European Commission

SET Plan

PROGRESS REPORT 2023

Coordinated energy research and innovation for a competitive Europe

CONTENTS

EXECUTIVE SUMMARY

Since its inception in 2019, the European Green Deal has set out the route for a sustainable, secure and competitive energy system for the EU, achieving carbon neutrality by 2050. Four years later, the legislative framework continues to develop.

Earlier this year, the European Commission introduced the Green Deal Industrial Plan, which includes the Net-Zero Industry Act and the Critical Raw Materials Act. These legislative proposals are key to achieving the European Union's clean energy goals through the establishment and reinforcement of resilient clean energy supply chains.

Clean energy research and innovation are pivotal for the energy transition. The Strategic Energy Technology Plan (SET Plan) plays a key role in coordinating European and national R&I agendas for low-carbon energy solutions. As the policy landscape is changing fast, so too must the SET Plan. Following an extensive consultation process, the Commission published a Communication on 20 October outlining the SET Plan's revision.

The Communication proposes a refinement of the SET Plan's strategic objectives to align them with the new policy framework. It also proposes to elevate the SET Plan's political status, linking it structurally to the European Research Area (ERA), setting ambitious targets, expanding the technology scope, strengthening its reporting (in which this report plays a part) and establishing task forces for crosscutting issues.

The SET Plan stakeholders – participating in 14 working groups – are the beating heart of the SET Plan. Drawing extensively on their input, this report offers an overview of their recent work and the impact it has made, along with their expectations of the opportunities and challenges ahead.

The 2023 SET Plan conference in Viladecans in Spain comes at a time in which research and innovation in clean energy technologies is high on the global political agenda. Not only to achieve the European Green Deal, but also to safeguard our energy security and to build a flourishing, resilient European energy industry. This report, and the conference, aim to draw together the latest developments in technological innovation for a carbon-neutral future.

FOREWORD

In the ever-changing landscape of global challenges, one constant remains: the transformative power of research and innovation. Against a backdrop of multiple recent crises, our collective efforts in advancing clean energy technologies through the European Strategic Energy Technology Plan (SET Plan) have never been more crucial. Every European citizen now more than ever relies on the R&I community to provide the technological and scientific advancements necessary to bring about a clean and more affordable energy and a better living environment. Industry looks up to us for new solutions to maintain competitiveness. And the rest of the world needs Europe to lead.

The SET Plan was established in 2007 to accelerate the transition towards a climate-neutral energy system through the development of low-carbon technologies quickly and cost-competitively. Member States and Associated Countries, industry, research, and academic communities have significantly strengthened collaboration on clean energy research and innovation, thanks to the SET Plan. And while a lot has changed since 2007, we have also made significant advancements, notably through dedicated projects and the Clean Energy Transition Partnership, thanks to which more than EUR 500 million in national funding is pooled with EUR 2010 million from Horizon Europe to deliver on jointly agreed R&I priorities over 2021/2027.

Energy storage is a pivotal component in our effort to shift to renewables. The SET Plan has created Batteries Europe, bringing together more than 700 stakeholders in the European batteries R&I ecosystem to develop a sustainable and competitive battery value chain in Europe. In the solar photovoltaic (PV) field, the SET Plan helped align the R&I efforts of the participating countries, contributing to significant technological progress towards the world's most efficient solar cell to date. This will be instrumental not only as photovoltaic installations increasingly roll out for private and business applications, but also in our effort to reduce strategic dependencies. The SET Plan Ocean energy workstream inspired the EU offshore renewable energy strategy. It helped formulating guidance on setting up an insurance and guarantee fund for deploying large-scale demonstration projects. This will allow us to make better use of the great potential of offshore energy production, reducing the need to use valuable arable land.

Coming just after the recently adopted revision of the SET Plan, this report marks a new impetus for our initiative. The SET Plan is now aligned with the ambitious goals of other recent policy initiatives such as the Green Deal, REPowerEU and the Green Deal Industrial Plan. At the same time, we also anchor it in the European Research Area (ERA). The revised SET Plan will adapt its governance to ensure more visibility and impact by transforming its Steering Group into a subgroup of the ERA. In addition, new or updated joint strategic research agendas will forge strong synergies between SET Plan countries, for example in the field of renewable hydrogen and solar energy. These changes make the SET Plan better equipped to serve its purpose – to achieve the EU's energy and climate goals and to make Europe a global leader in clean energy and energy efficiency technologies.

I am confident that together we can propel the revised SET Plan forward to achieve its full potential.

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

The unprovoked war of aggression by Russia against Ukraine generated an unprecedented energy crisis for the EU with extremely high energy prices and strong negative impact on the economy and on citizens.

Our joint European response has been loud and clear: we must accelerate our clean energy transition to secure energy supply, stay competitive, protect consumers against high energy prices, and meet our climate targets.

Last year, the EU reduced its gas demand by 18% and deployed significantly more solar PV and wind energy capacity than the previous year. For the first time, wind and solar overtook gas in the production of energy.

This year was marked by equally impressive achievements. The Commission proposed a targeted reform of the Electricity Market Design. It aims at fostering the penetration of renewable energies and making energy bills less dependent on the short-term volatility in prices. The EU adopted a revised Renewable Energy Directive that raises the share of renewable energy in the EU's overall energy consumption to 42.5% by 2030. The EU also adopted a revision of the Energy Efficiency Directive, which establishes a legally binding target to reduce the EU's final energy consumption by 11.7% by 2030 compared to the projections of the 2020 reference scenario.

However, we also need to look beyond this horizon, towards 2050, and our aim to fully decarbonise the EU by then. To this end, we need more research and innovation. About 35% of the greenhouse gas emission reductions until 2050 will come from technologies that are not yet on the market.

At the same time, we must step up the efforts to turn innovations into marketable solutions and scale those up. Today our leadership in research and in deployment is not matched by an equally strong position in the manufacturing of net-zero technologies. The EU must secure a strong industrial base in clean technologies to secure its open strategic autonomy.

This year's Green Deal Industrial Plan will help by offering a conducive regulatory environment – in particular the Net Zero Industry Act and the Critical Raw Materials Act - as well as enabling measures improving access to finance, raising skills, and facilitating trading. The Net Zero Industry Act will play a crucial role to overcome barriers to the scaling up of the manufacturing of net zero technologies, while the Critical Raw Materials Act will provide access to rare earths that are vital for manufacturing.

The revised SET Plan is complementing this offer by reinforcing joint efforts between Member States and by giving more emphasis to key cross-cutting aspects. The new SET Plan provides a common vision, goals and coordination in accelerating the development and deployment of efficient and cost-competitive low-carbon technologies, and to enhance the EU's geo-political resilience and security of energy supply.

With the revision of the new SET Plan, we are pleased that the EU clean energy research and innovation ecosystem will become even stronger and more efficient. More consideration will be given to areas that have become increasingly important: digitalisation, skills gaps, social needs, access to funding, circularity, and market uptake.

By working together in the race to net-zero, the SET Plan countries will accelerate the clean energy transition, while enhancing the competitiveness of their net-zero industries. This is good for the planet and for the economy.

Kadri Simson
European Commissioner for Energy

INTRODUCTION

The main aim of the 2023 SET Plan progress report is to give a concise overview of the SET Plan landscape through the lens of its actors and their main activities.

The report also provides an overview of the current policy drivers, the Communication on the revision of the SET Plan, and the cross-sectoral issues for which new task forces will be formed. These proposals will underpin the SET Plan's future direction and will guide all future work across the various stakeholders in the SET Plan ecosystem.

In the second section, the report presents the status of clean energy R&I investment in the EU, the current SET Plan actors, the ongoing collaborations, and key stakeholder inputs. The latter is a new feature of this year's report, which showcases the work of the European Energy Research Alliance (EERA) and the European Technology & Innovation Platforms (ETIPs).

Also new this year are insights on materials & circularity for energy technologies, skills for the energy transition, and the National Energy and Climate Progress Reports (NECPRs). This enlarges the scope of the annual report by addressing transversal issues and situating the SET Plan in the wider European clean energy R&I landscape.

The final section presents highlights of the year from the perspective of each of the 14 implementation working groups. These offer a concise overview of recent developments, along with future opportunities and challenges, measured against the implementation plans of each group.

The Joint Research Centre of the European Commission prepared this report in close collaboration with DG Energy, DG Research and Innovation, the 14 SET Plan working groups, EERA and the ETIPs Forum. The report was published on the occasion of the 17th SET Plan Conference, organised jointly by the European Commission and the Spanish Presidency of the Council of the EU.

A NEW POLICY FRAMEWORK FOR THE SET PLAN

This chapter provides an overview of the evolving policy landscape, exploring the rationale behind the new SET Plan Communication and identifying the major changes.

POLICY DRIVERS

Recent years have seen a dramatic increase in geopolitical tension, and an acute awareness of the importance of securing Europe's clean energy supply. It is essential to strengthen its resilience, autonomy, and competitiveness, and to ensure that it remains affordable for all Europeans, as outlined in the REPowerEU Plan. This must be achieved in tandem with the overarching objectives of the European Green Deal, to chart a sustainable path towards a net-zero economy.

In 2023, the European Commission announced the Green Deal Industrial Plan[1], a strategy for a more autonomous and resilient clean energy industry. The Plan is centred around the proposed Net-Zero Industry Act (NZIA)[2] and Critical Raw Materials Act (CRMA)[3]. The NZIA outlines ambitious goals to enhance the EU's capacity to manufacture clean energy technologies domestically.

The CRMA responds to the urgency of securing the supply of vital materials for manufacturing these technologies with measures to develop domestic supply chains with circularity and sustainability at their core.

The Commission's proposals extend beyond industrial transformation. The revised directives for Renewable Energy and Energy Efficiency, for instance, seek to further integrate innovative low-carbon and energy-efficient technologies into Member State planning. This underscores the central role that innovative solutions play in shaping the energy landscape, especially when it comes to building stock and European cities.

Furthermore, the Communication on 'A new European Research Area for Research and Innovation' and the European Research Area Policy Agenda advocate for a more coordinated approach to R&I investment and reforms.

1 COM(2023) 62 final of 1.2.2023 *https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52023DC0062*
2 COM(2023) 161 final of 16.3.2023 *https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52023PC0161*
3 COM(2023) 160 final of 16.3.2023 *https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52023PC0160*

This strategic alignment resonates with the broader ambitions of the twin green and digital transitions.

In this evolving policy landscape, the SET Plan is a key instrument for the promotion of collaboration among stakeholders across European industry, academia, and government. Fostering joint approaches to clean energy research and innovation, the SET Plan enhances efficiency and expedites the attainment of the shared energy research goals.

This collective endeavour not only drives Europe towards a sustainable and prosperous future but it also underscores the EU's commitment to global leadership in the face of pressing climate challenges.

THE COMMUNICATION ON THE REVISION OF THE SET PLAN

The 2023 Communication on the revision of the SET Plan proposes4 to align the SET Plan's strategic objectives with the European Green Deal, REPowerEU, and the Green Deal Industrial Plan.

It also proposes the elevation of the SET Plan Steering Group to the status of expert group under the European Research Area (ERA). This important move will anchor the SET Plan firmly in the ERA framework, providing it with the means to perform its duties and increasing its political relevance.

The new Communication also sets clear aspirational targets for each of the SET Plan priorities and expands the technology scope. This will now encompass all the renewable energy technologies which are essential for achieving the decarbonisation goal, including those which have achieved prominence in the years since the SET Plan was launched. This includes the establishment of a dedicated workstream on hydrogen.

Additionally, the Communication proposes the systematic integration of critical cross-cutting issues through dedicated, time-bound task forces. These include digitalisation, circularity and sustainability by design, skills development, research and innovation tailored to societal needs and market accessibility.

Member States are encouraged to incorporate SET Plan objectives and research activities into their national energy and climate plans (NECPs) reporting and evaluate the adequacy of funding. The Commission will assess the national submissions and reinforce collaboration between the SET Plan and the NECPs.

The SET Plan will play a greater role in providing input to annual reports on clean energy technology competitiveness. The Commission will continue to monitor progress through the SET Plan Information System (SETIS), with the data informing the annual Energy Union reports and disseminated at the annual SET Plan conference.

The SET Plan will advance the coordination of clean energy research by fostering exchanges with the ERA Forum. Additionally, the SET Plan will inform EU energy and research strategies and legislation, including the Net-Zero Industry Act, with regular reporting to relevant European Parliament committees and Council working parties. Greater political support is key, to enhance consistency and mobilise investment in clean energy technologies from both public and private sectors.

4 COM(2023) 634 final of 20.10.2023 *https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2023:634:FIN*

These proposed measures are expected to improve the governance of the SET Plan, the participation of its member countries and the political visibility of its activities. Crucially, the revised SET Plan will accelerate the needed R&I activities towards a more sustainable, affordable, and secure energy system for all.

CROSS-SECTORAL ISSUES AND THE NEW TASK FORCES

To accelerate the development and deployment of clean and efficient energy technologies, the SET Plan will take a systematic approach to crucial cross-cutting issues. Five task forces will therefore be established to explore:

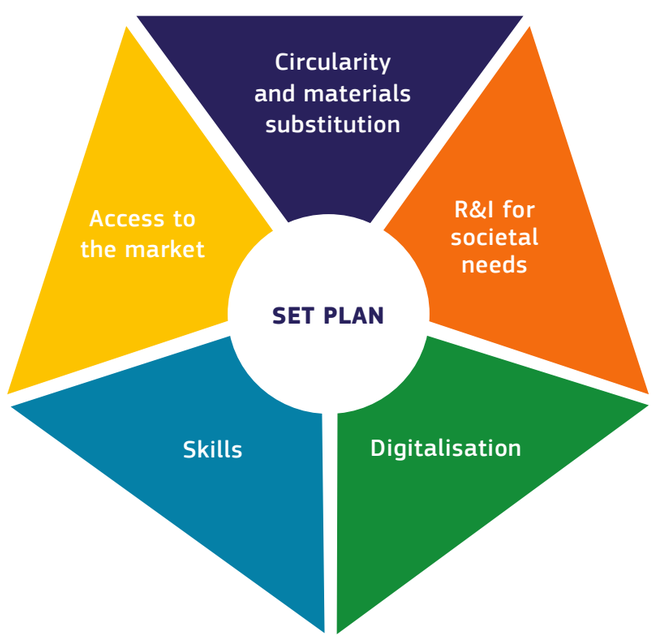
- digitalisation for the energy transition;
- circularity by design and the advanced materials needed for the production of renewable energy technologies;
- R&I for societal needs and human-centred technologies;
- upskilling and reskilling; and
- the acceleration of market uptake for new clean energy technologies.

Digitalisation

Digitalisation plays a pivotal role in driving the transition to cleaner energy sources and a more effective use of energy. Sharing data between suppliers and users leads to more flexibility and enhances the efficiency of various components within the energy system. While an energy dataspace, digital twins and artificial intelligence can improve the performance in the energy system and even minimise the costs of research and testing by conducting experiments in a virtual space.

In addition, the harmonisation of efforts is crucial in digitally transforming the entire energy system, enabling effective management of energy supply and demand while ensuring cybersecurity. This, in turn, fosters greater flexibility, facilitating the integration of decentralised renewable energy sources, new users, such as e-mobility, energy-intensive processes or heat-pumps and reducing the need to curtail any of these actors. To this end, this task force will aim to instil measures that aid the digital transition across all technological working groups.

SET Plan task forces.



Source: SETIS, 2023.

DIGITALISING THE ENERGY SYSTEM

The interlinkages between energy and digital become wider and stronger, to the point that we can no longer talk about energy without mentioning its digital aspects. To meet the Green Deal and REPowerEU objectives in the most cost-efficient way, i.e. contribute to the goals of the EU to reach up to 45% of the renewables in 2030, the EU requires an energy system that is much smarter and more interactive than it is today. This implies a different way of managing the network, one that relies on data access and exchange and digital technologies.

Digital solutions and new technologies open new perspectives on how we manage the energy system, in particular on the relation between the energy system and its end-users. Digital energy infrastructure can contribute to important savings in energy consumption, so we will be digitalising the energy system to green the energy grid, and generate savings for consumers at the same time.

Some aspects are not new. Energy is one of the frontrunners in using digital solutions and has been successfully done so for decades. However, what is new is the extent to which this is done and the complexity of the products and systems that are interacting nowadays. This also brings along new challenges related to the cybersecurity of our European energy infrastructure, access to and sharing of data, data protection and privacy, and the growing energy consumption of the IT sector.

The Commission's "Digitalising the energy system – EU action plan"[5] EU action plan on digitalisation of the energy system published on 18 October 2022 presents the main priorities for concrete actions in specific areas needed to fully exploit the potential of digital technologies and accelerate the digitalisation of the EU energy system while addressing the challenges it brings.

The actions are designed to be implemented in co-operation with the Commission, the Member States and the stakeholder.

The Action Plan on the Digitalisation of the energy system is about delivering on the Commission priorities of the European Green Deal and on making Europe Fit for the Digital Age priorities. It aims to do so by promoting a strategic vision on the following main areas:

- Seamless exchange of interoperable data between different actors along the energy value chain (e.g. network operators, suppliers, aggregators, energy service companies, building managers, financers, end-customers, appliances or car manufacturers);
- More and better coordinated investments in the electricity grid as the enabler for a smarter and more resilient energy system;
- Support and protection to consumers to benefit from new ways to engage in the energy transition or from better services based on digital innovations and more efficient energy use (or energy savings);
- Continuous effort and investment for a cyber-secure energy system;
- Ensure that the growing energy consumption of digital technologies themselves is a driver for the clean energy transition;
- Structural and joint learning of all actors involved in the twin transitions as well as continuous support for research and innovation.

5 COM(2022) 552 final of 18.10.2022 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52022DC0552&qid=1666369684560

Circularity and materials substitution

Circularity (recyclability and reusability) is one of the European Green Deal's building blocks, and an element that must be taken into consideration when designing, developing, manufacturing and deploying clean energy technologies. This includes the materials required for the manufacturing of renewable energy technologies. Research and innovation has a vital role to play in reducing the intensity of critical materials used, and developing high-performance advanced materials to substitute for them. This short-term task force will design ways to embed all aspects of circularity systematically in the development of clean energy technologies.

MATERIALS AND CIRCULARITY ARE KEY FOR THE ENERGY TRANSITION

The transition towards clean energy systems is not just a shift in energy sources but a transition rooted in materials. The production and deployment of clean and efficient energy systems rely heavily on a diverse array of minerals and metals and demand substantial resources. Even with an emphasis on sustainability and circularity, the energy transition creates substantial demand for raw materials. This demand has far-reaching implications, not just for the extraction of these materials but also for the global competition to secure access to them.

With the production of certain raw materials concentrated in just a few regions of the world, the exposure of the EU economy to significant geopolitical risks is well known. Vulnerabilities to the security of supply of raw materials critical for industrial production and for the green transition were aggravated in 2022 when Russia's invasion of Ukraine prompted the EU to confront its dependence on Russian oil and gas, further expediting its energy transition efforts. The renewed urgency towards the deployment of wind power and solar PV systems, the proliferation of batteries and hydrogen for energy storage and transportation, and the adoption of heat pumps for efficient heating and cooling, anticipates disruptions to global markets and the better functioning of value chains relying on these raw materials.

The Commission's proposal for a Critical Raw Materials Act[6] in 2023 is a comprehensive response to these challenges. The regulation intended to strengthen domestic capacities and improve access to materials, prioritises actions focusing on critical and strategic raw materials, the latter being those most crucial for green, digital, defence and space technologies, for which demand is projected to grow.

The JRC foresight study on supply chains and material demand[7], accompanying the regulation proposal, emphasises an unprecedented demand increase for critical materials driven by the EU's transition to cleaner energy and digitalisation goals. This surge in demand is met with heavy dependence on imports, particularly from China, across various technology value chains, raising the risk of disruptions due to environmental and geopolitical factors. The study highlights that the early stages of raw material extraction emerge as systematically critical across all technologies. Here, the EU's share in global production rarely exceeds 7%, indicating a substantial reliance on external sources.

However, as the supply chain progresses towards the final stages, the EU's vulnerability tends to decrease. In these latter stages of the chain, for some of the renewable technologies the EU demonstrates relative strength. Nevertheless, the criticality of upstream supply chain steps underscores the challenges faced by the EU in ensuring a secure and affordable supply of materials and components needed for manufacturing key technologies for the energy transition.

Based on the policy-driven demand scenarios for the EU for each technology, the data reveals a surge in material demand, which is particularly high in the e-mobility sector. According to the estimates, by 2030, lithium demand for batteries in the EU is expected to grow 12 times compared to 2020, and by 2050, this growth is projected to reach 21 times. Globally, the increase is even more substantial, reaching 18 times by 2030 and 90 times by 2050 compared to 2020.

6 COM(2023) 160 final of 16.3.2023 *https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52023PC0160*
7 *https://publications.jrc.ec.europa.eu/repository/handle/JRC132889*

R&I for societal needs

It is crucial to integrate the requirements of ordinary people into technology choices in order to ensure that investment is channelled towards technologies that will be widely accepted and used. Research and innovation efforts must therefore take into consideration the preferences, needs and requirements of people from all walks of life. This approach encompasses including health, safety, security, accessibility (both physically and financially) and affordability (both in terms of cost and the knowledge needed for technology use), among other considerations. This task force will aim to foster new and adapted tools for research and innovation with a more inclusive and responsive approach to shaping the future.

Access to the market

Making sure that technologies are embraced by the market involves integrating industrial methods, manufacturing requirements and associated expenses into the process of technology development. This also means that creators and pioneers of technology can promptly and effectively test their products within a well-equipped and easily accessible technological framework. This testing phase is designed to gear products for large-scale manufacturing in an industrial setting, while also providing pre-certification records and evaluating the technology's entire lifecycle impact. This task force is directly linked to the needs of NZIA and efforts towards developing a robust and independent EU industrial capacity for producing the necessary clean energy technologies.

A similar trend can be observed for graphite, with global demand for lithium and graphite for batteries in 2050 reaching 19 and 9 times the 2020 global supply, respectively.

The rare earth elements neodymium and dysprosium, which are essential for permanent magnets in traction motors and wind turbines, exhibit a relative increase in demand. By 2050, global demand for neodymium and dysprosium for the above technologies is estimated to reach around 3 and 5.5 times the current global supply, respectively.

To strengthen EU supply chains in the short-term and long-term, measures can include stockpiling and the joint procurement of critical materials, diversifying material supply, increasing component manufacturing within the EU, promoting recycling and resource efficiency, pursuing substitution and innovation, and developing domestic production and processing capacities.

Collaboration with like-minded countries, behavioural change for resource efficiency, and investment in research and innovation are vital. Skills and talent development are crucial, especially for specialised supply chain elements, and attention should be given to protecting intellectual property for EU-origin innovations in materials and technology. These actions aim to bolster supply chains and reduce dependency while enhancing resilience.

The transition to a clean energy future necessitates not only technological innovation but also a keen understanding of the materials that underpin it, making material sustainability a central concern in achieving the EU's strategic objectives.

SKILLS FOR THE ENERGY TRANSITION IN A CHANGING LABOUR MARKET

Jobs in renewable energy and other clean energy technologies are growing faster than in the rest of the economy[8]. In 2021, the renewable energy sector employed 1.5 million people, growing 12% on 2020 values[9]. Considering a broader clean energy sector (including energy efficiency and e-mobility), employment climbed to 2 million in 2020[10]. Approximately a third of clean energy jobs are in the manufacturing segment, which has increased by 12% since 2015 as compared to manufacturing jobs overall, which increased only 4% in the same timeframe[11]. To be on the path to climate neutrality, the accelerated deployment of clean energy technologies, as envisioned by REPowerEU and the European Green Deal, means that up to 1 million additional jobs could emerge by 2030[12]. The manufacturing of net-zero technologies alone will create 198 000 new jobs under the business-as-usual practice, 350 000 under the NZIA policy proposal and 468 000 under the NZIA+ scenario[13]. This will mean growing demand for workers with the right skills.

Demand for manual workers and technicians will remain high, as 75% of the job creation will be in low- and medium-skilled roles[14]. Many of the technical profiles needed are transferable from the declining fossil fuel energy industry and other related sectors, but often require some job-specific training or re-accreditation of skills.

Emerging clean energy technologies, and the digitalisation that permeates the economy, create new jobs and roles, which require up- and re-skilling. For example, automation and innovative manufacturing are already used to make clean energy assembly lines more efficient and productive, with 17% of workers in manufacturing and 12% in the energy supply sector operating robots in their daily activities, and 40% of tasks being digitalised or automated[15]. Still, 13% of workers in these sectors have an acute need to develop their digital skills further[16].

8 Kuokkanen. 2023. Skills for the energy transition in the changing labour market. JRC135382
9 EurObserv'ER. 2023. *The State of Renewable Energies in Europe Edition 2022 – the 21st EurObserv'ER Report*
10 JRC based on Eurostat data [env_ac_egss1].
11 JRC based on Eurostat data [env_ac_egss1].
12 European Commission. 2020. SWD(2020) 176 final. Impact assessment accompanying Communication: 'Stepping up Europe's 2030 climate ambition'.
13 NZIA policy proposal is based on EU manufacturing covering 40% of the demand of net-zero technologies in 20230, while NZIA+ scenario is based on EU manufacturing capacity meeting 100%. Estimates are from European Commission SWD(2023) 68 final.
14 Asikainen, et al. 2021. *The Future of Jobs is Green*. Publications Office of the European Union: Luxembourg.
15 JRC based on *CEDEFOP* data. The CEDEFOP European skills and jobs survey (ESJS), second wave carried out in 2021 in all EU Member States, Iceland and Norway, builds on the approach of the first 2014 survey.
16 JRC based on *CEDEFOP* data. The CEDEFOP European skills and jobs survey (ESJS), second wave carried out in 2021 in all EU Member States, Iceland and Norway, builds on the approach of the first 2014 survey.

Skills

The shift towards a greener and more digitally connected future means enhancing the skills of employees, ensuring that they are well equipped for the demands of a whole new system. There is already a substantial skills gap. To bridge this gap, a dedicated short-term task force will identify the necessary skillsets and areas for action, ensuring that the transition towards greener energy is supported by the right expertise and job profiles. The task force will concentrate on two key actions: a) developing tools within the SET Plan structure to address skills alongside technological advancements; and b) initiating measures at EU level to facilitate the harmonisation and mutual recognition of skills requirements and solutions for the workforce needed to operate these emerging technologies.

However, digitalisation does not only affect low-skilled jobs. In fact, it risks creating skills obsolescence in high-skilled occupations[17], and appropriate up- and re-skilling are therefore also needed at this level.

Despite rapid technological change, still many technologies needed for decarbonisation are not yet commercialised. Even in mature technologies, innovation still offers potential for technology cost reduction and is needed to make value chains more sustainable[18]. Therefore, attracting a supply of highly skilled labour, with science, technology, engineering and mathematics (STEM) skills in particular, is crucial for an innovative and competitive EU industry. The number of STEM graduates in the EU is increasing[19]. Yet, a marked gender gap prevails and trickles down to a lower share of female participation in the energy sector overall, as well as in innovation. According to the latest available data, in 2019, only 13% of inventors in Europe were women[20].

Improving gender balance would increase labour supply in fields where demand is high, and expand the talent pool underpinning inventive activity.

As demand for skills is growing, the EU labour market has become tighter since the pandemic[21]. Job vacancies have increased in all economic sectors relevant for the energy transition. For example, in manufacturing and energy supply, vacancy rates have doubled[22]. The availability of skilled labour is the most cited (85%) impediment to investment by European firms, with larger firms especially concerned about the availability of labour with the right skills[23]. While the current shortage of labour can be considered cyclical, structural factors should not be downplayed. Energy is among the sectors most affected by ageing[24]. At the same time, the post-pandemic job market has changed forever. Thus, it is very important to understand the up- and re-skilling needs, while attracting and supporting the supply of new talent.

17 Centeno, et al. 2022. *Supporting policies addressing the digital skills gap – Identifying priority groups in the context of employment*. Publications Office of the European Union: Luxembourg.
18 Kuokkanen et al. 2023. European Climate Neutral Industry Competitiveness Scoreboard (CINDECS) – Annual Report 2022. JRC134499.
19 Eurostat. 2023. *Tertiary education statistics*.
20 EPO. 2022. *Women's participation in inventive activity. Evidence from EPO data.*
21 Kuokkanen. 2023. Skills for the energy transition in the changing labour market. JRC135382
22 JRC based on Eurostat data [jvs_q_nace2]
23 EIB. Investment Report 2022/2023: *Resilience and renewal in Europe*
24 European Commission. 2023. *Employment and Social Developments in Europe (ESDE) report 2023*

THE SET PLAN LANDSCAPE

This chapter provides an overview of EU investment in clean energy R&I, and the overall implementation landscape of the SET Plan – including the involvement of the European countries, the working groups, and supporting initiatives such as the ETIPs and EERA.

R&I INVESTMENT IN THE EU

The SET Plan plays a pivotal role in coordinating R&I agendas centred around low-carbon energy solutions. It operates in alignment with an array of other EU instruments and funding mechanisms. The investment directed towards fulfilling the research and innovation priorities of the Energy Union is integral to this overarching policy context, emphasizing the interconnectedness of these collective efforts.

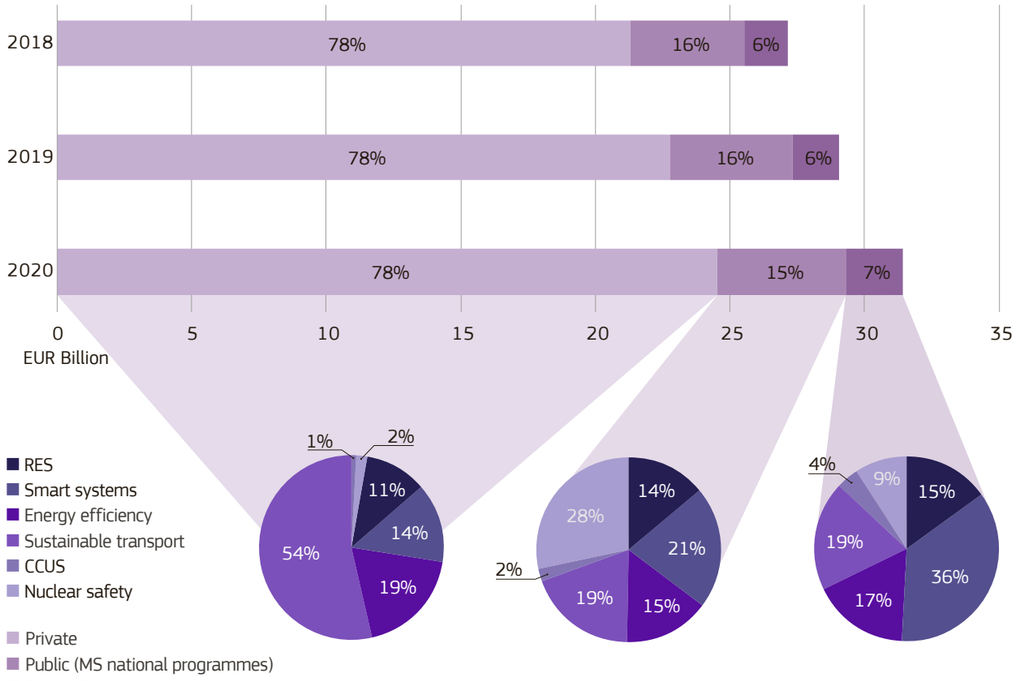
In 2020, the latest year for which near-complete public and private investment data are available, an estimated EUR 31 billion was invested in the clean energy technology R&I priorities of the Energy Union[25]. Roughly, 78% came from the private sector, while the remainder came from Member States' public funding (15%) and the EU (7%). Over the last 3 years, overall investment increased by EUR 2 billion or 7.5% on average per year. However, the share between private and public investment remains stable, with EU funds having a greater role within the latter in 2020. Similarly, the share of investment between the R&I priorities has remained more or less the same over the same period.

The private sector contributes nearly 90% of the R&I funding for sustainable transport and over two thirds of the funds for most priorities. The two exceptions are nuclear safety, which is primarily funded through public (national) investment, and carbon capture, utilisation and storage (CCUS), which receives almost equal parts of public and private R&I investment. This trend has remained constant throughout the years and could largely be explained by the nature of these industries and their projects.

The industry with the largest R&I investment share across all priorities in 2020 was sustainable transport – attracting 45% of R&I investment overall, and 54% of private investment, followed by energy efficiency measures (18% of the total) and smart systems (17% of the total).

25 The Energy Union R&I priorities are:
- Number 1 in renewable energy;
- The future smart EU energy system, with the consumer at the centre;
- Develop and strengthen energy-efficient systems;
- Diversify and strengthen energy options for sustainable transport;
- Driving ambition in carbon capture storage and use deployment; and
- Increase safety in the use of nuclear energy.

Investment in the Energy Union R&I priorities in the EU (2018–2020) in EUR billion.

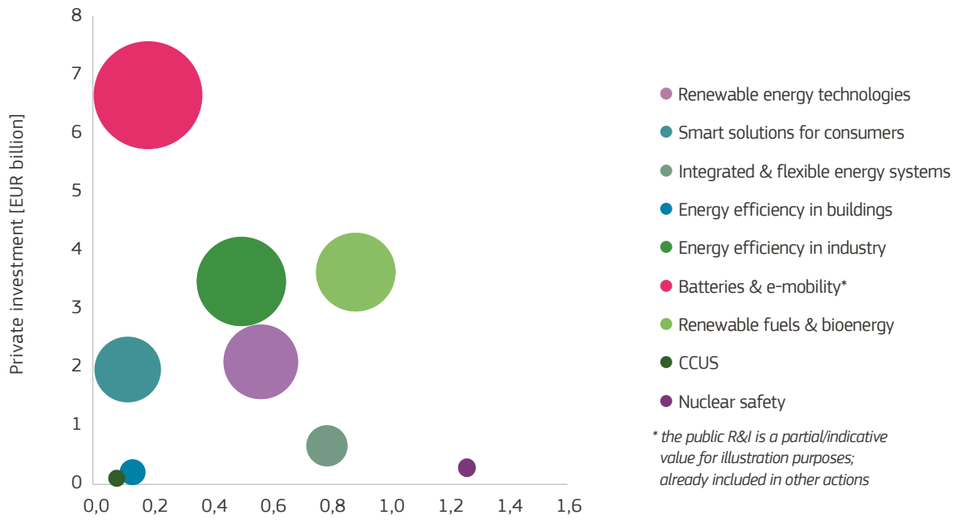


Source: SETIS, 2023.[26]

The increasing input in terms of R&I investment translates to increased research outputs, such as patent filings, in all Energy Union R&I priorities, and by extension SET Plan actions. The areas receiving more funding – and especially funding from the private sector – also show more prominent patenting activity. The EU is a global leader in international patent filings in renewables and energy efficiency, and comes second among major economies in all other priorities except for smart systems. The specialisation index shows the share of each of the SET Plan actions in EU patent filings compared to the global average. It confirms the relative importance of sustainable transport, renewables, energy efficiency in buildings and CCUS as areas of strength, while the remaining actions are relatively less represented in the patent filings addressing the Energy Union R&I priorities.

26 Mountraki, A., Georgakaki, A., Shtjefni, D., Ince, E. and Primavera, J., 2023, R&I data for SETIS and the State of the Energy Union Report, European Commission, JRC135385. http://data.europa.eu/89h/jrc-10115-10001
The data contain estimates.

Patenting activity, public (national programme) and private R&I funding per SET Plan action for 2020.



Source: SETIS, 2023.[27]

Change in the EU specialisation index for patent filings in the SET Plan actions between 2015 and 2020

	2015	2020
Renewable energy technologies	0,1	0,2
Smart solutions for consumers	-0,1	-0,2
Integrated & flexible energy systems	-0,3	-0,5
Energy efficiency in buildings	0,1	0,3
Energy efficiency in industry	-0,2	-0,1
Batteries & e-mobility	0,2	0,0
Renewable fuels & bioenergy	0,3	1,0
CCUS	0,6	0,7
Nuclear safety	-0,3	-0,5

Renewable energy technologies
Smart solutions for consumers
Integrated & flexible energy systems
Energy efficiency in buildings
Energy efficiency in industry
Batteries & e-mobility
Renewable fuels & bioenergy
CCUS
Nuclear safety

Source: SETIS, 2023.[28]

27 The size of the bubble indicates the relative number of filings.
Mountraki, A., Georgakaki, A., Shtjefni, D., Ince, E. and Primavera, J., 2023, R&I data for SETIS and the State of the Energy Union Report, European Commission, JRC135385. http://data.europa.eu/89h/jrc-10115-10001
The data contain estimates.

28 Ibid.

THE IMPLEMENTATION LANDSCAPE

IWG	WEBSITE	ETIP	CSA	Cofunded European Partnership (previously ERANET)	Industrial association	Additional project or other European coordination group
Solar photovoltaics	https://www.iwg-pv.eu/	https://etip-pv.eu/	-	www.solar-era.net/	-	-
CSTT	https://setis.ec.europa.eu/implementing-actions/concentrated-solar-thermal-technologies_en	-	https://cst4all.eu/en/	https://csp-eranet.eu/	https://estelasolar.org/	-
Wind energy	https://setipwind.eu/iwg-wind/	https://etipwind.eu/	https://setipwind.eu/	-	https://windeurope.org/	-
Geothermal energy	https://www.deepgeothermal-iwg.eu/	https://etip-geothermal.eu/	-	http://www.geothermica.eu/	https://www.egec.org/	-
Ocean energy	https://www.oceanset.eu/	https://www.etipocean.eu/	-	-	https://www.oceanenergy-europe.eu/	-
HVDC & DC	https://setis.ec.europa.eu/implementing-actions/high-voltage-direct-current-hvdc-direct-current-dc-technologies_en	-	-	-	https://www.entsoe.eu/	https://windeurope.org/
Positive energy districts	https://setis.ec.europa.eu/implementing-actions/positive-energy-districts_en	https://ectp.org/	-	-	-	
Energy systems	https://setis.ec.europa.eu/implementing-actions/energy-systems_en	www.etip-snet.eu		https://www.eranet-smartenergysystems.eu/	www.entsoe.eu	www.cetpartnership.eu
EE in buildings	www.iwg5-buildings.eu	www.rhc-platform.org	www.iwg5-buildings.eu	-	www.ectp.org	-
Sustainable and efficient energy use in industry	https://setis.ec.europa.eu/implementing-actions/sustainable-and-efficient-energy-use-industry_en	-	-	-	www.aspire2050.eu	-
Batteries	https://setis.ec.europa.eu/implementing-actions/batteries_en	https://batterieseurope.eu/	-	-	https://bepassociation.eu/	https://battery2030.eu/
Renewable fuels and bioenergy	https://setis.ec.europa.eu/implementing-actions/renewable-fuels-and-bioenergy_en	www.etipbioenergy.eu	www.set4bio.eu	-	-	https://hydrogeneurope.eu/, https://www.eera-bioenergy.eu/
CCS – CCU	https://www.ccus-setplan.eu/	https://zeroemissionsplatform.eu/	https://www.ccus-setplan.eu/	https://www.act-ccs.eu/	-	-
Nuclear safety	www.snetp.eu	www.snetp.eu	https://snetp.eu/snetpforward/	-	https://www.nuclearenergy.eu/	-

IMPLEMENTATION PLANS

In this reporting period (2022-2023), the working groups on Energy systems, Concentrated solar thermal technologies, and Solar PV updated their implementation plans (IPs). Five other plans are currently under revision.

With the addition of the three recently updated plans, half of all the working groups have now updated their actions and ambitions. Two groups have no need to revise their plans as these were formulated recently, and are aligned with the current ambitions of their respective sector and the EU. This brings the majority of the implementation plans of the SET Plan working groups in line with today's policy and industrial goals.

Of the 12 groups which have revised or are currently revising their implementation plans, 10 have done so primarily to align their work with the current EU policy framework.

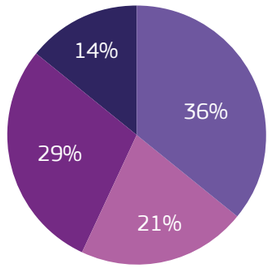
In the case of nine of these groups, a number of R&I activities also required revision to take into account updated Strategic research and innovation agendas and other key industrial developments. For three of the groups, namely Solar PV, Batteries and CCS-CCU, some original targets had already been met.

Status of the SET Plan implementation plans.
(link to the latest one in brackets).

Under Revision	Revised	Original Formulation
Positive energy districts (*2018*)	Carbon capture and storage – carbon capture and utilisation (*2020*)	Nuclear safety (*2019*)
Renewable fuels and bioenergy (*2018*)	Sustainable and efficient energy use in industry (*2021*)	HVDC & DC (*2021*)
EE in buildings (*2018*)	Ocean energy (*2022*)	
Batteries (*2020*)	Wind energy (*2022*)	
Geothermal (*2020*)	Energy systems (*2023*)	
	Concentrated solar thermal technologies (*2023*)	
	Solar photovoltaics (*2023*)	

Source: SETIS, 2023.

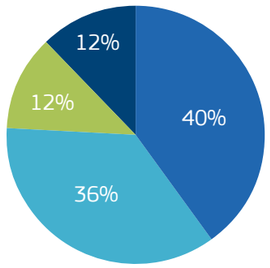
Status of the SET Plan implementation plans.



- Original formulation
- Under revision
- Revised in the last 1-2 years
- Revised in current reporting period

Source: SETIS, 2023.

Reasons for the changes.



- Alignment with EU policy framework
- Alignment with Strategic Research Agendas or other industrial developments
- The targets set in the original have been achieved
- Other

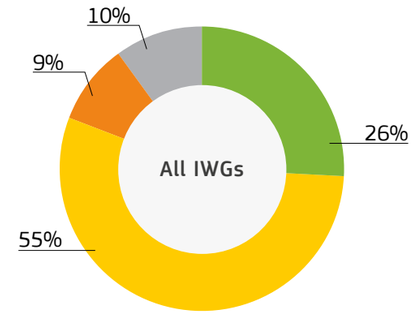
Source: SETIS, 2023.

Other reasons given by the working groups for revision include:

- efforts to establish stronger domestic value chains (especially in the case of Batteries, Wind, and Solar PV) extending from raw and advanced materials, component production and integration to use and recycling;
- getting the commercial framework right; accelerating deployment at scale; driving down costs; enabling EU citizens to make informed choices regarding the benefits of CCUS; and
- for Sustainable and efficient energy use in industry, the scope was extended to two additional industrial sectors – pulp & paper and cement.

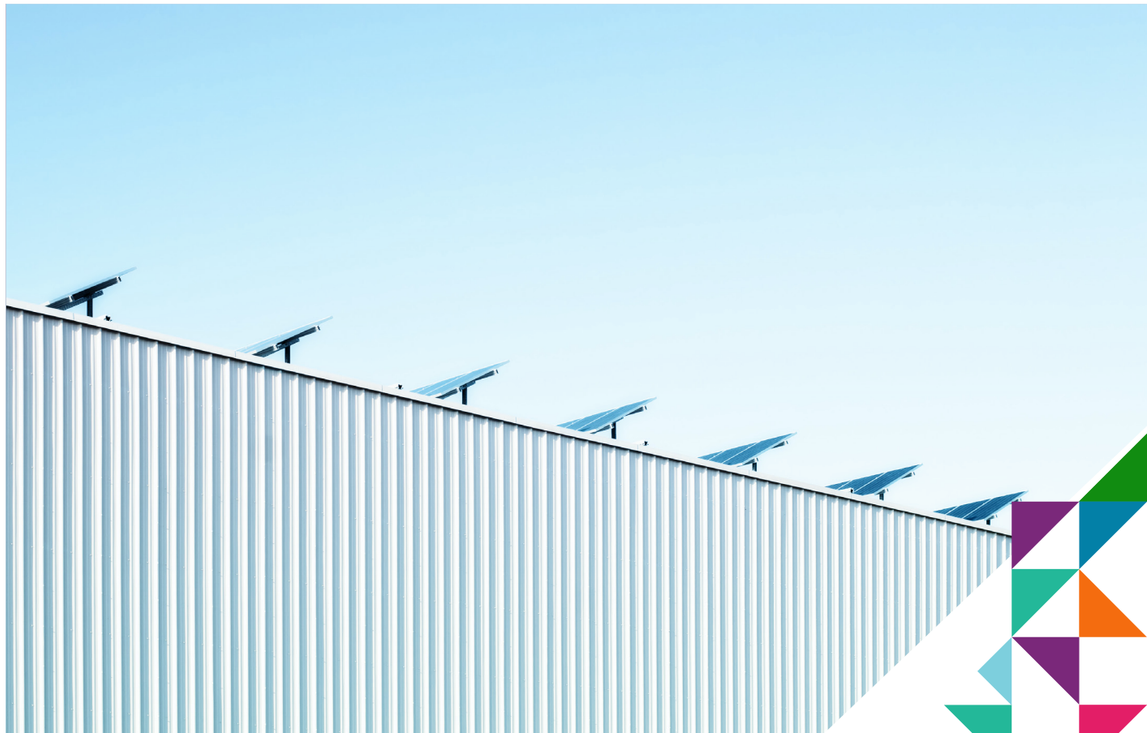
According to the latest implementation plans, there are 202 SET Plan activities, ranging from 5 activities per working group to 30. The working groups classified the majority of these as ongoing (yellow), and some as already completed (green). There are only 18 activities on which work is delayed (orange) and 21 activities which have not yet begun (grey). These are either intended for the longer term or have only recently been adopted.

SET Plan activities.



- Activity has achieved success; many projects have been launched and some have been completed
- Activity is ongoing; some projects have been launched but none so far completed
- Work is delayed; activity has begun but there are project delays
- No work has been carried out for this activity

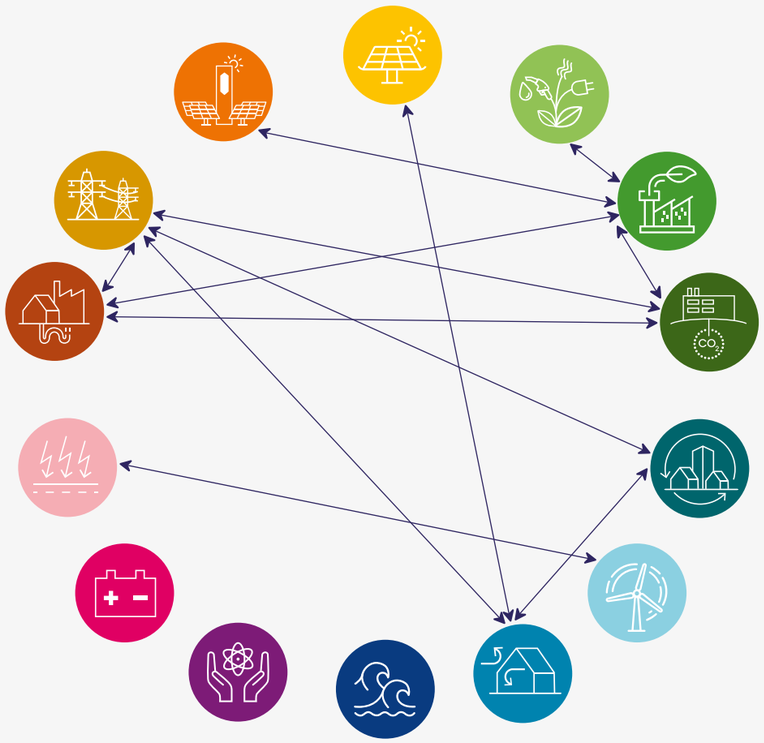
Source: SETIS, 2023.



COLLABORATIONS WITHIN THE SET PLAN

According to this year's reporting exercise, 2023 has seen the greatest number of meetings and collaborations between working groups in the history of the SET Plan. The figure illustrates these collaborations, which were undertaken to align implementation plans and to address cross-thematic challenges.

Existing collaborations reported by the working groups.

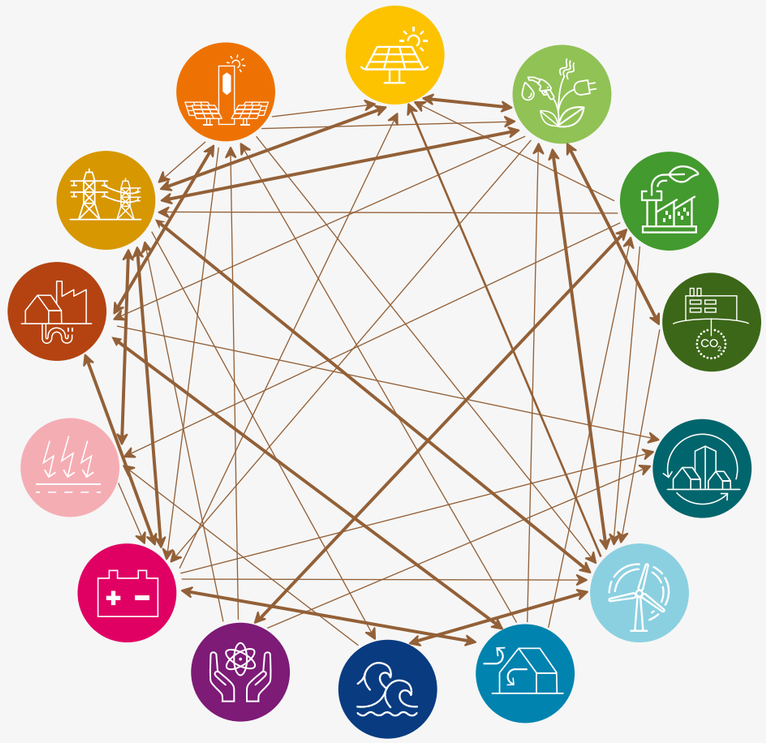


Cooperation has been established

Source: SETIS, 2023.

The working groups see the potential for yet more collaboration and integration between technologies. This confirms the trend towards establishing closer ties and breaking technological silos, a fundamental goal of the SET Plan. The task forces proposed in the Communication will offer the chance to build on this collaborative spirit.

Potential collaborations reported by the working groups.



Would like to cooperate

Both would like to cooperate

Source: SETIS, 2023.

THE EUROPEAN ENERGY RESEARCH ALLIANCE

This section is an invited contribution from EERA and does not necessarily reflect the European Commission's official position.

The European Energy Research Alliance (EERA) was created in parallel with the SET Plan as its official research pillar. Its primary objective was to establish a joint framework at EU level, promoting the alignment of the R&I agendas with the SET Plan priorities and to coordinate the research community. Through its 18 Joint Research Programmes (JPs), gathering approximately 250 leading research institutes and universities across 32 European countries, EERA coordinates research initiatives focused on the energy transition and low-carbon energy technologies. In doing so, it actively contributes to the endeavours of the SET Plan and its Implementation Working Groups (IWGs).

Achievements

The Joint Programmes (JPs) are at the core of EERA's contribution to the SET Plan, bringing together leading researchers and experts from the energy transition and low-carbon energy technologies fields. JPs, as collaborative platforms, facilitate knowledge exchange and ideas- sharing, guided by the principles of open science. This approach contributes to aligning research and innovation (R&I) priorities across the continent.

Over the years, EERA has actively contributed to executing the 10 SET Plan key actions[29] for the EU energy system transformation and has analysed in-depth cross-cutting issues within the SET Plan IWGs. It also played a vital role in aligning funding priorities and shaping the Strategic Research and Innovation Agendas (SRIAs) of key European Partnerships.

A notable milestone is the publication of the White Paper on the Clean Energy Transition[30], which advocates for a systemic approach to achieve a sustainable, climate-neutral society. This effort was underpinned by the publication of the EERA REPowerEU Manifesto[31], a flagship report putting forward EERA's analysis of this crucial policy file on the EU's road to the 2030 objectives.

Further noteworthy contributions include fostering collaboration and mobilising resources among stakeholders. This includes facilitating funding for research institutions in EU13[32] countries and bridging the gap between the research sector and industry by promoting a dialogue between them. To exemplify the first point, EERA has implemented a series of measures to enhance the visibility of the SET Plan within EU13 countries. This effort has increased their engagement in the R&I ecosystem and advanced the Alliance's support towards its mission.

Impact

One of the EERA's most relevant impacts is its key contribution to continuously shaping the SET Plan's strategic planning process and the directing of R&I efforts toward pioneering technologies at European and national levels. EERA members actively contribute to the formulation of national R&I strategies, facilitating the mobilisation of public and private funding, and driving the execution and revision of the SET Plan's Implementation Plans (IPs).

A series of collaborative efforts with industrial stakeholders have significantly contributed to the adoption of innovative low-carbon technologies and the cost reduction of existing ones. In this context, EERA actively promotes these collaborations across various SET Plan technology domains and facilitates their alignment through the ETIP Forum platform. EERA has established itself as a link between EU policymaking and low-carbon energy research. On one side, it supports the alignment of the SET Plan with evolving EU policy priorities (e.g., Green Deal and Fit for 55), while on the other side, it translates EU strategies and policies into concrete R&I challenges. Notably, the EERA REPowerEU Manifesto[33] and regular policy briefs addressing critical EU policy matters demonstrate EERA's ability to rally collective efforts on urgent policy concerns.

29 https://energy.ec.europa.eu/topics/research-and-technology/strategic-energy-technology-plan_en
30 https://www.eera-set.eu/index.php?option=com_attachments&task=download&id=675:Digital-final_EERA_White_Paper_Clean_Energy_Transition
31 https://www.eera-set.eu/component/attachments/?task=download&id=928:EERA_REPowerEU_Manifesto_Final
32 13 EU MSs that joined after 2004 – Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia and Slovenia.
33 https://www.eera-set.eu/component/attachments/?task=download&id=928:EERA_REPowerEU_Manifesto_Final

Another tangible instance of EERA's influence within the SET Plan was its role in the revision process. EERA made significant contributions by providing specific recommendations for improvements, synthesising input from its Joint Programmes and the ETIPs.

As the SET Plan is demand driven, central to EERA's mission is fostering dialogue and collaboration among stakeholders in the clean energy sector. For example, EERA actively supports the operation of the National and Regional Coordination Group to foster cooperation between SET Plan countries within the ETIP Batteries.

Challenges

In the rapidly evolving socio-economic landscape, where the EU faces new challenges in meeting its climate and energy objectives, the SET Plan needs to adapt and enhance its effectiveness in response to these evolving challenges.

Currently, the structure of IWGs within the SET Plan primarily focuses on technology-specific issues, which limits its ability to effectively address broader cross-cutting aspects of the transition. To remedy this, SET Plan IWGs should shift towards more a comprehensive, mission-oriented approach that would offer a broader perspective beyond individual technologies. Essentially, the SET Plan should transition from a siloed approach to embrace a more holistic, top-down, systemic, and interdisciplinary strategy.

Achieving this transformation requires close collaboration between the research community and industrial stakeholders. They must work together to identify, analyse, and tackle implementation bottlenecks, thereby expediting the deployment of existing technologies.

To succeed in this endeavour, equal engagement from stakeholders across Europe is crucial, especially those with limited involvement in the SET Plan (i.e. EU13 countries). Addressing the challenge of low engagement is vital to preventing disparities in the adoption of low-carbon technologies, variations in societal acceptance levels, and potential obstacles to Europe's 2030 and 2050 goals.

Efficient coordination between national and European R&I activities is paramount to achieving the SET Plan goals, an aspect that has not been adequately tackled so far. The SET Plan countries should take the lead in enhancing, reinforcing, and expediting the alignment of their R&I agendas with the goals of the SET Plan and the broader EU climate and energy policies and initiatives.

Future role and expectations

Recognised as the research pillar of the SET Plan, EERA stands as an independent and technology-neutral community of scientific experts free from third-party interests. In this capacity, it can strengthen the SET Plan in the context of the clean energy transition by serving as a key strategic advisor to EU decision-makers.

From this perspective, EERA can support the SET Plan by providing informed and evidence-based decision-making input and integrating contributions from the scientific community into the core of the policymaking process. In this regard, the SET Plan can further leverage the output of EERA's Joint Programmes to support the definition of R&I funding frameworks (e.g., by assessing the execution of the SET Plan).

EERA strongly advocates for a redesigned SET Plan architecture that promotes a cross-sectoral approach to the energy transition, departing from the current, mostly technology-centric, bottom-up approach.

With extensive expertise in clean energy domains, EERA can act as a dialogue facilitator on common challenges, often referred to as cross-cutting topics. These can be better addressed through coordinated strategies spanning various technologies and sectors (e.g., skills, materials, storage, research infrastructure and digitalisation).

Finally, considering the increased impact of the energy transition on the fundamental structure of society, EERA envisions a comprehensive SET Plan that fully embeds social sciences and humanities at the core of the policymaking process. This approach might also generate socioeconomic advantages, and positively impact the social acceptability and citizen's engagement in the transition process.

THE EUROPEAN TECHNOLOGY AND INNOVATION PLATFORMS FORUM

This section is an invited contribution from ETIPs FORUM and does not necessarily reflect the European Commission's official position.

In June 2021, the ETIPs FORUM was created as a bottom-up initiative facilitated by the ETIP-SNET Coordinator and supported by EERA (via the project SUPEERA) to foster communication among the 11 European Technology and Innovation Platforms (ETIPs) and assimilated associations such as the European Solar Thermal Electricity Association. The ETIPs are:

- ETIP Wind
- ETIP PV
- ETIP Ocean
- European Geothermal Energy Council
- Smart Networks for Energy Transition
- ETIP on Renewable Heating and Cooling
- ETIP Bioenergy
- ETIP Batteries
- CCS Platform
- Sustainable Nuclear Energy Technology Platform
- ETIP HYDROPOWER

The ETIPs FORUM's main goals are to tap into the collective expertise of ETIP experts, unite efforts and avoid overlaps in the shared mission of decarbonisation by 2030 and 2050. Regular roundtable discussions streamline topics, identify common interests, and establish collaboration plans. Working sessions address common themes, aiming to identify potential activities for collaboration and eliminate duplication.

Achievements

ETIPs serve as key advisory and coordination bodies within the SET Plan, providing targeted and unbiased R&I recommendations and helping to guide and facilitate the research, development and deployment of sustainable and low-carbon energy technologies in Europe. They are a vital part of the European energy R&I ecosystem as they provide policymakers with a single point of entry to industry and research and drive the implementation of technology strategy at national level with the support of the Implementation Working Groups. They promote collaboration, knowledge sharing, and strategic planning to advance the EU's energy and climate objectives.

The ETIPs recently collaborated on a contribution to the SET Plan revision exercise. With the support of EERA, the ETIPs FORUM developed eight key recommendations on how the SET Plan could increase its effectiveness and the inclusiveness of its implementation[34].

ETIPs have provided continuous support to their respective IWGs in various forms. They have assessed Implementation Plan targets vis-à-vis the European Green Deal, published joint position papers and given feedback on strategic documents. Furthermore, in many SET Plan actions, ETIPs play a major role in the operation of the IWGs. In particular, they help to align the national energy research agenda with EU R&I priorities, providing the SET Plan country representatives with the research perspective.

Impact

ETIPs define the research and innovation priorities for the sector. They represent and give guidance to all funders of innovation by presenting concrete research and innovation plans. These are typically known as Strategic Research and Innovation Agendas. These documents inform individual SET Plan Implementation Plans and their targets. Since its inception, ETIPs FORUM is the only platform in the SET Plan environment that facilitates the collaboration of all ETIPs, although ETIPs have worked together before ETIPs FORUM and do reach out to each other where it makes sense to do so. ETIPs FORUM has helped the work of ETIPs by enabling knowledge-sharing activities across the SET Plan and providing the space for coordination in areas of common interest. Additionally, ETIPs FORUM is the banner under which ETIPs participated in the SET Plan, ENLIT, SMARTER E and the EUSEW Conferences. It made a major contribution to the organisation of ENLIT 2023, drafting the programme of the EU project Zone and participating in the ENLIT Impact Circle.

Amidst the ongoing revision of the SET Plan, ETIPs have contributed both individual and collaborative insights regarding structural challenges, proposing a range of refinements aimed at enhancing the efficiency and functionality of the European research and innovation ecosystem. ETIPs work together bilaterally and in small groups, but in this context, also via the ETIPs FORUM where a multilateral approach is more appropriate to consolidate the perspectives of ETIPs stakeholders and proactively tackle their shared challenges.

34 https://snetp.eu/wp-content/uploads/2022/11/ETIPs-Forum-%E2%80%93-1st-Position-Paper-and-recommendations-for-the-SET-Plan-review-process_FV.pdf

Challenges

In order to promote an inclusive and efficient collaboration, the SET Plan should undergo structural adjustments, supported by a clear governance framework. To achieve this, it is vital to clarify stakeholder roles and provide transparent descriptions of key actors' responsibilities.

The current structure of ETIPs and SET Plan IWGs rightly focuses on technology-specific issues, which enables the development of individual technologies, but there are cross-cutting topics of concern to many IWGs which would be suitable for discussion in a wider group, for example in ETIPs FORUM. These topics may be non-technological in nature, or relate to the energy system as a whole.

Improving communication and collaboration among decision-makers, and the aforementioned stakeholders, is critical. The primary aim is aligning priorities, such as the SET Plan IPs, national research and innovation agendas, roadmaps, and the specific and thematic goals of ETIPs. This alignment is essential for effective discussions and the integration of legislative proposals with research and development efforts. In pursuit of this objective, ETIPs fulfil a vital role through a range of value-added initiatives, including annual conferences, responses to public consultations, and material explaining their technology and its place in the energy system.

The role played by ETIPs is unique and has proven to be pivotal in the functioning of the SET Plan. It is imperative that they are provided with sufficient resources to enhance their effectiveness in the coming years.

Future role and expectations

ETIPs play an essential role in fostering collaboration among diverse groups of stakeholders vertically (within the same technological domain). Where appropriate, they work horizontally (across different technological and non-technological domains). They accomplish this by effectively coordinating input from both industry and the scientific community, thereby offering valuable input to the policymaking process.

Apart from providing recommendations to enhance the current collaboration structures of the SET Plan, they also undertake vigorous actions in the areas of their competence. At the time of writing, the agenda of the ETIPs FORUM includes several ad-hoc activities poised to yield valuable results in the near future. For instance, some ETIPs recently launched a collaboration to define joint recommendations on the revised National Energy & Climate Plans (NECPs).

It will undertake a comprehensive mapping exercise across their numerous working streams to pinpoint groups, task forces, committees, and other relevant entities focused on technological and non-technological cross-cutting themes. This initial step is pivotal in paving the way for collaboration regarding cross-cutting issues within the technology-centric framework of the SET Plan. Such collaboration will foster the alignment of efforts and facilitate the exchange of knowledge and expertise.

The path ahead for the SET Plan community entails harnessing the efforts and dedication of ETIPs, providing them with the opportunity to effectively articulate their pivotal role and notable accomplishments to fellow SET Plan stakeholders during the annual SET Plan conference.

SET PLAN COUNTRIES AND THEIR INVOLVEMENT

The involvement of all SET Plan countries is crucial for its success. According to the IWG 2023 reporting exercise, Italy currently takes the lead by chairing or co-chairing four working groups, followed by Germany, the Netherlands and Finland, each active in managing the activities of three working groups. Austria, Belgium and France chair or co-chair two working groups each. Italy, France, and Spain have organisations in all of the SET Plan working groups, followed by Belgium, Germany and Türkiye in 13 each.

Research, industrial, and academic organisations in all SET Plan countries demonstrate a strong commitment to collaborating on various initiatives within the SET Plan framework, contributing their expertise and resources to advance strategic energy technology development and implementation across Europe. However, as some working groups have highlighted in their reporting, the overall goal should be to increase the geographical spread to cover all SET Plan countries wherever possible.

THE SET PLAN IN THE INTEGRATED NATIONAL ENERGY AND CLIMATE PROGRESS REPORTS

Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action imposes on Member States obligations to report their progress in the implementation of five dimensions of the Energy Union. For the first time in 2023, Member States submitted their National Energy and Climate Progress Reports (NECPRs) which indicate progress towards their national objectives[35]. Within the 'Research, Innovation and Competitiveness' dimension, Member States *inter alia* reported national measures translating SET Plan targets and policies into national R&D landscapes.

Based on the NECPRs submitted, among 20 Member States who reported measures implementing SET Plan objectives, most indicated comprehensive research-funding programmes. The scope of such programmes covers a wide range of technologies included within the SET Plan Implementation Working Groups.

More specifically, 18 Member States submitted information on support for clean technologies, which enabled the alignment of their engagement with Implementation Working Groups.

The most frequently reported measures relate to renewable energy technologies; energy systems; energy efficiency in buildings, sustainable and efficient energy use in industry; and renewable fuels and bioenergy. In contrast, the least addressed were nuclear safety, positive energy districts and HVDC & DC technologies. Additionally, 12 Member States also provided information on the progress of their implementation (e.g. the number of demonstration projects supported and spending on R&D), noting progress towards the achievement of at least one of their targets. The most frequently used progress indicator is public spending in terms of the budget dedicated to research programmes or the number of financed projects.

Measures implementing the SET Plan actions as reported by the EU MSs in their integrated National Energy and Climate Progress Reports (September 2023).

Source: JRC based on the NECPRs.

35 The Commission's *technical assessment of the National Energy and Climate Progress Reports* is part of the *2023 State of the energy union report*. The integrated NECPRs are publicly available on the *CIRCABC* e-platform.

COUNTRY INVOLVEMENT IN THE SET PLAN ACCORDING TO THE WORKING GROUPS

★ Chair

● Observer

- Solar PV
- CSTT
- Wind
- Geothemal
- Ocean
- HVDC & DC
- PED
- Energy systems
- Buildings
- Industry
- Batteries
- Renewable fuels and bioenergy
- CCUS
- Nuclear safety

Source: SETIS, 2023.

THE WORKING GROUPS IN FOCUS

This section includes contributions from the SET Plan working groups and does not necessarily reflect the European Commission's official position.

SOLAR PHOTOVOLTAICS

The Solar photovoltaics (PV) working group has undergone several recent developments. These include the revision of the Implementation Plan and the re-establishment of contacts between the working group and ETIP-PV, facilitated by the new Chair and member structure within the ETIP. This collaborative effort has also led to a close exchange in the CETPartnership SRIA process, aiding the coordination of input to construct a comprehensive view of the PV landscape in Europe.

Recent developments and achievements

Progress is being made on the establishment of the IWG PV website, intended to serve as both an overview and a contact point. This platform, which is currently under development, will particularly focus on assisting Member States in collecting and presenting information about their respective national funding schemes.

Since the previous reporting period, the Implementation Plan has undergone significant changes[36]. These revisions include the adoption of a new topic structure, aligning with the 2022 ETIP PV Strategic Research and Innovation Agenda (SRIA). The new structure encompasses five main areas: Performance enhancement and cost reduction, Enhancing lifetime, reliability, and sustainability, Diversified application and integration, Smart energy system integration, and Socio-economic aspects of the transition.

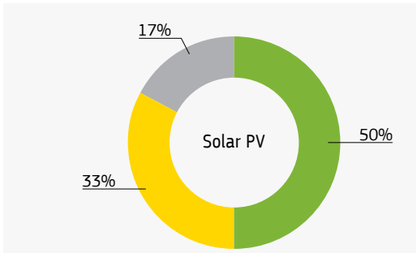
Additionally, overarching challenges have been outlined, emphasizing the role of PV in ensuring the success of Europe's energy transition. To achieve this, efforts focus on enabling rapid and sustainable large-scale deployment of PV, reducing the levelised cost of electricity, expanding PV applications, and promoting circularity in PV components and systems.

Furthermore, strategic value chain reformation is pursued by leveraging Europe's technological leadership for high-performance circular product manufacturing, extensive deployment across various applications, and seamless energy system integration. Technical parameters have also been redefined in response to partially achieved targets.

Investment and other needs

The needs and challenges of the Solar PV group remain similar to previous reporting periods. However, according to the group, there is an ever-increasing need to enhance the visibility and influence of both the SET Plan and the working groups within the renewable energy sector, both at the European and national levels. These actions should be considered in view of the current security of energy supply crisis, as well as the challenges posed by the agreed targets set at the UNFCCC Paris Climate Conference (COP21) and specifically, in light of the EU 55% emissions reduction target for 2030.

Within this context, there is substantial potential for improvement in the participation of Member States and regions within the working group. The management of the Solar PV working group faces a continuous challenge in maintaining even basic levels of support. By clearly communicating the persistent and growing significance of the SET Plan today, amidst and in relation to various other initiatives and instruments, the Commission should provide further crucial backing to the working groups and its achievements.



Source: SETIS, 2023.

Future prospects and expectations

The expectations of the working group remain unchanged from previous reporting periods. The solar PV working group is prepared to support all measures aimed at reinforcing the influence of the SET Plan and its implementation plans in aligning EU and national research, development, and innovation (RD&I) policies more strategically within the energy sector. This commitment is particularly pertinent in the context of climate change mitigation goals and the ongoing energy supply crisis.

Activities

Although currently not a leader in terms of manufacturing capacity, Europe continues to stand at the forefront of research and innovation in the PV field, contributing significantly on a global scale. Current funding efforts are directed towards revitalising European PV production using advanced high-efficiency technologies, with a focus on intensifying and expediting the adoption of PV installations. Positive steps are already being made in this direction, with installation rates increasing at an unprecedented rate.

36 Once approved, the Implementation Plan will be published on the SETIS website and on *https://www.iwg-pv.eu/implementation-plan*

The achievements of the working group on Solar PV can be seen in the attainment of a number of the IP's targets, and the successful completion of relevant projects. Currently, five out of six activities are either ongoing (yellow) or include projects which have reached their conclusion (green).

While these efforts are yielding results, more robust strategies are needed to ensure that the ambitious targets set for 2030 and 2050 are met.

Due to spatial constraints, integrated PV solutions are poised to play a significant role in the coming years. Nonetheless, the current market landscape offers a limited selection of integrated PV.

The majority of available options are bespoke and tailored, and thus, difficult to scale up to reach a wider market. To propel this sector forward, more emphasis is needed on standardisation and strategic planning tools. In addition, ongoing funding initiatives are also directed towards bolstering the actions on integrated solar PV. However, the rate of market adoption remains considerably lower compared to conventional module counterparts, thus contributing to the current delay in these actions. Recent attention has also been directed towards power plant and inverter technologies, exemplified by dedicated funding programmes such as the initiative currently under way in Germany.

CONCENTRATED SOLAR THERMAL TECHNOLOGIES

In 2023, the working group on Concentrated solar thermal technologies (CSTT) updated and delivered the new Implementation Plan, reflecting the readiness of the European CST sector to contribute to the ambitious goals of ongoing EU energy policy. This technology is well-equipped to offer substantial bulk storage capabilities at competitive rates, facilitated by its sizeable high-temperature thermal systems. These characteristics allow for the provision of flexibility to the electricity system by delivering significant synchronous power and dispatchable renewable electricity whenever needed.

Recent developments and achievements

The Implementation Plan update includes an expansion of the focus of the working group. This focus extends beyond power generation, encompassing the production of solar heat and the storage of medium-to-high-temperature solutions for industrial processes and solar fuel production[37]. Within this framework, seven distinct domains of research and innovation activity have been identified, resulting in the formulation of eighteen specific R&I initiatives. Furthermore, new targets have been agreed in terms of cost reduction, increased efficiency and thermal energy costs for industrial processes and the production of green hydrogen and other solar fuels.

1. Cost reduction of electricity provided during periods with low wind, PV or hydropower infeed, to values below EUR 15 ct/kWh from CSTT in Southern European locations by 2025, targeting below EUR 10 ct/kWh by 2030, considering 2050 kWh/m²/year as reference conditions and no constraints regarding the size/type of the plant, and Power Purchase Agreements (PPA) with a duration of at least 25 years.
2. Development of the next generation of concentrated solar power/ solar thermal energy (CSP/STE) technology (NEXTGEN) to achieve at least 3 points of increase in the overall power plant efficiency from the reference value 39.4 % to 42.4 % by 2025.
3. At least one First of a Kind (FOAK) integrated into the energy system by 2025, demonstrating either the cost reduction or the efficiency increase.
4. Thermal energy cost for industrial process heat applications below EUR 3 ct/kWh by 2030 for the same Southern European locations as target 1, with process temperatures higher than 200°C and 25 years' lifetime.
5. Demonstration of 24/7 economically viable solar thermal baseload production of green hydrogen and other solar fuels by 2030.

Incorporating the insights gained from the Spanish auction, the updated IP also offers recommendations to Member States regarding auction design. Additionally, it takes into account considerations pertaining to non-technological framework conditions for CSTT, ensuring a comprehensive and holistic approach.

Highlights

In 2021, the CSP-Eranet launched a joint call for transnational projects. This garnered a notable response, with 27 applicants, over half of which were enterprises. The total costs for these projects amounted to EUR 6.4 million, while the funding requested totalled EUR 4.8 million. The call was supported by five funding agencies representing four participating countries/ regions – namely, Germany, North-Rhine-Westphalia, Spain and Türkiye. Furthermore, the initiative attracted three associated partners from Germany and Portugal.

The HORIZON-STE project, funded through H2020, aimed to support the implementation of the CSTT working group. Engaging with stakeholders and decision-makers from nine countries, the project ensured that CSP, an important element in the energy transition, received due attention. It underlined the need to decarbonise beyond electricity and assessed conditions for replicating commercial cost levels in EU countries. The project identified key aspects and potential gaps in national strategies related to CSP/STE from both research and industry standpoints. Concluding in September 2022, the project produced a final report available on its web page[38].

37 Due to this enlarged focus, the group was renamed from Concentrated solar power/solar thermal energy (CSP/STE) to Concentrated solar thermal technologies (CSTT).

38 https://horizon-ste.eu/

CST4ALL is a new initiative backed by the Commission, aimed to extend assistance to the CSTT working group. This collaborative effort aims to streamline the implementation of the recently updated IP, which was endorsed by the SET Plan Steering Group in March 2023.

Investment and other needs

On 25 October 2022, Spain held its third Renewable Energy Economic Regime (REER) tender, assigning 520 MW to solar thermal, biomass, and photovoltaic sources (including a quota of 380 MW shared between biomass, solar thermal and other renewable technologies and a minimum reserve of 220 MW for CSP). Despite the allocation split between these sources, the tender declared no winners due to bids exceeding maximum price limits. The exclusive focus on levelised cost of electricity failed to fully recognise CSP's role in supply security. The CSTT working group suggests incorporating in future auctions firmness, security of supply and system integration to capture the market welfare increase that a non-intermittent and synchronous production like CSP can help realise.

Refining auction designs is pivotal for streamlined CSP cost bids. Auction frameworks significantly impact outcomes and energy costs. Most CSP/CST cost references predate COVID and were established during more stable financial times. Post-COVID disruptions in transport and commodity markets have inflated supply costs, leading to increased energy costs for new European power plants. Nonetheless, the sector's ongoing technology advancements and cost-cutting efforts are notable.

Elevating awareness among the public, energy planners, TSOs, DSOs, and policymakers about CSP/STE's power system benefits is essential. Targeted initiatives are key to fostering wider CSP adoption. While distinct, CSP and PV can be effectively integrated for cost-effective, dispatchable power production round the clock.

Future tender designs should be optimised in order to converge price bids into optimal CSP costs. It is clear that the design of the auction or tendering process can significantly affect the result and the final energy cost. In addition, most of the international references related to costs on CSP/CST technologies are pre-COVID-based, framed in the context of many years of financial stability. In 2022, after the COVID crisis and in the midst of an intensive energy and economic crisis, tensions in the transports and commodities markets caused cost overruns in supplies of over 30%. Therefore, the energy cost of new power plants in Europe has increased, but this is due to non-technological reasons, as the technology itself has not changed since pre-COVID times. In fact, in recent years, the sector has continuously worked to improve the technology and reduce costs.

Another relevant issue is to raise general awareness, not only among the public but also among energy planners, TSOs, DSOs and policymakers, of the benefits that CSP/STE can provide to the electrical system. To this end, specific initiatives to promote the further deployment of CSP are considered necessary. CSP and PV are separate technologies, but there is plenty of room to implement as a single unit as existing PV/CSP plants operate independently and are not hybridised. Such integration can provide a significant cost reduction of fully dispatchable and flexible power, targeting 24/7 production.

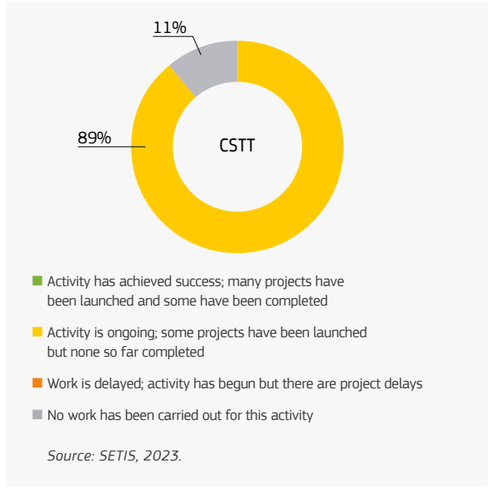
Future prospects and expectations

Fully related to the needs and challenges described in the former section, the future prospects of the working group are focussed on increasing the awareness of the benefits of this technology not only to the electrical system, but also to the industrial and transport systems. These two sectors could benefit, respectively, from the production and storage of medium and high temperature heat for industrial processes (any level up to 600°C) and high-capacity factor using TES and new "solar" fuels (green hydrogen derivatives), allowing an efficient carbon-free operation at constant load and at high-capacity factor.

Related to this heat production, an expansion of the scope of work of the working group with the inclusion of solar non-concentrated technologies is foreseen.

A Solar Energy Joint Research Agenda, with the working group on Solar PV and focussed on cross-cutting issues is currently under development.

The development of a Solar Energy Joint Research Agenda (Solar SRIA), integrating all solar technologies (PV, CST, Low Temperature Solar Heat) is considered to be an excellent opportunity to accelerate and reinforce collaboration across all these technologies to provide further renewable penetration in national grids and to increase stability and flexibility in energy systems.



Source: SETIS, 2023.

Activities

A large number of R&D projects have been funded at European & national levels, demonstrating progress made in achieving the targets and R&D activities. Almost all the activities of the CSTT group are ongoing (yellow) with the exception of two that were launched with the new IP.

Activity 1.1 focuses on developing high-performance coatings for tube receivers using Molten Salt (MS) as a Heat Transfer Fluid (HTF), aiming to enhance the efficiency and operational temperature of parabolic trough power plants. In Activity 1.2, two main projects, Si-CO and SING, are underway to design a specialised parabolic trough collector for silicone oils and assess the feasibility of a new silicone fluid (Helisol XLP). These efforts have raised the nominal operating temperature of parabolic trough power plants from 400 to 425 ^{0}C. Additionally, ongoing initiatives related to linear-focusing technology involve innovative coatings for glass tubes and cost-effective composite mirror facets, contributing to the overall efficiency and performance of Concentrated Solar Power (CSP) systems.

Activity 2.1 involves international collaboration to evaluate and compare heliostat assessment tools and methods, aiming to identify the most effective tools for optimising heliostat field performance by 2024. This activity also includes the development and testing of an improved solar absorber coating for high-temperature absorbers. In Activity 2.2, efforts are ongoing to develop new nanostructured selective coatings for efficient solar radiation absorption in tubular receivers. Activity 2.3 includes projects to assess existing methodologies for optical characterisation of solar receivers using particles, develop protective coatings for receiver particles, and analyse the economic feasibility of a particle-based multi-tower solar power plant with an unfired combined cycle for evening peak power generation. Additional initiatives in this area are anticipated for launch in 2024.

In Activity 3.1, the primary focus is on designing an improved Molten Salt (MS) thermocline Thermal Energy Storage (TES) system powered by thermal/electrical energy. In Activity 3.2, there are several key ongoing initiatives, including the development of materials for new thermochemical storage using perovskites and encapsulated CaO, the design of concrete-based TES solutions coupled with MS and Phase Change Materials (PCM) modules, the development and demonstration of an integrated dual-bed thermochemical reactor/heat exchanger based on porous ceramic structures, and the establishment of a complete particle loop with MW-scale storage and heat exchange capabilities. The ultimate impacts of these initiatives will depend on their results and successful implementation.

Activity 4.2 involves multiple projects working on the development of a new supercritical CO_2 power cycle, including associated machinery, although estimating their real impact is challenging due to the complexities of supercritical CO_2 turbo-machinery. In contrast, Activity 4.1, which deals with steam turbines, lacks reported projects, and it is uncertain if any are planned due to high costs and difficulties in testing in high Technology Readiness Level (TRL) contexts or commercial environments. The turbo-machinery topic is relevant to CSP but has limited engagement from the IWG stakeholders, limiting the number of organisations capable of addressing related initiatives.

In Activity 5.1, ongoing initiatives focus on developing innovative linear solar concentrators, including parabolic troughs and linear Fresnel devices, to provide thermal solutions for small and medium industries, particularly for process heat applications in the medium temperature range (150-400 °C) in areas with limited space. In Activity 5.2, significant achievements include the production of clinker, melting Al-Si alloy, and creating foam nodules from construction waste using concentrated solar radiation, with potential applications in circular economy practices. Additionally, a prototype is in development to deliver 50 kWth at maximum temperatures above 800 °C and about 80% thermal efficiency for high-temperature applications of CST technology. These activities, introduced in the updated IP, are expected to see substantial growth in the coming years due to the rising gas prices, especially those related to Activity 5.1.

In Activity 6.1, a significant achievement is the successful demonstration of a thermochemical kerosene production chain from CO_2 and H_2O using concentrated solar energy in a tower-type solar plant. This ground-breaking project achieved a solar-to-syngas energy conversion efficiency of 4.1% without heat recovery systems, earning recognition with the International Energy Agency SolarPACES Technological Innovation Award in 2022. This achievement paves the way for future technological advancements and cost reductions in commercial hydrogen (H_2) production using this method. In Activity 6.2, an assessment of solar dry reforming of methane, water splitting, and innovative solar thermochemical plant concepts is ongoing, with promising results. Activity 6.3 involves the development of durable materials for ceramic receivers and the evaluation of a fluidised bed reactor using solid particles. These activities are newly introduced by the updated IP, formally approved in early 2023.

In Activity 7.2, the primary ongoing initiatives involve the development of lead-free protective coatings for mirrors in solar thermal power plants, assessment of innovative copper-free solar reflectors, testing of anti-soiling coatings for solar reflectors, and accelerated aging tests for aluminium reflectors. These efforts aim to create innovative reflectors with enhanced quality and characteristics. Activity 7.3 focuses on analysing and developing technological solutions for CSP-PV hybridisation, along with the assessment and development of models and tools for Virtual Power Plants (VPPs) that integrate multiple renewable energy power supply systems.

The goal is to enhance dispatchability and flexibility in response to weather variations and system demand through improved VPP control and management. Activity 7.4 highlights the development of efficient medium-voltage electric heaters, which could facilitate PV-CSP hybridisation and bolster grid flexibility by storing surplus power from PV and Wind sources in Molten Salt Thermal Energy Storage (TES) of CSP plants. However, a notable challenge is the lack of an adequate legislative and regulatory framework in this context. No initiatives have been reported for Activity 7.1 due to a lack of suitable calls for proposal submissions. These activities are newly introduced by the updated IP, formally approved in early 2023.

WIND ENERGY

The Offshore wind energy working group offers a platform for R&I agenda-setting that brings together the SET Plan community and international fora such as the IEA TCP Wind.

In response to the COVID and energy crises, the EU launched significant initiatives to revamp economic growth through the green and digital transitions. Under the revised renewable energy target of 42.5%, WindEurope calculates that 420 GW of wind energy capacity is required by 2030, up from 205 GW today. This will require a massive expansion of wind energy in Europe.

To better tackle this challenge, the scope of the SET Plan Implementation Working Group on Offshore wind has been extended. The new Implementation Working Group on wind energy (IWG Wind) now covers both onshore and offshore wind technologies.

Recent developments and achievements

To launch the activities of the renewed IWG Wind under a new Secretariat, a kick-off meeting was organised on 16 January 2023. During the kick-off meeting, six IWG Wind members, together with representatives from the European Commission and the IWG Wind Secretariat, looked at the goals of the group and defined its work programme over the next three years. The new structure, including the joint secretariat shared by the IWG Wind and ETIPWind, has been inaugurated, and new terms of reference have been approved.

New members have since joined the IWG Wind, including Belgium, Italy, France and Hungary. The IWG Wind Secretariat continues to encourage other Member States to join the group.

In March 2023, the IWG Wind organised a meeting dedicated to the national funding landscapes for wind energy. Belgium, Germany, Italy, Portugal, Spain, and Türkiye presented their national funding schemes for clean energy technologies and the available opportunities for wind energy R&I.

The main priority of the IWG Wind is now to adapt the SET Plan targets for wind energy to the new EU energy and climate ambitions. Once agreed, the new targets will be the basis for the IWG Wind to provide recommendations to Member States in the context of the revision of the National Energy and Climate Plans.

The work of the IWG Wind is now supported by a joint secretariat, managed by WindEurope and funded under the CSA SETIPWind, which oversees the activities of both the IWG Wind and ETIPWind. The joint secretariat helps to enhance synergies and collaboration between the two entities. ETIPWind members are, for instance, invited as observers to IWG Wind meetings, and IWG Wind members will be consulted during the process of updating the ETIPWind Strategic R&I Agenda.

Thanks to this new framework, exchanges within the group – which had been on hold since the culmination of the previous secretariat – are now rekindled.

Changes to the IP targets

The previous SET Plan targets for wind energy were set out by the IWG on Offshore wind and published in November 2020[39]. These targets focused on cost-reduction and annual installed capacity but only for offshore wind, whereas the scope of the new IWG covers both offshore and onshore wind technologies. Some of these targets were met, and others became outdated in light of the massive expansion of renewables needed to deliver the new EU climate and energy targets. Cost reduction was seen as the industry's main priority a few years ago, but Russia's invasion of Ukraine and the ensuing energy crisis changed the paradigm. The priority is now to reduce Europe's energy dependence on foreign countries, ensuring that wind energy technology manufacturing stays in Europe and accelerating its deployment. The previous targets included the following;

- Achieve 8.7 GW annual installed capacity by 2030. In order to meet the 42.5% renewable energy target, 420 GW of installed wind energy capacity will be needed in the EU by 2030, requiring annual installations to rise by 2030 to 22.9 GW of onshore wind and 19.7 GW of offshore wind. This target is therefore outdated.
- Reach an average levelised cost of energy (LCOE) of between 35 and 45 EUR/MWh by 2030 for bottom-fixed offshore wind; and reach an average LCOE of between 62 and 106 EUR/MWh by 2030 for floating offshore wind: According to the 'Getting fit for 55 and set for 2050' report published by ETIPWind in 2021, the LCOE of bottom-fixed solutions will be between 38 EUR/MWh and 60 EUR/MWh in 2030. For floating offshore wind, this LCOE will reach between 53 EUR/MWh to 76 EUR/MWh. Cost reduction is still an important element but no longer the main lever to safeguard the competitiveness of the European wind energy supply chain.

IWG Wind members therefore propose the following new targets:

1. At least 3% increase of national R&I funding dedicated to wind.
2. At least 0.5 percentage points increase per year of wind energy penetration in electricity needs at European level thanks to R&I actions.
3. At least 2 GW of wind manufacturing capacity added per year at European level enabled by the implementation of R&I actions.
4. Each Member State dedicates R&D budget to materials recovery technologies.
5. At least 100 000 workers trained by 2025 at EU level.
6. One research project on average per year enabling faster permitting for wind projects.

39 https://setis.ec.europa.eu/implementing-actions/wind-energy_en

Investment and other needs

To support the competitiveness of the European wind energy sector, it is essential to invest in R&I activities both at EU and national levels. However, the EU funding dedicated to wind energy in the current Horizon Europe Work Programme (2023-2024) has decreased by EUR 54 million compared to the last programme (2021-2022).

To safeguard EU leadership in wind energy technologies, investment is particularly needed in five R&I areas:

- Wind energy system integration;
- Industrialisation, scale-up and competitiveness;
- Operations & maintenance and digitalisation;
- Sustainability and circularity; and
- Skills & coexistence.

In the update of their Implementation Plan next year, IWG Wind members will spell out, for each of these areas, the R&I actions that must be implemented at the national level to accelerate the deployment of wind energy in Europe.

To enhance the potential for collaborations, the IWG Wind would benefit from more participation from SET Plan countries. The IWG Wind currently has 10 members: Belgium, France, Germany, Hungary, Ireland, Italy, Norway, Portugal, Spain and Türkiye. Other EU Member States with an interest in wind energy would benefit from membership by participating in shaping wind energy targets and defining the R&I actions to be implemented at national level.

Where Member State representatives are given a clear mandate by national governments, they are far better placed to implement R&I actions and commit national funding to meet the IWG's objectives.

It is also noted that closer coordination with DGs RTD and ENER would help to reinforce the integration of SET Plan activities on wind energy (and other renewables).

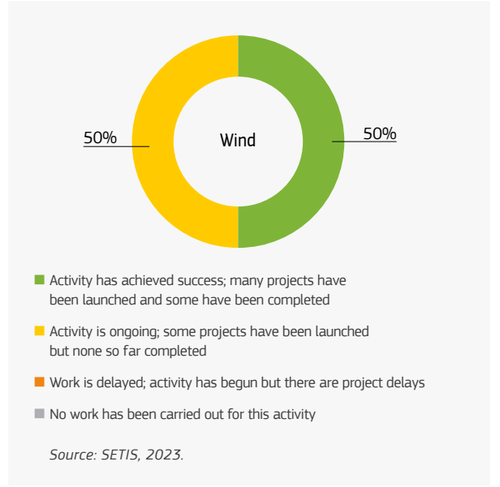
Future prospects and expectations

The objective of the IWG Wind is to accelerate the deployment of wind energy in Europe through targeted research & innovation efforts. The next step for the group will be to define concrete R&I actions and projects, to be implemented at national level, to achieve the new SET Plan target for wind energy. These actions will be defined in the Implementation Plan update of mid-2024.

The IWG Wind will also collaborate closely with ETIPWind. IWG Wind members will review the updated ETIPWind Strategic R&I Agenda to ensure industry's R&I priorities are aligned with the targets and ambitions of Member States.

In the coming months, the IWG Wind will also collaborate with ETIPWind, ETIP SNET, ETIP Ocean, the IWG Ocean energy and the IWG on HVDC to develop a joint study on how to achieve 500 GW of offshore renewables by 2050. Closer collaboration with the Clean Energy Transition Partnership will also be explored.

The SET Plan provides a forum for discussing priority areas but it is important to ensure that its objectives remain aligned with the EU's evolving energy objectives. R&I efforts across Europe need to be aligned to deliver on these ambitions, for example through the National Energy and Climate Plans (NECPs).



Source: SETIS, 2023.

To achieve the EU's climate and energy objectives, ETIPs and IWGs should focus their efforts on the accelerated deployment of smart cleaner technologies that deliver on Europe's energy security, technology development and manufacturing leadership, affordability and sustainability for the environment and society.

There are 14 IWGs today, each of them working with its own set of objectives. It is the view of the IWG Wind that there should be a more centralised process of prioritisation among the SET Plan IWGs, given that energy technologies will play differing roles in the energy transition. A leaner SET Plan ecosystem would also be easier to understand and more impactful.

The role of the IWGs should also be clarified at EU and national levels. IWG members should have a clear mandate for setting and coordinating national R&I policies and budgets. Moreover, the connection between IWGs recommendations and NECPs should be clearly defined in the SET Plan framework.

Members of the IWGs invest significant effort in defining targets, recommendations, reporting, measuring KPIs and drafting Implementation Plans. This work should be better recognised and the outcome more impactful.

Activities

Of the Wind group's six activities, half are reported as ongoing (yellow) and half include some projects which have reached completion (green).

Offshore wind farms and systems integration

In Portugal, the BEHYOND[40] project completed in 2021 a feasibility study for offshore hydrogen production using excess electricity from wind farms. The ongoing M4WIND project, initiated in 2022, emphasizes monitoring, modelling, and machine learning for wind farm operation management. In Germany, five ongoing projects include WindRamp for grid bottleneck forecasting, VISSKA for pile driving effects assessment, FlexiWind for virtual offshore wind farm modelling, C2-Wakes for wake effect reduction in offshore wind expansion, and UDW, exploring transport drones in wind farm upgrades. In Italy, the Energy from the Sea RP, set to conclude in 2024, focuses on integrating various marine renewable energy sources for energy generation and green hydrogen production at sea within the Floating Energy Archipelago concept.

Wind Energy Operation, maintenance, and installation

In Portugal, the WindFarmSHM project, completed in 2022, focused on developing and optimising methodologies to assess structural elements of wind turbines, including towers, blades and foundations. In

40 https://www.behyond.eu/

Germany, ongoing projects include GruenWinT, which examines wind energy plant foundations on open pit dumps, REFINE, focusing on tower structures with IoT vibration measurements, AIDA for autonomous offshore wind turbine inspection and maintenance using Unmanned Aerial Vehicles, CompARe for maintenance optimisation using image processing on remote AR terminals, and SONYA, which investigates enhanced reliability of segmented rotor blades through hybrid condition monitoring.

Ecosystem, social impact & human capital agenda

Portugal's SOS-WindEnergy project, completed in 2021, explored the potential for repurposing decommissioned offshore jacket-type platforms for offshore wind energy. In Germany, the Hemm-den-Wind project comprises three subprojects aiming to identify conditions under which legal actions and citizens' petitions against onshore wind projects hinder wind power expansion. Germany also initiated the WINSENT project for a research platform in South German mountainous terrain, the BBR 2.0 project for advanced bird and bat monitoring technology, and the KliWiSt project investigating climate change's influence on wind energy site assessment. In Italy, the MSP4BIODIVERSITY project focuses on mainstreaming biodiversity in Maritime Spatial Planning to promote a Sustainable Blue Economy. The REMAP project is dedicated to developing strategies for reviewing maritime spatial plans, emphasizing data tools, models, and interoperable data infrastructure to facilitate the sharing of MSP data among Member States.

Next Generation Wind turbine technology

Portugal initiated a project in 2020 focusing on offshore turbine blades incorporating intelligent architectures with hybrid and nano-enabled multilaterals. Meanwhile, in Germany, the recently concluded EnerWing_xM project centered on the conception and design of blade technology for system-serving flight wind turbines in the megawatt class.

Floating Offshore Wind and wind energy industrialisation

In Portugal, the ongoing Loop Wind project involves AI software aimed at optimising the location and design of offshore wind platforms. Germany's recently concluded VAMOS project focused on validating, measuring, and optimising floating wind energy systems. Italy's NEST Project-Spoke 2, set to conclude in October 2025, encompasses the development of breakthrough technologies for floating wind turbines in the Mediterranean region, including platform, turbine, and electric machine innovations, as well as the integration with wave energy converters. Additionally, digital tools are being developed to identify suitable Mediterranean areas for renewable marine sources, considering authorisation constraints, technologies and maintainability factors.

Basic Wind Energy Sciences

Recently, Portugal has participated in EU-funded projects within this domain, while Germany has initiated five projects addressing various aspects, such as power semiconductor and converter innovations, control concepts, hybrid switches with 'load cycling resistance,' power converters with high power density (the LHUVkaft project), and the operation, adaptation, and updating of the FINO database to meet new standards (the FINO-Datenbank project).

GEOTHERMAL ENERGY

During the 2022/23 reporting period, the world changed. Russia's invasion of Ukraine and the consequent energy crisis brought new urgency to the heat transition and the security of Europe's energy supply. Self-sufficiency and resilience for Europe have become high priority. Geothermal energy has the potential to become a key energy sector as it is a local renewable energy source, supplying power, heat and minerals such as lithium; it offers thermal underground storage; and has few geopolitical dependencies. Against this backdrop, geothermal energy and the Geothermal IWG are gaining some momentum.

The market developments are favourable. Geothermal district heating and cooling systems, geothermal power generation, and geothermal heat pumps continued their growth trend in 2022, adding typically 5% to the existing stock. The installed capacity of geothermal district heating and cooling is now 5.8GWth, geothermal power generation has reached 3.5 GW and geothermal heat pumps 36 GWth. In 2022, there was the largest ever volume of geothermal heat pump sales, with more than 141 300 systems installed. The contribution of geothermal energy needs to be tripled by 2030 in order for Europe to reach its energy and climate goals.

Recent developments and achievements

The EU has recently introduced policy initiatives which support the geothermal energy industry, including the Net-zero industry act (NZIA); electricity market design reform; the upcoming Heat pump action plan; and the EU Solar strategy, which called for a tripling of geothermal capacity by 2030. Several European countries have released a national geothermal roadmap in the last couple of years, including France (2023), Poland (2022) and Germany (2022).

The Geothermal IWG actively promotes transnational cooperation and advancement in the geothermal sector. Achievements in 2022 include ongoing work on the revision of the Implementation Working Plan; support of the GEOTHERMICA Initiative, active contribution to the inter-IWG collaboration at the SET Plan conference in Prague; and 15 new projects resulting from the GEOTHERMICA/SES joint call. The Geothermal IWG has strong links to the CETPartnership, in the thematic area of Heating & Cooling. The links between the ETIP Geothermal and the Geothermal IWG were strengthened during 2022. The ETIP Geothermal is currently finalising its Strategic Research and Innovation Agenda with a structure similar to that of the Geothermal IWG.

Implementation Plan

In the previous IWG Implementation Plan, targets focused on the cost of geothermal energy production. In the revised Implementation Plan, the Geothermal IWG proposes a vision for market size instead, with a target for geothermal heat to supply more than 25% of Europe's demand for space heating and cooling, and significant portions in the agricultural and industrial sectors in the low to medium temperature range.

Working group visit to the Kizildere power plant (Türkiye).

Source: GEORG Geothermal Cluster, 2019.

Targets further include that 10% of power production in SET Plan countries should be from geothermal power; that underground thermal energy storage supplies more than 10% of Europe's demand for space heating; and that co-production of minerals and critical raw materials (CRM) for resilient mobility occurs in at least ten European regions. The Net-zero industry act proposes that 40% of the supply chain be made in European by 2030, which will be one of the Geothermal IWG's targets in the revised Implementation Plan. While costs and relevant cost targets are affected by the quality of the geothermal resource, the price of steel, the competition of other renewable energy technologies, and the potential for geothermal energy, cost targets can lead to cost reduction and better integrated concepts.

Investment and other needs

The Geothermal IWG estimates that current annual investment, both public and private, in national and transnational research and innovation projects in the geothermal sector needs to be tripled from EUR 100 million to EUR 300 million by 2030 in order for Europe to reach its goals on transitioning to renewable energy sources. This is in line with the ambitions and potential for geothermal energy.

For the Geothermal IWG itself, political priority and sufficient support for geothermal are probably the most important challenges. Only with such support the market failure which holds geothermal energy back because of the high initial cost and the scale of the investment can be addressed. Non-technical barriers that affect the geothermal sector include lack of subsurface data; knowledge-transfer and training; open access to geothermal information; standardisation; risk mitigation; awareness; and public acceptance. Authorisations and permitting processes need to be simplified to enable the implementation of projects and development.

Other challenges include establishing more favourable market conditions in all European countries. Fair competition, taking into account real costs, is needed everywhere in Europe. The Geothermal IWG calls for more collaboration across the continent, and additional members from Mediterranean countries would be most welcome. Capacity building, i.e. training and education in the geothermal sector, is also needed to triple production of geothermal energy. Favourable development of market conditions in Europe and increased interest in the sector will undoubtedly affect the geothermal sector positively. A Europe-wide scope is needed for the geothermal sector to reach its full potential.

Future prospects and expectations

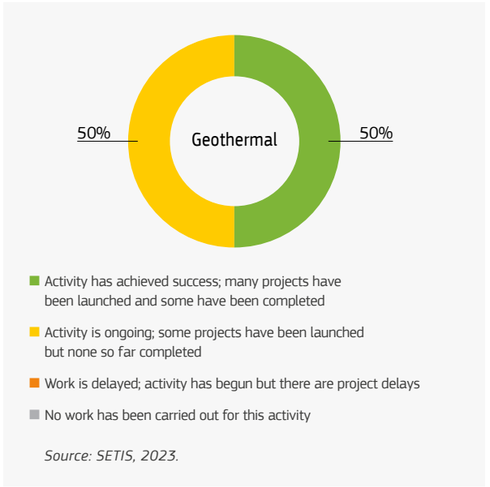
The future prospects of the industry are good. The changes that the year 2022 brought put energy security and the energy transition back in the centre of political attention. There is much to be gained by taking geothermal heating, cooling, power generation, thermal storage and co-production of minerals into the plans for the energy transition of many countries and regions.

After the revision of the IP, the Geothermal IWG intends to work actively to increase its membership. The IWG also needs to expand its activities in the key priority areas of thermal storage and co-production of minerals, as well as understanding the specific challenges related to low temperature geothermal heating and cooling production and its integration into the energy system. The role of the Geothermal IWG will be to understand the potential and follow up on technical and non-technical barriers.

Activities

Of the ten activities of the Geothermal group, half are reported as ongoing (yellow) and half include projects which are successfully completed (green). Some key projects contributing to Activities 1 and 2 include the Heatstore[41] project, which highlighted the crucial role of high-temperature underground thermal energy storage through pilots and demonstrations. The Heatstore findings were subsequently integrated into the Dutch energy storage roadmap for 2023. Activities 3 and 5 also included several projects, notably the Perform project, which yielded new tools to address scaling and corrosion challenges, along with a tool for selecting the most suitable method for specific geothermal fluids. Activity 7 saw contributions from projects like Velizy-Villacoublay, which employed a multidrains borehole well architecture to enhance production at limited additional cost. This innovative drilling approach earned the 2021 Ruggero Bertani European Geothermal Innovation award, underscoring its advanced development in the field.

Additionally, these two developments illustrate both technological and non-technological progress in the geothermal energy sector and are fully in line with the priorities of the Geothermal IWG:Geothermal Emission Control (GECO) is an industry-driven project funded under the H2020 programme. With a consortium of 18 partners, GECO focuses on R&I activity D of the Geothermal Implementation Plan, which deals with zero-emission power plants with capture of greenhouse gases, storage and reinjection schemes for the development and exploitation of geothermal reservoirs, in particular those with high content of non-condensable gases (NCGs). Building on the success of CARBFIX, GECO's mission was to demonstrate the viability of carbon capture, storage, and utilisation (CCSU) technologies in different geological reservoirs throughout Europe. In line with this development, several innovative "closed loop" projects for electric power generation are under development in Italy. These projects apply the total reinjection of the geothermal fluids into the original reservoir rocks with no aeriform emissions into the atmosphere. More than 200 MW of new capacity will be installed within 2030 with a total investment of EUR 2 billion.



The Ruggero Bertani European Geothermal Innovation Award 2023 was awarded to Huisman Geo, with its innovative project, 'Composite Downhole tubulars'. These Huisman Composite Tubulars provide a smooth, corrosion-free surface, a significant reduction in pump losses and substantial cost savings in scaling and corrosion inhibitors. The system features include a full composite pipe body and strong yet slender threaded connections developed for downhole applications. This success has been the result of years of development work, fully in line with the IWG R&D priority for 'sustainable and efficient production technologies', and was supported in a GEOTHERMICA funded project and though several projects supported by the national government.

41 www.heatstore.eu

OCEAN ENERGY

The start of the Horizon Europe CSA project SEETIP Ocean in August 2022 has re-invigorated the ocean energy implementation working group. The nature of the SEETIP Ocean project, which combines support for the implementation working group and the ETIP Ocean, has resulted in even greater collaboration between the two entities.

The aim of the IWG remains to support the development of cost-competitive ocean energy technologies with high market potential for Europe. The focus is evolving from supporting research to supporting deployment of first-of-a-kind prototype systems and initial pre-commercial devices with the ambition of achieving an installed capacity of around 1 GW by 2030 and progressively reducing LCOE to EUR 10 ct/kWh (tidal stream) and EUR 15 ct/kWh (wave) by 2030.

Recent developments and achievements

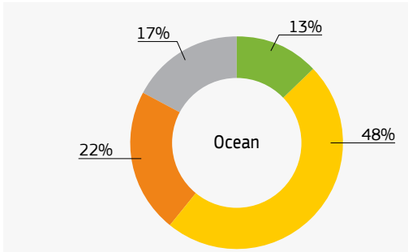
The tidal stream sector continues to make progress towards these targets. Contracts to deliver approximately 40 MW capacity by 2026 were awarded to three technology developers in round four of the UK's Contracts for Difference scheme, and the TIGER project, funded through an Interreg programme, is preparing the groundwork for other deployments in France.

The IWG continues to engage with other bodies relevant to the sector. The group was represented at the 16th SET Plan conference in Prague, contributing to the discussion of the updated SET Plan, and has engaged with the CETPartnership to develop the specification for the next joint call (2023) to ensure the requirements of the ocean energy sector are reflected in the call's focus.The technical priority actions in the current Implementation Plan were updated in 2021 to align with the priority actions identified in the sector's Strategic Research & Innovation Agenda published by ETIP Ocean in May 2020.

Investment and other needs

Public sector support for R&I activities continues to be well resourced at both national and European level. However, as ocean energy technology matures, the sector needs to move towards the demonstration of pre-commercial devices and with this the need for significant investment will become even more pressing. In the 2023 progress report on the competitiveness of clean energy technologies, it is stated that to strengthen the EU's competitiveness in the ocean energy sector, a combination is needed of technological innovation, supportive policies, cost reduction, a commitment to sustainability and the successful long-term demonstration of technologies to provide the necessary reassurance and confidence to investors. The transition to multi-year, all-season deployments of commercial-scale devices, from model-scale and bench testing to short duration deployment of partial-scale prototypes, will require a significant commitment of financial resources and exposure to financial risk.

The Implementation Plan identifies two financial actions, to establish a dedicated investment support fund and to establish an insurance and warranty fund, to support these initial deployments of ocean energy technology. While further studies continue to define how the latter might be structured, there is no evidence of progress towards the creation of a collaborative investment support fund, combining EU and national funds.



Source: SETIS, 2023.

Future prospects and expectations

The ETIP Ocean is reviewing and updating its Strategic Research and Innovation Agenda in 2023, re-prioritising the technical topics that will be key to enabling the sector to achieve commercial success. The IWG will engage with this process.

The IWG will continue to strengthen relations between its member countries and organisations to ensure a coordinated response to the requirements of the sector. Additionally, the group would also welcome the proactive support of the SET Plan secretariat in facilitating networking and collaboration with other IWGs. Of particular relevance to the Ocean Energy IWG is opportunities to collaborate with the IWGs for Wind, HVDC and Hydrogen in the future.And finally, the IWG and ETIP for the ocean energy sector jointly call for the Commission to continue to provide financial support for their activities. The close collaboration and joint working of these two groups that was required by the structure of the current supporting CSA project (SEETIP Ocean) is proving beneficial for the sector. This should be continued.

Activities

Almost half of the group's activities are reported as ongoing (yellow), three include completed projects (green) and the rest are either experiencing delays (orange) or the projects have not yet started (grey). Further study is required to establish the impact of the projects and to ascertain the reasons for delay in some of the actions (e.g. 1.8 - Improvement and demonstration of foundations and connection systems for bottom-fixed ocean energy devices; 1.14 - Open-data repository for

ocean energy operation and performance; and 1.15 - Standardisation and certification). There is one action which has not progressed (3.2 - Investment Support Fund). So far, the IWG has not found a mechanism for financing the studies needed to progress on this.

Under action 3.4, funding at both European and national level continues to support a portfolio of projects that primarily address the technical actions identified in the Implementation Plan.

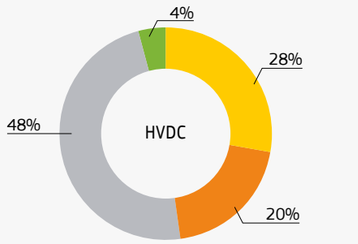
A key success story for action 3.5 is the collaboration between Wave Energy Scotland (UK) and the Basque Energy Agency (Spain) which has resulted in the EuropeWave project. EuropeWave is implementing the pre-commercial procurement (PCP) model for innovation procurement to progress the development of promising wave energy converter designs that will culminate in the deployment of scaled prototypes.

HVDC & DC TECHNOLOGIES

The main activity during this period was to promote HVDC technology and the main points of The main activity during this period was to promote HVDC technology and the main points of the IWG's Implementation Plan (IP). The HVDC IP was presented at various events, including the AEIT HVDC conference, Rome, the IEEE PowerTech conference, Belgrade, and various other events and webinars associated with EERA, ETIPWind, and more.

The IWG representatives also provided input in the call for proposals developed by CETPartnership TR1. As a result, the CM2023-01 Direct current (DC) technologies for power networks was developed with direct input from the HVDC IP.

A proposal was also submitted under the HORIZON-CL5-2023-D3-01-16 topic. The proposal aims to create a consortium that will support the activities of the SET Plan HVDC IWG. All consortium partners are active members of the HVDC IWG.



- Activity has achieved success; many projects have been launched and some have been completed
- Activity is ongoing; some projects have been launched but none so far completed
- Work is delayed; activity has begun but there are project delays
- No work has been carried out for this activity

Source: SETIS, 2023.

Investment and other needs

The main challenge so far has been the lack of dedicated resources for supporting the IWG activities. The chairs of the IWG have been providing the administrative and logistical support and have covered the expenses related to the physical IWG meeting and dissemination activities. This has, to some extent, constrained the group.

As HVDC and DC technologies are rather new to the SET Plan, dissemination efforts need to be much broader and consistent. Even inside the SET Plan groups, there is a lack of understanding of HVDC technology and its role in the energy transition. It would therefore be beneficial if resources were allocated (the CSA proposal would provide substantial help in this direction) and if the group had more visibility at European level, for instance during Commission events.

Future prospects and expectations

There is no doubt that the decarbonisation of electric power systems will not happen without HVDC and DC technologies. The massive ambitions and expectations from offshore wind will not be achieved without the development of HVDC technology. The European interconnection requirements will not be met without HVDC technology.

In general, albeit an enabling technology, HVDC and DC technologies are critical for the development of clean energy. These are realities well known in the working group, where many experts are developing the roadmaps and identifying the actions required to reach these targets. At the same time, the industry is getting ready to meet the massively increased requirements for the technology's deployment.

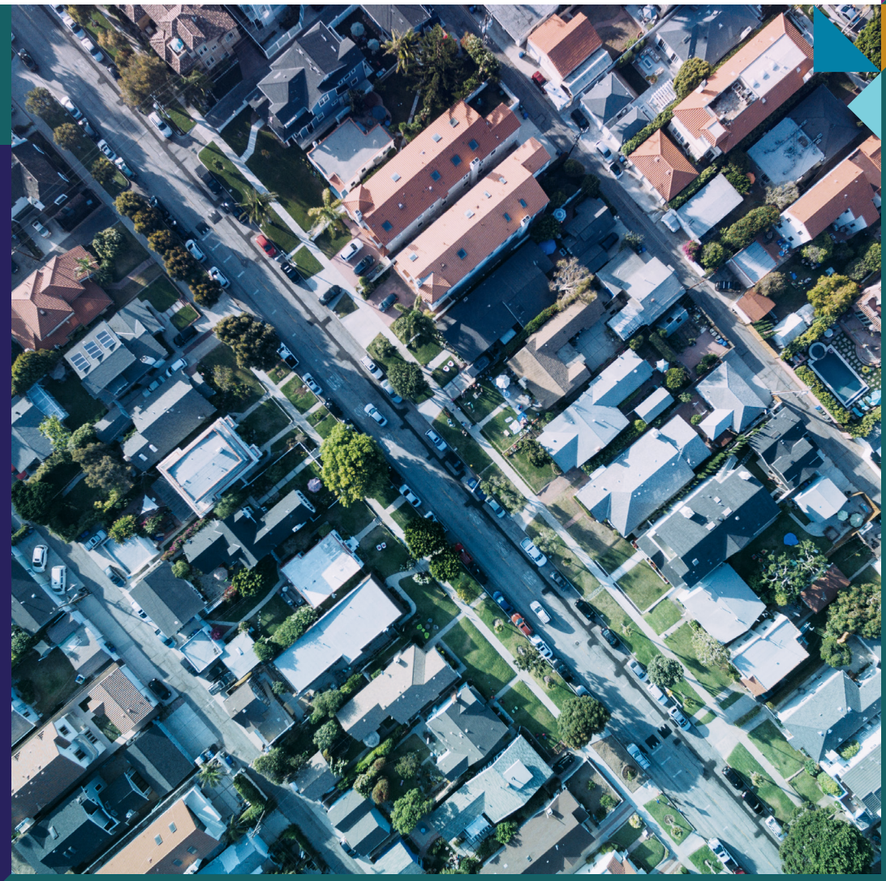
It is therefore expected that the area will grow so much that it may require a dedicated ETIP on HVDC and DC technologies. Since the expectation is to broaden the group to include medium (MV) and low voltage (LV) DC, stronger support from the SET Plan group – both administratively but also in terms of visibility – would be beneficial.

Work is ongoing to create a temporary working group (TWG) for LV DC that will later be integrated into the existing IWG on HVDC and DC technologies.

Activities

Around 70% of the group's 25 activities are reported as delayed (orange) or made up of projects which have not yet started (grey). This is due to the recent establishment of the group and its IP, as well as the fact that some of the activities have long-term goals as far ahead as 2050. There is one activity with completed projects (green) and the rest are reported as ongoing (yellow).

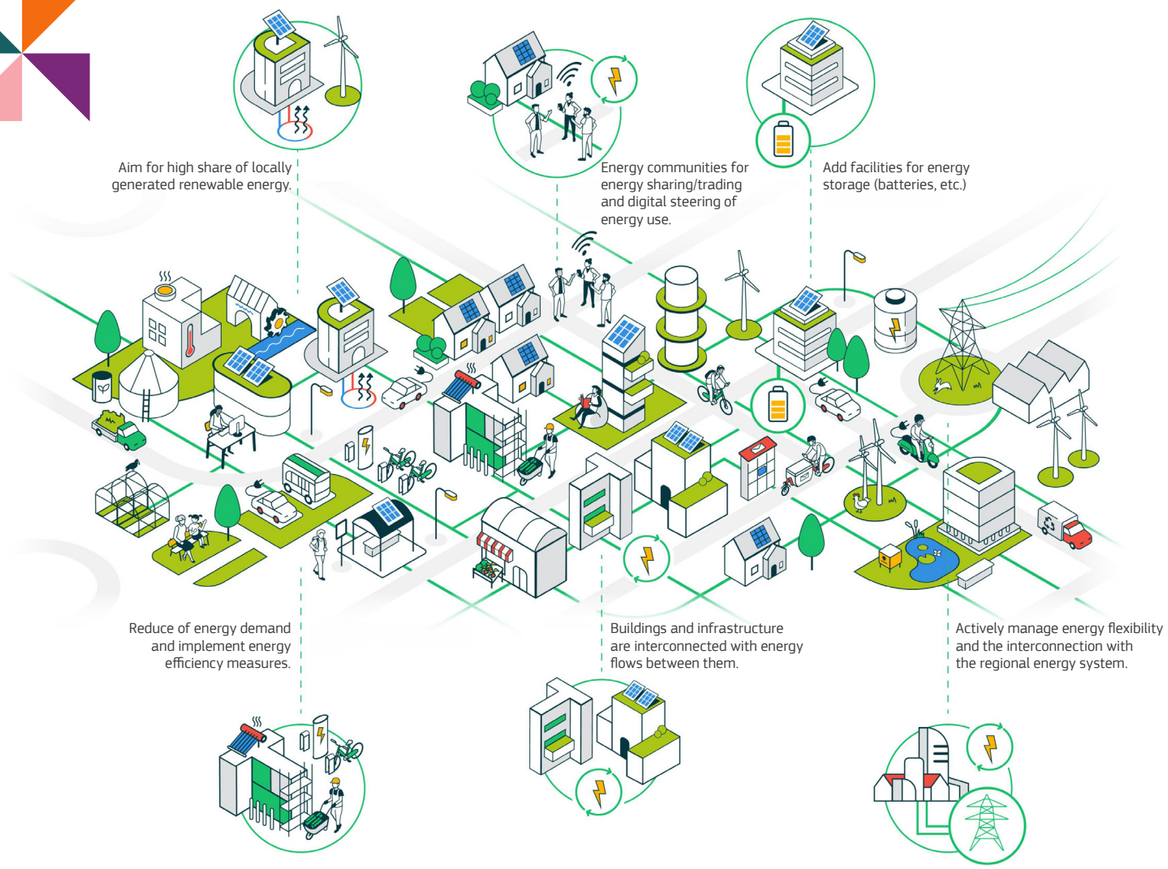
The main ongoing efforts are contributing to the short-term activities on Control & protection, Operation and Technology. Notable projects include READY4C and InterOPERA. Some of the medium and long-term activities are covered in ongoing projects like HVDC-Wise.



POSITIVE ENERGY DISTRICTS

The working group on Positive energy districts (PEDs) is operationalised by Joint Programming Initiative (JPI) Urban Europe since 2016 (as the PED Programme) and has been integrated into the Driving Urban Transitions (DUT) Partnership in 2022. It is one of three thematic priorities (Transition Pathways) of the partnership, supporting integrated solutions for the supporting urban transformation processes. DUT coordinates closely with the Mission on Climate-neutral and Smart Cities, and the PED Transition Pathway has specifically established cooperation with the CETPartnership.

Positive energy districts (PEDs).



Source: DUT Partnership

Recent developments and achievements

Key achievements include the launch of the DUT Call 2022 with a budget of approximately EUR 90 million and the participation of 28 countries, encompassing three PED topics, with outcomes expected in 2023. Additionally, preparations for the DUT Call 2023 involved an extensive scoping process to define PED priorities and topics, including stakeholder surveys and workshops. JPI Urban Europe played a significant role in the Mission Innovation Urban Transitions Mission, with a focus on the PED Transition Pathway. Cooperation and dissemination of outcomes from JPI UE-funded PED Pilot Call projects took place, along with the kick-off of eight JPI UE-funded PED Call II projects and the establishment of a PED Export Support Facility. A PED City Panel comprising over 30 European cities was established, and a PED Database was developed in collaboration with COST PED-EU-NET. Cooperation was also established with the European Cities Mission and Net-Zero Cities initiatives.

Implementation Plan

Currently, the IP is being updated with the DUT Roadmap and specifically includes an update of PED Mission and integration into Green Deal/Cities Mission policies, adapted key areas of action and adapted implementation tools in terms of PED Calls, stakeholder engagement and dissemination.

Investment and other needs

The PED working group is delivering results and is on track to achieving its mission. However, impact on the ground in the cities and mainstreaming of solutions is lagging. The working group is supporting cities with applied research results and capacity-building, but better links to implementation investment and the involvement of private financing is needed.European structural and investment funds (ESIF) regulations in the multiannual financial framework (MFF) 2014-2020 still left too many loopholes so that Operational Programmes could neglect the needs of cities. In the MFF 2021-2027 there is still little focus on financial incentives for net-zero investment in cities. Even the Recovery and Resilience Facility (RRF) was excessively oriented towards quick implementation to cater for the needs of urban investment in climate neutrality.

Future prospects and expectations

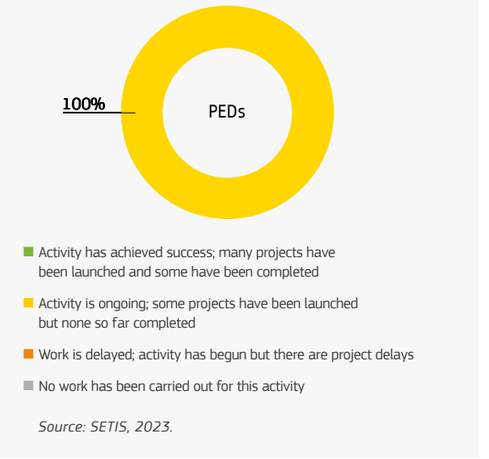
The working group on PEDs/DUT PED Transition Pathway will discuss and update the PED concept and IP according to feedback from the stakeholder community in 2023/2024.

In 2025, the PED Mission of initiating 100 PED projects will be achieved, followed by a continued innovation portfolio approach as support for the Mission on Climate-neutral and Smart Cities.

DUT will continue to launch annual calls with PED topics until 2028. By then, a portfolio of 100+ PED projects is expected.

International cooperation with Mission Innovation and the Belmont Forum will be continued, with the expectation of more international partners joining the calls.

The group plans to continue the successful cooperation with other IWGs and the CETPartnership.



Source: SETIS, 2023.

Activities

All five of the IWG activities are reported as ongoing (yellow). The projects from the PED Pilot Call (2020) have finished their work. Cities4PEDs, INTERACT, PED-ID and TRANS-PED delivered important learnings on the suitability of the PED concept, on challenges, barriers and potential pathways. Results reflect on the requirements on local, city, and regional levels, and provide guiding material for policymakers and decision makers. The working group on PEDs supported dissemination activities (public webinar series, reports, workshops, etc.). In addition, this outcome has an impact on the update of the PED concept within the IWG/DUT PED TP.

ENERGY SYSTEMS

The working group on energy systems has highlighted the successful alignment and coordination with ETIP-SNET, ensuring continuous updates. Projects originating from ETIP-SNET contribute significantly to the IWG's targets. Substantial progress has been achieved in ERA-Net Projects. Furthermore, a dedicated call has been issued under the Clean Energy Transition Partnership (CETPartnership), focusing on flexibility demonstrators and the development of tools and methods for energy system planning and operation, aligning with key topics of the IWG on energy systems. Within the National Stakeholders Coordination Group, a series of events has been organised, focusing on local-level flexibility, including discussions on needs, the role of local energy communities, policies and technologies.

Investment and other needs

During the Covid-19 pandemic, participation in the working group decreased significantly. Contact with several of those nominated to participate in this IWG has decreased in frequency and intensity. To resolve this, the Chair and Vice-Chair are planning to relaunch the activities of the IWG and the collaboration with the other IWGs.

Future prospects and expectations

The integrated energy system will become increasingly important for reaching the net-zero emission targets. The pace of the integration of renewables is increasing, and in several countries, electricity networks are approaching their hosting capacity, requiring additional measures such as sector coupling and flexibility. The importance of the digitalisation of the energy system is also continuously increasing. Observability, interoperability, cyber security and controllability are key elements extensively addressed by the IWG.

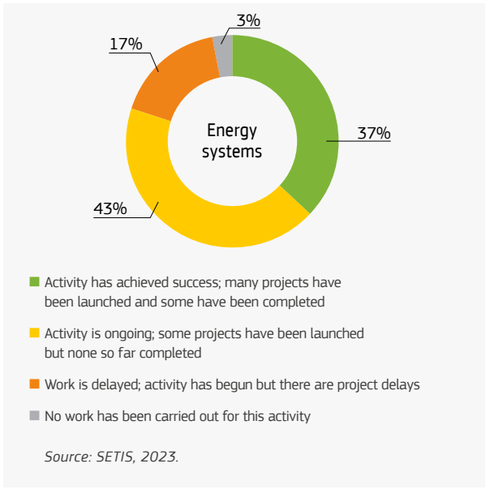
The mobilisation of various stakeholders from research, industry, policy and civil society is needed, as well as coordination among policy actors at national, regional and municipal levels. The efficient utilisation of high shares of renewables in regional supply becomes possible with the smart management of available energy sources and infrastructures. This includes users from different sectors like communities, commerce, industry and transportation. Such integrated regional systems can increase acceptance and uptake of new solutions, by ensuring that citizens, companies, communities and other stakeholders take part in the related exchange of values on different levels.

The development of skills in the European workforce is also necessary to bring recent developments and plans to industrial application.

Activities

Around 80% of the group's 30 activities are reported as ongoing (yellow) or as including some successfully finished projects (green). There are five reported activities that have some delays (orange) and only one for which no project has yet started (grey).

Completed projects in Flagship 1 (Optimised European power grid) covered the portion of subjects of interest detailed in the related fiches for the outlined period (the fiches and timeline, prepared as part of the Implementation Plan, are aligned with the ETIP SNET documents). The results of the projects (mostly funded through H2020, HE and some national/regional) have been applied in networks or are being considered for application. The related research cycle for the completed projects can, however, not yet be considered complete, as there are additional steps in the Roadmap and Implementation Plan for the period to 2030. Effort therefore needs to be made to ensure the implementation of these finished projects. This analysis is in line with the Monitoring report of collaborative research carried out by ETIP SNET.



Source: SETIS, 2023.

The delay in the development of some of the projects is linked with timing and priorities. The subjects addressed will increase in importance when the integration of renewables reaches a level such that the current technologies and solutions will no longer suffice, and variability and flexibility will be crucial (system stability, FACTS and long-term planning fall into this category). Cost reduction is also important; FACTS can be designed to address various network issues, but their application is still very costly and are considered only in situations where no other solution is available. This influences the pace of R&D. Finally, limited budgets and skills limit the dedication of resources to costly demonstrators by operators, research centres or equipment providers.

Flagship 2 (Local and regional energy networks) has been revised, based on recent analysis of priorities and needs. All activity fiches were updated and two new ones were created. Flagship Initiative 2 – Integrated local and regional energy systems – now covers the following:

- Heating and Cooling;
- Integrated Industrial energy systems;
- Battery energy storage in an integrated regional energy system – for which a new fiche was made;
- Innovation ecosystems for integrated regional and local energy systems;
- Linking European Initiatives to create the basis for action;
- Process chain for interoperability of ICT systems;
- Hydrogen production, trading and usage in an integrated regional energy system – for which a new fiche was made; and
- Digital Services.

A first CETPartnership call has been launched at Transition Initiatives 1[42] and 5[43]. Additionally, a Pilot on Collaboration platform on Interoperability Testing is still in preparation and is expected to be implemented by the end of 2023.

42 TRI 1: Integrated Net-zero-emissions Energy System – https://cetpartnership.eu/tri/1

43 TRI 5: Integrated Regional Energy Systems – https://cetpartnership.eu/tri/5

ENERGY EFFICIENCY IN BUILDINGS

Currently, white papers are being developed in eight working groups to feed into the revision of the Implementation Plan and the National Energy and Climate Plans of the EU Member States. The papers produced will be used to review the IP by 2024. The areas covered in the revision include energy efficiency as well as heating and cooling topics. Technical topics considered include heat pumps, digitalisation and active facade modules, and societal topics include the just transition and public acceptance of new technologies in the built environment.

Recent developments and achievements

The European Construction, built environment and energy efficient building Technology Platform (ECTP) committees updated their position papers on research objectives and priority areas in June 2022[44]. The SmartBuilt4EU project focused on the Smart Readiness Indicator (SRI) which is part of the Energy performance of buildings directive (EPBD). One of the key results of the project are policy recommendations and a strategic research agenda for the smart built ecosystem[45].

ETIP RHC recently published two collaborative documents. The White paper on Coupling of Heating/Cooling and Electricity Sectors in a Renewable Energy-Driven Europe[46], prepared jointly with ETIP SNET, shows that the electricity and heating/cooling sectors can be decarbonised nearly completely with existing technologies and resources. However, significant investment is required to develop, improve and deploy the necessary technology at scale. Alongside general political support for deploying sustainable solutions, there is a need for streamlining, simplification and the standardisation of application procedures.

The Position paper on Renewable Hydrogen[47], prepared jointly with ETIP Bioenergy, notes that renewable hydrogen is an energy carrier which can be one contributor, among many, to support the energy transition in Europe. However, there is a risk that excessive focus on certain capital-intensive technologies such as hydrogen will be to the detriment of other RE technologies with much faster impact, creating serious obstacles to the rapid and efficient decarbonisation of the thermal sector.

Since September 2022, a CSA Project has been running to support the IWG on Energy efficiency in buildings. Some of its key results include: bi-monthly IWG meetings focusing on national funding programmes, European policies and technological developments; the full revamp of the IWG website; an update of the terms of reference; the bi-monthly Policy Radar Newsletter with updates related to the building sector, including policy developments, new project calls and the results of existing ones, funding instruments and innovations in technologies to decarbonise buildings; the organisation of a side session at the 2022 SET Plan Conference in Prague; and a successful recruitment campaign with new members from Hungary, Slovenia and Poland.

Investment and other needs

Investment in renovation has to scale up to an unprecedented level in order to reach the goals of the Paris Climate Agreement and the new EU objectives (including the Fit-for-55 revision and REPowerEU). Existing and new public funding is needed, as well as the full-scale mobilisation of private funds with the help of policy tools.

At IWG level, one challenge is the low visibility of the SET Plan and a lack of understanding by external people on how the SET Plan works and its objectives. In order to better address new members, it would be helpful if the Commission could provide clear and comprehensive material on the SET Plan and the IWGs (such as brochures, a "SET Plan for beginners" webinar and presentations). The CSA project currently running will develop some of these communication tools, although a wider effort by all stakeholders is needed to communicate on the SET Plan activities.

Another challenge of this working group is the broad portfolio with very heterogeneous members and technologies (both in energy efficiency and renewable energy technologies) and the many urgent topics (e.g. heat pumps). This IWG propose to continue working in subgroups to allow experts to make focused contributions in their field. However, the next challenge is the very limited resources of the Chair and Co-Chairs. Further support is needed, e.g. a funded secretariat and/or continued support from a CSA (beyond 2025). This is essential for the successful work of the IWG.

Furthermore, an additional challenge is that there is often no active participation in the IWG or not enough feedback from the Member States and Associated Countries. A solution could be to link IWGs and NECPs. However, this requires clear and binding guidance from the Commission. The CSA is addressing the challenge with bi-monthly meetings, regular surveys on members' needs and engagement in a campaign to find new IWG members.

Future prospects and expectations

There is great potential to improve and renew Europe's building stock, in particular due to the twin energy and climate crises. The ambitious 2030 climate targets and the aim to reduce carbon imports from Russia are expected to prompt an unprecedented renovation wave.

44 www.ectp.org/resources/publications
45 www.smartbuilt4eu.eu/strategic-research-agenda-and-policy-recommendations-for-smart-buildings-available-now
46 www.rhc-platform.org/content/uploads/2022/11/coupling-of-heatingcooling-and-electricity-sectors-MJ0922659ENN.pdf
47 www.rhc-platform.org/content/uploads/2023/03/RHC-Renewable-Hydrogen-paper_v2.pdf

This is expected to increase industrial demand and create millions of new jobs in the building sector. At the same time, this is likely to put further stress on Europe's reliance on imports (raw materials and manufactured products), as well as on the current shortage of skills (particularly the need to retrain, retain and find new installers). There are also transversal topics that will be crucial in this transition, particularly circularity and digitalisation.

The research and innovation sector and this working group can play a role in all of these topics. Efforts in material substitution/reduction and standardisation can help Europe's industry to step up its production capacity of commercial products, such as heat pumps. Material research can reduce the impact and increase the recyclability/reusability of insulation panels and other products. Increased digitalisation of buildings promises to optimise new heating systems to reduce energy demand. The IWG's task forces are looking into several of these questions.

Expectations from the SET Plan

The visibility of the SET Plan should be increased. This is particularly important to engage new Member States to work in the IWGs.

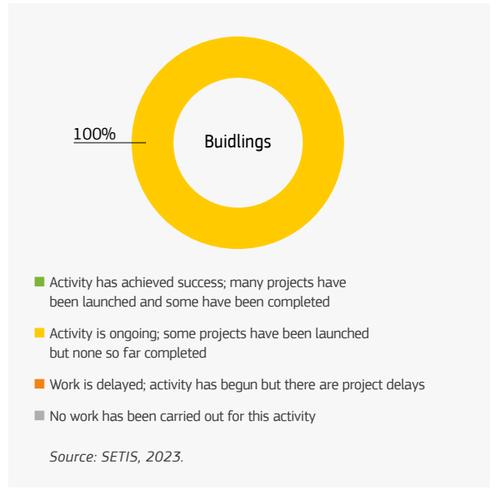
Synergies between regional, national and European funding programmes can help to promote the objectives of the SET Plan. Therefore, synergies and alignment should be strengthened across the ERA.

Synergies need to be strengthened with European funding programmes working on SET Plan topics, e.g. Horizon Europe, Life- Programme, Joint Programming Initiatives, Innovation Fund, Modernisation Fund, Just Transition Fund, Social Climate Fund, and European Regional Development Fund (ERDF).

It should support the alignment of national and regional funding programmes and policies with European programmes and policies.

Activities

In recent years, the working group's members have initiated and carried out hundreds of regional, national and EU-wide research and development projects in the building sector. The EeB PPP Project Review 2021[48] summarises the building industry's key innovation achievements from 103 projects between 2014 and 2020. The project database on the ETIP RHC platform[49] currently includes more than 160 projects on district heating and cooling, heat pumps, hybrid systems and thermal storage.



In all eight activities, projects have been launched and some have already been successfully finished. However, the activities are not yet completed, as the targets of the current IP have not yet been achieved.

Impact of exemplary projects

The PACE project[50] has installed more than 2 600 fuel cell micro-CHP systems in residential buildings and business premises spread across nine European countries, demonstrating the market and consumer readiness of this technology in Europe. European industry has invested more than EUR 200 million in the development and manufacturing of fuel cell technology for stationary applications, thereby expanding the EU's manufacturing capacity by as much as 400%. Additionally, more than 3 400 installers have received training in how to install and maintain fuel cell micro-CHP systems.

The Upgrade DH project[51] supported and initiated the upgrading process of eight district heating demo cases in Europe and provided the basis for replication to other cities. The proposed measures for upgrading

48 http://ectp.ectp.org/cws/params/ectp/download_files/36D4584v1_EeB_PPP_Project_Review.pdf
49 www.rhc-platform.org/projects
50 www.pace-energy.eu
51 www.upgrade-dh.eu

Working group study visit.

Source: IWG Buildings.

led to a reduction of 16.9% of the primary energy demand and 51.9% reduction of greenhouse gases of the DH systems at the eight demo sites. The share of using waste heat increased by 3.3% and the share of renewable energies increased by 21.7%.

The EU-funded TEMPO project[52] introduced six technological innovations that enable DH networks to operate at lower temperatures. Three of these come in digital form: an automated online supervision platform to detect faults in DH substations, visualisation tools for expert and non-expert users, and a smart DH network controller to optimise the supply and return temperatures. The other three constitute an innovative piping system, building installation optimisation and decentralised storage buffers. The TEMPO solution packages have been implemented, tested and evaluated at two demo sites in Germany and Italy. TEMPO proposed new business models and demonstrated their replication potential for the roll-out of sustainable and economically viable DH networks across the EU. This has contributed substantially to the further development and deployment of DH networks in Austria, Flanders, Germany, Italy and at a European scale.

The use of Ultra-Low Temperature, waste heat and RES in DH systems in the Related project[53] has resulted in final energy savings in the range of 570 MWh/year. The impact of all the interventions resulted in economic savings in the range of EUR 7.5 million (2023). 12.5 GWh/year of residual heat recovery and 64 GWh th/year of cogeneration are already in operation.

The project MOEEBIUS[54] introduced a Holistic Energy Performance Optimisation Framework that enhances current modelling approaches and delivered innovative simulation tools which deeply grasp and describe real-life building operation complexities in accurate simulation predictions that significantly reduce the "performance gap" and enhance multi-fold, continuous optimisation of building energy performance as a means to further mitigate and reduce the identified "performance gap" in real-time or through retrofitting. MOEEBIUS reduced the gap between energy prediction and real/measured energy performance of buildings to values below 10%, achieved energy demand reductions of 32%, reduced energy peak-demand by at least 28%, and significantly reduced unscheduled maintenance or corrective actions. Given the energy mix in the pilot countries and consumption data of the pilot buildings, the foreseen peak and overall demand reduction enables large GHG emissions savings on an annual basis and increased integration of intermittent and fluctuating energy sources.

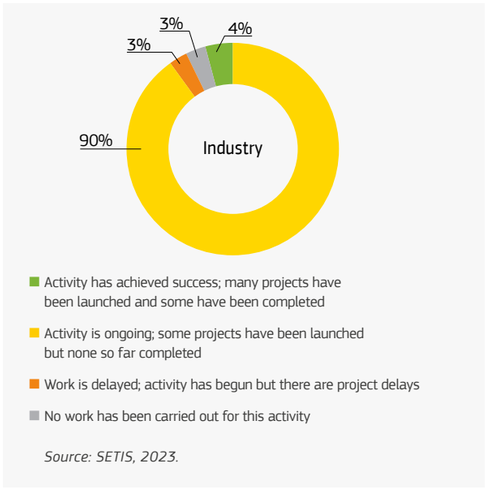
The project Bio-Nrg-Store[55] has investigated the functional incorporation of biomolecules into wood fibres, charcoal, veneer and solid wood to increase heat storage and conduction while improving the strength, thermal insulation properties and biological resistance of the feedstock. The thermal mass and heat capacity of the wood/BPCM composites was successfully increased compared with the untreated wood. The thermal performance stability of the studied mixtures after accelerated thermal cycling showed that the mixtures were thermally stable after 700 cycles. Furthermore, the mixtures were chemically stable after thermal cycling. Therefore, these new developed materials could be a potential bio-based phase change material (BPCM) for energy storage in building applications.

52 www.tempo-dhc.eu
53 www.relatedproject.eu
54 www.moeebius.eu
55 www.ktu.edu.tr/bionrgstore

SUSTAINABLE AND EFFICIENT ENERGY USE IN INDUSTRY

In March 2022, the working group on Sustainable and efficient energy use in industry (IWG Industry) held its Networking Event (organised by the previous service contract); the first parallel sessions kicked off the cross-IWG cooperation in three areas; the second session presented and discussed the Waste Heat Recovery roadmap, which was developed by the IWG; the third session addressed the non-technical barriers to the deployment of energy efficiency technologies.

In November 2022, the IWG organised a session covering various technologies and approaches on how to cut down emissions in hard-to-abate industrial sectors through energy efficiency measures (Panel 1) and the integration of heat renewables (Panel 2). The IWG also organised a side event to share experiences, allow cross-fertilisation of ideas and reinforce interaction across the IWGs, regarding the integration of high temperature renewable heat sources and storage in industrial applications. Concrete project realisations were presented, as well as innovative cooperation models between technology provider associations and end-user industrial sector associations, which have the potential to accelerate clean energy technology deployment.



Source: SETIS, 2023.

Recent developments and achievements

Throughout the year, the R&I activities prioritisation (in the IP) served as inputs for defining R&I topics in the Horizon Europe work programme, as well as in the CETPartnership programme. The group has also extended the scope of the IP to two new industrial sectors (Pulp & Paper and Cement). The following key projects started in 2022 in support of the transition of industry to more sustainable and efficient energy use.

Horizon Europe

Under Cluster 5 (Climate, Energy and Mobility): SPIRIT and PUSH2HEAT for Implementation of sustainable heat upgrade technologies for industry (project budget EUR 11.2 million and EUR 9.7 million respectively); project DECAGONE for demonstrator of industrial waste-heat-to-energy systems. Under Cluster 4 (Digital, Industry and Space): 40 projects were launched in 2022 with a total budget of EUR 238.9 million under the topic of the Twin Transition.

Innovation Fund: Large scale projects

Steel sector: HYBRIT for demonstration of iron-making using hydrogen (EU funding of EUR 143 million).

Cement sector: CCS projects: GO4ECOPLANET in Poland (EUR 228 million), EQIOM in France (EUR 153 million) started in 2022. Other Cement projects awarded in 2022 that started in 2023 include the CCS projects CalCC in France (EUR 125 million), ANRAV in Bulgaria (EUR 190 million) and the CCU project C2B in Germany (EUR 110 million).

Chemical sector: PULSE project in Finland dealing with chemical recycling of waste plastic (EUR 135 million) and AIR dealing with methanol production from CCU and H_2 electrolysis (EUR 97 million awarded in 2022 and project started in 2023).

Investment and other needs

Depending on the industrial sectors (Heat and cold, systems, cement, chemical, iron & steel, pulp & paper) and the maturity of the technologies covered by the Implementation Plan, further research activities are needed to establish pilot demonstrations and large scale first-of-a-kind (FOAK) projects. The cumulated support amounts to EUR 3-4 billion, from funding instruments corresponding to the project maturity and size (Horizon Europe, Innovation Fund combined with loans from the European Investment Bank (EIB) and other banks, and private equity.)

The challenge facing the transformation of the energy-intensive industries is not only the investment (CAPEX) but also the level and the uncertainty on operational costs of the technologies using new energy vectors and feedstock, as well as the availability of energy in the required volumes and prices at the point of use, requiring a very significant enhancement of energy generation and transmission infrastructure.

Future prospects and expectations

The expectation of the IWG-Industry members from the SET Plan is to relay the R&I&D funding needs and the future renewable and low-carbon energy generation and transmission needs, so that the necessary funding support is made available at European and national level in good coordination, and that the necessary energy infrastructure is planned and developed in time for reaching the EU climate and energy targets related to industry.

Activities

Around 90% of the group's 30 activities are reported as ongoing (yellow) or including some successfully finished projects (green). There are only two reported activities that have some delays (orange) or where no project has yet started (grey).

Various projects on industrial symbiosis were completed under H2020, with the development of tools to identify the potential and organise the symbiosis and their demonstration in specific use cases. The activity on waste heat to cold generation is planned to start with the Horizon work programme 2023-2024.

BATTERIES

There is rapid evolution in battery technology and the European ecosystem, with the establishment of a domestic battery value chain from raw and advanced materials, cell production and integration to use and recycling. This means that R&I requirements are under rapid revision. New applications in transport and stationary storage are also evolving, with different requirements (KPIs and target KPIs).

The upcoming Batteries Europe / BEPA SRIA (that can be seen as the IP of the IWG) will be published in Q4 2023.

Recent developments and achievements

- Collaboration with EU R&I Battery Initiatives – periodic meetings with BEPA, Batt2030+, EBA and IPCEIs for alignment and generation of joint initiatives.
- Batteries Europe and BEPA Working Groups and Task Forces have been merged to harmonise the work of the R&I community and maximise and facilitate the contribution of stakeholders.
- Active involvement in the ETIP Forum activities and contribution to the revision of the SET Plan feedback exercise (complementarily to the SETIS questionnaire and Deloitte report).
- Publication of six factsheets that provide key information on the national battery ecosystems in China, Japan, USA, Australia, South Korea and the EU.
- Publication of the Batteries Europe Technology Roadmap (2023) to support strategic planning of research and innovation by identifying and elaborating the short-, medium-, and long-term needs for supporting the establishment and development of a European battery ecosystem across the whole value chain.
- Publication defining a set of KPIs across the battery value chain with baseline state-of-the-art values and future expected values (2027, 2030, 2035, 2050), along with a glossary of terms to establish a common understanding.
- Publication of Safety KPIs report (in coordination with JRC).
- Joint participation and organisation of events: Battery Innovation Days, European Sustainable Energy Week 2022/2023, Transport Research Arena 2022.

Investment and other needs

For R&I and R&D needs and challenges, please see the latest Batteries Europe Technology Roadmap[56].

Future prospects and expectations

The IWG looks forward to closer collaboration with all players of the EU Batteries Ecosystem and efforts to explore interactions with other ETIPs (via the ETIPs Forum), raising the debate on selected topics at an international level, while interacting with other actors within the SET Plan for a more systemic incorporation of batteries in the EU Agenda.

The Batteries group also looks forward to the establishment of collaboration mechanisms across the IWGs. This collaboration can be based on (semi-) permanent structures with the objective to facilitate the interaction of the different actors across the IWGs in transversal topics (e.g. education, sustainability, digitalisation, skills, citizens' empowerment etc.). In terms of governance, the Batteries group calls for specific and measurable targets for IWGs, and a clear role for their chairs.

Activities

In all ten of the Batteries working group activities, projects have been launched and some have already reached a successful conclusion.

Several projects and initiatives have been undertaken under Activity 1.1, including BEMA2020II, which involves a study and impact analysis. Additional support for the Faraday Battery Challenge in 2020-2021 has been provided by KTN, resulting in a study and impact analysis. The DigiBatMat project's main focus is knowledge transfer and the development of a database. An innovative testing system for battery management systems with real-time impedance simulation has been developed. Lastly, the RiskBatt project encompasses a study and risk assessment.

Under Activity 1.2, several projects are in progress, including HELENA, which focuses on halide-based solid-state cell technology with the overarching goal of enhancing battery adoption in aircraft and electric vehicles. GENSOR aims to establish graphene sensors as essential tools for battery monitoring and predictability in fully electric, zero-emission vehicles. Additionally, the 6-minute EV project is developing an innovative high-current battery design capable of rapid charging from flat to full in just six minutes, complemented by a scalable rapid DC charger capable of delivering up to 1 MW charging capacity.

For Activity 1.3, SONAR[57] involves the development of multi-scale workshops, including internal workshops and joint pre-conference workshops, with publications in peer-reviewed journals and contributions to a new textbook. Commercialisation plans include protecting a 3D model of a lab-sized cell (RFB-SCL-3D) and test cell setup under a commercial license for marketing by Isomorph to flow battery manufacturers. SOLSTICE focuses on the development of high-temperature sodium-zinc molten salt batteries for stationary energy storage. Bi3BoostFlowBat aims to create bioinspired, biphasic, and bipolar flow batteries with boosters for sustainable large-scale energy storage. LOLABAT is dedicated to developing a novel rechargeable nickel-zinc battery with high energy and power densities and cost-efficiency.

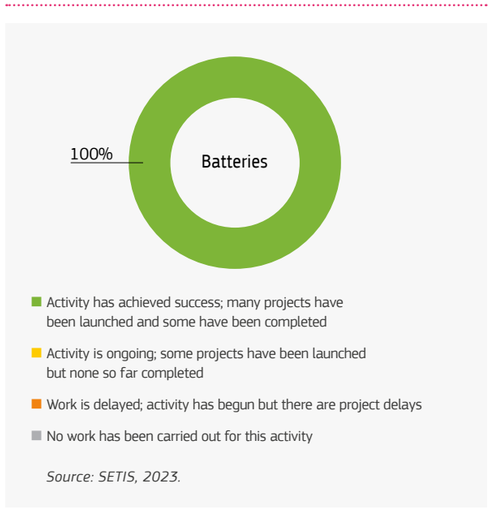
Projects underway for Activity 1.4 include the creation of a database for metal-oxide porous materials (Metal oxides by Design). SIMBA aims to develop a highly cost-effective and safe all-solid-state battery using sodium as a mobile ionic charge carrier for stationary energy storage, with a focus on supply chain analysis and materials sourcing for manufacturing. Additionally, a scalability and economic feasibility study on advanced metamaterials for sodium-ion battery anodes has been launched to identify alternatives to critical raw materials (lithium, cobalt) by investigating the potential of novel metamaterial-carbon core/shell composites as high energy density.

Several projects are focused on sustainable battery production and recycling as part of Activity 1.5. ECO2LIB aims to achieve ecologically and economically viable production and recycling of lithium-ion batteries. RESPECT focuses on flexible, safe, and efficient recycling of Li-ion batteries to support a competitive, circular, and sustainable European battery manufacturing industry. RHINOCEROS is dedicated to reusing, repurposing, reconditioning, and recycling end-of-life electric vehicle (EV) and stationary batteries. Meanwhile, ReALBatt is working on recycling end-of-life lithium-ion batteries to obtain second-use anode and cathode materials for reuse in recyclate lithium-ion cells, contributing to sustainability and circular economy goals.

Under Activity 1.6, projects are focused on advancing battery production and raw material sourcing. BatMix aims to quantitatively assess the future raw material mix for battery production. BrineRIS focuses on building the capacity of Regional Ins[58] in recovering carbon-neutral critical raw materials (CRMs) from geothermal brines. Additionally, there's a project working on a disruptive solvometallurgical flowsheet for the production of battery-grade lithium hydroxide (LiOH) from lithium chloride (LiCl), enhancing the sustainability and efficiency of battery materials production.

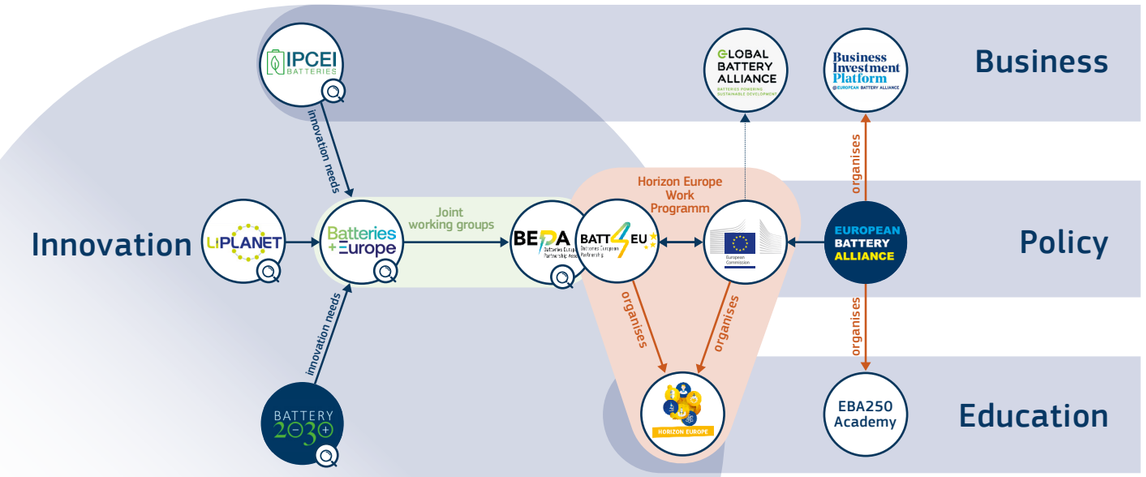
Under Activity 2.1, BatWoMan aims to achieve carbon-neutral European battery cell production through innovative processes and 3D electrode design, with an estimated cost reduction of 63.5% and a reduction in energy consumption by 52.6%. eKoZell focuses on environmental and cost assessments, modeling, and communication management for the battery cell production competence cluster, including cost analysis and life cycle assessment (LCA). The Biobattery project explores large-scale lightweight construction using natural fiber-reinforced bio-based plastics for lithium-ion battery housing, while Sim4Pro develops a digitisation platform – a simulation for battery cell production.

For Activity 2.2, GIGABAT aims to create a sustainable and digitalised gigafactory for battery production in Europe by developing energy-efficient cell manufacturing machinery tailored to gigafactory requirements. SeNSE works on lithium-ion batteries with a silicon anode, nickel-rich cathode, and in-cell sensor for electric vehicles, focusing on next-generation battery packs. DEFACTO focuses on battery design and manufacturing optimisation through multiphysic modeling, particularly in Li-ion cell materials and transport modelling. COBRA explores cobalt-free batteries for future automotive applications, also in the context of Li-ion cell materials and transport modelling. IMAGE strives to establish innovative manufacturing routes for next-generation batteries in Europe, particularly for transport applications.



56 https://batterieseurope.eu/results/technology-roadmap/
57 https://www.sonar-redox.eu/en/H2020-project-SONAR.html
58 https://brineris.pwr.edu.pl/

R&I battery ecosystem in Europe.



Source: Batteries Europe.

Under Activity 3.1, StoRIES has established a European ecosystem of industry and research organisations to develop innovative and cost-effective energy storage solutions. The project aims to accelerate knowledge and technology development in the energy storage field and has organised events like the "Energy Conversion and Storage Days"[59]. FLORES[60] is a network of 15 EU-funded projects focused on next-generation redox flow batteries, fostering collaboration and sharing ideas for more stable and efficient energy storage systems. HYBAT focuses on a hybrid lithium-ion battery storage solution with 1500 V system technology as well as innovative thermal and operational management, while HyFlow[61] aims to develop a sustainable hybrid storage system based on high-power vanadium redox flow batteries and supercapacitors.

Finally, for Activity 3.2, OptiCarge PLUS aims to increase the efficiency and optimisation of regenerative charging infrastructure using vanadium redox flow batteries, innovative DC network structures, and internet connectivity. Battery Passport introduces a robust mechanism for recording battery usage throughout its life assuring future buyers of their worth and thus reducing the net cost and CO_2 footprint of electric vehicles through standardisation. BATREV is conducting a feasibility study on using autonomous robots and operations planning systems for remanufacturing electric vehicle batteries. GreenBattNutzung[62], focuses on developing technologies and methods for energy-efficient battery lifecycles and closed material cycles. SafeLiBatt is dedicated to the development of safety guidelines and risk assessment methods for the first and second life of lithium-ion batteries, ensuring their safe and efficient utilisation.

59 https://www.storiesproject.eu/event-details/energy-conversion-and-storage-days
60 www.linkedin.com/company/flores-–-network-of-flow-battery-research-initiatives
61 https://hyflow-h2020.eu/
62 Part of the German Federal Ministry of Education and Research (BMBF) battery research initiative.

RENEWABLE FUELS AND BIOENERGY

The policy landscape has changed significantly since the introduction of the Fit for 55 package. The unprovoked Russian invasion of Ukraine has also changed the drivers significantly, making security of supply an urgent issue. Renewable fuels and bioenergy can contribute significantly to energy security, however, this is not yet reflected in European policies and strategies.

Recent developments and achievements

The ETIP is due to complete the process of updating the SRIA in 2023; the priorities and status of the value chains have been reviewed in detail. For the CSA SET4BIO, a large number of activities are ongoing. SET4BIO has established funding and financing roadmaps to help project developers to accelerate. Projects and initiatives at EU and Member State level have been mapped and categorised in order to suggest actions and coordination opportunities. The concept of innovation challenges has been refined and described in terms of how it can contribute to the TRL scale. A global outlook has identified all of the initiatives and how they could integrate and collaborate to speed up research, innovation and deployment. Policy recommendations for the Member States and the EU were disseminated by SET4BIO at the EUBCE 2023 conference. At EUBCE 2023 in Bologna, SET4BIO also presented "The Implementation Toolbox" during the session "SET4BIO - a framework to accelerate renewable fuels and bioenergy solutions across Europe and beyond"[63].

There is significant advancement in advanced biofuels technology and demonstration, albeit with limited scale-up and market deployment. The IWG reports a missed IP target for production volumes in 2020 (0.43 Mtoe of the 2.15 Mtoe target). Some examples of projects include BTG-BTL (TRL 9), Chemcell Ethanol (TRL 9), HTL (TRL 5-6) Methanol (TRL 8) BIOMCM and Södra, Clariant Ethanol (TRL 8). A key challenge to scaling up and deploying remains the cost of production compared to fossil fuels.

Other renewable low and gaseous fuel technologies are also advancing in development. Demonstration activities are increasing, but face the same challenges with regard to scale-up and deployment. Several technologies have reached high TRL level but still need to reduce costs. Bioenergy (large scale CHP) technologies are mostly developed and demonstrated but deployment has stalled. Solid, liquid and gaseous intermediate bioenergy carriers have made significant progress in development, demonstration and deployment.

Implementation Plan

SET4BIO presented a proposal for an update of the IP and a status review in a meeting in Brussels on the 31 May 2023. A revision of most targets is foreseen. A review of the current IP identified the following needs for update:

- policy context (e.g. European Green Deal and Fit for 55);
- specific sector targets; the new reference frame – used to be fossil fuels but now changing;
- targets in general;
- investment needs by MS, industry and EU;
- cost data;
- revisiting and confirming value chain priority; and
- revisiting connections to other sectors such as industry and the chemical sector.

So far the focus has mostly been on TRL levels. The inclusion of a Social Readiness Level (SRL) and Commercial Readiness Index (CRI) were also discussed, to facilitate deployment and faster market uptake. Currently, most targets are for 2030. The working group has discussed the inclusion of longer-term 2040 and 2050 targets.

Investment and other needs

The review of investment in the Member States clearly shows that there is significant investment in hydrogen, where the recent RRP-related investment resulted in a sharp increase. For the other technologies such as advanced biofuels, which represent the largest share of the needed investment, there is still a large funding gap. At the moment, 14% of the investment needs for advanced biofuels have been met, 75% for the other renewable liquid and gaseous fuels, 1970% for renewable hydrogen (a 20-fold investment compared to expectations in 2018), 7% for bioenergy and 7% for intermediate bioenergy carriers.

Future prospects and expectations

Renewable fuels and bioenergy have significant potential to replace fossil fuels in existing and future vehicle/vessel fleets with combustion engines, as well as for shipping, aviation and in the transition of sectors/segments where electrification will take over eventually. Renewable hydrogen, when used to increase the yield of biofuels or to produce RFNBOs, can act as a complementary solution in the heat and power sector, balancing the grid as intermittent energy sources continue to grow. It can also be a complementary solution coupled to energy storage with energy security benefits, and become a key technology that adds value within the cascading principle of the broader bioeconomy.

63 https://programme.eubce.com/abstract.php?idabs=20407&idses=1571&idtopic=14

NECP and RRP observations

SET4BIO analysed the reporting under the National Energy and Climate Plans and the Recovery and Resilience Plans (RRP) of the Member States.

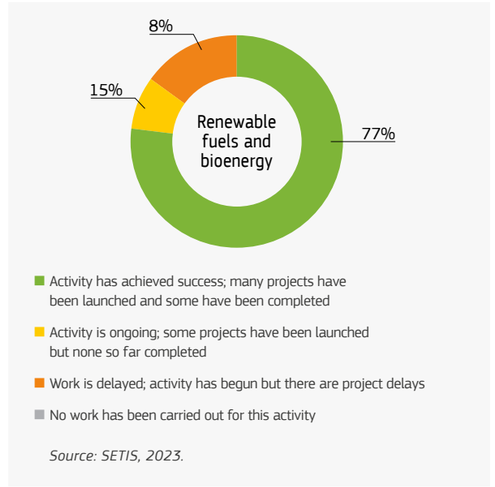
For the NECPs the following observations were made. There is a shift from bioenergy towards advanced liquid biofuels and biomethane, and bio-based products; with a focus on use of residue and waste streams. Some of the trends include circular economy, energy storage, PtX, biofuels, energy efficiency, H_2 synthesis and integration. Its importance in heating and cooling sector will further increase. The NECPs describe the national plans in different ways, and employ a diversity of levels for putting the planned activities into practice. Almost all countries advance the use of biomass for heating and cooling. However, they encourage paying attention to particulate emissions and efficiency of heating appliances, and therefore regulate heating with incentives and restrictions on heating devices.

There is a shift from power-only plants to efficient CHP plants, especially if large domestic resources are available – feed-in tariffs and market incentives are in place. Several countries have decided to phase out coal in power plants. Decarbonisation of the transport sector is expected through the use of alternative fuels, including biofuels, electrification and hydrogen. There is a quota obligation for biofuels in the transport sector set by many countries. Feed-in tariffs for biogas are present in Austria, France, Germany, and Portugal. Though only Poland and Portugal give explicit targets for hydrogen, several countries mention hydrogen for vehicles, development of refuelling infrastructure, and hydrogen injection in the natural gas grid. In terms of the RRPs, renewable hydrogen production and infrastructure development, and strengthening of value chains are strategic areas, which is a clear synergy and acceleration between NECPs and RRPs. There is barely any dedicated funding for bioenergy and biofuels. However, there is dedicated funding (EUR 1.92 billion) for biogas development.

Activities

Almost 80% of the group's 13 activities are reported as including some successfully finished projects (green), two are reported as ongoing (yellow), and only one is experiencing some delays (orange).

Several technologies have progressed despite many challenges. Factors holding back progress include:



Source: SETIS, 2023.

- Policy uncertainty on various levels;
- The combined effect of the multi-layer policy initiatives;
- Lack of technology neutrality with unbalanced focus on single technologies such as electrification and hydrogen;
- The biomass sustainability debate – questioning biomass in general and placing a higher priority on other technologies; and
- Market risk combined with technology risk and capital intensive investments, which often represents too much risk at the same time.

For advanced biofuels, there are currently 18 planned projects, four plants under construction and 39 operational plants (TRL 8-9). The latter consist of:

- 14 HVO plants (10 producing both HVO and SAF);
- 11 Ethanol plants;
- 6 Pyrolysis oil plants;
- 2 SNG/Hydrogen plants;
- 2 Methanol plants;
- 1 Syngas/biochar plant;
- 1 BioLPG plant;
- 1 Isobutene plant; and
- 1 Diesel substitute plant.

Bioenergy (large scale biomass cogeneration of heat and power) technologies are developing and demonstration activities are planned. Scale-up and deployment has somewhat stalled due to strong competition from other power supply technologies. The technology has future potential for grid balancing with more intermittent power.

CARBON CAPTURE AND STORAGE – CARBON CAPTURE AND UTILISATION

CCS-CCU technology will be needed if Europe is going to reach climate neutrality by 2050, and there is a process ongoing to define a strong target for 2040. In short, there is a huge need for investment in development and deployment in these technologies going forward.

The proposed Net Zero Industry Act is setting out a strong basis for investment in both innovation and deployment of these technologies, highlighting the objective of 50 million tonnes of CO_2 operational injection (storage) capacity. This means upscaling of the entire value chain by 2030.

Recent developments and achievements

Some key recent highlights of the IWG on Carbon capture and storage – carbon capture and utilisation (CCS-CCU) include:

- Effective coordination between the IWG and ETIP ZEP, addressing various aspects from carbon removal, CCS, and CCU to supply chain development and biodiversity conservation.
- Active engagement with the Commission/CINEA through IWG/ETIP meetings, workshops, and participation in the CCS/CCU panel at the SET Plan conference in Prague.
- Leading involvement in the CCUS Forum activities, including the development of recommendations for the European CCS and CCU Strategy, particularly in the area of CO_2 transport and storage infrastructure.
- Effective contribution to shaping the Horizon Europe work programme for 2023-2024, aligning research priorities with the European Commission's goals.
- Ongoing monitoring and follow-up of both large- and small-scale CCS and CCU Innovation Fund projects, ensuring progress and success.
- Active participation in ERA-NET ACT projects, fostering collaboration and innovation in the field of carbon capture and utilisation.
- Coordinated input to the Clean Energy Transition Partnership (CETPartnership) from EERA JP CCS and the wider CCUS R&I community, contributing to the transition towards cleaner energy sources.
- Active engagement in the Renewable and Low Carbon Fuel Industrial Alliance, particularly in the context of CCU fuels, to advance sustainable fuel production.

Investment and other needs

There is an abundance of planned and ongoing projects across Europe, with more than 70 becoming operational within five years - given the right preconditions. There are also a great number of announcements regarding agreements and MoUs on CO_2 cross-border transport and storage. The Commission President has communicated that the EU needs to capture and utilise or store between 300 and 640 million tonnes of CO_2 per year by 2050.

The main challenges going forward include:

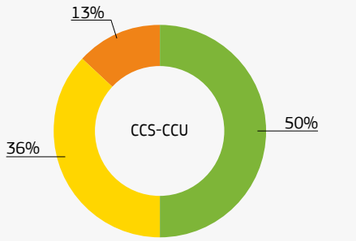
- the need for a CCS and CCU strategy;
- a regulatory framework and network codes/standards/interoperability for Europe-wide CO_2 transport, and a functional business case along the value chain;
- clear incentives/framework for certificates/possible inclusion in the EU ETS, including methodologies and MRV;
- ratification of the London Protocol/bilateral cross-border agreements;
- sustained and coordinated R&I support; and
- a link between the Innovation Fund and the Horizon Europe programme.

It is absolutely crucial that the Member States' plans and strategies for Energy and Climate are updated in line with the EU strategy, ensuring an effective ramp-up of CCS/CCU/CDR.

In this perspective there is a need for the front-loading of public funds at EU and national level for capital-intensive CCS/CCU/CDR.

Future prospects and expectations

The development of the CCS/CCU/CDR industry in the coming years is expected to be highly influenced by policy developments. The CCS Directive, together with the revised EU ETS Directive and TEN-E regulation, and the proposed NZIA, is a good starting point, with the crucial EU CCUS strategy to be published in 2024. Sector-specific instruments like REDII, Refuel EU and Fuel EU Maritime also create a framework for the further deployment of CCU. The price of EU ETS allowances has increased strongly but needs to be complemented by further national support schemes, such as the Dutch SDE++, the Danish support, and the newly presented German programme, in order to really drive deployment across Europe.



- Activity has achieved success; many projects have been launched and some have been completed
- Activity is ongoing; some projects have been launched but none so far completed
- Work is delayed; activity has begun but there are project delays
- No work has been carried out for this activity

Source: SETIS, 2023.

Project support and knowledge-sharing will be crucial going forward, regarding the new challenges that will emerge during implementation. There will also be a strong focus on R&I based on the many new challenges that will emerge from scale-up.

It will be crucial for the revised SET Plan to be much more focused on these challenges and more actively interacting and supportive. More focus on public communication campaigns will be necessary for wide social acceptance.

Activities

The IWG has 8 activities. These are all ongoing and include some successfully finished projects, except Activity 4, "Establish a European CO_2 Storage Atlas", which is slightly delayed for the moment. More detailed information on all deliverables can be found on the IWG's website[64].

64 https://www.ccus-setplan.eu/grant-period-july-2019-june-2022/

NUCLEAR SAFETY

According to the IWG on Nuclear safety, an increased effort is needed to develop, maintain, and reclaim EU industrial capacity, leadership, and skills in innovative nuclear energy technologies, with special regard to small modular reactors (SMR), taking into consideration that a market for such technologies is emerging fast. Advanced SMR types, with high temperature heat energy production potential, will enable the use of these low-carbon technologies for industrial processes and hydrogen generation.

Nuclear energy can substantially contribute to EU decarbonisation ambitions to achieve goals of carbon neutrality of the economy by 2050. It can ensure an even bigger role in energy security than today, and can rely on a high level of technology sovereignty.

Nuclear energy, as a low carbon, dispatchable and affordable source has been recognised by many Member States as part of their energy mix. Currently, there are more than 25 industrial projects (both large nuclear power plants and SMRs) considered in the NECPs of 16 Member States and more if the neighbouring countries are taken into account.

Integrated energy system.

Source: ENGIE Tractebel

Recent developments and achievements

The SET Plan action on Nuclear safety includes ten R&I activities benefitting from increased cooperation and joint programming between the Member States and EU/Euratom, where research consortia, and public and private investment involve industry, research centres, academia and technical safety organisations.

Nuclear energy is the largest dispatchable low-carbon technology which is non-weather dependent and therefore already contributing to the EU's GHG emissions reduction and it will continue to do so in the long run. Both the existing fleet that needs to continue operating, and development and deployment of a new fleet of reactors including SMRs, will ensure a carbon-free European economy. It is important to note that nuclear reactors have a positive impact on raw materials consumption which is low compared to other technologies, as well as a small land-use footprint.

SMRs will go beyond power production and will provide capabilities of crucial importance for, for example, hydrogen production, heat production for industrial applications, district heating and desalination. Due to their technical characteristics, SMRs can bring benefits to small and remote communities for energy production as well as industrial clusters which seek a stable and secure electricity or heat source for the development of their industrial activities.

Some key projects are noted below.

- Olkiluoto 3 (OL3) is an EPR (European Pressurised Water Reactor) plant unit that includes modern proven technology and advanced new safety features, and is delivering 1 600 MW capacity to the Finnish grid.
- Small Modular Reactor (SMR) initiatives within Europe (e.g. NUWARD-TM, GEMINI4.0) are being developed to help decarbonise power systems efficiently from early 2030. For this purpose, EU-funded projects are being carried out (e.g. ELSMOR, ECC-SMART,GEMINI, PASTELS) to design methods and tools for stakeholders to assess and verify SMRs' safety for deployment in the EU.
- The European-SMR pre-partnership has been launched in cooperation between the Commission (DG-ENER), the industry (Nucleareurope), the regulators (ENSREG) and the ETIP (SNETP) to set up a new working programme.
- A European Joint Programme, EJP on Radioactive Waste Management, Geological Disposal and decommissioning (EURAD), launched in June 2019, with the participation of 23 countries (20 EU MS) and more than 110 R&D organisations.
- Together with SNETP, there is an EERA Joint Programme on Nuclear Material (EERA-JPNM) on Innovative materials to improve plant safety and efficiency, and qualification for advanced nuclear fission and fusion systems
- The European Joint Programme in radiation protection, PIANOFORTE, was launched in 2022, supporting MENAS associations to implement the SAMIRA roadmap.
- EUROfusion, the Euratom Joint Programme Implementing the European Fusion technology roadmap, and F4E Euratom Joint Undertaking, support the construction of ITER and the following operation.
- MYRRHA (Multi-purpose hYbrid Research Reactor for High-tech Applications) is the world's first large-scale, accelerator-driven system project that offers unparalleled research opportunities in spent nuclear fuel, nuclear medicine and fundamental and applied physics.
- Advanced Reactors (AR) initiatives are being developed within the EU (e.g. ALLEGRO gas-cooled fast reactor) to help decarbonise the power systems efficiently from 2035. EU-funded projects are being performed (e.g. SAFEG) to design methods and tools.
- Many start-ups emerged last year to develop and implement advanced small modular reactors that are able to make nuclear fission sustainable and that can be used to produce not only electricity but also heat for industrial processes and district heating, hydrogen and others. Some start-ups are also developing micro-reactors (less than 10 MWe) to be used for space exploration.

Investment and other needs

In order to be fit for the challenges ahead with regard to nuclear energy for power and for heat generation for industry, district heating and transport, the SET Plan should pay close attention to:

- The facilitation of deployment of large nuclear reactors to support electrification using state-of-the-art light water technologies which include advanced safety features based on proven technologies by reasonable simplification and acceleration of licensing and permitting processes.
- The harmonisation of licensing of Small Modular Reactors (SMRs) technologies for deployment in European countries willing to do so, with the aim not only to help decarbonise the power systems but also the large market for non-electricity application.
- Ensuring that regulators and TSOs are attractive employers and equipping them with sufficient resources to ascertain capacity and competence availability for fluid application processes.
- Supporting the utilisation of nuclear energy for non-electric applications, especially the delivery of industrial process heat including for large-scale production of low-carbon hydrogen, hydrogen products, district heating/cooling and seawater desalination.
- Maintaining and strengthening existing European know-how, skills, and nuclear technology infrastructure to establish European industrial leadership in nuclear energy sector.
- Corroborating European industrial leadership and technology sovereignty in the nuclear energy sector, especially in innovative nuclear technologies.
- Reinvigorating all elements of the nuclear supply chain including manufacturing of large components. In particular, increasing conversion, enrichment and fuel fabrication capacities available in Europe for nuclear power plants. Enabling advanced SMRs and fuel cycle facilities to minimise nuclear waste.
- Identifying and utilising suitable funds for accelerating the demonstration and deployment of innovative nuclear energy technologies.

Future prospects and expectations

To achieve the objectives in the areas and actions listed above, the IWG on Nuclear safety and the SET Plan SG should cooperate with other relevant initiatives, including the EU SMR Pre-Partnership. The results of such cooperation would have a meaningful impact. The IWG considers the following outcomes to have the highest importance:

- Creating financial incentives to support the demonstration and deployment of new nuclear plants.
- Initiating demonstration and deployment projects in the short term: creating consortia, ensuring financing, committing customers and stakeholders (including policymakers and the public), supporting the development of regionally adapted business models, and identifying sites.
- Accelerating licensing: the harmonisation of the regulatory framework in interested EU countries, with a focus on licensing for all types of nuclear plant.
- Ensuring sufficient human resources: the promotion of technical disciplines and skills in high schools, universities and other tutorial bodies to ensure sufficient human resources for nuclear energy research, development and operation of nuclear reactors, including collaboration between universities and encouraging the involvement of students in nuclear technology research.
- Resuscitating the necessary domestic and international supply chains and infrastructure to perform the necessary R&D for qualification (e.g. in fuel, materials and components).
- The research, development and demonstration of nuclear low-carbon high temperature process heat generation technologies.
- Research and development in low-carbon hydrogen production technologies from nuclear energy, including low and high-temperature processes, such as PEM and HTSE.
- The research, development and demonstration of nuclear low-carbon high temperature process heat generation technologies. European nuclear energy would then be accepted as a safe, reliable and zero-emissions energy source to power European communities, while meeting the requirements of an evolving economy and carbon neutrality to 2050.

All balanced energy mix scenarios in Europe with a strategic long-term vision for a prosperous, modern, competitive and climate-neutral economy by 2050 include nuclear energy. While it is for each EU country to choose whether to make use of nuclear power, it remains the role of the EU, together with its Member States and in the interest of all its citizens, to establish a framework to further develop and support EU/Euratom research and training. The EU has recognised the importance and benefits of this technology through international cooperation, in the context of the Ukrainian war following the Russian invasion, and in a post COVID-19 pandemic EU resilient recovery for the immediate future.

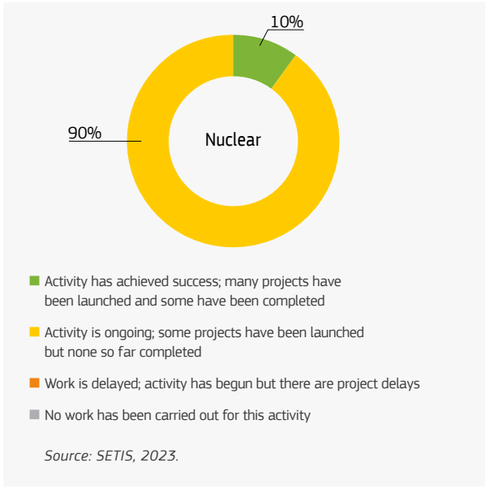
Since all low-carbon technologies are needed to reach the net-zero carbon target by 2050, the IWG has identified the following challenges with regard to the EU's energy R&I objectives:

- Need for better collaboration with the other ETIPs, especially on cross-cutting activities.
- Need for more resources and long-term vision both at MS and EU levels.
- Need for a de-siloed approach to EU energy strategy and the utilisation of all available tools to reach the net-zero goals.
- Need for better coordination between the decision makers within the EU.

Activities

Out of the ten IP activities of the working group on Nuclear safety, one has been reported as including completed projects (green), while the rest are ongoing (yellow).

The projects take place online, with the EURATOM programme regularly bringing together research and training organisations, academia, industry, small and medium enterprises, spin-offs, start-ups, technology platforms, waste management organisations and technical support organisations.



Source: SETIS, 2023.

This enables more collaboration and complementarity with national government, EU Institutions, European fora e.g. Nucleareurope[65], European civil society and International Organisations e.g. OECD/NEA, IAEA and WNA.

Most of the ongoing activities relate to the main pillars of the EU/Euratom Fission Programmes, on the safety of reactor systems, radioprotection and health, radioactive waste management and training and education.

65 https://www.nucleareurope.eu/

CONCLUSION

The SET Plan plays a vital role in bringing together European stakeholders in clean energy research and innovation. The active participation in this report of its 14 working groups, alongside the ETIPs and EERA, demonstrates the effectiveness of the SET Plan's collaborative approach to meeting the ambitious targets of the European Green Deal.

The recently adopted Communication on the revision of the SET Plan will elevate its status and align it with the changing European policy framework. Key cross-cutting R&I challenges such as digitalisation, circularity & materials substitution and skills will be integrated into its work. Monitoring and reporting of the progress of the SET Plan's working groups will also be reinforced. The Joint Research Centre of the European Commission will be working in collaboration with the Directorates-General for Energy and for Research and Innovation and the SET Plan community to strengthen this monitoring and reporting function.

Next year's annual progress report will be the first to record the new, improved SET Plan, and we would welcome your constructive feedback. Your contribution will play a crucial role in shaping the future trajectory of SET Plan reporting, which, in turn, should enhance our collective efforts to implement the European Green Deal. In the words of the Commission President, Ursula von der Leyen, "What gets measured, gets done".

LIST OF ABBREVIATIONS AND DEFINITIONS

AI ..... Artificial intelligence
BEPA ..... atteries European Partnership Association
CAPEX ..... capital expenditure
CCS-CCU ..... carbon capture and storage - carbon capture and utilisation
CDR ..... carbon dioxide removal
CETPartnership ... Clean Energy Transition Partnership
CHP ..... combined heat and power
CINDECS ..... European Climate Neutral Industry Competitiveness Scoreboard
CINEA ..... European Climate, Infrastructure and Environment Executive Agency
COP ..... Conference of the Parties to the United Nations Framework Convention on Climate Change
CRI ..... Commercial Readiness Index
CRM ..... critical raw material
CRMA ..... Critical raw materials act
CSA ..... coordination and support action
CSP ..... concentrated solar power
CST ..... concentrated solar thermal
CSTT ..... concentrated solar thermal technologies
DC ..... direct current
DG ..... Directorate General
DH ..... district heating
DSO ..... distribution system operator
DUT ..... Driving Urban Transitions to a Sustainable Future Partnership
EBA ..... European Battery Alliance
ECTP ..... European Construction, built environment and energy efficient building Technology Platform
EE ..... energy efficiency
EERA ..... European Energy Research Alliance
EIB ..... European Investment Bank
EJP ..... European Joint Programme
EPBD ..... Energy performance of buildings directive
EPO ..... European patent office
EPR ..... European Pressurised Water Reactor
ERA ..... European Research Area
ERA-NET ..... European Research Area Network
ERDF ..... European Regional Development Fund
ESDE ..... Employment and Social Developments in Europe
ESIF ..... European structural and investment funds
ETIP ..... European Technology & Innovation Platform
ETS ..... emissions trading system
EU ..... European Union
EUR ..... euro
EURAD ..... European Joint Programme on Radioactive Waste Management
EURATOM ..... European Atomic Energy Community
EUSEW ..... European Sustainable Energy Week
EV ..... electric vehicle
FOAK ..... first-of-a-kind
GECO ..... Geothermal Emission Control
GHG ..... greenhouse gas
GW ..... gigawatt
HE ..... Horizon Europe
HTF ..... Heat Transfer Fluid
HTSE ..... High-Temperature Steam Electrolysis
HVDC ..... high voltage direct current
HVO ..... Hydrogenated vegetable oil
IAEA ..... International Atomic Energy Agency
ICT ..... information and communications technology
IEA ..... International Energy Agency
IP ..... Implementation Plan
IPCEI ..... Important Project of Common European Interest
IT ..... Information technology
ITER ..... International Thermonuclear Experimental Reactor
IWG ..... Implementation Working Group
JP ..... Joint Programme
JPI ..... Joint Programming Initiative
JPNM ..... Joint Programme on Nuclear Material
JRC ..... Joint Research Centre
KPI ..... key performance indicator
LCA ..... life cycle assessment
LCOE ..... levelised cost of energy
LV ..... low voltage
MFF ..... multiannual financial framework
MS ..... Member State
MV ..... medium voltage
MW ..... megawatt
NCG ..... non-condensable gas
NEA ..... Nuclear Energy Agency
NECP ..... national energy and climate plan
NECPR ..... national energy and climate progress report
NRCG ..... national and regional coordinators group
NZIA ..... Net-zero industry act
OECD ..... Organisation for Economic Co-operation and Development
PCM ..... Phase Change Material
PCP ..... pre-commercial procurement
PED ..... positive energy district
PEM ..... Proton exchange membrane electrolysis
PPA ..... Power Purchase Agreement
PV ..... solar photovoltaic
R&I ..... Research & Innovation
RES ..... renewable energy sources
RFNBO ..... Renewable Fuels of Non-Biological Origin
RHC ..... Renewable Heating and Cooling
RRF ..... Recovery and Resilience Facility
RRP ..... Recovery and Resilience Plan
SAF ..... sustainable aviation fuel
SET Plan ..... Strategic Energy Technology Plan
SETIS ..... Strategic Energy Technology Information System
SG ..... Steering Group
SMR ..... small modular reactor
SNET ..... Smart Networks for Energy Transition
SNETP ..... Sustainable Nuclear Energy Technology Platform
SNG ..... synthetic natural gas
SRIA ..... Strategic Research and Innovation Agenda
SRL ..... Social Readiness Level
STE ..... solar thermal energy
STEM ..... science, technology, engineering and mathematics
SWD ..... staff working document
TES ..... thermal energy storage
TRL ..... technology readiness level
TSO ..... transmission system operator
TWG ..... temporary working group
UNFCCC ..... United Nations Framework Convention on Climate Change
VPP ..... Virtual Power Plant
WNA ..... World Nuclear Association
ZEP ..... Zero Emission Platform

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