

SET PLAN

PROGRESS REPORT 2021

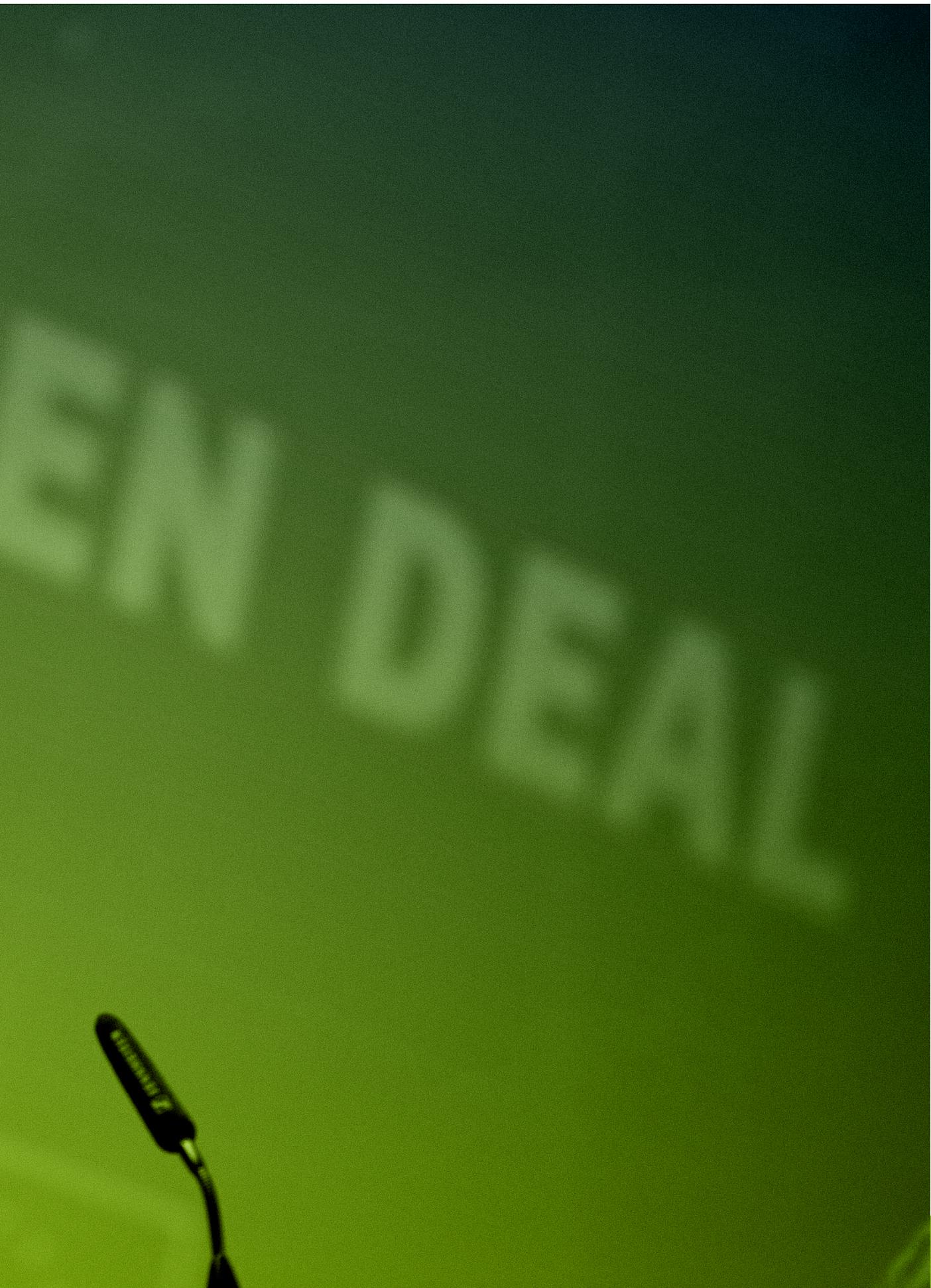
CONTRIBUTING
TO THE EU GREEN DEAL
AND THE PATH FORWARD
TO A GREEN RECOVERY



2021
REPORT

JRC126881





FOREWORD



Since 2007, the SET Plan has been instrumental in fostering collaboration between SET Plan countries, industry and research institutes to facilitate the achievement of the EU's climate and energy goals and to strengthen industrial competitiveness throughout the European Union.

The SET Plan has been successful in coordinating national R&I agendas on low-carbon energy and has leveraged much-needed resources at both European and at national level. However, additional public and private investments in clean energy research and innovation are necessary to deliver on the Green Deal's ambitions and to support the EU's Green and Digital Recovery. R&I is also crucial to ensure that our industry remains resilient and competitive, including for future markets of clean energy technologies. Technologies that will help reach many of these targets are now emerging, but most of them still need R&I support to become more sustainable, efficient, safe and cost-competitive. By channelling funds towards the green and digital technology, Europe can become a global leader in clean energy and show the way for increased global mobilisation towards zero carbon energy for all.

The European Green Deal aims to transform the EU into a modern, resource-efficient and competitive economy along the path to net zero emissions by 2050. Research & Innovation lies at the heart of the challenge and, as such, the SET Plan shall continue to be the place where members can combine their complementary strengths to accelerate the clean energy transition. I welcome the SET Plan's ambitious vision, which spans the array of clean energy technologies needed over the next decades. I look forward to updates on its R&I activities, which will continuously evolve to support Europe's political priorities, market changes, and industry developments. The European Green Deal is an opportunity for a revamped SET Plan to mobilise the R&I funding in Europe towards achieving climate-neutrality by mid-century.

Mariya Gabriel

European Commissioner for Innovation, Research,
Culture, Education and Youth



The recent increases in energy prices remind us again of the urgency to reduce our dependence on fossil fuels and increase energy efficiency and the share of renewable energy sources. In this context, the role of research and innovation to make our energy system cleaner, more secure, more affordable, and more competitive¹ is key.

The European Green Deal framework, and in particular its energy-related strategies, such as hydrogen², Offshore Renewable Energy³, Energy System Integration⁴, and Renovation Wave⁵, set the direction for new EU R&I policies developments. Moreover, the adoption of the NextGenerationEU⁶, the Innovation Fund, the Multiannual Financial Framework⁷, including Horizon Europe⁸, provides unprecedented financial support for these developments.

In order to reach the 2050 decarbonisation target, the European Commission adopted in July 2021 an ambitious 'Green Deal' package⁹ of 13 legislative proposals to make the EU's climate, energy, land use, transport and taxation policies fit for reducing net greenhouse gas emissions by at least 55 % by 2030, compared to 1990 levels. The new legislation will help accelerate the market uptake of innovative solutions and create the sizable markets needed to compete with the fossil-based alternatives. The SET Plan is instrumental in anticipating and designing the innovation needed and aligning funding efforts at

national and European level, leveraging also on the Recovery and Resilience Facility reforms and investments planned and undertaken by Member States.

Moreover, the SET Plan supports the implementation of the European industrial strategy. By facilitating R&I efforts across clean energy technologies and breaking down the barriers to cooperation, it helps make the EU industry more competitive globally. At the same time, it targets future markets and enhances Europe's strategic autonomy, thus strongly supporting the twin transition towards a green and digital economy.

Reaching the EU energy and climate targets requires increased cooperation and synergies among stakeholders and Member States at both national and European level. In this respect, the SET Plan represents the core mechanism to engage with governments, industry and stakeholders, providing a European platform for aligning initiatives and efforts.

The Green Deal is ambitious. Yet, with the new financial instruments available and increased cooperation through the SET Plan and its alignment with other EU collaboration partnerships it is possible to deliver the innovation needed to reach its targets.

Kadri Simson
European Commissioner for Energy

1 <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2021%3A660%3AFIN&qid=1634215984101>

2 https://ec.europa.eu/energy/topics/energy-system-integration/hydrogen_en

3 https://ec.europa.eu/energy/topics/renewable-energy/eu-strategy-offshore-renewable-energy_en

4 https://ec.europa.eu/energy/topics/energy-system-integration/eu-strategy-energy-system-integration_en

5 https://ec.europa.eu/energy/topics/energy-efficiency/energy-efficient-buildings/renovation-wave_en

6 https://ec.europa.eu/info/strategy/recovery-plan-europe_en

7 https://ec.europa.eu/info/strategy/eu-budget/long-term-eu-budget/2021-2027_en

8 https://ec.europa.eu/info/research-and-innovation/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en

9 https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/delivering-european-green-deal_en#documents

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EXECUTIVE SUMMARY

The Strategic Energy Technology Plan (SET Plan) plays a key role in serving the goals of the European Green Deal by facilitating the delivery of clean energy innovations necessary to achieve the European transition to climate neutrality by 2050. To this end, 14 SET Plan Implementation Working Groups (IWGs) have established ambitious research and innovation targets to be reached in the next decade(s) in energy efficiency and low-carbon energy technologies.

The 2021 Progress Report features three interconnected chapters that cover the political relevance of the SET Plan, the main collective developments of the last 12 months, and a concise overview of the individual achievements of the working groups.

This year's results show that the working groups adapt their activities to the changing policy landscape and to market developments. Cross-sectorial collaboration has increased, both within and beyond the SET Plan. The working groups' monitoring of developments in research and innovation (R&I) at national level is strengthening and efforts are being made to increase public and private R&I funds.

In light of the launch of the Fit for 55 package, and the need to enhance EU competitiveness in clean energy technologies, the SET Plan is working to extend its ambition in terms of the objectives and targets to be achieved, expanding its scope to include emerging technologies.





INTRODUCTION



The 2021 Strategic Energy Technology Plan (SET Plan) Progress Report assesses the progress of the SET Plan, particularly in terms of implementation and key achievements for the year 2020-2021. It outlines the research and innovation (R&I) activities carried out under the leadership of the working groups, and the targets completed and milestones reached vis-à-vis the 13 implementation plans.

This year's progress report has a two-fold objective: to demonstrate the SET Plan's policy relevance in delivering the European Green Deal; and to pave the way for future SET Plan developments.

The report is organised in three parts. The first provides background information on the SET Plan and the EU clean energy R&I investment landscape. The second part focuses on key developments since the last SET Plan progress report a year ago. In the third part, the report offers an overview of the activities and progress for each working group. Moreover, for the first time in this series, the report highlights key projects that contribute to the implementation of the SET Plan.

The Joint Research Centre of the European Commission prepared the report in close collaboration with DG Energy, DG Research and Innovation, and the 14 SET Plan working groups.

The report was compiled for publication on the occasion of the 15th SET Plan Conference in Bled, Slovenia.

THE SET PLAN

The SET Plan was established in 2007 to support the EU's energy and climate goals and make Europe a global leader in low-carbon energy and energy efficiency technologies. It is linked to the 5th dimension of the Energy Union – research, innovation and competitiveness – which is structured around six R&I priorities¹⁰. The SET Plan addresses the R&I priorities of the Energy Union by translating them into 10 key actions, which are delivered by thematic working groups through their implementation plans¹¹.

The SET Plan is made up of the Steering Group, the Bureau of the SET Plan Steering Group and 14 Implementation Working Groups (IWGs).

The Steering Group is the decision-making body of the SET Plan. It consists of representatives of the SET Plan countries – the EU Member States as well as Iceland, Norway, Switzerland and Turkey. The Bureau supports its work with the preparation of internal meetings and discussions. The SET Plan Information System (SETIS) underpins the operations of the SET Plan by providing the necessary scientific evidence for decision-making. SETIS also monitors and reports progress, and publishes SET Plan outcomes on its dedicated website, ensuring transparency.

The 14 working groups monitor and report progress to SETIS on the SET Plan targets and R&I activities carried out at national and European levels. The activities and targets, published in the working groups' implementation plans, are identified in cooperation with national governments and stakeholders (industry and research bodies). The implementation plans represent the reference document of the SET Plan in each field

and ensure that it is aligned with the key industrial developments.

Membership of the working groups includes representatives from industry, research institutes and non-governmental organisations, as well as national and regional authorities in charge of research, innovation, education, climate action and energy.

The activities of each working group benefit from continued liaison and support from other EU R&I initiatives such as:

- the European Technology and Innovation Platforms (ETIPs), in which industry, research organisations and academia work together on the implementation of the SET Plan priorities along the innovation chain and develop strategic research agendas;
- the European Energy Research Alliance (EERA), which represents the research community and seeks to catalyse European energy research in line with the objectives defined by the SET Plan;
- the various Coordination and Support Actions (CSAs), funded under Horizon 2020, to support the IWGs in communication, dissemination and mutual learning activities;
- the European Research Area Networks (ERA-NETs), one of the main instruments allowing Member States to support the SET Plan with increased funding for transnational research and R&I Framework Programmes. Following the establishment of Horizon Europe, the ERA-NET Cofund and the European Joint Programme (EJP) Cofund under Horizon 2020 are succeeded by the Co-funded European Partnerships.

¹⁰ Actions are grouped around the following six priorities: (i) the EU being the world leader in developing the next generation of renewable energy technologies; (ii) facilitating the participation of consumers in the energy transition; (iii) efficient energy systems; (iv) sustainable transport systems; (v) a forward-looking approach to carbon capture, utilisation and storage; and (vi) nuclear safety. https://setis.ec.europa.eu/system/files/2021-03/Communication_Energy_Union_en.pdf

¹¹ https://ec.europa.eu/energy/topics/technology-and-innovation/strategic-energy-technology-plan_en#key-action-areas

SET PLAN IMPLEMENTATION LANDSCAPE

	WWW	ETIP	CSA	ERANET
Solar photovoltaics	www.iwg-pv.eu	www.etip-pv.eu	www.pvimpact.eu	www.solar-era.net/
CSP/STE	http://www.horizon-ste.eu/		www.horizon-ste.eu	www.csp-eranet.eu
Offshore wind		www.etipwind.eu	www.setwind.eu	
Deep geothermal	https://www.deepgeothermal-iwg.eu/	www.etip-dg.eu/	www.deepgeothermal-iwg.eu/	www.geothermica.eu
Ocean energy	www.OceanSET.eu	www.etipocean.eu/	www.oceanset.eu/	www.oceancofund.eu/
Positive energy districts	https://jpi-urbaneurope.eu/ped/	http://www.ectp.org/ https://www.euroheat.org/		
Energy systems		www.etip-snet.eu/		www.eranet-smartenergysystems.eu/
EE in buildings	https://setis.ec.europa.eu/implementing-actions/energy-efficiency-buildings-implementation-working-group_en	www.rhc-platform.org		
EE in industry	https://setis.ec.europa.eu/implementing-actions/energy-efficiency-industry-implementation-working-group_en			
Batteries	https://ec.europa.eu/energy/topics/technology-and-innovation/batteries-europe_en	https://ec.europa.eu/energy/topics/technology-and-innovation/batteries-europe_en	https://battery2030.eu/	
Renewable fuels and bioenergy		www.etipbioenergy.eu/	www.etipbioenergy.eu/set4bio www.set4bio.eu	www.eranetbioenergy.net
CCS-CCU	https://www.ccus-setplan.eu/	www.zeroemissionsplatform.eu/	https://www.ccsassociation.org/	www.act-ccs.eu/
Nuclear safety	https://setis.ec.europa.eu/implementing-actions/nuclear-safety-implementation-working-group_en	www.snetp.eu		

THE EU CLEAN ENERGY R&I INVESTMENT LANDSCAPE

In 2018, the latest year for which near-complete investment data is available, an estimated EUR 28.7 billion was invested in the clean energy technology R&I priorities of the Energy Union¹². Roughly 83 % came from the private sector, while the remainder came from Member States’ public funding (12 %) and the EU (5 %). With the exception of nuclear safety, which is primarily funded through public (national) investments, the private sector is the major source of R&I investment in all other clean energy technologies. This trend has remained constant throughout the years.

R&I investment grew by more than 24 % in the period 2015-2018. This is mostly due to increased spending by the private sector and, to a lesser extent, by the EU. By contrast, the share of public (national) funding in R&I has seen a decreasing trend over the same period.

In 2018, sustainable transport remained the sector with the highest R&I investment share across all the priorities, attracting 45 % of R&I investment overall, and 51 % of private investment. Compared to previous years, R&I investment also increased in renewable energy technologies, energy efficiency measures and smart systems, albeit at a slower pace.

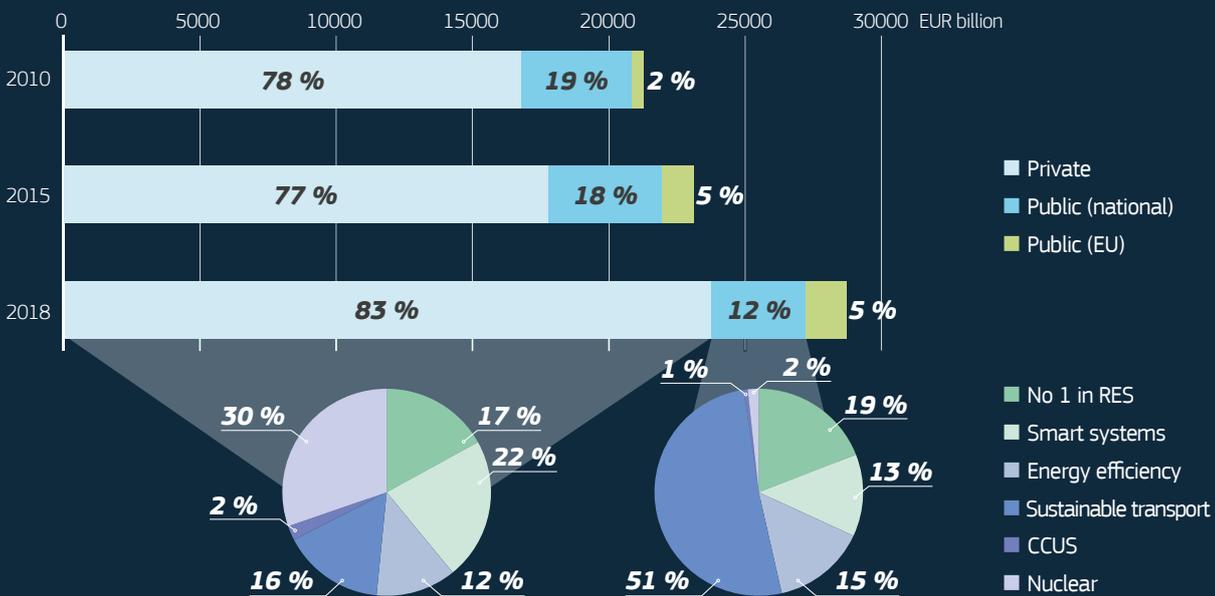


Figure 1 - Investment in the Energy Union R&I priorities in the EU (2010-2018)

¹² Public (national) investment: International Energy Agency RD&D online data service; Public (EU) investment: Directorate-General for Research & Innovation and SETIS/Joint Research Centre; Private investment: as estimated by SETIS/Joint Research Centre (detailed methodology - Fiorini, Georgakaki, Pasimeni, and Tzimas (2017), Monitoring R&I in low-carbon energy technologies: methodology for the R&I indicators in the State of the Energy Union Report – 2016 edition. Joint Research Centre, European Commission); Note: public (national) and private data are estimates.

THE SET PLAN: TAKING STOCK OF PROGRESS

This chapter provides an overview of the key developments of the SET Plan during the period 2020-2021. It offers findings and recommendations regarding the future development of the SET Plan and outlines the work carried out in the framework of the SET Plan in terms of collaboration and the updating of implementation plans.



KEY FINDINGS AND RECOMMENDATIONS ON THE POLITICAL RELEVANCE OF THE SET PLAN

RAISING THE BAR IN SYNERGY WITH THE EU GREEN DEAL AND FIT FOR 55 GOALS

With the adoption of the European Green Deal in 2019, the SET Plan reflected on its targets in support of the clean energy transition. In the lead up to the 2020 SET Plan conference, a strategic assessment was carried out of the relevant energy technology areas to ensure that the R&I implementation plans are aligned with the energy initiatives of the Green Deal, namely energy integration, offshore renewables and the renovation wave. One of the outcomes was the need to break down the silos between technologies and to strengthen collaboration in horizontal areas, such as the critical role of raw materials and the digitalisation of the energy system. Another outcome was the creation of a new working group on HVDC technologies.

In July 2021, within the framework of the European Green Deal and in the run up to the 2021 United Nations Climate Change Conference (COP26), the European Commission launched the first tranche of its Fit for 55 measures. This will support Europe's climate policy framework and put the EU on track for a 55 % reduction in carbon emissions by 2030. The package is comprised of thirteen proposals, including a number of energy-related measures such as the revision of the Renewable Energy Directive¹³ and the Energy Efficiency Directive¹⁴. This lays the groundwork for the SET Plan community to increase its ambition in terms of objectives and targets, and to consider the exploration of new topics and technologies.

13 <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021PC0557>

14 <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021PC0558>

REINFORCING ALIGNMENT BETWEEN R&I AND ENERGY POLICIES, BOTH AT EUROPEAN AND NATIONAL LEVEL

The European R&I framework can fully support the clean energy transition only if research policies and funding are aligned with energy and climate policy objectives, both at European and national level. At national level, the planning and implementation of the measures highlighted in the R&I and competitiveness dimension of the National Energy and Climate Plans (NECPs) need to be more operational, closely linked and developed in conjunction with the other Energy Union dimensions. This will ensure that national R&I programmes contribute to the achievement of energy and climate objectives set by Member States and enhance their competitiveness.

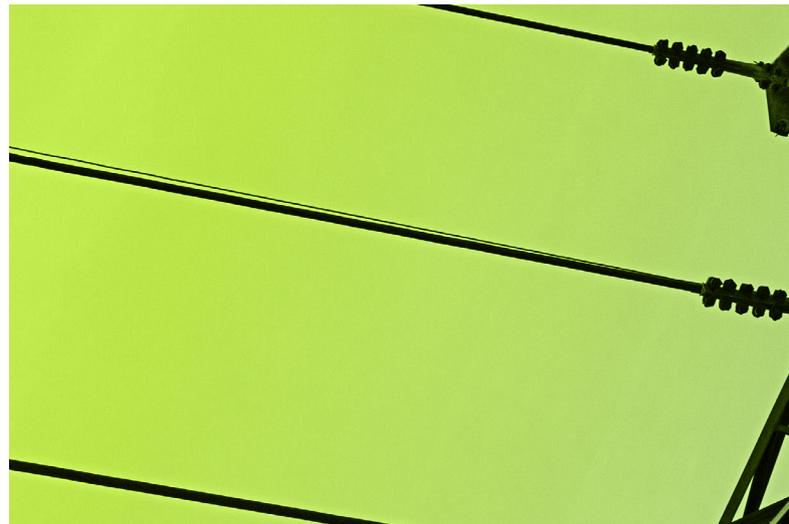
Moreover, more efforts need to be made to ensure the alignment of national and European programmes and priorities, especially through the SET Plan mechanism. As highlighted in the NECP EU-wide assessment¹⁵, the SET Plan received full support from most Member States. However, the majority did not specify the SET Plan areas in which they are involved or the way that national funds are allocated. The link between their participation in the SET Plan and how this could help to achieve their national energy and climate objectives was unclear. There is huge potential to further explore the synergies between actions at national and transnational level.

The SET Plan, as the framework for cooperation on clean energy R&I, would benefit from reinforcement and reshaping to live up to the objectives of the European Green Deal. The EU as a whole needs better coordination between Member States on R&I actions in order to maximise complementarities, avoid duplication and align efforts on key technologies.

According to the EU Energy Governance Regulation, Member States will need to report on progress achieved so far on the implementation of their NECPs by 15 March 2023. This will be a unique opportunity for national governments to present their efforts in better aligning their R&I policies and measures to the more ambitious energy and climate targets, as well as to explain how the SET Plan is helping them to achieve these goals. The reinforced SET Plan could in turn provide inputs to the update of the NECPs, whose draft versions are expected by 30 June 2023.

ENHANCING THE MONITORING OF R&I SPENDING AT NATIONAL LEVEL

SET Plan countries have expressed difficulties in tracking and reporting R&I investments, especially private ones, due



in part to the absence of a legal obligation, the lack of a commonly accepted methodology and confidentiality issues.

Monitoring R&I public and private investment is fundamental for the observation of the evolution of spending in clean energy and the identification of trends and progress made at national and EU level. Thus, EU countries, supported by the European Commission, are invited to reflect on how to improve their monitoring of R&I investments, especially in view of the NECP progress reports.

MOBILISING PUBLIC AND PRIVATE INVESTMENTS

The private sector is the major source of investment in the SET Plan R&I priorities. Mobilising additional investments for clean energy research and development is crucial for the further development of technologies, the scale-up of necessary infrastructure and, ultimately, the delivery of the European Green Deal. The European Commission and SET Plan countries work together to strengthen the public research and innovation system and facilitate private investment with an enabling business environment. The SET Plan was designed to create synergies and avoid duplication of efforts in clean energy research and development. The mobilisation of public and private resources in a targeted and coordinated way will continue to be the SET Plan's key priority.

INVOLVING ALL SET PLAN COUNTRIES

The SET Plan represents a unique form of collaboration in areas that can accelerate the energy transition and keep Europe at the forefront of the next generation of low-carbon energy technologies. It is an initiative of all participating countries. Their involvement provides the basis for the SET Plan's success.



KEY DEVELOPMENTS 2020-2021

ESTABLISHMENT OF THE SET PLAN WORKING GROUP ON HIGH VOLTAGE DIRECT CURRENT (HVDC)

A key achievement of the SET Plan for the year 2020-2021 is the establishment of a working group on high voltage direct current (HVDC) and direct current (DC) technologies¹⁶. The rollout of offshore wind and ocean energy, expected to take place in all EU sea basins, requires the development of energy-transportation infrastructure such as HVDC¹⁷. For this reason, one of the actions foreseen under the European offshore renewable energy strategy was the establishment of a new working group on HVDC technologies.

The working group was launched by the European Commission in cooperation with the SET Plan Steering Group members, representatives of industry, and research institutes. It is co-chaired by Belgium and Denmark and includes 16 other European countries¹⁸.

HVDC is a key technology for grid interconnection, power transmission and offshore integration. Medium-voltage direct current (MVDC) is becoming attractive for future distribution network segmentation and applications towards an improved distribution grid controllability that can facilitate the transmission and integration of local renewable generation, while also exploiting the inclusion of fast recharge units for electric vehicles (EVs). Direct current (DC) technologies – HVDC and/or MVDC – can be applied in different areas of the electric energy sector and can play a key role in integrating renewable energy sources (RES) seamlessly into the European energy system.

To exploit fully the potential of HVDC and DC Technologies and Systems, more research, innovation and demonstration actions are needed. Therefore, the role of the SET Plan HVDC working group is to set targets for HVDC technology development; increase collaboration and raise interest in the technology at national and EU level; and facilitate other supportive research activities in the areas of market integration, regulation & governance, and integration of renewables.

In November 2021, the working group finalised the HVDC implementation plan and was established as the 14th SET Plan Implementation Working Group.

¹⁶ https://setis.ec.europa.eu/system/files/2021-09/SET%20Plan%20Action%20HVDC_Declaration%20of%20Intent_endorsed.pdf

¹⁷ <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0741>

¹⁸ See map on p22

INCREASED COLLABORATION AMONG THE SET PLAN WORKING GROUPS

Cross-sectorial collaboration has been one of the successes of the SET Plan, both internally, between the working groups, and externally, in broader partnerships. With strong collaboration, work plans are aligned, common challenges addressed, and cross-industry synergies enhanced. However, there is room for improvement in the areas of Energy System Integration and the Renovation Wave, where stronger collaboration and more integration between technologies would be of benefit.

Existing collaborations reported by the IWGs

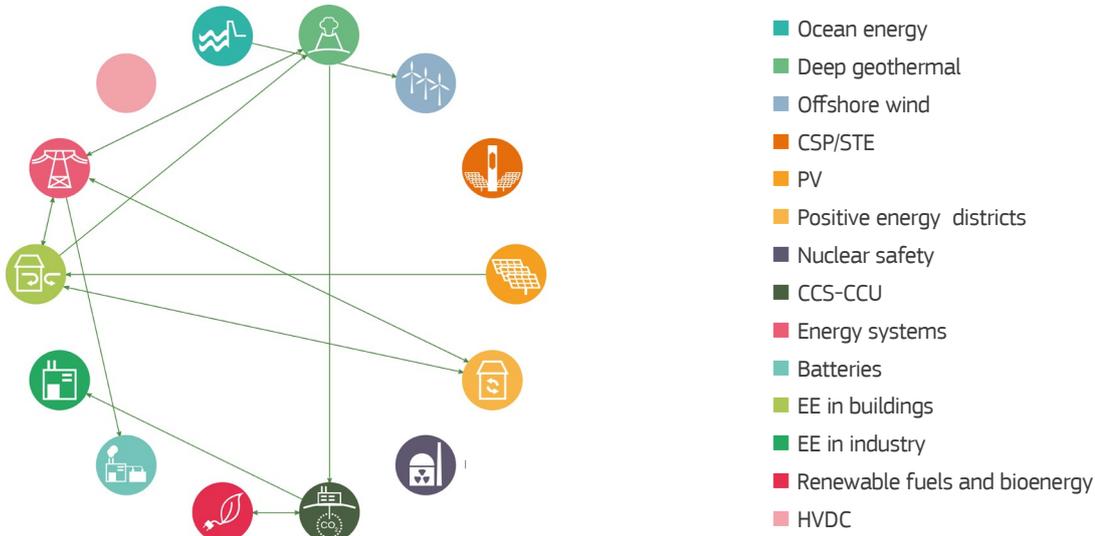


Figure 2 - Existing collaborations reported by the IWGs (SETIS, 2021)

There are 11 ongoing collaborations between the working groups.

New in 2021 are collaborations between the working groups on ocean energy and offshore wind, as well as between CCS-CCU and renewable fuels and bioenergy.

Potential collaborations reported by the IWGs

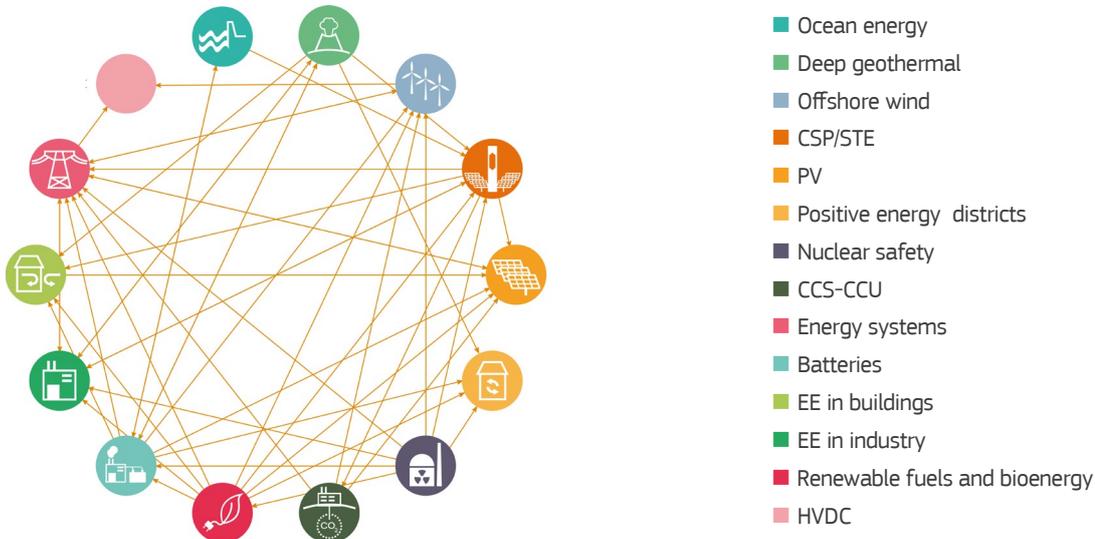
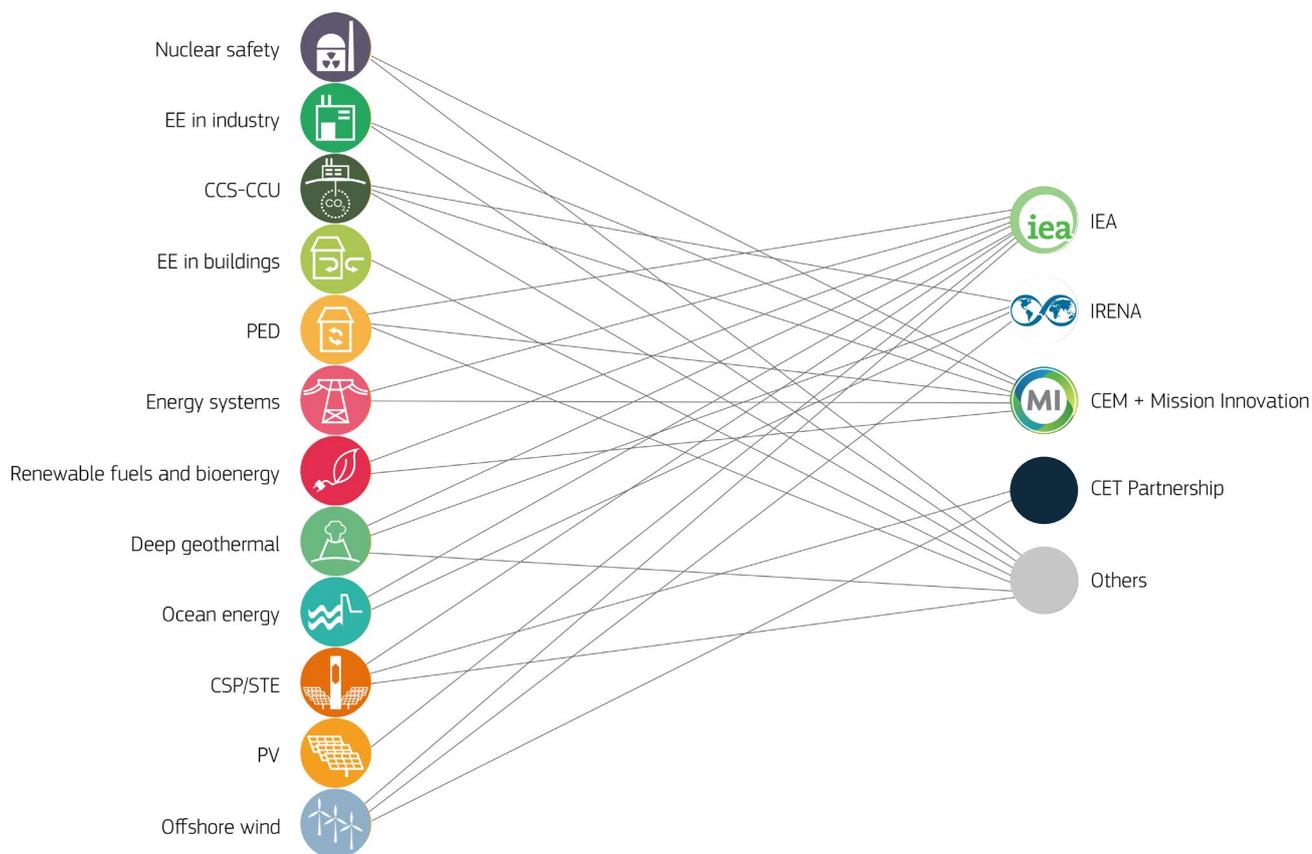


Figure 3 - Potential collaborations reported by the IWGs (SETIS, 2021)

There is more readiness for collaboration between the working groups than ever before.

Existing collaborations reported by the IWGs



Based only on the existing collaborations reported by some of the IWGs. This does not mean that the unlisted IWGs do not have any external cooperation

Figure 4 - Collaborations beyond the SET Plan reported by the IWGs (SETIS, 2021)

Collaboration and the alignment of the SET Plan with other EU partnerships involving governments and industry are crucial to maintaining global leadership in the clean energy transition.

At EU level, several initiatives, closely connected to the SET Plan goals, have been established to address the decarbonisation of the energy system.

- Clean Energy Transition (CET) partnership – linked with the SET Plan IWGs dealing with renewable energy sources, as well as energy efficiency in industry and buildings.
- Driving Urban Transitions to a Sustainable Future Partnership (DUT) – linked with the SET Plan IWG on positive energy districts and energy efficiency in buildings.
- Made in Europe – linked with the IWGs on offshore wind, photovoltaics, and batteries.
- Industrial Battery Value Chain – linked with the IWG on batteries.

- Clean Steel – linked with the IWGs on energy efficiency in industry, CCU-CCS and renewable fuels and bioenergy.
- Clean Hydrogen – linked with the IWGs on offshore wind, photovoltaics, CCU-CCS and renewable fuels and bioenergy.
- Processes4Planet – linked with the IWGs on energy efficiency in industry, CCS-CCU and hydrogen in renewable fuels and bioenergy.
- Zero-emission waterborne transport – linked with the IWGs on renewable fuels and bioenergy.
- Towards zero-emission road transport (2ZERO) – linked with the IWGs on batteries, renewable fuels and bioenergy.

In addition, the work of the IWGs is in line with the goals of international initiatives such as the International Energy Agency Technology Collaboration Programme (IEA TCP), the International Renewable Energy Agency (IRENA) initiatives, Mission Innovation, and the Clean Energy Ministerial (CEM).

REVISION OF THE IMPLEMENTATION PLANS, TARGETS & ACTIVITIES

An important outcome of the work of the SET Plan working groups in 2020-2021 has been the update of their implementation plans. Only around a third have retained their original formulation, while the rest were either revised in 2020 or are under revision during the 2021-2022 period. The main reasons for revision are the need to adapt to changing markets, stronger political ambitions – including alignment with the European Green Deal objectives – rapid technological developments, and for some working groups, the accomplishment of some of their milestones and targets.

Half of the working groups revised their implementation plans in 2020/2021 and three others are expected to finalise theirs in 2021/2022. The plans of the working groups on positive energy districts, energy efficiency in buildings and nuclear safety are still deemed fit for purpose, while the one on HVDC is new¹⁹.

Original Formulation	Revised
EE in buildings (2018)	Batteries (2020)
Positive energy districts (2018)	CCS – CCU (2020)
Nuclear safety (2019)	Deep geothermal (2020)
New	EE in industry (2021)
HVDC (2021)	CSP / STE (2021)
Under Revision	Energy systems (2021)
Offshore wind energy (2021/2022)	Ocean energy (2021)
Renewable fuels and bioenergy (2021/2022)	
Solar photovoltaics (2022)	

Table 1 - Status of the SET Plan implementation plans (SETIS, 2021)

The 13 implementation plans contain, in total, more than 150 R&I targets. The majority of the targets are considered fit for the challenges ahead. 29 % of the SET Plan targets were updated in recent years.

Some of the working groups, such as solar photovoltaics are updating their targets after having achieved their goals for 2020. Others, like batteries, CSP/STE, energy systems, ocean energy, and energy efficiency in industry, adopted bolder targets to respond to market changes in the last two years.

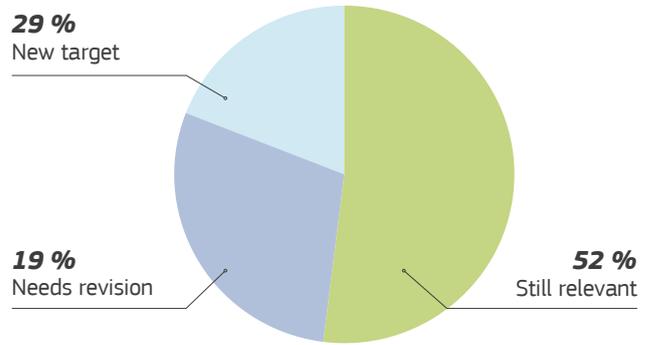


Figure 5 - Status of targets across 13 working groups (SETIS, 2021)

Considering the revisions, 81 % of working group targets are now fit for purpose. A further 19 % of targets are expected to be revised in the near future to align with European Green Deal objectives and the latest technology and market developments.

The 13 implementation plans include 151 R&I activities. These activities across the EU are crucial to boosting Europe’s innovation capacity, competitiveness and jobs growth in clean energy technologies.

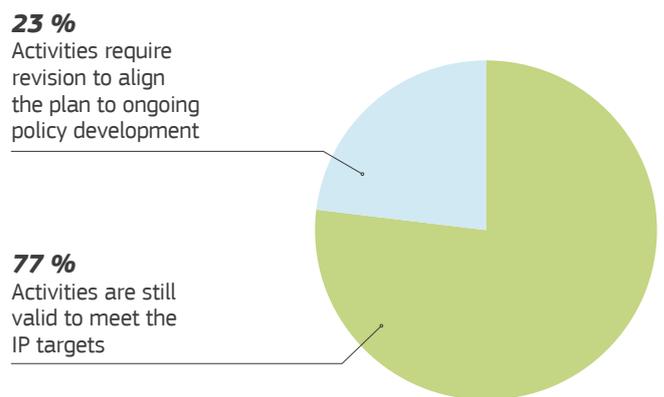


Figure 6 - Is there a revision of activities needed to meet the implementation plan targets? (SETIS, 2021)

According to the 2021 data from the 13 working groups, 77 % of the activities are still valid to meet the existing targets, while 23 % require revision to align with recent policy and market developments.

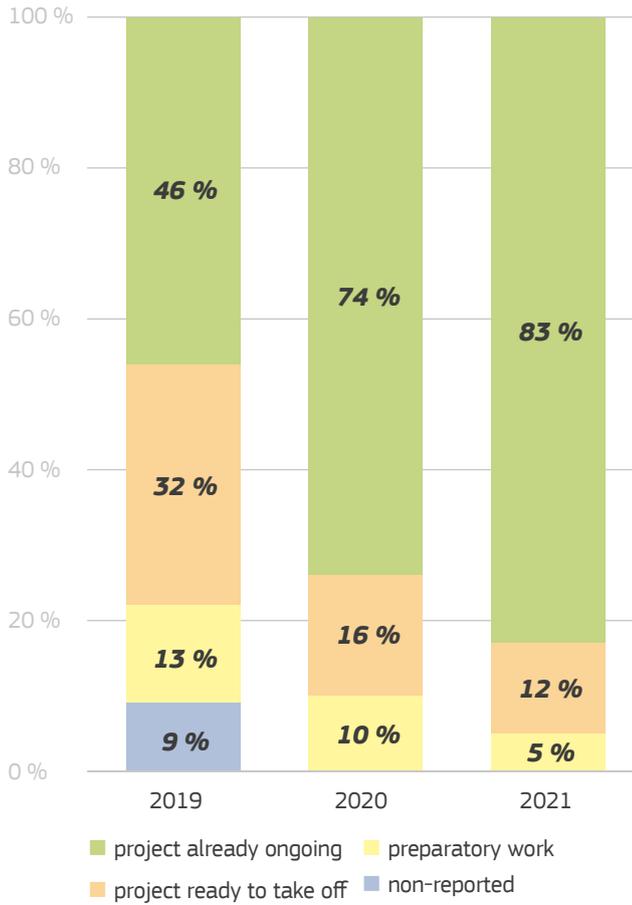


Figure 7 - Status of projects addressing the proposed activities (SETIS, 2021)

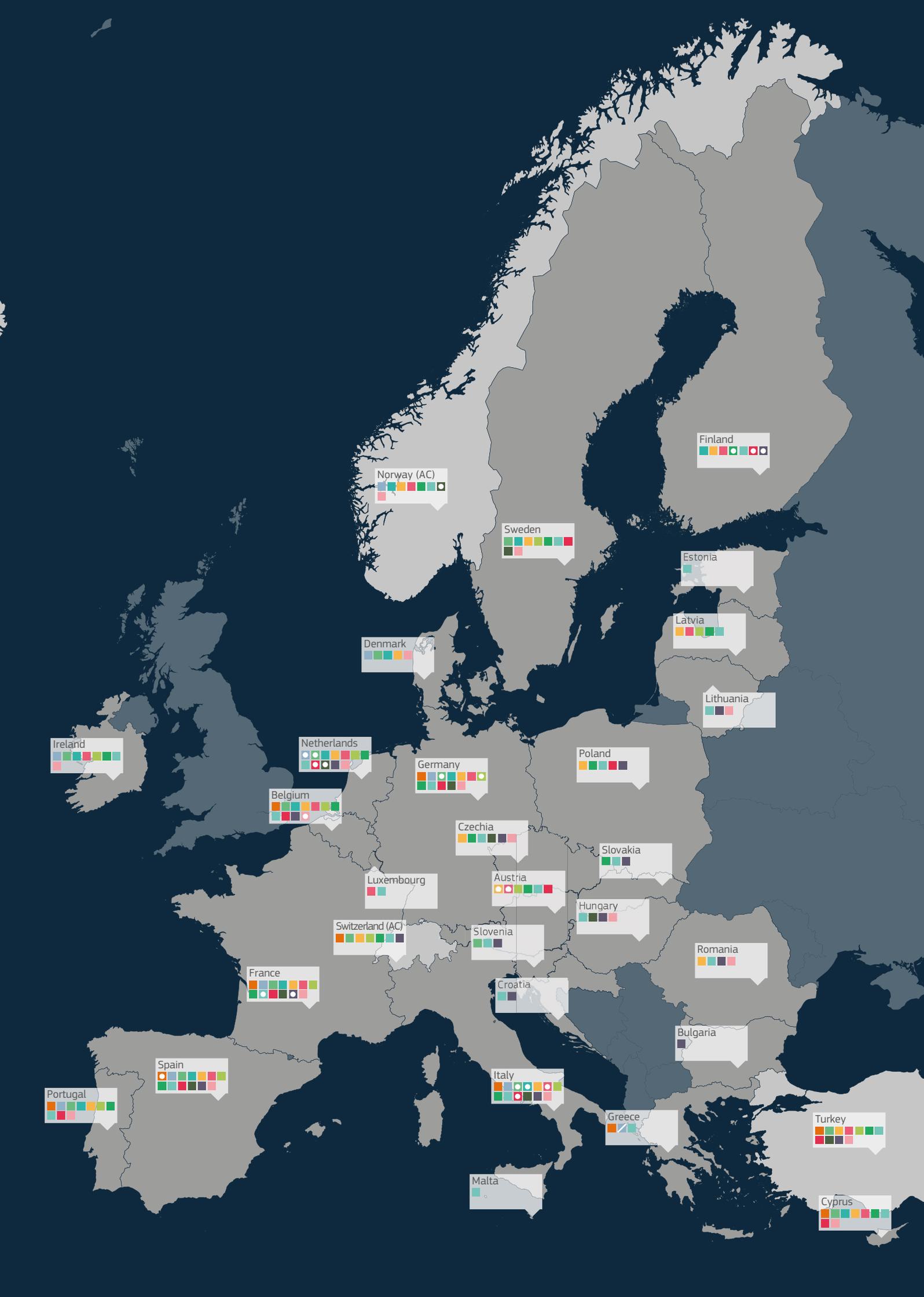
The 13 working groups have reported an increase in ongoing projects addressing SET Plan activities over the years. Today, 83 % of projects are ongoing, with the rest ready for launch or in the preparatory phase.





INVOLVEMENT OF EUROPEAN COUNTRIES IN THE SET PLAN

- Member
- Observer
- CSP/STE
- Offshore wind
- Deep geothermal
- Ocean energy
- Positive energy districts
- Energy systems
- EE in buildings
- EE in industry
- Batteries
- Renewable fuels and bioenergy
- CCS-CCU
- Nuclear safety







THE WORKING GROUPS IN FOCUS



PHOTOVOLTAICS

Established in 2019, the IWG on solar photovoltaics (PV) is co-chaired by Germany and the Netherlands²⁰, with the support of the European Technology and Innovation Platform for Photovoltaics (ETIP PV).

The Horizon 2020 coordination and support action (CSA) project – PV Impact – also supports the group in executing the implementation plan and monitoring its delivery.

The group's work focuses on strengthening and rebuilding European technological leadership in the PV sector by pursuing high-performance PV technologies and integrating them into the EU energy system. It also aims to further reduce the levelised cost of electricity from PV, in a timely and sustainable manner, to allow competition in electricity markets throughout Europe; and enable large-scale use of Power-to-X (P2X).

KEY DEVELOPMENTS

Revision of the implementation plan. At the moment of publication of this report, the PV IWG is revising its implementation plan, with updated targets and key performance indicators (KPIs) reflecting recent market developments and milestones achieved.

The initial target of reducing turnkey system costs by at least 50 % by 2030 compared to 2015 has been achieved. A new target of 60 % or higher is currently being discussed.

The target of increasing the average module efficiency by 20 % in five years is considered ambitious and will be revisited. The average module efficiency did not increase by 20 %, but with the transition to the new passivated emitter and

rear cell (PERC) technology, modules that go beyond a 20 % improvement are already available on the market. However, the upgrade of production lines takes longer than five years, in particular when taking into account the price competition and the limited investment funds of PV manufacturers over the last five years, thus necessitating a reassessment of this target.

The updated implementation plan will be better aligned with the structure of the ETIP PV strategic research innovation agenda (SRIA). The main difference between the PV implementation plan, published in 2017, and the ETIP PV SRIA, published in 2021, is that the first is organised along the lines of PV research and innovation (R&I) activities, while the second focuses on the overarching challenges as shown in the table below.

PV R&I activities	The 2021 ETIP PV SRIA overarching challenges
1. PV for building-integrated photovoltaics and similar applications	1. Making the energy transition a European success
2. Technologies for silicon solar cells and modules with higher quality	2. Supporting economic recovery and building the value chains for renewables.
3. New technologies & materials	Challenge 1: Improving performance and reducing costs (through advanced photovoltaic technologies, manufacturing and applications)
4. Operation and diagnosis of photovoltaic plants	Challenge 2: Improving lifetime, reliability and sustainability (through advanced photovoltaic technologies, manufacturing and applications)
5. Manufacturing technologies	Challenge 3: New applications through integration of photovoltaics (for diversified and double-use deployment and better value)
6. Cross-sectoral research at lower technology readiness level (TRL)	Challenge 4: Smart energy system integration of photovoltaics (for large-scale deployment and high penetration)
	Challenge 5: Socio-economic aspects of large contributions of photovoltaics (to the clean energy transition)

Table 2 - Differences among the PV R&I activities and the 2021 ETIP PV SRIA (PV IWG, 2021)

By adopting the SRIA's structure, based on the above challenges and the link to current EU policies (Green Deal²¹, Fit for 55²², NextGenerationEU²³ and the industrial strategy²⁴), the PV IWG will be able to better monitor and assess progress towards reaching the PV targets in support of the EU policies.

The working group collaborates closely with the ETIP PV²⁵ and CSA PV Impact²⁶. These collaborations are important as they ensure more coordination and enable a comprehensive overview of the PV innovation and financial landscape, and priority areas in Europe. The PV IWG has a dedicated website²⁷.

21 https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

22 https://ec.europa.eu/commission/presscorner/detail/en/ip_21_3541

23 https://ec.europa.eu/info/strategy/recovery-plan-europe_en

24 https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/european-industrial-strategy_en

25 <https://etip-pv.eu>

26 <https://pvimpact.eu>

27 www.iwg-pv.eu

HIGHLIGHTS OF KEY PROJECTS

CHEER-UP

CHEER-UP²⁸ will demonstrate that upgraded metallurgical grade (UMG) multicrystalline silicon is a competitive alternative for polysilicon, in terms of economics and environmental impact, in the production of high efficiency solar cells. The project's results will help reduce the cost of key technologies, and improve lifetime, quality, sustainability, and environmental performance. CHEER-UP started in February 2020 and is expected to be finalised by January 2023.

SUNDRIVE

Solar multi-junction cells integrated in 3D curved roofs of electric Vehicles (SUNDRIVE)²⁹ aims to develop an efficient, reliable, high-power-density and cost-competitive integrated photovoltaic sunroof for EVs. The project is expected to help advance the efficiency of established technologies (crystalline silicon and thin films) and new concepts. SUNDRIVE started in October 2020 and is expected to run until September 2022.

SYMBIZON

The Symbizon³⁰ project's goal is to show how to achieve the right combination of PV energy generation and strip farming that would provide a positive business case for the farmer, maintain the use of land for food production and improve ecological characteristics. Symbizon started at the end of 2020 and is expected to be finalised by 2024.

ANALYST PV

The ANALYST PV³¹ consortium develops a fault diagnosis framework that relies on Internet of Things (IoT) sensors, AI-enabled root cause analysis and automatic image analysis. The proof of concept will be used to simplify practices for preventative PV asset management using the power of data. The project addresses quality and sustainability and hence improves the lifetime and environmental performance of solar panels. ANALYST PV started in October 2019 and is expected to be finalised in September 2021.

TOP

The project TOP³² is related to the PV IWG activity on technologies for silicon solar cells and modules with higher quality by addressing one of the most cost-intensive and technically challenging processes for both cell technologies – the production of their electrical contacts. TOP started in 2020 and is expected to be finalised by 2023.

GENESIS

The objective of the project GENESIS³³ is the development of novel and enhanced production processes for highly efficient crystalline silicon solar cells with efficiencies up to 23.5 %. The project is directly related to the PV IWG's targets for advances in efficiency, manufacturing and installation, as well as the reduction of the cost of key technologies. GENESIS started in May 2018 and was finalised by October 2021.

PV4.0

The objective of the project PV4.0³⁴ is to develop a technological system for the management of the activities of O&M companies according to the principles of industry 4.0, in order to optimise the decision-making process, thus minimising time and operating cost. The project is related to the implementation plan activities on the operation and diagnosis of photovoltaic plants. PV4.0 started in December 2018 and is expected to be finalised by December 2021.

ROLLING SOLAR

The Rolling Solar³⁵ project aims to catalyse a lasting collaboration between industry, research and stakeholders on photovoltaics, materials, manufacturing, installation, grid, and road infrastructure. The project is related to the PV implementation plan activities on Building Integrated Photovoltaics and similar applications. Rolling Solar started in September 2018 and is expected to be finalised by August 2022.

28 <https://cheerup708231729.wordpress.com>

29 <https://www.imec-int.com/en/research-portfolio/sundrive>

30 <https://zoninlandschap.nl/projecten/i219/symbizon>

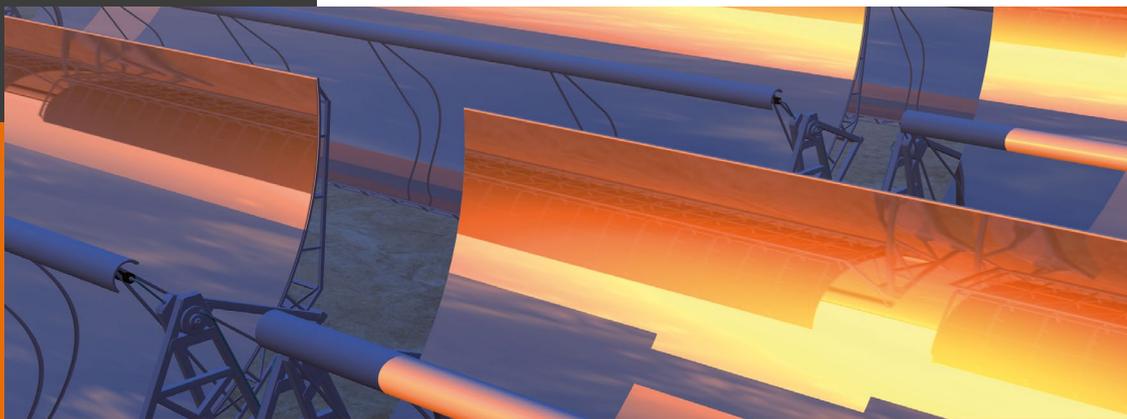
31 <https://www.imec-int.com/en/what-we-offer/research-portfolio/analyst-pv>

32 <https://www.enargus.de/search?q=03EE1080>

33 <https://www.enargus.de/search?q=0324274>

34 <https://www.eurac.edu/en/institutes-centers/institute-for-renewable-energy>

35 <https://rollingsolar.nl/home>



CONCENTRATED SOLAR POWER/ SOLAR THERMAL ELECTRICITY

Established in 2016, the IWG on Concentrated solar power/Solar thermal electricity (CSP/STE) is chaired by Spain and includes representatives from nine other countries³⁶. The European CSP industry intends to help fight climate change by providing solutions for decarbonising the energy systems in the electricity, heating, cooling, industry and transport sectors.

Through thermal energy storage, CSP/STE can significantly help transform Europe's energy system by ensuring it has an essential share of dispatchable renewable electricity. By providing flexibility for grid services, CSP can help integrate variable renewables, such as PV or wind energy, into the energy system. This helps to improve the reliability of the transmission grid. Concentrated solar thermal technologies can support the implementation of EU strategies for energy system integration and adaptation to climate change, as well as contribute towards achieving the EU goal of climate neutrality by 2050.

In 2017, the CSP/STE IWG adopted its implementation plan³⁷, which contains key targets, actions and recommendations. HORIZON-STE, a H2020 CSA, is helping to carry out the implementation plan. HORIZON-STE:

- provides concrete suggestions for the CSP-ERANET call for proposals, taking into account the recent technological developments and stakeholders' interests;
- follows technological development in the SET Plan countries and assesses the European role in a worldwide context; and
- identifies cooperation opportunities among stakeholders.

One of the goals of this project is to assess the conditions needed to replicate, in EU countries, the commercial cost levels (< €0.10/kWh) achieved by the CSP/STE industry on world markets. These conditions include financial conditions, types of auctions and the R&I contribution to innovation. Furthermore, the project supports the implementation of first-of-a-kind CSP/STE projects.

³⁶ See map on p22

³⁷ https://setis.ec.europa.eu/system/files/2021-04/set_plan_-_csp_initiative_implementation_plan.pdf

KEY DEVELOPMENTS

Revision of the implementation plan. The CSP/STE IWG has finalised its proposed update to the implementation plan and it has been endorsed by the Steering Group. The updated plan includes new R&I activities addressing solar fuels and solar heat in industrial processes and new objectives related to interaction between CSP and solar fuels, as well as solar heat for industrial applications. The plan will be in line with recent technological progress and European Green Deal objectives.

The HORIZON-STE project. The CSP/STE IWG participated in meetings held by HORIZON-STE with decision-makers & stakeholders from nine different European countries to learn about their energy strategies and needs. Participants highlighted the need to decarbonise the electricity, industry and transport sectors through solutions such as concentrated solar thermal (CST) technologies.

The European Solar Thermal Electricity Association (ESTELA) position paper. The CSP/STE IWG contributed to the

ESTELA position paper, 'From Green Deal to Green Recovery: A joint initiative of the EU solar industry'³⁸, supported by 176 companies, research centres and associations throughout Europe. The paper, published in 2020, provides a comprehensive overview of the extended use of the CST technologies.

The CSP-Eranet international joint call. An international joint call³⁹ for transnational projects was launched under the CSP ERA-NET, co-founded by the European Commission. The call closed in 2020 with eight countries taking part: Germany, Greece, Italy, Israel, Portugal, Spain, Switzerland and Turkey. The call highlighted that Spain, Germany and Turkey were the countries most interested in CSP/STE technology: approximately 65 % of the project partners taking part were Spanish and German, with both countries receiving 80 % of the approved funding between them, followed by Turkey. Regarding the topics, 50 % of the approved projects deal with thermal energy storage, while the other half address parabolic trough both with molten salts and silicone oil. These projects began their work in 2021.



38 https://www.estelasolar.org/Docs/2020_FROM%20GREEN%20DEAL%20TO%20GREEN%20RECOVERY_A%20joint%20initiative%20of%20EU%20solar%20industry_20200527.pdf

39 <https://csp-eranet.eu/new/1st-csp-co-funded-joint-call-8-pre-proposals-received>

HIGHLIGHTS OF KEY PROJECTS

SI-CO

The Si-CO⁴⁰ project, along with three international demo projects (SING, SITEF, SIMON), successfully established a silicone-based heat transfer fluid (Si-HTF) as a very promising alternative with respect to the state-of-the-art technology for heat transfer fluid (HTF). This project aims also to demonstrate and evaluate the exchange of this Si-HTF in existing power plants. The combination proposed (Si-PTC + Si-HTF), enables a reduction in the cost of solar plants. Si-CO started in April 2021 and is expected to be finalised in September 2023.

PHOTON

The PHOTON⁴¹ project focuses on the development of a new, more efficient tower plant model built around the design and prototyping of a new heliostat technology and tailored receiver design, aiming to reduce construction and maintenance costs, as well as energy production costs. PHOTON started in 2018 and was finalised by 2020.

HIFLEX

The EU-funded HiFlex⁴² project will demonstrate a flexible CSP prototype where conventional molten salts will be replaced with a suspension of solid particles that can store and transfer heat. The thermal storage system is expected to provide an energy storage density that is 2.5 times higher at an energy storage cost that is 50 % lower. The pre-commercial prototype will be built and tested at a pasta plant in Foggia, Italy. HiFlex started in September 2019 and is expected to be finalised in August 2023.

NEXTOWER

NEXTOWER⁴³ aims to demonstrate high-performance durable materials for the next generation of CSP atmospheric-air based tower systems. This project contributes to R&I activity 4 on Open Volumetric Air Receiver. NEXTOWER started in January 2017 and is expected to be finalised by June 2021.

POLYPHEM

POLYPHEM⁴⁴ is a Horizon 2020 project aimed at improving the flexibility and performance of small-scale CSP plants, thanks to a solar-driven micro gas-turbine technology. As a final result, the project will build a 60 kW prototype plant with a 1.3 MWh thermal storage unit and will validate this innovative power cycle in a relevant environment (TRL 5), at the Themis solar tower in Targassone. This project contributes to R&I activity 7 on pressurised air cycles for high efficiency solar thermal power plants. POLYPHEM started in April 2018 and is expected to be finalised by March 2022.

PEGASUS

PEGASUS⁴⁵ is a Horizon 2020 project that investigates a novel power cycle for renewable electricity production combining a solar centrifugal particle receiver with a sulphur storage system for baseload operation. This project contributes to R&I activity 9 on thermal energy storage. PEGASUS started in November 2016 and was finalised in October 2020.

40 <https://csp-eranet.eu/results/high-performance-parabolic-trough-collector-and-innovative-silicone-fluid-csp-power-plantssi>
 41 <https://projectphoton.eu>
 42 <http://hiflex-project.eu>
 43 www.h2020-nexttower.eu
 44 www.polyphem-project.eu
 45 www.pegasus-project.eu



OFFSHORE WIND ENERGY

Established in 2016, the IWG on Offshore wind energy helps to coordinate SET Plan countries' R&I agendas for offshore wind and promotes increased collaboration between national research activities.

In November 2020, the working group agreed upon and published new SET Plan targets for offshore wind in Europe⁴⁶:

- achieve 8.7 GW annual installed capacity by 2030;
- achieve 21.4 GW annual installed grid capacity by 2030;
- reach an average levelised cost of energy (LCOE) of between 35 and 45 €/MWh by 2030 for bottom-fixed offshore wind; and
- reach an average LCOE of between 62 and 106 €/MWh by 2030 for floating offshore wind.

The group is chaired by the Netherlands, and includes nine other European countries and one observer⁴⁷.

It is supported by the ETIPWind⁴⁸ and SETWind projects⁴⁹.

⁴⁶ https://setwind.eu/wp-content/uploads/2020/11/Outline-of-DRAFT-2nd-SET-Plan-Implementation-Plan-for-Offshore-Wind_2020.pdf

⁴⁷ See map on p22

⁴⁸ <https://etipwind.eu>

⁴⁹ <https://setwind.eu>

KEY DEVELOPMENTS

The working group on offshore wind has worked to strengthen coordination between the offshore wind SET Plan stakeholders, including stronger links with the social sciences and humanities community. In recent years, efforts have been made to expand activities on offshore wind to all European sea basins from the Black Sea in Southeast Europe to the North Atlantic Ocean on the Norwegian coast. The latter will be reflected in the

updated implementation plan for offshore wind.

Updated implementation plan. At the moment of publication of this report, the implementation plan is being revised in order to update targets, expand the scope for offshore wind development in all European basins and strengthen the focus on the social science aspects of offshore wind.

HIGHLIGHTS OF KEY PROJECTS

RELIABLADE

ReliaBlade⁵⁰ develops and demonstrates techniques to create digital twins for wind turbine blades with their unique defects and imperfections. The digital twin can not only track the current state of the blade but also predict its future state. Reliablade is a unique project, simultaneously funded by the Energy Technology Development and Demonstration Program, a funding scheme under the Danish Energy Agency (Energistyrelsen), and the German Federal Ministry for Economic Affairs and Energy. Reliablade started in November 2018 and is expected to be finalised by October 2022.

FLAGSHIP

FLAGSHIP⁵¹ is a Horizon 2020 project that aims to reduce the levelised cost of energy for floating offshore wind to the range of 40-60 €/MWh by 2030. To validate and demonstrate it, FLAGSHIP project will design and manufacture the first 10MW floating offshore wind turbine assembled on a floating semi-submersible concrete structure in the Norwegian North Sea. This demonstration project will manage EUR 25 million in funding during its four-year duration, aimed at optimising floating offshore wind towards commercialisation. FLAGSHIP started in

September 2020 and is expected to be finalised in August 2024.

AFLOWT

The AFLOWT (Accelerating market uptake of Floating Offshore Wind Technology) project⁵² will demonstrate how a floating offshore wind technology can be sustained and remain cost-competitive. It will also help develop an active supply chain in the north-west region of Europe, which has some of the strongest wind and ocean resources in the world. AFLOWT started in 2018 and is expected to be finalised by 2022.

SMART4RES

Smart4RES⁵³ aims to substantially improve the performance of the whole model and value chain in renewable energy forecasting, with particular emphasis placed on optimising synergies with storage and supporting power system operation and participation in electricity markets. The idea for this project stemmed from the steady increase in the amount of data being collected and in computational capabilities, along with recent advances in meteorological forecasting and data science. Smart4RES started in November 2019 and is expected to be finalised in April 2023.

50 <https://www.reliablade.com>

51 www.flagshipproject.eu

52 <https://www.nweurope.eu/projects/project-search/aflowt-accelerating-market-uptake-of-floating-offshore-wind-technology>

53 <https://www.smart4res.eu>



DEEP GEOTHERMAL ENERGY

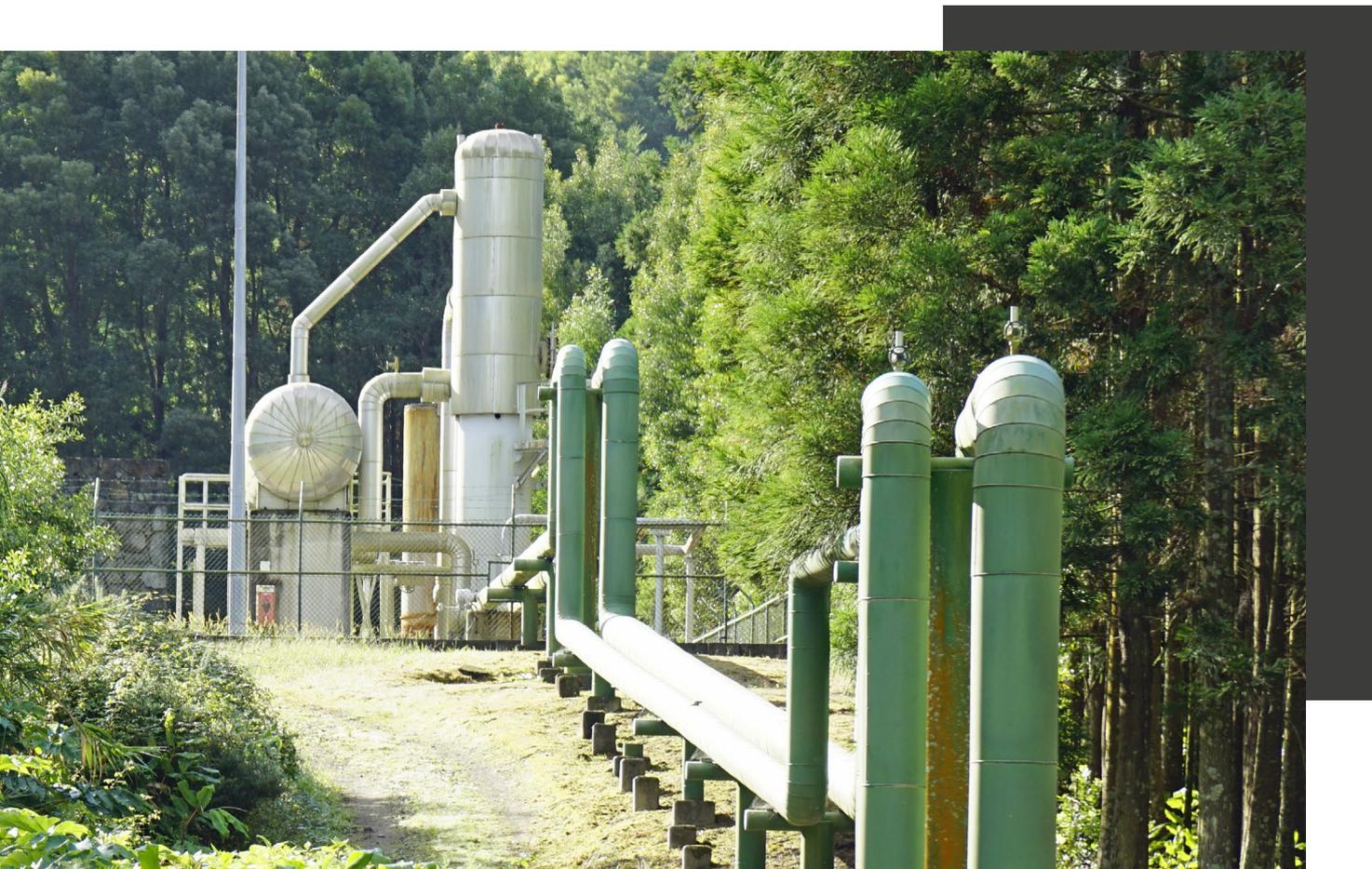
Established in 2016, the IWG for deep geothermal energy is co-chaired by Germany, Italy and the Netherlands and includes 12 other European countries⁵⁴.

The geothermal industry makes a significant contribution to the accomplishment of the European Green Deal and the Horizon Europe mission through providing renewable power, heating & cooling, thermal energy storage and geothermal minerals. Heating and cooling with renewables will be central to the renovation wave.

Switching from fossil fuels to geothermal energy can decarbonise up to 25 % of the EU population's energy needs and reduce energy bills. With today's technology, 25 % of the European population can cost-effectively deploy geothermal heating. Geothermal power plants could provide up to 10 % of Europe's power demand. Underground thermal energy storage will be crucial for the energy transition to bridge the seasonal gap. Furthermore, with the mineral extraction from geothermal fluids, the geothermal industry is set to become a key player in the production of sustainable lithium made in Europe.

The implementation of the geothermal implementation plan is supported by the European Technology & Innovation Platform on Deep Geothermal (ETIP-DG)⁵⁵ and the support unit on deep geothermal⁵⁶.

54 See map on p22
55 <https://www.etip-dg.eu>
56 <https://www.deepgeothermal-iwg.eu>



KEY DEVELOPMENTS

Update of the implementation plan. In 2020, the working group updated its 2018 implementation plan⁵⁷ to include new targets and activities. The new plan addresses cost reductions, integration issues, and non-technological barriers such as social acceptance of geothermal energy and risk management for geothermal projects. The implementation plan includes key actions on geothermal heat in urban areas, integration of geothermal electricity and heating & cooling in the energy system, development and exploitation of geothermal resources and cross-cutting issues such as knowledge transfer and data unification.

Increasing European and national funding for geothermal R&I projects. Together with GEOTHERMICA, a Horizon 2020 project aiming to support the uptake and commercialisation of geothermal technologies, the working group organised a round table bringing together

industry representatives, researchers and public authorities to discuss innovation and the geothermal potential for the climate transition.

The working group supported the increase in the European and national budget for geothermal projects: more than EUR 100 million was dedicated to R&I projects each year, and an additional EUR 40 million was spent on GEOTHERMICA projects every second year.

The Clean Energy Transition Partnership (CETP). The Deep geothermal IWG has been a leader in preparing the CETP on heating and cooling, underlining the importance of geothermal energy for the climate transition. This resulted in a joint call involving GEOTHERMICA and JPP Smart Energy Systems: 'Accelerating the heating and cooling transition'⁵⁸, which was launched in May 2021.

57 <https://setis.ec.europa.eu/system/files/2021-04/Implementation%20plan%20on%20deep%20geothermal%20energy.pdf>

58 https://www.eranet-smartenergysystems.eu/Calls/Regsys_Calls/Joint_Call_2021

HIGHLIGHTS OF KEY PROJECTS

MULTIDRAIN BOREHOLES IN FRANCE

The Vélizy-Villacoublay geothermal well⁵⁹ demonstrates double production capacity through multidrain technology and steering while drilling. This first European demonstrator of multi-drain technology for geothermal has three drains that extend through the productive parts of the reservoir using steering while drilling techniques. The project started in 2020 and as of 2021, the new geothermal district heating network covers 60 % of the heat demand for this area in the Paris region. The project can be replicated in municipalities all over Europe.

IW³

The project IW³ plans to establish a climate-friendly, efficient and at the same time affordable heat supply for Hamburg-Wilhelmsburg, Europe's largest river island. The project⁶⁰ could be an example for other cities in northern Germany and throughout Europe for converting a fossil-driven energy system to a renewable one. The project, one of 20 winners of the funding competition, 'Regulatory Sandboxes for the energy transition' in Germany, started in 2021 and is expected to be finalised by 2024.

GECO

The goal of Geothermal Emission Control (GECO)⁶¹ is to lower the gas emissions from geothermal power generation by capturing them for either reuse or storage. Re-injection of non-condensable gases will be applied in four distinct geothermal systems in four European countries, in Iceland, Italy, Turkey and Germany, connected to the existing pilot in Iceland. GECO aims to increase public acceptance by addressing the issue of emissions from geothermal operation. The project started in October 2018 and is expected to be finalised in September 2022.

GEORISK

The GEORISK⁶² project aims to develop financial schemes to mitigate the impact of the resource risk by spreading it in such a manner that project developers can accept their fair share of it. This mitigation of the

risk through financial instruments lowers the financial exposure of developers in case of failure to develop a geothermal reservoir. GEORISK started in October 2018 and was finalised by March 2021.

DEEPEN

The DEEPEN⁶³ project aims to contribute to the reduction of the upstream risk and cost of exploration by increasing the probability of success when drilling for geothermal fluids in magmatic systems. The project fits very well with the IWG R&I Activity on 'Innovative exploration techniques for resource assessment and drilling target definition'. It is expected to increase the likelihood of successful exploration wells by 20 % in 2025 and 50 % in 2030, thereby reducing the exploration costs. This EUR 4 million project has ten contributing partners from 7 countries and about 42 % of the total project cost is covered by industry. DEEPEN started in September 2020 and is expected to be finalised in August 2023.

EUGELI

EuGeLi⁶⁴ (European Geothermal Lithium Brine) is the world's first pilot project that demonstrates the technical feasibility of directly extracting lithium from geothermal brines under pressure and at high temperature. The pilot is taking place at the Rittershoffen geothermal heat plant, in the French/German Upper Rhine Graben. The EuGeLi project brings together nine partners to study the economic and technical feasibility of electricity and lithium co-production in one single geothermal site for a period of three years. The project started in January 2019 and is expected to be finalised in December 2021.

59 <https://www.engie-solutions.com/fr/actualites/geothermie-velizy-66-enr>

60 <https://www.iw3-hamburg.de>

61 <https://geco-h2020.eu>

62 <https://www.georisk-project.eu>

63 <http://www.geothermica.eu/projects/call-2/deepen>

64 <https://www.eramet.com/en/activities/innovate-design/eugeli-project>



OCEAN ENERGY

The IWG on ocean energy was established in 2017. Its objective is to conduct research and develop roadmaps that set out the aspirations of the wave and tidal sectors. It is chaired by Italy and includes 13 other European countries⁶⁵.

The working group is supported by the ETIP Ocean⁶⁶ and the OceanSET project⁶⁷. The OceanSET project helps implement the IWG's implementation plan⁶⁸ and promotes knowledge sharing among EU countries, regions and other stakeholders in the ocean energy sector.

ETIP Ocean helps to define research and innovation priorities for the ocean energy sector.

65 See map on p22

66 <https://www.etipocean.eu>

67 <https://www.oceanset.eu>

68 https://setis.ec.europa.eu/system/files/2021-04/set_plan_ocean_implementation_plan.pdf

KEY DEVELOPMENTS

Update of the implementation plan. The existing targets for tidal technologies, included in the working group declaration of intent⁶⁹, are expected to be met by 2025, and those for wave technologies by 2030. The IWG on ocean energy has finalised its proposed update to the implementation plan and it has been endorsed by the Steering Group. The revised plan introduces new targets closely aligned with the EU offshore renewable energy strategy. The working group has identified targets and actions, both cross-cutting (i.e. related to all ocean energy technology) and technology-specific (i.e. related to either wave or tidal), to be carried out at both national and EU level.

ETIP Ocean achievements. In June 2020, the ETIP Ocean published an updated SRIA⁷⁰. The SRIA identifies the priority R&I actions to focus on in the coming years. It promotes the working group's objective of making progress on the TRL of wave and tidal stream technologies. In this way, the SRIA guides the industry, and European, national and regional supporters of ocean energy innovation to meet the SET Plan targets.

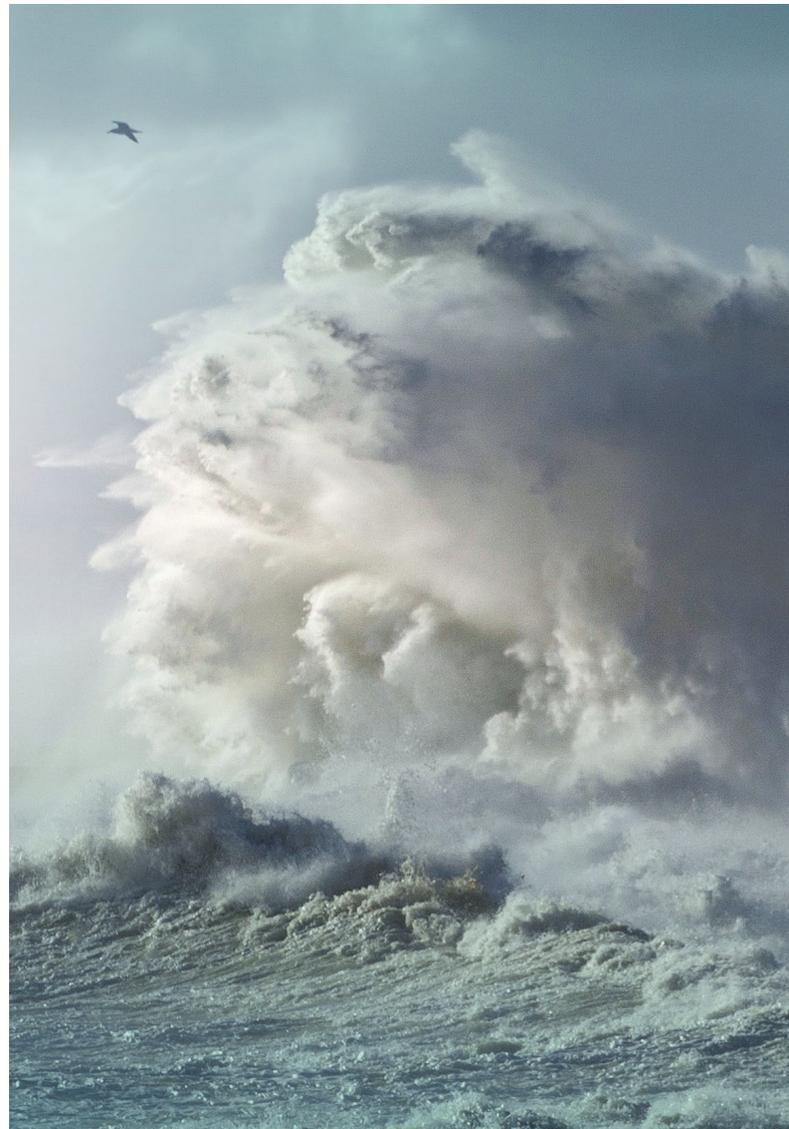
In October 2020, a 2030 '*Ocean Energy Vision*'⁷¹ was published, supported by the ETIP Ocean. This document outlines high- and low-growth scenarios, maps the extensive supply chain and makes recommendations on policy actions in order to reach and exceed the SET Plan targets on ocean energy.

The ETIP Ocean supports the IWG objective on environmental actions and de-risking consenting. The report, '*Ocean energy and the environment: Research and strategic actions*'⁷² published in December 2020, looks at the latest research on the environmental impact of ocean energy and makes recommendations on how to accelerate consenting.

OceanSET achievements. The OceanSET project delivered on a number of activities and produced some excellent outcomes:

- It identified key metrics to collect more granular data and compare, on a yearly basis, the progress of projects and programmes in different European countries.
- It produced a two-year mapping and analysis of the ocean energy sector in Europe, presented in the OceanSET annual reports⁷³.

- It promoted knowledge sharing through workshops.
- It set out a strategic approach on a European pre-commercial procurement (PCP) programme. The proposed mechanism for collaboration complies with the EU H2020 model for PCP and makes effective and efficient use of available funding from European countries/regions for wave energy to encourage a wide participation of developers throughout Europe.
- It started drawing up a draft proposal for an ocean energy insurance and guarantee fund.



69 https://setis.ec.europa.eu/system/files/2021-04/declaration_of_intent_ocean_0.pdf

70 <https://www.etipocean.eu/assets/Uploads/ETIP-Ocean-SRIA.pdf>

71 https://www.oceanenergy-europe.eu/wp-content/uploads/2020/10/OEE_2030_Ocean_Energy_Vision.pdf

72 <https://www.etipocean.eu/assets/Uploads/ETIP-Ocean-Ocean-energy-and-the-environment.pdf>

73 <https://www.oceanset.eu/documentation/public-deliverables>

HIGHLIGHTS OF KEY PROJECTS

WAVEROLLER WAVEFARM

AW-Energy has developed, certified and demonstrated the WaveRoller, a submerged oscillating wave surge converter. In October 2019, a full-scale commercially applicable WaveRoller unit was deployed in Portugal. This project will prepare AW-Energy to deliver the world's first large-scale 'WaveFarm'⁷⁴, with up to 24 integrated WaveRoller units. The project's objective is to develop a scalable technical and commercial strategy to deploy WaveFarms. The project started in 2019 and is expected to be finalised by 2022.

HIWAVE-5

HiWave-5⁷⁵ is the flagship demonstration project of the wave energy technology developer Corpower. It is designed to prove the survivability, performance and economics of a grid-connected 1.2 MW array consisting of four full-scale devices at the Agucadoura site in north Portugal. HiWave-5 started in 2018 and is expected to be finalised by 2023.

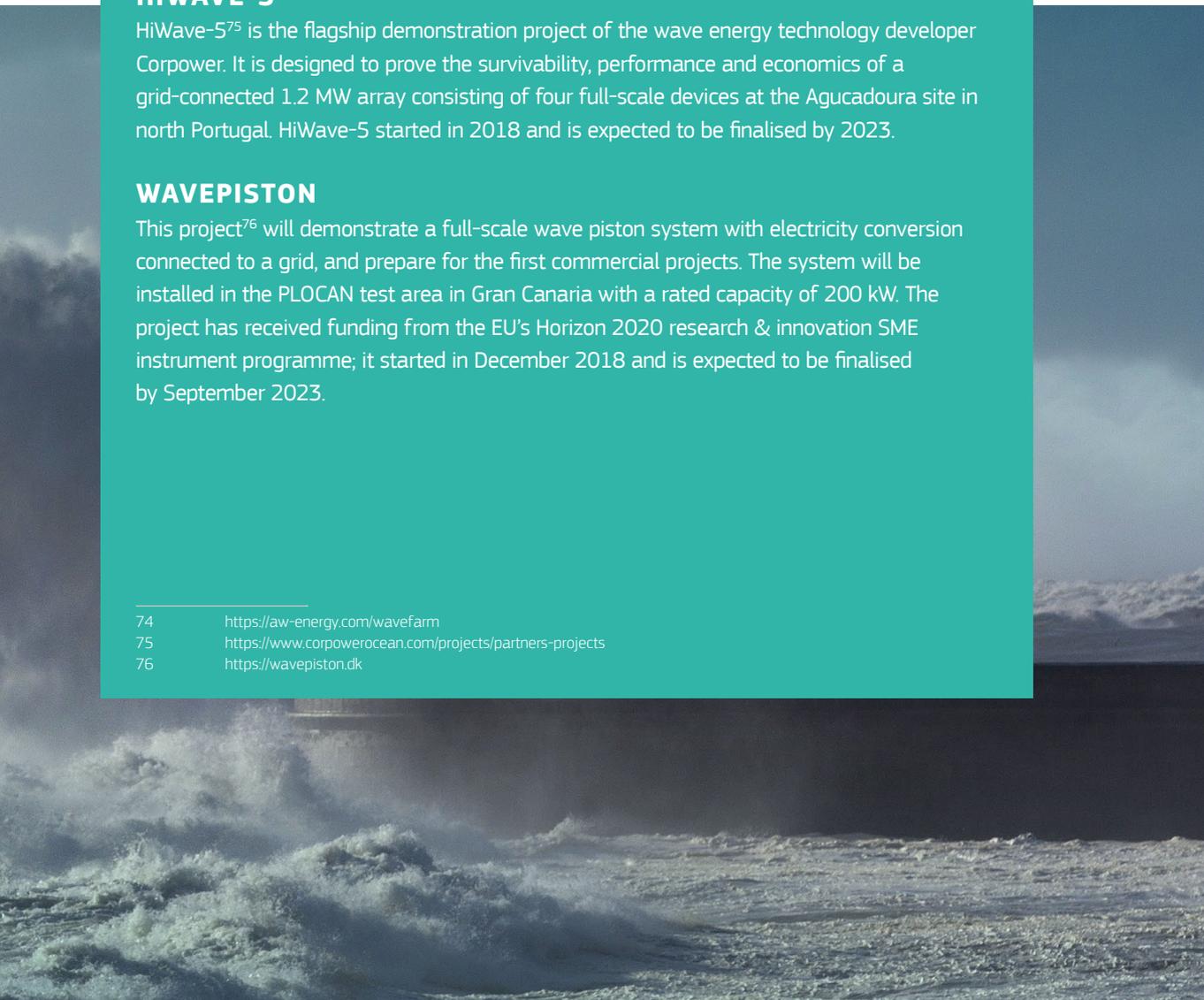
WAVEPISTON

This project⁷⁶ will demonstrate a full-scale wave piston system with electricity conversion connected to a grid, and prepare for the first commercial projects. The system will be installed in the PLOCAN test area in Gran Canaria with a rated capacity of 200 kW. The project has received funding from the EU's Horizon 2020 research & innovation SME instrument programme; it started in December 2018 and is expected to be finalised by September 2023.

74 <https://aw-energy.com/wavefarm>

75 <https://www.corpowerocean.com/projects/partners-projects>

76 <https://wavepiston.dk>





POSITIVE ENERGY DISTRICTS

The IWG on Positive Energy Districts (PED) was established in October 2018. It is chaired by Austria and supported by 18 European countries⁷⁷ with their national R&I programmes, networks of European cities and industry.

The PED IWG contributes to key EU ambitions such as the European Green Deal and the Horizon Europe climate-neutral cities mission by supporting the planning, deployment and replication of 100 'Positive Energy Districts' by 2025.

Its activities include developing tools and guidelines on PEDs, managing annual calls for PED R&I projects and supporting capacity-building at national level for climate-neutral cities and for the implementation of the Renovation Wave through joint calls on PED renovation.

The working group carries out the PEDs implementation plan in conjunction with JPI Urban Europe⁷⁸. This collaboration enables the implementation of a transnational R&I programme. Therefore, the development of R&I projects is accompanied by exchanges with "problem-owners" (cities, real estate developers, utilities) on a transnational level, providing challenge-driven and impact-oriented outcomes.

A fossil-free energy system is one of the goals for this working group. To this end, the IWG contributes to the development of feasible business models and innovative forms of public-private partnership for PED implementation by addressing stakeholder groups, technologies and services for consumers. Furthermore, the working group focuses on contributing to a sustainable urban energy system by focusing on the transformation process in existing urban neighbourhoods, including renovation and retrofitting strategies and establishing PEDs as key building blocks for climate-neutral cities.

77

See map on p22

78

<https://jpi-urbaneurope.eu>

KEY DEVELOPMENTS

Recent achievements of the working group include:

- the launch of a series of joint calls for implementing R&I PEDs projects across the EU –
 - 2020 – 1st Joint Call launched⁷⁹ – four projects received EUR 2.4 million⁸⁰. Call topics: a) contributing to the climate-neutral city: holistic approaches for PED implementation; b) embeddedness in local contexts: applied approaches for integrating PEDs in different urban contexts and the legal framework; c) engagement and governance: urban governance, stakeholder involvement concepts and business models;
 - 2021 – 2nd Joint Call of EUR 7.85 million;
 - 2022 onwards - Joint calls within the framework of the prospective co-funded DUT Partnership;
- the development and publication⁸¹ of a European PED Framework Definition endorsed by all IWG countries;
- the development of the PED Comparison Scheme and PED Inventory⁸²;
- the implementation of a PED City Panel as advisory board to the PED Programme;
- the development of a scheme for valorising the impact of R&I projects and showcasing best practice in a tangible way; and

- the establishment of dialogues between SET Plan countries to develop an overview and exchange how national recovery plans of EU Member States (submitted in April 2021) can support climate neutrality in cities.

The PED Programme will become a ‘transition pathway’ of the prospective Driving Urban Transitions to a Sustainable Future Partnership (DUT Partnership) from 2022 onwards and will integrate with other pathways on urban mobility and circularity.

At the moment of publication of this report no revision is foreseen on the PEDs implementation plan.

Cooperation with JPI Urban Europe. The cooperation established with JPI Urban Europe is important in order to:

- become an innovation pillar in the future DUT Partnership and launch annual co-funded R&I calls on PEDs;
- continue an IWG programme management office and share the service and infrastructures of the JPI Urban Europe/DUT Partnership; and
- better address the interfaces between PEDs and urban mobility as there will be a neighbouring innovation pillar on urban mobility in the DUT.

PED Framework: functions of PED/PENs in the regional energy system

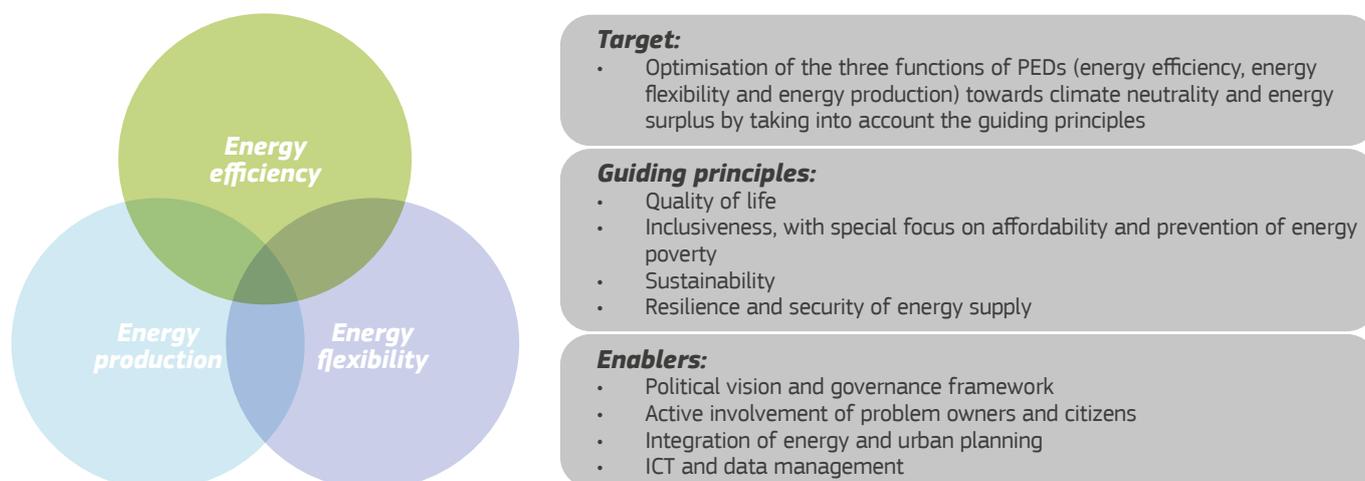


Figure 8 - PED Framework (JPI Urban Europe⁸¹)

79 <https://jpi-urbaneurope.eu/calls/ped-pilot-call>

80 <https://jpi-urbaneurope.eu/wp-content/uploads/2021/06/PED-Pilot-Call-Projects.pdf>

81 <https://jpi-urbaneurope.eu/wp-content/uploads/2020/04/White-Paper-PED-Framework-Definition-2020323-final.pdf>

82 https://jpi-urbaneurope.eu/wp-content/uploads/2020/06/PED-Booklet-Update-Feb-2020_2.pdf



HIGHLIGHTS OF KEY PROJECTS

CITIES4PEDS

The cities of Brussels, Vienna and Stockholm joined forces to initiate and steer in-depth exchange and capacity building, fed with first-hand experiences⁸³. Enlarged by R&I partners, the consortium dives deep to understand how decisive legal instruments and planning processes of cities need to be adapted to realise PEDs, including strategies for the missing administrative existence of the district/neighbourhood level. Cities4PEDs started in 2021 and is expected to be finalised by 2022.

TRANS-PED

Trans-PED⁸⁴ is a 2-year pilot project to develop a governance approach for PED stakeholders to better realise deep changes to their cities. Trans-PED is an international project involving 11 partners from Austria, Belgium and Sweden, led by KTH Royal Institute of Technology and co-funded by JPI Urban Europe. The team will develop the governance approach through collaboration with five established and aspirational PEDs. TRANS-PED started in February 2021 and is expected to be finalised in February 2023.

INTERACT

INTERACT⁸⁵ – Integration of Innovative Technologies of Positive Energy Districts into a Holistic Architecture – is an international research and innovation project with a cross-sectional collaboration between academia, municipalities, and businesses with participants from Austria, the Czechia and Sweden. The project will design an optimal organisation and structure for energy communities and their integration into the power system structure, focusing on two pilot regions in Sweden and Austria. INTERACT started in February 2021 and is expected to be finalised by February 2023.

PED-ID

This project⁸⁶ provides decision-makers with improved information at an early stage and creates a corresponding data-based participation process. The data will be collected and calculated with the help of a methodology and prepared for the appropriate target group. This process will be tested using real Living Labs of potential PED projects. PED-ID started in January 2021 and is expected to be finalised in July 2022.

83 <https://jpi-urbaneurope.eu/project/cities4peds>

84 <https://trans-ped.eu>

85 <https://www.ped-interact.eu>

86 <https://jpi-urbaneurope.eu/project/ped-id>



ENERGY SYSTEMS

Established in 2016, the IWG on energy systems aims to identify and carry out the research, innovation and deployment actions needed to achieve SET Plan Action 4: ‘Increase the resilience and security of the energy system’.

Currently, the IWG on energy systems is co-chaired by Austria and Italy and includes 13 other European countries⁸⁷. It is supported by the ETIP smart networks for energy transition (SNET)⁸⁸ and European Research Area Network for Smart Energy Systems (ERA-NET SES)⁸⁹.

87 See map on p22

88 <https://www.etip-snet.eu>

89 <https://www.eranet-smartenergysystems.eu>



KEY DEVELOPMENTS

Update of the implementation plan. In November 2018, the working group produced an implementation plan for energy systems⁹⁰, including targets and two flagship initiatives, which will contribute substantially to achieving the goals of the European Green Deal, and in particular the EU strategy on energy system integration. The IWG on energy systems has finalised its proposed update to the implementation plan and it has been endorsed by the Steering Group.

The work programme under Flagship 1, addressing the development of an optimised European power grid, has been aligned to that of the ETIP SNET implementation plan 2021-2024⁹¹. The revision of Flagship 1 strengthens the ETIP SNET's work programme and ensures synergy. There is a strong collaboration between ETIP SNET and ERA-NET SES – the two initiatives share workspaces and resources.

The revision of Flagship 2, addressing the development of integrated local and regional energy systems, adds a new approach that leverages the collaborations and relationships with other working groups and ETIPs (e.g. the European Technology and Innovation Platform on Renewable Heating and Cooling (RHC-ETIP)). In addition, the revision focuses on digitalisation, stakeholder involvement, innovation ecosystems and industrial systems.

Many working groups have asked for more collaboration with the IWG on energy systems. This is particularly relevant for Flagship 2, on integrated regional energy systems. That, and the respective Transition Initiative in the CETP, have various connections with other thematic groups within the CETP. Flagship 2 therefore provides a solid framework for discussion on the aspects that need to be addressed in coordination with other working groups and initiatives.

Particular topics under consideration are:

- heating and cooling – the ambition to go beyond 'low

temperature heating networks' in the old implementation plan and create a common understanding on system integration topics together with the IWG on geothermal energy, CETP Heating and Cooling and the RHC-ETIP;

- Integrated Industrial Energy Systems – together with CETP and relevant IWGs as well as other relevant partnerships such as i4planet;
- how to strengthen the role of the established National Stakeholders Coordination Group (NSCG) as a link between different European groups on the one hand, and a sounding board for national RDI communities on the other hand; and
- the activities on interoperability which will be revised in the light of the interoperability testing pilot planned in the Joint Programming Platform Smart Energy Systems, as well as its cooperation with other interoperability initiatives in Europe.

For future revisions, discussions are planned with groups, for example, that work with power systems (offshore wind, PV, etc.).

Merging with the energy consumers working group. In 2020, the activities of the IWG on energy systems and the IWG on energy consumers were merged.

The energy system integration and Clean Energy Transition Partnership (CETP). In the framework of the CETP, the IWG's work has helped to align the R&I priorities of participating countries in the field of integrated energy systems and to foster innovation by framing national programmes and activities in a European context. The working group has helped define a significant part of the future CETP's goals and strategy.

90 https://setis.ec.europa.eu/system/files/2021-04/set_plan_esystem_implementation_plan.pdf

91 https://www.etip-snet.eu/wp-content/uploads/2020/05/Implementation-Plan-2021-2024_WEB_Single-Page.pdf

HIGHLIGHTS OF KEY PROJECTS

GAIN

The GaIN project⁹² aims to enable several companies to participate successfully in the energy markets by digitalising small and medium-sized businesses. For this purpose, the forecasting quality for energy demand and flexibility availability are increased by data-based models based on machine-learning methods. The research project covers almost the entire value chain and has a high potential for upscaling. GaIN started in May 2018 and is expected to be finalised in October 2021.

TBIENERGY

The German-led project 'Trusted Blockchains for the open, intelligent energy grid of the future' (tbiEnergy)⁹³ builds on the existing regulated energy market and addresses the current lack of comfort services of today's smart grid through a comprehensive blockchain approach. The concept aims to bring new dynamics into the traditional energy market by developing smart-contract models and increasing security through hardware security modules. tbiEnergy started in June 2020 and is expected to be finalised by May 2023.

AUSTRIAN FLAGSHIP REGION ENERGY - GREEN ENERGY LAB

Green Energy Lab⁹⁴ is the largest innovation lab in Austria and enables a valuable exchange of expertise, new partnerships and synergies. The Open Data Platform project is the central interface within the Green Energy Lab: it brings together all results generated within the overall project. ThermaFlex deals with the increase of system flexibility and the resulting reduction in CO₂ emission within the district heating sector. Blockchain Grid investigates how to best distribute free grid resources for the benefit of prosumers instead of limiting feeds. SecondLife Batteries involves testing used batteries of EVs for remaining lifetime/usability in applications for peak shaving and energy recovery.

FLEXQGRID

The flexQgrid⁹⁵ project makes a significant contribution to both the realisation of flexibility utilisation in the distribution grid and the provision of flexibility for higher voltage levels. The project started in November 2019 and is expected to be finalised by October 2022.

FLAGSHIP REGIONS AUSTRIA - NEW ENERGY FOR INDUSTRY

New Energy for Industry (NEFI)⁹⁶ is an Energy Model Region funded by the Austrian Climate and Energy Fund. NEFI focuses on six fields of innovation and follows a systemic approach in which the company is an important part of an integrated energy network. This also leads to new business models.

92 <https://www.ipa.fraunhofer.de/de/referenzprojekte/gain.html>

93 <https://www.devolo.global/about-devolo/research-projects/tbienergy>

94 <https://greenenergylab.at/en>

95 <https://flexqgrid.de/english>

96 <https://www.nefi.at>



ENERGY EFFICIENCY IN BUILDINGS

Established in 2016, the IWG on energy efficiency in buildings⁹⁷ (EE in buildings IWG) works to unlock the energy savings potential of the building sector. This includes boosting the potential of existing and new buildings. To achieve this, the IWG is divided into two subgroups:

- New materials and technologies for energy efficient solutions for buildings
- Cross-cutting heating and cooling technologies for buildings.

The group is chaired by Germany and includes 12 other European countries⁹⁸. The working group is supported by the European Technology and Innovation Platform on Renewable Heating and Cooling (RHC-ETIP) and the European Construction Technology Platform (ECTP).

⁹⁷ <https://www.iwg5-buildings.eu>
⁹⁸ See map on p22

KEY DEVELOPMENTS

The implementation plan. The energy efficiency in buildings implementation plan⁹⁹, published in 2018, is in line with the objectives of the IWG and of the EU policy framework on buildings. All of the targets are still relevant and, currently, a revision of the implementation plan targets and activities is not necessary. Nevertheless, the IWG on energy efficiency in buildings participants evaluate the necessity of operating adjustments on a continuous basis.

Projects related to the Renovation Wave. Several research and development projects have been launched and carried out in recent years in the EU and associated countries in support of the Renovation Wave's implementation, which aims to double the renovation rate of the EU's building stock. More projects will be launched thanks to the **Clean Energy Transition Partnership (CETP)**. Challenge 7 of the CETP – 'Integration in the built Environment'¹⁰⁰ – focuses on solutions and technologies for existing and new buildings, so that buildings can become an active component of the energy system.

The Built4People (B4P) partnership. The ECTP is driving the B4P partnership¹⁰¹, together with the World Green Building Council (WGBC) Europe and the European Commission. This partnership will focus on people-centric innovation in the built environment and is expected to bring together stakeholders across the value chain. It will address buildings' climate-neutrality – but also broadly speaking sustainability, reducing resource intensity and increasing recyclability, taking into consideration other policies relevant to buildings, including the need to preserve European cultural heritage.

The Living Labs Europe Competition. The Living Labs Europe Competition (LLEC) is soon to be launched in cooperation with the PED IWG and the DUT partnership. It will support the 'new European Bauhaus' initiative. The LLEC focuses on the end users,

using a competitive format addressing all interest groups. The competition will create a situation where individuals and society can change their behaviour through face-to-face discussion and exchange of ideas.

The SRIA for heat pumps. In May 2021, the RHC-ETIP's technology panel on heat pumps published its strategic R&I agenda for heat pumps: 'Making the technology ready for mass deployment'¹⁰².

The SRA for district heating & cooling (DHC) and thermal energy storage (TES) technologies. In May 2021, the RHC-ETIP's technology panel on the DHC and TES published its strategic research agenda for DHC and TES technologies¹⁰³. This document outlines the current state of the art for DHC and TES technologies and details KPIs for research actions during the specified time period (2021-2027) as well as for the wider sector.

The SRIA for geothermal technologies. This SRIA on geothermal heating and cooling technologies¹⁰⁴ constitutes an update and blending text of the previous Geothermal Strategic Research Agenda (SRA) and subsequent Geothermal Implementation Roadmap. It intends to define the new research topics to answer the challenges of the geothermal energy sector in Europe and to bring them into a quantifiable timescale and dimension in terms of required funding.

The SRIA for climate-neutral heating and cooling in Europe. In October 2020, the RHC-ETIP published the SRIA for climate-neutral heating and cooling in Europe¹⁰⁵. This document responds to the need for an update of the priorities identified in 2013 and promotes RHC technologies in order to achieve carbon-neutrality in the EU by 2050.

99 https://setis.ec.europa.eu/system/files/2021-02/set_plan_buildings_implementation_plan.pdf

100 https://eranet-smartenergysystems.eu/global/images/cms/CETP/CETP_SRIA_v1.0_endorsed.pdf

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

102 https://www.ehpa.org/fileadmin/user_upload/RHC_ETIP_SRIA.pdf

103 <https://www.euroheat.org/wp-content/uploads/2021/05/DHC-SRIA-FINAL-1.pdf>

104 <https://www.egec.org/media-publications/strategic-research-and-innovation-agenda-for-geothermal-technologies>

105 <https://www.rhc-platform.org/content/uploads/2020/10/RHC-ETIP-SRIA-2020-WEB.pdf>

HIGHLIGHTS OF KEY PROJECTS

RENOZEB

RenoZEB¹⁰⁶ aims to unlock the nearly zero-energy buildings (nZEB) renovation market, leveraging the gain on property value through a new systemic approach to retrofitting that will include innovative components, processes and decision-making methodologies to guide all value-chain actors in the nZEB building renovation process. The project started in 2017 and is expected to be finalised by April 2021.

GEOFIT

GEOFIT¹⁰⁷ is an integrated industrially-driven project, which will make the use of advanced efficient geothermal systems for heating and cooling viable and cost-effective by introducing a novel concept in building retrofitting based on geothermal energy and small-to-medium scale heat pumps. The project's aim as regards heat pumps is to reduce running costs by 30 % and initial costs by 10 %. GEOFIT started in May 2018 and is expected to be finalised in April 2022.

REWARDHEAT

The overall objective of REWARDHeat¹⁰⁸ is to demonstrate, at eight pilot sites, a new generation of low-temperature district heating and cooling networks that can recover renewable and waste heat from multiple sources spread over an urban area. The project started in October 2019 and is expected to be finalised in September 2023.

BIM-SPEED

The goal of the BIM-Speed¹⁰⁹ project is to implement Building Information Modeling (BIM) with a holistic approach across all stakeholders involved and to provide a cloud-based and affordable BIM platform that can interact with a range of BIM tools. This is expected to help make BIM-based renovation widely available across the EU. BIM-Speed started in 2018 and is expected to be finalised by 2022.

ENVISION

ENVISION (Energy Harvesting by Invisible Solar Integration in Building Skins)¹¹⁰ is a concept project that aims to harvest solar energy from the 120 billion square meters of building surface available within the EU. ENVISION demonstrates a full renovation concept that, for the first time, harvests energy from all building surfaces (transparent and opaque). The solutions will harvest maximum amount of solar energy and simultaneously retain the aesthetic and functional properties of the façade. ENVISION started in October 2017 and is expected to be finalised in March 2022.

106 www.renozeb.eu
 107 www.geofit-project.eu
 108 www.rewardheat.eu/en
 109 www.bim-speed.eu
 110 www.energy-envision.eu





ENERGY EFFICIENCY IN INDUSTRY

Established in 2016, the IWG on energy efficiency in industry (EE in industry IWG) supports the overarching objective of decarbonising the energy system, focusing on the most energy-intensive sectors, such as iron & steel, chemicals, pulp & paper and cement, while also addressing cross-cutting themes – heating & cooling, systems and industrial symbiosis – that are relevant to all industrial sectors.

The group is chaired by Finland, supported by a stakeholder co-chair – A.SPIRE, and thematic group leaders, and includes 18 other European countries¹¹¹, industrial stakeholders from the relevant sectors and research institutions.

The working group is helping to implement the SET Plan strategy and European Green Deal strategy on energy system integration¹¹², along with the Emissions Trading System, and the Energy Efficiency and Renewable Energy directives. It builds on EU and national initiatives to boost cooperation between R&I sectors, for the improvement of energy efficiency and cost effectiveness in industry and to promote the wider use of renewables and alternative energy sources for reducing greenhouse gas emissions.

Fostering energy efficiency and supporting R&I programmes in energy-intensive sectors will help achieve a climate-neutral economy. Energy efficiency in industry will help:

- increase European industry competitiveness and support the development and commercialisation of future disruptive technologies;
- integrate renewable energy into the energy system;
- increase circularity through, for example, the reuse of waste heat or the development of biofuels; and
- develop and integrate into the energy system hydrogen-based technologies and infrastructures.

¹¹¹ See map on p22

¹¹² https://ec.europa.eu/energy/topics/energy-system-integration/eu-strategy-energy-system-integration_en

KEY DEVELOPMENTS

Update of the implementation plan. In 2021, the working group revised its implementation plan¹¹³ to align its targets and activities with recent R&I developments and the European Green Deal policy framework. There are 44 new targets that cover the years up to 2025, 2030 and 2050. Of all the targets, 16 are cross-cutting, covering heating & cooling and systems. The rest are split into specific goals for cement, chemicals, iron & steel, and pulp & paper.

SET Plan countries and the European Commission will play a fundamental role in collaborating with industry to enable the deployment and market penetration of emerging technologies. The revised implementation plan collects information from industry leaders to support national governments in Action 6 of the SET plan, which aims to make EU industry less energy-, resources- and emissions-intensive and more competitive in the following ways:

- Create a shared understanding of R&I challenges and opportunities;
- Provide an overview of priority areas to focus R&I efforts on energy-intensive industries;
- Identify priority activities where funding should be targeted (facilitate road-mapping by the European Commission and SET Plan countries);
- Enable national governments to make informed policy decisions that further increase support to these areas.

The working group has organised several workshops and other networking events in recent years involving stakeholders from various European countries, for the purpose of exchanging project ideas and stepping up cooperation between national programmes.

HIGHLIGHTS OF KEY PROJECTS

CO2OLHEAT

This project¹¹⁴ is a direct result of the implementation plan's priority on heat and cold. During the IWG workshop in 2018, several project ideas were merged into the R&I topic, 'Further development and adaptation of next generation power cycles (especially supercritical CO₂)'. In line with the targets of activity 5.2 of the implementation plan, this project is focused on developing the supercritical CO₂ (sCO₂) cycle, so it can be deployed in energy-intensive industries with the main objective of unlocking the potential of unused industrial waste heat and transforming it into power. The development of innovative and cutting-edge sCO₂ technologies will be used to design and demonstrate in a real industrial environment the first-of-its-kind sCO₂ plant in the EU. The project, funded through Horizon 2020, will run between June 2021 and May 2025.

HYBRIT

The HYBRIT¹¹⁵ project was launched in 2016 as a joint venture between Vattenfall, LKAB and SSAB, working together to develop the first fossil-free steel. The HYBRIT technology has the potential to reduce Sweden's total carbon dioxide emissions by 10 %. The project was co-funded by Sweden, and the EE in industry IWG helped it gain better visibility.

STEELANOL

This project¹¹⁶ focuses on the production of sustainable, advanced bioethanol through an innovative gas-fermentation process using exhaust gases emitted by the steel industry. Starting in May 2015, the project received funding from Horizon 2020's R&I programme and benefited from a European Investment Bank loan under the InnovFin Energy Demonstration Projects facility.

¹¹⁴ <https://cordis.europa.eu/project/id/101022831>

¹¹⁵ <https://www.hybritdevelopment.se>

¹¹⁶ <http://www.steelanol.eu/en>



BATTERIES

Established in 2016, the SET Plan Action on batteries is implemented by **Batteries Europe**¹¹⁷. Batteries Europe is the technology platform of the European Battery Alliance and benefits from European Commission support since 2019.

Batteries Europe has its roots in the work done within SET Plan action 7: Competitive in global sector and e-mobility, and most of the experts from the IWG on batteries are now strongly involved in Batteries Europe, which has also attracted many new industrial, research and national representatives.

In addition, the work on the batteries topic is supported by the coordination and support action BATTERY 2030+¹¹⁸, which is focussed on long-term, ICT-driven battery research. Batteries Europe and BATTERY2030+ are linked through the emerging technologies strand of Batteries Europe.

117 https://ec.europa.eu/energy/topics/technology-and-innovation/batteries-europe_en

118 <https://battery2030.eu>

The governance structure of Batteries Europe includes the following:

- Thematic working groups with members from industry, research and public organisations in charge of preparing research roadmaps covering all parts of the battery value chain and the Strategic Research Agenda. In addition, dedicated task-forces address cross-cutting topics such as education and skills, sustainability, safety and the role of digitisation in battery technology. Working groups and task forces carried out a detailed review of key performance indicators for 2030 in the course of 2020 and 2021.
- An independent, but closely associated, national and regional coordinators group (NRCG) composed of Member States and associate country representatives, ensuring a mutual flow of information between countries and regional representatives and facilitating common Member State actions.

The members of the NRCG of Batteries Europe share information on developments in their own countries and regions in battery research while receiving updates from the European Commission and the Batteries Europe Secretariat on policy and funding developments, including those of Horizon Europe. Batteries Europe promotes cooperation between members and minimises duplication of research activities.

The NRCG is chaired by France and includes all SET Plan countries except Bulgaria and Iceland, making it the working group with the highest country representation¹¹⁹. Closer cooperation, mostly on high TRL battery research, takes place within two multi-billion Important Projects of Common European Interest, where 12 Member States participate¹²⁰. This cooperation is organised through the governing structures of two Important Projects of Common European Interest (IPCEIs).

Batteries are a key enabler for the green transition. The European Green Deal aims to make the economy sustainable, including the transport, energy and other sectors, which are highly relevant to the battery value chain. Europe must act fast and in a coordinated way to continue building a domestic battery industry and to develop the skills needed to maintain this industry in Europe. Batteries Europe represents a one-stop-shop for collaboration and information exchange for battery research in Europe, working towards a sustainable, competitive, and self-sufficient value chain and a place where initiatives can interconnect and create synergies.

¹¹⁹ See map on p22

¹²⁰ Austria, Belgium, Croatia, Finland, France, Germany, Greece, Italy, Poland, Slovakia, Spain, Sweden.

KEY DEVELOPMENTS

Update of the implementation plan. In 2020, Batteries Europe revised the batteries implementation plan, its targets and R&I activities, as reflected in the updated Strategic Research Agenda (SRA) for batteries¹²¹ and as supplemented with roadmaps for various segments of the value chain. The newly published Batteries Europe SRA should be seen as

the new batteries implementation plan. The updated SRA helps identify gaps in funding and neglected topics which could lead to weaknesses in the value chain and a loss of industrial momentum. Batteries Europe is committed to continuously updating the SRA on the basis of technological developments in the field of batteries.

In the last five years, the battery industry has experienced dramatic technology and market development, during which Europe has developed a thriving battery ecosystem with several industrial projects developed or in the pipeline. Thus, the initial KPIs have been evaluated and revised to accommodate these market, policy and regulatory changes.

Contribution to the R&I topics in the Horizon

Europe programme. Batteries Europe contributed to the development of the Horizon Europe R&I topics for 2021-2022 while the Batteries Partnership was nascent. This task is now performed by the newly founded Batteries Partnership¹²² with which Batteries Europe is closely cooperating (inter-alia by contributing through its strategic research agenda and technology roadmaps).

HIGHLIGHTS OF KEY PROJECTS

EUBATIN

Funding R&I activities in battery manufacturing is one of the EU's priorities. Announced in 2021, the second IPCEI – European Battery Innovation (EuBatIn)¹²³ – marks yet another milestone in the development of an innovative and sustainable European battery industry. In view of the growing importance of batteries for decarbonising the transport and energy system, it will become essential to create a safe, circular and sustainable battery value chain. The project is expected to benefit Europe by improving the sustainability of mobility and energy, creating more jobs and strengthening competitiveness. Twelve EU Member States will provide up to EUR 2.9 billion for the project in the coming years, which is estimated to unlock an additional EUR 9 billion in private investments. The project complements the first IPCEI in the battery value chain¹²⁴ that the European Commission approved in December 2019 with EUR 3.2 billion in public support.

123 <https://vdivde-it.de/en/project/project-management-agency-plus-battery-cell-manufacturing>; <https://www.eba250.com/eu-approves-e2-9-billion-state-aid-for-a-second-pan-european-research-and-innovation-project-along-the-entire-battery-value-chain/?cn-reloaded=1>
124 https://ec.europa.eu/commission/presscorner/detail/en/ip_19_6705

State aid: Second important European project in battery value chain



122 <https://bepassociation.eu>



RENEWABLE FUELS AND BIOENERGY

The IWG on bioenergy and renewable fuels for sustainable transport¹²⁵ was established in 2016. In 2018, the working group produced the renewable fuels and bioenergy implementation plan¹²⁶. Key targets include: improving the production performance of advanced biofuels and other renewable liquid and gaseous fuels; and addressing GHG performance and cost. The group is co-chaired by Finland, Italy, and the Netherlands and includes 10 other European countries¹²⁷.

The IWG is supported by the CSA project SET4BIO¹²⁸ and ETIP Bioenergy¹²⁹. Members of ETIP Bioenergy actively participate in the work of this working group.

125 This also includes hydrogen.

126 https://setis.ec.europa.eu/system/files/2021-07/setplan_bioenergy_implementationplan.pdf

127 See map on p22

128 <http://www.set4bio.eu>

129 <https://www.etipbioenergy.eu>



KEY DEVELOPMENTS

The updated implementation plan. Bioenergy will play a key role in the energy transition and help achieve a sustainable society. At the moment of publication of this report, the working group is updating the targets included in its implementation plan to comply with the new policy framework and in particular the ambitions of the Renewable Energy Directive¹³⁰ for 2030 and 2050. Out of the 14 targets in the implementation plan, four will need to be updated: target 1.1.B that sets the goal for energy delivered by advanced biofuels in 2020; target 2 on improving GHG savings; and targets 5.2 and 5.3 on intermediate bioenergy carriers. The first two targets will be updated for 2030 while the latter two will need to be updated for 2040/2050.

SET4BIO developments. The project, launched in the spring of 2020, helps to fulfil the renewable fuels and bioenergy

implementation plan. SET4BIO is active within the areas of financing, industry engagement and innovation support through the 'Innovation Challenge'. In 2020, the project produced and presented in webinars a mapping of bioenergy programmes and projects that were supported by national funding. An interactive map of around 200 national projects is available on the SET4BIO website¹³¹.

The SET4BIO Innovation Challenge¹³² aims to create innovation that stimulates the increased production and use of bioenergy and renewable fuels. The Innovation Challenge will select seven innovative proposals that help to implement the European Green Deal and provide them with the opportunity to accelerate the development of their solution via five virtual events and a final demonstration day, and match innovative solutions with potential funding opportunities.

130 https://ec.europa.eu/info/news/commission-presents-renewable-energy-directive-revision-2021-jul-14_en

131 <https://www.etipbioenergy.eu/set4bio/outputs-and-resources/set4bio-map>

132 <https://www.etipbioenergy.eu/set4bio/innovation-challenge>

HIGHLIGHTS OF KEY PROJECTS

BLAZE

BLAZE¹³³ aims to develop an innovative, highly efficient and fuel-flexible technology for combined heat and power (CHP) from biomass. The project is expected to achieve a net electric efficiency of up to 50 % and an overall CHP efficiency up to 90 %, which will help feed the innovation cycle, laying the basis for the next generation of biomass technologies in Europe. BLAZE started in March 2019 and is expected to be finalised by February 2022.

LIGNOCELLULOSIC ETHANOL

In Romania, Clariant¹³⁴ is building a new commercial-scale plant for the production of cellulosic ethanol from agricultural residues based on the sunliquid® technology. The EU project SUNLIQUID funded tasks that focus on the scoping, planning and execution phases in the construction of a first-of-its-kind sunliquid® production plant, which was successfully completed in October 2021. In addition, the EU project LIGNOFLAG is funding tasks that focus on building and operating the production plant, which includes optimising the conversion to cellulosic ethanol, using co-products for energy production and soil fertilisation, and organising the distribution of the final (co)products.

SYNKERO

Synkero¹³⁵, a project development start-up, was launched during the 2021 European Conference for Sustainable Aviation Fuel (SAF). Synkero aims to develop a commercial plant for the production of SAF. The factory will be located in the Port of Amsterdam, which has an existing kerosene pipeline to Schiphol Airport. The factory is scheduled to be completed in 2027. The project will seek to connect with sustainable initiatives in the North Sea Canal area, such as the Hermes project.

BIOTFUEL

The BioTfuel¹³⁶ project, launched by Total along with five partners, is designed to transform lignocellulosic biomass (straw, forest waste, and dedicated energy crops) into high-quality biodiesel and biojet fuel via thermochemical conversion. The process can also convert fossil feedstock mixed with biomass into biofuel to account for seasonal variations in resource availability.

BIOMASS TECHNOLOGY GROUP'S FAST PYROLYSIS

The company¹³⁷ has utilised the fast pyrolysis process in commercial-scale plants in the Netherlands, Finland and Sweden. Empyro in the Netherlands has been in operation since 2015, being the first commercial-scale 24/7 fast pyrolysis bio-oil (FPBO) production plant in the world. The Swedish plant was commissioned in 2021.

SILVA GREEN FUEL

Silva Green Fuel¹³⁸ is a collaboration between Statkraft and Sødra, formed in 2015 to develop and produce advanced biofuel to replace fossil fuels. Silva Green Fuel is constructing a demonstration plant, scheduled for launch at the end of 2021, to test ground-breaking production technology at the Statkraft Tofte site.

GICO GASIFICATION INTEGRATED WITH CO₂ CAPTURE AND CONVERSION

GICO¹³⁹ aims to develop an advanced, smart and flexible approach to convert bioenergy and RES electricity excess into biofuel and on-demand power production, thereby producing fuel for the transport sector while balancing grid stability. Regarding SET-Plan Key Action 8, GICO is in line with the activities on: developing advanced liquid and gaseous biofuels; developing high efficiency biomass cogeneration plants by 30 %; developing solid intermediate bioenergy carriers through thermochemical conversion; reducing costs of advanced biofuels at 35-50 €/MWh; GHG reduction greater than 60 %. GICO started in December 2020 and is expected to be finalised by November 2024.

OULUN ENERGIA'S LAANILA BIOWATER PLANT

Inaugurated in the beginning of 2021, Oulun Energia's Laanila biowater plant¹⁴⁰ represents the latest technology that runs on biomass and solid recovered fuel (SRF). Its boiler can use a wide range of fuel compositions and their ratios can be easily changed. Process steam-using industries can be integrated around the biowater plant, opening up new opportunities for the region's bioeconomy.

133 <https://www.blazeproject.eu>

134 www.clariant.com

135 www.skynrg.com

136 www.ifpenergiesnouvelles.com

137 www.btg-bioliquids.com

138 www.statkraft.no

139 <https://www.gicoproject.eu>

140 www.ouluenergia.fi



CARBON CAPTURE AND STORAGE - CARBON CAPTURE AND UTILISATION

The IWG on Carbon capture and storage - carbon capture and utilisation (CCS-CCU) was established in 2017 to help advance the R&I activities required to achieve the 2020 CCS and CCU targets agreed by the European Commission, SET Plan countries, and industry. The 2017 CCS-CCU implementation plan¹⁴¹ is based on research and innovation activities that include:

- developing commercial-scale CCS projects from industrial CO₂ sources, as well as in the power sector;
- developing European cross-border CO₂ infrastructure and monitoring the progress of European CO₂ projects of common interest;
- promoting pilot projects on promising new capture technologies and CCU; and
- unlocking European CO₂ storage capacity.

The European Green Deal is creating a strong CCS-CCU momentum in Europe, with more than 40 'market-ready' projects – operational before 2030 – being planned, and others moving forward. These projects will play an important role in achieving the climate neutrality objective by 2050 and supporting a higher 2030 emissions reduction target. However, reaching these targets requires an enabling policy framework and the revision of key policies – such as the Trans-European Networks for Energy Regulation and the EU Emissions Trading System Directive – will provide an opportunity to highlight the role of CCS/CCU in the decarbonisation pathway.

The group is co-chaired by the Netherlands, Norway and the Zero Emissions Platform, and includes nine other European countries¹⁴². The Zero Emission Platform (ZEP) ETIP¹⁴³ is the technical adviser on the deployment of CCS-CCU for the SET Plan.

¹⁴¹ https://setis.ec.europa.eu/system/files/2021-04/set_plan_ccus_implementation_plan.pdf

¹⁴² See map on p22

¹⁴³ <https://zeroemissionsplatform.eu>

KEY DEVELOPMENTS

Update of the implementation plan. In 2020, the working group updated its implementation plan targets¹⁴⁴. The updated and more ambitious targets for 2030 reflect the EU's climate neutrality goal by 2050 and the urgent need to accelerate the CCS-CCU deployment during the 2020s, in view of the fact that the majority of the initial targets have been reached or are on track.

The Roadmap to 2030. The working group is preparing a 'CCUS Roadmap to 2030', which will describe the status of and ways to support CCS and CCU development in Europe for the rest of this decade. The roadmap will be aimed specifically at policymakers, industrialists and investors, as well as the

wider CCS/CCU community. It will be connected to the updated targets and integrate the work of CCS-CCU IWG.

Collaborations. The working group is cooperating with other organisations in the CCS/CCU community such as: the ZEP ETIP, ERA-NET Accelerating CCS Technologies, EERA, Carbon Capture Utilisation and Storage Projects Network, Mission Innovation and the Clean Energy Ministerial. Successful cooperation has taken place within the CETP on the CCS/CCU R&I priorities for Horizon Europe. The CCS-CCU IWG and the ETIP ZEP have jointly produced a list of market-ready projects¹⁴⁵ and have collaborated on monitoring and reporting the working group's activities for 2020.



HIGHLIGHTS OF KEY PROJECTS

LONGSHIP

Started in 2020, Longship¹⁴⁶, the Norwegian government's full-scale CCS project, is one of the first industrial CCS projects to develop open access infrastructure with the capacity to store significant volumes of CO₂ from across Europe. It captures and liquefies CO₂ from industrial sources in the Oslo-fjord region (from cement and waste-to-energy plants) and ships liquid CO₂ from these industrial capture sites to an onshore terminal on the Norwegian west coast. The Northern Lights project, which has project of common interest (PCI) status since the third PCI list¹⁴⁷, is responsible for developing and operating CO₂ transport and storage facilities, open to third parties, as part of the Longship project.

PORTHOS

Started in 2020, Porthos¹⁴⁸ is developing a project in which CO₂ from industry in the Port of Rotterdam is transported and stored in depleted gas fields beneath the North Sea. CO₂ will be captured by various industrial companies, compressed, transported through an offshore pipeline to a platform in the North Sea approximately 20 km off the coast and pumped into depleted gas fields. The possibility for inland connections – from neighbouring countries to the Netherlands – will be evaluated in a second phase. The project has PCI status since the third PCI list¹⁴⁹.

NORTH-CCU-HUB

North-CCU-Hub¹⁵⁰ is a public-private consortium of more than 20 partners, developing a CCU strategy for the North Sea Port region (Belgium-Netherlands). The first flagship project of the North-CCU-Hub is the North-C-Methanol project, which aims to produce 46 000 tonnes of low-carbon methanol for local use, by synthesis from local CO₂ and green hydrogen, generated by renewable energy in a new 65 MW electrolyser plant. Side products like oxygen and heat are also used locally. The North-CCU-Hub project began in 2018 and is expected to be realised by 2030.

POLAND EU CCS INTERCONNECTOR

The Poland EU CCS interconnector¹⁵¹ aims to establish an open access, multi-modal CO₂ export hub from Gdańsk and its hinterland, connecting the main industrial CO₂ emitters in Gdańsk to a permanent storage CCS chain currently being developed in the North Sea. The CO₂ export hub will collect the CO₂ from emitters for further loading onto ships. The offloading facilities of LCO₂ and import hubs will be located in the North Sea basin, connected to the CO₂ geological storage. The Poland EU CCS Interconnector is expected to be operational by 2025-2026.

H-VISION

The focus of H-vision¹⁵² is on the production of low-carbon hydrogen using natural gas and refinery fuel gas. The CO₂ that is captured during production will be safely stored in depleted gas fields under the North Sea or used as a building block for basic chemicals. The project foresees the production of renewable hydrogen as a later step. Thus, contributing to targets 1, 2, 3, 6 and 10 of the implementation plan. The project will be developed in the Port of Rotterdam area and its aim is to use hydrogen to substantially reduce the Port's CO₂ emissions by 2030.

COLUMBUS

COLUMBUS¹⁵³, is a CCS project in Wallonia (Belgium), in which emissions from the lime production process will be transformed into synthetic methane (e-methane) with the addition of renewable hydrogen. The project is expected to be operational in 2025. It is expected that at full scale the project will help avoid 900.000 kt of CO₂ emissions during the first 10 years of operation. COLUMBUS is linked to targets 8 and 9 of this working group.

146 <https://ccsnorway.com>

147 <https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A32018R0540>

148 <https://www.porthosco2.nl/en/project>

149 <https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A32018R0540>

150 <https://northccuhub.eu>

151 https://ec.europa.eu/energy/sites/default/files/detailed_information_regarding_the_candidate_projects_in_co2_network.pdf

152 <https://www.h-vision.nl/en>

153 <https://www.laborelec.com/columbus-project-engie-carneuse-cockerill-reduction-of-co2-emissions-in-wallonia>



NUCLEAR SAFETY

Established in 2016, the IWG on nuclear safety supports the European Green Deal goal of decarbonisation by 2050.

The aim of the working group is to pursue excellence in R&I, to ensure a high level of safety and efficiency for nuclear reactors (including innovative fission and fusion systems, and cross-sectorial industrial applications), to deliver high-quality infrastructures, skills and competences in the sector, and to enhance European and international cooperation.

For 2030, the goal is to ensure the safe, long-term operation and new-build of the European fleet of fission reactors, offering flexible, reliable, low-carbon energy, but also to develop applications further in areas such as supply for industrial process heat and co-generation plants.

Another goal is the development of sustainable reactor designs and closed fuel cycles, offering increased uranium resource efficiency and reduced generation of long-lived waste, together with the implementation at industrial scale of geological disposal as of 2025.

The European Green Deal should benefit from low-carbon nuclear energy to achieve an EU 2050 climate-neutral economy, enhance European industrial leadership, and tackle today's EU/Global societal challenges. In doing this it can benefit from the support of innovative research infrastructures identified within the European Strategy Forum on Research Infrastructures¹⁵⁴ (ESFRI). For example, the Multi-purpose hYbrid Research Reactor for High-tech Applications¹⁵⁵ (MYRRHA) in Belgium, Jules Horowitz Reactor¹⁵⁶ (JHR) in France, and PALLAS¹⁵⁷ in the Netherlands.

A full list of goals and objectives is available in the nuclear safety implementation plan, published in 2019¹⁵⁸.

The group is co-chaired by Finland and France and includes 15 other European countries¹⁵⁹. In addition, this working group is supported by the ETIP on Sustainable Nuclear Energy Technology Platform (SNETP)¹⁶⁰.

154 <https://www.esfri.eu>

155 <https://myrrha.be>

156 <http://www-rjh.cea.fr/index.html>

157 <https://www.pallasreactor.com/en/en-pallas-van-levensbelang-voor-miljoenen>

158 https://setis.ec.europa.eu/system/files/2021-04/set_plan_nuclear_safety_implementation_plan_3.pdf

159 See map on p22

160 <https://snetp.eu>



KEY DEVELOPMENTS

Delivery of the implementation plan actions. The existing R&I actions identified within the nuclear safety implementation plan help to deliver several key European Green Deal climate and environmental objectives by:

- ensuring nuclear fission remains EU's largest, secure, competitive, flexible and reliable supplier of low-carbon electricity (50 % today), together with renewables.
- exploring alternative nuclear applications: hydrogen production, process heat for heavy industry, district heating and medical applications in addition to reliable, flexible and sustainable electricity generation, allowing the stability of the EU grid, independence, competitiveness and a low-carbon source of energy.
- developing new smart technologies, processes and synergies: new designs including small, modular and advanced reactors with the potential to close the fuel cycle, digitalisation, artificial intelligence, new manufacturing routes, and harmonisation of codes and standards.
- focusing on key enablers to deliver the working group ambitions: EU high-quality skills and competencies, R&D infrastructure, knowledge management and international cooperation.

Successful joint partnerships. Several European joint programmes (partnerships or initiatives) were

or will be launched, in support of the working group's implementation plan and SET Plan Industry/R&D/national research programmes. Some of the partnerships are listed in the project highlights.

International collaborations have taken place through the:

- ETIP SNETP¹⁶¹ pillars
 - Nuclear Generation II & III Alliance Gen-II-III Water-cooled reactor technology (NUGENIA)¹⁶²;
 - European Sustainable Nuclear Industrial Initiative (ESNII)¹⁶³ Gen-IV – Advanced fast reactor technology and sustainable closed fuel cycle;
 - European Nuclear Cogeneration Industrial Initiative (NC2I)¹⁶⁴ – Cogeneration of electricity and heat together;
- Implementing Geological Disposal of radioactive waste Technology Platform (IGDTP)¹⁶⁵;
- EERA Joint Programme on Nuclear Materials¹⁶⁶;
- MELODI initiative on low-dose research¹⁶⁷;
- International Atomic Energy Agency (IAEA)¹⁶⁸; and
- Organisation for Economic Co-operation and Development (OECD) Nuclear Energy Agency (NEA)¹⁶⁹.

161 <https://snetp.eu>

162 <https://snetp.eu/nugenia>

163 <https://snetp.eu/esnii>; ESNII has a roadmap supporting design, licensing, construction and commissioning of the flexible fast spectrum irradiation facility MYRRHA, the sodium-cooled ASTRID, lead-cooled ALFRED and gas-cooled ALLEGRO fast reactor systems (see below in project highlights)

164 <https://snetp.eu/nc2i>

165 <https://igdtp.eu>

166 <https://www.eera-set.eu/component/projects/projects.html?id=192>

167 <https://melodi-online.eu>

168 <https://www.iaea.org>

169 <https://www.oecd-nea.org>

HIGHLIGHTS OF KEY PROJECTS

SMALL MODULAR REACTORS (SMRS)

Small Modular Reactors (SMRs), led by the French demonstrator 200-400 MWe NUWARD-TM¹⁷⁰ Light Water Reactor within Europe, are being developed to help decarbonise the power systems efficiently from early 2030. SMRs are also a crucial concept for the next generation of nuclear reactors.

Light water small modular reactors (LW-SMRs) are a promising new technology whose features make them a potentially attractive energy source. The EU-funded ELSMOR (Towards European licensing of small modular reactors)¹⁷¹ project seeks to design methods and tools for stakeholders to assess and verify LW-SMRs' safety when installed across Europe. The project will devise procedures to evaluate their safety, improve European experimental research infrastructure to help in assessing future LW-SMR safety features, and enrich European nuclear safety analysis codes for evaluating future LW-SMR safety. Ultimately, the licensing procedure will be smoother and more complete.

EUROFUSION AND ITER

Longer-term fusion technology is developed through the implementation of the European Fusion technology roadmap of EUROfusion¹⁷². This is supported by the Fusion for Energy Joint Undertaking (F4E) as well as Euratom in view of the construction and operation of ITER and the progress towards a first-of-a-kind demonstration project. The latter includes the R&D activities needed to demonstrate the scientific and technological feasibility of fusion energy within tokamaks, to test and validate experimental data within key supporting infrastructures, e.g. International Fusion Materials Irradiation Facility DEMO Oriented Neutron Source (IFMIF-DONES¹⁷³), and through international cooperation.

EURAD

The EURAD (European Joint Programme on Radioactive Waste Management)¹⁷⁴ project, which started in 2019, is

a step change in European collaboration towards safe radioactive waste management, including disposal. Through the development of a robust and sustained science, technology and knowledge management programme, EURAD supports a timely implementation of RWM activities. EURAD also serves to foster mutual understanding and trust between Joint Programme participants, and supports the implementation of the Waste Directive in EU Member States, by taking into account the various stages of advancement of national programmes but also the national policy and socio-political landscape with respect to longer-term storage and geological disposal.

CONCERT

CONCERT (European Joint Programme for the Integration of Radiation Protection Research)¹⁷⁵, a project under Horizon 2020, aims to contribute to the sustainable integration of European and national research programmes in radiation protection. As a co-fund action, the project strives to achieve the attraction and pooling of national research efforts in radiation protection with EURATOM research programmes in order to make better use of public R&D resources and to tackle common European challenges in radiation protection more effectively by joint research efforts in key areas. In order to rise to this challenge, CONCERT operates as an umbrella structure for the research initiatives of the radiation protection research platforms, MELODI, ALLIANCE, NERIS, EURADOS and EURAMED. It also supports the implementation of the Euratom Basic Safety Standards directive. CONCERT started in 2021 and is expected to run until 2023.

GEMINI PLUS

Launched in September 2017, GEMINI¹⁷⁶, a European Horizon 2020 project funded under the Euratom programme, is a transatlantic partnership for which Europe and the US are sharing their resources and efforts to accelerate the development of modular High Temperature Gas cooled Reactor (HTGR) technology.

170 <https://www.technicatome.com/en/activites/nucleaire-civil/smr>

171 <https://cordis.europa.eu/project/id/847553>

172 <https://www.euro-fusion.org>

173 <https://ifmifdones.org>

174 <https://www.ejp-eurad.eu>

175 <https://concert-h2020.eu>

176 <https://gemini-initiative.com>

ALLEGRO

ALLEGRO¹⁷⁷ is a concept of a demonstration unit of the gas-cooled fast reactor (GFR) technology, developed in Europe. The main aim is to prove viability, safety, and reliability of the whole concept of a high temperature, gas-cooled, fast spectrum reactor. ALLEGRO was launched in 2015 and the conceptual design is expected to be completed by 2025.

ALFRED

ALFRED (Advanced Lead-cooled Fast Reactor European Demonstrator)¹⁷⁸ is a demonstrator of the lead fast reactor technology. The conceptual design of the ALFRED reactor and the integrated project were led by Ansaldo Nucleare under the seventh Euratom framework programme. A demonstration unit is being developed in Romania through the European Sustainable Nuclear Industrial Initiative (ESNII), which brings together industry and research partners in the development of so-called Generation IV Fast Neutron Reactor technology, as part of the SET Plan.

OLKILUOTO 3 GENERATION III NUCLEAR POWER PLANT

Olkiluoto 3 (OL3)¹⁷⁹, currently under construction, is an EPR (European Pressurised Water Reactor) plant unit that includes modern proven technology and advanced new safety features benefitting from the latest integration of innovations and safety R&D activities for 60 years' operation. Grid connection took place in late 2021 and regular net electrical power of approximately 1 600 MW is expected from February 2022.

MYRRHA

MYRRHA (Multi-purpose hYbrid Research Reactor for High-tech Applications)¹⁸⁰ is the world's first large-scale, accelerator-driven system project at power levels scalable to industrial systems. MYRRHA offers unparalleled research opportunities in spent nuclear fuel, nuclear medicine and fundamental and applied physics. In September 2018, the Belgian Federal Government announced their support with the financing of EUR 558 million for the realisation of MYRRHA in 3 phases, which are expected to be finalised by 2027.

177 <http://allegroreactor.eu>

178 <http://proalfred.nuclear.ro>

179 <https://www.tvo.fi/en/index/production/plantunits/ol3.html>

180 <https://myrrha.be>





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LIST OF ABBREVIATIONS

AI – artificial intelligence	JHR – Jules Horowitz Reactor
BIM – building information modelling	KPI – key performance indicator
CCS-CCU – carbon capture and storage - carbon capture and utilisation	LCOE – levelised cost of energy
CCUS – carbon capture utilisation and storage	LLEC – Living Labs Europe Competition
CEM – Clean Energy Ministerial	LW-SMR – light water small modular reactor
CETP – Clean Energy Transition Partnership	MVDC – medium-voltage direct current
CHP – combined heat and power	MW – megawatt
CO ₂ – carbon dioxide	MWe – megawatt electrical
CSA – coordination and support action	MWh – megawatt hour
CSP-STE – concentrated solar power - solar thermal electricity	MYRRHA – Multi-purpose hYbrid Research Reactor for High-tech Applications
CST – concentrated solar thermal	NC2I – European Nuclear Cogeneration Industrial Initiative
DC – direct current	NEA – Nuclear Energy Agency
DH – district heating	NECP – national energy and climate plan
DHC – district heating & cooling	NRCG – national and regional coordinators group
DUT – Driving Urban Transitions to a Sustainable Future Partnership	NUGENIA – Nuclear Generation II & III Alliance
EE – energy efficiency	nZEB – nearly zero-energy buildings
EERA – European Energy Research Alliance	O&M – operation and maintenance
EJP – European Joint Programme	OECD – Organisation for Economic Co-operation and Development
ERA – European Research Area	P2X – Power-to-X
ERA-NET – European Research Area Network	PCI – project of common interest
ERA-NET SES – European Research Area Network for Smart Energy Systems	PCP – pre-commercial procurement
ESFRI – European Strategy Forum on Research Infrastructures	PED – positive energy district
ESNII – European Sustainable Nuclear Industrial Initiative	PEN – positive energy neighbourhood
ESTELA – European Solar Thermal Electricity Association	PERC – passivated emitter and rear cell
ETIP – European Technology and Innovation Platform	PV – solar photovoltaic
EU – European Union	R&I – research & innovation
EURAD – European Joint Programme on Radioactive Waste Management	RES – renewable energy sources
EV – electric vehicle	RHC-ETIP – European Technology and Innovation Platform on Renewable Heating and Cooling
FPBO – fast pyrolysis bio-oil	SAF – sustainable aviation fuel
GHG – greenhouse gas	sCO ₂ – supercritical carbon dioxide
HTF – heat transfer fluid	SET Plan – Strategic Energy Technology Plan
HVDC – high voltage direct current	SETIS – Strategic Energy Technology Information System
IAEA – International Atomic Energy Agency	SME – small and medium-sized enterprise
ICT – information and communications technology	SMR – small modular reactor
IEA – International Energy Agency	SNET – Smart Networks for Energy Transition
IFMIF-DONES – International Fusion Materials Irradiation Facility DEMO Oriented Neutron Source	SNETP – Sustainable Nuclear Energy Technology Platform
IGDTP – Implementing Geological Disposal of radioactive waste Technology Platform	SOFC – solid oxide fuel cell
IoT – Internet of Things	SRA – Strategic Research Agenda
IPCEI – Important Project of Common European Interest	SRF – solid recovered fuel
IRENA – International Renewable Energy Agency	SRIA – Strategic Research and Innovation Agenda
IWG – Implementation Working Group	TES – thermal energy storage
	TRL – technology readiness level
	UMG – upgraded metallurgical grade
	ZEP – Zero Emission Platform



This report was developed by the Joint Research Centre of the European Commission in collaboration with the Directorates-General for Energy and for Research and Innovation.

SETIS team thanks the working groups for their valuable contributions to this report.

Shtjefni, D., Kuzov, T., Clocchiatti, A., Lecomte, E., Lonning, E.V.W., Baleva, S. and Tzimas, E. – authors
Black, C. – editor
Ruehringer, M. – cartography
Andre, S. – graphic design

JRC126881

EN PDF	ISBN 978-92-76-43092-6	doi:10.2760/804820	KJ-05-21-318-EN-N
EN Print	ISBN 978-92-76-43742-0	doi:10.2760/12610	KJ-05-21-318-EN-C

Luxembourg: Publications Office of the European Union, 2021

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