Integrated SET Plan

CETP

Clean Energy Transition Partnership

Strategic Research and Innovation Agenda

v1.0

Endorsed by European Countries and the European Commission

November 2020

The Clean Energy Transition Partnership is a transnational joint programming initiative to boost and accelerate the energy transition, building upon regional and national RDI funding programmes.

Editorial

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Clean Energy Transition Partnership (CETP)

Strategic Research and Innovation Agenda

November 2020

Content

Executive Summary

The planned **Clean Energy Transition Partnership (CETP)** is a multilateral and strategic partnership of national and regional RDI programmes in European Member States and Associated Countries with the aim to contribute substantially to the implementation of the *European Strategic Energy Technology Plan (SET Plan)*. It will deliver to higher level European policy goals towards *Stepping up EU 2030 Climate Ambitions* and the *New European Research Area* with the ultimate objective to achieve a climate-neutral society by 2050. It will also address the strategies outlined in latest EC communications like *A Clean Planet for all* and the *European Green Deal*[1]. It intends to ramp up as quickly as possible, building on exiting SET Plan initiatives (ERA-Nets, IWGs, ETIPs, etc.), in order to create synergies with the *National Energy and Climate Plans* and with the *Recovery and Resilience Facility (RRF).*

This **Strategic Research and Innovation Agenda (SRIA)** is the keystone for the implementation of the CETP. It will serve as a guidance and "compass" for the multilateral collaboration in Europe and beyond for the next 10 years. The national and regional RDI programme owners and managers constituting the partnership share a common vision and objectives, which frame the CETP's transformative research, development and innovation programme. The SRIA reflects their coordinated and harmonised view as well as their high expectations to the impact of the RDI activities resulting from its implementation. To deliver highly transformative outcomes, it follows a challenge-driven and transdisciplinary approach.

Eight **CETP Challenges** (Figure 1) related to enabling technologies, system integration and crosscutting dimensions indicate the overarching main topics and RDI goals. They are expected to be addressed by the CETP joint programming activities and are designed to accentuate the particular contribution that multilateral collaboration can make as well as to lay the ground for the operationalisation of the CETP. Interfaces to other initiatives and partnerships have been identified and will ensure that the CETP will be complementary and embedded in the SET Plan ecosystem.

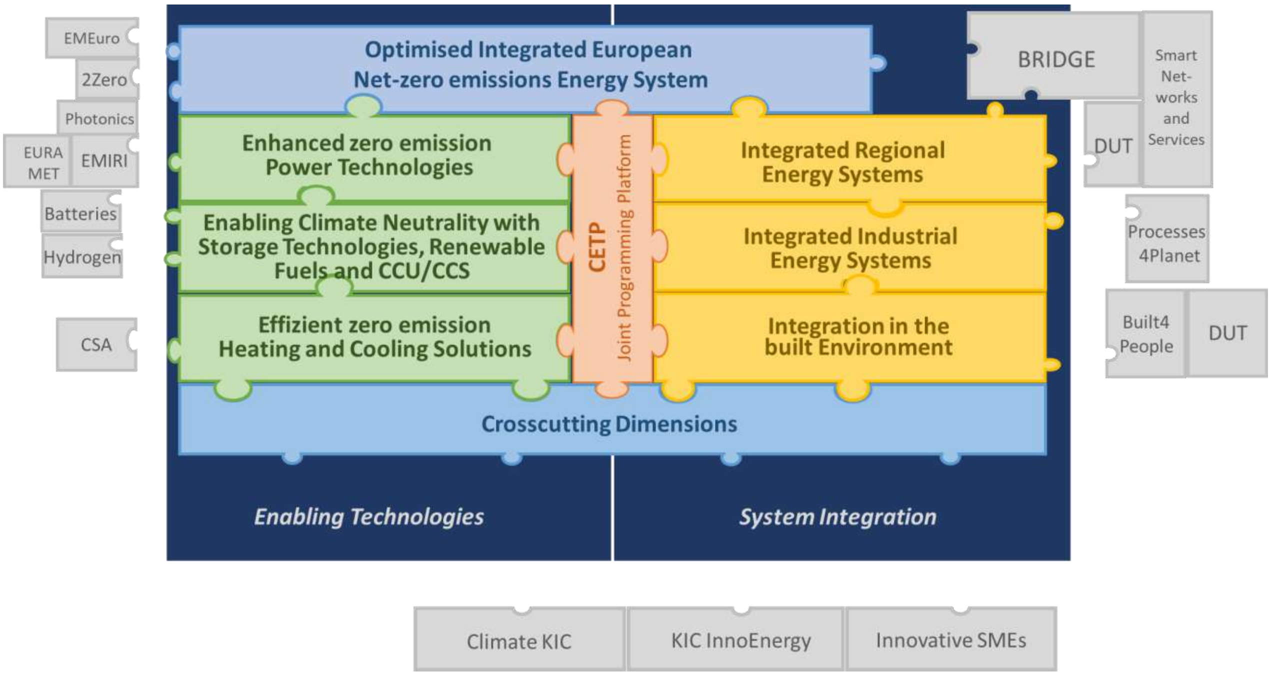

Figure 1 The CETP SRIA - Enabling joint programming for transformative energy system solutions along synergetic key challenges embedded in the ecosystem of complementing initiatives

[1] Moreover the *Strategies for Energy System Integration*, *Offshore Renewable Energy* and the *Renovation Wave.*

1. Introduction

The **European Strategic Energy Technology Plan (SET Plan)**[2] is the research, development and innovation (RDI) pillar of the European Energy Union. It aims to accelerate the development and deployment of low-carbon technologies, improve new technologies and bring down their costs, by coordinating regional, national and European research efforts and facilitating financing of innovation projects in the energy sector.

The planned **Clean Energy Transition Partnership (CETP)** is a multilateral and strategic partnership of national and regional RDI programmes in European Member States and Associated Countries with the aim to contribute to the implementation of the SET Plan. The CETP addresses the challenge of clean energy transition through coordinating national and regional research, development and innovation strategies, programmes, activities and stakeholders. Initiated under the 10th European EU Framework Programme for Research and Innovation Horizon Europe (2021-2027), it also brings together the European Commission and public partners, addressing some of Europe's most pressing challenges and contributing to reduce the fragmentation of the research and innovation landscape in the EU.

There is agreement among all interested CETP countries that the CETP shall foster **challenge driven research, development and innovation that stimulate transition** and amplify the cooperation of research with "problem owners" or "need owners" (potential buyers, procurers and users of solutions). This transformative approach in RDI is mirrored in the Strategic Research and Innovation Agenda (SRIA) for the CETP in the objectives and expected impacts of the CETP (Section 2), the process to develop the SRIA (Section 3) as well as the RDI challenges to be addressed (Section 6). By its highly transformative ambition the CETP delivers to the EU climate ambition and the new European Research Area as higher level policy goals (Section 2) and builds interfaces on European and international level (Section 7).

The CETP builds on the existing **SET Plan Implementation Working Groups and their Implementation Plans**, which bring together member states, industrial initiatives and stakeholders and researchers, as well as on the energy-relevant **ERA-NETs**, constituting experienced and effective transnational program networks.

The CETP will enable Member States and Associated Countries and the EU to align their RDI programmes to maximise impact and to accelerate the up-take of cost-effective clean energy technologies underpinning the energy transition and fostering system transformations.

[2] https://setis.ec.europa.eu/actions-towards-implementing-integrated-set-plan

2. Policy Context: Stepping up climate ambitions

The CETP is embedded and will deliver to higher level European policy goals. Firstly, the CETP will contribute to reach the UN Sustainable Development Goals and the EU climate and energy targets by stimulating clean energy transition. Secondly, the CETP will contribute to deliver a European Research Area with international outreach with focus on research, development and innovation for clean energy transition.

2.1 Stepping up UN Sustainable Development Goals

The 2030 Agenda for Sustainable Development, adopted by all 193 United Nations Member States in 2015, provides a shared blueprint for peace and prosperity for people and the planet, now and into the future. At its heart are the 17 Sustainable Development Goals (SDGs), which are an urgent call for action by all countries - developed and developing - in a global partnership. They aim among others to ensure access to affordable, reliable, sustainable and modern energy for all (SDG7), build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation (SDG9), take urgent action to combat climate change and its impacts (SDG 13) and make cities and human settlements inclusive, safe, resilient and sustainable (SDG 11).

2.2 Stepping up EU climate ambitions

Europe has firmly set out a pathway towards climate-neutrality by 2050 with the ambition to become the first-ever economy with net-zero greenhouse gas emissions, in line with the commitments under the Paris Agreement. Achieving a climate-neutral economy requires all the economic sectors to undertake a profound system transformation, with the energy sector at the very core of the transition. Today, energy is responsible for more than 75% of the EU's greenhouse gas emissions and it is therefore crucial to accelerate the clean energy transition to meet the ambitious goals of an economy compatible with the goal of climate neutrality by 2050.

Over the last years, Europe has demonstrated that reducing emissions while creating prosperity, jobs and improving people's quality of life is an achievable goal, and that is possible with current technologies and those close to development or deployment. However, to reach climate neutrality, Europe needs to decarbonise at least six times faster by increasing the share of renewable energy sources and clean energy carriers drastically, improving energy efficiency, optimizing energy quality management by matching demand and supply, and integrating sustainability and circularity in its practices. Research and innovation are critical for the delivery of solutions and system transformations that Europe needs to step up climate ambitions.

To respond to this challenge, the EU has put in place a consistent **policy framework** defining a clear strategy, actionable plans to reduce emissions in all sectors, and a set of instruments to support the transition and transformative research and innovation, while also making it an opportunity for growth and jobs all across Europe. This wider policy context represents the framework of the CETP, within which the platform sets its scope and boundaries.

In the Communication ***'A Clean Planet for all'***[3] the European Commission (EC) has defined the **long-term strategy** for Europe to become a prosperous, modern, competitive and climate neutral economy by 2050. The strategy shows that the transition is feasible and can enhance the competitiveness of EU economy and industry on global markets, securing jobs and sustainable growth. By setting a long-term pathway, the strategy creates the enabling framework to push stakeholders, researchers, entrepreneurs and citizens to develop new and innovative solutions to transform economy. It shows that Europe can

[3] COM (2018) 773 - A Clean Planet for all - A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy

lead the way to climate neutrality by leveraging innovation potential to deliver new technologies, supporting investment into new technological solutions and aligning action in key areas of industrial policy, finance, and research.

Anchored to the long-term strategy, the ***European Green Deal***[4] provides Europe with a new growth strategy based on the twin "green and digital transition" to transform the EU into a sustainable, modern, resource-efficient and competitive economy, with net-zero emissions of greenhouse gases by 2050 and respect to biodiversity[5]. It designs a sound action plan to move to a clean and circular economy, whilst ensuring a fair and just transition. All parts of society and economic sectors are asked to play a role in the transition, from the power sector to industry, mobility, buildings, agriculture and forestry. In particular the Green Deal identifies the priority actions to decarbonise the energy system and the economy.

To fully address the challenges of decarbonisation, the **EU strategies for Energy System Integration**[6]**,** alongside the upcoming **Offshore Renewable Energy,** represent a new clean energy investment agenda, in line with the Next Generation EU recovery package and the European Green Deal, paving the way towards a fully decarbonised, efficient and interconnected energy sector. The EU Strategy for Energy System Integration provides the framework for the green energy transition, pushing towards the creation of interlinkages among different energy carriers and infrastructures to have a connected and flexible system which is more efficient and cost-effective and thus reduces the costs of the transition for society. The Hydrogen strategy focuses the role of clean hydrogen as a key factor to achieve the European Green Deal and Europe's clean energy transition, in particular for its applications to decarbonise the power sector, transport and hard-to-abate industry sector. The **Renovation Wave**[7] tackle energy efficiency in the building sector that contributes to 40% of total energy demand in the EU, and it is therefore crucial to achieve climate-neutrality targets. The strategy aims at doubling the renovation rate of the building stock to improve the energy performance of buildings and foster new models based on energy communities and zero-energy districts.

Europe is firmly committed in spearheading the clean energy transition, building on Europe's success story in renewable energy technologies. With the Communication on ***'Stepping up Europe's 2030 Climate Ambition'***[8] issued in September 2020, the EC has outlined a plan for a more ambitious and cost-effective path to achieving climate neutrality by 2050, relying – among other measures – on reinforcing energy efficiency and renewable energy policies. The ambition, according to European Commission President Ursula von der Leyen, is for Europe to *"lead the way to a cleaner planet and a green recovery. Europe will emerge stronger from the coronavirus pandemic by investing in a resource-efficient circular economy, promoting innovation in clean technology and creating green jobs".* The EC raised the ambition for climate-neutrality, proposing a 55% emissions reduction target by 2030 to keep in track with the pathway towards 2050. According to the impact assessment carried out *ex ante*, and based on the member states' National Energy and Climate Plans (NECPs) as well as on the Competitiveness Progress Report (as part of the State of the Energy Union 2020), a 55% reduction of GHG emissions is a sound and realistic target for Europe, which puts the clean energy transition at the heart of the decarbonisation.

[4] A Green Deal https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

[5] EU Biodiversity Strategy for 2030 Bringing nature back into our lives. COM/2020/380 final-https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1590574123338&uri=CELEX%3A52020DC0380

[6] Powering a climate-neutral economy: An EU Strategy for Energy System Integration, COM(2020) 299 final; A hydrogen strategy for a climate-neutral Europe, COM(2020) 301 final

[7] A Renovation Wave for Europe - greening our buildings, creating jobs, improving lives, COM(2020) 662 final

[8] Stepping up Europe's 2030 Climate Ambition https://ec.europa.eu/clima/sites/clima/files/eu-climate-action/docs/com_2030_ctp_en.pdf

The new ***Recovery and Resilience Facility*** (RRF) set out with the Next Generation EU Programme to support the EU to recover from the Corona pandemic, is further strengthening the commitment towards the climate targets. The facility will provide large-scale financial support to Member States to implement reforms and investments to mitigate the impacts of the pandemic and make the EU economies more sustainable, resilient and better prepared for the challenges of the green and digital transitions. This will provide an opportunity for a massive push to investments and innovation in clean energy technologies. Resources made available from the RRF fully consistent with the National Energy and Climate Plans, and shall be allocated to the EU Green Deal objectives for the following purposes and in respect with the do 'no harm' principle and the minimum safeguard requirements of the EU Taxonomy[9] for all investments:

- The frontloading of future-proof clean technologies and acceleration of the development and use of renewables
- The improvement of energy efficiency of public and private buildings
- The promotion of future-proof clean technologies to accelerate the use of sustainable, accessible and smart transport, charging and refuelling stations and extension of public transport

2.3 Stepping up the European Research Area and beyond: RDI for the clean energy transition

The **Communication on a new European Research Area (ERA) for Research and Innovation**[10] issued on 30th September 2020, sets strategic objectives to enhance integration and cooperation among Member States supporting the Green Deal and the Recovery and Resilience, and namely:

- Prioritise investments and reforms in research and innovation towards the green and digital transition
- Improve access to excellent facilities and infrastructures for researchers across the EU
- Transfer results to the economy to boost business investments and market uptake of research output
- Strengthen mobility of researchers and free flow of knowledge and technology, through greater cooperation among Member States

In this framework, RDI plays a fundamental role to deliver the cost-effective technologies needed for the transition to happen.

In this regard, the **European Strategic Energy Technology Plan,** is the main instrument for the EU, Member States and Associated Countries to align their strategies and investments for clean energy transition. The objective is to accelerate the development and deployment of low-carbon technologies, improve new technologies and bring down their costs, by coordinating national research efforts and facilitating financing of innovation projects in the energy sector.

Beyond Europe international initiatives such as **Mission Innovation** and the **International Energy Agency** Technology Collaboration Programmes (IEA-TCPs) address climate change as a global challenge through worldwide collaboration, also RDI cooperation (see Section 7). They build a framework to extent RDI cooperation and alignment for clean energy transition beyond Europe.

[9] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32020R0852
[10] COM/2020/628 final

Research and Innovation is also a dimension of the **National Energy and Climate Plans**[11] (NECPs) that set out national objectives and pathway to meet the 2030 goals. At the national level, the NECP provides a framework for the prioritisation of specific R&I objectives and a link to participation in EU platforms and initiatives as well as international collaboration. The conclusions of the NECPs wide assessment (September 2020) highlight the need for better link research programmes with the energy policies and for Member States to better formulate research objectives, accompanied by suitable policies and measures.

Annex 1 of this document presents a **systematic mapping of the contributions of the CETP to higher level policy goals**.

3. A co-creative process towards the CETP SRIA

The overarching research, development and innovation challenges to be addressed by the CETP have been identified in **a co-creative process**. This process (Figure 2) followed five principles with the aim to lay the ground for a high commitment for its implementation to finally stimulate transformative change.

1. Co-creation of the SRIA: interested Member States and Associated Countries, SET Plan Implementation Working Groups (IWGs), ERA-NETs, EERA Joint Programs, European Technology and Innovation Platforms (ETIPs) and national stakeholders have been engaged and mobilised through the entire process. They have been active in several workshops and meetings, have been invited to the public consultation as well as in discussion fora and contributions in an online collaboration work space dedicated to the CETP SRIA development.
2. Empowerment of key stakeholders: Key stakeholders from the SET Plan IWGs and the ERA-NETs have been empowered to jointly identify RDI challenges for the clean energy transition. They delivered 5 Input Papers to the CETP SRIA on enabling technologies (summarising 9 technology specific input papers), heating and cooling solutions, system integration, storage and fuels as well as on cross-cutting issues. The essence has been collected in a SET Plan Stakeholder Groups Dialogues Summary Paper, which this SRIA makes reference to (details see Annex 4).
3. Challenge-orientation of the SRIA: The SRIA of the CETP follows a challenge-oriented approach, identifying RDI challenges for clean energy transition with high relevance for “problem owners“ or “need owners” (potential buyers, procurers and users of solutions).
4. Commitment to the SRIA: Interested CETP Member States and Associated Countries take ownership and show commitment through active contribution to several meetings, consultations and participation in the CETP SRIA Editors and Publishers Group.
5. Transparency of the SRIA process: All interested representatives from CETP Member States and Associated Countries, IWGs, ERA-NETs, EERA JPs, ETIPs and national stakeholders as well as from the EC could follow the process in real time on an online collaboration work space (expera). All participants always had access to all relevant documents, presentations, discussion fora, living documents etc.

[11] To meet the EU’s energy and climate targets for 2030, EU Member States need to establish a 10-year integrated national energy and climate plan (NECP) for the period from 2021 to 2030. Introduced under the Regulation on the governance of the energy union and climate action (EU/2018/1999) https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/national-energy-climate-plans#national-long-term-strategies

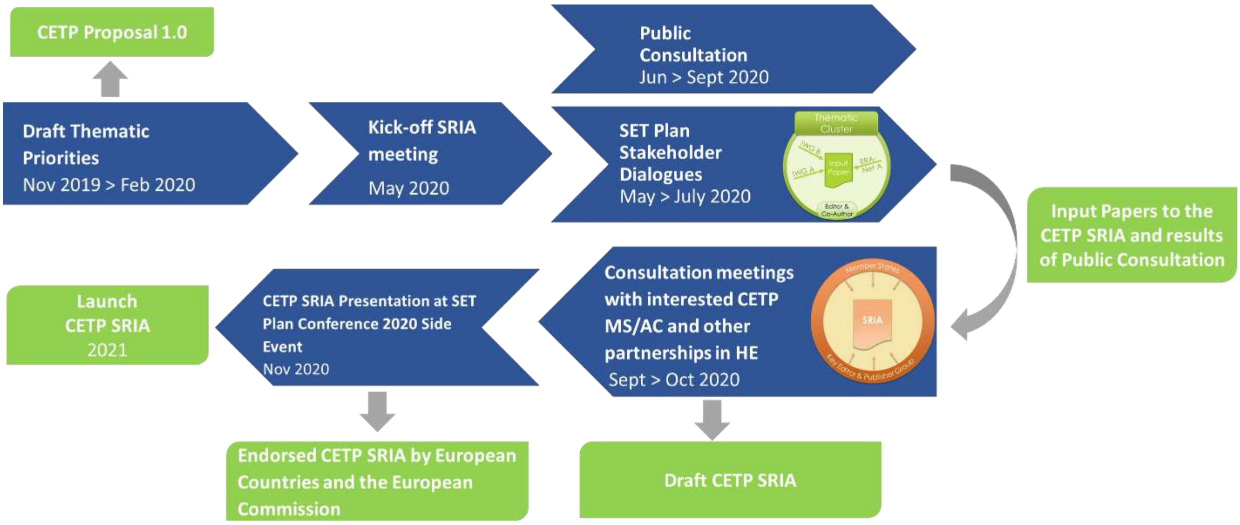

Figure 2 The co-creative SRIA initiation process

The **CETP SRIA co-creation process was kicked off** on the 26 May 2020 in a meeting inviting representatives of the SET Plan Implementation Working Groups (IWGs) and ERA-NETs engaged in relevant topics concerning clean energy.

The Kick-Off Meeting was followed by **CETP Stakeholder Groups Dialogues** in thematic cluster from May to July 2020. The CETP Stakeholder Dialogues provided all ERA-NETs and SET Plan IWGs with the opportunity to present themselves and identify the key need owners and key challenges for the upcoming years. Seven CETP Stakeholder Group Meetings were held with thematic focus on renewable technologies, heating and cooling technologies, system integration, storage systems and fuels and cross-cutting. The meetings were attended by 361 persons in total, with attendance ranging from 32 to 63 persons.

Based on the findings of the CETP Stakeholder Dialogues, **five input papers to the CETP SRIA** have been developed from July to September 2020, to identify high-level RDI challenges from the perspective and experience of all SET Plan IWGs, ERA-NETs and stakeholders involved (policy, industry, research). Those input papers have been written as a joint effort by nominated experts from IWGs and ERA-NETs (who contributed in the forms of co-authors, commenters as well as discussants). Experts from the **European Energy Research Alliance (EERA)** acted in a coordinating role as editors. The Input Papers have been developed as living documents on an online collaboration work space. In total, 146 editors, co-authors, commenters and discussants had the opportunity to contribute to the input papers. As a result, 64 challenges have been described within the input papers.

A **public policy stakeholder consultation** was open from July to September 2020 to mobilise feedback from national and European policy stakeholders (initiatives, networks, organisations). 54 responses from policy stakeholders have been received.

The Input Papers and the public consultation were both input to the **CETP SRIA** which was then developed by the **MS/AC Editors and Publishers Group** with input from other partnerships. The group jointly developed the CETP SRIA using the same online collaborative work space making the development transparent and open. Finally, the SRIA was endorsed by all interested CETP countries. A regular update of the CETP SRIA is planned during the running time of the CETP.

4. Common Vision, Objectives and expected Impact

The SRIA is the keystone for the implementation of the CETP up to 2030. The national and regional RDI programme owners and managers that constitute the CET Partnership share a common vision and objectives of the SRIA which frame the CETP's transformative research, development and innovation programme. The SRIA reflects the coordinated and harmonised expectations of call interested CETP countries of the impact by the research, development and innovation activities that result from the implementation of the SRIA.

4.1 Vision

The Clean Energy Transition Partnership is a transformative research, development and innovation programme across Europe boosting and accelerating a just energy transition in all its dimensions for Europe to become the first climate-neutral continent. It enables the energy transition rooted in security of supply from regional to national and global level, co-transformed by industry, public organisations, research and citizens organisations to make Europe frontrunner in energy innovation and implementation. The setting and execution of such an agenda to realise Europe's ambitions will be the key for the diffusion of knowledge and solutions for a cost-efficient and just energy transition, and will benefit strongly from collaborating with international partners within and outside Europe.

4.2 Objectives

The common vision of the CETP SRIA and agreement among European RDI programme owners and managers on the SRIA contributes to **innovation-based growth of the European economy**. Building on comprehensive input papers from SET Plan Stakeholder Groups that crystallize RDI needs, the CETP SRIA aims to concentrate the programme, activities and resources of regional and national RDI programme owners and managers to **science, technology and innovation for Europe's energy transition** and provide an **innovation ecosystem** for the clean energy transition.

The SRIA provides the framework that **strengthens national and regional research, development and innovation policies** by coordinating, pooling and increasing of RDI funding for Europe's pathway towards the energy transition. The need-owner and challenge driven approach together with effective knowledge sharing concepts will enable high impact RDI activities, providing for **faster market diffusion, upscaling and replication of technologies**. Ultimately, the SRIA drives clean energy technologies towards **commercial readiness** and contributes to the success of Europe's energy research, innovation and technology at the global scale.

4.3 Expected Impact

The implementation of the CETP SRIA is expected to create and diffuse **high-quality new knowledge, skills and technologies** and thus **provides solutions** to a well-defined transition. Addressing the CETP Challenges in its transformative RDI programmes that fund RDI projects, the CETP is expected to yield **improved access and higher use of research results, innovation, services and knowledge** for Europe's energy transition. Adherence to principles of open data, open government, a strong emphasis on participatory processes that underlie democratization and decentralization are strong contributing factors to have a high impact. Funded projects involve actors from research, industry, society and policy and span the spectrum from basic technology research to development, piloting and demonstration, as well as the actual implementation of transformative, disruptive and cost-efficient technologies and system solutions.

The transnational joint programming features **advanced call instruments, joint budget cycles, funding rules and call implementation procedures.**

The increased **utilisation and sharing of research infrastructures** in the context of energy related European research infrastructures, particularly those framed by the European Strategy Forum on Research Infrastructures (ESFRI), will foster diffusion of knowledge and open science.

The Europe-wide setting of the SRIA will have a durable **impact on the mobilisation of Europe's energy and innovation community** and, ultimately, global outreach. The SRIA's implementation will encourage **international partners** from outside Europe to join and mutually benefit from a strong cooperative implementation of the SRIA.

The CETP SRIA implementation **strengthens and steers the impact of research and innovation requisite for Europe's climate and energy policies**. Outcomes of RDI activities together with strategic knowledge management will provide an **evidence and fact base for policymaking in support of Europe's energy transition** in domains of innovation, market entry and diffusion, as well as regulation, and procurement.

High on, the SRIA features the **orientation of research and innovation on strong market deployment** of innovative solutions. The SRIA implementation strengthens the **uptake of innovation in society** via demonstration and validation of solutions in **living labs and real-life settings** that mirror Europe's diversity and multiple national and regional pathways towards climate-neutrality. **High quality jobs** will be created by generating innovation-based growth, particularly by transition initiatives that have a strong private-public-partnership character.

5. Pathways to impact: a transformative, system-oriented and transnational joint programming approach

The development of impact pathways is crucial to reach the expected impact of the CETP SRIA. In the following the CETP approaches to develop impact pathways and the principles for SRIA implementation are outlined.

5.1 Approaches towards Impact Pathways

Transnational cooperation for clean energy transition

The urgency for clean energy transition calls for highly efficient actions across Europe which can be reached by transnational and transregional cooperation. The CETP builds on established trust and positive examples of collaboration that are the results of the Horizon 2020 ERA-NETs and Joint Programming Platforms. The transnational approach of the CETP will deliver scale and span that will help Europe realise its ambition to become the world's first climate neutral continent.

Challenge-driven and transformative joint RDI programming

The CETP is a joint RDI programme that follows a challenge-driven and transformative approach to deliver highly transformative RDI outcomes stimulating clean energy transition. Innovation, clear commitment and targeted efforts are needed to achieve an energy system transition at a truly grand scale. However, delivering change that is transformative is still a challenge. The CETP will therefore address challenges identified by "problem" or "need-owners" to deliver transformative outcomes that bring the clean energy transition along. It will connect and orchestrate national innovation actors, activities and resources on European level and build joint capacities on clean energy transition, it will provide room for experimentation in specific technologies or regions and translate and enable learning, replication and upscaling of solutions across European countries and regions.

Trans- and interdisciplinary approach

Delivering change for clean energy transition call for immediate action by multi-actors from research, industry, policy and society. CETP applies a transdisciplinary approach, engaging and empowering the multi-stakeholder community already from the very beginning (e.g. for the development of the Input Papers to the SRIA). It will seek to identify relevant challenges from a "problem owner" or "need owner" point of view, by stimulating co-creation processes with relevant stakeholders. The transdisciplinary approach will also be followed when calling for projects to reach best solutions and highest commitment for actual change towards clean energy. The CETP will apply an interdisciplinary approach bringing together researchers from various disciplines, but with a special emphasis on bringing together knowledge from technology and humanities to reach better solutions in technology development, change of behaviour and change of systems.

Integration of energy technologies and system change

The CETP aims to deliver research and innovation on the integration of energy technologies, energy carriers and sectors to stimulate the system change.

5.2 Implementation Principles of the CETP SRIA

The following principles will guide the SRIA implementation to create and follow impact pathways and reach the highest impact for society, economy and science.

Strategic Research and Innovation Agenda

The Strategic Research and Innovation Agenda co-created by various stakeholders and endorsed by all participating CETP countries is the basis for the CETP. The CETP SRIA builds the common ground for all joint actions . A regular update of the SRIA is planned. Challenges are set from the perspective now in 2020, but over time other challenges will most likely appear.

National coordination of activities, resources and actors towards CETP

National coordination and alignment for clean energy transition is key for transnational coordination and implementation of the SRIA and impact of CETP. To drive clean energy transitions, the mobilisation of various stakeholders from research, industry, policy and civil society as well as the coordination among different policy actors on national, regional and municipal level is needed. Depending on the national context and responsible actors this requires national coordination across ministries, involvement in or contributions to related national strategy processes and/or dedicated actions.

Co-creation, involvement and capacity building at multi-actor level across Europe

Co-creation is key for CETP as a mission oriented and transformative RDI programme to respond to the needs of "problem-" or "need owners" (potential buyers, procurers and users of solutions) and stimulate clean energy transition. Co-creation of the SRIA and strategic priorities of the CETP by industry, public utilities, research organisations, public policy bodies and civil society organisation is key. Involvement of various stakeholders within a transnational clean energy transition community is planned to exchange on research needs, discuss research results, promote good practice and reflect on future RDI priorities and strategies. Capacity building across European countries and regions is an important element to stimulate uptake, replication and upscaling of solutions for clean energy transition.

Strategic relations with other EU partnerships and initiatives

CETP will develop strategic relations with other partnerships under Horizon Europe (see Section 7), other EU initiatives and networks. These relations will enable regular exchange on policy developments, opportunities for joint actions and events or promotion of results to enhance the impact of CETP.

Internationalisation and widening participation

CETP will establish an open governance approach to widen participation within Europe for new countries and regions with the aim to foster clean energy transition across Europe. The continuation of international cooperation, especially within Mission Innovation and the IEA International Energy Agency is planned. Benefits from international cooperation will include the alignment of strategies and research agendas, promoting scientific evidence and good practice on international level, establishing entry points for European cooperation. This strengthens Europe as a role model for clean energy transition and increase competitiveness of European industry.

Joint RDI Funding

CETP builds on 10 energy related ERA-NETs and its portfolio of research and innovation projects and stakeholders. CETP will continue to fund joint RDI projects along the defined challenges . Attention needs to be given to balance knowledge creation, testing, innovation and demonstration efforts and share knowledge across Europe through carefully choosing the most appropriate instrument for the various activities and calls. This is of particular importance as learning and science-policy cooperation from early stages onwards should be prioritised to support co-creation and the uptake of research results in practice. In order to be a transformative RDI programme and stimulate clean energy transition, CETP funded projects need to follow high-level principles:

- *Problem orientation* - address a key challenge from a practical side to implement change in the energy system
- *Stakeholder empowerment* - actively engage and empower entities that seek a solution to a specified need (problem), these can for example be infrastructure providers or utilities, building owners, local/regional authorities, regulators, technology providers etc. throughout the project (in a leading role starting from project development)
- *Innovation orientation* – conduct research and innovation activities that demonstrate how changes can work in practice and support capacity building
- *Output orientation* - deliver clear and useful outputs and solutions that stimulate clean energy transition
- *Transnational benefit* – projects add value and are of mutual benefit to all partners in the different countries
- *Replication, upscaling, market orientation* – design actions in a way that replication, upscaling and market update potential is key from the very beginning

Additional activities to maximise the impact of CETP

The programme management structure of the CETP will aim to develop and coordinate the additional activities. The additional activities have the aim to maximise the impact of CETP and deliver policy recommendations, good practices and solutions, policy and innovation briefs or case studies/demonstrations.

Self-monitoring and evaluation

To keep track of the progress in terms of CETP SRIA implementation and its contribution to achieve the defined goals requires monitoring and evaluation. Monitoring and evaluation will be a central part of the strategy process. It will provide strategic and operational feedback about the appropriateness of selected instruments and the results of specific implementation measures.

6. Overarching RDI challenges for the implementation of the CETP

The CETP SRIA is expected to serve as a guidance and "compass" for the multilateral collaboration of national and regional public RDI funding programmes in Europe and beyond for the next 10 years. It is intended to be a "living document" in a sense, that it shall be revised and updated during the implementation of the CETP (see Section 3). In this context the **CETP Challenges** shall indicate in appropriate detail the overarching main topics and RDI goals that the jointly promoted RDI activities shall aim for.

6.1 From Enabling Technologies towards an Integrated Energy System

Our energy system is not just an "infrastructure" or a "supply system". It is - to a growing extent - a complex and dynamic system of systems, with not only technical but also social, economic, environmental and more dimensions. In order to enable the clean energy transition, innovation is needed on different levels. Starting from the key enabling zero emission technologies over to the provision of efficient energy services with various energy vectors up to the organisation and management of user group specific energy systems and the overall integration into a sustainable, secure and resilient energy system (Figure 3).

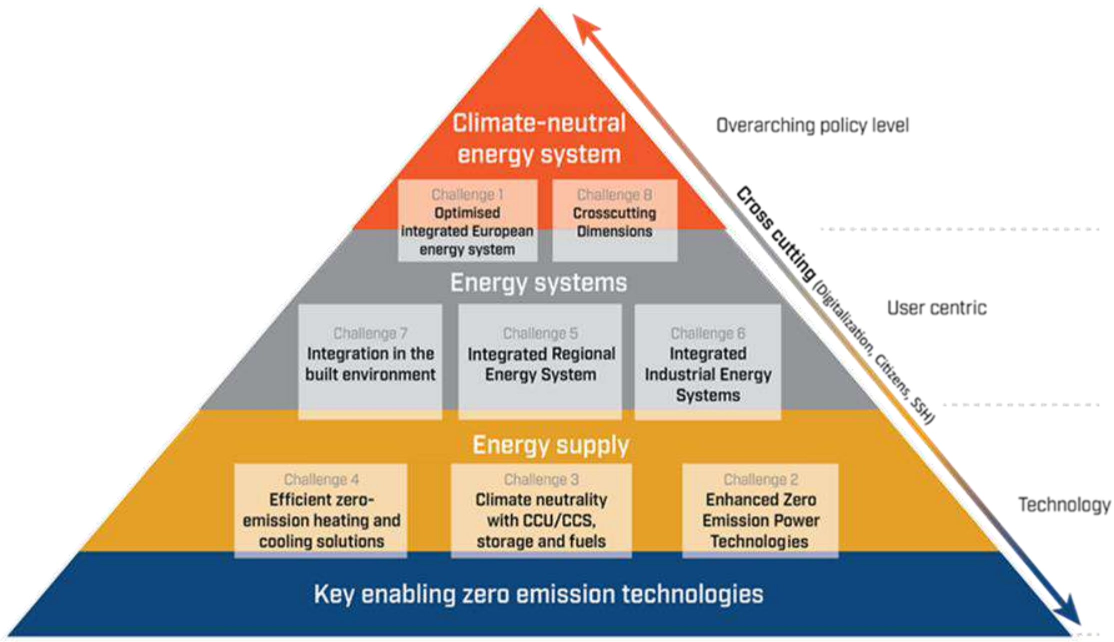

Figure 3 From enabling technologies towards and integrated energy system

A remarkable portfolio of **enabling zero emission technologies** for the energy system has become available in recent years, with a large industrial potential. The ongoing deployment is driving a transformation of energy systems around the world as well as exponential learning curves of these technologies, implicating decrease of production cost per unit as well as gains in efficiency and performance. In combination these energy conversion, storage and process technologies constitute energy system components, providing **energy provision or flexibility services for supply and use** in different energy sectors. For instance, these can be high performing power supply systems. It can be efficient heating and cooling solutions and networks. Or it can be fuel systems, sometimes in combination with carbon processing. In many cases, these technologies exist but need to become more competitive, or regulation is not yet in place, or they are not yet socially accepted.

On a next level, these components have to interact in **user groups specific energy systems**. In the context of the built environment they can help transform existing or new buildings, blocks and districts into active elements in the energy system, providing high level services to their inhabitants or commercial users. Integrated industrial power, heating and cooling systems as well as enhanced processes enable efficient carbon-neutral industrial sites and production, that at the same time provide flexibility to the power system or make access heat available for local networks. The efficient utilisation of high shares of renewables in the regional supply becomes possible with a smart management of available energy sources and infrastructures as well as users from different sectors like communities, commerce and industry or the transportation system. Such integrated regional systems can increase acceptance and uptake of new solutions, by ensuring that citizens, companies, communities and other stakeholders take part in the related exchange of values on different levels.

At the end all these elements are requested to seamlessly link to an **overarching European energy system compatible with climate neutrality**, with a high level of integration among all energy carriers, infrastructures and networks. This will ensure an appropriate level of reliability, resilience and economic efficiency. However, managing the transition on all levels will require the consideration of a number of **cross-cutting dimensions**, like ensuring interoperability and circularity, connecting regional and global innovation ecosystems, ensuring participation and just transition or unleashing the potential of digital transformation.

6.2 The Approach to CETP Challenges

This section outlines the overarching **CETP Challenges** that the joint programming partnership will focus on to support the development towards common goals. At the same time they shall accentuate the contribution that multilateral collaboration can make, complementing the national and regional programs on the one hand and the European programs, notably the new framework program Horizon Europe, on the other hand. The structuring of the SRIA in overarching challenges is also meant to lay the ground for the operationalisation of the innovation management that the CETP will implement with its joint programming initiatives. The CETP Challenges have been structured and formulated based on the following **underlying principles**:

- follow a **challenge-driven approach**, describing “what shall be achieved”
- focus on the **contribution that multilateral collaboration can make** in accordance with national and European programmes
- describe a portfolio of challenges that the CETP wants to focus on while
    - anticipating the formation of a **reasonable number of joint programming initiatives** in variable geometry within the CETP that will make contribution to these challenges
    - assuming that the aim is not to draw sharp borderlines and create new silos, but to **provide structure**; synergies and interlinks between the challenges are natural and will be subject to the active dialogue and collaboration between the related joint programming initiatives within the CETP
- follow the request from MS/AC to collaborate in the CETP
    - on the development of **enabling technologies** for the energy transition
    - on s**ystem integration** aspects to foster the (co-) transition of European energy system(s), contributing to an integrated energy system for a climate-neutral Europe

6.3 The CETP Challenges

Following the approach described above, CETP Challenges are structured in two major groups according technologies (see Section 6.3.1) and system aspects (see Section 6.3.2), plus a bundled presentation of cross-cutting dimensions (see Section 6.3.3) relevant for all other challenges.

The CETP Challenges in a nutshell

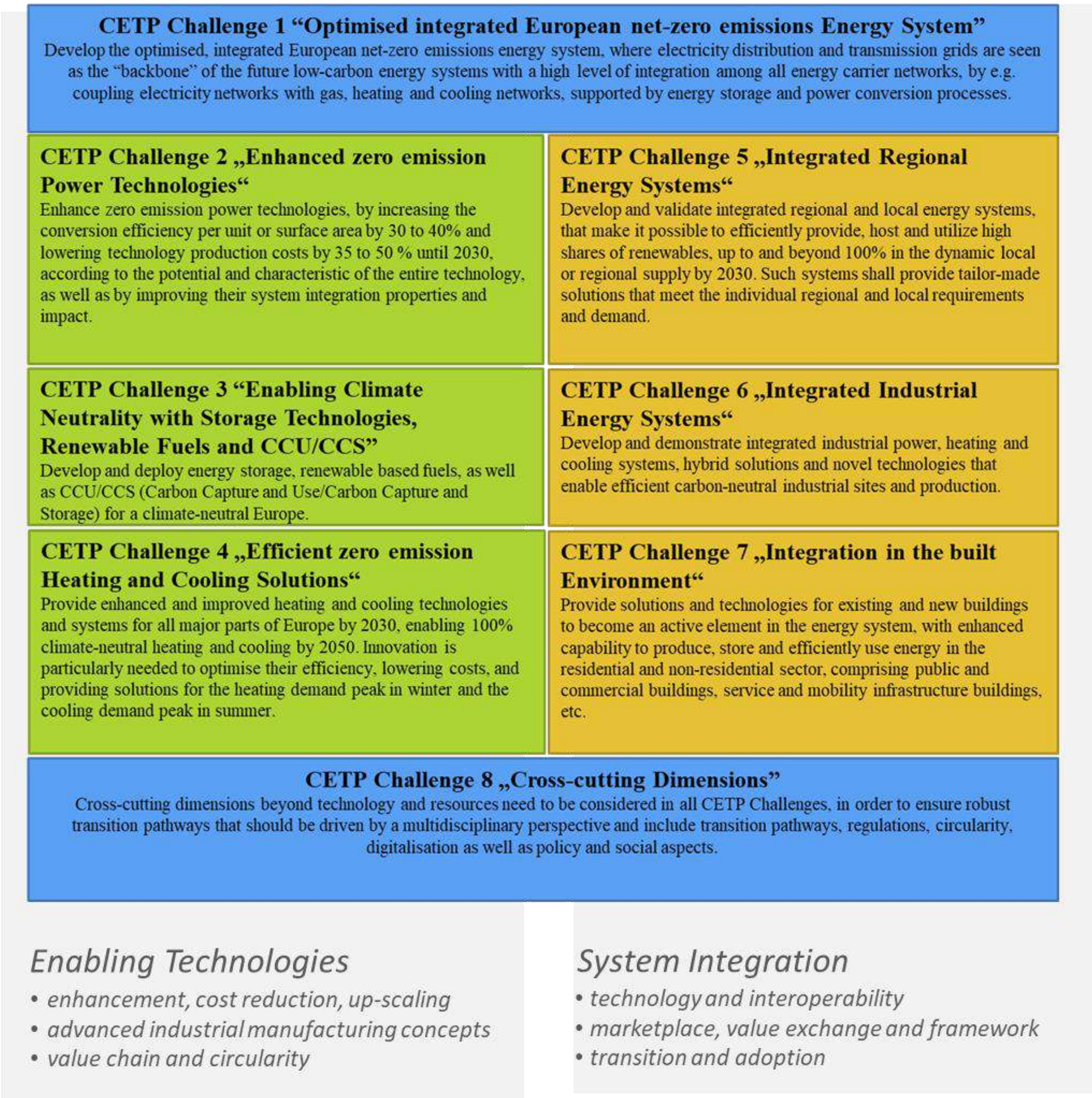

Figure 4 CETP Challenges in a nutshell

The CETP Challenges (Figure 4) are referencing the identified RDI challenges in the SET Plan Stakeholder Groups Dialogues Summary Paper (download) as developed in the course of the SET Plan Stakeholder Groups Dialogues[12] (see Figure 2 and Section 3). The development of the CETP Challenges made intensive use of the identified challenges in the Input Papers provided by the SET Plan Stakeholder

[12] Clean Energy Transition Partnership (CETP) - SET Plan Stakeholder Groups Dialogues, Summary Paper; Overview of Relevant RDI Challenges identified in the SET Plan Stakeholder Groups Dialogues in preparation of the CETP Strategic Research and Innovation Agenda, September 2020.

Groups to the CETP SRIA (Figure 5). A mapping of Input Paper challenges and CETP Challenges in Annex 4 displays the connections .

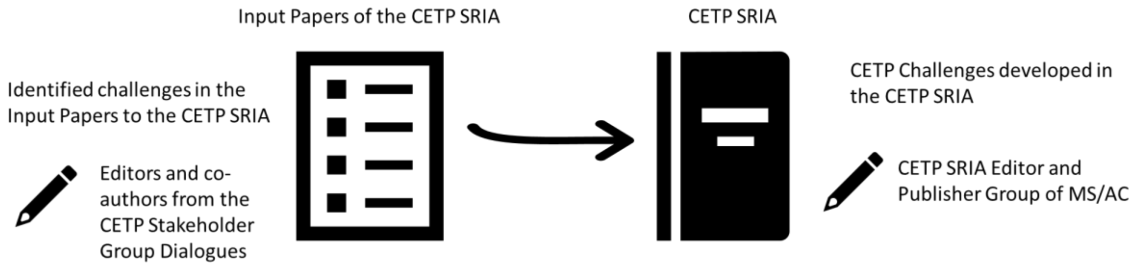

Figure 5 CETP Challenges referencing challenges identified in the SET Plan Stakeholder Groups Dialogues

6.3.1 Enabling Technologies and Energy System Components

There is a broad **portfolio of technologies for energy conversion and storage as well as for providing carbon management and sinks**, that are considered as the enabling renewable energy technologies for the energy system. These are technologies like Concentrated Solar Power (CSP), Solar Thermal (ST), Photovoltaic (PV), Offshore and Onshore Wind, Geothermal energy and heat pumps, Bio Energy and Fuel technologies, Carbon Capture Utilization and Storage (CCU/CCS), Ocean Energy, and Hydropower, etc. Moreover, there are storage technologies such as batteries, thermal storage, hydrogen, and compressed air, but also the technology that will enable a more flexible demand, technologies adding to the electrification and a cleaner industry with power-to-x. What binds them together is their connection to energy. The capabilities of these technologies as enablers in the clean energy transition comes in various shapes. Some can deliver energy. Some can provide energy and storage, while others can provide carbon sinks or enable the capture of carbon from processes and its permanent storage as well as its utilization for new fuels or materials. The enabling technologies themselves need to be explored and improved, including the optimisation of their production processes. And they also combine to **energy system components** such as onshore or offshore wind- or solar parks, offshore or onshore power stations, storage systems or heating and cooling networks, which need innovation to be able to provide the right level of service, flexibility, efficiency, robustness, etc.

Aspects to be considered in this SRIA are e.g.:

- Performance enhancement of technologies, modules and energy system components
- cost reduction and up-scaling of technologies for mass markets
- advanced industrial manufacturing concepts for materials, modules and components
- value chain and circularity aspects: materials, re-use and recycling, services, etc.
- CO_2 footprint reduction and sustainability in accordance with the biodiversity strategy.

6.3.2 System Integration

In its recently published communication[13] "*Powering a climate-neutral economy: An EU Strategy for Energy System Integration*", the European Commission stimulates Energy system integration towards an effective, affordable and deep decarbonisation of the European economy. It builds on the assumption, that "*Europe's energy future must rely on an ever growing share of geographically distributed renewable energies, **integrate different energy carriers flexibly, while remaining resource efficient***

[13] COM(2020) 299 final

and avoiding pollution and biodiversity loss". However, constituting an EU climate-neutral energy system, based on renewables, entails new challenges related to the inherent complexity of such large-scale heterogeneous system. According to the communication, today's energy system is still built on several parallel, vertical energy value chains, which rigidly link specific energy resources with specific end-use sectors. Different networks are planned and managed independently from each other. Market rules are also largely specific to different sectors. This model of separate silos cannot deliver a climate neutral economy. It is technically and economically inefficient and leads to substantial losses in the form of waste heat and low energy efficiency. Thus, **Energy system integration across multiple energy carriers, infrastructures, and consumption sectors** is identified as the pathway towards an effective, affordable and deep decarbonisation of the European economy. Energy system integration ensures, that all available technologies and components of the energy system can work seamlessly together under the conditions of a highly dispersed and distributed system with a rapidly growing number of participants. It enhances the function and efficiency of energy systems and thereby facilitate greater deployment and use of renewable energy. This means, it enables the integration of renewable energy not only into networks and infrastructures, but also into energy markets and the actual supply under the conditions of a highly dynamic system behaviour. And it ensures a high level of resilience and reliability. Required enabling technologies comprise both, physical infrastructures as well as related automation, communication and information technology. Particular emphasis is also necessary to develop the infrastructures themselves, including questions regarding the design, operational management as well as policies and regulations.

In this SRIA, in the context of system integration the need for innovation to be encouraged on the following layers will be considered:

- technology - how to integrate the growing portfolio of energy technologies, energy system components and infrastructures? Related aspects are e.g. enabling technologies for interoperability, system planning and operation, sector coupling, energy distribution and management.
- marketplace - how to organise and enable value exchange on different levels, with increasing dynamic? Related aspects are e.g. market rules, regulation, business processes and business models.
- transition and adoption - how to make the new solutions part of our daily life and business? Related aspects are e.g. user readiness, circularity, tools for system analysis and decision making.

The different integration aspects can be tackled on certain levels of intervention such as

- overarching European level, national level
- (sub-national) regional level
- end-use sector specific, with a particular focus on industry and the built environment

6.3.3 Cross-cutting Dimensions

A number of cross-cutting issues are central in the energy transition. This is natural, as the energy system vice versa plays a key role in the transition of other sectors in society like transport, the built environment and industry. The integration of a number of renewable, storage and low emission technologies into a distributed but still reliable and resilient energy system where consumers play a central role, requires multidimensional innovation, which considers technology as such as well as techno-economic, socio-technical and environmental aspects. The energy transition will take place in the facets between these dimensions. Cross-cutting aspects that are considered to enable and speed up the transition towards a net zero society have been summarised in a "CETP Challenge 8", as they are relevant for a number of CETP- Challenges and shall not be repeated over and over in this document:

- Identifying robust pathways as alternative strategies towards a net zero society
- Accelerate the transition through innovation ecosystems
- Regulation and market design to support optimal resource allocation and value creation both in the short term and long term.
- Policy and actions in support of fair, just and democratic transition
- Encouraging digitalisation of the energy transition processes[14]
- Encouraging transition based on resource efficiency and circularity principles

[14] E.g. the upcoming Digitalisation Action Plan for the Energy System, as announced in the ESI communication

6.4 Detailed Description of CETP Challenges

CETP Challenge 1: **Optimised integrated European net-zero emissions Energy System**

> ***Develop the optimised, integrated European net-zero emissions energy system, where electricity distribution and transmission grids are seen as the "backbone" of the future low-carbon energy systems with a high level of integration among all energy carrier networks, by e.g. coupling electricity networks with gas, heating and cooling networks, supported by energy storage and power conversion processes.*** *Such energy systems will be fully-digitalised, with a high level of automation. They will enable the appropriate level of reliability, resilience and economic efficiency, while integrating variable renewables, such as wind and solar generation by providing increased flexibility thanks to innovative technologies and solutions e.g. enhancing customer participation, better integrating of storage, making the best use of connections with other energy vectors, networks and sectors (e.g. heat and cooling networks, transport sector, etc.) and optimising the use of flexible sustainable combined power and heat generation. Appropriate tools for overarching Energy system analysis, planning and operation will need to be developed.*

Leveraging the indications of the ETIP SNET Roadmap 2020-2030 and the SET Plan IWG4 Implementation plan (revision 2020), RD&I activities needed can be summarized in the following clusters:

- **System modelling and planning- understanding and analysing the integrated energy system of the future**[15]: modelling, design and planning of the Integrated Energy System overcoming the silos among energy vectors. Necessary approaches and tools to plan and analyse the Integrated Energy System under all perspectives: from scenario setting based on reliable and transparent hypotheses, parameters and relations down to integrated and complete planning tools, addressing holistically an energy system where all vectors interact and foster one another. There is a particular need to further develop and connect bottom-up national modelling exercises to consistent European model results, providing a basis for a future-proof industrial investment strategy, infrastructure investment strategy for utilities, and a robust set of national policies. Important aspects of innovative model development are the inclusion of cross-border energy flows, the selection of consistent transnational, transregional and beyond Europe scenarios. This will deliver better consistency and informed policy choices as well as reduced investment uncertainty in industries and utilities. The availability of appropriate and transparent data will be key.
- **System flexibility- robust and clean energy transition pathways**[16]: needs, solutions, and tools to ensure the adequate level of flexibility to cope with all the uncertainties and variabilities of the progressively Integrated Energy System. The flexibility issues addressed in this research area embrace the entire energy system: flexible generation (conventional and renewable), energy storage, networks (e.g. applications of FACTS in the electricity networks, enhancement of electric networks transfer capacities or gas pressure dynamics, including the contribution of energy storage in all forms (e.g. electrochemical, pumped and reservoir hydro, compressed air etc.), the interaction with non-electrical energy vectors (gas, heating, cooling, water, hydrogen, carbon neutral fuels) and conversion (P-t-X); management and controllability of flexibility including communication interfacing). CCS can be used as an enabler to balance the electricity system particularly when there

[15] Research Area RA4 of the ETIP SNET Roadmap 2020-2030 – Planning – holistic architectures and assets
[16] Research Area RA5 of the ETIP SNET Roadmap 2020-2030 – flexibility enablers and system flexibility

is a high share of variable renewable electricity as well as an enabler for hydrogen production and negative emissions.

- **System operation- operational integration of integrated energy systems**[17]: Tools and systems for the development of the overall energy system control architecture (central and decentralized) and optimal operation of the integrated energy system under progressively increasing variabilities, constraints and uncertainties, also linked with extreme events and climate changes. Tools, communication systems and devices for system observability and controllability through advanced monitoring, control and protection, leveraging the advanced forecasting capabilities in all sectors.
- **Economics- market design and regulation for an integrated energy system**[18]: business models, market design, governance and operation linked with the energy system, its opportunities and constraints. Market design for an integrated energy system taking a holistic approach (as opposed to defining optimal market design for separate energy vectors) and taking into account the specifics of different energy vectors so that cost-effective decarbonisation of the EU economy can be achieved. This includes innovations in regulation to achieve efficient development and operation of European energy infrastructures for integrating renewable energy.

Particularly the management of the future European power system will have to rely on a sound interaction of various elements, including power provided from intermitting sources, a portfolio of flexibility options as well as subsystems (e.g. in regions or industrial sites) that are managed in accordance to the overall system. The optimized, integrated energy system therefore must - amongst others -enable a greater flexibility and effective capacity of the power system which, in turn, allows connecting effectively and efficiently an ever-increasing share of variable renewables, particularly from wind and solar and coping with new consumption profiles coming, for instance, from electric vehicles. Conversely, contribution to system flexibility can be gained in several ways: upgrading of the entire electricity value chain (generation, transmission, distribution and customers, and energy storage), reinforcing / creating new links with other energy networks, via for example power to heat/cold, power to gas / liquid and connections with the electrical components of the transport system. Further increasing the capabilities of energy production through the improvement of RES predictability and mechanism for their contribution to systems and network services as well as utilising the potential offered by carbon capture, utilisation (CCU) and storage (CCS).

Interoperability[19] shall allow infrastructure providers, consumers and other technology users to mix appliances, services and solutions from different manufacturers, so optimising consumer choice and facilitating competition among manufacturers. Moreover, it would prevent from being locked-in and tied to products of one and the same company. Smart appliances and all features of energy management which may be used in the future must be able to communicate with each other so that e.g. consumers can switch the supplier easily and move homes without having to change appliances or communication systems, etc. Thus, interoperability will have to be considered as a cross-cutting requirement in innovation activities.

This CETP Challenge ***would comprise challenges*** *as identified by the* SET Plan Stakeholder Groups Dialogues Summary Paper *(download). A detailed mapping can be found in Annex 4. The CETP challenge is not necessarily formulated exclusively based on these challenges.*

Expectations for the transnational collaboration: *The energy systems are interconnected at European level. Especially here, the developments must be aligned and challenges need to be addressed in a*

[17] Research Area RA6 of the ETIP SNET Roadmap 2020-2030 – System operation
[18] Research Area RA2 of the ETIP SNET Roadmap 2020-2030 – System economics
[19] SET Plan Action 3.1 Energy Consumers Implementation Plan November 15, 2018

coordinated manner across Europe. According to needs and potentials, however, the specifics of regional energy systems must be taken into consideration. Therefore, a successful approach must have a local and regional as well as a larger-scale component (CETP Challenge 1 in synergy and complementarity with the other CETP Challenges, particularly 5, 6 and 7). The transnational RDI collaboration based on this SRIA will provide a great opportunity to study and design transregional and transnational as well as trans-sectoral scenarios. It will foster the exchange of experiences and the identification of good practices and thereby facilitate and accelerate the energy transition. The cooperation among national programmes along common agendas will strengthen directionality and effectiveness of the related RDI investments. It will build on experiences, tools and processes developed in the framework of the Joint Programming Platform Smart Energy Systems and other ERA-Nets. Transnational collaboration in the framework of the CETP together with the coordination with EU programs (e.g. BRIDGE) will help establish a systematic, extensive and permanent exchange between regional and national innovation ecosystems (incl. related infrastructure providers) and the European knowledge base.

CETP Challenge 2: Enhanced zero emission Power Technologies

> ***Enhance zero emission power technologies, by increasing the conversion efficiency per unit or surface area by 30 to 40% and lowering technology production costs by 35 to 50 % until 2030, according to the potential and characteristic of the entire technology, as well as by improving their system integration properties and impact.*** *This will require break through innovations beyond scale effects as well as innovating industrial manufacturing concepts for materials, modules and components, resulting in increased lifetime and reliability as well as in reduced maintenance and operation costs. Together with increasing the size of units (wind) and up-scaling, these innovation efforts shall also lead to lower power production cost. Innovation in the design of power technologies shall also improve their compatibility with arising energy system requirements as well as with natures, landscape, multiple soil/land use, fostering sustainability and social acceptance.*

There have been significant advancements recently regarding zero emission power technologies, however, increasing performances and guaranteeing low values for LCOE is still a challenge for some of the emerging technologies and business needs. Resulting increased efficiency and reduced electricity prices as well as enhanced system integration are expected to accredit the further enhancement by promoting the uptake of the technologies and help increasing the sustainability of the energy system as a whole.

Zero emission power technologies include concentrated solar power (CSP), photovoltaics (PV), offshore and onshore wind, geothermal energy, bioenergy, ocean energy and hydropower. The zero emission power technologies are able to deliver carbon neutral electricity, and some of them even provide energy storage functionalities, ancillary services, and increase the system resilience. Innovative hybrid solutions and systems shall also offer increased flexibility engaging different technologies in an integrated manner.

The ambitions in the zero emission power technologies deal with the following challenges[20]:

[20] The contribution at the specific challenge of each technology will be defined on the bases of the expected impacts described in the input papers

- **Higher efficiency:** enhancing performance by innovative materials and technologies and solutions increases produced power per module/unit or area.
- **Lower costs**: cost reduction by increasing size (wind), improving and enhanced lifetime, reliability and operation and maintenance cost (all), scale up systems or decrease material and component costs.
- D**evelop a sustainable production chain** based on a **circular economy approach**, decreasing critical materials and foster the second use and improving recyclability of materials and units.
- **increase sustainability and social acceptance** by increasing integration and compatibility of power technologies with natures, landscape, multiple soil/land use and other solutions for reducing impact. This includes a better understanding of fundamentals (basic science) of the technologies, and their interaction with the environment.
- **Increase production flexibility,** extend use of technologies, testing and piloting the power production in different context application, in real and in extreme weather conditions.
- **Optimize electric power storage** technologies and P2x2P (power to x to power) technologies to cover real-time (milliseconds and seconds), seconds to minutes up to intra-week and seasonal modulation needs (in accordance with Challenge 3, considering and leveraging on relationships between technologies, stakeholders and innovation ecosystems).
- **Hybrid solutions** with the aim of increasing efficiency and lowering cost: integration of two or more renewable energies, integration of power production and energy storage, P2x2P, and production of multiple products or energy carriers.
- **Negative carbon dioxide emissions**, CCU/CCS as enablers for net-zero energy system integration and power technologies.

This CETP Challenge ***would comprise challenges*** *as identified by the* SET Plan Stakeholder Groups Dialogues Summary Paper *(download). A detailed mapping can be found in Annex 4. The CETP challenge is not necessarily formulated exclusively based on these challenges.*

Expectations for the transnational collaboration: *Reaching ambitious EU target in zero emissions power generation while maintaining the technological leadership is the product of a multitude of technological breakthrough and progress from materials to component to system integration. The challenges accompanied with this development have EU-wide and global dimensions. They can be preferably and faster addressed on a transnational level where the contribution of specialist and competence of each country cooperate to valorise their technological achievement thanks also to the transnational market dimension and economy of scale. Sharing competences, taking advantage from advances in components development cross-borders, benefitting from complementary knowledge and industrial capabilities will enable faster development, upscaling and commercialization. The CETP provides the overarching framework to strengthen EU technological leadership in clean energy technologies and the optimal space where hybrid and integrated power technologies can be developed. It will build on the experiences, outcomes and networks from Solar and CSP ERA-Net, Demowind, ERA-Net Bioenergy, Ocean ERA-Net and other ERA-Nets. It provides opportunities for research organisations, material and component suppliers, manufacturers and technology providers, etc. from different countries to set up strong and innovative European value chains for power technologies.*

CETP Challenge 3: **Enabling Climate Neutrality with Storage Technologies, Renewable Fuels and CCU/CCS**

> ***Develop and deploy energy storage, renewable based fuels, as well as CCU/CCS (Carbon Capture and Use/Carbon Capture and Storage) for a climate-neutral Europe****. Storage technologies and solutions need to meet short (seconds and minutes) to medium (intra-day and week) and long term (seasonal) energy storage needs for various energy carriers and provide valuable ancillary services to the energy system. Utilization of a wide range of energy vectors, in particular hydrogen and renewable fuels, as well as hybrid solutions are expected to support cross-sectoral integration. Appropriate liquids and gases, fuel and chemicals technologies will serve flexibility and sector coupling needs in the energy system, and are an important enabler for sector integration with, for example, industry or transport. Finally, CCU/CCS technologies need to be deployed and upscaled to maximise carbon reuse in a circular economy and to remove carbon from the energy system and in particular from hard-to-decarbonize sectors to ultimately deliver negative emissions and to strengthen sector integration with industry*.

Europe's drive towards climate neutrality and integrated energy markets is faced with regionally differing energy policies, meteorological conditions, geography and macroeconomic conditions. An energy system for climate neutrality will have to be facilitated particularly by energy storage and sector coupling, the use of a wide range of sustainable fuels, as wells as the deployment of CCU and CSS technologies. This will ensure flexibility in matching energy supply and demand. Corresponding innovative technologies and solutions for such an energy system will play different roles in different regions, offering a wide range of possibilities for their demand-driven deployment. Innovative solutions for **energy storage** will be key in accounting for temporal and modal shifts of energy supply, demand and consumption. **Fuels and fuel technologies** for hard-to-carbonize sectors (e.g. air and sea transport) will be at the heart of achieving climate neutrality by 2050. Continued development and much-needed implementation of **CCU/CCS technologies including integrated hydrogen production** as renewable fuel of non-biological origin are essential to this challenge.

Energy storage providing flexibility for system integration and sector coupling: the robustness and resilience of Europe's future energy system increasingly depends on the flexibility in the short-term to seasonal response of energy production, transport, conversion and consumption. Solutions such as distributed generation, storage technologies for various energy carriers, energy conversion technologies (e.g. energy carriers, power-to-X), demand-side management need to work together. The solutions for energy storage, fuels and CCU/CCS require a high degree of systems integration. Deployment of solutions require integrated operation of infrastructures, appropriate market designs and regulation. This will require techno-economic analysis and input for modelling energy systems and their networked operations.

Specific technological challenges vary according to related energy sources. For example, concentrated solar power (CSP) needs to enhance its system value by lowering the unit technical cost of electricity and by offering system services via the development of hybrid solutions in combination with other generation and storage technologies. Likewise, reliable and cost-effective **mid- to long term thermal storage systems** need to be further developed, towards a lower unit technical storage cost and applicability in a wider range of applications and settings. Development of materials, reliable and cost-effective systems for **direct solar fuels production** via photo- and/or electrochemical routes can play a crucial role in the forthcoming energy transition.

Sustainable bioenergy can serve as a source of renewable fuels. Finally, bioenergy offers the opportunity to deliver much needed negative emissions when coupled with CCS.

An important factor for Europe's success for flexible storage and sector coupling is the successful build-out and enhanced utilization of its **hydropower storage** capacity with the focus on increasing storage capability through research on dam safety, moderate expansions and flexible operation of existing reservoirs, and increased power output is important. **Thermal energy storage** needs to match the heating and cooling demand profiles and supply profile fluctuations over various time-scales - from hourly to seasonal - and size scales - from building to city level. Advanced reliable and cost-effective low, medium and high-temperature thermal storage systems are needed. **Efficient storage technologies for electric power** need to harness renewable energy supply and storage capacities to meet seconds-to-minutes up to intra-week and seasonal modulation needs. This includes existing as well as radically new solutions for different application scenarios. The **development of cross-sectoral and hybrid energy storage solutions** will promote the efficient inclusion of high shares of renewable and excess energy sources into the energy system. The integration of storage solutions will also require advanced **digital technologies to optimize system performance**.

Renewable based liquid and gaseous fuels are not only environmentally friendly energy carriers but also an important flexibility option required to achieve a sustainable energy system. Important for a net-zero energy system is the cost-effective provision of thermo-chemical, photo and electro-chemical solar fuels, as well as the supply of advanced biofuels from sustainable biomass. Renewable fuel and particularly, integrated bio-fuels and bioenergy production when coupled with power-to-X (e.g. biogas or biosyngas upgrading, solar fuels) and CCU/CCS offer major opportunities for greenhouse gas mitigation and the supply of negative emissions. The provision of such renewable fuels is crucial for industry as well as for the residential and transport sectors. Low cost production of such fuels to meet the needs of specific market segments (heavy-duty road transport, shipping, aviation, heat and power generation) require a clear strategy for entry.

CCS/CCU and in hard-to-decarbonise sectors of Europe's economy (industry, refining sector, energy sector) is crucial for realizing Europe's ambition for carbon neutrality. In addition, CCS on waste-to-energy/value plants is critical for delivering much-needed and large-scale negative emissions that offset **hard-to-decarbonise industrial sectors**, the **agricultural** sector and the **transport** sector. The focus will be on: getting the commercial framework right, accelerating timely deployment at scale of CCS and CCU technologies, driving down costs, and enabling rapid scale-up to deliver on the climate goals). **CCU** is, however, essential for maximizing carbon recycle and thus is a major contributor for Europe's **circular economy.**

Europe's goal of a **hydrogen economy** can be met cost-effectively when considering the production of **green and blue hydrogen**, particularly during integrated natural gas reforming and CO2 capture. Hydrogen enables the decarbonisation of the heating/cooling of the building stock, transport sector, power sector and other industrial facilities. However, upscaling of Europe's hydrogen infrastructure, liquid hydrogen conditioning as well as the large-scale, safe transport of liquate hydrogen energy carriers are major challenges.

Since hydrogen will be critical for the Clean Energy Transition and for reaching climate neutrality by 2050, it is crucial to coordinate the R&I initiatives between the CETP and the Clean Hydrogen partnership (e.g. where is blue vs. green hydrogen covered and what can be the topics for collaboration). In the short and medium term, hydrogen from reformed natural gas with CCS can kick start the hydrogen economy, enabling infrastructure build-out and early, large volumes of hydrogen for the chemical industry, the oil-refining industry and for electricity production; thus, paving the way for hydrogen from renewables.

This CETP Challenge ***would comprise challenges*** *as identified by the* SET Plan Stakeholder Groups Dialogues Summary Paper *(download). A detailed mapping can be found in Annex 4. The CETP challenge is not necessarily formulated exclusively based on these challenges.*

Expectations for the transnational collaboration: *The challenge is perfectly suited for transnational programming in Europe and beyond, due to the excellent alignment with national and regional RDI programming. Projects that address the challenge will be substantial in terms of technical and social sciences scope, as well as in environmental and geographical scopes and industry and business related issues. With the challenge in place, financial leverage of regional/national funding is expected to be significant and thus help deliver comprehensive RDI projects. The added-value for value chains in storage technologies and services, renewable fuels, and carbon capture utilisation and storage technologies is expected to grow much stronger, provided the ongoing ERANETs, particularly ACT and Bioenergy, are fully transitioned into the CETP with good practices being preserved and replicated. Responders to calls set up under this challenge are expected to encompass European technology companies and research organisations, builders and operators of European energy infrastructures, original equipment and component manufactures as well as materials suppliers. Deployment and market diffusion of technologies and solutions developed in response to this challenge are expected to be engines for job growth, essential knowledge sharing and will strengthen European value chains thus contributing to a just transition.*

CETP Challenge 4: **Efficient zero emission Heating and Cooling Solutions**

> ***Provide enhanced and improved heating and cooling technologies and systems for all major parts of Europe by 2030, enabling 100% climate-neutral heating and cooling by 2050. Innovation is particularly needed to optimise their efficiency, lowering costs, and providing solutions for the heating demand peak in winter and the cooling demand peak in summer.*** *This requires innovations in geothermal energy and solar thermal techniques for heating and cooling, cost-effective solutions to utilize various sources of ambient heat and excess heat, and also advances in distribution and conversion technologies. A close interconnection between sources and their temperature level, conversion and distribution technologies, and the end-user requirements is mandatory. Efficient heating and cooling solutions shall be made available for specific end-user, or groups of end-users, featuring a fit-for-purpose end user system, as well as affordable and robust local sources of heating or cooling, either subsurface or above ground. Between source and the end user, thermal storage technologies at various time and size scales, conversion technologies such as heat pumps, and local distribution networks will determine the energetic, exergetic and cost efficiency of the various concepts. A significant focus should be on technologies suitable for retrofit.*

Heating and cooling must be supplied locally and should be developed with an eye on the application. Temperature matters, as e. g. low temperature heating grids can be supplied by a broader range of renewable sources. Exploiting the possibilities of low-temperature heat and cold sources, balancing heating and cooling in the various applications and at various scales, short-time to seasonal storage (see also CETP Challenge 3) for excess heating and cooling (including excess thermal energy generated from excess renewable electricity), and providing cost-efficient climate-neutral sources for the annual balance of the heating and cooling demand need cost-effective and robust technologies.

This challenge includes innovation for collective heating and cooling systems, such as e.g. low temperature networks that enable integration of heat from different sources or affordable systems providing seasonal transfer of energy, but also for individual buildings (feeding into CETP Challenge

7- Integration in the built environment) and for process heat and cold for industry (feeding into CETP Challenge 6 - Industrial Energy Systems). It also includes the technologies which can supply and adjust the annual balance: heat pumping technologies, solar thermal heating and cooling, geothermal, and biomass. While the focus will be on developing solutions for today's challenges, better understanding the fundamentals of these technologies could also be part of the work.

Concept and envisaged solutions

Efficient heating and cooling solutions require a fit between end user system, heat and cold sources (underground or above ground), distribution and conversion technologies and thermal storage (CETP Challenge 3). While CETP Challenge 4 'heating and cooling' focuses on technologies and concepts, system integration and cross-cutting issues should be paid due attention, so there will be collaboration with system-related CETP Challenges (CETP Challenge 5, 6 and 7).

Next to the development and implementation of cost-effective and energy-efficient innovative heating & cooling grids (like 4th& 5th generation grids), key for a fast progress in heating and cooling is also the transformation of already existing (fossil driven) heating and cooling grids. These infrastructures can be used to supply a large part of the society with renewable energy using a holistic approach for a system change including the grids and the available sources.

Important challenges include:

Heating and cooling technologies

- Advances in geothermal energy technology, as identified in the SET Plan Implementation Working Plan Deep Geothermal
- Advances in solar thermal, as identified in the solar thermal input paper
- Thermal storage technologies at different size and time scales, in accordance with CETP Challenge 3

Collective systems for the built environment

- Cost effective retrofitting of existing districts through affordable, highly efficient, easy to install, and intelligent heating and cooling networks including innovative storage concepts.
- Develop and validate robust and efficient local heating and cooling sources, including solar thermal, geothermal, various ambient sources (ambient air, surface water, seawater) but also excess heating and cooling sources.
- Develop and validate robust and efficient seasonal thermal storage solutions for various settings, in accordance with CETP Challenge 3.
- Develop and validate improved robust and efficient conversion technologies and distribution networks, to get the heating and cooling at the end-user at the right temperature level
- Integrated solutions for the next generation of district heating and cooling networks.

Individual buildings

- Cost effective retrofitting of existing buildings, with affordable, compact, highly efficient, easy to install, and intelligent renovation kits including innovative storage concepts
- Optimised heating and cooling systems for individual new buildings.

Industrial heating and cooling

- High-temperature heat pumping technologies for industrial heating

- Further develop and validate solar and geothermal heating for high-temperature industrial applications.

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Expectations for the transnational collaboration: *The heating transition is a key challenge in many European countries. It is important to join forces on a European level. Several European countries mention that it is important to collaborate on various topics related to heating and cooling, such as geothermal, next generation of district heating and cooling systems, sharing knowledge and experiences, low enthalpy heat sources, and solar cooling. Transnational collaboration under the CETP can build on the experiences and networks of GEOTHERMICA and other ERA-Nets. Larger markets and more efficient use of member state funding, jointly developing capabilities that many countries need - these are some of the reasons that justify the heating and cooling Challenge within CETP.*

CETP Challenge 5: **Integrated Regional Energy Systems**

> ***Develop and validate integrated regional and local energy systems, that make it possible to efficiently provide, host and utilize high shares of renewables, up to and beyond 100% in the dynamic local or regional supply by 2030. Such systems shall provide tailor-made solutions that meet the individual regional and local requirements and demand.*** *They shall leverage synergies and utilize flexibilities in locally and regionally available energy sources and related production characteristics, the local and regional infrastructures as well as the user and consumer structures from different sectors (including e.g. communities, industry facilities, or the transportation system) and related consumption patterns. At the same time such systems shall contribute to a secure and resilient European energy system, enabling the participation in inter-regional exchange of energy as well as in sharing responsibility to maintain the overall system, considering a sustainable use of local and global resources. Solutions shall be designed in a way they enable citizens, companies, communities and other stakeholders to partake in the related value chains and the exchange of values on different levels, including the development of appropriate market and business models.*

This will imply to modernise and enhance infrastructure (specifically smart grids) as a key enabler, develop and adapt energy system components to become interoperable in the energy system as well as to unleash the potential of digital transformation for the regional energy system transition. The development of regional and local energy systems should be orchestrated within a large framework to reach the maximum impact so that all relevant stakeholders of the local and regional (SMEs, infrastructure providers, crafts, etc.) but also the global innovation ecosystems (start-ups, etc.) are involved.

Innovation for regional integration is required along the following **three dimensions**:

Smart energy system integration. From a technical perspective, new solutions must optimise the integration of renewable energy, provide infrastructure that can host generation and demand (in some cases a large number of distributed units), increase flexibility by efficiently integrating different energy carriers as well as utilising (local) storage, network flexibility, supply side coordination and demand side response. They should also provide technology service systems that support highly dynamic business processes with a large number of participants enabling the implementation of complex business models serving different market participants such as individual consumers and prosumers or customer groups and energy communities, as well as system operators, facility managers, energy suppliers, service providers and aggregators.

Cross-sectoral integration. On a local or regional level, smart energy activities often involve multiple economic sectors. Particularly that means cross-sectoral integration of smart energy systems and energy transition processes with transport (e.g. vehicle-to-grid- including concepts for optimal integration of e-mobility vehicle charging of as well as and using the storage capacities of e-mobile fleets for the management distribution grids) or industry and trade (e.g. industrial facilities or data centres, requiring electricity and providing waste heat, enterprises or stores and buildings using their large thermal storage capacities for excess electricity and balancing the electricity grid, etc.), or municipal infrastructure (e.g. heating and cooling networks, water supply and sanitation, public transport, buildings, street lighting) or agriculture (e.g. farms as facilities to generate renewable energy and fuels, flexibilise demand patterns, etc.).

Innovation ecosystems and Integration with local & regional development. The energy system transformation must be sustainably integrated and adopted to local and regional processes, which means driven by local municipalities, communities, industry and stakeholders. We need to better understand local and regional processes and the implementation paths of innovative energy systems. Beyond the well-established research and development division (RDD) stakeholders from industry, research institutes and universities, key players of the local and regional energy and innovation eco-system (e.g. local councils and local municipalities, consumers, infrastructure providers, etc) will have to be involved. Supporting new cooperative approaches as well as common standards will not only strengthen local and regional transition dynamics and entrepreneurship, but also enable steps towards EU level solutions in the integration of energy systems. This will help sustain European industrial leadership in sustainable energy solutions worldwide while paving the way to a low-carbon economy.

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***Expectations for the transnational collaboration**: Some regions are dominated by large urban systems. In many, the integration of municipalities and strengthening smart energy communities is of particular interest. Some require a focus on the integration of industry, others of the agriculture sector, some on the design of specific solutions addressing tourism facilities and resorts. Transnational collaboration will help obtain more in-depth understanding of different infrastructural and socio- economic contexts within which the energy transition is taking place across Europe. Knowledge transfer and the transfer of solutions to other regions with similar conditions, larger markets for solution providers and more efficient use of resources will speed up the co-transition of regional energy systems. The CETP can build on experiences and networks from the Joint Programming Platform Smart Energy Systems and other ERA-Nets in connecting relevant programs and initiatives. The enhanced exchange between the European and the local and regional innovation ecosystems will speed up the learning.*

CETP Challenge 6: **Integrated Industrial Energy Systems**

***Develop and demonstrate integrated industrial power, heating and cooling systems, hybrid solutions and novel technologies that enable efficient carbon-neutral industrial sites and production.** In the future, electricity will play a significant role as a "primary" energy source for the industries and new innovations are needed to accomplish the transformation of industrial* *electrification. Further, a large share of the industrial energy supply shall be based on renewable sources. Where carbon emissions cannot be avoided, CO_2 shall be captured, utilized for production of preferably long-lifetime products or permanently stored. To produce negative emissions, capture and storage of biogenic CO_2 from the exhaust gases, i.e. bio-CCS, is an option. While the energy transition of industries advance*

s, industrial energy systems shall integrate with local, regional and national heat and power networks and systems. Moreover, the energy and industrial systems as a whole shall integrate as renewable power will also be used to produce hydrogen which can be utilized as energy carrier or raw material in industrial processes or with CO_2 utilization (CCU) to synthesize e-products for the replacement of fossil-based fuels and chemicals. E-fuels may serve as power storage and, as the integration of the energy and industrial systems proceeds, new flexibility sources, e.g. extended industrial demand response, shall be established.

Due to the significant amounts of difficult-to-avoid CO_2 emissions from the energy-intensive industries, building a climate-neutral energy system of the future requires the involvement of these industries. In fact, these industries have to be developed as part of the entire energy system. Fortunately, European process industries are fully supportive to the mitigation of greenhouse gas emissions and to helping to meet the objectives of the Paris Agreement and the EU's target of a climate neutral economy. Process industries are, however, very capital intensive. Shifting to innovative technologies and processes and operating them at industrial scale will entail high technological and economic risks due to the international competition. To mitigate those risks, European technologies need to be supported by research in industrial deployment. While some enabling technologies are advancing well, their integration into the production systems as well as high operating costs still remain a challenge.

In order to establish carbon-neutrality in industrial (energy) systems, several development steps are needed. Decentralized, renewable-based electrification of industrial processes is an important innovation challenge. In a carbon-neutral society of the future, electricity from renewable sources will play a significant role also for the industries and therefore the demand will increase drastically. All forms of renewable power production, *e.g.*, on- and offshore wind, ocean energy, hydropower and solar power, require research and development activities to improve their technological performance, to tackle different aspects of system integration and to lower the costs.

Another important step is to introduce, develop and deploy new renewable heating and cooling solutions in the industries. Solar thermal, geothermal and bioenergy, for example, provide sustainable sources of renewable heat. The full utilization of their potential still requires essential developments in sector coupling concepts and innovative new combined solutions. Another option is to adopt large-scale heat pumps but that still requires improvements in cost-effectiveness. Electrification of heating (Power-to-heat, P2H) in heavy process industries is also possible but calls for product and material development to cope with the needed high temperatures. In addition to switching to renewable sources of heat and cool or to electricity, emissions can be reduced and energy saved in the industries by developing new combined solutions including also thermal storage and by utilising digital energy management systems. Furthermore, the energy that is produced as a side stream of industries can be fully utilized by developing and deploying innovative solutions for system integration. Sector coupling can, for instance, allow surplus electricity or heat to provide heating and cooling for both local buildings and other industries.

The third required step on the way to industrial climate-neutrality involves introduction of renewable hydrogen as an energy carrier and/or a raw material for industrial processes. Hydrogen provides opportunities to decarbonize high-grade heat and/or to replace carbon-intensive feedstocks (e.g. steel, ammonia, refining and petrochemicals). It is also possible to combine hydrogen with carbon dioxide into different hydrocarbon products (e-products) such as chemicals, synthetic fuels (e-fuels), methane and even food. This concept is often referred as to Power-2-X or P2X. E-fuels can also be used for energy storage, which brings the much-needed flexibility to the energy system. Further, X-to-power (X2P) refers to technologies that convert the stored power from e-fuels back to electricity. Cost-effective production of renewable hydrogen and related infrastructure solutions at industrial sites still require research and development efforts. Moreover, technologies for the production of cost-competitive e-products as well as technologies for efficient X2P need to be researched, too.

Further, one important possibility for the process industries on their way to climate-neutrality is to switch to bio-based carbon reactants, e.g. bio-carbon, and replace fossil carbon in their processes. This will significantly reduce the fossil carbon emission from such industries. Research and development is needed on the availability of suitable and sustainable bio-resources, the technical quality of the bio-based reactants and for lowering the production costs.

Bringing carbon capture and utilization (CCU) technologies to commercial scale and their deployment would enable carbon circularity in the full industrial system. As described, the captured CO2 can be combined with hydrogen to synthesize different types of e-products. Innovative processing technologies and novel hybrid solutions need to be developed to produce cost-competitive e-products that can replace fossil counterparts in the already existing, enormous markets. Long-lifetime products would serve as carbon storages whereas short-lifetime e-fuels would send the carbon back the cycle via X2P. Driving costs down for the already invented CO2 capture solutions still requires development work and more research is needed to create next generation capture technologies. Furthermore, CO2 processing technologies need further development to enable rapid scale-up and achieve large-scale deployment of CCU. To produce negative emissions, capture and storage of biogenic CO2 from the industrial exhaust gases, i.e. bio-CCS, is an option.

Extensive cross-sectoral cooperation is needed to facilitate this enormous integration of the energy and industry sectors. Building climate-neutrality will require development and adoption of new technologies, new regulatory frameworks and new business models. As a first step, a greater sector-coupling within energy is needed (electricity, heat, cool, gas). In the long run, the entire energy-industry system needs to become more flexible and adaptable and the system must involve new mechanisms for extended industrial energy demand response.

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Expectations for the transnational collaboration: *The integration of industrial energy systems with local, regional or trans-regional energy systems support national and European goals for carbon-neutrality. As RDI activities for industrial carbon-neutrality are already funded at a national level in many countries, a broader experience and knowledge sharing at an international level will be an advantage. Transnational co-operation will boost efficient technology transfer and leverage complementarities for building competitive European value chains.*

CETP Challenge 7: Integration in the built Environment

Provide solutions and technologies for existing and new buildings to become an active element in the energy system, with enhanced capability to produce, store and efficiently use energy in the residential and non-residential sector, comprising public and commercial buildings, service and mobility infrastructure buildings, etc. *They will enable the climate neutrality of the building* *stock in Europe, by fostering the penetration of renewable energy production as well as the number of producing and prosuming buildings. Particular solutions shall contribute to the European target to renovate 25 Mio building units by 2030. Innovation will boost capabilities for the integration of energy services with storage and fuel systems in the built environment with building modules and components, active facades, glass elements and roofs, building elements as a storage, building management, etc. Buildings as an active element will contribute to the integration in the energy system while increasing performance, stability and resilience of the energy system. Affordable solutions for integration of energy technologies in the built environment will lead to limited soil consumption, increased inclusiveness, both contributing to social acceptance.*

Innovative solutions and technologies will be developed and will help to integrate renewable energy conversion technologies for power, heat and cold in buildings, to connect buildings with power and heating/cooling networks and to integrate energy storage and zero emission fuel or activate building parts as energy storage. This will include solutions for existing buildings, including historical buildings, contributing to a massive reduction in Europe's CO2 emissions by doubling the rate of building renovation to 2% by 2030. The focus on this CETP challenge is on integrated energy solutions for the built environment. Innovations for energy-efficient buildings are of crucial importance, too, but they are not in focus here. Digitisation plays an increasingly important role in these more and more complex systems during planning, construction phase, commissioning and operation. The development of future-proof methods of building energy performance assessment will support the transition to a carbon-neutral housing stock. To intensify the transfer of research and innovation into building practice a broader application and demonstration of outstanding concepts for new and existing buildings and neighbourhoods is needed. The transformation towards a carbon neutral building stock requires an integrated approach which takes societal issues and the economy as serious factors, which creates acceptance and includes the need of education and training of actors, architectural issues, urban planning and synergies with the transport sector.

The renewable energy production integrated in individual buildings and blocks is expected to enhance its contribution to the reduction of emission in synergies of the widespread of energy communities, positive energy districts (PED) and climate neutral cities policies. All these new paradigms for energy integration with the built environment will open new markets for building modules and components such as energy active windows, façade elements, roof tiles, sun-shading units, etc., will increase the number of jobs and create new professional roles. Research and innovation challenges can be identified for a massive integration of clean energy technologies in buildings, such as

- **Energy integration in building or block** by development of highly efficient energy conversion systems, their integration into the buildings supply-chain and an integrated-design approach where the specifications of the energy production take into account the overall optimization of the building system in terms of energy management, storage and operation (e.g. electrical interconnections, thermal and lighting management solutions ensuring safety and an easy installation), aesthetic and environmental impact, functionality, and economical availability (to ensure an inclusive, just transition also in regions with energy poverty and in social buildings).
- **Building concepts** that best support a highly efficient energy system such as Solar Energy Buildings, Nearly Zero Energy Buildings, etc.
- **Old, historical and special buildings** in which renewable energy production need to highly consider the aesthetic impact and the architectural constraints. Furthermore, retrofit strategies (standardization, prefabrication, serial renovation, etc.) and solutions for zero emission heating and

cooling and integration with renewable energy production should be developed. A sound strategy needs to be developed.

- **Large public and private building, commercial malls, service and mobility infrastructures, logistic platforms** (ports, airports and railway terminals or roads and large parking areas) are characterized by large surfaces and can be used for renewable energy production at intermediate scale with a high possibility of integration with the local consumption needs and services. The possibility of integrating production with solutions for energy storage and energy conversion is crucial for powering different energy services which are significant at this scale.
- **Dedicated innovative and emerging technologies** that can be developed at the building level for a clean transition are:
  - Development and integration of highly efficient renewable technologies for active facades, glass elements, roofs: mainly but not exclusively based on solar innovative technologies (building integrated PV/solar thermal/PVT technologies) .
  - Integrated thermal and electrical storage systems and heat and power technologies
  - Climate neutral fuels obtained/converted in the built environment
  - Innovative solutions for CHP/CCHP and p2x2p (power to x to power)
- **Cross-cutting issues of system integration are:**
  - Effective planning and decision-support tools and maps of renewable energy opportunities for urban planning and policy makers, integrating LCOH calculations
  - Integration of the building in the energy districts and communities by means of virtual connections and data exchange systems;
  - Design of new software and hardware architectures for managing a highly digitalized new multi-directional energy system.
  - regulatory and market solutions for increased effective applications of the energy in the built environment; mobility /transport included (e.g. charging of electrical cars).
  - Challenge 7 will also relate to the progress made in Challenges 2, 3 and 4 .

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***Expectations for the transnational collaboration:** Collaboration among national programs will support fast-track development of energy integration in buildings and will guarantee economies of scale while also considering different climate context. The prospects of standardized solutions, components and modules will benefit from larger markets and contribute to the efficient use of member state funding. Furthermore, the diffusion of knowledge is the base of efficient responses in the integration of zero emission energy in existing, historical and special buildings as well as in mobility infrastructure (port airport, railway station) where the possibility of a wide UE and international market is crucial. The CETP can build on the experience and networks of ERA-Nets and SET - Plan initiatives (e.g. IWG 5) in connecting relevant stakeholders and programmes.*

CETP Challenge 8: Cross-cutting Dimensions

Cross-cutting dimensions beyond technology and resources need to be considered in all CETP Challenges, in order to ensure robust transition pathways that should be driven by a

multidisciplinary perspective and include transition pathways, regulations, circularity, digitalisation as well as policy and social aspects. *The pivotal role of societal stakeholders and innovation ecosystems that engage in transdisciplinary demonstration, innovation and research activities is important and requires adequate framework conditions. Aspects like regulatory frameworks, tariffs, education and training shall accelerate the fulfilment of climate and energy ambitions in the EU.*

Considering the importance of the energy sector in the society and the economy, moving towards climate neutrality will have a significant impact that needs to be addressed beyond technologies and resources. The cross-cutting dimensions are crucial to align transition with industrial and societal goals to mobilise businesses and citizens. Engaging and empowering different actors and societal stakeholders need an adequate set of framework conditions to support the implementation of a fair and just energy transition in the EU. The challenge is to guarantee alignment and coordination of all sectors to accelerate climate neutrality of the European energy system in a sustainable way, including the following subchallenges:

Robust transition pathways for a sustainable integrated European energy system

This challenge concerns methodology and analysis in support of the energy transition by focusing on transition pathways. A large variety of transition strategies could potentially achieve climate neutrality by 2050, taking into account regional diversities and different policy and technology strategies towards 2030 and 2050, as well as specific territorial, political, societal and industrial factors. This in turn requires the integration of energy infrastructures across borders between energy vectors and from European to local level.

Accelerating transition and innovation ecosystems

The process of accelerated energy transition primarily includes (i) radical system and service innovations and (ii) massive deployment of integrated energy systems combining existing and new technologies. New policies need to be put into place along with a new financing structure and new business models. This also includes the diversity of socio-economic contexts across Europe as well as "Willingness To Pay" from consumers and stakeholders according to the different business models. The overall challenge is aligning transition, societal and industrial goals in order to mobilise citizens and businesses as well as legitimise transition policies, while at the same time de-legitimising unsustainable practices.

Developing policies and actions to ensure a fair, just and democratic transition

Fairness and justice principles (including procedural, recognition and distributional ones) should be at the centre of designing and implementing clean energy technology transition solutions. For this, relevant methods and tools from social sciences and humanities need to be applied. The main questions to be explored with the regard of this challenge relate to (i) inclusive policy-making process, (ii) acknowledging societal groups who are beneficiaries and losers of particular transition strategies, (iii) understanding potential levels of these impacts and how to measure them.

Encouraging transition based on resource efficiency and circularity principles

Circularity is a paradigm that, acknowledging resource scarcity (materials and energy), strives to make the best of available resources, extracting from them the maximum benefit possible through appropriate choice of materials, increased component/device lifetime, materials recycling/reuse and energy recuperation.

Regulation and market design to support optimal resource allocation and value creation both in the short term and long term

The ultimate goal of market design and regulation for an integrated energy system is an appropriate coordination between all energy vectors in order to achieve the most cost-efficient resource allocation both in the long run and in the short run. This includes incentives to ensure optimal investments and operations for a secure and reliable integrated energy system. The mono-sectoral, national focus needs to be integrated in order to develop the European energy infrastructure of the future. To understand the potential effects of changes in policy and regulation in this area, holistic system modelling as well as evidence based knowledge from sandboxes is needed.

Encouraging digitalisation of the energy transition processes

The digital transformation is affecting all types of economic sectors. Understanding digital transformation and its implications on aspects like business models, the operation and management of assets, markets and business processes or on communication processes, can play a fundamental role to unleash its potential to support and accelerate the energy transition. There are many parts of the existing European energy systems with low digitalisation levels and a big effort is needed to achieve appropriate digitalisation levels so as to allow real market integration, energy system integration and user empowerment.

In this context, these actions among others need to be implemented, namely the following:

- Identifying main challenges in different socio-economic contexts, **actors and mechanisms** that currently drive the acceleration of energy transition, as well as others to identify **new ways for cooperation as well as financing schemes** between public and private sectors to accelerate the energy transition
- Creating and reinforcing regional stakeholder **innovation ecosystems** with co-creation of solutions with diverse groups of stakeholders from local communities, industry and public sector decision makers to strengthen local value chains and bridging them with global networks (e.g. start-up networks or RDI networks) for mutual exchange of knowledge, technology and best practices
- Identifying innovations generated by ecosystems (systems, services, processes and technologies) to deliver solutions that simultaneously and measurably advance Technology Readiness Levels (TRL) and Societal Readiness Levels (SRL), requiring **integrated TRL-SRL assessment** methods that include and combine societal, technological, environmental, spatial, regulatory and other critical aspects.
- Build up roadmaps to accelerate the implementation of new innovations in commercial investments also in public procurements. From the side of the different stakeholders, consider Willingness to Pay according to the different business models targeting policy frameworks along with regulatory and standardisation, in an integrated manner considering technology, systems and digitalisation, socio-economic aspects, in a complex environment of **multi-level, multi-sectoral, multi-functional, and multi-type nature of the energy system planning and operation**.
- Structuring **interdisciplinary education and cross-sectoral training** and implementing collaboration between countries when organizing cross-sectoral initiatives.

The development of Key Performance Indicators (KPI's) for climate neutral energy systems is crucial and guide policy makers and actors when designing, analysing and implementing clean energy transition solutions including those of social justice and fairness principles. Methods and tools need to be put in place to measure and monitor achievements in an integrated manner including cross-cutting dimensions. This will mobilise "All" to accept advancements for implementation and meet targets set up for an effective energy transition.

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Expectations for the transnational collaboration: *This challenge is cross cutting with all other CETP challenges and relevant aspects will become an integral part of the other challenges during the implementation phase of the CETP. The benefit for addressing also cross-cutting issues in a transnational approach is that good practice and learnings can be shared across Europe to make the transition pathways robust across Europe (see also Section 6.3.3).*

7. Interfaces with other RDI Initiatives in Horizon Europe and International Cooperation

To maximise its impact and capability to deliver on its ambitious RDI objectives, the CETP has identified cooperation opportunities with a relevant number of actors in the EU funding landscape. The goal is to avoid duplication and search for synergies and complementarities to better leverage the available resources for the energy transition to happen.

European Partnerships

Horizon Europe requests that the partnerships establish a formal and regulative collaboration with other relevant R&D initiatives to ensure an optimal interconnectivity and efficiency. As stated in the EC document ***Coherence and synergies of candidate European partnerships under Horizon Europe***[21] issued October 2020, the partnerships are encouraged to coordinate their activities with others and reflect this in the governance model and in joint actions.

The CETP has identified interfaces with mainly partnerships in the same Cluster (Climate, Energy and Mobility) alongside connections with partnerships in the Cluster for Digitalisation, Industry and Space, on areas relevant to the objectives of the CETP. Synergies and complementary with the EIT KICs Climate and Innoenergy are envisaged as well.

Cooperation with relevant partnerships is pursued on two level:

- Strategy development: aiming at identifying gaps in specific R&I areas of common interest, as well as avoiding overlaps and exploiting synergies.
- Implementation: identification of joint activities in the context of the annual work programmes, such as coordinated calls between partnerships, knowledge exchange, regular meetings, joint outreach activities.

To ensure effective interfaces and regular dialogue, an advisory body including representatives from the Partnerships identified hereinafter will be included in the governance structure of the CETP, in order to plan joint activities, identify topics of relevance in calls, coherence in research and innovation agendas, investments and funding opportunities, and other relevant tasks like dissemination and policy advice.

Figure 6 presents the 19 Partnerships and other RDI initiatives identified as relevant for the CETP. Annex 2 outlines in detail respective areas where cooperation is expected, basing on a preliminary consultation process undertaken in view of the present SRIA. Annex 3 identifies the self-assigned potential interfaces by initiatives and partnerships according to CETP Challenges.

[21] https://ec.europa.eu/info/sites/info/files/research_and_innovation/funding/documents/ec_rtd_coherence-synergies-of-ep-under-he.pdf

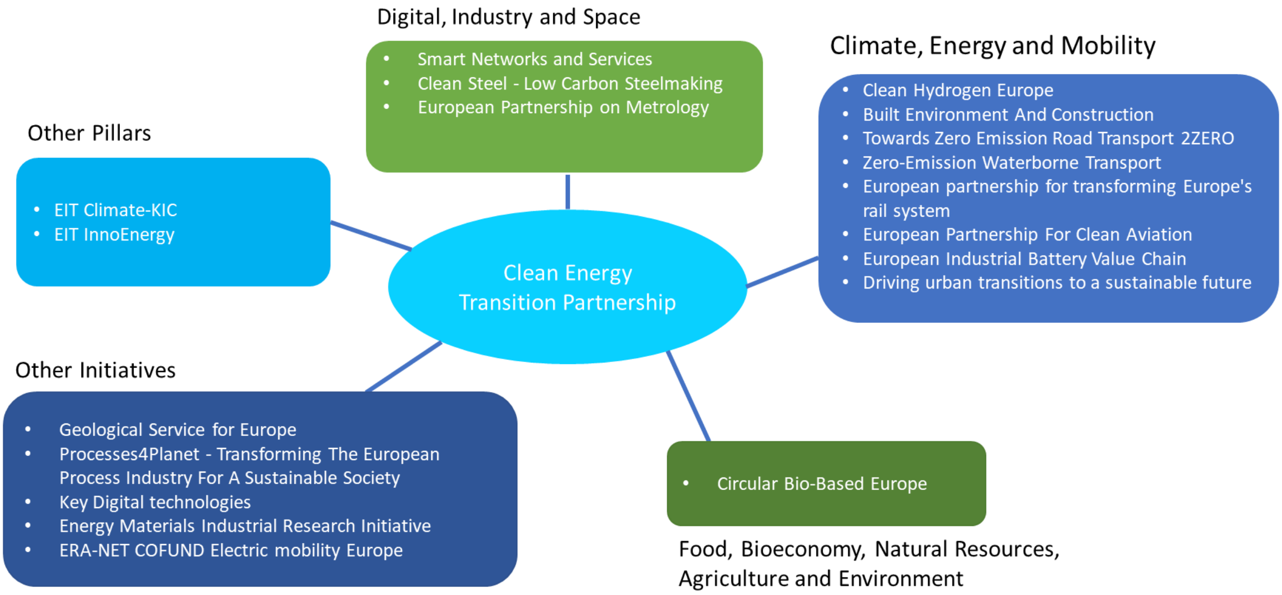

Figure 6 CETP interfaces with other European Partnerships and RDI initiatives

According to the level of integration of the respective SRIAs and complementarity of topics, cooperation interfaces range from knowledge exchange to joint calls. However, the interlinkage with other Partnerships will be regularly considered, as priorities will develop throughout the duration of the Partnerships, and topics for collaboration are to be identified according to market and users need.

EU Programmes

Besides cooperation and interfaces with partnerships in the frame of Horizon Europe, synergies with other relevant Union Programmes will be explored to maximise impact and delivery on the strategic objectives. To this regard, suitable interfaces are to be established with funding instrument targeting innovation and scale-up, to ensure an integration of funding (sequential funding or complementary funding) along the TRL scale, to support successful projects going towards demonstration and scale-up, or infrastructure deployment.

Main Programmes or financial tools the CETP will establish links to, include:

- **InvestEU:** the EU investment support facility, providing investment capital to research, innovation and digitisation projects, as well as technical support and assistance to help structuring and implement projects
- **Innovation Fund:** the facility supports demonstration projects of innovative low-carbon technologies that are in the scope of the CETP such as: innovative low-carbon technologies and processes in energy intensive industries; Carbon capture and utilisation (CCU); Construction and operation of carbon capture and storage (CCS); Innovative renewable energy generation; Energy storage
- **CEF:** the Connecting Europe Facility addresses the investment gap in the energy sector, providing financial support projects targeting the upgrade, digitization and interconnection of the energy networks and infrastructure.
- **ERDF:** Cohesion Funds represents a large funding sink for innovation projects. In the frame of the new Regulation allowing the commitment of ERDF funding to EU R&I initiatives, a major effort to engage Regional Managing Authorities into the CETP and establish effective links with the

relevant Smart Specialization Platforms and Interregional initiatives relating to clean energy technologies.

Other Programmes

Besides the EU Programmes, EUREKA – the largest network for transnational cooperation in RDI - is a relevant actor in the funding landscape that the CETP will establish interfaces in view of targeting co-ordinated calls. As already successfully experienced in the context of the SET Plan, cooperation can be explored with the **EUREKA EUROGIA2020 cluster** to support close-to-market projects. EUROGIA2020 provides support to and promote trans-national consortium developing innovative projects in low-carbon energy technologies. It addresses all innovative energy technologies that will: reduce the carbon footprint of energy production and use; develop new technologies for energy such as solar, wind, biomass, geothermal, energy efficiency.

National and Regional Programme

CETP will build bridges to national and regional programme for market introduction and stimulation, investment and procurement.

International Cooperation

The international cooperation in RDI is essential for tackling global issues, such as climate change. In the field of clean energy technologies, on the international and global level, there are well-established cooperation fora, namely the International Energy Agency (IEA) and its Technical Collaboration Programmes (TCP), Mission Innovation (MI), the Clean Energy Ministerial (CEM) and the International Renewable Energy Agency (IRENA).

International activities and outreach of the CETP will aim at establishing effective relations with the relevant working groups operating in the above mentioned agencies, to foster alignment of strategies and research agendas, promote scientific evidence and good practice on international level, share information about priorities and research and innovation portfolios.

Annex

Annex 1 Mapping of CETP Challenges to higher level policy goals

Table 1 aims at identifying the contributions of the CETP Challenges to international policy goals such as the Green Deal, Stepping up Europe's 2030 climate ambition, EU Strategy for Energy System Integration, Recovery and Resilience Facility and the Sustainable Development Goals.

EU Policy				Contributing CETP CHALLENGES							
	Strategic objectives	Domain	Targeted technologies	CETP Challenge 1 „Optimised integrated European net-zero emissions Energy System"	CETP Challenge 2 „Enhanced zero emission Power Technologies"	CETP Challenge 3 "Enabling Climate Neutrality with Storage Technologies, Renewable Fuels and CCU/CCS"	CETP Challenge 4 „Efficient zero emission Heating and Cooling Solutions"	CETP Challenge 5 „Integrated Regional Energy Systems"	CETP Challenge 6 "Integrated Industrial Energy Systems"	CETP Challenge 7 „Integration in the built Environment	CETP Challenge 8 „Cross-cutting Dimensions"
GREEN DEAL	Supplying clean, affordable and secure energy	Decarbonising the energy system	Energy efficiency	X	X	X	X	X	X		X
			Increased Renewable energy sources		X	X	X		X	X	X
			Smart sector integration	X		X	X	X	X	X	X
			Decarbonisation of the gas sector	X		X		X			X
		Smart infrastructure: deployment of innovative technologies and infrastructure	Smart grids	X		X	X	X			X
			Hydrogen networks	X		X		X	X		X
			CCUS		X	X			X		X
			Storage		X	X	X		X		X
	Mobilising industry for a clean and circular economy	Energy-intensive industries	Decarbonisation of energy-intensive industries			X	X		X		X
	Building and renovating in an energy and resource efficient way	Energy performance of buildings	Deep renovation of buildings (RH&C, energy efficiency)			X	X			X	X

EU Policy				Contributing CETP CHALLENGES							
	Strategic objectives	**Domain**	**Targeted technologies**	**CETP Challenge 1 „Optimised integrated European net-zero emissions Energy System“**	**CETP Challenge 2 „Enhanced zero emission Power Technologies“**	**CETP Challenge 3 “Enabling Climate Neutrality with Storage Technologies, Renewable Fuels and CCU/CCS”**	**CETP Challenge 4 „Efficient zero emission Heating and Cooling Solutions“**	**CETP Challenge 5 „Integrated Regional Energy Systems“**	**CETP Challenge 6 “Integrated Industrial Energy Systems”**	**CETP Challenge 7 „Integration in the built Environment**	**CETP Challenge 8 „Cross-cutting Dimensions”**
	Accelerating the shift to sustainable and smart mobility	Production and deployment of sustainable alternative transport fuels	Sustainable alternative fuels		X	X			X		X
Stepping up Europe’s 2030 climate ambition	**Energy system transformation including buildings, transport and industry**	Renewable energy policies	RES	X	X	X			X		X
			Energy communities and decentralised renewable energy technologies	X	X	X		X		X	X
			RH&C	X		X	X	X	X	X	X
			Low-temperature district heating systems			X	X	X		X	X
		Deep renovation of buildings	RH&C			X	X			X	X
			Smart digitalisation					X		X	X
			Integration of renewable energy		X	X	X	X		X	X
		Transport sector	EV deployment	X	X			X		X	X
			Advanced biofuels and other renewable and low carbon fuels			X			X		X
		Industry	Medium and high heat electrification		X				X		X
			Hydrogen		X	X			X		X
			CCUS			X			X		X
EU Strategy for Energy	**A more circular energy**	Prioritize demand-side solutions				X		X	X	X	X

EU Policy				Contributing CETP CHALLENGES							
	Strategic objectives	Domain	Targeted technologies	CETP Challenge 1 „Optimised integrated European net-zero emissions Energy System“	CETP Challenge 2 „Enhanced zero emission Power Technologies“	CETP Challenge 3 “Enabling Climate Neutrality with Storage Technologies, Renewable Fuels and CCU/CCS”	CETP Challenge 4 „Efficient zero emission Heating and Cooling Solutions“	CETP Challenge 5 „Integrated Regional Energy Systems“	CETP Challenge 6 “Integrated Industrial Energy Systems”	CETP Challenge 7 „Integration in the built Environment”	CETP Challenge 8 „Cross-cutting Dimensions”
System Integration	**system, with ‘energy-efficiency-first’ at its core**	Reuse of waste heat via	Re-integration of process heat within manufacturing plants			X	X	X	X		X
			District heating and cooling network				X	X			X
		Wastewater and biological waste and residues for bioenergy production	Biogas		X	X					X
			Biomethane		X	X			X	X	X
	Accelerating the electrification of energy demand, based on RES	A renewables-based power system	RES (all)	X	X	X	X	X			X
			Offshore technologies		X	X					X
			Solar energy		X	X	X			X	X
			Deployment of storage and other flexibility options	X	X	X	X	X	X	X	X
			V2G as a storage and flexibility option	X	X	X		X		X	X
		Electrification in Buildings	RH&C				X			X	X
		Electrification of Transport	EV	X	X			X			X
			Alternative fuels		X	X					X
		Industry	Electrification of low-temperature process heat			X	X		X		X
	Promote renewable and low-carbon fuels, including hydrogen, for hard-to-	Renewable fuels produced from sustainable biomass	Biogas, biofuels, biomethane			X			X		X
		Renewable hydrogen in hard-to-decarbonise sectors	Application in transport		X	X					X
			Application in industrial processes		X	X			X		X
			Application in the energy system as a flexibility resource		X	X					X

EU Policy				Contributing CETP CHALLENGES							
	Strategic objectives	**Domain**	**Targeted technologies**	**CETP Challenge 1 „Optimised integrated European net-zero emissions Energy System“**	**CETP Challenge 2 „Enhanced zero emission Power Technologies“**	**CETP Challenge 3 “Enabling Climate Neutrality with Storage Technologies, Renewable Fuels and CCU/CCS”**	**CETP Challenge 4 „Efficient zero emission Heating and Cooling Solutions“**	**CETP Challenge 5 „Integrated Regional Energy Systems“**	**CETP Challenge 6 “Integrated Industrial Energy Systems”**	**CETP Challenge 7 „Integration in the built Environment**	**CETP Challenge 8 „Cross-cutting Dimensions”**
	decarbonise sectors	Enabling carbon capture, storage and use to support deep decarbonisation	CCS in industrial processes			X			X		X
			CCUS for synthetic fuels			X			X		X
	A more integrated energy infrastructure	Energy infrastructure	Links between energy carriers	X		X	X	X			X
			Infrastructures for large-scale storage and transportation of pure hydrogen	X		X			X		X
			CO2-dedicated infrastructure			X					X
	A digitalised energy system	Digitalisation for the energy system integration	Enabling lower maturity technologies to come to the market	X	X	X		X			X
			Large scale demonstrations of mature technologies through Horizon Europe and its partnerships	X		X	X	X	X		X
Recovery and Resilience Facility	**Power up**	Building and sector integration of almost 40% of the 500 GW of renewable power generation needed by 2030	RES	X	X	X		X	X	X	X
		instalment of 6 GW of electrolyser and production/transportation of 1 million tonnes renewable hydrogen by 2025	Renewable hydrogen	X	X	X			X		X
	Renovate	By 2025, contribute to the doubling of the renovation	Deep renovation			X				X	X

EU Policy				Contributing CETP CHALLENGES							
	Strategic objectives	**Domain**	**Targeted technologies**	**CETP Challenge 1 „Optimised integrated European net-zero emissions Energy System“**	**CETP Challenge 2 „Enhanced zero emission Power Technologies“**	**CETP Challenge 3 “Enabling Climate Neutrality with Storage Technologies, Renewable Fuels and CCU/CCS”**	**CETP Challenge 4 „Efficient zero emission Heating and Cooling Solutions“**	**CETP Challenge 5 „Integrated Regional Energy Systems“**	**CETP Challenge 6 “Integrated Industrial Energy Systems”**	**CETP Challenge 7 „Integration in the built Environment”**	**CETP Challenge 8 „Cross-cutting Dimensions”**
		rate and the fostering of deep renovation.									
	Recharge and refuel	By 2025, aim to build one out of the three million charging points needed in 2030 and half of the 1000 hydrogen stations needed.	EV charging		X	X				X	X
			Hydrogen refuelling	X	X	X		X			X
Sustainable Development Goals	**SDG 7 ‘Affordable and clean energy’**	Ensure access to affordable, reliable, sustainable and modern energy for all		X	X	X	X	X		X	X
	SDG 9 ‘Industry	Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation		X	X	X	X	X	X		X
	SDG 11 ‘Sustainable Cities and Communities’	Make cities and human settlements inclusive, safe, resilient and sustainable			X	X	X	X		X	X
	SDG 13 ‘Climate Action’	Take urgent action to combat climate change and its impacts		X	X	X	X	X	X		X

Table 1 Mapping of CETP Challenges to higher level policy goals

Annex 2 Fields for cooperation with complementary initiatives and partnerships

Table 2 below provides an identification of potential interfaces between the CETP and other initiatives and partnerships based on the meeting on 22 October 2020.

Partnerships/initiatives relevant to CETP	Type of Partnership	Focus area	Field for cooperation with CETP	Potential joint activities
Smart Networks and Services	Co-programme (or Art. 187)	• Securing European leadership in the development and deployment of next generation network technologies and services. • Developing the technologies and standards for the digital infrastructures of the future • Support a dull digitization of industry sectors, in line with the Green Deal objectives. The technology focus is mostly on: • 5G and 6G networks and ICT solutions • Standards and architecture • IoT and multi-sense networks; AI and HPC • Cybersecurity	• The digital transformation and the digital infrastructure as key enabling solutions for the energy transition. • Can be regarded as prerequisites to build new services for a decarbonised, secure and resilient energy system. • 5G technology could pay a huge role in the transformation of the energy sector Common areas of interest include: • Digitalisation of power grids and networks • Smart energy services • Utility operation	• Knowledge exchange
Geological Service for Europe (CSA)	CSA	• Develop and deploy a sustainable service and information system for geoscientific knowledge, data, tools and innovations that are required by policy makers, industry and R&I organizations. • The outcomes support safe and sustainable use of subsurface resources and capacities • Help research activities on novel technologies and toolsets to support environment and society. • Geothermal, using the subsurface for energy storage and CCS are within scope	• Geothermal, subsurface energy storage • CCS • Optimised siting for offshore windfarms • Supporting R&I with pilot/testbed development • Assess subsurface potential, subsurface management for novel subsurface activities (incl. risk/impact analysis) • FAIR data principles.	• Aligning Strategic Research and Innovation Agenda • Knowledge sharing

Partnerships/initiatives relevant to CETP	Type of Partnership	Focus area	Field for cooperation with CETP	Potential joint activities
European partnership for transforming Europe's rail system	Art. 187	• Make rail transportation realise its potential at the core of a competitive and resource-efficient multi-modal European transport network, • Facilitating a shift from dependence on less sustainable modes. Further decarbonisation is within scope.	• Sources of energy not in focus. Energy is only mentioned in relation to energy efficiency. • Hydrogen and CCS can be a candidate for collaboration	• Knowledge sharing
Clean Hydrogen Europe	Art. 187	• Accelerate development and deployment of European clean hydrogen technologies • Production, distribution and storage of clean hydrogen in heavy industries and heavy-duty transport applications.	• Production of hydrogen as source of energy in many sectors/industries (steel, cement etc) and as a feedstock. • A cooperation should be envisaged with respect to energy system integration, sector coupling, storage	• Define codes and standards and the use of CCUS in the production of hydrogen
Built Environment And Construction	Co-programme	• Construction • Demolition • Circularity of buildings	• Energy efficiency of buildings through energy management technologies and integration of renewables at the building level (e.g. integrated PV) • Climate neutral production of building materials	• Knowledge sharing
Towards Zero Emission Road Transport 2ZERO	Co-programme	• Accelerate the development of zero tailpipe emission road transport in Europe with a systems approach. • Improve mobility and the safety of people and goods, ensure future European leadership in innovation, production and services. • Introduction of zero-emission and competitive long distance heavy-duty vehicles.	• Source of energy (electricity and hydrogen, also in cooperation with Clean Hydrogen partnership). • Synergies regarding V2G (vehicle-to-grid) technologies and demonstration	• Knowledge sharing

Partnerships/initiatives relevant to CETP	Type of Partnership	Focus area	Field for cooperation with CETP	Potential joint activities
European Industrial Battery Value Chain	Co-programme	• Establish sustainable and circular European battery value chain to drive transformation towards carbon-neutral society and to commercialize the next-generation battery technologies in Europe by 2030 • Research on future battery technologies which are to ensure long term European competitiveness	• Integration of battery-based stationary storage in the power sector as well as in the regional/local energy system	• Joint workshop • Joint calls for demo/pilot projects
Driving urban transitions to a sustainable future (DUT)	Co-funded	• Develop pathways, strategies, tools, technologies, methods, etc for urban transformations with an integrated, inter- and transdisciplinary approach	• Energy system • Integration of urban energy systems into regional one • Energy efficient buildings • Renewable energy technologies for urban application • Complementarities regarding local energy systems, RH&C, energy communities	• Joint efforts in mobilising stakeholders and connecting the community, • Joint Calls and networking across calls land projects • Exchange on models for replication, implementation, • Strategic exchange and cooperation
Circular Bio-Based Europe	Art. 187	• Produce major contributions to the climate targets by 2030, reach climate neutrality by 2050, and increase sustainability and circularity of production and consumption systems in line with the European Green Deal • Develop and expand the sustainable sourcing and conversion of biomass into bio-based products	• Complementarity • bio-based focus on products from biomass • biomass used for energy can be the topic for CETP	• Joint calls on selected topics • Joint workshops on impacts

Partnerships/initiatives relevant to CETP	Type of Partnership	Focus area	Field for cooperation with CETP	Potential joint activities
		• Deploy bio-based innovation at regional scale with the view to revival of rural and marginal regions.		
European Partnership on Metrology (by EURAMET e. V.)	Art. 185	• Develop and disseminate an integrated, cost effective and internationally competitive measurement infrastructure for Europe • Metrology also underpins trustworthy and up-to-date regulation in areas related to the energy transition and climate neutrality	It can cover measurement challenges in the field of: • Energy generation from PV, wind, biomass, hydro, alongside energy storage systems; • Gas grids; • Batteries and thermal storage technologies • Low CO2 steelmaking and carbon capture and storage in industrial applications; • Coupling of energy sectors; • Energy efficiency in buildings and for lighting.	• Knowledge sharing, exchange of information • Shaping of calls on topics where metrology is relevant, • Roadmap generation for clean energy related research fields.
EMIRI - Energy Materials Industrial Research Initiative	Industrial Research initiative	• Promotes, facilitates and supports R&I activities in Europe on Advanced Materials for Clean and Sustainable Energy and Mobility Applications	• Cross-cutting topics on Advanced Materials for more performant, • Cost-competitive and sustainable energy technologies	• Knowledge exchange • Joint workshops • Techno roadmaps

Partnerships/initiatives relevant to CETP	Type of Partnership	Focus area	Field for cooperation with CETP	Potential joint activities
ERA-NET COFUND Electric mobility Europe (EMEurope)	ERA-NET COFUND (H2020) running until 2022*	• Designed to take transnational e-mobility research and policy exchange towards deployable solutions. • Employs a dual strategy through co-funded research and innovation projects and cooperation on policy level.	• Electrification of transport • Charging infrastructure/grid integration/V2G	• Knowledge sharing/joint workshops • Joint calls, depending on the future of EMEurope
Zero-Emission Waterborne Transport	Co-programme	• Provide and demonstrate zero-emission solutions for all main ship types and services. • Enable zero-emission waterborne transport before 2050.	• Will not develop the fuels themselves.	• Knowledge sharing
Key Digital Technologies	Art. 187	• Electronic and photonic components and software defining how they work as part of a system.	• Possibilities for cooperation on technologies relevant to the power-sector, industry and society in general	• Knowledge sharing
Clean Steel - Low Carbon Steelmaking	Co-programme	• Reinforce industrial strongholds having seized emerging opportunities to establish technological sovereignty and boost competitiveness.	• Develop new technologies for renewable energy (and CCUS applications) for decarbonising the energy sector. • Hydrogen as energy and reducing agent in this industry.	• Formal consultation. • Joint calls under industrial energy system?
Processes4Planet - Transforming the European process industry for a sustainable society	Co-programme	• Extensive decarbonisation of energy systems within the process industries. • Strong focus on circular, climate neutral and competitive process industry. • Develop and deploy the innovations needed for a profound transformation of process industries. • Cross-sectorial approach, ASPIRE gathers 10 sectors: cement, ceramics, chemical, engineering, non-ferrous metals, minerals, pulp & paper, refining, steel and water to achieve the EU Green Deal targets by 2050.	• Energy Efficiency, heating & cooling issues, power and storage, and CCUS are relevant	• Formal consultation. Joint calls under industrial energy system ++?

Partnerships/initiatives relevant to CETP	Type of Partnership	Focus area	Field for cooperation with CETP	Potential joint activities
European Partnership For Clean Aviation	Art. 187	• Develop the next generation of ultra-efficient low-carbon aircraft, with novel power sources, engines, and systems, which will emerge from the research and demonstration phase at a high technology readiness level.	• Source of energy (synthetic fuels etc.)	• Knowledge sharing
EIT Climate KIC	EIT-KIC	• Climate-KIC works on transformative, systemic innovation leading to systemic change. • Cities, land use and manufacturing are identified as the three major systems with the most potential to cut-emissions and realise a climate-resilient economy.	• Enabling district-scale energy and transition in carbon-intensive regions to promote climate-neutral solutions • Innovation and implementation.	• Exchange information and knowledge sharing. • Joint activities in pilot and business model testing in the areas of energy systems in the urban context or sustainable production.
EIT InnoEnergy	EIT-KIC	• The partnership aims to build a sustainable, long-lasting operational framework among the knowledge actors in the energy sector. • The goals include generating new talents, fostering the emergence and deployment of new innovative solutions and the creation and development of companies.	• Scale up project results or push them towards commercialisation. • CETP could provide test-beds for demonstration	• Exchange information and knowledge sharing, • Further exchange on potential benefits of collaboration

Table 2 Fields for cooperation with complementary initiatives and partnerships

Annex 3 Overview of interfaces between CETP Challenges and complementary initiatives and partnerships

Table 3 includes self-assigned interfaces by the partnerships that have been collected before and after the meeting to identify interfaces with other initiatives and partnerships on the 22 October 2020.

Partnerships/initiatives relevant to CETP	CETP Challenge 1 „Optimised integrated European net-zero emissions Energy System" “	CETP Challenge 2 „Enhanced zero emission Power Technologies“	CETP Challenge 3 “Enabling Climate Neutrality with Storage Technologies, Renewable Fuels and CCU/CCS”	CETP Challenge 4 „Efficient zero emission Heating and Cooling”	CETP Challenge 5 „Integrated Regional Energy Systems“	CETP Challenge 6 “Integrated Industrial Energy Systems”	CETP Challenge 7 „Integration in the built Environment”	CETP Challenge 8 “Cross-cutting Dimensions”
Built environment and construction	x	x	x	x	x	x	x	x
Circular bio-based Europe			x				x	
Clean Hydrogen Europe	x	x	x	x	x	x	x	x
Driving urban transitions to a sustainable future (DUT)				x	x	x	x	x
Energy Materials Industrial Research Initiative (EMIRI)		x						
ERA-NET COFUND Electric mobility Europe (EMEurope)*	x				x			
European industrial battery value chain	x		x		x			
European Partnership on Metrology (by EURAMET e. V.)	x	x	x	x	x	x		x
Geological Service for Europe (CSA)		x	x	x	x	x	x	x
Processes4Planet	x	x	x	x	x	x	x	x
Smart Networks and Services					x			x
Towards zero emission road transport 2ZERO	x	x			x		x	
BRIDGE	x				x			
EIT KIC InnoEnergy	x		x		x		x	

Table 3 Overview of interfaces between CETP Challenges and complementary initiatives and partnerships

Annex 4 Mapping of identified challenges in the SET Plan Stakeholder Groups Dialogues Summary Paper to the CETP Challenges

The CETP Challenges are referring to RDI challenges that have been identified in the course of the **SET Plan Stakeholder Groups Dialogues Summary Paper (download).** The assignment of the RDI challenges to be of relevance for the CETP Challenges has been done in coordination with the authors of the draft SRIA (Table 4). Entries marked with an upper case "X" are considered of key relevance for the CETP Challenge, while lower case "x" translates to higher or normal relevance. The list should not be considered as exclusive and might change over the running time of the CETP.

Input Paper	Identified challenge by stakeholder			1 Optimised integrated European net-zero emissions Energy System	2 Enhanced zero emission Power Technologies	3 Enabling Climate Neutrality with Storage Technologies, Renewable Fuels and CCU/CCS	4 Efficient zero emission Heating and Cooling Solutions	5 Integrated Regional Energy Systems	6 Integrated Industrial Energy Systems	7 Integration in the built Environment	8 Cross-cutting Dimensions
1. Enabling Technologies	CH1.1 Concentrated Solar Power	CH1.1.1	Central Receiver and Line-Focusing power plants with lower LCOE		**X**						
		CH1.1.2	Reliable and cost-effective medium and high-temperature thermal storage systems.			**X**			**X**		
		CH1.1.3	Turbo-machinery developed for specific conditions of solar thermal power plants.		**X**						
		CH1.1.4	Reliable and cost-effective solar fuels production.			**X**		x	**X**		
	CH1.2 Photovoltaics	CH1.2.1	Powering the energy transition		**X**			x	x	**X**	
		CH1.2.2	Supporting economic recovery and building the Strategic Value Chains for renewables (i.c. PV)	x	**X**				x		x
	CH1.3 Offshore Wind	CH1.3.1	Improved Wind Turbine Technology		**X**						
		CH1.3.2	Offshore Wind Farms & Systems Integration	x	**X**				x		

Input Paper	Identified challenge by stakeholder			1 Optimised integrated European net-zero emissions Energy System	2 Enhanced zero emission Power Technologies	3 Enabling Climate Neutrality with Storage Technologies, Renewable Fuels and CCU/CCS	4 Efficient zero emission Heating and Cooling Solutions	5 Integrated Regional Energy Systems	6 Integrated Industrial Energy Systems	7 Integration in the built Environment	8 Cross-cutting Dimensions
		CH1.3.3	Floating Offshore Wind & Wind Energy O&M and Industrialisation		X						
		CH1.3.4	Ecosystem, Social Impact & Human Capital Agenda		x				x		X
		CH1.3.5	Basic Wind Energy Sciences for Offshore Wind		X						
	CH1.4 Onshore Wind	CH1.4.1	Wind Turbine Technology		X						
		CH1.4.2	Grid & Systems Integration	X				X	x		
		CH1.4.3	Wind Energy Operation, Maintenance & Installation		X			x			
		CH1.4.4	Ecosystem, Social Impact & Human Capital Agenda		x			x	x		X
		CH1.4.5	Basic Wind Energy Sciences for Onshore Wind		X						
	CH1.5 Deep Geothermal Energy	CH1.5.1	Optimal integration of geothermal heat in urban areas				X	x		X	
		CH1.5.2	Role of geothermal electricity and heating & cooling in the energy system responding to grid and network demands				X	X			
		CH1.5.3	Improvement of overall geothermal energy conversion performance for electricity production, heating & cooling				X	x		x	

Input Paper	Identified challenge by stakeholder			1 Optimised integrated European net-zero emissions Energy System	2 Enhanced zero emission Power Technologies	3 Enabling Climate Neutrality with Storage Technologies, Renewable Fuels and CCU/CCS	4 Efficient zero emission Heating and Cooling Solutions	5 Integrated Regional Energy Systems	6 Integrated Industrial Energy Systems	7 Integration in the built Environment	8 Cross-cutting Dimensions
		CH1.5.4	Develop full reinjection electric and heating & cooling plants integrated in the circular economy				X				
		CH1.5.5	Methods, processes, equipment and materials to ensure the steady availability of the geothermal resources and improve the performance of the operating facilities				X				
		CH1.5.6	Development of geothermal resources in a wide range of geological settings				X				
		CH1.5.7	Advanced drilling/well completion techniques				X				
		CH1.5.8	Innovative exploration techniques for resource assessment and drilling target definition				X				
	CH1.6 Bioenergy	CH1.6.1	Sustainable carbon for the globe		x		x	x	x		x
		CH1.6.2	Integration of biomass to future sustainable energy system	x		X	x	X	x		
	CH1.7 Carbon Capture Utilisation & Storage	CH1.7.1	Getting the commercial framework right			X					x
		CH1.7.2	Accelerating timely deployment at scale of CCS and CCU technologies		x	X			x		

Input Paper	Identified challenge by stakeholder			1 Optimised integrated European net-zero emissions Energy System	2 Enhanced zero emission Power Technologies	3 Enabling Climate Neutrality with Storage Technologies, Renewable Fuels and CCU/CCS	4 Efficient zero emission Heating and Cooling Solutions	5 Integrated Regional Energy Systems	6 Integrated Industrial Energy Systems	7 Integration in the built Environment	8 Cross-cutting Dimensions
		CH1.7.3	Driving costs down – through R&I, learning by doing and economies of scale			**X**			x		
		CH1.7.4	Enabling rapid scale-up to deliver on the climate goals			**X**					
		CH1.7.5	Enabling EU citizens to make informed choices regarding the benefits that CCS and CCU bring			**X**					x
		CH1.7.6	Production, optimisation and integration of blue hydrogen with CCUS			**X**					
	CH1.8 Ocean Energy	CH 1.8.1	Design and Validation of Ocean Energy Devices		**X**						
		CH1.8.2	Foundations, Connections and Mooring		**X**						
		CH1.8.3	Logistics and Marine Operations		**X**						
		CH1.8.4	Integration in the Energy System	**X**				x	x		
	CH1.9 Hydropower	CH1.9.1	Increased flexibility from hydropower plants	x	**X**			x			
		CH1.9.2	Utilization and expansion of European hydropower's storage capacity		**X**						
		CH1.9.3	Markets and services for hydropower's	**X**	x						**X**
		CH1.9.4	Environmental design		**X**			x			**X**
		CH1.9.5	Social acceptance		x						**X**

Input Paper	Identified challenge by stakeholder			1 Optimised integrated European net-zero emissions Energy System	2 Enhanced zero emission Power Technologies	3 Enabling Climate Neutrality with Storage Technologies, Renewable Fuels and CCU/CCS	4 Efficient zero emission Heating and Cooling Solutions	5 Integrated Regional Energy Systems	6 Integrated Industrial Energy Systems	7 Integration in the built Environment	8 Cross-cutting Dimensions
		CH1.9.6	Basic Hydropower Sciences		X						
	CH1.10 Solar Thermal Heating & Cooling	CH1.10.1	Solar District Heating (SDH)				X	x			
		CH1.10.2	Solar Heat for Industrial Processes (SHIP)				x		X		
		CH1.10.3	Solar thermal use in buildings				x			X	
		CH1.10.4	Financing/business models for solar thermal				x	x			X
2. Heating and Cooling Solutions	CH2.1 Towards 100% renewable heating and cooling of individual buildings						x	x		X	
	CH2.2 Heating/cooling in climate-neutral Energy Districts							x		X	
	CH2.3 Next generation of District heating and cooling systems						X		x	x	
	CH2.4 Towards 100% renewable industrial heating						x		X		
3.System Integration	CH3.1 Develop an optimised integrated European energy infrastructure			X	x	x		x	x		x
	CH3.2 Develop Integrated Local and Regional Energy Systems			x	x	x	x	X	x	x	x
	CH3.3 System modelling as a fundamental tool for the integrated energy system development			X				x	x		
4. Storage & Fuels	CH4.1 Reliable and cost-effective mid- to long-term thermal storage systems					X					x
	CH4.2 Development of efficient storage technologies for electric power grids based on renewables			x		X		x			
	CH4.3 Renewable Fuels					X		x	x	x	x
	CH4.4 Development of Cross-sectoral and hybrid energy storage solutions					X			x	x	
	CH4.5 System integration and cross-cutting issues for energy storage			X		X		X	X	X	X
5. Cross-cutting challenges	CH5.1 Robust transition pathways for an integrated European energy system			X				x	x	x	X
	CH5.2 Accelerated transition and innovation ecosystems							x		x	X
	CH5.3 Market design and regulation in support of the energy transition			x	x	x	x	x	x		X

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	CH5.4 Policies and actions to ensure a fair, just and democratic transition	x				x			**X**
	CH5.5 A resource efficient and sustainable energy system based on circularity					x			**X**
	CH5.6 Cost reduction, market integration and user empowerment in the energy transition through digital transformation	x				x			**X**

Table 4 Mapping of identified challenges in the SET Plan Stakeholder Groups Dialogues Summary Paper to the CETP Challenges