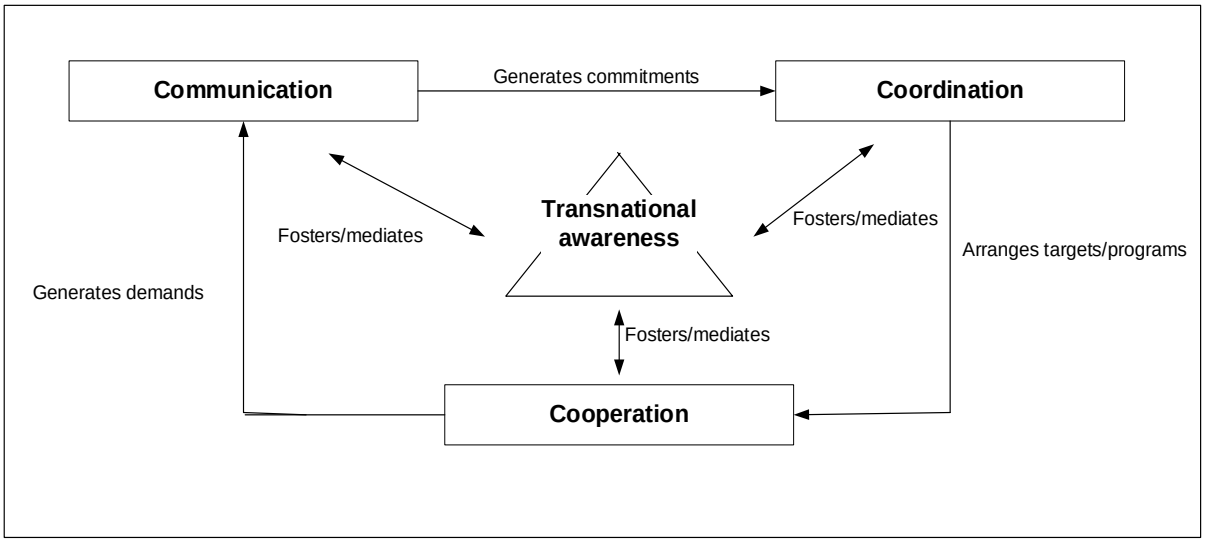


Figure 1. Schematic presentation of the operational transnational collaboration.

These three sectors can be considered a pre-defined group of actors (i.e., three nodes) who align strategic objectives, priorities, and policies for the transition to a climate-friendly economy. To succeed in accelerating innovation and uptake of research and innovation by industry it is imperative to establish a **solid and continuous dialogue (communication).**

There are several sectors and countries in which collaboration between these three nodes, named as the collaboration triangle or "triple helix", is often established and well-functioning. Nonetheless, the "triple helix", namely the three levels of the collaboration triangles as such, is no longer sufficient to deliver - or at least no quickly enough - the innovations Europe needs to reinvent large parts of the economy and, by consequence, to provide solutions to the current (energy and climate) challenges. It is of utmost importance that **knowledge sharing through these important collaborations (i.e., coordination and cooperation)** takes place across boarders by interconnecting or aligning existing collaboration triangles at regional, national, and European levels. For this purpose, mapping the existing cooperation and dialogue between different actors at different levels was performed, and the simplified outcome is presented in a schematic way, as per Figure 2.

Through this collaboration model, a more holistic approach is proposed, embedding novel collaboration concepts such as: i) interfaces across European territories/geographical levels (presented both in terms of illustrations and table-matrix); ii) cross-sectorial aspects (focused on energy sector regulation) and iii) new collaborative platforms such as European Centres of Excellence. Figure 2 illustrates such a model, considering the energy sector as an example, including three collaboration triangles at regional, national, and European levels and the interdependency between key stakeholders within each triangle and between geographical levels.

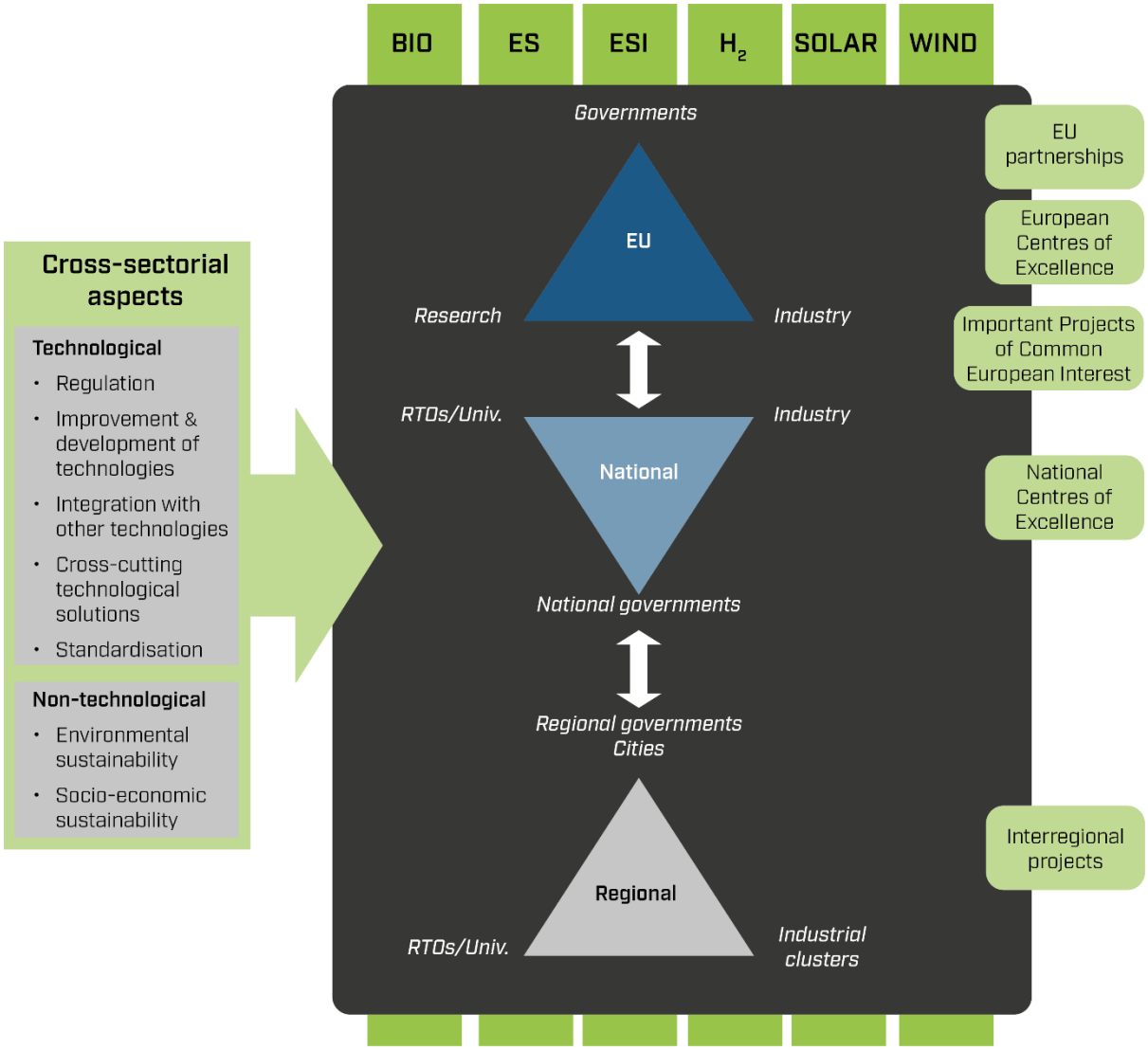
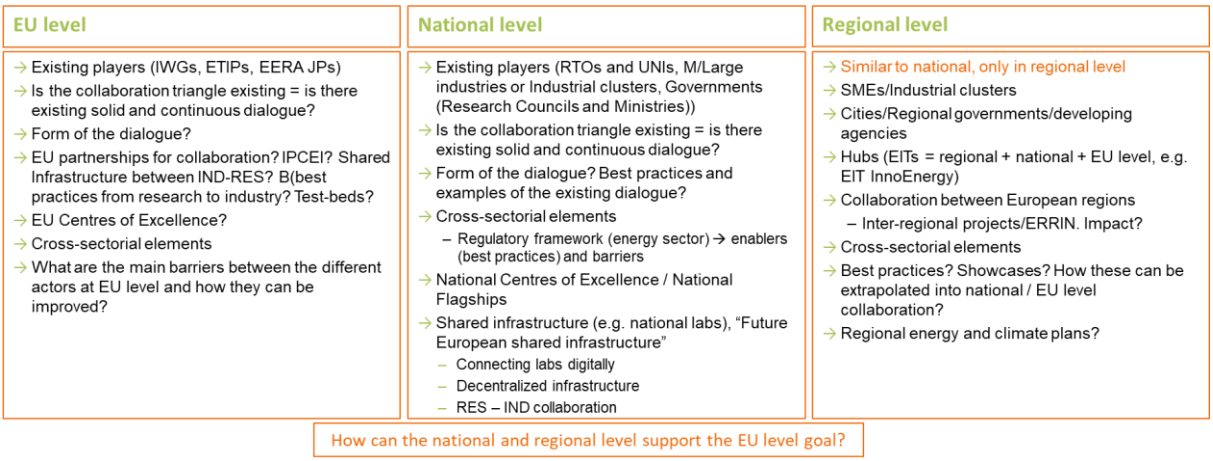


Figure 2. Collaboration interface schematic concretising the operational transnational collaboration model.

For Europe to provide continental solutions, it has to build largely on (existing) national and local initiatives. To accelerate innovation and development uptake at national and regional levels and ensure alignment with European decision-making, it is fundamental that national and local (municipalities, provinces) policymakers, businesses (large industries and SMEs/Industrial clusters) and research organisations are, beyond national collaboration, connected to European ecosystems.

In the next chapter, this model will be applied to the six technological pathways identified in Task 2.1, with the aim to improve current collaboration matrixes within these sectors and provide best-practices for replicability in other geographical territories/geographical levels and/or technological areas. When mapping these collaborations, e.g., the following issues can be considered:



Country selection for the collaboration interfaces was made based on the previous analyses on the forerunners in each technological pathway, with advanced activities and exemplary best practices. The presentations below are divided into three levels, starting from dialogue in EU level, then national and regional levels.

3.1 Collaboration interface on bioenergy

Bioenergy and biofuels – European level

Across the whole breadth of bioenergy and biofuels, a collaboration between the research community, industry and governments at the EU level is widely established, but not exclusively, by interactions between SET Plan IWG8 "Renewable Fuels and Bioenergy", ETIP Bioenergy, ETIP Renewable Heating and Cooling, and EERA JP Bioenergy.

IWG8, as such, acts as a small version of the collaboration triangle, with the presence of country representatives, industry, and research community. The governments are usually represented by senior ministerial staff and national funding agencies. Yet, in a few cases, countries appoint a person from the research community to represent them, e.g., Italy. With regards to the private sector, it is both individual companies, e.g., Neste, and members of ETIP Bioenergy, typically the Chair and Vice-Chair of this entity, who are invited to attend the meetings and activities. The research community is also part of this collaboration platform but is limited to the IWG8 supportive (CSA-project) initiative SET4BIO, with research organisations as project partners and a few additional research organisations. For the well-functioning and smooth operation of IWG8, a secretariat driven by JRC was established. The operation of IWG8 has been significantly impacted from the pandemic and has slowed-down activity during the past couple of years. However, an IWG8 core group consisting of IWG8 Co-Chairs, JRC, ETIP Bioenergy Chair and SET4BIO representatives has met more regularly during these times and has kept discussions alive. For the first time since the pandemic, a physical meeting is planned in Q1 2023 to accelerate once again the realisation of IP8. To support, stimulate and bridge the gap between research and market, IWG8 has been supported by SET4BIO project which kicked-off in 2020 and finalised in fall 2023. This project has, among other activities, focused on funding/financing mechanisms for up-scaling/market uptake initiatives and on the organisation of innovation challenges engaging promising and ambitious innovators all over Europe. SET4BIO has also organised, on behalf of IWG8, joint events with ETIP Bioenergy to put special emphasis on strengthening cooperation between

industry and national authorities/governments. The success of the progress of IP8 can be largely attributed to the outcomes from SET4BIO and hence, it is strongly recommended to continue supporting the existence of such CSA-type of project beyond 2023 once SET4BIO is finalised.

To ensure a dynamic and fruitful mediation between all IWG players, it is essential to have a clear picture of the governance and structure of the platform, including the distinguished roles a single institution may represent. A challenge IWG8 has faced since its establishment is that some of the members represent several institutions, and it might be unclear which organisation they represent when participating in meetings. For instance, the Chair (RISE) and Vice-Chair (VTT) of ETIP Bioenergy are also members of SET4BIO, thus providing on the one side the European industry view that goes into IP8 (ETIP Bioenergy) and on the other side, supportive actions fulfil IP8, with a science-based approach from RTO's.

This overlapping of roles also occurs across EU-national-regional collaboration triangles.

Table 1 and Figure 3 show examples of such organisation overlap. On the one hand, individual/institution-dependent collaborations can be very risky as collaboration/alignment between stakeholders within collaboration triangles might fall apart when these persons/institutions exit the eco-system. On the other hand, they provide an enormous added value and are beneficiary when aligning R&I needs between the research community and industry and accelerating innovation and uptake by industry.

Beyond IWG8, the collaboration between the research community and the industry on bioenergy and biofuels has often been formalised by collaboration within ETIP Bioenergy, with representatives from both the research community and the private sector, as well as collaboration between ETIP Bioenergy and EERA JP Bioenergy. During the past years, these two platforms have established a solid and continuous dialogue. Both are represented in each other's Steering Committee meetings, facilitating joint discussions, organisation of joint events and alignment of SRIAs, thus with several best practices of inspiration to other sectors.

The governance of ETIP Bioenergy also allows fostering collaboration between their members (industry and research) and national governments through an advisory board consisting of technical experts appointed by MS/ACs (11) involved in relevant bioenergy issues as identified in the SET Plan priorities. This group is not fully aligned with the country representatives in IWG8 and has the objective to give advice/direction and feedback on the activities of the platform and can be considered as the interface between ETIP Bioenergy and national governments.

Cooperation between the research community and authorities on bioenergy and biofuels at EU level is generally materialised by key research organisations providing input to national strategies/plans. These research organisations, which usually are EERA JP Bioenergy members, contribute to i) aligning such strategies/plans across the EU and ii) developing a joint European Roadmap on research and innovation priorities.

Complementary to ongoing discussions/collaborations between the aforementioned players, it is worth mentioning the unique co-funded European Partnership on energy, i.e., Clean Energy Transition Partnership, which will also contribute to realise IP8 through dedicated transnational research and innovation projects based on national priorities/needs.

Bioenergy and biofuels in Finland – National level

The bioenergy sector in Finland is an example of a mature business ecosystem and, currently, a mixture of mature technologies with emerging ones. Forest industries and bioenergy have been among the most significant sectors in Finnish economy for decades if not centuries. Collaborations on national and regional levels occur between research organisations, national and regional governments, and industrial players of all sizes throughout the country.

Research environment

As a result of regional policy, all greater regions of Finland have at least one university that carries out research and teaching in disciplines relevant to bioenergy, namely energy and process or chemical engineering. In addition, universities of applied sciences, which focus on bachelor-level education, carry out research activities. Also, the national technological research centre VTT Finland operates six centres throughout the country, collaborating closely with the universities that carry out bioenergy-related research. Beyond research institutions, some research is also conducted by the government's research units relevant to bioenergy i.e., the Finnish Environment Institute (SYKE) under the Ministry of the Environment and the Natural Resources Institute Finland (LUKE) under the Ministry of Agriculture and Forestry. Related to biobased energy sources, SYKE works on the circular economy, waste streams and environmental impacts. LUKE's task is to promote competitive business based on the sustainable use of renewable natural resources. The collaboration of the units named here and the other actors in the collaboration triangle are elaborated below.

Government environment - National innovation funding

Business Finland is the central Finnish government-owned organisation for innovation funding, trade, and investment. The Ministry of Economic Affairs and Employment directs the activities of Business Finland. Based on its aims and activities, Business Finland can be considered a national innovation triangle, as players from industry, research organisations, as well as the public sector, can apply for joint project funding. Business Finland offers funding and networking services to large companies, SMEs and start-ups, as well as research organisations. Also, public sector actors such as municipalities can receive expert services and funding for low-carbon energy transition.

Business Finland has been the central collaboration platform in bioenergy and fuels R&I. It is worth mentioning one dedicated financing programme by Business Finland which is particularly relevant for R&I in the private sector, namely Veturi Programme. In this ongoing Veturi Programme, Business Finland has competitively selected large, internationally operating Finnish companies to become business network locomotives (Finnish: *Veturi*) to solve significant future challenges and increase their R&I investments in Finland. Each Veturi company is responsible for presenting an R&I roadmap for the industrial sector it represents and leading the execution of this roadmap. The companies selected by competition must demonstrate global networks and the know-how and indicate their intention to accelerate innovation in their industries. Parallel Veturi programmes in several sectors include large industrial players in Finland. In the domains of bioenergy and biofuels, Neste, Fortum, Metsä Group, and Valmet function as current business locomotives that lead R&I with their roadmaps.

In 2022-2023, Veturi Programme opened calls for applications for partnership funding in line with the locomotive companies' roadmaps for R&I joint projects where companies and

research organisations are eligible to participate. Consortiums are formed around each respective roadmap. The projects are envisioned to take the industry in the direction of the roadmap, e.g., the one of Neste. Partnership projects around the locomotive companies' R&I roadmaps are partly funded by the EU Recovery Facility. While the joint projects may involve locomotive companies, the locomotives themselves cannot receive funding through individual projects. Instead, they are independently funded to lead the entire roadmap collaboration. As an example of sustainable transportation fuels (even if it is not related to bioenergy and biofuels), VTT Finland is leading an e-fuel research project related to Neste's Veturi programme, bringing together fifteen partners with the goal of large-scale production and commercialisation of e-fuels. The Programme, in its entirety, will fund several consortia. Business Finland is known as a flexible actor who knows how to support project development in genuine interaction.

Bioenergy and biofuels in Finland – Regional level

The Ministry of the Environment and its associated research centre, the Finnish Environment Institute (SYKE), coordinate climate actions and national research as well as other projects pertinent to clean energy transition, including e.g., bioenergy in municipal district heating. SYKE established the Hinku network in 2008, together with forerunner municipalities in climate change mitigation. The Hinku network now includes more than 80 municipalities and five provinces that have committed to reducing 80% of GHG emissions by 2030 as compared to 2007 levels. Numerous municipalities have established development companies to realise projects that push new technologies from the R&I stage to use, when it would not occur by the business sector only. These collaborations achieve the final step and are necessary for accelerating the application of R&I. Therefore, Hinku can be considered a best practice of collaboration between the public and the private sector. This is pertinent to bringing green transition projects to local action.

Regional Centres for Economic Development, Transport and the Environment

The Centres for Economic Development, Transport, and the Environment (ELY Centres) represent the national government on the regional level, including the activities of several ministries. In total, there are 15 ELY Centres around the country. ELY Centres have three areas of responsibility: 1) Business and industry, labour force, competence, and cultural activities; 2) Transport and infrastructure, as well as 3) Environment and natural resources. Notably, all these areas bear relevance to bioenergy and biofuels.

The ELY Centres also represent Business Finland regionally and manage the European Regional Development Fund (ERDF) in Finland. ERDF funding is important for regional collaboration and R&I in bioenergy. The collaboration for regional bioenergy or fuels R&I would be formed, e.g., around municipalities, regional councils or the Hinku network with ERDF funding. National research institutes, regional universities or universities of applied science are often the coordinators in such collaborations.

The building blocks of the "collaboration triangle" exist in regions, and collaboration takes place in regional development projects, even if there is no permanent forum where all the actors pertinent to a regional triangle would meet regularly. As mentioned earlier, the research side of the triangle, namely, the regional universities and VTT are present in all greater regions of the country. Typically, regional utilities and industries carry out bilateral and joint development projects in collaboration with the local university of the region where they are

located and VTT. In addition, the regional councils and the central city of the region carry out research and development projects with respective universities and VTT.

Multiple regional development projects have been carried out throughout the country to develop energy efficiency and renewable energy in municipalities. Bioenergy development, e.g., fuel shift in district heating plants or biogas development, is often taking place inside the wider scope of these projects, as renewable energy has traditionally had a strong connotation with bioenergy in Finland. R&I Collaborations play out in these projects in multiple ways, which is a hallmark of a mature business ecosystem.

A nationally recognised best practice in regional R&I uptake was a regional development project (VÄLKE) 2015-2017, which SYKE coordinated in the Uusimaa region to increase energy efficiency and cleantech uptake with several Hinku network municipalities. The Hinku network had evidenced the lack of investments in low-carbon and economic solutions by the public and private sectors even though financial instruments were available for that. There was also a concern about the lack of a sufficient domestic cleantech market to support emerging businesses with new technologies. As a response to these challenges, the VÄLKE project brought together SMEs with significant energy use and emissions, municipalities and other real estate owners, public actors and private enterprises making cleantech purchases, as well as companies manufacturing and implementing low-carbon products and solutions e.g., in renewable energy and cleantech.

The project developed an operating procedure that municipal energy experts carried out in their work with SMEs and municipalities. The project also established a joint procurement model to enable municipalities, SMEs and individuals to acquire the most advanced technologies in renewable energy or energy efficiency. During the project, numerous procurements were initiated. These acquisitions are also references for implementers and examples for other potential customers. Demonstrations and communication played an important role in the project. The joint procurement process proved its efficacy and will continue to be used within the Hinku network.

Interface across geographical levels

To realise collaboration across geographical levels, EERA JP Bioenergy supports members in shaping research to national priorities and the implementation through national research programmes. In the case of Finland, VTT, being a research pillar in the Finnish research arena (both national and regional) and acquiring key roles within the EU collaboration triangle on renewable fuels and bioenergy (e.g., member of EERA JP Bioenergy, Vice-Chair of ETIP Bioenergy and partner in SET4BIO), is one of the key figures facilitating the alignment of European and national/regional R&I priorities in close dialogue with the Ministry of Economic (through Business Finland) and regional (through ELY Centres) R&I funding). A second crucial player contributing to coordination and interconnection across EU and national dimensions is Neste, the world's leading producer of sustainable aviation fuel and renewable diesel. On the EU level, the Finnish company is a member of the ETIP Bioenergy Steering Committee and participates in IWG8. In Finland,

Neste is one of the national business network locomotives with an R&I roadmap on biofuels. With this double role, Neste fosters alignment of European and national industrial efforts in

this discipline. In addition, the globally operating Finnish forest industry corporation UPM Kymmene is a member of the ETIP Bioenergy Steering Committee.

In terms of initiatives, it is worth mentioning SET4BIO, outlining a roadmap to fund and finance IP8-activities, identifying and mobilising financing instruments for this purpose, and activating private and public actors in a coordinated manner.

Examples of organisational overlap within and across collaboration triangles is shown in Figure 3 and

Table 1.

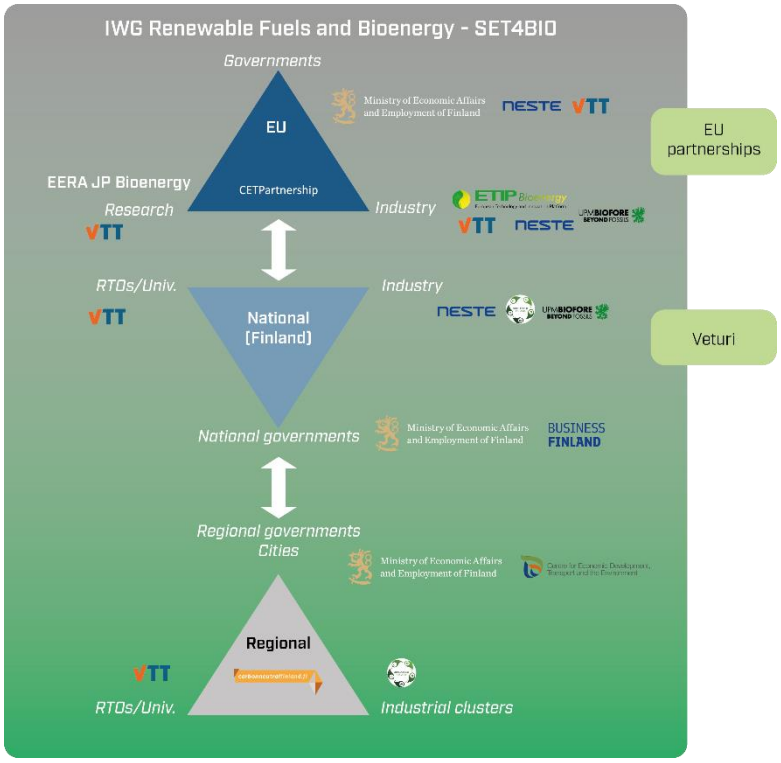


Figure 3. Collaboration interface for bioenergy presenting the cooperation on EU as well as national and regional levels in Finland.

Table 1. Main collaborative actors on bioenergy on EU level as well as on national and regional levels in Finland.

		EU level				National level	Regional level
Organisation	**Sector**	**EERA JP BIO**	**ETIP Bioenergy**	**IWG Bioenergy and Renewable Fuels**	**SET4BIO**	**Veturi**	**Hinku**
VTT	Research	Member	Vice-Chair	Member	Partner	Partner	Partner
Universities	Research					Partner	Partner
Business Finland	Public body					Funding body	
Neste Oyj	Industry		Steering Committee	Member	Steering Committee	Coordinator (Locomotive)	
UPM	Industry		Steering Committee		Steering Committee		Partner
TEM (Ministry of Economic affairs and Employment)	Public authority		Advisory Board member	Chair			
National and regional industrial clusters	Industry					Partner	Partner

EERA JP Bioenergy addresses the R&I challenges of the European energy and environment policies related to bioenergy. This network of research organisations covers a wide range of value chains from low-grade biomass feedstocks through primary and secondary conversion technologies to wide bioenergy production in all its forms, i.e., biofuels, heat, and power.

ETIP Bioenergy focuses on the development of cost-competitive, innovative world-class bioenergy and biofuels value chains, the creation and strengthening of a healthy European bioenergy industry and the acceleration of the sustainable deployment of bioenergy in the European Union.

SET4BIO was funded to support IWG8 in the realisation of the SET Plan Implementation Plan on Renewable Fuels and Bioenergy (IP8). SET4BIO is designed around three pillars: 1) activating the stakeholders, primarily industries and MS representatives, 2) mobilizing resources to fund and finance initiatives contributing to IP8, and 3) stimulating innovation through Innovation Challenges for getting hold of new business models, technologies and processes supporting the decarbonisation of the European transport sector through renewable fuels and bioenergy.

Ministry of Economic Affairs and Employment. The National Government of Finland consists of 12 ministries. Several are important to the bioenergy and bioeconomy areas; in particular, the Ministry of Economic Affairs and Employment (TEM) is active in European research collaboration on bioenergy and fuels development.

Business Finland is the main research, innovation, and technology funding agent in Finland, with 760 specialists at 40 foreign locations and 16 offices in Finland.

VTT, Technical Research Centre of Finland Ltd, is a Finnish, state-owned, non-profit company and one of Europe's leading research institutions. VTT, as an independent and impartial research centre, promotes the wide-ranging utilisation and commercialisation of research and technology in commerce and society. VTT develops and experiments with low-carbon energy solutions and smart energy systems, including bioenergy and biomass processing.

Universities. The national universities in all greater regions of Finland carry out research and teaching in disciplines relevant to bioenergy, namely energy, process, or chemical engineering. In addition, universities of applied science, which focus on bachelor-level education, carry out R&I activities in relevant disciplines at regional level.

Neste Oyj is a large Finnish, globally operating fuel refinery company that aims to become the world's leading producer of sustainable aviation fuel, renewable diesel, and renewable feedstock solutions for various polymers and chemicals industry uses. Neste is active in national and international research collaboration, a research programme leader in Business Finland's Veturi programme. Neste's main R&I facilities are in Porvoo, Finland.

UPM has a long tradition in the Finnish forest industry. The group's first mechanical pulp mill, paper mills and sawmills started operations in the early 1870s. The present group comprises of numerous production facilities, which were originally functioning as independent companies. UPM has research centres in Finland, Germany, and China.

Industrial clusters. Regional industrial clusters, relevant to bioenergy and biofuels, bring together bioeconomy, agricultural and circular economy companies, and associations to collaborate with companies, R&I organisations, financiers, and the public sector.

3.3 Collaboration interface on batteries in energy storage

Due to the complex nature and large variety of technologies within energy storage, batteries were selected as a case study for the collaboration model.

Batteries – European level

At European level, batteries technology is a complex ecosystem in terms of stakeholders' involvement in many parallel initiatives. The collaboration triangle of the battery sector comprises stakeholders from research organisations, industry and the government represented by MS/ACs representatives.

The government's side of the collaboration triangle on batteries is constituted by the Implementation Working Group on Batteries (IWG Batteries), also known as the National and Regional Coordinators Group (NRCG). This group is chaired by France and includes all SET Plan countries except Bulgaria and Iceland, making it the working group with the highest country representation. This IWG implements its SET Plan Action through Batteries Europe (ETIP Batteries).

Batteries Europe is the European Technology and Innovation Platform aiming at accelerating the establishment of a globally competitive battery industry in Europe. Batteries Europe comprises stakeholders from both, industry, and research, thus facilitating alignment of interests and collaboration opportunities between both sectors. There is a specific action in Batteries Europe to interconnect Batteries Europe with the NRCG, consolidating the establishment of continuous and bilateral communication channels with this group. This action allows the exchange of best practices between the research community, industry, and MS/regions, allowing for synergies across national and regional dimensions in battery research and innovation funding. This action is led by EERA (the European Energy Research Alliance), representing the largest energy research community in Europe.

Another relevant initiative in the sector is the Batteries European Partnership Association (BEPA), which is the international non-profit-making association representing research organisations and the private side of the BATT4EU Partnership (the public side is represented by the EC). This partnership has similar ambitions as Batteries Europe. However, while Batteries Europe aims mainly at identifying, in a holistic way, all the R&I needs across the battery value-chain at every TRL level, the BATT4EU Partnership focuses on prioritising (within the strategic inputs provided mainly by Batteries Europe), the most urgent R&I priorities to be addressed within the Horizon Europe Work Programme. Because of their similarities, close coordination and priorities alignment is carried out between these initiatives. More concretely, the collaboration mechanisms of Batteries Europe's and BATT4EU (through BEPA) have been integrated to join forces and facilitate the participation of relevant stakeholders, as many of them, are involved in these initiatives. Therefore, Batteries Europe and BEPA since 2022 operate joint Working Groups and Task Forces to improve efficiency of experts' collaboration and eliminate overlaps. Additionally, Batteries Europe serves as an Advisory Committee member in BEPA, facilitating information exchange and coordination between the Horizon Europe Partnerships, MS/ACs, relevant regions, and other structures directly addressing different parts of the batteries value chain. Moreover, R&I priorities identified by Batteries Europe experts are taken as inputs by BEPA in the elaboration of its SRIA to identify high-priority R&I topics for batteries.

Another large collaboration network on batteries involves research organisations and industry to invent the batteries of the future is Battery2030+. This initiative has the same vision as Batteries Europe and BATT4EU Partnership/BEPA. Nevertheless, the main difference is that it not only defines the battery 2030+ roadmap but also implements it. Battery 2030+ consists of seven EU funded projects; one coordination and support action (CSA) and six research and

innovation projects, and it has strong links to other European battery initiatives mentioned above, such as Batteries Europe, and ongoing dialogue with national stakeholders across Europe (i.e., NRCG).

The industry-led European Battery Alliance (EBA) is an initiative launched by the EC in 2017. EBA's mission is to create a competitive and sustainable battery cell manufacturing value chain in Europe. The EBA network includes organisations from both research and industry. A collaboration of more than 800 participants covering the entire battery value chain. EIT InnoEnergy, an independent body of the European Union that brings together business, education and research organisations catalysing and accelerating the energy transition, organises stakeholder involvement in EBA on behalf of the Commission.

Contributing to cooperation between industry and governments, mostly on high TRL battery research, the so-called Important Projects of Common European Interest (IPCEIs) are strategic instruments for the implementation of the EU Industrial Strategy. Two multi-billion-euro IPCEIs on batteries have been recently (2019 and 2021) approved. IPCEIs are developed by groups of willing MSs and their enterprises to implement common projects in situations where systemic or market failures, as well as societal challenges, require public financing. Through IPCEIs, such willing MS can financially support such projects. Seven MSs (Belgium, Finland, France, Germany, Italy, Poland, and Sweden) and 17 industrial actors from these seven countries participated in the first IPCEI (approved in 2019) with EUR 5 billion. This project will end in 2031. The number of MSs participating in the most recent IPCEI (approved in 2021) is even higher, 12[3] (Austria, Belgium, Croatia, Finland, France, Germany, Greece, Italy, Poland, Slovakia, Spain and Sweden). The project involves 42 industrial participants, and it will end in 2028. Other key actors involved in both IPCEIs are the EC and the European Battery Alliance.

Batteries in Germany – National level

In Germany, the collaboration triangle comprises National Government, industries (small and large size), non-profit foundations and research organisations, including Research and Technology Organisation (RTO), research associations, research centres, and universities (Science and Applied Science Universities). All the players, as mentioned earlier, collaborate on many cross-cutting national activities for batteries, and on technological solutions for energy storage. Batteries are considered as one of the most efficient technical solutions nationally because such technology offers diversified options for portable, mobile, and stationary applications.

The German Federal Ministry of Education and Research (BMBF), the German Research Foundation (DFG) and the Federal Ministry for Economic Affairs and Climate Actions (BMWK) are the critical governmental players that fund R&I and the development of battery energy systems in Germany. They promote programs to strengthen the collaboration among the other players under a specific topic of interest.

BMBF links research organisations and industries, including companies with national and international target groups, focused on science & technological progress. More than 40

[3] Since IPCEIs are funded from national budgets, Member States are in the driving seat to identify the scope of the project, to select (preferably following open calls) participating companies, and to agree on project governance.

research projects and 100 partners from consortia between research facilities (from research organisations) and industries are granted through the Program "Batterie 2020", the largest and most important governmental program on batteries until now. The main goal of such a program is related to specific topics: progress on the latest battery systems (e.g., lithium-ion batteries), the next generation of battery systems (beyond lithium-ion batteries), new battery technologies still in early development for private-sector investment and second-use strategies for lithium-ion batteries. Among those, it is worth mentioning ZilSicher, a project in performance-stable, secondary zinc-air batteries, with a research-industry collaboration covering the entire value chain, from material supply to marketing of the targeted innovation. Four industries (Varta Gmbh, Alantum Europe GmbH, Eisenhuth GmbH & Co. KG, Covestro Deutschland AG) and four research organisations (Clausthal Technical University, Technical University of Braunschweig, Fraunhofer Society, Heinrich-Hertz-Institute), allowing for close collaboration between both sectors, became an example of the knowledge gained in the project to be transferred to an industrial scale. The collaboration with large-size industries provided considerable advantages in this project for the exchange of research to practice on an industrial scale. VARTA, for example, is the oldest and largest German battery supplier. VARTA has intensive in-house research departments with activities at national, EU and global level. VARTA's battery department focuses on both existing technologies (e.g., rechargeable lithium-ion cells) and battery energy storage of the future (e.g., post-lithium systems) with ambitions to becoming the leading global battery supplier. Another critical player among research organisations is the Fraunhofer Society. Fraunhofer Society is the German Research and Technology Organisation (RTO) with many projects at the EU and German levels. Among other German research organisations, Fraunhofer Society distinguishes itself in research with substantial technologies available for commercial applications.

The German Research Foundation (DFG) promotes science and research progress among research organisations by providing financial and collaboration support for research excellence on two different scales, i.e., individual (e.g., group building of researchers) and consortium (i.e., cluster of universities). In 2019, the first cluster of research excellence on Batteries called PoLiS was granted. POLiS is a joint research collaboration between the Karlsruhe Institute of Technology (KIT) and the Ulm University with associated collaborators, the Centre for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW) and the University of Giessen. PoLiS coordinates national research and innovation efforts on batteries beyond lithium and other critical materials in the situation of the exponential growth of the battery market and the pressure imposed on the supply chain worldwide. PoLiS aims to find alternatives for batteries bundled on non-toxic, affordable, and abundant materials that are not subject to political restrictions. POLiS duration is scheduled for seven years, with a total budget of about EUR 47 million. PoLiS is part of the Helmholtz Institute Ulm (HIU), a decentralized institute created for batteries under the Helmholtz Association. HIU was founded by the Karlsruhe Institute of Technology (KIT) in cooperation with Ulm University and the two associated partners, namely, German Aerospace Center (DLR) and the Center for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW). HIU is a key player with projects focused on the next generation battery systems at national, European, and global level. For example, HIU is involved in BATTERY 2030+.

While BMBF and DFG are governmental organisations strengthening the collaboration between research and industries, BMWK offers programs for SMEs and start-ups, for example, the EXIST program. EXISTS program supports initiatives in preparing technology-oriented and knowledge-based start-ups with less bureaucratic conditions. Among those, it is

worth mentioning E-Lyte Innovations. Since 2019, E-Lyte Innovations has produced high-qualified electrolytes made in the battery storage market in Germany. It is the first start-up company out of the MEET Battery Research Centre. MEET Research Centre joined the collaboration competencies of three partners: Forschungszentrum Jülich, RWTH Aachen University and MEET Battery Research Center at the University of Münster. As mentioned earlier, the collaboration competencies of the three partners expanded the boundaries of the German collaboration triangle as the second example active at the EU level. MEET takes part in the BATTERY 2030+, previously mentioned, with other international industries and research organisations at EU level.

Batteries in Germany – Regional level

At the regional level, the Ministry of Economics has established a collaboration program in Baden-Württemberg with around EUR 7.2 million to develop battery research activities. The German state aims to increase its international competitiveness by establishing Baden-Württemberg as a leading region for climate protection and sustainability. The research activities cover the production of new batteries until recycling. A "battery round table" is an agile dialogue format found by the Ministry of Economics and Science to flexibly discuss current topics in the battery field with all participants to develop possible measures and activities from this. All projects accepted under this program closely involve industry (e.g., ZSW) and research institutions (e.g., KIT, Fraunhofer Society, Furtwangen Applied Science University, Esslinger Applied Science University and Stuttgart University).

Interface across geographical levels

There are a few key German players from all sectors of the triple helix that adopt several roles across geographical levels: BMBF and BMWK from the government side, VARTA providing the industrial perspective, and the Helmholtz Association and the Fraunhofer Society providing the research one.

BMBF and BMWK are the German representatives participating in the IWG on batteries and the main public authorities providing funding for R&I and fostering the development of battery energy systems in Germany; thus, both entities are facilitating the alignment of European and national/regional R&I priorities and funding through those interconnections.

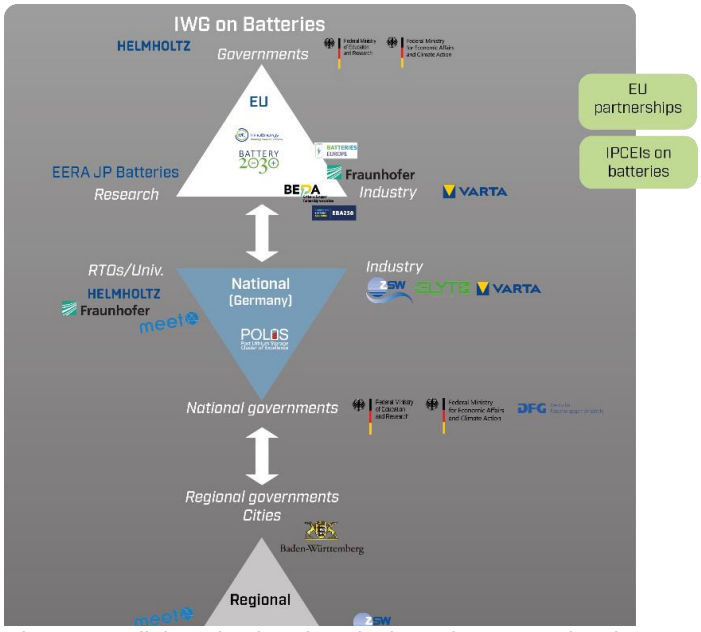


Figure 4. Collaboration interface for batteries presenting the cooperation on EU as well as national and regional levels in Germany.

VARTA is one of the key industrial players at EU and national levels, contributing to the coordination and interconnection across EU and national dimensions. VARTA is participating in four of the EU batteries initiatives explained above and is a consortium partner of one of the projects (INSTABAT) under BATTERY 2030+ and of the IPCEI on

Batteries. In addition, VARTA is a member of the BATT4EU Partnership and a participant of the European Battery Alliance.

While Helmholtz Association is involved in the BATTERY 2030+ and in the IWG of batteries through Forschungszentrum Jülich, Fraunhofer is a BATT4EU Partnership member; thus, those organisations are facilitating the interconnections at European and national/regional levels.

Table 2. Main collaborative actors on batteries on EU level as well as on national and regional levels in Germany.

		EU level					National level			Regional	
Organisation	**Sector**	***IWG Batteries***	***Batteries Europe***	**BATT4EU Partnership**	**Battery2030+**	**EBA**	***Batterie Program****	**PoLiS**	**MEET**	**HIU**	**Battery Research**
EIT Innoenergy	EU body		Coordinator		Supporting organisations	Manager					
EERA AISBL	Association	Supporting initiative	Partner and coordinator of NRCG group		Supporting organisations						
BEPA	Association			Coordinator							
EASE	Association		Partner	Member	Partner	Participant					
Fraunhofer Society	Research organisation			Member			Research member				Research partner
Helmholtz Association	Research organisation	Member			Partner		Research member				
Varta	Industry		Member of all WG	Partner	Partner	Participant	Industry member				
BMBF	Public Authority	Member					Funding Organisation		Funding Organisation	Funding Organisation	
BMWK	Public authority	Member							Funding Organisation		
DFG	Public authority							Funding organisation		Funding Organisation	
MEET Battery Research Center	Research organisation				Partner		Research member		Research partner		
ZSW	Industry										Partner
E-Lyte	Industry								Partner		
Baden-Württemberg Ministry	Public Authority										Funding Organisation

* Batterie Program: The program has many Research community and industry members that were not listed in this table. From Research community, many of the research institutions are part of a University or member of the Fraunhofer Society and Helmholtz Association.

A short description of the stakeholders/initiatives mentioned in Figure 4/Table 2 is available below.

Batteries Europe, the European Technology & Innovation Platform on batteries provides the community with a forum to spearhead Research and Innovation actions so to accelerate the establishment of a globally competitive European battery industry and in so doing enact the Implementation Plan of the SET Plan Action 7, among other priority actions that could contribute to accelerate the energy system transformation and the realisation of the EU's aim to become the global leader in the deployment and use of renewable energy.

BATT4EU is a Co-programmed Partnership established under Horizon that aims to achieve a competitive and sustainable European industrial value-chain for e-mobility and stationary applications. It is a contractual public-private Partnership gathering – on the public side – the European Commission; and – on the private side – BEPA, which regroups all the battery stakeholders from the European Research community.

BATTERY 2030+ is a large-scale cross-sectoral European research initiative bringing together the most important stakeholders in the field of battery R&I. The initiative is working on concrete actions to support the European Green Deal with a long-term vision of cutting-edge research reaching far beyond 2030.

EERA Joint Programme on Energy Storage strongly fosters the efficient development of new energy storage technologies and supports the SET Plan objectives and priorities by "pooling and integrating activities and resources, including international partners" on all levels of the value chain.

IPCEI on Batteries IPCEI is the abbreviation of "Important Project of Common European Interest ". It's a transnational project with an important contribution to the growth, employment and competitiveness of the European Union industry and economy funded by state aid. They are designed to bring together public and private sectors to undertake large-scale projects that provide significant benefits to the Union and its citizens.

Federal Ministry of Education and Research (BMBF – Bundesministerium für Bildung und Forschung) is the cabinet-level ministry of Germany that provides funding for research projects and institutions (aiming for «research excellence» and sets general educational policy. BMBF has the institutional goal of financing the development of new ideas and technologies in a broad spectrum of research areas of tomorrow. It means many technologies funded through BMBF can play a role in 30 to 40 years.

Federal Ministry for Economic Affairs and Climate Action (BMWK - Bundesministerium für Wirtschaft und Klimaschutz) is the cabinet-level ministry of Germany for strengthening forward-looking investment in research and development and in start-ups. A new emphasis is being placed in the field of energy efficiency on industry and commerce, the transformation of the heating networks and the establishment of battery cell production.

German Research Fondation (DFG - Deutsche Forschungsgemeinschaft) is a self-governing institution for the promotion of science and research in the Federal Republic of Germany through a variety of grant programmes, research prizes, and by funding infrastructure.

Baden-Württemberg Ministry is one of the supreme state authorities in Germany.

Helmholtz Association is the largest scientific organisation in Germany, with 18 scientific-technical and biological medical research centres with offices worldwide. The Energy Program brings seven renowned Universities together to provide contributions with research on Renewable energies, energy efficient conversion, nuclear fusion and nuclear safety.

Fraunhofer Society is a German research organisation with more than 70 institutes spread in the country with offices and subsidiaries in USA, Asia and UK. The Fraunhofer Energy Alliance is made up of 20 Fraunhofer institutes which deal with different topics in the field of energy generation, storage, distribution and integration.

KIT. Karlsruhe Institute of Technology (KIT) Energy Center is one of the largest energy research centres in Europe and an integration of the Helmholtz Association. It bundles the energy research, teaching and innovation activities of KIT and renowned cooperation partners. The team consist of about 1800 scientists and technical staff from diversified disciplines and sub-research institutions for combining basic and applied research on all relevant energies for industry, households, services, and mobility.

ZSW is a non-profit foundation "Centre for Solar Energy and Hydrogen Research Baden-Württemberg" (ZSW), based in Stuttgart and in Ulm. The foundation's purpose is to transfer already existing knowledge from fundamental research in the fields of renewable energy and rational energy conversion to market-ready, application-based technology to be used by industries located in the state.

Münster Electrochemical Energy Technology (MEET) is a battery research centre at the University of Münster. MEET has an interdisciplinary team with holistic, systemic research and development on electrochemical energy storage systems and transducers. In addition, the research at MEET focuses on the synthesis, production, characterisation and analysis of materials, components and cells; it naturally also covers the various aspects of an application, including economic efficiency, environmental impact and social impact.

VARTA is a German company manufacturing batteries for global automotive, industrial, and consumer markets. As a technology leader and innovative pioneer, Varta is committed to long-term R&I on the sustainability of innovative batteries systems.

E-Lyte is a German start-up company producing high-performance electrolytes for electrical energy storage devices. E-Lyte targets to contribute to the successful transformation of the energy sector and to directly drive the energy transition.

3.4 Collaboration interface on hydrogen and power-to-x

Hydrogen – European level

At European level, hydrogen has become, in recent years, one of the main energy vectors of the future, especially after the energy crisis triggered by the war in Ukraine. In 2019, the primary European collaboration network within this field, i.e., Fuel Cells and Hydrogen Joint Undertaking (FCH JU), published the Hydrogen Roadmap Europe[4], a roadmap to realise hydrogen's potential for Europe. One year later (2020), the EC published 'A Hydrogen Strategy for a Climate-Neutral Europe', consisting of a roadmap for the establishment and scale-up of value chains based on the production of "green" hydrogen, with the purpose to accelerate the development of clean hydrogen. The importance of hydrogen uptake by industry is shown in the creation of a European Hydrogen Bank by the EC in September 2022. It links to REPowerEU, with a EUR 3 billion investment, trying to support the achievement of 10 Mt/y production of renewable hydrogen by 2030, hence enabling immediate actions that can support research–industry collaboration.

The most important European player committed to all roadmaps and strategies on hydrogen in Europe is the Clean Hydrogen Partnership, which is the successor of the FCH JU's. The main objective of the partnership is to contribute to EU Green Deal and Hydrogen Strategy through optimised funding of R&I activities. The Clean Hydrogen Partnership as such acts as a collaboration triangle, with representations from the public and private sectors as well as the research community. The public sector is represented by the EC on the one hand and by MS/ACs on the other; the latter by taking part in the States Representative Group of the Clean Hydrogen Partnership. Hydrogen Europe, with about 100 company members focusing on fuel cell and hydrogen, represent the private sector, and Hydrogen Europe Research representing over 200 RTOs is the research body of this ecosystem. The EU will support the Clean Hydrogen JU with EUR 1 billion for the period 2021-2027, complemented by at least an equivalent amount of private investment (from the private members of the partnership), raising the total budget to above EUR 2 billion.

The Clean Hydrogen Partnership has the multi-annual funding plan and the Annual plans. Based on the roadmap and plans, prioritisation has been made for project calls, the latest opened in January 2023, with a total of EUR 195 million made available for projects of Clean Hydrogen Partnership in an unprecedented drive to support the creation of cutting-edge hydrogen technologies. The calls belong to Horizon Europe – the Framework Programme for Research and Innovation. Synergies with other European partnerships and programmes, as well as with MS and regional programmes, are at the core of several call topics. In the Clean Hydrogen Partnership, the Governing Board has representatives from industry and the Hydrogen Europe Research's chair (representing RTOs), thus enabling alignment of R&I priorities between research and industry. Beyond the Governing Board, a stakeholder group has been founded for the partnership. It includes industrial players who are in connection with hydrogen and its usage, but not directly linked to Hydrogen Europe. The stakeholder group provides comments/guidance to the

[4] Fuel Cells and Hydrogen 2 Joint Undertaking, (2019) « Hydrogen roadmap in Europe. A sustainable Pathway for the European energy transition». https://www.clean-hydrogen.europa.eu/system/files/2019-02/Hydrogen%2520Roadmap%2520Europe_Report.pdf

collaboration and plans of the Clean Hydrogen Partnership. The Clean Hydrogen Partnership works well in connecting all the main players in Europe.

Another key collaboration instrument in Europe on hydrogen is the Hydrogen IPCEIs (Important Projects of Common European Interest), a very important funding instrument for collaboration between research and industry, and it has unified the hydrogen field in Europe. The Hydrogen IPCEI was established in 2022 by 22 EU countries and Norway. The projects should cover the full clean hydrogen value chain, notably in industrial sectors. The projects receive public funding, with the expectation to attract private investments over double the public funding. The projects involve companies, including SMEs and start-ups, with activities in one or more MS. The direct participants will closely cooperate with each other through numerous planned collaborations, such as universities, research organisations and SMEs across Europe. Especially Germany and France have been strong in paving the way with high activity and funding. Further IPCEIs on hydrogen are expected in 2023.

Hydrogen Valleys are instruments that concretise the collaboration on hydrogen between different actors. The Hydrogen Valley initiative was launched in January 2021, developed by Mission Innovation Challenge 8 (IC8) 'Renewable and Clean Hydrogen'. A "Hydrogen Valley" is a geographical area – a city, a region, an island, or an industrial cluster - where several hydrogen applications are combined into an integrated hydrogen ecosystem that consumes a significant amount of hydrogen, improving the economics behind the project. The Clean Hydrogen Partnership, Mission Innovation and the EC are committed to continuing their hydrogen-related efforts, such as the long-standing support to The Hydrogen Valley project. Together, they have established the Mission Innovation Hydrogen Valley Platform, which intends to feature new, recently emerged Hydrogen Valley projects from around the world.

The Clean Hydrogen Partnership provides funding to the projects in the context of REPowerEU. The Hydrogen Valleys strongly support the EU strategy to target a successful European hydrogen economy: production, usage, and storage in transportation and different industrial fields. In 2022, there were several EU Horizon calls for the development of Hydrogen Valleys.

Hydrogen does not have its own SET Plan Implementation Working Group (IWG) and it was not originally included in the ten key actions. However, since the revision of the SET Plan in 2015, its importance has grown strongly. Open issue is, if there will be a dedicated IWG on hydrogen in the revamping of the SET Plan in 2023. In addition, it will also remain as a cross-cutting aspect in several existing IWGs.

One key actor in the European hydrogen ecosystem is EERA Joint Programme Fuel Cells and Hydrogen (EERA JP FCH), which represents European universities and research centres in that field. JP FCH members perform research and development in collaboration with industry in Europe. The JP Management Board, led by the JP Coordinator, interacts with the Clean Hydrogen Partnership, relevant ETIPs, Hydrogen Europe, the EC (DG ENER and DG RTD), and the MS. EERA JP FCH is not directly involved in the Clean Hydrogen Partnership. However, some of its organisations are members of the partnership, such as DTU from Denmark.

Hydrogen and Power-to-X in Denmark – National level

In Denmark, there is a strong tradition for cooperation between research organisations, industries, and the government, and as such, there are many different national and regional organisations designed to facilitate collaboration within Power-to-X (P2X) and Hydrogen. The overall P2X ecosystem in Denmark is highly interlinked with new initiatives building on the existing ones enabling a high degree of collaboration. This collaboration enables high levels of trust to pave the way for successful partnerships towards the green transition. Much of the activity within this energy pathway is connected to The Government's strategy for Power-to-X, launched in 2021. The strategy is based on the Energy Agency's analyses and dialogue with the P2X industry and proposes EUR 170 millions of investment towards 2030 targets in P2X from the Government.

At the national level, the largest initiative is the 4 Innomissions from the Innovation Fund Denmark within the Danish Ministry of Higher Education and Science (UFM). The Innomissions focussed on creating partnerships within the four selected green transition themes (carbon capture and storage or use of CO_2), green fuels for transport and industry (Power-to-X), climate and environment-friendly agriculture and food production, recycling, and reduction of plastic waste). One of these 4 Innomissions, the MissionGreenFuels partnership, addresses green fuels for transport and industry (Power-to-X) in a focused and coordinated way, using their roadmap to align and guide research and innovation activities and ensuring knowledge sharing that identifies and builds on synergies whilst avoiding lock-ins. The partnership is composed of universities, e.g., DTU, Aalborg University and Copenhagen Business School, companies such as Topsoe, Copenhagen Airports, Maersk, and Orsted, as well as DK Research and Technology Organisations ("GTS institutes") - Danish Technological Institute, FORCE and Alexandra Instituttet. The partnership also has cluster organisations such as Energy Cluster Denmark and Danish Center for Energy Storage (DaCES), and municipalities, e.g., Fredericia Kommune. During the shaping of these partnerships, relevant actors from research organisations (e.g., DTU, Aalborg University), industry (Topsoe and Green Hydrogen Systems), and governments (UFM and Danish Agency for Higher Education and Science, UFS) relevant to that green transition theme worked together to create the roadmap and are now working together in smaller project teams to deliver project results aligned to this. Most recently, there is also a call for a second set of projects that address the roadmaps where new partners can join the partnership. In this way, all interested stakeholders can be involved. However, it was not always clear from the outset who would be responsible for each aspect of the green transition as there are a lot of large players in the energy sector which overlap across the four Innomissions.

Each of the Innomission partnership covers all three sides of the 'triangle' with relevant stakeholders taking a role in different projects. Within MissionGreenFuels, there are 60 partners covering universities, companies, DK Research and Technology Organisations ("GTS institutes"), which are non-profit institutions that are operated as private companies with the aim of building and communicating technological competencies to the Danish business community, cluster organisations, and municipalities. MissionGreenFuels thus facilitates collaboration between the different actors both within individual projects and across its portfolio.

Working together within MissionGreenFuels are Energy Cluster Denmark (with a substantial focus on P2X) - one of Denmark's 13 national clusters, and the Danish Center for Energy Storage

(DaCES). Both organisations aim to facilitate collaboration: for Energy Cluster Denmark, this is between small and large companies, research organisations and public players throughout the energy sector; and for DaCES, this is between companies and universities across the entire value chain funded by Industriens Fond. In Denmark, the sector focused clusters ensure a common platform for channelling public R&I funding for SMEs in Denmark and ensure that sector development is aligned.

There are also overlaps with another of the selected Innomissions, INNO-CCUS, where the use of biogenic CO_2 is a key component in creating green fuels (incl. green P2X).Alongside the investments related to the Government's Strategy, there are a number of national (and regional) initiatives that are funded with a mix of public and private funding. For collaboration on early-stage research, a new pioneer centre has recently been announced. The Pioneer Centre CAPeX unites leading P2X experts from five Danish and three international universities.

At the national level, there are also the privately funded agencies/initiatives - the VILLUM P2X Accelerator and the MAERSK Mckinney Møller Center for Zero Carbon Shipping; as well as green (e.g., Green Power Denmark) and open national agencies/initiatives that facilitate collaboration.

During the workshops organised by SUPEERA, a best practice in the field of hydrogen was presented by ENEL Green Power through its Hydrogen Innovation Project, i.e. NextHy. In **Italy**, the NextHy Initiative is a good example of how to foster green hydrogen competitiveness with an Open Innovation Approach. NextHy is an innovation platform whose goal is to speed up the commercial maturity of all technologies that allow the production of green hydrogen sustainably and competitively. The new platform will take full advantage of the Catania Innovation Hub&Lab, one of the largest and most advanced industrial innovation districts for renewable technologies worldwide.

Hydrogen and Power-to-X in Denmark – Regional level

Denmark is well positioned to play an important role in P2X for the future due to the larger electricity capacity from wind power and the strong history of partnerships in the energy sector. There is not a single body or initiative for P2X, as such. P2X is fostered and encouraged through many of the green and regional initiatives. At the regional level, the key P2X bodies and initiatives are GreenLab Skive, the Triangle Energy Alliance, the 2 Lighthouses Sydjylland and Bornholm, Green Hub Denmark, Hydrogen Valley, and the upcoming DTU and TotalEnergies Centre of Excellence. Many of these are connected via overlapping collaborations and the Government P2X strategy. As mentioned, there are also region-specific innovation hubs and collaboration-facilitating agencies and initiatives that are open to members of that region.

GreenLab Skive connects companies, innovation, and technology partners (including DTU) and is partly owned by Skive Kommune. This public/private partnership works at a system level to transform the way green energy is produced, converted, stored, and used via P2X.

Triangle Energy Alliance covers the Triangle area (Billund, Fredericia, Haderslev, Kolding, Middelfart, Vejen and Vejle) that is Denmark's strongest industrial region in the heart of the country. It facilitates close collaborations between private sector companies, municipalities, and the state on large-scale P2X demonstration projects.

Lighthouse Bornholm has been awarded DKK 27.2 million for the utilisation of green power, including P2X from offshore wind turbines and for establishing Bornholm as an energy island. The ambition is to secure Bornholm as the Baltic Sea's green transport hub and create business synergies for Bornholm as a test island by ensuring local, national, and international players the opportunity to develop and assess future energy technology solutions on an energy island. A further DKK 105.3 million has been awarded to Lighthouse Sydjylland for the development of green energy and sector coupling (including P2X). The ambition here is to create a national centre for research and technology development within green energy and sector coupling in South Jutland, which can also attract great attention from global markets.

Green Hub Denmark, based in Aalborg, connects businesses, consumers, researchers, the utility sector and authorities in order to co-create a world-class platform for green growth and a green societal transition through the development, testing, and application of sustainable technologies.

Hydrogen Valley in Hobro has 15 years of experience in developing and fundraising (especially internationally funded) development projects within P2X. Hydrogen Valley accelerates collaborations between research environments, industry and other stakeholders.

The newly agreed upon DTU-Total Energies Excellence Centre for Clean Energy will be located at DTU Wind and Energy Systems at Risø. The centre will establish an advanced clean energy research program that involves hybrid power plants and hydrogen technologies. It includes the construction of a pilot hybrid power plant to supplement the existing plant at DTU Risø Campus. Other activities include a graduate school in hybrid power plant research and an education and training program.

Interface across geographical levels

The collaboration triangle on hydrogen is very well in place at the European level due to the Hydrogen Europe Partnership. All relevant sectors, namely public, research community and industry. The Partnership contributes to the EU Green Deal and Hydrogen Strategy through optimised funding of R&I activities. EERA community interacts in the Partnership via its members in the Hydrogen Europe Research. Hydrogen, as technology and energy carrier, is a horizontal topic in several energy forms and is on the agenda of several ongoing SET Plan Implementation Working Groups. Due to hydrogen’s importance, a specific IWG is planned to enhance the uptake of hydrogen technology. The forthcoming IWG, gathered by the Commission, should support the dialogue between relevant industrial and research players in committed MS. Denmark is well represented in the EU-level dialogue. UFS belongs to the Clean Hydrogen Partnership States Representative Group. From the research community, Denmark has representatives in Hydrogen Europe Research and EERA JP FCH (e.g., DTU). The industry sector is part of Hydrogen Europe (e.g., Topsoe, Green Hydrogen Systems and Everfuel).

In Denmark, for connection across all levels, the Government's P2X strategy focuses on large, regional partnerships with different sector-focused solutions using P2X. As such, the Danish Government used REACT-EU funding to establish eight local commercial beacons in DK, the Just Transition Fund, an Important Project of Common European Interest (IPCEI) in the Hydrogen value chain - IPCEI Hy2Use, and envisages allocating additional EU funds towards 2027.

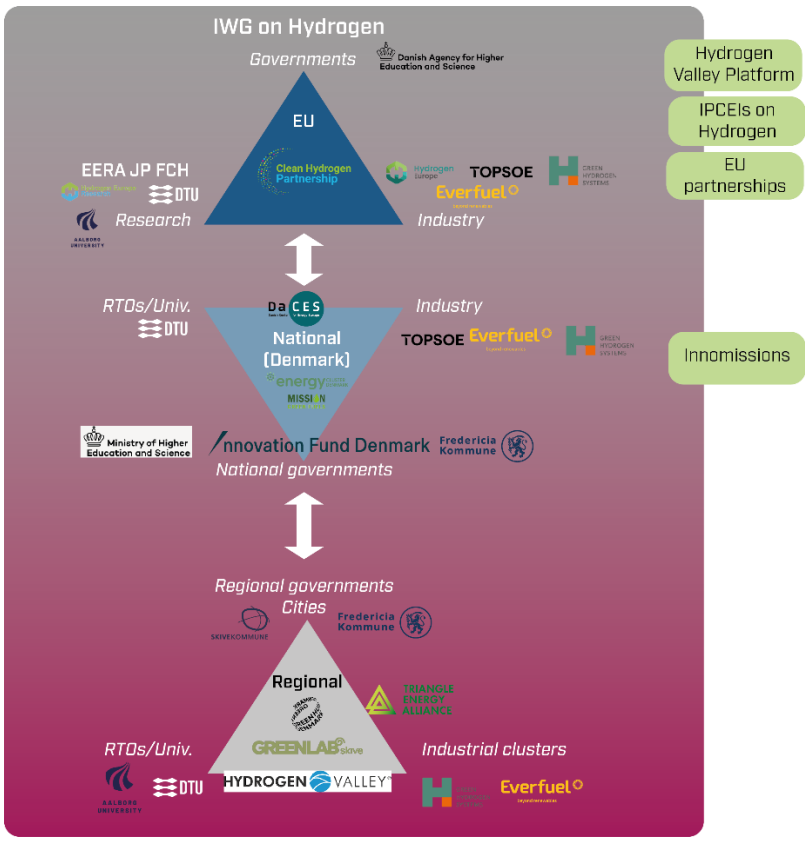


Figure 5. Collaboration interface for hydrogen and power-to-X presenting the cooperation on EU as well as national and regional levels in Denmark.

For connection from the national level to the EU level, there is both a national (e.g., Green Power Denmark, Danish Industry, Danish Maritime) and international (EU and selected 3rd countries) advisory board for the Innomission partnership consisting of experts in the energy transition, innovation, entrepreneurship, and investing that will facilitate collaboration outside of the partnership. It is expected that partners will leverage these connections to seek further investment at the national, EU, and international levels.

For connection from the regional level to the EU level, there are four EU offices representing the universities, municipalities, and businesses in their respective regions at the EU level.

A short description of the stakeholders/initiatives mentioned in Table 3 and Figure 5 is available below.

Clean Hydrogen Partnership is a public-private partnership supporting research and innovation (R&I) activities in hydrogen technologies in Europe. It was founded on November of 2021 as a successor to the Fuel Cells and Hydrogen 2 Joint Undertaking (FCH 2 JU), with the legal name Clean Hydrogen Joint Undertaking. The partnership was established under Council Regulation (EU) 2021/2085 of 19th November 2021, establishing the Joint Undertakings under Horizon Europe (the Single Basic Act). The Partnership consists of three members: the EC, Hydrogen Europe, which represents the industries, and Hydrogen Europe Research, which represents the research community.

EERA Joint Programme Fuel Cells and Hydrogen (JP FCH) gathers almost 40 European universities and research centres to collaborate on strategic topics in development and innovation. Currently, the JP is led by VTT, Finland.

Innovation Fund Denmark, funded by the Danish Government, invests in entrepreneurs, researchers and businesses that create value for Denmark and new solutions to society's biggest challenges.

DTU, the Technical University of Denmark, is a national hub for technological development through education, research, innovation and scientific advice. DTU is focused on ensuring that this technological research contributes to the development of society and addresses global challenges.

Pioneer Center CAPeX for Accelerating P2X Materials Discovery is part of DTU. It develops and implements a new powerful Materials Accelerating Platform (MAP) for rapid development of materials and a closed-loop data infrastructure for power-to-x.

Aalborg University works on global, national and regional challenges in partnership with society, with ambitions to the most pressing global and local trouble spots across disciplines.

Topsoe is a global leader in energy efficient technologies to produce clean transportation fuels. Topsoe's driver is the transition towards renewable energy to reduce the carbon emissions.

Energy Cluster Denmark is Denmark's cluster organisation for the entire energy sector. Their vision is for Denmark to be a leading green nation in the development and demonstration of innovative and global energy solutions.

Table 3. Main collaborative actors on hydrogen and power-to-X on EU level as well as on national and regional levels in Denmark.

		EU level				National level	Regional level
Organisation	**Sector**	**EERA FCH**	**Clean Hydrogen Partnership**	**Hydrogen Europe**	**Hydrogen Europe Research**	**Mission Green Fuels**	**Triangle Energy Alliance**
DTU	RTO	Member			Member	Partner	
Aalborg University	RTO					Partner	
Pioneer Centre CAPeX	RTOs						
Topsoe				Member			
Green Hydrogen Systems				Member		Partner	Partners
Everfuel				Member		Partner	Partner
Energy Cluster Denmark	Industries + RTOs + public players						
Danish Center for Energy Storage	Industries + RTOs + public players						
Innovation Fund Denmark	Public authority					Funding body	
Fredericia kommun	Public actor						Member Partner
Danish Ministry of Higher Education and Science (UFM)	Public authority					Government	

Danish Agency for Higher Education and Science (UFS)	Public authority		States Representative Group			Funding body	

3.5 Collaboration interface on solar energy and photovoltaics

Solar Photovoltaic – European level

At the EU level, the collaboration across the government, industry and research of the PV sector is taken place through the following European initiatives: the SET Plan Implementation Working Group on Photovoltaics (IWG PV), ETIP PV, PV-IMPACT, the European Solar Photovoltaic Industry Alliance and EERA JP PV.

The IWG PV acts as a collaboration triangle itself. It comprises 11 representatives of nine SET Plan countries (BE, CY, FR, DE, IT, NL, NO, ES and TR) and 15 representatives that belong to industry or research organisations. Although country representatives lead the group, there is a formal representation of industry and/or research, having a governing role in the IWG (i.e. co-chairs). Country representatives are either government representatives (ministerial staff or national funding agencies) or non-governmental individuals nominated by their governments. For example, the IWG representatives of Cyprus and Greece belong to research organisations and are also involved in the Programme Committee of Horizon Europe. Other stakeholders involved in the IWG (the above-mentioned co-chairs) are experts from ETIP PV. The research community is also represented through EERA (the European Energy Research Alliance), Europe's largest energy research community, more specifically through its Joint Programme on Photovoltaics (EERA JP PV). Germany and the Netherlands co-chair the PV IWG with the support of ETIP PV. The IWG also works in collaboration with PV IMPACT. These two initiatives are described below.

ETIP PV plays an essential role in mobilising and bringing together experts from industry and research community, sharing a long-term European vision for PV and gathering more than 200 experts covering the entire PV value chain. Although ETIP PV involves industry and research organisations, this initiative is industry-led. Additionally, there is no national representation in ETIP PV. Nevertheless, this collaboration has been created with a strong presence of those stakeholders in the IWG (as IWG co-chairs). Furthermore, one seat in the ETIP PV Steering Committee is reserved for a representative from EERA; thus, representing the research community. The ETIP PV secretariat is coordinated by Solar Power Europe, which is an association representing over 280 organisations, from industry and research, across the entire solar sector. The main difference between both initiatives is that while ETIP PV brings stakeholders to define a common approach to R&I PV priorities, the main goal of Solar Power Europe's members is to network and do business together.

PV-IMPACT is a H2020 project coordinated by EUREC. The PV IMPACT's consortium counts on the participation of research organisations and industry committed to executing all or some of the SET Plan-related R&I activities specified in the Implementation Plan. Two consortium partners of this H2020 project are also involved in other EU initiatives presented in this document, IMEC and SolarPower Europe. IMEC coordinates the EERA JP PV. SolarPower Europe is the secretariat of

ETIP PV as well as one of the stakeholders in charge of setting up the European Solar Photovoltaic Industry Alliance.

In addition, the connection between PV IMPACT and ETIP PV is made through EUREC. The Secretary General of EUREC acts in PV IMPACT's secretariat and is one of the Steering Committee's representatives of ETIP PV. EUREC is an association of European research centres and university departments active in renewable energy.

Finally, the European Solar PV Industry Alliance was launched in December 2022. It brings together industrial partners to accelerate solar photovoltaic deployment in the EU. ETIP PV initiated the Alliance, and thus, it is currently a very active stakeholder. Therefore, the industrial stakeholders are connecting both initiatives, ETIP PV and the Alliance.

Solar Photovoltaic in Italy – National level

In Italy, the collaboration triangle is realised through several collaboration schemes between the government, industry, and research organisations in the field of solar photovoltaics that aim to promote innovation and the development and use of solar photovoltaics in the country. It involves several entities with different roles and involvement, where some of the most prominent are summarised below.

ENEA (National Agency for New Technologies, Energy and Sustainable Economic Development), one of the largest RTOs in Italy, collaborates closely with industry in the field of photovoltaics, aiming at making solar PV competitive by focusing on process and product innovation applied to manufacturing and system technologies, and advanced services to enterprises. It provides several laboratories for different types of research in renewable energy, and in the domain of solar PV. Also, in terms of research infrastructure, ENEA collaborates closely with industry players and provides advanced services for industries ranging from the design and development of innovative PV components to modules qualification tests and others. As a concrete example, in 2022, ENEA launched the National Network for Sustainable Agrivoltaics that brings together 800 members such as public institutions, companies, trade associations, researchers and civil society. The Network's objective is to promote the definition of a regulatory framework for the sector and produce tools to support decision-makers and guidelines to build plants that allow the production of electricity from solar panels while at the same time cultivating the land. A fruitful outcome of the Network will accelerate the development of agrivoltaics, which is envisaged to receive EUR 1.1 billion support from the National Recovery and Resilience Plan to install a production capacity of 1.04 GW capable of producing around 1,300 GWh per year.

Regarding its collaboration with Italian Ministries, ENEA acts under specific Programme Agreements with ministries, regions and local bodies. Among these, one of the most important is the Programme Agreement signed with the Italian Ministry for Economic Development on the Electric System Research. Under the Electric System Research Programme, ENEA collaborates with the main national universities and with the companies SOTACARBO and FN Nuove Tecnologie Avanzate in the framework of research projects relevant to the energy grid, including solar PV. Another example signifying ENEA's position as advisor to the Italian Ministries is their involvement (together with other research organisations in Italy, e.g., RSE) in drafting the Italian National Energy and Climate Plan (NECP).

The Italian National Research Council (CNR) is a leading public research organisation (under the Italian Research Ministry) in the field of solar energy, and it collaborates with various Italian entities to promote the development and use of this renewable energy source. CNR has signed agreements with big industry renewable energy players in the country, such as Enel Green Power and Terna, thus fostering public-private partnerships. The collaborations focus on developing new technologies and improving the performance of existing photovoltaic systems with the aim of supporting the growth of the photovoltaic sector and promote the use of clean and renewable energy. One of the outcomes of these agreements is the establishment of a joint laboratory with Enel Green Power (Enel Innovation Passo Martino Lab, Catania) for the development -among others- of innovative high-efficiency solar cells and photovoltaic systems, with particular attention to the aspects of reliability and cost. The research facilities are benefiting from Enel's investment program with a worth of more than EUR 100 million, where various research activities are taking place in the facilities in the framework of national and EU-funded projects (e.g., ESFRIs, H2020 etc.) and in collaboration with several universities across the country and international technological front-runners in the field. Beyond its collaboration with the private sector, CNR also cooperates with the Ministry of Economic Development (public-public collaboration) with the aim to support the growth of the photovoltaic sector in Italy. In this respect, CNR supports funding for research projects and the promotion of the use of photovoltaics by providing information and training to companies and individuals.

RSE (Energy System Research) is a research organisation that specialises in the study and development of sustainable energy systems (e.g., integration of renewables, energy efficiency, smart grids etc.), also providing technical and scientific support to the Italian government and other stakeholders in the energy sector. Apart from the various activities RSE is involved in at EU (EU-funded projects, coordinator of EERA Joint Programme Smart Grids etc.) and international level (Mission Innovation), it is actively collaborating with research institutes across the country as well as with public authorities and industry players. As an example, under the national project: "Smart Polygeneration Microgrid", RSE is collaborating with all stakeholders of the collaboration triangle, namely, research organisations (e.g., Università di Bologna), industrial partners (e.g., Enel Distribution S.p.A., Termomeccanica Ecologia), regional authorities (i.e. Municipality of Palombara Sabina), and the Italian Ministry of Economic Development. The project is funded under the "Sustainable Development and Competitiveness of the Regions" programme, and its aim is to develop a decentralized energy system that integrates solar power, energy storage, and other renewable energy sources. In another example, RSE collaborates with ENEA, Enel Green Power, Falck Renewables and several Italian universities under the project SOFIE, a three-year long project funded by the Italian Ministry of Economic Development. SOFIE aims to develop innovative forecasting and monitoring tools for solar energy management, with a focus on improving the accuracy and reliability of solar forecasting models. At a wider scope, and as briefly mentioned above, RSE had an important contribution to the Italian National Energy and Climate Plan (NECP), where with the collaboration of several partners (e.g., ENEA, several national agencies, chambers, ministries etc.) developed energy scenarios and analysed their impact on the electricity system.

Additional important collaborations between research organisations and industry are materialised in the grounds of the Italian Photovoltaic R&I network, where public research organisations

(ENEA, CNR and RSE) collaborate with several Italian Universities (Catania, Ferrara, Lucca-IMT, Milano Bicocca, Padova, Parma, Perugia, Roma Tor Vergata, Siena, Torino, Verona) and industrial players in the country. Their combined contribution to national and international R&I and innovation projects amounts to about 75% of the total person effort invested by the national community of the PV stakeholders. The Photovoltaic R&I network encompasses more than 40 laboratories distributed all over the country. In the context of the network, a best-practice of a fruitful collaboration between industry and research organisations is the adoption of the Hetero-Junction Technology (HJT) by ENEL for their manufacturing facilities in Catania. Research organisations developed the technology up to TRL 5-6 and industry facilitated its scale up to TRL 8-9.

An important strategic role in terms of critical mass, extensive industrial relations and ability to attract national and European investments is played by EURAC Research in Bolzano and by the Innovation Hub&Lab of Enel Green Power in Catania. These two centres have been playing an increasingly important role as virtual R&I hubs for industrial research and demonstration on utility-scale photovoltaics and building-integrated photovoltaics. The Innovation Hub&Lab is acting as an innovation pipeline for Enel Green Power in the field of photovoltaics (and beyond). It is located close to the largest solar-cell and module manufacturing site in Italy and hosts already several technology transfer projects, involving private companies as well as public research organisations.

In the non-profit world of the solar PV sector in Italy, Italia Solare is a non-profit organisation in Italy that aims to promote the development and use of solar energy in the country. The organisation works closely with various stakeholders, including the government, industry, and research organisations, to advance the technology and promote the growth of the solar energy sector in Italy. One of the main ways Italia Solare collaborates with these stakeholders is through the development of research and development projects. The organisation partners with industry and research institutes to conduct research on the latest developments in solar energy and to develop new technologies that can improve the efficiency and performance of solar systems. It also works closely with the government to promote the use of solar energy. The organisation provides information and training to companies and individuals to help them understand the benefits of solar energy and how to install and maintain photovoltaic systems. Through its annual event (Italia Solare Forum), it facilitates the discussion between all entities represented in the collaboration triangle at national level to address the most prominent priorities of the photovoltaic sector.

Finally, it worths mentioning the involvement of Eni New Energy in the development of solar PV plants in Italy. Apart from its rich global portfolio in the sector, through its subsidiary Plenitude has developed 88 MW in the country. Eni also collaborates closely with several stakeholders in the field, and especially with ENEA, PoliMi and CNR, on R&I activities related to solar PV applications.

Solar Photovoltaic in Italy – Regional level

At regional level, Eni and CNR have established a partnership since 2009 (Joint Research Agreement[5]) with the aim of developing research activities for sustainable economic and environmental development in several Italian regions. Their collaboration is implemented across four research centres located in four regions: Campania, Sicily, Basilicata and Puglia. This collaboration has led to innovative solutions in various technology fields, including solar energy.

As an example of collaboration between industry and regional authorities, Enel and the Emilia-Romagna regional administration signed an MoU to support the sustainable energy transition and the development of technologies with the collaboration of private and public stakeholders in the field of energy production from renewable energy sources. This has been materialised, among other, with the development of large-scale solar PV plants, some of which pay particular attention to the involvement of the local communities.

The National Technology Clusters (CTN) are public/private non-profit partnerships operating on the national territory for industrial research, training, and technology transfer, with the aim of coordinating and strengthening the link between the research and the industrial world through national and international initiatives. The CTN Energy founders are representatives of public research organisations (ENEA, CNR, RSE), the industry (e-distribuzione, Eni, NUOVO PIGNONE TECNOLOGIE, TERNA), and non-profit research organisations (EnSiEL). The cluster counts 77 members, from which 16 regional bodies (some of which – territorial district/cluster – represent numerous SMEs), 12 large industries and 49 research organisations. The CTN Energy (including the Clusters in other sectors) is supported by the Italian government and several ministries by providing funding, resources, and policy support.

Interface across geographical levels

The connection of the EU-level collaboration platforms with the national level (i.e., key Italian stakeholders) is taking place through the participation of Italian stakeholders in the mentioned platforms. For instance, Eni, Enel, ENEA, EURAC research and Italia Solare are all members of the SolarPower Europe association, while ENEA is a member of EERA JP PV, and EURAC research and CNR are partners in the PV Impact project. Similarly, connections made through individuals occur not only between the different initiatives/platforms at EU level, but also between those at EU and national level. For instance, the Vice-Chair of ETIP PV is from EURAC, while both ENEL and Eni are members of the Steering Committee of the ETIP PV. The mentioned Italian players above, apart from their collaboration at national level with SME's, the Ministry of

[5] Eni, CNR. "The Joint Research Agreement (JRA)" in Press released 24 March 2019, Lecce "Eni and CNR: sign renewal of the Framework Agreement for Collaboration in Research and Technological Innovation". https://www.eni.com/assets/documents/press-release/migrated/2021-en/11/PR_Eni_CNR_eng.pdf

Economic Development and the entire research community in Italy they, are also active at regional level.

They collaborate with regions (e.g., region of Emilia-Romagna) and municipalities on various projects and initiatives, providing support to the development of regional projects, investing in industrial production of PV modules and collaborating at regional level (e.g., CTN Energy), offering training, technology transfer activities while supporting innovation and the improvement of R&I landscape.

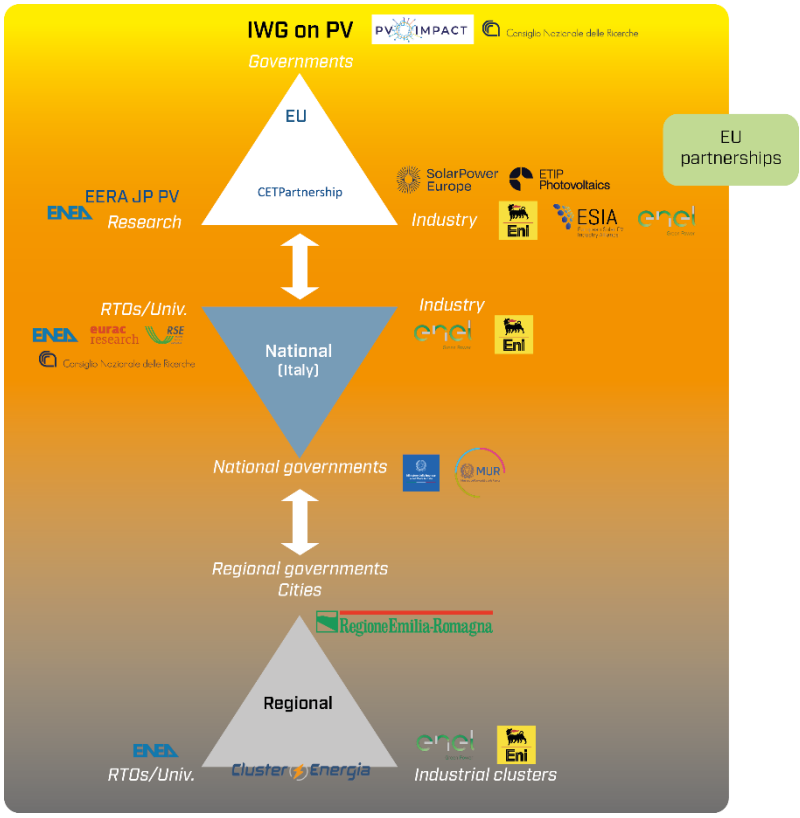


Figure 6. Collaboration interface for photovoltaics presenting the cooperation on EU as well as national and regional levels in Italy.

Table 4. Main collaborative actors on solar PV on EU level as well as on national and regional levels in Italy.

		EU level						National level					Regional Level	
Organisation	**Sector**	**IWG PV**	**ETIP PV**	**PV IMPACT**	**EERA JP PV**	**European Solar Photovoltaic Industry Alliance**	**Solar Power Europe**	**Smart Polygeneration Microgrid**	**SOFIE project**	**Electric System Research project**	**Enel Innovation Passo Martino Lab**	**Italian Photovoltaic R&I network**	**MoU to support the sustainable energy transition**	**National Technology Clusters**
ENEA	Public research organisation				Member	Member through SolarPower Europe	Member	Partner	Partner	Partner		Partner		Founder
Enel	Industry		Member	Partner		Member through SolarPower Europe	Member	Partner	Partner		Owner/partner	Innovation uptake example	Partner	
Eni	Industry		Member			Member through SolarPower Europe	Member							Founder
EURAC Research	Research Institute		Member	Partner		Member through SolarPower Europe	Member							
CNR	Public research organisation			Partner							Co-founder	Partner		Founder
RSE	Research organisation							Partner				Partner		Founder
Ministry of Economic Development	Public Authority							Partner	Funding organisation	Funding organisation				Funding organisation
Ministry for Universities and Research	Public Authority	Member												Member
Solar Power Europe	European Association		Secretariat			Signatory								
National Energy Technology Cluster (CTNE)	Non profit organisation													
Region of Emilia-Romagna	Public Authority												Partner	

A short description of the stakeholders/initiatives mentioned in Table 4 and Figure 6 is available below.

ENEA is the National Agency for New Technologies, Energy and Sustainable Economic Development, a public body aimed at research, technological innovation, and the provision of advanced services to enterprises, public administration and citizens in the sectors of energy, the environment and sustainable economic development.

Enel is one of the largest electricity utilities in Europe, with a presence in over 30 countries. The company is focused on the production and distribution of electricity, as well as the development of renewable energy sources, and is committed to reducing its carbon footprint and promoting the use of clean energy.

Eni is a multinational oil and gas company based in Italy. It is active in the exploration, production, transportation, transformation, and sale of oil and natural gas, as well as in the production and sale of petrochemicals, refining, and marketing of oil products. The company also invests in the research and development of new technologies in the energy sector and has a significant presence in the renewable energy market.

EURAC Research is an interdisciplinary research institute based in Bolzano, Italy. It focuses on a range of topics, including renewable energy, energy efficiency, and energy policy, and works to promote sustainable energy solutions through its research and collaborations with government, industry, and other research institutes.

The Italian National Research Council (CNR) is a leading research organisation in the field of solar energy, and it collaborates with various Italian entities to promote the development and use of this renewable energy source.

Energy System Research - RSE SpA is an Italian joint-stock company controlled by the Energy Services Manager, for the development of research activities in the electro-energy sector, with particular reference to national strategic projects.

The Ministry of Economic Development (Ministero dello Sviluppo Economico or MISE) is a government ministry of the Italian Republic. It deals with production, economic activities, energy and mineral resources, telecommunications, consumers, tourism, internationalisation, and business incentives.

The Italian Ministry for Universities and Research (MUR) is the key RTD policy actor and funding agency in Italy at state level. MIUR is in charge to prepare and to submit the National Research Programme proposal to the Government and to directly manage it. It also has key responsibilities for international co-operation. It concludes bi- and multilateral agreements on research and technology collaboration and is in charge of coordinating Italy’s participation in the European Union’s Framework Programme.

Italia Solare is a non-profit organisation in Italy that aims to promote the development and use of solar energy in the country. The organisation works closely with various stakeholders, including

the government, industry, and research institutes, to advance the technology and promote the growth of the solar energy sector in Italy.

The National Energy Technology Cluster (CTNE) is an Italian non-profit association that promotes actions aimed at supporting research, development and technology transfer in the energy sector, with the aim of combining the demand for innovation in the industrial sector with the offer of innovation from the country's highly qualified research structures to support the achievement of the expected targets, in terms of research planning from the main international and national strategic agendas (Mission Innovation, SET-Plan, Energy Union Strategy, PNIEC, PNR, Smart specialisation strategy, Industry 4.0, PNRR).

ETIP PV mobilises all stakeholders sharing a long-term European vision for PV, helping to ensure that Europe maintains and improves its industrial position in order to achieve a leadership position within the global PV market.

Solar Power Europe is a leading association dedicated to promoting solar power in Europe. Its mission is to shape the regulatory environment, raise public awareness, and develop business opportunities for solar power. The organisation represents more than 200 members from across the solar value chain.

PV-IMPACT project supports the actual execution of the Implementation Plan for Photovoltaics of the SET Plan and monitoring the Implementation Plan's delivery. PV IMPACT, coordinated by EUREC, will try out a variety of approaches to stimulate the private sector to spend more on PV research, development, and innovation in Europe.

EERA JP Photovoltaics: The objective of the EERA-PV Joint Programme is to accelerate the development of Photovoltaic Solar Energy towards an energy technology that can be implemented at a very large scale through Joint Programming activities by key research institutes in Europe.

EUREC is an association of European research centres and university departments active in the area of renewable energy. The purpose of the association is to promote and support the development of innovative technologies and human resources to enable a prompt transition to a sustainable energy system.

The European Solar Photovoltaic Industry Alliance will help the EU reach over 320 GW of newly installed solar photovoltaic capacity by 2025 and almost 600 GW by 2030. Once set up, the Alliance will bring together industrial actors, research institutes, consumer associations, NGOs and other stakeholders interested in the solar PV sector. It will deliver an action plan for the solar industrial value chain in Europe and engage with the EU and MS on issues ranging from research and innovation, technology, industrial supply chain, raw materials, access to finance, off-takers, international partnerships and global supply chain resilience, circularity, sustainability, and skills.

Concentrated Solar Power – European level

The collaboration triangle on CSP at EU level comprises research organisations, industry and MS representatives involved in four main initiatives: The CSP Implementation Working Group, the public-public partnership CSP ERANET, EU-SOLARIS ERIC and EERA Joint Programme on CSP (EERA CSP). Spain, through CIEMAT, plays a central role in the CSP sector. CIEMAT is a public research body assigned to the Ministry of Science and Innovation that focuses on energy, the environment, and related technologies.

The CSP IWG is chaired by Spain and brings together SET Plan representatives from Portugal, Italy, Germany, France, Belgium, Greece, Cyprus, Turkey and Spain. Other active members in this IWG are research organisations (e.g., CIEMAT) and industrial players. ESTELA, a European association representing more than 50 members from the industry and research organisations, is also an active member of this IWG.

While the CSP IWG defines the priorities and objectives of the SET Plan Implementation Plan, CSP ERANET aims to coordinate the efforts of MS/ACs and regions towards achieving CSP SET Plan objectives by pooling their financial resources to implement joint calls for R&I proposals. CSP ERANET constitutes a public-public partnership gathering 11 representatives from eight MS/ACs (Spain, Switzerland, Germany, Greece, Israel, Italy, Portugal and Turkey). CSP ERANET will count on at least one call for proposals with a budget of EUR 13 million.

EU-SOLARIS ERIC establishes and operates a world-class distributed research infrastructure on CSP/STE to be set up as a central hub responsible for the coordinated operation of national research centres in CSP/STE technologies. 15 partners (13 Scientific,1 Ministry and the EU STE Industry Association) representing 11 EU countries are participating, covering all the modes and technologies of Solar Energy Concentrating Systems. EU-SOLARIS ERIC central hub is situated in CIEMAT's premises in Spain.

Eventually, the research community is represented by EERA JP CSP, whose primary role is to integrate and coordinate the scientific collaboration among the leading European research organisations in CSP to contribute to achieving the targets set by the SET-Plan. CIEMAT is the coordinator of this JP.

Concentrated Solar Power in Spain – National level

Spain is the world leader in concentrated solar power (CSP) production, and the golden triangle is primarily accomplished through the following initiatives and organisations.

In terms of research, CIEMAT is one of the principal actors on CSP in Spain, playing a central role at both European and national levels. It has offices in several regions of the country and is collaborating with other research organisations and industries in the sector to transfer knowledge and technology. Further, CIEMAT owns The Plataforma Solar de Almería (PSA), formally considered by the ECas a European Large Scientific Installation. It is also the world's largest and most complete R&I centre devoted to solar thermal concentrating systems. PSA is integrated into the CIEMAT organisation as an R&I division of the Department of Energy. Therefore, it is a laboratory crucial in reinforcing the cooperation between industry and research organisations at

national level. On top of that, the central node of EU-SOLARIS is also in CIEMAT (the CSP/STE RIs of CIEMAT-PSA). At the Spanish level, this research infrastructure comprises a group of universities and research centres (e.g., IMDEA, CENER, Tekniker, University of Sevilla, University of Lleida, UPC, Carlos III) that are active stakeholders on CSP at national level and have been invited to the EU-SOLARIS board.

In close collaboration with CIEMAT, the public sector within the CSP-golden triangle in Spain is represented by two major public institutions providing funding for R&I on CSP in Spain:

- Centro para el Desarrollo Tecnológico Industrial (CDTI) is a Public Business Entity that belongs to the Ministry of Ecological Transitions, which provides funding and support for Spanish industries' national and international R&I projects.
- Agencia Estatal de Investigación (AEI) is a public funding agency that belongs to the Ministry of Science and Innovation. The Agency's purpose is to finance research projects of Spanish research organisations.

As for collaboration between research and industry, relevant stakeholders of the CSP sector in Spain cooperate within the association PROTERMOSOLAR, which is the Spanish Association for the Promotion of the Solar Thermal Industry, to promote the development of the Spanish solar thermal industry. Currently, it has 57 members from both industry and research fileds, including ABENGOA, SENER and ACS-COBRA. PROTERMOSOLAR is also a founder and active member of ESTELA, its European counterpart, thus, linking initiatives at EU and national level.

One good activity that could be highlighted in the collaboration of research and industry is the organisation of a SUPEERA workshop in Almeria, Spain, in December 2022.

Concentrated Solar Power in Spain – Regional level

At regional level, Extremadura is the most active region in Spain, with the Extremadura Energy Agency (Spanish: Agencia Extremeña de la Energía) and the government of Extremadura (Spanish: Junta de Extremadura), which is the regional public institution providing funding for CSP projects. Notably, in the region are located several CSP plants, for instance, the Extremadura Solar Complex, a 200MW plant which is one of the biggest CSP plants in the world.

Concentrated Solar Power – Interface across geographical levels

CIEMAT plays a central role in the CSP sector to realise collaboration across geographical levels, connecting several initiatives at EU, national and regional levels, as explained in the section above. CIEMAT is one of the critical figures in the IWG facilitating the alignment of European and national/regional R&I priorities in close dialogue with the Ministry of Science and Innovation and the Ministry of Ecological Transition (IWG Chair and co-chair respectively and foremost responsible for defining national R&I priorities and providing funding for R&I through AEI and CDTI).

As for industry, there are also a few stakeholders with key roles across geographical levels. This is the case for Abengoa, ACS COBRA and Sener, all of them members of IWG CSP at EU level, and members of both ESTELA, and Protermosolar at national level. In terms of initiatives, it is worth mentioning ESTELA, an industrial association that acts as an ETIP in this sector and EU-SOLARIS ERIC for the coordination of national research centres in CSP/STE technologies in Europe, in which CIEMAT plays a central role since it is the central hub of this initiative. On top of that, the EU partnerships, i.e. CSP ERANET in the past and now the CET Partnership, are fostering collaboration between Spanish (at regional and national level) and other EU entities.

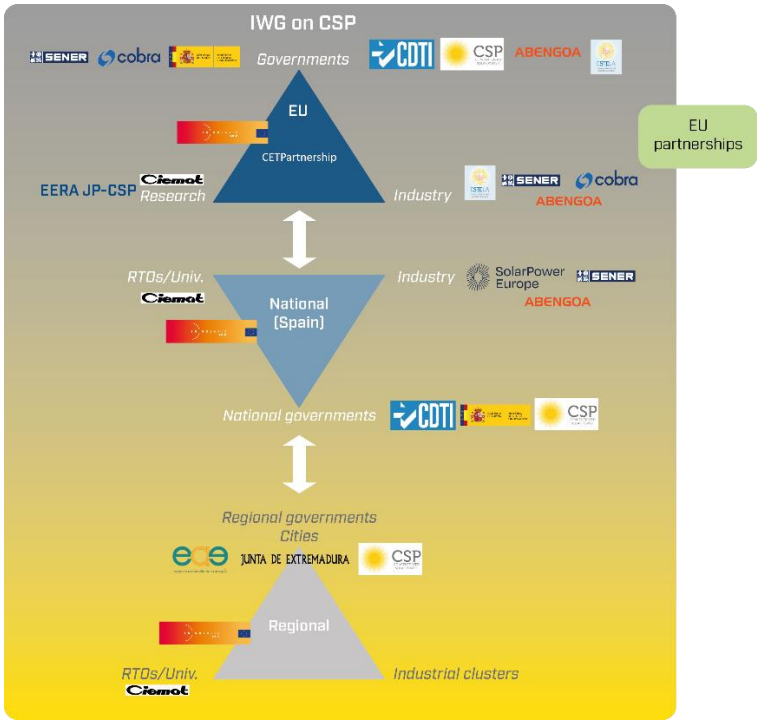


Figure 7. Collaboration interface for concentrated solar power presenting the cooperation on EU as well as national and regional levels in Spain.

Table 5. Main collaborative actors on concentrated solar power on EU level as well as on national and regional levels in Spain.

		EU level					National level		Regional level
Organisation	**Sector**	**IWG CSP**	**CSP ERANET**	**EU-SOLARIS ERIC**	**EERA JP CSP**	**ESTELA**	**PSA**	**Protermoslar**	
CIEMAT	Research organisation	Member (core group)		Member (central hub)	Coordinator		PSA Owner		
ESTELA	Industrial Association	Member (core group)							
Ministry of Ecological Transitions - CDTI	Public body	MS representative	Partner						Funding authority
Ministry of Science and Innovation - AEI	Public body	MS representative	Partner						Funding authority
Agencia Extremeña de la Energía	Public body		Partner						Funding authority
SENER						Member		Member	
ABENGOA		Participant				Member		Member	
ACS COBRA		Participant				Member		Member	
Junta de Extremadura	Public body		Partner						Funding authority

A short description of the stakeholders/initiatives mentioned in Table 5 and **Error! Reference source not found.** is available below.

CSP ERANET constitutes a public-public partnership gathering 11 representatives from MS/ACs and Regions to bridge the gap between research and commercial deployment in the Concentrated Solar Power (CSP) technology.

EU-SOLARIS ERIC shall establish and operate a world-class distributed research infrastructure on concentrated solar power/solar thermal energy (CSP/STE) to be set up as a central hub responsible for the coordinated operation of national research centres in CSP/STE technologies, which shall dedicate part of their research and development capacities to EU-SOLARIS ERIC, sharing contents, tools and know-how related to CSP/STE technologies.

EERA Joint Programme on CSP. The overall objective of this JP is to integrate and coordinate the scientific collaboration among the leading European research institutions in CSP to contribute to the achievement of the targets initially set by the "Solar Thermal Electricity-European Industrial Initiative" (STE-EII) and, later, by the SET Plan.

ESTELA is the largest industry association in the world promoting the solar thermal electricity sector.

CIEMAT is a public research body assigned to the Ministry of Science and Innovation that focuses on energy, the environment, and related technologies.

SENER is a private engineering and technology group founded in 1956, specializing in activities related to Infrastructure, Energy and Marine.

ABENGOA is an international company that applies innovative technology solutions for sustainability in the infrastructures, energy, and water sectors. They have wide experience in engineering, construction, assembly and commissioning of conventional power generation and renewable energy plants.

ACS COBRA is a global Leader with more than 75 years of experience in all fields related to the engineering, installation, and industrial maintenance of infrastructures.

3.6 Collaboration interface on offshore wind energy

Offshore wind – European level

At the EU level, the cooperation across government, industry, and research community is mediated by IWG on Offshore Wind, ETIP Wind, EERA JP on Wind, WindEurope, European Commission's Joint Research Centre in Petten, and European projects.

The Offshore Wind IWG is composed of representatives from relevant European countries (MS, governmental agencies from NL, BE, DE, EE, ES, FR, IT, NO, TR and UK) and stakeholders,

representing both industry and research community with interests in offshore wind, as well as from representatives of the EC (DG RTD, DG ENER, JRC). The IWG works in collaboration with SETWind (an EU-funded project) and has developed the Implementation Plans in close coordination with ETIPWind, EERA JP Wind, and WindEurope.

EERA JP Wind and ETIP Wind have a consolidated collaboration approach, both in terms of agenda setting, aligning R&I agendas, and in terms of implementation, with the aim to turn wind research into industrial opportunities. The ETIP Wind and EERA JP Wind platforms develop, inform, and influence Research & Innovation policy and priorities at European and national level. As such, both involve collaboration across the "triangle"; however, the focus is on institutions with significant R&I.

Beyond their internal networks, ETIP Wind interacts with the EC and the European Parliament, the SET Plan Steering Group, other ETIPs and MS representatives. EERA JP Wind interacts with the European wind energy industry and societal stakeholders. Through interactions via the SETWind project, they have identified, in close collaboration with leading industry partners (several workshops/webinars), two key areas for European Lighthouse research projects: 1) Integration of large-scale offshore wind energy; and 2) floating wind energy. While discussing those two lighthouse initiatives, the idea of European Centres of Excellence (ECoE) has been aroused. These two focus areas could form the basis for a ECoE, given that research challenges for these two key areas are already defined.

As described above, at the EU level most of the interaction within the triangle is between industry and the Research community, with policy/government as receivers of R&I recommendations. There is close collaboration between Research community and industry as their strengths have been developed together. This gives a strong, well-balanced understanding and separation of influence and expertise whilst still being open to collaboration. Due to this close collaboration, R&I recommendations towards European government bodies from the Research community and industry are well-aligned, and thus, they speak with one voice in position papers that are shared with the European Commission.

For collaboration at the international level, it is noted that: the Implementation Plan for Offshore Wind was developed in collaboration with IEA Wind TCP; EERA JP Wind aims to provide members with potential global outreach to collaborative partners; WindEurope seeks to facilitate international policies and initiatives that strengthen the development of global wind energy markets, infrastructure, and technology; ETIP Wind, with multiple multi-nationals, exchanges best practices on wind energy R&I needs with the international community; and IEA Wind TCP is an international cooperation of 23 countries and sponsor members who share information and research activities to advance wind energy deployment.

Offshore wind in Norway – National level

In Norway, the collaboration triangle is primarily accomplished through so-called Centres for Environment-friendly Energy Research (FME). These centres are instrumental to demonstrate the potential for innovation and value creation by carrying out long-term research in close collaboration between the research community, trade and industry, and the public administration.

In 2021, a new Centre of Excellence on Offshore Wind Energy called NorthWind was granted. The Centre joints and coordinates national research and innovation efforts on offshore wind energy and represents, thus, “Norway AS” in that energy sector. NorthWind is scheduled for eight years, with a total budget of about NOK 350 million (~EUR 33 million) of which NOK 120 million is from the Research Council of Norway, and the remaining sum comes from industry and research partners. Northwind gathers leading research institutions and over 40 companies.

The triangle is effectively realised on several levels. In terms of agenda setting and strategic positioning, the Centre Board of Northwind, where decision-making takes place, consists of industry (in the majority) and key research partners. Further, Northwind has adopted a crucial role in national strategy-shaping processes. The Centre provides recommendations to the national energy strategy “Energi21” and is a member of the national body “Collaboration Forum for Offshore wind”, recently established by the Ministry of Oil and Energy. In this forum, NorthWind is involved in the discussions on industry and technology R&I. As compared to the Strategic Energy Technology (SET) Plan IWG Wind, where discussions are not thematically structured and are mainly led by high-level country representatives, the national Collaboration Forum for Offshore wind allows for more specific and tailored-made debates with people with that expertise.

The research-industry collaboration in Northwind is also materialised through a Technology Transfer Committee, responsible for bringing results towards commercial use, with strong links with business development units of the Centre partners. In terms of research development and innovation, the collaboration between research groups and industrial players is reflected across several dimensions. Firstly, excellent research with a significant budget and duration is directed towards industry needs. Secondly, industry proposes end-user case studies, and thirdly, industry has first access to i) detailed results for business development and ii) knowledge and innovations reducing the cost of energy from offshore wind farms and reducing the environmental and societal impacts.

In a workshop organised in The Netherlands in April 2022 on the role of research-industry collaboration in accelerating innovation and uptake of new technologies in wind energy (and energy systems integration), several best practices were presented. Among those, it is worth mentioning GROW, a Dutch joint research program in offshore wind, with a very strong research-industry collaboration covering almost the full value chain, like NorthWind. One of the main differences as compared to the Norwegian Centre is that GROW did not receive large governmental support right from the start, and instead, the partners need to apply for governmental funding for each of the projects developed within the programme. In the GROW Partnership, the research-industry collaboration takes place across nearly all technology readiness levels (TRLs), from fundamental research (in TRL 2) to testing and demonstration of large systems (in TRL 8), ensuring innovations towards commercialisation. That is crucial to accelerate innovation and the uptake of new technologies by industry. A second-best practice on research-industry collaboration was presented by TU Delft which introduced the Wind Energy Technology Platform. Concretely, TU Delft exemplified its best practices for collaboration with industry by showcasing the role industry takes in technology studies and reference systems/scenarios, ensuring relevant industrial conditions, and sharing industrial data.

Offshore wind – Regional level

In Norway, collaboration on offshore wind at regional level is dominated by the activities conducted by one of the partners in Northwind. This industrial cluster is the largest offshore wind representative body in Norway, with more than 370 members from all over the country. Their partnership in Northwind enables alignment between regional and national research-industry joint actions such as meetings, conferences, dissemination, etc.

Offshore wind – Interface across geographical levels

To realise collaboration across geographical levels, EERA JP Wind supports members in shaping research to national priorities and the implementation through national research programmes; SETWind facilitates a breakthrough in the coordination across borders of nationally funded R&I projects; and ETIP Wind informs on R&I policy at a national level, thus providing clear interlinks between collaboration triangles at EU and national levels. This is, for instance, facilitated via 1) the organisation of joint conferences, e.g., EERA DeepWind offshore wind energy R&I conference 2022 was

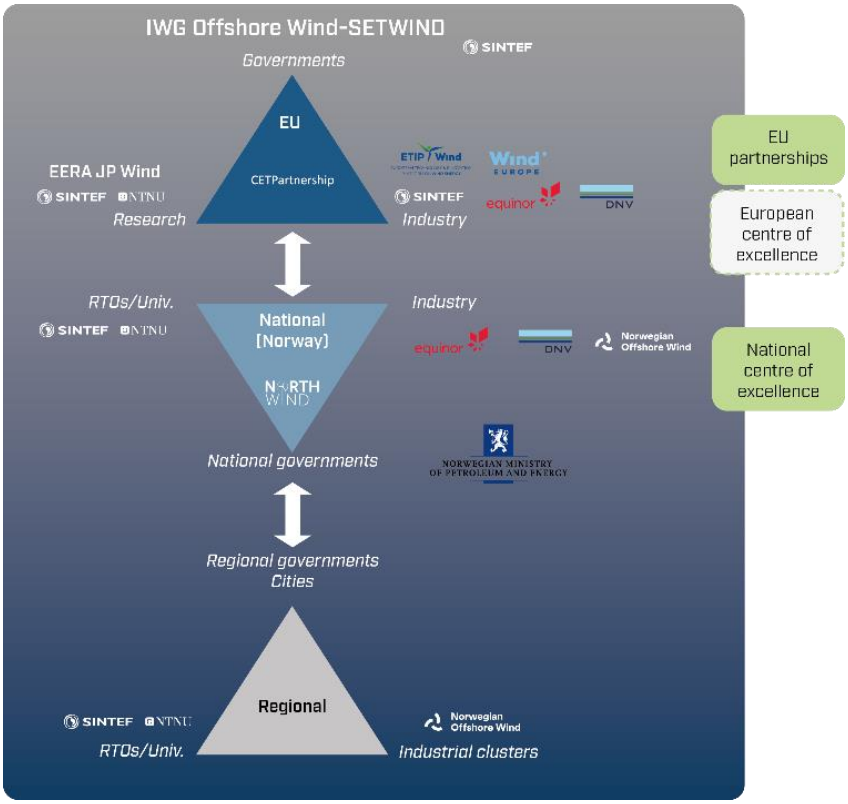


Figure 8. Collaboration interface for offshore wind energy presenting the cooperation on EU as well as national and regional levels in Norway.

organised by SINTEF (host institution and Centre manager for NorthWind), NTNU and EERA JP Wind; and 2) the overlap of membership between the national and EU levels. An example of this overlap is that a member of the IWG Wind is also the director of the NorthWind research centre and Sub-programme leader in EERA JP Wind, hence contributing directly to the alignment of R&I strategies, and activities. This significant overlap across regional/national/European levels is also experienced by industrial players and national authorities who are members of Northwind, IWG Wind and/or ETIPWind. Table 6 and Figure 8 show examples of such organisational overlap. Financing mechanisms for EU Wind projects consist of Horizon Europe (including the Clean Energy Transition Partnership), Innovation Fund,

European Climate Infrastructure and Environment Executive Agency (CINEA), LIFE, and European Sustainable Energy Awards. For the establishment of EECoE, a few national governments need secure funding to demonstrate national commitment to the EECoC. From the Norwegian side, key national players are working to make it happen, and if some national funding was secured, then the EC could match this funding with top funding.

Table 6. Main collaborative actors on offshore wind energy on EU level as well as on national and regional levels in Norway.

		EU level					National level	Regional level
Organisation	**Sector**	**EERA JP Wind**	**ETIPWind**	**WindEurope**	**IWGWind**	**SETWind**	**NorthWind**	**Norwegian Offshore Wind**
SINTEF	Research community	SP6 leader	Steering committee		Member	Partner	Coordinator	
NTNU	Research community	Associate member					Partner	
Equinor	Industry		Steering committee	Board of Directors			Partner	Member
DNV	Industry		Steering committee				Partner	Member
Norwegian Offshore Wind	Industry						Partner	
Ministry of Oil and Energy	Public authority						Partner	

A short description of the stakeholders/initiatives mentioned in Table 6/Figure 8 is available below.

DNV is an independent expert in assurance and risk management with the purpose to safeguard life, property, and the environment. The company invests substantially in research, development, and innovation on renewables (wind and solar) to make sure that DNV stays at the very forefront of research and its application to their business and the industry as a whole.

EERA JP Wind. This Joint Program aims to provide strategic leadership for medium to long-term wind energy R&I and to support the European wind energy industry and societal stakeholders. EERA JP Wind covers a wide range of research areas, from material science to infrastructure, system integration or environmental/economic aspects, to mention a few.

Equinor is an international energy company committed to long-term value creation in a low-carbon future. Equinor's portfolio of projects encompasses oil and gas, renewables, and low-carbon solutions, with an ambition of becoming a net-zero energy company by 2050. Equinor has invested heavily in renewables, with the offshore wind being a large portion of such investment.

ETIP Wind provides a public platform to wind energy stakeholders to identify common Research & Innovation (R&I) priorities and to foster breakthrough innovations in the sector. This platform is active in policy making by providing policy recommendations to European and national governments and is key in supporting the implementation of the Integrated SET Plan.

NorthWind is a Centre of Excellence (Centres for Environment-friendly Energy Research) in Norway with the overall objective to bring forward outstanding research and innovation to reduce the cost of wind power and facilitate its sustainable development, which will grow exports and create new jobs.

NTNU has energy as one of the four strategic research areas for the period 2014-2023 and the university has a dedicated team on wind, with experts in wind power. The team consist of people from different disciplines, departments and faculties across NTNU. The main task of the team is to coordinate wind power education and research at NTNU.

SETWind is a project to support the implementation of the SET Plan Implementation Plan for Offshore Wind by monitoring and reporting on the progress of such Plan, strengthening policy coordination in European offshore wind energy R&I policy and facilitating a breakthrough in the coordination across borders of nationally funded R&I projects.

SINTEF is an independent, non-profit research institute. SINTEF has world-leading research communities within offshore wind power and is building bridges to the international market. SINTEF collaborate with leading industries to reduce the levelised cost of electricity for offshore wind power and to accelerate innovation and value creation.

Wind Europe represents the wind industry and actively promotes wind energy across Europe. The platform covers the whole value chain: turbine manufacturers, component suppliers, power utilities, wind farm developers, financial institutions, research organisations and national wind energy associations. Wind Europe works intensively on policy matters of key strategic importance for their members.

3.7 Collaboration interface on energy systems integration

Energy Systems Integration – European Level

At the EU level, the collaboration structures are similar to those found in the other pathways, with three main pillars: IWG 4 'Increase the resilience and security of the energy system', representing the public sector, ETIP 'Smart Networks of the Energy Transition', representing industries, and EERA JP 'Energy Systems Integration', representing research. However, there seems to be a disconnection between these bodies to some degree. The energy systems integration research community, for instance, does not seem to have any institutional platform to inform about policymaking.

IWG 4 'Increase the resilience and security of the energy system' is co-chaired by Austria and Italy and includes 13 other European countries (AU, BE, CY, ES, DE, FI, IE, IT, LU, LV, NL, NO, TR). It is supported by the ETIP Smart Networks for energy transition (ETIP SNET) and the European Research Area Network for Smart Energy Systems (ERA-NET SES). However, the energy research community represented by EERA JP ESI does not take part in the IWG nor have access to information about this group's activities, thus weakening collaboration between research and governments.

The ETIP SNET brings together stakeholders and experts from the energy sector to guide RD&I that supports the Europe's energy transition, including the integration of energy systems. This network gathers a wide range of stakeholders, including industry, research and national representatives and all three sectors are represented in the Governing Board, thus facilitating collaborative decision-making in a triple helix approach. EERA is part of this Governing Board; however, it is limited to the EERA JP Smart Grids. On the contrary, the EERA JP Energy Systems Integration (JP ESI) is not part of it and therefore, those research aspects of ETIP SNET related to integration of energy systems are lacking as of today.

Furthermore, the ETIP SNET governance includes a dedicated platform, the National Stakeholders Coordination Group (NSCG), for national R&I stakeholders, such as ministry representatives, funding agencies, regulators, and national platforms, in order to support the execution of the Implementation Plan on Integrated and Flexible Energy Systems. This platform is a significant meeting place for transnational collaboration. Beyond the structured collaboration platforms (ETIP SNET, EERA JP SG and IWG), personal initiative is key to driving the communication and alignment between the ETIP, the NSCG and the Implementation Working Group (IWG 4). This is particularly evident in this Action of the SET Plan, where the same experts have active participation across all three platforms.

EERA Joint Programme in Energy Systems Integration (JP ESI) brings together 34 European universities and research centres to collaborate in developing the technical and economic framework that governments and industries need to develop an efficient and sustainable European energy system. It is aligned with the SET Plan Integrated Roadmap. The Joint Programme is organised into five strongly interlinked sub-programmes (SP) that target different aspects of energy systems integration. There is an initiative for an EERA Centre of Excellence in ESI to involve industry more closely. In addition, EERA JPs Smart Grids and E3S are linked to ESI themes, particularly in societal aspects.

European Research Area Network for Smart Energy Systems (ERA-Net SES) is a funding and knowledge community that has provided a research management structure for multilateral joint programs. ERA-Net SES is financed by public funding institutions from different countries and regions. The funding partners are participating in the focus initiatives and are launching joint calls for Research Design and Development (RDD) proposals.

ERA-NET SES' Transnational Joint Programming Platform consists of owners and managers of national and regional public funding programs in the field of research, technical development and demonstration. The associated partners consist of energy agencies, technology associations, research infrastructure providers and businesses. It appears at the connection to energy research community has not been fostered in any evident manner.

The Clean Energy Transition Partnership (CETP) is a multilateral and strategic partnership of national and regional R&I programmes in EU/EEA MS and non-EU/EEA Partner Countries, aiming to substantially support the implementation of the European Strategic Energy Technology Plan (SET Plan). Importantly, the Partnership seeks to build an innovation ecosystem that fosters capacity building at all levels to achieve faster market diffusion. The objective of the Partnership appears to be becoming a collaboration triangle.

In ESI area, the CETP is replacing replace ERA-net SES, which participated in developing the Partnership. ERA-Net SES works closely together with other initiatives of the European SET Plan, particularly on SET Plan Action 4. EERA JP ESI also participated in developing the CETP.

Energy Systems Integration in the Netherlands – National Level

The Ministry of Economic Affairs and Climate Policy (Dutch: Ministerie van Economische Zaken en Klimaat; EZK) is responsible for energy and climate policy, along with industry, investment, and other areas. The government of the Netherlands has indicated economic top sectors that receive priority in the economic stimulus and research. Within each top sector, the parties have established research agendas and goals for the coming years.

The Top Sector Energy (TSE) is implemented to drive innovations necessary for the transition to an affordable, reliable, and renewable energy system. In July 2018, the government outlined the top sector's policy focus on the economic opportunities offered by social challenges, including the energy transition and sustainability. The Top Sector Energy and the Knowledge and Innovation Top Consortia are organising the core tasks, which are programming in cooperation with research organisations, companies, and governments, building Public Private Partnerships (PPP) and knowledge dissemination.

The Energy Top Sector recognises that Social Missions for Energy Transition and Sustainability require solutions that link innovations to necessary changes in regulations and behaviour. Energy Top Sector seeks close cooperation with other top sectors.

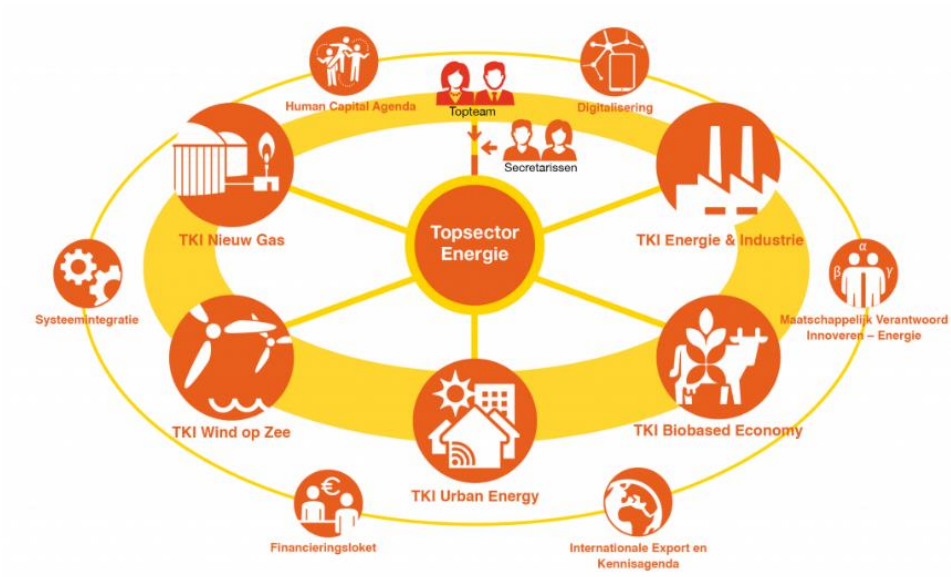


Figure 9. Top Sector Energy diagram showing the different collaboration structures. Source: https://www.topsectorenergie.nl/topsector-algemeen

The Dutch Research Council (NWO) is one of the most important science funding bodies in the Netherlands and realises quality and innovation in science. Each year, NWO invests almost EUR 1 billion in research related to societal challenges and research infrastructure. Research on system integration is part of NWO's programming for Top Sector Energy. The programme on system integration will last from 2015 to 2025 and will have EUR 12 million. To guarantee quality and innovation in science and to promote the impact of research, NWO also functions as a connector, bridging between researchers, governments,

politics, research institutions, industry and other users of scientific knowledge. TSE allocates funding annually to pilot projects and system integration research calls, and it is matched by the national science funding (Dutch Research Council, NWO). This is innovative because science funding has been traditionally divided between social sciences and engineering. energy system integration, involving both perspectives, fell earlier into the gap between the disciplines and did not receive financing.

In the Netherlands, the government is recognising that ESI is not a commercial product. energy system integration involves guidance about how to better plan and operate the energy systems. Therefore, system integration research in the Netherlands invites the private sector to participate with a very small financial contribution. Effectively e.g., network companies or large industries can commit data and some time off of their own modelling. The research contributes by linking these (sectoral) models together. The output of the models becomes public and supports evidence-based decision-making, while the data remains private.

There are several projects in the Netherlands that focus on energy system integration, facilitating close collaboration between research institutes, industry, and governmental agencies.

For instance, in the PosHYdon project, Nexstep, the Dutch association for decommissioning and reuse, and TNO, the Dutch organisation for applied scientific research, work in close collaboration with other industry partners (i.e. Nel Hydrogen, InVesta, Hatenboer, IV-Offshore & Energy and Emerson Automation Solutions, Neptune Energy, Gasunie, Noordgastransport, NOGAT, DEME Offshore, TAQA and Eneco). The project aims to validate the integration of three energy systems in the Dutch North Sea: offshore wind, offshore gas and offshore hydrogen and involves the installation of a hydrogen-producing plant on an offshore platform (Q13a-A). This is a first-of-its-kind project (offshore green hydrogen production) with a budget of EUR 3.6 million, funded by the Netherlands Enterprise Agency (RVO).

Under the SEIN (System Integration Energy in the Netherlands) project, several Dutch partners (KVGN, TenneT, NVDE, Energie Nederland, VNCI, VNO-NCW, EBN, Gasunie, GasTerra, NOGEPA and Shell) have taken the initiative to investigate how good cooperation can be achieved in the domain of energy system integration. This collaboration resulted in a guide giving recommendations for the system integration organisation, i.e., the report Handreiking SEIN 'Exploring the orchestration of System Integration in the Energy System in the Netherlands'[6]. Practical examples show how this already works at a local scale, highlighting that more cohesion and control are needed on a national scale in the Netherlands. It also contains the lessons learned about cooperation between organisations and the orchestration of four system integration programs in the Netherlands, i.e., Ameland, GZI Next Emmen, II3050 and the hydrogen backbone.

[6] EBN Element, NL Energy Netherlands, Gasterra Gasunie KVGN NVDE Shell TenneT VNCI VNO NPV, Energy transition Report (2020) “Guide SEIN: System integration Energy in the Netherlands – EBN”. https://www.ebn.nl/wp-content/uploads/2022/10/HandreikingSEIN_september2020_final.pdf

Energy system integration – Regional level

At regional level, several big companies collaborate with authorities and research organisations in the field of energy system integration. Two examples of these collaborations are summarised below.

An example is the Integral Infrastructure exploration 2030 – 2050 (II3050) programme, where Gasunie and TenneT are working together with regional network operators with the aim of creating a robust and CO_2-neutral energy system of the future. This cooperation is organised within a working group of Netbeheer Nederland (the association of energy network operators in the Netherlands). The aim of II3050 is to provide a broadly supported long-term perspective for such a system and the associated energy networks. This picture of the future must provide a basis for government policy and investment decisions. To this end, the government, industry, energy companies, market players and grid managers aim to develop a joint vision of the energy system in 2050 and the pathway towards it.

In the New Energy Coalition (also known as the Dutch Energy Valley), regional authorities (the provinces of Drenthe, Fryslân, Groningen and Noord-Holland Noord) collaborate closely with industry and research institutes in the field of energy system integration. The New Energy Coalition is a continuously growing network of knowledge institutions, businesses, government bodies and NGOs working together to accelerate the energy transition. Through its various cooperation schemes (e.g., energy ecosystems, energy hubs), the network has entailed several collaboration and investments in new infrastructures, knowledge centres and innovative energy systems. The aggregated knowledge from all connected activities is publicly available in the "Knowledge Database" online.

Energy system integration – Interface across geographical levels

TNO is an important organisation in the domain of energy system integration at EU level, participating in various collaboration platforms (e.g., ETIP SNET, JP SG, JP ESI). It is also a key partner in several national and regional projects on energy system integration, facilitating in this way the exchange not only between the different actors of the golden triangle but also across the three geographical levels. TU Delft is the coordinator of the JP ESI, and it was a major contributor to the SRIA of the CETP, facilitating a close collaboration with national and regional funding agencies, but also industry players. Together with TNO they are key partners of the Energy Top Sector, where there is a continuous and multi-level collaboration at national level with industry players and the associated Dutch ministry. Continuous support and funding from governmental funds are essential for the development of collaboration structures in the domain of energy system integration in the Netherlands. NWO, as the instrumental organisation of the Dutch Ministry of Education, Culture and Science, financially supports several projects and initiatives at both national (e.g., Top Energy Sector) and EU level (e.g., EU Partnerships).

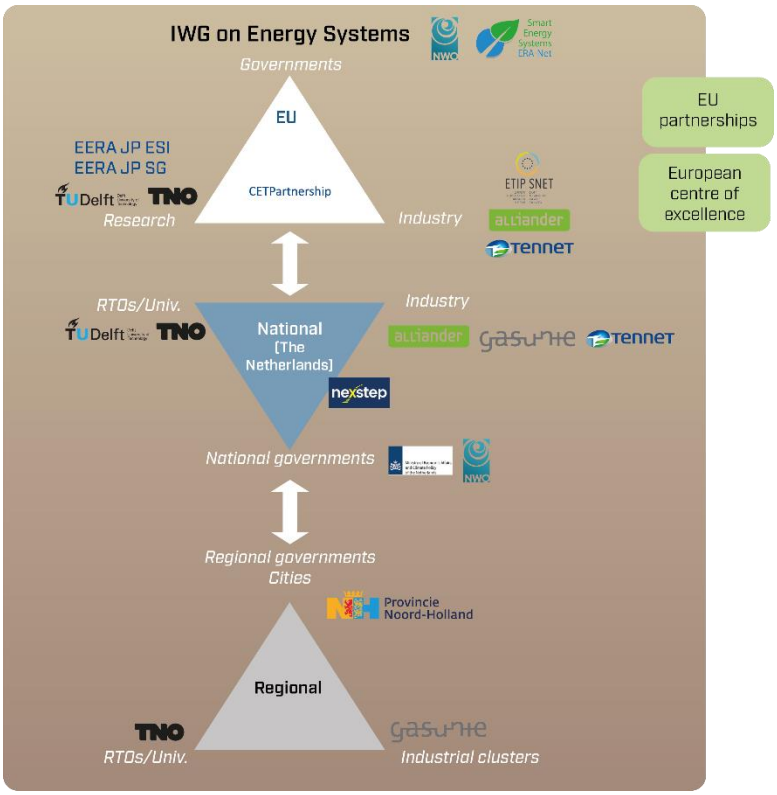


Figure 10. Collaboration interface for energy systems integration presenting the cooperation on EU as well as national and regional levels in the Netherlands.

At national level, such funding provides incentives to industry players to collaborate in a domain with no commercial value, such as the “energy system integration”, where research institutions have a crucial role in bringing them together. energy system modelling is a big part of the energy system integration domain and inputs from both industry and research are brought together to inform decision-making at a political level.

Table 7. Main collaborative actors on energy systems integration on EU level as well as on national and regional levels in the Netherlands.

		EU level					National level				Regional level
Organisation	**Sector**	**EERA JP SG**	**EERA JP ESI**	**ETIP Smart Networks of the Energy Transition**	**IWG 4 Increase energy system resilience and security**	**ERANET - SES / CET**	**Top Sector Energy (ESI TKI)**	**PosHYdon**	**Netbeheer Nederland**	**SEIN**	**INew Energy Coalition**
TNO	Research community	Member	Member	Member			Member	Partner			member
TU Delft	Research community		Member				Member				
Alliander				Member			Member	Partner			
Gasunie	Industry				Member				Industry Partner	Partner	member
TenneT	Industry						Member		Industry Partner	Partner	
Province of Noord-Holland	Public body										member
NWO						Funding partner	Funding partner		Funding organisation		
Nexstep								Partner			

A short description of the stakeholders/initiatives mentioned in Table 7 and Figure 10 is available below.

EERA JP ESI brings together over thirty European research institutions and universities to optimize the energy system, by benefiting from the synergies between heating, cooling, electricity, renewable energy and fuel pathways at all scales. The energy elements of the water and transport system are also included, as well as the data and control network that enables the optimisation. The JP ESI is designed to develop the technical and economic framework that governments and industries will need to build the future efficient and sustainable European energy system. The targeted impacts include increased reliability and performance, minimisation of cost and environmental impacts and, in particular, increased penetration of renewable energy sources.

EERA JP SG aims to extend cross-disciplinary cooperation involving many R&I participants with different and complementary expertise and facilities. It also aims at addressing, from a medium to long-term research perspective, one of the most critical areas directly relating to the effective acceleration of smart grid deployment: smart grid technology, its application and integration.

NWO is one of the most important science funding bodies in the Netherlands and realises quality and innovation in science. NWO works under the auspices of the Dutch Ministry of Education, Culture and Science. Each year, NWO invests almost EUR 1 billion in research related to societal challenges and research infrastructure. Research on system integration is part of NWO's programming for the Top Sector Energy.

TU Delft is a well-regarded technical university in the Netherlands known for its research and education in energy system integration. The university is committed to sustainability and collaborates with industry, government, and other academic institutions to find innovative solutions to global challenges.

Nexstep is a Dutch national program focused on the decommissioning and reuse of offshore oil and gas infrastructure in the Netherlands. The program is a joint initiative of the Dutch government and the oil and gas industry, aiming to promote sustainable decommissioning practices while preserving value for the industry. Nexstep provides a platform for collaboration and knowledge-sharing among stakeholders involved in the decommissioning process.

TenneT also plays a key role in the integration of energy systems in the Netherlands, connecting offshore wind farms and interconnecting the Netherlands and neighbouring countries to enhance the stability and security of the European energy grid. With its expertise in high-voltage grid technology, TenneT is a key player in the energy transition towards a more sustainable and low-carbon energy system.

Alliander is a Dutch electricity and gas distribution network operator and is involved in energy system integration in the Netherlands. The company operates the local electricity and gas grids in several regions of the country and is responsible for distributing energy to consumers. It plays an important role in the integration of renewable energy sources into the energy system, by

connecting new wind farms and solar parks to the grid and upgrading the existing network to accommodate increased amounts of renewable energy.

Gasunie is a Dutch natural gas infrastructure company that operates a pipeline network and storage facilities to transport and distribute natural gas within the country and abroad. The company is involved in energy system integration, including the integration of renewable energy, through the development of biomethane production and injection facilities.

Dutch Ministry of Economic Affairs and Climate Policy is the Dutch government agency responsible for energy policy and climate action. In terms of energy system integration, the Ministry sets policies and regulations to support the transition to a more sustainable and low-carbon energy system in the Netherlands. The Ministry works to promote the integration of renewable energy sources into the energy system and to encourage the use of energy-efficient technologies and practices. The Ministry also collaborates with other government agencies, industry organisations, and academic institutions to support research and development in the field of energy system integration.

Enexis is a Dutch electricity and gas distribution network operator responsible for the distribution of electricity and gas to consumers in several regions of the country. It is also involved in the integration of renewable energy sources into the energy system connecting new wind farms and solar parks to the grid and upgrading the existing network to accommodate increased amounts of renewable energy. The company is also involved in various smart grid initiatives.

Stedin is a Dutch electricity and gas distribution network operator that is responsible for the distribution of electricity and gas to consumers in several regions of the country and involved in the integration of renewable energy sources into the energy system. Stedin connects new wind farms and solar parks to the grid and upgrades the existing network to accommodate increased amounts of renewable energy.

TNO is a Dutch research organisation that is involved in energy system integration in the Netherlands. The organisation conducts research and provides solutions to address the challenges of the energy transition and supports the integration of renewable energy sources into the energy system. TNO works with a variety of partners, including government agencies, industry organisations, and academic institutions, to advance the integration of sustainable energy solutions into the energy system.

The Province of Noord-Holland is a Dutch province committed to the energy transition and energy system integration. It aims to reduce carbon emissions and promote sustainable energy practices by facilitating the integration of renewable energy sources and supporting innovative energy solutions. The province also collaborates with businesses, municipalities, and research institutions to develop and implement sustainable energy initiatives.

IV Way forward

The present report aggregates information and knowledge gained during the execution of the activities within Work Package 2, that have as a final outcome the formulation of a comprehensive transnational collaboration model. The model essentially portrays the collaboration among research, industry, and governments (decision bodies), also known as the "collaboration triangle," at the European, national, and regional levels. It also highlights the connections between different geographical levels and showcases exemplary methods that could be adopted in other countries or sectors. It focuses on the six identified technological pathways after a thorough review of all the NECPs within the framework of the same Work Package.

Before the end of the project in June 2023, one more workshop will be organised (on the Pathway of Bioenergy and within the framework of the European Biomass Conference, 07 June 2023) in cooperation with the EERA Joint Programme Bioenergy and BIOPLAT, the Spanish Technology and Innovation Platform on Biomass for the Bioeconomy. The discussion during the workshop will further contribute to the collaboration model (on bioenergy) and will also function as the groundwork for the discussions during the workshop.

The main findings of the analysis of the six common pathways and the formulated collaboration model will provide the basis for the recommendations on R&I priorities in support of the Clean Energy Transition goals across Europe and will serve as input to improve cooperation between research, industry, and public authorities within the coming SUPEERA Deliverable 2.4 “Recommendations” in April 2023.

Beyond the scope of the SUPEERA project, the report will provide valuable insights and information to various stakeholders. The primary beneficiaries of the report are likely to be policymakers, researchers, industrial players, and professionals in the field of low-carbon energy technologies. Among researchers, it is expected to be useful for the members of the EERA Joint Programmes, not only those that were actively involved in the SUPEERA workshops, but also all the rest, as the main aim of the collaboration model is inspire the potential of replicability of best-practices on collaboration across countries and technological pathways.

Moreover, it is expected to bring very high value to the members of the ETIP Forum, as they have limited view on the collaboration landscape in technologies that are beyond the scope of the one they are involved in. It is also shedding light on national and regional collaboration schemes that ETIP Forum representatives might not be aware of – given their focus mainly at European level. In the same way, the report could not only inform about different realities (both at technology and country level) but also provide inspiration and set the basis for its replicability potential across different technological domains.

Overall, other type of stakeholders could also benefit a holistic collaboration model that embeds novel collaboration concepts such as: i) interfaces across European territories/geographical levels (presented both in terms of illustrations and table-matrix); ii) cross-sectorial aspects (focused on energy sector regulation) and iii) new collaborative platforms such as national and European Centres of Excellence, Partnerships, company-led ecosystems/programs, etc.

Appendix I – Summary of the Workshop 1

Accelerating innovation and uptake of new technologies in Wind Energy and Energy Systems Integration: the role of research-industry collaboration

More than 40 participants gathered experts from research and industry to discuss alternatives for bringing closer these two worlds to speed up Wind Energy and Energy Systems Integration innovation chains.

Following a series of introductory webinars, the first of six knowledge-generating workshops took place in a hybrid format on 20 April 2022, online and physically, at the Delft University of Technology, in the Netherlands. This is the first of SUPEERA's series of workshops to discuss how research and industry can get closer to accelerating innovation and uptake of new technologies. The topics discussed in this session covered research-industry cooperation practices and opportunities to increase the innovation speed in the wind energy and energy systems integration sectors.

The workshop was joined by over 40 participants, gathering experts from the EERA community and representatives of successful Dutch implementation examples of wind energy and energy systems integration initiatives. The session offered the chance to spur lively discussion and favoured exchanges of ideas between the experts.

Key outcomes of the discussion

The webinar was introduced by **Ivan Matejak**, SUPEERA Project Coordinator and EERA Operations Director, who presented the two pathways and illustrated the possibility of collaboration between research and industry. The first part of the event was dedicated to sharing best practices, barriers, and replicability potential of different initiatives in the two selected areas.

Attention was given to the fact that wind energy and energy systems integration have different levels of interdependencies, and both sectors have EU relevance for making possible the Clean Energy Transition. It also outlined how the SET Plan could be employed as a tool to promote EU-wide collaboration on R&I priorities of low-carbon technologies.

The session continued with the intervention of two EERA JP Coordinators, **Peter Eecen** for Wind Energy and **Laurens de Vries** for Energy Systems Integration, who presented their respective Joint Programmes. After this, **Prof. Dominic von Terzi**, Chair of Wind Energy Technology at TU Delft, reinforced the need for the Research community and industry collaboration, followed by the Director of GROW, **Davide de Jager**, who shared with the audience the best practices and experiences from the GROW Offshore Wind consortium. To end the first part of the workshop, ETIP SNET coordinator and Senior Project Manager at Zabala, **Maria Laura Trifiletti,** presented the best practices in the ETIP SNET Roadmap and Implementation Plans.

This workshop section prompted an active Q&A and panel discussion, both on-site and online. Relevant reflections were made by European Commission's Senior Policy Officer **Matthijs**

Soede, noting the importance of an offshore wind 'target' for the Black Sea and questioning the possibility of lowering the Levelized Cost of Hydrogen (LCoH) by offshore wind in the future. Other panellists furtherly shared the relevance of offshore wind, which is likely to become the primary source of power production in Europe in the future, according to JP Wind Coordinator Peter Eecen.

The second part of the event, introduced by EERA Project Manager **Spyridon Pantelis,** covered topics on cross-sectorial dialogue for system solutions toward the CET objectives. In 2021, SUPEERA created a template for identifying and categorising cross-cutting issues in energy. The goal was to help improve a conceptual framework for planning technological solutions for the Clean Energy Transition.

Various projects were presented as implementation examples and reflected on upcoming challenges. These included MAGPIE project, presented by **Rogier Nijssen**, a scientist at TNO, and a case study on the integration of offshore wind in the industrial cluster in North Sea Port in the Netherlands, covered by Ørsted's Senior Business Developer **Daan van Hameren**. Additionally, **Durgesh Kawale**, TNO scientist, presented large-scale hydrogen production from offshore wind to decarbonise the Dutch and German industries.

An interesting ecological point of view was offered by **Remment ter Hofstede**, a biology specialist at Van Oord. The expert underlined the importance of considering marine ecosystems when planning offshore wind energy systems. Moreover, he addressed potential alternatives to making sure the two coexist.

Additional discussions animated the second part of the workshop. They focused on how closer collaboration between industry players in cross-cutting topics may enable faster uptake of new technologies. Each panellist shared their observations and later agreed on the challenge that working together and promoting data sharing entails whilst highlighting its essential role for the collaboration to be beneficial. Furthermore, they brought forward industries that are already internally looking at how to be part of the green transition, as they recognise the need to become active players in the Clean Energy Transition. In this regard, they concluded that a shared vision between research and industry would be valuable.

Conclusions

Accelerating innovation and fostering the uptake of new technologies in the wind energy and energy systems Integration sectors still demands an ever-growing collaboration between the spheres of the research community and industry. More particularly, the role of research is crucial to deliver on the SET Plan targets and those of the Clean Energy Transition.

EERA is committed to supporting the implementation of the SET Plan through the SUPEERA project by disseminating the existing knowledge within our community and bringing together meaningful insights from experts and initiatives from all over the EU.

Access to the recording of April's workshop can be found at this link.

Agenda of the Delft Workshop 20.3.2022

09:00 Welcome and objectives of the workshop

09:05 Background: Presentation of two pathways: Wind & Energy System Integration, Ivan Matejak - SUPEERA coordinator, EERA

09:20 **Collaboration between research and industry: best practices, barriers, and replicability potential**

- The SET Plan as a tool for EU-wide collaboration on R&I priorities of low-carbon technologies, Ivan Matejak - SUPEERA coordinator, EERA
- EERA Joint Programme Wind Energy - Collaboration with industry, P.J Eecen - Coordinator JP Wind, TNO
- EERA Joint Programme Energy System Integration – Industry participation in system integration research, Laurens de Vries - Coordinator JP ESI, TU Delft
- Wind Energy Technology: The Need for Collaboration of Research community with Industry, Prof. Dominic von Terzi - Chair of Wind Energy Technology, TU Delft
- Best practices and experiences from the GROW Offshore Wind consortium, a collaboration among 20 industry partners and research groups to accelerate innovations, David de Jager - Director GROW
- The ETIP SNET - Industry and research together towards CETP objectives – Best practice in the ETIP SNET Roadmap and Implementation Plans, Maria Laura Trifiletti - ETIP SNET coordinator, Senior project manager at Zabala

10:50 Panel discussion and Q&A

11:25 **Cross-sectorial dialogue for system solutions towards the CET objectives**

- Systemic and cross-sectorial issues pertaining to the Clean Energy Transition, Spyridon Pantelis - Project Manager, EERA
- MAGPIE project - smart green ports, Rogier Nijssen - Scientist at TNO and Professor of Applied Sciences in Composites, Hogeschool Inholland
- Offshore wind & Ecology Remment ter Hofstede - specialist coastal and marine ecosystems, Van Oord
- Hy3 – Large-scale Hydrogen Production from Offshore Wind to Decarbonise the Dutch and German Industry, Durgesh Kawale - Scientist subsurface energy storage, TNO
- Case study on integration of offshore wind in the industrial cluster in North Sea Port / Zeeland (NL), Daan van Hameren - Senior Business Developer, Ørsted

12:40 Panel discussion and Q&A

Appendix II – Summary of the Workshop 2

Energy storage, Fuel Cells & Hydrogen. Bringing research and industry closer: accelerating innovation and uptake of new technologies

Following a series of introductory webinars and coming on the heels of the workshop on Wind Energy and Energy Systems Integration that took place in Delft, Netherlands, in April 2022, on the 10th of May, the SUPEERA Project made a stop in Padova, Italy, to discuss research-industry cooperation practices and opportunities to accelerate innovation in two specific pathways: Energy Storage and Fuel Cells and Hydrogen technologies.

The full-day workshop, which took place in hybrid mode, was co-organised with EERA Joint Programmes ES and FCH, and it allowed a fruitful knowledge exchange between the panellists and the participants. The main objective of the workshop was to facilitate knowledge exchange and promote a dialogue between the energy research community and industrial stakeholders. The workshop was joined by 50 participants in presence and about 70 online, gathering professionals, experts, and researchers across the EERA community, along with key representatives from the energy industry in Italy. The workshop was divided into three main sections, at the end of which a panel discussion offered the opportunity to boost lively discussions, animate insightful debates and encourage knowledge exchange activities.

Opening the workshop

The workshop was opened by Prof. **Alberto Bertucco**, Head of the Interdepartmental Center Levi Cases, who introduced the topic by stressing the importance for the research community of considering economic and social aspects in the challenge of achieving the objectives of Clean Energy Transition.

The first session continued with a keynote speech from Professor **Vito di Noto**, from the Department of Industrial Engineering of the University of Padova, on the topic of electrochemical energy storage and conversion systems with a focus on the Venetian Region. He highlighted that Veneto is one of the highest industrialized regions in Europe today, providing a picture of the production of secondary and redox flow batteries and of the practical implementation of the green hydrogen economy in the region.

Ivan Matejak, SUPEERA's coordinator and Operations Director from EERA, after giving a brief overview over the Project's objectives and partnership, he presented the purpose, aims and expected results of the workshop. He also brought to the audience's attention the dynamism of the R&I in the energy transition by reminding of the rich European regulatory framework that has been produced in the latest years, i.e., EU Set Plan, European Green Deal, the Recovery Plans and the recent REPowerEU plan.

Next, **Maria Oksa**, Senior Scientist and Project Manager at VTT, expanded on the contents of the REPowerEU plan based on the two Energy Storage and Hydrogen technological pathways. Maria Oksa presented the key findings on NECPs' best practices (regional cooperation in research, regulation, projected storage capacity, remote areas and circular economy) and gaps in energy storage among MS. Emphasis was finally placed on the EU Clean Hydrogen Partnership and on the calls for proposals under its scope that have been launched this year.

Collaboration between research and industry: best practices, barriers and replicability potential

Myriam E. Gil Bardají, Manager of the Joint Programme (JP) Energy Storage, followed with an overview on the JP's structure, mission and activities, underlining the importance of collaboration and mobility among European Universities and other research institutes in order to encourage the involvement of students in the activities of the JP and to foster the JPs' ability to usefully influence industry.

The workshop continued with **Stephen Mc Phail**, outgoing coordinator of the JP Fuel Cells & Hydrogen, who gave an introduction on the JP's positioning in the Hydrogen Panorama of research and development and its collaboration with industry in Europe. In his closing remark, he underlined the need to "preserve research freedom while maintaining scientific acumen and upholding unbiased investigation into the role of hydrogen in our society".

After the first round of contributions coming from the research sector, the perspective of the industrial sphere was delivered by representatives of the two main Italian energy suppliers: ENI and ENEL.

Andrea Bernardi, Head of Solar Storage & Bioenergy technologies at ENI, illustrated ENI's vision and approach to energy storage and underlined that ENI had adopted an open innovation model thanks to which the applied technology derives both from internally born ideas and from the external network, made up of universities, academies, and research centres. One successful example of this collaboration can be traced to the cooperation between ENI and the Polytechnic of Milan Joint Research Center aimed at elaborating a Battery Energy Storage System Modeling and Monitoring.

Going from a global energy sector leader to another, ENEL's best practice in the field of renewables was presented by **Paolo Prevedello**, Hydrogen Innovation Project Engineer at ENEL Green Power, who, after introducing the company's aims and work, described the NextHy Initiative on how to foster green hydrogen competitiveness with an Open Innovation Approach. NextHy is an innovation platform whose goal is to speed up the commercial maturity of all technologies that allow to produce green hydrogen sustainably and competitively. The new platform will take full advantage of the Catania Innovation Hub&Lab, one of the largest and most advanced industrial innovation districts for renewable technologies worldwide.

Panel discussion and Q&A

The first section of the workshop prompted an active Q&A session and panel discussion, both on-site and online, which was moderated by Ivan Matejak. **Adelbert Goede** from DIFFER commented that the safety aspects of H2 technologies need to be taken into consideration both at a regulatory and implementation level. Linking back to Mr Goede's observation, **Prof. Bertucco** first underlined that the community should only support *green* H2 technologies. He mentioned the challenges of transporting H2, underlining that it comprises a great solution when it is produced and consumed locally. In response to Prof. Bertucco's comment, **Mr Bernardi** added that in the short term, we should instead leverage blue Hydrogen to start the transition towards an H2 economy. The first session was wrapped up by **Myriam E. Gil Bardají,** who underlined the importance of fostering mobility schemes between industry and university, in a perspective of structured collaboration and enhanced improvement of both sectors.

Cross-sectoral dialogue for system solutions towards the CET objectives

The second session of the workshop focused on cross-sectoral dialogue for system solutions towards the CET objectives. **Spyridon Pantelis**, Project Manager at EERA, highlighted the importance of facilitating the dialogue on cross-cutting issues (e.g., policy, regulation, education etc.), presenting the outcomes of the analysis and categorisation of these issues that was performed in the framework of the SUPEERA project.

The floor was then given to **Dina Lanzi**, Head of Technical Business Unit Hydrogen at SNAM, who displayed the role of SNAM as an enabler of the hydrogen value chain. Ms Lanzi explained SNAM's 10-year view, by outlining the potential of SNAM's existing gas pipelines in the future distribution of Hydrogen with the aim of creating an efficient energy system and connecting Italy to the EU H2 Backbone.

The session continued with **Stefano Passerini**, StoRIES Project Coordinator at KIT, who, following an introduction on the Project's main objectives and outcomes, reinstated that energy storage must be prioritised being the key to renewable energy, energy independence and decarbonisation.

Alessandro Romanello, ETIP (European technology and innovation platform) on Batteries coordinator, presented Batteries Europe, undertaking the role of shaping the EU battery ecosystem in Europe to effectively support the industrial uptake of innovative energy storage technologies. Mr Romanello explained the actions through which Batteries Europe can contribute to accelerate innovation and to support the industry, underlining the strong collaboration between the different entities and stakeholders across Europe (i.e., Industry, Research community and MS representatives).

Maider Zarrabeitia Ipina, Postdoctoral Researcher at KIT, wrapped up the second session by presenting two best practices in the field of R&I: the SIMBA Project, whose aim is to develop highly cost-effective, safe sodium-ion batteries and the SPIRIT Project, started in October 2022 with the purpose of creating sustainable and cost-competitive potassium-ion batteries.

Panel discussion and Q&A

Throughout the second Q&A session, the discussion was framed around the economic feasibility of the battery storage systems. **Alessandro Romanello** mentioned that the research arena is hosting a discussion in order for all green energy production to be economically feasible. In the same line, **Manuel Baumann** from KIT (JP ES) raised the issue of the increasing prices of raw materials for batteries with a parallel increase of their demand, which drives up the prices of battery storage. There was a consensus among the attendees that the economic feasibility of ambitious projects is a decisive success factor towards CET.

Towards EU's strategic autonomy: The crucial role of energy storage and hydrogen

The third and last part of the workshop was moderated by the two Joint Programs' coordinators, Stephen McPhail and Stefano Passerini and it aimed to investigate the crucial role of Energy storage and Hydrogen within the EU's strategic autonomy.

Linda Barelli, Associate Professor at the University of Perugia, gave a presentation on Chemical Energy Storage with a focus on an Italian case study. She also presented the SBAM Project, funded by the Italian Ministry of Ecological Transition with the objective of fostering research on energy storage through salt-water batteries.

An interesting perspective was then given by **Vincenzo Mulone**, from the University of Rome Tor Vergata, who presented the potential role of biomass in linking energy storage and hydrogen by underlining the benefits linked to the exploitation of biomass, which, other than being cheap and abundant, is also a resource from which H2 can be synthesized without combustion.

Giovanna Cavazzini, from Interdepartmental Center Levi Cases at the University of Padova (UNIPD), focused on hydropower and energy storage, underlining the lack of R&I funds for hydropower. After presenting UNIPD's research on innovative design and control strategies in collaboration with industries, she shared her concern about the fact that hydropower, being considered a mature technology, has not been allocated any funds for R&I in the latest years. In light of this, Ms Cavazzini underlined that in order to effectively face the new emerging challenges, hydropower will need more attention from the Research community, the institutions and the industry.

Klaus Taube, Representing Director of the Institute of Hydrogen Technology, introduced the topic of underground storage, liquid organic hydrogen carriers and compression, presenting the H2CAST project, focusing on the adaptation of existing gas caverns and relevant surface facilities as part of the transition process to an H2 economy.

Xavier Granados, Senior Scientist at CSIC-ICMAB, presented the role of magnetic fields and superconductors in energy storage and the concrete ways to use them, highlighting the availability of these materials in the market.

Afterwards, **Paulo Ferreira**, Group Leader of the Atomic Structure-Composition of Materials at INL, took over with a presentation on the potential of advanced instrumentation, in particular microscopy and spectroscopy, for monitoring and understanding fuel cells.

Lastly, **Madalina Rabung**, Scientist and Project Manager at Fraunhofer IZFP, provided an overview of the upcoming calls of Horizon Europe for 2023-24, which is of particular interest to the members of the JP ES and JP FCH.

Panel discussion and Q&A

In the panel discussion that followed, two interesting issues animated a fruitful exchange of views between the audience and speakers: the first would refer, again, to the costs of the implementation of some of the aforementioned green technologies and the second about what would be the optimal geographical distribution of different kinds of energy storage technologies in Europe, taking into account each area's distinctive features in terms of the potential production of green energy solutions.

Conclusions

Promoting the uptake of new technology in the Energy Storage and Fuel Cells and Hydrogen sectors demands a steady collaboration between the research community and industry in order to be able to materialize and concretely implement what has been designed at a more theoretical level.

By organising this kind of event, the SUPEERA Project aims to boost connections among different areas of the sustainable energy production sector and several categories of actors involved within each area. One of the next SUPEERA workshops of the series will focus on Energy Storage and Concentrated Solar Power, and it will take place in Almeria, Spain, between 15-17 November 2022 with the participation of the respective EERA Joint Programmes.

The recording of May's workshop will be available at **this link**.

Agenda of the Padova Workshop 10.5.2022

09:00	**Welcome and greetings** *Alberto Bertucco, Head of the Interdepartmental Center Levi Cases*
09:10	**Keynote speech** *Vito Di Noto, Professor of Electrochemistry for Energy and Solid-State Chemistry in the Department of Industrial Engineering of the University of Padova*
09:25	**Workshop background: the SUPEERA project** *Ivan Matejak, SUPEERA coordinator, EERA* **Presentation of two pathways: Energy Storage, Fuel Cells & Hydrogen** *Maria Oksa, Senior Scientist - Project Manager, VTT*
09:45	**Collaboration between research and industry: best practices, barriers and replicability potential**
	The SET Plan as a tool for EU-wide collaboration on R&I priorities of low-carbon technologies *Ivan Matejak, SUPEERA coordinator, EERA* **EERA Joint Programme Energy Storage** *Myriam Gil Bardaji, JP Energy Storage Manager, KIT*

	EERA Joint Programme Fuel Cells & Hydrogen *Stephen Mc Phail, JP Fuel Cells & Hydrogen coordinator* **R&I and Open Innovation: Eni's Vision and Approach to Energy Storage** *Andrea Bernardi, Head of Solar Storage & Bio-Energy Technologies, ENI* **How to foster green hydrogen competitiveness with an Open Innovation Approach: the NextHy Initiative** *Paolo Prevedello, Hydrogen Innovation Project Engineer, ENEL Green Power*
11:00	**Panel discussion and Q&A** *Moderator: Ivan Matejak, SUPEERA coordinator, EERA*
11:45	**Cross-sectorial dialogue for system solutions towards the CET objectives**
	Systemic and cross-sectorial issues pertaining to the Clean Energy Transition *Spyridon Pantelis, Project Manager, EERA* **The infrastructure role as enabler of hydrogen value chain** *Dina Lanzi, Head of Technical Business Unit Hydrogen, SNAM* **Creating an energy storage ecosystem for innovation: The StoRIES project** *Stefano Passerini, StoRIES project coordinator, KIT* **Batteries Europe - shaping the EU battery ecosystem to effectively support the Industrial uptake** *Alessandro Romanello, ETIP Batteries coordinator, InnoEnergy* **Good practice of R&I funding programmes: SIMBA project** *Maider Zarrabeitia Ipina, Postdoctoral Researcher, KIT*
13:00	**Panel discussion and Q&A** *Moderator: Spyridon Pantelis, Project Manager, EERA*
14:30	**Towards EU's strategic autonomy: The crucial role of energy storge and hydrogen**
	Chemical energy storage *Linda Barelli, Associate Professor, University of Perugia* **Biomass: the natural link between energy storage and hydrogen** *Vincenzo Mulone, University of Rome Tor Vergata* **Pumped-hydro energy storage** *Giovanna Cavazzini, Interdepartmental Center Levi Cases, University of Padova* **Underground storage, liquid organic hydrogen carriers, compression** *Klaus Taube, Representing Director, Inst. of Hydrogen Technology, Hereon* **Superconducting Magnetic energy storage** *Xavier Granados, Senior Scientist, CSIC-ICMAB* **Monitoring catalyst degradation using electron energy loss spectroscopy and microscopy** *Paulo Ferreira, Group Leader* *Atomic Structure-Composition of Materials,INL*

16:15	**Horizon Europe calls scheduled for 2023-24 in Cluster 5 and Cluster 4 relevant for JP FCH/ES with the aim to defining potential participants** *Madalina Rabung, Scientist, Project Manager, Fraunhofer IZFP*
16:45	**Panel discussion and Q&A** Moderators: *Stefano Passerini, StoRIES project coordinator, KIT* *Stephen Mc Phail, JP Fuel Cells & Hydrogen coordinator*
17:45	**Wrap-up and next steps**

Appendix III – Summary of the Workshop 3

Bringing research and industry closer: accelerating innovation and uptake of new technologies. Energy storage & Concentrated Solar Thermal Energy

Following a series of introductory webinars and two physical workshops (in Delft, Netherlands and on Energy Storage, Fuel Cells and Hydrogen in Padova, Italy), the SUPEERA project travelled to Almería, Spain to discuss research-industry cooperation in the topics of Energy Storage and Concentrated Solar Thermal (Power & Heat) technologies (CSP/CST). The full-day workshop, which took place in hybrid mode, was co-organised with EERA Joint Programmes ES and CSP/CST, and it allowed a fruitful knowledge exchange between the panellists and more than 60 participants, the majority of them travelling to PSA facilities (CIEMAT) in Almería. The workshop saw the participation of professionals, experts, and researchers across the EERA community, along with key representatives from the energy industry in Spain. The agenda was divided into four main sections, at the end of which a panel discussion offered the opportunity to boost lively discussions and animate insightful debates.

Opening the workshop

The workshop was opened by **Julian Blanco,** Director of the Plataforma Solar de Almeria (PSA), who presented the institution and briefly described its concentrated solar power research facilities and laboratories.

The introductory session continued with a keynote speech by **Cristina Trueba**, Chair of the Implementation Working Group (IWG) on Concentrated Solar Power and Solar Thermal Electricity (CSP/STE). After an introduction of the European political context in which the SET Plan has emerged, she gave an overview of the Plan, explaining its objectives and structure with particular attention to the CSP IWG. She finally discussed the importance of cross-cutting issues related to CSP, such as the integration of CSP and PV.

Ivan Matejak, SUPEERA coordinator and Operations Director at EERA, presented the objectives of the project and the workshop. In his introductory speech, he also highlighted some of the key factors and trends of the European clean energy transition. For example, he brought the audience's attention to the fact that nearly all new capacity in Europe comes from renewables but also warned that current energy policies are largely insufficient to keep the global temperature rise below 1.5° by 2050.

Maria Oksa, Senior Scientist and Project Manager at VTT, presented some key findings from the analysis of all 27 National Energy and Climate Plans (NECPs) best practices (e.g., regional cooperation in research, regulation, projected storage capacity, remote areas, and circular economy) and gaps in energy storage among MS. In addition, she explained how the six common pathways of the SUPEERA project were selected according to different criteria and gave an overview of European policies related to energy storage and solar technologies.

Collaboration between research and industry: best practices, barriers, and replicability potential

Ivan Matejak underlined the dynamism of R&I in the energy transition, remarking how the SET Plan has been influenced by the new energy priorities of the EC (e.g., the European Green Deal and Repower EU). Moreover, he presented some takeaways from the EERA's latest publication, such as the need to decarbonize the heating & cooling sector and reduce energy demand. He concluded that the research community could have a crucial impact on the development of low carbon technologies in both the long and short-term, where it can contribute to accelerating existing knowledge implementation to scale up already tested and validated solutions and technologies.

Ricardo Sanchez (CIEMAT), CSP Joint Programme Coordinator, provided information on the joint programme, describing how it is structured, presenting the team, and illustrating the objectives of each sub-programme. Important objectives highlighted by the coordinator were, for example, consolidating and improving the technology of Line-Focusing CSP systems, reducing the capital and operating costs of the CSP plant, and improving the materials used in CSP/CST.

Myriam Gil Bardajì (KIT), Joint Programme Energy Storage (JP ES) Coordinator, presented the mission and vision of the JP also giving an overview of its latest activities and events, such as mobility schemes, PhD days, and workshops. She finally illustrated the JP ES flagship project, StoRIES, whose main objectives aim at fostering a European ecosystem of industry and research organisations on hybrid energy storage technologies and providing access to world-class research infrastructures related to materials and energy storage.

After the presentation of the joint programmes, the perspective of the industry sector was delivered by representatives of some prominent CSP actors: Protermosolar, Malta inc. and SENER, who brought the audience's attention to the importance of bringing closer research and industry and highlighted some crucial challenges that the sector is currently facing.

David Trebolle, Secretary General at Protermosolar, described some of the challenges that need to be tackled to improve the scalability of CSP technologies. For example, he stressed the problems related to the decoupling of the Spanish CSP tenders and grid access, and he questioned whether the levelised cost of electricity (LCOE) is the most accurate indicator to estimate the whole system's costs. In addition, he discussed some key aspects relevant to the regulatory framework and the design of the latest CSP tender in Spain. In his closing remark, he underlined the most crucial issues that will help to accelerate innovation and development of the CSP market, such as the establishment of a stable regulatory framework, the optimisation of tenders, the minimisation of CAPEX costs, and closer cooperation between research and industry.

Escarlata Muñoz, Senior Industrial Engineer at Malta Inc., presented the main activities of the company, highlighting that their services on providing synchronous pumped-heat electricity storage are crucial to enable the transition from fossil fuels to renewables. Moreover, she gave an overview of their work and partners (e.g., Siemens, Google, Proman, etc.) and briefly explained their innovative process to produce heat and electricity. Finally, she pointed out how they

collaborate with research institutes, highlighted future R&I collaboration opportunities (e.g., development, testing and qualification of innovative components for Malta's molten salt Pumped Heat Electricity Storage), and pointed out the importance of a specific regulation for storage technologies (which should differ from the one on generation that is currently applied).

The first session was closed by **Sergio Relloso**, from the New Technologies Business Unit at SENER, who illustrated SENER's deep involvement in the CSP sector and described their contribution to R&I activities. He identified that by lowering the price of electricity generation and increasing the reliability of CSP technologies, it would be possible to increase their deployment in the future. In that end, R&I plays a crucial role in overcoming these challenges. He also stressed that the energy market is currently not perceiving CSP as a reliable technology due to the various incidents that many power plants have experienced (mainly technical issues related to the hot tank).

Panel discussion and Q&A

The discussion during the Q&A session focused on several **key areas for improvement** in the CSP and energy storage sectors.

Sergio Relloso clarified that SENER encountered some problems related to the construction of the hot tank and highlighted the need for a qualitative improvement in the way these are built. **David Trebolle** brought up in the discussion the exceptional reduction of CSP technologies' CAPEX price over the last 30 years and pointed out that this has been due to increased R&I efforts. Finally, he noticed that the commodity market is in a difficult situation because of the increasing cost of raw materials and transport. **Myriam Gil Bardajì** focused on the lessons learnt in the implementation of the StoRIES project. She specified that the main difficulty in the first year of the project was engaging all the stakeholders in the ecosystem and highlighted the importance of bringing on board experts from the industry. At the end of the session, **Escarlata Muñoz** remarked that although reducing prices is a fundamental challenge, it is also crucial to address issues related to the electricity grid regulation.

Cross-sectorial dialogue for system solutions towards the CET objectives

Spyridon Pantelis, Project Manager at EERA, introduced the importance of facilitating the dialogue on cross-cutting issues (both technological and non-technological) relevant to the clean energy transition. He stressed that identifying them is a fundamental part of the SUPEERA project as they provide coordinated input to decision-makers and they improve the conceptual framework of the clean energy transition. He added that the cross-cutting issues provide a context that goes beyond the specific technologies and ensure that the transition is designed to adopt a system-thinking approach.

The first speaker of the session, **Miguel Frasquet**, CEO of Solatom, stressed the importance of CSP technologies to decarbonise energy-intensive industrial processes, especially regarding industrial heat production. He explained that there is a window opportunity for these technologies that Solatom is currently targeting, and he clarified that their strategy is using modular design solutions as it is not possible to standardize CST from an engineering perspective. Finally, he described some of the advantages (e.g., no commercial interest, possibility to keep longer

projects) and disadvantages (e.g., lack of commercial experience, different timing) of the collaboration between industry and research institutes.

Eduardo Zarza, the technical coordinator at PSA, illustrated the benefits of the integration of thermal storage into STE plants, notably dispatchability, higher yearly efficiency of the plan, and enhanced plant control under solar radiation transients (the possibility to control even during cloudy days), providing also data from the system operator depicting the actual use of STE plant to the energy grid. He concluded by remarking that in comparison to photovoltaics, CSP is much more dispatchable than other renewable energy sources.

Rocío Bayón, Senior Scientist at CIEMAT/PSA, provided further technical details about the functioning of CSP plants in Spain. In particular, she focused on the differences between parabolic through collectors, central receiver plants, and linear Fresnel, and the various applications of thermal energy storage. Finally, she explained how electricity is generated at night-time utilising thermal storage technologies and highlighted that one advantage of thermal storage is that it can be integrated even into dismantled coal power plants.

Cristobal Villasante, Renewable Energy coordinator at Tekniker, illustrated the importance of digitisation to accelerate the development of CSP technologies, underlining that this is an important topic for CSP. In particular, he highlighted how digitisation could reduce overall costs (both CAPEX and OPEX), as well as increase CSP reliability and facilitate system integration. For example, an important aspect is that the use of wireless technology allows cost reduction for wiring and other expensive materials. Finally, he pointed out that digitalisation enables better control and data analysis and reduces inspection and maintenance needs.

Panel discussion and Q&A

The following discussion provided some deeper insights into the **technical and economic aspects** mentioned in the presentations.

For example, **Miguel Frasquet** stressed that in the CSP sector, there are many opportunities for integration with different technologies, notably geothermal systems and heat pumps. He added that CST would play an important role in the energy transition due to the high-temperature heat it can provide compared to other renewable energy technologies. **Eduardo Zarza** explained that, in Spain, it is possible to produce electricity up to seven and a half hours after sunset when the CSP plant is running at full power, and this allows them to provide a fraction of the generated power to grid operators when it is needed in the wintertime. Moreover, he clarified some technical differences between power and temperature related to CSP plants and pointed out that in such plants, thermal losses are very low. **Rocío Bayón** elaborated on the different roles of molten salt and oil in reaching high temperatures. Finally, **Cristobal Villasante** reiterated that digitalisation could increase the efficiency of a CSP plant and reduce the uncertainty related to manual operations.

The role of energy storage in future power grids

The session was opened by **Javier García-Barberena**, Strategy and Business Development Manager at CENER. At the beginning of his speech, he outlined the context of the energy

transition, highlighting that it includes many interrelated challenges, notably technical, economic, environmental, social, and strategic ones. As for the strategic aspects, he stressed the importance of adopting a common European approach to compete with key players at international level, such as the US, China, and Russia. Furthermore, in line with what was previously mentioned by David Trebolle, he agreed that the levelised cost of electricity (LCOE) might not be the most appropriate indicator for conducting cost analysis and basing the relevant auctions upon. He finally stressed the necessity to exploit the contributions of different technologies to the energy system and identify the most optimal energy mix. In this sense, he explained how cheap and massive storage systems are needed in the short term to increase the flexibility and dispatchability of the entire electricity system.

Walter Gaggioli, Head of the Solar Thermal and Smart Network Division of the Department of Energy Technologies and renewable energy source at ENEA, argued that thermal energy storage (TES) is one of the enabling technologies for the energy transition. He pointed out that the rising share of variable renewable energy can have a strong impact on the power systems in terms of alterations of the electricity markets, supply, security, stability and reliability of the power networks. Thus, he concluded that storage technologies could provide several benefits, notably time-shifting, an extension of the production period, and integration with other renewables.

Salvatore Vasta, research engineer at ENEA, talked about the role of TES in reducing the impact of industrial processes on the grid (especially related to heating and cooling). He highlighted that although solar energy is regarded as one of the most promising substitutes for traditional energy sources in the industrial field, its intermittent and unstable nature leads to a mismatch between supply and demand. In this context, solar heat storage can be a suitable solution to alleviate this challenge. Concluding, he presented some insights from ongoing research, testing the properties and suitability of several materials in the scope of a closed-cycle sorption system coupled with solar heat for industrial applications.

Linda Barelli, associate professor at the University of Perugia, illustrated how hybrid storage systems can be integrated into the power grid. At the beginning of her presentation, she gave an overview of the latest challenges and trends in the energy storage and electricity grid sectors. She stressed the need for more flexibility of the electricity grid and presented the benefits of the hybridisation of complementary storage technologies.

Manuel Baumann, researcher at KIT, illustrated some of the challenges related to the availability of raw materials for energy storage technologies. In particular, he pointed out that supply chain constraints might slow down the scaling up of these technologies. As the market of critical raw materials is monopolized by individual countries (China being the country with a major concentration of raw materials and related processing), and this imposing an increase in costs of these materials and subsequently to the related components, battery prices could increase significantly in the next few decades. For this reason, sustainability assessment should be carried out in early technological readiness level (TRL) research. Finally, he underlined that although battery recycling can mitigate these risks, such practices should be integrated with other strategies, such as making use of technologies that are based on abundant materials (e.g., Mg, Na) and combining several storage technologies (as well as focusing on other grid flexibility options).

Panel discussion and Q&A

The presentations delivered by the speakers stimulated insightful discussions on the critical role of **raw materials** and **seasonal storage** in the context of the clean energy transition.

Manuel Bauman, further elaborated on the topic of the price of raw materials. He brought the audience's attention to the point that this is not directly related to the abundance of the material, as it also depends on mining and process capacity and geographical concentration (e.g., China is the monopolist of many rare earth materials). **Walter Gaggioli** and **Javier García-Barberena** agreed that there is not a single energy storage technology that covers all energy storage needs. For example, for large-scale capacity, thermal energy storage is a cheap technology for the primary market and should be used in proximity to the end user. **Salvatore Vasta** tackled the issue of materials and technologies for seasonal thermal energy storage. He remarked that seasonal energy storage solutions already exist and are suitable for domestic and residential applications, but the critical point is to scientifically prove that it is possible to use them with low costs and maintenance needs. **Linda Barelli** commented that seasonal, long-term storage is a crucial issue for the energy transition, specifying that the related technologies are not yet completely available to the market. In her opinion, while hydrogen technologies can support long-term storage, these are not able to guarantee seasonal storage to large-scale capacity that will be needed in the future. She instead mentioned the positive role that reactive metals could play in this regard. Finally, she remarked that in the long term, the development and market uptake of energy storage technologies has to be reflected in national and EU policies.

Conclusions

Promoting the uptake of new technology in the Energy Storage and Concentrated Solar Power sectors demands a steady collaboration between the research community and industry to be able to materialize and concretely implement what has been designed at a more theoretical level. By organising this kind of events, the SUPEERA Project aims to boost connections among different areas of the sustainable energy production sector and several categories of actors involved within each area.

The recording of the workshop is available at this link.

Agenda of the Almeria Workshop 10.5.2022

09:30	**Welcome and greetings**
09:40	**Keynote speech** *Cristina Trueba, Chair of the Implementation Working Group on CSP/STE*
09:50	**Workshop background: the SUPEERA project** *Ivan Matejak, SUPEERA coordinator, EERA* **Presentation of two pathways: Energy Storage, Concentrated Solar Power** *Maria Oksa, Senior Scientist - Project Manager, VTT*
10:10	**Collaboration between research and industry: best practices, barriers and replicability potential**
	The SET Plan as a tool for EU-wide collaboration on R&I priorities of low-carbon technologies *Ivan Matejak, SUPEERA coordinator, EERA* **EERA Joint Programme Concentrated Solar Power** *Ricardo Sanchez, EERA JP CSP Coordinator, PSA* **EERA Joint Programme Energy Storage** *Myriam Gil Bardaji, JP Energy Storage Manager, KIT* **Current challenges of CSP: the vision from the industry** *David Trebolle, Secretary General, Protermosolar* **Synchronous pumped heat electricity storage for the energy transition from fossil to renewables** *Escarlata Munoz Granero, Senior Industrial Engineer, Malta Inc.* **R&I and CSP: How close are they?** *Sergio Relloso, New Technologies Business Unit, SENER [online]*
11:30	**Panel discussion and Q&A** *Moderator: Ivan Matejak, SUPEERA coordinator, EERA*
11:50	**Cross-sectorial dialogue for system solutions towards the CET objectives**
	Systemic and cross-sectorial issues pertaining to the Clean Energy Transition *Spyridon Pantelis, Project Manager, EERA* **Integrating concentrated solar heat in industrial processes** *Miguel Frasquet, CEO, SOLATOM (topic: energy system integration) [online]* **Thermal storage integration into STE plants - A success story from Spain** *Eduardo Zarza, Technical coordinator, PSA (topic: energy system integration)* **Thermal storage for electricity production** *Rocío Bayón, Senior Scientist, CIEMAT/PSA (topic: energy storage)* **Digitisation to accelerate CSP development & considerations for an open discussion** *Cristóbal Villasante, Renewable Energy Coordinator, Tekniker & Tekniker representative at the JP-CSP of EERA (topic: digitalisation)*
	Panel discussion and Q&A *Moderator: Spyridon Pantelis, Project Manager, EERA*

14:00	**Visit to PSA**
15:30	**The role of energy storage in future power grids**
	Energy Storage and Energy Transition, Challenges and Concerns *Marcelino Sánchez, Director at Solar Thermal Energy Department, CENER* **The thermal energy storage systems at support of new renewable power networks** *Walter Gaggioli, Head of Solar Thermal and Smart Network Division, Department of Energy Technologies and Renewable Energy Source, ENEA* **Investigation of the potentialities of CLOSED CYCLE sorption TES for industrial applications** *Salvatore Vasta, Research Engineer & Coordinator of the EERA JP-ES - Sub-Programme on Thermal Energy Storage, Italian National Research Council (CNR) [online]* **Hybrid energy storage systems integration into power grid** *Linda Barelli, Associate Professor, University of Perugia [online]* **Energy storage in future power grids - potential sustainability challenges** *Manuel Baumann, Researcher at KIT, Institute for Technology Assessment and System Analysis (ITAS)*
	Panel discussion and Q&A Moderators: *Ricardo Sanchez, EERA JP CSP Coordinator, PSA* *Myriam Gil Bardaji, JP Energy Storage Manager, KIT*
17:45	**Wrap-up and next steps**

Appendix IV – Summary of the Workshop 4

The SUPEERA workshop on offshore wind and biodiversity

Copenhagen Business School, December 15, 2022.

Energy production is moving out into the North Sea, and there will be a battle for space, as the area is already under heavy pressure due to human activity in the form of ship traffic, fishing, and raw material extraction.

On 18 May 2022, Denmark, the Netherlands, Belgium, and Germany entered into an agreement to establish 10,000 of the world's largest offshore wind turbines in the North Sea. This is an important step towards the green transition, but one of the questions that is urgent is how the establishment and operation of the many wind turbines will affect the environment and biodiversity in the area? The necessary green transition sometimes goes hand in hand with strict environmental requirements and is met with resistance from nature conservation institutions, because they see fossil-free energy production occupying areas that can further threaten biodiversity.

On December 15th, 2022, 50 experts from public authorities, universities, companies, and governmental bodies joined the expert workshop on offshore wind and biodiversity. The workshop was jointly organised by European Energy Research Alliance (EERA), DTU and CBS as part of the SUPEERA project funded by the European Commission. The workshop was a step towards mapping how biodiversity and renewable energy can coexist and how research institutions, industry and public agencies can collaborate to find new ways to reach climate goals without putting biodiversity out of control.

The introduction to EERA and the SUPEERA project by Spyridon Pantelis from EERA was followed by three keynotes.

He explained that biodiversity encompasses all aspects of life diversity, including different species, individuals within the species, interactions between species, and ecosystems. Researchers usually measure biodiversity based on species' contributions to an ecosystem and the richness of the ecosystem, but it always depends on comparison with other ecosystems as there is no absolute high or low biodiversity.

Hildebrand emphasized that despite oceans being perceived as wilderness, only a small portion (13%) of them can be classified as such, and only 4.1% are adequately protected areas. To halt the decline in biodiversity, Hildebrand presented an action plan that involves understanding the change in biodiversity, predicting future biodiversity, comprehending its impact on ecosystems, developing conservation and operational guidelines, and creating public bodies that implement and maintain the guidelines.

The second keynote, with the title “A marked North Sea”, was presented by marine biologist and marine environment consultant Tim Dencker.

Through his many dives in the North Sea with photographic documentation, he has ascertained that the North Sea is a disturbed ecosystem that is under pressure due to human activity in the form of raw material extraction and fishing, especially trawl fishing. And this is further pressured by climate change, where warm-water species appear, and cold-water species disappear.

In other words, the area where, in relation to the Esbjerg Declaration, we want to set up an enormous number of wind turbines is already heavily affected by human activity and climate change.

Tim Dencker, with his underwater photos and his research, was able to demonstrate how the seabed in the North Sea is, unfortunately, not home to exuberant biodiversity.

The seabed appears barren in many places; the water is saturated with nutrients caused by human activity. Around the already existing offshore wind turbines, you may be lucky to find small oases of biodiversity because once the turbine is established, the area is undisturbed. He called the state of the ocean a political and philosophical disaster.

The offshore wind farms are perceived as a "new" human element that moves into areas where others have learned to share the space. Fishermen, shipping and the mineral extraction industry have had many years to learn to coexist. Therefore, there is a particularly large focus on how this new station.

The third keynote on the topic of “Biodiversity and offshore wind are more than just wind farms“ was presented by Emma Hospes, head of the strategic environment in Ørsted. Emma Hospes described how the company's strategy is that offshore wind turbine projects from 2030 must have a net positive impact on biodiversity in the areas where they operate. For example, they have developed:

- Bubble curtains that capture the piloting of the wind turbine foundation and protect marine mammals from noise pollution.
- Artificial reefs for the benefit of cod
- Artificial nest towers for seagulls
- 3D-printed stone reefs

Ørsted has identified six challenges in relation to their 2030 strategy on the net positive impact on biodiversity:

- The need to understand current biodiversity and how we can measure biodiversity
- Contribute positively to the dynamic marine ecosystems in which Ørsted operates
- Increase investments
- Manage stakeholders' expectations and attitudes
- Adapt to a changing political landscape
- Be aware of potential conflicts with other users of the sea

Sometimes marine areas can be so marked by human activity that the money is better spent investing in nature restoration projects elsewhere. For example, Ørsted has invested in the Humber Estuary pilot project, where 3 ha of salt marsh will be restored, and 500,000 oysters will

be introduced. In collaboration with WWF and DTU Aqua, Ørsted is also working to restore the population of horse mussels and flat oysters in the North Sea and Kattegat. In addition, Ørsted has established coral reefs on the wind turbine foundation in an offshore wind farm off the coast of Taiwan.

The three keynotes were followed by two sets of break-out sessions on how to unlock private data for research, how to change the way we think about biodiversity monitoring, how to make space for renewables without damaging other ambitions and on biodiversity impacts of renewable development.

Findings from the break-out sessions were presented in a panel discussion. By the end of the day, a list of conclusions finalized the workshop. To minimise the decline in biodiversity during the establishment of the offshore wind farm, the following were proposed:

- A wide-ranging estimation of biodiversity, i.e., based on private data provided by the industry, against the risk of being held liable retroactively.
- A roadmap for dialogue for the users of the sea. The various public agencies must coordinate cooperation, e.g., the Ministry of the Environment, Energy and Fisheries must coordinate cooperation - also across countries.
- Offshore wind farms should be designed so that they support the livelihood of biodiversity.
- As cheap as possible must, therefore, not be the only parameter in connection with tenders. There should also be a focus on biodiversity.

Workshop agenda

Workshop chair: Professor David Lusseau, DTU Aqua

09:00 Welcome (EERA & DTU)

09:15 Keynote ”What is biodiversity and why do we care?”

Professor Helmut Hillebrand, Carl-von-Ossietzky University Oldenburg (online)

09:45 Biodiversity in the North Sea

Tim Dencker, Consultant, Rambøll

10:00 Wind industry state of the art

Emma Hospes, Head of Environment and Permitting CoEx, Ørsted

10:30 Break-out sessions I

- Session 1: How do we unlock private data for research (Birte Hansen). Session moderator: Birte Hansen, WSP
- Session 2: How do we change the way we think about biodiversity monitoring. Session moderator: Marie Storr-Paulsen, DTU Aqua

- Session 3: How do we think about making space for renewables without damaging other ambitions. Session moderator: Mathilde Højrup, Tænketanken Hav
- Session 4: How do we think differently about the biodiversity impacts of renewable development. Session moderator: Lea Bigom Wichmand, GreenPowerDenmark

13:00 Break-out sessions II

15.00 Panel discussion: Key topics to advance the coexistence of marine environment and renewable energy

- Introduction to Discussion by David Lusseau, Professor at DTU Aqua

Panel Participants:

- Birte Hansen, Technical Director for Offshore Renewables at WSP
- Marie Storr-Paulsen, Head of Section for Monitoring and Data at DTU AQUA
- Marie Højrup, Consultant at Tænketanken Hav
- Lea Bigom Wichmand, Head of Depart. Business and Innovation at Green Power Denmark
- Emma Hospes, Head of Environment and Permitting CoEx, Ørsted
- Panel chair: Mattias Andersson, Senior Adviser, DTU Wind and Energy Systems

16:00 Summary and next steps – David Lussea

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Appendix V – Summary of the Workshop 5

Bringing research and industry closer: accelerating innovation and uptake of new technologies. Energy Storage & Solar Photovoltaics

The workshop on the SUPEERA project took part on the first day of the Energy Conversion and Storage Days, a three-day event organised by the Karlsruhe Institute of Technology (KIT). The workshop featured a hybrid format, which attracted a total of 70 attendees in-person and 12 virtually. Among the participants were individuals from diverse backgrounds, including research, local organisations, government officials, and industry representatives.

Opening the Workshop

Ivan Matejak, the coordinator of the SUPEERA project, delivered a detailed presentation on the project's objectives, which included establishing connections between industry and energy experts, analysing proposed energy measures, and offering recommendations to the European Commission. He spoke about the SET Plan, which is currently being revamped to align with the European Green Deal, the Recovery Plan, the Energy Union, and the ERA policy communications. Furthermore, Matejak provided an overview of the REPowerEU initiative and introduced the EERA Manifesto as a result of feedback to the REPowerEu by the EERA community .

Maria Oksa, Senior Scientist and Project Manager from VTT, explained how the SUPEERA project analysed the National Energy and Climate Plans (NECPs) to identify gaps and enabling factors. The project team examined 27 NECPs and selected the six most relevant technological pathways for energy. Oksa then presented an overview of the project team's findings on the Energy Storage and Solar Photovoltaics pathways. The team discovered that marketing development of storage is already underway in Europe, particularly in the Northern countries. On the other hand, they concluded that the expansion of solar technology will be driven by steady and predictable funding mechanisms, simplified permitting processes, and collaborations between project teams and international initiatives.

Collaboration between research and industry: best practices, barriers and replicability potential

Francesco Matteucci, Programme Manager from the European Innovation Council (EIC), delivered a presentation on the support that the EIC provides through grants and equity investments to the development and scaling up of DeepTech startups**.** He underlined that EIC was created under the programme of Horizon 2020 and is the only European Agency with the authority to make and enforce policies related to innovation in Europe. He cited the example of the first regulation on the second life of batteries, implemented in December 2020, as enabling new recycling technologies. He concluded with the example of the first regulation on the second life of batteries which has been put in place in December 2020 to enable new type of policies of recycling technologies. To conclude

Matteucci emphasised the importance of large-scale technologies in solar PV and energy storage and the need to consider market applications and strengthen existing collaborations. He finally pointed to successful collaborative projects like SUPEERA as demonstrating best practices and the benefits of working together.

Ivan Gordon, EERA Joint Programme (JP) PV Coordinator and Manager at IMO-IMOMEC/Energyville, presented the Joint Program for Photovoltaic Solar Energy, which aims to achieve large-scale implementation of solar energy in the European Union and make the PV systems more affordable and accessible. This is to be achieved by improving the performance of PV systems, developing manufacturing processes that are cost-effective, and increasing the reliability and lifespan of PV components. The JP PV consists of 34 universities and research institutes across Europe and collaborates with the European platform of Photovoltaics (ETIP PV) to achieve European climate targets. The European Strategic Research and Innovation Agenda on Photovoltaics document is the result of this collaboration and outlines the objectives and goals for the next ten years. The presentation also emphasised the collaboration between EERA-PV and the industry, highlighting engagement between European Solar Manufacturing Council (ESMC), ETIP, and SolarPower Europe. This collaboration led to the creation of the European Solar Photovoltaic Industry Alliance which aimed at accelerating solar PV deployment in the EU.

Myrial Gil Bardaji from KIT, on behalf of Joint Programme (JP) Energy Storage (ES) presented a brief overview of the Joint Programme on Energy Storage. The JP ES consists of 40 RTOs and universities from 15 countries and aims to accelerate European energy storage research to achieve a renewable-based carbon-neutral Europe by 2050. The JP ES has implemented several EU projects, including SmiLES, StoRIES, and RISEnergy, which is a proposal that has recently been submitted. Ms Gil Bardaji also emphasised that EERA Joint Programme collaborates with industry through organising workshops focused on policy; technology, and industry-oriented topics. An example of this collaboration is the European energy storage Technology Development Roadmap developed by EASE and EERA JP Energy Storage which provides recommendations of R&I, developed by EASE and EERA JP Energy Storage which provides recommendations ofr R&D policies and regulatory developments.

Tim Boltken, Founder and Managing Director of INERATEC GmbH, provided a brief overview of INERATEC GmbH. This German technology company specialises in the production of modular chemical plants for the decentralised and sustainable production of synthetic fuels, such as e-fuels. The company was founded in 2016 as a spin-off of the Karlsruhe Institute of Technology (KIT) in Germany and the EIC. By introducing the company, he presented various examples of collaborations between INERATEC GmbH and both industry and research institutes. As research collaboration he presented the successful work between INERATEC GmbH and the Technical University of Munich (TUM) to develop their Power-to-Liquid technology for producing synthetic fuels using renewable energy. Another successful collaboration with research partners is the PtL/GtL project, where they installed a pilot plant in Finland in 2016, demonstrating the potential for commercialisation of their technology and the benefits of industry partnerships. Since then, INERATEC has continued to work with industry partners on projects in various sectors.

Simon Philipps, Head of R&D Strategy of the Fraunhofer Institute for Solar Energy Systems ISE and EERA JP PV Coordinator, delivered a presentation on the advancements in photovoltaic (PV) technology and the collaboration between research and industry at the institute. According to Philipps, the PV price experience curve has seen a 25% price reduction with each cumulative doubling of PV module production over the last 41 years, which is attributed to the collaborative efforts of the research and industry sectors. This remarkable progress has been made possible due to Fraunhofer ISE's commitment to scientific excellence, knowledge sharing and innovation, as well as its infrastructure for scaling, techno-economic considerations, and industrial R&D partnership and support.

Panel discussion and Q&A

Following the presentation by each speaker, a 30-minute panel discussion took place where **Francesco Matteucci** and **Ivan Gordon** emphasised the disparity in investments towards Europe, specifically regarding the competitiveness of innovative PV technologies in comparison to 2011. According to **Francesco Matteucci**, it is evident that the ECis seeking to encourage investors who are not ready to take the risk independently in the early stage of solar technology. He underlined that the EIC has an equity-based funding approach which should push private investors to invest in the initial scale-up phase, leading to exponential growth. He referred to the Impact Report 2022, which demonstrates that providing equity to a company through EIC venture capitalists led to substantial leverage. From a policy perspective, he mentioned the Interest project of European common interest IPCEI, which permits each MS to provide funding to companies for the manufacturing and development of facilities. Similar to the project recently undertaken in Sicily with ENEA, the goal of such initiatives is to scale up the production of solar technology. **Gordon** added that the focus should not solely be on cost competitiveness but also on sustainability. He emphasised that technology should be chosen for sustainability reasons in addition to technological advancement. **Matteucci** expressed concerns regarding the potential for a sustainability-focused approach in northern countries to create incentives that may contradict other MS within the European Union. He also highlighted the issue of energy dependency within each MS and recognised the European Commission's acknowledgement of individual MSs' responsibility for their energy policies. In response, **Gordon** acknowledged the importance of sustainability in the energy sector but noted that cost constraints might limit some MSs' potential for energy production growth. He also emphasised the north's shift towards sustainable solutions and the industry's increasing emphasis on sustainability. **Matteucci** also acknowledged that an IPCEI might not be a universal solution for all energy sector and company problems, as different situations may require different solutions. However, he recognised the EU's policy and political will to involve national value chains and enable private investment. He noted that financial investors are not deterred by costs but require the EC and MS to de-risk their initial investment. He cited INERATEC as an example of successful support provided by EIC, emphasising the importance of small steps in enabling startups. **Matteucci** concluded by stating that European and national politicians are increasingly engaging in conversations regarding this matter. **Tim Boltken** highlighted the advantages of INARETEC remaining in Europe, despite the potential short-term benefits of the new Inflation Reduction Act and the European response with the net-zero Industry Act. He emphasised the strong European identity that is fostered by conducting research and innovation with European partners

and contributing to the local economy and community. In addition, having production based in Europe makes the industry more resilient to potential shutdowns, job losses, and political and regulatory risks, he added. Boltken acknowledged that while the Inflation Reduction Act may offer cost savings, it is important to consider the established supply chains and the possibility of local economic crises. **Myriam Gil Bardaji** noted that hybrid storage technology has predominantly focused on batteries, which has led to increased collaboration in this area. However, she stressed that energy storage encompasses a wide range of other technologies that need to be addressed for various applications, including long-duration storage. To promote these new technology solutions, collaboration among investors, research, and industry is crucial, not just limited to batteries. Moreover, Gil Bardaji pointed out that previous feedback from energy storage collaboration indicated lower levels of collaboration compared to batteries.

Panel discussion conclusion

The panel discussion focused on key aspects of the European energy sector, highlighting the importance of collaboration, investment, and sustainability. The speakers emphasised the need for equity-based funding approaches, such as the European Innovation Council (EIC), to encourage private investors to invest in initial scale-up projects and support startups. Sustainability was identified as a crucial consideration in the energy sector, along with the need to explore and promote other energy storage technologies beyond batteries. The impact of individual MSs' energy policies was also discussed, and collaboration among investors, research, and industry was emphasised as essential to promote new technology solutions. Finally, the importance of a strong European identity and resilience in the face of potential risks was also highlighted.

Cross-sectorial dialogue for system solutions towards the CET objectives

Spyridon Pantelis, Project Manager at EERA, provided some background on energy-related cross-cutting topics and presented the outcomes of the analysis that SUPEERA project conducted for identifying the cross-cutting issues after analysing all SET Plan Implementation Plans. The dialogue on cross-cutting issues is needed to provide coordinated input to decision-makers for systemic solutions in the energy sector. Pantelis stressed that considering cross-cutting aspects in technological planning for the Clean Energy Transition is critical to achieving ambitious goals defined in the European Green Deal and SDGs.

Ruben Hünig, Co-Founder and CEO of Phytonics, presented the company's new bio-inspired coatings for solar modules, specifically the Anti-Reflective Coating Bionic nano & microtextures. Hünig's presentation focused on the journey from lab to market, including the company's development and testing process. Furthermore, Hünig introduced the "Lab to farm" concept, which aims to bridge the gap between laboratory research and real-world applications by fostering collaboration between academic research institutions and industry partners.

Sagar Venu, software engineer at Fenecon, delivered a presentation on the topic of energy system integration, specifically highlighting the company's work on grid integration with energy storage systems using their product: OpenEMs. The company's Fenecon Energy Management System (FEMS) incorporates an application that utilises generation and consumption forecasting to optimise storage loading, leading to increased self-consumption and grid efficiency. Fenecon emphasises

the importance of collaboration in research and industrial partnerships, citing better understanding and structure on timelines as key benefits.

Catarina Augusto, Senior Technical Advisor at SolarPower Europe presented an overview of the organisation's efforts in shaping policy and business opportunities in the solar energy industry. SolarPower Europe focuses on various workstreams, including Grids & Flexibility, and works on challenging topics to promote solar energy. Augusto emphasised the need for collaboration between industry and research and called for policies that facilitate such partnerships. She cited ETIP-PV as an example of an organisation that promotes collaboration between industry and research. SolarPower Europe is also involved in international cooperation efforts to advance solar energy.

Peter Fischer, Head of Redox Flow Battery and Stationary Storage Group at Fraunhofer ICT, presented the FLORES network, an interest group of 15 EU-funded research projects that focuses on flow battery technology. The group offers a platform for networking, joint outreach activities, and cross-topic initiatives to increase the visibility and impact of flow battery research while avoiding duplication of efforts. **Fischer** highlighted the group's involvement in policy discussions, including collecting and discussing key performance indicators (KPIs) for flow batteries during EU energy week, advocating for the recycling of critical raw materials to reduce environmental impact, and lobbying for flow batteries to be included in EU battery regulations aimed at sustainability. Additionally, he mentioned the group's work on an LCA review article[7] based on the Battery 2030 roadmap statement that flow batteries have a poor environmental footprint.

Panel discussion and Q&A

During the panel discussion that followed the presentation of the FLORES network, **Peter Fisher** emphasised that the FLORES group aims to offer solutions and give equal importance to different strategies. He noted the necessity for increasing lobbying efforts, citing that roadmaps are frequently late in their implementation. **Sagar Venu** addressed technical questions regarding the FENECON Energy Management System. He emphasised that the FEMS operating system is designed for real-time monitoring and control of the energy system, allowing users to visualise energy consumption and production, track system performance, and adjust as needed. **Caterina Augusto** addressed the requirements for generators to connect with the grids, which involve standardisation and harmonisation. She emphasised the need for two different networking codes - the first code pertains to connecting generators to the grid, while the second code focuses on bringing flexibility to the grid. The aim is to ensure that all involved actors in the energy transition have a close collaboration and a common understanding. She finally discussed the benefits of research communities' involvement in solar power activities, highlighting the role of SolarPower Europe in shaping policies related to solar power. **Ruben Hünig** emphasised the importance of outdoor test stand measurements to determine the performance of solar modules under real-world conditions. These measurements validate the expected increase in energy production calculated by software programs used to model the performance of solar photovoltaic systems. He also noted that using an anti-reflective coating

[7] Michael Dieterle a, Peter Fischer a, Marie-Noëlle Pons b c, Nick Blume d, Christine Minke e, Aldo Bischi (2022) “Life cycle assessment (LCA) for flow batteries: A review of methodological decisions.” https://doi.org/10.1016/j.seta.2022.102457

with bionic nano and macrotextures could increase the efficiency of solar modules and reduce the cost of solar energy. **Peter Fisher** elaborated on the FLORES network's global cooperation with experts, ministries, and researchers outside of Europe. He further mentioned the network's plans after the EU-funded projects are under consideration, with a focus on catering to the next generation and possibly becoming an association. It was noted that real-time R&I applications at the grid and industrial scale are already in place, and although collaboration with China is ongoing, establishing a connection with the USA has been challenging.

Conclusion

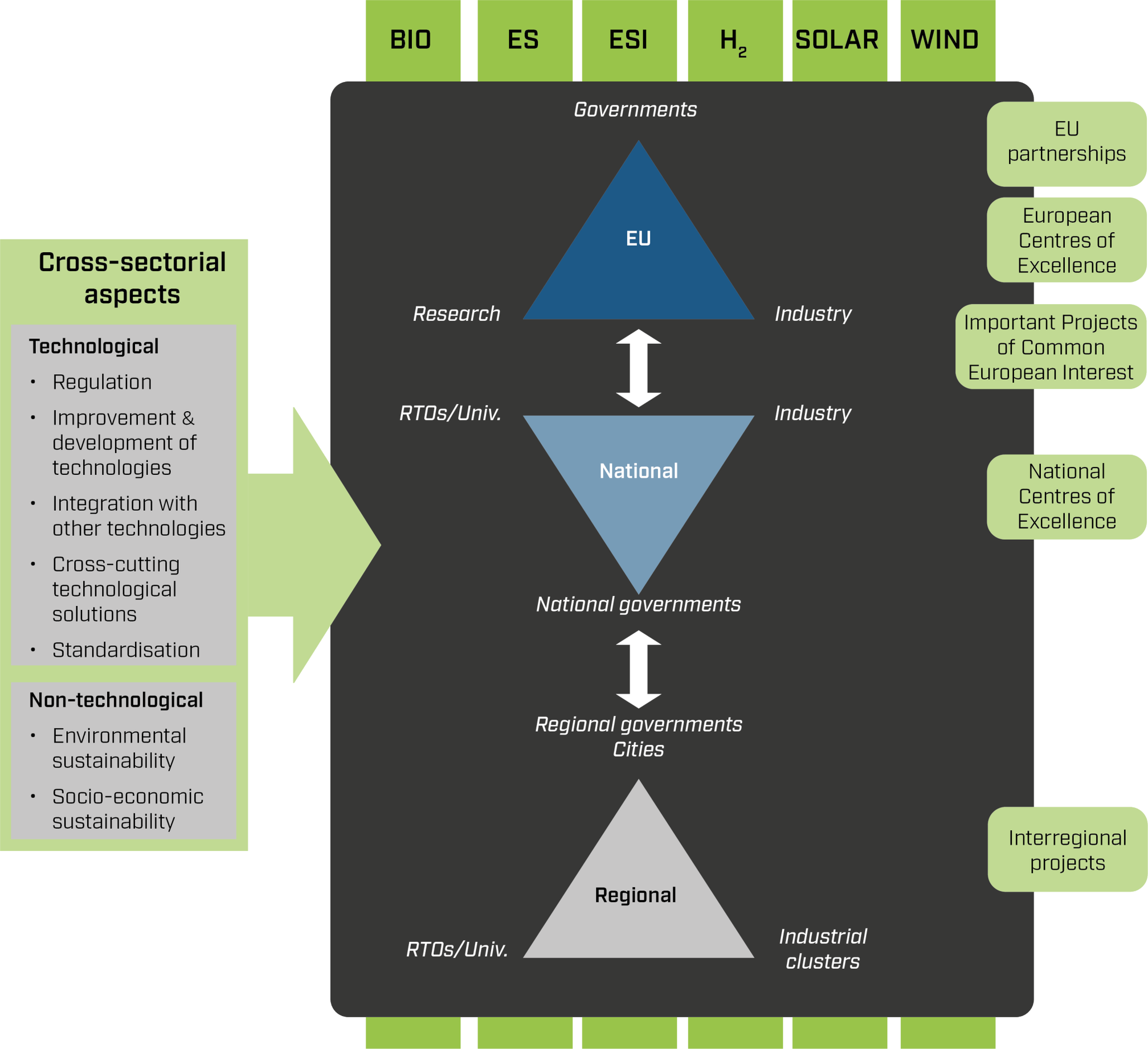
The workshop on the SUPEERA project was a key part of the activities in the framework of the Energy Conversion and Storage days, and it brought together a wide range of experts from the research sector, local organisations active in R&I activities, government officials, and industry representatives. In the first part, following the presentations of each speaker, a 30-minute panel discussion took place where the panellists discussed key aspects of the European energy sector, highlighting the importance of collaboration, investment, and sustainability. The speakers emphasised the need for equity-based funding approaches, such as the European Innovation Council (EIC), to encourage the private sector to invest in initial scale-up projects and support startups. Sustainability was identified as a crucial consideration in the energy sector, along with the need to explore and promote other energy storage technologies beyond batteries. The impact of individual MSs' energy policies was also discussed, and collaboration among investors, research, and industry was emphasised as essential to promote new technology solutions. The importance of a strong European identity and resilience in the face of potential risks was also highlighted. In the second session of the workshop, the discussion touched upon a wide range of topics, including European partnerships, energy management systems, networking schemes, solar modules, and the benefits of research communities' involvement in solar PV deployment. The participants emphasised the importance of lobbying efforts and standardisation at national and European level to achieve sustainable energy solutions.

Workshop agenda

09:00	**Welcome and greetings**
09:10	**Keynote speech** *Walter Tromm, Scientific Spokesperson Energy Centre, KIT*
09:20	**The SUPEERA project / The SET Plan as a tool for EU-wide collaboration on R&I priorities of low-carbon technologies** *Ivan Matejak, SUPEERA coordinator, EERA* **Presentation of two pathways: Energy Storage, Solar Photovoltaics** *Maria Oksa, Senior Scientist - Project Manager, VTT - online*
09:40	**Collaboration between research and industry: best practices, barriers and replicability potential**
	Fundraising opportunities and innovation trends within the solar PV and energy storage area *Francesco Matteucci, Programme Manager, European Innovation Council* **EERA Joint Programme Solar Photovoltaics** *Ivan Gordon, EERA JP PV Coordinator, IMO-IMOMEC / Energyville*

	EERA Joint Programme Energy Storage *Myriam Gil Bardaji, JP Energy Storage Coordinator, KIT* **Modular e-Fuel production – the story of the university spin-off INERATEC.** *Tim Böltken, Founder and Managing Director, INERATEC GmbH* ***Collaboration examples between research and industry at Fraunhofer*** *Simon Philipps, Head of R&D Strategy, Fraunhofer Institute for Solar Energy Systems ISE (EERA JP PV Coordinator)*
	Panel discussion and Q&A *Moderator: Ivan Matejak, SUPEERA coordinator, EERA*
11:10	Coffee break
11:30	**Cross-sectorial dialogue for system solutions towards the CET objectives**
	Systemic and cross-sectorial issues pertaining to the Clean Energy Transition *Spyridon Pantelis, Project Manager, EERA* **From lab to market - new bio-inspired coatings for solar modules** *Ruben Hünig, Co-Founder and CEO, Phytonics (energy efficiency)* **Grid integration with Energy Storage System through OpenEMS** *Sagar Venu, Software Engineer, Fenecon (energy system integration)* **Engagement of solar PV industry and research at SolarPower Europe** *Catarina Augusto, Senior Technical Advisor at SolarPower Europe (policy & international cooperation) - online* **EU cooperation - The FLORES network** *Peter Fischer, Head of Redox Flow battery and stationary storage group, Fraunhofer ICT (international cooperation)*
	Panel discussion and Q&A *Moderator: Spyridon Pantelis, Project Manager, EERA*
13:00	Lunch break

Appendix VI – Figures of the six Collaboration Interfaces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Industrial clusters
EU partnerships
European Centres of Excellence
Important Projects of Common European Interest
National Centres of Excellence
Interregional projects
Cross-sectorial aspects
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• Cross-cutting technological solutions
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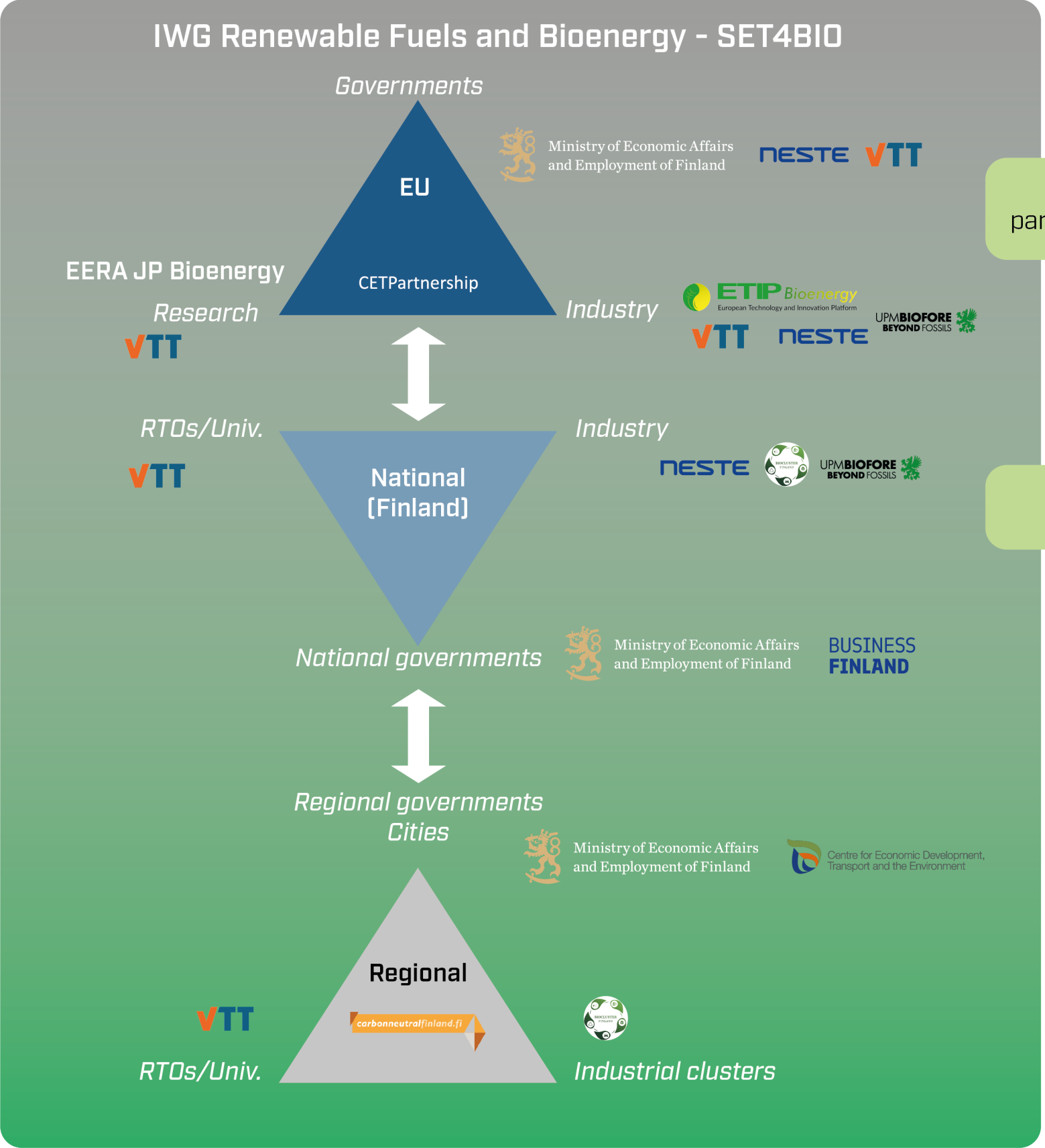
• Environmental sustainability
• Socio-economic sustainability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EERA JP Bioenergy
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ETIP Bioenergy
European Technology and Innovation Platform
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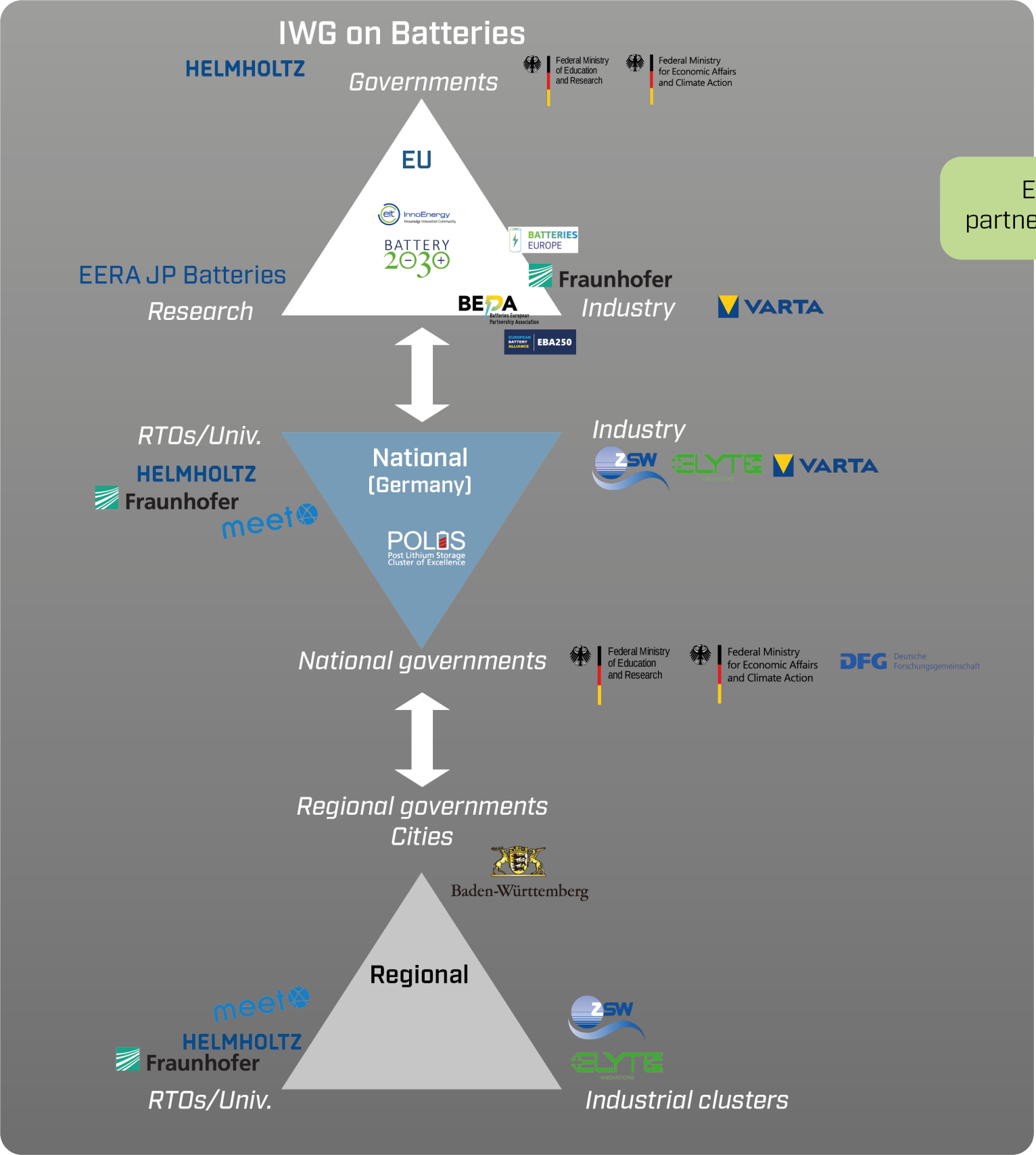
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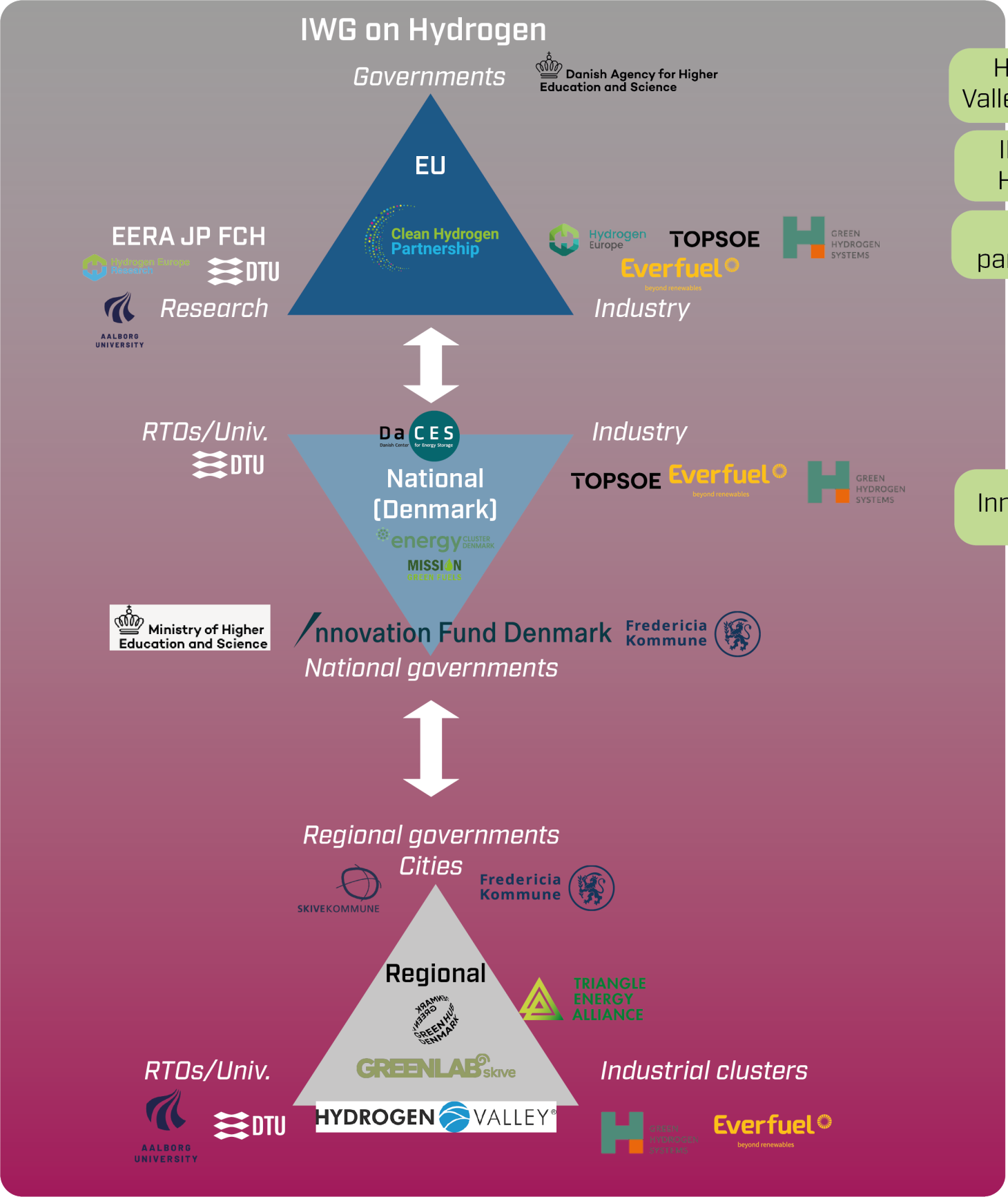
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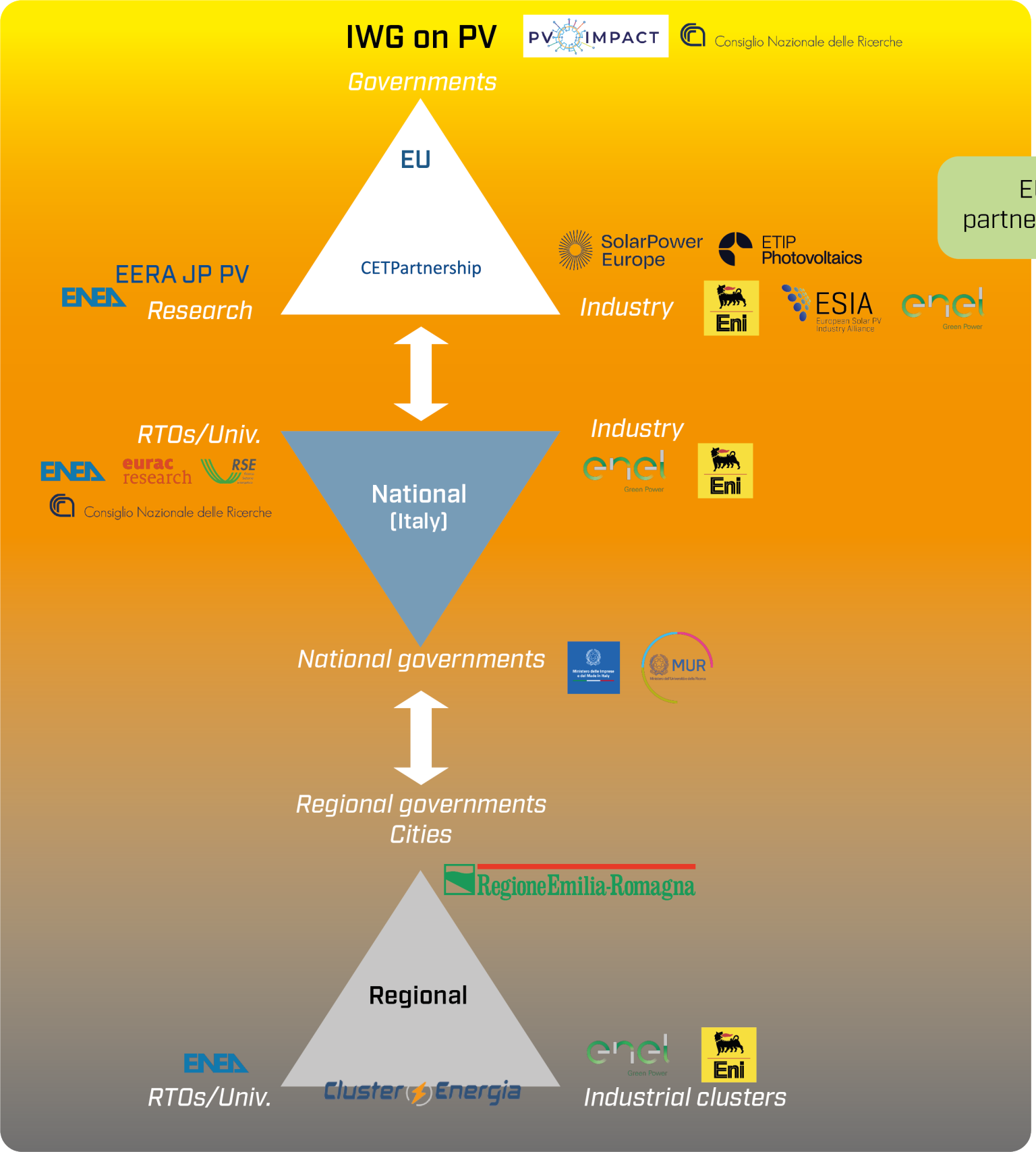
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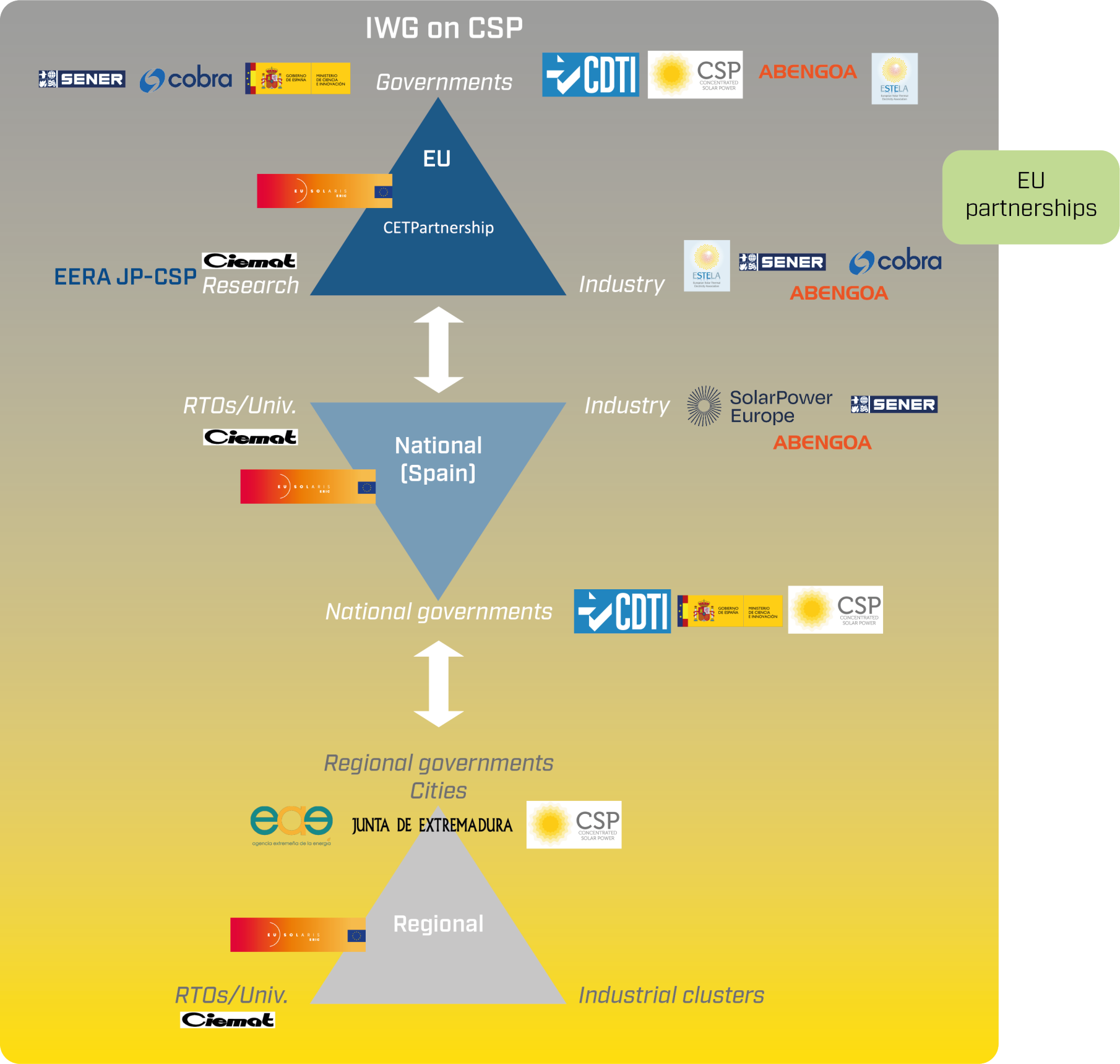
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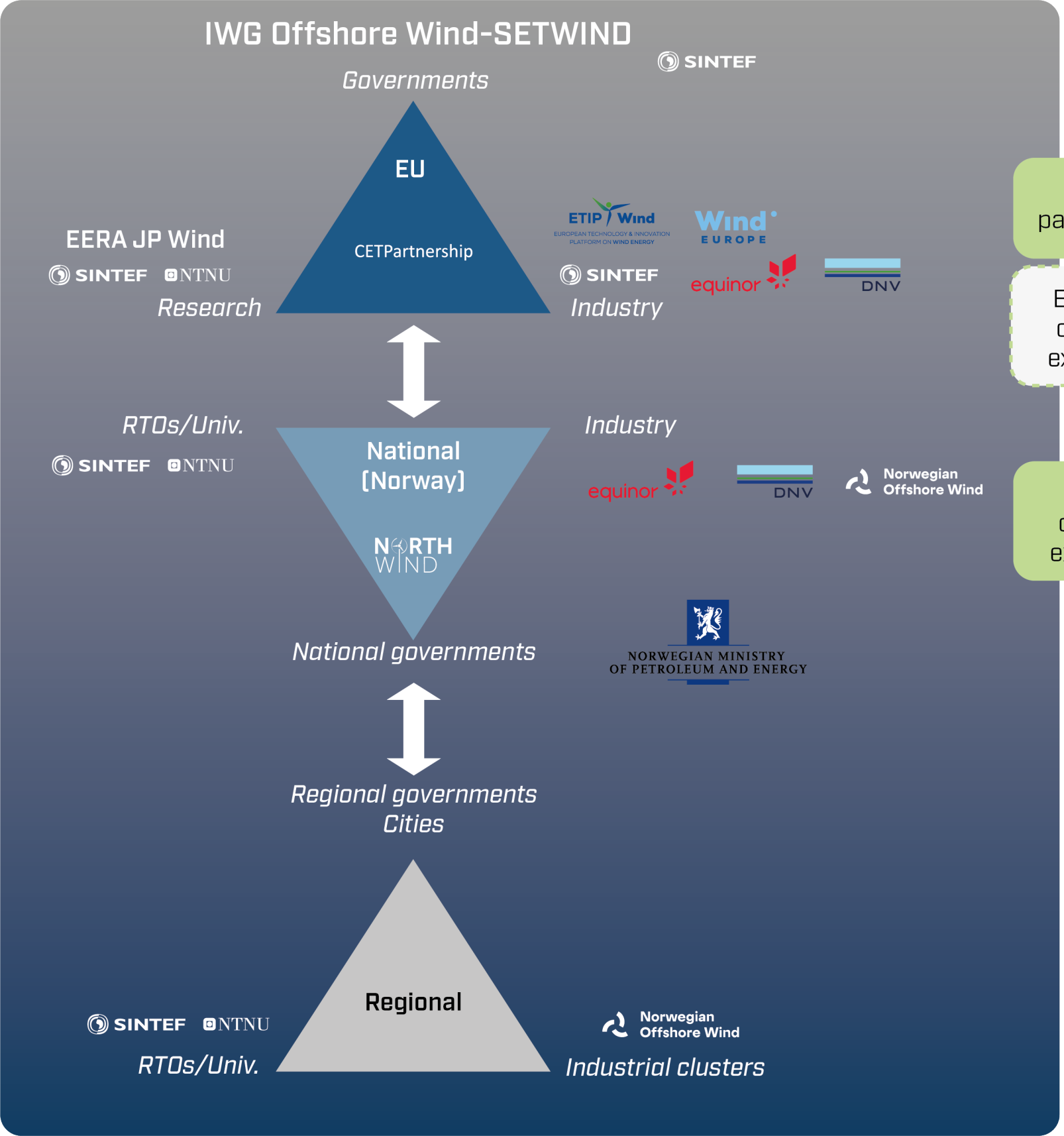
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EERA JP Wind
SINTEF NTNU
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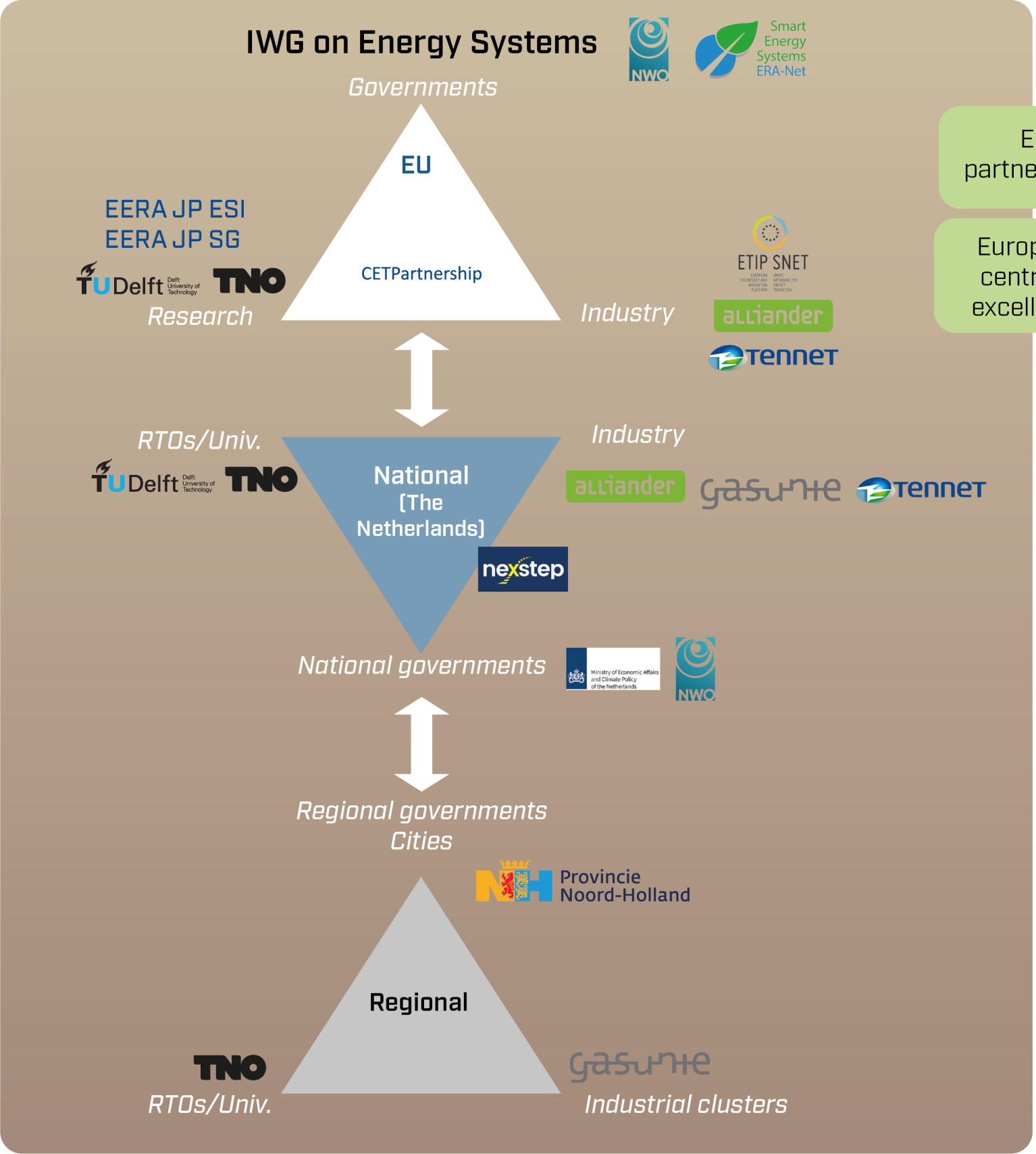
National centre of excellence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