Strategic priorities in energy research and innovation

The Swedish Energy Agency's research and innovation commitments for a sustainable transition

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Preface

Climate change is the greatest societal challenge of our time. For Sweden, and the world, significant changes must be made to the existing energy systems to achieve the ambitious energy and climate goals within a relatively short timeframe. Regard-less of the path this development takes, there is a need for more knowledge, expertise and solutions that will guide the transition of our future society towards a fossil-free, robust, and competitive existence. Governance, choice of pathways, and potential conflicts of interest need to be analysed at a systems level to gain a thorough overview and understanding.

The key to success lies in executing an energy transition that benefits the entirety of Swedish society. The transition should bolster Sweden's competitiveness and create new job opportunities in Sweden.

By enhancing collaboration with key stakeholders in Sweden, the EU and globally, the conditions are created for Sweden to be able to influence the EU's current and future energy policy. This approach simultaneously opens up greater avenues for Swedish businesses to penetrate into international markets.

The Swedish Energy Agency is Sweden's foremost funder of energy research, actively engaging in the energy transition at every societal level: locally, nationally, and internationally. Our mandate includes strategically and cohesively financing research and innovation, in close collaboration with other energy and climate policy measures and instruments. Over the years, we have developed the tools required for successful research and innovation. The initiatives we support are of high quality and contribute to the energy transition in various ways.

To maintain its status as a nation in the forefront of innovation and knowledge in the energy field, Sweden needs to bolster efforts in both academic research and marketdriven innovation initiatives in the business sector.

In this report, the Swedish Energy Agency outlines its prioritised initiatives for research and innovation in the energy sector for the period 2025-2028. This report serves as a complement to the government's research and innovation policy, jointly submitted by Formas, Forte, the Swedish National Space Agency, the Swedish Research Council, Vinnova and the Swedish Energy Agency.

It is my hope that this report will provide in-depth knowledge on how intensified efforts in research and innovation in the energy field can contribute to the critical green transition that we are currently experiencing and will continue to face in the future.

Robert Andrén Director General

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Summary

Climate change is the most significant societal challenge of our era. To achieve ambitious energy and climate targets within a relatively short time frame, Sweden and the world must undertake substantial changes to the existing energy systems. Around the world, initiatives are underway to transition to fossil-free energy production and more energy efficient energy systems. Sweden has long held a leading position in this transition, boasting numerous strong research environments contributing innovative sustainable technologies and solutions. Swedish companies in the export sector not only exhibit high ambitions but are also strategically positioned to provide the innovations necessary for this global transition. Simultaneously, there is a growing demand for specialized expertise, with businesses highlighting the need for increased public funding in energy related research and innovation. For the energy and climate transition to be truly successful, it must be executed in a manner that benefits the Swedish society and its citizens.

The objective is a sustainable energy transition that significantly reduces greenhouse gas emissions, strengthens Swedish competitiveness, and generates new job opportunities within the country. The Swedish Energy Agency is a central stakeholder in the energy and climate transition, tasked with strategically and cohesively funding research and innovation in close collaboration with other energy and climate policy initiatives and instruments, both domestically and internationally. Aided by both the holistic approach and system perspective that the Swedish Energy Agency has within the energy area, initiatives within research and innovation are formed and developed that effectively contribute to a sustainable energy transition. The increased need of system-level initiatives for the energy and climate transition is characterised by an enhanced interconnection between sectors and stakeholders. Challenges that once could be addressed within traditional industries and sectors now demand a more holistic, system-wide approach.

Strengthening of five prioritised areas

In this report, the Swedish Energy Agency identifies five key areas at the system level that require increased funding for research and innovation.



Figure 1. The Swedish Energy Agency's areas of priority

Technology and sustainable value chains for energy transition and competitiveness

To equip society with the products and solutions necessary for the energy transition, the development of new technologies and the creation of new value chains are essential. This necessitates new resource flows, business models, competencies and the emergence of an entirely new ecosystem of stakeholders. There is a particular need to enhance research and innovation in the fields of batteries, hydrogen, nuclear power, and fossil-free aviation.

Accelerated energy system transition through system demonstrators and business development

The use of demonstrators reduces both technical and commercial risks for business and societal stakeholders. Many of the technologies essential for the energy transition have not yet passed the demonstrator stage. System demonstrators are designed with the aim to solve complex system-level challenges by conducting tests in relevant contexts, often involving extensive collaboration among societal stakeholders. Technological and system demonstrators hold great potential to accelerate the transition but can be costly. Consequently, there is a need for enhanced resource allocation for these purposes. Additionally, the Swedish Energy Agency identifies a requirement for increased support in transforming knowledge and ideas into new, innovative companies.

A resilient and robust energy system

The need for research and innovation to understand and identify potential risks and threats grows as the energy system evolves towards becoming fossil-free, electrified, and digitalised. Additionally, the escalating demand for electricity necessitates further research and innovation focused on flexibility, diversification, robustness, and capacity within the energy system.

Governance, conflicting objectives, and pathways for the energy system

The energy system is currently undergoing extensive transformations, with various developmental trajectories being plausible. Governance, strategic choices, and potential conflicts of interest necessitate analysis at a comprehensive system level. To this end, increased resources for methodological development in the areas of modelling and analysis are essential, facilitating the evaluation and strategic planning of a future energy system. This approach can contribute to well-informed decisions and policy development at all levels of society.

Enhanced competence for energy transition

The energy transition often involves radical technological shifts and the establishment of entirely new value chains. It is particularly dependent on a well-functioning supply of expertise. With this in mind, the persisting downward trend in the number of new doctoral students in technical disciplines is a cause for concern. Initiatives are needed to ensure a steady flow of researchers and educators in higher education, as well as a sufficient number of doctorate-level professionals in the business and public administration sectors of the energy field.

Research and innovation to facilitate the energy transition

The Swedish Energy Agency's allocation of research and innovation, the so called "energiforskningsanslaget," has largely remained unchanged since 2019. This stands in contrast to a time when the energy transition is high on the agenda, with significant resources being allocated to energy and climate areas in both the EU and other countries. The Agency assesses that this research and innovation funding needs an increase of 870 million SEK annually in a fully developed programme by 2028. Additionally, the administrative allocation should be increased with 10 million SEK per year to enhance both EU-focused efforts and international collaborations.

Table 1. Summary of proposed increases in resources for energy research and innovation

Year	2025	2026	2027	2028
Technology and sustainable value chains for energy transition	150	240	300	300
System demonstrators and business development for accelerated energy transition	200	240	270	270
A resilient and robust energy system	50	70	100	100
Increased competence for energy transition	50	150	150	150
Governance, conflicting objectives and pathways for the energy system	30	40	50	50
Total	480	740	870	870
The administrative allocation				
both EU and international forums.	10	10	10	10
Total	10	10	10	10

Opportunities and challenges of the energy transition



1. Opportunities and challenges of the energy transition

Climate change is the greatest societal challenge of our era. For Sweden and the world to achieve the ambitious energy and climate goals within a relatively short timeframe, substantial changes to existing energy systems are necessary. To ensure the success of the energy transition, it needs be conducted in a way that benefits Swedish society, strengthens Sweden's competitiveness, and creates additional job opportunities within the country.

The rising levels of carbon dioxide in the atmosphere are altering Earth's living conditions. The UN's Intergovernmental Panel on Climate Change (IPCC) assesses that greenhouse gas emissions are already causing an increased frequency of extreme weather and climate events across the globe, with severe consequences for both nature and humanity.¹ To mitigate greenhouse gas emissions, ambitious energy and climate policy targets have been set. Achieving these goals necessitates contributions from all societal actors in the transition process.

The energy and climate transition presents a major challenge, yet it also offers substantial opportunities for Sweden as research and industrial nation. The country has many strong research environments capable of advancing new technologies and solutions. Swedish companies in the export industry not only have high ambitions but are also strategically positioned to make significant contributions to the global transition. Simultaneously, these companies are calling for greater access to knowledge and expertise, highlighting the necessity for increased public funding in energy-related research and innovation to meet this demand.

An increasing number of Swedish companies recognize the need for a more proactive policy that supports both Sweden's energy and climate transition and the competitiveness of Swedish businesses, a factor that is essential for creating employment opportunities and generating export revenues.

¹ IPCC, 2023: Sections. In: Climate Change 2023: Synthesis Report. https://www.ipcc.ch/report/sixth-assessment-report-cycle/

1.1. The transition needs to occur swiftly and affect the entire society

Currently, 74 per cent of Sweden's total greenhouse gas emissions are related to energy.² In Sweden, the industrial and transport sectors account for the largest share of emissions, while globally, electricity production and heating are significant sources of emission. Since 2010, Sweden's greenhouse gas emissions have been reduced by 26 per cent.³ The transition of the energy system is imperative to continue this reduction and to mitigate the impact of global warming.

The energy transition necessitates the acceleration of electrification in the industrial and transport sectors, leading to a significant increase in electricity demand. The Swedish Energy Agency's scenarios indicate that electricity demand will double within 20-25 years, compared to current levels.⁴ To manage such a significant increase in electricity production, the expansion of all forms of fossil-free energy sources must be facilitated. The increasing degree of electrification calls for an entirely different power system from what exists today, with an enhanced focus on flexibility, resilience, and robustness. Matters concerning energy storage, demand-side flexibility, energy efficiency and the efficient use of resources, as well as energy infrastructure such as the electricity grid, are becoming increasingly crucial. Furthermore, the transition will necessitate considerable investment to develop new value chains, which in turn will require access to various raw materials and critical resources.

The energy system includes all aspects of energy use, production, and distribution across all sectors of society, as well as the stakeholders involved.

The term "energy transition" here refers to the from today's fossil-fuel intensive society to one that is free from fossil-fuels like coal, oil, and natural gas.

Globally, significant efforts are being made to shift towards fossil-free energy production and a more energy-efficient energy system. Sweden has long been at the forefront of this transition, receiving considerable backing from both public institutions and the private sector in pursuit of ambitious targets.^{5,6}

² National Inventory Report Sweden 2022, Naturvårdsverket 2022, sid 15. UNFCCC.

³ Sveriges officiella statistik, Naturvårdsverket..

⁴ Scenarier över Sveriges energisystem 2023, ER2023:07, Energimyndigheten, 2023.

⁵ regeringsforklaringen-2022.pdf (regeringen.se).

⁶ https://fossilfrittsverige.se/



Figure 2. Illustration of the development of Sweden's electricity production. Source: The Swedish Energy Agency.⁷

Over the past year, the geopolitical landscape, most notably marked by Russia's invasion of Ukraine, has underscored the necessity of the energy transition to ensure the security of Sweden's energy supply in times of crisis.⁸ By reducing dependence on imported energy sources like coal, oil, and natural gas, Sweden can further the phasing out of fossil fuels in Sweden. However, this transition, coupled with increased electrification, presents new challenges in maintaining a reliable energy supply.

The practical implications of the energy transition can differ. In some instances, it involves replacing fossil fuels with renewable alternatives or changing specific components within a technical system or value chain. In other cases, it may require changes that introduce entirely new technologies, systems, or configurations of stakeholders. Consequently, this leads to a growing need to develop new value chains and resource flows.

Many of the value chains currently in development, such as those for batteries and hydrogen-related technologies, rely on raw materials that are subject to intense global competition and lack established value chains. In these areas, it is crucial to consider the social, ecological and economic aspects, particularly in activities like mineral extraction.

Emerging applications of Artificial Intelligence (AI), together with digitalisation, will likely influence the evolution and operation of both the energy system and society in multiple ways. This includes smarter management and optimisation, enhanced capability to analyse large available datasets, various forms of automation/autonomous systems, and support in development and innovation processes. However, such technologies may also result in increased energy consumption, along with new systemic risks and vulnerabilities.

⁷ Scenarier över Sveriges energisystem 2023 – Med fokus på elektrifieringen 2050, ER 2023:07, Energimyndigheten.

⁸ World Energy Outlook 2022, IEA.

1.2. EU's energy and climate policy is focused on strengthening competitivity and security of supply

Within the EU, there is a pronounced ambition to expedite the energy transition. Presently, substantial changes are being made to legislation and various policy instruments at the EU-level, all of which are crucial for the energy and climate sectors. One such example is the EU's Green Deal wherein the Green Deal Industrial Plan aims to accelerate the EU's journey towards climate-neutrality.⁹ The plan aims to establish conditions conducive to enhancing the EU's ability to produce the products and technological solutions necessary meeting the EU's climate objectives. Key components are being implemented through the Fit for 55 package and the RePowerEU plan.¹⁰

The RePowerEU plan, presented in May 2022, focuses on reducing the EU's reliance on imported fuels by increasing energy efficiency and reducing energy consumption, diversifying the energy supply, and hastening the replacement of fossil fuels through an accelerated energy transition. A key component of its implementation is the intelligent combination of reforms and investments.

The EU's energy policy highlights the strong interlinkage between energy policy, economic policy, and security policy. There is a distinct aspiration within the EU for its business sector to capitalize on the opportunities for industrial development and the establishment of new industries that the transition offers. The EU's implementation strategy involves a variety of tools to improve policy frameworks and access to financing. This development presents substantial opportunities for the Swedish business sector to exploit.

Policy changes at the EU-level, such as revised directives and regulations, are integrated into Swedish legislation, thereby significantly influencing the development of the energy sector in Sweden. Often, policy changes concerning markets, technologies, and value chains are of strategic relevance to Sweden, including biofuels, hydrogen, metals/ ores, and batteries. It is crucial for Sweden to engage in this work at the EU-level, both to comprehend the consequences of the energy transition for Sweden and the EU, but also to capitalize on the opportunities that arise.

⁹ A European Green Deal (europa.eu).

¹⁰ REPowerEU: affordable, secure and sustainable energy for Europe (<u>europa.eu</u>) 55 %-paketet –EU:s plan för en grön omställning - Consilium (<u>europa.eu</u>).

The energy issue has evolved into a matter of considerable strategic and geopolitical importance. To protect Swedish interests, there is an increasing need for Swedish representation at various international and energy-related forums.



Figure 3. Energy research and innovation (R&I) are connected to energy policy at both the national and EU levels.

1.3. Research and innovation is a part of the solution

Strengthening research and innovation initiatives in the field of energy is vital in facilitating of society's energy transition and to safeguard both Swedish competitiveness and the security of the energy supply. In the report "Science, Technology and Innovation Outlook 2023" from the Organisation for Economic Co-operation and Development (OECD), the need for more ambitious efforts in policy portfolios that create markets for new fossil-free products and solutions is emphasized.¹¹ The report also lifts the need for greater investments in targeted research and innovation initiatives as a key component of such a portfolio.

A fundamental requirement for enabling various stakeholders to act and make wellinformed decisions during the transition is a comprehensive understanding of potential development pathways and their implications. In this context, there is a growing demand for research-based evidence, analyses, and models.

In addition to research-based knowledge and new solutions, it is equally important to have a workforce with the right competence to implement the energy transition.¹² Challenge-driven research and innovation programmes, conducted in collaboration with companies, help ensure that corporate research and development efforts are increasingly performed in Sweden.¹³ The transition of the energy system thereby creates an environment for Swedish companies to contribute new technologies and innovations on the global markets.

¹¹ Science, Technology and Innovation Outlook 2023, OECD.

¹² En ny politik för en ny tid. Svenskt näringslivs inspel till forskningspropositionen 2024, Svenskt näringsliv 2023; Kunskap för Framtiden: STEM i ljuset av den gröna och digitala omställningen. Naturvetarna, juni 2023; Undersökning om kompetensbehov bland Energiföretagens medlemmar och branschens attraktivitet på arbetsmarknaden, Energiföretagen 2022; Teknikföretagens inspel till forsknings- och innovationspropositionen 2024, Teknikföretagen 2023.

¹³ The long-term effects of R&D subsidies on firm performance: Evidence from a regression discontinuity design, WP 2022:02, Tillväxtanalys 2022.

Goals that impact the Swedish Energy Agency's research and innovation mandate

The overarching objective of the energy policy is to establish conditions conducive to effective and sustainable energy use and a cost-effective energy supply in Sweden, with minimal adverse impacts on health, the environment, and the climate. The policy aims to harmonize security of supply, competitiveness, and ecological sustainability.

By 2045, Sweden aims to achieve net zero emissions of greenhouse gases to the atmosphere, and subsequently, negative emissions. By 2030, Sweden's energy use is to be 50 per cent more efficient compared to 2005. All electricity production is targeted to be fossil-free by 2040. Greenhouse gas emissions from domestic transport are expected to decrease by at least 70 per cent by 2030 compared to 2010 levels.

The European Climate Law (Regulation (EU) 2021/1119) sets a target for Europe's economy and society to achieve climate neutrality by 2050. An interim target for 2030 is to reduce greenhouse gas emissions by at least 55 per cent compared to the levels in 1990.

The aim of the economic policy is to strengthen Swedish competitiveness and create conditions for increased job opportunities and a greater number of growing companies. The objective of the research policy is to position for Sweden among the world's foremost research and innovation nation, and as a leading knowledge-nation. This entails promoting high-quality research, advanced higher education, and innovation that contribute to societal development and welfare, boost the competitiveness of the business sector, and address the societal challenges faced both in Sweden and globally.

The policy objectives for civil preparedness aim to strengthen Sweden's ability to manage increased readiness and, ultimately, preparedness for war on a broad front. Energy policy is an important part of Sweden's civil defence, as reflected in the Swedish Energy Agency's mandate as the authority responsible for preparedness in the energy area.

The Swedish Energy Agency's role and methods



2. The Swedish Energy Agency's role and methods

The Swedish Energy Agency serves as both the preparedness authority and the responsible authority within the field of energy. A key aspect of these mandates involves strategically and cohesively funding research and innovation, in close collaboration with other energy policy initiatives.

As an expert authority, the Swedish Energy Agency is tasked with enhancing knowledge about the energy system and the interconnectivity of the energy system with other sectors in society. The task also entails providing insight to energy and climate policies, both nationally and within the EU. Additionally, the Agency is responsible for managing and developing policy instruments to provide long-term and effective tools within energy and climate policy. The Swedish Energy Agency also oversees energy statistics and analysis.



Figure 4. An overview of systems, prerequisites and resources that must interoperate for change in the energy system to take place.

A fundamental principle guiding the Swedish Energy Agency's work is the necessity for a system-level perspective to understand and influence the evolution of both the energy system and society at large. As Figure 4 illustrates, a multitude of factors must align for meaningful development to occur. Introducing a new technology to the market, for instance, requires more than just technological maturity, with capital invested in the development, and widespread adoption. It also necessitates appropriate legal frameworks, public willingness to use the technology, and the competence for its implementation. The most critical factors, naturally, vary from case to case. By ensuring a breadth and depth of knowledge in several different areas, the Swedish Energy Agency is well equipped to execute well-balanced initiatives in numerous areas.

2.1. The Swedish Energy Agency is a key stakeholder in the energy and climate transition

Collaboration with other essential stakeholders is an inherent aspect of the Swedish Energy Agency's facilitation of the transition process.

Securing competence for electrification

The Swedish Energy Agency has a government assignment to coordinate a national joint effort aimed at ensuring the supply of competence for electrification. The Agency initiated this task by conducting a comprehensive review and analysis of required competencies. This review serves as a knowledgebase and overview guiding prioritisation and the direction of the continued investigative work. The other part of this assignment involves identifying potential barriers and challenges in securing necessary skills for the energy sector and related fields, as well as suggesting measures to address both immediate and long-term competence needs. The assignment will also lead to a closer and more coordinated cooperation between agencies and industry stakeholders.¹⁴

Coordination within the area of hydrogen

Hydrogen is anticipated to play a central role in the transition to a fossil-free energy system, both in Sweden and globally. As an energy carrier, hydrogen has the potential to contribute both flexibility and robustness to the energy system. Hydrogen can also serve as a raw material in industrial processes, contributing to reducing emissions. In 2021, the Swedish Energy Agency undertook several hydrogen-related assignments and formulated a proposal for a Swedish Hydrogen Strategy.

The government has tasked the Swedish Energy Agency with coordinating the hydrogen-related activities in Sweden. The purpose of this coordination assignment is to identify and eliminate barriers to enabling the integration of fossil-free hydrogen production, distribution, storage, and utilization into the energy system in a socio-economically efficient manner. The assignment consists of three parts: coordination, analysis, and monitoring of current events.¹⁵

¹⁴ Kompetensförsörjning för elektrifiering - kartläggning och analys ER 2023:21, Energimyndigheten 2023.

¹⁵ Nationell samordning vätgas (energimyndigheten.se).

Coordination within the Battery value chain

The Swedish Energy Agency has a government assignment to coordinate and promote Sweden's role in a sustainable European battery value chain. In the assignment the Swedish Energy Agency will, in collaboration with the Swedish Environmental Protection Agency and the Geological Survey of Sweden, foster a broad dialogue on battery-related prospects and promote collaborative efforts with relevant stakeholders across the entire battery value chain. Within the first part of the assignment, completed in 2022, opportunities and challenges were identified and various proposals and initiatives were presented in a report.¹⁶ In the other part of the assignment, the Swedish Energy Agency, together with the Swedish Environmental Protection Agency and the Geological Survey of Sweden, continues to work with both collaborative dialogue and proposals for indicators to monitor progress in the battery sector, and formulating a plan for follow-up and evaluation.

The Swedish Energy Agency contributes to policy development within the battery sector through its roles as a funder of research and an expert authority. This applies, for example, to the work with EU's Battery Regulation and EU's Critical Raw Materials Act.¹⁷

National Centre for CCS

The Swedish Energy Agency is designated as the national centre for Carbon Capture and Storage (CCS).¹⁸ This mandate involves collaborating with industries, the business sector, authorities, and the Government Offices to coordinate and promote CCS in Sweden.

To achieve negative emissions, CCS can be applied on bio-based carbon dioxide, known as bio-CCS. Sweden has favourable conditions for bio-CCS as we have large point source emissions of biogenic carbon dioxide and the presence of several industries willing and capable of investing in this technology's development. The Swedish Energy Agency supports bio-CCS initiatives via the Industrial Leap Programme and also acts as the auctioneer in a support system for reverse auctions for bio-CCS.

Coordination of charging infrastructure

Since 2015, the Swedish Energy Agency has been responsible for coordinating the electric vehicle charging infrastructure in Sweden. This role is expected to expand in scope by 2024. Additionally, the government has assigned the Swedish Energy Agency and the Swedish Transport Administration to develop a national action-plan for both charging and hydrogen infrastructure. This plan aims to facilitate a rapid, coordinated, and socio-economically efficient expansion of appropriate public and private charging infrastructures. The programme also covers hydrogen infrastructure intended for both light and heavy vehicles.

At the Nordic level, the Swedish Energy Agency collaborates with the Swedish Transport Administration to lead a project called "Accelerated Electrification of Road Transport" in the Nordic countries. This project will conclude in 2024 and is funded by the Nordic Council of Ministers.

¹⁶ Energimyndigheten, Naturvårdsverket, Sveriges Geologiska Undersökningar, Batterisamordningsuppdraget, okt 2022.

¹⁷ New law on more sustainable, circular and safe batteries enters into force (<u>europa.eu</u>), Critical Raw Materials Act (<u>europa.eu</u>).

¹⁸ https://www.energimyndigheten.se/klimat--miljo/ccs/nationellt-centrum-for-ccs/

Sector responsibility for energy preparedness

The Swedish Energy Agency's responsibility for the energy sector includes developing and coordinating societal emergency preparedness for an energy crisis, monitoring of current events and analysis, and providing other authorities with expert knowledge within the field. With the reactivation of Total Defence Planning in Sweden, the scale and importance of the Agency's civil preparedness activities have significantly increased. This involves, ensuring a reliable energy supply, securing critical societal functions, and strengthening societal resilience to both peacetime crises and war. The Swedish Energy Agency also strives to meet the fuel and electricity needs of both civil and military defence.

Sustainable cities

Cities play a pivotal role in the energy and climate transition, and considerable efforts are underway in both Sweden and the EU, to create the climate-neutral cities of the future. The Swedish Energy Agency is one of 13 authorities participating in the Council for Sustainable Cities. This Council plays a strategic role in enhancing Sweden's transition capabilities and establishing the prerequisites needed for creating long-term, sustainable, and desirable environments where people want to live. Additionally, these authorities are involved in the national collaborative platform "The Swedish Model for Sustainable Urban Development," aimed at providing more operational support to municipalities and regions in their journey towards sustainable urban and societal development.

Another mechanism to expedite the climate transition is the Climate City Contract 2030, developed under the strategic innovation programme, Viable Cities. Its objective is to encourage stakeholders to coordinate and accelerate the pace of transition efforts at local, regional, national and EU levels. To date, 23 Swedish municipalities and six authorities, including the Swedish Energy Agency, have signed the contract. Seven of these Swedish signatory municipalities are part of the EU's mission with the target of achieving 100 climate-neutral cities in Europe by 2030. An initial evaluation indicates that this initiative is aligned with the objectives of the European Green Deal.¹⁹

Collaboration for initiatives within business development

Initiatives and support for business development in both new companies and established small and medium-sized companies are part of a concerted effort involving multiple stakeholders. The Swedish Energy Agency maintains ongoing collaborations with key public entities such as Vinnova, the Swedish Agency for Economic and Regional Growth, and Almi to coordinate and enhance support aimed at strengthening the ecosystem around innovative companies. The Agency supports intermediaries within the innovation system, including incubators, innovation offices, and technology parks. The aim is to foster innovative environments where researchers, entrepreneurs, and new companies can thrive and receive support for the expedited implementation of new solutions within the energy area.

19 EU Missions two years on: assessment of progress and way forward. COM(2023) 457 final.

Collaboration to coordinate export promotion and enhance competitiveness

The Swedish business sector is highly competitive in numerous energy and energyrelated sectors, such as transport, construction, and industry. In these domains, there is a demand for innovations in energy efficiency, electrification, and renewable energy.

Swedish Energy Agency's participation in Sweden's export and investment strategy is funded through the energy research budget (energiforskningsanslaget). The Agency undertakes cohesive initiatives in several major economies, such as the USA, Germany, India and Indonesia, and a range of thematically focused programmes. These promotional activities are conducted in collaboration with various stakeholders within Team Sweden.

The Swedish Energy Agency's collaboration with other promotional stakeholders, including Swefund, SIDA, the Swedish Export Credit Corporation, and the Swedish Export Credit Agency facilitates the export of Swedish energy and climate solutions, which is instrumental in the global energy transition.

The Swedish Energy Agency also holds a government mandate for acquiring emission credits under Article 6 of the Paris Agreement. Projects under Article 6 are tendered in an international competitive environment. The Agency's coordination of the mandate, combined with its other export-promotion initiatives, strengthens the overall prospects for Swedish companies to export energy solutions.

The Swedish Energy Agency's role in EU-activities

The Swedish Energy Agency's presence in European research and innovation forums can contribute to building expertise and enhance Sweden's attractiveness. By assisting the Government Offices in various EU processes and overseeing energy-related research in both Sweden and the EU, the Agency is well-positioned to contribute to this.

The Swedish Energy Agency supports the Government Offices in managing the Strategic Energy Technology Plan (SET Plan) and the EU's innovation fund. The fund supports demonstrations of innovative technologies that aim to reduce greenhouse gas emissions. The Agency participates in an advisory expert group comprising representatives from various industries, EU's member states, associated countries and the European Commission. Additionally, it serves as the National Contact Point (NCP) for the Innovation Fund. The Agency is tasked with representing Sweden within the EU, particularly in facilitating companies to receive higher levels of state aid for specially designated projects, known as Important Projects of Common European Interest (IPCEI). Currently, Sweden is focusing on projects related to batteries and hydrogen.

Horizon Europe integrates the EU's research and innovation initiatives, complementing other policy instruments and measures. The Swedish Energy Agency acts as the national delegate in partnership with the European Commission and the business sector, focusing on areas such as batteries, buildings, hydrogen, a circular and biobased Europe, as well as zero-emission transportation.

The International Energy Agency (IEA)

Sweden is an active participant in the International Energy Agency (IEA), which has been operational since the 1970s. Initially, the IEA's focus was on security of supply and emergency oil reserves. Its activities have since subsequently expanded to include research and development, statistics, policy issues, climate, renewable energy, and energy efficiency. In recent years, the IEA has also intensified its engagement with non-member states such as Brazil, India, Indonesia, China and South Africa. The member states collaborate in so called technical cooperation programmes.

The Swedish Energy Agency assists the Government Offices in their involvement with the IEA's committees, working groups, and other groups, and in establishing new partnerships and fields within these areas. The Agency also participates in more than half of the IEA's technical cooperation programmes, which are designed to facilitate knowledge exchange in research and innovation regarding new technologies and solutions.

2.2. The Swedish Energy Agency is Sweden's largest funder within energy research and innovation

The Swedish Energy Agency's research and innovation portfolio covers the entire innovation system and is designed to work in conjunction with, and complement, other policy instruments to achieve the nation's energy and climate policy objectives. The Agency's research and innovation initiatives aligns closely with its role as an expert authority, including its different coordinative assignments, analyses, policy preparation and investigations.

The energy research budget (energiforskningsanslaget) for 2023 was 1.4 billion SEK, marking a decrease from the previous year in both relative and absolute terms. However, the total public funding for research and innovation has increased since 2010 and totals approximately 46 billion SEK in 2023.



Figure 5. The total research and innovation funding in the government budget in proportion to funds within the expenditure area of Energy. Source: SCB.

Research stakeholders involved in the Swedish Energy Agency's research and innovation initiatives

On average, the research and innovation funding disbursed by the Swedish Energy Agency is equally matched by co-financing from the participating stakeholders, mainly companies. Projects equivalent to half of the research and innovation funding are coordinated by universities and other institutes of higher education, while companies coordinate projects equivalent to a quarter of the funding.



Figure 6. The distribution of research and innovation funding for different types of coordinating organisations, 2022. Source: The Swedish Energy Agency's Annual Report 2022.

Thematic areas within the Swedish Energy Agency's research and innovation initiatives

Presently, research and innovation initiatives are organised into several thematic areas. The four largest are: electricity production and the electricity system, the transport system, industry, and buildings within the energy system. Initiatives within these thematic areas cover the entire innovation chain, from research to implementation and dissemination. The topics are relevant to universities, institutes of higher education, research institutes, the business and the public sector.



Figure 7. Distribution of research and innovation funding for thematic areas, 2022. Source: The Swedish Energy Agency's Annual Report 2022.

Common perspectives within the Swedish Energy Agency's research and innovation initiatives

It is essential that the research and innovation funded by the Swedish Energy Agency is internationally competitive. Applications are evaluated in a competitive setting by panels consisting of both scientific experts and experts within the relevant subject. The assessment criteria always include a criterium related to scientific quality and/or level of innovation, tailored to the objectives of each specific call. This approach promotes excellence in both research and innovation. Data from the Swedish Research Council indicate that the impact of research funded by the Swedish Energy Agency is significant and aligns with the global average.²⁰



Figure 8. The distribution of senior project members and doctoral students who are women, men, or other. 2022. Source: The Swedish Energy Agency's Annual Report 2022.

A sustainable energy transition is only achievable if men and women have equal rights, responsibilities, and opportunities to contribute. In the context of the Swedish Energy Agency's research and innovation, emphasis is placed on promoting an equal distribution of research funding and advocating for the inclusion of a gender perspective in the research and innovation initiatives.

Projects funded under the Swedish Energy Agency's portfolio are frequently implemented in collaboration between researchers at higher education institutions and various stakeholders, including companies, public entities, and civil society organisations.

Promoting doctoral degrees is a key component of the Swedish Energy Agency's research and innovation support. Doctoral students are funded within the framework of competence centres, research and innovation projects, and through a research school focused on energy systems.

20 Statistikunderlag om Vetenskapsrådets utlysningar samt om FoU i högskolan. dnr 2023-05616.

2.3. The Swedish Energy Agency's tools for research and innovation

Funding for overall challenges related to the entire energy system is provided through various initiatives characterised by thematic, multidisciplinary, and system-oriented approaches. Business development and commercialisation includes initiatives targeting small and medium-sized companies as well as collaboration with international stake-holders and promoting opportunities for export within the entire energy system.

In addition to this, there are funding tools that are focused on different parts of the innovation system, as well as an interdisciplinary and system-oriented approach to developing knowledge and competence. New funding tools are always being developed and existing funding tools are subject to continuous improvements.



Figure 9. Schematic illustration of the Swedish Energy Agency's funding tools.

Thematic research and innovation programmes

The largest proportion of the Swedish Energy Agency's budget for research and innovation consists of approximately twenty thematic programmes. The programmes aim to both develop and implement technologies and new solutions as well as foster the creation of knowledge relating to how the energy system works and evolves. The development of these thematic programmes is based upon the Swedish Energy Agency's thematic strategies and external evaluations, along with input from hearings and other forms of dialogue. Regular meetings are held with the business sector, the public sector, academia, as well as stakeholders in civil society. Each program also has a long-term plan for communication including regular activities connected to, for example, calls, approved projects, and project results.

The energy system is becoming increasingly integrated across multiple sectors.²¹ This is reflected in the Swedish Energy Agency's programmes that are consolidated into fewer but broader programmes. Broader research and innovation programmes are better adapted to cope with complex societal challenges and have a clearer and more challenge-driven approach. A few current examples of the new programmes are the Future's Electricity System (Framtidens elsystem), Sustainable Transport Systems (Hållbara transportsystem) and Resource-Efficient Buildings (Resurseffektiv bebyggelse), that commenced during 2022 and 2023.

Sustainable Transport Systems encompasses the built environment, infrastructure and issues related to how different methods of transport can be combined in a more efficient manner. The programme covers the transport of both goods and people by road, sea, land, and air. Here there are many system-level challenges and opportunities.

The Future's Electricity System encompasses challenges connected to electricity production, electricity use, and the future of the electrical grid. Calls have so far included areas such as robustness, resilience, security of supply and increased competence connected to the electrical system.

Resource-Efficient Buildings encompasses energy-use within the built environment during its entire lifecycle. This area includes buildings, systems, artifacts and people, that are relevant at different levels and in different roles. This can be, for example, both residential and non-residential buildings, their construction, peoples' way of living, energy sources and energy use that is related to buildings and built environment, including renovation, reconstruction, and demolition.

Two other broad programmes are the Battery Fund Programme (Batterifondsprogrammet) and the Fossil-Free Aviation Initiative (Fossilfritt flyg). The Battery Fund Programme provides funding for research and innovation initiatives within battery recycling and batteries for use in the electricity system or vehicles. The programme's costs have been covered by environmental charges on batteries containing lead, cadmium, and mercury, however the resources available in the fund are running out. During 2018, the Swedish Energy Agency was tasked with supporting research and innovation of sustainable aviation fuels and has now established an innovation cluster working towards fossil-free aviation by 2045. This initiative was expanded in 2021 to also include research and development for all types of renewable aviation fuels, electric aviation as well as hydrogen-powered aviation, including charging and refuelling infrastructure.²²

²¹ Energimyndighetens övergripande strategi för forskning och innovation 2021–2024, dnr 2022–005825.

²² Vägen mot ett fossilfritt flyg – forsknings- och innovationsprojekt som bidrar till omställningen, ET 2023:04 Energimyndigheten 2023.

Competence centres

Competence centres are research environments located at an institute of higher education that are focused on knowledge development, doctorial education and providing support to researchers in the early stages of their careers. The Swedish Energy Agency supports competence centres as an effective way of encouraging collaboration between academia and companies where knowledge and the acquisition of competence are based on both societal and the company's needs. Previous evaluations of competence centres have shown that a large proportion of the researchers from these centres continue their careers in the business sector, which strengthens commercial competitiveness.²³

In 2020, the Swedish Energy Agency launched a call for renewing its existing portfolio of competence centres. Eleven competence centres have received support for an initial period of five years, with the possibility of extension for five-years. Long-term financial stability helps create the conditions needed to build more in-depth relationships and increase collaboration between the stakeholders as well as facilitating the long-term acquisition of academic knowledge and competence. This helps promote the development of networks between the different stakeholders. The Swedish Energy Agency has also helped create the conditions for the development of networks and the exchange of knowledge between the different competence centres through a specific leadership forum that has a focus on leadership and organisation. There are competence centres within several relevant areas such as nuclear power, hydrogen, and resilience.

Uppsala University coordinates the competence centre ANItA (Academic-industry nuclear technology initiative to achieve a future sustainable energy supply) with the aim of supporting the development of knowledge-based strategies for the introduction of small modular nuclear reactors in Sweden. The work within the centre is multidisciplinary and includes, not only nuclear technology, but also issues such as licences and legislative aspects.

The competence centre Resilient Energy Systems aims to increase knowledge and competence related to how sector coupling between transport infrastructure, industry and the built environment, including business models and organisational structures, can help create resilient energy systems.

Technologies and innovations for a future sustainable hydrogen-economy is the primary aim of a competence centre that conducts applied multidisciplinary hydrogen research with a focus on heavy haulage. The centre's main focus is primarily on integrating technical solutions into practical applications, an area that creates many new multidisciplinary research needs.

National and international business development and commercialisation

The Swedish Energy Agency supports business development, commercialisation, and the internationalisation of new solutions. The initiatives have a broad span and encompass support for business development for small and medium sized companies who are working with projects involving the transformation of research results and early pilot solutions towards commercialisation. The Swedish Energy Agency additionally facilitates support for companies engaged in energy innovations by fostering collaborations with various stakeholders within the innovation system and by procuring services from intermediaries.

²³ Utvärdering av energimyndighetens finansiering av forskarstuderande, WSP 2021.

Sweden is both an innovative and export-dependent country. Technologies and innovations developed in Sweden, including those fostered by the Swedish Energy Agency's research and innovation support, have the potential to contribute to a large decrease in global emissions. The Swedish Energy Agency is an authority that takes part in Team Sweden, and therefore has responsibilities within the framework of Sweden's strategy for export and competitiveness. The Swedish Energy Agency supports initiatives in selected countries and initiatives within certain thematic areas such as sustainable heating and cooling, built areas, the battery value chain, renewable electricity production and smart electricity grids. The Swedish Energy Agency also undertakes activities to promote investments in Swedish companies.

Pilot and demonstrator initiatives

The Pilot and Demonstrator Programme aims to facilitate the introduction, up-scaling, and dissemination of new energy innovations to the market. Within the framework of the programme, larger prototypes, system-demonstrators, and pilot facilities can receive support. The transition from testing a solution on a small scale to its establishment in society is often a long process which can entail large impacts on other parts of the system that may be difficult to foresee. If a new solution is to be successfully introduced to the energy system, and have a large-scale impact, then demonstration in a relevant context and subsequently scaled-up is a critical step.

An example of a project that has received funding from the programme is Mobile Charging for Electricity and Hydrogen. In the mobile charging station, there will be hydrogen storage for the refuelling of hydrogen-driven vehicles and a fuel-cell that can convert hydrogen to electricity for the charging of electric vehicles. The innovation aims to enable charging in areas without access to the electrical grid, or in remote areas.²⁴ Other examples include floating wind turbines, wave-energy converters, systemdemonstrators for locally shared energy, and battery recycling.

Research and innovation programmes in national and international collaborations

To coordinate the efforts of Swedish public research funding within the EU and internationally, there are specific coordinating functions, EUsam and Intsam. The Swedish Energy Agency participates in both coordinating functions.

The Swedish Energy Agency also participates in two national research programmes (NFP), within sustainable urban development and climate. The programmes are run in close collaboration with many relevant authorities and are coordinated by Formas.

Strategic Vehicle Research and Innovation programme (FFI) is a collaboration between the state (Vinnova, the Swedish Transport Administration and the Swedish Energy Agency) and the automotive industry. FFI contributes to the vital transition towards sustainable transport.

The Swedish Energy Agency also collaborates with Vinnova and Formas within the strategic innovation programmes Viable Cities and RE:Source. The programmes are jointly run and funded by companies, research institutes, universities, institutes of higher education as well as the public sector. RE:Source is focused on resource

²⁴ https://www.energimyndigheten.se/forskning-och-innovation/stod-till-affarsideer-test-och-lansering/pilot-och-demonstrationsprojekt/mobil-laddlosning-for-el-och-vatgas-mojliggor-elektrifieringen-av-arbetsmaskiner/

efficiency and circular material flows whereas the work within Viable Cities is related to climate neutral and sustainable cities.

Viable Cities is also connected to the European partnership Driving Urban Transition (DUT) where Swedish stakeholders have the opportunity to apply for funding for projects undertaken in collaboration with other countries. The Swedish Energy Agency has the national responsibility for one of the thematic areas within DUT, focusing on Positive Energy Districts.

The Swedish Energy Agency leads, together with Austria, work within the European partnership Clean Energy Transition Partnership (CETPartnership). Within this partnership, the Swedish Energy Agency also contributes with funding to Swedish stakeholders who are part of transnational projects. The aim of the CETPartnership is to promote efforts related to the energy transition and to EU's goal of being the first climate neutral continent by 2050. This is undertaken through the funding of research and innovation within areas connected to industry, buildings, electricity production, energy storage, energy systems and the energy grid, carbon capture and use, renewable fuels as well as heating and cooling.

The Swedish Energy Agency's research and innovation collaborations at the Nordic level are undertaken mainly within the Nordic Energy Research (NEF). This is an intergovernmental collaborative organisation with the primary goal of supporting the Nordic energy collaboration. NEF funds and promotes Nordic collaboration, prepares research results for policy decisions within the energy area, and is a link between industry, research and policy stakeholders.

The Industrial Leap programme

In close collaboration with the Swedish Energy Agency's research and innovation initiatives, the government assignment Industrial Leap is also being carried out.²⁵ The allocated government funding for the Industrial Leap Program in 2023 amounted to approximately 1.3 billion SEK, and the programme can fund projects that run until 2030. Since 2021, the Industrial Leap Programme has also been part of the EU initiative Next Generation EU.

The Industrial Leap Programme encompasses support to industry to reduce emissions and to contribute to the climate transition in society as a whole. In the initiative, companies can apply for support for both research and innovation as well as investments within capture, storage, and use of carbon dioxide (CCS and CCU), for production of fossil-free methanol and for pilot facilities for fossil-free hydrogen within steel and iron production. The Industrial Leap programme has provided support to, for example, Ovako's facilities in Hofors where steel that is be to rolled is heated with fossil-free hydrogen.²⁶

²⁵ Industrin – nuläge och förutsättningar för omställning, En nulägesanalys inom Industriklivet, ER 2023:22.

²⁶ https://www.energimyndigheten.se/nyhetsarkiv/2021/ovako-satsar-pa-vatgas-och-far-stod-av-energimyndigheten/

Prioritised initiatives within energy research and innovation 2025-2028



3. Prioritised initiatives within energy research and innovation 2025-2028

By providing meaningful support for energy research and innovation, Sweden makes it possible for Swedish academia, public sector and business sector to development the knowledge and solutions needed to drive the energy transition.

In this chapter, the Swedish Energy Agency's research and innovation requirements are presented for the period of 2025-2028. These essential initiatives exceed the current scope of the research and innovation budget, and therefore the Swedish Energy Agency proposes an increase to the current allocation.

The energy transition is characterised by an increasing degree of integration across multiple sectors. Issues that could previously be solved within traditional branches and sectors now require a systems-level approach. Many of the challenges traverse across the Swedish Energy Agency's thematic areas.

The Swedish Energy Agency proposes an incremental increase in the energy research and innovation budget from circa 1.4 billion SEK for 2024 to 2.2 billion SEK for 2027 and 2028. Below is an illustration showing the existing energy research and innovation budget and the Swedish Energy Agency's proposed increases.





Figure 10. The energy research and innovation budget's expected development for the period 2024-2028 as well as the increases described in this report.

The Swedish Energy Agency's five priorities for research and innovation for the period 2025 to 2028 include: technology and sustainable value chains for energy transition, accelerated transition through system demonstrators and business development, a resilient and robust energy system, competence for energy transition, and finally research regarding governance, conflicting objectives, and transition pathways.



Figure 11. Critical system-level initiatives that need to be prioritised in order to achieve a sustainable transition to a fossil-free, competitive, and resilient energy system.

The table below shows a summary of the areas requiring extra resources within each area of priority.

Table 2. Required increases in research and innovation allocation to the Swedish Energy Agency

Year	2025	2026	2027	2028
Energy research budget				
Technology and sustainable value chains for energy transition	150	240	300	300
Nuclear power	50	100	100	100
Batteries	40	60	100	100
Hydrogen power	30	40	50	50
Fossil-free aviation	30	40	50	50
System demonstrators and business development for accelerated energy transition	200	240	270	270
Pilot and demonstration iniatives	100	140	170	170
Impact Innovation	60	60	60	60
Strengthen business development in small and medium-sized companies	40	40	40	40
A resilient and robust energy system	50	70	100	100
Increased competence for energy transition	50	150	150	150
Governance, conflicting objectives and pathways for the energy system	30	40	50	50
Total	480	740	870	870
The administrative allocation				
Strengthen the Swedish presence in both EU and international forums	10	10	10	10
Total	10	10	10	10

3.1. Technology and sustainable value chains for energy transition and competitiveness

The Swedish Energy Agency proposes an increase in resources to technology and sustainable value chains for energy transition and competitiveness. This initiative is divided up into four sub-categories and, when fully developed by 2028, will account for 300 million SEK.

To supply society with the products and solutions required to achieve an energy transition, new technologies need to be developed and new value chains need to be created. This requires new resource flows, new business models and new competences. Parallel to this, an ecosystem of stakeholders needs to be built up and developed. As many parts of such an ecosystem need to be developed simultaneously, and different types of obstacles need to be cleared, the Swedish Energy Agency sees an increased need for coordination, monitoring of current events and analysis. The direction of this research and innovation needs to be identified in collaboration with the relevant stakeholders from the business sector, research and the public sector.

Resources and raw materials are critical for the energy transition. As new value chains are developed it will be of great importance to simultaneously scale up the supply of both primary and secondary raw materials. This is an important step in achieving a rapid and sustainable shift to a more circular use of resources, ultimately reducing the long-term need for primary raw material extraction. Research and innovation related to resource efficiency is also of importance here.

Many of the technical solutions that are important for the transition are already on the market and have established value chains. In the future, it will be essential to develop and improve these technical solutions with regards to cost efficiency, energy efficiency and resource efficiency.

Within industry and its related value chains, there is a need to increase both process efficiency and the reuse of materials, as well as to develop products that increase energy efficiency. Digitalisation and developments in technology along with increases in efficiency with regards to materials and energy, lead to lower transition costs for both industry and society.

The transport sector is an area where the issue of materials is becoming increasingly important as the sector undergoes electrification. In the future, the largest emission volumes will be related to the production of the vehicle and the charging infrastructure, rather than emissions from the vehicle itself. This will require an increased focus on research related to how the reuse and new production of materials can interact. The Swedish Energy Agency has identified a number of areas for research and innovation of technology and value chains critical to the transition and competitiveness.

Nuclear power

Research and innovation within the area of nuclear power has long been neglected in Sweden. If the sector is to grow, then a significant addition of competence is required. Here, doctoral education along with both academic and industrial research play important roles. Research and innovation connected to existing reactors needs to support extending lifespans, raising effect levels, modernisation, and increasing security. Additionally, research is needed within the development of new types of reactors. There are Swedish companies exploring various concepts for new nuclear power, employing a range of technologies at different stages of development. There is on-going development of fuel production for both conventional and new types of fuel.^{27, 28}

To prepare for a possible expansion of nuclear power, research and innovation initiatives will be required within the areas of markets and business models, society's expectations, and inclusion, as well as regulations and policy instruments.

Batteries

Batteries are a key technology for the electrification. They are required in phasing-out fossil fuels in transport, coping with intermittent electricity production, and increasing flexibility of the electrical grid. There is a need for increased funding for research, innovation and business development within the area of batteries, focusing on both long-term research programmes as well as open test and development infrastructure.²⁹ Some of the largest challenges include the function of the battery value chains from a systems perspective; alternative and complementary battery technologies; as well as resource and energy efficient production processes along the entire battery value chain, including recycling.

Due to the rapid level of development within the area of batteries, there is a high level of international competition for researchers with competence within the field. Funding is therefore required in order to create appealing research environments capable of attracting talent. Strong research environments are also required to facilitate collaboration between institutes of higher education, research institutes and the business sector.

Hydrogen

Hydrogen is expected to play a central role in the transition to a fossil-free energy system. Hydrogen as an energy carrier can contribute with flexibility and robustness to the energy system. Fossil-free hydrogen creates opportunities for connecting sectors, and this requires systems perspective for research. Value chains for fossil-free hydrogen, electro-fuels, and ammonia are undergoing technical development within several sectors and for different applications, at the same time as implementation and up-scaling is taking place.

The Industrial Leap Programme has the possibility to provide support for investments in hydrogen projects, however, the initiatives that can be funded within the framework of the Industrial Leap need to be supplemented with research and innovation connected to the entire hydrogen system. This applies to technical components, economic

²⁷ Kunskapssammanställning om forskning och innovation på kärnkraftsområdet i Sverige, ER 2020:27, Energimyndigheten 2020.

²⁸ Startprogram för ny kärnkraft, Svenskt näringsliv 2023.

²⁹ Energimyndigheten, Naturvårdsverket, Sveriges Geologiska Undersökningar, Batterisamordningsuppdraget, okt 2022

issues, and how hydrogen, from a technical and regulatory perspective, can be integrated into the energy system.³⁰

Fossil-free aviation

Aviation, like other parts of society, needs to undergo a transition and to contribute to the energy and climate policy goals. There are currently several development paths that complement each other. To facilitate a transition of the aviation sector, more research and innovation is required within the areas of sustainable and renewable fuels for existing aircraft, development of electric aviation and hydrogen-powered aviation, as well as different system-related issues. These new technologies and values chains are under development and need continued support.³¹

3.2. Accelerated transition through system demonstrators and business development for accelerated energy transition

The Swedish Energy Agency proposes an increase in funding for accelerated transition through system demonstrators and business development for an accelerated energy transition. This initiative is divided into three sub-categories and, when fully developed, accounts for 270 million SEK for 2028.

Pilot and demonstrator initiatives

The Swedish Energy Agency sees a significant need for demonstrators within new technologies, both for Sweden's energy transition and also to create new business opportunities for Swedish companies. Demonstrator activities reduce both technical and commercial risks and create an increased potential for transition amongst the business sector and societal stakeholders.

The character of demonstrator initiatives can vary. Some demonstrator activities are of a more technical nature and focus on the challenges involved with scaling-up and developing technical solutions. Many of the technologies and solutions necessary for the energy transition are already on the market, however, the IEA states in the report Net Zero by 2050 that a large portion of the technologies required to achieve the long-term climate goals have not yet passed the demonstration stage.³²

System demonstrators are activities that aim to solve complex system-level challenges by conducting tests in relevant contexts, often in a broad collaboration between societal stakeholders. This can, for example, encompass site-based demonstrators showing how new system-solutions can be integrated and function locally in a town or rural area.

³⁰ Förslag till Sveriges nationella strategi för vätgas, elektrobränslen och ammoniak. ER 2021 34, Energimyndigheten, 2022

³¹ Vägen mot ett fossilfritt flyg – forsknings- och innovationsprojekt som bidrar till omställningen, ET 2023:04, Energimyndigheten 2023.

³² Net Zero by 2050. A Roadmap for the Global Energy Sector, IEA 2021.

A realistic environment for experimental activities and demonstrators provides the opportunity to analyse the expected and unexpected effects on the market and society before the solution is scaled-up and introduced on a wider scale.

Impact Innovation

The Swedish Energy Agency, Formas and Vinnova have been tasked by the government with forming and implementing the next generation of strategic innovation programmes - Impact Innovation. Impact Innovation aims to strengthen Sweden's global competitiveness and increase the rate of societal transition based on the needs of the business sector and society in general. Impact innovation will also contribute to the development of policy and regulations as well as remove obstacles that pose a risk of limiting new markets in the future.

Further, Impact innovation will contribute to increasing participation within the EU's initiatives for research and innovation, attracting international expertise, as well as increasing connections with international centres of excellence. The programmes within Impact Innovation will be fewer but more comprehensive with the aim of establishing broader constellations of stakeholders from different branches and sectors that can collaboratively set the agenda.

Five programmes are expected to commence during the first quarter of 2024. The initiatives originate from the aspiration to solve broad societal challenges by achieving high level and equable health for everyone, attractive and well-functioning societies, as well as production, consumption and value chains that are within planetary boundaries.

Strengthened business development in small and mediumsized enterprises (SME)

Innovative companies play a crucial role in achieving energy and climate goals, while at the same time contributing to economic growth by both addressing existing demand and generating new demand within the transition to a sustainable energy system.³³ In this context, it is important to offer incentives for successful researchers and entrepreneurs to convert knowledge and ideas into new innovative companies that can empower the energy transition.

Innovations that can contribute to the energy transition have been identified as one of Sweden's strongest areas. Advanced technical solutions require a longer period for commercialisation, and therefore have a greater need of funding in the scaling-up phase. The Swedish Energy Agency's funding for demonstrator projects and access to risk capital has therefore been an import contribution in the implementation of new solutions and the growth of new companies. The Swedish Energy Agency has identified the need for extra resources to improve early access to risk capital through collaboration with The Swedish Agency for Economic and Regional Growth and Almi.³⁴

The Swedish Energy Agency sees the need to develop support for innovative environments that strengthen the collaboration between researchers, companies, and intermedi-aries, thereby reducing obstacles for development. In this way, the pace of commercialisation and implementation of innovations in the energy area can be increased. In a similar manner, we see that there is a need to improve coordination between public funders who support innovative environments and companies.

³³ Effekter av innovationsstöd med samverkanskrav, Rapport 2020:04, Tillväxtanalys 2020.

³⁴ Gröna fondens förutsättningar för att bidra till övergången till en koldioxidsnål ekonomi, Tillväxtverket, 2019.

The market for energy innovations is often global. Rapid development and large demand create the need to support companies, both at an earlier stage and to a greater extent, in their internationalisation efforts. The Swedish Energy Agency needs to support companies' commercialisation on international markets as well as international launches, both of which can increase exports and also lead to growth and new job opportunities in Sweden.

3.3 A Resilient and robust energy system

The Swedish Energy Agency proposes an increase in funding for research and innovation initiatives to ensure, through a comprehensive approach, the robustness and resilience of the energy system. When fully developed, these initiatives account for 100 million SEK in 2028.

A future energy system needs to be resilient and robust to ensure that society can continue to function regardless of the given circumstances. The system for production, transfer and use of energy needs to be able to resist and recover from negative impacts such as electricity outage, disruption or attacks. As our energy system becomes more fossil-free, electrified, and digitalised, there is an increased need of research and innovation that can develop knowledge to better understand and identify risks and threats within the energy system.

The increased demand for electricity entails the need for more research and innovation throughout different parts of the energy system with regards to, for example, flexibility, diversification, robustness as well as capabilities and capacity. This also applies to continuity planning, development of energy preparedness tools, as well as how domestically producing biomass can contribute to security of supply.

The Swedish Energy Agency has previously concluded that there is a need for more research examining how power-structures and geopolitical conflicts along with global trends impact on Swedish energy and climate policy and the management of security measures in the on-going energy transition.³⁵ The energy system is a potential target for hostile actions and a growing proportion of the stakeholders on the energy market have been subjected to unwanted influence. Here, there is a need for focused research initiatives in collaboration with the affected stakeholders.

An additional important aspect is the adaptation required due to a changing climate. The public sector, for example municipalities and the government, have an important role when it comes to creating long-term sustainable, transparent and legitimate processes within areas such as land and water use as well as changing conditions for the electrical grid, for example due to storms or ice formation. These challenges are to a certain extent new and are increasing rapidly.

³⁵ Energimyndigheten (2019) Accelerera energiomställningen för ett hållbart samhälle. Underlag för forskning och innovation på energiområdet 2021–2024.

3.4 Competence for energy transition

The Swedish Energy Agency proposes increased funding for highly educated competence to further the energy transition. Resources for competence centres should be increased in an initiative that, when fully developed, will account for 150 million SEK in 2028.

The shortage of highly educated competence is an increasingly significant constraint for the Swedish business sector and Swedish competitiveness.³⁶ The energy transition, that in many cases entails radical shifts in technology and the construction of completely new value chains, is particularly dependent on a well-functioning supply of competence.³⁷ With this in mind, it is concerning that the downward trend seen over the past few years in the number of new doctoral students pursuing a PhD in technical fields continues.³⁸ It is important to safeguard the inflow of researchers and teachers in higher education, and the number of staff with a doctoral-level education within both the business and public sectors.

A members survey conducted by the Federation of Swedish Innovation Companies showed that a third of Swedish innovation companies would have invested more in research and innovation if they had been able to recruit the right competence.³⁹ In order to change this trend, significant efforts are required in all of the Swedish Energy Agency's areas of research and innovation.

The Swedish Energy Agency supports long-term research environments in the form of competence centres. The support of competence centres has proven to be particularly successful in addressing the long-term knowledge and competence requirements for Sweden's energy system by creating the conditions for more in-depth collaborations between researchers at institutes of higher education and stakeholders from the business and/or public sectors. As these centres work on longer timeframes, they can help build up long-term collaborations leading to greater trust and confidence for the stakeholders involved. The mutual development of knowledge between the stakeholders contributes to the business sectors' perspective being integrated into the doctoral education connected to these environments, and this can influence the competence profile for the doctoral students. Previous evaluations have shown that a large proportion of the researchers from the centres progress to a career in the business sector.⁴⁰ The majority of these doctoral students have also joined a company that participated in the competence environments where they graduated.

³⁶ FoU-barometern 2023, IVA 2023.

³⁷ Långsiktiga förslag för att möjliggöra den gröna industriomställningen i Sverige. 11 förslag för att skapa förutsättningar för att klara klimatmålet för 2045. Fossilfritt Sverige, 2023.

³⁸ Universitetskanslerämbetet, Högskolan i siffror.

³⁹ Undersökning om kompetensbehov bland Energiföretagens medlemmar och branschens attraktivitet på arbetsmarknaden, Energiföretagen 2022.

⁴⁰ Utvärdering av energimyndighetens finansiering av forskarstuderande, WSP 2021.

3.5. Governance, conflicting objectives, and pathways for the energy system

The Swedish Energy Agency proposes strengthening resources for research regarding governance, conflicting objectives, and pathways for the energy system. With this in mind, resources should be increased in an initiative that, when fully developed, accounts for 50 million SEK in 2028.

The energy system is undergoing significant changes, and several paths of development are possible. More resources are needed for developing methods within the areas of modelling and analysis in order to evaluate and plan for the future energy system. This can contribute to well-informed decisions and policy development at all levels of society.

Governance, transition pathways and conflicting objectives need to be analysed on an overall systems-level. This applies to, for example, issues related to society's expectations of an expansion in fossil-free nuclear power or the extraction and refinement of critical raw materials.

To continue to support the societal stakeholders in the energy transition, more research and knowledge is needed regarding policy instruments, regulations, as well as incentives that are effective, well-functioning and interact across different sectors in an energy system undergoing change. Sweden's electricity market is integrated with the Nordic and European electricity markets and a consequence of this is that they share many common research issues related to policy, markets and infrastructure.

The pathways to transition of the future energy system need to be inclusive, legitimate and cost-effective. There are many perspectives that need to be considered, not least the consumer perspective. An increased understanding for fairness-related aspects in the energy transition is required. This includes the policy implications of regional and allocation decisions as well as issues related to the opportunities for different groups to act in the transition.

3.6. Increased participation in European and international collaborations

The Swedish Energy Agency proposes an increase in the administrative allocation with 10 million SEK per year to strengthen a Swedish presence in both EU and international forums.

The formations of energy policy that takes place to a significant extent within EU and other international forums and organisations such as NATO has a significant impact on Sweden's energy transition. Increased presence to influence EU's energy policy is therefore of great importance to Sweden. This applies not least to the forming of research and innovation initiatives, given the detailed nature of regulations at the EU level. A Swedish presence in both European and international forums is also important to follow and understand the geopolitical events that can have implications for energy supply. Sweden's opportunities to contribute with new technology and other solutions to achieve the energy transition, and thereby promote Swedish export and the Swedish business sectors competitiveness, is also dependent on a participation in European and international collaborations. To increase Sweden's visibility, greater resources and different promotion initiatives are required.

The Swedish Energy Agency is, through its role as expert authority in the energy area, already active within the European decision bodies and participates in several exportpromoting initiatives. Further, the Swedish Energy Agency is involved in several partnerships. The work within these partnerships requires significant resources, but at the same time offers extensive opportunities to create new contacts and collaborations with stakeholders in other countries.

Currently the Swedish Energy Agency's capacity to participate in these forums is insufficient. To safeguard Swedish interests and to take advantage of the opportunities created in these international and European forums, the Swedish Energy Agency proposes that the government increases the administrative allocation with 10 million SEK per year.

The Swedish Energy Agency's strategic work



4. The Swedish Energy Agency's strategic work

The Swedish Energy Agency shall promote research and innovation within strategic initiatives that encompass the entire innovation system, in close collaboration with other initiatives and policy instruments.

The strategic direction for research and innovation funding is formed and developed in interplay with the rest of society. This is undertaken through both dialogue and collaboration with relevant stakeholders from academia, the business sector, and the public sector, along with a systematic monitoring of current events. The Energy Development Board is one of the agency's decision-making bodies that plays an important role through its task of promoting more in-depth collaboration with the business sector.

Prior to the commencement or extension of a programme or other research and innovation initiatives, strategic work is undertaken that is based on evaluations, current scenarios and an on-gong monitoring of current events, along with experience from the previous period. When it is deemed necessary, the Swedish Energy Agency also assigns a strategic council to different research and innovation programmes. The council consists of experts from academia and the business sector and acts as a support in discussions regarding the programme's strategic direction, project portfolio and future development.

Within the framework of the government assignments that the Swedish Energy Agency is tasked with, the analysis of current events, the current situation, and research needs are often undertaken. This provides valuable insights for strategic work at both an overall level as well as with the forming of different programmes.

The strategy is based on the Swedish Energy Agency's work with scenarios, prognoses, and other analyses for the development of the energy system. Followup and evaluation of current initiatives contributes with valuable knowledge to this strategic work. Work for the period 2021-2024 is summarised in the Swedish Energy Agency's overall strategy.⁴¹

The Swedish Energy Agency works continuously with developing its strategic priorities and methods.

Energimyndighetens övergripande strategi för forskning och innovation 2021–2024, dnr 2022–005825.



Affordable and Clean Energy

Our assignment is to unite sustainability, competitiveness, and security of energy supply for cost-efficient energy systems with minimum impact on health, environment and the climate.

We contribute with data, knowledge, and analyses regarding energy use and supply in Sweden. We are also dedicated to maintaining a secure energy supply on a national level.

We support and fund national research on innovative energy technologies, smart grids, vehicles, and fuels of the future. Furthermore, we support business development, commercialisation, and export of cleantech innovations.

Official statistics and support schemes, such as the Electricity Certificate System and the EU Emission Trading System, are some of our responsibilities. We participate in international collaboration and provide information on efficient energy use to households, industries, and public authorities.

The Swedish Energy Agency also holds the overall responsibility for the energy sector due to civil preparedness.



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