European Commission

Policy Brief: Clean energy R&I actions to ensure European energy security[1]

Background and introduction to the study

RAND Europe, with partners CE Delft and E3-Modelling, have carried out a study on clean energy R&I opportunities to ensure European energy security.[2] Recent events have brought Europe's vulnerabilities in energy security to the fore, with the energy crisis following Russia's invasion of Ukraine compounded by the lingering financial, supply chain and economic impact of the COVID-19 pandemic.[3] Objectives of the European Energy Union, the *European Green Deal* and the *Fit for 55* package, have included assuring security of supply, contributing to the EU's energy security as well by promoting energy efficiency and the further development of renewable energy production on European soil.

Box 1. A note on the study scope

17 clean energy technologies were considered as in scope for this study as specified in the TOR: advanced biofuels, bioenergy, concentrated solar energy, geothermal energy, hydropower, ocean energy, photovoltaics, wind energy, renewable and solar fuels, carbon capture utilisation and storage, electricity and heat storage (including batteries, hydrogen and intermediate energy carriers), heat pumps, smart energy grid technologies, energy building and district technologies, off-grid energy systems, energy transmission and distribution technologies, and smart cities. Nuclear energy is out of scope.

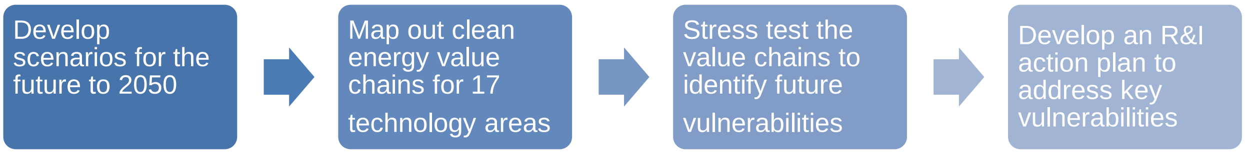
In the coming decades energy security will depend less on uninterrupted access to fossil energy sources but will be increasingly determined by access to energy technologies as well as access to the materials required to produce equipment throughout the stages of the value chain. Clean energy technology value chains not only consist of hardware, in terms of accessibility and availability, but are also shaped by how the value chains are operated, both financially and organisationally, and by the type of stakeholders and entities. At a more detailed level, these phases are embedded in, and supported by, other elements, such as the availability of skilled labour, financial resources and material resources like raw materials, fuels and infrastructure.

As clean energy technologies are deployed at increasing scale and pace, we must consider the energy security of clean energy technology value chains, and where R&I can help prepare, prevent and mitigate against the risk and possible impacts of disruption. The aims of this study were, therefore, to (1) identify the energy security challenges of clean energy value chains now and with a long-term horizon to 2030 and 2050 and R&I opportunities to address

[1] Commissioned under specific contract RTD/2022/SC/023 - Study on clean energy R&I opportunities to ensure European energy security by targeting challenges of distinct energy value chains for 2030 and beyond.
[2] The International Energy Agency defines energy security as 'the uninterrupted availability of energy sources at an affordable price'; International Energy Agency (IEA), Energy Security, (accessed 2024).
[3] Rabbi, M.F.; Popp, J.; Máté, D.; Kovács, S. Energy Security and Energy Transition to Achieve Carbon Neutrality. Energies 2022, 15(21):8126. https://doi.org/10.3390/en15218126

these and (2) produce an action plan to enhance energy security across whole energy technology value chains over the next 10 years, prioritised based on an assessment of potential impact and strategic management tools.

Methodological Approach



The study was delivered across four tasks. In Task 1, the study team refined the overall methodology and developed the scenarios for use throughout the study. Task 2 consisted of in-depth analysis of the energy security of clean energy technology value chains, bringing together technology specific analysis and the wider future context explored in the scenarios to assess energy security criticalities now and with a 2030 and 2050 horizon. Task 3 identified R&I interventions to maintain, boost or mitigate risks for energy security across whole technology value chains, and drew on SWOT analysis to develop an action plan for the next 10 years. In Task 4, a validation workshop convened experts and key stakeholders from across the different technologies in scope to review and refine the study findings.

1. Scenarios

Scenarios (Task 1) are plausible futures and useful tools to consider uncertainty and future developments, designed to represent a wide range of criticalities to inform thinking and decision-making around the selection of R&I actions. The study developed three scenarios out to 2050, based on a structured analysis of trends and drivers, which can act as a 'stress-test' for our analysis of clean energy value chains to ensure the R&I action plan developed is 'future-proofed' across a range of possible future landscapes.

For each scenario (see Figure 1), the study assessed the status of a set of 10 energy security indicators at two timepoints: 2030 and 2050 using a 'RAG' rating approach. This has directly informed the identification of key criticalities for which R&I actions should be developed, by allowing us to consider for different value chains how any existing weaknesses or concerns could be amplified as different futures play out.

These qualitative scenarios have been complemented by quantitative analysis using the GEM-E3 model, providing estimates for global production of clean energy technologies and market shares across the EU and other geographies, and providing insights into the challenges that the EU may face in pursuing decarbonisation and what would be needed to overcome these.

Figure 1. Scenario development

Scenario 1
The EU decarbonises alone, amidst global challenges

- EU has met its Net Zero ambitions, pursuing the green transition at any cost. The rest of the world has not decarbonised, pursuing their policies of the 2020s.
- The world is multipolar, with protectionism and regional instability. Supply chains have regionalised, with some short-lived disruption in particular to critical raw materials.
- The economy is in recession, but the EU has continued to increase investment in energy R&I.
- Public opinion is polarised with regard to the energy transition.
- Global temperature rises are on track for 2.7 ºC warming by 2100.

Scenario 2
A digital EU meets Net Zero with global collaboration

- Net Zero is achieved globally. The EU successfully pursued a Just Transition and public opinion supports the energy transition.
- The world is collaborative, with limited conflict.
- The EU relies on global supply chains and digitalisation to decarbonise. Demand from supply chains and the workforce were strained due to high demand in the 2030s.
- The economy is growing, and the EU has continued to increase investment in energy R&I.
- The cost of energy is lower than in the 2020s.
- Global temperature rises are on track to remain below 2 ºC warming.

Scenario 3
Global conflict overshadows decabonisation priorities

- The EU has missed its decarbonisation target.
- Conflict between major powers, with trade wars and cyberwarfare, has led to major supply chain disruption and regionalisation.
- The economy is in recession and the EU energy R&I investment did not increase compared with the 2020s.
- Global temperature rises are on track to meet 3ºC warming by 2100.

2. Energy security analysis of clean energy technology value chains

The energy security assessment (Task 2) was carried out through a three-step approach (Figure 2). First, the 48 selected clean energy value chains were assessed for energy security using 10 energy security indicators. Then, a longlist of energy security criticalities was compiled by combining the value chain assessments with the scenarios developed in Task 1. Finally, a shortlist of key energy security criticalities was established by selecting the most urgent criticalities from the longlist based on several criteria. These are summarised in Figure 3.

Figure 1. Steps in value chain assessment

Overall, the geopolitical availability and abundance of Critical Raw Materials (CRMs), digital vulnerability and skills came out as the main energy security risks across the clean energy technology landscape. In several cases, digital vulnerability and skills were originally not shortlisted as key criticality, but validation workshop participants indicated that the sector perceived them as significant risks.

Identified risks related to the supply chain complexity or supply chain location often were linked to geopolitical availability and abundance of CRMs. Also, several risks identified as issues of broader sustainability were linked to CRMs, for instance their mining or their end-of-life disposal.

In addition to advanced electronics for 'smart' technologies, the availability of which was identified as a key criticality by the initial assessment, validation workshop participants pointed at the importance of 'standard', low technology electronics as well. Supply chains for this type of electronics have been disrupted recently and are projected to remain under pressure in the future.

Box 2. Validation workshop

The study included a hybrid validation workshop with 50 participants from research organisations, academia, trade bodies, think tanks, industry), DG RTD, DG ENER and JRC. Participants brought expertise in 16 technologies and expertise on CRM, sustainability, international trade, energy policy and climate adaptation. In the workshop, the participants validated and provided feedback on the shortlist of key energy security criticalities; and worked with the study team to develop and refine R&I interventions to address the energy security criticalities.

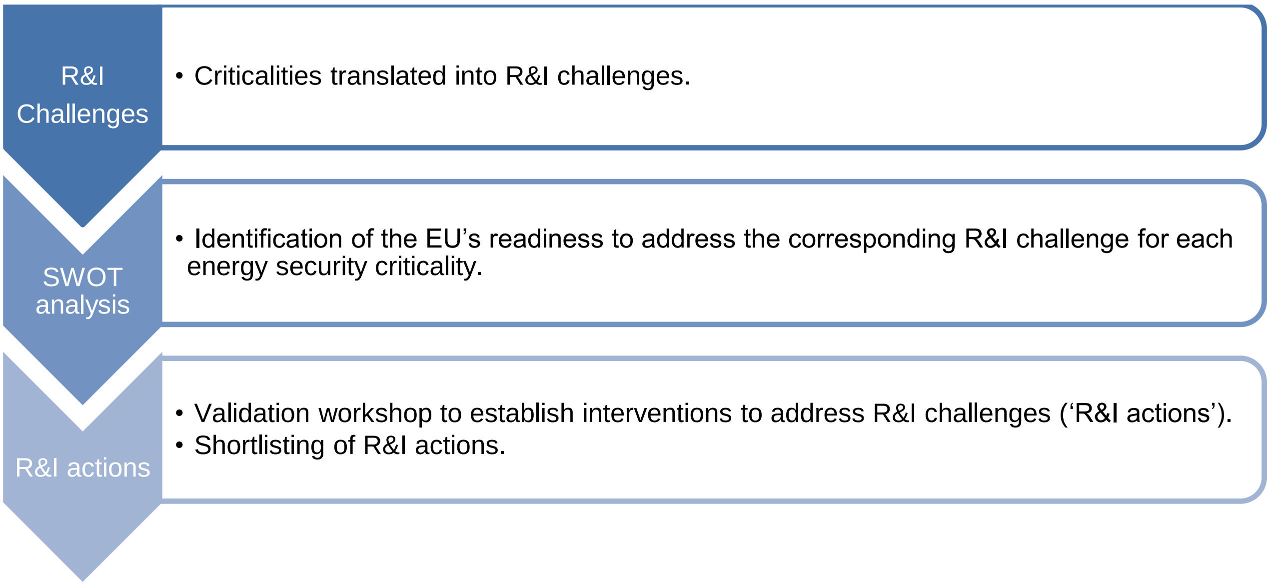
As for digital connectivity, 'smart' technologies are especially vulnerable, but also technologies where cyberattacks may cause significant physical damage, such as wind turbines. To this, validation workshop participants added digital vulnerabilities arising from interconnectivity between several devices in a single household or industrial facility, such as heat pumps, solar panels and charging devices.

For skills, it was noted that there is a general shortage of 'installation skills', arising from competing clean energy technologies all struggling to reel in sufficient installation capacity. On the other hand, the current situation is not necessarily an accurate prediction of skills availability in the longer term, when clean energy technologies will have had the opportunity to establish themselves more strongly.

3. R&I action plan

To develop an R&I action plan (Task 3), the shortlisted criticalities were evaluated to identify the EU's readiness to address the corresponding R&I challenge for each energy security criticality. A SWOT analysis considered whether existing R&I programmes are addressing the energy security criticality, to what extent the EU is globally competitive for R&I in that area, opportunities for collaboration, whether solutions to the criticality are already in development, and potential threats.

Figure 3. Process for development of the R&I action plan



The findings were presented to experts in the validation workshop (Task 4), who highlighted missing criticalities, validated the suggested R&I interventions ('actions'), and proposed alternative/modified interventions to address the criticalities (see Box 2). The table below presents the top nine highest-priority R&I actions, prioritised based on our SWOT analysis. Full details on all 30 actions are provided in Section 10 of the full report, including criticalities covered, expected outcome and scope (which criticality and value chain the action addresses), suggested Technology Readiness Level (TRL) by the end of the project and potential funding programmes.

Highest-priority energy security criticalities	R&I actions	Relevant value chain
Batteries *Supply chain location*	**Improving the energy efficiency of battery manufacturing and recycling** *Improving the energy efficiency of these processes would provide a mechanism to increase competitiveness for an EU-based supply chain; address currently missing capabilities, such as raw materials processing; and develop skills and know-how for an EU battery supply chain.*	Lithium-based batteries
CRM *Security of supply of CRMs*	**Research and public engagement on mining of CRMs** *Research and public engagement on mining of CRM would provide a better understanding of public concerns and mechanisms to address them (e.g. sustainable mining practices with minimal environmental impact, improved working conditions and operations). This will be important to enable domestic production to be increased, thereby de-risking a range of clean energy technologies, and would inform both technical approaches and policy and regulation in this area, as well as international production to ensure consistent supply and imports from countries outside of the EU. This is a shared, international challenge requiring cooperation.*	Mining of all CRM, in particular: cadmium telluride and perovskite PV (supply of cadmium, telluride, copper, lead); batteries (cobalt, lithium); semiconductors and microchips in smart technologies, where public opposition is a risk within and out of the EU due to mining practices and environmental impact

Energy transmission and distribution technologies *Availability and abundance of CRMs (copper and aluminium)*	**Increasing circular economy processes, recycling and reuse of electronics for smart energy technologies** *R&I programme to increase recycling and reuse in energy transmission and distribution and develop the sustainable production of aluminium and other alternatives. The call would take a two-pronged approach, looking at opportunities to replace copper with aluminium more energy efficiently, and considering how to incorporate sustainable aluminium.*	HVDC cabling
Geothermal energy *Availability and abundance of CRMs (aluminium, copper, nickel, titanium, chromium)*	**Implementing a 'design to recycling' scheme for geothermal energy** *This Horizon Europe call would aim to implement a 'design to recycling' scheme, including reducing and reusing CRMs in geothermal energy.*	Construction phase of geothermal plants (CRM usage), end-of-life phase (all materials, including for casing and cementing)
Hydrogen *Supply chain resilience*	**A call for solutions to increase the resilience of hydrogen value chains** *With hydrogen technologies still in development, a call would support the development of solutions to increase the resilience of a future commercial value chain. This may include digital solutions, process efficiency improvements, reduced reliance on CRMs and water, design considerations for reduced complexity, and standard performance benchmarks.*	Solid oxide electrolysers (work at high temperature), electrodes and catalysts (CRM), and anion exchange membranes (AEM) (membrane component, water usage)
Compressed air energy storage (CAES) *Sustainability and environmental impacts*	**Developing a better understanding of the potential locations for underground CAES** *This research programme would aim to develop a better understanding of the potential locations for underground CAES. The extensive exploration for underground storage space adds considerable complexity to the construction and use of CAES, since CAES can only be deployed in areas where suitable underground cavities are available. The (environmental) risks of compressed air storage in depleted gas fields are relatively unknown and necessitate additional research. This could also help to ensure local social acceptance*	Compressor and expansion system, above-ground storage tanks prior to injection, location of storage sites
PV *Supply chain location*	**Collaborative industry programme to increase the efficiency of PV manufacturing in the EU** *This Horizon Europe collaborative industry programme would support initial new supply chains focused on increasing the efficiency of solar PV manufacturing processes in the EU. This would support the development of solutions enabling onshoring and cost competitiveness of EU-based PV supply chains.*	Construction of silicon-based PV modules and CRM within modules
Smart energy grid technologies and energy building and district technologies *Digital vulnerability*	**Addressing cybersecurity risks to smart energy grid, building and district heating technologies** *This intervention would develop solutions to address cybersecurity risks, including research to ensure cybersecurity can be maintained for legacy systems. Understanding of the landscape of threats will help inform regulation and standards.*	Advanced meter infrastructure, advanced control technologies and home energy management systems

Smart energy grids, smart cities, and energy buildings and district heating technologies *Availability and abundance of CRMs and location of advanced electronics supply chains (palladium, cobalt, gallium, germanium, silicon, rare earth materials)*	**Increasing circular economy processes, recycling and reuse of electronics for smart energy technologies** *Recycling and reuse of electronics is currently low, and as early generation technologies reach end of life, there is an opportunity to support EU supply through recycling and reuse of these resources. This intervention would develop circular economy processes to increase the recycling and reuse of electronics for smart energy technologies. In particular, this should focus on the opportunities to reuse CRMs and will provide mechanisms to increase self-sufficiency within the EU.*	Construction and end-of-life phases in these technologies (less relevant for electric vehicle smart charging), including e-waste and cable waste, advanced metering infrastructure (which often incorporates semiconductors)

4. Reflections

Through a detailed analysis of clean energy value chains, the R&I landscape and potential futures for energy security, this study has developed a comprehensive R&I action plan for the EU, which sets out 30 actions that can be taken to mitigate risks and capitalise on strengths to help ensure EU energy security to 2050 as the EU transitions to clean energy technologies.

Across the study, the question of the energy system and how clean energy technologies will interact and interconnect with each other in the future clean energy technology system is crucial (e.g., hybridisation, co-benefits, social dimension to futureproof the energy system). A systems-level study would, therefore, complement the findings of this study, in particular identifying where energy security criticalities of one technology can be mitigated through the system, and which introduce potential cascading or compounding risks into the energy system.

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