Integrated SET Plan

CETP

Clean Energy Transition Partnership

Input Paper to the Strategic Research and Innovation Agenda

Crosscutting Challenges

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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.

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1. Introduction to Crosscutting Challenges

A number of cross-cutting issues are central in the energy transition. The energy sector will play a central role when the rest of the economy aims for net zero emissions, with its natural links to transport, industry and the built environment.

The integration of a number of renewable, storage and low emission technologies into a distributed but affordable and reliable and resilient energy system where consumers play a central role requires multi-faceted and multidisciplinary approaches. The issues of energy transition research therefore span dimensions like:

Technological research: This line of research is at the core of the SET-Plan, and is essential to develop a wide portfolio of complementary, low-carbon technologies that can be effectively integrated and competitively combined within a global energy system, as well as the carbon-negative technologies required for deep decarbonization.

Techno-economic research: This research discipline applies empirical and model-based quantitative assessments of the economic and technological characteristics of a system, taking into account capital, operational and end-of-life expenditures, as well as systems integration. The ultimate objective is to optimize the global performance of the energy system with respect to climate impact, reliability and cost.

Socio-technical research: This research field focuses on how actors in society make operational and investment decisions regarding the energy sector. This builds on social science and humanities disciplines such as evolutionary economics, innovation studies, sociology, science & technology studies (STS), psychology, geography, political science, law and planning in order to analyse how societal sectors, systems and technologies co-evolve.

Environmental sustainability research: This line of research identifies different transition pathways for mitigating climate change and other relevant environmental impacts at local, regional and global levels, while providing tools for addressing the complex puzzle of how to meet long-term climate objectives.

This input paper tries to capture some of the central cross cutting challenges in such a multifaceted and multidisciplinary perspective. Some of these cross-cutting challenges are joint for a number of individual technologies, some are at the system level. That means that there will be overlap and complementary information on cross cutting aspects identified also in the more single technology oriented and system-oriented papers coming from the other input papers.

2. Overview of Challenges

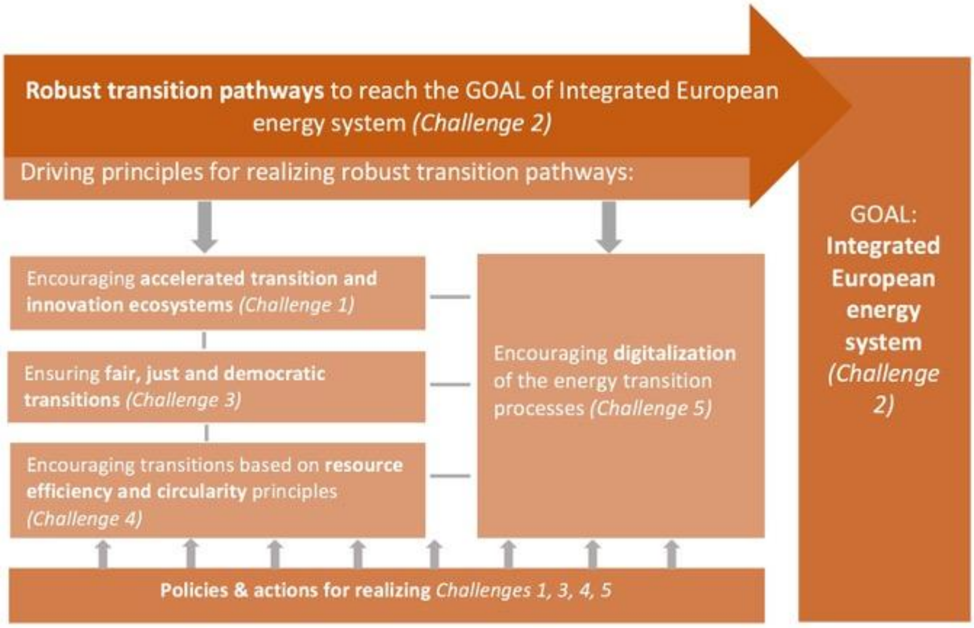

Figure 1: Connection between different Cross-Cutting Energy Transition Challenges

2.1 Challenge 1: Accelerated Transition and Innovation Ecosystems

Accelerated energy transition process is essential for reaching the two-degrees goal. The process of accelerated energy transition primarily includes (i) radical system and service innovations and (ii) massive deployment of integrated energy systems combining existing technologies.

In contrast with the past, when energy transitions were mostly driven by new technologies/resource discoveries and initiated by Distribution System Operators (DSOs), Transmission System Operators (TSOs) and large generation plants, the energy transition currently needs to be accelerated, fostering the development of new technologies. New policies need to be put into place along with a new financing structure and new business models. The overall challenge is aligning transition, societal and industrial goals in order to mobilize citizens and businesses as well as legitimize transition policies, while at the same time de-legitimizing unsustainable practices.

Current trend in the European energy transition is characterized as moving towards an integrated, renewable and decentralized energy market structure. Energy transition solutions are expected to be (i) financially attractive, (ii) with a minimum negative environment impact, (iii) based on the digitalization advancement, (iv) favourable towards reaching the goals of public wellbeing (including public health and economic recovery goals) while maintaining the same level of comfort and unburden.

Successful energy transitions require (i) fast growing investments and (ii) full integration of local sustainable energy resources. Active engagement of the relevant actors, especially outside traditional energy sector, is crucial for successful implementation of the energy transition towards climate-neutral Europe.

There are 6 key research and innovation activities associated with this challenge:

Research Activity 1: Identifying actors driving and hampering the energy transition, developing inclusive cooperation models

The energy transition shifts power structures between the existing actors, and creates new roles (i.e. prosumers, energy cooperatives).

Research Activity 2: Co-create and reinforce local and regional stakeholder innovation ecosystems, supporting their integration with global value chains

Diverse groups of stakeholders from local communities, industry and public sector need to be involved in this action. There is a need to define positive spill-overs between the different stakeholders.

Research Activity 3: Developing Societal Readiness Levels (SRL) assessment framework and corresponding funding structures

Social reality needs to be better connected to the technological development to ensure timely transition policy implementation. SRL assessment methods need to be developed and connected to TRL leading to TRL-SRL assessment framework.

Research Activity 4: Setting-up policy, regulatory and standardization frameworks for accelerated innovation using experimental mechanisms.

This action focusses on creating the mechanism to address the bottlenecks preventing boosting socio-economic impacts of the energy transition (e.g. regulation for businesses integrating several energy vectors, permits of energy supply and production, fiscal incentives and tariffs, health, safety and security regulation). Solutions of the bottlenecks include unbundling of grid, generation, supply and consumption by using experimental regulatory mechanisms (e.g. regulatory sandboxes, living labs and test beds, new types of public-private partnerships).

Research Activity 5: Building capacity for interdisciplinary education and cross-sectoral training

This action includes professional training, joint master programmes and PhD courses supporting the entire TRL/SRL scales and enabling professionals from different sectors to develop interdisciplinary projects together covering technological, social, spatial, economic, regulatory and other innovation perspectives.

Research Activity 6: Creating networks of energy transition demonstration sites and activities to achieve synergies between innovation activities in the different member states and regions.

Impacts

- **Impact 1:** Boosting the potential for European leadership in value and welfare creation from the energy transition.
- **Impact 2:** Creating tariffs, regulation and standardisation frameworks capable of being the backbone of the energy transition
- **Impact 3:** Empowering and supporting key energy transition actors

2.2 Challenge 2: 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 carbon-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.

Research Activity 1: Pathways to support the energy transition for Member states and at the EU policy level

The analysis of possible pathways and the policies to go with them will provide decision support at all relevant policy levels from EU to local processes, by addressing questions related to; European leadership in the transition; Robust and feasible strategies: Utilizing and respecting regional differences: Recognize how technology acceptance and energy citizenship should shape policy creation and implementation; Fair and inclusive transition ; Macro-economic aspects and competitiveness:;Environment and health and the impact of enabling technologies.

Research Activity 2: Support governance, tariffs, regulation and markets to enable the transition

The governance, i.e. how the transformation process is managed will influence the translation of pathways into policy and implementation. Thus additional effort should be made to ensure relevance for policy makers at the local level when planning and implementing the energy transition, as well as to ensure European leadership in implementing net zero solutions and export competence and technologies addressing legal, policy & regulatory framework and market design as well as transnational collaboration in the energy transition.

Research Activity 3: Developing the models and methodologies to support the energy transition

Pathway analysis combines quantitative model scenarios and qualitative storylines based on social sciences, aimed at establishing consistent and holistic pathways including technology choice, timing of investments, policy measures, environmental aspects and socio-technical issues. A number of methodological research questions arise to achieve this: New approaches to combining modelling and social sciences; Modelling sector coupling and system integration in long term models to understand how the interplay between transport, industry, the built environment and energy as well as managing uncertainty in the integrated energy system.

Impacts

- **Impact 1**: Identification of robust strategies for arriving at the net zero society in 2050, while respecting intermediate socio-economic and environmental objectives.
- **Impact 2:** Support for creating policy, governance structures, regulation and markets consistent with the net zero society and the objectives in the Green Deal.
- **Impact 3:** Frameworks for analysing the transition in a holistic and consistent way, respecting both technological feasibility, socio-economic aspects like welfare, fairness, justice democracy and environmental targets.
- **Impact 4:** Research based knowledge supporting both private and public decision makers in the energy transition.

2.3 Challenge 3: 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.

Among the obstacles associated with fairness and justice transition challenge is (i) the absence of clear understanding of what justice and fairness in the EU policy documents as well as (ii) lack of understanding what are potential injustices and ethical dilemmas associated with specific renewable energy technologies and carbon neutral transitions overall. At the same time, there are important enablers favouring realizing fairness and justice transition challenge, among which is (i) recognition of the techno-optimist mindset limitations for realizing sustainable transitions as well as (ii) availability of relevant methods and tools provided in social sciences and humanities that can be incorporated into the policy-making frameworks at the EU level.

Research Activity 1: Defining justice and fairness applied for clean energy transitions policies. Stating more clearly justice and fairness dimensions based on existing knowledge (e.g. energy justice pillars: distributive, generational, procedural, recognition justice).

Research Activity 2: Defining a set methods and tools to measure and monitor (ex-post and ex-ante) justice and fairness goals/sub-topics and possible policy actions.

Research Activity 3: Establishing methodological support for projects funded under the CETP in questions on justice and fairness at crucial times for the projects (at least beginning and at important milestones).

Expected impacts from successfully solving fairness and justice transition challenge are as follows:

- **Impact 1:** Transforming the role of energy consumers/prosumers/energy citizens in designing and implementing clean energy transition solutions.
- **Impact 2:** Supporting local economies and fair jobs creation while transitioning to a carbon-neutral energy system in the EU.
- **Impact 3:** Securing technological leadership in Europe without compromising ethical, social and environmental justice performance.

2.4 Challenge 4: A Resource Efficient and Sustainable Energy System based on Circularity

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. Impact: minimize waste, reduce costs, limit environmental impact. Crucial for a sustainable CET.

Research Activity 1: Sustainable materials choice and extraction

- Make technologies work with acceptable raw materials.
- Develop environmentally friendly and circular extraction technologies
- Produce life cycle datasets on innovative materials, secondary raw materials and technologies, based on primary data representative of the European context

Research Activity 2: Redesign installations/components/devices for energy generation, storage, conversion and distribution for higher sustainability and longer lifetime

- Change and optimise design, including the possibility to reuse and recycle parts and materials
- Develop advanced/innovative materials solutions and fabrication processes to increase lifetime/efficiency and facilitate reuse/recycling.
- Develop common tools and methodologies to accelerate materials development.
- Develop advanced recyclable materials/sustainable processes of use for groups of energy technologies, e.g. high temperature & corrosion resistant structural materials.
- Develop common standards for materials testing and characterisation.

Research Activity 3: Monitoring and optimisation of installations/components/devices for energy generation/storage/conversion/distribution

- Development and optimisation of non-destructive evaluation (NDE) techniques
- Development of data-driven and/or physical models of materials degradation.

Research Activity 4: Energy flow optimisation

- Energy cascading
- Waste heat recuperation
- Intelligent hybrid systems that combine complementary low carbon technologies for energy and heat production

This research should be based on pilots and demonstrators or feasibility studies.

Research Activity 5: End-of-life considerations – sustainable dismantling and disposal of installations/components/devices for energy generation/storage/conversion/distribution

- Enable or optimise recycling of a wider spectrum of materials
- Identify possibilities of reuse/recycle
- Regulate safe disposal for parts/materials
- Design legal and regulatory frameworks
- Develop life cycle datasets of end-of-life processes

Impacts

- **Impact 1 to outputs generated and planned:** Safer, more efficient and durable technologies, more sustainable in terms of optimised used of resources, both in the sense of materials and energy resources, with higher level of reuse and recyclability and thus minimal negative environmental impact.
- **Impact 2 with respect to Clean Energy Transition:** Ensure sustainable transition (best possible use of resources); increase social and geopolitical acceptability of technologies; reduce costs; reduce negative environmental impact; better informed decision-making process.

2.5 Challenge 5: Digital Transformation for Cost Reduction, Market Integration and User Empowerment in the Energy Transition?

Digitalization is affecting all types of economic sectors. For the CETP SRIA purpose, it is quite important to understand the Digital Transformation can play a fundamental role 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 digital levels so as to allow real market integration, energy system integration and user empowerment.

The following research activities have been identified:

Research Activity 1: Energy-relevant data collection, interpretation, diffusion

For achieving reliable, complete, and transparent (open access) information for decision and policy making and enabling citizen decisions (citizen empowerment).

Research Activity 2: Intelligent (artificial intelligence driven) generation, distribution and storage of energy (renewable electricity, carbon-free gas, heating/cooling)

For optimal use of resources, cost minimization, possibility of citizens to decide from where to take energy, new business model for interaction with citizens, better market integration in Europe; help to better design relevant legal frameworks, energy systems robustness, or avoidance of failures.

Research Activity 3: (Online) Monitoring (through sensors) of materials and components, digital twins for the simulation of their behaviour

For a better plant/component lifetime management (e.g. timely component replacements) thanks to intelligent systems, accident/failure prevention (predictive maintenance), higher safety standards, longer lifetime, higher efficiency, lower costs, new materials, or optimal operation of facilities (digital twins)

Research Activity 4: Digitalization as enabler of industry 4.0, advanced and automated materials and component manufacturing and processing

For faster production and installation, faster production and replacement of damaged parts, more efficient systems thanks to better materials, produced in faster, cheaper, better controlled way, higher efficiency, and lower costs.

Research Activity 5: New business models, new human interaction

For avoiding disruption of the transition and achieving citizen empowerment and wellbeing (prosumers).

The mission of this challenge is to design a digital transformation that will integrate not only the energy research entities and companies, but also the citizenship in a way in which all actors will be actively and proactively involved. Thus, the challenge (and the underlying strategy to pursue it) itself is not the mere application of digitalization for a CET, but also the full integration of citizens as final users and actors in this strategy.

3. Detailed Description of Challenges

3.1 Challenge 1: Accelerated Transition and Innovation Ecosystems

3.1.1 Describing the Transition Challenge

Evidence shows that the energy transition must be accelerated for the world to stay below 2-degrees warming. This calls for radical system and service innovations, alongside massive deployment of integrated energy systems combining existing technologies, such as smart distributed and integrated energy systems, PV, hydrogen, biofuel, wind, CCS and nuclear in countries that so decide.

Whereas earlier transitions were driven by new technologies/resource discoveries, the current energy transition is purposive, i.e. policy and societal goals play a key role. The overall challenge is to align transition and industrial as well as societal goals to mobilize businesses and legitimize transition policies, while de-legitimizing unsustainable practices by mobilizing citizens.

3.1.2 Mission and Objectives

Europe's energy supply and consumption are in the middle of a paradigm shift, transitioning towards an integrated, renewable and decentralized energy market structure. Rapid advances in technology within energy, e-mobility and digitalization present financially attractive alternatives for an energy transition. These will in turn result in an improved environment, smarter solutions, digitalisation and better information, and a positive impact on public health and economic recovery.

The energy transition requires fast growing investments and the full integration of local, sustainable energy resources. Actors and bodies outside the traditional energy sector are and will be important for this progress. Societal stakeholders need an adequate set of framework conditions to support and accelerate their advancement towards a climate-neutral Europe.

Here we identify key multi-sector research actions and powerful incentives (e.g., regulatory frameworks, tariffication, education) that will accelerate the fulfilment of climate and energy ambitions as laid out in the European Green Deal. Specifically, we overview the pivotal role of societal stakeholders and innovation ecosystems that engage in trans-disciplinary demonstration, innovation and research activities, and the framework conditions required to support them.

3.1.3 Activities and Research Questions addressing main Obstacles and Enablers

We have selected 5 key research and innovation activities to strengthen stakeholder innovation ecosystems and accelerate the energy transition:

1. Actors driving and hampering the energy transition and corresponding need for new cooperation models.
2. Regional stakeholder innovation ecosystems, and their interaction with global value chains.
3. Technology and Societal Readiness Levels, and corresponding funding structures.
4. Policy, regulatory and standardisation frameworks, including experimental mechanisms such as regulatory sandboxes.
5. Interdisciplinary education and cross-sectoral training.
6. Creating networks of energy transition demonstration sites and activities to achieve synergies between innovation activities in the different member states and regions.

A first action is to identify which actors are currently driving the acceleration of the energy transition, which ones are hampering it, and which ones might be lacking altogether from this novel process. The current energy and power market is well-regulated, and combines electricity generation, transport and supply with a range of products and services[1]. The energy transition will shift power structures between the existing actors and will create new roles. Citizens, local businesses, housing associations and similar actors traditionally regarded as energy consumers, are aiming to become active prosumers instead. New and updated cooperation models and financing schemes between public and private actors are required to accelerate the energy transition.

A second key action is the creation and reinforcement of 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. This can include ecosystems within and across projects and the cities, regions and Member States in which they are embedded. The role of intermediaries to boost the impact of the ecosystems needs to be better understood and supported. The impact of such ecosystems can be increased drastically by connecting them firmly with global networks for mutual exchange of knowledge, technology and best practices.

Thirdly, innovations generated by such ecosystems - systems, services, processes and technologies - need to be identified, tracked and nurtured with revolving innovation funds[2], so they may get better embedded in society and be able to influence policy at a much earlier stage in their development. In this manner, it will be possible to deliver solutions that simultaneously and measurably advance Technology (TRL) and Societal Readiness Levels (SRL)[3]. This will require integrated TRL-SRL assessment methods that include and combine societal, technological, environmental, spatial, regulatory and other critical aspects, in a unique holistic framework.

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[1] Bertelsen S. et al. (2019). Report on Enabling Regulatory Mechanism to Trial Innovation in Cities. Deliverable 2.1 of the +CityxChange project. Available for download at: https://cityxchange.eu/knowledge-base/report-on-enabling-regulatory-mechanism-to-trial-innovation-in-cities/

[2] Gouldson A. et al. (2015). Innovative financing models for low carbon transitions: Exploring the case for revolving funds for domestic energy efficiency programmes. Energy Policy, Volume 86, pp.739-748.

[3] https://innovationsfonden.dk/sites/default/files/2019-03/societal_readiness_levels_-_srl.pdf

Fourthly, policy frameworks need to be targeted to positively impact the rate and direction of innovation across sectors in the acceleration of the energy transition. Regulatory and standardisation frameworks must be set up to be able to be the backbone of the energy transition, in a holistic perspective. This will require upgrading to encompass technology shifts, digitalisation and other challenges to safe-guard and boost beneficial socio-economic impacts accompanying the energy transition. In the transition towards the creation and operation of local sustainable energy systems and markets, bottlenecks reside at the levels of regulations of the electricity grid, trade/supply of electricity, building regulations, health and safety, security etc. Tensions arise between the technical requirements of keeping the electricity grid in balance at every moment, the actual situation of increasing decentralised and multi-actor production and the guaranteed principles of a free market. Unbundling of grid, generation, supply and consumption gives important incentives and a better understanding and clarification of roles that may lead to improvements in local multi-energy systems including production, conversion, storage, transport and consumption.

Experimental regulatory mechanisms that acknowledge the multi-level, multi-sectoral, multi-functional, and multi-type nature of energy system planning and operation are needed to solve these bottlenecks, such as regulatory sandboxes, living labs and test beds need to be structured and documented in order to be scalable. Such mechanisms need to be accompanied by innovation procurement and performance contracting to enable new roles and new types of public-private partnerships. Bottlenecks to be tackled are, for example, transparency, how to regulate businesses that integrate several energy vectors, development of new and changed roles, mandates and responsibilities, digitalisation, permits of supply and production, and taxation, fiscal incentives and tariffs/pricing.

Interdisciplinary education and cross-sectoral training will be required, e.g. professional training, joint master programmes and PhD courses merging practically viable and scientifically valid approaches, supporting the entire TRL/SRL scales and enabling professionals from different sectors to get first-hand experience in developing projects together to cover technological, social, spatial, economic, regulatory and other innovation perspectives. This kind of initiative will boost the potential for European leadership in value and welfare creation from the energy transition. In this also lies the possibility to export packages of integrated technologies, work processes, community engagement, market design and regulation.

3.1.4 Impacts

- Boosting the potential for European leadership in value and welfare creation from the energy transition.
- Tariffication, regulatory and standardisation frameworks capable of being the backbone of the energy transition
- Empowering and supporting key energy transition actors

Actors driving the energy transition, and corresponding need for new cooperation models

- New and improved cooperation models to support the energy transition, based on the updated roles and responsibilities that will be needed in a climate-neutral energy market
- A canvas of actors, stakeholders and regulatory and plan-making agencies that are required to take an active role in the climate-neutral energy market, but traditionally have not been
- Boosting the active role of prosumers through ICT-enabled services, data and technologies

Regional stakeholder innovation ecosystems, and their interaction with global value chains

- Strengthening local value chains and ecosystems will boost the impact of investments and measures implemented, by anchoring them in a broader group of stakeholders, with better accessibility and trust

- Connecting these value chains to global networks will similarly boost the transfer and distribution and new knowledge, practices and technologies among a broader group of stakeholders, and accelerate their implementation across the already established value chains.

Technology and Societal Readiness Levels, and corresponding funding structures

- Revolving innovation funds create predictability in upcoming funding opportunities, giving actors time to gain the necessary political approval. It also allows a broader suite of actors in different levels of development and with different levels of ambition the opportunity to apply for funding that fits their needs, rather than only appealing to frontrunners.

- Innovations that are firmly embedded within a regulatory, spatial, economic, social, environmental and technological context, will gain accelerated uptake in society and markets. Creating an assessment system that acknowledges the duality of Technological and Societal Readiness Levels, rather than only the former one, will help boost such well-rounded innovations, in particular when paired with incentives or other support mechanisms.

Policy, regulatory and standardisation frameworks, including experimental mechanisms such as regulatory sandboxes

- Policy, regulatory and standardisation frameworks that are aligned with the target of a climate-neutral Europe, will provide directionality to all societal and market stakeholders and boost socio-economic impacts.

- Upgrading of these frameworks needs to encompass a broad set of perspectives to ensure technology-neutrality, and to generate trust and acceptance among all stakeholders

- Experimental mechanisms will help inform evidence-based decisions, in particular when organised in a structured manner that allows systematic testing, analysis, comparison and scaling of alternatives by various stakeholders in different settings. Testing includes technological, cross-vector solutions as well as process innovations such as innovation procurement and performance contracting

Interdisciplinary education and cross-sectoral training

- Educational and training frameworks provide directionality. Aligning them with the target of a climate-neutral Europe will boost the competency and capacity of current and future professionals to contribute and lead the energy transition with evidence-based approaches including technological, regulatory, spatial, economic, environmental, social and other energy innovation perspectives

- Offering this type of education and training not only to European but also to global professionals, will consolidate Europe’s access to leading the transition in international markets and society as well.

3.1.5 Embeddedness and Interfaces to other Initiatives

- Stakeholder innovation ecosystems are important for all initiatives within the CETP as well as other Platforms such as Built4People and Driving Urban Transitions

- Experimental mechanisms are most likely also addressed in Built4People and DUT, though potentially in a different manner

3.2 Challenge 2: Robust Transition Pathways for an Integrated European Energy System

3.2.1 Description of the Transition Challenge

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 carbon-neutrality by 2050, taking into account regional diversities and different policy and technology strategies towards 2030 and 2050. While it is the prerogative of MS/AC to design their own clean energy system according to specific territorial, political, societal and industrial factors, a fully integrated, interconnected and resilient energy system must be created in Europe – not limited by frontiers or regulatory barriers. This is crucial to enable a constant and optimal balancing of sustainable energy sources (depending on availability and cost) as a consequence of different choices made at local level and the specific conditions and situation of each country or region ("United in diversity"). This in turn requires the integration of energy infrastructures across borders between energy vectors and from European to local level.

In developing these pathways, the focus is on technology choice, timing of investments, policy measures, societal change, potential impacts on environment and socio-technical issues, taking into account different scenarios for technological breakthroughs. From a long-term perspective, it is important to have sufficient representation and understanding of system operations, with a balance between the role of different energy vectors (e.g. electricity, heat, and hydrogen), the interplay between sectors and local political criteria. Pathways should also take into account physical limitations to deployment and the economic, environmental, societal, political and regulatory features of a country or a region.

3.2.2 Mission and Objectives

- Outline a variety of transition pathways that could potentially achieve carbon-neutrality by 2050, taking into account regional diversities and different policy and technology strategies.
- Provide advice to the legal, policy & regulatory framework and market design on the role these factor may play both as enablers and barriers for sustainable transition and European cooperation.
- Develop further methodology for pathway analysis focusing on:
    - Linking techno-economic, socio-technical and environmental considerations into a unified framework;
    - Managing both short-term and long-term uncertainty in order to create robust and feasible transition strategies.

3.2.3 Activities and Research Questions addressing main Obstacles and Enablers

Research Activity 1: Pathways in support the energy transition for Member states and at the EU policy level

A crucial part of the European Green Deal is to reach net- zero GHG emissions by 2050 in a cost-efficient way, while supporting a low-carbon European economic recovery, delivering sustainable growth, preserving jobs and industrial activity. The introduction of new technologies and new ways of life will provide new business models, new market opportunities and new jobs, while maintaining Europe's leading role in a climate- neutral world. The analysis of possible pathways and the policies to go with them will provide decision support at all relevant policy levels from EU to local processes, by addressing the following research questions:

- *European leadership in the transition*: How can promoting and utilizing EU technological leadership in carbon-neutral technologies help society in designing and implementing the most ambitious climate neutral pathways?

- *Robust and feasible strategies*: With a number of potential ways to reach a net zero society, which factors make the strategies robust under the long-term uncertainties we are facing and feasible to implement, while complying with the mid-term and long-term societal and environmental targets?

- *Utilizing and respecting regional differences*: The needs and capabilities, the state of the economy, the resources at hand, the access to technology and importantly the highly variable approach to democratic consensus building in European countries differ from region to region. How can this be taken into account in the choice of the transition pathway? Similarly, the question of affordability has to be answered in regional or country- specific contexts. Recognize how technology acceptance and energy citizenship should *shape policy creation and implementation:* for the transition to succeed, the citizens need to take ownership of the transition, how will pathways differ in their attractiveness from this perspective? New insights are needed to understand what affects the choices of individuals and institutions, in order to construct the policy that will be effective and efficient to support the transition.

- *Fair and inclusive transition*: New insights are also needed to understand how different transition strategies affect welfare distribution, as well as just and fair transition, both in demographical groups, between different industrial sectors and between countries. Taking into account the urgency of the climate crisis and in connection to just transition, should changes be disruptive or stepwise?

- *Macro-economic aspects and competitiveness*: The pathways need to be analysed also focusing on their ability to create jobs and ensure sustainable value creation, with potential benefits between different policy areas like industrial, transport and environmental and climate policy, as well as energy policy. A better understanding of these aspects may improve the socio-economic impacts of clean energy, better addressing objectives like affordability, tackling fuel poverty, and creating employment opportunities.

- *Environment and health*: Currently the negative environmental and societal impacts of fossil fuels in terms of health issues, environmental damage, etc. may not be priced sufficiently high. The pathways analysis may provide support in understanding the effects that new technologies and ways of life have on the environment and climate and pricing these effects.

- The impact of enabling technologies and paradigm shifts like the circular economy and digitalization will dramatically change the relations between inputs and outputs in the economy, having a major impact on most of the areas above

Research Activity 2: Support governance, regulation and markets to enable the transition

The governance, i.e. How the transformation process is managed will influence the translation of pathways into policy and implementation. Thus, additional effort should be made to ensure relevance for policy makers at the local level when planning and implementing the energy transition, as well as to ensure European leadership in implementing net zero solutions and export competence and technologies. The following aspects should be addressed:

- *Legal, policy & regulatory framework and market design*: Understand and develop the role these factors may play both as enablers and barriers for sustainable transition and European cooperation.

- *Transnational collaboration in the energy transition*: Europe has a big advantage because it can create a homogeneous and widely shared regulatory framework. Spanning from very focused technological projects to large research clusters around Europe, very strong communication/dissemination focus and working together to solve a joint problem can be promoted. How can this be utilized in the implementation of transition strategies?

Research Activity 3: Developing the models and methodologies to support the energy transition

Pathway analysis combines quantitative model scenarios and qualitative storylines based on social sciences, aimed at establishing consistent and holistic pathways including technology choice, timing of investments, policy measures, environmental aspects and socio-technical issues. A number of methodological research questions arise to achieve this:

- *Combining modelling and social sciences*: New methodological approaches are needed to ensure sufficient representation and understanding of both human and technological systems and their operations. One way would be by iterative approaches, starting with quantification and model studies and then combining these with social science-based storylines into pathways (see Figure 2)

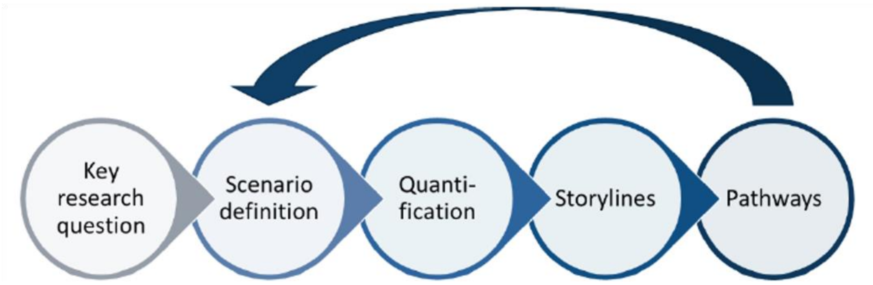

Figure 2: The Process of Establishing and Analysing Pathways

New methodologies should aim for more integrated and holistic approaches where the modelling itself to a larger degree captures social sciences and humanities aspects like new ways of life, the decisions of agents and new regulations and markets.

- *The integrated energy system*: Modelling sector coupling and system integration in long term models will be critical in order to understand how the interplay between transport, industry, the built environment and energy will play out. Large shares of renewables, CCUS, storage technologies and clean energy carriers like hydrogen all play together in the future economy. Long term models needs to capture these interplay in a better way, understanding both physical limitations and the economic, environmental, societal, political and regulatory effects.

- *Managing uncertainty*: In the integrated energy system the short-term interplay between different sectors and between different energy vectors plays a central role. Some of the driving factors are uncertainty, intermittency and variability. The representation of short-term uncertainty and this interaction also in the long-term analysis will be crucial to design the future economy. In addition long-term uncertainty regarding technology development, climate effects, demand and policy plays a role. Managing long-term uncertainty in these pathways will be crucial to identify robust strategies and the factors that make them robust, while complying with the mid-term and long-term societal targets.

- *Openness and transparency*: Establishing open modelling platforms and fora for analysis and comparison of pathways with climate and energy models is key. Open databases at the global and European level will have high value.

3.2.4 Impacts

- Identification of robust strategies for arriving at the net zero society in 2050, while respecting intermediate socio-economic and environmental objectives.
- Support for creating policy, governance structures, regulation and markets consistent with the net zero society and the objectives in the Green Deal.
- Frameworks for analysing the transition in a holistic and consistent way, respecting both technological feasibility, socio-economic aspects like welfare, fairness, justice democracy and environmental targets.
- Research based knowledge supporting both private and public decision makers in the energy transition.

3.2.5 Embeddedness and Interfaces to other Initiatives

Respective problem owners and need owners

Policy makers as well as private and public decision makers at European level, in member states, regions and municipalities:

- The outcome of the challenge will be a fact base spanning different alternative and outlining the decision space and consequences in the energy transition
- It will provide advice for governance, regulation and market design for implementation.

Interfaces to other thematic clusters/ transition challenges

There are links to the thematic clusters on fuels & storage, enabling technologies as well as to heating & cooling and system integration. The interaction goes both ways with this challenge takes technology descriptions and learning curves as input, it also provide advice on the future technology mix and needs in long-term perspective under different assumptions

To Energy system integration: Energy system integration and sector coupling are key in the energy transition and long-term pathways, both on the technologies, the governance and regulation as well as socio-technical aspects.

Interfaces to other Partnerships

- People-centric sustainable built environment - Built4People
- European Partnership on zero-emission waterborne transport
- European Partnership – Towards zero-emission road transport (2ZERO)
- European Partnership – driving urban transitions to a sustainable future (DUT)
- European Partnership for a Circular bio-based Europe
- Made in Europe

Interfaces to other existing initiatives (national, regional, EU, global)

- EIT InnoEnergy
- Climate-KIC
- Most of the SET Plan Actions

Contribution to the Green Deal and the Recovery Plan of the EC

This research can provide a fact base for transition strategies as well as insights for implementation and governance of these.

3.3 Challenge 3: Policies and Actions to Ensure a Fair, Just and Democratic Transition

3.3.1 Description of the Transition Challenge

While clean energy transition in the EU is supposed to create opportunities for more sustainable development and welfare, it is also supposed be disruptive and rapid, which may lead to increased existing social and geographical disparities. It is therefore critical that transition strategies and policies pay attention to potential consequences and that they are attentive to the question of which societal groups and industrial sectors benefit and loses from particular transition strategies, what are the potential levels of these impacts and how to measure them. We need to address, and tackle consequences related to energy-poverty, ethics and fairness, and ensure that they are inclusive in such a way that reduces disparity and fosters collective support of diverse groups of citizens, local communities, regions and nations.

To meet the societal expectations of fair, just and democratic energy pathways, it requires developing options that mirror shared and conflicting moral values. An added benefit of exploring the fairness and justice dimension of the energy transition is the possibility to co-create the process while involving relevant actors. These are crucial steps in designing and implementing inclusive and fair energy transition solutions.

3.3.2 Embeddedness and Interfaces to other Initiatives

Respective problem owners and need owners

1. EU citizens, especially (i) employees in businesses positively and negatively affected by the transition, (ii) marginalized and vulnerable groups that are typically not involved in energy transition discussions, but which might be massively impacted by the developments (e.g. children/adolescents, minorities, elderly people).
2. EU member states
3. Energy policymakers
4. All energy producers and energy consumers in the EU, including fossil fuels industries.

Overall, fair and just transitions challenge especially focuses on actively engaging those actors and social groups that are generally under-represented in or excluded from clean energy transition discussions.

Interfaces to other thematic clusters/ transition challenges

In the next step of the SRIA process consolidated cross cutting issues will be made and there are clear links to clusters 1&2 on renewable technologies and to cluster 4 on integrated energy systems as well as connections to most other clusters.

Interfaces to other Partnerships

Generally, an ethical framework applied to different technologies and their systems and defining the "ethico-social sustainability" components of technologies can be applicable in a broader context of socio-technical transitions beyond CETP. The "fair and just transitions cross-cutting challenge" can be applied for cross-cutting analysis of other technologies in other Partnerships. Experiences can be drawn upon from other sectors.

- **Experience of nano-technology regulation**

Due to the social and technological criticality of nanomaterials nano-enabled products, stakeholders and decision-makers found necessary to create a decision support system that would include evidence-based (i.e., interdisciplinary scientific data and knowledge, including environmental, economic, social and ethical aspects) and participative (i.e., engaging all stakeholders in decision making) governance. In accordance, it was elaborated an Ethics Assessment which is defined as the "process of judging the ethical impacts of research and innovation activities, outcomes, and technologies that incorporates both means for a contextual identification and evaluation of these ethical impacts and development of a set of guidelines or recommendations for remedial actions aiming at mitigating ethical risks and enhancing ethical benefits, typically in consultation with stakeholders''.[4] The idea of mitigating the ethical risks and enhancing the ethical benefits has a potential to be most helpful in the design, evaluation, and implementation of fair transition pathways.

- **Experience of electronics sector regulation**

  Electronics sector has already experience with addressing ethical challenges in supply chains (see EU Conflict Minerals Regulation entering into force in 2021 [5], voluntary Transparency Register for due diligence [6]; OECD Due Diligence Guidelines[7]).

Interfaces to other existing initiatives (national, regional, EU, global)

Other Initiatives relevant for fair, just and democratic transition challenges include:

- *Just Transition Centre* (2016) by the International Trade Union Confederation [8]
- European Energy Poverty Observatory (EPOV) [9]
- Just Transition Platform [10] and Just Transition Fund [11]
- Energy-Shifts [12]

Contribution to the Green Deal and the Recovery Plan of the EC

Just and inclusive transition for all is one of the key priorities stated in the European Green Deal. The European Commission has defined that the European Green Deal is set out to "boost the economy, improve people's health and quality of life, care for nature, and leave no one behind" [13]. The latter encompasses two dimensions: the individual level, i.e. the most vulnerable members of our society, as well as regions and Member States where the levels of economic and social development vary.

At the moment, EU policy documents do not provide explanations of how to define, measure or monitor just and fair transition. It is thus important to formulate clear definition and set of key performance indicators (KPIs) to better understand and guide policy makers and actors when designing, analysing and implementing clean energy transition solutions inclusive of social justice and fairness principles.

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[4] Malsch, Ineke, et al. "Embedding Ethical Impact Assessment in Nanosafety Decision Support." [Small (2019): 2002901

[5] https://trade.ec.europa.eu/doclib/docs/2017/march/tradoc_155423.pdf

[6] https://ec.europa.eu/trade/policy/in-focus/conflict-minerals-regulation/

[7] http://www.oecd.org/daf/inv/mne/mining.htm

[8] https://www.ituc-csi.org/?lang=en

[9] https://www.energypoverty.eu/

[10] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/actions-being-taken-eu/just-transition-mechanism/just-transition-platform_en

[11] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12113-Fast-track-interservice-consultation-on-the-SEIP-including-a-JTM-and-the-JTF-

[12] https://energy-shifts.eu/wp-content/uploads/2019/10/04_Inclusive-Engagement-in-Energy.pdf

[13] https://ec.europa.eu/commission/presscorner/detail/e%20n/ip_19_6691

3.3.3 Objectives, Obstacles and Enablers associated with the Challenge

Obstacles	Enablers
There is no clear and shared understanding of what is fair and just in relation to the EU's clean energy transitions. Many different concepts of fairness exist which need to be balanced. It is often taken for granted that renewable energy or zero-emission transitions automatically equals just, fair and democratic, but this is, of course, not the case and therefore we need to have a clear understanding of the potential dimensions of injustices that may emerge in connection to the ·clean energy system, identifying who is affected, what is the potential level of injustice and which measures would counteract them. How may we govern technological development in order to prevent risks and ensure that injustices are not deepened; and do we have the necessary tools, methods, data, and instruments to forecast and prevent harm?	Justice and fair transitions are already explicitly mentioned in the EU policy documents (e.g. European Green Deal), but a clear definition and agreement on what is meant by these terms should be added, as well as how they could be measured. In this context, it is also important to decide who defines what is understood as fair and just and in which process. There is a general agreement among both research and the policy-makers community that purely technological solutions are not enough for designing and implementing clean energy transition policy and measures, and social sustainability aspects need to be considered while designing clean energy solutions. There is already an existing knowledge base build in the energy research, social science and humanities domains that has potential to be mobilized towards giving input to energy policy design and impact assessments

Table 1: Main obstacles and enablers for implementing fair and just clean energy transitions in the EU

Objectives of fair, just and democratic transition challenge

- Define justice and fairness and anchor this definition in a broad and democratic process.
- Ensure that justice and fairness principles are the placed at the centre of clean energy transitions.
- Put mechanisms in place to ensure that justice and fairness principles are central in the development of clean energy transition solutions.

Highlights

- Reinforcing the notion of the need for inclusiveness (or recognition justice) and not just participation during any socio-technological transition and clarifying how justice and fairness can act as underlying principles in the clean energy transition process (see Energy-SHIFTs project materials [14]).
- Making sure that evidence-based research supporting the importance of community-led energy projects success is fully recognized and addressed when designing clean energy transition solutions. There are examples of integrative solutions for societal problems where energy justice is a crucial dimension (e.g. Smartees project [15][16]). There is also evidence that members of energy cooperatives, where energy efficiency measures have been implemented, e.g. smart meters, consume less energy.[17] Including consumers, such as via cooperatives, is therefore crucial for a successful transition. What seems to be lacking in these initiatives, though, is a clear strategy

[14] https://energy-shifts.eu/wp-content/uploads/2019/10/04_Inclusive-Engagement-in-Energy.pdf

[15] https://local-social-innovation.eu/energy-efficiency-against-fuel-poverty/

[16] ResCoop factsheet: http://www.rescoop-ee.eu/statistical-research

[17] Coopernico-Green Energy, sustainability, and citizenship: https://www.coopernico.org/

and structures for up-scaling and multiplying, and thus forming larger alliances empowering community-led projects to impact the energy system at large.

- Put broadly agreed tools, KPIs, and open-access data in place to assess and monitor (both ex-post and ex-ante) justice and fairness in a transparent way, which is especially challenging considering the current situation with lack of reliable, trustworthy, independent, easy-to access measurable data.

3.3.4 Activities and Research Questions addressing main Obstacles and Enablers

Research Activity 1: Defining justice and fairness

- Understanding what is justice and fairness from the perspective of all relevant stakeholders make the definitions applicable for energy policy design, impact assessments and implementation. Among the things to-do here:

- Developing definitions of justice and fairness aspects related to the energy system that are prescriptive in terms of respect to recognition and procedural justice aspects but not prescriptive in terms of formulating policies;

- Stating more clearly justice and fairness dimensions based on existing knowledge (e.g. energy justice pillars: distributive, generational, procedural, recognition justice).

Research Activity 2: Defining a set methods and tools to measure and monitor (ex-post and ex-ante) justice and fairness goals/sub-topics and possible policy actions

- Fairness and justice Key Performance Parameters (KPIs) should be designed and included into cross-cutting analysis. Formulation and use of meta-theoretical frameworks to integrate techno-economic, socio-technical, ethical, and political perspectives in assessments;

- Formulating the critical questions for which the answers and the research are not there yet and making the joint calls for those (e.g. transforming decision making processes, incumbent actors strategies of innovation/implementation, determinants for behaviour and social change, governing rapid and deep energy transitions).

In relation to Activity 2:

POLICIES & ACTIONS
Transforming the role of energy consumers/prosumers/energy citizens in designing and implementing clean energy transition solutions • Designing clear principles of citizens participation and engagements at the different stages of energy policy design and implementation as well as technology development/scientific processes; • Prioritizing user needs, energy affordability and energy poverty as one of the key objectives when designing energy policies; • Provide local affordable energy and business and employment opportunities; • Focusing on affordable cost and high-performance technologies suitable for a wide range of applications (e.g. for household and industrial use) in less developed, rural and remote areas; • Focusing on the technologies that are dispatchable, create jobs, and have other positive effects on environment or the economy; • Recognizing energy communities as an essential energy transitions building block; • Raising consumer awareness about the risks associated with different technological solutions and with taking and not taking an action; • Conducting studies for understanding better what drives and motivates human choice and action in the energy system in order to create policies where the citizen not passively accepts solutions but engage and take ownership; • Enabling a fair and balanced discussion on affordability and equity among stakeholder groups involved, explicitly identifying winners and losers of the clean energy transition process. Enabling a fair and

balanced discussion on affordability and equity among stakeholder identifying groups involved. Stimulating research & innovation and supporting progress on the non- technical barriers and enablers;

- Supportive and sustainable legal and regulatory framework as well as a supporting innovation ecosystem for integrated regional energy systems, including energy communities as an essential building block

Supporting local economies and jobs creation

- Creating the required labour qualifications by training, re-training and education, including fossil fuel industries workers re-training
- Learning from the experiences of fossil fuel industries
- Revitalising the infrastructure and supply chains that serviced historical sectors such as ship- building, fishing and oil & gas, coal, etc. across Europe and meets the needs for affordable local energy
- Supporting transition of fossil fuel producing regions acknowledging that communities can provide solutions as well as inherit the problems (e.g. heating from warm water in flooded coal mine regions – significant potential in coal regions of Europe) willingness to evaluate technologies at scale – be prepared to test at scale multiple technologies that can offer significant GHG mitigation. Additionally, important aspect of supporting transition of local identities in fossil fuel regions.
- Supporting workers across Europe, in e.g. Eastern Europe in the coal business, in the North Sea O&G industry, peat in North-East Europe and Ireland, etc. through employment and helping develop new skills for new industries.
- At different levels, encourage discussions on understanding the nature of democratic participation and just inclusion making sure such discussions are evidence-based and informed by knowledge and expertise.
- Learnings from businesses like coal, oil & gas and other fossil industries are beneficial from the transition point of view and stimulating such industries to engage in new practice. This includes issues were some of the already existing fossil fuel infrastructure can be "re-cycled" and adapted for the new technological uses, (e.g. hydrogen) which can provide such a service of a "stranded assets re-cycling".
- Policies need to be oriented at having gender equality as one of the explicit criteria within the energy projects. Job creation cannot be abstract anymore (like if it was with fossils employing mostly men and thus leading to mostly men being affected by fossil fuels phase-out). The jobs created in by the new transformed energy system should be accessible for all genders.
- Ensuring knowledge transfer and training create the required labour qualifications. The education challenge should include the international market opportunity dimension. Prioritizing (when possible) "convivial" technologies which can be accessible for the use and maintenance by local communities (especially those who are disadvantaged) without long, expensive, inaccessible education.
- Involving rural areas as the areas for renewable energy plants deployment, creating jobs and growth in less developed regions. Development of renewable energy technologies, which are dispatchable, create many jobs, have a high local content and is crucial for creating a feeling of local ownership.
- Ensuring that all EU regions benefit from the transition through value chains and technological diversity (e.g. offshore energy favours Northern countries with sea access; to mitigate this, exploitation of geothermal potential is a potential pathway for less favoured regions in Southern and Eastern Europe)

Securing technological leadership in Europe

- Providing evidence-based observations and facts on the strengths and weaknesses of different technologies in different contexts
- Fair valorisation of the cost of CO_2 emissions and material recycling capacity associated to each technology considering the importance they should have concerning carbon neutrality, environmental degradation and social equity
- Willingness to evaluate technologies at scale – be prepared to test at scale multiple technologies that can offer significant CO_2 mitigation
- Technology specific tenders are an important element. Permitting processes should be implemented in accordance with the recognition and procedural justice principles. Standardization: not only define standards but support the technology providers to practically make their equipment and solutions interoperable cross companies, sectors, infrastructures.

Table 2: Collection of the justice and fairness goals and policies based on the questionnaires and the previous discussions with the ERA-NETs and IWGs.

Research Activity 3: Establishing methodological support for projects funded under the CETP in questions on justice and fairness at crucial times for the projects (at least beginning and at important milestones).

3.3.5 Impacts

The main impacts of realizing fair, just and democratic energy transitions are as follows:

Transforming the role of energy consumers/prosumers/energy citizens in designing and implementing clean energy transition solutions:

- Making clean energy affordable for all
- Changing the narrative of citizens´ acceptance of energy technologies and infrastructures by empowering citizens participation in the energy system planning and to become active energy prosumer and/or market player.

Supporting local economies and jobs creation:

- Supporting a low-carbon European economic recovery and deliver sustainable development
- Supporting rural and local economies
- Preserving employment
- Supporting transition of fossil fuel producing regions

Securing technological leadership in Europe:

- Prioritizing the highest-performance technologies (including the highest "ethico-social and environmental justice performance")
- Strengthening trans-national and trans-regional collaboration

3.4 Challenge 4: A Resource Efficient and Sustainable Energy System based on Circularity

3.4.1 Description of the Transition Challenge

Circularity is a paradigm that, starting from the acknowledgement of resource scarcity (materials and energy), provides a way to make the best of the resources that are available, by extracting from them the maximum benefit possible, largely through appropriate choice of materials, increased component/device lifetime, materials recycling/reuse and energy recuperation, thereby reducing costs, minimizing waste and ensuring a positive environmental impact. It is crucial for a sustainable CET.

3.4.2 Missions and Objectives

- Select abundant, geopolitically neutral and socially/environmentally acceptable raw materials for a given technology, to ensure its sustainability.
- Minimise environmental impact and guarantee social acceptability of raw material extraction.
- Increase lifetime and efficiency of installations/components/devices, thereby reducing waste and costs.
- Optimise maintenance and replacement plans of installations/components/devices and parts thereof and reduce manned inspections, thereby increasing the overall plant lifetime and reducing wastes.
- Increase safety by anticipating failure, with corresponding cost reduction.
- Optimise energy flow to minimise losses and increase efficiency, e.g. energy cascading and reuse from high to low grade.

- Include or enhance the possibility of reusing/recycling in connection with installations/components/devices/materials: easy dismantling, easy separation for material collection, separability of reusable parts, choice of materials (see 1.), etc.

- Foster waste heat recuperation projects, identify suitable business models and mitigate risks for waste heat owners and heat networks.

- Reduce waste and negative environmental impact as much as possible when dismantling.

3.4.3 Activities and Research Questions addressing main Obstacles and Enablers

Research activity 1: Sustainable materials choice and extraction

- Redesign technologies (installations/component/device) to make them work with abundant, geopolitically-neutral and socially/ethically/environmentally acceptable raw materials. *This research issue is technology specific.*

- Develop environmentally friendly and circular extraction technologies; enforce suitable regulations to guarantee socially fair extraction methods. *This non-technological research issue somewhat exceeds the scope of the CETP.*

- Produce life cycle datasets on innovative materials, secondary raw materials and technologies, based on primary data representative of the European context, to be collected via a survey with input from the main European industry stakeholders, to assess the actual life cycle impacts of the different technologies, following a life cycle thinking approach. Actual and reliable data availability is the only way to produce correct assessments on technologies and make justified and robust choices and decisions.

<u>Impact</u>: Ensure sustainability; minimise negative environmental impact and increase social and geopolitical acceptability of clean energy technologies, support decision-making processes.

Research activity 2: Redesign installations/components/devices for energy generation, storage, conversion and distribution for higher sustainability and longer lifetime

- Change and optimise the design of specific components/devices in order to function using sustainable raw materials, with higher efficiency, increasing the component/device design lifetime, while enabling or enhancing reuse/recycling.

- Consider by design the possibility to reuse and recycle parts and materials also in other technologies.

These research issues are largely technology specific.

Design alone, however, cannot solve all problems: it is therefore <u>crucial</u> to develop <u>advanced/innovative materials solutions and fabrication processes</u> that increase lifetime/efficiency and facilitate reuse/recycling, while using abundant, geopolitically-neutral and socially/environmentally acceptable raw materials (link with Research Activity 1), possibly also reducing costs. *This research issue is PARTLY technology specific.*

The research on the methodology or on the development of materials solutions is of wide spectrum of use, cross-cutting through different technologies; for instance:

- **Develop common tools and methodologies to accelerate materials development**: high throughput automated materials synthesis and characterisation (robotics); advanced manufacturing and its optimisation (additive manufacturing, powder metallurgy, ...); automated microstructural characterization, testing and modelling; collection in correct format and analysis of key data, relevant for the entire material/component lifetime, etc. – *link with digitalization.*

- **Develop advanced recyclable materials/sustainable processes** of use for several energy technologies (*organise technologies into clusters*), e.g. high temperature & corrosion resistant structural materials.[18]

- **Develop common standards for materials testing and characterisation**, in support of accelerated materials development and to reduce the quantity of material that is needed for qualification, e.g. specimen miniaturisation and microstructural examination, . Non-destructive examination (NDE) techniques can be an asset here (see Research Activity 3). Monitorability by NDE should be a criterion in the materials development process.

Impact: Lifetime and efficiency increase, cost reductions, easy dismantling allowing reuse/recycling with corresponding reduction of negative environmental impact.

Research Activity 3: Monitoring and optimisation of installations/components/devices for energy generation/storage/conversion/distribution

Research on component/device monitoring is largely technology specific. However, several aspects of this research activity are not so strongly technology specific and can be cross-cutting, for instance:

- Development and optimisation of NDE techniques: correlation with material microstructure and properties changes and between microstructure and macroscopic properties.

- Development of data-driven and/or physical models of materials degradation, prediction maintenance, sensor data collection and analysis, elimination of spurious warnings. *A link exists with digitalization.*

Impact: Increased safety, efficiency and lifetime of installations; cost and waste reduction.

Research Activity 4: Energy flow optimisation

- **Energy cascading**. including optimisation of industrial processes, heat streams, re-using waste heat from energy-intensive processes, and energy balancing (e.g. between building clusters with different thermal needs).

- **Waste heat recuperation:** identify waste heat sources and synergy regions with matching demand and supply to enable future projects; investigate risk mitigation for waste heat projects, for example insurance schemes and risk analysis methodologies; promote training of finance actors to fund waste heat projects - *link with heating and cooling* .

- **Intelligent hybrid systems** where two or more technologies are combined to increase each other’s efficiency or to minimise each other’s loss or inefficiency, e.g. intermittency versus stable production, alternating heat/electricity production depending on demand guaranteeing stable output and continuous use of surplus energy for conversion (e.g. hydrogen production).

This research should be largely based on pilots and demonstrators or their feasibility study, as well as finding suitable business and contractual models. *A link exists with energy system integration.*

Impact: Increased efficiency, energy loss reduction, stable energy supply without the need for storage, waste heat as flexibility provider to the general energy system.

Research Activity 5: End-of-life considerations – sustainable dismantling and disposal of installations/components/devices for energy generation/storage/conversion/distribution

[18] https://www.eera-set.eu/wp-content/uploads/FINAL-June-2018-EERA-EUMAT-position-paper-HT-materials.pdf

- Research on technologies to enable or optimise recycling of a wider spectrum of materials or with higher efficiency *(can be cross-cutting)*.
- Identify possibilities of reuse/recycle, either in the same type of installation/component/device or in other types *(technology specific)*.
- Regulate safe disposal for parts/materials that cannot be recycled, to minimise environmental impact *(can be partly cross-cutting)*.
- Design legal and regulatory frameworks to incentivise recycling and reusing *(non-technological, cross-cutting)*.
- Develop life cycle datasets of end-of-life processes, based on primary data representative of the European context collected by survey submitted to the main industrial European stakeholders, to assess their actual life cycle impacts following a life cycle thinking approach.

Impact: Waste reduction, best possible use of resources, avoidance of landfill.

3.4.4 Impacts

- **Outputs generated and planned:** safer, more efficient and durable technologies, more sustainable in terms of optimised used of resources, both in the sense of materials and energy resources, with higher level of reuse and recyclability and thus minimal negative environmental impact.
- **Impact with respect to Clean Energy Transition:** ensure sustainable transition (best possible use of resources); increase social and geopolitical acceptability of technologies; reduce costs; reduce negative environmental impact; better informed decision-making process.

3.4.5 Embeddedness and Interfaces to other Initiatives

Respective problem owners and need owners

- Energy technology installation/device/component designers
- Energy equipment and materials manufacturers
- Waste heat producers such as energy-intensive industries, ports
- Recycling and waste processing plants

Interfaces to other thematic clusters/ transition challenges

Cluster 4 – Digital, Industry and Space (4.3 Advanced materials, climate-neutral and circular industry, digitised production)[19].

Interfaces to other Partnerships:

- Built4People[20]: focussed amongst others on circularly built environment and construction.
- Made in Europe[21]: focussed on competitive manufacturing industry with reduced environmental footprint, ensuring well-being for workers, consumers, society.

[19] https://ec.europa.eu/research/pdf/horizon-europe/annex-4.pdf

[20] https://ec.europa.eu/info/events/sustainable-built-environment-research-and-innovation-partnership-under-horizon-europe-2019-dec-12_en

[21] https://ec.europa.eu/info/publications/made-europe_en

- Artificial Intelligence, Data and Robotics[22]: addresses the applicability of these techniques in a wide spectrum of cases.

Interfaces to other existing initiatives (national, regional, EU, global):

- EIT Raw materials-KIC[23]: focussed on enabling sustainable competitiveness of the European minerals, metals and materials sector along the value chain by driving innovation, education and entrepreneurship.
- SPIRE (Sustainable Process Industry through Resource and Energy Efficiency)[24].
- SET Plan Action 6 Industry[25].

Contribution to the Green Deal and the Recovery Plan of the EC:

GD: Area 3: Industry for a clean and circular economy: more circular product designs and technologies to enable or optimize recycling; reduce waste and negative environmental impact as much as possible; introduce supportive policy measures (Circular and Climate-Neutral Industries[26]).

3.5 Challenge 5: Digital Transformation for Cost Reduction, Market Integration and User Empowerment in the Energy Transition?

Digitization, digitalization, and digital transformation are conceptual terms that are closely associated and often used interchangeably in a broad range of literatures. In order to properly frame these concepts in this SRIA, it is assumed that:

- Digitization is creating a digital (bits and bytes) version of analog/physical things such as paper documents, microfilm images, photographs, sounds, and more, so, it’s simply converting and/or representing something non-digital into a digital format which then can be used by a computing system for numerous possible reasons. In industry, it can also refer to the automation of existing manual and paper-based processes, enabled by the digitization of information
- Digitalization mostly refers to enabling, improving, and transforming (business) operations, functions, models, processes, and activities by leveraging digital technologies and a broader use and context of digitized data. It requires digitization of information, but it means more and at the very centre of it is data. As for this SRIA, digitalization goes beyond the former and refers to the ongoing adoption of digital technologies across all possible societal and human activities.

Digital transformation is broader than digitalization as a way to move to digital research environments, government services, and business operations. It requires far more bridges to be built in an encompassing digital transformation strategy. If you take the English definition of Google as “Digital Transformation” you will find “the profound and accelerating transformation of business activities, processes, competencies and models to fully leverage the changes and opportunities of digital technologies and their impact across society in a strategic and prioritized way”.

For the sake of easiness, digital transformation is the final strategy that is proposed with the following digitalization objectives, activities, and expected impacts.

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[22] https://ec.europa.eu/info/sites/info/files/research_and_innovation/funding/documents/ec_rtd_he-partnerships-artificial-intelligence-data-robotics.pdf

[23] https://eitrawmaterials.eu/

[24] https://www.spire2030.eu/intro

[25] https://setis.ec.europa.eu/system/files/set_plan_ee_in_industry_implementation_plan.pdf

[26] https://ec.europa.eu/info/sites/info/files/research_and_innovation/funding/documents/ec_rtd_he-partnerships-european-partnership-for-carbon-neutral-and-circular-industry.pdf

Digitalization is affecting all types of economic sectors. For the CETP SRIA purpose, it is quite important to understand the Digital Transformation can play a fundamental role 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 digital levels so as to allow real market integration, energy system integration and user empowerment.

This scenario must be also affected by a new reality: the role to be played by the final users. A key reference in this sense is given by the Clean energy package of the European Commission that clearly states the central role of the customers in future energy systems. Thus, with respect to the traditional concept of a Smart Grid, the digitalization process involves other new factors such as [DIGITALIZATION OF THE ELECTRICITY SYSTEM AND CUSTOMER PARTICIPATION - Technical Position Paper WG4 - ETIP SNET]:

- Customer involvements and possible disruptive new business models that could emerge from this involvement;
- Greater attention to sector coupling and then correspondingly to the convergence of Smart Energy and Smart Cities and Communities;
- New concepts and technologies that are emerging also at the physical layers thanks to a greater role played by electronics in the new digital energy system.

Then, the CET must be envisioned with a significant social component and focused on the service. The aforementioned reference from ETIP SNET structures the energy sector in three layers: physical; infrastructure; and, business layers and a deep analysis about them can be found therein. In this document, the research activities that should be reinforced for achieving such a social component focused on the service are presented.

3.5.1 Mission and Objectives

Digital technologies are believed to make the whole energy system smarter, more efficient, and reliable and to boost the integration of more renewables into the system. We will be able to use the connected infrastructures as efficiently as possible, time their production according to forecasted demand and, enhance the usage of renewables. The mission of this challenge is to design a digital transformation that will integrate not only the energy research entities and companies, but also the citizenship in a way in which all actors will be actively and proactively involved. Thus, the challenge (and the underlying strategy to pursue it) itself is not the mere application of digitalization for a CET, but also the full integration of citizens as final users and actors in this strategy.

Also, A lot of research, projects and studies are available. However, the work is complex and hard-to-reach, especially for small to medium sized utility companies. More effort should be put into identifying useful business cases and implementing already established knowledge.

In this way, specific objectives to achieve are:

- Reliable, complete and transparent (open access) information for decision and policy making and enabling citizen decisions (citizen empowerment)
    - Data on where and how energy is produced and consumed, in real time; raw and interpreted/simulated data, as well as on (local) demand (for the management of local production)
    - Data on energy costs, environmental impact, and all aspects of the energy flow cycle
    - Modelling and planning based on the data

- Optimal and safe management of systems and resources, cost minimization, change of business model in the interactions with citizens, better market integration in Europe, support to design relevant legal frameworks

- High performance computing, artificial intelligence, robotics, and automation in general at the service of the clean energy transition

    - Transparent technologies from which industry and citizens will be able to play their role

    - Efficiency in distribution and renewable production optimisation thanks to digitalisation between different energy flows (electricity, heating, gas, transport)

    - Education on energy as transformed by digitalization at all VET (Vocational, Education and Training) levels, to ensure the citizenship involvement.

3.5.2 Activities and Research Questions addressing main Obstacles and Enablers

The following activities have been identified for properly addressing the previous objectives.

Research activity 1: Energy-relevant data collection, interpretation, diffusion

Services based on the optimal exploitation of data.

- Data management and curation: define data and metadata format, ensure full data collection, define open access data policy, apply FAIR principles, integration with major European open repositories if possible, perform (high performance) data analysis (development of suitable artificial intelligence tools, data-driven continuum models...);

- Analysis on which platforms will provide optimum data infrastructure, in order to make data more easily available to simulation software, data dashboards, and analysis applications at large.

- Activities on data related to modelling and planning, such as (further) development of interfaces between existing tools in order to make them applicable for co-simulation approaches and integrated planning processes. One example could be digital models that include trans-national energy systems (electricity/gas) and local ones (district heating and cooling, transport) and potential sources for planning and modelling of the future energy system.

<u>Impact:</u> Reliable, complete, and transparent (open access) information for decision and policy making and enabling citizen decisions (citizen empowerment)

<u>Enablers:</u> digital related technologies (big data, FAIR, high performance data analytic, efficient distributed repositories, high performance, fog, and edge computing, data-driven continuum models, artificial intelligence methodologies, visualization and user-friendly tools…)

<u>Obstacles:</u> Access to the infrastructures; availability of real and updated information; citizenship involvement.

Research activity 2: Intelligent (artificial intelligence driven) generation, distribution and storage of energy (renewable electricity, carbon-free gas, heating/cooling

Based on real time availability and demand, costs, predictions (of demand, of weather...) and several other variables and parameters

- Development of intelligent energy production/distribution/storage management system, blockchain as a valid tool for energy economic transactions

- Development of mathematical models for prediction (both forecast and hindcast), data-driven continuum modelling (AI tools), suitable use and exploitation of high performance computing

- Guarantee cybersecurity (in connection to other research activities in this Challenge): protection of personal and sensitive data; avoid external interference with energy system management; blockchain for companies and use; resilience of energy systems in case of breech

- In connection to Challenge 2, further research and testing of technical and operational modelling, simulation, and optimisation of multi energy technologies and systems is required to identify the technological and systemic constraints. Globally, ICT systems for sector coupling should strengthen AI smart algorithms and operational specifications for an optimum energy system integration in aspects such as real time supervision, forecast, power dispatch control, financial transactions, etc. At the same time, energy consumption of the different data processing steps should be taken into account.

Impact: optimal use of resources; cost minimization; possibility of citizens to decide from where to take energy; new business model for interaction with citizens; better market integration in Europe; help to better design relevant legal frameworks; energy systems robustness; avoidance of failures

Enablers: aim of cost reduction; geographical distributed (renewal) energy sources; energy storage necessities; digital transactions.

Obstacles: Availability of real and updated information; citizenship involvement; easiness of use of new concepts (such as blockchain) by citizens; real digital integration of 'small' energy providers; cyberattacks

Research activity 3: (Online) Monitoring (through sensors) of materials and components, digital twins for the simulation of their behaviour

Digitalization can also enhance the successful sensorization and replication of energy systems and the developments of advanced materials of interest.

Achieving real interoperability to allow full market competition in sensing devices and components, based on international standards but certifying for European market applications.

- Development of mathematical models and/or data-driven continuum modelling (AI tools), development of sensors, training of sensor signal and data analysis system to connect materials microstructure with macroscopic property evolution, relevant exploitation of edge, fog, and high performance computing.

- Pilots, demonstrators (different TRL depending on context and goals), digital twins

- Energy systems resilience

Impact: Better plant/component lifetime management (e.g. timely component replacements) thanks to intelligent systems; accident/failure prevention; higher safety standards; longer lifetime; higher efficiency; lower costs; new materials; optimal operation of facilities (digital twins)

Enablers: AI tools; data analytic; computing infrastructures; electronics and processors; low latency bandwidths; data-driven continuum simulations.

Obstacles: Access to computational infrastructures.

Research activity 4: Digitalization as enabler of industry 4.0, advanced and automated materials and component manufacturing and processing

Industry 4.0 profiting from high-throughput systems, robotics, advanced manufacturing methods (e.g. 3D printing), automated materials development platforms based on automated characterization, testing, modelling, etc.

- Development of suitable robotics systems for automated materials/component manufacturing and quality control (characterization)
- Materials and component characterization and modelling
- Optimized automated application of advanced manufacturing processes (e.g. 3D printing)
- Development and training of intelligent models for automated characterization and testing, development of interpretation and prediction models, relevant exploitation of high-performance computing
- Pilots, demonstrators (different TRL depending on context and goals)

Impact: Faster production and installation; faster production and replacement of damaged parts; more efficient systems thanks to better materials, produced in faster, cheaper, better controlled way; higher efficiency; lower costs.

Enablers: AI tools; computing infrastructures; 3D printers; robotics.

Obstacles: Manufacturing of new materials; inefficient collaboration industry– research entities–citizens

Research activity 5: New business models, new human interaction

As aforementioned, the digital transformation follows a strategy in which the citizenship must be involved, being an actor in all the involved aspects. Thus, a success human interaction and a new business model including it must be taken into account.

- User-oriented services, user -friendly interfaces to techies and services
- Business models integrating the prosumers' interaction
- Digital marketplaces for real-time energy trading at local level, including prosumers
- Business models and offerings on local energy grids, including district energy, to include building owners and make them more inclined to allow their buildings to participate in making the energy grid work better.
- Business models enabling grid operators to manage, and possibly own, the substation. This will provide ways to develop the offer to building owners and tenants, as well as to integrate the substation into the energy system of the grid.

Impact: Avoid disruption of the transition, citizen empowerment (prosumers).

Enablers: AI tools; visualization techniques, blockchain.

Obstacles: Citizen access to valid information, avoidance of easy decision-making processes.

3.5.3 Impacts

Outputs generated and planned as well as impact with respect to the Clean Energy Transition have been identified per research activity.

3.5.4 Embeddedness and Interfaces to other Initiatives

Due to the digitalization that society in general and the energy sector in particular are facing, this challenge is connected to the rest of challenges compiled in this document. Also, there is a close connection with the European Energy Research Alliance and their ongoing Joint Programmes, in particular, the transversal and cross-cutting Joint Programme Digitalization for Energy.

Other European initiatives that will link to this challenge are EuroHPC, BDVA, ETP4HPC…

Ongoing H2020 projects of interest are EERAdata, EoCoE-II, EU4, EU4AI… in addition, the coming Horizon Europe is fostering the creation of European Partnerships on both ‘Digital, industry and space’ and ‘climate, energy and mobility’.