European Commission

Study on clean energy R&I opportunities to ensure European energy security by targeting challenges of distinct energy value chains for 2030 and beyond

Executive summary

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Research and Innovation

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Study on clean energy R&I opportunities to ensure European energy security by targeting challenges of distinct energy value chains for 2030 and beyond

Executive summary

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RAND Europe, CE Delft and E3-Modelling

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EXECUTIVE SUMMARY

In the coming decades, energy security[1] will depend less on uninterrupted access to fossil energy sources and will be increasingly determined by the access to clean energy technologies, materials and components. This study, delivered by RAND Europe, CE Delft and E3-Modelling for the European Commission, aims to assess the energy security challenges of clean energy value chains now and looking to 2050, and to identify research and innovation (R&I) actions to address them.

Study approach. The methodology for this study brings together plausible future scenarios complemented with macroeconomic modelling from GEM-E3, with in-depth analysis of the energy security components of clean energy technology value chains. With this understanding of internal strengths and weaknesses for energy security and external opportunities and threats, research and innovation interventions were identified and strategically prioritised with the aim to strengthen European energy security.

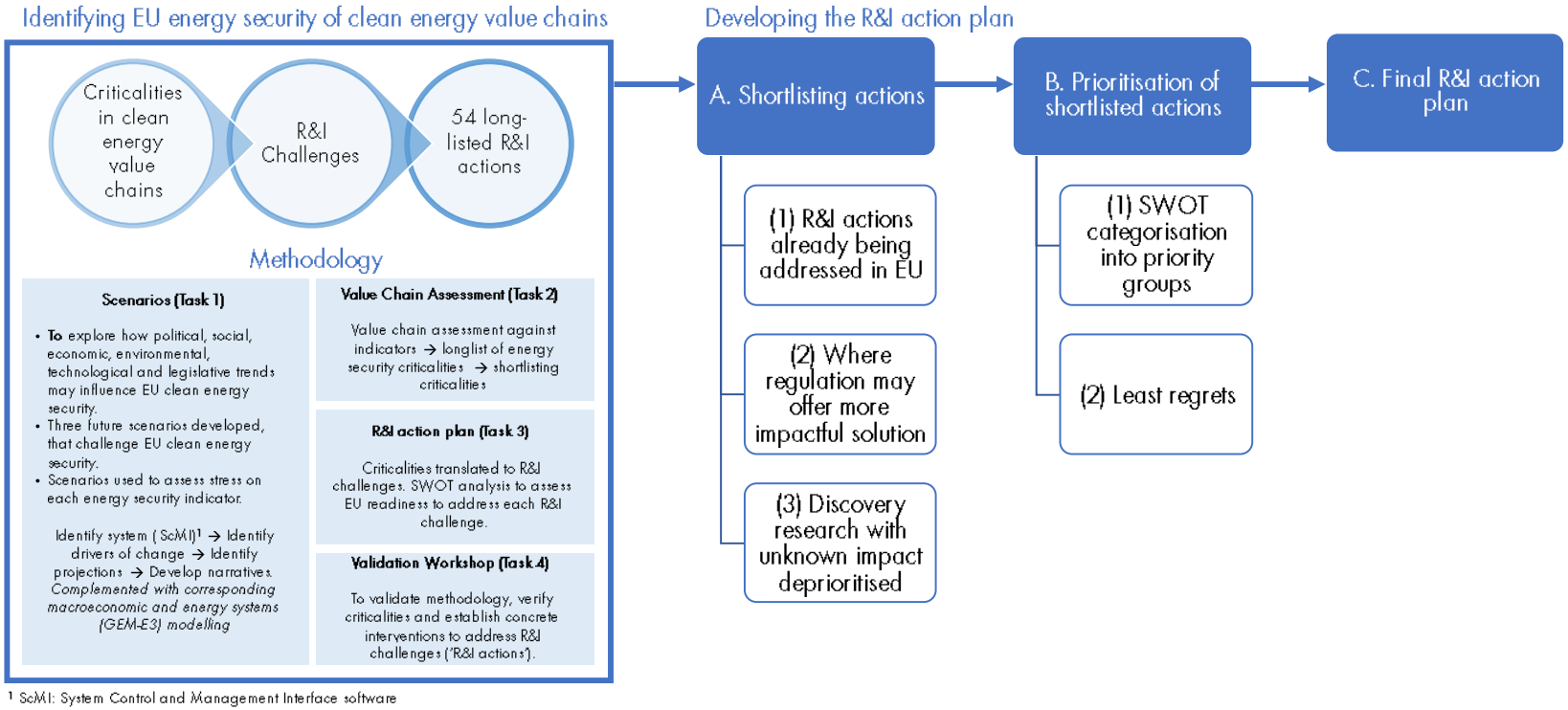
Future considerations for EU clean energy security. Three scenario narratives were developed to explore the context influencing EU clean energy security. Key drivers of change include the pace of EU and global decarbonisation, international relations and global trade, geopolitical uncertainty and conflict, digitalisation and cybersecurity, and climate adaptation.

Energy security criticalities of clean energy technology value chains. Analysis was conducted for 48 specific clean energy technology value chains across 17 technologies: Advanced Biofuels, Bioenergy, Concentrated Solar Energy, Geothermal Energy, Hydropower, Ocean Energy, Photovoltaics (PV), Wind Energy, Direct 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 Heating Technologies, Off-grid Energy Systems, Energy Transmission and Distribution Technologies, and Smart Cities. For each technology, we identified energy security criticalities (points of failure in the value chain) based on the assessment of each value chain against 10 key indicators: geopolitical availability of critical raw materials (CRMs); natural abundance of CRMs and biomass; circularity of the value chain; supply chain complexity; supply chain location (with the assumption that value chains outside the EU are less secure); digital vulnerability; physical vulnerability; broader sustainability; affordability; and skills. We also holistically assessed these criticalities in the context of the wider technology clusters. The key energy security criticalities were then shortlisted for R&I intervention based on qualitative assessment and expert judgement, with consideration of the assessment against energy security indicators as described above and of the future scenarios and how they may interact with these indicators at two time points: 2030 and 2050. We also took into account the expected scale of the technology and role in the energy system. This generated a list of criticalities against which we could generate potential R&I actions.

R&I action plan. R&I can help develop a greater understanding or solutions to challenges. This action plan was developed based on strengths, weaknesses, opportunities, and threats (SWOT) analysis of the EU R&I ecosystem; a review of existing R&I programmes; and expert input to ensure relevance, feasibility, potential impact and futureproofing. Actions were shortlisted and prioritised in the following steps:

[1] Energy security is defined as 'the uninterrupted availability of energy sources at an affordable price', International Energy Agency, Energy Security.

Figure 1. Representation of the study methodology and steps towards identifying the final R&I action plan. ScMI: System Control and Management Interface software.



In the table below, we present the top 9 highest-priority R&I actions, prioritised based on our SWOT analysis. Full details on all 30 actions are provided in Section 10, 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 derisking 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 increase 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)

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In the coming decades energy security will depend less on uninterrupted access to fossil energy sources and will be increasingly determined by the access to clean energy technologies, materials and components. This study, delivered by RAND Europe, CE Delft and E3-Modelling for the European Commission, assessed the energy security challenges of 17 clean energy value chains now and looking to 2050, and identified 30 research and innovation actions to address them. The bespoke methodology brought together futures methods and macroeconomic modelling, value chains analysis and strategic decision-making tools to set out priorities for action.

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