Project Number: 949125

Start Date of the Project: 01 January 2020

Duration: 42 months

Deliverable 1.5

Final report and recommendations on the optimisation of SET-Plan related EERA resources

DISSEMINATION LEVEL	**Public**
DUE DATE OF DELIVERABLE	31/12/2022
ACTUAL SUBMISSION DATE	31/01/2023
WORK PACKAGE	WP1 - Facilitating the execution of the SET Plan
TASK	Task 1.2 - Identification and mapping of EERA resources
TYPE	Report
NUMBER OF PAGES	28
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KEYWORDS	SET Plan Implementation Plans; EERA Joint Programmes; EERA resources; Energy research, REPowerEU

Version	Date	Description
0.1	10.09.2022	The first draft
0.2	02.11.2022	Updated version
0.3	18.12.2022	First revision
0.4	23.01.2023	Second revision
1	31.01.2023	Final and submitted version

Disclaimer

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 949125.

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EXECUTIVE SUMMARY

This report D1.5 "*Final report and recommendations on the optimisation of SET-Plan related EERA resources*" – relates to Task 1.2. – "Identification and mapping of EERA resources" – of the SUPEERA project.

The previous two deliverables of this task (i.e. D1.4 *Interim report and recommendations on the optimisation of SET Plan related EERA resources* and D1.9 *Second interim report and recommendations on the optimisation of SET Plan related EERA resources*) produced an analysis of EERA resources supporting the implementation of the SET Plan Implementation Plans (IPs) in terms of 1) the public institutional and competitive funding and 2) the appropriate EERA human resources and infrastructures.

In line with the revamp of the SET Plan to align it with the current European energy policies (European Green Deal, Fitfor55, REPowerEU, etc.), the new *European Innovation Agenda* and the new *European Research Area*, SUPEERA partners, (in coordination with the EC) have agreed that the focus of the 2022 report will be placed on EERA members' expertise analysing REPowerEU plan and reflect on critical aspects related to R&I challenges that are missing from or are insufficiently addressed in the REPowerEU.

Given REPowerEU's strategic nature, the current report is based on collecting and analysing rather qualitative than quantitative data. The focus on REPowerEU provides key and timely information by EERA members', which will also be useful for the analysis of the revised SET Plan, given the expected changes to its structure and objectives.

Therefore, Chapter I of this deliverable summarises the research from SUPEERA project's first two years for Task T1.2, including the methodology and key findings from D1.4 and D1.9. The Chapter II summarises the continuously evolving landscape of EERA resources, demonstrated in a series of structural changes of its Joint Programmes.

Chapter III provides a thorough reflection of EERA research community on the REPowerEU Plan producing a set of critical recommendations.

Chapter IV complements Chapter III summarising key information to set-up compact policy recommendations considering the socio-economic and energy system perspectives.

LIST OF ACRONYMS

CCS	Carbon Capture and Storage
CO_2	Carbon Dioxide
CSP	Concentrated Solar Power
EC	European Commission
EERA	European Energy Research Alliance
ERDF	European Regional Development Fund
ESI	Energy Systems Integration
ETIP	European Technology and Innovation Platform
EU	European Union
HR	Human Resources
IP	(SET Plan) Implementation Plan
IPCEI	Important Projects of Common European Interest
IWGs	Implementation Working Groups
JP	(EERA) Joint Programme
JP E3S	Joint Programme Economic, Environmental and Social Impacts
JP ES	Joint Programme Energy Storage
JP PV	Joint Programme Photovoltaic Solar Energy
JP Wind	Joint Programme Wind Energy
JPC	Joint Programme Coordinator
LNG	Liquified Natural Gas
MS	Member States
NECP	National Energy and Climate Plans
PED	Positive Energy Districts
PM	Person Months
PRIMES	Price-Induced Market Equilibrium System (energy modelling tool)
PV	Photovoltaics
R&I	Research & Innovation
R&I&D	Research, Innovation and Demonstration
RIA / IA	Research & Innovation Actions / Innovation Actions
SET Plan	Strategic Energy Technology Plan
SETIS	SET Plan information system
SFC	Solar Fuels & Chemicals
SMR	Small and medium-sized modular reactor
SSH	Social Sciences and Humanities
SUPEERA	Support to the coordination of national research and innovation programmes in areas of activities of the European Energy Research Alliance
TES	Thermal Energy Storage
Y1	Year 1
Y2	Year 2

LIST OF TABLES AND CHARTS

I. PRELIMINARY CONSIDERATIONS

1.1 Introduction

The task 1.2 of the SUPEERA project aims at identifying and mapping EERA members' resources that can prove useful in the execution of the identified SET Plan Implementation Plans' actions. This final deliverable D1.5 builds on the knowledge gathered throughout the last three years and the two interim deliverables:

- *Deliverable D1.4 – Interim report and recommendations on the optimisation of SET-Plan related EERA resources* which aimed at both displaying the first mapping of EERA members' resources and at designing the methodology that would be used to carry out this analysis;
- *Deliverable D1.9 – Second interim report and recommendations on the optimisation of SET-Plan related EERA resources* which built on the conclusions of D1.4 and further developed its methodology focusing more specifically on IPs activities marked as "orange" or "red" (respectively, activities with a lack of or no project take-off) in the SETIS' 2020 SET Plan annual progress report[1].

Considering the announcement of the revamp of the SET Plan to better align it with the latest European energy policies (*European Green Deal*, *Fitfor55, REPowerEU*, etc.), the new *European Innovation Agenda* and the new *European Research Area*, given also the absence of the analysis of the IPs from SETIS in 2022, it has been decided by SUPEERA and its partners, in coordination with the European Commission, that the present report would focus on the collection and analysis of qualitative rather than quantitative data. The focus on REPowerEU provides key and timely information by EERA members', which will also be useful for the analysis of the revised SET Plan, given the expected changes to its structure and objectives.

1.2 Lessons learned from the interim Deliverables

This first section provides a summary of the research carried out throughout the first two years of the SUPEERA project for the task T1.2, presenting also the followed methodology and main findings from the deliverables D1.4 and D1.9.

1.3 Methodology

To achieve the objectives of T1.2, i.e. mapping EERA members' resources potentially functional to cover identified IPs actions, a two-fold methodology was followed. First,

[1] Strategic Energy Technology Information System (SETIS), Implementing the SET Plan: Making the SET Plan fit for the EU Green recovery, Nov. 2020, https://setis.ec.europa.eu/progress-implementation-working-groups-2020_en

SUPEERA partners designed a set of surveys to gather homogenous information from EERA members.

The activity consisted of preparing separate surveys focusing on each SET Plan Implementation Plan. During the project's first year, the surveys were focused on the activities labelled as prioritised in the SETIS 2019 report. Nevertheless, based on the redefined strategy agreed between both the European Commission and the SUPEERA partners for the second year of the project, only those activities that were qualified as “orange” and “red” on SETIS’ analysis of the SET Plan IPs’ implementation progress were selected and pre-filled in the survey.

Secondly, all the surveys were sent to JP coordinators, soliciting them to mobilise and involve respective members in filling in the surveys according to their field of expertise.

Questionnaires were sent to EERA JPs in order to identify and map EERA resources, potentially valuable for supporting the needs of specific IPs actions, covering two directions:

1. The public institutional and competitive funding for the execution of the SET Plan Implementation Plans;
2. The appropriate EERA human resources and infrastructures for the execution of the SET Plan Implementation Plans.

Eventually, the data provided by JP members were analysed and compared with answers already received during SUPEERA’s first year, as well as with the data provided by IWGs for SETIS’ 2020 progress report.

1.4 Metrics studied

Four data types have therefore been studied within the two interim reports of the Task 1.2.

FOR DIRECTION 1. THE PUBLIC INSTITUTIONAL AND COMPETITIVE FUNDING FOR THE EXECUTION OF THE SET PLAN IMPLEMENTATION PLANS

- Competitive funding: Public funding allocated through competitive programmes and calls from funding bodies (e.g.: European funding such as Horizon 2020 or Euratom; national and regional funding such as ERDF and cohesion funds; transnational funding such as Interreg; or other types of funding);
- Institutional funding: Resources at the disposal of an organisation or resources directly granted by/received from a governmental body (ministries, funding agencies, etc.), without a competition.

FOR DIRECTION 2. THE APPROPRIATE EERA HUMAN RESOURCES AND INFRASTRUCTURES FOR THE EXECUTION OF THE SET PLAN IMPLEMENTATION PLANS

- Human resources: Human resources financed by both competitive and institutional funding have been taken into account. However, the metric used for this indicator had to be changed between the first and the second interim reports. Indeed, Person Months

(PM) being used by most European-funded projects, it therefore, allowed to get more easily accessible and comparable data in the second interim report (D1.9).

  - *Full Time Equivalent (FTE):* is the equivalent of one person working full time on the project on a yearly basis. This metric was used in deliverable D1.4;
  - *Person Months (PM):* corresponds to the human effort performed by a number of identified workers during a 12-months-period. This metric was used in the second interim report (D1.9).

- Research infrastructures: EERA members were asked to mention infrastructures essential to the realisation of one or more activities mentioned in the Implementation Plans. Such infrastructures can be laboratories, instruments (as of Y2), test sites or virtual facilities.

1.5 Summary of Findings

DELIVERABLE 1.4: INTERIM REPORT AND RECOMMENDATIONS ON THE OPTIMISATION OF SET PLAN RELATED EERA RESOURCES

Considering that the findings in Y1 were updated in Y2 with the second interim report, only the information related to data collected in Y1 will be provided in this section.

Out of the 304 surveys sent to EERA members, 46 answers offering sufficient qualitative and quantitative data for the analysis were collected. The rather low response should be ascribed firstly to the numerous difficulties the research centres have been facing during the COVID-19 pandemic and secondly to the difficulty of gathering all the data for resources coming from different funding sources, in particular from those national and regional ones.

Nevertheless, SUPEERA partners were able to draw conclusions focusing on the input of five JP members who had provided a reasonable number of responses: JP Bioenergy, JP Energy Storage, JP Fuel Cells and Hydrogen, JP Geothermal and JP Wind Energy.

For more information on the content on D1.4, please consult the Deliverable available on SUPEERA website.

DELIVERABLE D1.9: SECOND INTERIM REPORT AND RECOMMENDATIONS ON THE OPTIMISATION OF SET-PLAN RELATED EERA RESOURCES

Data collected

In Y2, the survey was sent again to EERA JP members through JP coordinators. 36 filled-in surveys were sent back allowing SUPEERA partners – as was done during Y1 – to focus on the input of the three JPs which had provided the most answers: JP Energy Storage, JP Bioenergy and JP Wind energy.

These three JPs were among the five JPs which had already provided what had been considered a reasonable number of answers during Y1. Additionally, while the overall number of answers had decreased, the number of answers received for each of these three JPs raised.

Results

In 2021, EERA JP members have reported 177 more projects. Therefore, a total of 436 ongoing projects were declared as contributing to the actions of the IPs of the SET Plan either lagging behind or which had not started yet.

For direction 1. The public institutional and competitive funding for the execution of the SET Plan Implementation Plans

In total, approximately €262 million resulted potentially available to EERA members contributing to the execution of the activities marked “red” and “orange”.

In both years, most of the contribution of EERA members to the activities of the Implementation Plans was made of competitive funding (e.g.: 90% in Y1) with European funds (either from Horizon 2020 or other EU funds) representing the highest part of these funding in most IPs.

In Y2, when focusing in particular on competitive funding supporting IPs’ “red” and “orange” activities, national and regional funds represent approximately 80% of the total reported competitive funding, and European funding less than 20%. However, national and regional funding are significantly higher for PED (Positive Energy Districts)[2] where competitive fundings are subsequently higher than in every other IP and for which European funds represent less than 5%.

Considering this bias, the analysis must also be carried out without PED data. Once it is removed, European funds represent on average more than 50% of the competitive funding received.

[2] See Figure 1. Volume of competitive funding reported by EERA members as supporting IPs’ “red” and “orange” activities

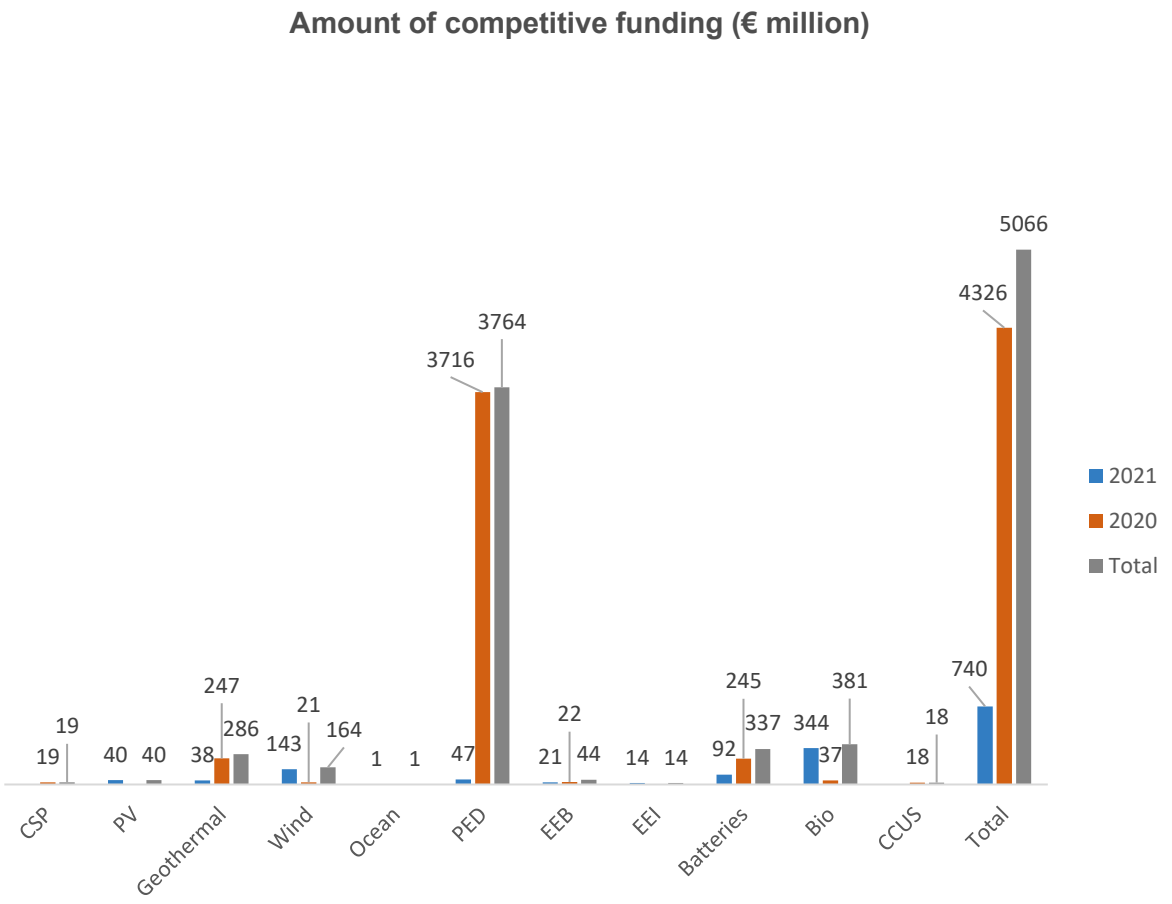

Figure 1. Volume of competitive funding reported by EERA members as supporting IPs' "red" and "orange" activities

Finally, the competitive funding received by EERA members and contributing to "red" and "orange" activities, represents approximately 3% of the total contribution received by all stakeholders involved in the reported projects. This amount reaching approximately 14% for the IP Bioenergy, and 13% for the IP Batteries.

For direction 2. The appropriate EERA human resources and infrastructures for the execution of the SET Plan Implementation Plans

- **Human resources:** In Y2, EERA members reported 11.018,22 PM contributing to the activities related to the SET Plan IPs' "red" and "orange" activities. Among these, 61% were financed through competitive funding, and 39% through institutional funding. Overall, the activities benefiting from the largest HR investments targeting "red" and "orange" activities in 2021 among EERA members, being: IP Bioenergy (4.282,22 PM (59% competitive funding (CF) and 41% institutional funding (IF))); IP Batteries (3.992,5 PM (36% CF/64% IF)); and IP Offshore wind (1.102 PM (100% CF)).

- **Research infrastructures:** EERA members have listed throughout Y1 and Y2 348 laboratories, 2785 instruments, 300 test sites and 51 virtual facilities that would prove essential in supporting “red and orange” activities. IPs Wind (1591) and Batteries (1002) in particular, were declared to be benefitting from the highest number of infrastructures for these activities. IPs Ocean, Positive Energy District, and Energy Efficiency for Buildings on the other hand, could not count on any infrastructure for its “red” and “orange” activities.

For more information on the content on D1.9, please consult the Deliverable available on SUPEERA web site.

The analysis of the two deliverables above shows how European funding still heavily supports the SET Plan activities, particularly those lagging behind (e.g. “red” and “orange” activities of the SET Plan). During the second year’s reporting, more institutional funding was reported by EERA JP members, highlighting the potential of coordination between European, national and regional levels for their common energy research priorities. However, aligning of funding at all levels and encouraging transnational synergies need to be further strengthened as they currently tend to prioritise the goals of specific groups of stakeholders, and as a consequence neglecting others. An analysis of available infrastructures and human resources among EERA JP members supports this conclusion. Some EERA JPs have created a projects’ catalogue for better monitoring of the IP’s dynamic, such as the JP on Bioenergy and Wind Energy.

II. RESTRUCTURING OF THE EERA COMMUNITY

The EERA community is continuously evolving to address new challenges and to respond to the needs related to European energy ecosystem. Cross-cutting collaboration, international outlook, increased focus on socio-economic aspects of the transition and, most recently, addressing the needs deriving from the REPowerEU are all considered as crucial drivers that have triggered important structural reforms across EERA's Joint Programmes. Some of the most relevant ones for the achievement of (revised) climate and energy goals are briefly explained in the paragraphs below.

2.1 EERA Joint Programme on Economic, Environmental and Social Impacts of the Energy Transition (JP E3S)

One of the transversal Joint Programmes of EERA (JP E3S) is addressing the Economic, Environmental and Social aspects of the energy transition. It aims to promote scientific cooperation on social, economic and environmental aspects affected and affecting energy transition pathways, thereby contributing to the market and societal success of emerging energy technologies. Launched in 2013, it numbers 35 active EERA members and it is currently under a revamping process with the aim to aligning its scope with the evolving context and make it a transversal "SSH" provider for other, rather technology oriented, EERA JPs facing similar SSH-Environmental challenges.

In this sense, and in order to ensure a continuous exchange on SSH topics across entire EERA, the JP E3S will allow the participation of researchers from other JPs, adopting its structure via inclusion of at least one member from each JPs. Content wise, its workstream will be implemented along four scientific domains and two transversal ones. More specifically, its members will address topics related to: engagement and communication, behavioural and organisational change, energy justice, economic and business, as well as the overarching ones on Policy (Regulation, Implementation and Evaluation) and on Modelling and impact assessment. The revamping phase is expected to be finalised by the 1st Quarter of 2023.

2.2 EERA Joint Programme Energy Storage

The members of the JP Energy Storage have a central role on creating the largest ecosystem in Europe of research infrastructures on the topic of (hybrid) energy storage. This is implemented, inter alia, through the StoRIES project which brings together the established research capabilities of ESFRI institutions, members of the European Energy Research Alliance (EERA) and the European Association for Storage of Energy (EASE), as well as national agencies such as CNR, ENEA, and CSIC, to form a stronger network focused on implementing innovative solutions. The partners have a history of successful collaboration and will continue to work together to create a cohesive European Energy Storage ecosystem.

The main technological objectives of the JP now supported by StoRIES are linked to the energy storage development by providing access to world-class research infrastructures and services, with a focus on improving materials for devices and optimising hybrid energy systems with a

view to make energy technologies more competitive and reducing costs, taking also into account other aspects such as security of supply and environmental and social sustainability.

2.3 EERA Joint Programme Wind Energy

The JP Wind Energy has the vision of launching “The Lighthouse Initiative”, a project that aims to develop large European research projects that will address the grand scientific and technical challenges that are crucial for the further advancement of offshore wind energy, providing new knowledge and basis for innovation. The Joint Programme also has the ambition of becoming a European Centre of Excellence on offshore wind with the aim to assure and maintain European leadership on offshore wind and providing new knowledge and basis for innovation in the sector. At the core of this ambition is to build new generations of young researchers working and learning from senior experimented researchers, creating reference data basis open to research and providing all necessary resources to support development of new challenges and European collaborative projects.

Since 2014, the JP is organising the annual event: “EERA JP Wind Innovation Forum”. It brings together research managers in wind energy from academia, institutes and industry, but also policy makers from member states and the EU. The Forum is an interactive EERA event of 4 days with workshops, presentations and discussions on strategic wind energy research. The aim of the forum is to provide the European R&I community in wind energy opportunities to create synergy advantages for European research organisations and industry in support of the green energy transition and the SET-Plan goals. This event has been organised together with the industry platform ETIPWind, SET Wind project and the SET Plan Implementation Working Group on offshore wind.

2.4 EERA Joint Programme Solar Photovoltaics

The work implemented in the framework of the EERA Joint Programme Solar Photovoltaics is split between eight subprogrammes. Since late 2022, an updated structure and division of work within the subprogrammes was introduced, aiming at aligning the targets of the Joint Programme activities with the Strategic Research and Innovation Agenda produced by ETIP PV and the JP. Therefore, the new structure reflects the new challenging priorities of the sector, both in terms of technology and synergies with other actors.

The updated structure of the JP mainly involves structural changes on its sub programmes which are responsible for addressing specific topics. For instance, new sub programmes were created that focus on aspects that stretch beyond the technology-specific dimensions of the PV industry. More specifically, sub programme 8 is addressing socio-economic aspects, policy and communications, as well as a closer link with the industry. Sub programme 7 focuses on energy system integration aspects addressing also the topic of digitalisation. Finally, to enhance the cross-collaboration between the sub programmes, but also their connection to the industry, there will be at least a person in each of them to link with each of the other sub programmes and a member to link the sub programme to the industry.

III. CONTRIBUTION OF EERA TO THE REPOWEREU

3.1 The REPowerEU Plan

In response to the hardships and global energy market disruption caused by Russia's invasion of Ukraine, the European Commission published in March 2022 the Communication "REPowerEU: Joint European Action for more affordable, secure and sustainable energy"[3]. REPowerEU is the European Commission's plan to make Europe independent from Russian fossil fuels well before 2030. It sets out a series of measures to rapidly reduce dependence on Russian fossil fuels and fast forward the green transition while increasing the resilience of the EU-wide energy system. The European Energy Research Alliance has analysed the REPowerEU Plan producing a set of critical recommendations that, in the opinion of the EERA research community, are missing from or they are insufficiently addressed in the Plan. The following chapters are based on information included in the publication: EERA REPowerEU Manifesto.

3.2 REPowerEU perceived by the EERA community

REPowerEU bears a unique chance to reformulate energy policies in a way which is conducive to emancipate the EU from Russian fossil fuels, tackle high prices and reach 2030 and 2050 climate goals. It provides a set of measures related to energy savings, diversification of energy supplies, and accelerated roll-out of renewable energy to replace fossil fuels in homes, industry and power generation.

After thoroughly reviewing the REPowerEU Plan, EERA's team of experts covering different technologies and aspect of transition, has identified several areas for improvement. The team considers that in order to address the transition effectively it is important to implement a holistic and systemic approach to be aligned with societal objectives.

PRIORITISING REDUCTION IN ENERGY DEMAND

According to EERA experts, the scope of the proposed demand-reduction measures in the REPowerEU Plan and the expected impact level needs to be significantly increased.

The REPowerEU demand-reduction plan primarily focuses on individual consumers, rather than the industrial sector. However, it is crucial that REPowerEU prioritises reducing electricity, heating, and cooling demand in the industrial sector through technology changes and higher energy-efficiency targets, as it can minimise the need for importing alternative natural gas from other countries and avoid creating new dependencies.

Secondly, the EERA community recommends additional demand-reduction measures for buildings, individuals and consumers. In order to maximise energy efficiency, buildings' insulation and quality of heating systems should be improved by, e.g., using the EC's

[3] Official Communication Text: https://eur-lex.europa.eu/resource.html?uri=cellar:71767319-9f0a-11ec-83e1-01aa75ed71a1.0001.02/DOC_1&format=PDF

Renovation Wave strategy as well as developing solutions for common use of multiple energy services (electricity, transportation, heating and cooling).

Particular attention should be paid to social acceptance and attractiveness. Available knowledge on this topic should be integrated into energy-efficiency policy design. In addition, ongoing research on social acceptance and attractiveness of different energy-efficiency and energy demand-reduction solutions must be ensured.

Regarding the change of demand structurally, three measures are proposed by the EERA community. Firstly, all subsidies for fossil heating systems should be prohibited in both new and renovated buildings. Secondly, the end-user electricity price reform should be implemented. Eventually, research should be funded on exploring alternative energy-demand models based on energy sufficiency, energy sobriety and alternative-to-growth paradigms.

ENERGY DEMAND ON PRIVATE SECTOR AND INDUSTRY

EERA proposes to design regulations encouraging private companies to conserve energy and reduce natural gas demand for the industrial sector. Additionally, more efficient industrial separation technologies and process intensification solutions should be developed, including energy-efficient solutions for drying and dewatering and heat-to-power technologies.

The following measures are proposed aiming to change industrial demand structurally:

- Prioritise **industrial decarbonisation targets** that go beyond increased industrial energy efficiency.
- Scale up **industrial symbiosis solutions** and other circularity-oriented business models.
- Reduce **energy use in building material** production and in the entire building life cycle
- Fund research on developing **new business models for industry** that would fit in with the energy sufficiency/ energy sobriety/ alternative-to-growth models and would implement the “energy-as-a-service” approach.

DIFFERENTIATING BETWEEN ELECTRICITY AND HEAT

Another aspect highlighted by the EERA community is that the REPowerEU Plan primarily focuses on the electricity sector. It is essential to underline that electricity currently represents only about 23% of the final energy consumption in EU-27 (see Figure 2 Final energy consumption in EU-27, 2020).

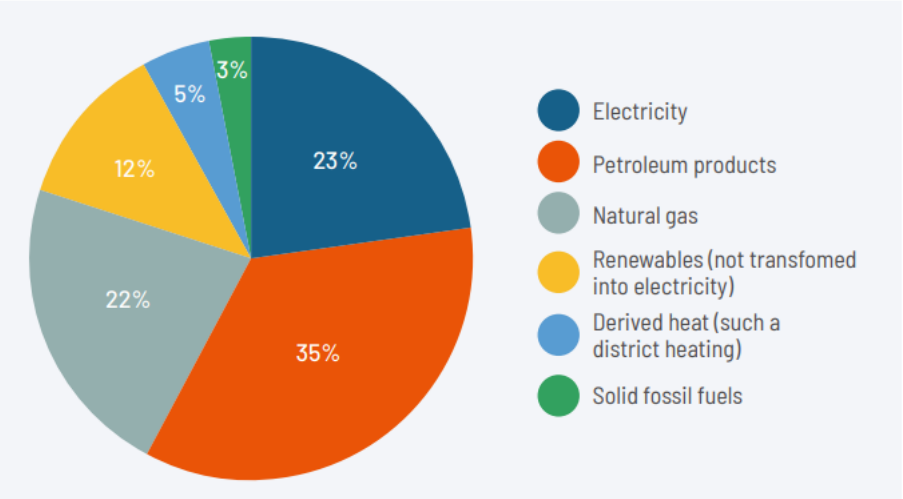

Figure 2 Final energy consumption in EU-27, 2020[4]

Nevertheless, it is important to note that heating and cooling make up around 50% of Europe's final energy demand, and it is the most significant energy sector that needs to be decarbonised. Therefore, it is crucial to give special attention to reducing the demand for heating, which is the primary contributor to gas consumption.

In light of the above, the following measures and priorities should be addressed in the heating sector to minimise energy demand and speed up the clean energy transition, the measures are focused to the heating sector for buildings and individual consumers.

The heating and cooling roadmaps developed by Heat Roadmap Europe[5] contain valuable information that can be used to better address heating and cooling within the REPowerEU Plan. These roadmaps should be used as a guide to support heating-related measures that are in line with REPowerEU's goals. The community stresses the importance of highlighting the role of heating savings and the role of solar thermal energy and low-enthalpy geothermal energy as direct sources of renewable heating. Additionally, they recommend scaling up district heating solutions in a manner that is most suitable for particular areas of Europe, maximising the use of combined heat and power for district heating solutions, scaling up the use of individual heat pumps in a manner that is most suitable for particular areas of Europe, modernising heat networks initially designed for fossil fuels and biomass and using them for renewable heat, and increasing the number of heating plants that deliver higher heating efficiencies and better pollution control than localised boilers.

As R&I priorities, EERA proposes to develop solutions to accommodate fluctuating supply and demand from renewable energy sources, especially combined with large-volume seasonal heat storage and foster research into solar thermal technologies to provide both clean electricity and heat in large quantities.

[4] https://ec.europa.eu/eurostat/cache/infographs/energy/bloc-3a.html?lang=en
[5] https://heatroadmap.eu/

On the other hand, industry is the other pillar that should be addressed in the heating sector. It is essential to encourage the use of technologically mature low-temperature heat pumps for industrial processes, specifically when combined with solar thermal and/or geothermal technologies.

Moreover, the use of solar heat to partially replace gas use in industry for heat production in the low-mid temperature range (50-400°C). Eventually, technologies' integration approach should be applied when designing industrial heating solutions as well as the integration of thermal energy storage (TES) technologies with other thermal technologies, for instance waste heat recovery and CSP, in a modular manner to satisfy different industrial needs.

In addition, the EERA community stresses the importance of several R&I priorities for industrial heating. Designing high-temperature (up to 200°C) heat pumps for industrial use is considered one of the main potential game-changing technologies. Developing solutions that help connect the heat sector with the electricity, gas, fuel, and chemical sectors is also important. The community also emphasises the need for developing solar heat-to-electricity-generation solutions for high-temperature industrial processes above 200°C (up to 1500°C), researching into small and medium-sized modular reactor (SMRs) for producing heat in addition to electricity in cogeneration mode, effectively contributing to the decarbonisation of heat production and designing operating temperature for the reactor to provide district heating or industrial heat.

STRENGTHENING THE ENERGY SYSTEM INTEGRATION PERSPECTIVE

An energy system integration approach should be at the core of the REPowerEU strategy for achieving the goals of the clean energy transition in Europe. Otherwise, a fragmented, silo-based approach to the transition will affects its speed, cost and effectiveness.

Power system stability

Marking smarter and better-connected distribution and transmission grids, as well as increased storage will support the movement towards an integrated energy system, ensuring the increased flexibility and stability that the power system will need with the expected increasing electrification level and the larger penetration of intermittent renewable power-generating sources.

In addition, REPowerEU should leverage the potential of dispatchable renewables, such as hydropower, geothermal energy, CSP (with storage capacity) or waste-to-power solutions, all of which can make key contributions to system stability.

Energy storage

Energy storage is a key component for achieving the clean energy transition as it ensures the security and stability of the energy system. However, it is not presented as an integral part of the REPowerEU Plan. This is a significant limitation, as it will jeopardise the accelerated scale-up of intermittent renewable power generation capacity.

Market design and investment mechanisms should therefore incentivise the development and deployment of energy storage technologies - both electricity and heat - in parallel with renewable energy generation technologies.

Energy storage should be an integral part of EU, national and regional transition plans, and energy transition plans should be able incorporate large-capacity renewable storage into national targets to protect the EU's energy system during periods when little or no energy can be generated by wind and solar power. Moreover, the requirement for heat storage on electrification of industrial processes should be incorporated into EU policies, which should also adapt electricity market rules to ensure fair remuneration for flexibility services and storage. Additionally, clear conditions and long-term perspectives for investments should be developed in the domain of hydropower and industrial thermal energy storage to de-risk them for investors. Storage solutions should be scaled up in district heating and cooling systems and the use of thermal energy storage for industry should be maximised to reduce natural gas use.

The EU's strategic autonomy

Accelerating deployment of clean power generation technologies, such as wind energy and solar PV should be prioritised against creating new dependencies on the value chains beyond Europe. EERA community, through their Joint Programme Coordinators, has identified the following measures and R&I priorities per clean energy technology in order to accelerate the clean energy transition in line with the principles of the EU's strategic autonomy.

As general recommendations, the EERA community indicates the following topics:

- Develop coordinated pan-european legislation and legal rules for renewable energy deployment.
- The design of policy instruments that encourage the use of locally produced renewables and storage use is strongly recommended as well as for supporting renewable energy communities.
- Structural shortages of qualified labour is a barrier encountered when planning all new projects aiming to increase renewable energy deployment.
- Research across a variety of SSH topics that can directly inform legislation and policy design should be strengthen.

As per technology, the EERA Joint Programme Coordinators propose the following recommendations and R&I priorities:

- Prioritise the use of Integrated PV which is key to speeding up renewable energy deployment in Europe. Furthermore, CSP should be included in the solar strategy part of the REPowerEU, in addition to solar PV.
- Use CSP to complement PV plants and to replace existing combined-cycle and coalfired power plants and maximise the use of renewable energy technologies that are less prone to critical raw material supply limitations such as CSP.
- Support R&D to speed up PV deployment. In particular, initiatives such as the IPCEI can bring EU research and industry closer to help swiftly return the PV value chain to Europe. The R&D support for CSP should focus on cost reduction, enhancing component lifetime and sustainability, and optimisation and further integration of hybrid systems.
- R&D efforts in designing solutions should be accelerated to help overcome dependency of renewable energy technologies on critical materials. Lithium and other

critical materials extracted from geothermal brines should be included in the research priorities.

- Simplify and shorten the permitting procedures for wind energy deployment and ensuring concerted action for strengthening Europe's wind energy supply chain.
- Increase substantially the investments in offshore grid infrastructure to speed up offshore wind deployment.
- Extend the operating lifetime of existing nuclear power plants in Europe, where possible, during the transition to renewable electricity generation.
- Acknowledge the energy role of hydropower and deep geothermal as the main renewable energy contributors to the flexibility of the European energy system in the context of the planned increase in the share of wind and solar power. In this regard, hydropower should be added to the SET Plan in the list of priority technologies to achieve the REPowerEU goals.
- Support R&I priorities on:
    - Assessment of wind power generation resources onshore and offshore given the latest technology developments and latest existing data on wind conditions.
    - Floating offshore wind technology (including R&D) to maximise exploitation of offshore wind resources in the EU.
    - Fourth generation SMR technology, which can potentially provide long-term, flexible low-carbon solutions to complement renewable electricity generation.
    - The development of sustainable methods of wind power generation compatible with the net-zero goals.

Natural Gas, hydrogen and other chemicals

Expected energy demand scenarios should be considered to design plans related to the use of natural gas, hydrogen and other chemicals in the EU. In particular, the development of gas infrastructure should be carefully assessed against the potential for decreasing gas use in the years ahead. Gas price volatility and the impact of creating investments or contractual lock-ins that would be incompatible with EU decarbonisation objectives are aspects to take into consideration. Regarding green hydrogen production, aspects such as the electrolyser capacity and the availability of corresponding clean power required for the electrolysis process should be assessed.

The following are concrete recommendations for natural gas and hydrogen R&I identified by EERA experts:

- Support investment in LNG and hydrogen infrastructure with modelling exercises assessing feasibility and associated medium- and long-term risks.
- Increase R&I&D in infrastructure for hydrogen transport. Hydrogen transport safety is one of the key topics requiring research on polymeric and metallic materials.
- Increase R&I in the areas targeting renewable fuels and gases instead of targeting hydrogen only. For example, solar-driven, biomass and plastic-waste fuel production can take place via various processes (pyrolysis, gasification, Fischer-Tropsch, etc.).

- Support research on power-to-gas technologies (e.g. for hydrogen, synthetic methane) as a method of absorbing surplus renewable electricity produced during phases of high electricity supply.
- Support the development of solutions targeting hydrogen production methods that use neither fossil fuels nor renewable electricity (e.g. solar-driven high-temperature thermochemical water splitting).
- Adopt a long-term R&D programme for CSP technologies that have the potential to produce hydrogen, synthetic fuels and chemical commodities.
- Foster research on high-temperature SMRs that can benefit the low carbon hydrogen production process.
- When planning new natural gas and hydrogen infrastructure, ensure ongoing support for developing CCS solutions and a supportive infrastructure to avoid potential lock-ins incompatible with the climate goals.

Energy modelling

Energy modelling is another essential component for optimally integrating the energy system. Currently, modelling that supports the quantitative targets and technological priorities set in the REPowerEU Plan is performed using PRIMES, which is a proprietary model that is not available for external investigation except for limited aspects. As a result, the model is in many aspects considered as a "black box" by experts and their results are taken with caution by the research community.

Additionally, synergies and trade-offs between solutions should be explored using simulation modelling tools and digital twin technology to test different energy supply and demand scenarios in Europe over time. Such analysis can provide insights into opportunities to limit dependency on fossil fuels, help identify potential lock-ins, and ensure that governments proceed with implementation of the scenarios most favourable for individual EU Member States.

Solar fuels and chemicals

Solar fuel cells have the potential to significantly advance the use of solar energy in the short, medium, and long term, with various developments coming online at different time frames. These developments include the production of e-fuels and chemicals by 2025, the transition to partially decentralised production by 2030 through the use of direct conversion processes, and the use of SFCs to efficiently convert CO_2 into long-lasting materials after 2030 to support sustainable energy development and negative emission technologies.

SFC technologies can help with seasonal energy storage issues in the use of solar energy by developing low-carbon, cost-efficient technologies that convert and store solar energy into fossil-free fuels and base chemicals. These technologies should be viewed as complementary to established solar technologies (and in in competition with them), and they are important for decarbonising the energy, transportation, and chemical sectors. SFC technologies use abundant resources to produce solutions through multi-step processes or via direct solar conversion.

ADDRESSING LIMITATIONS AND BOTTLENECKS OF ACCELERATED DEPLOYMENT OF LOW-CARBON TECHNOLOGIES

According to EERA, some of the main risks and bottlenecks in accelerated deployment of renewable energy technologies include:

- Supply chain limitations: The increase in renewable electricity generation is likely to be limited by global manufacturing capacity and supply chain constraints that are often out of the EU's control.
- Human resource limitations: The structural shortage of labour in the clean energy sector already existed before the current energy crisis and has been significantly slowing down the transition process. There will be a shortage of technical skilled manpower across the implementation cycle of the various technologies (e.g. designers, construction workers, installation engineers, operations and maintenance technicians, grid engineers, etc.), as well as non-technology stakeholders, such as policymakers, regulators and legal practitioners who play a crucial role in supporting the clean energy transition at local, regional and national level.
- New resource dependencies associated with scaling up renewables on imports from less stable and/or less reliable countries or partners, such as critical minerals, critical components, such as micro-chips; finished products, such as PV modules and the end of life of materials and component disposal.

IV. POLICY RECOMMENDATIONS ON REPOWEREU

The purpose of this section is to highlight the most critical recommendations considering the socio-economic and energy system perspectives that, in the opinion of the EERA research community, are missing from or insufficiently addressed in the REPowerEU Plan.

Socio-economic perspective

1. **Communicating comprehensively with EU citizens on the energy and inflation crises**

   In order to maintain popular support for EU political choices, preserving and further consolidating cohesion within the European Union, and successfully driving REPowerEU implementation, a communication initiative at EU and national level should provide EU citizens with a clear understanding of the root causes, implications and remediation strategies adopted, supported by a transparent and comprehensible analysis of the expected short-, medium- and long-term impacts.

2. **Reassessing our current economic paradigm, recognising the shifts in fundamentals**

   Such a reassessment should be carried out considering the new EU security of supply paradigm, within the limits of biodiversity, climate change and resource constraints, while recognising the imperative to accelerate the transition towards a sustainable, fair and climate-neutral society by 2050.

Energy system perspective

3. **Fostering a structural, sustainable and fair reduction in energy demand**

   Demand-reduction measures should be driven at all levels of society even though considering specific characteristics of the diverse consumer groups. The most vulnerable groups should be protected while primarily targeting those with most reduction potential. Additionally, appropriate approaches should be developed to support this societal shift, for example by upskilling experts and policymakers and by further informing and empowering citizens to make the right decisions. In the industrial sector, targeted sustainable demand-reduction policies should be designed to protect the EU's economic and industrial independence.

4. **Embracing all energy uses beyond power only**

   It is crucial to carefully address all energy vectors in connection with each other since reference energy transition scenarios all rely on the massive deployment of renewable

technologies and accelerated electrification. In this respect, it is important to highlight that electricity still only represents less than 25% of the EU's final energy demand. The use of open-source modelling and simulation tools is key to enable the research community to provide a robust analysis of the EU's clean energy transition pathways, including those that are specifically related to REPowerEU.

5. **Empowering the research community to be part of accelerated technology deployment**

   Policymakers should fully empower the research community with mission-oriented instruments to channel research efforts towards the implementation challenges, recognising its capabilities to contribute to identifying, analysing and addressing implementation bottlenecks to faster deployment of existing technologies.

   In addition, close collaboration between the research community and industrial players is essential to ensure that demonstration projects in the EU Member States use the best available knowledge. Similarly, the clean energy research community benefits from engaging with industry and participating in demonstration projects, thereby having the opportunity to test research results and further accelerate development of research methods and tools.

6. **Operationalising R&I recommendations on REPowerEU into the SET Plan**

   The SET Plan and associated funding instruments should incorporate the R&I recommendations put forward by the energy research community in the context of REPowerEU.

7. **Integrating climate adaptation within energy system planning**

   Given the rapidly increasing frequency of extreme weather events and their impact on energy infrastructure, climate adaptation considerations should be fully integrated into the design of REPowerEU strategies, recognising their current and expected impact on energy infrastructure (e.g. impact of heatwaves and droughts on hydropower and nuclear power generation).

8. **Aligning immediate energy needs with longer-term environmental objectives**

   REPowerEU strategies need to be assessed against achieving climate objectives. Thus, any investments in fossil fuel-based infrastructure must be critically assessed, considering their repurposing potential from a strategic and technical point of view (for example, repurposing the use of LNG infrastructure for hydrogen should be not only feasible but also desirable from the strategic clean energy transition pathway perspective). Additionally, the production, deployment and operation of new energy

infrastructure must be critically assessed against its environmental footprint to minimise its impact on ecosystems, especially their biodiversity.

9. Assessing REPowerEU against the EU's strategic autonomy objectives

Particular attention should be paid to assessing the diversification of energy imports against political risks and environmental and ethical implications associated with the partner exporting country. In addition, increased EU geopolitical dependency on countries exporting clean technology, finished goods, intermediate components and/or critical minerals should also be considered.

Thus, policymakers should design clean technology procurement strategies about the implementation of REPowerEU by focusing on:

- Sourcing from EU industry whenever possible and reshoring critical value chains.
- Diversifying import sources (finished products, components, critical minerals) and assessing them in terms of their political, ethical and environmental implications.
- Boosting material research to minimise usage of critical minerals, foster higher recyclability of critical minerals, use alternative-to-mining ways of extracting critical minerals (such as lithium and other critical materials extracted from geothermal brines) and promote their substitution by non-critical minerals.
- Funding energy system modelling initiatives to include critical materials and other components needed in energy system models.

10. Matching the deployment of clean energy technologies with value chain constraints

Global supply chain considerations, especially those not under EU control, need to be carefully analysed in order to achieve the accelerated deployment of low-carbon technologies, including wind, solar PV, heat pumps, green hydrogen and biomethane.

EERA recommends setting up technology-specific multidisciplinary expert groups tasked with assessing deployment conditions through research-based analysis, including dependencies on:

- External value chains, such as manufacturing and transport of finished or intermediate products.
- EU value chains, such as those resulting from planning, permitting, financing, procurement, installation, integration, commissioning and operation of clean energy assets.
- Other components of the energy system (e.g. dependency of wind and PV on grid infrastructure or dependency of clean hydrogen production on availability of green power).

11. Strengthening the Energy Union

EU solidarity mechanisms and collaboration will be essential to collectively minimise the impacts of import cuts, as well as to create stronger negotiation power on international energy markets. Furthermore, harmonising policy response within the EU will enable fairer and more effective management of crises, particularly related to handling windfall profits, which should be done in a way that will preserve a level playing field in order to avoid internal market distortions.

12. Boosting cooperation with strategic neighbouring countries and energy trading partners

Greater collaboration with neighbouring countries and energy trading partners are required to rebuilding the security of supply in the EU requires. Therefore, policymakers are urged to encourage measures that contribute to this objective, while ensuring that political, environmental and ethical imperatives are in line with European needs.

V. Afterword

In 2022, the scope of Task 1.2 was repurposed to address several changes that would impact the execution of an exercise similar to the previous years (i.e. D1.4, D1.9). The absence of analytical data in the SETIS progress report in 2022 regarding the execution of IPs actions, the response of the publication of the REPowerEU Plan and the current revamping process of the SET Plan, were the three main drivers for such shift that enabled a different type of mapping and analysis of the EERA resources, of rather qualitative than quantitative nature as opposed to the previous years. Given the dynamic energy scenario in Europe, some of information included in this report may require updates before the end of the Project. Therefore, and in order to accomplish to its high-level objectives, any relevant change and update that will influence the content of present deliverable will be duly incorporated in the final report of SUPEERA.